# ENGIE Renewable Energy Sources Outlook

2020 Edition

#Act With ENGIE

ENGIE

# Foreword

**Gwenaëlle Avice-Huet**,
Executive Vice President, responsible for the Global Renewable Business Line

**I am pleased to share with you** this first edition of our ENGIE renewable Outlook which encompasses both a strategic view on renewable resources and solutions as well as a documented approach on energy transition challenges.

The strong trends to fight climate change, the real urge for a low carbon economy, the clear shift towards a greener energy paradigm, have not been derailed by Covid. They have been reaffirmed despite the health and economic crisis, pushing many stakeholders to align on a trajectory for carbon neutrality during the first half of the century.

**Challenges linked with climate change** are a concern for our societies as a whole: they will require engagement from territories, institutional players, companies, industrial players and from individuals. In this report we intend to give an update on energy transition and to describe what still needs to be done to meet our collective environmental imperatives.

In many ways, the pandemic has shown us the way to build a more sustainable system tomorrow. It notably emphasised the key role that renewable energy solutions could play to make our energy system more resilient should it be through power production, storage, green gases or green hydrogen. This report will also explore how those solutions could be used, developed and combined to draw a sustainable future.

Of course, strong efforts will be needed to stop and reverse the increase of $CO_2$ emissions. There will be struggles and the battle is far from being won to contain the rise in global temperatures below 2°C. Nevertheless, we can already notice that the approach on energy has changed with a global awareness on social and environmental challenges, with a drop in production costs for renewables, with technological breakthroughs that have made green, sustainable energy reach a whole new dimension. And what we can already say is that this trend is set to continue and to intensify.

**Since 2000**, global installed renewable capacity has more than tripled, and if we look specifically at wind and solar: installed capacity has been multiplied by almost 70. Several factors are driving this tremendous growth of renewable energy, among them: government policies. Over the last few years, almost all countries have adopted renewable energy targets and, today more than ever, we see strong policy initiatives to support renewable development. In a post-covid context, the EU €750 billion recovery package, with funds at European level, is a first of a kind with 30% of this package to fight against climate change. This is a clear choice to invest in a green, digital and resilient Europe, including in ambitious, innovative technologies like Hydrogen. We see daring ambitions in other continents too, notably pushed by the newly elected US President to reach carbon neutrality by 2050.

And it's not only about states and about public engagement: private sector and corporate also play their part of the game and set strong targets. There is a strong surge in corporate sustainability commitments around the world. Nearly 400 companies around the world committed to setting a science-based target in 2019, more than doubling the total number of firms with these goals. These firms have pledged to reduce their emissions in line with the Paris Agreement, and clean energy will be an essential part of this strategy.

Of course, the Energy sector has a specific responsibility when it comes to environmental targets as 75% of greenhouse gases come from energy combustion. But at the same time, the sector could provide a large proportion of the solutions. Thanks to the commitment of a wide range of stakeholders, including ENGIE, the steps that need to be taken are now clearly identified.

**At ENGIE**, we are engaged to increase the development of renewable energy capacities, keeping notably in mind one of the learnings of this crisis: namely the importance of local energy resources and production, favoring short supply chains. But we are also convinced that no decarbonisation pathway is achievable without significant deployment of energy efficiency measures. Should we talk about buildings, cities, industry, transports. Through energy efficiency we could potentially reduce global energy consumption by over a third. A decarbonised energy system in a secure, and cost-effective manner will require a full range of solutions, including district cooling and heating or energy storage.

Finally, to reach a zero-carbon world and complement the deployment of renewables we'll also need to link up technologies across energy carriers: we'll notably need low carbon energy vectors (hydrogen, biogas, etc.) and sector coupling to make our future power systems stronger, cost-effective and reliable.

We dedicate a large portion of this document to explore the wide range of solutions which will play a part in the energy transition, describing their potential and current stage of development. Our analysis has notably benefited from the enlightened views of renowned expertise centers that responded to our invitation to comment on energy transition.

Obviously, at the end of the day, the energy transition agenda will be subject to different approaches depending on geography and local or national priorities. But to reach the ambitious global long-term targets that the world needs we'll have anyway to push, combine and accelerate the implementation of effective solutions including efficient technologies, green finance, innovative business models and incentivising policy measures. And that way, we'll be able to make it.

I hope this report can bring new angles to your thoughts on the energy challenges ahead and interesting inputs to your work towards new solutions. Wishing you a nice read.

# Summary



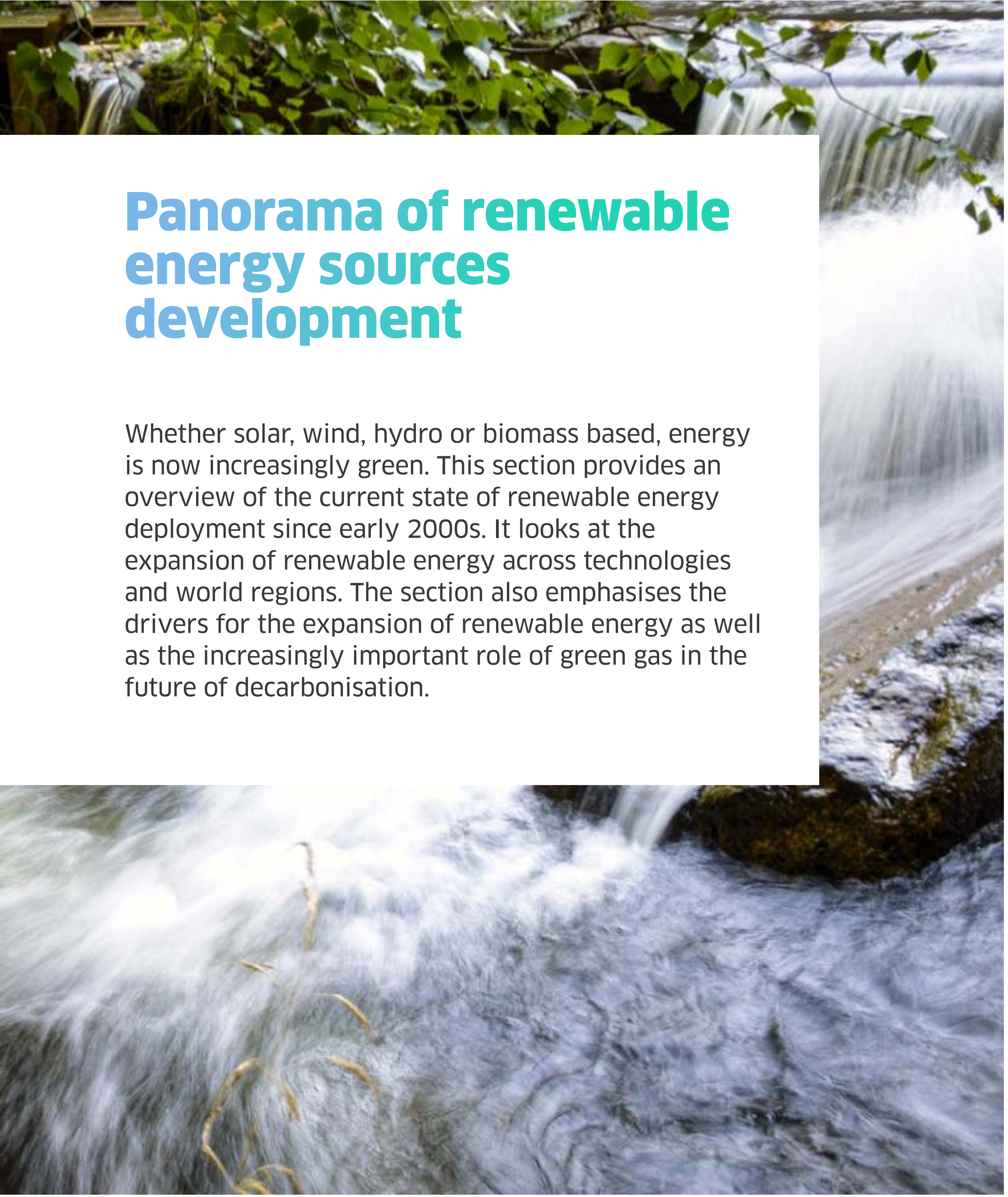




# Setting the scene

With the Paris Agreement, the international community set the objective to limit the increase in global temperature to well below 2°C[1]. Reaching this objective will require a sharp reduction in greenhouse gas emissions (GHG). Aspirations of consumers towards low-carbon solutions are growing, and countries are pushing for increasingly ambitious regulations. This environmental consciousness places the energy sector as a whole in the limelight. Whereas electricity generation only represents 25% of global greenhouse gas emissions, the use of the combustion energy of fossil fuels altogether represents around 75% of GHG emissions[2].

The energy sector therefore has a major role to play, not only in reducing its own emissions but also in enabling emission reductions for all the different usages of energy. While energy-efficiency remains the first objective, another fundamental component of lowering GHG emissions will be the decarbonisation of energy vectors. This will require a full range of solutions, from the further deployment of renewable electrical and thermal energies, to the greening of gas, and the search for local, system-oriented solutions within a circular economy approach.



# Panorama of renewable energy sources development

Whether solar, wind, hydro or biomass based, energy is now increasingly green. This section provides an overview of the current state of renewable energy deployment since early 2000s. It looks at the expansion of renewable energy across technologies and world regions. The section also emphasises the drivers for the expansion of renewable energy as well as the increasingly important role of green gas in the future of decarbonisation.

## MASSIVE ACCELERATION OF RENEWABLE DEVELOPMENT AROUND THE WORLD

Massive acceleration of renewable development around the world is driven by growing societal expectations, increasingly stringent regulations and falling costs. The relationship to energy has changed drastically in the past ten years, with a global awareness of social and environmental challenges and increasing regulation. The drop in production costs and technological breakthroughs have made renewable energy more competitive and this trend is set to continue.

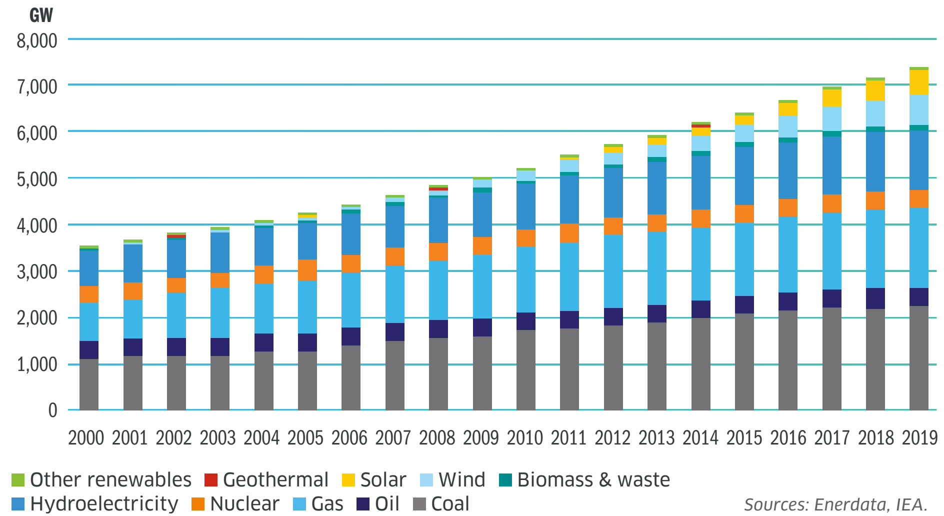
### Significant acceleration over the past decades

Over the past decades, global installed renewable energy sources (RES) capacity has more than tripled, going from 754 GW in 2000 to 2,537 GW in 2019[3]. As a result, installed RES capacity was enough to provide an estimated 27% of global electricity generation at the end of 2019[4]. The International Energy Agency (IEA) projects an even greater increase in renewable capacities worldwide, with 1,123 additional GW for wind and solar by 2025[5]. In terms of technologies, hydropower accounts for more than 50%[6] of cumulated RES capacity in 2019 (1,308 GW out of 2,537 GW). Yet wind and solar power have accounted for more incremental capacity than hydropower and have attracted most of the RES investments since 2015. More recently, the production of biogas and biomethane has experienced a significant growth. These green gases can be used in a variety of applications such as electricity, heating, and transport. Global installed capacity of biogas-based electricity generation has more than doubled, from 8.2 GW in 2009 to 18.1 GW in 2018[7] and another estimated 700 plants upgrade biogas to biomethane[8] for injection into the gas grids. Overall, although fossil-fuel generation capacities still dominate the global energy mix, renewable energy grew faster than any fossil fuel. **Fig. 1**

### Emerging economies are becoming leading players

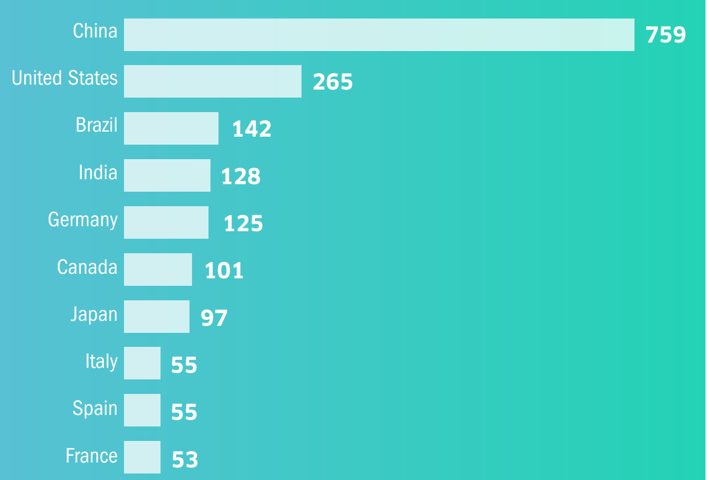
Attention is more and more being focused on emerging economies as the growth in RES developments moves beyond Europe and the U.S. to new markets. For almost a decade, China has been a leader in the global deployment of renewables. The country is the largest market for solar PV globally, with a cumulative installed capacity representing more than 30% of the global market in 2019. Solar PV capacity in the country rose significantly, from 0.8 GW in 2010 to 204.6 GW in 2019 at a compound annual growth rate of 85%. As for India, it is now among the world top emerging markets for clean energy investment[9]. Installed renewable capacity is today at 83 GW[10], plus 31 GW under development and a further 35 GW out for tender. In particular, the aggressive drive to bring solar capacity up to 100 GW by 2022 has seen solar capacity more than triple since 2015 mostly due to

**Fig. 1 - WORLDWIDE ELECTRICITY CAPACITY PER TECHNOLOGY, 2000-2019**




*Sources: Enerdata, IEA.*

**Fig. 2 - LEADING COUNTRIES IN INSTALLED RENEWABLE ENERGY CAPACITY WORLDWIDE IN 2019 (GW)**




*Sources: IRENA (2020), Renewable Capacity Statistics 2020; & IRENA (2020), Renewable Energy Statistics 2020, The International Renewable Energy Agency, Abu Dhabi).*

government-backed auctions. In America, Brazil has also achieved a visible presence as it stands as a world reference for the development of biofuels and because of the major role of hydropower in its electricity generation mix, resulting in very low emissions from its power sector. Regarding biogas and biomethane, currently over 60% of biogas production capacity lies in Europe and North America, with some countries such as Denmark and Sweden having more than 10% shares of biogas/biomethane in their total gas sales[11]. Still, countries outside Europe and North America are catching up quickly, with the number of upgrading facilities in Brazil, China and India tripling since 2015. Fig. 2

### Regulatory push created markets for RES

Several factors are driving this tremendous growth of renewable energy. Leading among these are government support policies and targets. These policies can have numerous goals, from combating global warming and reducing air pollution to ensuring energy security, providing local jobs and access to energy for all. By the end of 2019, 166 countries had renewable power targets[12]. Falling costs also play a major part in RES development. Indeed, policy incentives – in combination with substantial technology developments, boosted RES investment, allowing for economies of scale and driving down costs for many renewable technologies. The most telling example is that of solar and wind. In ten years, electricity costs from utility-scale solar PV fell 82% and declined about 39% for onshore wind and 29% for offshore wind[13]. In the end, this will allow government support mechanisms to be progressively phased out.

But if power generation has been a key focus of renewable energy policies, renewable incentives also contributed to the rise of the green gas industry. These alternative fuels have progressively come to the forefront in debates about the future of decarbonisation.

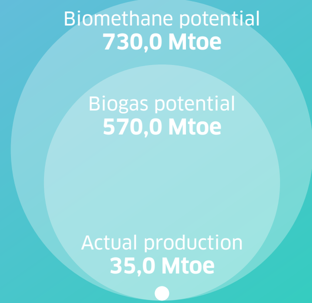
## GREEN GASES ARE ESSENTIAL TO THE ENERGY TRANSITION

“Green gases” encompass gas products originated from sustainable inputs, i.e. biogas, biomethane, renewable hydrogen and synthetic methane. Green gases constitute a double lever essential to the energy transition. Not only do they contribute to the greening of uses that are highly dependent on fossil fuels (mobility, heat, industrial processes), they are also ultimately set to play a role in balancing a low-carbon electricity system at low cost, thanks to their flexibility. Their growth has been boosted by the need to decarbonise the electricity sector and the overall energy system, owing to their distinctive ability to permeate all energy sectors.

### Biogas and biomethane have a key role to play

As flexible energy carriers, biogas and biomethane have a key role to play for decarbonisation. The biogas market largely

**Fig. 3 - BIOGAS AND BIOMETHANE PRODUCTION IN 2018 AGAINST THE SUSTAINABLE POTENTIAL TODAY**




*Source: IEA (2020), Outlook for biogas and biomethane: Prospects for organic growth, IEA, Paris*

developed out of strong policy support and incentives along with regulations mandating certain levels of adoption. IEA statistics show that biogas and biomethane[14] production in 2018 was around 35 million tonnes of oil equivalent (35 Mtoe or around 407 TWh of energy equivalent), only a fraction of the estimated overall potential[15]. Full utilisation of the sustainable potential could cover around 20% of today's worldwide gas demand[16]. Europe, the leading biogas-producing region, has around 20,000 biogas plants, with the majority situated in Germany. In Britain, recent initiatives also illustrate this growing trend towards green gas production. The five main gas network operators called for their Government to unlock £900m in switching Britain's gas grid from using methane natural gas to hydrogen and biomethane[16]. **Fig. 3**

As a flexible energy source, biogas has the potential to be used not only for renewable electricity but also for heat and, if upgraded to biomethane, to replace a portion of natural gas demand or to be used in the transport sector. This energy source has also many positive externalities. Studies conducted for the French market estimate the value of positive externalities of biomethane between 55-75 EUR/MWh[17]. Chiefly among them, the recovery of agricultural waste and the reduction in the use of chemical fertilisers by using the digestate from the fermentation process. Social and economic externalities are also important, such as job creation in rural areas to ensure the development and operation of facilities and additional income for farmers. Biogas and biomethane technologies thus create a virtuous link with the agricultural sector, contribute to local employment and rural development and put in practice the concept of a circular economy.

## Renewable hydrogen is at the heart of the carbon-neutral economy

While still in its infancy, renewable hydrogen opens significant market opportunities for RES and is at the heart of the carbon-neutral industry of tomorrow. Hydrogen is a very versatile energy carrier and feedstock which can tackle various critical energy challenges and has the potential to become a true strategic value chain. It is, moreover, the basis for synthetic gases (e-methane) and liquid fuels, which will be a crucial decarbonisation option for "hard-to-abate sectors". Historically, hydrogen was mainly used as a feedstock for industrial processes. Currently around 70 million tonnes (70 Mt, or around 2,800 TWh of energy equivalent) of hydrogen are produced globally each year [18], coming essentially from dedicated production from fossil fuels (mainly natural gas) or as a co-product of the oil industry. Hydrogen produced from renewable electricity via electrolysis ("green hydrogen") represents less than 1% of all hydrogen production[19]. Yet, in the future, these figures are expected to change dramatically. First, hydrogen can bring renewable energy to sectors (heat, industry, heavy transport) for which complete reliance on electrification would not be cost-efficient or even technically possible. Moreover, hydrogen from renewables has the potential to balance renewable power supply and demand as green hydrogen makes it possible to store variable renewable energies in big quantities. The gas infrastructure can accommodate large volumes of electricity converted into hydrogen. Hydrogen can be reconverted into electricity via fuel cells, injected into the natural gas grid or transformed into synthetic methane through methanation. This methane is indistinguishable from natural gas. The hydrogen molecule will therefore represent a critical intermediate step in the supply of the specific energy best suited to each need and an essential raw material for industry. According to the IEA, low-carbon hydrogen is expected to raise to an estimated 7.92 Mt (~300 TWh ) by 2030[20].

# Global trends in renewable energy

At a time when climate emergency is increasingly integrated into decision-making processes – at global, national, and local levels – profound changes can be observed in the energy sector. The first major trend over the past few years has been a shift away from public subsidies towards zero-subsidy projects. Another crucial trend is that the energy transition is now increasingly being driven by corporates and local authorities. In addition, as the energy sector is responding to society's demands to more decentralised and green energy, integrated solutions are emerging to replace conventional services.

## AUCTIONS AND CORPORATE PPAS ARE BOOMING

Around the world public subsidies are gradually being phased out and the use of auctions is spreading to a growing number of countries. The recent development of corporate PPAs is also part of this fundamental movement in the energy transition by which states limits their commitments and, in return, businesses and local authorities are increasingly involved. 2020 is even set to become the biggest year to date for corporates buying clean energy[21], with corporate PPAs being mainly concentrated in the U.S. and in Europe.

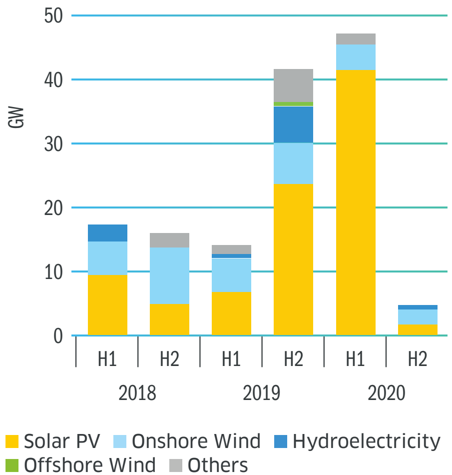
### Countries wind down subsidies for renewables projects

Growing renewable energy capacity and falling investment costs are pushing countries to wind down subsidies for renewables projects. In most countries, support schemes were a key driver for renewable energy deployment. Two main types of policies were widely used to encourage RES development. First, regulatory policies such as feed-in tariff (FiT), renewable portfolio standards (typically requiring that a percentage of electric power sales comes from renewable energy sources), net metering, biofuels or heat obligation/mandate and tendering. Second, various fiscal incentives have been implemented, from tax incentives (e.g exemption, tax credits), to direct incentives (e.g capital subsidy, grant, or rebate). Europe was a pioneer in implementation with Germany being the first European country to adopt a feed-in tariff program, followed by Denmark and Spain. FiTs cover different types of energy technologies (e. g, from residential rooftop PV to CSP plants). Yet the tariffs differ across countries or geographical locations, type, and size of technology. For example, German feed-in payments are technology and scale-specific, with larger projects receiving a lower feed-in tariff rate to account for economies of scale. In the United States, a mix of policies that includes several federal government incentives (tax credits, grants, and loan programs), net metering and renewable energy certificates helped renewables' deployment[22].
Nevertheless, while many countries all over the world have implemented this type of programs, some market grew too fast (e.g. PV) incurring significant costs and, in some cases, electricity supply-demand imbalances, calling for system optimisation and better regulation. Therefore, even if support mechanisms still play an important role in the development of renewable energy, they are gradually being reduced or phased out. This has led to more RES commercialisation, including via market-based auctions.

### Auctions for large-scale, centralised projects

Many countries are using competitive auctions instead of feed-in policies for large-scale, centralised projects. Renewable projects around the world are increasingly willing to take fluctuating market prices. In the first half of 2020, 13 countries awarded almost 50 GW of new renewable capacity to become operational during 2021-24, the highest amount to date[23]. China's solar PV auction awarded 25 GW in June 2020, marking the trend globally[24].In 2019, at least 68 renewable energy auctions or tenders were held across 41 countries at the national or state/provincial level[25]. The ensuing competition through auctions triggered record low bid levels for new solar PV and wind power. **Fig. 4**

## Fig. 4 - RENEWABLE ELECTRICITY AUCTION RESULTS BY TECHNOLOGY, 2018-2020



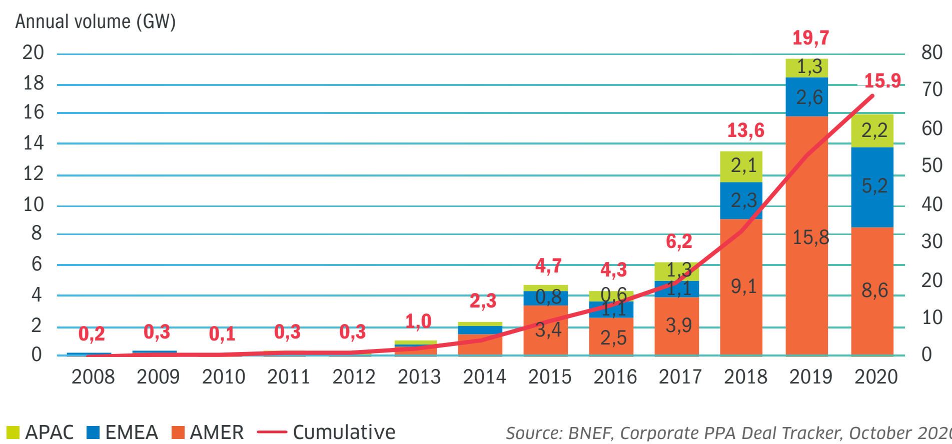

*Source: IEA (2020), Renewables 2020, IEA, Paris.*

In 2010, energy was contracted at a global average price of almost USD 250/MWh for solar and USD 75/MWh for wind[26]. With falling technology costs, in 2019, global average solar PV prices reached USD 57/MWh[27] and onshore wind prices USD 48/MWh. Concentrated solar power (CSP) was most notably auctioned in the United Arab Emirates (e.g Dubai awarded 700 MW at a price of USD 73/MWh[28]). As for biomass auctions, they were concentrated in South America and Europe. For instance, Argentina awarded 143 MW of biomass at an average price of USD106.7/MWh[29]. Overall, auctions have proven to be an effective mechanism for large RES generation, less so in the case of for small and medium-sized installations. A growing number of countries are thus adopting a combination of policies to develop renewable energy sources on a more tailor-made basis to adapt to technologies and applications.

## PPAs are on the rise

PPAs are on the rise as more corporates and local authorities strive to "go green" while controlling their energy costs. In recent years, there has been a growing trend in projects that do not fall within the framework of direct or indirect subsidies granted by the states. This movement started in the United States, continued in Latin America and recently in Europe. The answer to guarantee the development of such projects and their long-term viability are corporate PPAs. PPAs are long-term contracts (typically 10 to 20 years) under

## Fig. 5 - WORLDWIDE CORPORATE PPA VOLUMES, BY REGION




*Source: BNEF, Corporate PPA Deal Tracker, October 2020.*

which a purchaser "offtaker" (e.g. a supply company) agrees to purchase electricity directly from a power producer (e.g. a wind or solar plant). The interest of cities and large companies is twofold: ensuring their supply of green energy while benefiting from long-term visibility on prices. Born from the GAFA[30] for the supply of their data centers with energy, this movement today extends far beyond. An illustration of this trend is RE100, a collaborative, global initiative with over 260 businesses committed to 100% renewable electricity[31]. To achieve this goal, they must match on an annual basis 100% of the electricity used across their global operations with renewable electricity – biomass (including biogas), geothermal, solar, hydro and wind – either sourced from the market or self-produced[32]. Likewise, C40 – a group of 97 of the world's leading cities – is focused on tackling climate change and driving urban action reducing greenhouse gas emissions and climate[33]. Overall, over the years, global corporate PPA volumes have experienced a tremendous growth, from 0.1 GW annual volume in 2010 to 19.7 GW in 2019 and already 15.9 GW in 2020 (ahead by 0.5 GW compared to last year at the same point in time)[34]. ENGIE was the No.1 world seller of clean energy Corporate PPAs in 2019[35]. The Group signed over 2,000 MW in 2019 mostly in the U.S. but also in Spain and aspires to sign 4,500 MW by 2021. **Fig. 5**

## DECENTRALISATION OF THE ENERGY SYSTEM

Decentralisation of the energy system – a source of resilience – is accelerating and leading to progressively more integrated solutions. The development of new technologies and the increasing disintermediation of actors is also enabling the decentralisation of energy production. From private individuals to industrial operators, customers are now looking for customised and comprehensive solutions.


### A more and more local energy production

With the rapidly falling costs of RES and storage, energy production is becoming more and more locally embedded. Historically, the operation of energy systems relied on large electricity production plants and vast gas fields, along with electricity and gas transmission and distribution networks. Ultimately, some of the energy needs will be produced at the consumption site (individual housing, companies, industrial sites, local authorities). Individual consumers, both private and industrial, become energy producers ("Prosumers").

A decentralised energy system is characterised by the integration of energy production and consumption in a common location. Decentralisation is occurring for various reasons throughout regions, materialising very differently. In Europe or North America, decentralisation comes along with an energy transition targeting climate change mitigation. Other drivers also contribute to this decentralisation process such as a willingness of consumers to have access to a cheaper and more reliable energy. In regions such as Africa or a large part of Asia Pacific, access to energy in remote rural areas is a big challenge. There, it is more a consequence of an economic trade-off between decentralised generation costs and grid extension costs. For example, where there is no grid access for heat and electricity, decentralised applications of biogas in rural zones are promising as the needed wet biomass input is local and rural. Biogas is thus recognised for its easy access (local resource, production on site, consumption on site). A lot of programs for biogas development are emerging in rural areas in developing countries (e.g Tanzania Domestic Biogas Programme to install 10,000 biogas plants)[36]. This revolution has been facilitated by the development of distributed energy resources (DER), which include dispatchable technologies like cogeneration units or biogas plants, variable renewable energy sources like wind and solar as well as energy storage (e.g batteries) and demand response (DR). These technological breakthroughs are changing business models and require infrastructure and offerings to be adapted to the coexistence of centralised and decentralised production systems.

All this being said, while decentralised production will certainly continue to increase, studies indicate that by far most of the new renewable energy investments in the next decades will be in utility-scale renewable energy production, and mega-scale renewable energy projects (>1000 MW) will become more and more common in regions with excellent renewable resources.

### Opportunities for integrated energy solutions

The growth of decentralised generation provides opportunities for integrated energy solutions. With the appearance of "behind-the-meter" solutions next to centralised renewable energy projects, new business opportunities are emerging. More and more cities and corporates are asking partners that can advise, design, install, operate, and finance integrated energy solutions. Integrated solutions including equipment financing and on-site production, excess heat and cooling, storage, as well as large-scale central assets can support the uptake of decentralised energy systems. For instance, optimal and coordinated integration of decentralised production and storage assets with smart energy management and electric vehicle charging solutions are some of the essential steps towards energy-efficient, smart building.

To adapt to these new needs in the carbon-neutral transition, ENGIE offers complete and integrated services, with tailored and co-financed solutions (energy, lighting, mobility, etc.) combining the latest technologies with a multi-disciplinary approach. For example, in 2017, the Group launched a 50-year partnership with Ohio State University in the United States to manage the sustainability, operations, and supply of their energy assets. ENGIE invested 1.2 billion euros and will be responsible for managing the university's energy systems with guaranteed energy efficiency improvements covering 485 buildings. ENGIE's expertise in facility management, supply, distributed generation, and efficiency helped develop a portfolio of custom-made solutions to address Ohio State's plans of a 25% decrease in campus buildings energy consumption by 2025.

# Going forward: the role of renewables in a decarbonised economy

Renewables have a key role in the decarbonisation of power, building, industry and transport sectors. Driven by public support over many years and enabling regulatory frameworks, electricity generation from renewables makes an important contribution to an increasingly decarbonised power mix. There remains, however, sectors for which decarbonisation is a challenge. Renewable heating (and cooling) still offers vast unexploited potential for buildings and industry. Achieving ambitious levels of RES is also particularly challenging for transportation, which began to decarbonise with e-mobility, bio-CNG and bio-LNG and a rapidly growing role for hydrogen fuel cell. In each of these sectors, renewable gases, renewable electricity, and a more integrated use of energy carriers are required for the emergence of a carbon-neutral world.

## MAINTAINING A RESILIENT AND COST-EFFECTIVE ENERGY SYSTEM

The power sector has already made great achievements toward decarbonisation. However, wind and solar generation is variable by nature, requiring flexibility and back-up solutions to keep the power system in balance and ensure security of supply while continuing to decarbonise in a cost-efficient way. Making full use of green gases will play an important role in maintaining a resilient and cost-effective energy system.

### More flexibility is needed

The share of renewable generation technologies in the electricity sector is growing continually. However, some renewables are variable, and the cost of accommodating a rising proportion of RES is growing. Flexibility needs increase strongly with RES penetration. To address these challenges, flexibility sources are multiple. Among them, demand-side management (energy efficiency and time-based management) and storage are complementary and poised to grow rapidly. Demand side management consists in reshaping customer load profile by using its flexibility. In particular, Demand Response (DR) is a competitive source of capacity and flexibility with a large market potential (it could represent 10-20% of the peak demand). It consists in valorising flexibility by curtailing or shifting part of the load, that can be used to release the constraints of the power system, take advantage of the market context (arbitrages) and sell customers innovative offers. But if demand-side management surely has a role to play, storage solutions are just as essential. Several storage technologies exist, at different scales and different maturities. Large scale technologies include for instance pumped hydro storage and compressed air storage. For short duration storage use cases, batteries will likely lead the way. One of batteries' key advantage is that they are versatile and modular. The current Lithium-ion (Li-ion) battery's dominance has been largely driven by declining costs following the increase in production to meet growing demand for consumer electronics and electric vehicles. Li-ion batteries are indeed the most suitable solution for battery electric vehicle (BEV), with their high energy density per volume and good power/energy ratio. However, the family of battery technologies is very large and other technologies than lithium-ion might be preferred for stationary storage. Moreover, for some uses (e.g. requiring large capacity of long duration storage), batteries will not be the most affordable solution. Other flexibility sources are therefore indispensable, in particular the conversion of electrical energy into chemical energy (hydrogen, e-methane,...).

### An energy transition relying on multiple energy

An energy transition relying on multiple energy carriers – including green gases - is more resilient and more cost-efficient.

Green gases have a much-needed role in the energy transition. They can use existing infrastructure and do not have variability issues. Biomethane has already started to substitute natural gas in various developed countries. Also, hydrogen and synthetic fuels can be a solution to the challenges of variable renewable energy production via "Power-to-Gas". Electricity is converted to hydrogen using an electrolyser, then pressurised and injected into a natural gas grid. This technology is expected to be deployed on a mass scale starting in 2025[37] and ENGIE has been coordinating two major experimental projects since 2013: the GRHYD project near Dunkirk (Cappelle-la-Grande) which tests the injection of green hydrogen into the gas distribution network and the production of hythane (a blend of hydrogen and natural gas) for NGV buses; and the Jupiter 1000 demonstrator in Fos-sur-Mer, the first project at industrial scale in France where ENGIE tests the production of methane from renewable electricity. In addition to being a great medium for long term storage, green gas is the “missing link” for coupling the electricity, gas and heat sectors thus ensuring a decarbonised energy system. Indeed, while the power sector demonstrates the most important RES share, other sectors, such as buildings, industry and transport still rely largely on fossil fuels. To decarbonise these sectors, a mix of electrification and substitution of the fossil fuels by green gases, along with synthetic fuels, is necessary.

## Unexploited potential in buildings and industry

Heat is the largest energy end-use, accounting for 50% of global final energy consumption, significantly more than electricity (20%) and transport (30%) [38]. Yet fossil fuels continue to lead heat supplies. Therefore, the use of renewable energy systems for both industrial and domestic heating (and cooling) applications is receiving increasing attention. According to the IEA, heat generated from renewable energy is set to expand by one-fifth between 2019 and 2025[39]. Buildings should account for 24% of global renewable heat growth, followed by industry (15%). Several technologies exist to tackle the colossal task of incorporating renewable energy into these sectors. For buildings, mature renewable heating and cooling technologies using biomass, solar, geothermal or green gases are available to reduce $CO_2$ and fossil fuel use. For industrial applications, hydrogen and synthetic fuels could play a key role.

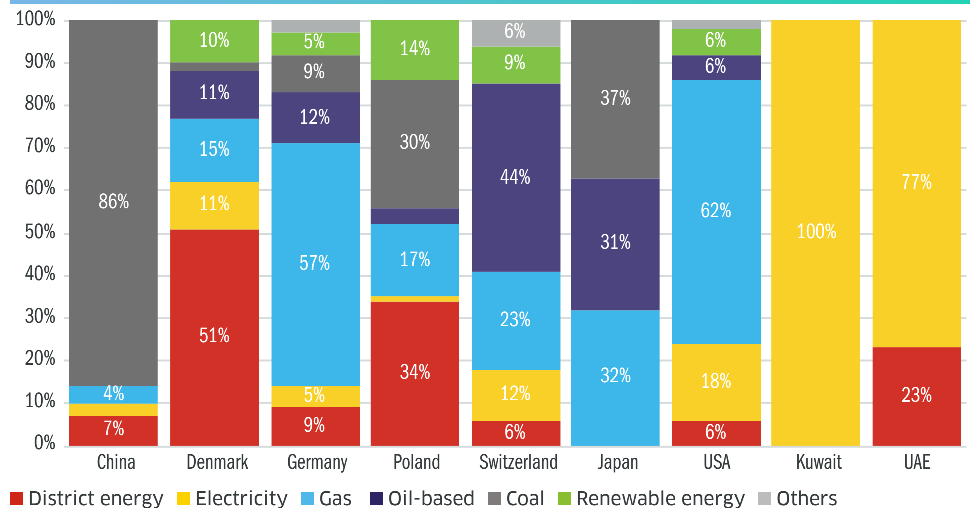
## A wide range of renewable technologies to decarbonise heating and cooling

While heating and cooling are currently largely served by fossil fuels, a wide range of renewable technologies exist to decarbonise these applications. Industrial processes accounted for 50% of total heat consumed in 2020, while another 47% was consumed in buildings[40]. With rising temperature, cooling is also a major driver of energy demand. Renewable heating and cooling are therefore expected to accelerate their development. Clearly, energy efficiency will be a component of the equation, but in addition to energy savings, different technologies (district heating, green gas, electrification) will have to play a major role. Fig. 6

Renewable energy met less than 12% of total energy demand in buildings in 2020[41]. Yet a wide range of renewable technologies exist to raise renewable heat consumption. Among them figures district-level energy.

District heating and cooling (DHC) networks distribute heat for domestic hot water, space heating or cooling in buildings, and industrial processes[42]. It is an old and well proven technology, which historically developed in Europe, in the United States, in Russia and in Asia (mainly China). While it used to rely mainly on fossil fuel-based energy supply, DHC can today use many different energy sources such as green gas and other RES which allow DHC to play a key role in the energy transition, as an integrator of many

**Fig. 6 - BREAKDOWN OF HEATING AND COOLING ENERGY USE TODAY*: SHARE OF TOTAL HEATING AND COOLING DEMAND**




*Source: IRENA (2017), Renewable Energy in District Heating and Cooling: A Sector Roadmap for REmap, International Renewable Energy Agency, Abu Dhabi.*

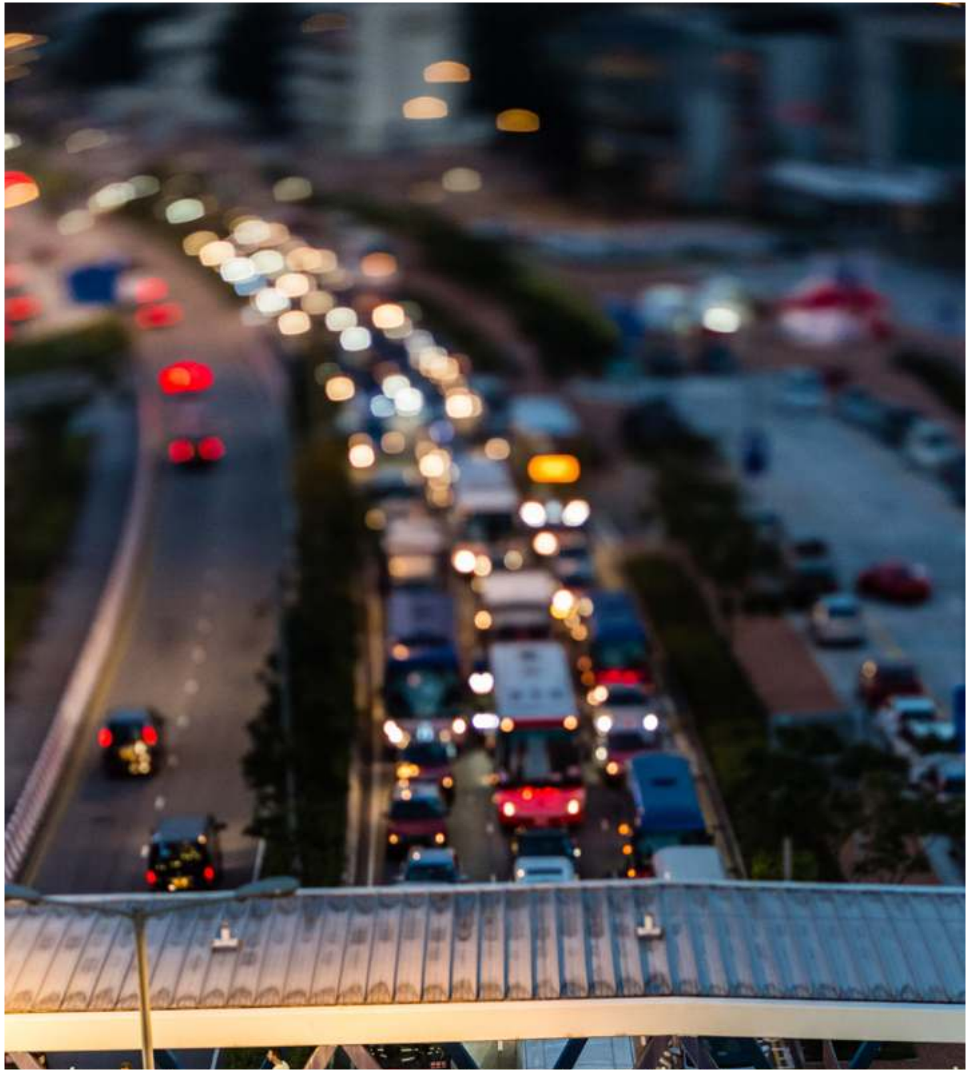
* Cooling is included for Japan, the U.S., Kuwait and the UAE.

different energy solutions. District heating systems also become increasingly integrated with other parts of the energy system. Either through waste heat from industry, cogeneration solutions, and use of electricity in large-scale heat pumps during hours of high production of variable renewable energy. Renewable energy sources are also available for district cooling system (e.g via electric or absorption chiller with RES, free cooling sources such as rivers or lakes etc.). Furthermore, thermal storage can help to develop RES in district heating and cooling. DHC can therefore represent an important source of flexibility to integrate variable electric renewable energy sources. Worldwide growing urbanisation should reinforce the interest for DHC, especially in developing countries as population growth and urbanisation are projected to add 2.5 billion people to the world's urban population by 2050, with nearly 90% of the increase concentrated in Asia and Africa.

At the house level, insulation and individual heating system will still play a major role in the energy transition. Most buildings in Europe are connected to the gas grid and many of them already have gas boilers installed – making renewable methane an easy and competitive solution to decarbonise heating systems. Hence, keeping a water loop in buildings is important as green gas represents an opportunity to make use of existing gas infrastructure. Green gas is also an attractive option for new buildings both from an individual financial perspective and from a system-perspective as it avoids an increase of power peak demand and corresponding investments in the power system. For instance, hybrid heat pumps (coupling of an electric heat pump and high-performance gas boiler) are a solution to combine renewable power and efficiency with highly efficient gas heating thus shaving peaks and providing flexibility to the power grid.

## GHG emissions can be significantly reduced

GHG emissions from industry can be significantly reduced with renewable and decarbonised gases. In industry, the share of renewables in heat consumption globally is projected to remain almost unchanged at 10% in 2020[43]. The wide range of temperatures and processes make the industry sector difficult to decarbonise. Electrification is challenging (or even not possible for some applications with temperatures above ~200°C) and the sector is anticipating stronger constraints on $CO_2$ emissions, resulting in a real demand around the $CO_2$-free factory. A promising solution consists in replacing natural gas and grey hydrogen by renewable and decarbonised gases, including bio-/e-methane and renewable hydrogen. Indeed, industries are important consumer of natural gas, mainly for combustion processes (e.g. in industrial cogeneration or high temperature applications) but also as a feedstock (production of hydrogen via SMR, methanol, ammonia etc.). Hydrogen ($H_2$) is already the key ingredient to make ammonia, but the vast majority of $H_2$ today is made from fossil fuels making the ammonia sector responsible for around 1% of global greenhouse gas emissions. In the ammonia chemical industry, hydrogen could be substituted with renewable hydrogen, thus removing virtually all carbon emissions from the ammonia production process. In the steel sector, hydrogen could potentially displace part of the need for fossil fuels by acting as a feedstock for the chemical reaction necessary to reduce iron ore to pig iron, and also by providing high-temperature heat for the steel-making process, thereby eliminating coal or replacing gas-based processes.



## A RECONFIGURATION IN THE TRANSPORT SECTOR

A profound reconfiguration is needed in the transport sector, requiring a system-based approach, not only in the vehicle fleet, but in the energy infrastructure and energy carriers. Despite sustained growth in biofuels and electric vehicles (EVs) as well as energy efficiency improvements, transport remains the sector with the lowest share of renewable energy, at only 3.3%[44]. Most of its energy needs are still met by oil and petroleum products. Yet with cities increasingly taking strong measures to solve their problems of air pollution and urban congestion, greener mobility solutions are emerging. E-mobility will play an important role, notably for passenger cars, light commercial vehicles and progressively heavier vehicles (buses, trucks) for peri-urban uses.

Electrification of long-distance trucks or coaches is however extremely challenging both for technical/operational reasons and economic reasons. Already today, alternative solutions exist. Biomethane-fueled vehicles offer a pathway to reduce the carbon and polluting effects of the road transport sector, in particular public transportation and goods transporation. Vehicles powered by renewable hydrogen could also be used to develop vehicles with no harmful emissions, able to run for substantial periods without refuelling.

### The transport sector needs a profound reconfiguration

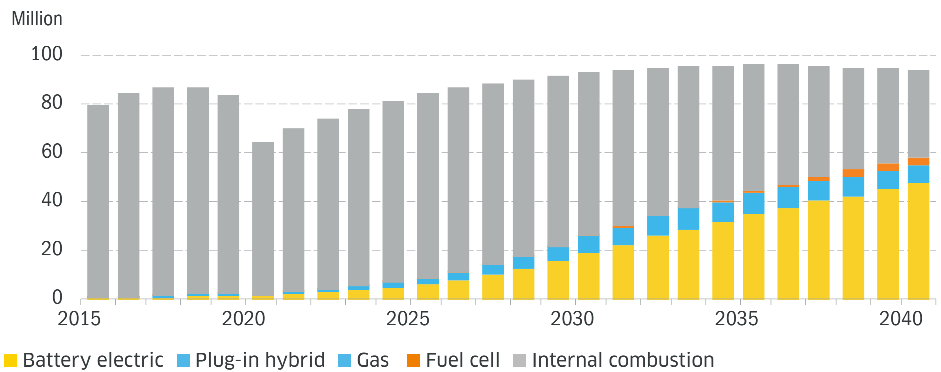
Faced with high levels of $CO_2$ emissions, fossil fuels depletion, and population growth, the transport sector will undergo a profound reconfiguration. Mobility alone accounts for 20% of global energy consumption, 24% of global $CO_2$ emissions[45], and a 95% dependency on oil. In addition, with more than half of the world's population now living in urban areas, local air pollution (particulate matters) is a key local concern. Governments will be instrumental in shifting green mobility from a vision into a reality, from establishing stringent $CO_2$ emissions targets to providing incentives. Some countries are planning to ban petrol and diesel cars from sales in a near future (Austria, Germany, India, Norway etc.). At a more local level, several cities are already taking strong measures to solve their problems of air pollution and urban congestion. Examples of local initiatives include the Global Covenant of Mayors for Climate & Energy[46], which aim to be the world's largest coalition of mayors promoting and supporting voluntary action to combat climate change and move to a low-carbon economy. By 2030, Global Covenant cities and local governments could account for 2.3 billion tons CO2eq of annual emissions reduction[47]. To achieve these goals, improving energy efficiency of combustion technologies will clearly not be enough. Cleaner solutions need to offer cost-effective and convenient transportation for users. Not all solutions are suitable for all types of mobility, so it will be necessary to adopt a mix of technologies and make them co-exist.

## E-mobility will play an important role

While most car still run on fossil fuels, the present dynamics in electric mobility are set to change this situation. Traditional engines will lose market share in favour of electric drive systems. The transitional solution will move from hybridisation to plug-in hybrid vehicles, and then 100% electric due to strong political support. By 2030, over 100 million electric cars are expected on the roads[48]. Half of the electric vehicles should circulate in China, the second half in India, in the United States and in Europe (15% of the vehicles transporting passengers in Europe could be electric vehicles). E-mobility will play an important role for light vehicles, but electrification of heavy vehicles is a lot more challenging. Fig. 7

However, as electric vehicles develop, their contribution to the integration of renewable energies raises many questions which remain open today. A growing number of EV can lead to a challenging situation for the electricity grid if charging of those vehicles is uncoordinated, thereby increasing the stress on the electricity network. Smart charging will be key to avoid network issues at peak hours and vehicle-to-grid (V2G) can become a source of flexibility to the power grid. But V2G is only at the beginning of its development. Moreover, other barriers such as long recharging times, weight of the battery and high CAPEX of electric trucks remain a challenge and still limit e-mobility potential for some applications.

**Fig. 7 - WORLDWIDE ANNUAL PASSENGER VEHICLE SALES BY DRIVETRAIN**




*Source: BNEF, Electric Vehicle Outlook 2020, May 19, 2020.*

## Mobility powered by green gas

Gas vehicles (CNG and LNG) operating with an increasing share of biomethane offer many benefits in transport. Among them, comfortable driving range, fast refuelling times, cost competitiveness with diesel and petrol, reduction of noise and air pollution, etc. As for fuel cell electric vehicles (FCEVs) - powered by hydrogen – they are currently at their beginnings but are believed to be a game changer in the next decades, notably thanks to high vehicle autonomy and short refuelling time. If hydrogen is produced from RES, it does not generate any greenhouse gases, nor does it emit NOx, Sox or particulate matter.

Going forward, technological breakthroughs in the field of synthetic fuels (e-methane and others) could further transform the transport sector. Synthetic fuels are different than biofuels as they do not rely on agriculture crops. They require the conversion of $H_2$ and $CO_2$ to fuels, via Fischer Tropsch conversion or methanol synthesis. This combination of gases including hydrogen and hydrogen-derived synthetic liquid fuels could be used for heavy-duty vehicles, and no modification of the ICE would be needed as the synthetic fuel nature is the same as the fossil one. Other sectors are under study, such as rail travel, river transport, cruise ships and aviation. For instance, maritime transport today relies strongly on heavy fuel oil, and LNG is the only available decarbonisation option in the short term. Still, in the medium term, fossil LNG could increasingly be mixed with liquified renewable methane. In the longer term, liquid hydrogen could also be a suitable option. However today, available solutions for producing, storing, and transporting liquid hydrogen are limited. ENGIE has launched a research program that aims to halve the costs of producing and transporting hydrogen by developing new liquefaction processes. Projects are also ongoing in South America to provide industry with hydrogen-based maritime transport solutions[49].

# Panorama of renewable solutions

Renewables account today for 2,537 GW of installed capacities across the world[50]. Massive financial support, improving technologies, economies of scale and increasingly competitive supply chains have enabled the cost-competitiveness of renewable power generation to reach historic levels. Since 2010, electricity costs from utility-scale solar PV fell 82%, followed by a 47% decline in concentrating solar power (CSP), with onshore wind at 39% and offshore wind at 29%[51]. But if the share of renewables in global electricity generation reached almost 27% in 2019[52], these energies are by nature variable, requiring flexibility and back-up solutions to preserve the balance of the electricity system and guarantee the security of supply. To achieve a truly sustainable energy system, flexible low-carbon energy vectors (biogas, biomethane, hydrogen) constitute a double lever essential to the energy transition. They contribute to the greening of uses that are highly dependent on fossil fuels (mobility, heat, industrial processes) and they are ultimately set to play a role in balancing a low-carbon electricity system at low cost.

This chapter 2 provides a panorama of the different renewable energy solutions, highlighting key facts and figures and showing examples of ENGIE's expertise in each of them.

# Wind power

Between 1990 and 2019, wind power increased from 3.8 TWh to 1427 TWh, achieving an average annual growth rate of 23%. This is the second fastest growth rate of renewable electricity after solar photovoltaic [53]. Owning to technology improvements and cost decline, onshore wind is now one of the most competitive sources of electricity available, consistently delivering electricity for $0.05 to $0.12/kWh without financial support (compared to a range of $0.045 to $0.14/kWh for fossil fuel power[54]). In the coming years, offshore will be the most promising wind segment as its global cumulative installed capacity is expected to increase almost ten-fold by 2030 (from 29 GW in 2019 to 228 GW in 2030)[55], with emerging markets in Asia taking the lead in the coming decade.

## NEW OPPORTUNITIES IN WIND ENERGY

While onshore wind appears today as one of the most competitive sources of electricity, rapid development of the technology opens new opportunities for offshore wind power projects. Wind power describes the process by which wind turbines harness the strength of the wind to convert its kinetic energy into mechanical energy, which is then used to generate electricity. This technology has been improving rapidly, with larger turbines – increasing from 30 kW to 10 MW in just 30 years[56] – allowing better energy capture. These improvements are reflected by the costs of generation of both onshore and offshore wind, which have plummeted by 39% and 29% respectively over the past ten years. In 2019 alone, electricity costs from onshore and offshore wind both declined by about 9%, reaching $ 0.053/kWh and $ 0.115/kWh, respectively[57].
Offshore wind is particularly promising as this technology offers higher capacity factors compared with onshore[58]. The technical potential for offshore wind worldwide is huge, representing more than 120,000 GW, with the capability to generate 420,000 TWh of electricity per year (more than the total amount of electricity consumed worldwide)[59]. However, a large share of offshore wind resource is in deep waters, off the coasts of South America, the United States (where 61% of offshore wind resource are deeper than 100 m), Japan, Korea and parts of Europe. Several innovations are thus being tested to realise the full potential of wind. For instance, floating foundations aim to overcome technical and financial challenges of deep water. While they are not a substitute of offshore fixed foundations, floating structures allow projects to be installed further from the coast in areas of great depth (> 50 m). As for airborne wind energy (AWE), it can also unlock suitable wind resources unreachable by conventional wind turbines as it is capable to fly at altitudes of 300 m. At such high altitudes, the capacity factor is estimated to reach between 50 and 70%. Another challenge has to with practical constraints (e.g. securing legal and physical access to grid) and in integrating higher levels of variable wind power into the grid. In this regard, offshore-generated hydrogen could be a promising solution as hydrogen can be transported in both pipelines and ships. In large-scale offshore wind farms in the German North Sea and other locations, producing hydrogen from wind could improve energy security, lower price volatility and be a solution to curtailment [60], thus offering further market growth opportunities for wind.

> **Technical potential for offshore wind:**
> **120,000 GW**
> **offshore wind worldwide**
> **420,000 TWh**
> **of electricity production per year**

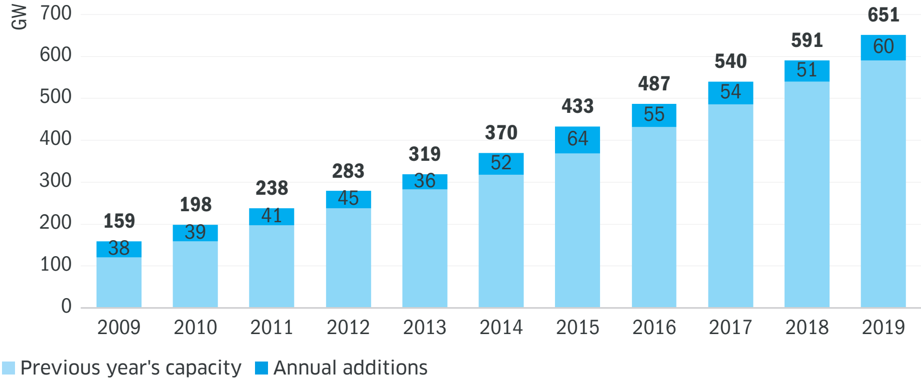
## OFFSHORE WIND, THE ENERGY OF TOMORROW

In 2019, the wind energy market reached a record of 651 GW global cumulative installed capacity. Globally there is just over 29 GW of offshore wind installed capacity, accounting for a tiny 5% of global wind capacity. Yet, going forward, it is the segment that provides the most potential for expansion.

Offshore wind is expected to grow much faster than onshore at 15%[61] over the next 10 years against a compound annual growth rate of less than 2% for onshore wind. **Fig. 8** By 2030, 163 GW of new offshore wind capacity and 631 GW of new onshore capacity are projected to be installed, making the cumulative capacity of wind reach more than 1,400 GW[62]. **Fig. 9**

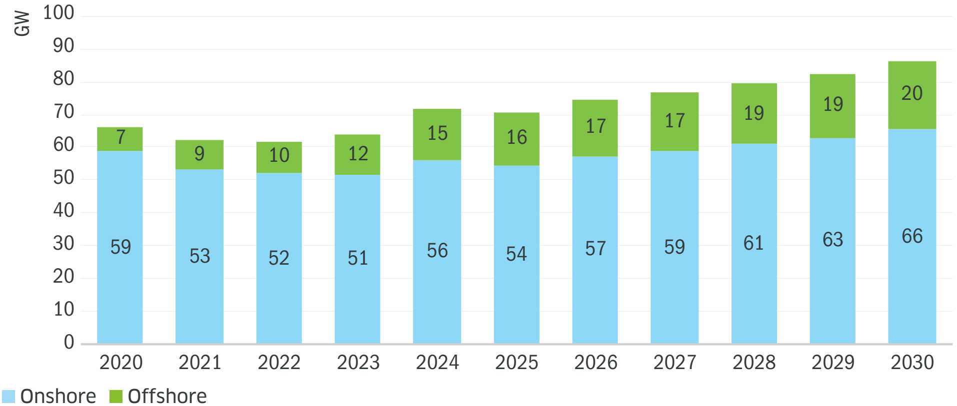
In Europe, Denmark, Germany and the United Kingdom were pioneer markets for wind and remain established leaders with the United States. Europe saw a 30% growth in new installations in 2019, which is primarily due to strong demand in Spain, Sweden and Greece. But in terms of annual capacity additions, Asia Pacific ranks as the No.1 in onshore wind with 27.3 GW in 2019 (largely in China) and also appears as the most promising offshore market, growing at the fastest rate with the most capacity (Asia pacific is expected to add 58.6 GW of offshore wind capacity over the next 10-years).

**Fig. 8 - GLOBAL WIND POWER CAPACITY AND ANNUAL ADDITIONS 2009-2019**




*Source: REN21. 2020. Renewables 2020 Global Status Report (Paris: REN21 Secretariat).* REN21

**Fig. 9 - GLOBAL ANNUAL WIND CAPACITY ADDITIONS BY TECHNOLOGY**




*Source: Guidehouse Insights, Global Wind Energy Database, 2Q 2020.*

## ENGIE: THE EMERGENCE OF A SUSTAINABLE INDUSTRIAL SECTOR

ENGIE is investing in major projects and actively participates in the emergence of a sustainable industrial sector. The leader in wind energy in France, with 2.57 GW installed capacity (@100%), ENGIE has launched numerous projects worldwide. The Group has a total of 8.5 GW onshore wind installed capacities, across the 5 continents and aims to achieve more than 12 GW of installed capacity in wind by 2021 [62]. To capture the tremendous potential of offshore wind, ENGIE is investing in major projects, including the world's largest floating offshore platform, Windfloat Atlantic, in Portugal.

**As an integrated operator, ENGIE plans, builds, operates, and manages wind generation assets.**

- **In France,** the Caudresis Wind Farm was commissioned in January 2020. With a generation capacity of 50.4 MW and 14 wind turbines, it is a joint project with Predica Energie Durable (PED) a subsidiary of Prédica, Groupama and la Caisse des Dépôts.
- **In Belgium**, a key project of the Group is the Maldegem Eeklo Kaprijke wind complex. It has a 21 MW generation capacity (commissioned in 2020) and 9 wind turbines operated by a 50:50 joint venture with Conquest.
- **In Brazil**, ENGIE's largest wind project is the Umburanas Wind complex. It counts 605 MW of generation capacity (of which 360 MW commissioned in 2019) with 144 wind turbines across 18 wind farms.
- **In Morocco**, ENGIE operates Africa's largest wind farm in terms of capacity: Tarfaya. The farm has a 316 MW generation capacity with 131 wind turbines. Commissioned in December 2014, it is operated by a joint venture with Nareva.
- **In Egypt**, ENGIE operates the country's largest wind farm: Ras Ghareb (262.5 MW). The Ras Ghareb project started commercial operation in October 2019. It is the first wind farm tendered on a Build-Own-Operate (BOO) scheme in the country.

> **ENGIE is the leader in wind energy in France, with 2.57 GW**

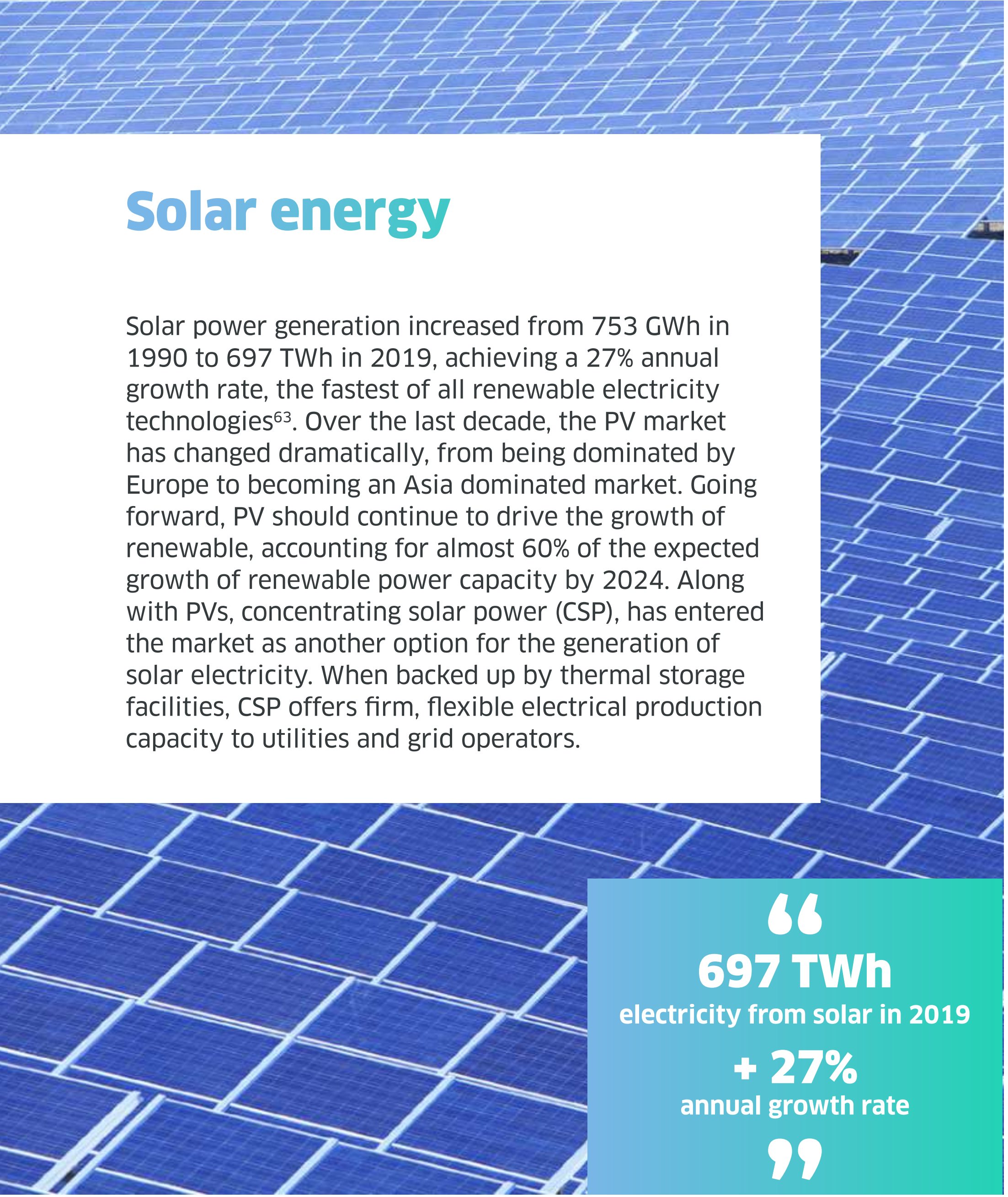
**Offshore wind power represents a strong area of development. ENGIE operates through two technologies: fixed and floating offshore wind.**

- In January 2020, ENGIE established Ocean Winds, a 50 50 joint venture with its Portuguese peer EDP Renewables. The objective is to create a world leader in offshore wind energy, reaching between 5 GW and 7 GW of projects in operation or under construction and between 5 GW and 10 GW in advanced development by 2025. The joint venture allows faster growth, large scale projects and improved operational efficiency.

→ **In Portugal**, 25 MW of floating offshore wind were commissioned in 2020 for the world's largest wind turbine on a floating platform.

→ **In France**, two offshore wind farms off the coasts of Dieppe-Le Tréport and the Yeu and Noirmoutier islands with a total capacity of approximately 1,000 MW will produce the equivalent of the energy consumption of 1.5 million inhabitants.

→ **In the United Kingdom and in Belgium**, two offshore projects – Moray East (United Kingdom) and SeaMade (Belgium) are in construction for a total of 1.5 GW.



# Solar energy

Solar power generation increased from 753 GWh in 1990 to 697 TWh in 2019, achieving a 27% annual growth rate, the fastest of all renewable electricity technologies[63]. Over the last decade, the PV market has changed dramatically, from being dominated by Europe to becoming an Asia dominated market. Going forward, PV should continue to drive the growth of renewable, accounting for almost 60% of the expected growth of renewable power capacity by 2024. Along with PVs, concentrating solar power (CSP), has entered the market as another option for the generation of solar electricity. When backed up by thermal storage facilities, CSP offers firm, flexible electrical production capacity to utilities and grid operators.

**697 TWh**
electricity from solar in 2019

**+ 27%**
annual growth rate

## SOLAR ENERGY CAN BE USED IN A MULTITUDE OF APPLICATIONS

One of the key advantage of PVs is that they can be deployed in a modular way almost everywhere on the planet. The PV technology is exceptionally scalable, ranging from watt-scale to hundreds of megawatts. Photovoltaics cost fell by 82%, between 2010 and 2019[64], with the lowest levelised cost of electricity (LCOE) of utility-scale solar PV now reaching 10 euros/MWh, under best possible sites. These cost improvements were driven by a 90% reduction in module prices, along with declining balance-of system costs and should continue to drop over the next decade[65]. In addition, the distributed use of PV is raising the prospect of industrial plants and other businesses to generate their own electricity. But despite attractive economics there remain significant technical and logistical barriers to solar projects, from energy yield to land requirements and pressures on critical materials (silicon, gallium, germanium, indium and selenium[66] etc). To address these challenges, module and system components innovation are continuing to increase energy efficiency and push LCOEs lower and lower. Bi-facial modules might potentially increase the energy yield at system level by 5-10% without optimisation of designs[67]. Another example of innovation are thin films and organic solar cells, driven by the need for low-cost, lightweight, and easy to manufacture PV[68]. As for the challenge of competition for land, several concepts have emerged, such as floating PV which are already being developed on lakes and dams as well as agri-photovoltaics ("agrivoltaics") – a solution combining food and solar energy production on the same area of land. Finally, possible actions to avoid raw material shortages include increasing recycling or substitution of critical materials whenever possible and economically feasible[69].

On top of PV, solar power can also be used in form of concentrated solar power (CSP). While photovoltaics generate electricity directly from sunlight, CSP plants concentrate solar irradiation to heat a fluid, which runs a turbine and an electricity generator. Costs for CSP – still less-developed than PV– fell 47% over the past 10 years, now amounting to USD 0.182/kWh on average[70]. CSP's significant advantage is that it can integrate low-cost thermal energy storage to generate electricity, thus enabling the production of dispatchable electricity. Yet systems need to be large (tens of megawatts or larger), implying large land requirements and they can only exploit direct solar radiation. CSP is therefore of most interest in power generation in sun-rich regions, thus restricting the land base suitable to regions in Africa, the Middle East, the Mediterranean, and in the United States (California).

## A STRONG GROWTH IN DISTRIBUTED INSTALLATIONS

Currently, the global cumulative solar capacity is estimated at 633 GW, with 627 GW for solar PV and only 6.2 GW for CSP. This represents an impressive increase compared to 2010, when solar PV accounted only for 40 GW and CSP for 1.2 GW[71]. In 2019 alone, the PV market increased 12%, with 115 GW new additions. Even though CSP is much less deployed, its capacity still grew 11% in 2019, with 600 MW of capacity added. **Fig. 10**

Regionally, the past decade has seen strong demand for solar PV in Europe and the United States, but since 2015 China is the country with the largest PV power capacity, with more than 200 GW. The European Union follows with a cumulative installed PV power of 130 GW.

Looking forward, an estimated 1,955 GW of solar PV is expected to be installed between 2019 and 2028[72]. Currently, annual additions are largely driven by utility-scale projects but the deployment of distributed solar PV systems has increased significantly in recent years and should continue, with steady growth in commercial and industrial applications. Distributed solar PV is expected to account for about 1,028 GW, or just over 52.5% of overall capacity additions. Utility-scale installations are anticipated to make up the remaining 927 GW or 47.5%[73]. **Fig. 11**

As for CSP, development remains slow, despite interest. The United States and Spain are the two largest markets in terms of cumulative capacity (Spain with 2.3 GW, U.S. with just over 1.7 GW). The pipeline in other countries is strong, with 230 MW commissioned in Israel in 2019, followed by China with 200 MW (the country has a target of 10 GW operational CSP plants by the end of 2020) and South Africa with 100 MW (Kathu plant).

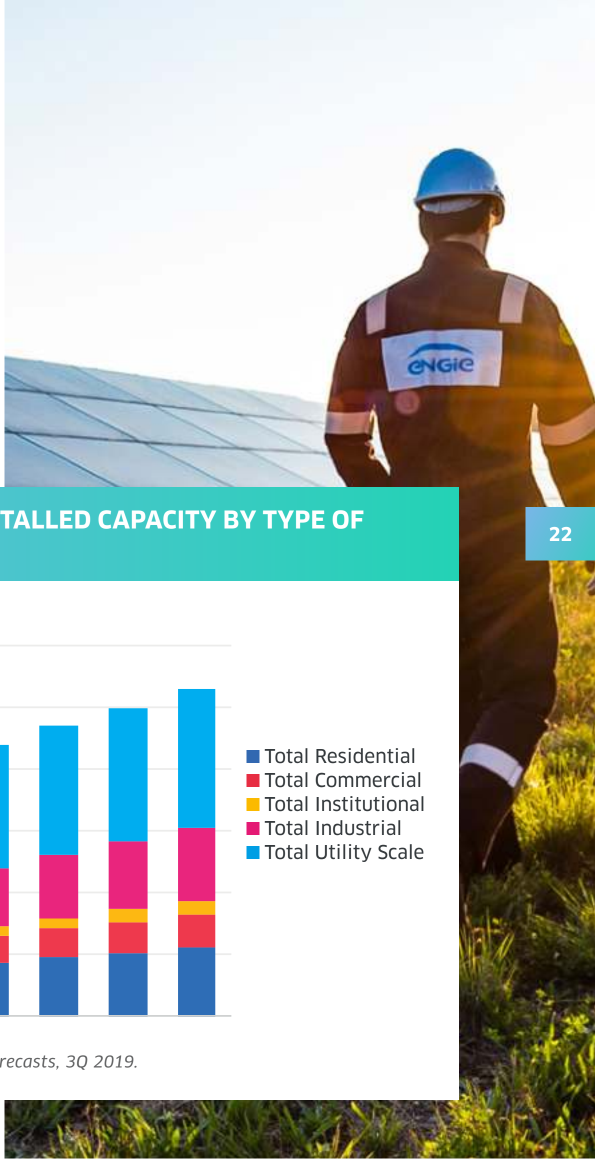
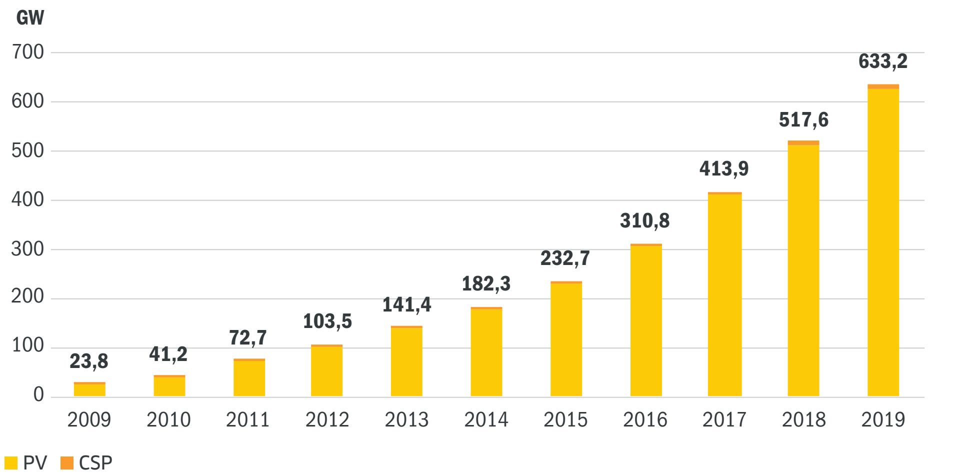


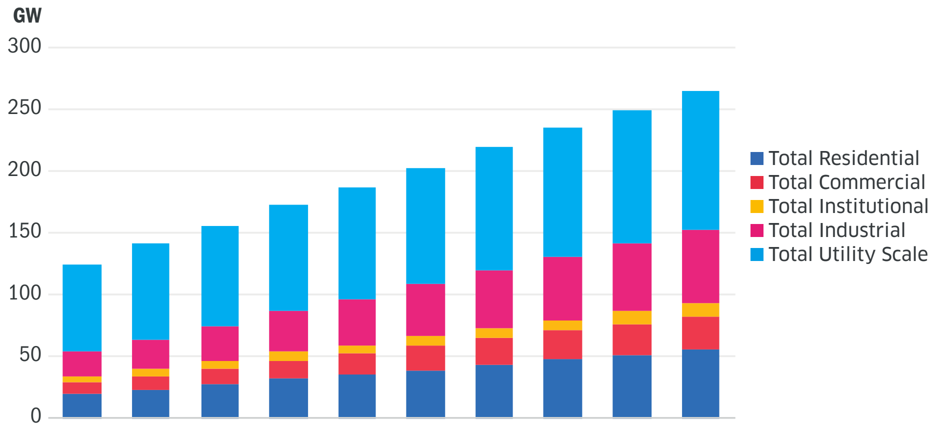



**Fig. 10 - GLOBAL SOLAR CAPACITY PER TECHNOLOGY, 2009-2019**




*Source: REN21. 2020. Renewables 2020 Global Status Report (Paris: REN21 Secretariat).* REN21

**Fig. 11 - GLOBAL ANNUAL SOLAR PV INSTALLED CAPACITY BY TYPE OF INSTALLATION: 2019-2028**




*Source: Guidehouse Insights, Market Data: Solar PV Country Forecasts, 3Q 2019.*

## ENGIE HAS CAPABILITIES IN A WIDE RANGE OF SOLAR TECHNOLOGIES

Over the years, ENGIE has made solar energy a key pillar, increasing from 621 MW installed in 2015 to 2.6 GW in 2020, and the objective of more than 4 GW by 2021. The Group's portfolio covers photovoltaic and concentrated solar power, centralised, and decentralised production, combined with energy storage. ENGIE continues to invest in testing and validating new technologies.

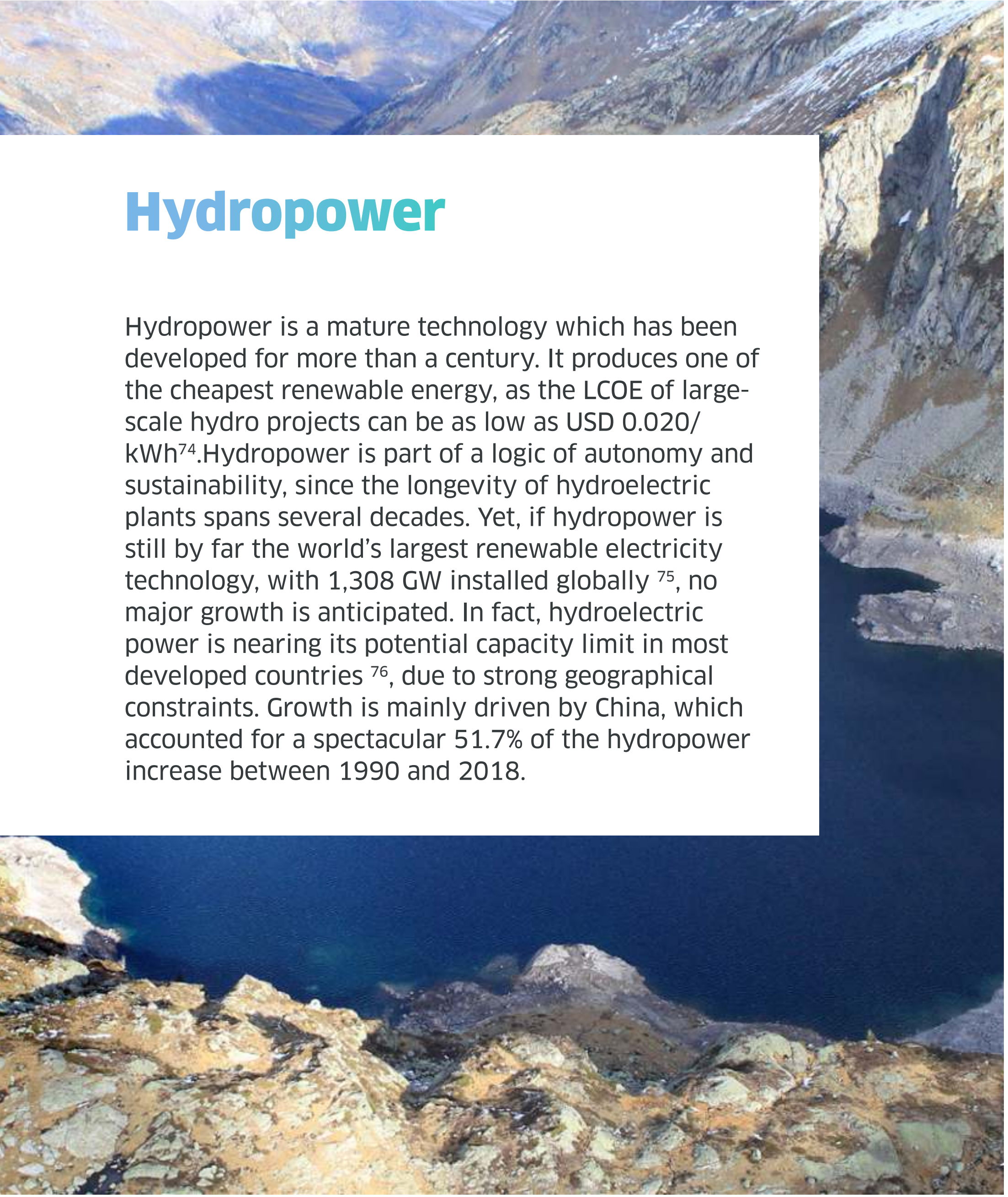
**ENGIE R&D tests and validates new PV technologies to further reduce the LCOE of solar power, develop new techniques to operate and maintain solar farms at record-low costs and meet customer needs.**

- **ENGIE operates a large test infrastructure in the Atacama Desert**, in Chile, a region where solar power radiation is the highest in the world. The site is ENGIE's most important R&D facility for solar energy. Bi-facial solar panels, autonomous cleaning robots and sun tracker are all examples of market available products and future emerging technologies being assessed or compared here.
- **ENGIE is also testing the feasibility of organic photovoltaic films** through several pilots and demonstration projects, in collaboration with industrial partners. The Group invested in Heliatek, a German industrial start-up specialised in the manufacture of organic photovoltaic film for buildings. This technology matches ENGIE's ambition to become an "energy architect" and growing clients demand for carbon neutral buildings.
- **In South Africa**, the Kathu solar park is a landmark project for the Group. This concentrated thermal power plant, in the Northern Cape province, is the first CSP project for ENGIE, using parabolic troughs with more than 100 MW capacity and equipped with a molten salt storage system that allows 4.5 hours of thermal energy storage, thereby limiting the variable nature of solar energy.

> **ENGIE installed**
> **2.6 GW**
> **of solar energy in 2020**

**ENGIE is also developing solar energy and mini-grid projects for energy access purposes, with ENGIE PowerCorner activities in sub-Saharan Africa.**

- **Concerning PowerCorner,** ENGIE is leading the development of solar mini-grids for rural communities in Africa. The Group is supplying electricity to the village of Ketumbeine, Tanzania, which has 800 residents. The gradual installation of such mini-networks, which will progressively expand, fulfills one of the Group's key objectives: to provide rural populations with access to eco-friendly energy.



# Hydropower

Hydropower is a mature technology which has been developed for more than a century. It produces one of the cheapest renewable energy, as the LCOE of large-scale hydro projects can be as low as USD 0.020/kWh[74].Hydropower is part of a logic of autonomy and sustainability, since the longevity of hydroelectric plants spans several decades. Yet, if hydropower is still by far the world's largest renewable electricity technology, with 1,308 GW installed globally [75], no major growth is anticipated. In fact, hydroelectric power is nearing its potential capacity limit in most developed countries [76], due to strong geographical constraints. Growth is mainly driven by China, which accounted for a spectacular 51.7% of the hydropower increase between 1990 and 2018.

## HYDROPOWER, A FLEXIBLE AND RELIABLE ENERGY

Due to the maturity and dispatchability of the technology, hydropower can be very attractive provided that the right location can be found. Hydroelectric power plants generate electricity using the kinetic and potential energy of water. The water drives turbines that in turn drive generators which convert mechanical energy into electricity. Hydropower plants can be divided into three main categories, based on the different kinds of water storage:

- Storage (or reservoir) hydropower is a type of hydropower in which the water is stored in a reservoir and released when needed to satisfy the energy demand. Such a scheme can be a multipurpose project allowing energy generation, flood control, water storage for domestic, industrial, agricultural uses, navigation, or recreational activities.
- Run-of-river is a type of hydropower with no or very little storage capacity. This implies that the water released by the hydropower plant is equal to the natural flow of the river.
- Pumped-storage is a type of hydropower project which aims to store energy, like a huge battery. The water is pumped from a lower reservoir to an upper reservoir for storage and can later be used for electricity generation.

Hydropower facilities accompany the development of other RES, meeting demand when variable sources are not available and

> **Hydropower is by far the world's largest renewable electricity technology, with 1,308 GW installed and 4,306 TWh of electricity generation globally**

allowing energy storage when there is a surplus. Indeed, hydropower can be switched on rapidly to produce electricity at times of peak demand, and switched off at other times. This flexibility of operation makes it an important adjustment lever. Naturally, hydropower project are characterised by large upfront capital expenditure during construction. But this is followed by a very long period of operation (possibly more than 50 years) with low maintenance costs. Reservoirs also provide crucial water management services (such as protection from the impacts of unpredictable floods and droughts).

Overall, with its 90% efficiency in converting the kinetic energy to electricity, and the fact that no fuels are burnt and no direct emissions are released into the atmosphere, hydropower is commonly considered as a clean renewable energy. Greenhouse gas emissions from hydroelectricity are mainly due to the use of cement (depending on the type of cement and its production method) and, in the form of methane (the decomposition of the flooded biomass), during the first years of filling reservoirs in tropical areas.

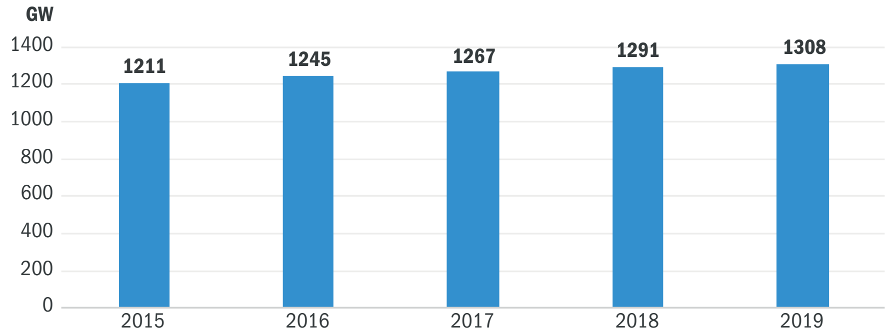
## HYDROPOWER, THE WORLD'S LARGEST SOURCE OF RENEWABLE ELECTRICITY

Hydropower is the world's largest source of renewable electricity generation and is expected to remain so in the coming years. In 2019, total global hydropower installed capacity reached 1,308 GW and hydropower facilities generated a record 4,306 TWh of electricity[77]. This corresponds to around 16% of the total electricity produced in the world and more than 60% of electricity generated from renewable energies. During the year 2019, 17 GW of new installed capacity were added, including 304 MW of pumped storage[78]. **Fig. 12**

Geographically, the trio of China, North America and Brazil remain the world's biggest producers. China is the leader – with a total of 356 GW installed capacity, representing ~1/4 of the global hydropower installed capacity. Its Three Gorges Dam is the world's largest hydropower station in terms of installed capacity (22,500 MW). The country is far ahead of the Brazil (about 8% of the global hydropower installed capacity), the United States (8%) and Canada (6%). However, development in China has slowed significantly over the past few years, as costs have increased due to resource availability and social acceptance[79]. Interestingly some smaller countries appear to be among the leaders for hydroelectricity, for example Norway (32.6 GW) or France (25.5 GW) due to their specific geographical features. **Fig. 13**

Going forward, a major constraint for development is that available sites for these types of projects are limited. Moreover, large hydropower projects can raise social acceptance issues and environmental aspects are always more considered. As a result, hydropower is moving beyond using large-scale dams with what is known as "run-of-the-river" plants. These hydropower projects use the natural flow of rivers and small turbine generators to produce energy. In recent years, they have emerged as a viable, low-impact alternative to existing large-scale projects.

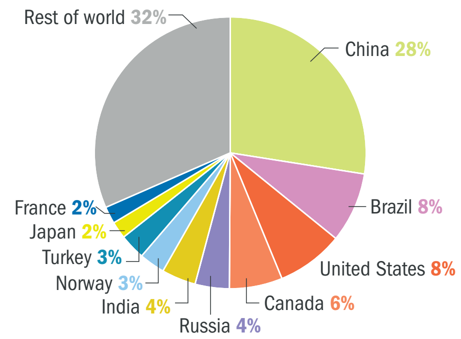
### Fig. 12 - HYDROPOWER INSTALLED CAPACITY GROWTH, 2015-2019




*Source: International Hydropower Association, Hydropower Status Report, 2020.*

Growth prospects for new hydropower capacity remain (121 added GW by 2024) but the pipeline of projects is concentrated in emerging economies. Pumped storage hydropower capacity is expected to increase 26 GW by 2023[80], with the largest growth happening in China driven by the increased need for system flexibility to reduce wind electricity curtailment and optimise coal and nuclear plant operations [81].

### Fig. 13 - DISTRIBUTION OF WORLDWIDE HYDROPOWER CAPACITY AS OF 2019, BY MAJOR COUNTRY




*Source: International Hydropower Association, Hydropower Status Report, 2020.*

## ENGIE HAS OPERATIONS IN 6 COUNTRIES

ENGIE, with its 16.2 GW[82] installed capacity, has gained national and international recognition in the development and operation of hydroelectric plants. The Group is currently reinforcing its presence in Portugal, adding 1.7 GW of hydro capacity[83] in the next months, totaling 18 GW of hydropower installed capacity at the end of 2020. This flexible green capacity allows ENGIE to perfectly complement other existing renewable assets.

**ENGIE is the second largest national producer in France.**

**In France**, ENGIE is contributing to the promotion of hydropower through its two subsidiaries, Compagnie Nationale du Rhône (CNR) and La Société Hydro Electrique du Midi (SHEM).

- CNR operates hydroelectric facilities on the Rhône, mainly run-of-river plants.
- SHEM operates hydroelectric installations in the Pyrenees, mainly reservoir power stations.

**In the United Kingdom**, ENGIE operates Dinorwig, one of Europe's largest pumped storage facilities and the fastest power generation asset in the UK, able to deliver 1.7 GW in 16 seconds.

“

**18 GW**

**of hydropower installed capacity by ENGIE at the end of 2020**

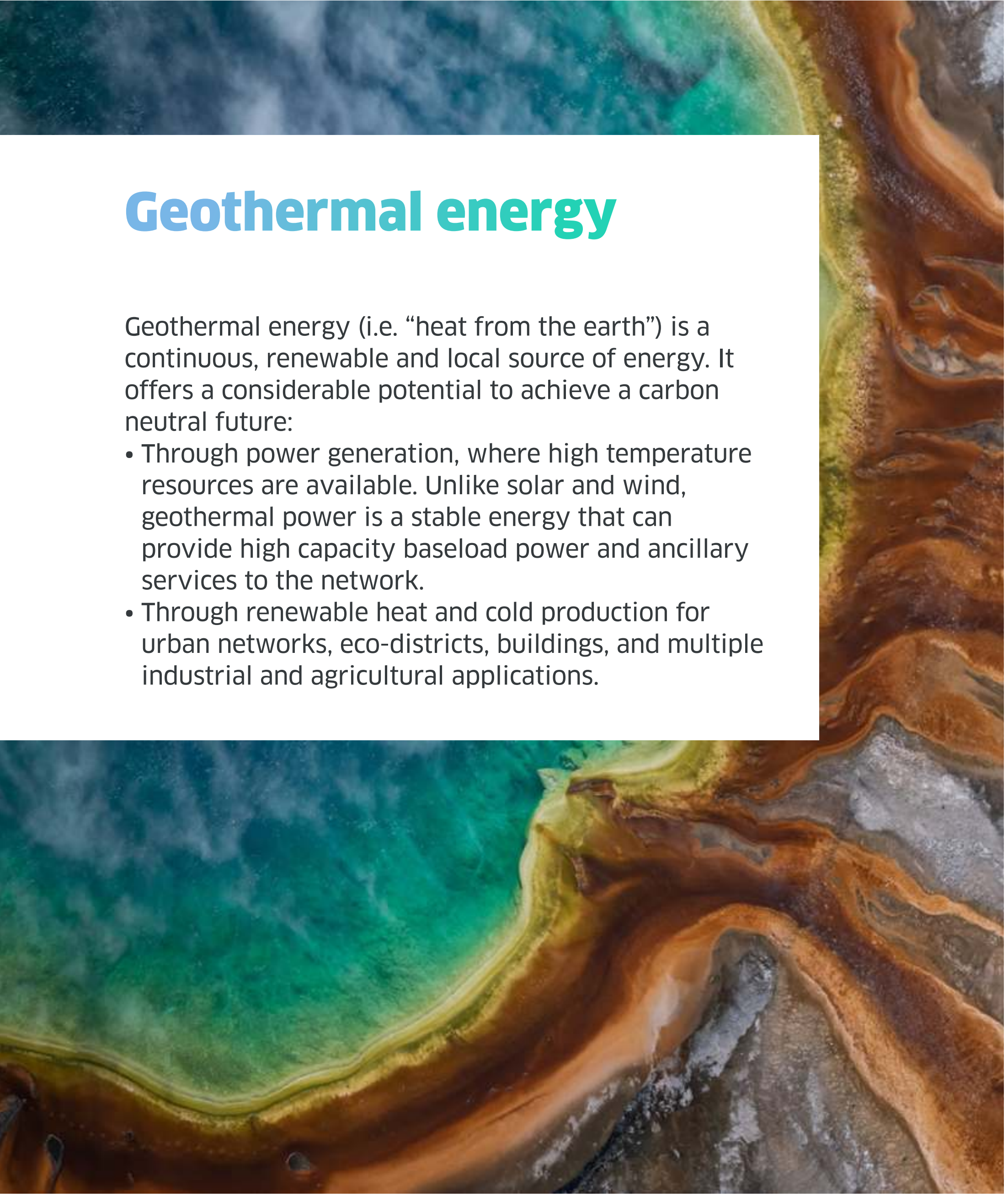
”

**In South America, ENGIE is Brazil's leading independent power producer, operating 13 hydroelectric plants.**

**In Brazil:**

- The Estreito plant, of 1,087 MW, produces enough electricity to supply power to 4 million residents.
- The run-of-the-river Jirau dam has a capacity of 3,750 MW. It makes it possible to meet the country's growing demand for energy with the guarantee of a secure supply.
- The Ita hydroelectric plant cover 90% of Paraguay's electricity demand and 19% of Brazilian consumption.

**In Chile**, ENGIE led the construction of the Laja hydroelectric plant, the country's first run-of-the-river power plant. A system of turbines installed at the foot of the dam avoids the need to divert the river and minimises the dam's environmental impact. This project is one-of-a-kind in Chile.



# Geothermal energy

Geothermal energy (i.e. "heat from the earth") is a continuous, renewable and local source of energy. It offers a considerable potential to achieve a carbon neutral future:

- Through power generation, where high temperature resources are available. Unlike solar and wind, geothermal power is a stable energy that can provide high capacity baseload power and ancillary services to the network.
- Through renewable heat and cold production for urban networks, eco-districts, buildings, and multiple industrial and agricultural applications.

## GEOTHERMAL ENERGY IS A LOCAL, STABLE AND RENEWABLE SOURCE OF ENERGY

The term geothermal energy encompasses all the applications that make it possible to recover the thermal energy contained in the subsoil or groundwater (steam or hot water in aquifers or faulted reservoirs). Generally, the geothermal fluid is produced through wells drilled to tap the geothermal resources and reinjected at a lower temperature after thermal energy recovery. Boreholes (closed-loop system) are also used to recover the heat from the earth where a suitable geothermal reservoir is not available. The thermal energy can be used directly or converted into electricity (through steam or organic rankine cycle turbines), hotter water or cool water through heat pumps.

There are two main types of geothermal energy, and associated applications:

- Shallow geothermal energy, which can be used with ground-source heat pumps for heating and/or cooling residential and commercial buildings as well as eco-districts or industrial process. Located less than 200m below ground level, these geothermal resources below 10 and 25 ºC are well adapted to meet heating and cooling demands ranging from 200 kW to 3 MW.
- Deep geothermal, which can be used directly or through heat pumps for district heating and cooling, agriculture, aquaculture, and in industrial process heating with temperatures above 30 °C. Deep geothermal can also be used for power generation if temperatures reach more than 110 ºC. These resources are usually found from 500 m to 4500 m below ground level, depending on site location and geology.

> **Geothermal energy is:**
> - **a local source of energy**
> - **a continuous resource that can provide high capacity baseload power**
> - **a competitive solution on different markets**

Among the strengths of geothermal energy compared to other renewable energies:

- It is a continuous resource, not affected by seasons or wheather, usable 24/7 for baseload production;
- As most of the production facilities are underground, footprint of geothermal production facilities is limited;
- As a local energy, it does not require any supply chain and is not exposed to market price variability;
- It can be coupled with underground energy storage solutions to enhance efficiency or thermal solar.

On a general basis, compared to other renewables, geothermal energy requires higher investment costs but thanks to limited operational costs and higher load factor with baseload production, it is a competitive solution on different markets. The main challenges for geothermal development are subsurface uncertainties and longer development time especially for deep geothermal resources that need to be confirmed. On top of specific technical expertise required in geosciences and drilling, risk mitigation funds or insurance schemes are available in many countries to reduce the financial risk at the early stage of geothermal development. Extensive R&D programs are on-going worldwide with a focus on innovative techniques to improve resource assessment, and drilling technologies to reduce costs and risks.

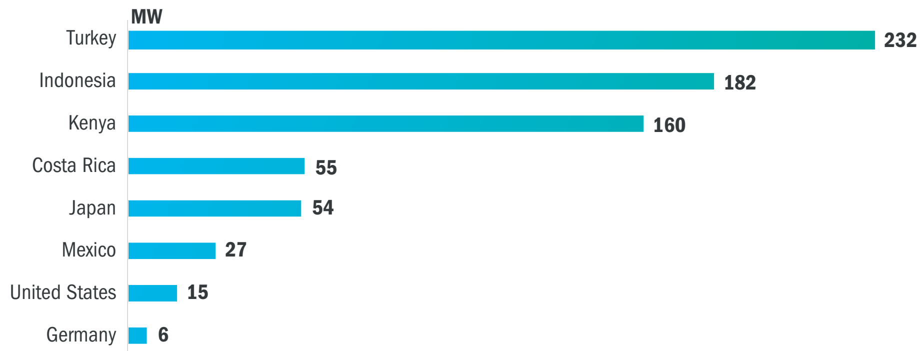
## GEOTHERMAL HAS CONSIDERABLE POTENTIAL FOR GROWTH

After decades of slow development, the past few years have seen a revival of interest in geothermal applications in terms of electricity generation and direct uses of heat (e.g district heating)[84].
Worldwide, about 13.9 GW geothermal power generating capacity were installed by end 2019[85]. Geothermal electricity generation totalled around 95 TWh , while direct useful thermal output reached around 117 TWh[86]. In terms of geographies, the United States, Indonesia and the Philippines lead the world for cumulative installed capacity[87]. But over the past few years Turkey and Indonesia have been the most active geothermal markets[88]. Fig. 14

Looking forward, geothermal global installed capacity is 7% to 16.5 GW by 2022, with Indonesia, Kenya, Turkey and the Philippines responsible for two-thirds of this growth[89]. In Europe, electricity generation from geothermal resources has also a huge potential, estimated at 34 TWh , or about 1% of the projected total electricity supply in the EU in 2030[90]. Fig. 15

The potential for development of geothermal energy for heating and cooling by direct-use or through heat pumps is also tremendous worldwide and should play a significant role in a future low carbon world for cities or industries. With 5.5 GWth installed capacities, deep geothermal for district heating is already significantly developed in Europe, especially in Iceland, Turkey and France, and the dynamic for new geothermal DHC is particularly strong in countries such as Netherlands and Germany. The potential for development in North America (cities, campus,...) is huge, as well as the use of geothermal energy for district cooling. The use of shallow geothermal, already widespread in some European countries (Finland, Denmark, Norway, Austria and Switzerland), should also rise in many countries worldwide in answer to meet energy transition targets.

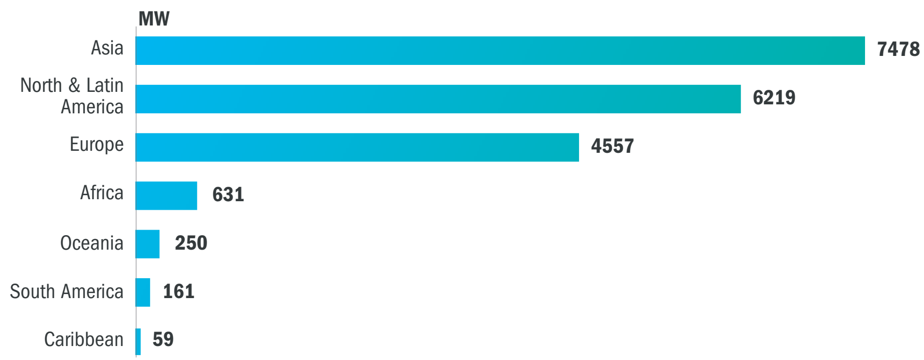
**Fig. 14 - NEWLY INSTALLED GEOTHERMAL POWER CAPACITY IN 2019, BY COUNTRY**




*Source: REN21. 2020. Renewables 2020 Global Status Report (Paris: REN21 Secretariat)* REN21



**Fig. 15 - PROJECTED GEOTHERMAL POWER CAPACITY IN 2025**




*Source: Gerald W. Huttrer, Geothermal Power Generation in the World 2015-2020 Update Report, World Geothermal Congress, May 2020.*

## ENGIE, A STRONG PLAYER IN GEOTHERMAL SOLUTIONS

ENGIE is one of the few players combining all the competences to develop geothermal solutions on all energy markets worldwide. Geothermal is already embedded in the DNA of ENGIE, through a strong historic position in France for direct-use in district heating (Paris and Ile-de-France region, more recently Bordeaux), a new dynamic in Europe (Netherlands, Belgium...) and promising opportunities in the United States (especially for campuses). In power generation, ENGIE has developed in Indonesia, one of the most dynamic markets for geothermal power, two projects from exploration to operation (Muara Laboh, 85 MW, operating since December 2019 and Rantau Dedap, which shall be commissioned in Q1 2021) in a challenging environment.

Storengy, 100% affiliate of ENGIE, masters all subsurface competences in geosciences and drilling to develop geothermal energy bringing innovation to geothermal solutions through a dedicated R&D program and is developing a geothermal project portfolio focusing on the most promising opportunities within ENGIE's geographical footprint, combining all ENGIE skills in renewables and customer solutions.

**Power generation: ENGIE works on pilot projects to demonstrate innovative concepts.**

A zero-emission power plant in the geothermal fields of Tuscany, Italy: the project consists in developing, building, and operating a geothermal power plant of 5 MW. It will be a zero-emission plant thanks to an innovative solution: extracted geothermal fluid will be reinjected in the same reservoir together with non-condensable gases ($CO_2$ and others), sustaining a production cycle without atmospheric emissions. When it is fully operational, the geothermal plant will reach 40,000 MWh per year (enough to supply electricity to 14,000 families), generating also important economic benefits for the local communities.

> **Geothermal is already embedded in the DNA of ENGIE, through a strong historic position in France for direct-use in district heating**

**Direct use for District Heating: the first geothermal doublet in the French Aquitaine Region.**

In 2017, the city of Bordeaux, France, selected ENGIE, led by Storengy and ENGIE Solutions, to design, build and operate a new district heating network in central Bordeaux under a 30-year public service delegation contract. The flagship of the project was an innovative well design to carry out the exploration of an unknown deep reservoir and secure a fall-back position to a proven one.

**A special case: Marine geothermal energy.**

Marine geothermal energy makes use of the difference in temperature between warm surface water and cold water found on the seabed. In Marseille, France, the Thassalia marine geothermal power station is the first in France, and even in Europe, to use the sea's thermal energy to supply linked buildings with power for heating and cooling – over an area which will eventually comprise 500,000m² – while reducing greenhouse gas emissions by 70%.

# Solid biomass

Biomass, mainly in the form of wood, is the oldest form of energy used by humans. This energy makes it possible to produce heat by the combustion of organic materials (wood, plants, dry agricultural waste such as straw etc) and electricity when that heat is converted to steam. Biomass is a flexible and dispatchable source for heat and power generation.

## BIOMASS IS A VERSATILE FEEDSTOCK

Biomass is a versatile feedstock that can be converted into energy using a wide range of conversion technologies. The term “solid biomass” encompasses a broad range of organic material such as trees, plants, and dry agricultural and urban waste[91]. It can be used for heating, electricity generation, and transport fuels and is generally classified as follows:

- Primary biomass: from forestry (wood) and – agriculture (including algae, oil & sugar biomass).
- Secondary biomass: by-products from the 1st conversion of primary biomass (mainly wood pellets, wood chips).
- Tertiary biomass: post consumer organic material (waste) like recycled wood, refuse derived fuels from municipal waste and solid recovered fuel from sorted organic waste.

> “Solid biomass can be used for heating, electricity generation, and transport fuels”

The use of solid biomass is typically categorised as either “traditional” or “modern”. Traditional use of biomass is the use of solid biomass with basic technologies for cooking or heating. Modern biomass relies on more advanced technologies, mainly in electricity generation and industrial applications. A multitude of biomass feedstock can be converted using a wide range of conversion technologies:

- Direct combustion is the usual method of converting ligneous biomass (logging slash, straw or energy crops) into energy. Biomass is burned in a boiler to generate heat, electricity, or both (cogeneration).
- Another family of processes consist in converting biomass into green gases, through anaerobic digestion of wet biomass, or gasification of dry biomass (the section on biogas and biomethane will provide more details on these types of solutions).

Biomass is considered to have a neutral carbon balance, as the carbon released when solid biomass is burned will be re-absorbed during tree growth[92]. Yet, the use of biomass still questions about its carbon neutrality, resource availability and impacts on the environment, biodiversity. The carbon balance of biomass to heat and power depends on a wide range of factors, including forest management, harvest area and source of biomass (i.e. waste from other forest activities or specific tree felling). The time lapse for the carbon released during combustion to be stored through forest growth can also vary, from years to decades

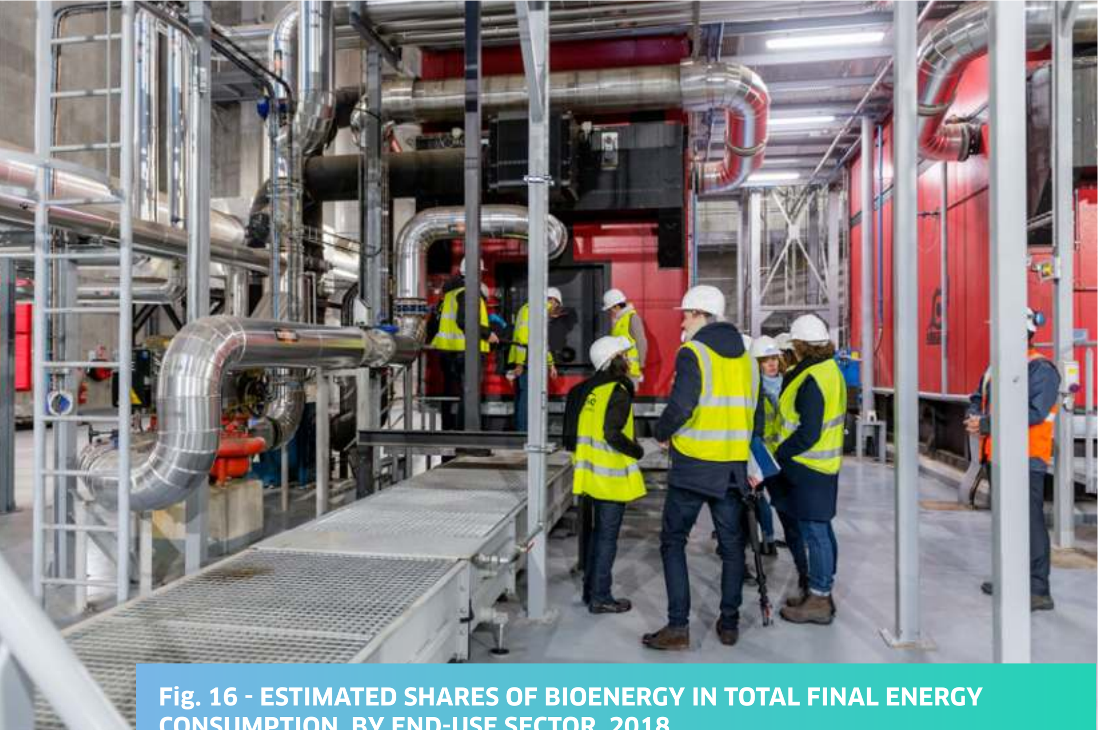
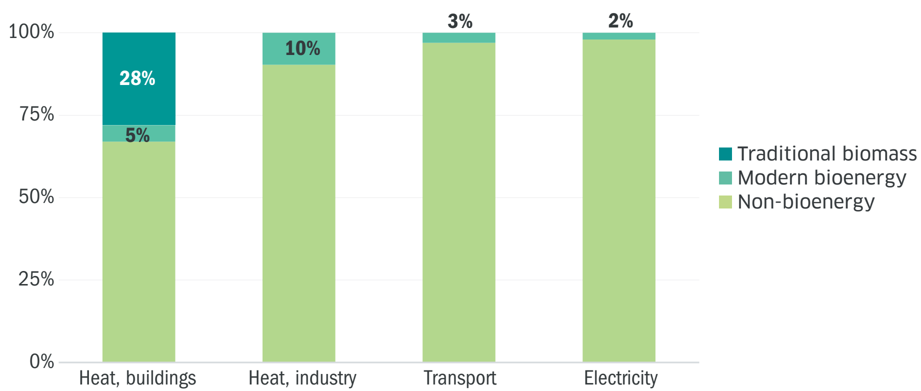


**Fig. 16 - ESTIMATED SHARES OF BIOENERGY IN TOTAL FINAL ENERGY CONSUMPTION, BY END-USE SECTOR, 2018**




*Source: REN21. 2020. Renewables 2020 Global Status Report (Paris: REN21 Secretariat).* REN21

and the value chain emissions depends on conversion technology, fuels used, transport etc. Moreover, biomass use may compete with other, non-energy uses of agricultural residues such as straw, or with wood processing industry (i.e. pulp and paper). Lower resource availability due to population growth and deforestation as well as climate change could also impact biomass feedstock. There are however several ways to address these risks and to meet increasing energy demands. These include increasing the area of managed forests, getting access to more efficient primary resources (e.g harvesting residues), using the best technology available to increase efficiency, increasing the use of secondary resources, developing use of tertiary resources and the principle of the cascading use of biomass, whereby it is used more than once, with energy conversion typically as the last step. Energy poly-generation (e.g tri-generation of electricity, heat, and cooling) is also an interesting option for biomass energy conversion as it may substantially increase the efficiency of energy conversion. In addition, international trade of biomass will likely play a role in meeting the increasing global demand.

## MARKETS FOR BIOMASS-DERIVED ENERGY

Markets for biomass-derived energy are expected to increase in the long term. In 2019, bioenergy accounted for 12% (or 45.2 EJ, 12,555 TWh ), of final energy consumption [93]. Yet, around two thirds of the biomass is consumed in developing countries for cooking and heating. Excluding the traditional use of biomass, modern bioenergy provided 19.3 EJ (5,361 TWh ) or 5.1% of total global final energy demand in 2018. This corresponds to around half of all renewable energy in final energy consumption. Modern bioenergy provided around 13.9 EJ for heating (8.6% of the global energy supply used for heating), 3.7 EJ in transport (3.1% of transport energy needs) and 1.7 EJ to the global electricity supply (2.1% of the total). Fig.16

Today, the largest and most well-established global market for solid biomass is that of wood pellets. Europe is currently the largest consumer, the largest producer and the largest importer of wood pellets in the world. North America follows in second place[94]. However, in recent years, the sector has declined in Europe as governments have reached tighter regulation of emissions and biomass sustainability[95]. Going forward, the greatest deployment is anticipated in areas with access to biomass resources and policies to phase out coal-fired boilers to improve air quality. Asia in particular is set to be among the most promising markets. China has recently introduced a new clean-heat initiative that is expected to raise the deployment of biomass- and waste-fuelled co-generation plants[96].

# ENGIE SUPPLIES, TRADES, TRANSPORTS AND HANDLES BIOMASS

**With over 50 sites in Europe, the United States and Brazil, ENGIE supplies, trades, transports and handles 2.5 million tons of biomass a year.**

**ENGIE is a player in all parts of the biomass to energy value chain and follows a strict policy of sustainable forest management and promotion of biodiversity.**

**In France**, ENGIE is building a biomass combined heat and power plant (Novawood project). The 14.6 MW biomass combined heat and power plant will replace two coal-fired boilers in Laneuveville-devant-Nancy (France). To consume less energy and use it better, the project will use sustainable reclaimed wood as fuel, 60% of it collected in the Grand Est region and 40% coming from replaced railway sleepers from the national rail network. It will produce 115 GWh of green electricity annually, equivalent to the consumption of 50,000 homes. In addition to reducing $CO_2$ emissions, it will create more than 100 jobs in plant operation and fuel preparation[97].

**In Switzerland**, to help the Nutrition & Health company DSM Nutritional Product reduce its carbon footprint, ENGIE supplies steam and power through a single biomass cogeneration unit under a 20-year contract. The biomass steam generation plant runs on locally sourced wood chips (within a 100km radius maximum) and supplies green energy—not only to DSM, but also to several other manufacturers as well as the equivalent of 17,500 local households. The plant generates 67 GWh of steam and 42 GWh of renewable electricity per year and is one of Switzerland's largest and efficient biomass plants.

> **ENGIE supplies, trades, transports and handles 2.5 million tons of biomass a year**

**ENGIE is a recognised leader in biomass trading, logistics and storage and has a 10% market share in the global trade in industrial wood pellets (~2.5MT).**

**In Japan**, in 2018, ENGIE signed a 15-year biomass supply contract with Mitsui & Co. The contract secures the delivery of 4.2 million tons of wood pellets over a period of 15 years to a power plant being constructed by Kansai Electric in the port of Kanda, which is expected to begin operations in 2021. 75% of the wood pellets is expected to be sourced from Australian suppliers, using sustainable fibre from certified and sustainably managed forest.

# Biogas and biomethane

As a flexible energy source, biogas has the potential to be used not only for renewable electricity but also for heat and, if upgraded to biomethane, to replace a portion of natural gas demand. Moreover, with modern societies producing ever-increasing quantities of organic waste, biogas and biomethane can be an answer to the major challenge of waste incineration, energy recovery and to the development of sustainable agriculture. Biogas and biomethane technologies can create a virtuous link with the agricultural sector, contribute to local employment and rural development and put in practice the concept of a circular economy.

## BIOGAS AND BIOMETHANE: CREATE A VIRTUOUS CIRCULAR ECONOMY

Biogas and biomethane are an opportunity to build a new filière and create a virtuous circular economy with local stakeholders. Biogas is a gas mixture composed mainly of methane ($CH_4$) and carbon dioxide ($CO_2$). Biogas production plants can process a wide range of organic materials, including sewage sludge, animal and vegetable by-products, household biowaste and crops. Biogas can also be upgraded to produce biomethane after removal of the $CO_2$ and other impurities.

Biogas and biomethane can be produced using different technological pathways:

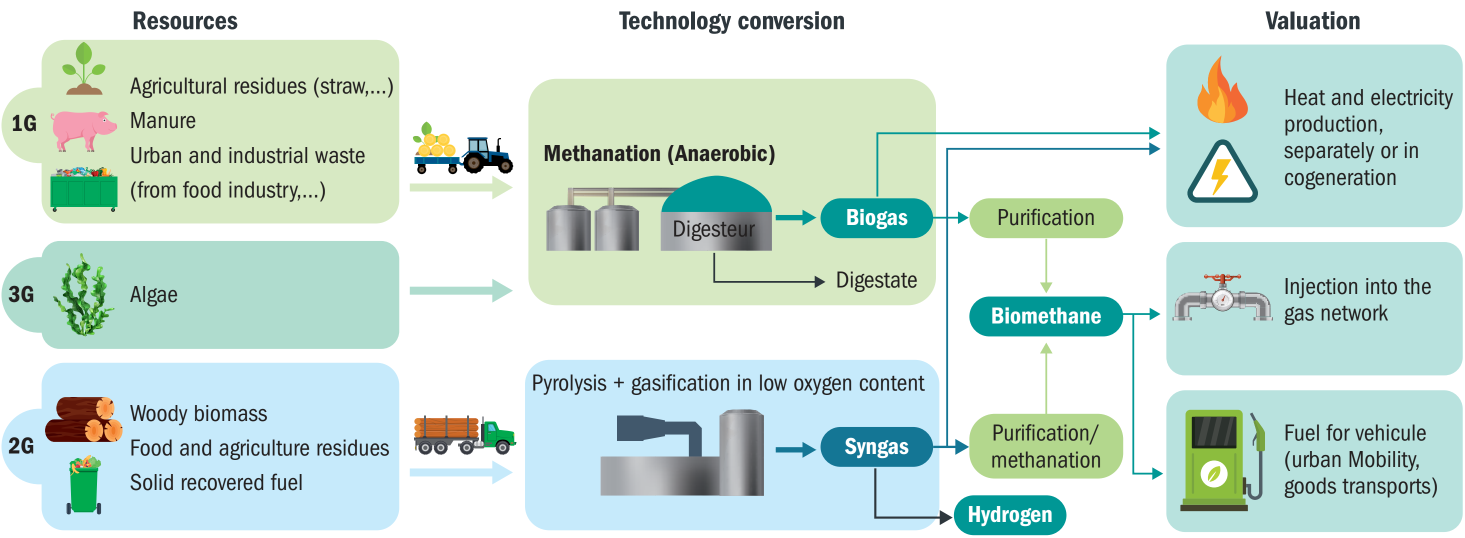
- **Anaerobic digestion** is the conversion of wet biomass (e.g agriculture residues, manure, industrial/municipal wastes.) or microalgae into biogas through a disintegration process. Biogas can be used directly for cooking and lighting, for combined heat and power (CHP) or be upgraded to become biomethane, which can be injected into the grid or used as biofuel for transportation (bioNGV).
- **Gasification** is an alternative technology consisting in the gasification of lignocellulosic (dry) biomass inputs (such as woods, forests, bio-wastes) and non-recyclable waste such as Solid Recovered Fuels into a range of end-products, and in priority syngas. Syngas can be used directly for power and heat, be transformed into biomethane (grid use or bioNGV) thanks to the methanation process or into other products such as liquid biofuels for transport or industry like biokerosene or methanol.

There have been three generations of biomethane to date. These three generations involve different production techniques and biomass resources and can be fed into existing gas networks.

- 1st generation biomethane (in industrialisation phase): produced by methanisation from organic, domestic, farming or wastewater plant waste.
- 2nd generation biomethane (at the pilot stage): produced by gasification followed by methanation from lignocellulosic biomass (wood, straw) and Solid Recovered Fuels (plastics, textile, foam, etc.).
- 3rd generation biomethane (emerging technology under R&D): produced from micro-algae. Fig. 17

> **In France, job creation due to the development of anaerobic digestion represents nearly**
> **5,000 jobs**

**Fig. 17 - BIOGAS AND BIOMETHANE PRODUCTION PATHWAYS**




*Source: ENGIE Impact study on biogas cost curves.*

Despite its potential, biomethane production costs are still significant compared to that of natural gas. The global average cost of biomethane from anaerobic digestion varies between €70/MWh and €90/MWh (€0.65/m³ to €0.90/m³) in 2020[98]. Biogas purification represents at least 30% of the biomethane production costs. Studies conducted for the French market estimate the value of positive externalities of biomethane between 55-75 EUR/MWh[99]. Among these externalities, the recovery of agricultural waste and the reduction in the use of chemical fertiliser. There are also social and economic externalities, such as job creation in rural areas to ensure the development and operation of facilities. Engaging in biomethane production can turn into additional income for farmers (15,000 to 20,000 euros) as they can diversify their activity while contributing to the greening of the energy mix. In France, job creation due to the development of anaerobic digestion represents nearly 5,000 jobs. Moreover, where there is no grid access for heat and electricity, decentralised applications of biogas in rural zones are promising as needed wet biomass input is local and rural. Future technological developments will imply to industrialise the technology for larger scale. In this regard there is a growing interest in solid fuels (biomass, waste,...) gasification. Production costs are relatively high today, above €100 MWh (€1.0/m³),but costs could come down if large facilities are deployed[100].

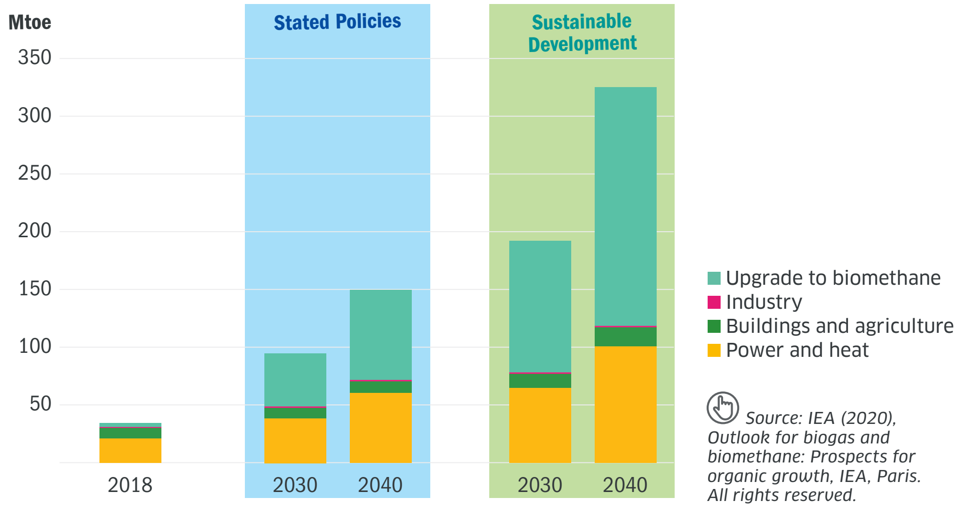
## BIOGAS AND BIOMETHANE HAVE SIGNIFICANT POTENTIAL FOR FURTHER GROWTH

The biogas market has made tremendous advances in development since the early 2000s. It is expected to continue to grow with a large and relatively established market in Europe and a rapidly growing market in Asia Pacific[101]. Currently, Europe, China and the United States alone account for 90% of the global biogas production[102]. There is around 18 GW of installed power generation capacity running on biogas around the world and capacity increased on average by 4% per year between 2010 and 2018[103]. In 2018, biogas and biomethane production was around 35 million tonnes of oil equivalent (35 Mtoe or around 407 TWh of energy equivalent). The biogas market largely developed out of strong policy support and incentives along with regulations mandating certain levels of adoption. As for biomethane, its production is also growing exponentially. Since 2010, global biomethane production has increased from 0.5 billion cubic meters (4.8 TWh ) to almost 3 bcm in 2017 (29.3 TWh )[104]. Most of the growth has happened in Europe, but biogas upgrading is expanding around the world. Growth drivers in this market include government regulations, increasing demand for renewable energy, emission reduction targets as well as a growing need to treat urban and rural wastes. While it is already significant, it is only a fraction of the estimated overall potential. According to the IEA. full utilisation of the sustainable potential could cover some 20% of today's global demand for gas[105]. Fig. 18

The consumption of biogas will increase considerably until 2030 and beyond. The potential for biomethane is also enormous. Biogas and/or biomethane can be produced in every part of the world and the availability of sustainable feedstocks for these purposes is set to grow by 40% by 2040, according to the IEA[106].

> According to the IEA,
> Biogas and biomethane production was around
> **407 TWh**
> of energy equivalent
>
> Full utilisation of the sustainable potential could cover some
> **20%**
> of today's global demand for gas

**Fig. 18 - OUTLOOK FOR GLOBAL BIOGAS CONSUMPTION BY SECTOR: HISTORICAL, STATED POLICIES, AND SUSTAINABLE DEVELOPMENT SCENARIO**




*Source: IEA (2020), Outlook for biogas and biomethane: Prospects for organic growth, IEA, Paris.* 

# ENGIE WORKS PROACTIVELY TO DEVELOP BIOGAS

ENGIE works proactively to develop biogas (mainly for upgrading to biomethane) and is positioned throughout the value chain – from project development, in close collaboration with farmers, to sales to end customers. With its long-lasting natural gas expertise, strong local foothold, and involvement in several projects – the Group participates in the development of biogas and biomethane production and injection facilities. As such, the Group contributes towards the progressive decarbonisation of the natural gas network while proposing circular solutions nourishing an entire ecosystem of players, stimulating the local economy, and preserving nature.

**ENGIE develops and operates biomethane injection units in the French gas network and abroad, with a long-term commitment to the regions.**

- **In France**, ENGIE operates 14 biomethane plants with a total capacity of 270 GWh/year.
- The Group also has 123 methanisation units connected to the T&D network at the end of 2019 with an injection capacity of 2.2 TWh /year.
- ENGIE plans to invest in biomethane plants to reach 52 plants in 2023 (1.1 TWh per annum) and 126 plants in 2030, thus producing 4 TWh per year of biomethane by 2030.

**ENGIE is concentrating on standardising, massifying and digitising projects.**

- The Group's objective is to support the sector's industrialisation to reduce costs by 20% by 2030 according to industrial roadmap.
- Optimizing biogas production with digital tools developments:
  - ➔ The WEBio Platform allows user to identify, quantify and characterise the biomasses present on its territory (forest co-products, livestock effluents, straw and sewage sludge).
  - ➔ The MAPPED partnership develops digital tools to boost biogas production and anaerobic digestion.
- Developing new technologies to reduce the costs of biogas purification:
  - ➔ The Picachaux R&D project in ENGIE is a low-cost technology based on lime use to eliminate $CO_2$ from biogas.

**Over the years, ENGIE has conducted several pioneering R&D projects to develop and prepare the 2nd generation biomethane via the gasification of biomass.**

- In 2010, ENGIE launched the GAYA dry biomass-to-gas R&D demonstration project in France. This project aims to test the production of biomethane from dry biomass (forest products, wood chips, bark, or residues from the food industry) and Solid Recovered Fuels in Saint-Fons (Rhône). To do so, a semi-industrial experimental platform has been built to carry out tests aimed at removing technological barriers and optimising the operating conditions of the production chain. GAYA has made it possible to demonstrate the technical, environmental and economic feasibility of the biomethane production by gasification of biomass and methanation of synthesis gas.
- The BioVive project led by ENGIE in Champagne, France, is also emblematic. It aims to design a hollow glass melting furnace capable of burning syngas (CO, $H_2$, $CH_4$, etc.) produced by biomass gasification[107].

# Hydrogen

Hydrogen has emerged nowadays as a solution to accelerate the energy transition by allowing numerous green energy technologies to be used with much greater flexibility. It is a highly versatile basic chemical which can be used both as an energy vector and as a feedstock. While today, 95% of hydrogen is produced from fossil fuels, hydrogen produced through electrolysis of water using renewable energies (solar, wind) or biomethane, is a clean resource. Once barriers are overcome, renewable hydrogen can connect different energy sectors, store energy in large quantities, over long periods of time and across great distances. As such, hydrogen can increase the operational flexibility of future low carbon energy systems.

## HYDROGEN IS AT THE CORE OF A NEW GREEN FUEL ECONOMY

While hydrogen is the simplest and most abundant chemical element in the universe, on Earth, it is found in more complex molecules, such as water or hydrocarbons. To be used in its pure form, it must be extracted. Multiple pathways exist:

- The most common, via steam methane reforming (SMR), uses natural gas and is not a carbon free process. $H_2$ via SMR is called Grey Hydrogen.
- Electrolysis of water, using green electricity, is currently the only available zero-carbon technology at scale for $H_2$ generation. $H_2$ via water electrolysis is called Green Hydrogen.
- $H_2$ via SMR with Carbon Capture (CCS), called Blue Hydrogen, is also in development.

While the uses for hydrogen are broad, currently it is mainly used as a feedstock for industrial processes, (95% of total $H_2$ consumption worldwide is used for ammonia, iron and steel, methanol and refineries). In the future, it could be used as decarbonised solution in industrial heat applications. Hydrogen can also be used in transports, including transportation for individuals and for logistics in urban zones, fleets of buses and rail travel. Other sectors are under study, such as river transport, cruise ships and aviation. In buildings, hydrogen could be blended into existing natural gas networks. Overall, once produced, hydrogen can be used in much the

"In the future, it could be used as **decarbonised solution** in industrial heat applications."

same way as natural gas. It can then be stored, injected into the natural gas network, provide heat in cities, and be converted back into electricity using fuel cells. Hydrogen can therefore provide consumers with energy from renewable sources at any time of the year and in particular during peaks in consumption.

However, these innovative technologies are still on laboratory or demonstration scale today. Sufficient quantities of power are required, performance aspects such as low electrolyser efficiencies, durability and standardisation need to be enhanced and technologies throughout the hydrogen value chain (notably electrolysis) are still expensive. According to BloombergNEF[108], green hydrogen costs between $2.50 and $4.50 / kg to make, due to the relatively high price of renewable-powered electrolysis. These costs would need to fall below $1.5 in order to make renewable hydrogen competitive with fossil fuels based hydrogen. Mass production is thus needed to reach significant volumes as fuel cells, refuelling equipment, and electrolysers can all benefit from mass manufacturing[109]. To ramp-up hydrogen production, projects have already moved into the megawatt-scale but switching to gigawatt-size plants appears to be a necessity. IEA analyses finds that the cost of producing hydrogen from renewable electricity could fall 30% by 2030 through declining costs of renewables and the scaling up of hydrogen production.

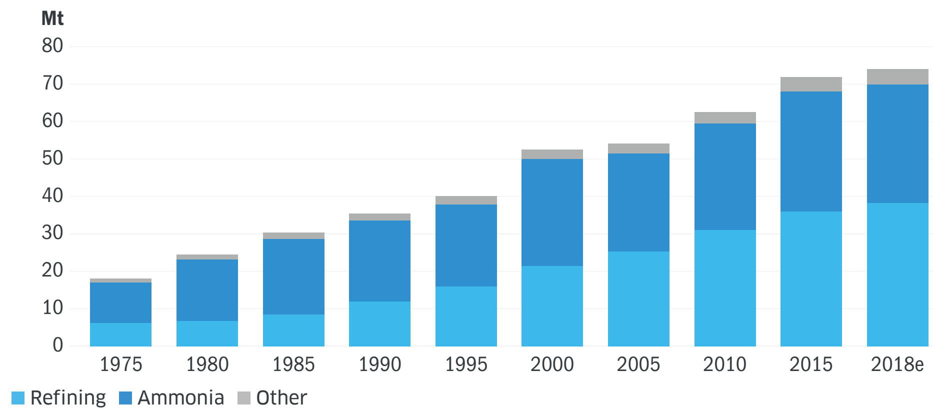
## RENEWABLE HYDROGEN IS EXPERIENCING UNPRECEDENTED MOMENTUM

Hydrogen has been used in industry for a century. Its demand has grown more than threefold since 1975, and continues to rise. But while there is no significant hydrogen production from renewable sources today, renewable hydrogen is experiencing unprecedented momentum and is at the beginning of a learning curve which promises substantial cost reductions. Fig. 19


Overall, there are around 50 targets, mandates and policy incentives in place today that support hydrogen, with the majority focused on transport[110]. For instance, in June 2020, Germany presented a €9 billion hydrogen strategy with a focus on mobility-related developments. In July 2020, the European Union unveiled its hydrogen strategy: at least 40 GW of renewable hydrogen electrolysers by 2030, the equivalent in installed capacity of 40 nuclear reactors. In september 2020, France also presented its new Hydrogen plan, with a target to have 6.5 GW of hydrogen production capacity by 2030. In Asia too, several countries are pursuing hydrogen. Japan is the country which has the world-largest renewable powered hydrogen project, with 10 GW of capacity[111]. Fig. 20

Through scaling up capacities and unprecedented support, the IEA projects that the production of low carbon hydrogen should grow from 0.46 Mt/y announced in 2020 to an estimated 7.92 Mt/y by 2030[112].

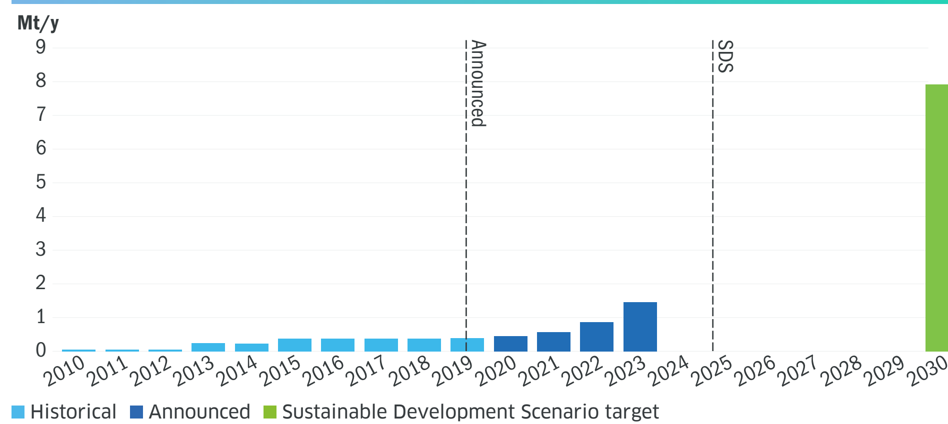
**Fig. 19 - GLOBAL DEMAND FOR PURE HYDROGEN, 1975-2018**




*Source: IEA, Global demand for pure hydrogen, 1975-2018, IEA, Paris. All rights reserved.*



**Fig. 20 - LOW-CARBON HYDROGEN PRODUCTION, 2010-2030, HISTORICAL, ANNOUNCED AND IN THE SUSTAINABLE DEVELOPMENT SCENARIO, 2030**




*Source: IEA, Low-carbon hydrogen production, 2010-2030, historical, announced and in the Sustainable Development Scenario, 2030, IEA, Paris. All rights reserved.*

# ENGIE HAS THE AMBITION OF BEING A MAJOR PLAYER IN CLEAN AND GREEN HYDROGEN

ENGIE is investing in clean hydrogen in the belief that it will become a key component in accelerating the energy transition. It is a belief that is being translated into a massive rollout of projects in several countries around the world across the value chain, such as industrial applications, the creation of mobility ecosystems or "Power to gas" platforms.

**ENGIE offers manufacturers who need hydrogen in their process an on-site offer to produce renewable hydrogen by electrolysis.**

ENGIE and YARA test green hydrogen technology in fertiliser production: The project consists in feeding the existing YARA Pilbara ammonia plant in Western Australia with renewable-based hydrogen, thereby reducing $CO_2$ emission when producing ammonia, that in turn will massively reduce the injection of $CO_2$ in the ground. With an anticipated capacity of 100 MW solar field and more than 50 MW electrolysis system, this first step would be the largest green hydrogen-to-ammonia plant on the planet.

**ENGIE is also involved in enhancing storage and methanation technologies.**

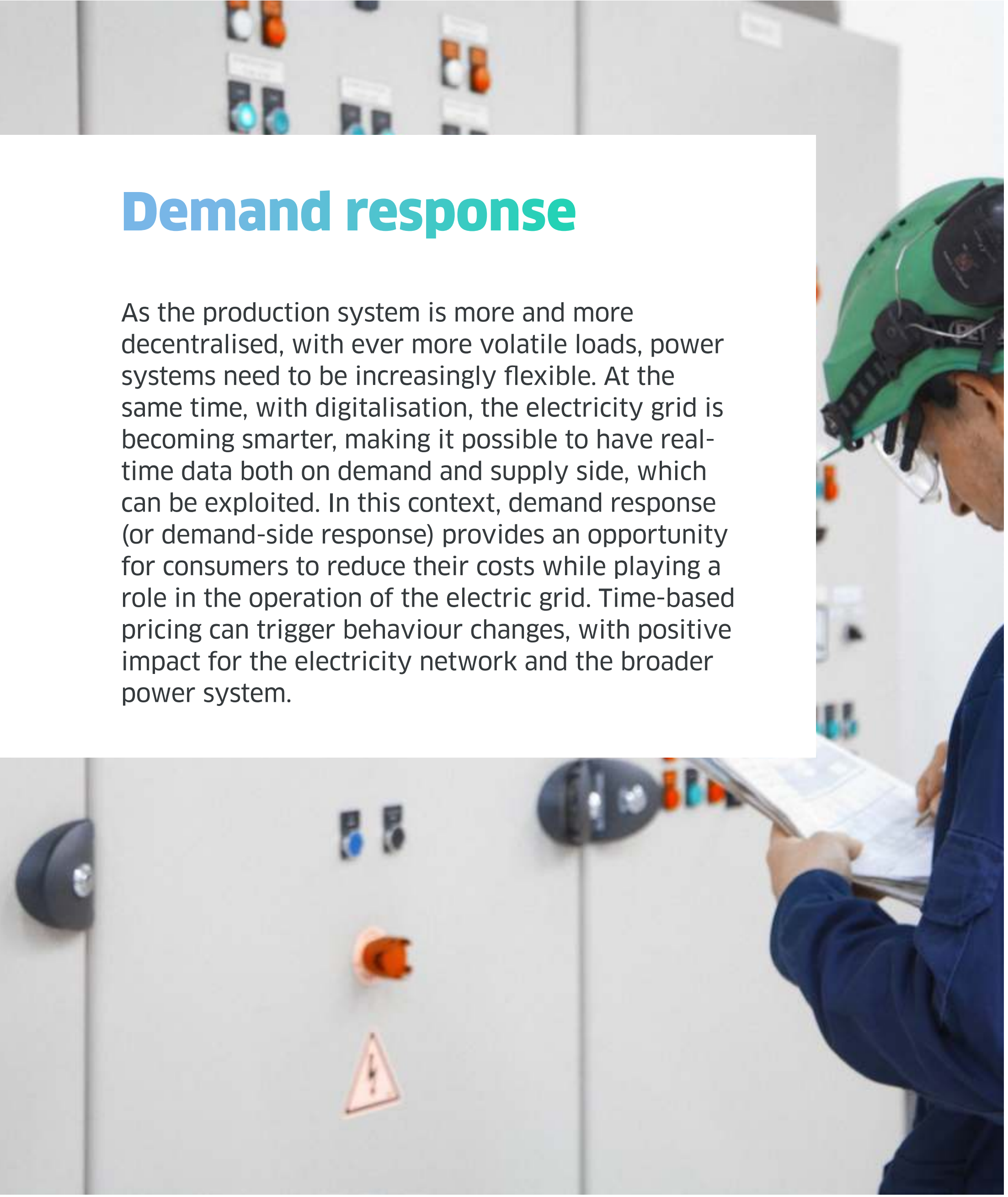
- **The GRHYD project in Dunkirk**, France, tests the injection of green hydrogen into the natural gas distribution network, and the production of hythane (a blend of hydrogen and natural gas) for NGV buses operating in the Dunkirk Urban Community.
- **Jupiter 1000** is the first project at industrial scale in France, In Fos-sur-Mer, with a power rating of 1 MW for electrolysis and a methanation process with carbon capture.

**ENGIE has launched several prospects in France and globally to develop low emission mobility solutions integrated with renewable supply**

- **In the city of Pau**, in southwestern France, eight hydrogen-powered buses operate in the city centre since 2019. With a range of 350 kilometers, they are powered by the world's first hydrogen refuelling station for buses, from renewable and local energy sources[113].
- **In South Africa**, ENGIE and the global mining industry firm Anglo American are developing the world's first hydrogen-powered haul truck.


# Enablers in a decarbonised energy system

Shaping a decarbonised energy system in a resilient, secure, and cost-effective manner will mobilise a full range of solutions, across energy carriers and infrastructures. While energy-efficiency is the first objective, a variety of technologies will complement this approach. These include demand-side management technologies, renewable electricity, the different low carbon energy vectors (hydrogen, biogas, etc.) as well as technologies that reverse the accumulation of $CO_2$ in the atmosphere (through carbon capture, direct air capture, and soil carbon sequestration). Linking up these technologies across energy carriers, infrastructure and sectors will accelerate the decarbonisation, reduce its costs, and bring in a more circular approach to energy production at a territory level. At the same time, the development of new flexible business models built around customers' needs and preferences such as power purchase agreements or integrated offerings will contribute to make the energy transition accessible and cost-effective for all, thereby taking down the barriers on the path to a low-carbon world.



# Demand response

As the production system is more and more decentralised, with ever more volatile loads, power systems need to be increasingly flexible. At the same time, with digitalisation, the electricity grid is becoming smarter, making it possible to have real-time data both on demand and supply side, which can be exploited. In this context, demand response (or demand-side response) provides an opportunity for consumers to reduce their costs while playing a role in the operation of the electric grid. Time-based pricing can trigger behaviour changes, with positive impact for the electricity network and the broader power system.

## DEMAND RESPONSE CAN SUPPORT A GREENER, MORE EFFICIENT GRID

Current advancements in metering, communication and control infrastructure allow energy consumers to have access to precise information about when and where energy is consumed in their operations. Demand response (DR) is a form of demand-side flexibility requiring that end-users adjust consumption – temporarily reduce their demand on the electricity network (negative demand) or lower the level of demand by using their onsite generation assets – in response to incentives or signals from the market, an energy supplier or the grid operator.

One can distinguish two main types of demand-side flexibility:

- “Incentive driven” demand-side flexibility: committed, dispatchable flexibility that can be traded (mostly large commercial and industrial during peak events).
- “Price-based” demand-side flexibility: consumer’s reaction to price signals. Time of use load shifting (encouraged by time varying pricing schemes).

In this way, demand response can help better integrate renewable energies by correcting the imbalances in the generation of certain green energy resources.
Demand response shares several characteristics with another electricity-related program: Virtual Power Plant (VPP). The need for VPP comes from the proliferation of distributed energy resource (DER) generation assets whose generation profile varies too strongly. There is also a scale challenge as, often, DER simply do not meet the minimum bid size of the markets. The aggregation (i.e. grouping the energy consumption or generation) of thousands of DER owners with wind, solar, co-generation, battery or thermal energy storage into a VPP can deliver large amounts of generated or stored electricity to the grid along with simultaneous demand reductions. VPP can thus provide the same service and trade on the same markets as large central power plants or industrials.

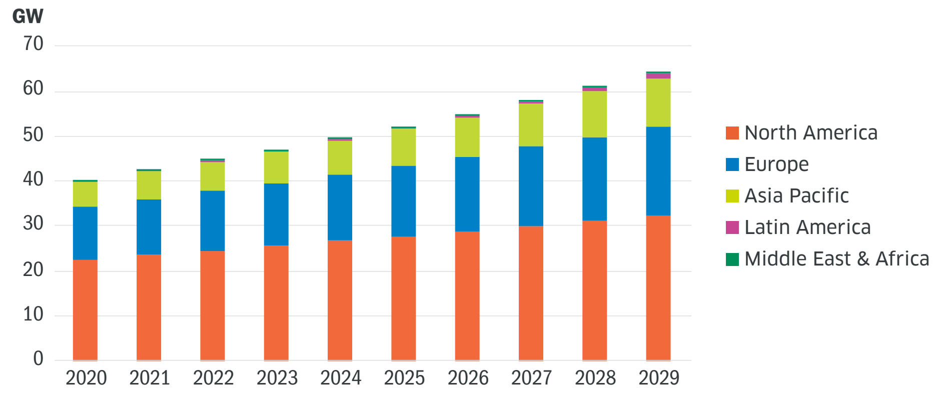
> **“Current advancements in metering, communication and control infrastructure allow energy consumers to have access to precise information about when and where energy is consumed in their operations.”**

## DEVELOPMENT PERSPECTIVES FOR DEMAND-SIDE MANAGEMENT

The expansion of variable energies within the electric system offers development perspectives for demand-side management. Today, 40 GW of demand response are in use. Global capacity of all forms of demand-side flexibility expanded 5% in 2019[114]. Demand-side flexibility is thus already a reality and is being deployed in some parts of the world. Driven by capacity constraints, aging infrastructure, and the need for increased grid stability, DR programs also benefit from local emissions targets and CSR initiatives. In 2019, deployment increased across the United States, Australia and in some European markets and this trend is set to continue[115]. Fig. 21

Overall, commercial & industrial demand response capacity is expected to increase 60% from 2020-2029[116]. However, there is still a long way to reach the full potential of this flexibility source. Less than 2% of the worldwide potential for demand-side flexibility is currently being utilised. Among the challenges are the lack of reliance on dynamic, real-time pricing. Enlarging the reach of DR will require that markets and regulatory conditions allow it to compete equally with other forms of flexibility.

**Fig. 21 - Commercial and Industrial Demand Response Capacity by Region, 2020-2029**




*Source: GuideHouse Insights, Market Data: Commercial and Industrial Demand Response, 1Q 2020.*

## ENGIE TAKES UP THE ROLE ON BOTH DEMAND SIDE AND SUPPLY SIDE

ENGIE is able to take up the role as intermediary, managing and optimising flexibility on the demand side, but also on the supply side of the market. Directly linked to the Group's strategy of becoming leader in energy and climate transition, ENGIE believes in demand response as an efficient and revenue-enhancing service for consumers to meet the challenges of a low carbon economy.

**Created 5 years ago through internal incubation, NextFlex combines the Group's demand management skills.**

NextFlex is a solution offered by ENGIE to industrial and commercial customers to save on energy costs. The role of an aggregator like NextFlex is to create a pool of industrial or tertiary sites capable of adapting their consumption when notified. Currently, NextFlex valorises the demand response ability of more than 300 industrial and commercial sites in Europe. Concretely, in the event of a peak in consumption at the national level or a drop in production (e.g if there is little sun and wind), NextFlex activates the erasable capacities of industrial and tertiary partners sites to balance generation and consumption on the grid, and remunerate them for their engagement.

**ENGIE can also act as an aggregator on the supply side of the market.**

ENGIE, via its Global Energy Management (GEM) business unit, is a demand response aggregator that serves commercial and industrial consumers to help them take advantage of their green assets. As an aggregator, GEM monitors electricity markets and consumer sites' capabilities and seeks the most profitable revenue opportunities. GEM aggregation offers for renewable energy producers are available in Belgium, France, Germany and the Netherlands, and fully adapted to meet local market specificities.

# A variety of energy storage technologies

The rapid growth and cost competitiveness of renewables allows it to service a growing share of energy demand. However, some of these energies are variable in nature, requiring flexibility and back-up solutions. To address this challenge, energy storage will likely become an important element of the future energy system. Different storage technologies exist at all steps of the energy value chain, yet their full potential appears untapped due to the lack of market signals to stimulate investments. Storage could offer more benefits to the energy system, provided that technological progress is made, and long-term objectives are effectively reflected in the regulations and design of the markets.

## ENERGY STORAGE TECHNOLOGIES ARE CONCRETE MEANS IN A LOW CARBON SYSTEM

As the world advances towards more and more renewables, solutions are developing to compensate for both fast and slow fluctuations, encourage the development of local energy and microgeneration and massively store electricity. Beyond the traditional storage in the form of kinetic energy in pumped hydro, energy storage covers a broad range of technologies. In particular, the deployment of grid-scale batteries – which are modular and allow a wide range of applications – is ramping up as costs continue to fall.

### Energy storage is encompassing a broad range of technologies

Energy storage technologies absorb energy and store it before releasing it to supply energy or power services[117]. Several technologies exist, at different scales and different maturities. Some technologies are fully commercial, while some others are still in demonstration or early R&D. Technologies can be mechanical (pumped hydro storage, flywheels, etc.), electrochemical (classic batteries, flow batteries), thermal (cold or heat storage), chemical (hydrogen storage for example) etc. Each of them have different properties and aim to deliver different services. Energy storage technologies can be characterised by power rating and discharge duration.

> **Solutions are developing to compensate for both fast and slow fluctuations, encourage the development of local energy and microgeneration and massively store electricity**

First, power-oriented storage are fast responding storage technologies, typically to respond to fluctuations induced by variable renewables or weak grid (e.g. batteries, flywheel, supercapacitors etc.). Second, energy-oriented storage are designed for use for longer durations, to provide services such as peak load shaving. Already today, gas plays a key role in integrating variable renewable energies into the electricity system. Likewise, "Power to gas" will be a key technology for the integration of the energy sector because it has the unique advantage of providing seasonal storage for renewable energies by using existing gas infrastructure. Finally, capacity-oriented storage are typically seen as a "last resort" / back up system.

On top of saving surplus energy, energy storage devices can provide services to the electrical system, from supply-demand balancing, to frequency and voltage adjustment, and congestion resolution. The storage capacities can be connected to the networks in a centralised way, or decentralised (storage installed in a logic of self-consumption by private, residential, or industrial customers). They can also be distinguished by their stationary (storage connected to a fixed point on the network) or mobile nature (on-board storage in electric vehicles). The relative importance of these diverse technologies in the long term will depend on the future evolution of low-carbon electricity systems.

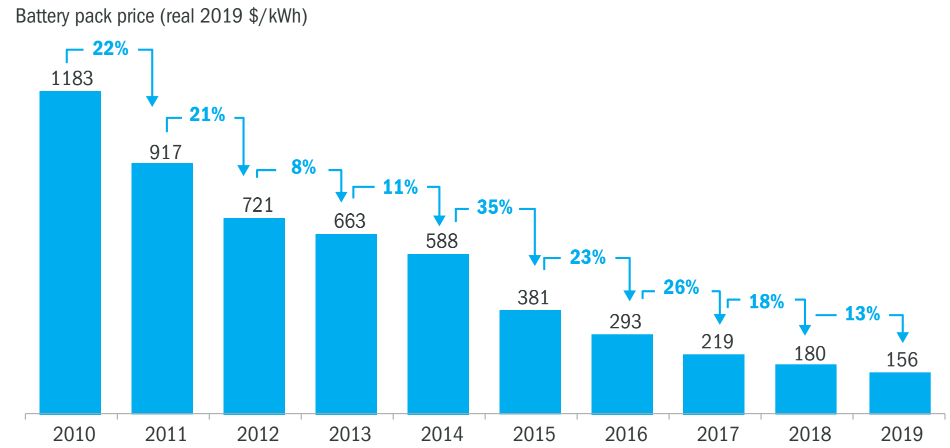
## Pumped hydro storage is one of the oldest and most widely used storage technologies

Pumped hydro storage represents today more than 96% of installed energy storage capacity worldwide[118]. It is among the cheapest as well as the most mature and largest capacity technology available. Pumped hydro storage (PHS) consists of two reservoirs connected by an underground shaft and a powerhouse containing a turbine-generator. Energy is stored by pumping water in the highest reservoir. When the water is released, it goes through the turbine which turns the generator to produce electric power.
PHS has traditionally been a technology of choice for delivering long duration storage services. One crucial advantage of this technology is that gravitational energy stored in the upper reservoir can stay for long periods of time with virtually no energy loss. In addition, pumped storage has an important role for balancing the electricity system, since it can react quickly if electricity is needed. This complementarity applies at the scale of the electric system but also at the scale of a specific project where it can combine with other variable renewables (e.g hybrid systems with wind or solar PHS plant[119]). However, despite some innovations, no major growth is anticipated due to the lack of suitable locations. The technology faces strong geographical and societal constraints. Suitable geologic formations vary from country to country and tend to be found in remote locations (e.g mountains). Pumped hydro also faces complex and long development processes for projects and environmental impact concerns limit site locations. Overall, although storage remains dominated by PSH, a large part of the uptake of energy storage is rather expected to come from batteries due to cost reductions and technology progress.

## Batteries, one of the key enablers of a low-carbon economy

Batteries' modular and fully scalable nature, combined with falling costs, make them one of the key enablers of a low-carbon economy. Battery storage systems can be used for a variety of applications in the power sector. Home batteries and electric vehicles ('behind-the-meter') can help manage better the distribution grids. Recent technological advances combined with falling costs have also opened opportunities for utility-scale use cases, allowing batteries to provide a much broader range of services. For instance, batteries can provide frequency control, shifting consumption and flattening intraday demand peaks. They can act as buffers to store renewable energy near the place of production for later use or injection into the grid at times of high demand and high prices. In this respect, the co-location of renewable energy production facilities with energy storage assets [120] (combined solar plus storage projects and the emergence of "hybrid PPA": solar, wind integrated with a battery storage project) has emerged as a major opportunity and driver of new growth. These combined projects account for a large percentage of newly announced energy storage capacity, and lithium ion battery technology leads this growing market[121]. Li-ion battery's dominance has been largely driven by declining costs (from 1,183 $/kWh in 2010 to 156 $/kWh in 2019[122]), which has in turn been driven by the increase in production to meet growing demand for consumer electronics and electric vehicles. BNEF projects that the cost of Li-ion batteries should continue to decrease at the same rate as today (-6% / year) and be cheaper than pumped storage in 2030, going down to 70€/ kWh. Fig. 22

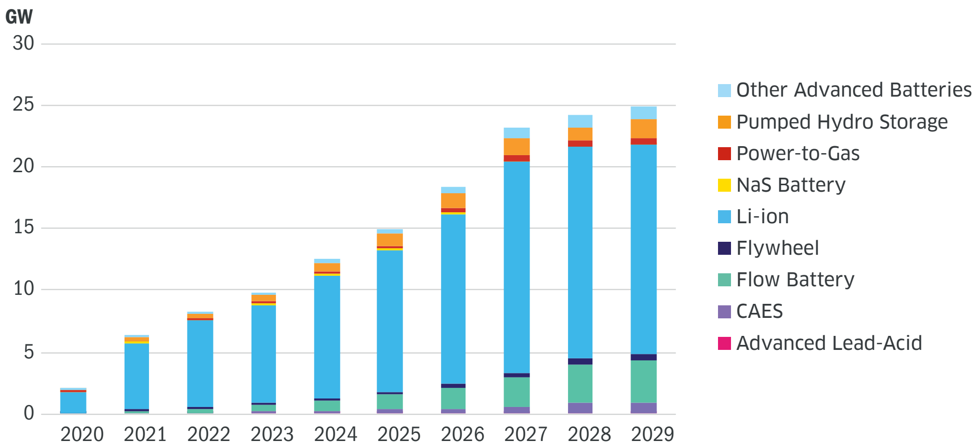
**Fig. 22 - Evolution of lithium-ion battery pack price 2010-2019 in $/kWh**




*Source: BNEF NEO, Lithium-ion battery price survey results: volume-weighted average, 2019.*

As a result of these spectacular cost decrease, lithium-ion batteries will likely be the dominant technology in terms of annual installed capacity for the next five to 10 years. Yet, several alternative options are also finding support for utility scale energy storage. Potential candidates range from flow batteries, to lithium-sulphur, solid electrolyte, sodium-ion, and metal-air batteries which are currently being evaluated and tested by ENGIE in the laboratory, or even as part of demonstration projects. Some of these technologies provide longer life, lower costs and a more sustainable life cycle when compared to the current technologies. Fig. 23

### Fig. 23 - Annual Installed Utility scale energy storage Power Capacity by Technology, World Markets: 2020-2029

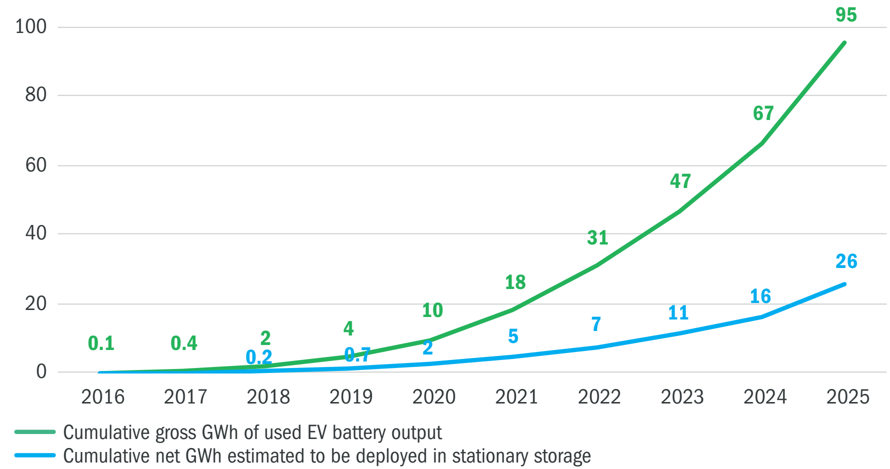



*Source: Guidehouse Insights, Market Data: Utility-Scale Energy Storage Market Update, 3Q 2020.*

## Second-life batteries could boost battery storagee

It is expected that in the coming years, "second-life" batteries will emerge as a new opportunity and will take a substantial place in the stationary battery market. As the electric vehicle market is set to grow quickly, finding ways to reuse the batteries is also becoming more urgent. According to BNEF, the global stockpile of EV batteries is forecasted to exceed the equivalent of 3.4 million packs by 2025[123]. Indeed, lithium-ion batteries in EV applications degrade strongly during the first years[124]. Yet, at the end of their service life in electric vehicles around 70 to 80%[125] of the original capacity could be further utilised. Possible applications range from stationary storage (e.g to increase photovoltaic self-consumption in households), to managing peak demand and regulating grid frequency. By 2025, global second-life batteries used for stationary storage is expected to reach 26 GWh. The main benefits of this storage method include competitive kWh price, estimated life after being taken off the roads of 7-10 years as well as the circular economy aspect of this approach. Moreover, finding applications for these batteries can ultimately help bring down the cost of storage to enable further RES integration. Fig 24

### Fig. 24 - Forecast for second-life batteries, and availability for stationary storage, 2016-2025 (GWh)




*Source: BNEF, Used EV batteries for stationary storage, August 2016.*

Business models of battery second use already exist. The Umicore / Renault / ENGIE Connected Energy consortium is an illustration of this concept. With the help of ENGIE, Umicore - a global materials technology and recycling group - has installed a "second life" energy buffer battery at its site in Olen (Belgium). The buffer uses 48 EV batteries that Umicore received from Renault kangoo vans. The battery packs are integrated in the most economical way and have a combined storage capacity of 720 kWh. At the end of their life, Umicore will recycle the batteries to produce new battery cells containing recycled cobalt and nickel.

## THERMAL STORAGE TECHNOLOGIES: AN EFFICIENT WAY TO SUPPORT THE DECARBONISATION

At present, thermal energy storage (TES) is still a relatively niche market. Yet, this technology is receiving increasing interest as efforts to decarbonise heat further develop. Thermal energy storage can be used to manage variations in supply and demand at different scales, from large scale industrial applications, CSP plants or DHC networks, to smaller scale for commercial buildings and household dwellings[126]. Thermal storage technologies may be an efficient way to support the decarbonisation of the heating and cooling sector.

### Three categories of thermal energy storage technologies

Thermal energy storage technologies can be divided into three categories: sensible, latent and thermochemical heat storage. Thermal energy storage refers to the concept of storing energy in the form of heat or coolth, enabling its use later for heating, cooling or power generation. Applications can store heat on an intra-day basis, from one day to another, on a weekly basis, as well as providing interseasonal storage[127]. Thermal energy storage technologies can be divided into three categories. First, sensible heat storage, resulting in an increase or decrease of the storage material temperature. The most commercial heat storage medium is water (residential and industrial applications), but the storage material can also be air, oil, bedrock, brick, concrete, etc. Second, latent heat storage. It is based on the phase transformation of the storage materials (phase change materials, or "PCM"), for example from solid to liquid and vice versa. Finally, thermochemical storage (less mature) refers to the use of reversible chemical reactions to store large quantities of heat in a compact volume. Current R&D efforts in the field cover storage material, containers, thermal insulation development and aim at increasing the efficiency of these processes. Significant cost reductions are expected for phase change materials and thermochemical storage as R&D and commercialisation advancements are made.

### Thermal energy storage could support the take-up of renewable heating and cooling

Currently, thermal energy storage still appears to be looking for its market. However, as the penetration of renewable energies progresses, with increasing demand for cost-effective cooling services and in some areas the electrification of heating, its role could become more and more important. TES has many possible applications. It can, for example, be implemented in district heating and cooling networks. In this application, thermal storage generally stores heat in the form of hot water in tanks. It introduces additional flexibility on the balance supply-demand of heat which can reduce the investment costs (biomass power plants and peak capacities). Moreover, the integration of thermal storage in concentrated solar power (CSP) plants can also contribute to address issues associated with fluctuating renewable power. In South Africa for instance, ENGIE operates the 100 MW Kathu Solar Park, equipped with a molten salt storage system that allows for 4.5 hours of thermal energy storage to provide reliable electricity in the absence of solar radiation and during peak demand. Additionally, thermal storage at factory-level can offer flexibility in the industrial sector. Electric heat appliances could make use of real time electricity prices to improve demand response.TES can also support the use of waste heat from industry, thus offering operational flexibility and efficiency gains to industrial processes (e.g in combined heat and power). These systems can help commercial and industrial owners meet company and government sustainability goals and facilitate increased distributed renewables generation.
Overall, Asia Pacific is projected to be the largest regional market for commercial and industrial (C&I) thermal energy storage in

the coming decade. Annual power capacity deployments in the region are expected to increase from 5.1 MW in 2018 to 226.2 MW in 2027 at a CAGR of 52.5%[128]. **Fig. 25**

## THE ESTABLISHMENT OF A ROBUST ENABLING FRAMEWORK

Success in getting the full benefit from energy storage technologies will depend on the establishment of a robust enabling framework. Storage technologies can provide many benefits to the energy system, yet their potential appears untapped. Various barriers for energy storage technologies exist, which prevent them from participating in the different energy markets or even from being competitive compared to traditional energy technologies. Adequate regulations and market design, combined with financial support for research, development, and demonstration, will be key in making energy storage competitive.

### Develop long term visibility on storage remuneration

The lack of adequate price signals is one of the important barriers currently preventing storage from offering all its benefits. Storage revenue streams carry a significant risk as they can be object to cannibalisation. Any additional storage will absorb revenue from earlier storage providers. Yet, current remuneration schemes are not matching storage value creation in terms of flexibility, capacity, and additional storage services. To overcome this challenge, a clear market that sends long-term signals to investors – such as mechanisms to reward capacity availability and flexibility - will be essential.

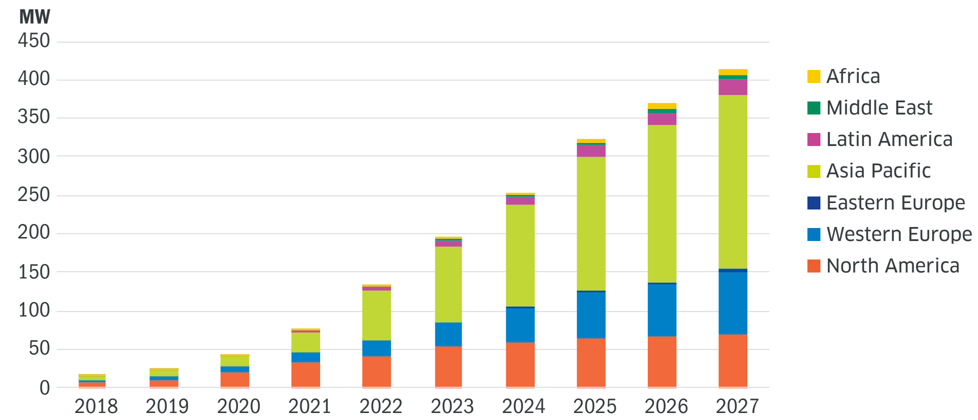
### Facilitate the insertion of storage in the electrical system

Energy storage systems behave successively as consumption sites and production sites. This dual nature means that storage facilities sometimes pay grid fees both as consumer and producer. Such grid fees may hinder the integration of energy storage. They do not reflect the balancing benefits of storage and raise the question of equal treatment vis-à-vis consumption and production assets that are paying the cost in only one way. Recognising energy storage as a specific asset class in energy related regulations could be an important step to acknowledge its characteristics. Reviewed grid tariffs, reflecting storage positive effects on grid constraints, grid extension costs, and reduced curtailment will contribute to ease the insertion of storage in the system.

### Allow storage to easily offer its services

At the demand side, distributed storage can compensate the variability of RES and stabilise the local system. To help better integration of renewable energy resources, these distributed storage assets could be used in the markets through aggregators. Yet, a minimum capacity is often necessary to access certain markets and only physical (and not virtual) capacities are accepted. Removing unnecessary barriers to market participation by aggregated DER resources will help to overcome this issue. This can be achieved notably by encouraging the introduction of aggregators in balancing markets (e.g via more collaboration with TSOs) and by having the market operators reducing their minimum capacity level for participation.

**Fig. 25 - Annual C&I Thermal Energy Storage power capacity by region: 2018-2027**




*Source: Guidehouse Insights, Thermal Energy Storage Systems for Residential and C&I Applications: Global Market Analysis and Forecasts, 4Q 2018.*

# Energy system integration

Energy system integration across energy carriers, infrastructures, and sectors is the pathway towards a resilient, secure, and cost-efficient decarbonisation. Linking up the different energy carriers, infrastructure and sectors would not only allow greater integration of renewable energies – including at the local level - but would also reduce the costs of decarbonisation by optimising the use of existing infrastructures. It would also offer a more circular approach to energy production, improved resilience, and security of supply. But for this vision to happen, a more cross-sectoral approach to energy policy need to be accompanied by strong financial support to foster technological advancement.

## ACHIEVE A SUSTAINABLE AND COST-EFFICIENT ENERGY SYSTEM

Sector integration emphasises synergies across multiple energy carriers to achieve a sustainable and cost-efficient energy system. Although they were not thought of together, the gas and electricity systems complement each other. The flexibility and resilience provided by the gas system to the electricity one alleviate the stress of the power grid, significantly reduce investments needed and facilitate the integration of large-scale variable renewable energy. The concept of sector integration uses this complementarity to strengthen the links between energy carriers, infrastructures, and sectors.

### System integration will create stronger links

Current energy systems are built on several separate silos (electricity, gas, heat), thereby often leading to inefficiencies, both technically and economically. The electricity and gas networks are planned and managed independently from each other. Market rules are also generally specific to distinct sectors. This way of thinking about the energy system naturally leads to inefficiencies. Energy system integration – defined by the European Commission as the coordinated planning and operation of the energy system 'as a whole', across multiple energy carriers, infrastructures, and consumption sectors[129] – could go a long way towards

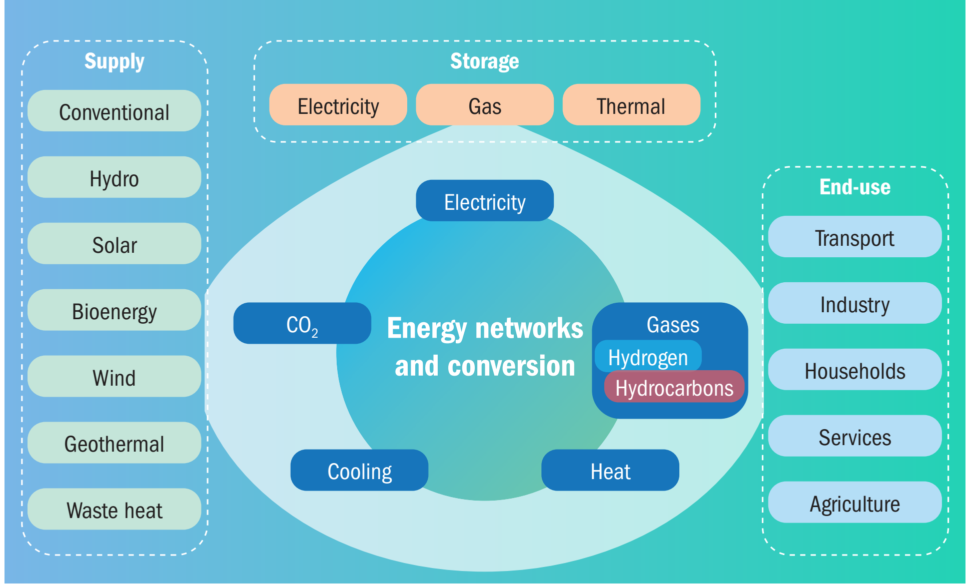
"The flexibility and resilience provided by the gas system to the electricity one alleviate the stress of the power grid"

achieving a low-carbon, reliable, resource-efficient and affordable energy transition. It encompasses three complementary and mutually reinforcing concepts: a more 'circular' energy system, a greater direct electrification of end-use sectors and the use of renewable and low-carbon fuels, including hydrogen. Energy system integration will rely on clean technologies and value chain. These technologies can be very diverse, from gas-to-power technologies (e.g. CCGTs) to power-to-gas technologies (e.g. electrolysis and methanation), or hybrid technologies (e.g. hybrid heat-pumps). Rather than making individual efficiency gains in each sector separately, sector integration leads to the optimisation of the energy system, thereby avoiding additional infrastructure costs. Fig. 26

### Energy integration reduces emissions and provides flexibility

At the production level, "Power to gas" (hydrogen or e-methane) will be one of the cornerstones of the future energy system. It

**Fig. 26 - Coupling of the energy system sectors**




*Source: European Parliament, Sector coupling: how can it be enhanced in the EU to foster grid stability and decarbonise?, November 2018.*

will usefully complement batteries, pumped storage, and demand response, since it has this unique advantage of providing seasonal storage for renewable energies, using existing gas infrastructures. Next to economic efficiency, the use of gas infrastructures has further advantages: gas pipelines and storage are not only able to balance demand at all time frames up to seasonal variations, but can also cover energy demand in case of power supply failure and/or peak consumption.

At the users' level, green gases can replace fossil fuels in many end-use applications. In buildings, smart hybrid appliances such as hybrid heat pump (coupling of an electric heat pump and high-performance gas boiler) will open the way for a dynamic management of the electric demand, with no impact on the end user's comfort. This flexibility will increase energy safety by giving the possibility to shave local/national electric peaks, thus saving on the high costs (in euros and $CO_2$), of peak electricity production and grid capacity. This flexibility can as well be used to prioritise the most carbon efficient source of energy available, either renewable electricity or renewable gas. In transport, fuel cell electric vehicles (FCEVs) fuelled by hydrogen could complement electric vehicles in specific segments, such as heavy vehicles or buses. Likewise, a combination of gases including hydrogen and hydrogen-derived synthetic liquid fuels could be used for heavy-duty vehicles, shipping, aviation. In industry, hydrogen can play an important role as it can be used for high-temperature heat production, as a feedstock in the chemical industry or as a reductant in steelmaking, thereby eliminating coal or replacing gas-based processes. Additionally, for industrial areas, a key area of interest is represented by industrial symbiosis, where geographically close industries can develop a competitive advantage by the synergetic exchange of materials, energy, water and byproducts. BE CIRCLE, a consulting service based on a web platform, is among the tools designed by ENGIE to help build industrial synergies that increase resource use efficiency and competitiveness.

## Strong financial support and cross-sectoral approach to regulation will be key

The extent to which energy system integration can be achieved will depend on the creation of a level playing field for all solutions, allowing for competition and innovation. Creating this level playing field will include dedicated policies to help emerging technologies to reach maturity and making them able to compete. An appropriate regulatory framework will also be needed to facilitate coordination between different energy systems and realise the benefits of sector integration.

## Distorted investment signals

Several barriers to efficient sector integration are related to distorted investment signals. These apply both for operators and final consumers, notably the lack of a coherent $CO_2$ price signal, insufficient internalisation of externalities, tariffs, methodologies, etc. which do not properly reflect system cost. As priority measure, it is important to set a robust and stable price for $CO_2$ in all sectors and for all energy carriers. This will contribute to provide the right signals to operators and consumers in favour of low-carbon options. It will also reduce the need for financial support to decarbonisation technologies and alleviate customers' bills from levies to finance support mechanisms. Moreover, other externalities should be internalised as far as possible, including positive externalities of biomethane production for the agricultural sector, waste treatment, rural development, circular economy, etc. In addition, consumers need to have clearer signals regarding the impact of their purchase decisions on the total system. For instance, when investing in a new electric heating system which contributes to increasing peak demand and needs to invest in networks and/or back-up,


consumers should be exposed to network tariffs and prices reflecting these costs. Necessary firm capacities and flexibility solutions need to be properly valued through an appropriate market design including capacity mechanisms and local markets for congestion management.

### Lack of maturity and/or commercial scale of technologies

Important technologies for sector integration such as biomethane, syngas (i.e. gasification of organic and inorganic waste), renewable hydrogen and other power-to-gas options are emerging technologies. They are still at the beginning of a learning curve which promises substantial cost reductions through scaling up capacities. However, to realise these cost reduction potentials, players along the value chains need long-term visibility. In Europe, this could be achieved through a binding European target for green gases which is broad enough to give Member States the freedom to develop different types of renewable gases while at the same time encouraging injection in gas networks up to a certain extent. National support mechanisms and EU Funds, but possibly also sector-specific objectives for instance for renewable (and decarbonised) hydrogen and/or biomethane use in industry, could help reaching this target. Finally, a market for these gases needs to be created based on a common classification of renewable and decarbonised gases (based on carbon content and allowing a clear differentiation between renewable and non-renewable) and interoperable guarantee of origin schemes. Both renewable and non-renewable, decarbonised hydrogen will be part of the panel of solutions to achieve ambitious climate targets. Nevertheless, a dedicated policy approach will help to promote hydrogen from renewable power which is less competitive than “blue hydrogen” (i.e. for which the carbon emissions are captured and stored or reused) today but has many specific virtues.

### Roles and responsibilities

Unclear roles and responsibilities can be a significant barrier and risk for investors, for commercial (i.e. non-regulated) actors. A clarification regarding new activities such as Power to gas (P2G) would therefore be beneficial. These are in principle market activities. If the market does not bring forth the needed investments despite appropriate incentives and information, it should be possible to grant limited and temporary exemptions to system operators allowing them to invest and operate P2G assets. Moreover, unbundling, third party access, and other rules applicable to natural gas networks should also apply to other gas networks (hydrogen, $CO_2$).

### Cooperation of system operators

As regards planning and investment in networks, development of electricity, gas, and district energy systems “in silos”, each based on its own assumptions about future developments, is unlikely to bring about the most efficient solutions. At EU level, the transmission system operators ENTSO-G and ENTSO-E have taken first steps to better coordinate their respective ten-year network development plan (TYNDPs). ENGIE encourages them to go further and develop a robust, joint TYNDP for gas and electricity with full transparency and updated assumptions, in particular on peak power demand, geographical location and $CO_2$ content of power generation, and efficiency of heat pumps as a function of outdoor temperature. Beyond those necessary steps, the best way to ensure an efficient sector integration would be to enable a holistic vision on the energy sector and a truly integrated approach to infrastructure development.



## CARBON CAPTURE USE AND STORAGE (CCUS) MAY ALSO PLAY A ROLE

Even with an integrated energy system, it is unlikely that all $CO_2$ emissions be completely eradicated. Carbon sinks may also be part of the range of solutions to be implemented to offset carbon emissions. At present, there are two main approaches to carbon sinks. On the one hand, natural carbon sinks, such as oceans and forests, which are already important for atmospheric $CO_2$. On the other hand, technical solutions are also emerging. At present, carbon capture is the most promising carbon absorption technology. A recent study suggested that carbon removal solutions have the potential to mitigate 37 gigatons of carbon dioxide per year, where annual emissions are roughly 38 gigatons of carbon dioxide per year[130].

## CCUS: a possible solution

Process industries (e.g cement, steel, aluminium, paper, and refineries) have inherent $CO_2$ emissions resulting from raw material conversion. Carbon Capture Use and Storage (CCUS) technologies – as they prevent $CO_2$ from being released into the atmosphere – thus offer significant potential. There are two main carbon capture technologies. $CO_2$ point sources (PSCC), which separate $CO_2$ from concentrated sources like power plants. And direct air capture (DAC), with which carbon dioxide can be removed from ambient air through chemical processes. The main aim of CCS is the moderation of climate change by storing large amounts of carbon dioxide underground. The technology involves several steps, from capturing $CO_2$ to compressing it for transportation and then injecting it deep into a rock formation, where it is permanently stored. However, such technology raises social acceptance issues along with concerns that carbon will not be permanently sequestered and may leak out over time. An alternative to $CO_2$ storage is thus to valorise it. This is called carbon capture and utilisation (CCU). $CO_2$ can be used as buildings materials (e.g cement-based building materials) or for the synthesis of products with high added value or energy content. As an example, hydrogen produced with green electricity combined with $CO_2$ from sustainable biomass or direct air capture can make a carbon-neutral alternative of the same molecules as natural gas or oil. This synthetic fuel can be distributed via existing transmission/distribution system and used by existing installations.

## CCUS barriers

Nowadays, there are more than 50 largescale CCS facilities at various stages of development[131]. At R&D stage, ENGIE is involved in “Horizon 2020” projects like C2Fuel to demonstrate and improve CCU technologies. Nevertheless, the technology has not reached the commercialisation stage, most notably due to the lack of demonstration, economic viability, regulatory barriers, and limited public acceptance. Overall, the costs of CCS is still high. First, the process of carbon capture is highly energy intensive. Access to cheap and abundant electricity is one of the prerequisites for deployment. Moreover, huge volumes to store and time scales (1,000 – 10,000 years) make $CO_2$ storage technically challenging and there is high uncertainties on geological data. To decrease the costs, industrial facilities sharing CCS infrastructure (CCS hubs and clusters) are an emerging trend. These facilities take advantage of the fact that many emission intensive facilities (both power and industrial) tend to be concentrated in the same areas. Hubs and clusters offer commercial synergies that reduce the risk of investment and significantly decrease the unit cost of $CO_2$ storage through economies of scale. Creating markets for premium lower-carbon materials through public and private procurement can also accelerate the adoption of CCUS and other lower-carbon industrial processes[132]. Additionally, a long-term regulatory framework, including aspects such as $CO_2$ pricing, long term responsibility for storage and financing for pilot projects would contribute to provide long term visibility to the technology.

# New business models will provide further opportunities

A holistic approach to the energy transition also implies the development of new business models, - combining the best technologies while optimising the use of capital and energy. Corporates and local authorities themselves have been evolving, playing a more active role in energy generation, sourcing more green energy and looking to reduce the associated risks. Power purchase agreements, integrated offerings and circular business models will - each in their own way, contribute to these goals, while ensuring that the energy transition is accessible and cost-effective for all.

## THE RISE OF POWER PURCHASE AGREEMENTS

The rise of power purchase agreements allow corporates and local authorities to ensure their supply of green energy while benefiting from long-term visibility on prices. Over the past few years, the climate ambition has left the sole field of regulation to fully enter the economic world. Corporate PPAs are part of this fundamental movement in the energy transition by which states limits their commitments and, in return, involvement from businesses and local authorities is rising. Energy can be a major contributor to an organisation's carbon footprint, so a combination of reducing usage and buying from renewable sources can go a long way towards achieving zero-carbon goals.

### PPAs enables companies to secure green energy supply

The combination of falling renewable power costs and mounting corporate appetite for renewable energy has driven the era of corporate PPAs enabling companies to secure green energy supply. PPA contracts involves a direct supply agreement between a power producer and an offtaker (i.e. end-user). In the case of corporate PPAs, the main offtakers are large energy consumers coming from different sectors, including IT, heavy industries, food, and beverage etc. In less than a decade, annual renewable energy created from corporate power purchase agreements went from near zero to 19.7 GW[133] in 2019. This tremendous growth of corporate PPAs was primarily driven by the combination of falling renewable power costs and mounting corporate appetite for renewable energy. The benefit for corporate customers is twofold. First, the assurance of renewable energy from a known source at a fixed price as opposed to a volatile commodity electricity price. Second, it helps reducing the environmental footprint of operations. Additionally, in the absence of subsidies, corporate PPAs are becoming an increasingly common way for renewable developers to fund new-build plants. At present, several types of PPAs exist. PPAs may be off-site (e.g for industrial sites that have limited space) or on-site if resources are available. They can be physical or virtual. With a physical PPA, the offtaker takes title to the physical energy at a specified delivery point on the electric grid. Conversely, a virtual PPA does not require the developer

> **Energy can be a major contributor to an organisation's carbon footprint, so a combination of reducing usage and buying from renewable sources can go a long way towards achieving zero-carbon goals.**

and offtaker to be connected to the same grid. The electricity generator sells its electricity in the spot market and then exchanges the floating revenue for fixed payments from a corporate offtaker.
ENGIE aims to become one of the leaders in renewable PPAs for businesses. In 2019, the Group signed 2.1 GW of corporate PPAs[134] with industrial and local authority customers worldwide, including 1.2 GW in the United States and was the No.1 world seller of clean energy corporate PPAs.

### As the PPA market matures, contracts are evolving

Initially, PPA contracts were "as produced". There was no commitment on the volume, the companies consumed up to the available production. Then, contracts started focusing on defined and regular volumes (baseline) for a given period. Now, more flexibility conditions are introduced in these commitments. Contracts are evolving towards 24/7 supply offers based on actual consumption by customers. These contracts thus offer integrated solutions based on the specific needs of each client: they combine different sources of production or even storage to allow customers to benefit from competitive solutions.
With its Business Unit dedicated to trading and energy management (GEM), ENGIE increasingly offers these innovative solutions to support the development of renewable and decentralised energies. For instance, Microsoft Corp. and ENGIE pioneered a strategy in 2019 to convert variable renewable supply into a fixed 24/7 power solution aligned to Microsoft's specific energy requirements. Concretely, Microsoft wanted 24/7 green power for a new data centre in Texas. ENGIE combined a solar and a wind project (for a total of 230 MW) and structured a product to be able to provide 15 years of renewable energy. The deal increases Microsoft's renewable energy portfolio and helps them achieve their sustainability goals while paving the way to ENGIE's larger ambition to offer renewable energy as a service.

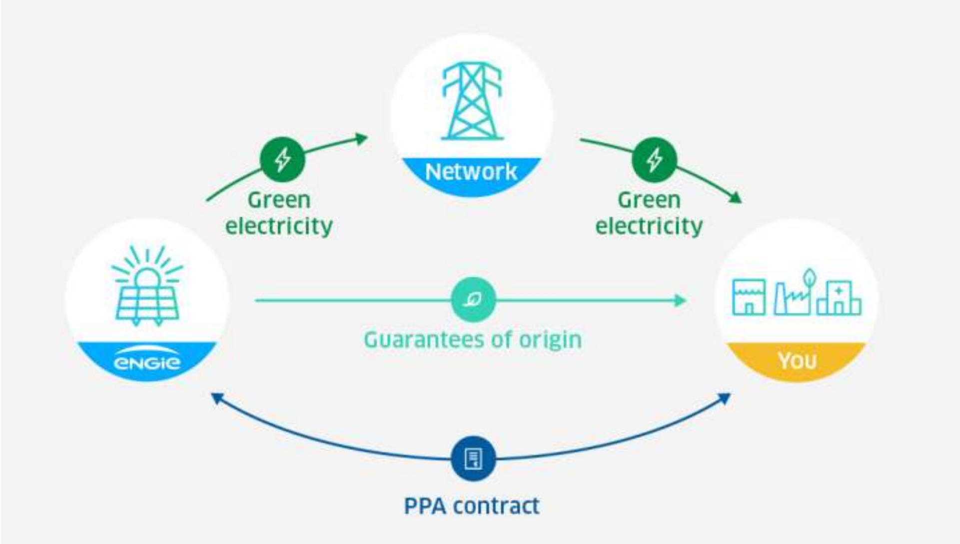
## INTEGRATED OFFERS, WITH EQUIPMENT FINANCING AND USAGES OPTIMISATION, CAN BE AN ANSWER

Energy markets are becoming a more and more fertile ground for integrated business models. A shift in focus away from centralised generation and distribution toward "behind-the-meter" zero carbon transition solutions, along with a long term outsourcing trend of customers who remain reluctant to take risk on solutions which are not in their core "know-how" can be observed. It creates room for specialised solutions including equipment financing and usages optimisation.

### Integrated offers, business model of the circular economy

Integrated offers allow clients to benefit from a combination of technologies and facilities, for the delivery of a service (such as thermic comfort or performance, mobility, lighting, etc.) without having to buy any asset and by paying per usage or per a monthly fee. In a nutshell, these offers encapsulate the whole value chain from advice to customers, asset design, construction, operation, maintenance and financing. Most business models deployed today are in the digital field (e.g. software-as-a-service) with no connection with the zero-carbon transition. However, recent examples show encouraging impacts in reducing usages carbon footprint (e.g. mobility, lighting, etc.). The

**Physical *offsite* PPA contract**



rising prices of raw materials, growing interest of companies to outsource non-core activities and the need for more flexibility in individual usages (housing, mobility, etc.) due to socio-economic transformation (aging population, increasing economic constraints, changing lifestyles, etc.) are all trends which have driven the multiplication of integrated offers since the years 2000s.

### ENGIE solutions are customised to sustainability strategies

ENGIE can help customers to avoid CAPEX while reducing energy use and risk. Example of offers include onsite and offsite energy supply, notably via PPA or virtual PPA that provide immediate savings with no up-front costs and long-term stability against fluctuating power prices. ENGIE can also provide financed, guaranteed energy savings solutions, for instance with energy performance contracts. Other available financing mechanisms include equipment leases or loans. ENGIE's contract with the Ohio State University (OSU) is a good illustration of these kinds of solutions. ENGIE launched a 50-year partnership with OSU to manage the sustainability, operations, and supply of their energy assets. The Group invested around 1.2 billion euros in 2017 and will be responsible for managing the university's energy systems with guaranteed energy efficiency improvements covering 485 buildings.

## VALORISATION OF RESOURCES AND STRENGTHENING OF THE LOCAL ECOSYSTEMS

With circular economy, renewable energy becomes a way to provide solutions based on the valorisation of resources and strengthening of the local ecosystems. With a population foreseen to reach 9 billion people by 2050[135], challenges will accelerate for the deficiencies of resources and the huge production of waste. This leads to a real paradigm shift in the way of perceiving energy, which is no longer solely associated with the extraction of resources but also as an opportunity for the provision of energy solutions from other valorised resources. An example is the use of industrial waste heat to heat buildings, for instance through a district heating network. This introduction of local loops – and capturing their positive or negative externalities – as well as associated concepts related to management of supply chain closer to the territories to reduce dependence and increase resilience are among the major developments to expect.

### A more "circular" energy system

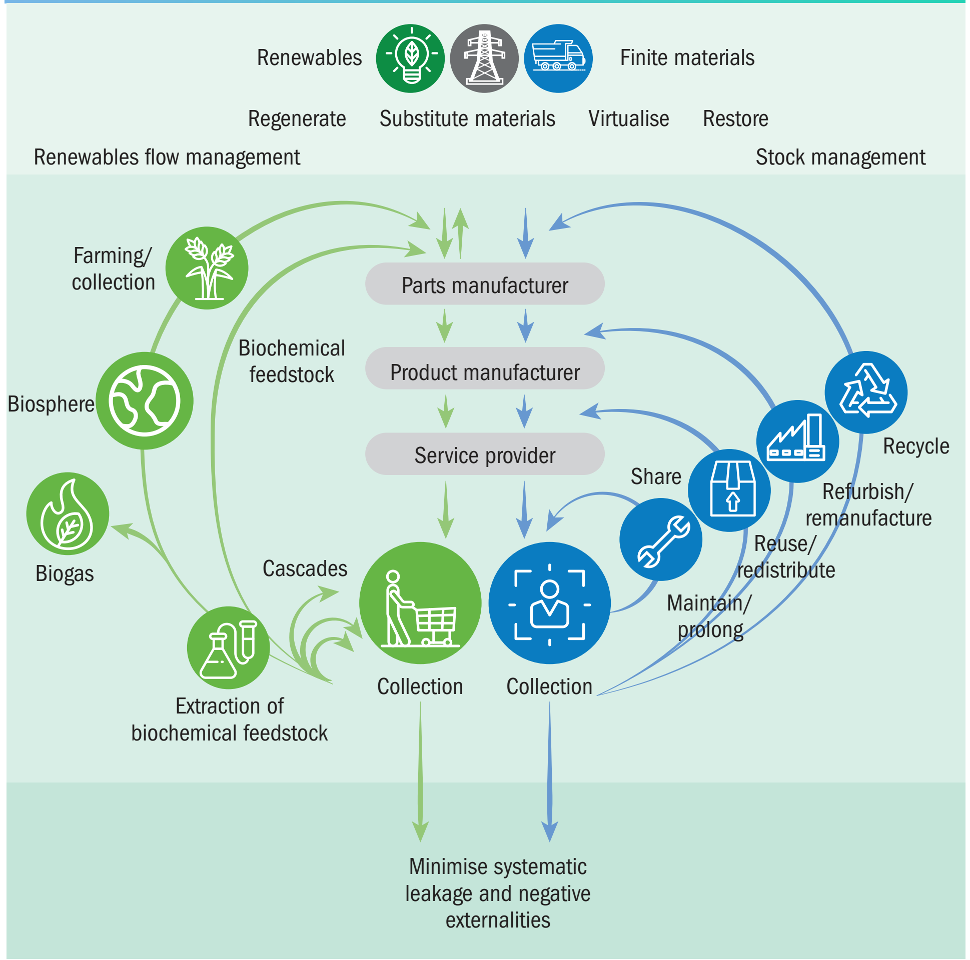
A more "circular" energy system, with increased energy efficiency and reuse, will be one of the foundations of energy system integration. At present, most economic models – from raw materials extraction, to the production, distribution, consumption, and disposal phase – follow a linear path. The world is only 9% circular and the trend is negative[136]. Of the 19.4 billion tonnes of materials classified as waste, only 8.4 billion tonnes of total material use of society is cycled, with the remainder incinerated, landfilled, or dispersed into the environment[137]. Therefore, moving from linear systems with high emissions, waste, and high impacts on ecosystems, towards circular systems that use resources more efficiently and sustainably is crucial. The economic benefit of transitioning to this new business model is estimated to be worth more than $1 trillion in material savings by 2030[138].
The European Commission defines a circular economy as an economy where "the value of products and materials is maintained for as long as possible. Waste and resource use are minimised, and when a product reaches the end of its life, it is used again to create further value"[139]. Circular economy, thus defined, proposes to rethink our production and consumption methods to optimise the

use of natural resources and thus limit the waste generated. For example, the valorisation of ashes resulting from the combustion of biomass plants to further produce crop or supplying green energy to data centres and valorising the fatal heat in a neighbouring industrial plant. Fig.27

## The circular economy models: a key area of development for ENGIE

An increasing number of customers are expressing a desire to recycle energy at their production sites, along with a need for new territorial approaches in terms of valorisation of local resources. A true example of what the circular economy can represent for a region, is the development of biomethane. Indeed, biomethane nourishes an entire ecosystem of players, stimulating the local economy and preserving nature. It offers farmers a tremendous opportunity to diversify their activity. Thanks to methanisation, their organic waste becomes a resource: farming residues and livestock effluents can be recovered to produce gas. The digestate, a by-product of methanisation, can replace mineral fertilisers to improve the soil and fertilise crops. By recovering organic waste through methanisation, industry can also reduce its environmental footprint. Finally, local authorities are finding a new outlet in the biomethane sector for their food waste, fermentable household waste and green waste. The GAYA platform which has been developed and is operated by ENGIE in France illustrates this circular approach. It aims to test the production of biomethane from dry biomass (forest products, wood chips, bark, or residues from the food industry) collected within a radius of 50 to 70 kilometers around Saint-Fons (Rhône). In this way, GAYA contributes to local and regional dynamism as part of a circular economy and low carbon approach. Along with boosting renewable gases, developing an industrial symbiosis strategy to valorise local circular loops is also a promising circular model. Circular economy in industrial areas is currently being explored by CRIGEN via the development of BeCircle. This geodata-based web platform allows to represent territorial clusters in terms of resources flows (water, materials, energy). It can help territories to get a better knowledge of their resources, and codevelop territorial strategies in a collaborative way embarking the local stakeholders. The platform defines scenarios closing the local resource loops, leading to positive impacts on competitiveness and environmental excellence for the local players. BeCircle can help produce estimations of the volume of organic wastes deposit usable for methanation plant, heat liberated from data centres to reuse, or plastic stocks available for pyrogasification and working in an innovative way to support decision-making on circular economy in industrial areas.

**Fig. 27 - Diagram circular economy**

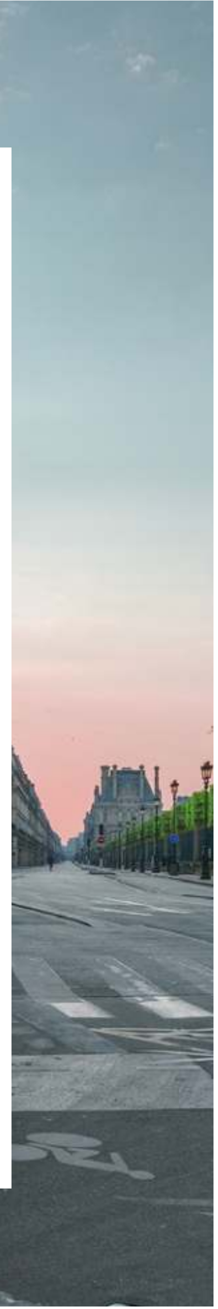



*Source: The Ellen MacArthur Foundation*

# Renewables in COVID times

The COVID-19 crisis resulted in a major health emergency and economic shock across the world, having a profound impact for citizens, societies and economies. But while countries are injecting considerable resources into their economies, this moment is also an opportunity to create a catalyst for even more changes in addressing both the economic and climate crisis. To reconcile the restart of activity with a stronger commitment to fight climate change, more sustainable, resilient organisations are essential.

The energy industry is at the core of this push and can promote green energy goals while creating jobs to foster economic recovery. ENGIE supports this movement and is developing on all energy transition solutions to advance a low carbon future and help corporates, cities and states in their transformation for a green recovery post-pandemic.



# The COVID-19 pandemic: a economic, financial and social shock

With over 100 countries having gone into lockdown, the COVID-19 pandemic triggered a historic economic, financial and social shock to the world. In recent months, unprecedented means have been mobilised to deal with the crisis created by Covid-19. These restrictions have reduced the spread of the virus, however with serious impacts on employment and investment for economies. The global coronavirus crisis is having a profound impact on every aspect of people's lives, bringing health, economic and social challenges for regions, countries and communities. The energy market is no exception, with supply and demand facing challenges such as a plunge in energy demand and investments, which could decrease respectively by 5% and 18% in 2020[140], and historically low fossil fuel prices (50%[141] lower than pre-crisis levels). Although renewable energy technologies were also affected by the pandemic, they have shown their resilience, making the call for green recovery even stronger.

## THE COVID-19 PANDEMIC HAS PLUNGED THE GLOBAL ECONOMY INTO A SEVERE CONTRACTION

The Covid-19 pandemic has brought a brutal shock to countries worldwide. At the height of the lockdowns in April 2020, about 4.2 billion people, representing almost 60% of global GDP, were subject to some form of confinement[142]. While the immediate focus of governments has been on public health, the restrictions imposed to contain the spread of the virus slowed and in some cases almost interrupted economic activity. Supply chains have been disrupted and the trade in goods and services has been halted. This translated into job losses and revenue declines in all sectors. According to the International Monetary Fund (IMF), the global economy is set to drop by 4.4% in 2020[143], and some 300 million jobs may have been lost during the second quarter of 2020[144]. This crisis is expected to leave long-lasting traces on the world economy, including strengthening protectionism, and possibly relocations and restructuring of supply chains as the pandemic has re-ignited the old debate about the supply chain risks associated with international production [145]. All the economies, both emerging and developed are threatened. At the country level, the extent of the recession will depend on the state pre-existing economy (indebtedness, unemployment rate, etc.). France's GDP is expected to shrink 9.8% for the year, Germany 6% and overall, the EU economy is expected to drop by 7% in 2020, its biggest decline since World War II[146]. In America, GDP in the United States could fall by 4.3% and Brazil could shrink 5.8%. Sub-Saharan African GDP is expected to contract by 3% and Middle East and North Africa by 5%[141]. As for Asia-Pacific economies, the International Monetary Fund (IMF) expects their output to contract by 1.7% in 2020, the region's worst performance in more than 50 years. Only a very small number of economies in Asia and the Pacific are expected to grow this year, including China by 1.9%[147]. A return to economic growth should be observed in 2021, as the IMF predicts a global growth at 5.2%. Yet, this would leave 2021 GDP around 6 percentage points lower than in the pre-Covid-19 projections of January 2020 [148]. The economic impact of the crisis will vary significantly between different parts of the economy. The most affected sectors should include transport, travel and retail, all of which are big consumers of energy.

## BUT RENEWABLE ENERGY HAS SHOWN GREAT RESILIENCE

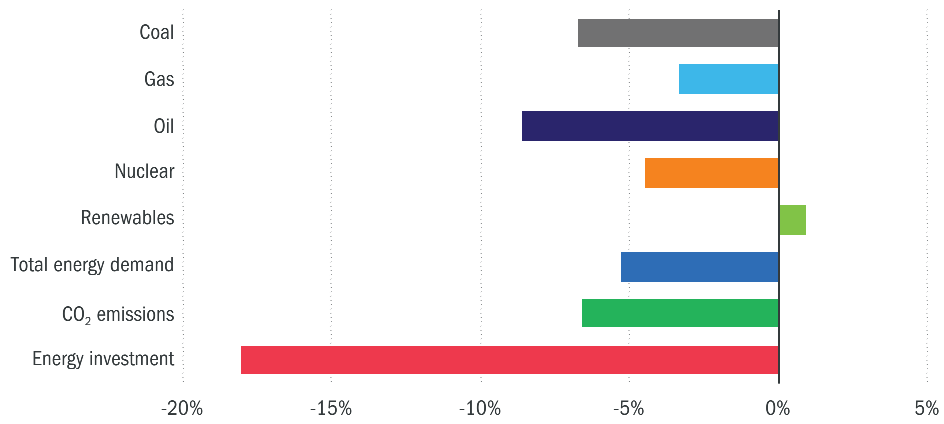
The energy sector has been deeply affected by the Covid-19 pandemic. Global energy demand during the first quarter of 2020 already shrinked by 3.8% relative to the first quarter of 2019[149]. Impeded growth and behavioural changes will see global annual energy demand reduce by 5% in 2020 relative to 2019[150]. Such a decline has not been seen for the past 70 years. Around 8% of the 40 million jobs provided directly by the energy sector are at risk or have already been lost [151]. Oil and coal are most brutally impacted, followed by nuclear and gas, with renewables least affected. The pandemic's limited impact on generated volumes for renewable assets can be explained by their position in the merit order, as they are considered as "must run" assets. The share of renewables in the electricity generation mix even rose substantially during the first quarter of 2020, with records for wind and solar, which accounted for 23% of EU27+UK electricity production in April, the highest ever share for a 30-day period and up five percentage points on the 18% share in the same period last year. In contrast to all other fuels, renewable energy demand has seen an increase of 1% in 2020 [152]. **Fig. 28**

The slowdown in demand has also led to cleaner air. The annual global $CO_2$ emissions are expected to decrease by around 7% in 2020[153], representing 2,6 Gt from a 33 Gt total in 2019, reaching their 2010-level of 30 Gt. However, emissions could jump back if investments are not dedicated to clean energy and resilient infrastructures. According to the IEA, global energy investments could decrease by 18% in 2020 from $1,900bn in 2019 to $1,550bn but may spare green investments. The oil and gas sectors are suffering the most (-25 to -33% decline in investment in 2020), while the decline in other investments is expected at 6,5%, in carbon capture, batteries, energy efficiency, nuclear, renewables. The IEA still projects the rise in renewable power capacities to continue in 2020 (+7,5%). COVID measures imposed by authorities to limit the spread of the virus have had very limited impact on renewable energy production, as most of the renewable energy technologies do not require permanent presence on site. Construction projects have incurred delays ranging to a few months, mainly due to local lockdowns or stress on supply and logistics chains, in particular when factories were closed in China. Overall, however, the industry expects that the delays in development seen in 2020 will be fully recovered as from next year.

Moreover, as governments are about to respond to large financing needs from COVID-19, the private sector can play a vital role in delivering the large investments and there are already good signals that firms are keeping or reinforcing their "green" commitments, as confirmed by data regarding voluntary carbon offsets programs, sustainable funds and demands to obtain the Science Based Target label. In addition, PPAs for renewable energy projects continued to grow. So far in 2020, corporations have announced contracts for 15.9 GW of clean energy[154].

> "corporations have announced contracts for **15.9 GW of clean energy**"

**Fig. 28 - Key estimated energy demand, $CO_2$ emissions and investment indicators, 2020 relative to 2019**




*Source: International Energy Agency (2020), World Energy Outlook 2020, IEA, Paris. All rights reserved.*

# Recovery plans are heavily weighted towards the ecological transition and tackling climate change

After dealing with economic emergency needs following the COVID-19, some countries are already looking beyond the crisis to the recovery efforts that will be required. Instead of rebuilding the world of 2019 at a moment when countries around the world are making recovery plans of billions of dollars, there is a clear push to make the economy greener and more sustainable.

## THE EU HAS UNVEILED GREEN POLICIES IN ITS STIMULUS PACKAGES

In the context of the Covid-19, the EU has unveiled green policies in its stimulus packages, with a particular attention to energy efficiency, circular economy and hydrogen. To date, European countries are well ahead of other economies in terms of green versus carbon-intensive stimulus, with a total of finalised and draft EU green support reaching $821 billion[155]. Stimulus programs, both at national and European offer a unique opportunity to put into effect a political path for the future of Europe that is in line with its objective of becoming the first climate neutral continent by 2050.

**The European Green Deal**, as proposed by the European Commission end of 2019, is a new growth strategy that aims to make Europe the first carbon-neutral continent by 2050. Reaching the targets of the European Green Deal requires action across all sectors of the economy, including through RES projects and kick-starting a clean hydrogen economy, supporting industry to innovate, rolling out cleaner forms of private and public transport, ensuring buildings are more energy efficient and supporting the circular economy[156].
The Green Deal thus appears as a cornerstone of the EU's strategy to drive the economic recovery from the COVID-19, in particular through Next Generation EU, a €750bn stimulus package announced in May 2020. Among the key pillars of the Next Generation EU recovery package figure a massive renovation wave of buildings and infrastructure and a more circular economy, bringing local jobs; the EU also aims at rolling out renewable energy projects and kick-starting a clean hydrogen economy to increase domestic production and enable rapid upscaling; another pillar is cleaner transport and logistics, including the goal to reach 1 million electric charging points and a boost for rail travel and clean mobility in cities and regions[157].

**The European Commission** furthermore announced that it will increase decarbonisation targets for 2030 to at least 50% and up to 55% vs 1990, i.e. significantly higher than the current target for 2030 (-40%) and current emissions (-23% already achieved in 2018). Overall, meeting the existing 2030 climate and energy targets can add 1% of GDP and create almost 1 million new green jobs[158]. Investing in a more circular economy has the potential to create at least 700,000 new jobs by 2030 and help the EU to reduce its dependency on external suppliers and increase its resilience to global supply issues.

**At the national level**, EU Member States have also begun announcing recovery plans. In line with the European Commission priorities, these plans tend to have significant green components, on topics such as energy renovation of buildings, low-carbon mobility, as well as low-carbon hydrogen.

**Germany**'s €130 bn 'Package for the Future' was the first to contain widespread green measures, including funding for green infrastructure and R&D, especially in the energy and transport sectors. Germany is particularly ambitious on hydrogen, as the country wants to become the "world leader" in the field. Germany is working towards partnerships with other importing countries (e.g Australia and Japan) to send a clear message that, in the long term, the country will seek to import substantial amounts of hydrogen. In 2019 the Government had already decided to allocate 100 million euros per year for hydrogen research and announced the creation of 20 "real laboratories" to test solutions on an industrial scale.

**In France**, the country's overall package equates €100 bn, representing 4% of GDP – more than any other big EU country – and has three key objectives: increasing competitiveness, boosting jobs, and greening the economy. Of this 100 bn post-Covid economic stimulus package, one-third will be spent on "ecological transition" and "greening the economy". On hydrogen, the country set a target to have 6.5 GW of hydrogen production capacity by 2030.

**In the United Kingdom**, the Government will make 350 million pounds available to support industry efforts to cut carbon emissions. It includes funding for supporting a switch from gas to clean hydrogen for fuel-heavy industry, projects to scale up carbon capture and storage, new building techniques in the construction industry and research into more efficient electric motors[159].

## IN OTHER PARTS OF THE WORLD FEW COUNTRIES HAVE YET COMMITTED TO PLANS

**In China** – the world's top emitter of $CO_2$ with 28.6% of global emission in 2018[160] – the recent pledge to become carbon neutral before 2060 has surprised the world[161]. This represents China's first long-term climate pledge beyond its Paris Agreement commitment of achieving peak carbon emissions by 2030 [162]. While the country's pathway to carbon neutrality remains widely unknow, China has recently supported big spending on low-carbon infrastructure and development priorities. Its $1.4 trillion "New infrastructure" scheme, announced in May 2020 aims at accelerating investments in several fields including high-speed rail and electric vehicle charging stations. For the moment, however, the signals are mixed. Local authorities approved 48 GW of coal-fired power plants in just the first five months of 2020 already, more than the entire coal fleets added in 2019 [163]. Total coal-fired capacity under construction now stands at 98 GW, equivalent to all operational coal-fired capacity in Germany and Japan combined[164].

**South Korea** also announced a Green New Deal in July 2020, which aims at overcoming the economic crisis while addressing climate and environmental challenges. South Korea will commit approximately $61 bn in five years to boost renewable energy capacity to 42.7 GW by 2025 from 12.7 GW in 2019 and expand its green mobility fleet to 1.33 million electric and hydrogen-powered vehicles[165]. The plan also ensures refurbishment of public rental housing and schools to make them zero-energy, and transformation of urban areas into smart green cities.

**In Australia**, to fast track the development of renewable hydrogen and achieve the goal of '$H_2$ under $2', the national Renewable Energy Agency (ARENA) has opened a $70 million Renewable Hydrogen Deployment Funding Round in April 2020[166]. However, the country has also announced a lot of less green measures, such as a series of stimulus programs to promote oil and gas investments. At the state level, some pursue renewables-led economic recovery such as the state government of Victoria which considers building 600 MW of renewables to help drive economic recovery[167]. The Queensland Government has announced a $500 million Renewable Energy Fund for state-owned companies to invest in renewables assets and Western Australia announced a funding package of A$66.3 million, mostly toward solar and battery storage[168].

**In the Americas**, several countries still are not expected to announce substantial green funding (Mexico and Brazil). As for the United States, the House of Representatives passed in September an extensive bill intended to increase policy and fiscal support for low-carbon energy technologies, energy storage and electric vehicles[169]. However, the White House has threatened a veto. In fact, the true direction of the U.S. recovery will only be known after the results of their elections.

# Designing sustainable, resilient and future-proof territories appears more important than ever

The unprecedented crisis the world is currently facing provides an opportunity to realise the vulnerability of societies to external shocks. Worldwide, more than half of the global population (55%) live in cities, and by 2050, nearly 70% of the world population is projected to be living in urban areas. Cities have long been lauded for their effectiveness, with better access to jobs and local services, short distances and public transport systems[170]. Yet, at the same time, cities account for two-thirds of global energy demand, with buildings in particular representing over one-third of global final energy consumption[171]. Moreover, they represent 75% of global $CO_2$ emissions[172] and air pollution kills an estimated seven million people worldwide every year[173].

In this context, the temporary reduction in carbon emissions triggered by the pandemic provide ample opportunities to rethink radically consumption, production and travelling model for more circular, productive and resilient cities. To improve the energy performance of tomorrow's buildings, solutions like BIM (Building Information Modelling), capture building data to better optimise its management and use. Other key solutions for cities include district-level energy, distributed renewable production and energy storage as well as a complete rethinking of the urban mobility system.

Mobility has indeed been greatly impacted by the COVID-19 pandemic. In regions with lockdowns, there was a decrease of 50-75% in road transport activity and up to 95% in rush-hour congestion in major cities[174]. Such a drop had a positive impact on air quality during the confinement. Daily global $CO_2$ emissions decreased by 17% at the peak of the shutdown, compared with 2019 level, with almost half the decrease due to fewer car journeys[175]. Globally, $CO_2$ emissions are expected to fall by 7% in 2020, according to the International Energy Agency. These reduced traffic and pollution can create a catalyst for even more changes towards cleaner and sustainable urban mobility. Some cities have been advocating cycling and multimodal urban mobility as one of the preferred options post-lockdown. Others have already been investing in low carbon transport solutions, such as electric vehicles as well as biomethane-fueled vehicles or vehicles powered by renewable hydrogen.

> **Daily global $CO_2$ emissions decreased by**
> **17%**
> **at the peak of the shutdown**

BNEF estimates that the number of electric vehicles in circulation in the world should reach 500 million by 2040 (against 3 million in 2017)[176], making possible the diffusion of mobility-as-a-service and autonomous vehicles.

In rural areas, the COVID-19 crisis may also lead to increased social demands for sustainable growth, relying on proximity and local jobs to cope with the economic shock[177]. In that regard, the development of a bioeconomy based on the transformation of biological resources (agriculture or forestry biomass/residues) can be a remarkable stimulus to rural development, benefiting the long-term economic growth of territories and creating jobs that cannot be relocated. In the EU alone, in the bio-based industries, one million new jobs could be created by 2030[178].The emergence of biomethane in recent years, which benefits several sectors of economic activity, is a successful example of the search for shared economic and environmental gains at the heart of territories. The circular economy it supports is also a model for controlling local supply chains, the importance of which we have all been able to measure during the crisis we are going through.

At the heart of global, ambitious and complex societal projects, the renewable energy industry is thus poised to play a leadership role in the dual crises of climate change and the COVID-19 pandemic. ENGIE, by investing heavily in renewables – with a target of 4 GW per year over the medium-term –, infrastructure, and energy efficiency solutions supports these transformations and is able to offer comprehensive and sustainable approach to corporates, cities and territorial authorities. An engagement that should continue to be supported by governments and citizens, to improve responses to crisis and increase the resilience of territories.

# Main references


- BNEF, 2020 Corporate energy market outlook, 2020.
- BNEF, Global Clean Energy Auctions Update, 2Q 2020.
- BNEF, Green Stimulus: The Policies and Politics, September 2020.
- BNEF, Sector coupling in Europe, powering decarbonisation, 2020.
- DNV, Energy Transition Outlook 2020, 2020.
- ENTSO-E – ENTSO, Power to Gas – A Sector Coupling Perspective, October 2018.
- EU JRC, PV Status Report 2019.
- European Commission, Fourth report on the State of the Energy Union, 2019.
- European Commission, Potentials of sector coupling for decarbonisation, 2019.
- European Commission, State of the Union Address 2020, September 2020.
- European Commission, The EU budget powering the Recovery Plan for Europe, May 2020.
- European Parliament, Energy storage and sector coupling: Towards an integrated, decarbonised energy system, 2019.
- European Technology and Innovation Platform on Deep Geothermal (ETIP-DG) (2018). "Vision for deep geothermal".
- Florence School of regulation, Sector Coupling: The New EU Climate and Energy Paradigm? 2018.
- Frontier Economics, gas decarbonisation and sector coupling, 2020.
- Gerald W. Huttrer, Geothermal Power Generation in the World 2015-2020, May 2020.
- GIE, Sector Coupling and policy recommendations, 2019.
- Global CCS Institute, Global status of CCS 2019.
- Guidehouse / Gas for Climate, Gas Decarbonisation Pathways 2020-2050, April 2020: https://www.europeanbiogas.eu/wp-content/uploads/2020/04/Gas-for-Climate-Gas-Decarbonisation-Pathways-2020-2050.pdf.
- Guidehouse, Batteries and Business Models Driving Utility-Scale Energy Storage Markets, 2016.
- Guidehouse, Energy as a Service Overview Commercial and Industrial Energy as a Service Solutions, 2019.
- GWeC, Global wind report 2019, 2019.
- Hydrogen Council, Hydrogen scaling up, November 2017.
- IEA (2019), The Future of Hydrogen, IEA, Paris https://www.iea.org/reports/the-future-of-hydrogen.
- IEA (2020), Global Energy Review 2020, IEA, Paris https://www.iea.org/reports/global-energy-review-2020
- IEA (2020), Outlook for biogas and biomethane: Prospects for organic growth, IEA, Paris https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth.
- IEA (2020), World Energy Investment 2020, IEA, Paris https://www.iea.org/reports/world-energy-investment-2020
- IEA (2020), Bioenergy Power Generation, IEA, Paris https://www.iea.org/reports/bioenergy-power-generation.
- IEA (2020), Demand Response, IEA, Paris https://www.iea.org/reports/demand-response.
- IEA (2020), Sustainable Recovery, IEA, Paris https://www.iea.org/reports/sustainable-recovery.
- IEA (2020), World Energy Outlook 2020, IEA, Paris. https://www.iea.org/reports/tracking-buildings-2020.
- IEA, Renewables Information: Overview (2020 Edition) Statistics report, 2020.
- Imperial College London, Unlocking the potential of Energy Systems Integration, 2018.
- International Monetary Fund, World Economic Outlook Update, June 2020.
- International Hydropower Association, 2020 Hydropower Status Report, 2020.
- International Monetary Fund. 2020. World Economic Outlook: A Long and Difficult Ascent. Washington, DC, October.
- IRENA (2018), Solid biomass supply for heat and power: Technology brief, International Renewable Energy Agency, Abu Dhabi.
- IRENA (2019), Demand-side flexibility for power sector transformation, International Renewable Energy Agency, Abu Dhabi.
- IRENA (2020), Renewable capacity statistics 2020 International Renewable Energy Agency (IRENA), Abu Dhabi.
- IRENA (2020), Renewable Power Generation Costs in 2019, International Renewable Energy Agency, Abu Dhabi.
- IRENA (2020), The post-COVID recovery: An agenda for resilience, development and equality, International Renewable Energy Agency, Abu Dhabi.
- IRENA, IEA and REN21, (2018), 'Renewable Energy Policies in a Time of Transition'.
- IRENA, Power system flexibility for the energy transition part 1: overview for policy makers, 2018.
- IRENA, Technology brief, geothermal, 2017.
- Mathiesen, B. V., Bertelsen, N., Schneider, N. C. A., García, L. S., Paardekooper, S., Thellufsen, J. Z., & Djørup, S. R. (2019). Towards a decarbonised heating and cooling sector in Europe: Unlocking the potential of energy efficiency and district energy. Aalborg Universitet.
- OECD, Bioeconomy and the sustainability of the agriculture and food system: opportunities and policy challenges, 2019.
- OECD, COVID-19 and global value chains: Policy options to build more resilient production networks, June 2020.
- Pour la Science N° 497 / Mars 2019.
- REN21. 2020. Renewables 2020 Global Status Report (Paris: REN21 Secretariat).
- UFE, Demand response, a promising segment for the flexibility of the electricity system, 2018: https://ufe-electricite.fr/en/news/editorials/article/demand-response-a-promising-segment-for-the-flexibility-of-the-electricity.
- UK Government Department for Business, Energy & Industrial Strategy, Thermal Energy Storage (TES) Technologies, 2016.
- Wind europe, Wind Energy in Europe: Outlook to 2023, 2019.
- World biogas Association, Global Bioenergy Statistics 2019.
- World Economic Forum, Virtual industry transition day, 2019.
- World energy council, New hydrogen economy - hope or hype, World energy council, 2019.

# Notes


1. Paris Agreement (Dec. 13, 2015), in UNFCCC, COP Report No. 21.
2. World Resources Institute (blog), “4 Charts Explain Greenhouse Gas Emissions by Countries and Sectors”, February 2020: https://www.wri.org/blog/2020/02/greenhouse-gas-emissions-by-country-sector
3. IRENA (2020), Renewable Power Generation Costs in 2019, International Renewable Energy Agency, Abu Dhabi.
4. REN21. 2020. Renewables 2020 Global Status Report (Paris: REN21 Secretariat).
5. IEA (2020), Renewables 2020, IEA, Paris https://www.iea.org/reports/renewables-2020.
6. IRENA (2020), Renewable capacity statistics 2020 International Renewable Energy Agency (IRENA), Abu Dhabi.
7. IRENA (2020), Renewable capacity statistics 2020 International Renewable Energy Agency (IRENA), Abu Dhabi.
8. World biogas Association, Global Potential of Biogas, June 2019.
9. ClimateScope (2019): http://global-climatescope.org/results. Top: India, Chile, China, Brazil, Kenya.
10. Sumant Sinha, “Why India is the new hotspot for renewable energy investors”, World economic forum (Blog), 14 Jan 2020.
11. IEA (2020), Outlook for biogas and biomethane: Prospects for organic growth, IEA, Paris https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth.
12. REN21. 2020. Renewables 2020 Global Status Report (Paris: REN21 Secretariat).
13. IRENA, Renewable power generation costs in 2019, International Renewable Energy Agency (IRENA): Abu Dhabi, UAE, 2020.
14. Biogas is a combustible gas obtained from methanisation of organic material and can be used for heat and/or power generation, usually at the site of production of biogas. Biomethane is upgraded biogas, suitable for injection into gas grids as a substitute for natural gas or for transport fuel.
15. IEA (2020), Outlook for biogas and biomethane: Prospects for organic growth, IEA, Paris https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth.
16. Amy Craven, “Britain’s gas networks call for Government to unlock £900m green infrastructure investment”, Northern Gas Networks, May 2020: https://www.northerngasnetworks.co.uk/2020/05/29/britains-gas-networks-call-for-government-to-unlock-900m-green-infrastructure-investment.
17. ENEA, Revue des externalités positives de la filière biométhane, ENEA Consulting, 2019.
18. Committee on Climate Change, Hydrogen in a low-carbon economy, November 2018.
19. Wood Mackenzie, “The future for green hydrogen “, 25 October 2019: https://www.woodmac.com/news/editorial/the-future-for-green-hydrogen/
20. IEA (2020), Tracking Energy Integration 2020, IEA, Paris https://www.iea.org/reports/tracking-energy-integration-2020.
21. BNEF, Corporate PPA Deal Tracker: October 2020.
22. EIA, Renewable energy explained – incentives: https://www.eia.gov/energyexplained/renewable-sources/incentives.php.
23. IEA (2020), Renewables 2020, IEA, Paris https://www.iea.org/reports/renewables-2020.
24. IEA (2020), Renewables 2020, IEA, Paris https://www.iea.org/reports/renewables-2020.
25. REN21. 2020. Renewables 2020 Global Status Report (Paris: REN21 Secretariat).
26. IRENA (2019), Renewable energy auctions: Status and trends beyond price, International Renewable Energy Agency, Abu Dhabi.
27. Jäger-Waldau, PV Status Report 2019, EUR 29938 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-12608-9, doi:10.2760/326629, JRC118058.
28. IRENA (2019), Renewable energy auctions: Status and trends beyond price, International Renewable Energy Agency, Abu Dhabi.
29. IRENA (2019), Renewable energy auctions: Status and trends beyond price, International Renewable Energy Agency, Abu Dhabi.
30. Google, Apple, Facebook, Amazon.
31. RE100 Members: http://www.there100.org/companies.
32. RE100, Requirements of RE100 companies: http://there100.org/going-100.
33. C40 cities: https://www.c40.org/.
34. BNEF, Corporate PPA Deal Tracker: October 2020.
35. BNEF, “Whatever ENGIE is Selling, Corporations are Buying it”, 25 February, 2020: https://about.bnef.com/blog/whatever-engie-is-selling-corporations-are-buying-it/.
36. ENEA Consulting, “Domestic biogas development in developing countries: https://www.enea-consulting.com/wp-content/uploads/2015/05/Open-Ideas-Domestic-biogas-projects-in-developing-countries.pdf
37. ENGIE Integrated report, 2020.
38. IEA (2020), Renewables 2020, IEA, Paris https://www.iea.org/reports/renewables-2020.
39. IEA (2020), Renewables 2020, IEA, Paris https://www.iea.org/reports/renewables-2020.
40. IEA (2020), Renewables 2020, IEA, Paris https://www.iea.org/reports/renewables-2020.
41. IEA (2020), Renewables 2020, IEA, Paris https://www.iea.org/reports/renewables-2020.
42. IEA (2019), How can district heating help decarbonise the heat sector by 2024?, IEA, Paris https://www.iea.org/articles/how-can-district-heating-help-decarbonise-the-heat-sector-by-2024.
43. IEA (2020), Renewables 2020, IEA, Paris https://www.iea.org/reports/renewables-2020.
44. REN21. 2020. Renewables 2020 Global Status Report (Paris: REN21 Secretariat).
45. IEA (2019), Tracking SDG7: The Energy Progress Report, 2019, IEA, Paris https://www.iea.org/reports/tracking-sdg7-the-energy-progress-report-2019.

46. Global Covenant of Mayors for Climate & Energy: https://www.globalcovenantofmayors.org/.
47. Global Covenant of Mayors for Climate & Energy: https://www.globalcovenantofmayors.org/.
48. BNEF, Electric Vehicle Outlook 2020, May 19, 2020.
49. Pour la Science N° 497 / Mars 2019.
50. IRENA. Renewable Capacity Statistics 2020; International Renewable Energy Agency (IRENA): Abu Dhabi, UAE, 2020.
51. IRENA, Renewable power generation costs in 2019, International Renewable Energy Agency (IRENA): Abu Dhabi, UAE, 2020.
52. IEA (2020), Global Energy Review 2020, IEA, Paris https://www.iea.org/reports/global-energy-review-2020.
53. IEA, Renewables Information: Overview (2020 Edition) Statistics report, 2020.
54. UN, How Renewable Energy Can Be Cost-Competitive: https://www.un.org/en/chronicle/article/how-renewable-energy-can-be-cost-competitive.
55. IRENA (2019), Future of wind: Deployment, investment, technology, grid integration and socio-economic aspects (A Global Energy Transformation paper), International Renewable Energy Agency, Abu Dhabi.
56. Siemens, https://www.siemensgamesa.com/explore/journal/transform-offshore-wind.
57. IEA (2019), Renewables 2019, IEA, Paris https://www.iea.org/reports/renewables-2019.
58. IEA (2019), Offshore Wind Outlook 2019, IEA, Paris https://www.iea.org/reports/offshore-wind-outlook-2019.
59. IEA (2019), Renewables 2019, IEA, Paris https://www.iea.org/reports/renewables-2019.
60. IEA (2018), Offshore wind and hydrogen for industry in Europe, IEA, Paris https://www.iea.org/commentaries/offshore-wind-and-hydrogen-for-industry-in-europe.
61. Guidehouse Insights, The Next Big Offshore Wind Market Has Arrived, June 2020.
62. ENGIE, integrated report, 2020.
63. IEA, Renewables Information: Overview (2020 Edition) Statistics report, 2020.
64. IRENA, Renewable power generation costs in 2019, International Renewable Energy Agency (IRENA): Abu Dhabi, UAE, 2020.
65. Wood Mackenzie, "Solar power to become cheaper and more efficient in 2020s", 04 February 2020.
66. Carrara, S., Alves Dias, P., Plazzotta, B. and Pavel, C., Raw materials demand for wind and solar PV technologies in the transition towards a decarbonised energy system, EUR 30095 EN, Publications Office of the European Union, Luxembourg, 2020.
67. CRIGEN, ENGIE Research program on bifacial PV.
68. Q Wang, Progress in emerging solution-processed thin film solar cells – Part I: Polymer solar cells, 2016.
69. Carrara, S., Alves Dias, P., Plazzotta, B. and Pavel, C., Raw materials demand for wind and solar PV technologies in the transition towards a decarbonised energy system, EUR 30095 EN, Publications Office of the European Union, Luxembourg, 2020.
70. IRENA, Renewable power generation costs in 2019, International Renewable Energy Agency (IRENA): Abu Dhabi, UAE, 2020.
71. REN21. 2020. Renewables 2020 Global Status Report (Paris: REN21 Secretariat).
72. Guidehouse Insights, Market Data: Solar PV Country Forecasts, 3Q 2019.
73. CRIGEN, ENGIE Research program on bifacial PV.
74. IRENA, Hydropower: https://www.irena.org/costs/Power-Generation-Costs/Hydropower.
75. IHA, 2020 Hydropower Status Report, 2020.
76. IEA, Renewables Information: Overview (2020 Edition) Statistics report, 2020.
77. IHA, 2020 Hydropower Status Report, 2020.
78. IHA, 2020 Hydropower Status Report, 2020.
79. IEA, Hydropower, 2020: https://www.iea.org/fuels-and-technologies/hydropower.
80. IEA (2019), Will pumped storage hydropower expand more quickly than stationary battery storage?, IEA, Paris https://www.iea.org/articles/will-pumped-storage-hydropower-expand-more-quickly-than-stationary-battery-storage.
81. IEA (2019), Will pumped storage hydropower expand more quickly than stationary battery storage?, IEA, Paris https://www.iea.org/articles/will-pumped-storage-hydropower-expand-more-quickly-than-stationary-battery-storage.
82. Excluding pump storage.
83. In December 2019, ENGIE announced the purchase of a number of hydroelectric power plants owned by EDP. ENGIE will own six facilities, including three run-of-the-river power stations and three pumped storage plants with installed capacity of 1.7 GW. This represents €2.2 bn of investment for the Group, with an average concession term of 45 years.
84. European Technology and Innovation Platform on Deep Geothermal (ETIP-DG) (2018). "Vision for deep geothermal".
85. IRENA (2020), Renewable capacity statistics 2020 International Renewable Energy Agency (IRENA), Abu Dhabi.
86. REN21. 2020. Renewables 2020 Global Status Report (Paris: REN21 Secretariat).
87. IRENA (2020), Renewable capacity statistics 2020 International Renewable Energy Agency (IRENA), Abu Dhabi.
88. REN21. 2020. Renewables 2020 Global Status Report (Paris: REN21 Secretariat).
89. IEA (2020), Renewables 2020, IEA, Paris https://www.iea.org/reports/renewables-2020.
90. European Technology and Innovation Platform on Deep Geothermal (ETIP-DG) (2018). "Vision for deep geothermal".
91. European Commission, Biomass: https://ec.europa.eu/energy/topics/property-fieldtopicparent/biomass_en.
92. European Parliament Briefing, Biomass for electricity and heating: opportunities and challenges, September 2015.
93. REN21. 2020. Renewables 2020 Global Status Report (Paris: REN21 Secretariat).
94. IRENA (2018), Solid biomass supply for heat and power: Technology brief, International Renewable Energy Agency, Abu Dhabi.
95. BNEF, 2020 Global Biomass Market Outlook, September 11, 2020.

96. IEA (2020), Bioenergy Power Generation, IEA, Paris https://www.iea.org/reports/bioenergy-power-generation.
97. ENGIE Solutions, Novawood project: https://www.ENGIE-solutions.com/en/business-cases/biomass-heat-power-novawood.
98. Guidehouse and Gas for Climate, 2020 Gas Decarbonisation Pathways 2020-2050, Gas for Climate, April 2020: https://www.europeanbiogas.eu/wp-content/uploads/2020/04/Gas-for-Climate-Gas-Decarbonisation-Pathways-2020-2050.pdf.
99. ENEA, Overview of the biomethane sector in France, October 2017.
100. Guidehouse and Gas for Climate, 2020 Gas Decarbonisation Pathways 2020-2050, Gas for Climate, April 2020: https://www.europeanbiogas.eu/wp-content/uploads/2020/04/Gas-for-Climate-Gas-Decarbonisation-Pathways-2020-2050.pdf
101. Guidehouse Insights, Renewable Natural Gas, Overview of the Current State of the Biogas and Renewable Natural Gas Markets, 1Q 2020.
102. IEA (2020), Outlook for biogas and biomethane: Prospects for organic growth, IEA, Paris https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth.
103. IEA (2020), Outlook for biogas and biomethane: Prospects for organic growth, IEA, Paris https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth.
104. Cedigaz, Global biomethane market: green gas goes global, 2019: https://www.cedigaz.org/global-biomethane-market-green-gas-goes-global/
105. IEA (2020), Outlook for biogas and biomethane: Prospects for organic growth, IEA, Paris https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth.
106. IEA (2020), Outlook for biogas and biomethane: Prospects for organic growth, IEA, Paris https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth.
107. Pour La Science N° 497 / Mars 2019.
108. Vanessa Dezem, "How Hydrogen Became the Hottest Thing in Green Energy", BNEF, September 24 2020: https://www.bloomberg.com/news/articles/2020-09-24/how-hydrogen-became-the-hottest-thing-in-green-energy-quicktake.
109. IEA (2019), The Future of Hydrogen, IEA, Paris https://www.iea.org/reports/the-future-of-hydrogen.
110. IEA (2019), The Future of Hydrogen, IEA, Paris https://www.iea.org/reports/the-future-of-hydrogen.
111. Vanessa Dezem, "How Hydrogen Became the Hottest Thing in Green Energy", BNEF, September 24 2020: https://www.bloomberg.com/news/articles/2020-09-24/how-hydrogen-became-the-hottest-thing-in-green-energy-quicktake.
112. IEA (2020), Tracking Energy Integration 2020, IEA, Paris https://www.iea.org/reports/tracking-energy-integration-2020.
113. ENGIE, Mobilité verte: une première ligne de bus hydrogène en France: https://www.ENGIE.fr/actualites/mobilite-verte-bus-hydrogene/.
114. IEA (2020), Demand Response, IEA, Paris https://www.iea.org/reports/demand-response.
115. Guidehouse Insights, Research report, Market Data: Commercial and Industrial Demand Response, 1Q 2020.
116. Guidehouse Insights, Research report, Market Data: Commercial and Industrial Demand Response, 1Q 2020.
117. IEA (2014), Technology Roadmap - Energy Storage, IEA, Paris https://www.iea.org/reports/technology-roadmap-energy-storage.
118. Guidehouse Insights, Energy Storage Tracker, 4Q19.
119. Muhammad Shahzad Javed, Tao Ma, Jakub Jurasz,Muhammad Yasir Amin, "Solar and wind power generation systems with pumped hydro storage: Review and future perspectives", Renewable Energy Volume 148, April 2020.
120. IEA (2020), Tracking Power 2020, IEA, Paris https://www.iea.org/reports/tracking-power-2020.
121. Guidehouse Insights, Market Data: Utility-Scale Energy Storage Market Update, 3Q 2020.
122. BNEF NEO, Lithium-ion battery price survey results: volume-weighted average, 2019.
123. David Stringer and Jie Ma, "Where 3 Million Electric Vehicle Batteries Will Go When They Retire", Bloomberg 2018.
124. The battery of an electric car needs replacing after 8 to 10 years on average.
125. BNEF, Utilities eyeing used EV batteries, 2016.
126. EASE, Thermal Storage Position Paper, July 2017: https://ease-storage.eu/wp-content/uploads/2017/07/2017.07.10_EASE-Thermal-Storage-Position-Paper__for-distribution.pdf.
127. UK Government Department for Business, Energy & Industrial Strategy, Thermal Energy Storage (TES) Technologies, 2016.
128. Guidehouse Insights, Thermal Energy Storage Systems, 2018.
129. European Commission, powering a climate-neutral economy: An EU Strategy for Energy System Integration, 2020.
130. World Economic Forum, Virtual industry transition day, 2019.
131. Global CCS institute, scaling up the ccs market to deliver net-zero emissions, 2020.
132. .IEA (2019), Transforming Industry through CCUS, IEA, Paris https://www.iea.org/reports/transforming-industry-through-ccus.
133. BNEF, Corporate PPA Deal Tracker: May 2020.
134. ENGIE, Integrated report, 2020.
135. United Nations: https://www.un.org/development/desa/en/news/population/world-population-prospects-2019.html
136. Circle economy, The circularity gap report 2019: https://circulareconomy.europa.eu/platform/sites/default/files/circularity_gap_report_2019.pdf.

137. Circle economy, The circularity gap report 2019: https://circulareconomy.europa.eu/platform/sites/default/files/circularity_gap_report_2019.pdf.
138. Ellen MacArthur Foundation, Circular Economy System Diagram: https://www.ellenmacarthurfoundation.org/circular-economy/concept/infographic
139. European Commission, Sustainability: https://ec.europa.eu/growth/industry/sustainability/circular-economy_en.
140. IEA (2020), Global Energy Review 2020, IEA, Paris https://www.iea.org/reports/global-energy-review-2020.
141. Deloitte, Earnings, Cash & Working Capital impact of Covid-19 and Oil Price Crash, 2020: https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/energy-resources/deloitte-uk-er-covid-19-and-oil-price-crash-sector-impact.pdf
142. IEA (2020), Global Energy Review 2020, IEA, Paris https://www.iea.org/reports/global-energy-review-2020.
143. IMF, world economic outlook update, June 2020.
144. IEA (2020), Sustainable Recovery, IEA, Paris https://www.iea.org/reports/sustainable-recovery.
145. OECD, COVID-19 and global value chains: Policy options to build more resilient production networks, June 2020.
146. International Monetary Fund. 2020. World Economic Outlook: A Long and Difficult Ascent. Washington, DC, October.
147. International Monetary Fund. 2020. World Economic Outlook: A Long and Difficult Ascent. Washington, DC, October.
148. IMF, World Economic Outlook Update, June 2020.
149. IEA (2020), Global Energy Review 2020, IEA, Paris https://www.iea.org/reports/global-energy-review-2020.
150. IEA (2020), World Energy Outlook, IEA, Paris.
151. IEA (2020), Sustainable Recovery, IEA, Paris https://www.iea.org/reports/sustainable-recovery.
152. International Energy Agency (2020), World Energy Outlook 2020, IEA, Paris. All rights reserved.
153. IEA (2020), Sustainable Recovery, IEA, Paris https://www.iea.org/reports/sustainable-recovery.
154. BNEF, Covid-19 Indicators: Sustainability, October 2020.
155. Victoria Cuming, Green Stimulus: the Policies and Politics, BNEF, September 2020.
156. OECD Policy Responses to Coronavirus (2020), Making the green recovery work for jobs, income and growth: https://www.oecd.org/coronavirus/policy-responses/making-the-green-recovery-work-for-jobs-income-and-growth-a505f3e7/
157. European Commission, press release “Europe's moment: Repair and prepare for the next generation”, May 2020.
158. European Commission, press release “Europe's moment: Repair and prepare for the next generation”, May 2020.
159. Reuters,:“Britain to provide 350 mln stg to help industry cut carbon emissions”, 21 Jul 2020: https://www.reuters.com/article/britain-emissions-idAFL5N2ES66U.
160. BNEF, China’s Road to Carbon Neutral will Reshape World Economy, September 2020.
161. The Guardian, China-pledges-to-reach-carbon-neutrality-before-2060”, September 2020.
162. BNEF, China’s Road to Carbon Neutral will Reshape World Economy, September 2020.
163. Center for Climate and energy solutions, “Will China Choose a Green Recovery?“, August 6, 2020: https://www.c2es.org/2020/08/will-china-choose-a-green-recovery/.
164. Global Energy Monitor, 2020.
165. OECD Policy Responses to Coronavirus (2020), Making the green recovery work for jobs, income and growth: https://www.oecd.org/coronavirus/policy-responses/making-the-green-recovery-work-for-jobs-income-and-growth-a505f3e7/
166. Blake Matich, “ARENA launches $70 million hydrogen funding round”, PV magazine, April 16, 2020: https://www.pv-magazine-australia.com/2020/04/16/arena-launches-70-million-hydrogen-funding-round/.
167. Jules Scully, “Victoria considers 600MW of new renewables to help drive economic recovery”, PV-tech (Blog) Sep 02, 2020: https://www.pv-tech.org/news/victoria-considers-600mw-of-new-renewables-to-help-drive-economic-recovery.
168. BNEF, Australian States Seek Renewables-Led Economic Recovery, September 2020.
169. BNEF, U.S. Energy Bill's Bounty Will Have to Wait Until 2021, September 2020.
170. OECD Policy Responses to Coronavirus (2020), Cities policy responses, July 2020: https://www.oecd.org/coronavirus/policy-responses/cities-policy-responses-fd1053ff/.
171. IEA (2020), Tracking Buildings 2020, IEA, Paris https://www.iea.org/reports/tracking-buildings-2020.
172. REN21, Renewables in Cities Global Status Report, 2019.
173. World health organisation, air pollution: https://www.who.int/health-topics/air-pollution#tab=tab_1;
174. OECD Policy Responses to Coronavirus (2020), Cities policy responses, July 2020: https://www.oecd.org/coronavirus/policy-responses/cities-policy-responses-fd1053ff/
175. C.Le Quéré, R.B. Jackson, M.W. Jones, A.J.P. Smith, S. Abernethy, R.M. Andrew, A.J. De-Gol, D.R. Willis, Y. Shan, J.G. Canadell, P. Friedlingstein, F Creutzig, G.P. Peters (2020). Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement. Nature Climate Change. https://doi.org/10.1038/s41558-020-0797-x, Nature, May 2020.
176. BNEF, Electric Vehicle Outlook, 2020.
177. OECD, Policy implications of Coronavirus crisis for rural development, 16 June 2020.
178. EuropaBio Report, Jobs and growth generated by industrial biotechnology in Europe, 09.2016.

# ANNEX:

# Abstract of the Dashboard of Energy Transition

2020 Edition

https://www.engie.com/sites/default/files/assets/documents/2020-10/Dashboard%20of%20energy%20transition%202020.pdf

# Contents





https://www.engie.com/sites/default/files/assets/documents/2020-10/Dashboard%20of%20energy%20transition%202020.pdf

# Post-Covid energy markets

## 2020 outlook and 2019 review

**ECONOMY**

By locking down 4 billion people, the Covid-19 pandemic plunged the world economy into its worst crisis since World War II

**ENERGY**

The energy sector has been particularly affected by the health crisis, with a much more severe impact on fossil fuels than on renewables.

# World economy

By locking down 4 billion people, the Covid-19 pandemic plunged the world economy into its worst crisis since World War II

**World GDP could well shrink by more than 3% in 2020, and perhaps by as much as 8%,** depending on the duration of restrictions, success in easing them, the occurrence of a second wave of infections and national support measures. In individual countries, the depth of recession will also reflect the pre-existing state of the economy (debt, unemployment rate, etc.). All countries, emerging and developed alike, are under threat.

Economists' projections converge towards a U-shaped, rather than a V-shaped recovery. This means that the decline in activity in 2020 shortfall will not be overcome any time soon. Some countries could even suffer an L-shaped recovery. The problem is that unlike during the 2008 financial crisis, the real economy has been badly damaged. Industrial production (22% of world GDP) is set to contract by 5% in 2020, which will mean structural changes and adjustments across industry worldwide. The most affected sectors are transport, tourism, hospitality, oil and gas, real estate and non-essential goods and services.

Financial crisis need not follow. Governments and international organisations have introduced unprecedented fiscal, financial and socio-economic measures to keep national economies afloat, notably tax reductions or deferrals, unemployment benefits and state guarantees for bank loans. In the meantime, central banks are focusing on lowering interest rate and purchasing assets (quantitative easing). No previous health crisis has had so much impact on national economies; this explains why the current shock has much in common with wartime and post-war economics.

**This crisis may leave long-term scars on the world economy** in the form of additional protectionism, relocation, value chain restructuring, accelerating digitalisation, teleworking and e-business development, heightened security and environmental concern and less urbanisation. World GDP will start increasing again no earlier than the first half of 2021, and not before 2022 where a second wave to occur.

**The world economy was already showing signs of slowdown in 2019.** GDP rose 3%, compared with 3.6% the year before, reflecting protectionist policies and a trade war between the two largest economic powers, the USA and China. The USA maintained dynamic growth at 2.3%, while China and the eurozone disappointed at 6.1% and 1.2%, respectively.

We recall that the USA started the trade war by introducing tariffs on aluminium and steal imports in March 2018. It went on to impose additional tariffs on other Chinese goods, and by end-2019 Chinese exports to the USA had plummeted 35% (Source: UN). China retaliated with tariffs on US exports, mainly of agricultural products. Against this backdrop, international trade growth slowed from 3.8% in 2018 to 1% in 2019, and particularly affected European and Asian capital goods.

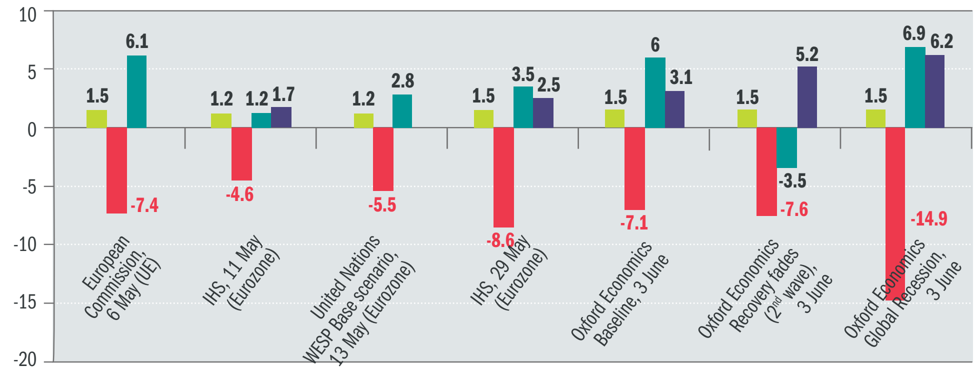
Despite this situation, share prices climbed in 2019 (S&P 500 up 28.5%) and low-revenue countries reported stable growth rates amid continued investment in infrastructure and significant support to several African countries in the form of foreign direct investment (FDI).

# World economy

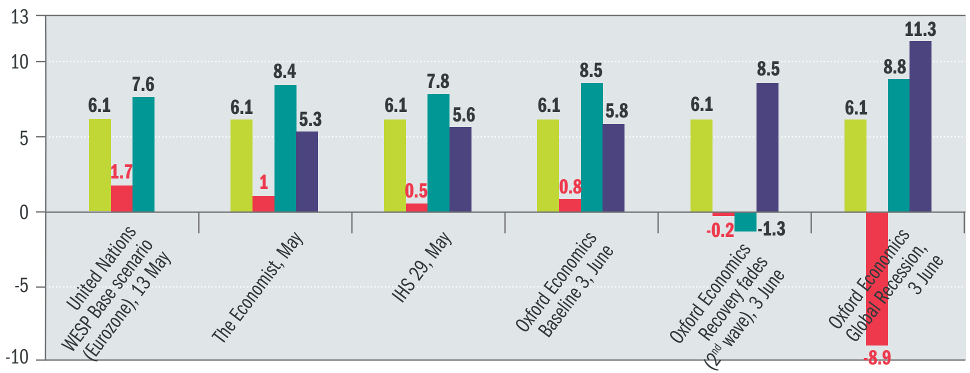
## Post-Covid economic growth forecasts for 2020, 2021 and 2022, by various institutes

### WORLD GDP FORECAST (%)


### EU GDP FORECAST (%)

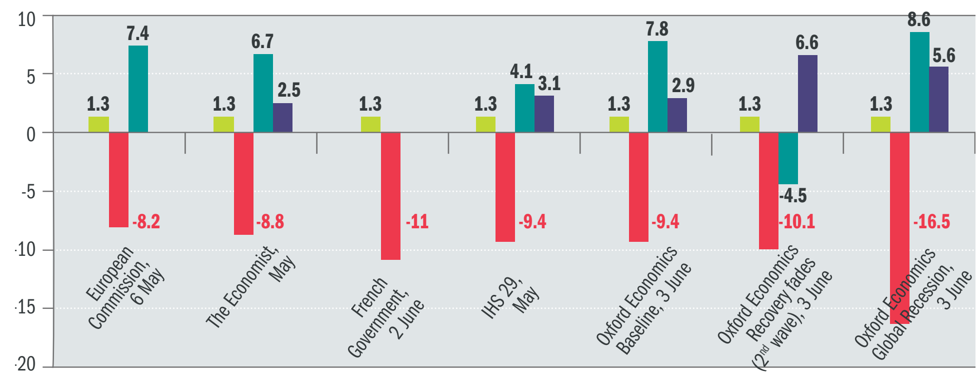



### CHINA GDP FORECAST (%)




■ 2019 ■ 2020 ■ 2021 ■ 2022

### FRANCE GDP FORECAST (%)




*Source: GDP forecasts published in June 2020 by external economic research institutes*

# World economy

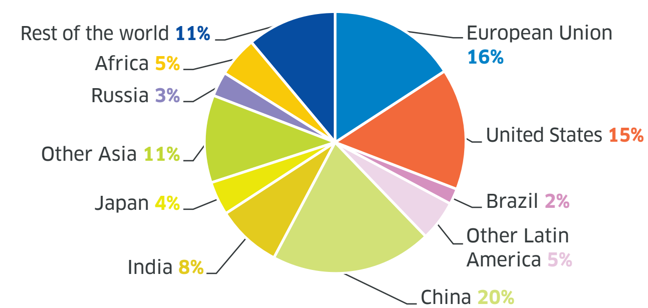
## 2010-2019 economic growth and 2020-2021 forecasts

| GDP & Population | Real GDP growth rate* | | GDP growth forecasts** | | GDP, purchasing power parity, US$2015 (US$ billion) | | Per capita GDP, US$2015 | | Population (million) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2010-2019 | 2019 | 2020 | 2021 | 2010 | 2019 | 2010 | 2019 | 2010 | 2019 |
| Europe | 1.7% | 1.4% | -7.0% | 6.3% | 21,044 | 24,927 | 28 | 32 | 608 | 630 |
| European Union | 1.5% | 1.5% | -7.1% | 6.0% | 18,610 | 21,432 | 31 | 34 | 504 | 515 |
| North America | 2.3% | 2.3% | -7.3% | 8.8% | 17,770 | 21,647 | 52 | 59 | 343 | 367 |
| Canada | 2.1% | 1.6% | -10.7% | 11.0% | 1,424 | 1,724 | 41 | 45 | 34 | 38 |
| United States | 2.3% | 2.3% | -7.0% | 8.6% | 16,346 | 19,923 | 53 | 60 | 309 | 330 |
| Latin America | 1.3% | -0.2% | -5.5% | 4.4% | 8,404 | 9,517 | 8 | 8 | 592 | 654 |
| Brazil | 0.7% | 1.1% | -4.8% | 4.5% | 3,056 | 3,238 | 9 | 8 | 197 | 213 |
| Asia | 5.2% | 4.5% | -1.5% | 7.4% | 33,776 | 55,307 | 5 | 7 | 3,800 | 4,137 |
| China | 7.4% | 6.1% | 0.8% | 8.5% | 13,609 | 25,675 | 6 | 10 | 1,338 | 1,401 |
| South Korea | 2.9% | 2.0% | -1.0% | 3.5% | 1,574 | 2,027 | 24 | 30 | 50 | 52 |
| India | 6.9% | 5.3% | -3.0% | 11.3% | 5,868 | 10,304 | 1 | 2 | 1,231 | 1,370 |
| Japan | 2.4% | 0.7% | -6.5% | 3.2% | 4,888 | 5,332 | 33 | 36 | 128 | 126 |
| Pacific | 2.7% | 1.9% | -5.7% | 4.9% | 1,142 | 1,449 | 35 | 38 | 36 | 41 |
| Australia | 2.6% | 1.8% | -5.9% | 4.5% | 959 | 1,207 | 48 | 53 | 22 | 25 |
| CIS | 2.1% | 2.0% | -5.3% | 4.2% | 4,573 | 5,460 | 6 | 7 | 281 | 293 |
| Russia | 1.5% | 1.3% | -6.5% | 3.7% | 3,240 | 3,712 | 9 | 10 | 143 | 145 |
| Middle East | 2.4% | -0.6% | -7.2% | 4.4% | 4,969 | 6,076 | 10 | 10 | 214 | 255 |
| Saudi Arabia | 3.2% | 0.3% | -7.5% | 5.2% | 1,330 | 1,771 | 19 | 20 | 27 | 34 |
| Iran | -0.2% | -10.2% | -9.7% | 1.7% | 1,429 | 1,438 | 5 | 5 | 75 | 83 |
| Qatar | 3.8% | -0.3% | -4.4% | 4.3% | 238 | 335 | 68 | 60 | 2 | 3 |
| Africa | 4.0% | 3.5% | -2.7% | 4.4% | 4,961 | 6,608 | 2 | 2 | 1,048 | 1,320 |
| South Africa | 1.5% | 0.2% | -7.2% | 4.0% | 655 | 752 | 6 | 6 | 52 | 58 |
| **World** | **3.0%** | **2.6%** | **-5.0%** | **7.1%** | **96,639** | **130,991** | **9** | **11** | **6,922** | **7,698** |
| OECD | 1.9% | 1.7% | -6.8% | 6.8% | 47,941 | 57,256 | 34 | 39 | 1,240 | 1,312 |
| No OECD | 4.8% | 3.9% | -2.1% | 7.2% | 48,699 | 73,736 | 4 | 5 | 5,681 | 6,385 |

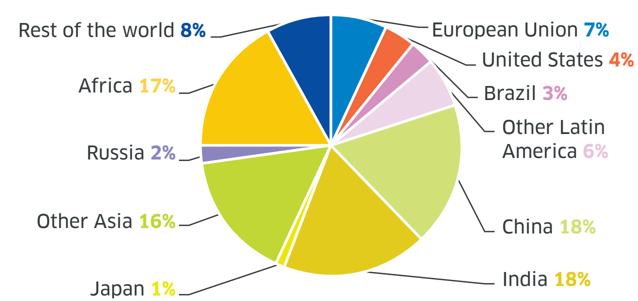
*Compound annual growth rate.
**Oxford Economics forecasts, June 2020.

*Source: Enerdata, Global Energy and $CO_2$ Data (June 2020)*

### WORLD GDP IN 2019
(PURCHASING POWER PARITY)
**TOTAL: US$ 131,000 BILLION**




### WORLD POPULATION IN 2019
**TOTAL: 7.7 BILLION**




*Source: Enerdata, Global Energy and $CO_2$ Data (2019)*

# World economy

**China, first country in and then out of lockdown, suffered in 2020 from an 11 week-long reduction of economic activity as well as contracting of foreign and domestic demand.** Economic growth is projected to be around 1.2% for 2020, the slowest for half a century. Given that the pandemic hit the country three months earlier than elsewhere, the shape of China's economic rebound will help inform expectations for other regions.

**The Chinese economic model has shifted recently towards a more domestic focus,** which helped GDP to rise 6.1% in 2019. While this is still vigorous, it is modest compared with the past few decades. Indeed, 2019 saw the slowest growth in 28 years, after 6.6% in 2018 and 6.9% in 2017. The trade war with the USA weighed on exports, a major component of the Chinese economy (up 0.5% in 2019). Industrial production decreased, in line with the country's "economic rebalancing" policy.

In order to develop the domestic market, the Chinese government has introduced financial instruments that facilitate credit and investment for SMEs and private companies: lower personal income tax, reduced VAT for the manufacturing, transport and building sectors, and tax exemptions for cutting-edge technology.

**The European Union will be one of the regions most affected by Covid-19.** Its GDP is projected to decline by between 5% and 7.4% in 2020 (European Commission estimates). Despite swift intervention by the EU and national governments, the outlook for Southern member states caught between existing economic pressures and the pandemic is very bleak (-9.7% for Greece and -9.5% for Italy, according to Eurostat).

**The severity of recession in 2020 also reflects economic slowdown prior to the pandemic.** EU growth faded from 2.1% in 2018 to 1.2% in 2019, mainly because of stagnating exports. That said, the EU unemployment rate had eased from 11% in 2013 to 7% in 2018 and 6% in 2019.

**In the USA, the Covid-19 crisis prompted an economic meltdown,** and GDP is expected to decrease 6% in 2020. Amid a heavy death toll (140,000 at the end of June 2020), unemployment surged dramatically to 36 million unemployed at the peak of the crisis. The unemployment rate jumped from very low levels in 2019 to 15% in April 2020. The latest statistics (June) point towards a tangible rebound on the labour market, however. The Trump administration launched colossal recovery plans worth $2,000bn to bolster the economy.

US GDP rose 2.3% after a 2.9% gain the year before, thanks to corporate and personal tax cuts effective in December 2017 under the Tax Cuts and Jobs Act and to strong domestic demand. The labour market was particularly robust, with an unemployment dropping to a 50-year low at 3.5% despite a participation rate above 63%. This combination resulted in higher salaries and labour productivity.

By early 2020, and despite budget stimulus, the US economy's longest expansion cycle since World War II was losing steam. In the longer run, this crisis rekindles concern about softer productivity trends and the economy's potential growth rate.

# World economy

**The Japanese economy will also be in recession in 2020, with GDP expected to drop by around 5%,** and it will not benefit from growth related to the 2020 Olympics, postponed to 2021.

**Hit earlier by natural disasters, Japanese GDP growth had been steadily declining** (0.8% in 2019, after 1.1% in 2018 and 1.7% in 2017). During this period, the Bank of Japan's expansionist policy resulted in a weaker yen. This in turn bolstered profits in exporting sectors and protected the labour market (unemployment rate close to 2% in 2019). The budget deficit was reduced from 4.5% of GDP in 2017 to 3% in 2019 via an increase in the VAT rate from 8% to 10%. Shinzo Abe pressed on with structural reforms ("Abenomics"), focusing in 2019 on social care in a population that is both shrinking and ageing (extending pension contribution periods and a migratory policy favouring foreign labour).

**Russian GDP will decline by 5.5% in 2020. In 2019, the economy was already suffering from lower oil revenues. GDP growth was down to 1.1%** after 1.7% in 2018. Domestic demand was also contracting as the impetus from the 2018 World Football Cup faded. Oil and gas production reached record highs in 2019, with increasing exports. But the economy's lack of diversification is not a negligible risk. Oil and gas represent 59% of exports and investments is focused on this sector; other sectors suffer from chronic under-investment, despite efforts in recent years directed mainly at agriculture. Unemployment remained low at 4.6%, salaries and pensions increased, but productivity remains well under that of the EU and the USA.

**In India, despite the Covid-19 crisis and the lockdown declared since March 2020,** GDP is forecasted to rise 1.9%, partly thanks to the opening of some public sectors to the private sector (mines, nuclear energy).

**Before the pandemic, the Indian economy was experiencing a sharp slowdown, with growth slowing from 7.8% in 2018 to 4.9% in 2019.** This reflected structural deficiencies such as the corporate tax burden as well as economic shocks. Amongst the most striking were the contraction of private sector investment, lower oil prices, Prime Minister Modi's decision to withdraw highest value banknotes from circulation (85% of banknotes) and the harmonisation of taxes on goods and services introduced in 2017 (GST), poorly understood by companies and shops.

**Brazil became the world's second-largest casualty of Covid-19 at the end of May** and its economy is expected to contract 5.3% in 2020.

**Already sluggish in 2019** (GDP rose 1.1%, after 1.4% in 2018), the Brazilian economy posted an 11.2% unemployment rate and a 5.2% budget deficit in 2019. Although the deficit contracted following a deregulation of the economy, business circles await further reforms from President Bolsonaro to boost recovery.

**Oil-producing economies are set to move into recession in 2020** (-4.3% in Qatar, -2.3% in Saudi Arabia), mainly because of plummeting oil prices.

**These economies were already slowing in 2019** as a result of lower oil prices. Crude cheapened by over 10% over the year to an average $64/bbl because of increased US shale oil production. Unable to diversify, these countries remain vulnerable to oil price volatility.

# Energy balance

The energy sector has been particularly affected by the health crisis, with a much more severe impact on fossil fuels than on renewables

**The health crisis associated with Covid-19 has seriously affected energy markets,** especially so in markets particularly exposed to recession. In these exceptional circumstances, IEA and Enerdata have published initial 2020 estimates based on 2019 and early 2020 analysis.

**Primary energy demand will contract in 2020,** from between 6% according to the IEA and 7.5% according to Enerdata. These figures are based on economic recession forecasts of -6% and -3%, respectively. During lockdown, energy consumption in industrialised countries generally fell in the same proportions as GDP, i.e. by about 25%.

**Most energy types will be affected, but particularly oil** (-9%), as the lockdowns brought most transport to a halt. Freight and passenger traffic dropped 50% and air transport by 60%. This sector represents 60% of world oil demand.

**Coal consumption will decline 8% in 2020,** its biggest fall since World War II. This reflects the heavy impact of the crisis on coal-fired plants, as well as the prominent role of China, first country to be affected by the virus. Chinese demand is expected to contract 5%. In the US and in the EU, the projected drop in consumption is even worse, at 25% and 20%, respectively, in 2020. Lower gas prices and healthy renewable electricity production during the crisis helped accelerated a withdrawal from coal that was already well under way. This market's recovery will depend mainly on leading consumers China and India, especially for power generation.

**Natural gas demand will also contract in 2020, but to a lesser extent than oil and coal.** The IEA forecasts a 5% drop in 2020, mainly because of the implications of the crisis for industrial activity and electricity demand over the rest of the year. Natural gas remained relatively unaffected during lockdown (-2%). According to IEA projections, natural gas demand will recede 7% in the electricity sector and 5% in the industrial sector. Moreover, unseasonably mild weather in the first quarter in the Northern Hemisphere has dampened gas demand. A faster economic recovery would reduce the fall to 2.7% (IEA).

**Electricity demand, particularly sensitive to economic activity, is set to contract 5% this year** (or by 2% in a fast economic recovery scenario, IEA). During lockdown, declines amounted to between 15% and 20%, depending on the country. This profile is similar to that of a long weekend, meaning an increase in residential consumption largely offset by reductions in the service sector and industry.

**In 2019, world primary energy demand increased slightly** (0.7% after 2.2% in 2018), with a moderate 2.2% increase in non-OECD countries and a 0.9% decline in OECD countries.

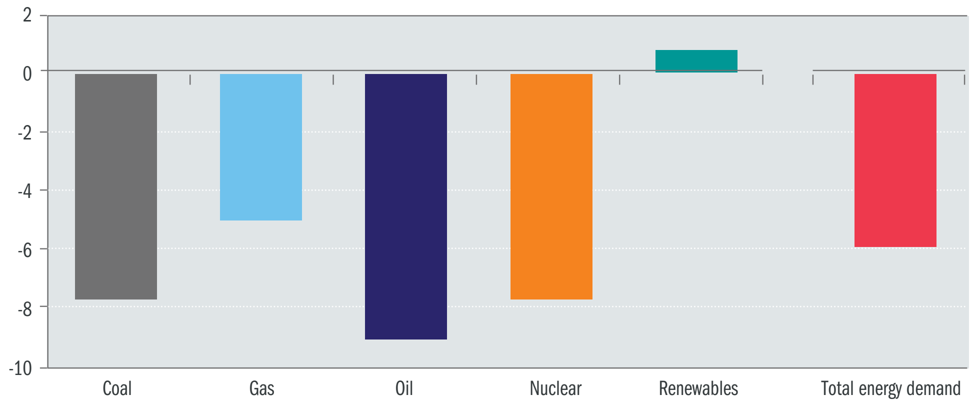
**This reflects not only the economic slowdown** (3% after 3.6% in 2018) **but also improved energy efficiency** (up 2.1%) compared to previous years (closer to 1.5%). It should be recalled that a 2°C climate change objective requires an annual 3.5% improvement in energy efficiency.

**Another important development in 2019 was a decline in coal demand** (-2.1% against +0.4% in 2018) in several major countries: slowdown in China (+1%), slight decrease in India, substantial contraction in Europe (-15%) and in North America (-13%). This performance meant better news on $CO_2$ emissions, which stabilised in 2019 (+0.2% after +2% in 2018). Following several years of virtually no change, the carbon factor dropped 1%.

**Natural gas demand remained strong in 2019** (up 3.2%) as a result of coal substitution promoted by energy transition, while solar and wind energy continued their meteoric rise in the electricity sector (production up 22% and 12% respectively). Lastly, oil demand remained stable (up 0.3%), still subject to OPEC and Russian quotas.

# Energy balance

## WORLD PRIMARY ENERGY DEMAND 2019-2020 – IEA ESTIMATES



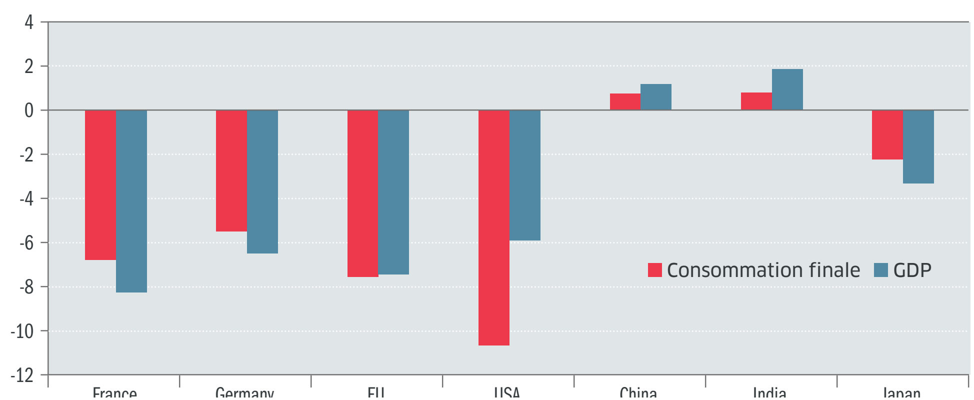

**These projections were produced in April and May 2020 and will be revised over the course of the year.** Energy consumption and $CO_2$ emissions depend greatly on the depth of national economic recessions, which remain difficult to assess, and also on the way governments deal with lockdown and subsequent easing of restrictions.

*Source: IEA, Global Energy review 2020 – Covid-19 impacts on energy and $CO_2$ emissions, 28 April 2020*

This review is based on data available by mid-April 2020. They come from numerous sources and represent about two thirds of world primary energy demand.



## ENERGY CONSUMPTION 2020/2019 FORECASTS (%)




*Source: Enerdata Bilan énergétique mondial – 2020 edition, 2 June 2020*

Enerdata estimates follow a detailed methodology, integrating year-round projection updates from major international institutions (European Commission, IMF, ADB for Asia).

Consumption and emission estimates are produced by country for each of the G-20 countries:
• at major energy consuming sector level, to take into consideration their respective sensitivities to recession and lockdown,
• at the electricity sector's level, to take into consideration changes within the electricity mix.

# Energy balance

**Final energy demand will contract less than primary demand in 2020.** The difference, around 3 points, stems from the heavy impact of the crisis on processing, power generation and refining sectors, all of which are excluded from final demand (Enerdata).

Most severely hit are the transport and the industrial sectors, where consumption is expected down around 10% and 2% respectively in the major economies in 2020. Conversely, residential demand held up and services was hardly impacted.

Final demand growth should remain slightly positive in China at c.1%, but plunge severely in Europe (-7.5%) and the USA (-11%).

**Regarding global energy production expectations for 2020, fossil energy sources will bear the brunt of lower consumption,** with a c. 5% decline in 2020 (IEA).

**In contrast, renewable energy production, largely represented by biomass, will enjoy continued 1% growth in 2020,** driven by power generation RES. The latter will increase by a robust 5% (IEA) despite supply chain disruption slowing activity in several key countries.

Power generation RES was particularly resilient during lockdown, thanks to their precedence in the order of merit of electricity production and even though electricity production is itself expected to drop 5% in 2020 (IEA). Renewable sources offering low marginal costs and flexibility gained a foothold in power generation with 5% growth expected in 2020 in spite of supply chain difficulties and Covid-19 construction delays. This performance is being led by wind (up 12%) and solar power (16%). Some countries are set to report even more impressive increases in wind and solar power in 2020, notably France (+26%), the UK and the USA (+17%).

Progress in power generation from RES will not be as great in 2020 as expected prior to the pandemic, however, and will increase by less than it did in 2018 and 2019. Coal and gas-fired production will be severely affected, on the other hand. They are expected at -10% and -7%, respectively.

All in all, the RES in the electricity mix will continue with its upward trend initiated several years ago to reach 30% worldwide in 2020, 40% in the USA, 69% in Europe and 34% in China (Enerdata estimates).

**In 2019, energy production involved continuing but slow decarbonization, with a decline in oil (-1%) and a marked slowdown in coal (+1% compared to +3% in 2018),** to the benefit of natural gas (+4%) and RES (+5).

Despite an acceleration in its decline before the pandemic, the pace of coal's demise remains uncertain as it also depends on slowdowns in emerging countries.

Power generation RES increased by another solid 5% in 2019 despite a slight loss of momentum in recent years as solar and wind power gained ground.

For power generation RES to maintain an annual progression of 6%, a pace that would take their share up to 60% of the electricity mix by 2040 – in line with the IEA's 2°C scenario (SDS) – new capacity spending would have to double by the end of the decade.

**The crisis has amplified uncertainty around energy transition,** making the next few years even more critical. The major variables are investments in low-carbon technology, energy policies, the use of recovery plans and the behaviour companies, local authorities and individuals people. This report will examine each issue specifically in the chapters that follow and will highlight current trends.

# Primary energy consumption

| Primary energy production in 2019 in Mtoe | Fossils | | | | | | | | | Biomass | | | Primary electricity | | | Heat | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coal & Lignite | | | Crude oil & NGL | | | Natural gas | | | Biomass & Wastes | | | Primary electricity | | | Geothermal & Solar | | | | | |
| | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world |
| Europe | 139 | -12% | 4% | 165 | -4% | 4% | 190 | -6% | 6% | 163 | 2% | 12% | 345 | 1% | 25% | 7 | 4% | 14% | 1,010 | -3% | 7% |
| European Union | 109 | -14% | 3% | 78 | -2% | 2% | 88 | -7% | 3% | 152 | 2% | 11% | 295 | -1% | 22% | 3 | 0% | 7% | 725 | -3% | 5% |
| North America | 368 | -7% | 9% | 1,054 | 9% | 23% | 943 | 8% | 28% | 114 | -4% | 8% | 352 | 1% | 26% | 3 | 12% | 6% | 2,833 | 5% | 19% |
| Canada | 27 | -4% | 1% | 275 | 2% | 6% | 154 | -4% | 5% | 13 | -3% | 1% | 62 | -0.2% | 5% | 0 | - | 0% | 530 | -0.3% | 4% |
| United States | 342 | -7% | 9% | 779 | 12% | 17% | 789 | 10% | 23% | 101 | -4% | 7% | 290 | 1% | 21% | 3 | 12% | 6% | 2,303 | 6% | 16% |
| Latin America | 64 | -2% | 2% | 429 | -5% | 9% | 170 | -0.3% | 5% | 151 | 2% | 11% | 91 | 2% | 7% | 1 | 8% | 3% | 906 | -2% | 6% |
| Brazil | 2 | 21% | 0.1% | 149 | 7% | 3% | 22 | 3% | 1% | 93 | 2% | 7% | 43 | 2% | 3% | 1 | 11% | 2% | 310 | 5% | 2% |
| Asia | 2,618 | 2% | 66% | 351 | -1% | 8% | 392 | 3% | 12% | 546 | 3% | 40% | 447 | 13% | 33% | 39 | 5% | 75% | 4,392 | 3% | 30% |
| China | 1,941 | 4% | 49% | 195 | 1% | 4% | 146 | 10% | 4% | 109 | -2% | 8% | 256 | 13% | 19% | 37 | 6% | 71% | 2,684 | 4% | 18% |
| India | 277 | -4% | 7% | 39 | -0.4% | 1% | 26 | -4% | 1% | 197 | 3% | 14% | 37 | 17% | 3% | 1 | 10% | 2% | 577 | 0% | 4% |
| Indonesia | 310 | -1% | 8% | 40 | 1% | 1% | 57 | -9% | 2% | 66 | 7% | 5% | 28 | 9% | 2% | 0 | - | 0% | 501 | -1% | 3% |
| Pacific | 300 | 1% | 8% | 18 | 15% | 0.4% | 133 | 17% | 4% | 8 | -4% | 1% | 12 | 3% | 1% | 1 | 0% | 1% | 471 | 6% | 3% |
| Australia | 298 | 1% | 8% | 17 | 16% | 0.4% | 119 | 18% | 4% | 5 | -5% | 0.4% | 4 | 9% | 0.3% | 0 | 0% | 1% | 443 | 6% | 3% |
| CIS | 313 | 0.3% | 8% | 711 | 1% | 16% | 813 | 3% | 24% | 16 | -0.3% | 1% | 101 | 1% | 7% | 0 | - | 0% | 1,953 | 2% | 13% |
| Russia | 244 | 1% | 6% | 563 | 1% | 12% | 618 | 3% | 18% | 9 | -2% | 1% | 72 | 3% | 5% | 0 | - | 0% | 1,506 | 2% | 10% |
| Middle East | 1 | -7% | 0% | 1,407 | -6% | 31% | 570 | 3% | 17% | 1 | 2% | 0.1% | 6 | 34% | 0.4% | 1 | 0% | 1% | 1,985 | -4% | 14% |
| Qatar | 0 | - | 0% | - | - | - | - | - | - | 0 | - | 0% | 0 | - | 0% | 0 | - | 0% | 0 | -100% | 0% |
| United Arab Emirates | 0 | - | 0% | 186 | 2% | 4% | 51 | 1% | 2% | 0 | - | 0% | 1 | 217% | 0.1% | 0 | - | 0% | 238 | 2% | 2% |
| Saudi Arabia | 0 | - | 0% | 556 | -5% | 12% | 80 | 1% | 2% | 0 | - | 0% | 0 | 305% | 0% | 0 | - | 0% | 637 | -4% | 4% |
| Iran | 1 | -7% | 0% | 140 | -34% | 3% | 203 | 6% | 6% | 1 | 2% | 0% | 4 | 29% | 0.3% | 0 | - | 0% | 348 | -15% | 2% |
| Africa | 165 | 2% | 4% | 407 | 2% | 9% | 201 | 1% | 6% | 369 | 3% | 27% | 22 | 6% | 2% | 0 | 0% | 0.4% | 1,163 | 2% | 8% |
| Nigeria | 0 | 0% | 0% | 101 | 5% | 2% | 37 | 1% | 1% | 126 | 3% | 9% | 1 | 17% | 0% | 0 | - | 0% | 264 | 3% | 2% |
| **World** | **3,966** | **1%** | **100%** | **4,542** | **-1%** | **100%** | **3,410** | **4%** | **100%** | **1,368** | **2%** | **100%** | **1,374** | **5%** | **100%** | **52** | **5%** | **100%** | **14,713** | **1%** | **100%** |
| OECD | 795 | -5% | 20% | 1,332 | 6% | 29% | 1,280 | 6% | 38% | 325 | 0% | 24% | 788 | 2% | 57% | 12 | 6% | 23% | 4,531 | 3% | 31% |
| no-OECD | 3,172 | 2% | 80% | 3,210 | -3% | 71% | 2,131 | 3% | 63% | 1,043 | 2% | 76% | 587 | 8% | 43% | 40 | 6% | 77% | 10,182 | 1% | 69% |

*Source: Enerdata, Global Energy & $CO_2$ Data (June 2020)*

79

# Primary energy consumption

| Primary energy consumption in 2019 in Mtoe | Fossils | | | | | | | | | Biomass | | | Primary electricity | | | Heat | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coal & Lignite | | | Crude oil & NGL | | | Natural gas | | | Biomass & Wastes | | | Primary electricity | | | Geothermal & Solar | | | | | |
| | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world |
| Europe | 238 | -15% | 6% | 592 | -0.2% | 15% | 450 | 1% | 13% | 175 | 3% | 13% | 347 | 1% | 25% | 9 | 4% | 16% | 1,810 | -2% | 13% |
| European Union | 182 | -18% | 5% | 524 | 0.1% | 13% | 402 | 3% | 12% | 164 | 2% | 12% | 298 | -1% | 22% | 5 | 4% | 8% | 1,574 | -2% | 11% |
| Germany | 55 | -20% | 2% | 100 | 2% | 2% | 76 | 3% | 2% | 31 | 2% | 2% | 34 | 10% | 3% | 1 | -2% | 2% | 296 | -2% | 2% |
| France | 7 | -20% | 0.2% | 70 | -0.4% | 2% | 37 | 2% | 1% | 18 | -0.3% | 1% | 108 | -3% | 8% | 0.4 | 8% | 1% | 241 | -2% | 2% |
| North America | 290 | -13% | 8% | 907 | -1% | 22% | 846 | 3% | 25% | 113 | -3% | 8% | 351 | 1% | 26% | 3 | 11% | 5% | 2,509 | -1% | 18% |
| Canada | 278 | -12% | 7% | 808 | -1% | 20% | 733 | 3% | 22% | 99 | -3% | 7% | 293 | 1% | 21% | 3 | 12% | 5% | 2,214 | -1% | 16% |
| United States | 13 | -14% | 0.3% | 99 | -2% | 2% | 113 | 2% | 3% | 13 | -3% | 1% | 58 | 0% | 4% | 0 | 0% | 0.1% | 296 | -1% | 2% |
| Latin America | 42 | -3% | 1% | 328 | -4% | 8% | 199 | -1% | 6% | 150 | 2% | 11% | 91 | 2% | 7% | 2 | 7% | 3% | 811 | -1% | 6% |
| Brazil | 17 | -1% | 0.4% | 103 | -1% | 3% | 31 | -0.3% | 1% | 92 | 2% | 7% | 46 | 2% | 3% | 1 | 8% | 2% | 288 | 0.4% | 2% |
| Asia | 2,805 | 0.1% | 75% | 1,492 | 4% | 37% | 661 | 3% | 20% | 544 | 2% | 40% | 447 | 12% | 33% | 39 | 5% | 72% | 5,988 | 2% | 43% |
| China | 1,987 | 1% | 53% | 647 | 7% | 16% | 249 | 9% | 7% | 109 | -2% | 8% | 254 | 13% | 19% | 37 | 6% | 68% | 3,284 | 3% | 24% |
| India | 387 | -3% | 10% | 237 | 3% | 6% | 55 | 5% | 2% | 197 | 3% | 14% | 37 | 18% | 3% | 1 | 7% | 2% | 913 | 1% | 7% |
| Indonesia | 63 | 9% | 2% | 76 | 0.1% | 2% | 40 | -3% | 1% | 63 | 5% | 5% | 28 | 9% | 2% | 0 | - | 0.0% | 269 | 4% | 2% |
| Japan | 113 | -1% | 3% | 160 | -4% | 4% | 92 | -5% | 3% | 16 | 1% | 1% | 40 | 18% | 3% | 0.3 | -4% | 1% | 421 | -2% | 3% |
| South Korea | 79 | -5% | 2% | 107 | -1% | 3% | 49 | -3% | 1% | 24 | 5% | 2% | 40 | 9% | 3% | 0.3 | 10% | 1% | 298 | -1% | 2% |
| Pacific | 42 | -2% | 1% | 53 | -1% | 1% | 47 | 28% | 1% | 8 | -4% | 1% | 12 | 3% | 1% | 1 | 3% | 1% | 163 | 6% | 1% |
| Australia | 41 | -3% | 1% | 44 | -1% | 1% | 42 | 29% | 1% | 5 | -5% | 0.4% | 4 | 9% | 0.3% | 0.4 | 5% | 1% | 136 | 6% | 1% |
| CIS | 191 | -1% | 5% | 216 | 2% | 5% | 569 | 3% | 17% | 16 | -0.3% | 1% | 98 | 1% | 7% | 1 | 7% | 1% | 1,090 | 2% | 8% |
| Russia | 120 | 1% | 3% | 156 | 1% | 4% | 423 | 2% | 13% | 9 | -2% | 1% | 70 | 2% | 5% | 0 | - | 0% | 779 | 2% | 6% |
| Middle East | 8 | 4% | 0.2% | 305 | -8% | 8% | 457 | 3% | 14% | 1 | 2% | 0.1% | 5 | 28% | 0.4% | 1 | 2% | 1% | 776 | -1% | 6% |
| Iran | 1 | -7% | 0% | 61 | -27% | 2% | 191 | 5% | 6% | 1 | 2% | 0% | 4 | 25% | 0.3% | 0 | - | 0% | 258 | -5% | 2% |
| Saudi Arabia | 0 | - | 0% | 127 | 1% | 3% | 80 | 1% | 2% | 0 | 0% | 0% | 0.1 | 305% | 0% | 0 | - | 0% | 207 | 1% | 2% |
| Africa | 116 | 2% | 3% | 195 | 0.2% | 5% | 128 | 2% | 4% | 369 | 3% | 27% | 22 | 6% | 2% | 0.3 | 5% | 1% | 829 | 2% | 6% |
| **World** | **3,732** | **-2%** | **100%** | **4,086** | **0.3%** | **100%** | **3,356** | **3%** | **100%** | **1,375** | **2%** | **100%** | **1,372** | **5%** | **100%** | **54** | **6%** | **100%** | **13,975** | **1%** | **100%** |
| OECD | 760 | -11% | 20% | 1,891 | -1% | 46% | 1,550 | 3% | 46% | 338 | 1% | 25% | 787 | 2% | 57% | 13 | 5% | 24% | 5,338 | -1% | 38% |
| no-OECD | 2,972 | 0.3% | 80% | 2,196 | 1% | 54% | 1,806 | 3% | 54% | 1,037 | 2% | 75% | 585 | 8% | 43% | 41 | 6% | 76% | 8,636 | 2% | 62% |

*Source: Enerdata, Global Energy & $CO_2$ Data (Juin 2020)*

# Final energy consumption

| Final energy consumption in 2019 in Mtoe | Fossils | | | | | | | | | Biomass | | | Primary electricity | | | Heat | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coal & Lignite | | | Crude oil & NGL | | | Natural gas | | | Biomass & Wastes | | | Primary electricity | | | Geothermal & Solar | | | | | |
| | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world | Volume | Change 2018-19 | Share in the world |
| Europe | 70 | -0.4% | 6% | 541 | 0.4% | 15% | 275 | -2% | 18% | 105 | 2% | 10% | 280 | -2% | 15% | 57 | -1% | 16% | 1,328 | -1% | 14% |
| European Union | 54 | -1% | 5% | 478 | 1% | 13% | 248 | -2% | 16% | 97 | 2% | 9% | 237 | -2% | 12% | 50 | -2% | 14% | 1,163 | -1% | 12% |
| Germany | 13 | -1% | 1% | 92 | 2% | 3% | 54 | 0.1% | 3% | 16 | 4% | 2% | 44 | -2% | 2% | 10 | -2% | 3% | 228 | 1% | 2% |
| France | 5 | 4% | 0.4% | 65 | -0.4% | 2% | 29 | -3% | 2% | 13 | 4% | 1% | 37 | -1% | 2% | 4 | 0.4% | 1% | 153 | -1% | 2% |
| North America | 24 | -0.2% | 2% | 853 | -0.2% | 23% | 406 | 1% | 26% | 91 | -2% | 9% | 364 | -2% | 19% | 10 | 5% | 3% | 1,747 | -1% | 18% |
| Canada | 20 | -0.3% | 2% | 764 | -0.2% | 21% | 355 | 0.1% | 23% | 80 | -2% | 8% | 320 | -3% | 17% | 9 | 5% | 3% | 1,548 | -1% | 16% |
| United States | 4 | 0.3% | 0.3% | 89 | -1% | 2% | 52 | 6% | 3% | 11 | -4% | 1% | 44 | 0.1% | 2% | 1 | 0.2% | 0.2% | 200 | 1% | 2% |
| Latin America | 19 | -4% | 2% | 291 | -2% | 8% | 72 | 3% | 5% | 109 | 2% | 10% | 115 | 1% | 6% | 1 | 8% | 0.4% | 608 | -0.1% | 6% |
| Brazil | 11 | -5% | 1% | 96 | -0.1% | 3% | 11 | -6% | 1% | 64 | 2% | 6% | 44 | 1% | 2% | 1 | 9% | 0.3% | 228 | 0.3% | 2% |
| Asia | 1,008 | -1% | 83% | 1,341 | 4% | 37% | 343 | 5% | 22% | 443 | 2% | 42% | 899 | 3% | 47% | 154 | 6% | 43% | 4,187 | 2% | 43% |
| China | 18 | -2% | 2% | 97 | 1% | 3% | 23 | -4% | 2% | 20 | 3% | 2% | 46 | -1% | 2% | 6 | -4% | 2% | 209 | -1% | 2% |
| India | 753 | -1% | 62% | 580 | 6% | 16% | 171 | 7% | 11% | 78 | -2% | 7% | 541 | 5% | 28% | 145 | 6% | 41% | 2,268 | 3% | 23% |
| Indonesia | 43 | 1% | 4% | 144 | -2% | 4% | 28 | -2% | 2% | 7 | 4% | 1% | 78 | -4% | 4% | 1 | -5% | 0.2% | 299 | -2% | 3% |
| Japan | 115 | -4% | 10% | 208 | 3% | 6% | 40 | 8% | 3% | 164 | 3% | 16% | 106 | 0.3% | 6% | 1 | 7% | 0.3% | 634 | 2% | 7% |
| South Korea | 18 | 7% | 2% | 78 | 7% | 2% | 17 | 1% | 1% | 60 | 5% | 6% | 21 | 5% | 1% | 0 | - | 0% | 194 | 6% | 2% |
| Pacific | 4 | 0.4% | 0.3% | 54 | -0.3% | 2% | 17 | 9% | 1% | 7 | -2% | 1% | 23 | 1% | 1% | 1 | 3% | 0.2% | 105 | 1% | 1% |
| Australia | 3 | 1% | 0.3% | 45 | -1% | 1% | 14 | 8% | 1% | 4 | -2% | 0% | 19 | 1% | 1% | 0.4 | 5% | 0.1% | 85 | 1% | 1% |
| CIS | 63 | 1% | 5% | 172 | 2% | 5% | 196 | 1% | 13% | 8 | 1% | 1% | 95 | 1% | 5% | 132 | 1% | 37% | 666 | 1% | 7% |
| Russia | 36 | 6% | 3% | 123 | 1% | 3% | 148 | 2% | 10% | 4 | -2% | 0.4% | 66 | 1% | 3% | 109 | 1% | 31% | 486 | 2% | 5% |
| Middle East | 4 | 2% | 0.3% | 234 | -2% | 6% | 202 | 6% | 13% | 1 | 2% | 0.1% | 83 | 1% | 4% | 1 | 2% | 0.2% | 524 | 2% | 5% |
| Iran | 1 | 1% | 0.1% | 63 | -8% | 2% | 121 | 8% | 8% | 1 | 2% | 0% | 22 | 0.2% | 1% | 0 | - | 0% | 209 | 2% | 2% |
| Saudi Arabia | 0 | - | 0% | 89 | 1% | 2% | 23 | 1% | 2% | 0 | 0% | 0% | 24 | -1% | 1% | 0 | - | 0% | 136 | 1% | 1% |
| Africa | 24 | 4% | 2% | 164 | -2% | 5% | 42 | 2% | 3% | 295 | 3% | 28% | 58 | -0.3% | 3% | 0.2 | 5% | 0.1% | 583 | 1% | 6% |
| **World** | **1,216** | **-1%** | **100%** | **3,649** | **1%** | **100%** | **1,553** | **2%** | **100%** | **1,058** | **2%** | **100%** | **1,916** | **1%** | **100%** | **355** | **3%** | **100%** | **9,746** | **1%** | **100%** |
| OECD | 159 | -0.2% | 13% | 1,753 | -0.4% | 48% | 753 | -0.3% | 49% | 227 | 1% | 22% | 812 | -2% | 42% | 69 | -1% | 20% | 3,774 | -1% | 39% |
| no-OECD | 1,057 | -1% | 87% | 1,895 | 2% | 52% | 800 | 4% | 52% | 831 | 2% | 79% | 1,104 | 3% | 58% | 285 | 4% | 80% | 5,972 | 2% | 61% |

*Source: Enerdata, Global Energy & $CO_2$ Data (June 2020)*

# Investments in the energy sector

Green investments should be spared by the very sharp decline of investments in the energy sector expected in 2020

**Investments in the energy sector have suffered heavily from the consequences of the Covid-19 crisis, notably the oil sector.** The IEA forecasts a -20% contraction in 2020 down to $1,520bn, against $1,891bn in 2019.

The impact of the crisis on investments stems from both reduced spending due to lower revenues, and operational constraints, such as people an goods limited circulation.

IEA projections presented here have been produced in April and May. They are based on investments data for the first months of 2020, 2019 trend and the analysis of the Covid-19 crisis impact on the energy sector presented in the IEA report Global Energy Review 2020. Underlying hypothesis are that of a -6% world economic recession in 2020, with continued mobility restrictions and social and economic activity reductions.

**All sectors are impacted, but oil and gas are the most severely hit.** The impact of both lockdown and economic crisis on oil demand (estimated at -9mbbl/d on average over 2020), thus on oil prices too, has affected producers and the whole supply chain. According to the IEA, investments in the oil and gas sector in 2020 (E&P and transport) shall recede -32% (-$244bn down to $511bn). Investments in the coal sector plunged too (-24%, IEA forecast), but retained some resilience in China, which represents two thirds of world investments.

**Investments in non carbon technologies (CCUS, batteries, nuclear, renewables) and in energy efficiency shall hold up much better.** The IEA forecasts a near -6.5% decline down to $580bn in 2020, against $620bn in 2019, a level close enough to previous years' (c. $600bn on average since 2015).

**The power sector shall be relatively spared,** with a decline expected at -7% (down $79bn to $678bn), although performances shall be contrasted amongst energy sources.

Investments in electricity RES shall shrink approximately -10% in 2020. The impact shall be much worse on solar at -21% than on wind power at -2%, while hydro shall gain +3.8%. Regarding thermal projects, natural gas is set to suffer more (-24%) – especially in the weakened Middle East and North African producing countries – than coal (-12%), which retains China's support.

**All in all, the share of RES in power generation investments will continue to grow in 2020** (from 34% in 2019 to 37.5% in 2020), as well as net electricity RES capacity (+7.5%).

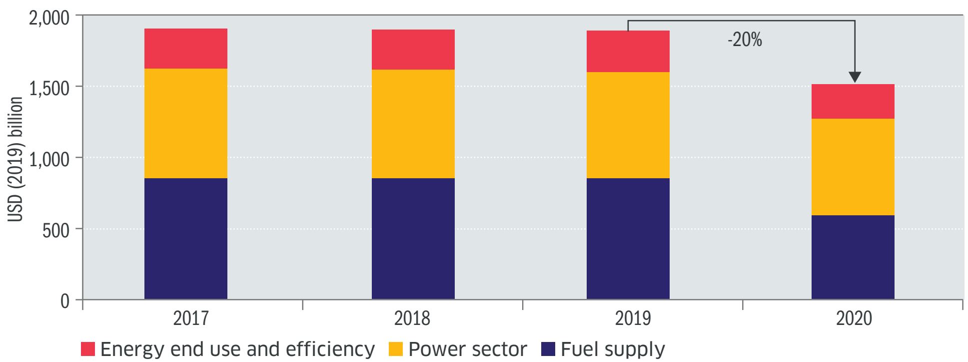
Nonetheless, at $281bn in 2020, investments in renewable power are well below what is required for a 2°C objective ($576bn per year from 2020 to 2025, according to the IEA's SDS scenario).

**Investments in 2020 remain subject to how the situation develops in China and in the USA.** In China, leading investor in energy, the -12% contraction forecast by the IEA will depend above all on the recovery in industrial activity. In the USA, the -25% shortfall projection stems from the predominance of the oil and gas sectors in the country's energy investments (one half). In Europe, the fall is expected at -17%, but some sectors will be spared, such as investments in electricity networks, energy efficiency and wind power.

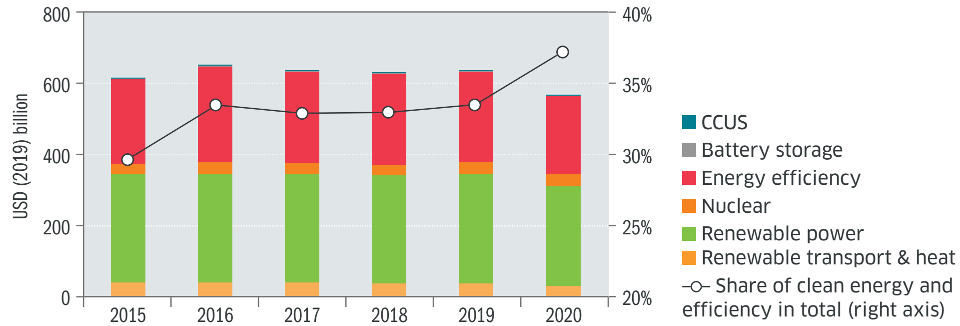
**Although in favour of green technologies, these estimates are insufficient to make of 2020 the tipping point of energy transition.** RES still do not offer all the guaranties that investors are looking for in terms of market capitalisation, dividends or liquidity. Low-cost financing opportunities by institutional investors remain centered on Europe and North America. In addition, although coal investments decrease in many regions, the number of new plants approvals granted in the first quarter, notably in China, has doubled compared to 2019.

# Investments in the energy sector

## TOTAL INVESTMENTS IN THE ENERGY SECTOR WORLD – 2017 TO 2020

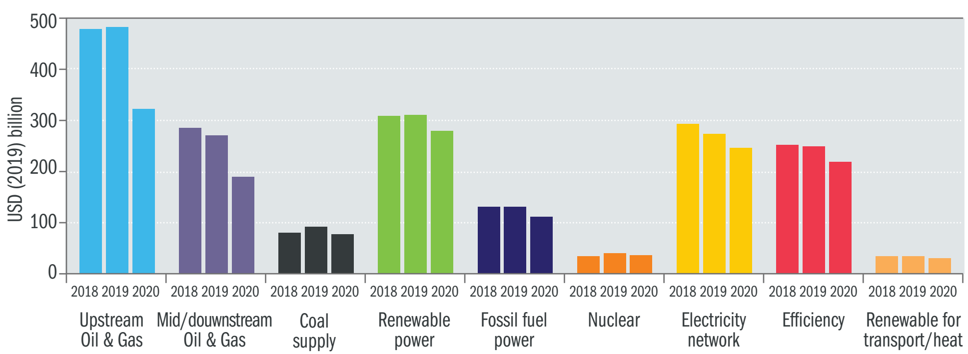



## INVESTMENTS IN "CLEAN" TECHNOLOGIES COMPARED TO TOTAL INVESTMENTS WORLD – 2015 TO 2020

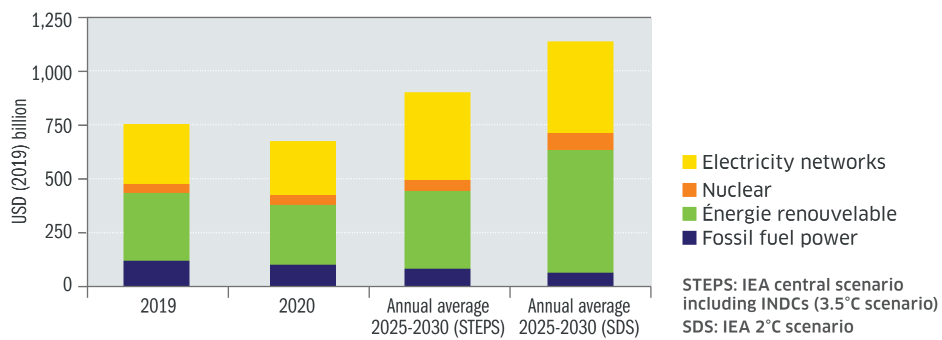





## INVESTMENTS IN VARIOUS ENERGY SECTORS WORLD – 2018 TO 2020




## 2019 AND 2020 WORLDWIDE INVESTMENTS IN POWER GENERATION COMPARED TO IEA'S STEPS AND SDS SCENARIOS OVER THE 2025-2030 PERIOD




**STEPS: IEA central scenario including INDCs (3.5°C scenario)**
**SDS: IEA 2°C scenario**

*Source: IEA World Energy Investment 2020, May 2020*

# Investments in the energy sector

## The Covid-19 crisis reveals a persisting weakness in energy investments

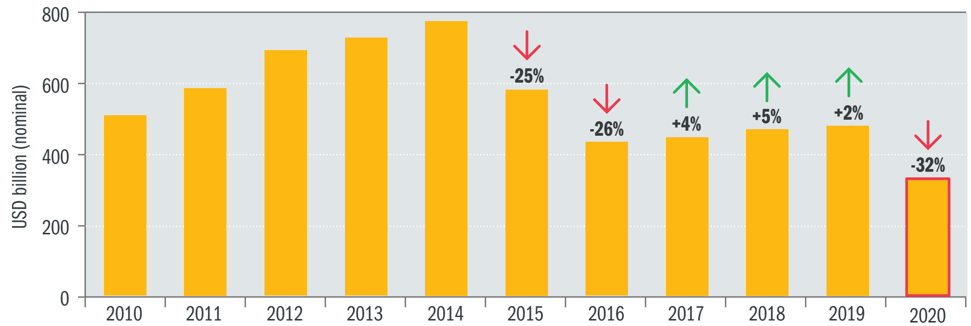
**In 2019, investments in the energy sector grew 0.7%** at $1,904bn against $1,891bn in 2018, in line with several years of stabilisation, if not contraction, since their share in world GDP dropped below 2%, from 3% in 2014.
This situation reflects the end of a vigorous expansion period in the oil and gas industry at the beginning of the decade, without the necessary investments in clean technologies really taking over, or not to the extent required by global warming to say the least.

**Investment is weak in almost all energy sectors.** Spending in oil and gas exploration has been steadily declining over the last years, to the exception of a small +2% rise in 2019. This fall results partly from abundant unconventional resources, which do not require exploration as such, and partly from low oil prices, which deepens uncertainties over the long term profitability of oil investments. At the same time, petrochemicals and LNG, despite their positive medium term perspectives, faced overcapacity, eroding margins and leading to the postponement of many projects.

Conversely, the coal industry stands in an bullish cycle after some restructurings in China in 2016-2017. In 2019, as new mines developed in China, world coal investments jumped +15% (+$90bn), in spite of public pressure.

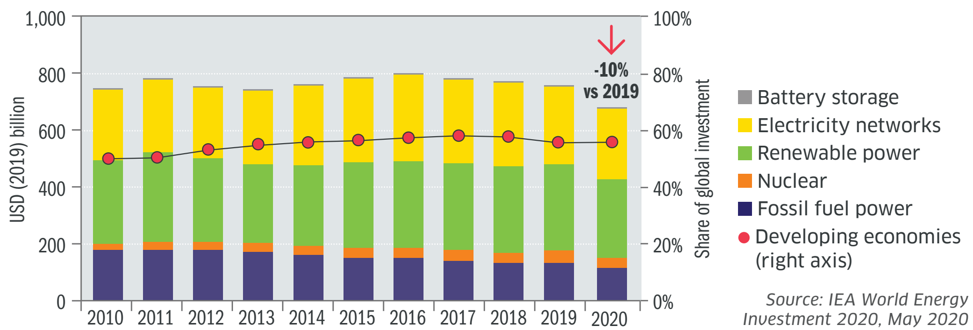
**In the power sector, investments dipped -2% in 2019** at $760bn, mainly due the +7% decline in electricity network investments, driven mostly by China for regulatory reasons. This sharp fall offset the 18% gain in nuclear power linked to Japanese plants' reopening and Chinese projects, as well as the more modest surge of electricity RES (+1% at $310bn), reflecting major wind power projects in the USA and in India, but hiding lower investments in solar power. Investments in natural gas and batteries' new capacity remained stable, while that of coal receded -6%. This shortfall, attributable to China, did not prevent an increase in net capacity though.

### TOTAL INVESTMENTS IN THE OIL & GAS SECTOR WORLD – 2017 TO 2020




*Sources: IEA, Global Energy review 2020 – Covid-19 impacts on energy and $CO_2$ emissions, 28 April 2020*

### INVESTMENTS IN VARIOUS ELECTRICITY SECTORS WORLD – 2010 TO 2020




*Source: IEA World Energy Investment 2020, May 2020*

# Green recovery plans

## Opportunities for a green recovery

**Green recovery offers better potential than traditional recoveries.** Green recovery measures rest on economic growth potential of green investments facilitated by near zero interest rates, job creation short term, resilient systems development and a lower cost than inaction.

More precisely, investments in energy efficiency, such as thermal renovation, RES or transport infrastructure, all have in common, besides saving energy, an easy implementation and a strong potential to revive the economy, innovate and create jobs.

These arguments are supported by many research institutes, think tanks, NGOs, institutions, and known politicians prompting public authorities to spend recovery funds on resilient investments, for they are readily available and offer a stronger knock-on effect than traditional investments.

These benefits have been attested in a study published 4th May by Oxford University, edited by Nicholas Stern and Joseph Stiglitz, Nobel prize in economic science. With the participation of a vast number of experts worldwide and the analysis of 700 stimulus policies, the authors measured the economic and climate impact of green recovery packages. Compared to traditional fiscal stimulus, green projects create more jobs, offer better return short term for every dollar spent and on the longer term allow savings.

**The rightfulness of green recovery packages lies also on society expectations, which the crisis heightened,** as shown by opinion polls and citizens initiatives.
The issue of supporting fossil fuels is also raised, on the ground that state aid should not target sectors where long term prospects are nihil. Lastly, brought to light by the crisis is the fact that economic dependence concerns RES technologies too and some relocations need to be further examined.

**Far heavier than the cost of energy transition, recovery packages could be a historical opportunity to switch towards a low-carbon world.** The European Central Bank committed to inject €1,000bn in the European financial system as early as March 2020. In April, the European Union decided on emergency measures mounting to €540bn. And in May, the European Commission suggested to the Parliament a €750bn community loan, in line with the French-German proposal made May 18th. Off this sum, €500bn in the form of subsidies will be transferred to member states that are the most affected by Covid-19, under the condition that they present reforms and investments that are compatible with EU priorities, in other words the Green deal, energy transition and Europe's greater sovereignty.

Since the cost of reducing $CO_2$ emissions in the EU has been valued by the Commission at €260bn per year until 2030, recovery plans appear to be meeting the double objective of rescuing the European economy and the climate.

Another interesting comparison is the level of support packages announced by the G20 member states at $7,300bn, and that of EIA's 2°C scenario cost, estimated at $2,000bn per year until 2040.

**Public authority will play a decisive role.** Energy policy represent, directly or indirectly, 70% of energy investments. Therefore, through recovery packages of unprecedented size, it would be possible to implement economic planning that would structurally reduce emissions.

That is the IEA's message to governments. *"By their size, recovery plans only happen once a century. This will structure the economy and shape our world for many years to come"*, said Fatih Birol IEA's executive director. Similarly, BNEF recommends to take advantage of public authority to launch expensive projects, such as the transformation of electricity networks and storage infrastructures, in a coordinated action between public procurement and private sector.

# Green recovery plans

## Recovery plans' guidelines

**Many governments have taken measures towards energy to exit the crisis, yet relatively few chose the way of sustainable solutions.**
The above-mentioned study* by Nicholas Stern and Joseph Stiglitz also examines the impact that the major fiscal rescue measures launched during the 2nd quarter of 2020 by G20 member countries will have on climate. These emergency measures aim at protecting balance sheets, reducing bankruptcies and answering immediate concerns regarding care during lockdown. In April 2020, all G20 members (including most EU members) had enacted such fiscal measures for a total spending of over $7,300bn.

By distinguishing rescue from recovery measures, the authors observe that a large majority of these policies are of rescue type, such as vast compensation schemes for employees and companies livelihood.

The subjective assessment is that 4% of these policies are "green", with potential to reduce long-run GHG emissions, 4% are "brown" likely to increase net GHG emissions beyond the base case, and 92% are "colorless", meaning that they maintain the status quo.

**While current observations lead to a certain pessimism, the international debate in favour of green recovery is very intense and should prompt some positive reactions, as shown by the recent EU decisions.**
The EU stood by its ambitions to implement decarbonization. Even if some deadlines have been extended, the Commission has delivered unambiguous messages; the Biodiversity Strategy was passed in May and subsidies from the €750bn recovery plan will be submitted to meeting EU priorities: Green Deal, energy transition and sovereignty (more details in the chapter $CO_2$ and Climate – Climate policies).

*Référence: University of Oxford – SSEE " Will Covid-19 fiscal recovery packages accelerate or retard progress on climate change?" – Cameron Hepburn, Brian O'Callaghan, Nicholas Stern, Joseph Stiglitz, Dimitri Zenghelis, 4th May.

### ENERGY COMPONENT OF NATIONAL RECOVERY PLANS

**CONTINUATION**

**EU:** Green Deal objective maintained; numerous calls for a green recovery plan. Strengthening opposition may weaken ambitions and rapid action however.
**France:** RES development continues during the sanitary crisis: new offshore wind projects of worth 8,7GW announced end of April.
Senate calls government to keep energy transition on track and places the carbon neutrality objective as major recovery plan incentive. During audition, senators ask Minister of Ecological Transition E. Borne's to enhance support measures towards companies and households for energy transition to be pursued. Minister of Economy B. Le Maire (7th May) expresses ambition to make France the first low-carbon economy in Europe: "Distinguish economic from environmental issues would make no sense. The current crisis does not question the necessity of the energy transition. To the contrary, it boosts it."
**United Kingdom:** support to green recovery. Offshore wind projects' biddings maintained. The budget passed in March 2020 includes strong support measures to energy transition (Low carbon heat support scheme aimed at CCS, biomethane, heat pumps, biomass). However, risk of insufficient financing and of taking advantage of low gas prices.
**South Korea:** Green deal to be passed (carbon neutrality by 2050)
**New York state:** announcement of a recovery plan supporting low carbon strategies, as well as measures attracting private investment towards RES projects. Other states maintain their commitments too.

**STATUS-QUO**

**Germany:** A. Merkel confirmed her commitment to the Paris Agreement during the Petersberg Dialogue on Climate (28th April). 68 major companies (Bayer, Puma, Allianz, etc.) ask for state aid to be conditioned on action over climate. The automotive sector calls for further incentives to scrap combustion engines. Conversely, coal exit could be delayed, and Environment Minister took a stand on rescuing airlines.
**Canada:** announcement of a $750m federal budget to reduce carbon leakage. Government in favour of a green recovery. Federal funding of a program to clean up abandoned oil wells.
**India:** coal's share remain significant, solar projects continue (3.6 GW announced in April). India prepares to compete with China as a manufacturing centre for solar and wind installations.

**BACKWARD STEP**

**China:** more new coal-fired power plants permitted. No mention of climate in the first recovery measures. Subsidies to EV extended another 2 years.
**USA:** systematic unravelling of environmental policies by the Trump administration (again in March 2020, with the reversal of automotive standards). The $2,2trn recovery plan includes no support to sustainable activities, no environmental conditionality to aids and sets priority on saving coal and oil industries.
**Japan:** return to coal with new plants. Weaker climate change objectives with NDCs unchanged since 2015. A policy that could cause Olympic Games boycotts. Strong hydrogen strategy however.
**Indonesia:** no green stimulus to maintain the economy.
**South Africa:** carbon tax postponed.
**Mexico:** all current green projects stopped.
**Brazil:** J. Bolsonaro announces a return to fossil fuels (oil and gas).
**Netherlands:** new measures to reduce $CO_2$ emissions cancelled

# $CO_2$ & Climate

## $CO_2$ EMISSIONS

$CO_2$ emissions dropped sharply in 2020 because of the health crisis, but could rebound swiftly unless recovery plans favour green investment

# $CO_2$ emissions

## The coronavirus-related reduction in $CO_2$ emissions in 2020 should only be temporary

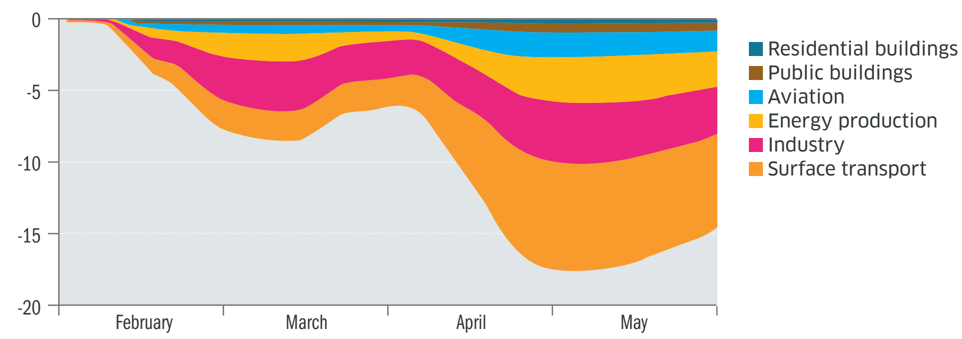
**$CO_2$ emissions declined during the pandemic lockdown. The subsequent economic recession will extend the impact over the rest of 2020.**
The lockdown's direct impact on $CO_2$ emissions was around 20%, in line with that on economic activity, and reflects reduced road traffic (40%), industrial activity (30%) and coal-fired power generation (20%).

Other air pollutants such as nitrogen dioxide ($NO_2$) and fine particles, which are responsible for about 9 million premature deaths worldwide every year (WHO), have also been declining. $NO_2$ concentrations fell by 40% in Europe in April, saving 11,000 lives (CREA). Fine particles reduced only 10%, mainly because of their association with agriculture.

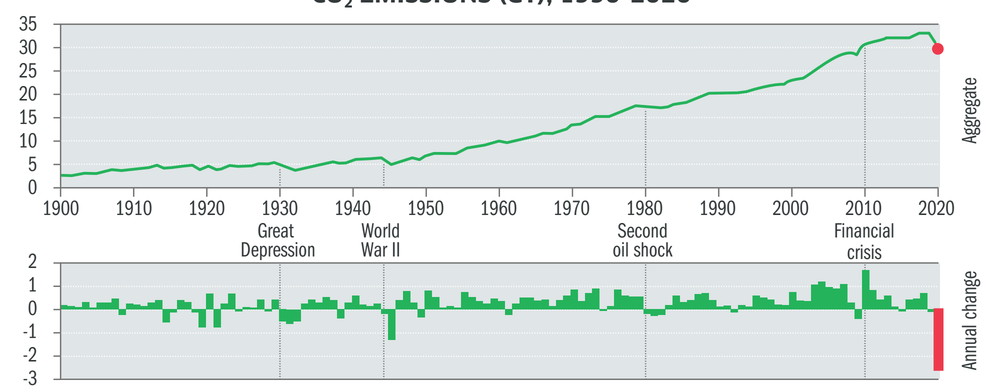
**An historic contraction in $CO_2$ emissions is expected in 2020,** worth around 8%, or 2.6 Gt. That would take their level back to that of 2010, or 30 Gt, against 33 Gt in 2019.
The drop is twice as great as total of all reductions since WW2 and six times as great as the dip caused by the 2007-2008 financial crisis (-0.3 Gt).
Of the 2.6 Gt decline, 1.1 Gt will come from reduced coal consumption, 1 Gt from reduced oil use and 0.4 Gt from lower natural gas consumption. Nearly a quarter (600 Mt) will stem from lower emissions in the USA, reflecting reduced road and air traffic and a slowdown in coal-fired power production.
This IEA projection is based on GDP and energy demand both declining 6% worldwide in 2020. We recall that the 1.5°C climate change objective requires an annual 6% reduction in $CO_2$ emissions until 2030 (IPCC estimates in its special report "Global Warming 1.5°C")*.

**$CO_2$ emissions will increase as a result of massive recovery plans,** unless investments are redirected towards clean energies and resilient infrastructures. Our economies are still largely based on fossil energy (nearly 80%).

**REDUCTION OF $CO_2$ EMISSIONS WORLDWIDE, JAN-MAY 2020 (%)**




**$CO_2$ EMISSIONS (GT), 1990-2020**




*Sources: Nature Climate Change, 19 May 2020; IEA Global Energy review 2020 – Covid-19 impacts on energy and $CO_2$ emissions, 28 April 2020; Enerdata Bilan énergétique mondial – 2020 edition, May 2020*

*The 1.5°C target recommended by the IPCC is much more demanding than the 2°C target and requires almost double the effort: halving emissions by 2030 to reach zero emissions in 2050 and then going into negative emissions after 2050.

# $CO_2$ emissions

## The exceptional situation in 2020 should not obscure the weakness of decarbonization progress

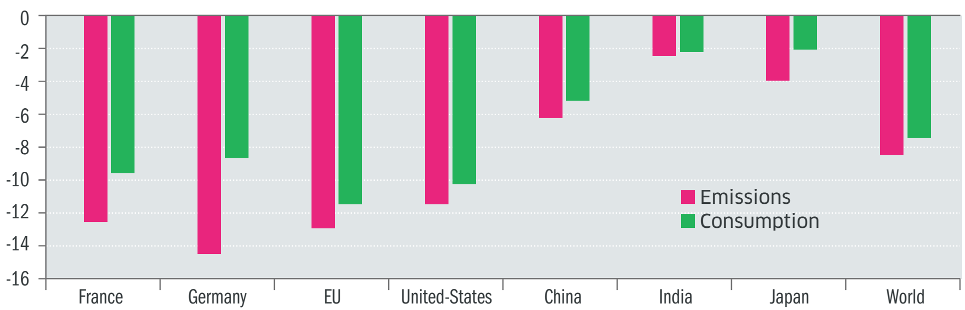
### The reduction in emissions in 2020 stems from a slowdown in the transport sector and a less carbon-intensive electricity mix.

Reduced road and air traffic has had a major impact on 2020 $CO_2$ emissions. It is estimated to account for 42% of the $CO_2$ emission reduction in the EU, 30% in France, 27% in the USA and 36% in China.

The other significant impact on emissions in 2020 is the higher share of carbon-free energy in electricity production. Lower power consumption initially affects modular power production and coal-fired power, while RES and nuclear power are hardly impacted at all. According to Enerdata, for example, the share of low-carbon sources in power generation will reach 98% in France, 60% in Germany, 69% in the EU, 40% in the USA and 35% in China this year.

**On a regional scale,** 2020 $CO_2$ emissions are set to diminish by 12% in France, 13% in the EU-28, 11% in the USA, 2% in India and 5% in China (Enerdata).

**ENERGY-RELATED $CO_2$ EMISSIONS AND ENERGY CONSUMPTION CHANGE 2020-2019 FORECASTS (%)**




*Source: Enerdata estimates, May 2020*

### 2019 saw only very modest decarbonization: emissions declined 0.4% as world coal consumption plunged.

After a 2% rise in 2018, carbon emissions declined in 2019 for the first time since 2009. They dropped 2.8% in OECD countries (after a 0.8% rise in 2018) and slowed in the rest of the world (up 1.3%, after a 3% increase in 2018).

The decline was particularly noticeable in the EU (-4%), Japan (-3.5%), the USA (-2.5%), where coal retreated despite Trump's policy, and in India (-1%, against +4% in 2018), where coal demand eased in a depressed economic context.

There was no change in China, where emissions rose 3%. In contrast with other countries, this stemmed more from the industrial sector and booming steel and cement sectors than from power generation.

In France, $CO_2$ emissions decreased 1% in 2019, confirming a downtrend initiated in 2017. They still remain 4.5% above the national low-carbon economy (SNBC) objective, however.

**Limited decarbonization also showed in a carbon factor improvement in 2019** ($CO_2$ emissions/Energy consumption). The carbon factor declined 1%, which was the first time since the 2000s.

This progress is extremely slow. There is no hope of reaching environmental objectives in the short run (the IEA's SDS scenario requires a 3.3% annual decline to 2040). Time will tell whether the 2020 crisis will trigger the necessary structural changes under the impetus of green recovery plans and act as a wake-up call on climate challenges, as the acceleration of the energy transition is more urgent than ever.

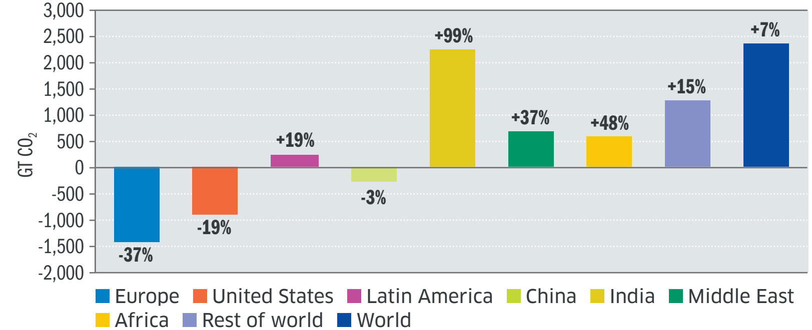
# $CO_2$ emissions

| $CO_2$ emissions (Mt) | 1990 | 2000 | 2010 | 2015 | 2018 | 2019 | Change 1990-2019 | AAGR 1990-2019 | Change 2018-2019 | Share in world 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| Europe | 4,401 | 4,246 | 4,176 | 3,824 | 3,824 | 3,673 | -17% | -1% | -4% | 11% |
| European Union | 4,098 | 3,892 | 3,727 | 3,331 | 3,267 | 3,136 | -24% | -1% | -4% | 10% |
| Germany | 953 | 830 | 781 | 755 | 720 | 673 | -29% | -1% | -7% | 2% |
| France | 365 | 386 | 357 | 317 | 309 | 301 | -17% | -1% | -2% | 1% |
| North America | 5,296 | 6,347 | 5,994 | 5,625 | 5,614 | 5,490 | 4% | 0% | -2% | 17% |
| Canada | 4,866 | 5,817 | 5,446 | 5,047 | 5,042 | 4,920 | 1% | 0% | -2% | 15% |
| United States | 430 | 530 | 548 | 578 | 572 | 569 | 33% | 1% | -1% | 2% |
| Latin America | 859 | 1,206 | 1,552 | 1,683 | 1,573 | 1,536 | 79% | 2% | -2% | 5% |
| Mexico | 264 | 364 | 445 | 445 | 438 | 433 | 64% | 2% | -1% | 1% |
| Asia | 4,789 | 6,818 | 12,745 | 14,837 | 15,700 | 15,879 | 232% | 4% | 1% | 49% |
| China | 2,257 | 3,145 | 7,799 | 9,083 | 9,463 | 9,729 | 331% | 5% | 3% | 30% |
| India | 523 | 910 | 1,583 | 2,026 | 2,248 | 2,222 | 325% | 5% | -1% | 7% |
| Korea | 244 | 447 | 594 | 638 | 675 | 650 | 167% | 3% | -4% | 2% |
| Japan | 1,040 | 1,123 | 1,104 | 1,135 | 1,082 | 1,045 | 1% | 0% | -3% | 3% |
| Indonesia | 148 | 273 | 377 | 470 | 547 | 581 | 293% | 5% | 6% | 2% |
| Pacific | 286 | 371 | 431 | 421 | 434 | 440 | 54% | 2% | 2% | 1% |
| CIS | 3,553 | 2,208 | 2,373 | 2,316 | 2,464 | 2,488 | -30% | -1% | 1% | 8% |
| Russia | 2,189 | 1,522 | 1,610 | 1,592 | 1,725 | 1,755 | -20% | -1% | 2% | 5% |
| Middle East | 590 | 961 | 1,608 | 1,875 | 1,947 | 1,980 | 236% | 4% | 2% | 6% |
| Saudi Arabia | 156 | 244 | 435 | 551 | 530 | 534 | 243% | 4% | 1% | 2% |
| Iran | 181 | 320 | 515 | 579 | 626 | 638 | 252% | 4% | 2% | 2% |
| Africa | 538 | 680 | 1,040 | 1,179 | 1,250 | 1,257 | 134% | 3% | 1% | 4% |
| South Africa | 252 | 296 | 429 | 427 | 442 | 447 | 77% | 2% | 1% | 1% |
| World | 20,311 | 22,836 | 29,918 | 31,759 | 32,805 | 32,741 | 61% | 2% | 0% | 100% |
| OECD | 11,179 | 12,753 | 12,616 | 11,984 | 11,961 | 11,634 | 4% | 0% | -3% | 36% |
| no-OECD | 9,132 | 10,084 | 17,302 | 19,775 | 20,844 | 21,108 | 131% | 3% | 1% | 65% |
| BRICS | 5,414 | 6,172 | 11,798 | 13,591 | 14,292 | 14,562 | 169% | 4% | 2% | 45% |

*Source: Enerdata Global Energy & CO2 Data (2020)*

NB: The $CO_2$ emissions reported here are those related to the combustion of energy, i.e. 90% of $CO_2$ emissions (see following pages "GHG distribution").

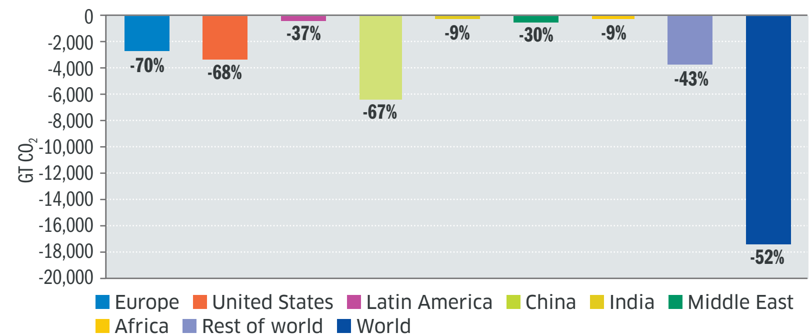
## EVOLUTION OF $CO_2$ EMISSIONS BETWEEN 2018 AND 2040 IN THE STATED POLICIES SCENARIO (IEA)




*Source: IEA – World Energy Outlook 2019*



## EVOLUTION OF $CO_2$ EMISSIONS BETWEEN 2018 AND 2040 IN THE SUSTAINABLE DEVELOPMENT SCENARIO (IEA)




*Source: IEA – World Energy Outlook 2019*

# $CO_2$ emissions by sector

| $CO_2$ emissions by sector (Mt) | Energy sector | | | | Residential, Services & Agriculture | | | | Industry | | | | Transport | | | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 2019 | TC 1990-2019 | TC 2018-2019 | 1990 | 2019 | TC 1990-2019 | TC 2018-2019 | 1990 | 2019 | TC 1990-2019 | TC 2018-2019 | 1990 | 2019 | TC 1990-2019 | TC 2018-2019 | 1990 | 2019 | TC 1990-2019 | TC 2018-2019 |
| Europe | 1,669 | 1,211 | -28% | -10,5% | 870 | 662 | -24% | -1% | 1,039 | 733 | -30% | -1% | 821 | 1,068 | 30% | 0% | 4,401 | 3,673 | -17% | -4% |
| European Union | 1,567 | 993 | -37% | -11,5% | 805 | 587 | -27% | -1% | 966 | 617 | -36% | 0% | 760 | 939 | 24% | 0% | 4,098 | 3,136 | -24% | -4% |
| Germany | 349 | 231 | -34% | -17,4% | 213 | 127 | -40% | 1% | 232 | 150 | -35% | -1% | 159 | 166 | 4% | 1% | 953 | 673 | -29% | -7% |
| France | 60 | 39 | -36% | -13,4% | 97 | 74 | -23% | -2% | 95 | 65 | -31% | 2% | 114 | 124 | 9% | -1% | 365 | 302 | -17% | -2% |
| North America | 2,300 | 2,212 | -4% | -5,3% | 664 | 692 | 4% | 1% | 807 | 708 | -12% | 0% | 1,525 | 1,878 | 23% | 0% | 5,296 | 5,490 | 4% | -2% |
| United States | 2,154 | 2,013 | -7% | -5,4% | 584 | 589 | 1% | 0% | 721 | 611 | -15% | 0% | 1,407 | 1,707 | 21% | 0% | 4,866 | 4,920 | 1% | -2% |
| Canada | 145 | 199 | 37% | -4,4% | 81 | 103 | 27% | 7% | 86 | 96 | 12% | 1% | 118 | 172 | 45% | -1% | 430 | 569 | 33% | -1% |
| Latin America | 240 | 427 | 78% | -4,9% | 105 | 150 | 42% | -2% | 224 | 365 | 63% | -2% | 290 | 594 | 105% | -1% | 859 | 1,536 | 79% | -2% |
| Mexico | 96 | 158 | 65% | -0,5% | 26 | 30 | 16% | -5% | 59 | 93 | 58% | 2% | 84 | 153 | 83% | -3% | 264 | 433 | 64% | -1% |
| Asia | 1,627 | 7,997 | 392% | 0,8% | 902 | 1,284 | 42% | 2% | 1,703 | 4,436 | 161% | 0% | 557 | 2,162 | 288% | 4% | 4,789 | 15,879 | 232% | 1% |
| China | 725 | 5,287 | 629% | 2,3% | 524 | 767 | 46% | 2% | 912 | 2,678 | 194% | 3% | 95 | 997 | 946% | 6% | 2,257 | 9,729 | 331% | 3% |
| India | 207 | 1,025 | 395% | -3,0% | 85 | 188 | 121% | 3% | 167 | 694 | 316% | -1% | 64 | 316 | 391% | 4% | 523 | 2,222 | 325% | -1% |
| Korea | 50 | 317 | 536% | -6,2% | 73 | 56 | -23% | -4% | 77 | 171 | 123% | -2% | 44 | 106 | 142% | 1% | 244 | 650 | 167% | -4% |
| Japan | 386 | 469 | 22% | -5,8% | 136 | 123 | -10% | -2% | 316 | 252 | -20% | -1% | 203 | 202 | -1% | -1% | 1,040 | 1,045 | 1% | -3% |
| Indonesia | 48 | 175 | 267% | 4,9% | 23 | 32 | 39% | 2% | 45 | 216 | 385% | 7% | 32 | 158 | 390% | 8% | 148 | 581 | 293% | 6% |
| Pacific | 144 | 221 | 53% | 1,2% | 15 | 26 | 73% | 2% | 55 | 75 | 38% | 6% | 72 | 117 | 62% | -1% | 286 | 440 | 54% | 2% |
| CIS | 1,986 | 1,340 | -33% | 0,5% | 623 | 340 | -46% | 2% | 600 | 540 | -10% | 0% | 344 | 268 | -22% | 4% | 3,553 | 2,488 | -30% | 1% |
| Russia | 1,276 | 955 | -25% | 1,1% | 382 | 208 | -45% | 3% | 310 | 409 | 32% | 1% | 221 | 182 | -18% | 4% | 2,189 | 1,755 | -20% | 2% |
| Middle East | 193 | 792 | 310% | 0,6% | 77 | 198 | 159% | 6% | 167 | 594 | 255% | 3% | 152 | 395 | 160% | 1% | 590 | 1,980 | 236% | 2% |
| Saudi Arabia | 53 | 185 | 248% | 0,4% | 3 | 5 | 83% | 1% | 51 | 243 | 382% | 2% | 49 | 101 | 105% | -1% | 156 | 534 | 243% | 1% |
| Iran | 40 | 192 | 384% | -2,8% | 53 | 157 | 197% | 6% | 49 | 151 | 209% | 3% | 40 | 138 | 247% | 2% | 181 | 638 | 252% | 2% |
| Africa | 242 | 579 | 139% | 2,5% | 50 | 133 | 164% | 0% | 133 | 187 | 41% | -4% | 113 | 358 | 216% | 0% | 538 | 1,257 | 134% | 1% |
| South Africa | 143 | 285 | 99% | 1,1% | 14 | 45 | 214% | 3% | 65 | 62 | -4% | 0,6% | 30 | 54 | 84% | 0% | 252 | 447 | 77% | 1% |
| World | 8,401 | 14,780 | 76% | -1,3% | 3,307 | 3,484 | 5% | 1% | 4,728 | 7,639 | 62% | 0,0% | 3,876 | 6,840 | 77% | 2% | 20,311 | 32,741 | 61% | 0% |
| OECD | 4,463 | 4,546 | 2% | -6,3% | 1,736 | 1,575 | -9% | -1% | 2,256 | 2,009 | -11% | -0,2% | 2,724 | 3,503 | 29% | 0% | 11,179 | 11,634 | 4% | -3% |
| no-OECD | 3,938 | 10,234 | 160% | 1,1% | 1,571 | 1,908 | 22% | 2% | 2,472 | 5,630 | 128% | 0,1% | 1,152 | 3,336 | 190% | 3% | 9,132 | 21,108 | 131% | 1% |
| BRICS | 2,381 | 7,626 | 220% | 1,4% | 1,033 | 1,240 | 20% | 2% | 1,508 | 3,954 | 162% | 1,6% | 493 | 1,743 | 254% | 5% | 5,414 | 14,562 | 169% | 100% |

NB: The $CO_2$ emissions reported here are those related to the combustion of energy, i.e. 90% of $CO_2$ emissions (see following pages "GHG distribution").

*Source: Enerdata Global Energy & $CO_2$ Data (June 2020)*

# $CO_2$ & climate: GHG breakdown

## The Kyoto protocol identifies 6 major green house gases:

**$CO_2$** (carbon dioxide) mostly comes from the combustion of fossil fuels. It represents 83% of GHG emissions. As a reference gas, its global warming potential, or GWP, is set to 1. $CO_2$'s estimated lifespan nears 100 years.

**$CH_4$** (methane), is mainly associated with agriculture, but it is also found in fugitive and landfill emissions. It accounts for 10% of GHG emissions, but for 20% to 30% of the increase in temperatures, due to a GWP 28 times that of $CO_2$.

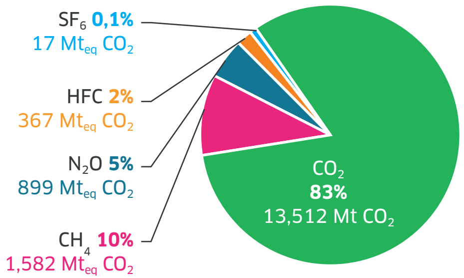
**$N_2O$** (nitrous oxide) ranks third in GHG emissions. It comes from the decay of nitrogen compounds, such as fertilizers, as well as the combustion of aviation fuels and savannah fires, amongst others. With a GWP of 265 and a lifespan of 120 years, nitrous oxide is a particularly harmful to the ozone layer.

**HFC** (hydrofluorocarbons) have a GWP 13,000 times that of $CO_2$. Made of carbon, fluor and hydrogen, there are mainly used in air-conditioners and refrigerators. An amendment to the Montreal protocol signed in 2016 in Kigali, provides for their gradual phase-out, yet millions of tonnes are still illegally placed on the market every year.

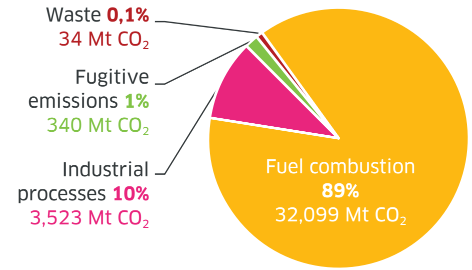
**PFC** (perfluorocarbons) are present in some cookware such as non stick pans. Their GWP is 7,600 times is that of $CO_2$. Being very volatile, they contaminate removed natural areas such as the North pole or some Himalayan lakes. Within the human body, they are powerful endocrine disrupters, affecting fertility in particular. They cause neurological adverse effects too, such as attention deficit and hyperactivity.

**$SF_6$** (sulphur hexafluoride) represents a mere 0.1% of $CO_2$ equivalent GHG emissions, but remain 3,200 years in the atmosphere. Used in medium and high voltage electric equipment for stability and resistance reasons, this artificial gas has a "greenhouse" potential 22,800 times that of $CO_2$.

### GHG EMISSIONS OF ANNEX I* COUNTRIES (EXCLUDING LULUCF) TOTAL: 16,359 MTEQ $CO_2$ IN 2017




### GLOBAL $CO_2$ EMISSIONS (EXCLUDING LULUCF) TOTAL: 35,997 MT $CO_2$ IN 2017




*Annex I: see Glossary.

*Source: Enerdata Global Energy & $CO_2$ Data (2020), UNFCCC Greenhouse Gas Inventory Data – 2017 figures are the latest available*

## Sources of $CO_2$ emissions:

**Fossil fuel combustion** represents 89% of world $CO_2$ emissions.

**Industrial processes,** including among others chemicals, steel and cement, account for 10% of $CO_2$ emissions. In countries where heavy industry is developing, this source of emissions is growing rapidly. This is the case in India, with a 45% rise since 2010.

**Fugitive emissions or gas flaring** remain very important in oil and gas producing countries. They represent just 1% of $CO_2$ emissions worldwide, but reach 20% of Russia's $CO_2$ balance. Russia, together with Iran and Iraq make up 40% of this source of emissions.

**Waste treatment** weighs relatively little in $CO_2$ emissions (even though in France waste incineration is the $CO_2$ equivalent to 2.3 million cars). Conversely, they weigh heavily on methane emissions (organic waste decomposition represents 16% of methane emissions every year in France). Waste recycling or recovery are among these practices that offer a major lever to emission reduction and even energy saving.

# $CO_2$ & climate: emission factors

### FUEL EMISSION FACTORS (KG $CO_2$ / TEP)

| Fuel | Direct emissions | LCA emissions |
|---|---|---|
| Coal | 345 | 377 |
| Heavy fuel oil | 283 | 324 |
| Domestic heating oil | 272 | 324 |
| Diesel | 256 | 323 |
| Unleaded gasoline | 253 | 314 |
| LPG | 233 | 260 |
| Natural gas | 204 | 243 |
| Fuelwood | 18.8 | 29.5 |

*Source: ADEME's Carbon Base (Jan. 2015)*

### $CO_2$ EMISSIONS FROM POWER GENERATION (IN GRAMS OF $CO_2$ EQUIVALENT PER KWH OF ELECTRICITY PRODUCED)

| Values for France | Coal-fired | Oil-fired steam | Gas-fired* | Nuclear | Gas cogeneration | HWIP** | Onshore wind | Offshore wind | Solar PV | Hydro with reservoir | Hydro run-of-the-river |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Excluding life cycle analysis | 915 | 676 | 404 | | 230 to 380 | 860 to 1,548 | 0 | 0 | 0 | 0 | 0 |
| Including lifecycle analysis | 1,058 | 730 | 418 | 6 | _ | _ | 14 | 16 | 55 | 10 | 13 |

*Combustion turbine (50% efficiency) – ** HWIP: Household Waste Incineration Plant.
Values excluding LCA were established by ADEME in 2015; values including LCA were established by ADEME in 2017.

*Source: ADEME's Carbon Base (latest available figures)*

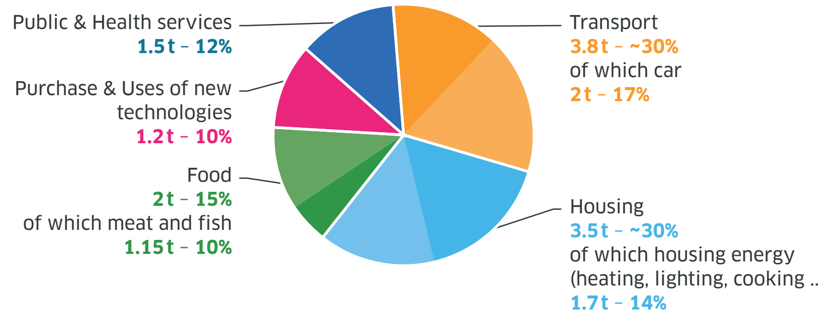


**$CO_2$ emissions are evaluated according to two conventions:**

- Direct emissions: only emissions resulting from the use of energy by the consumer are considered.
- Life Cycle Assessment (LCA): take into account all emissions from extraction to end use (extraction, production, transport, distribution, use, even waste management).

**GHG reporting answers the GHG Protocol, an international initiative,** bringing together businesses, NGO, governments and universities. It is carried out by the World Resources Institute (WRI). Launched in 1998, its mission is to provide standards, as well as GHG accounting and reporting tools that are accepted worldwide. Adopting these standards is a key element in promoting a world low-carbon economy.
The standards developed within the GHG Protocol are the most widely used accounting tools for measuring, managing and reporting GHG emissions.
The IPCC also designed a methodology aimed at measuring GHG emissions by sector.
Emission factors produced by these two institutions are considered as reference worldwide and ENGIE adopted them for its regulatory environmental reporting.

### CARBON FOOTPRINT* OF A FRENCH RESIDENT: 11.2 $TCO_2E$ PER YEAR, OF WHICH 8 T OF $CO_2$ (2018, $TCO_2E$)




* Carbon footprint: direct and indirect GHG emissions

*Source: ADEME, French Ministry of Ecological Transition*

# $CO_2$ & climate: climate change

## More and more signs of climate change in the atmosphere, on land and at sea

**Temperatures are the prime indicator of ongoing climate change and keep rising. 2019 was the planet's second warmest recorded year, after 2016.**

Records for high temperatures are concentrated in the past few years: 2015-19 include the five warmest years ever reported, 2010-19 was the warmest decade and since 1980 each decade has been 0.3°C warmer than the previous one. Since pre-industrial times (1850-1900), average temperature on the surface of the globe has increased 1.1°C.

In France, 2019 was the third warmest year since records started in 1900, after 2018 and 2014. At 13.7°C, the average temperature for 2019 was 1.2°C higher than the 1981-2010 reference average.

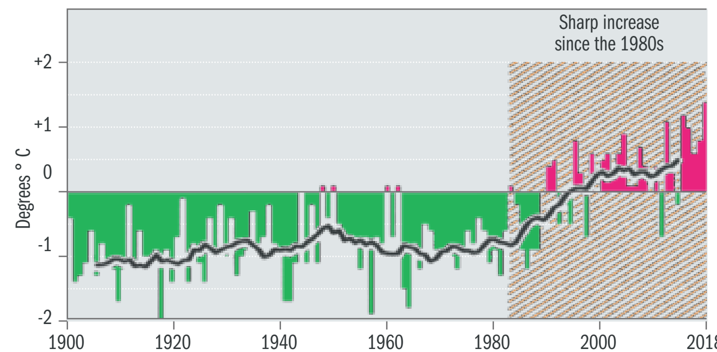
Heatwaves were also hotter in 2019. France reported a new peak at 46°C.

January 2020 also saw new highs for the month, and in June the temperature reached an unprecedented 38°C in Verkhoyansk in Eastern Siberia. This weather station is notorious for being the coldest in the Northern Hemisphere. This new record only confirmed alarming reports on accelerating climate change in the Arctic.

Were these trends to continue, global temperatures will rise by 6-7°C by 2100 (IPCC estimates).

**Another feature of 2019 was a series of uncontrollable wildfires.** A substantial number of large fires, reported as "unprecedented", broke out throughout the year in several regions. They were more numerous than average in high latitudes, notably in Siberia and Alaska, and affected parts of the Arctic where they had been extremely rare. Severe drought in Indonesia and neighbouring countries led to the worst fire season since 2015. South America recorded its highest number of fires since 2010. Over the summer, fires devastated the world's second 'green lung', the Congo basin. In Australia, 3 million hectares burnt between September 2019 and January 2020, releasing fumes and pollutants that spread around the globe, causing peak emissions.

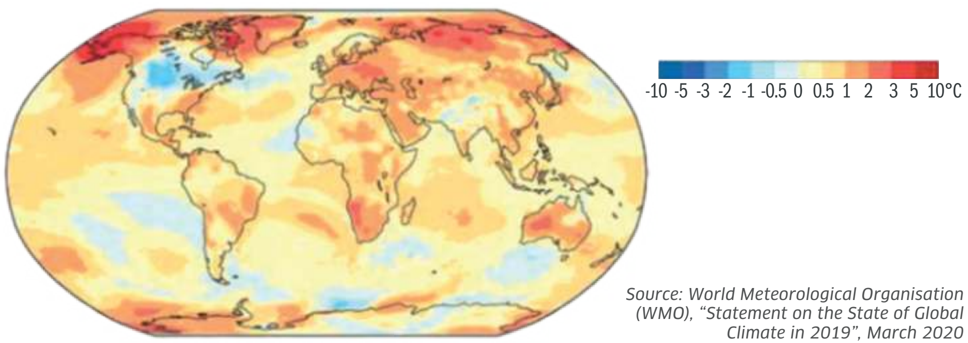
### TEMPERATURE RISE SINCE 1900




Line: 11-year moving average
Bars: Temperature annual average compared to normal (reference period: 1981-2010)

*Source: World Meteorological Organisation (WMO), "Statement on the State of Global Climate in 2019", March 2020*

### ABNORMAL TEMPERATURES IN 2019 COMPARED TO 1981-2010 AVERAGE




*Source: World Meteorological Organisation (WMO), "Statement on the State of Global Climate in 2019", March 2020*

# $CO_2$ & climate: climate change

The effects of global warming are multiplying in number and proving increasingly severe, with alarming consequences for our health and the economy

**The sea level has been rising at an increasing pace and hit a record high in 2019** (recording started in 1993). This mainly results from the thermal expansion of seawater and the melting of large glaciers in Greenland and Antarctica. Coastal regions and islands are exposed to increased flood risks, while low-lying areas such as Bangladesh and Florida are facing the threat of submersion.

According to IPCC estimates, the global sea level could rise by 23-82 cm by 2100. Other scientists explain that in case of runaway global warming, the sea level could rise by several metres by that time. By 2050, 300 million people could be facing annual floods (Nature Communications estimates).

**The oceans are heating up much faster than expected. They were at their hottest recorded levels in 2018 and again in 2019.**
As oceans retain over 90% of the excess heat accumulated in the atmosphere as a result of increased greenhouse gas, their warming is a major indicator of climate change. In 2019, the ocean heat content down to 2,000 metres beat its previous record established in 2018.

The consequences for climate are critical. Ocean warming is responsible for 30% of the rise in sea level, affects marine currents, indirectly alters hurricane paths and melts icebergs. Together with acidification and deoxygenation, ocean warming can disrupt marine ecosystems in a spectacular manner. By absorbing 23% of annual $CO_2$ emissions between 2009 and 2018, oceans cushioned the effects of climate change at the cost of their acidity, which in turn disrupted marine life (lower mussel, crustacean and coral reproduction).

**2019 confirmed the long-term thinning of Arctic pack ice** and the Antarctic icecap. The Arctic recorded its second warmest year since 1900, when records begin (the record high was 2015-16), at 1.9°C above the 1981-2010 average between October 2018 and August 2019. The 12 warmest seasonal minimums are those of the past 12 years.

**Climate change affects the social determinants of human health: clean air, clean drinking water, sufficient food and secure housing.** Extreme heat undermines heath, notably amongst elderly people, and accelerates the transmission of diseases by insects, such as dengue and malaria in Africa. Air pollution, indoor and outdoor, kills nearly 7 million people each year worldwide (WHO), representing one in nine deaths. Nine people out of ten breathe air containing pollutant levels higher than WHO's recommended limits. Most polluted air is found in the Eastern Mediterranean, Southeast Asia and many megacities (where pollution reaches 5 times WHO limits), followed by low or middle-income cities in Africa and the Western Pacific.

**In 2019, over 7 million people were forced to migrate because of natural disasters aggravated by climate change.** Last year's natural risk displacements were primarily attributable to floods and hurricanes, among which Cyclones Idai in South-East Africa and Fani in South Asia, Hurricane Dorian in the Caribbean and floods in Iran, the Philippines and Ethiopia (source: IDMC). Adding wars and resource depletion, this brings the total to nearly 22 million new refugees in 2019, of which 19 million in Asia and 3 million in Africa.

According to UN forecasts, climate refugees could number over 250 million worldwide by 2050, of which 143 million originating from sub-Saharan Africa, Southeast Asia and Latin America.

*Sources: Nature Communications, "New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding", October 2019*
*IDMC, Global Report on Internal Displacement, 2019*
*World Meteorological Organisation*

# $CO_2$ & climate: carbon markets and prices

Carbon pricing is gaining ground, but will need to strike a balance between price increases and social acceptance to become more effective

**So-called explicit carbon pricing systems, in the form of taxation or carbon markets, developed further worldwide in 2019.** As of 1 April 2020, 61 countries, provinces or cities had introduced carbon markets or taxes on fossil fuels (31 ETS and 30 carbon taxes). They represent about 60% of world GDP and cover 12 $GtCO_2e$, or 22% of world GHG emissions. Three more countries introduced a carbon pricing policy last year: Canada, opting for a federal approach, South Africa and Singapore. Mexico launched the first South American ETS, currently in pilot phase. More and more authorities are looking to extend their ETS to a wider range of sectors (Germany, Austria, Luxembourg). Lastly, carbon prices cover an increasing number of sectors and GHGs.

**Overall, explicit carbon prices remain insufficient to support the development of new low-carbon technologies.** As of March 2020, they ranged from less than $1 to $123/$tCo_2e$, with 75% of total covered emissions at below $10. The situation is contrasted, however: prices have exceeded €25/t in the EU, the world's leading market, and reached substantial amounts in China (between $2 and $12) given the purchasing power, playing a significant role in these regions. According to international scientific consensus estimates, optimal carbon prices range from $40 to $80/$tCO_2e$ in 2020, and $50 to $100/$tCO_2e$ in 2030 (Stern-Stiglitz). Currently, less that 5% of covered emissions are in that price range.

**46% of world carbon revenues are earmarked for low-carbon transition projects,** 44% for general government budgets and 6% for tax exemptions. 4% are directly transferred to companies and households.

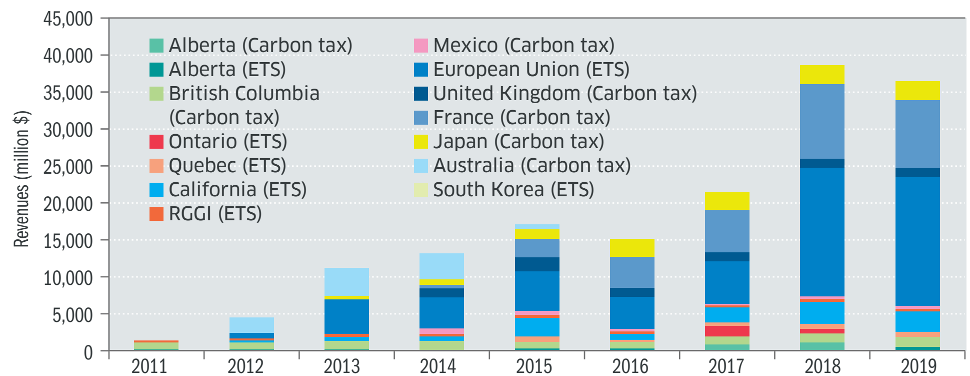
Carbon pricing schemes collected $45bn in 2019, slightly more than in 2018 ($44bn), of which 75% in the EU. France recorded the largest carbon revenue collection, at $9.3bn in 2019.

**By sharply reducing emissions in 2020, the Covid-19 pandemic has weighed on many carbon markets** and led to the postponement of several carbon tax rises or extensions due in 2020. In Norway, for instance, the removal of the natural gas tax exemption has been suspended.

Worldwide, Covid-19 related restrictions have deferred several major meetings and enhanced uncertainties over the future of the international carbon market. COP26 has been postponed to 2021, as have key international aeronautics and maritime transport meetings. Uncertainty over international funding has increased: airlines are asking what is to become of their obligations under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).
That said, other authorities and private sector organisations have stepped up their efforts on climate change. COP's Chilean presidency has announced that 120 parties within the UNFCCC are working towards carbon neutrality by 2050; while 15 sub-national regions, 398 cities, 786 companies and 16 investors declare they are targeting zero emissions.



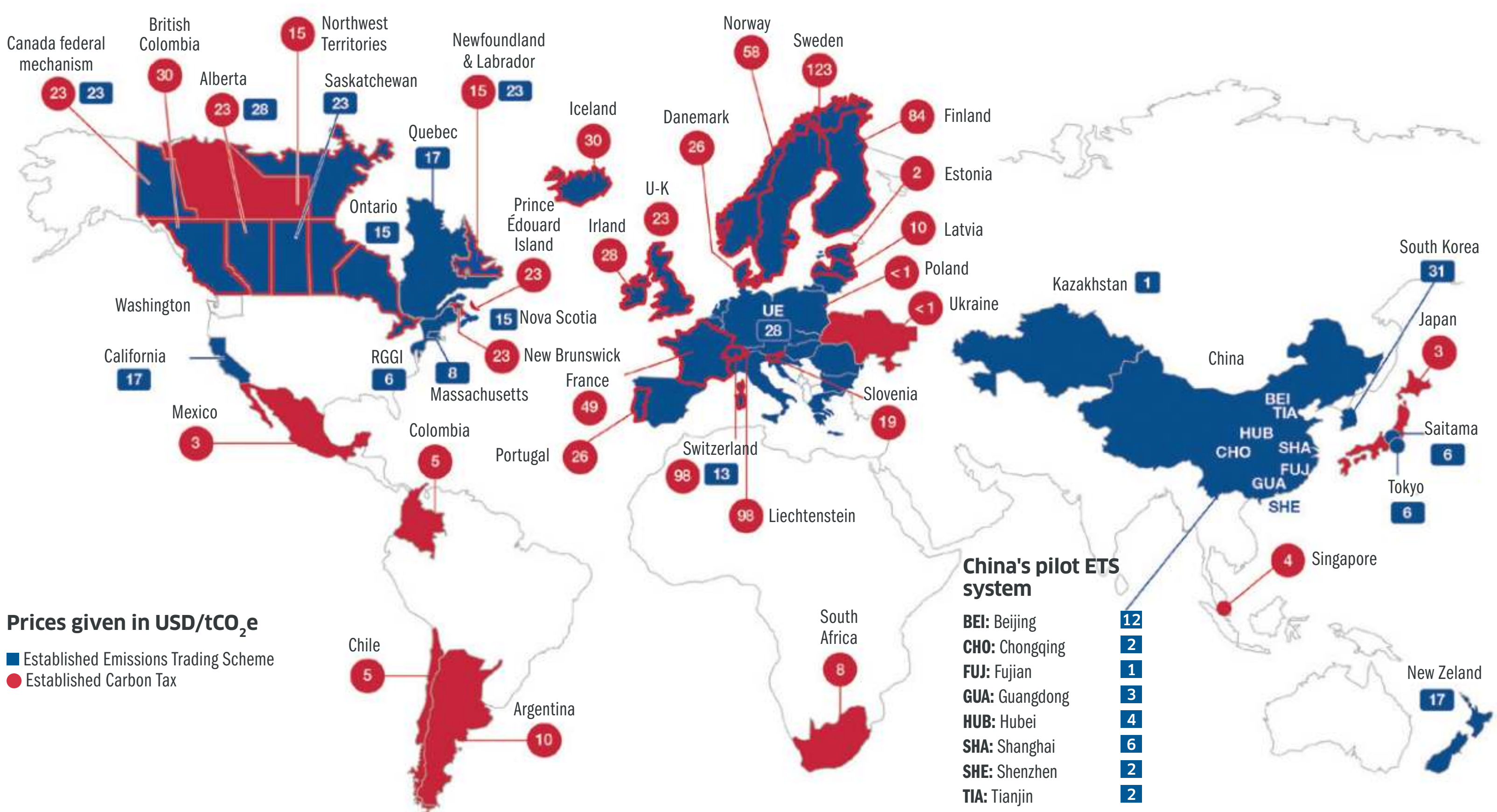
**CARBON REVENUES IN G20 COUNTRIES, 2011-2019 (MILLION $)**




*Source: 14CE, Global Carbon Account 2020 (May 2020)*

# $CO_2$ & climate: carbon markets and prices

**MAP OF EXPLICIT CARBON PRICES AROUND THE WORLD 2020**




*Source: I4CE, Global Carbon Account in 2020 (May 2020)*

# $CO_2$ & climate: the European carbon market

**The European carbon market (EU-ETS) is gradually proving its effectiveness, with a 9% decline in covered $CO_2$ emissions in 2019,** despite a 1.5% rise in EU GDP (European Commission publication dated 5 May 2020). Emissions contracted particularly sharply in the power sector (-15%), thanks to RES and natural gas capacity replacing coal. Emissions also decreased in industrial sectors (-2%), including heavy industries, cement, steel, refineries and chemicals. Along with lower emissions, carbon intensity receded in power and industrial sectors.

While EU-ETS played its role in 2019 thanks to the sharp rise in $CO_2$ prices in 2018-2019 (see details next page), it must be said that historically it has had little impact on emissions; their reduction is mostly the result of EU energy policies, in particular the support for electric renewables and energy efficiency.

Although EU-ETS - the cornerstone of EU climate policy - will meet (and even exceed) its first objective of a 20% cut in EU $CO_2$ emissions between 1990 and 2020, that will not be enough to meet the following targets of a 40% cut in $CO_2$ emissions between 1990 and 2030 (a target that the Commission plans to raise to 50-55%) and carbon neutrality by 2050. Consequently, in addition to the revision agreed upon early 2018 for phase 4 (2021-2030) that supports $Co_2$ prices by reducing excess quotas, the European Commission will propose in 2021 an extension of the ETS to other sectors (aviation in particular), as well as carbon prices targets outside the ETS.

**Also in the EU's 2021 agenda within the Green Deal, is the carbon tax,** with a twofold objective: tackling relocation aimed at escaping carbon costs ("carbon leakage") and taxing foreign and European companies equally (the tax would replace current free carbon allowance schemes or compensations for increases in electricity costs).

The EU directive on energy taxation, from which aviation and maritime transport are currently exempt, is scheduled to be revised in June 2021. The new directive will offer more support for alternative fuels for mobility (hydrogen, electricity, natural gas, biofuels, etc.), which the current taxation system sometimes hinders.

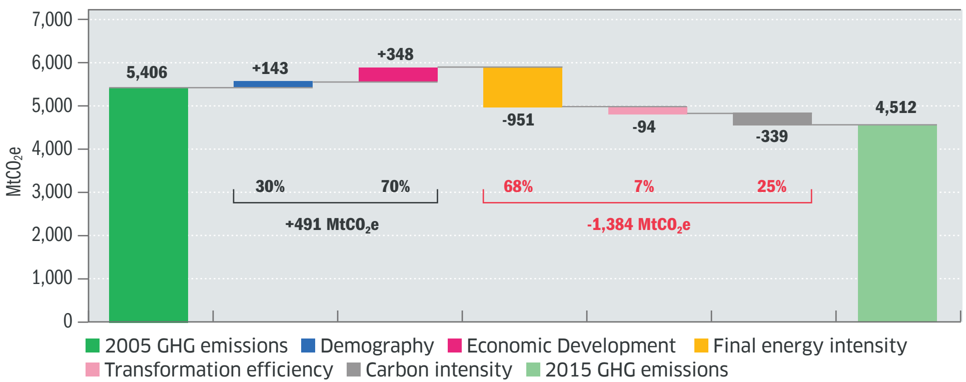
**$CO_2$ emissions in the EU**

| | 1990 | 2010 | 2017 | 2018 | 2019 | 2020* |
|---|---|---|---|---|---|---|
| $CO_2$ emissions (Mt) | 4,098 | 3,727 | 3,330 | 3,267 | 3138 | 2,730 |
| Annual change | | 3.3% | 1.3% | -1.9% | -4.0% | -13.0% |
| Change since 1990 | | -9% | -19% | -20% | -23% | -33% |
| AAGR since 1990 | | -0.5% | -0.8% | -0.8% | -0.9% | -1.3% |

* Estimates

*Source: Enerdata Global Energy & $CO_2$ Data (2020)*

## DRIVERS OF GHG EMISSIONS VARIATIONS IN THE EU 2005-2015




The decoupling of final energy demand and GDP was the most important driver of GHG emissions reductions in the EU over 2005-2015.

*Source: Institute for Climate Economics (I4CE) & Enerdata, "Mind the Gap", 2018*

As the world's number one carbon market, with three quarters of the international carbon trade, EU-ETS covers emissions from over 11,000 power plants, highly energy-intensive industrial facilities and airlines connecting participating countries. Altogether, this represents about 45% of EU $CO_2$ emissions.

# $CO_2$ & climate: the European carbon market

**Weakened by years of excess allowances and low prices, EU-ETS regained a measure of balance after the 2018 reform.** $CO_2$ prices are currently around €25/t, which boost gas-fired plants' competitiveness relative to coal.
In adopting EU-ETS phase 4 in early 2018, the European Council meant above all to support $CO_2$ prices by reducing emission allowances. The pace of allowance cuts was raised from 1.7% to 2.2% per year and the Market Stability Reserve, a long-term market adjustment tool, was strengthened.

As a result, after having ranged between €5 and €10/t over 2011-2017, $CO_2$ prices rapidly broke the €20 threshold at end-2018 and were drawing nearer €30 by the summer 2019, for an annual 2019 average of €25/t.

Market liquidity increased, as did volatility. In April 2020, during lockdown and as oil prices plummeted, $CO_2$ prices fell to €15, before bouncing back to €20 as early as May, and finally 25€ in June.

Although excess allowances remain substantial, equivalent to a full year's emissions, the fact that carbon prices have stabilised around €25/t is a sign of greater confidence in EU-ETS and its ability to offer a stable and foreseeable framework for investment.

Climate roadmaps require much higher $CO_2$ prices, however. Depending on scenarios and requirements, EU-ETS must climb much further: towards $€_{2018}$100/t by 2030 in the IEA's SDS scenario, and even $€_{2018}$250/t according to the Quinet report (Rapport Quinet 2019, February 2019).

## PRICE OF $CO_2$ ALLOWANCES ON THE EU-ETS MARKET (€/TONNE)

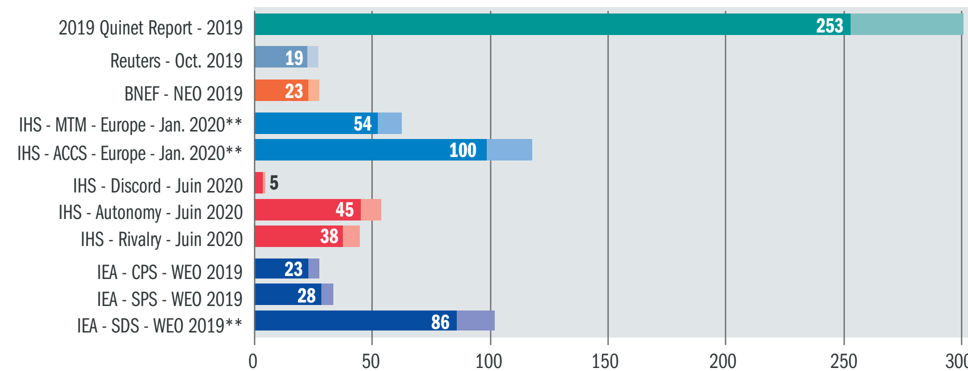

*Source: EMBER, Coal to Clean Energy Policy, July 2020*

## MINIMUM "SWITCH" PRICE FROM COAL TO GAS COMPARED TO THE EU-ETS PRICE (€/TONNE)


**This minimum "switch" price corresponds to the $CO_2$ price required to favour an efficient gas-fired power plant over an inefficient coal-fired power plant.**

*Sources: I4CE, à partir de données fournies par ICIS, la Banque de France, le GIEC et Eurostat L'état du marché carbone européen – Édition 2019*

## FORECAST OF $CO_2$ PRICES IN 2030 – BENCHMARK IN €2019/T*




*** Darker color: in € 2019; lighter color: in € nominal**
**** Scenarios in line with the 2°C trajectory**

*Source: Enerdata estimates, May 2020*

# $CO_2$ & climate: Green Deal and European recovery plan

Rather than stifling EU environmental efforts, the Covid-19 crisis kick-started a new dynamic, that materialised in the choice made towards a green recovery

**The Green Deal is a plan of action laid out by the European Commission in December 2019 for the EU to reach carbon neutrality by 2050.** Its main resolutions target a GHG emission reduction of at least 40% by 2030 compared to 1990 levels – a threshold that could be raised to 50% or even 55%, if the amendment obtains the Commission's approval –, a share of renewable energy brought up to a minimum of 32% of the mix, and an improvement in energy efficiency of at least 32.5%. The carbon neutrality principle will be inserted in the climate law.

In addition, the plan provides for the integration of climate issues in all European public policies (energy, industry, transport, agriculture, etc.). It rests on mutual actions, associating institutions (from mayors to heads of State) and private players.

The Commission wishes to promote circular economy and renewable technologies, such as hydrogen, fuel cells and other alternative fuels, as well as energy storage. With the planned "Just Transition" mechanism, €100bn worth of investments, according to Ursula von der Leyen, is to be mobilized in economically vulnerable regions and sectors.

Brussels will secure the financing through loans and redirected part of the traditional budgets towards emission reduction initiatives. As early as 2021, 40% of the budget for agriculture and 30% of the one for fisheries will be submitted to this priority.

**To secure the completion of the Green Deal, the Commission will reform carbon pricing.** As soon as 2021, the EU-ETS will extend to maritime and road transport. The two sectors will also be subject to tighter standards. Airline companies will be granted fewer free allowances. And a carbon tax imposed at EU boarders will discriminate foreign goods disrespectful of environmental policies (see previous page).

The Covid-19 crisis served as a reminder of the necessity of a carbon price floor. Fossil fuels plummeted to levels that far from reflect their environmental costs. Such market conditions jeopardize energy transition policies: they both annihilate incentive measures to decarbonize and create uncertainty, that is detrimental to energy transition investments.

**What changed with the health crisis.**

The crisis strengthened opposition to the Green Deal. Nevertheless, the EU stayed firm on both its ambitions and its decarbonization roadmap. Though some of the deadlines were deferred, mainly due to the postponement of COP26, the Commission delivered a clear message and was able to fulfil the 2020 agenda:

- 4 March: introduction of the draft European Climate Law; the impact assessment is to be presented in September;
- 30 March: launch of the online public consultation, regarding the enhancement of the 2030 $CO_2$ emission reduction target up to 50%, or even 55%, compared to 1990 levels,
- 20 May: publication of an ambitious plan towards biodiversity (EU Biodiversity Strategy to 2030) and nutrition ("From farm to fork").

**Above all, the EU very much responded to calls for a green recovery.**

Through its different bodies, the EU embarked on colossal recovery plans (first €1,000 bn injected by the central bank into the European financial system, then €540 bn allocated to emergency measures, and finally, in May, €750 bn granted in the form of a Community loan).

The European Commission submitted the granting of these aids to environmental conditions, however. Hence, €390 bn of the Community loan will be devoted to the hardest hit Member States, on the condition that the funds are used in accordance with EU's priorities, in other words the Green Deal, energy transition and Europe's greater sovereignty.

In addition, the Commission placed ecology at the heart of its recovery plan, giving priority to, notably, building renovation, RES, rail, and circular economy. It also presented on 8 July 2020 an ambitious plan to support renewable hydrogen, whereby catalysers are to be installed for at least a 6 GW capacity by 2025 and 40 GW by 2030. The objective is to cover 12% to 14% of the EU energy mix by 2050 (against 1% today).

# Decarbonization

**PERSPECTIVE**

*“ If we fail to significantly reduce $CO_2$ emissions, the future will be subject to disasters whose cost to humanity will be far greater than the cost of the measures needed to achieve such reduction”*

**Didier Holleaux,** Executive Vice President of ENGIE

**SCENARIOS**

The energy scenarios of the IEA, Enerdata and IHS all come to the same conclusion: existing and announced measures together can limit $CO_2$ emissions by 2040, but are not drastic enough to force a contraction



**Renewable energies, a key element of decarbonization, are covered in the chapters “Electricity & Electrical renewables" and “Natural gas & Renewable gases"**

# Decarbonize: how?

## Why decarbonize?

Already critical, the consequences of temperature rising 1°C since the industrial revolution call for collective action to reduce GHG emissions as they are the main cause of global warming. It is widely accepted that if warming is not to exceed 2°C by 2100, the level beyond which damage would be unsustainable, GHG emissions must be halved within the next two decades and carbon neutrality reached during the second part of the century.

Consisting of producers, suppliers and consumers, the energy sector has serious responsibilities in the matter: 75% of GHG emissions result from energy combustion. That said, the absolute necessity to decarbonize energy is not the end of it. Humanity as a whole has to become more respectful of the environment in order to preserve resources and ecosystems. This will undoubtedly come at a considerable cost, especially given continuing population growth and industrialisation. But as recent history shows, the cost is tiny compared with that of inaction, with all that means for the damage associated with global warming and natural habitat destruction.

## Decarbonization tools

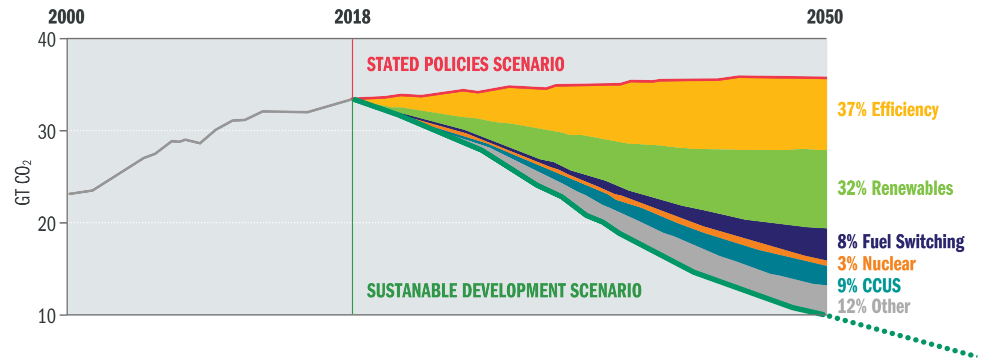
It will take all the various means of decarbonization to deliver results and strengthen the system's overall resilience. This chapter presents the main decarbonization tools available to the energy sector, assessing their scope and current stage of development. The list is by no means exhaustive, as it does not include related areas such as reforestation, recycling and digitalisation.

- **Improving energy efficiency is the number one lever:** it applies to the whole chain and still offers real room for improvement in a context of persistent obstacles (know-how, costs, limited profitability when energy is cheap).
- **RES development,** whether electricity or gas (biomethane, green hydrogen), ought to result in nearly complete decarbonization in power generation. It should also tackle specific pockets of resistance, such as transport and intensive industry, while favouring short distribution channels (decentralised production, agricultural waste reuse, unavoidable renewable energy use). RES are discussed in the "Electricity & Renewables' and "Natural gas & Green gas" chapters.
- **Energy sufficiency** (or sobriety), largely absent from policies and projects, is probably the most efficient lever, if not the fastest and the cheapest to implement. It is seen as restrictive, however, a feature that is hindering deployment. Covid-19 may well change mentalities on the subject.
- **Green finance** is proving a necessity for the materialisation of energy transition projects that otherwise fall foul of short-termism in loan policies and the excessively demanding returns required in traditional finance.
- **Lastly, $CO_2$ capture, utilisation and storage** may not have the support of environmental diehards but it is capable of decarbonazing the final core of $CO_2$ emissions, i.e. the most expensive or most difficult emissions to eliminate.

**Choices on priorities, technology and the pace of change are complex decisions that depend on the approach taken, which itself reflects varying ambitions as well as geography.** These choices will determine the trajectory of global decarbonization. In order to shed light on what that trajectory might be, we invited three internationally renowned centres of expertise to expound their views on energy transition.



**ENERGY-RELATED $CO_2$ EMISSIONS AND REDUCTIONS BY SOURCE IN THE IEA SUSTAINABLE DEVELOPMENT SCENARIO (SDS)**




*Source: IEA, World Energy Outlook 2019*

# Decarbonization: message from Laszlo Varro, IEA, August 2020

**The Coronavirus epidemic brought an unprecedented macroeconomic shock** with profound energy implications. Social restrictions and the subsequent deep recession constrained energy demand especially in mobility.

**However, the long term energy and climate challenge remained intact:** the world economy is still expected to emit around 30 billion tons of $CO_2$ in 2020, the reduction we observe was achieved at an unacceptable human and macroeconomic cost. The pandemic triggered social and behaviour changes but their energy impact is a double edge sword: people use more video conferencing instead of business trips, but they also became reluctant to use public transport and in home office they are more likely to use air conditioning. **Overall, if the world economy recovers without a major structural change, emissions are almost certain to rebound, quite possibly to above the 2019 level.**

**The epidemic hit energy investment hard,** to a level that is insufficient to power the eventual recovery of the global economy. The current underinvestment creates a fork in the road: **the nature of the investment rebound will determine the trajectory of the energy system for decades.** Corporate leaders have a responsibility to recognize the importance of this crossroad and act accordingly. As governments around the world are forced to implement expansive measures for economic stabilization and stimulus, **there is a window of opportunity to put the clean energy transition into the heart of economic recovery efforts.** A determined, coordinated push on clean energy investment from governments and the corporate sector would accelerate the recovery, create green jobs and would enable the energy system to move to an energy transition trajectory.

**Such a trajectory is embedded into the IEA Sustainable Development Scenario (SDS)** which depicts a comprehensive implementation of the Paris agreement for a well below 2 degrees climate stabilization. A **profound transformation and investment reallocation takes place in SDS: the largest scale up is investment in energy efficiency and end use services, keeping total final energy consumption declining despite the growth of the global economy.**

On the supply side, annual wind and solar deployment increases by a factor of 2.5 from the level prevalent in recent years, and **by 2040 wind and solar represent by far the largest component of power generation. Nevertheless the old workhorses of hydropower and nuclear continue to play an important role.** The rapid growth of variable renewables necessitates major investments into electricity networks, both into long distance transmission as well as into reinforcing and digitalizing distribution.

**While the role of electricity strongly increases the gas pipeline system remains an essential infrastructure,** serving homes and industrial users. Gas turbines operate with a low and volatile load factor but their contribution to supply security persist for decades. **Major new investments into both biomethane and low carbon hydrogen gradually decarbonize gas supply as well.** Meanwhile, innovation accelerates into new technologies that will provide low carbon solutions for hard to abate sectors including aviation and the heavy industry.

**The IEA Sustainable Development Scenario is feasible, the industry has all the technical and project management capabilities that are needed.** It would deliver major benefits beyond climate such as air pollution reduction and job creation. It is by no means easy. It will require a grand coalition of governments, the finance sector and the energy industry implementing a comprehensive set of policies, allocating investment and encouraging innovation. The energy transition is essentially a test of leadership.

NB from Laszlo Varro: please note that given the macroeconomic impact of the epidemic, our stated policies scenario will be significantly revised in WEO 2020 compared to last year's edition (WEO 2019).

**Laszlo Varro** Chief Economist – International Energy Agency

The International Energy Agency (IEA) is an international organization whose mission is to work with governments and industry to shape a secure and sustainable energy future for all. It is recognized worldwide, in particular for its prospective report « World Energy Outlook ».

# Decarbonization: message from Morgan Crénès, Enerdata, September 2020

**All eyes are on the Covid-19 crisis and its consequences on health, social and economic activities. The energy transition is of course impacted by the sanitary crisis, but the dynamics of greenhouse gases emissions just before the start of the outbreak should be reminded:**

- Over the past decade, global $CO_2$ emissions* have been **increasing by 1%** per year on average.
- In **2019 though, they slightly decreased by 0.2%,** thanks to improved energy intensity** and carbon factor***.

With the Covid-19 outbreak we will never know whether 2019 was the beginning of a new trend towards energy transition or just an exception. In any case, the efforts to meet the Paris agreement would have required a consequent acceleration to reach at least a 3% decrease in global $CO_2$ emissions every year****.

**For 2020,** the latest Enerdata estimates **forecast a 9% decrease in global $CO_2$ emissions** with a 12% drop in energy consumption in the USA, an 8% drop in Europe, and a sluggish 0.5% growth in China. A very large part of this dip is directly linked to the change in activity level (economy, transport, etc.) resulting from new social standards (working from home, decrease in the use of public transport etc.) or severe prophylactic measures (lockdown).

This 2020 trend does not at this stage rely on any structural change: energy consumption and the energy mix could go back to the previous situation quite easily, and thus $CO_2$ emissions could see a huge rebound effect.

**The “billion-dollar question” is, will the economic recovery policies put energy transition at their core?**

This would not only be a way to offset the current delayed investments in energy efficiency and low carbon technologies but also a **unique opportunity to put energy systems back on track to meet the Paris agreement commitments.**

The trend in recent years was far from a +1.5-2°C scenario (and even from NDCs*****). The stimulus packages under development are currently opening short-term possibilities that did not exist six months ago - and **will significantly guide long-term trends.**

Innovation and investments in energy efficiency and the decarbonization of all vectors will be essential. Electrification of uses will play a key role: gas and electricity could account for more than 50% of final energy consumption by 2050.

Beyond national and international policies and technology developments, following and anticipating the **behaviours of socio-economic actors** is also essential: citizens, companies, local authorities, NGOs... will all play a key role in this period of uncertainties.

*Energy related $CO_2$ emissions
**Energy consumed per unit of GDP
***$CO_2$ emissions per unit of energy consumption
****https://www.enerdata.net/research/forecast-enerfuture.html
*****National Determined Contributions

**Morgan Crénès** Head of Data & Research – Enerdata
Enerdata is an independent research company specializing in the analysis and modelling of energy and climate issues, at world and country level. Leveraging our globally recognized databases, intelligence systems and models, we help our clients shape their policies, define their strategies and plan their business.

# Decarbonization: message from Steven Knell, IHS Markit, September 2020

In July 2020, IHS Markit published its 2020 global scenarios, Rivalry (the base case), Autonomy (faster transition) and Discord (slower transition). These new energy balance projections to 2050 capture the significant impact the coronavirus 2019 (Covid-19) pandemic and resulting global economy recession has had on expectations of the energy transition.

**In the Rivalry base case, we see the pandemic recession weakening the global climate effort.** There are less greenhouse (GHG) emissions in 2020 due to lower economic activity - we've seen the largest year on year decline in energy related emissions in history with global GDP down more than 5% year on year – but there is also less willingness and capacity to act in most markets, especially in the first decade of the forecast. This is due to the impact Covid-19 has had on public sector and private budgets. There are some new opportunities for emissions reduction due to technology trends and local pushes for deeper reductions are to be expected, particularly in Europe, but ultimately in Rivalry climate policy goals face both existing challenges at the national and international levels as well as the new issues Covid 19 has created.

**In the Autonomy scenario, where a faster transition takes place, the outlook is greener than our 2019 projections.** In this case there is green recovery in the 2020s in more markets and lower energy demand through the forecast period contributing to greater policy ambition and better policy performance. Critically, we assume the mass social movements for climate action of 2019 to be very much in support of tougher national and international action in this scenario. In the Discord scenario, the outlook for climate action is dimmer than ever before. Fewer can afford climate action measures and fundamentals favour more emissions-intense activities.

**The Covid-19 crisis has decreased the growth pathways for global economy and total energy demand.** This has brought lower expectations of GHG emissions in all cases. Compared to last year, in 2050, Rivalry is down roughly 10% compared to our 2019 forecast, some 5.4 billion metric tonnes of carbon dioxide equivalent (Gt) – more than all the carbon dioxide ($CO_2$) emitted by the United States in 2019. Autonomy global GHG levels are down 12% compared to last year and Discord emissions in 2050 are 7% lower.

**Covid and the pandemic recession has brought a material downward shift in our expectations of emissions over the next 30 years.** That feeds into our estimation of how the world, the EU, its member states and other countries may progress towards climate policy emissions reduction goals. Looking first at the current Nationally Determined Contributions (NDCs) that support the Paris Agreement through 2030, IHS Markit analysis suggests that, when added together, the emissions goals of all the NDCs are aligned with the global emissions levels in each of our global scenarios.

**EU emissions in 2030 would be well within the range of the existing 40% reduction from 1990 NDC goal in each of our 2020 projections.** Key large emitting countries like France achieve their NDC emissions goals in the Rivalry and Autonomy projections but the slower transition foreseen in the Discord case leads to higher emissions above stated goals. It is notable that in the Autonomy Scenario, which includes policy, technology and market assumptions that are more conducive to further GHG emissions reductions, EU emissions in 2030 are more than 50% below 1990 levels, approaching the more ambitious 2030 target the European Commissions has proposed to support the net zero goal of the EU Green Deal.

**Looking beyond 2030 to 2050 and the net zero goals the EU, the UK, Japan and host of other countries have adopted as long-term climate policy ambitions, the picture is more mixed.** The IHS Markit Global Scenarios do not foresee large emitters reaching a point where sources of emissions balance sinks by mid-century, thereby re. Residual energy-related emissions in segments of the economy, such as transport, and persistent non-energy emissions, which tend to lay beyond the focus of climate policy, are key obstacles to the realisation of those the ambitious goals in the IHS Markit 2020 Global Scenarios.

**Steven Knell** **Senior Director Energy and Climate Scenarios – IHS Markit**
IHS Markit is a world leader in critical information, analytics and solutions for the major industries and markets that drive economies worldwide. Among other things, the company offers global energy scenarios, climate related data and expert analysis to support corporate strategy, investments, and decision making in the energy transition.

# Energy scenarios

What transformation does the energy system need if it is to meet environmental objectives?

**The scenarios presented here respond to two major concerns regarding climate change:**

- **To assess the impacts of energy policies and measures that have been, or are soon to be, introduced on $CO_2$ emissions and energy demand.** This is the purpose of the IEA's Stated Policies Scenario (STEPS) and the Enerdata's Ener-Blue scenario.
- **To define what policies, technologies and changes are needed now to meet the Paris Agreement's environmental targets,** i.e. to limit the world's average temperature rise to less than 2°C – or even 1.5°C if possible – over this century, compared to pre-industrial era. These are the IEA's Sustainable Development Scenario (SDS) and the Enerdata's Ener-Green scenario.

The scenarios presented here focus on the energy system that is responsible for three-quarters of GHG emissions (see Chapter $CO_2$ and Climate), with a 20-year projection for some visibility.

**Assessment of initiated or announced policies (STEPS and Ener-Blue scenarios).**

These scenarios reflect endorsed energy policies and States' commitments, notably under COP21 (Intended Nationally Determined Contributions, INDCs), but adjust their degree of realisation by country. The assumption is that policies are pursued as they are over time, meaning neither weakened nor strengthened.

Considered to be the most probable, these scenarios serve as central scenarios: they describe energy system developments over the next 20 or 30 years based on the current situation (laws that have been implemented or soon will be, new technologies, costs, etc.). There are not static, as they take into account announced policies and current dynamics. They differ in this from scenarios that only take introduced policies into account (IEA's Current Policies and Enerdata's Ener-Base scenarios).

The main conclusions from these scenarios are as follows: by 2040 energy demand will have stabilised in OECD countries, but will still be increasing elsewhere (by 1.6% per year on average); this global rise (1% per year, i.e. 1/4 over the period) will drive energy prices higher; fossil fuels will remain prominent within the energy mix (at 74%), but policies introduced to limit climate change – energy efficiency, RES development – will allow diversification towards other energy sources. The efforts described in INDCs lack ambition, however; they imply a 7% increase in $CO_2$ emissions between 2020 and 2040 and a 3.5°C rise in temperature by the end of the century.

**Assessment of policies and measures needed to meet the +2°C target (SDS and Ener-Green scenarios).**

These are commonly called "dream", "wishful thinking", or "normative" scenarios. They are calibrated to meet environmental objectives such as those defined in the Paris Agreement, the UN's Sustainable Development Goals (SDGs) or the IPCC's Representative Concentration Pathways (RCPs) 4.5 and 6.0.

They start with the desired result (i.e. the situation sought by 2040/2050) and work back to the measures required to get there.

The conclusions are clear: for the rise in temperature to remain below 2°C, there is no choice but to transform the world energy system without delay so that total decarbonization is achieved by the second half of the century.

This transformation requires considerable efforts in the matter of energy efficiency (to reduce energy consumption) and RES technology development (to decarbonize the energy mix) – see details below. Fossil fuel subsidies have to end and carbon taxes must be introduced, so that energy prices reflect respective environmental impacts. Under theses conditions, world $CO_2$ emissions would drop from 33 Gt in 2019 to 10 Gt in 2050, and zero by 2070.

These scenarios are used as benchmark to compare progress achieved with what is required.

*Scenario references:*
*International Energy Agency (IEA): World Energy Outlook (WEO)*
*Enerdata Global Energy Forecasting department*

# Energy scenarios: energy consumption and $CO_2$ emission trajectories according to the IEA

Existing and announced measures together can limit $CO_2$ emissions by 2040, but are not drastic enough to force a contraction

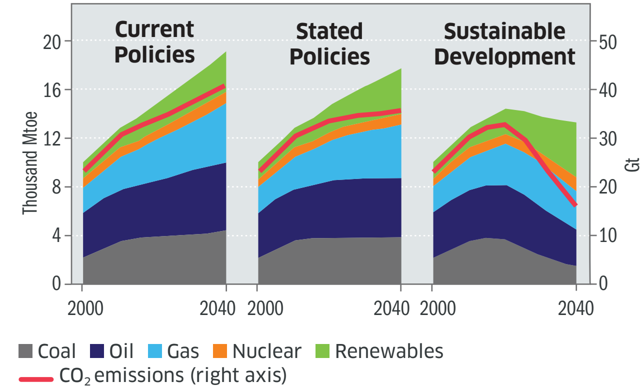
### ENERGY DEMAND AND $CO_2$ EMISSIONS BY SCENARIO (IEA)

| World Energy Demand in Mtoe | World | | | Current Policies (+ ~5 / 6 °C) | | | | Stated Policies Scenario (+ ~3,5 °C) | | | | Sustainable Development (+2°C) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2018 | Share 2018 (%) | 2030 | 2040 | Share 2018 (%) | CAAGR (%) 2018-2040 | 2030 | 2040 | Share 2018 (%) | CAAGR (%) 2018-2040 | 2030 | 2040 | Share 2018 (%) | CAAGR (%) 2018-2040 |
| **Total primary demand** | **12,853** | **14,314** | **100** | **16,960** | **19,177** | **100** | **1.3** | **16,311** | **17,723** | **100** | **1.0** | **13,750** | **13,279** | **100** | **-0.3** |
| Coal | 3,653 | 3,821 | 27 | 4,154 | 4,479 | 23 | 0.7 | 3,848 | 3,779 | 21 | -0.1 | 2,430 | 1,470 | 11 | -4.3 |
| Oil | 4,124 | 4,501 | 31 | 5,174 | 5,626 | 29 | 1.0 | 4,872 | 4,921 | 28 | 0.4 | 3,995 | 3,041 | 23 | -1.8 |
| Natural gas | 2,749 | 3,273 | 23 | 4,070 | 4,847 | 25 | 1.8 | 3,889 | 4,445 | 25 | 1.4 | 3,513 | 3,162 | 24 | -0.2 |
| Nuclear | 719 | 709 | 5 | 811 | 937 | 5 | 1.3 | 801 | 906 | 5 | 1.1 | 895 | 1,149 | 9 | 2.2 |
| Total Renewables | 659 | 1,391 | 10 | 2,139 | 2,742 | 17 | 2.3 | 2,287 | 3,126 | 21 | 2.8 | 2,777 | 4,382 | 34 | 3.7 |
| Hydro | 225 | 361 | 3 | 445 | 509 | 3 | 1.6 | 452 | 524 | 3 | 1.7 | 489 | 596 | 4 | 2.3 |
| Modern Bioenergy | 374 | 737 | 5 | 1,013 | 1,190 | 9 | 1.1 | 1,058 | 1,282 | 10 | 1.4 | 1,179 | 1,554 | 12 | 0.8 |
| Other renewables | 60 | 293 | 2 | 681 | 1,042 | 5 | 6.0 | 777 | 1,320 | 7 | 7.1 | 1,109 | 2,231 | 17 | 9.7 |
| Solid Biomass | 638 | 620 | 4 | 613 | 546 | 3 | -0.7 | 613 | 546 | 3 | -0.6 | 140 | 75 | 1 | -9.0 |

| World $CO_2$ emissions (Mt) | 2010 | 2018 | Share 2018 (%) | 2030 | 2040 | Share 2018 (%) | CAAGR (%) 2018-2040 | 2030 | 2040 | Share 2018 (%) | CAAGR (%) 2018-2040 | 2030 | 2040 | Share 2018 (%) | CAAGR (%) 2018-2040 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total $CO_2$** | **30,412** | **33,243** | **100** | **37,379** | **41,302** | **100** | **1.0** | **34,860** | **35,589** | **100** | **0.3** | **25,181** | **15,796** | **100** | **-3.3** |
| Coal | 13,808 | 14,664 | 44 | 15,548 | 16,609 | 40 | 0.6 | 14,343 | 13,891 | 39 | -0.3 | 8,281 | 3,424 | 22 | -6.4 |
| Oil | 10,546 | 11,446 | 34 | 12,905 | 14,053 | 34 | 0.9 | 12,031 | 12,001 | 34 | 0.2 | 9,436 | 6,433 | 41 | -2.6 |
| Natural gas | 6,057 | 7,134 | 21 | 8,927 | 10,639 | 26 | 1.8 | 8,486 | 9,697 | 27 | 1.4 | 7,464 | 6,032 | 38 | -0.8 |
| **Power sector** | **12,413** | **13,818** | **100** | **14,951** | **16,594** | **100** | **0.8** | **13,777** | **13,834** | **100** | **0.0** | **8,460** | **3,780** | **100** | **-5.7** |
| Coal | 8,942 | 10,066 | 73 | 10,839 | 11,813 | 71 | 0.7 | 9,920 | 9,641 | 70 | -0.2 | 5,126 | 1,552 | 41 | -8.2 |
| Oil | 844 | 692 | 5 | 555 | 497 | 3 | -1.5 | 526 | 418 | 3 | -2.3 | 325 | 200 | 5 | -5.5 |
| Natural gas | 2,627 | 3,060 | 22 | 3,558 | 4,284 | 26 | 1.5 | 3,332 | 3,776 | 27 | 1.0 | 3,009 | 2,123 | 56 | -1.7 |

*Source: IEA – World Energy Outlook 2019*

### WORLD PRIMARY ENERGY DEMAND BY FUEL AND RELATED $CO_2$ EMISSIONS BY SCENARIO (IEA)




*Source: IEA – World Energy Outlook 2019*

# IEA energy scenarios (WEO - November 2019)

| | | Stated Policies Scenario (STEPS) | Sustainable Development Scenario (SDS) |
|---|---|---|---|
| Policies & results | Political commitments | Environmental policies, including those pursued so far and those that have been announced and have a good probability of implementation. | Policies that have to be implement without delay in order to meet specific environmental objectives: complying with the Paris Agreement and tackling global warming. |
| Policies & results | Global warming | **Temperature rise:** from 3°C to 4°C.<br>$CO_2$ emissions: +0.3% p.a. by 2040. | **Temperature rise:** limited to 2°C with efforts towards 1.5°C.<br>$CO_2$ emissions: -3/3% p.a. by 2040.<br>The scenario is not decarbonization by 2040: the share of fossil fuels is 58%. |
| Eco | Growth | GDP growth 3.4% p.a. until 2040 and over 9 billion people by 2040 (+70 million p.a.). | GDP growth 3.4% p.a. until 2040 and over 9 billion people by 2040 (+70 million p.a.). |
| Energy demand | Energy efficiency & primary demand growth | **Energy demand:** +0.98% p.a. until 2040.<br>Investments in energy efficiency step up from an annual $238bn in 2018 to $635bn in 2040.<br>**Energy efficiency** progresses 2.3% p.a. by 2040. | **Energy demand:** -0.34% p.a. by 2040.<br>Investments in energy efficiency step up from an annual $238bn in 2018 to $916bn in 2040.<br>**Energy efficiency** progresses 3.6% p.a. by 2040. |
| Energy demand | Mobility | **Share of electrical cars in new cars:** 15% in 2030 and 27% in 2050.<br>**Oil (gasoline) demand:** up 0.41% p.a. until 2050.<br>Demand breakdown in 2040: 82% oil, 5% electricity, 6% biofuels. | **Share of electrical cars in new cars:** 47% in 2030 and 72% in 2050.<br>**Oil (gasoline) demand:** down 3.04% p.a. until 2050.<br>Demand breakdown in 2040: 60% oil, 13% electricity, 14% biofuels. |
| Energy demand | Industry | **Rate of electrification:** 29% in 2030 and 31% in 2050.<br>Breakdown of energy demand in the industrial sector in 2040: 22% coal, 8% oil, 28% natural gas, 30% electricity, 8% bioenergy. | **Rate of electrification:** 31% in 2030 and 40% in 2050.<br>Breakdown of energy demand in the industrial sector in 2040: 16% coal, 6% oil, 28% natural gas, 36% electricity, 9% bioenergy. |
| Energy demand | Residential & services | **Energy intensity:** 0,94 in 2030 and 0.88 in 2050.<br>Breakdown of energy demand in the residential and services sector in 2040: 22% natural gas, 43% electricity, 19% bioenergy. | **Energy intensity:** 0.72 in 2030 and 0.59 in 2050.<br>2030 objective of "zero energy" buildings, and use hydrogen fuel cells (notably in boilers) after 2030.<br>Breakdown of energy demand in the residential and services sector in 2040: 17% natural gas, 53% electricity, 10% bioenergy. |
| Energy supply | Hydrogen | 70 Mt/yr of so-called grey hydrogen **(fossil fuel-based) consumed in 2018, mainly in refining and chemicals (small share of the total).** | Share of hydrogen in energy consumption (all hydrogen production combined): 0.06% in 2030 and 0.68% in 2040.<br>Hydrogen injections to gas grids: 25 Mtoe in 2040.<br>10 GW of offshore wind necessary to produce 1 Mt of hydrogen per year. |
| Energy supply | Shares of primary energy in the mix | **Breakdown of primary energy in 2040:** 21% RES, 28% oil; 25% natural gas, 21% coal, 5% nuclear.<br>Biogas: 320 Mtoe, of which 200 Mtoe of biomethane (6% of gas demand in 2040). | **Breakdown of primary energy in 2040:** 34% RES, 23% oil; 24% natural gas, 11% coal, 9% nuclear. |
| Energy supply | Electricity production | **Electricity production breakdown by energy source in 2040:** 44% RES (of which 13% wind, 11% solar and 15% hydro), 25% coal, 1% oil, 22% natural gas, 8% nuclear. | **Electricity production breakdown by energy source in 2040:** 67% RES (of which 21% wind, 19% solar and 18% hydro), 6% coal, 0.5% oil, 14% natural gas, 11 nuclear.<br>RES costs decrease and digital technology improves. |
| Energy supply | CCS / CCUS | **$CO_2$ storage by par CCUS:** 71 Mt in 2030 (approx. one-tenth of the SDS scenario) and 154 Mt in 2050 (approx. one-twentieth of the SDS scenario). | **$CO_2$ storage:** 700 Mt/yr by 2030 and 2,800 Mt/yr by 2050.<br>Allows an additional 9% reduction in $CO_2$ emissions compared to the STEPS scenario. |

# Enerdata energy scenarios (EnerFuture - January 2020)

| | | EnerBase | EnerBlue | EnerGreen |
|---|---|---|---|---|
| Policies & results | Political commitments | Target NDCs unfulfilled.<br>No efforts to reduce $CO_2$ emissions. | Target NDCs fulfilled for 2030.<br>Slower growth of $CO_2$ emissions. | Target NDCs (Paris Agreement) fulfilled and exceeded thanks to more ambitious environmental policies to limit global warming to +2°C. |
| | Global warming | Temperature rise: from 5°C to+6°C.<br>$CO_2$ emissions: +1.12% p.a. by 2040. | Temperature rise: from 3°C to 4°C.<br>$CO_2$ emissions: +0.25% p.a. by 2040. | Temperature rise: limited to 2°C (low carbon pathway by 2050).<br>$CO_2$ emissions: -3.12% p.a. by 2040. |
| Eco | Growth | GDP up between 3.5% and 3.6% p.a. out to 2040. | GDP up between 3.5% and 3.6% p.a. out to 2040. | GDP up between 3.5% and 3.6% p.a. out to 2040. |
| Energy demand | Energy efficiency & primary demand growth | Energy demand up 1.44% p.a. out to 2040.<br>Strong demand growth in developing countries, moderate in OECD.<br>Little improvement in energy efficiency. | Energy demand up 0.99% p.a. out to 2040.<br>Increased demand in developing countries, although limited by NDCs. | Energy demand down 0.37% p.a. out to 2040.<br>Energy efficiency policies increasingly ambitious. |
| | Mobility | Share of electricity: 5.1% in 2040 and 6.3% in 2050.<br>Share of biofuels: 11.3% in 2040 and 11.9% in 2050. | Share of electricity: 8.4% in 2040 and 11.1% in 2050.<br>Share of biofuels: 10.1% in 2040 and 10.9% in 2050. | Share of electricity: 18.9% in 2040 and 25.4% in 2050.<br>Share of biofuels: 13.1% in 2040 and 16.5% in 2050. |
| | Industry | Share of electricity: 23.5% in 2040 and 23.5% in 2050.<br>Share of biomass: 8.1% in 2040 and 8.7% in 2050. | Share of electricity: 24.6% in 2040 and 25.8% in 2050.<br>Share of biomass: 9.3% in 2040 and 10.6% in 2050. | Share of electricity: 28.5% in 2040 and 30.6% in 2050.<br>Share of biomass: 17.8% in 2040 and 24.3% in 2050. |
| | Residential & services | Share of electricity: 44.5% in 2040 and 49.3% in 2050.<br>Share of biomass: 16.9% in 2040 and 14.4% in 2050. | Share of electricity: 44.0% in 2040 and 49.6% in 2050.<br>Share of biomass: 17,3% in 2040 and 14.7% in 2050. | Share of electricity: 45.9% in 2040 and 54.2% in 2050.<br>Share of biomass: 25.4% in 2040 and 23.8% in 2050. |
| Energy supply | Hydrogen | n/a | n/a | n/a |
| | Shares of primary energy in the mix | Slight increase in RES share: 19.7% in 2040 and 21.2% in 2050. | RES contribute to diversification: 22.9% share in 2040 and 26.7% in 2050. | Strong increase in RES share: 40.3% in 2040 and 50.2% in 2050. |
| | Electricity production | RES share in electricity production: 33.9% in 2040 and 37.5% in 2050.<br>Electrification rate: 25.7% in 2040 and 27.6% in 2050. | RES share in electricity production: 41.5% in 2040 and 48.2% in 2050.<br>Electrification rate: 26.7% in 2040 and 29.8% in 2050. | RES share in electricity production: 65.5% in 2040 and 73.0% in 2050.<br>Electrification rate: 32.4% in 2040 and 38.6% in 2050. |
| | CCS / CCUS | n/a | n/a | n/a |

# Energy efficiency

## Not nearly enough progress in energy efficiency, but substantial untapped large potential

**Energy efficiency is one of the main weapons in the fight against global warming and a critical part of energy transition.** It is one of the goals recognised in the UN 2030 agenda; published in 2015, the agenda calls for the doubling of its rate of improvement by 2030. Energy efficiency not only saves energy and reduces GHG emissions. It also contributes to socioeconomic development (industrial productivity, employment, public budget, health).

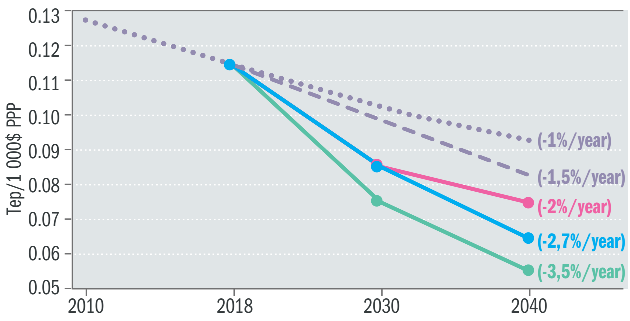
Its practical implementation can be divided into three themes: energy performance standards, market mechanisms and individuals' behaviour.

Energy intensity – energy demand per unit of GDP – is the usual means of measuring changes in energy efficiency. The IEA and Enerdata measure total primary demand per $1,000 of GDP at constant prices and at purchasing power parity.

**Energy efficiency has improved so much worldwide over the past two decades** that it is already the main component of energy services and one of the 'largest energy resources' in many countries. It has enabled energy consumption to contract nearly 20% over the period in the world's major economies (IEA members, Argentina, Brazil, Indonesia, Russia, South Africa). This is the equivalent of a 12% reduction in final demand and has avoided an additional 12% in GHG emissions.

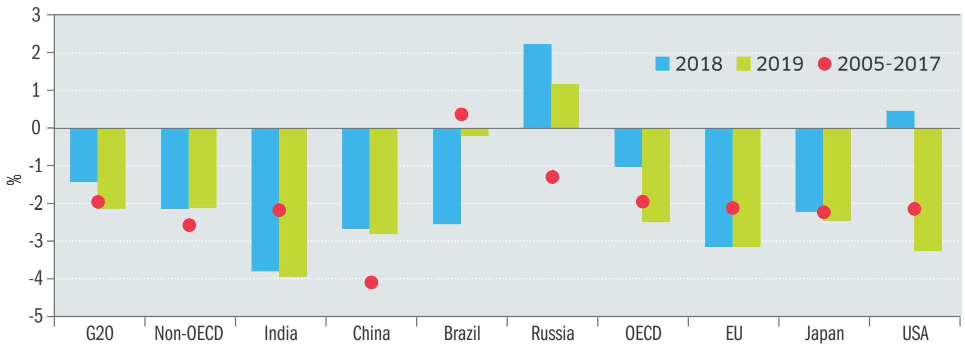
The trend represents an almost 2% annual average decline in energy intensity, although the fall has been slower in recent years. The trend rate resumed in 2019 (-2.1%, after -1.5% in 2018) on the back of favourable weather conditions, however. The past two years have seen a clear acceleration within the OECD, driven by the USA and Europe. In India, where modernisation in underway, energy intensity fell sharply; in China, where the economy is maturing, the decline in energy intensity slowed.

### ENERGY INTENSITY PROJECTION (TOE/$1,000 PPP) – WORLD




*Sources: IEA, World Energy Outlook 2019; Enerdata, Global, Energy and $CO_2$ data, 2020*

### ENERGY INTENSITY TRENDS IN THE G20 COUNTRIES (%/YEAR)




NB: Energy intensity: number of tonnes of oil equivalent per $1,000 of GDP at purchasing power parity

*Source: Enerdata*

# Energy efficiency

**Progress in reducing energy intensity to date is still inadequate to meet the 2°C global warming trajectory, however. This requires energy intensity to decline 3.6% par year until 2040.** In a nutshell, world energy consumption has to stabilise over the coming two decades and $CO_2$ emissions – with the support of renewable energy – have to be halved. So far, energy intensity and carbon intensity have been tracking each other.

Improving efficiency depends largely on investment, but it stagnated at $250 bn in 2019. The energy transition requires a great deal more: according to the IEA's SDS scenario, investment has to double by 2025, reach $625 bn per year by 2030 and total $920 bn by 2040. Because of its efficiency/costs ratio, energy efficiency is the main emission reduction factor in this scenario (it attributes 37% of the decline in $CO_2$ emissions to efficiency, with RES accounting for 32%, substitution between energy sources for 8%, nuclear for 3%, CCUS for 8% and others for 12%).

**Substantial untapped energy efficiency potential.** The drive towards more energy efficiency particularly concerns transport and buildings, and especially residential buildings.

**Buildings are a key source of energy efficiency improvement.** They represent 30% of final energy demand, and nearly 40% in the EU, of which 80% is heating. They also weigh heavily in GHG emissions, accounting for nearly 20% of direct emissions and much more when electricity consumption and construction are included. Efficiency gains can be made in housing and household equipment energy performance, primarily through the renovation of existing buildings (60% of the EU's likely housing stock in 2040 has already been built). Substantial renovation efforts are required: currently, only 1% of the housing stock is renovated each year, and tangible reductions in heating consumption would require at least 4%.

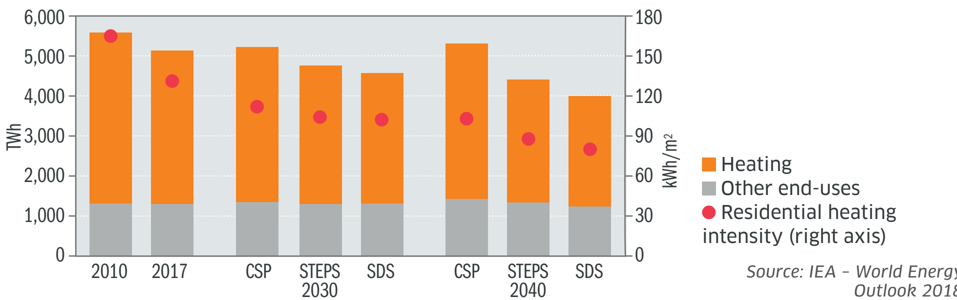
**Transport also offers significant potential:** it represents 30% of final energy demand and nearly 40% of $CO_2$ emissions (final demand). There is room for improvement in such areas as Internal combustion engine efficiency, hybrid vehicle use, vehicle size and tyre friction.

**In the European Union, energy efficiency policies gain momentum.** With buildings representing nearly 40% of final energy consumption and 30% of $CO_2$ emissions, the EU's Clean Energy Package includes a non-legally binding commitment to improve energy efficiency by 32.5% by 2030. The directive on buildings energy performance was revised in 2018 to include ambitious thermal renovation objectives such as near-zero energy buildings by 2050. It plans heavy investment in new technologies, such as smart grids, to lower energy consumption in buildings.

In addition, the European Green Deal intends to "at least double" the average thermal renovation rates of housing stocks in Member States (currently between 0.4% and 1.2%). This started in 2020 with the assessment of national long-term renovation plans.



### ENERGY CONSUMPTION IN BUILDINGS BY END-USE AND RESIDENTIAL HEATING INTENSITY BY SCENARIO IN THE EUROPEAN UNION




*Source: IEA – World Energy Outlook 2018*

Renovation rates in the different scenarios are as follows:
CPS: 0.8% of the housing stock is renovated each year, which generates a 3% rise in energy consumption attributable to buildings.
STEPS : 2% of the housing stock, implying a 10% decline in energy consumption.
SDS: 2.5% until 2025 and 4% beyond, implying an over 20% decline in energy consumption.
Each of the scenarios embed other measures, but renovation has the greatest impact.

# Energy sufficiency

## An essential lever but still confined to local initiatives

**Energy sufficiency', or sobriety, has long been overlooked but is now emerging as a crucial lever in the fight against global warming.** Reducing energy consumption through changes in behaviour, lifestyle and social organisation extends the logic of the 1987 Bruntland report*, highlighting the necessity of compromising between our material and social needs and the ecosystem's environmental limits.

A society committed to energy sobriety would alter its social norms, perceptions of individual needs and collective organisation to obtain **a voluntary and orderly reduction in energy consumption.** This collective effort would both limit the negative externalities associated with consumption and production (pollution, noise, health problems, etc.) and, more broadly, improve quality of life. It entails measures such as limiting room temperature at home, reducing the number of electronic devices, promoting cycling and working more from home, in other words "doing less to use less" (see table). In the context of climate emergency, more radical measures have also been suggested, notably by young people. Sweden's *flygskam* ('flight shame') initiative is a good example.

**Current energy sufficiency strategies mainly consist of incentives to reduce energy consumption, usually at local level.** The effectiveness of individual schemes has been measured and a great many practical examples have been collated. The Energise** consortium lists 1,067 sustainable energy consumption initiatives in the EU, covering a wide variety of local projects. For example, France's *Familles à énergie positive* ('positive energy families') initiative promoted energy savings in 30,000 households, resulting in a average 12% reduction in consumption. Similarly, the '2000-watt society'*** campaign in Zurich reduced primary energy consumption from 5,000 W to 4,200 W per inhabitant in ten years.

In the private sector, sharing has been one of the pillars of energy sobriety. In the USA, car sharing has lowered household fuel consumption by 5% by saving duplicated mileage and via parking infrastructure savings.

**Energy sufficiency has still not been deployed on a large scale, however. It remains the blind spot in most energy policies and scenarios, mainly because it continues to be seen as restrictive.** In political and economic terms, the concept is widely perceived as incompatible with the growth models that still guide public policy, with only timid attempts to challenge them. At the level of private individuals, preaching energy temperance runs counter to prevailing notions of comfort and social norms based on material abundance and consumerism. More generally, it also raises questions over the fair sharing of consumption reduction when energy poverty remains a threat to many households.

*The Brundtland Report is the name commonly given to the publication officially titled "Our Common Future", produced in 1987 by the United Nations World Commission on Environment and Development. Used as a basis for the Earth Summit of 1992, this report uses for the first time the expression "sustainable development".

**Energise: Research network, good practices and innovation for sustainable energy.

*** The concept of a 2,000-watt society aims to reduce primary energy consumption corresponding to a continuous average power of 2,000 watts per person for a year and to GHG emissions of 1 tonne of $CO_2$ equivalent per person and per year; primary energy consumption and GHG emissions are calculated from final energy consumption by applying primary energy factors or GHG emission factors.

Typology of energy sufficiency measures

| | INDIVIDUAL LEVEL | COLLECTIVE LEVEL |
|---|---|---|
| USE | **USAGE SUFFICIENCY**<br>Limitation of the level and duration of equipment use.<br>○ e.g., speed reduction, repairing, eco-design... | **COLLABORATIVE SUFFICIENCY**<br>Collective organizations and pooling of goods.<br>○ e.g., carpooling, house share, third places... |
| DESIGN | **SIZING SUFFICIENCY**<br>Adaptation of equipment sizing to needs.<br>○ e.g.,room temperature, car size, reduced diet... | **SPACIAL ORGANIZATION SUFFICIENCY**<br>Collective incentive organization (land use planning).<br>○ e.g., urban design, circular economy, local distribution... |

*Source: NégaWat*

# Energy sufficiency

**Despite its limited cost and its potentially immediate impacts, energy conservation measures at the global level are hardly considered in long-term trajectories.** 'NégaWatt 2050', one of the rare energy scenarios that explicitly takes account of sobriety, considers that it could reduce energy demand by 28% by 2050 (out of a 50% total contraction, the other 22% coming from energy efficiency - study for France).

IEA's SDS (2°C scenario), Greenpeace's Energy [R]evolution and BP's Rapid Transition scenarios include some sobriety measures, notably the circular economy and changes in transport modes, but do not identify sufficiency concept as such. For instance, recycling improves with a used plastics collection rate rising from 15% currently to 30% by 2040 in the Rapid Transition, and to 34% in the SDS; modal shifts accelerate with less than 200 million private cars by 2040 to the benefit of 2 and 3 wheelers and public transport in the SDS; rail is gradually preferred to air travel and road freight in the Energy [R]evolution; car sharing and the functional economy are part of the Rapid Transition; and reducing unnecessary journeys by teleworking and videoconferencing is mentioned in all three.

These scenarios offer no proactive or forward-thinking on energy sobriety, however, and the subject is often marginalised. Urban eco-design is not handle; changes in lifestyle are not central to any vision but are assumed to arise from exogenous trends. Measures relating to food systems and agricultural production are ignored altogether.

**As we have seen, reaching the 2°C trajectory will prove difficult if it is to rely solely on energy efficiency and electrification of final uses,** which in turn put severe pressure on the development of new technologies and questions their feasibility. **In contrast, energy sufficiency offers a certain and accessible reduction in energy consumption.** Focused on social changes rather than on technical progress, sobriety contributes to a more resilient model that depends less on financing capacities and the availability of raw materials. It is also less exposed to the rebound effects that have so far neutered most energy efficiency progress. By promoting behaviour that uses less energy, sobriety relieves pressure on renewable sources, particularly in terms of demand, thereby facilitating RES development.

**The Covid-19 pandemic has had marked environmental consequences. By highlighting ecosystem vulnerability, it may have a lasting effect on behaviour and encouraged energy sufficiency.** Many of the solutions put forward to stave off future pandemics match sobriety choices, such as local and circular economies, industrial relocation, digitalisation and reduced mobility.

Some of the major changes that the crisis triggered in a very short time could last:

- Teleworking and further digitalisation: a third of the world's workforce is expected to keep working from home at least part of the time post-crisis (source: Global Workplace Analytics, 2020).
- Air traffic: airlines expect a permanent change in travel patterns, with less business travel (source: Sorensen, 2020; Boone et al., 2020). The number of flights is expected to resume pre-crisis levels only slowly (source: IATA, 2020).
- Other attitudes could change, notably in areas such as consumption, prudential savings, health and food security, less concentration and relocation.

In France, for instance, the *Le jour d'après* ('the day after') online consultation launched in April by Matthieu Orphelin and 66 other parliamentarians from different parties showed what French people consider to be priorities: health, sobriety, solidarity and sovereignty.

# Green finance

## Financing the energy transition requires the development of specific instruments, collectively known as green finance

**Energy transition financing has long struggled with a number of difficulties related to poor returns on low-carbon projects, the higher risk of these projects compared with traditional projects and a lack of appropriate financial tools.** Moreover, the economic situation has tended to favour projects with the highest GHG emissions..

- Traditional financing is not sufficiently geared towards the specifics of energy transition projects: economic analysis of project financing is short-term, the banking system's macro-prudential rules limit access to credit for such projects and risks related to global warming are not factored in (physical risks: destruction of infrastructure; legal risks: compensation to victims; financial risks: stranded assets).
- Moreover, low carbon projects lack competitiveness because of their high capital costs (RES projects are very capital intensive and expensive), slow return on investment (20-40 years), low rates of return, high technical and economic risks and their failure to take positive externalities into account.
- Finally, a number of countries around the world still maintain economic regulations that favour high-carbon growth; these include in particular subsidies to fossils (coal and oil for 90%) through lower sales tariffs. By masking price signal, their enormous weight ($5 trillion* according to a 2017 IMF assessment) hampers economic incentives for energy transition projects.

**This explains why, despite of evident demand, abundant savings and low interest rates, private investment is still directed largely at fossil fuels.**

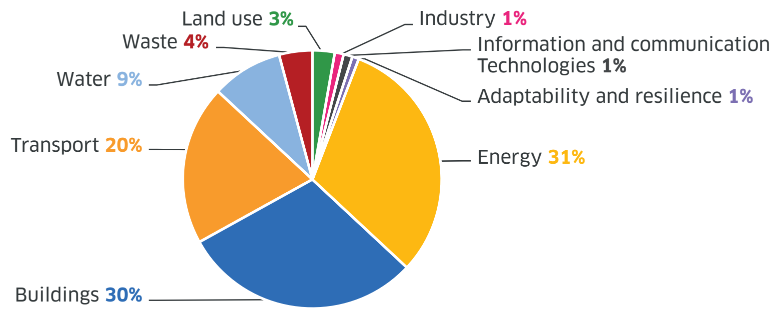
- In 2019, out of a total of $1,900 bn invested in energy, $600 bn went to clean technologies (RES, energy efficiency, batteries), $50 bn to nuclear, $250 bn to power networks, and over half of the total to coal, oil and gas ($1,000 bn).
- Green investments are far from sufficient to secure energy transition. Investment in renewable electricity amounted to $310 bn in 2019, for example, and $600 bn per year is required under 2°C scenario projections. Similarly, energy efficiency schemes totalled $250 bn in 2019, compared with the $900 bn annual requirement.

**In order to bypass these difficulties, the financial system adapted and developed specific instruments. In the space of a few years, green finance has become an important part of ecological transition financing.** The term covers all financial actions and operations aimed at redirecting funds towards the decarbonization of the economy and the fight against global warming (energy efficiency, RES, green mobility, electricity infrastructures, etc.). Dating back to a 2007 initiative on the part of the IPCC and European Investment Bank and the first-ever green bond issue, green financing has been booming recently. Cumulated issues exceeded $1,000 bn in 2019, although it has to be said that they accounted for just 0.9% share of the bond market at the end of that year. Such a trend, which reflects the fact that environmental issues are increasingly part of financial players' and investors' decision-making (climate risk mitigation, stakeholder pressure, willingness to act on climate issues), involves standardisation of processes, innovative tools and favourable regulations.

* After-tax public subsidies for the consumption of coal, motor fuels and petroleum fuels.



**DETAILED ALLOCATION OF GREEN BONDS AND LOANS IN 2019 (WORLD)**
**TOTAL: $257.7 BN**




*Source: Climate Bonds Initiative (2020)*

# Green finance

## Faster development of green finance following instrument standardisation and diversification

**Green bonds are currently the main instrument used in green finance.** They are issued on the bond market by financial institutions (37%) and states (29%), but also by large companies, such as Engie (the leading industrial issuer of green bonds in 2019 with €3.4 bn issued, and a total of €11 bn issued since 2014), and a few local authorities. They involve sustainable projects meeting specific ethical, environmental and social criteria in areas such as renewable energy, energy efficiency, clean transport and water management. In the USA, the Federal National Mortgage Agency has issued nearly $75 bn of green bonds to fund the renovation of rental accommodation in order to improve their energy and water efficiency.

**World bond issues and green loans hit a new record in 2019 at $257.7 bn, up 51% from 2018**. The European Union alone represents 45% of this volume; this share is set to increase further in the coming years, with the launch of the Green Deal Investment Plan, which is expected to fund at least €1,000 bn worth of green investment over the coming decade. Asia-Pacific and North America account for 25% and 23%, respectively. Driven mainly by China, emerging countries' issuance increased by 21% in 2019, to $52 bn. Continued geographical diversification saw green bond issues for the first time for Russia, Kenya, Greece, Ecuador and Saudi Arabia.

**The global standardisation and harmonisation of green finance principles has boosted its expansion.** The International Capital Market Association has circulated its 'Green Bond Principles', a set of rules and indicators providing a frame of reference for selecting investment projects and the use of funds. The EU is also pioneering in this area: apart from its 'Green Bond Standard' project, it is working on a common classification system to distinguish 'green' and 'sustainable' sectors. This will enhance market efficiency and help to direct capital flows towards assets that genuinely contribute to ecological transition.

**Momentum behind greener finance also depends on the diversification of its instruments and, more broadly, a change in attitudes.** New labels are emerging, such as Greenfin, introduced in June 2019 by the French ecological transition ministry. Their objective is to improve the efficiency, transparency, comparability and credibility of green investments and the market as a whole. So-called transition bonds are designed to help polluting industries fund conversion to cleaner operations. Their increasing popularity among issuers has led to fears among observers that they are being used for greenwashing purposes. In the light of these developments, some banks now specifically embed climate risk in their macro-prudential assessment systems and take environmental impacts into consideration in their credit decisions.

**The development of green finance is not obstacle-free, however, and needs continuing close support from government.** Green bond issuance involves demanding and complex formalities, notably with regard to the preparation and the release of environmental reporting. This turns many players away from green bonds, especially as the financial incentives – apart from demonstrating ecological commitment and diversifying sources of funding – are uninspiring. Investor demand for green financing now exceeds issuers' ability to identify eligible projects, resulting in a supply shortage.

# $CO_2$ Capture, Utilization and/or Storage (CCUS)

The interest for the CCUS chain has been gaining momentum, as the need to decarbonize is becoming increasingly critical. Despite significant progress and the technical maturity of the technology, CCUS is still facing challenges from a commercial and public acceptance side

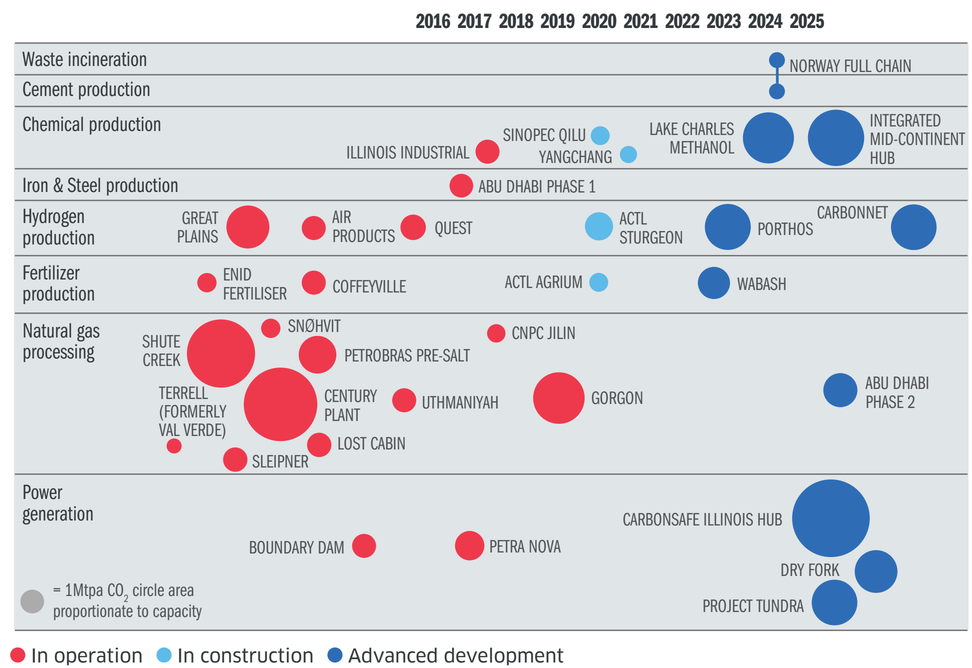


**Over the last 10 years, notable progress has been made in the deployment of the CCUS industry.** In 2019, the number of large-scale CCS facilities increased to 51: 19 are operating, 4 are under construction, 10 are in advanced development in a front-end engineering design phase (FEED); and 18 are in early development (CCS Institute).

- Most projects take place in the US in the oil & gas sector, where the captured $CO_2$ is largely being used for Enhanced Oil Recovery (EOR)*. Other key areas for the capture business include the natural gas processing as well as chemical and hydrogen production. Large industrial sites have also recently started operation in the power sector (coal). CCUS seem to be gaining momentum, with new projects in advanced and early development phase.
- The key players promoting the CCUS technology encompass mostly the oil & gas companies (to preserve their assets and resources), the mid-stream gas companies (TSO, to start decarbonizing their networks), power producers (to decarbonize their fleet) and industrial players (like iron & steel, cement or hydrogen producers, to decrease their carbon footprint).
- The CCUS chain is however still facing difficulties and there are only a limited number of large-scale commercial operations worldwide, in particular due to the lack of regulatory policy and incentives, tough competition from alternative technologies, public acceptance challenges, and the insufficient value of $CO_2$. The main issues to be tackled are however quite well known, including the question over the long-term liability on underground storage.
- New paths for the utilization of $CO_2$ are also emerging, as it can become a valuable feedstock to create new low carbon products, in particular decarbonized synthetic fuels (e-methane, e-kerosene, etc), but also for building materials for example.

*Enhanced oil recovery (EOR) is a technique based on $CO_2$ and water injection which allows to upgrade crude oil extraction from oil fields.

**INSTALLATIONS OF CCUS IN THE WORLD**




*Source: CCS Institute, Report 2019*

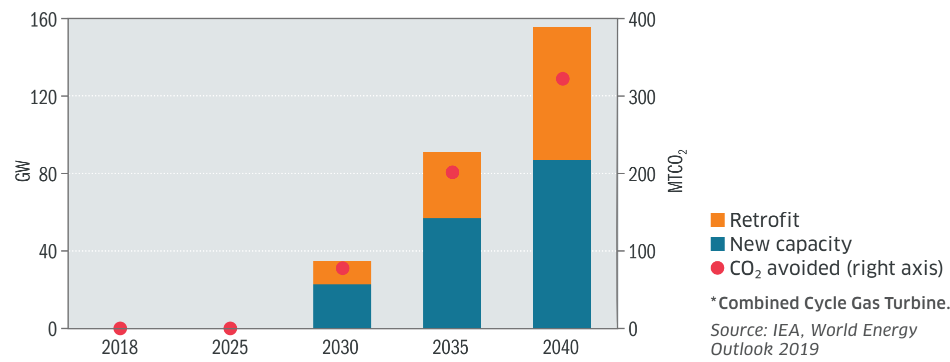
# $CO_2$ Capture, Utilization and/or Storage (CCUS)

On top of renewable energies, energy efficiency and green gases, CCUS is likely to play a role in the scenarios which target the highest decarbonization goals

**There is a broad consensus that CCUS should be one of the technologies in the portfolio of solutions to change the emissions trajectory of the energy systems in a cost effective way;** CCUS has indeed a role to play to reach the most ambitious climate targets, however it should be noted that its potential should be limited to certain segments like the harder-to-abate sectors, where alternatives are immature, too costly or unavailable. It should be noted that CCUS also offers the possiblity to foster negative emissions using bio-energy (BECCS).

- According to the IEA (WEO 2019), CCUS will need to contribute to 9% of the cumulative emissions reduction by 2050 in order to reach the targets of the Sustainable Development Scenario (SDS). They estimate that ~0.7 Gt of $CO_2$ should be captured each year by 2030, rising to 2.8 Gt in 2050, split between power and industry.
- According to IPCC (5th Assessment Report), the costs for achieving $CO_2$ levels consistent with temperatures 2°C above preindustrial levels will be more than twice as expensive without CCUS.
- The development of CCUS should not however hinder the resources allocated to energy efficiency and renewables (including green gases), which should remain the main pillars of the energy transition. The results on the role of CCUS in the mix and the cost of decarbonization are moreover very dependent on the costs of the CCUS chain, which remain uncertain in particular for storage. The storage volume potential is also uncertain.

**INSTALLED CCGTs* EQUIPPED WITH CCUS AND EMISSIONS AVOIDED IN THE SUSTAINABLE DEVELOPMENT SCENARIO (IEA)**




*Combined Cycle Gas Turbine.

*Source: IEA, World Energy Outlook 2019*

# Electricity & Electrical renewables

**PRODUCTION CAPACITY**

Renewable energy accounted for three quarters of additional power capacity in 2019

**COVID-19**

Lower demand during lockdown benefitted RES.
Their share in the electricity mix climbed to 28% over the first quarter of 2020

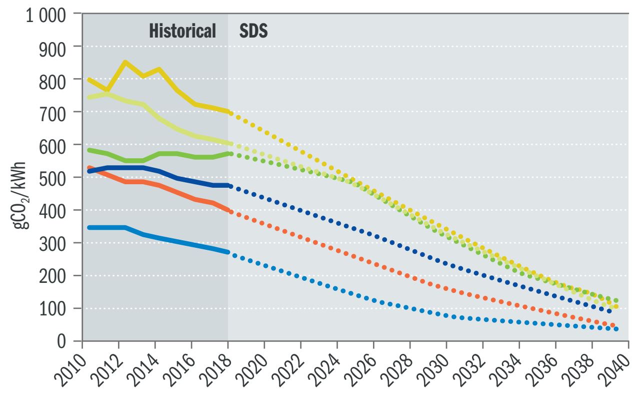
# Electricity and energy transition

## Despite recent progress, more effort on RES is needed to meet energy transition goals

**As electricity represents a rapidly growing share of energy consumption (20% of final demand in 2019) and is also the biggest source of energy-related $CO_2$ emissions (45% in 2019), power generation has become a critical element in the energy transition process.** The power sector's transformation started some twenty years ago and it is now a major lever in fighting global warming and extending energy access worldwide. Renewable energy costs have decreased – solar PV has become the most competitive power source in China and India in 2020 – and power generation is increasingly green, but additional efforts remain indispensable to meet the IEA's Sustainable Development Scenario (SDS) objectives.

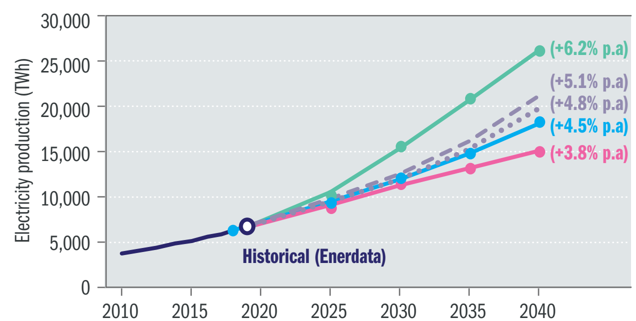
**Despite improving results and a positive overall dynamic, power sector trends are generally below SDS requirements.** This is the case of carbon intensity, for which the decline recorded in 2019*, although substantial (-2.5%, against -1% in 2018), remains far from sufficient compared to the 5.6% contraction that is required annually until 2030. Coal's resilience is particularly troublesome: despite a record contraction in output, coal still represented 36.4% of the power mix in 2019. That is far greater than its SDS targets (16.5% by 2030 and 6% by 2040). The main indicator of clean energy progress is the share of low carbon technologies (RES, nuclear, CCS**) in the power generation mix; it rose 1.1% to 37% in 2019, but is still a long way from the 60% objective set for 2030. Only the rapidly growing solar PV and biomass sectors, up 22% and 5%, respectively, were showing trends in line with the SDS at end-2019.

### CARBON INTENSITY OF ELECTRICITY GENERATION




*Source: IEA, Tracking Power 2020 (June 2020)*

### RENEWABLE ELECTRICITY PRODUCTION – WORLD




*Sources: IEA, World Energy Outlook 2019; Enerdata, Global Energy and $CO_2$ data, 2020*

*Carbon intensity of world power generation in 2019: 463 $gCO_2$/KWh.
**Decarbonization of fossil fuel-based electricity generation through carbon capture and storage (see chapter Decarbonization).

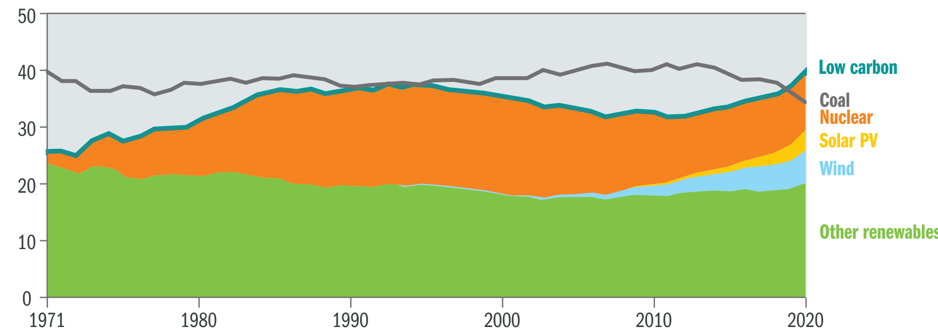
# Electricity and energy transition

**By causing unprecedented upheavals in demand, the Covid-19 crisis has ironically helped – temporarily at least – energy transition within the electricity sector.** While fossil power generation was severely hit – coal-fired production is expected to contract 10% in 2020, much more than the -6.4% SDS target out to 2040 –, renewable energy proved particularly resilient, reaching 28% of the electricity mix over the first quarter. Even though these figures are exceptional and may falter once the crisis is over, they do point to the magnitude of what is required to meet the Paris Agreement and offer early insight on the challenge facing the electricity sector in the coming years.

**The growing use of electricity and the increasing share of RES raise questions, notably regarding the robustness and security of electricity supply systems.** While electricity demand is expected to increase 50% by 2040 in the SDS (900 million people accessing the network, wider use of air conditioning, affordable electrical cars, etc.), the intermittency of renewable production, notably in solar and wind power, makes the balancing of electricity supply with demand a critical issue. Flexibility is a prominent concern. Apart from extending and upgrading networks (investments worth $270 bn in 2019), developing natural gas, biomethane and hydrogen production capacity, and enhancing demand-side management mechanisms, the deployment of battery storage capacity (+2.9 GW in 2019) stands out as a high-potential alternative, specially since it has become much cheaper over the recent years (-45% between 2012 and 2018) and offers great modularity.

Moreover, although the necessity for energy transition is increasingly accepted, large-scale deployment of renewable technology continues to fuel some debates. Among them, the controversy surrounding the extraction of the ores needed to produce PV panels and batteries, the impact of hydroelectric dams on ecosystems and local populations, or the protest movement against windfarm installation – 70% of these projects in France are subject to legal proceedings on the grounds of noise and visual pollution.

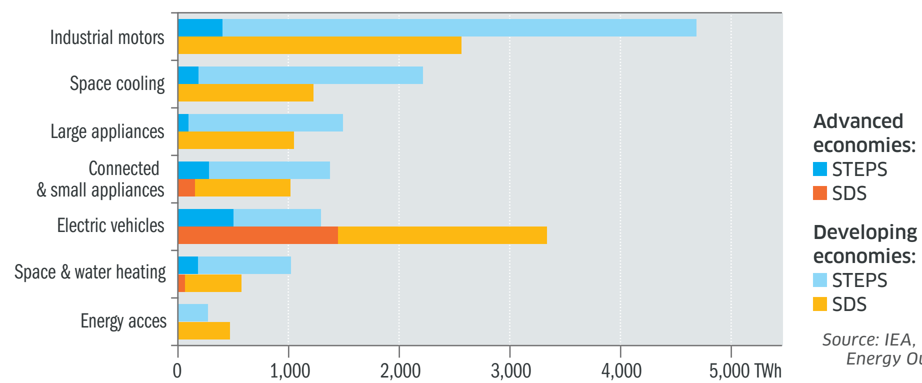
**GLOBAL GENERATION SHARES FROM COAL AND LOW-CARBON SOURCES (1971-2020)**




*Sources: IEA, Global Energy review 2020 – Covid-19 impacts on energy and $CO_2$ emissions, 28 April 2020*



**ELECTRICITY DEMAND GROWTH BY END-USE AND SCENARIO IN ADVANCED AND DEVELOPING ECONOMIES (2018-2040)**




*Source: IEA, World Energy Outlook 2019*

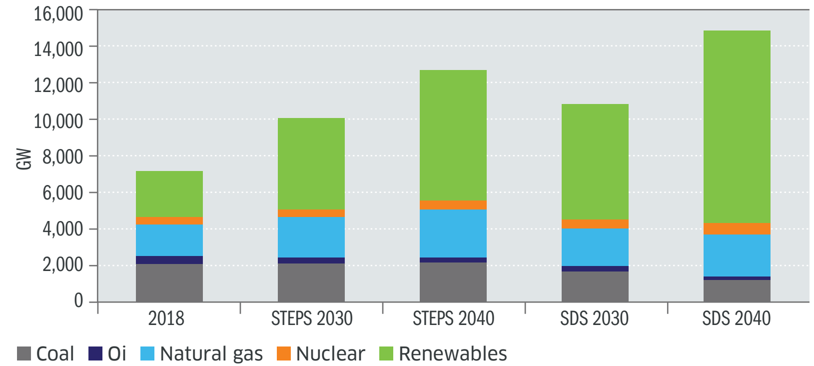
# Electricity and energy transition: generating capacity forecast

## GENERATING CAPACITY FORECAST BY SOURCE IN THE IEA SCENARIOS (GW)

| Generating capacity forecast by source (GW) | 2018 | Stated Policies Scenario | | | | Sustainable Development Scenario | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2030 | 2040 | AAGR 2018-2040 | Share in 2040 | 2030 | 2040 | AAGR 2018-2040 | Share in 2040 |
| Coal | 2,079 | 2,111 | 2,171 | 0.2% | 16.6% | 1,644 | 1,153 | -2.6% | 7.4% |
| Oil | 450 | 298 | 239 | -2.8% | 1.8% | 294 | 240 | -2.8% | 1.6% |
| Natural gas | 1,745 | 2,254 | 2,651 | 1.9% | 20.2% | 2,084 | 2,304 | 1.3% | 14.9% |
| Nuclear | 419 | 436 | 482 | 0.6% | 3.7% | 482 | 601 | 1.7% | 3.9% |
| Renewables | 2,517 | 5,019 | 7,233 | 4.9% | 55.2% | 6,359 | 10,626 | 6.8% | 68.7% |
| Hydro | 1,290 | 1,586 | 1,822 | 1.6% | 13.9% | 1,728 | 2,090 | 2.2% | 13.5% |
| Bioenergy | 146 | 224 | 286 | 3.1% | 2.2% | 272 | 425 | 5.0% | 2.7% |
| Wind | 566 | 1,288 | 1,856 | 5.6% | 14.2% | 1,721 | 2,930 | 7.8% | 18.9% |
| Geothermal | 14 | 27 | 46 | 5.5% | 0.4% | ,43 | 82 | 8.3% | 0.5% |
| Solar PV | 495 | 1,866 | 3,142 | 8.8% | 24.0% | 2,537 | 4,815 | 10.9% | 31.1% |
| CSP | 6 | 23 | 61 | 11.4% | 0.5% | 52 | 254 | 18.9% | 1.6% |
| Marine | 1 | 4 | 20 | 17.8% | 0.2% | 6 | 30 | 20.0% | 0.2% |
| Total capacity | 7,218 | 10,244 | 13,109 | 2.7% | 100% | 11,042 | 15,478 | 3.5% | 100% |

*Source: World Energy Outlook 2019 © OECD/IEA, November 2019*

## GENERATING CAPACITY FORECAST BY SOURCE IN IEA STATED POLICIES AND SUSTAINABLE DEVELOPMENT SCENARIOS



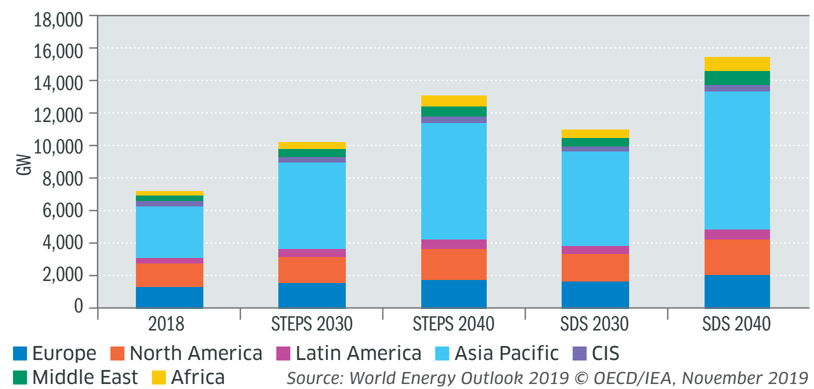

*Source: World Energy Outlook 2019 © OECD/IEA, November 2019*

## GENERATING CAPACITY FORECAST BY REGION IN THE IEA SCENARIOS (GW)

| Generating capacity forecast by region (GW) | 2018 | Stated Policies Scenario | | | | Sustainable Development Scenario | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2030 | 2040 | AAGR 2018-2040 | Share in 2040 | 2030 | 2040 | AAGR 2018-2040 | Share in 2040 |
| Europe | 1,305 | 1,579 | 1,753 | 1.4% | 13.4% | 1,691 | 2,066 | 2.1% | 13.3% |
| North America | 1,429 | 1,655 | 1,934 | 1.4% | 14.8% | 1,702 | 2,228 | 2.0% | 14.4% |
| Latin America | 359 | 483 | 600 | 2.4% | 4.6% | 472 | 603 | 2.4% | 3.9% |
| Asia Pacific | 3,218 | 5,287 | 7,161 | 3.7% | 54.6% | 5,841 | 8,522 | 4.5% | 55.1% |
| CIS | 331 | 365 | 407 | 0.9% | 3.1% | 344 | 424 | 1.1% | 2.7% |
| Middle East | 331 | 476 | 641 | 3.1% | 4.9% | 508 | 783 | 4.0% | 5.1% |
| Africa | 244 | 400 | 614 | 4.3% | 4.7% | 484 | 852 | 5.9% | 5.5% |
| Total capacity | 7,218 | 10,244 | 13,109 | 2.8% | 100% | 11,042 | 15,478 | 3.5% | 100% |

*Source: World Energy Outlook 2019 © OECD/IEA, November 2019*

## GENERATING CAPACITY FORECAST BY REGION IN IEA STATED POLICIES AND SUSTAINABLE DEVELOPMENT SCENARIOS




*Source: World Energy Outlook 2019 © OECD/IEA, November 2019*

# Electricity and energy transition: generation forecast

## ELECTRICITY GENERATION FORECAST BY SOURCE IN THE IEA SCENARIOS (TWH)

| Electricity generation forecast by source (TWh) | | Stated Policies Scenario | | | | Sustainable Development Scenario | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2018 | 2030 | 2040 | AAGR 2018-2040 | Share in 2040 | 2030 | 2040 | AAGR 2018-2040 | Share in 2040 |
| Coal | 10,123 | 10,408 | 10,431 | 0.1% | 25.2% | 5,504 | 2,428 | -6.3% | 6.3% |
| Oil | 808 | 622 | 490 | -2.3% | 1.2% | 355 | 197 | -6.2% | 0.5% |
| Natural gas | 6,118 | 7,529 | 8,899 | 1.7% | 21.5% | 7,043 | 5,584 | -0.4% | 14.4% |
| Nuclear | 2,718 | 3,073 | 3,475 | 1.1% | 8.4% | 3,435 | 4,409 | 2.2% | 11.4% |
| Renewables | 6,799 | 12,479 | 18,049 | 4.5% | 43.6% | 15,434 | 26,065 | 6.3% | 67.3% |
| Hydro | 4,203 | 5,255 | 6,098 | 1.7% | 14.7% | 5,685 | 6,934 | 2.3% | 17.9% |
| Bioenergy | 636 | 1,085 | 1,459 | 3.9% | 3.5% | 1,335 | 2,196 | 5.8% | 5.7% |
| Wind | 1,265 | 3,317 | 5,226 | 6.7% | 12.6% | 4,453 | 8,295 | 8.9% | 21.4% |
| Geothermal | 90 | 182 | 316 | 5.9% | 0.8% | 282 | 552 | 8.6% | 1.4% |
| Solar PV | 592 | 2,562 | 4,705 | 9.9% | 11.4% | 3,513 | 7,208 | 12.0% | 18.6% |
| CSP | 12 | 67 | 196 | 13.7% | 0.5% | 153 | 805 | 21.2% | 2.1% |
| Marine | 1 | 10 | 49 | 19.0% | 0.1% | 14 | 75 | 21.3% | 0.2% |
| Total generation | 26,603 | 34,140 | 41,373 | 2.0% | 100% | 31,800 | 38,713 | 1.7% | 100% |

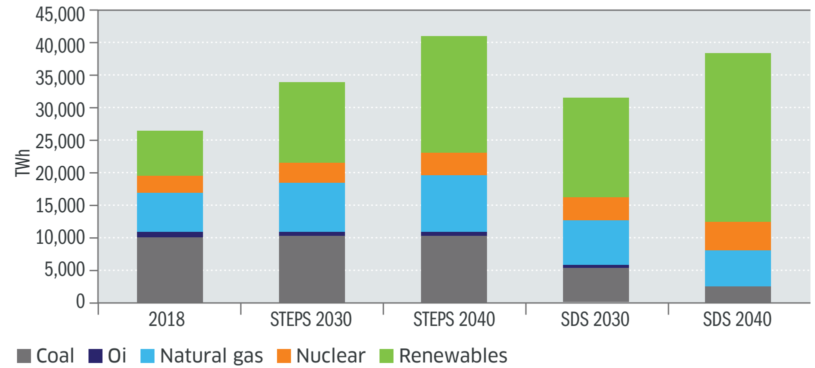
*Source: World Energy Outlook 2019 © OECD/IEA, November 2019*

## ELECTRICITY GENERATION FORECAST BY REGION IN THE IEA SCENARIOS (TWH)

| Electricity generation forecast by region (TWh) | | Stated Policies Scenario | | | | Sustainable Development Scenario | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2018 | 2030 | 2040 | AAGR 2018-2040 | Share in 2040 | 2030 | 2040 | AAGR 2018-2040 | Share in 2040 |
| Europe | 4,163 | 4,478 | 4,840 | 0.7% | 11.7% | 4,429 | 5,246 | 1.1% | 13.6% |
| North America | 5,430 | 5,780 | 6,277 | 0.7% | 15.2% | 5,527 | 6,186 | 0.6% | 16.0% |
| Latin America | 1,310 | 1,734 | 2,198 | 2.4% | 5.3% | 1,592 | 1,975 | 1.9% | 5.1% |
| Asia Pacific | 12,327 | 17,731 | 22,245 | 2.7% | 53.8% | 16,208 | 19,984 | 2.2% | 51.6% |
| CIS | 1,360 | 1,565 | 1,747 | 1.1% | 4.2% | 1,362 | 1,437 | 0.3% | 3.7% |
| Middle East | 1,147 | 1,570 | 2,169 | 2.9% | 5.2% | 1,416 | 1,909 | 2.3% | 4.9% |
| Africa | 866 | 1,284 | 1,898 | 3.6% | 4.6% | 1,267 | 1,976 | 3.8% | 5.1% |
| Total generation | 26,603 | 34,140 | 41,373 | 2.0% | 100% | 31,800 | 38,713 | 1.7% | 100% |

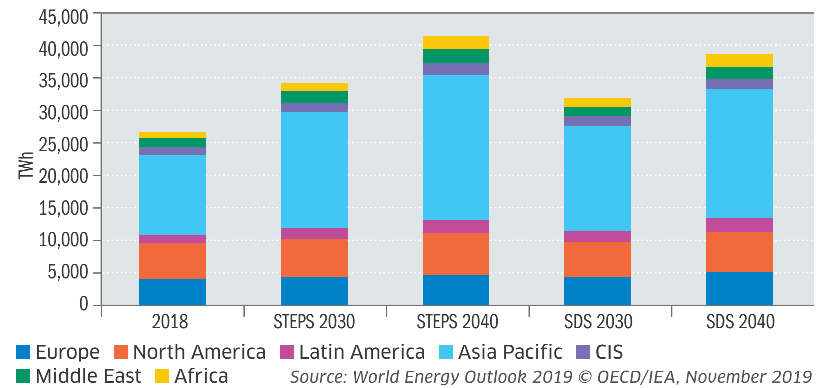
*Source: World Energy Outlook 2019 © OECD/IEA, November 2019*

## ELECTRICITY GENERATION FORECAST BY SOURCE IN IEA STATED POLICIES AND SUSTAINABLE DEVELOPMENT SCENARIOS (TWH)




*Source: World Energy Outlook 2019 © OECD/IEA, November 2019*

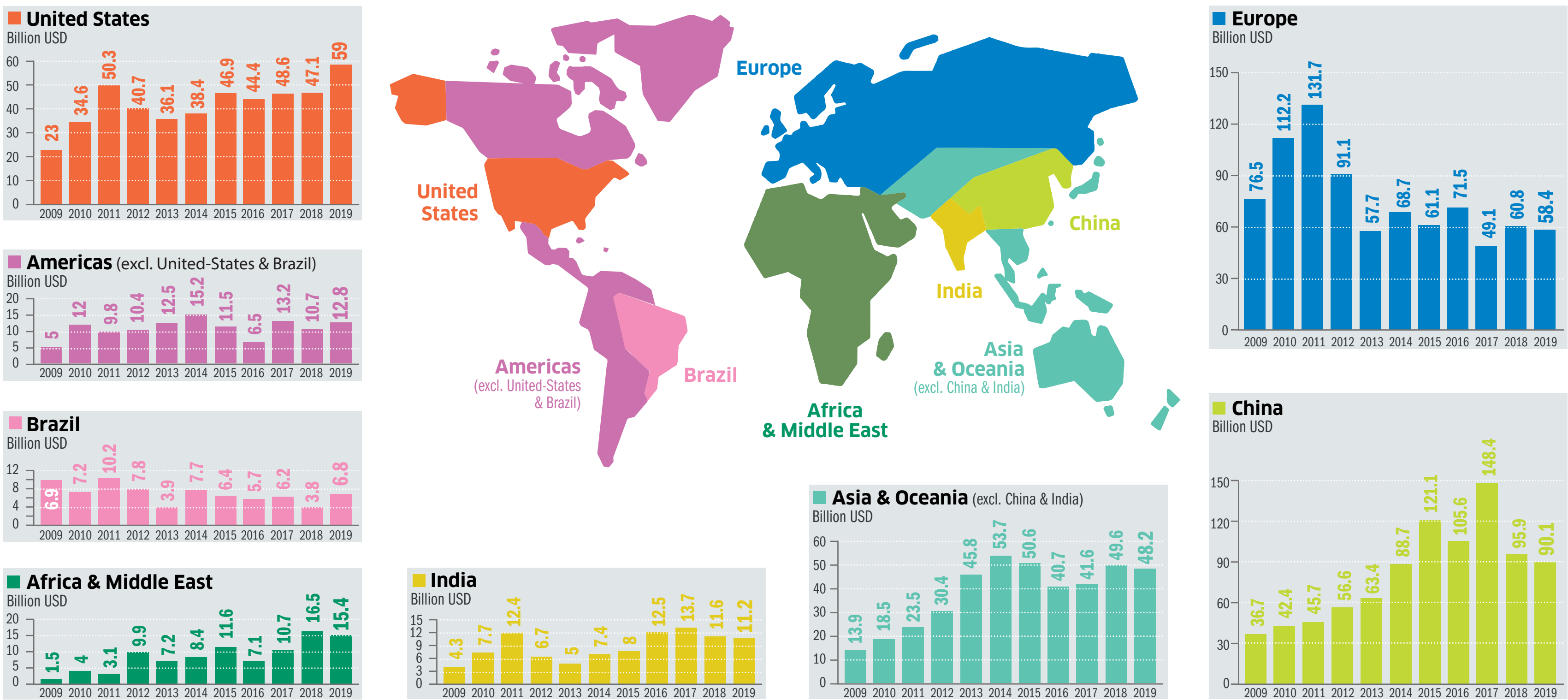
## ELECTRICITY GENERATION FORECAST BY REGION IN IEA STATED POLICIES AND SUSTAINABLE DEVELOPMENT SCENARIOS (TWH)




*Source: World Energy Outlook 2019 © OECD/IEA, November 2019*

# Electricity and energy transition: renewable electricity investment

## GLOBAL INVESTMENT IN RENEWABLE POWER AND FUELS BETWEEN 2009 AND 2019 (BILLION USD)




*Source: REN21, Renewables 2020 Global Status Report; Bloomberg New Energy Finance*

# Electricity: production capacity

## RES represented three-quarters of additional power capacity in 2019, and should remain largely prominent in 2020

**World electricity net capacity growth decelerated slightly to 3% (+223 GW) in 2019, following an average 4% since 2000. Total installed capacity reached 7,399 GW.** A geographical breakdown confirms Asia's prominent role, with a 65% share of world additional capacity (+147 GW), despite a certain loss of steam in 2019 (up 4.6%), compared to 2018 (up 5.4%). The Pacific region (up 7.5%) and Latin America (up 5.7%) progressed strongly, confirming momentum dating back to 2018. The trend is less marked in OECD countries, with Europe in the 2% range (up 2.2% in 2019 and 1.8% in 2018), and North America nearly unchanged (up 0.3% in 2019 and 0.6% in 2018). In Africa, and after a decade of vigorous growth worth an annual average 5.4% since 2010, capacity growth was limited to 0.9%, up just 2 GW.

**RES including biomass represented three-quarters of additional power capacity in 2019, with 176 GW coming on stream (up 7.6%).** Their share in the world electricity mix is now 34%, with over 2,535 GW installed. Benefitting from lower technology costs and ambitious environmental policies, solar and wind power made up 90% of the additional capacity, at +97 GW (up 21%) and +59 GW (up 11%), respectively.

China maintained its leading position in the solar sector with an additional 30 GW in 2019, despite fewer new PV installations (+17.4% in 2019 versus +33.7% in 2018) on the back of subsidy-related uncertainty. Including the 26 GW of wind power that came on stream in 2019, the country's RES capacity rose to 771 GW, representing 31% of the world total.

In Europe, solar capacity growth was a record 13.5% (+17 GW) in 2019. Wind capacity also rose sharply, by 14 GW (up 7.2%), driven by the connection of nearly 3.6 GW additional offshore capacity in the UK, Germany and Belgium (source: WindEurope).

Similarly, RES capacity rose significantly throughout the American continent, notably in the USA (up 6%), where the development of wind power accelerated (+9 GW; up 9.5%), and in Brazil, where hydro capacity gained 5 GW and solar capacity doubled.

Despite increases in Egypt (+25,5%) and the United Arab Emirates (+217%) - although volumes remain relatively low –, Africa and the fossil fuel producers of the CIS and Middle East did not participate in these trends.

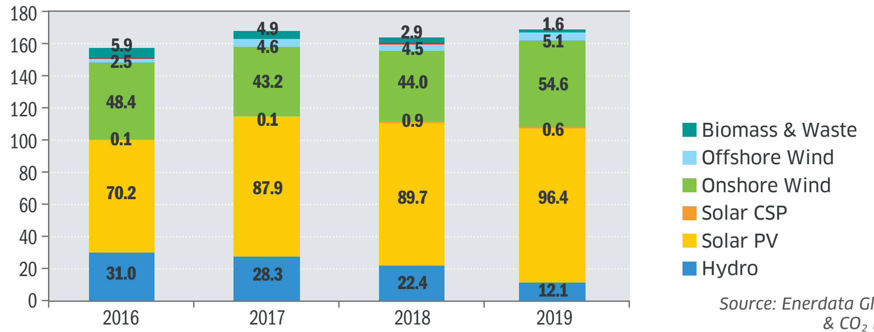
**The pace of RES development should slow in 2020 however;** supply chain disruption and financing issues have already caused construction delays.

According to the IEA, new RES capacity could be 13% lower in 2020 than it was in 2019, with solar PV down 17% and wind down 12%. Despite this downturn, world capacity is set to rise 6% in 2020 before resuming its previous rhythm, notably with two hydro mega-projects partially coming on stream in China.

Given the impact of Covid-19 on power investments (see Chapter 1, Energy investments), RES should suffer less than fossil fuels and remain largely prominent in terms of new power capacity in 2020.



### ANNUAL INCREASE IN GLOBAL ELECTRICAL RES CAPACITY BY SOURCE (IN GW)




*Source: Enerdata Global Energy & $CO_2$ Data (2020)*

# Electricity: production capacity

**Additional natural gas capacity slowed abruptly to just 1% in 2019, well below the 4% annual average recorded since 2000.** This represents an additional 17 GW worldwide, compared to 45 GW in 2018, for a total gas-fired capacity of 1,713 GW (23% of power capacity). The main contributors to the past few years' expansion, the US (+4 GW), the Middle East (+3 GW) and Africa (+2 GW) saw much weaker progressions in 2019 than in 2018. Led by Mexico (+3.2 GW), Latin America posted the biggest rise (up 5%).

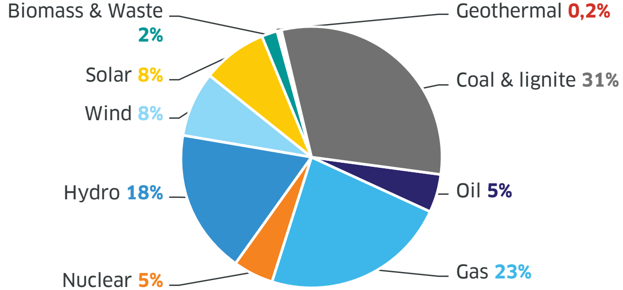
**Coal-fired capacity is now growing at a much slower pace than it was in the 2000s:** up 1.6% in 2019, 1.4% in 2018 and 2% in 2017, against an annual average 3% over the two previous decades.

Asia hosts 90% of the world's coal-fired power plants aged under 20 and is the only region reporting substantial new capacity. Its additional 55 GW (up 3.5%) mainly come from China (+46 GW; up 4.1%). Africa, up 1.7%, and Latin America, up 1.6%, are far behind. In Europe, energy transition policies are proving effective: coal capacity contracted 4%, and this momentum should strengthen given Germany's intention to exit coal by 2038. Similarly, coal-fired capacity contracted 14 GW (5.3%) in the US, as low gas prices sharpened competition.

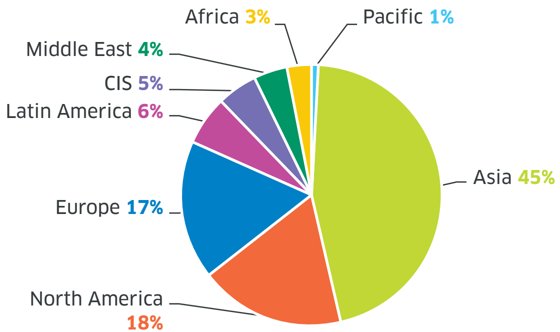
However, despite an increasing number of early shutdown plans and new project cancellations worldwide (Australia, Indonesia, South Africa), over 130 GW of capacity was under construction in early 2020 and an additional 500 GW were in planning stage (of which 180 GW in China and 100 GW in India), according to the IEA.

**Nuclear power capacity dropped 4.5 GW (0.9%) in 2019, after five years of steady growth (1.5% per year on average between 2014 and 2018).** The addition of 4 GW in China was not enough to offset the shutdown of 13 reactors, five of which in Japan, not counting the final decommissioning of the Fessenheim plant in France in June 2020. Nuclear capacity expansion is set to resume, however, since 54 reactors (57.4 GW), 35 of which in Asia (36.5 GW), are currently under construction in 19 countries (source: IAEA).

**SHARE OF GENERATING CAPACITY BY ENERGY IN 2019**
**TOTAL: 7,399 GW**




**SHARE OF GENERATING CAPACITY BY GEOGRAPHIC REGION IN 2019**
**TOTAL: 7,399 GW**




*Source: Enerdata Global Energy & $CO_2$ Data (2020)*

# Electricity: generating capacity by power station type

| Installed electricity generation capacity (GW) | Total capacity | | | Thermal capacity | | | | Nuclear capacity | | | | Renewable capacity (excluding biomass) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2019 | Change 2018-2019 | 2000 | 2019 | Change 2018-2019 | Share in area total 2019 | 2000 | 2019 | Change 2018-2019 | Share in area total 2019 | 2000 | 2019 | Change 2018-2019 | Share in area total 2019 |
| Europe | 800 | 1,226 | 2.2% | 442 | 514 | -0.9% | 42% | 141 | 122 | -1% | 10% | 217 | 591 | 5.6% | 48% |
| European Union | 709 | 1,053 | 2% | 416 | 453 | -1.5% | 43% | 138 | 119 | -0.7% | 11% | 154 | 481 | 6.3% | 46% |
| Germany | 119 | 223 | 2.1% | 81 | 91 | -1.5% | 41% | 22 | 11 | 0% | 5% | 16 | 121 | 5.1% | 54% |
| France | 115 | 135 | 1.7% | 26 | 21 | 0.5% | 15% | 63 | 63 | 0% | 47% | 25 | 52 | 4.9% | 38% |
| North America | 958 | 1,343 | 0.3% | 666 | 882 | -1.1% | 66% | 118 | 116 | -1.4% | 9% | 174 | 345 | 4.6% | 26% |
| Canada | 111 | 147 | 0.9% | 33 | 36 | 1.1% | 24% | 10 | 14 | 0% | 9% | 68 | 97 | 0.9% | 66% |
| United States | 847 | 1,197 | 0.2% | 633 | 847 | -1.2% | 71% | 108 | 103 | -1.6% | 9% | 106 | 247 | 6.1% | 21% |
| Latin America | 222 | 459 | 5.7% | 93 | 213 | 5.1% | 46% | 4 | 5 | 0% | 1% | 125 | 241 | 6.3% | 53% |
| Brazil | 74 | 172 | 5.4% | 11 | 41 | 1.7% | 24% | 2 | 2 | 0% | 1% | 61 | 129 | 6.7% | 75% |
| Asia | 932 | 3,321 | 4.6% | 673 | 2,074 | 2.7% | 62% | 69 | 116 | 0% | 3% | 190 | 1,131 | 8.8% | 34% |
| China | 336 | 2,054 | 5.7% | 254 | 1,235 | 3.9% | 60% | 2 | 49 | 9.1% | 2% | 80 | 771 | 8.4% | 38% |
| South Korea | 49 | 121 | 3.1% | 32 | 79 | -1.7% | 65% | 14 | 23 | 6.4% | 19% | 3 | 19 | 23.3% | 15% |
| India | 114 | 399 | 3.3% | 87 | 270 | 0.6% | 68% | 3 | 7 | 0% | 2% | 25 | 121 | 10.1% | 30% |
| Japan | 259 | 342 | 0.8% | 167 | 194 | 0.5% | 57% | 45 | 32 | -13.2% | 9% | 47 | 116 | 5.7% | 34% |
| CIS | 329 | 411 | 1.8% | 234 | 284 | 0.3% | 69% | 32 | 42 | -1.7% | 10% | 64 | 86 | 9.3% | 21% |
| Russia | 211 | 272 | 1.2% | 147 | 190 | 0% | 70% | 20 | 30 | 4.1% | 11% | 44 | 52 | 3.8% | 19% |
| Middle East | 118 | 323 | 2% | 111 | 300 | 1.3% | 93% | 0 | 1 | 0% | 0% | 7 | 22 | 12.7% | 7% |
| Saudi Arabia | 31 | 86 | 0% | 31 | 85 | -0.5% | 99% | 0 | 0 | - | 0% | 0 | 0.4 | 300% | 0% |
| Iran | 33 | 80 | 2.2% | 31 | 67 | 2.1% | 83% | 0 | 1 | 0% | 1% | 2 | 13 | 2.4% | 16% |
| Africa | 102 | 227 | 0.9% | 78 | 178 | 1.3% | 78% | 2 | 2 | 0% | 1% | 22 | 47 | -0.2% | 21% |
| Egypt | 15 | 57 | 2% | 12 | 52 | 0% | 90% | 0 | 0 | - | 0% | 3 | 6 | 25.5% | 10% |
| South Africa | 42 | 51 | 1.7% | 38 | 41 | 2% | 80% | 2 | 2 | 0% | 4% | 2 | 9 | 1.2% | 17% |
| Pacific | 55 | 89 | 7.5% | 40 | 49 | 0.2% | 55% | 0 | 0 | - | 0% | 15 | 40 | 18.6% | 45% |
| Australia | 46 | 78 | 8.5% | 37 | 46 | 0% | 59% | 0 | 0 | - | 0% | 9 | 32 | 23.6% | 41% |
| World | 3,516 | 7,399 | 3.1% | 2,337 | 4,493 | 1.3% | 61% | 366 | 403 | -0.9% | 5% | 813 | 2,503 | 7.2% | 34% |
| OECD | 2,118 | 3,181 | 1.6% | 1,355 | 1,777 | -0.5% | 56% | 313 | 291 | -2.1% | 9% | 450 | 1,114 | 6.4% | 35% |
| No OECD | 1,398 | 4,218 | 4.2% | 982 | 2,717 | 2.5% | 64% | 53 | 112 | 2.5% | 3% | 363 | 1,389 | 7.9% | 33% |

*Source: Enerdata Global Energy & CO2 Data (2020)*

# Electricity: detail of thermal capacities

| Detail of installed thermal capacity (GW) | Total Thermal capacity | | | Coal & Lignite capacity | | | | Oil capacity | | | | Gas capacity | | | | Biomass & Waste capacity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2019 | Change 2018-2019 | 2000 | 2019 | Change 2018-2019 | Share in area thermal total 2019 | 2000 | 2019 | Change 2018-2019 | Share in area thermal total 2019 | 2000 | 2019 | Change 2018-2019 | Share in area thermal total 2019 | 2000 | 2019 | Change 2018-2019 | Share in area thermal total 2019 |
| Europe | 442 | 514 | -0.9% | 208 | 189 | -3.3% | 37% | 87 | 39 | 2% | 8% | 137 | 240 | 0.3% | 47% | 10 | 46 | 1.4% | 9% |
| European Union | 416 | 453 | -1.5% | 192 | 160 | -4.1% | 35% | 84 | 38 | 1% | 8% | 130 | 211 | -0.2% | 47% | 10 | 45 | 0.3% | 10% |
| Germany | 81 | 91 | -1.5% | 52 | 51 | -2% | 56% | 7 | 3 | 0% | 3% | 20 | 27 | -1.4% | 29% | 2 | 11 | 0.6% | 12% |
| France | 26 | 21 | 0.5% | 3 | 3 | 0% | 14% | 17 | 3 | -2.8% | 16% | 6 | 12 | 0.4% | 59% | 1 | 2 | 3.7% | 10% |
| North America | 666 | 882 | -1.1% | 332 | 260 | -5.1% | 29% | 56 | 43 | -0.7% | 5% | 263 | 561 | 0.9% | 64% | 14 | 19 | -2.1% | 2% |
| Canada | 33 | 36 | 1.1% | 18 | 11 | 0% | 30% | 8 | 6 | 0% | 17% | 7 | 16 | 2.9% | 44% | 1 | 3 | 0% | 10% |
| United States | 633 | 847 | -1.2% | 315 | 249 | -5.3% | 29% | 49 | 37 | -0.9% | 4% | 257 | 546 | 0.8% | 64% | 13 | 15 | -2.6% | 2% |
| Latin America | 93 | 213 | 5.1% | 11 | 23 | 1.6% | 11% | 42 | 64 | 7.8% | 30% | 36 | 105 | 5.1% | 49% | 3 | 21 | 1.6% | 10% |
| Brazil | 11 | 41 | 1.7% | 2 | 5 | 7.4% | 12% | 5 | 8 | -1.3% | 19% | 1 | 13 | 1.9% | 32% | 2 | 15 | 1.6% | 36% |
| Asia | 673 | 2,074 | 2.7% | 412 | 1,638 | 3.5% | 79% | 130 | 106 | -2.1% | 5% | 127 | 297 | 0.4% | 14% | 4 | 34 | 3.3% | 2% |
| China | 254 | 1,235 | 3.9% | 225 | 1,163 | 4.1% | 94% | 20 | 15 | 0% | 1% | 8 | 48 | 2.2% | 4% | 1 | 9 | 0% | 1% |
| South Korea | 32 | 79 | -1.7% | 14 | 37 | 0.7% | 47% | 5 | 3 | 0% | 4% | 13 | 36 | -4.5% | 46% | 1 | 3 | 6.9% | 3% |
| India | 87 | 270 | 0.6% | 71 | 228 | 0.5% | 84% | 5 | 4 | -3.1% | 1% | 10 | 28 | 0% | 11% | 0 | 10 | 8.6% | 4% |
| Japan | 167 | 194 | 0.5% | 61 | 91 | 0.1% | 47% | 61 | 38 | -0.9% | 20% | 42 | 57 | 2.1% | 29% | 2 | 8 | 0% | 4% |
| CIS | 234 | 284 | 0.3% | 79 | 74 | -0.5% | 26% | 24 | 27 | 2.6% | 9% | 130 | 183 | 0.3% | 64% | 1 | 1 | 0% | 0% |
| Russia | 147 | 190 | 0% | 42 | 42 | -0.8% | 22% | 16 | 16 | 0% | 8% | 88 | 132 | 0.3% | 69% | 1 | 1 | 0% | 0% |
| Middle East | 111 | 300 | 1.3% | 4 | 5 | 0% | 2% | 49 | 90 | 0.5% | 30% | 58 | 205 | 1.7% | 68% | 0 | 0 | 0% | 0% |
| Saudi Arabia | 31 | 85 | -0.5% | 0 | 0 | - | 0% | 18 | 46 | -0.7% | 54% | 13 | 39 | 0% | 46% | 0 | 0 | - | 0% |
| Iran | 31 | 67 | 2.1% | 0 | 0 | - | 0% | 9 | 15 | 0% | 22% | 23 | 52 | 2.9% | 78% | 0 | 0 | 0% | 0% |
| Africa | 78 | 178 | 1.3% | 41 | 45 | 1.7% | 25% | 13 | 29 | -0.9% | 16% | 24 | 103 | 1.7% | 58% | 0.2 | 1 | 0% | 1% |
| Egypt | 12 | 52 | 0% | 0 | 0 | - | 0% | 2 | 5 | 0% | 10% | 10 | 47 | 0% | 90% | 0 | 0 | - | 0% |
| South Africa | 38 | 41 | 2% | 38 | 38 | 2% | 92% | 0.3 | 3 | 0% | 7% | 0 | 0 | - | 0% | 0.1 | 0.2 | 0% | 0% |
| Pacific | 40 | 49 | 0.2% | 28 | 25 | 0% | 52% | 4 | 3 | 3.6% | 6% | 8 | 20 | 0% | 40% | 1 | 1 | 0% | 2% |
| Australia | 37 | 46 | 0% | 27 | 25 | 0% | 55% | 4 | 2 | 0% | 4% | 6 | 18 | 0% | 40% | 0.4 | 1 | 0% | 2% |
| World | 2,337 | 4,493 | 1.3% | 1,115 | 2,258 | 1.6% | 50% | 407 | 399 | 0.9% | 9% | 783 | 1,713 | 1% | 38% | 33 | 123 | 1.3% | 3% |
| OECD | 1,355 | 1,777 | -0.5% | 635 | 605 | -3.1% | 34% | 222 | 141 | 0.4% | 8% | 469 | 953 | 1% | 54% | 28 | 78 | 0.5% | 4% |
| No OECD | 982 | 2,717 | 2.5% | 479 | 1,654 | 3.4% | 61% | 184 | 258 | 1.2% | 10% | 314 | 760 | 1% | 28% | 5 | 45 | 2.7% | 2% |

*Source: Enerdata Global Energy & CO2 Data (2020)*

# Electricity: detail of renewable capacities

| Detail of installed renewable capacity (GW) | Total Renewable capacity (excluding biomass) | | | Hydro capacity | | | | Wind capacity | | | | Solar capacity | | | | Geothermal capacity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2019 | Change 2018-2019 | 2000 | 2019 | Change 2018-2019 | Share in area renewable total 2019 | 2000 | 2019 | Change 2018-2019 | Share in area renewable total 2019 | 2000 | 2019 | Change 2018-2019 | Share in area renewable total 2019 | 2000 | 2019 | Change 2018-2019 | Share in area renewable total 2019 |
| Europe | 217 | 591 | 5.6% | 203 | 244 | 0.3% | 41% | 13 | 204 | 7.4% | 34% | 0.2 | 140 | 13.5% | 24% | 1 | 3 | 8.2% | 1% |
| European Union | 154 | 481 | 6.3% | 141 | 155 | 0.3% | 32% | 13 | 193 | 7% | 40% | 0.2 | 132 | 13.2% | 27% | 1 | 1 | 0.7% | 0% |
| Germany | 16 | 121 | 5.1% | 10 | 11 | 0% | 9% | 6 | 61 | 3.4% | 50% | 0.1 | 49 | 8.7% | 41% | 0 | 0 | 18.8% | 0% |
| France | 25 | 52 | 4.9% | 25 | 26 | 0.1% | 50% | 0 | 17 | 9% | 32% | 0 | 9 | 10.4% | 18% | 0 | 0 | 0% | 0% |
| North America | 174 | 345 | 4.6% | 168 | 182 | 0% | 53% | 3 | 118 | 8.9% | 34% | 0.4 | 41 | 15.5% | 12% | 3 | 4 | -0.1% | 1% |
| Canada | 68 | 97 | 0.9% | 67 | 81 | 0.1% | 83% | 0.1 | 13 | 4.7% | 14% | 0 | 3 | 6.6% | 3% | 0 | 0 | - | 0% |
| United States | 106 | 247 | 6.1% | 100 | 102 | -0.1% | 41% | 2 | 104 | 9.5% | 42% | 0.4 | 38 | 16.4% | 15% | 3 | 4 | -0.1% | 2% |
| Latin America | 125 | 241 | 6.3% | 123 | 197 | 3% | 81% | 0.1 | 30 | 17.5% | 12% | 0 | 15 | 54.6% | 6% | 1 | 1 | -53.4% | 0% |
| Brazil | 61 | 129 | 6.7% | 61 | 109 | 4.8% | 85% | 0 | 15 | 6.9% | 12% | 0 | 4 | 93.6% | 3% | 0 | 0 | - | 0% |
| Asia | 190 | 1,131 | 8.8% | 185 | 540 | 1.1% | 48% | 2 | 258 | 12.7% | 23% | 0.4 | 328 | 20.9% | 29% | 3 | 5 | 5.1% | 0% |
| China | 80 | 771 | 8.4% | 79 | 356 | 1.1% | 46% | 0.3 | 210 | 14% | 27% | 0.1 | 205 | 17.4% | 27% | 0 | 0 | 0% | 0% |
| South Korea | 3 | 19 | 23.3% | 3 | 7 | 0.3% | 35% | 0 | 2 | 6.4% | 8% | 0 | 11 | 47.3% | 57% | 0 | 0 | - | 0% |
| India | 25 | 121 | 10.1% | 24 | 50 | 0.3% | 41% | 1 | 38 | 6.7% | 31% | 0 | 34 | 33.8% | 28% | 0 | 0 | - | 0% |
| Japan | 47 | 116 | 5.7% | 46 | 50 | 0% | 43% | 0 | 4 | 1% | 3% | 0.3 | 62 | 11.4% | 53% | 1 | 1 | 9.1% | 0% |
| CIS | 64 | 86 | 9.3% | 64 | 77 | 2.1% | 90% | 0 | 2 | 94.8% | 2% | 0 | 7 | 221.6% | 8% | 0 | 0 | 0% | 0% |
| Russia | 44 | 52 | 3.8% | 44 | 50 | 2.8% | 97% | 0 | 0 | 96.2% | 0% | 0 | 1 | 98.9% | 2% | 0 | 0 | 0% | 0% |
| Middle East | 7 | 22 | 12.7% | 7 | 16 | 1% | 73% | 0 | 1 | 1.5% | 3% | 0 | 5 | 72% | 24% | 0 | 0 | - | 0% |
| Saudi Arabia | 0 | 0.4 | 300% | 0 | 0 | - | 0% | 0 | 0 | 0% | 0% | 0 | 0.4 | 369% | 100% | 0 | 0 | - | 0% |
| Iran | 2 | 13 | 2.4% | 2 | 12 | 1.3% | 94% | 0 | 0 | 7.1% | 2% | 0 | 0.4 | 28.3% | 3% | 0 | 0 | - | 0% |
| Africa | 22 | 47 | -0.2% | 22 | 34 | -5.2% | 71% | 0.1 | 6 | 5.5% | 12% | 0 | 7 | 21.8% | 15% | 0 | 1 | 23.9% | 2% |
| Egypt | 3 | 6 | 25.5% | 3 | 3 | 0% | 47% | 0 | 1 | 22.2% | 24% | 0 | 2 | 116.3% | 29% | 0 | 0 | - | 0% |
| South Africa | 2 | 9 | 1.2% | 2 | 3 | 0% | 40% | 0 | 2 | 0% | 24% | 0 | 3 | 3.4% | 36% | 0 | 0 | - | 0% |
| Pacific | 15 | 40 | 18.6% | 15 | 15 | 0.1% | 37% | 0.1 | 8 | 22.3% | 20% | 0 | 16 | 40.7% | 41% | 0 | 1 | 0% | 3% |
| Australia | 9 | 32 | 23.6% | 9 | 9 | 0.1% | 27% | 0 | 7 | 25% | 23% | 0 | 16 | 40.9% | 50% | 0 | 0 | - | 0% |
| World | 813 | 2,503 | 7.2% | 786 | 1 304 | 0.9% | 52% | 17 | 625 | 10.6% | 25% | 1 | 559 | 21% | 22% | 9 | 14 | -1.6% | 1% |
| OECD | 450 | 1,114 | 6.4% | 428 | 493 | 0.2% | 44% | 16 | 337 | 8.9% | 30% | 1 | 275 | 16.6% | 25% | 6 | 9 | -7% | 1% |
| No OECD | 363 | 1,389 | 7.9% | 358 | 812 | 1.4% | 58% | 2 | 287 | 12.6% | 21% | 0.1 | 284 | 25.5% | 20% | 3 | 6 | 7.3% | 0% |

*Source: Enerdata Global Energy & $CO_2$ Data (2020)*

# Electricity: generating capacity – long series

| GW | Installed electrical capacity | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2005 | 2010 | 2015 | 2018 | 2019 | Change 2018-2019 | AAGR 2010-2019 | Share of world 2019 |
| Europe | 800 | 866 | 1,012 | 1,140 | 1,200 | 1,226 | 2.2% | 2.2% | 17% |
| European Union | 709 | 763 | 892 | 991 | 1,032 | 1,053 | 2% | 1.9% | 14% |
| Germany | 119 | 128 | 162 | 203 | 219 | 223 | 2.1% | 3.6% | 3% |
| Spain | 55 | 77 | 102 | 107 | 107 | 113 | 5.6% | 1.1% | 2% |
| France | 115 | 116 | 124 | 129 | 133 | 135 | 1.7% | 1% | 2% |
| Italy | 76 | 86 | 107 | 117 | 115 | 117 | 1.5% | 1% | 2% |
| United Kingdom | 78 | 82 | 94 | 96 | 106 | 107 | 0.2% | 1.5% | 1% |
| North America | 958 | 1,186 | 1,275 | 1,309 | 1,340 | 1,343 | 0.3% | 0.6% | 18% |
| Canada | 111 | 122 | 131 | 142 | 145 | 147 | 0.9% | 1.3% | 2% |
| United States | 847 | 1,064 | 1,144 | 1,168 | 1,194 | 1,197 | 0.2% | 0.5% | 16% |
| Latin America | 222 | 263 | 315 | 382 | 434 | 459 | 5.7% | 4.3% | 6% |
| Brazil | 74 | 93 | 113 | 143 | 163 | 172 | 5.4% | 4.8% | 2% |
| Mexico | 42 | 52 | 62 | 67 | 76 | 83 | 8.3% | 3.3% | 1% |
| Asia | 932 | 1,226 | 1,834 | 2,633 | 3,174 | 3,321 | 4.6% | 6.8% | 45% |
| China | 336 | 531 | 1,012 | 1,564 | 1,944 | 2,054 | 5.7% | 8.2% | 28% |
| South Korea | 49 | 64 | 77 | 96 | 117 | 121 | 3.1% | 5.1% | 2% |
| India | 114 | 143 | 202 | 318 | 386 | 399 | 3.3% | 7.9% | 5% |
| Japan | 259 | 276 | 286 | 320 | 339 | 342 | 0.8% | 2% | 5% |
| Pacific | 55 | 60 | 73 | 80 | 83 | 89 | 7.5% | 2.3% | 1% |
| Australia | 46 | 50 | 62 | 69 | 72 | 78 | 8.5% | 2.6% | 1% |
| Middle East | 118 | 148 | 217 | 298 | 317 | 323 | 2% | 4.5% | 4% |
| Saudi Arabia | 31 | 39 | 60 | 82 | 86 | 86 | 0% | 4.1% | 1% |
| Iran | 33 | 44 | 61 | 73 | 79 | 80 | 2.2% | 3% | 1% |
| CIS | 329 | 337 | 357 | 393 | 404 | 411 | 1.8% | 1.6% | 6% |
| Russia | 211 | 216 | 231 | 259 | 269 | 272 | 1.2% | 1.8% | 4% |
| Africa | 102 | 117 | 142 | 185 | 225 | 227 | 0.9% | 5.4% | 3% |
| Egypt | 15 | 20 | 27 | 36 | 56 | 57 | 2% | 9% | 1% |
| South Africa | 42 | 43 | 45 | 48 | 51 | 51 | 1.7% | 1.5% | 1% |
| World | 3,516 | 4,202 | 5,224 | 6,420 | 7,176 | 7,399 | 3.1% | 3.9% | 100% |
| OECD | 2,118 | 2,464 | 2,751 | 2,981 | 3,130 | 3,181 | 1.6% | 1.6% | 43% |
| No-OECD | 1,398 | 1,737 | 2,473 | 3,439 | 4,046 | 4,218 | 4.2% | 6.1% | 57% |

*Source: Enerdata Global Energy & $CO_2$ Data (2020)*

# Electricity: consumption

## Already weakened by the 2019 economic slowdown, world electricity consumption contracted sharply in 2020 because of Covid-19

**In 2019, electricity demand broke its uptrend and decelerated sharply. Slower economic growth and warmer temperatures in several major countries limited the increase in electricity consumption to 0.7% that year, compared with growth worth 3.7% in 2018 and 2.5% per year over the previous decade.** In China, which accounted for 28% of the world total, demand remained vigorous, but the 4.5% increase was noticeably weaker than in 2018 (8.5%). The picture was similar in other developing countries, where a combination of increased industrial production, higher revenues and an expanding service sector drove albeit slower growth. All in all, nearly 78% of the additional demand since 2010 is attributable to BRICS alone (Source: Enerdata). In the OECD countries, a stagnation in consumption resulting from improved energy efficiency over recent years turned into outright decline (-1.9%), with lower demand from the industrial and residential sectors. OECD countries' share in world electricity demand has dropped to 42%, against 56% in 2000.

Worldwide, buildings (residential and services) represent 51% of final electricity consumption (11,910 TWh). Industry accounts for 41% (9,380 TWh). Despite higher numbers of electrical vehicles (1.52 million new units on the road in 2019; up 46%), transport still accounts for less than 2% of total demand.

**The Covid-19 pandemic and the lockdown measures that followed completely derailed electricity demand in 2020. It dropped 2.5% over the first quarter and will be down 5% over the whole year, according to IEA's early estimates.** This would be a decline eight times bigger than that caused by the 2008 economic crisis and would be the deepest plunge since the Great Depression in 1929. According to the IEA, each month of complete lockdown reduces demand by 20% on average, or by 1.5% per year.

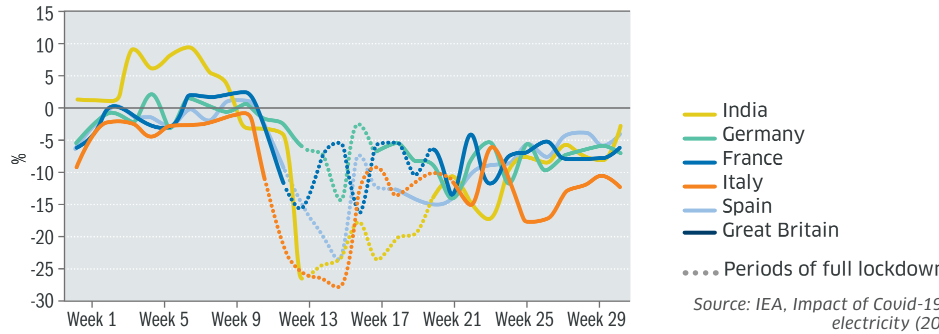
China was first country to be hit and recorded the largest decrease in electricity demand over the first quarter, at -6.5%. The impact proved more limited in other regions, where restrictions were introduced more gradually: declines ranged from 2.5% to 4.5% in Europe, Japan and South Korea. At the height of the crisis, France, India and the USA saw daily electricity consumption drop almost 15%.

At sector level, the massive reduction in commercial and industrial demand was only partially offset by an increase in residential consumption as more people stayed at home and worked from there (the rise in residential demand exceeded 40% by the end of March in some European countries). Lockdown also coincided with unseasonably warm weather. Economies heavily dependent on services (retailing, tourism, etc.) were hit particularly hard. This was especially true of Italy, where the impact on electricity has been the most severe in Europe (up to 75% drops in average electricity demand on weekdays in the service sector compared to the same period last year). In the USA, closures of business premises and reduced use of offices and plants is expected to translate into a 3.6% contraction in electricity consumption over 2020, according to the Energy Information Administration.

Although the easing of lockdown measures produced signs of recovery, electricity demand in June was still 10% below its pre-crisis levels in most regions (source: IEA).



### YEAR-ON-YEAR CHANGE IN WEEKLY ELECTRICITY DEMAND, WEATHER CORRECTED (2020)




*Source: IEA, Impact of Covid-19 on electricity (2020)*

# Electricity: consumption

| Electricity consumption TWh | Total consumption | | | | | | | Residential 2019 | | Services 2019 | | Industry 2019 | | Transport 2019 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2010 | 2018 | 2019 | Change 2018-2019 | AAGR 2010-2019 | Share in area total | TWh | Share in area total | TWh | Share in area total | TWh | Share in area total | TWh | Share in area total |
| Europe | 2,952 | 3,376 | 3,410 | 3,358 | -1.5% | -0.1% | 15% | 941 | 28% | 951 | 28% | 1,225 | 36% | 68 | 2% |
| European Union | 2,637 | 2,949 | 2,892 | 2,850 | -1.4% | -0.4% | 12% | 799 | 28% | 823 | 29% | 1,013 | 36% | 63 | 2% |
| Germany | 501 | 547 | 525 | 517 | -1.5% | -0.6% | 2% | 129 | 25% | 141 | 27% | 217 | 42% | 12 | 2% |
| Spain | 195 | 250 | 243 | 239 | -1.5% | -0.5% | 1% | 69 | 29% | 73 | 31% | 79 | 33% | 5 | 2% |
| France | 410 | 472 | 441 | 437 | -1.1% | -0.9% | 2% | 158 | 36% | 138 | 32% | 115 | 26% | 10 | 2% |
| Italy | 279 | 310 | 303 | 301 | -0.8% | -0.3% | 1% | 65 | 22% | 94 | 31% | 115 | 38% | 11 | 4% |
| United Kingdom | 340 | 338 | 308 | 303 | -1.7% | -1.2% | 1% | 104 | 34% | 91 | 30% | 92 | 30% | 5 | 2% |
| North America | 4,093 | 4,439 | 4,496 | 4,408 | -2.0% | -0.1% | 19% | 1,595 | 36% | 1,670 | 38% | 941 | 21% | 13 | 0.3% |
| Canada | 503 | 544 | 543 | 543 | 0.1% | 0% | 2% | 170 | 31% | 146 | 27% | 181 | 33% | 1 | 0.2% |
| United States | 3,590 | 3,894 | 3,953 | 3,865 | -2.2% | -0.1% | 17% | 1,425 | 37% | 1,524 | 39% | 760 | 20% | 11 | 0.3% |
| Latin America | 787 | 1,129 | 1,360 | 1,376 | 1.2% | 2.2% | 6% | 377 | 27% | 335 | 24% | 573 | 42% | 5 | 0.4% |
| Brazil | 329 | 459 | 528 | 536 | 1.6% | 1.7% | 2% | 140 | 26% | 140 | 26% | 201 | 37% | 2 | 0.4% |
| Mexico | 148 | 221 | 295 | 307 | 4.1% | 3.7% | 1% | 66 | 21% | 59 | 19% | 164 | 53% | 1 | 0.4% |
| Asia | 3,374 | 6,886 | 10,446 | 10,716 | 2.6% | 5% | 46% | 2,145 | 20% | 2,175 | 20% | 5,568 | 52% | 186 | 2% |
| China | 1,138 | 3,626 | 6,230 | 6,510 | 4.5% | 6.7% | 28% | 1,058 | 16% | 1,159 | 18% | 3,813 | 59% | 146 | 2% |
| South Korea | 263 | 458 | 560 | 553 | -1.2% | 2.1% | 2% | 70 | 13% | 169 | 31% | 278 | 50% | 3 | 1% |
| India | 376 | 729 | 1,227 | 1,230 | 0.3% | 6% | 5% | 304 | 25% | 201 | 16% | 491 | 40% | 15 | 1% |
| Japan | 986 | 1,051 | 960 | 918 | -4.3% | -1.5% | 4% | 256 | 28% | 303 | 33% | 325 | 35% | 16 | 2% |
| Moyen Orient | 400 | 742 | 982 | 989 | 0.7% | 3.2% | 4% | 405 | 41% | 303 | 31% | 206 | 21% | 0.5 | 0.0% |
| Saudi Arabia | 114 | 212 | 290 | 289 | -0.3% | 3.5% | 1% | 129 | 45% | 108 | 38% | 36 | 12% | 0 | 0% |
| Iran | 96 | 188 | 258 | 258 | 0.2% | 3.6% | 1% | 84 | 33% | 49 | 19% | 82 | 32% | 0.5 | 0.2% |
| CIS | 984 | 1,197 | 1,286 | 1,284 | -0.1% | 0.8% | 6% | 273 | 21% | 223 | 17% | 498 | 39% | 71 | 6% |
| Russia | 693 | 851 | 918 | 922 | 0.4% | 0.9% | 4% | 173 | 19% | 166 | 18% | 352 | 38% | 58 | 6% |
| Africa | 379 | 554 | 690 | 692 | 0.2% | 2.5% | 3% | 227 | 33% | 136 | 20% | 272 | 39% | 6 | 1% |
| Egypt | 64 | 124 | 163 | 163 | 0.6% | 3.1% | 1% | 70 | 43% | 40 | 24% | 45 | 28% | 1 | 0.4% |
| South Africa | 190 | 214 | 208 | 204 | -1.9% | -0.5% | 1% | 38 | 19% | 29 | 14% | 115 | 56% | 4 | 2% |
| Pacific | 218 | 266 | 279 | 282 | 1.1% | 0.7% | 1% | 73 | 26% | 81 | 29% | 96 | 34% | 6 | 2% |
| Australia | 180 | 221 | 232 | 235 | 1.1% | 0.7% | 1% | 60 | 26% | 70 | 30% | 78 | 33% | 6 | 3% |
| World | 13,187 | 18,588 | 22,948 | 23,104 | 0.7% | 2.4% | 100% | 6,036 | 26% | 5,874 | 25% | 9,380 | 41% | 356 | 2% |

*Source: Enerdata Global Energy & $CO_2$ Data (2020)*

# Electricity: generation

## Slower world generation has bolstered the share of RES in the electricity mix

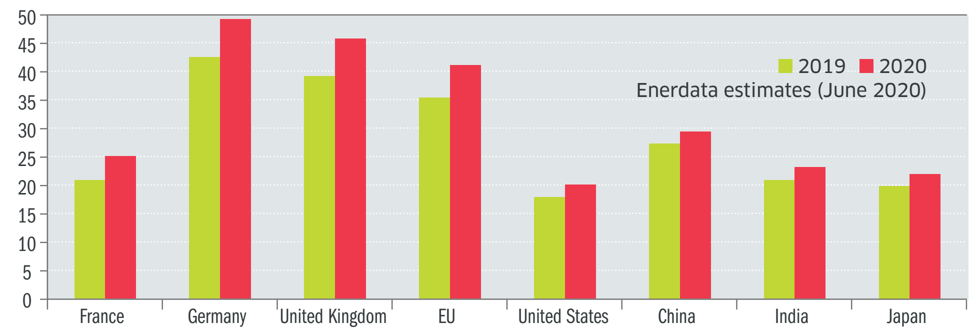
**After many years of robust progression (3% per year over 2000-2018), power generation decelerated noticeably to a meagre 1% gain in 2019, reflecting the drop in demand due to milder weather conditions and slower economic growth.** China kept the lead, recording a 4.7% increase, ahead of Brazil (2.2%) and Russia (0.9%), while India (0.3%) and Africa (0.5%) stagnated. Amongst OECD countries, virtual flatlining in recent years gave way to contraction in Europe (-1.8%), driven by a sharp fall in Germany (-4.9%), and in North America (-1.2% in the USA).

The downtrend is set to strengthen and broaden over 2020, as the Covid-19 pandemic caused a 2.6% contraction of world electricity production over the first quarter. The drop will near 5% for the whole year, according to IEA projections.

**Shrugging off this environment, RES power generation expanded further in 2019 (up 5.2%),** driven by solar and wind production, up 24% and 12%, respectively, as well as favourable hydro conditions in China, India, Turkey, Russia and Nigeria. RES (including biomass) generated 7,240 TWh, representing 27% of the world electricity mix, up 1.1% compared to 2018. China (+169 TWh) and India (+36 TWh) together made up 57% of the world's additional generation, boosted by solar production, up 31% (+61 TWh) and 25% (+10 TWH) respectively. In OECD countries, RES generation (including biomass) reached over 3,000 TWh (up 3%), widening the gap with coal-fired production, which fell behind for the first time in 2018. In the USA, good wind power results (+25 TWh) spurred RES generation growth (up 2.5%), while Germany's strong 11.5% gain lifted Europe 4.7%.

This trend strengthened during the health crisis, as RES proved particularly resilient (up 3% in the first quarter of 2020). Their share in world electricity supply reached nearly 28% (against 26% in the first quarter of 2019), a mechanical increase explained by their short-term economic preeminence due to lower marginal costs, in a context of slowing demand. By country, RES production increased sharply during the weeks that followed the beginning of lockdown, notably in China and in India, where the pace accelerated respectively from 23% to 28% and from 16.9% to 22% between January and March (source: IEA). All in all, the IEA expects RES generation to rise almost 5% in 2020.

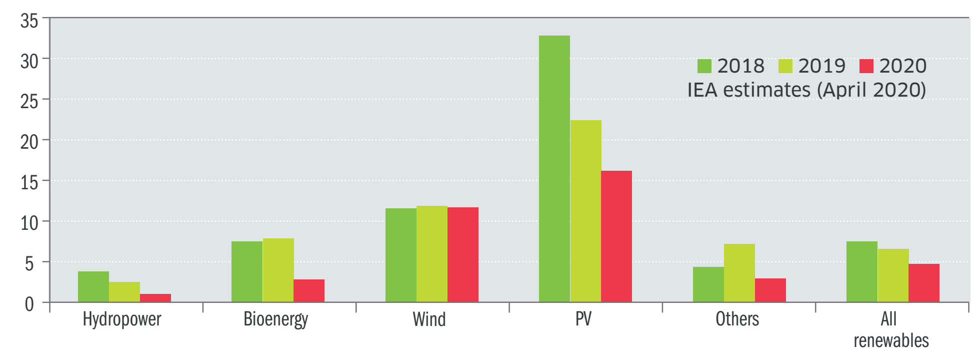
### SHARE OF RENEWABLE SOURCES* IN ELECTRICITY GENERATION BY COUNTRY




* Hydro, wind, solar, geothermal, biomass

*Source: Enerdata, Global Energy Statistical Yearbook 2020 (2 june 2020)*

### ANNUAL GROWTH IN GLOBAL RENEWABLE ELECTRICITY GENERATION BY SOURCE




*Source: IEA, Global Energy review 2020 – Covid-19 impacts on energy and $CO_2$ emissions (28 April 2020)*

# Electricity: generation

**Acknowledged as a major element of flexibility within power systems, natural gas-fired generation progressed 3.2% in 2019 (up 3.8% in 2018) and reached 6,324 TWh, a level three times higher that of 1996.** Boosted by much lower prices, natural gas consolidated its leading position in the OECD's power mix (30%). Its development was particularly marked in the USA, where an additional 117 TWh represented 60% of the world increase, but also in the EU (up 14.8%), where production expanded in 16 of the 27 countries, notably in Spain (+28.2 TWh; up 48.2%), the Netherlands (+13.6 TWh) and France (+10.6 TWh). Production was unchanged in Asia, where the 33 TWh decline recorded in Japan, partly due to the upswing in nuclear generation, entirely offset the rise in China (+34 TWh). Globally, this overall momentum resulted in a further increase in the load factor* of gas-fired power plants, which stood at 42.2% (41.3% in 2018).

Gas-fired power generation has been affected by the pandemic, however. According to IEA forecasts, the contraction will amount to 7% in 2020. The downturn looks particularly sharp in Europe (-20% over the first quarter), where demand decreased markedly in the industrial sector and RES proved resilient. In Italy and the UK, the two largest gas-fired power consuming countries in Europe, production dropped by 25% and 36%, respectively, between early March and end of May (source: IEA). In the USA, where natural gas remains the main power source, continued low gas prices should cushion the fall.

**2019 saw a historical 3.5% decline in coal-fired generation. Its share in the world mix dropped from 38% in 2018 to 36.3%.** Within the OECD, the production was 13.2% lower than in 2018; this was the largest drop ever recorded and reflects higher carbon prices, lower gas prices and plant closures. Apart from the USA (-176 TWh; down 14%), the biggest contractions were recorded in Germany (-59.8 TWh; down 25%) and Spain (-25.8 TWh; down 69.4%) and highlighted European efforts to remove coal from the electricity mix. In India, where it had been expanding by an average 5.8% per year since 2000, coal-fired power production contracted for the first time since 1973, at -3.3%. China, the world's leading producer, also posted a drastic deceleration at up 1.7%. The country's coal-fired plant utilisation rate dropped to 48%, against 54% worldwide (source: Carbon Brief).

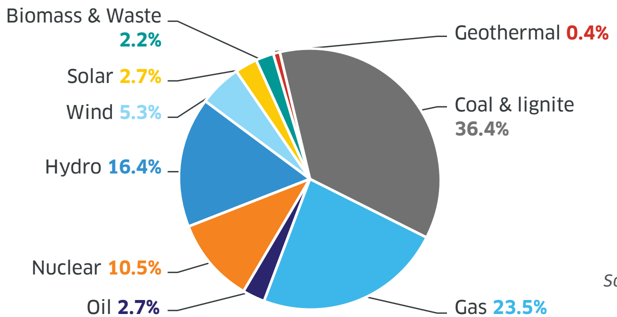
*The load factor of a power plant is the ratio between the energy actually produced over a given period of time and the energy it could have generated by operating at full nameplate capacity during the same period.

The decline in coal-fired electricity production accelerated during the weeks that followed the beginning of lockdown measures (-8% in the first quarter of 2020), driven by China (-100 TWh) and the USA (-33%). With a 10% drop in production in 2020, according to IEA's forecasts, coal is set to be the fuel most affected by Covid-19.

**The rise in nuclear production that started in 2015 continued with a 3.6% increase in 2019 to 2010 pre-Fukushima levels,** driven by further expansion in China (up 18.3%) and upturn in Japan (up 33.2%). Nuclear energy has effectively confirmed its leading position in low-carbon power generation amongst OECD countries, with a 18% share of the mix. It declined 1.7% in Europe, however, as Germany, Belgium and Spain are planning to abandon nuclear energy and France intends to reduce its share to 50% in 2035 (compared to nearly 70% currently).

Despite its overall uptrend, nuclear production did not escape Covid-19 turmoil and dipped 3% over the first quarter of 2020. According to the IEA, the contraction will amount to 2.5% over the year as a result of lower electricity demand and maintenance delays on several reactors.

**SHARE OF ELECTRICY GENERATION BY ENERGY IN 2019**
**TOTAL: 26,868 TWH**




*Source: Enerdata Global Energy & $CO_2$ Data (2020)*

# Electricity: generation by power station type

| Electricity Generation TWh | Total generation | | | Thermal generation | | | | Nuclear generation | | | | Renewable generation (excluding biomass) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2019 | Change 2018-2019 | 2000 | 2019 | Change 2018-2019 | Share in area total 2019 | 2000 | 2019 | Change 2018-2019 | Share in area total 2019 | 2000 | 2019 | Change 2018-2019 | Share in area total 2019 |
| Europe | 3,433 | 3,822 | -1.8% | 1,807 | 1,701 | -6.3% | 45% | 971 | 839 | -1.7% | 22% | 655 | 1,282 | 4.7% | 34% |
| European Union | 3,032 | 3,221 | -1.6% | 1,673 | 1,475 | -4.9% | 46% | 945 | 817 | -1.2% | 25% | 414 | 929 | 3.7% | 29% |
| Germany | 577 | 614 | -4.9% | 372 | 336 | -13.3% | 55% | 170 | 75 | -1.2% | 12% | 36 | 202 | 11.5% | 33% |
| France | 539 | 569 | -2% | 53 | 61 | 4.8% | 11% | 415 | 399 | -3.4% | 70% | 71 | 110 | -0.5% | 19% |
| North America | 4,658 | 5,029 | -1.1% | 3,128 | 2,951 | -2.4% | 59% | 871 | 944 | 0.3% | 19% | 660 | 1,134 | 1.3% | 23% |
| Canada | 606 | 649 | -0.2% | 174 | 134 | 1% | 21% | 73 | 101 | 0.5% | 16% | 359 | 414 | -0.6% | 64% |
| United States | 4,053 | 4,380 | -1.2% | 2,954 | 2,817 | -2.6% | 64% | 798 | 844 | 0.3% | 19% | 301 | 719 | 2.5% | 16% |
| Latin America | 982 | 1,644 | 1.3% | 370 | 727 | -0.6% | 44% | 20 | 37 | -1.6% | 2% | 592 | 880 | 2.9% | 54% |
| Brazil | 349 | 614 | 2.2% | 38 | 147 | 1.7% | 24% | 6 | 16 | 2.8% | 3% | 304 | 451 | 2.3% | 73% |
| Asia | 3,973 | 12,363 | 2.8% | 2,951 | 8,929 | 0.1% | 72% | 505 | 674 | 18.2% | 5% | 517 | 2,760 | 8.8% | 22% |
| China | 1,356 | 7,482 | 4.7% | 1,116 | 5,184 | 2.2% | 69% | 17 | 348 | 18.3% | 5% | 223 | 1,949 | 9.5% | 26% |
| South Korea | 290 | 574 | -1.5% | 176 | 408 | -4.9% | 71% | 109 | 146 | 9.3% | 25% | 6 | 19 | 0% | 3% |
| India | 570 | 1,614 | 0.3% | 477 | 1,282 | -3% | 79% | 17 | 47 | 24.3% | 3% | 76 | 285 | 14.3% | 18% |
| Japan | 1,048 | 987 | -4% | 625 | 739 | -8% | 75% | 322 | 87 | 33.2% | 9% | 101 | 161 | 0.6% | 16% |
| Pacific | 253 | 315 | 0.7% | 207 | 232 | -0.3% | 74% | 0 | 0 | - | 0% | 46 | 83 | 3.9% | 26% |
| CIS | 1,250 | 1,596 | 0.2% | 816 | 1,022 | -0.5% | 64% | 210 | 294 | 1.1% | 18% | 224 | 280 | 1.9% | 18% |
| Russia | 878 | 1,122 | 0.9% | 582 | 712 | 0% | 63% | 131 | 209 | 2.2% | 19% | 166 | 201 | 3.8% | 18% |
| Middle East | 472 | 1,243 | 1.3% | 464 | 1,189 | -0.4% | 96% | 0 | 7 | -6.9% | 1% | 8 | 47 | 81.4% | 4% |
| Saudi Arabia | 126 | 350 | -0.3% | 126 | 349 | -0.5% | 100% | 0 | 0 | - | 0% | 0 | 1 | 400% | 0% |
| Iran | 121 | 315 | 1.4% | 118 | 278 | -2.9% | 88% | 0 | 7 | -6.9% | 2% | 4 | 30 | 79.5% | 9% |
| Africa | 445 | 856 | 0.5% | 354 | 672 | -0.9% | 79% | 13 | 13 | 28.2% | 1% | 78 | 171 | 4.3% | 20% |
| Egypt | 78 | 195 | 0.6% | 64 | 176 | -1% | 90% | 0 | 0 | - | 0% | 14 | 20 | 12.6% | 10% |
| South Africa | 211 | 252 | -1.5% | 194 | 224 | -3% | 89% | 13 | 13 | 28.2% | 5% | 4 | 16 | 1.9% | 6% |
| World | 15,467 | 26,868 | 1% | 10,097 | 17,423 | -1.1% | 65% | 2,591 | 2,808 | 3.6% | 10% | 2,779 | 6,637 | 5.7% | 25% |
| OECD | 9,784 | 11,005 | -1.3% | 6,062 | 6,304 | -4% | 57% | 2,249 | 2,005 | 1.2% | 18% | 1,474 | 2,696 | 3.4% | 24% |
| No-OECD | 5,682 | 15,864 | 2.6% | 4,035 | 11,120 | 0.6% | 70% | 342 | 803 | 10% | 5% | 1,306 | 3,941 | 7.3% | 25% |

*Source: Enerdata Global Energy & $CO_2$ Data (2020)*

# Electricity: detail of thermal generation

| Detail of thermal electricity generation TWh | Total Thermal generation | | | Thermal generation – Coal & lignite | | | | Thermal generation – Oil | | | | Thermal generation – Gas | | | | Thermal generation – Biomass & Waste | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2019 | Change 2018-2019 | 2000 | 2019 | Change 2018-2019 | Share in area thermal total 2019 | 2000 | 2019 | Change 2018-2019 | Share in area thermal total 2019 | 2000 | 2019 | Change 2018-2019 | Share in area thermal total 2019 | 2000 | 2019 | Change 2018-2019 | Share in area thermal total 2019 |
| Europe | 1,807 | 1,701 | -6.3% | 1,039 | 638 | -21.9% | 38% | 192 | 65 | 16% | 4% | 527 | 770 | 6.9% | 45% | 48 | 227 | 2% | 13% |
| European Union | 1,673 | 1,475 | -4.9% | 966 | 484 | -26.2% | 33% | 181 | 57 | 2.2% | 4% | 480 | 716 | 14.8% | 49% | 46 | 219 | 1% | 15% |
| Germany | 372 | 336 | -13.3% | 304 | 179 | -25% | 53% | 5 | 5 | -1.9% | 2% | 53 | 93 | 10.3% | 28% | 10 | 59 | -0.8% | 17% |
| France | 53 | 61 | 4.8% | 31 | 4 | -62% | 7% | 7 | 7 | 7% | 11% | 12 | 41 | 34.6% | 67% | 4 | 9 | -15.7% | 15% |
| North America | 3,128 | 2,951 | -2.4% | 2,247 | 1,127 | -13.8% | 38% | 133 | 35 | -21.9% | 1% | 668 | 1,708 | 7.7% | 58% | 80 | 81 | -5.4% | 3% |
| Canada | 174 | 134 | 1% | 118 | 47 | -8.5% | 35% | 15 | 7 | 1% | 6% | 34 | 73 | 8% | 54% | 8 | 8 | 1% | 6% |
| United States | 2,954 | 2,817 | -2.6% | 2,130 | 1,080 | -14% | 38% | 119 | 27 | -26.4% | 1% | 634 | 1,636 | 7.7% | 58% | 72 | 74 | -6% | 3% |
| Latin America | 370 | 727 | -0.6% | 43 | 97 | -1.9% | 13% | 173 | 113 | -9.2% | 16% | 139 | 441 | 1.9% | 61% | 14 | 75 | 1.2% | 10% |
| Brazil | 38 | 147 | 1.7% | 11 | 25 | 8.8% | 17% | 15 | 7 | -44.9% | 5% | 4 | 60 | 9.7% | 41% | 8 | 55 | 1.5% | 37% |
| Asia | 2,951 | 8,929 | 0.1% | 1,983 | 7,159 | 0.3% | 80% | 382 | 153 | -7.3% | 2% | 569 | 1,407 | -0.1% | 16% | 16 | 211 | 0% | 2% |
| China | 1,116 | 5,184 | 2.2% | 1,060 | 4,856 | 1.7% | 94% | 47 | 11 | 12.4% | 0% | 6 | 236 | 16.7% | 5% | 2 | 82 | -3.7% | 2% |
| South Korea | 176 | 408 | -4.9% | 111 | 243 | -5.2% | 59% | 35 | 8 | -36% | 2% | 30 | 148 | -2.7% | 36% | 0.1 | 9 | 13.5% | 2% |
| India | 477 | 1,282 | -3% | 390 | 1,138 | -3.3% | 89% | 29 | 25 | 0.2% | 2% | 56 | 69 | -4.5% | 5% | 1 | 50 | 3.1% | 4% |
| Japan | 625 | 739 | -8% | 223 | 323 | -4.6% | 44% | 134 | 31 | -30.8% | 4% | 258 | 343 | -8.8% | 46% | 10 | 42 | -3.4% | 6% |
| Pacific | 207 | 232 | -0.3% | 176 | 153 | -3.8% | 66% | 3 | 9 | 1.8% | 4% | 26 | 67 | 9% | 29% | 2 | 4 | -13.5% | 2% |
| CIS | 816 | 1,022 | -0.5% | 266 | 317 | -1.4% | 31% | 57 | 7 | -18.9% | 1% | 491 | 695 | 0.2% | 68% | 3 | 3 | -0.2% | 0% |
| Russia | 582 | 712 | -0.3% | 176 | 188 | -1.3% | 26% | 33 | 7 | 1.4% | 1% | 370 | 515 | 0.1% | 72% | 3 | 3 | -0.5% | 0% |
| Middle East | 464 | 1,189 | -0.4% | 30 | 23 | 6% | 2% | 188 | 278 | -3.6% | 23% | 246 | 888 | 0.5% | 75% | 0 | 0.2 | 3.4% | 0% |
| Saudi Arabia | 126 | 349 | -0.5% | 0 | 0 | - | 0% | 68 | 122 | -4% | 35% | 58 | 228 | 1.4% | 65% | 0 | 0 | - | 0% |
| Iran | 118 | 278 | -2.9% | 1 | 1 | 0% | 0% | 25 | 29 | -4% | 10% | 92 | 249 | -2.8% | 90% | 0 | 0 | 0% | 0% |
| Africa | 354 | 672 | -0.9% | 208 | 253 | -3% | 38% | 52 | 70 | -4.4% | 10% | 94 | 347 | 1.5% | 52% | 1 | 2 | 0% | 0% |
| Egypt | 64 | 176 | -0.5% | 0 | 0 | - | 0% | 22 | 22 | -2.1% | 13% | 42 | 153 | -0.3% | 87% | 0 | 0 | - | 0% |
| South Africa | 194 | 224 | -3% | 193 | 223 | -3% | 100% | 0 | 0.2 | 0% | 0% | 0 | 0 | - | 0% | 0.3 | 0.3 | 0% | 0% |
| World | 10,097 | 17,423 | -1.1% | 5,992 | 9,767 | -3.5% | 56% | 1,181 | 729 | -5.1% | 4% | 2,760 | 6,324 | 3.2% | 36% | 164 | 603 | 0% | 3% |
| OECD | 6,062 | 6,304 | -4% | 3,780 | 2,496 | -13.2% | 40% | 591 | 160 | -18.1% | 3% | 1,548 | 3,282 | 4.9% | 52% | 143 | 366 | -0.5% | 6% |
| No-OECD | 4,035 | 11,120 | 0.6% | 2,212 | 7,271 | 0.4% | 65% | 589 | 569 | -0.7% | 5% | 1,213 | 3,042 | 1.4% | 27% | 21 | 237 | 0.9% | 2% |

*Source: Enerdata Global Energy & $CO_2$ Data (2020)*

# Electricity: detail of renewable generation

| Detail of renewable electricity generation TWh | Total Renewable generation (excluding biomass) | | | Renewable generation Hydro | | | | Renewable generation Wind | | | | Renewable generation Solar | | | | Renewable generation Geothermal | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2019 | Change 2018-2019 | 2000 | 2019 | Change 2018-2019 | Share in area renewable total 2019 | 2000 | 2019 | Change 2018-2019 | Share in area renewable total 2019 | 2000 | 2019 | Change 2018-2019 | Share in area renewable total 2019 | 2000 | 2019 | Change 2018-2019 | Share in area renewable total 2019 |
| Europe | 655 | 1,282 | 4.7% | 626 | 647 | -2.3% | 50% | 22 | 462 | 14.3% | 36% | 0.1 | 149 | 8.6% | 12% | 6 | 23 | 16.2% | 2% |
| European Union | 414 | 929 | 3.7% | 387 | 350 | -8.3% | 38% | 22 | 434 | 14.2% | 47% | 0.1 | 138 | 8.2% | 15% | 5 | 7 | 7.1% | 1% |
| Germany | 36 | 202 | 11.5% | 26 | 26 | 12.3% | 13% | 9 | 128 | 14.6% | 63% | 0.1 | 48 | 3.6% | 24% | 0 | 0.2 | 6.6% | 0% |
| France | 71 | 110 | -0.5% | 71 | 62 | -12.1% | 57% | 0 | 35 | 22.8% | 32% | 0 | 12 | 13.7% | 11% | 0 | 0.2 | 33.1% | 0% |
| North America | 660 | 1,134 | 1.3% | 639 | 675 | -3.5% | 60% | 6 | 333 | 8.3% | 29% | 1 | 106 | 14.7% | 9% | 15 | 20 | 0.3% | 2% |
| Canada | 359 | 414 | -0.6% | 359 | 380 | -1% | 92% | 0 | 31 | 3% | 7% | 0 | 4 | 11.1% | 1% | 0 | 0 | - | |
| United States | 301 | 719 | 2.5% | 280 | 296 | -6.4% | 41% | 6 | 303 | 8.9% | 42% | 1 | 101 | 14.9% | 14% | 15 | 20 | 0.3% | 3% |
| Latin America | 592 | 880 | 2.9% | 584 | 738 | -2.2% | 84% | 0.2 | 99 | 26.7% | 11% | 0 | 34 | 149% | 4% | 8 | 10 | 1.4% | 1% |
| Brazil | 304 | 451 | 2.3% | 304 | 389 | 0.1% | 86% | 0 | 57 | 16.5% | 13% | 0 | 5 | 55.6% | 1% | 0 | 0 | - | |
| Asia | 517 | 2,760 | 8.8% | 494 | 1,850 | 5.6% | 67% | 2 | 477 | 9.4% | 17% | 0.4 | 404 | 26.1% | 15% | 20 | 29 | 5.6% | 1% |
| China | 223 | 1,949 | 9.5% | 222 | 1,298 | 5.9% | 67% | 1 | 393 | 10% | 20% | 0 | 258 | 31% | 13% | 0.1 | 0.1 | 0% | 0% |
| South Korea | 6 | 19 | 0% | 6 | 6 | -14.3% | 32% | 0 | 3 | 5.6% | 14% | 0 | 10 | 10.6% | 54% | 0 | 0 | - | |
| India | 76 | 285 | 14.3% | 75 | 174 | 16.1% | 61% | 2 | 62 | 2.4% | 22% | 0 | 50 | 25.2% | 17% | 0 | 0 | - | |
| Japan | 101 | 161 | 0.6% | 97 | 78 | -10.1% | 49% | 0.1 | 8 | 13.3% | 5% | 0.4 | 72 | 13.4% | 45% | 3 | 3 | 5.7% | 2% |
| Pacific | 46 | 83 | 3.9% | 43 | 40 | -8.8% | 48% | 0.2 | 21 | 23.3% | 26% | 0 | 13 | 29.8% | 16% | 3 | 8 | 0.7% | 10% |
| CIS | 224 | 280 | 1.9% | 224 | 273 | 1.3% | 98% | 0 | 3 | 28.7% | 1% | 0 | 3 | 53.1% | 1% | 0.1 | 0.4 | -0.7% | 0% |
| Russia | 166 | 201 | 3.8% | 165 | 199 | 3.6% | 99% | 0 | 0.3 | 47.2% | 0% | 0 | 1 | 69.4% | 1% | 0.1 | 0.4 | -0.7% | 0% |
| Middle East | 8 | 47 | 81.4% | 8 | 33 | 77.5% | 70% | 0 | 2 | 10.3% | 3% | 0 | 13 | 107.7% | 27% | 0 | 0 | - | - |
| Saudi Arabia | 0 | 1 | 400% | 0 | 0 | - | 0% | 0 | 0 | - | 0% | 0 | 1 | 304.1% | 100% | 0 | 0 | - | - |
| Iran | 4 | 30 | 79.5% | 4 | 29 | 81.2% | 97% | 0 | 1 | 7.3% | 2% | 0 | 0.3 | 28.1% | 1% | 0 | 0 | - | - |
| Africa | 78 | 171 | 4.3% | 78 | 140 | 2.2% | 82% | 0.2 | 17 | 13.9% | 10% | 0 | 9 | 20.3% | 5% | 0 | 6 | 11.2% | 3% |
| Egypt | 14 | 20 | 12.6% | 14 | 14 | 0.2% | 70% | 0.1 | 5 | 37.5% | 23% | 0 | 1 | 143.5% | 7% | 0 | 0 | - | |
| South Africa | 4 | 16 | 1.9% | 4 | 6 | 0% | 37% | 0 | 6 | 0.7% | 38% | 0 | 4 | 6.6% | 26% | 0 | 0 | - | |
| World | 2,779 | 6,637 | 5.7% | 2,695 | 4,396 | 1.3% | 66% | 31 | 1,414 | 12% | 21% | 1 | 731 | 24% | 11% | 52 | 96 | 6.2% | 1% |
| OECD | 1,474 | 2,696 | 3.4% | 1,411 | 1,433 | -3.8% | 53% | 29 | 838 | 12.6% | 31% | 1 | 367 | 15.8% | 14% | 33 | 58 | 4.6% | 2% |
| No-OECD | 1,306 | 3,941 | 7.3% | 1,284 | 2,964 | 4% | 75% | 3 | 576 | 11.3% | 15% | 0 | 364 | 33.6% | 9% | 19 | 38 | 8.8% | 1% |

*Source: Enerdata Global Energy & $CO_2$ Data (2020)*

# Electricity: prices

## 2019-2020 trends confirm the impact of both the carbon market and renewables production on electricity prices

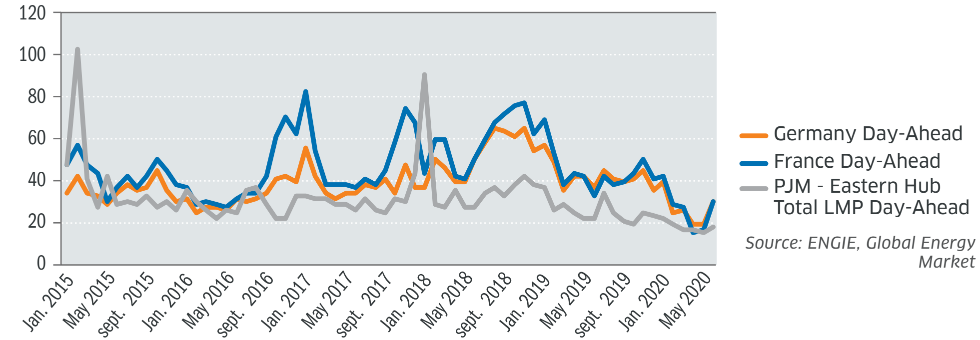
**Wholesale electricity prices continued their uptrend in 2018 but slumped in Europe in the second half of 2019 on the back of lower carbon and fossil fuel prices (natural gas and coal).** The year-ahead contract finished 2019 at €44.7/MWh in Germany, down €6.4/MWh from end 2018 (-14.2%), and at €46.3/MWh in France, after a peak at €55.4/MWh in July (Source: ENGIE Global Markets).

**The drop in prices accelerated with the Covid-19 pandemic and its negative effect on electricity demand. This context benefited renewable energies with low marginal production costs, which raised their share within the mix.** Weather conditions particularly favoured solar and wind power, so much so that prices turned negative on several occasions. On Monday 13 April for instance, electricity traded at -€91.4/MWh in Belgium, -€70.1/MWh in Germany and -€14.6 €/MWh in France (Source: EPEX Spot).

**In highly volatile market conditions throughout the health crisis, prices finally picked up in April 2020.** In the EU, discussions regarding the Green Deal and the spectre of a reform of the EU ETS (Emission Trading System) pushed carbon prices up. In France, prices were further supported by uncertainty over the availability of nuclear energy in the fourth quarter of 2020; lockdown measures hampered reactors' maintenance schedules.

**Despite these short-term fluctuations, electricity prices remain on a general uptrend, supported by increasing taxes and RES subsidies.** In 2019, the average retail price of electricity for a European residential client was €205/MWh, up 14% from €182/MWh in 2010; taxes accounted for 37%, up from 26% in 2010. In Germany, electricity prices have risen sharply in recent years following the implementation of an RES support mechanism. Household costs have climbed to an average €293MWh, the highest level in the EU, compared with €163/MWh in France, where the predominance of nuclear generation keeps the cost of supply relatively low.

### ELECTRICITY PRICES IN FRANCE, GERMANY AND USA ($/MWH)




*Source: ENGIE, Global Energy Market*

### RESIDENTIAL AND INDUSTRIAL ELECTRICITY PRICES

| Electricity prices in €2015/MWh | Residential prices in €2015/MWh | | | | Industrial prices in €2015/MWh | | | |
|---|---|---|---|---|---|---|---|---|
| | 2010 | 2019 | Change 2018-2019 | AAGR 2010-2019 | 2010 | 2019 | Change 2018-2019 | AAGR 2010-2019 |
| Germany | 258 | 293 | 1.8% | 1.4% | 110 | 124 | 4.9% | 1.4% |
| France | 131 | 163 | -2% | 2.4% | 79 | 98 | 8.1% | 2.4% |
| Italy | 215 | 249 | 7.4% | 1.6% | 163 | 165 | 14.1% | 0.1% |
| United Kingdom | 182 | 219 | -1.8% | 2.1% | 120 | 145 | 6.9% | 2.1% |
| United States | 113 | 109 | -0.9% | -0.5% | 67 | 57 | -3.2% | -1.7% |
| China | 82 | 73 | 0.2% | -1.3% | 126 | 89 | -6% | -3.9% |
| India | 62 | 58 | 1.4% | -0.8% | 98 | 112 | 0.3% | 1.5% |
| Japan | 165 | 203 | 4.4% | 2.3% | 105 | 132 | 1.6% | 2.7% |

*Source: Enerdata Global Energy & $CO_2$ Data (2020)*

# Natural gas & Renewable gases

**CONSUMPTION**

Favoured by environmental policies and lower gas prices,
the substitution of coal for gas is helping to reduce $CO_2$ emissions
Covid-19 has not halted this trend

**GREEN GASES**

The integration of green gases can maintain gas alternatives within the zero-carbon mix and offers diversification from electricity

# Natural gas and energy transition

## The role of natural gas in the energy transition

**Environmental scenarios suggest that natural gas is part and parcel of the energy transition and will be a particularly effective lever for decarbonization over the coming two decades.** Almost all of the projections that would meet climate targets* involve a largely unchanged share of natural gas in the energy mix between now and 2040-50. The IEA enhances the natural gas share from 23% in 2019 to 24% in 2040 in its SDS scenario (2°C target), for instance, and to 25% in its STEP scenario (including INDCs – environmental intended contributions announced at COP21). Volume projections offer another good indication of the importance of natural gas in energy transition: virtually no change over the period within the SDS (-0.2% per year) and rising moderately within the STEPS (+1.4% per year), compared with declines for oil and coal volumes (see scenario definitions in the Decarbonization chapter).

**Natural gas is included in medium-term decarbonization trends for several reasons:**

- **Lower carbon content and great flexibility of use.** It has a lower carbon content than other fossil fuels, has a large range of uses, combines availability with storage capacity and complements RES (bio gas or power RES).
- **Gas solutions can be implemented quickly and offer a higher cost-efficiency ratio than many power RES alternatives.** This mainly reflects existing gas infrastructures and the efficiency of gas-fired plants.
- **The energy mix cannot rely exclusively on renewable electricity.** It would be impossible to build a system big enough, for many reasons: costs, raw materials, land availability, public acceptability and networks. The use of gas considerably reduces the oversizing of power infrastructures required to cope with peak demand, RES intermittency and physical distances between production and consumption.

**This is precisely what we are seeing now, with natural gas benefiting from a surge in substitution for coal in the power generation sector** on the back of environmental policies and competitive prices. This trend is widespread in developed countries and is contributing to better control of $CO_2$ emissions, as gas-fired power plants emit 50% less GHG than their coal-fired equivalents. According to the IEA, the immediate replacement worldwide of coal-fired plants by gas-fired plants would reduce the power sector's emissions by 10%, or total emissions by 4%. Since 2010, these substitutions have cut $CO_2$ emissions by 500 Mt. In 2019, they were the main GHG reduction factor, notably in the USA and in Europe (see chapter $CO_2$ and climate).

**Although favourable to natural gas, environmental scenarios require an end to current growth rates** (+2% per year over the decade and +2.6% in 2019). The 2°C target requires a firm hand on world energy demand, as it has to be no higher than current levels by 2040. De facto natural gas consumption has to decline after 2030 and also to its current level by 2040 (see graphs).

The reduction in natural gas demand will mainly follow from increased energy efficiency (in buildings, industry, power generation), mixed solutions (gas and biomass or gas and heat pumps), and later on with the gradual introduction of zero-carbon gas (green gases), which is classed as renewable energy.

**In the second phase of energy transition, involving the complete decarbonization of the energy system, green gases will gradually replace natural gas as technology improves and costs decline.**
There are several zero-carbon gas solutions offering economic, environmental and social benefits:

- Biomethane, produced from fermentation of wastes, notably agricultural wastes,
- Green hydrogen, produced from renewable electricity through electrolysis of water,
- Synthetic methane, produced by combining green hydrogen with industrial carbon dioxide emissions (see 'Green gases' in the Natural gas and green gases chapter)

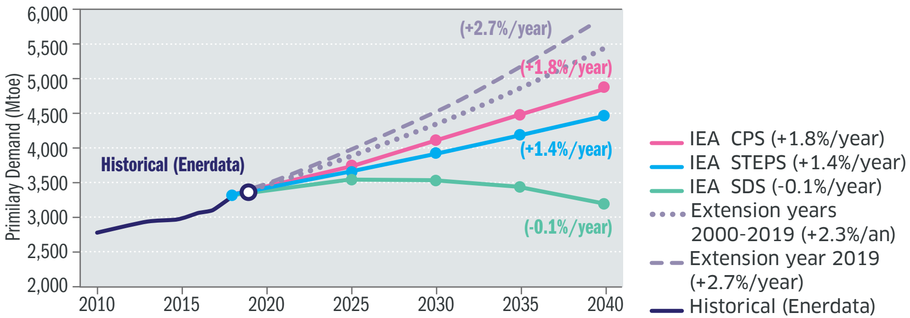
One of the advantages is the continuation of a mixed multi-energy system that is more resilient than a system relying on electricity alone. It is also more competitive, as it can combine solutions according to their performance with the advantages of gas (flexibility, infrastructures) and without GHG emissions.

Note also that locally-produced green gases reduce energy dependency, contribute to circular economies and create local value.
Lastly, residual natural gas can be decarbonized through carbon capture, utilisation and storage, or CCUS (see CCUS in the Decarbonization chapter).

*Scenarios: Greenpeace – R-Evolution; IEA – SDS; Enerdata-Green; IHS - Autonomy; NégaWatt and Ademe scenarios for France.

# Natural gas: consumption and production forecasts

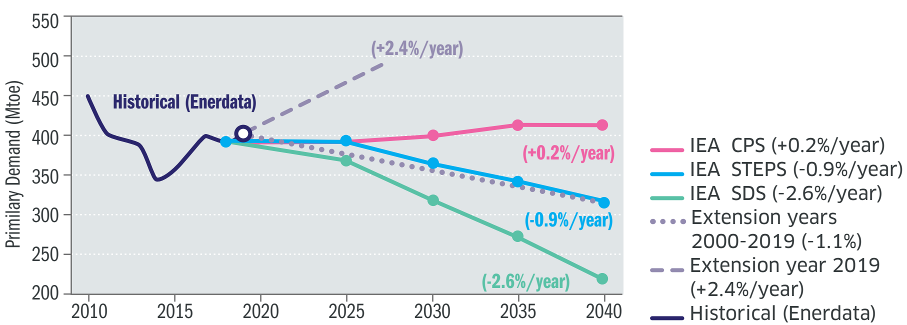
## GAS PRIMARY DEMAND FORECAST – WORLD




**Transition started but dynamic too slow**

The current growth of natural gas largely corresponds to substitutions for coal in electricity production, which contributes to reducing $CO_2$ emissions; but, insufficient efforts in terms of energy efficiency do not make it possible to weigh on overall energy demand.

## GAS PRIMARY DEMAND FORECAST – EUROPEAN UNION




**Transition started but dynamic too slow**

In the EU, the most demanding area, natural gas contributes to the decarbonization of the electricity system by replacing coal; from 2030, it will be necessary to accelerate the development of green gases in order to maintain gas solutions while decarbonising them; the overall reduction in energy consumption is a critical point.

## FORECASTS OF WORLD GAS CONSUMPTION IN STEPS AND SDS SCENARIOS FROM IEA (IN BCM)

| Forecast of Gas consumption In bcm | | Stated Policies Scenario | | | | Sustainable Development Scenario | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2018 | 2030 | 2040 | AAGR 2018-2040 | Share in 2040 | 2030 | 2040 | AAGR 2018-2040 | Share in 2040 |
| Europe | 607 | 593 | 557 | -0.4% | 10.3% | 519 | 380 | -2.1% | 9.9% |
| North America | 1,067 | 1,183 | 1,221 | 0.6% | 22.6% | 1,052 | 791 | -1.4% | 20.5% |
| Central and South America | 172 | 198 | 257 | 1.8% | 4.7% | 168 | 169 | -0.1% | 4.4% |
| Asia Pacific | 815 | 1,218 | 1,522 | 2.9% | 28.2% | 1,234 | 1,322 | 2.2% | 34.3% |
| CEI | 598 | 639 | 674 | 0.5% | 12.5% | 551 | 471 | -1.1% | 12.2% |
| Middle East | 535 | 646 | 807 | 1.9% | 14.9% | 550 | 507 | -0.2% | 13.2% |
| Africa | 158 | 221 | 317 | 3.2% | 5.9% | 176 | 200 | 1.1% | 5.2% |
| OECD | 1,823 | 1,905 | 1,910 | 0.2% | 35.3% | 1,699 | 1,262 | -1.7% | 32.7% |
| non OECD | 2,129 | 2,794 | 3,444 | 2.2% | 63.7% | 2,551 | 2,577 | 0.9% | 66.9% |
| Bunkers | 0 | 21 | 50 | 34.3% | 0.9% | 14 | 15 | 27.0% | 0.4% |
| World | 3,952 | 4,720 | 5,404 | 1.4% | 100% | 4,264 | 3,854 | -0.1% | 100% |

*Source: World Energy Outlook 2019 © OECD/IEA, November 2019*

## FORECASTS OF WORLD GAS PRODUCTION IN STEPS AND SDS SCENARIOS FROM IEA (IN BCM)

| Forecast of Gas production In bcm | | Stated Policies Scenario | | | | Sustainable Development Scenario | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2018 | 2030 | 2040 | AAGR 2018-2040 | Share in 2040 | 2030 | 2040 | AAGR 2018-2040 | Share in 2040 |
| Europe | 277 | 206 | 188 | -1.7% | 3.5% | 189 | 151 | -2.7% | 4% |
| North America | 1,083 | 1,336 | 1,376 | 1.1% | 25.5% | 1,209 | 909 | -0.8% | 24% |
| Latin America | 177 | 209 | 285 | 2.2% | 5.3% | 187 | 189 | 0.3% | 5% |
| Asia Pacific | 598 | 757 | 889 | 1.8% | 16.5% | 745 | 786 | 1.3% | 20% |
| CIS | 918 | 1,054 | 1,143 | 1.0% | 21.1% | 921 | 786 | -0.7% | 20% |
| Middle East | 645 | 787 | 1,016 | 2.1% | 18.8% | 681 | 651 | 0.0% | 17% |
| Africa | 240 | 372 | 508 | 3.5% | 9.4% | 333 | 383 | 2.2% | 10% |
| OECD | 1,454 | 1,693 | 1,735 | 0.8% | 32.1% | 1,542 | 1,209 | -0.8% | 31% |
| non OECD | 2,484 | 3,027 | 3,669 | 1.8% | 67.9% | 2,722 | 2,645 | 0.3% | 69% |
| Monde | 3,937 | 4,720 | 5,404 | 1.4% | 100% | 4,264 | 3,854 | -0.1% | 100% |
| Gas conventionnel | 3,004 | 3,293 | 3,694 | 0.9% | 68.4% | 3,004 | 2,689 | -0.5% | 70% |
| Tight gas | 274 | 267 | 238 | -0.6% | 4.4% | 262 | 141 | -3.0% | 4% |
| Shale gas | 568 | 1,020 | 1,290 | 3.8% | 23.9% | 863 | 871 | 2.0% | 23% |
| Coalbed methane | 88 | 103 | 129 | 1.7% | 2.4% | 101 | 103 | 0.7% | 3% |
| Autres productions | 3 | 36 | 54 | 14.2% | 1.0% | 34 | 50 | 13.9% | 1% |

*Source: World Energy Outlook 2019 © OECD/IEA, November 2019*

# Natural gas: consumption

## Although more resilient than other fossil fuels during the pandemic, natural gas demand is down sharply in 2020

**The pandemic will severely dent gas demand worldwide, but not to the extent of coal and oil.** Natural gas depends less on electricity production than coal and is not as exposed as oil in the transport sector. Though relatively untouched during lockdown (down 2%), natural gas consumption will contract significantly over 2020 as a whole because of sluggish economic activity. The drop is expected to amount to 4-5% (-160 to -200 bcm), according to several sources*. This would be the greatest ever shock to the gas markets, and twice as bad as that triggered by the 2008 financial crisis (-2% in 2009).

The annual decline in 2020 will be more severe than the correction in the first quarter because of the enduring impact of the pandemic on industrial activity and electricity generation (expected -5% and -7%, respectively, over the year); moreover, temperatures in the northern hemisphere were unusually mild over the first half of the year. A faster economic recovery would limit the fall in demand in 2020 to 3% (source: IEA).

**The 2020 recession will be just as bad on European markets, if not worse.** Mild weather, with a winter that was 5% warmer in degree days, significant wind production and the Covid-19 pandemic all contributed to drive natural gas consumption 7% lower in the year to the first half of 2020.
Some countries reported sharp declines in gas consumption during lockdown. In countries with strict lockdown regimes, such as Belgium, France, Italy, Spain and the UK, industrial consumption dropped over 15% year-on-year (-1 Bn $m^3$) from March to May. In Italy and the UK, gas-fired plants' consumption plunged around 30%.

Gas demand is expected down 7%** for the whole year. This estimate is based on a 7-8% fall in European GDP, assuming some benefit from substantial recovery plans, demand for air-conditioning during the summer and, above all, competitive gas prices. Prices are likely to stay low over the rest of 2020, favouring the arbitrage of gas over coal in electricity production. Stable $CO_2$ prices at around €20 per tonne will only amplify this effect. An EU directive on industrial $CO_2$ emissions will further hasten the decline in the use of coal by imposing upgrades on coal-fired plants, as will decisions by several EU Member States to close these installations down gradually.

The 2008 crisis impacted European markets in fairly similar proportions, weakening both industry and electricity production. The recovery proved laborious: apart from during a cold winter in 2010, gas demand continued to decline until 2014. This offers little clue to what is likely to happen after 2020, however, as the whole structure of the gas market has changed since that time.

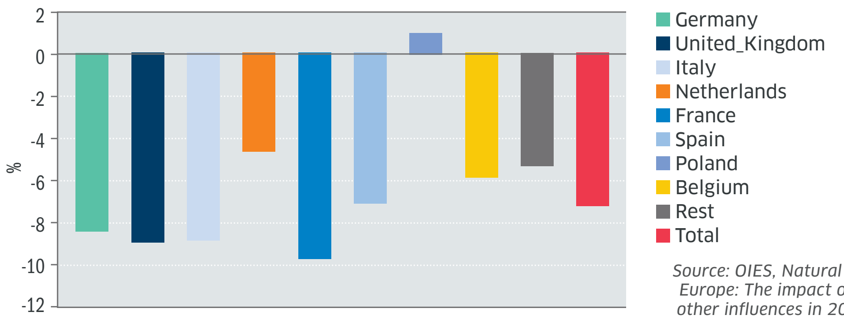
**There is a degree of consensus around a worldwide pick-up in natural gas demand post-pandemic,** based on gas cost competitiveness, tougher environmental policies and demand from Asian emerging countries led by China and India, where gas enjoys strong political support. The recovery will be gradual, however, and the repercussions of the crisis will resonate for some years to come. The IEA expects an annual loss of 75 bcm up until 2025.

*IEA, Global Energy review 2020 – Covid-19 impacts on energy and $CO_2$ emissions, 28 April 2020; IEA, GAS Report 2020, June 2020; International Gas Union (IGU), "Global Gas Report 2020" published in August 2020.

**IEA, Global Energy review 2020 – Covid-19 impacts on energy and $CO_2$ emissions, 28 April 2020; Oxford Institute of Energy Studies, Natural gas demand in Europe: The impact of Covid-19 and other influences in 2020, June 2020.



### NATURAL GAS DEMAND CHANGE IN 2020 VS 2019 IN EUROPE (%)




*Source: OIES, Natural gas demand in Europe: The impact of Covid-19 and other influences in 2020, June 2020*

# Natural gas: consumption

## Since 2019, natural gas has benefited from a shift out of coal in all major consumption areas

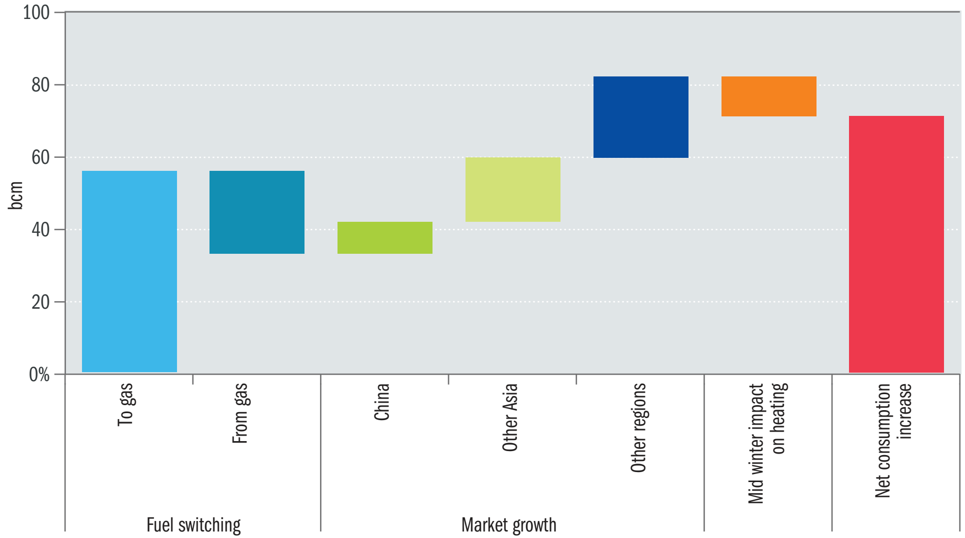
**This crisis has halted a several year-old positive trend in gas consumption in both OECD and non-OECD countries.** After two strong years (+5% in 2018, +4% in 2017), boosted by US shale gas and environmental policies, gas demand rose another 2.6% in 2019 to 4,018 bcm, while world energy demand progressed 0.7%. Although slower economic growth and a continuing rise in global temperatures – crucial to gas consumption – hampered its momentum, gas largely benefited from lower prices that made it more competitive against coal in power generation.

**The main drivers of gas demand are the USA and Asia.** They are the largest markets in volume terms and represented half of additional demand in 2019. In the USA (+3% in 2019), very low Henry Hub prices (high shale gas production) favoured gas within power generation and invigorated fertiliser production. In Asia (+3%), aggressive policy measures reduced coal power both in China (+8.6%), where a gas-against-coal programme was introduced in 2017 to address air pollution, and in India (+4.4%). China is the world's third largest gas consumer behind the USA and Russia, and the second largest LNG importer after Japan. Japanese gas consumption dropped 4.8% in 2019, when nine nuclear reactors were restarted and RES expanded.

**Demand was just as dynamic in Europe** (+3% in 2019 to 494 bcm), notably in Germany (+3.3%), Spain, Italy and France in a context of persistent economic weakness and high temperatures. As already described, Europe is seeing a wave of substitution out of coal and into gas in electricity production. Gas-fired plants increased production by 11% in 2019, or nearly 70 TWh, while coal-fired plants reported a 24% drop. The most spectacular change was in Spain, where consumption from gas-fired plants jumped 50%.

**In the Middle East and North Africa, consumption continued to rise** thanks to power generation and the extension of distribution networks (Algeria, Iran). On the other hand, Russian demand growth slowed to 2.4% after three years of robust expansion, reflecting weaker economic activity and unusually mild weather.

**BREAKDOWN OF ESTIMATED NATURAL GAS CONSUMPTION GROWTH BY MAIN (IN BCM)**



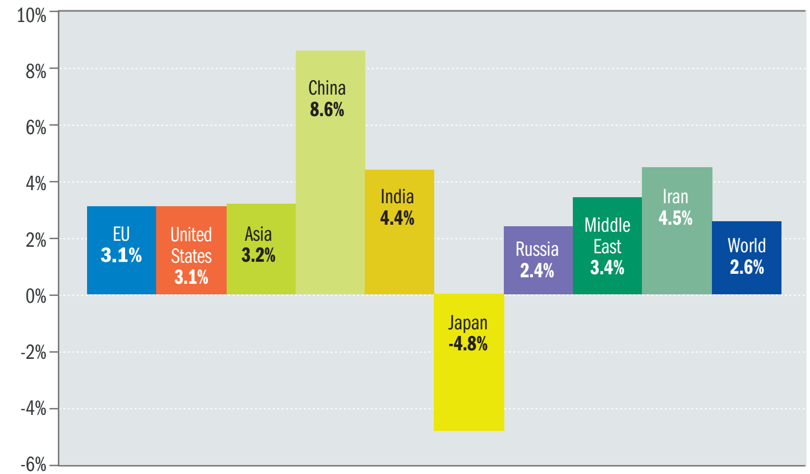

*Source: IEA, Gas Report 2020, May 2020*

# Natural gas: primary consumption

| Bcm | Natural gas primary consumption | | | | | | Change 2018-2019 | AAGR 2010-2019 | Share in the world 2019 |
|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2005 | 2010 | 2015 | 2018 | 2019 | | | |
| Europe | 505 | 575 | 597 | 499 | 543 | 552 | 1.7% | -0.9% | 14% |
| EU | 481 | 536 | 546 | 438 | 479 | 494 | 3.1% | -1.1% | 12% |
| France | 40 | 47 | 48 | 40 | 42 | 42 | 1.8% | -1.4% | 1% |
| Germany | 88 | 91 | 95 | 81 | 92 | 95 | 3.3% | 0.1% | 2% |
| Italy | 71 | 86 | 83 | 68 | 73 | 74 | 2.3% | -1.2% | 2% |
| Netherlands | 49 | 50 | 56 | 41 | 43 | 45 | 4.2% | -2.5% | 1% |
| United Kingdom | 102 | 100 | 99 | 73 | 80 | 80 | -0.5% | -2.4% | 2% |
| North America | 753 | 722 | 781 | 882 | 977 | 1,005 | 2.9% | 2.9% | 25% |
| United States | 661 | 623 | 683 | 767 | 850 | 877 | 3.1% | 2.8% | 22% |
| Canada | 92 | 99 | 97 | 115 | 127 | 129 | 1.7% | 3.2% | 3% |
| Latin America | 136 | 178 | 222 | 244 | 231 | 231 | -0.1% | 0.4% | 6% |
| Argentina | 37 | 41 | 47 | 51 | 51 | 50 | -0.9% | 0.8% | 1% |
| Mexico | 40 | 53 | 70 | 75 | 74 | 77 | 4.4% | 1.1% | 2% |
| Asia | 282 | 386 | 563 | 662 | 774 | 799 | 3.2% | 4% | 20% |
| China | 25 | 47 | 125 | 192 | 280 | 304 | 8.6% | 10.4% | 8% |
| India | 28 | 38 | 64 | 53 | 61 | 64 | 4.4% | -0.1% | 2% |
| Japan | 81 | 84 | 103 | 120 | 114 | 108 | -4.8% | 0.6% | 3% |
| Pacific | 29 | 30 | 37 | 42 | 46 | 53 | 14.0% | 4% | 1% |
| CIS | 568 | 622 | 655 | 616 | 657 | 668 | 1.7% | 0.2% | 17% |
| Russia | 391 | 426 | 466 | 445 | 489 | 501 | 2.4% | 0.8% | 13% |
| Middle East | 174 | 255 | 374 | 480 | 538 | 557 | 3.4% | 4.5% | 14% |
| Saudi Arabia | 38 | 56 | 73 | 87 | 97 | 98 | 1.4% | 3.3% | 2% |
| Iran | 62 | 99 | 144 | 184 | 217 | 226 | 4.5% | 5.1% | 6% |
| United Arab Emirates | 30 | 42 | 61 | 74 | 74 | 75 | 1.1% | 2.4% | 2% |
| Africa | 57 | 90 | 108 | 131 | 151 | 154 | 2.2% | 4% | 4% |
| World | 2,504 | 2,858 | 3,336 | 3,555 | 3,917 | 4,018 | 2.6% | 2.1% | 100% |
| OECD | 1,403 | 1,473 | 1,613 | 1,651 | 1,801 | 1,841 | 2.2% | 1.5% | 46% |
| Non OECD | 1,101 | 1,385 | 1,723 | 1,904 | 2,116 | 2,177 | 2.9% | 2.6% | 54% |

*Source: Enerdata, Global Energy and $CO_2$ Data, 2020*

## CHANGE IN PRIMARY CONSUMPTION OF NATURAL GAS IN 2019




*Source: Enerdata, Global Energy and $CO_2$ Data, 2020*

# Natural gas: consumption by sector

| Gas consumption by sector Bcm | Energy | | Industry | | Transport | | Services, Residential & Agriculture | | Non energy uses | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2019 | Change 2018-2019 | 2019 | Change 2018-2019 | 2019 | Change 2018-2019 | 2019 | Change 2018-2019 | 2019 | Change 2018-2019 | 2019 | Change 2018-2019 |
| Europe | 216 | 9% | 114 | -3% | 2 | -3% | 201 | -2% | 19 | -2% | 552 | 2% |
| European Union | 191 | 12% | 100 | -2% | 2 | -3% | 183 | -2% | 18 | -2% | 494 | 3% |
| Germany | 28 | 12% | 26 | -1% | 0 | 0% | 39 | 1% | 3 | 1% | 95 | 3% |
| France | 10 | 21% | 11 | -290% | 0 | -3% | 20 | -3% | 1 | -3% | 42 | 2% |
| Italy | 34 | 10% | 10 | -3% | 1 | -3% | 28 | -3% | 1 | -3% | 74 | 2% |
| Netherlands | 20 | 25% | 7 | -8% | 0 | -6% | 15 | -8% | 3 | -8% | 45 | 4% |
| United Kingdom | 34 | 1% | 9 | -3% | 0 | - | 37 | -1% | 0.4 | 0% | 80 | -1% |
| North America | 516 | 5% | 178 | 0.1% | 2 | 2% | 279 | 1% | 32 | 0% | 1,005 | 3% |
| United States | 448 | 6% | 158 | 0.1% | 2 | 1% | 241 | 0.1% | 28 | 0% | 877 | 3% |
| Canada | 67 | -2% | 20 | -0.4% | 0.1 | 10% | 38 | 10% | 4 | -0.3% | 129 | 2% |
| Latin America | 145 | -2% | 46 | 2% | 7 | 4% | 19 | 4% | 15 | 3% | 231 | -0.1% |
| Argentina | 26 | -4% | 9 | 2% | 3 | 2% | 11 | 2% | 2 | 2% | 50 | -1% |
| Mexico | 61 | 3% | 15 | 11% | 0.1 | 11% | 1 | 11% | 0.4 | 11% | 77 | 4% |
| Asia | 393 | 2% | 174 | 5% | 39 | 5% | 127 | 4% | 65 | 7% | 799 | 3% |
| China | 104 | 12% | 86 | 7% | 29 | 7% | 73 | 7% | 13 | 7% | 304 | 9% |
| India | 17 | -4% | 16 | 8% | 3 | 8% | 2 | 8% | 25 | 8% | 64 | 4% |
| Japan | 75 | -6% | 13 | -2% | 0.1 | -2% | 20 | -2% | 0.3 | -2% | 108 | -5% |
| Pacific | 32 | 18% | 12 | 12% | 0.1 | 8% | 7 | 3% | 2 | 7% | 53 | 14% |
| CIS | 434 | 2% | 63 | 2% | 1 | 2% | 115 | 1% | 56 | 2% | 668 | 2% |
| Russia | 326 | 2% | 49 | 2% | 0.3 | 2% | 74 | 2% | 51 | 2% | 501 | 2% |
| Middle East | 315 | 1% | 127 | 5% | 9 | 8% | 73 | 8% | 33 | 6% | 557 | 3% |
| Saudi Arabia | 70 | 1% | 22 | 1% | 0 | - | 0 | - | 7 | 1% | 98 | 1% |
| Iran | 83 | -1% | 49 | 8% | 9 | 8% | 67 | 8% | 18 | 8% | 226 | 5% |
| United Arab Emirates | 46 | -1% | 29 | 4% | 0 | - | 0 | - | 0.4 | 4% | 75 | 1% |
| Africa | 104 | 2% | 21 | 1% | 0.4 | 2% | 15 | 3% | 13 | 2% | 154 | 2% |
| World | 2,154 | 3% | 734 | 2% | 61 | 5% | 835 | 1% | 235 | 3% | 4,018 | 3% |
| OECD | 932 | 5% | 337 | -0.2% | 5 | -1% | 516 | -0.3% | 51 | -1% | 1,841 | 2% |
| Non OECD | 1,222 | 2% | 397 | 4% | 56 | 6% | 318 | 4% | 184 | 4% | 2,177 | 3% |

*Source: Enerdata Global Energy & CO2 Data (June 2020)*

# Natural gas: conventional and unconventional gas

**The development of hydraulic fracturing in the 2000s profoundly transformed assessments of world natural gas reserves, low-permeability bedrock suddenly became exploitable.** By convention, traditional exploitation supplies so-called "conventional gas" and bedrock "unconventional gas", although there is no difference in their chemical composition.

**Recoverable* natural gas reserves are estimated at à 803 Tm³,** almost evenly split between conventional and unconventional gas. This represents 200 years of current consumption.

**Conventional gas reserves** are the better known of the two. Their share of so-called proven reserves (exploitable under current economic conditions) was estimated at 225 Tm³ in 2019 (+15% over the decade). They lie mostly in the Middle East (40% of world reserves, of which Iran 16% and Qatar 13%) and in Eurasia (Russia 17%, Turkmenistan 10%). The USA possess only 7%. Conventional gas currently represents 75% of total gas production.

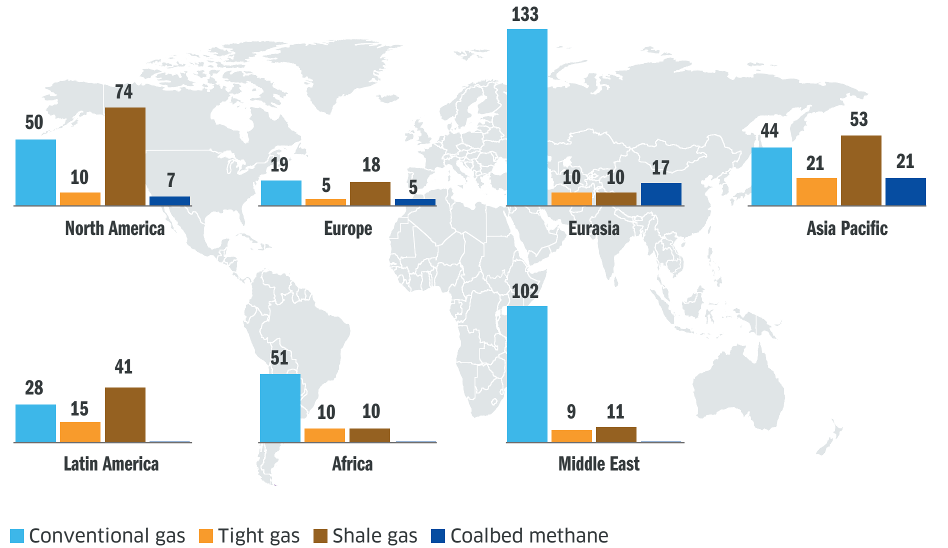
**Unconventional** gas, despite offering considerable potential and being more evenly spread around the planet, is mainly exploited in the USA** (85% of world production), and to a lesser extent in Canada, China and Australia. Other regions planning to produce it are still in exploration phase or produce little volumes (India, Argentina, South Africa, Algeria, etc.). Shale gas is developing rapidly in China, however (40% of gas production in 2019), and Australia has long produced coal bed methane (CBM). In Europe, where the focus is on energy transition and RES expansion, unconventional gas will not be developed further. The UK was the last European country to resort to fracking and ceased doing so in November 2019.

World production of unconventional gas represents 25% of total gas production, split between shale gas (15%), tight gas (8%) and CBM (2%). (Source: CEDIGAZ).

*Recoverable reserves are split according to their probability of being exploited: 90% for proven reserves, 50% for probable reserves, 10% for possible reserves, Cf. "Reserves" in the Glossary.

**Among unconventional gas, coal gas (Coal Bed Methane - CBM) differs from tight gas and shale gas. Unconventional resources are mainly shale gas (66%), tight gas and CBM respectively representing 21% and 13%.
Unconventional gas exploitation started with CBM around the end of the twentieth century. Shale and tight gas fields are more difficult to produce. They require specific drilling technics (horizontal drilling and hydraulic fracturing).

**CONVENTIONAL AND UNCONVENTIONAL GAS RESSOURCES (IN TCM)**




*Source: World Energy Outlook 2019 © OECD/IEA, Nov. 2019*

# Natural gas: conventional and unconventional gas

**Shale gas has boomed in the USA since 2008** and accounted for 75% of the country's gas production in 2019. This has dramatically altered the gas market, not to mention the US and Atlantic basin energy balance.

In its latest WEO version (November 2019) the IEA said it expected US shale gas to supply nearly 60% of world additional production until 2025 and then plateau. Beyond that point, shale gas is expected to develop in Canada, China and Argentina, and conventional gas will resume after 2030.

**By severely denting gas demand and prices, Covid-19 sent the US unconventional gas sector into unprecedented turmoil.** It could call into question the sustainability of this industry as well as LNG exports. Already undermined by economic constraints (shale gas is not economically viable below $52/bbl) and environmental considerations (fracking causes chemical pollution), shale gas faces challenges related to global warming: US natural gas consumption is set to stabilise then decrease, and green gas are to be introduced.

Conventional and unconventional gas ressources (in Tcm)

| Natural gas Trillion cubic meters | Proven reserves | Ressources | Conventional gas | Tight gas | Shale gas | Coalbed methane |
|---|---|---|---|---|---|---|
| North America | 15 | 141 | 50 | 10 | 74 | 7 |
| Central & South America | 8 | 84 | 28 | 15 | 41 | - |
| Europe | 5 | 47 | 19 | 5 | 18 | 5 |
| Africa | 19 | 101 | 51 | 10 | 40 | 0 |
| Middle East | 81 | 122 | 102 | 9 | 11 | - |
| Eurasia | 76 | 170 | 133 | 10 | 10 | 17 |
| Asia Pacific | 20 | 138 | 44 | 21 | 53 | 21 |
| World | 225 | 803 | 426 | 80 | 247 | 50 |

*Source: World Energy Outlook 2019 © OECD/IEA, Nov. 2019*

# Natural gas: production

Thanks to US shale gas, production significantly exceeded demand in 2019. The resulting build-up in stocks only worsened in 2020, when gas demand fell

**World natural gas production has been rising very rapidly over recent years (+4% in 2018 and 2019),** exceeding 4 Tm3 for the fist time. This strength is largely due to US shale gas, which represents nearly 60% of world additional supply. As production increased far more than demand (+67 bcm), stocks built up significantly in Europe and the USA. The gap widened further in the first half of 2020, as production remained high and barely adjusted to the Covid impact on demand. By the end of the spring, stocks had reached very high levels (20% and 80% higher than usual in the USA and in Europe, respectively).

**US production has been setting records from year to year** (+10% in 2019, or +89 bcm). A decade of uninterrupted growth (+4.6% per year on average since 2000) lifted the country to the top spot among rank gas producers. The USA is now well ahead of Russia in that respect. Taken together, the two major sites of unconventional gas – the Appalachian and Permian basins – account for two-thirds of that growth.

US shale production was still rising quickly in early 2020 (+6% over the first half). The pandemic could mean a sharp correction, however. Shale gas loses competitiveness rapidly when oil prices dip below $50/bbl. In June 2020, fracking pioneer Chesapeake filed for bankruptcy. 46 new pipelines for a total capacity of 165-175 bcm/year started operations in 2019. Built to facilitate exports towards Mexico and East Coast LNG terminals, they may well remained underutilised in 2020.

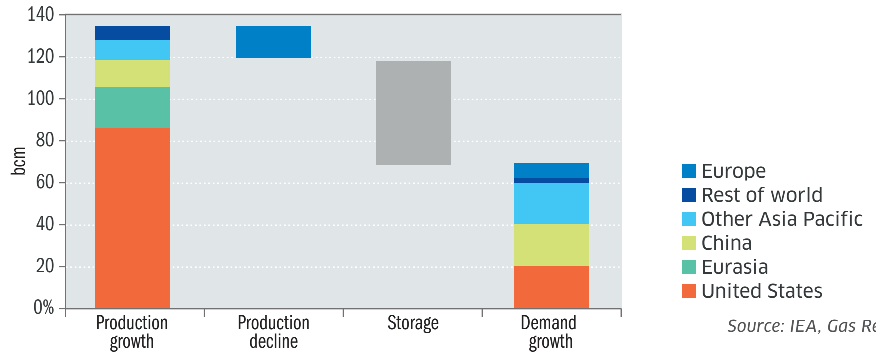
**China has become an important producer over the past two decades** and now ranks equal to Qatar. This rapid development (+10% in 2019) was largely based on shale gas (40%).

**Russia's production (+3.4%) was boosted in 2019 by higher exports,** partly related to the ramp-up of the LNG Yamal project. In the first half of 2020, production contracted 9% as exports plummeted and mild temperatures weakened domestic demand. Azeri gas production surged spectacularly with the exploitation of the Shah Deniz II field (+28 % in 2019, or +5 bcm).

**European gas production is in structural decline and dropped ed 6% in 2019** (-14 bcm). The Norwegian Troll and Oseberg sites, swing fields, are losing steam, and production from the Dutch Groningen field is falling because of earthquake risks.



**BREAKDOWN OF THE GAS PRODUCTION-CONSUMPTION BALANCE IN 2019 (IN BCM)**



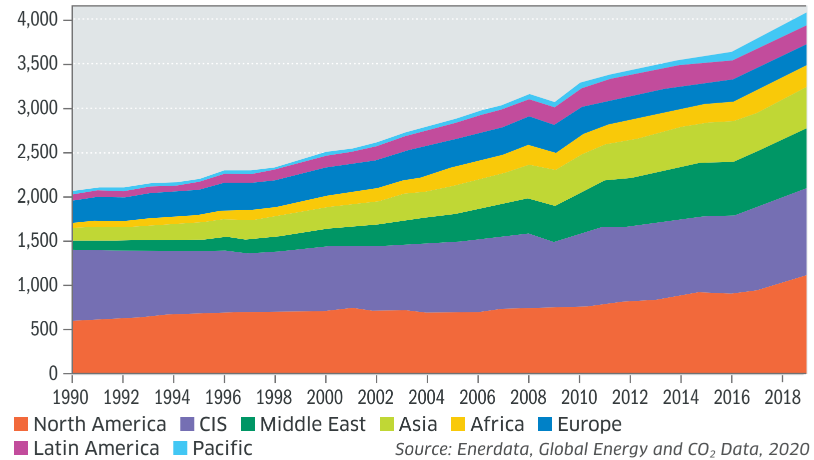

*Source: IEA, Gas Report 2020, May 2020*

# Natural gas: production

| Bcm | Natural gas production | | | | | | Change 2018-2019 | AAGR 2010-2019 | Share in the world 2019 |
|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2005 | 2010 | 2015 | 2018 | 2019 | | | |
| Europe | 320 | 329 | 317 | 261 | 246 | 232 | -5.7% | -3.4% | 6% |
| European Union | 265 | 241 | 206 | 138 | 120 | 111 | -7.1% | -6.6% | 3% |
| Norway | 53 | 87 | 110 | 121 | 126 | 118 | -5.7% | 0.8% | 3% |
| Netherlands | 74 | 78 | 90 | 55 | 39 | 34 | -13% | -10.4% | 1% |
| United Kingdom | 115 | 93 | 58 | 41 | 41 | 40 | -2.2% | -4.1% | 1% |
| North America | 726 | 700 | 760 | 932 | 1,053 | 1,135 | 7.8% | 4.6% | 28% |
| États-Unis | 544 | 512 | 604 | 767 | 863 | 951 | 10.3% | 5.2% | 23% |
| Canada | 182 | 188 | 156 | 165 | 190 | 183 | -3.6% | 1.8% | 5% |
| Latin America | 138 | 179 | 212 | 219 | 203 | 202 | -0.2% | -0.5% | 5% |
| Asia | 251 | 335 | 426 | 449 | 459 | 472 | 2.8% | 1.1% | 12% |
| China | 27 | 49 | 96 | 135 | 159 | 175 | 10% | 6.9% | 4% |
| Indonesia | 70 | 75 | 86 | 75 | 72 | 66 | -8.9% | -2.9% | 2% |
| Malaisia | 50 | 66 | 61 | 69 | 65 | 66 | 2.6% | 1% | 2% |
| Pacific | 39 | 40 | 58 | 82 | 132 | 155 | 17.5% | 11.7% | 4% |
| Australia | 33 | 36 | 53 | 68 | 118 | 139 | 17.9% | 11.4% | 3% |
| CIS | 709 | 797 | 828 | 861 | 941 | 973 | 3.4% | 1.8% | 24% |
| Russia | 573 | 628 | 657 | 638 | 715 | 740 | 3.4% | 1.3% | 18% |
| Turkmenistan | 47 | 63 | 45 | 84 | 81 | 83 | 2.7% | 7% | 2% |
| Middle East | 196 | 302 | 467 | 587 | 654 | 674 | 3.1% | 4.2% | 17% |
| Saudi Arabia | 38 | 56 | 73 | 87 | 97 | 98 | 1.4% | 3.3% | 2% |
| Iran | 59 | 99 | 144 | 184 | 228 | 240 | 5.5% | 5.9% | 6% |
| Qatar | 25 | 45 | 121 | 167 | 171 | 173 | 1.2% | 4.1% | 4% |
| Africa | 124 | 189 | 209 | 198 | 240 | 241 | 0.5% | 1.6% | 6% |
| Algeria | 82 | 89 | 85 | 84 | 97 | 91 | -6.8% | 0.7% | 2% |
| World | 2,504 | 2,870 | 3,276 | 3,588 | 3,928 | 4,085 | 4% | 2.5% | 100% |
| OECD | 1,110 | 1,104 | 1,181 | 1,305 | 1,451 | 1,539 | 6.1% | 3% | 38% |
| Non OECD | 1,394 | 1,766 | 2,095 | 2,283 | 2,476 | 2,545 | 2.8% | 2.2% | 62% |

*Source: Enerdata, Global Energy and CO2 Data, 2020*

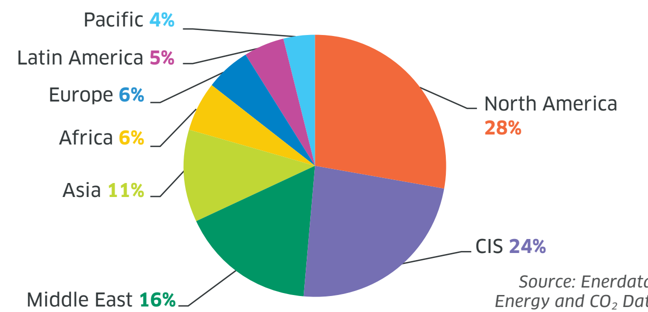
## NATURAL GAS PRODUCTION BY REGION FROM 1990 TO 2019 (IN BCM)




*Source: Enerdata, Global Energy and $CO_2$ Data, 2020*

148

## DISTRIBUTION OF NATURAL GAS PRODUCTION WORLDWIDE IN 2019 – TOTAL: 4,085 BCM




*Source: Enerdata, Global Energy and $CO_2$ Data, 2020*

# Natural gas: prices

## Natural gas prices were unable to avoid an historical plunge across all markets, except where indexed

**A long uptrend in natural gas prices in major consuming regions reversed in early 2019,** when booming world gas production far exceeded consumption.

Europe was the most affected region, as a record inflow of LNG added to an abnormally mild winter. Prices dropped 40% in 2019, averaging $4.5/MBtu on the NBP.

A similar trend was observed in Asia, where LNG prices plummeted 44%, averaging $5.5/MBtu on the Japan Korea Marker, in a context of abundant supply and moderate growth in traditional import markets (Japan and Korea). This did not translate into lower import prices, however, thanks to a continuing high proportion of oil-indexed contracts.

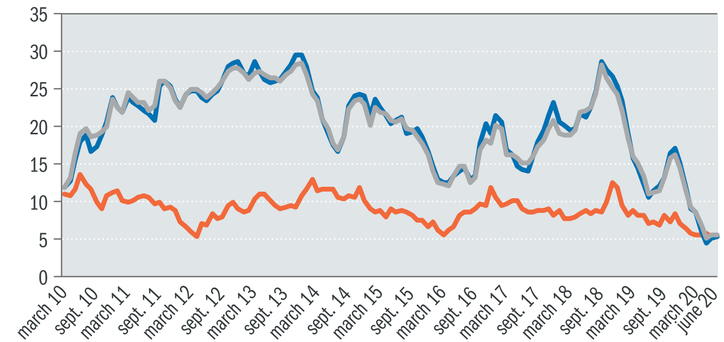
On the US market, Henry Hub prices shed 20% and averaged $2.5/MBtu in 2019. Again indexed prices proved resilient, as oil prices were stable.

**The situation deteriorated further over the first half of 2020,** reflecting a combination of continued strong production, mild winter temperatures and lockdowns. The shock has been unprecedented across all gas markets, associating historically low prices with high volatility.

Over the first half of 2020, the Henry Hub dived to its lowest average since 1999 ($1.9/MBtu) and the European TTF to its lowest level since its introduction back in 2003 ($1.5/MBtu in May). Oil-indexed prices have not suffered the same fate as yet. The 3- to 6-month indexation gap will have delayed it to the second half of the year.

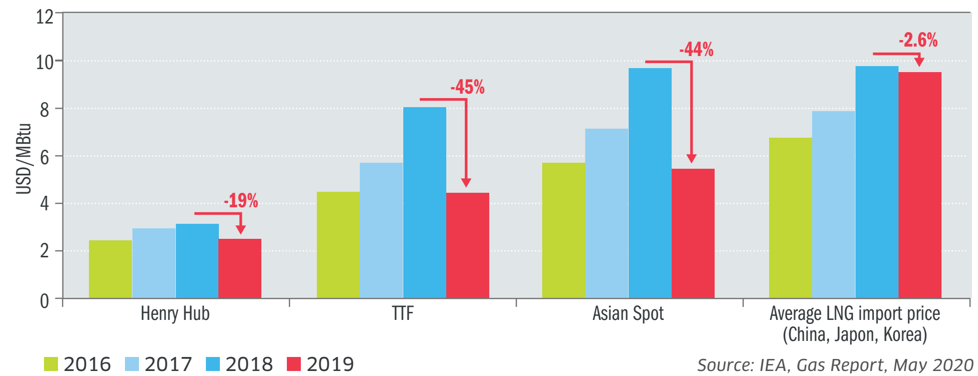
Natural gas prices will remain depressed throughout the summer in a context of grim demand, high stocks and continued LNG supply growth from liquefaction projects that have recently started operations.

**NATURAL GAS PRICES IN €/MWH (MONTH AHEAD)**




*Source: ENGIE Global Markets*

**NATURAL GAS PRICES IN SELECTED MARKETS, 2016-2019 (IN $/MBTU)**




*Source: IEA, Gas Report, May 2020*

# Renewables gases (green gases)

## Green gases are set to play an important role in the transformation of the global energy system

### Green gases: what are they?

- **Biogas** is produced from either landfill gas, sewage sludge, agricultural or agri-food residues through an anaerobic digestion process (also called methanisation). It can be used directly to generate electricity and heat (cogeneration).
Anaerobic digestion or methanisation is a biological process using microorganisms to decompose organic matter in the absence of oxygen. This process produces Biogas (methane, $CO_2$ and other gases) and a digestate that can be used as fertiliser.

- **Syngas** is produced by either pyrogasification or reformation of green hydrogen and carbon dioxide (methanation).
Pyrogasification or gasification is a thermo-chemical process that produces a gaseous fuel, called syngas, from lignocellulosic material (wood, straw, etc.). Syngas mainly consists of methane, hydrogen, carbon monoxide and carbon dioxide. It can be used directly in cogeneration or purified to produce biomethane.

- **Biomethane** is Biogas or purified synthesis gas that can be injected into the natural gas grid as a substitute to natural gas for any type of client and use, including mobility (NGV).

- **Green hydrogen** is produced from renewable electricity through electrolysis (power-to-gas) or through biomass (steam reforming or pyro-gasification). Mainly used as an industrial raw material today, hydrogen can be injected directly into the natural gas grid directly or in the form of methane after reformation with carbon dioxide (see following section).

Biomethane, synthesis methane or hydrogen can either be injected in the natural gas grid (up to a certain percentage for hydrogen) or used directly, off the grid, for specific purposes, such as transport.

**Most of today's green gases are Biogases from methanisation,** with heat and electricity produced through cogeneration engines. The production of biomethane for injection into the natural gas grid is developing, however, thanks to regulatory incentives in several European countries.
Pyrogasification and power-to-gas have not yet reached the technological maturity of methanisation, and their share of production remains limited compared to methanisation.

**Biogas has thrived over recent years because of two major factors: the availability of raw material and the political support given to Biogas production and use.** This explains its uneven development across the world. Europe, China and the USA together made up 90% of world production in 2018, for an estimated 35 Mtoe (approx. 410 TWh). This represents a tiny fraction of world potential however, estimated near 600 Mtoe (approx. 7,000 TWh).

### Biogas expansion continues in Europe

In 2018, European Biogas production reached 18 Mtoe (~20 bcm or 200 TWh), or 8% of European gas production. Biogas experienced exponential growth until 2014, and more attenuated since, mainly as a result of changes in the EEG law*. This law, promulgated in April 2000, creates a dedicated purchasing tariff in Germany, which until now remains the main producer in Europe. Indeed, Biogas production is still concentrated at 80% in 3 countries: Germany (10 bcm), UK (3 bcm), Italy (3 bcm). Biogas is the “bioenergy” that has the most rapidly increased since 2010, surpassing biofuel production.

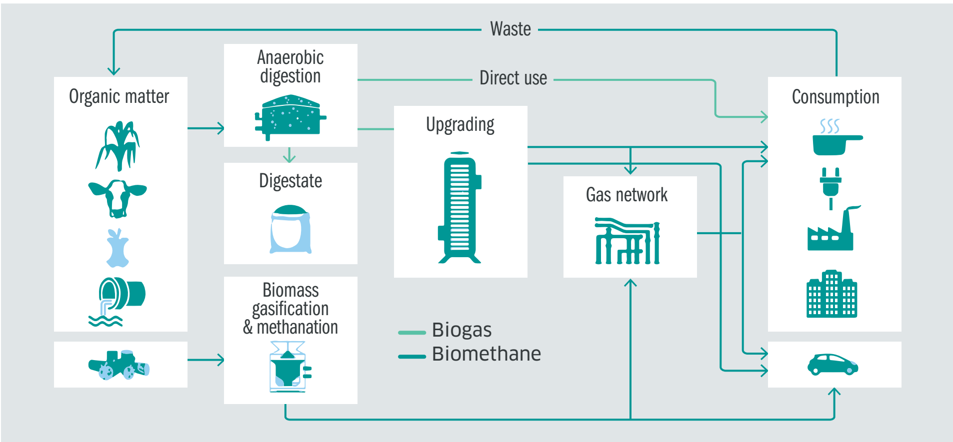
In Europe, 76% of Biogas is for power and heat production – to produce 63 TWh of electricity (i.e. 6% of renewable electricity in Europe) - then it is consumed for 7% in residential, 5% in agriculture, 2% in industry and 1% in transport. Finally 4% are injected into natural gas networks in the form of biomethane, thanks to 729 biomethane injection stations today (source: EBA / GIE, early 2020).

According to the European Biogas Association, renewable gases could reach 10% of natural gas consumption in the EU by 2030 (approx. 43 Mtoe, or 500 TWh). And by 2050, according to the Gas for Climate consortium, sustainable biomethane production could amount to 1,072 TWh (near 22% of current gas consumption).

*EEG: Erneuerbare Energien Gesetz, German law giving priority to renewable energies thanks to dedicated purchase prices.
1 Mtoe = 11.63 TWh = 41.9 PJ (petajoules).

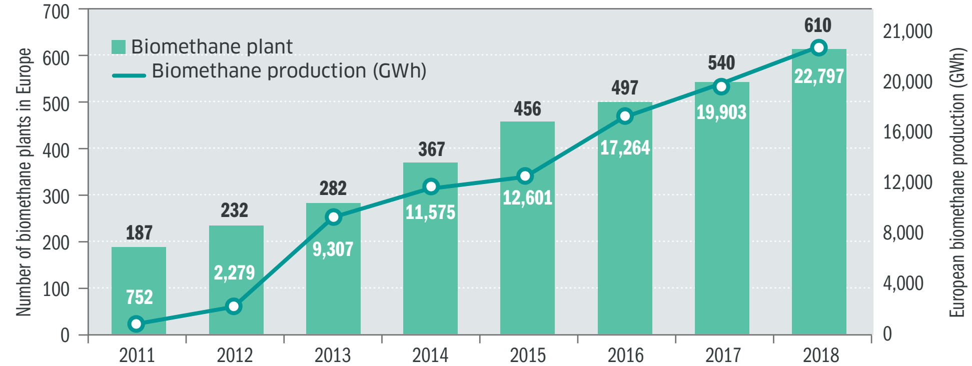
# Renewable gases: biogas and biomethane

## HOW BIOGAS AND BIOMETHANE ARE PRODUCED




*Source: European Biogas Association, Statistical Report (2019)*

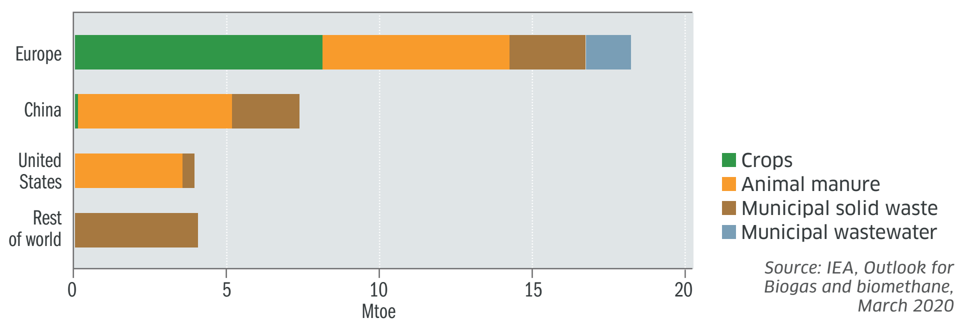
## EU BIOMETHANE PRODUCTION AND NUMBER OF INJECTION FACILITIES




*Source: European Biogas Association, Statistical Report (2019)*

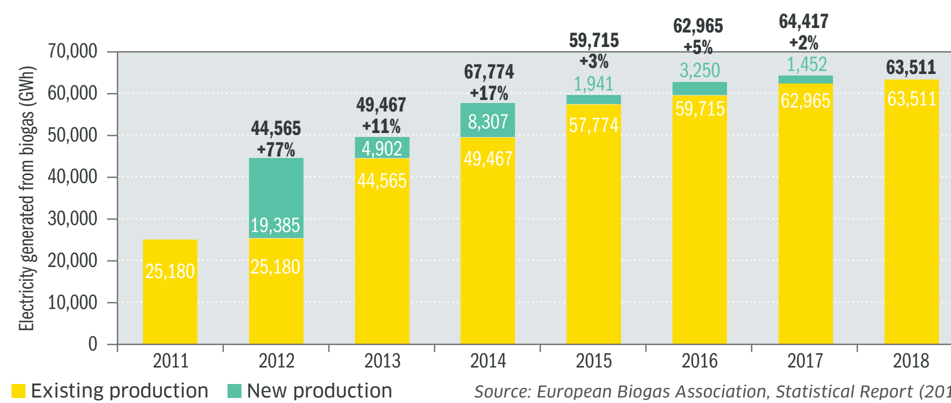


## WORLD BIOGAS PRODUCTION BY SOURCE IN 2018




*Source: IEA, Outlook for Biogas and biomethane, March 2020*

## EU ELECTRICITY PRODUCTION FROM BIOGAS – IN GWH




*Source: European Biogas Association, Statistical Report (2019)*

# Renewable gases within the energy transition

### Green gases meet energy transition requirements on several counts.

As they can be injected into natural gas grids, green gases offer specific advantages over other renewable sources: low transport costs, massive and competitive storability, and high inter-seasonal flexibility. In Europe in particular, green gases can benefit from existing and well-amortised infrastructures. For these reasons, green gases are an indispensable vehicle of energy transition and an integral part of decarbonization roadmaps, in which they are complementary to other renewables for electricity generation (see the Scenarios section in the Decarbonization chapter).

Because it is produced locally, biogas is an opportunity for decentralised solutions and non-relocatable job creation (about 3-4 direct jobs per facility). It helps address the community challenge of waste treatment, favours sustainable agriculture, helps to improve air quality and opens access to 'modern' energy for communities deprived of it.

### Market design is essential to take advantage of biogas and biomethane potential.

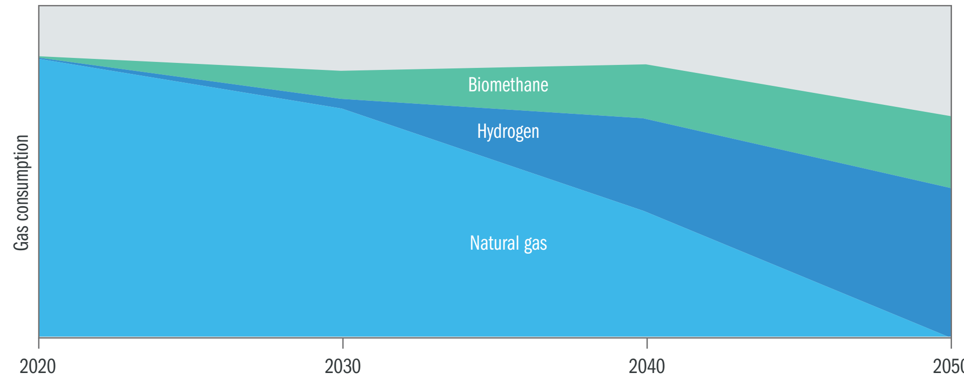
Biogas and biomethane development is very capital-intensive. Production costs largely depend on input prices, facility size and national support mechanisms. They range from €40 to €120 per MWh for production based on anaerobic digestion.

For biomethane and biogas to compete with fossil fuels, carbon prices must reflect their environmental benefit. Until then, support such as injection tariffs, support mechanisms as green certificates, or fiscal incentives will be needed for the market to develop.

The establishment of support policies, as was the case for electric renewables, should improve the productivity of anaerobic digestion units, professionalize the sector by massifying operations and standardizing them. The objective is to reduce biomethane production costs by a third by 2030.

At last, the cost of these mechanisms must be balanced with the positive externalities generated by biogas and biomethane.

**GREEN GAS PRODUCTION FORECASTS TO 2050 IN THE EUROPEAN UNION**




*Source: Gas for Climate (2020)*

**USE OF GREEN GAS BY SECTOR IN THE EU TO 2050**


*Source: Navigant (2019)*

# Renewable gases: green hydrogen

## Green hydrogen as the missing link in energy transition

**Hydrogen ($H_2$) is the most widespread chemical element on earth.** It is found in water ($H_2O$), for example, and in hydrocarbons such as oil and natural gas. **The molecule has a particularly high energy content and it can be transported and stored.** 1kg of hydrogen generates roughly three times more energy than 1kg of gasoline.

**Today, mainly "grey" hydrogen is produced.**

- **Grey hydrogen** is extracted from fossil fuels, notably through natural gas steam reforming. 48% of hydrogen is produced from natural gas, 30% from oil products and 18% from coal. In other words, 96% of the world's hydrogen production is grey hydrogen.

- Grey hydrogen is currently the cheapest solution available at around $2/kg$H_2$, depending on gas and $CO_2$ local prices. But it is also highly carbon-intensive: 1kg of $H_2$ produced generates about 10kg of $CO_2$. The sector emits 830 million tonnes of $CO_2$ each year, according to the IEA. By comparison, Germany's total emissions are smaller than that.

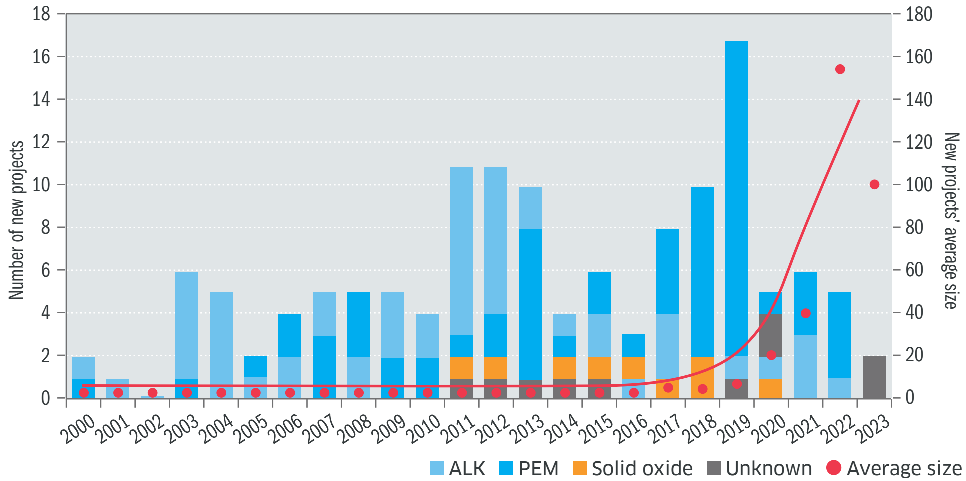
- **Blue hydrogen** is derived from grey hydrogen, complemented with carbon capture and storage (CCS). 60-90% of the $CO_2$ emitted during the production process is captured and stored underground. Huge storage capacity is required and its full costs are poorly understood.

- **Green hydrogen is the only fully decarbonized solution.** It produces hydrogen via the electrolysis of water, using renewable electricity (hydro, solar or wind) without $CO_2$ emissions or polluting particles. Renewable hydrogen remains about twice as expensive as grey hydrogen, and today only 4% of world hydrogen production uses electrolysis.

**Hydrogen is used mainly as an industrial raw material.**
Most of the 70 million tonnes of hydrogen produced each year in dedicated facilities is used to manufacture ammonia and fertilisers (44%), methanol (18%) and to refine oil (26%).

**Cheaper electrolysis and renewable energy will extensively reshape the hydrogen market in the years ahead.** Converging private initiatives and public support have helped the electrolysis sector to start scaling up. In combination with process industrialisation, electrolysers' production costs are coming down. Taken together, planned electrolysis projects represent 8.2 GW in installed capacity by 2030, according to the European Commission in March 2020. The cost of producing renewable hydrogen is nearly equally divided between the costs of the electrolyser and that of green electricity. **The downtrend in renewable power and electrolysis costs reduced renewable hydrogen production costs by 45% on average between 2015 and 2020, according to IHS.**

### HYDROGEN PRODUCTION PROJECTS BY ELECTROLYSIS




*More numerous and larger projects for H2 production by electrolysis.*
*Source: IRENA, 2019*

# Renewable gases: green hydrogen

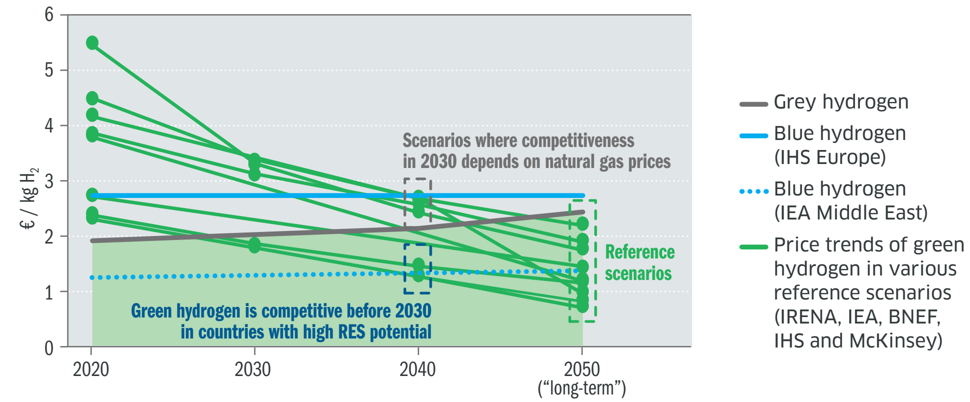
**There is now a consensus among scientists that green hydrogen will soon be a competitive alternative.**
- The continuing decline in renewable electricity and electrolysers' costs is expected to halve production costs by 2030.
- Most analysts consider that green hydrogen will be cheaper than grey hydrogen before 2030 in the most favourable locations (i.e. where wind and solar power is the most competitive).
- Establishing a high $CO_2$ price should accelerate the trend, as it would weigh on grey hydrogen production costs.

**Greener hydrogen production will go together with new uses.** Decarbonizing current hydrogen uses (refining, chemicals and steel production) is a first step in market development. Beyond that, most experts consider that green hydrogen will expand as a low carbon solution for 'heavy' mobility (road, rail, synthetic fuel for maritime and air transport), power storage and production, and heat generation.
The Hydrogen Council forecasts that the global market for hydrogen will increase tenfold by 2050, driven by renewable hydrogen and its new uses, and that hydrogen will account for about 20% of final energy demand by then (see opposite).

**In most energy transition scenarios, green hydrogen is a key element** in unlocking the full potential of electricity renewables. It can be stored to cope with intermittent renewable energy and to meet seasonal demand (heating and cooling).

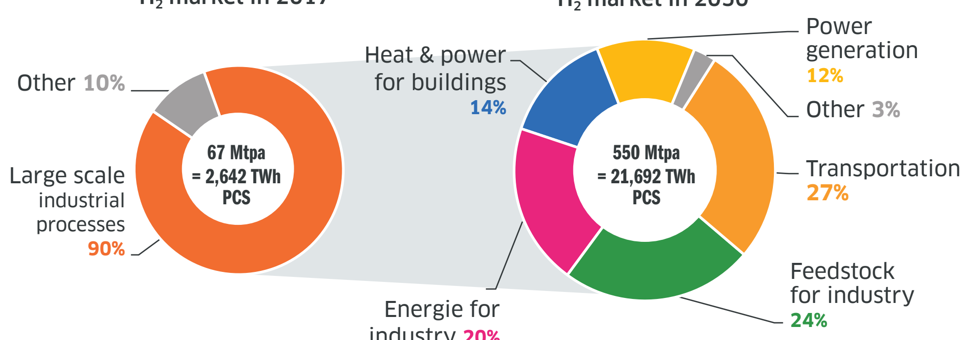
**Green hydrogen benefits from strong political support.** Many countries have implemented policies aimed at its development. In July 2020, for example, the European Commission published a hydrogen deployment strategy as part of carbon neutrality. The objective is 40 GW electrolysis installed capacity by 2030, producing 10 Mt of green hydrogen.

## HYDROGEN PRODUCTION COSTS IN THE MAIN BENCHMARKS






## 2050 HYDROGEN MARKET ESTIMATES (ALL TYPES OF HYDROGEN)




Source : Hydrogen Council

# Appendix

# Conversions

| Weight | kilograms |
|---|---|
| 1 pound | 0.453 |
| 1 American ton (short ton) | 907 |
| 1 British ton (long ton) | 1,016 |

| Denominations in the American system | |
|---|---|
| $10^0$ | unit |
| $10^1$ | tens |
| $10^2$ | hundreds |
| $10^3$ | thousands |
| $10^6$ | millions |
| $10^9$ | billions |
| $10^{12}$ | trillions |
| The French billion is $10^{12}$ | |

Multiples and decimal sub-multiples of the units of measurement

| Abbreviation | Name | Value | Power |
|---|---|---|---|
| P | peta | 1,000,000,000,000,000 | $10^{15}$ |
| T | tera | 1,000,000,000,000 | $10^{12}$ |
| G | giga | 1,000,000,000 | $10^9$ |
| M | mega | 1,000,000 | $10^6$ |
| k | kilo | 1,000 | $10^3$ |
| h | hecto | 100 | $10^2$ |
| da | deca | 10 | $10^1$ |
| unit | unit | 1 | $10^0$ |
| da | decu | 0.1 | $10^{-1}$ |
| c | centi | 0.01 | $10^{-2}$ |
| m | milli | 0.001 | $10^{-3}$ |
| µ | micro | 0.000 001 | $10^{-6}$ |

Other energies

| | Heavy fuel | Super fuel | Dry wood | Household waste | Paper waste | Natural uranium |
|---|---|---|---|---|---|---|
| Physical unit | 1 ton | 1,000 liters | 1 ton | 1 ton | 1 ton | 1 ton |
| Tons of oil equivalent | 0.95 | 0.79 | 0.33 | 0.18 | 0.33 | 12,000 |
| MWh | 11 | 9.1 | 3.9 | 2.1 | 3.9 | 140,280 |
| GJ | 40 | 33 | 14 | 7,6 | 14 | 505,000 |

*Source: Joint report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency – Uranium 2005: Resources, Production and Demand*

Volume unit

| From | To | | | | |
|---|---|---|---|---|---|
| | $m^3$ | liters | $ft^3$ | US gallon | barrel |
| | Multiply by | | | | |
| $m^3$ | 1 | 1,000 | 35.32 | 264 | 6.28 |
| liters | 0.001 | 1 | 0.0353 | 0.264 | 0.00629 |
| $ft^3$ | 0.0283 | 28.3 | 1 | 7.47 | 0.178 |
| US gallon | 0.00379 | 3.79 | 0.134 | 1 | 0.0238 |
| Barrel | 0.159 | 159 | 5.62 | 42 | 1 |

Energy unit

| From | To | | | | |
|---|---|---|---|---|---|
| | MWh | toe | GJ | MMBtu | Therm |
| | Multiply by | | | | |
| MWh | 1 | 0.0860 | 3.6 | 3.412 | 34.12 |
| toe | 11.63 | 1 | 41.9 | 39.68 | 396.8 |
| GJ | 0.2778 | 0.0239 | 1 | 0.948 | 9.48 |
| MMBtu | 0.293 | 0.0252 | 1.055 | 1 | 10 |
| Therm | 0.0293 | 0.00252 | 0.105 | 0.1 | 1 |

# Conversions



## Crude oil

| From | To | | | | | |
|---|---|---|---|---|---|---|
| | Tons | 1,000 liters | Barrels | US Gallons | MWh | GJ |
| | Multiply by | | | | | |
| Tons (Metric) | 1 | 1.212 | 7.6 | 320 | 12.1 | 43.5 |
| 1,000 liters | 0.825 | 1 | 6.290 | 264.17 | 10.0 | 35.9 |
| Barrels | 0.132 | 0.159 | 1 | 42 | 1.587 | 5.710 |
| US Gallons | 0.00313 | 0.0038 | 0.0238 | 1 | 0.0378 | 0.136 |
| MWh | 0.0827 | 0.100 | 0.630 | 0.630 | 1 | 3.60 |
| GJ | 0.0230 | 0.028 | 0.028 | 7.35 | 0.278 | 1 |

## Coal

| From | To | | | | |
|---|---|---|---|---|---|
| | Short ton | Metric ton | Ton of oil equivalent | MWh | GJ |
| | Multiply by | | | | |
| Short ton | 1 | 0.9071847 | 0.6248 | 7.560 | 27.22 |
| Metric ton | 1.102 | 1 | 0.6887 | 8.333 | 30 |
| Ton of oil equivalent | 1.601 | 1.452 | 1 | 12.1 | 43.5 |
| MWh | 0.1323 | 0.1200 | 0.08264 | 1 | 3.6 |
| GJ | 0.03674 | 0.03333 | 0.02299 | 0.278 | 1 |

## Natural gas (GN) & liquefied natural gas (LNG)

| From | To | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Bcm | Gft³ | Mtoe | Million tons of LNG | Millions of m3 of LNG | TBtu | Million barrels of oil equivalent | TWh | PJ |
| | Multiply by | | | | | | | | |
| 1 billion cubic meter NG (1 Bcm) | 1 | **35.3** | 0.93 | 0.739 | 1.63 | 37.0 | 6.37 | 10.8 | **39.0** |
| 1 billion cubic feet NG | 0.0283 | 1 | 0.026 | 0.0209 | 0.0460 | 1.05 | 0.18 | 0.307 | 1.10 |
| 1 million tons of oil equivalent | 1.07 | 37.9 | 1 | 0.794 | 1.74 | 39.69 | 6.84 | **11.6** | 41.9 |
| 1 million tons of LNG | 1.35 | 47.7 | 1.26 | 1 | 2.20 | 50.0 | 8.62 | 14.7 | **52.7** |
| 1 million cubic meter of LNG | 0.615 | 21.7 | 0.573 | **0.455** | 1 | 22.8 | 3.92 | 6.67 | 24.0 |
| 1 trillion British thermal units | 0.0270 | 0.955 | 0.0252 | 0.0200 | 0.0440 | 1 | 0.17 | **0.293** | 1.05 |
| 1 million barils of oil equivalent | 0.157 | 5.54 | 0.146 | 0.116 | 0.255 | **5.8** | 1 | 1.70 | 6.12 |
| TWh | 0.0923 | 3.258 | 0.0860 | 0.0683 | 0.150 | 3.41 | 0.588 | 1 | **3.6** |
| PJ | 0.0256 | 0.905 | 0.0239 | 0.0190 | 0.0417 | 0.948 | 0.163 | 0.278 | 1 |

1 m³ NG: 0.9 of crude oil – 1 m³ NG: 10,000 kcal – 1 m³ NG: 41.860 kJ.
NB: These conversions are based on eight assumptions identified by the figures in bold.

The change from cubic meters to kWh and more generally from volume units to energy units depends on the quality of the gas. We speak of HHV and LHV depending on whether we use the lower or higher estimate of the heating value of the gas. The HHV estimate includes heat recoverable from steam (including energy recoverable from condensation). In a gas context, we generally speak of HHV. We speak of LHV in domestic inter-energy reports, for example.

1 kWh LHV. . . . . . . . . . . . . . . . = 0.9 kWh HHV
1,000 m³ of HHV Natural Gas = 0,9 toe
1,000 m³ of LHV Natural Gas = 0,81 toe
1 toe (HHV context) . . . . . . . . = 1,111 m³ of Natural Gas
1 toe (LHV context) . . . . . . . . = 1,234 m³ of Natural Gas
1 m³ of HHV Natural Gas . . . . = standard of 42 MJ (HHV) (between 38 and 42 MJ)
. . . . . . . . . . . . . . . . . . . . . . . . . standard of 11.7 kWh (HHV) (between 9 and 12 kWh)
. . . . . . . . . . . . . . . . . . . . . . . . . European conversion: 39 MJ (HHV)
. . . . . . . . . . . . . . . . . . . . . . . . . European conversion: 10.8 kWh (HHV)
. . . . . . . . . . . . . . . . . . . . . . . . . conversion in France: 11.5 kWh (HHV)
1 Tcf PCS . . . . . . . . . . . . . . . . . = 25.48 Mtoe
1 ton of LNG . . . . . . . . . . . . . . = 1,320 – 1,380 m³ of gas

# Glossary

**Added value:** Usual method for measuring the net production of a branch or a sector in monetary units; added value is equal to the difference between the gross production and intermediate consumption; added value can be measured at the cost of the factor or at the market price. Added value of agriculture measures the activity of farming, fishing and for-estry. Added value of industry measures mining, manufacturing and construction activities, and electricity, gas and water. Added value of services or of the tertiary sector measures the activity of all services, both public and private: retail and wholesale commerce, banking, and public administration.

**Annex I:** UN Convention on Climate Change Annex I countries: Germany, Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Denmark, Spain, Estonia, United States of America, Finland, France, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechten-stein, Lithuania, Luxembourg, Malta, Monaco, New Zealand, Norway, Netherlands, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Switzerland, Czech Republic, Turkey, Ukraine, United Kingdom.

**ATEE:** Association Technique Énergie Environnement, a French association of energy and environmental operators (institutional, private, etc...).

**Aviation and marine bunker oils:** Marine bunker oils are the duty-free fuels for ocean vessels and aviation bunker oils are the aircraft fuels consumed for international transport. At coun-try level, they are excluded from primary consumption and are considered to be exports. At global level, they are included in primary consumption.

**Biogas:** a gas resulting from the fermentation, also called methanisation, of organic matter (animal or plant) in the absence of oxygen. It consists primarily of methane (from 50% to 70%), but usually also carbon dioxide, water vapour, hydrogen sulphide, etc. The energy pro-duced by Biogas solely comes from methane.

**Biomethane:** a Biogas whose undesired components have been removed (carbon dioxide, water vapour, hydrogen sulphide, etc.), so that methane only remains. Methane's properties are similar to those of natural gas. Biomethane can be handled in natural gas distribution and transport networks.

**Bituminous coal:** Type of coal transformed into coke.

**CAPEX-OPEX:** Operating expense (often abbreviated as OPEX) is the ongoing cost for running a product, business, or system. Its counterpart, capital expenditure (CAPEX), is the cost of developing or providing non-consumable parts for the product or system.

**CEA:** Commissariat à l'énergie anomique (French Atomic Energy Commission)

**CediGas:** International association of manufacturers for gas (GDF SUEZ is a member).

**CERA:** Cambridge Energy Research Associates.

**$CH_4$:** Methane, a hydrocarbon with a global warming potential 25 times greater than that of $CO_2$.

**Change in inventories:** In principle, these are the changes in inventory levels between two identical dates one year apart. The inventories are those of the energy producers and gene-rally exclude consumer inventories. However, depending on the measurement methods adopted by each country, these changes in inventories represent real data or may include statistical deviations or non-metering between the primary supply and the inputs trans-formed or consumed. The + sign indicates a decrease in inventories during the year; the - sign indicates an increase in inventories during the year. Changes in inventories that syste-matically have the same sign are an indication of accounting distortions or poor allocation.

**CI:** Cost Insurance Freight. CIF price, in contrast to FOB price, includes shipping costs, and the various taxes and insurance; the seller is responsible for the merchandise up to the port of arrival.

**CIS:** Community of Indiapendent States, composed of 11 of the 15 former Soviet Republics: Armenia, Azerbaijan, Belarus, Georgia, Kyrgyzstan, Kazakhstan, Moldavia, Russia, Federation of Tajikistan, Turkmenistan (Associate State), Ukraine, Uzbekistan - Mongolia as an observer.

**Coke:** Transformed coal used primarily in making steel.

**Coking plants and blast furnaces:** The inputs of coking plants are the coking coal consumed by coking plants. The inputs of blast furnaces are the coke consumed.

**Coking plants, briquette plants:** The inputs of coking plants are the coking coal consumed by coking plants. The inputs of blast furnaces are the coke consumed. The outputs of coking plants are coke and coking gas. The outputs of the blast furnaces are the blast furnace gases.

**DEP:** Department of Exploration Production.

**DGEMP:** Department of Energy and Raw Materials (Direction Générale de l'Énergie et des Matières Premières).

**DFO:** Domestic fuel oil (home heating oil).

# Glossary

**Domestic consumption:** Domestic consumption, for each energy product, is the balance of the total production, foreign trade, air and marine bunker oils (for oil) and changes in inven-tories.

**EIA-DOE:** Energy Information Agency - Department of Energy (USA).

**Electric power plants:** The inputs of electric power plants correspond (for thermal plants) to the consumption of fuels by the power plants. The production of the electric power plants corresponds to the gross production.

**Electric power plants (thermal):** The inputs of electricity power plants are the fuels consumed by public plants and by self-producers (including co-generation).

**Electricity production:** Gross electricity production including public production (private and public power companies) and the self-producers, by any type of power plant (including co-generation).

**Electricity production from co-generation:** Gross production of electricity by power plants that produce electricity and heat (power companies and self-producers).

**Energy sector self-consumption:** Consumption to run energy transformation units (power plants, refineries).

**ENTSO-E:** European Network of Transmission System Operators for Electricity.

**EU:** The European Union has 27 states members since the withdrawal of the United Kingdom January 1, 2020: Germany, Austria, Belgium, Bulgaria, Cyprus, Denmark, Spain, Estonia, Finland, France, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Czech Republic, Romania, Slovakia, Slovenia, Sweden. Croatia's membership is effective July 1, 2013, in the enlargement process in the Balkans started nine years earlier. The EU matters in total 515 million inhabitants and covers an area of 3,930,000 $km^2$.

**Exploration and development cost:** The average cost of exploration and development represents the dollar cost per barrel equivalent of additional reserves of a country coming from exploration activities, discoveries, improved recovery or update assessments. This cost does not include the licensing of proven reserves

**Exports:** Exports are the volumes of energy product exported from the national territory to another country, minus simple transit volumes and volumes “custom” processed on behalf of a third party country. In the case of geographic or geopolitical regions, exports are the aggregates of national exports, including those that are part of flows within the region. For accounting consistency, exports appear with a negative sign.

**Final consumption:** Final consumption is the balance between the interior consumption and consumption from the energy transformations and various losses. It measures the needs of the end consumers in the country. They are broken down by category as follows: industry, transport, residential, services, agriculture and non-energy uses. Final consumption of industry is broken down by business line or sector: steel, chemical, non metallic minerals (construction materials), and so on.

**Final consumption for non-energy uses:** This is the consumption of the products intended for petrochemicals (naphtha), the fabrication of ammonia (natural gas), use in electrode (carbon) form and the use of all products used for their physical-chemical properties (bitumen, paraffins, motor oils, etc.). They are divided into chemicals and other.

**FOB:** Free On Board. FOB price, in contrast to CIF price, does not include any transport cost, tax or insurance.

**Forward price:** Forward = forward price - given for different expirations.

**Fugitive emissions:** Intentional and non-intentional greenhouse gas emissions, from the extraction of a fossil fuel up to the point of use.

**GDP:** Gross Domestic Product: Measurement of the economic activity of a country; it is currently measured at market prices. GDP at market price is the sum of the value added to the cost of factors, plus indirect taxes, minus subsidies.

**GHG:** Greenhouse Gases.

**Henry Hub:** Point of determination of the prices of the gas traded on the NYMEX (New York Mercantile Exchange).

**HFC:** Hydrofluorocarbon (a category of fluorinated gases that actively contribute to the deterioration of the ozone layer, with a global warming potential 3,000 times greater than that of $CO_2$).

**IEA:** International Energy Agency.

**IIASA:** International Institute for Applied Systems Analysis.

**Imports:** Imports are the volumes of energy product imported from another country into the national territory, minus the volumes that are transiting to a third party country and the quantities intended to be “custom” processed on behalf of a third party country. In the case of geographic or geopolitical regions, imports are the aggregates of the national imports, including those that are flows within the region.

# Glossary

**Industry final consumption:** Industry final consumption includes the consumption of the mining, manufacturing and construction sectors. They exclude the consumption of fuel for transport activities, even when the means of transport belong to the industrial companies, and the consumption of fuels for the self-production of electricity. The energy products used as raw materials or maintenance products are in general separate, or at least identified under the name “non-energy uses.”

**LNG:** Liquefied Natural Gas.

**Light Tight Oil (Tight Oil)**: Light tight oil or tight oil is a type of oil present in relatively impermeable, non-porous layers and requires extraction techniques similar to those of shale gas. Tight oil primarily differs from shale oil in its degree of viscosity and is found in particular in the Niobrara and Eagle Ford formations in the United States.

**Lignite:** A type of low-carbon coal with a low calorific value.

**Liquefaction (of gas):** The inputs of gas liquefaction plants are natural gas consumptions. The production of liquid gas is the output.

**LPG:** Liquefied Petroleum Gas.

**ULUCF:** Land Use, Land Use Change and Forestry, with implications for $CO_2$, $CH_4$ and $N_2O$ emissions and capture. The notion covers tree felling and planting, woodland conversion (clearing) and prairies as well as soils whose carbon content is sensitive to the use to which it is put (forest, prairie, cultivated).

**Marginality:** In the production of electricity, the duration of marginality represents the time when the production method used is the one with the lowest marginal cost (cost of an additional unit).

**Mbl:** Million barrels.

**MMBtu:** 1,000,000 Btu (1 million Btus).

**NBP:** National Balancing Point is a virtual trading location for the sale and purchase and exchange of UK. It serves as a reference for forward contracts.

**Net production (electricity):** The net production of electricity is the balance between gross production and the auto-consumption of electric power plants.

Nitrogen oxide: NO, nitrogen oxide.

**$NO_2$:** Nitrogen dioxide.

**$N_2O$:** Nitrogen protoxide (also known as nitrous oxide) with the chemical formula $N_2O$ is a powerful greenhouse gas that remains in the atmosphere for a long time (about 120 years). It is partially responsible for the destruction of the ozone. The soil and oceans are the principal natural sources of this gas, but it is also produced by the use of nitrogen fertilizers, the combustion of organic matter and fossil fuels, the production of nylon, etc. In France, farming contributes to the 3/4 of $N_2O$ emissions that essentially come from the transformation of nitrogen products (fertilizer, manure, liquid manure, crop residues) in farm land. $N_2O$ is a colorless and non-flammable gas, stable in the lower levels of the atmosphere, but it decomposes in the higher levels (stratosphere) through chemical reactions involving sunlight.

**Non-conventional gases:** Like the gas known as “conventional”, “non-conventional gases” are essentially composed of methane, but are trapped in relatively impermeable rock, which until recently had limited their development. In fact, extraction requires production technologies that are much more complex than for traditional reservoirs.

**Non-conventional oils:** Oil extracted by methods other than from a well (in oil sands, for example).

**OECD:** Organization of Economic Cooperation and Development. Member countries: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Germany, Finland, France, Greece, Hungary, Ireland, Iceland, Israel, Italy, Japan, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, South Korea,,Spain, Sweden, Switzerland, Turkey, United Kingdom, United States.

**Particulate Matter:** Particles in suspension (PM 2.5 corresponds to the fine particles that can enter the pulmonary alveoli).

**PFC:** Perfluorocarbon (category of fluorinated gases, with a global warming power on average 7500 times greater than that of $CO_2$).

**Primary consumption:** Primary consumption is the balance from primary production, foreign trade, bunker oils, and changes in inventories. Primary consumption aggregated over all products measures the country’s total energy consumption, including all losses and self-consumption during transformations. For primary energies, primary consumption = domestic consumption.

# Glossary

**Primary production:** Primary production measures the quantity of natural energy resource extracted and produced for the purpose of consumption as is, on the production site or elsewhere, or for subsequent transformations. It excludes the quantities not use for energy or transformation purposes, particularly for natural gas, the quantities flared, reinjected into wells or discharged as is. On the other hand, it includes auto-consumption on the production sites (electricity generation, auxiliary motors, for example). The production of hydraulic, geothermal, wind and nuclear electricity is considered to be primary production.

**Private consumption:** Total consumption of goods and services in monetary units by households.

**Production:** Energy production corresponds to gross domestic production. It measures the volume of energy product produced directly or resulting from a transformation process, including the volume reused in the transformation process itself (hence the concept of gross production).

**Production cost:** The average production cost is the average lifting cost of oil and gas from the reservoir to the shipping interface towards the processing center.

**Power generation from cogeneration:** Gross production of electricity by power plants that produce electricity and heat (power companies and self-producers).

**Public production (electricity):** The public production of electricity is the gross production of electricity production companies, whatever their status (public or private).

**Pumping:** Pumping station inputs are their electricity consumption. The output is the gross production of hydroelectricity.

**RES:** Renewable energy sources.

# Sources

### POST-COVID CONTEXT

Enerdata 2020

IEA – Global Energy Review 2020

IEA – World Energy Investment 2020

IEA – WEO 2019

Macroeconomic forecasts from Oxford Economics, The Economist, IHS, World Bank, European Union

Stimulus packages: various sources

### $CO_2$ & CLIMATE

Enerdata 2020

IEA – Global Energy Review 2020

IEA – WEO 2019

IDMC

World Meteorological Organization 2020

World Bank, « State and Trends of Carbon Pricing », 2020

I4CE

### DECARBONIZATION

IEA – WEO 2019

Enerdata – EnerFuture 2020

NégaWatt

Climate Bonds Initiative 2020

CCS Institute, Rapport 2019

### ELECTRICITY & ELECTRICAL RENEWABLES

Enerdata

IEA – WEO 2019

BNEF – NEO 2019

REN21 – Renewables 2020 Global Status Report

IEA – Global Energy Review 2020

IEA – Tracking Power 2020

### NATURAL GAS & RENEWABLE GASES

Enerdata

IEA – WEO 2019

IEA, Gas Report 2020, May 2020

IEA, Global Energy review 2020 Covid-19 impacts on energy and $CO_2$ emissions, 28 April 2020

Oxford Institute of Energy Studies, Natural gas demand in Europe: The impact of Covid-19 and other influences in 2020, June 2020



# Enerdata methodology

**Primary energy data comes from the International Energy Agency (IEA).** It is completed with data from regional organizations (EUROSTAT, OLADE, ADB, OPEC) or specialized institutions (CediGas), as well as by data from national sources (national statistics or data specially prepared by local correspondents with more than 100 partners in around 60 countries). This complementary data is used for the assessment and correction of primary data, and for the quick update of our own data.

The methodology and definitions used by Enerdata are the same as that of IEA and Eurostat.

**Energy statistics in physical units are converted into energy units (ktoe or Mtoe) on the basis of the following coefficients:**

**Crude oil:** fixed coefficient for most countries: 1.02 toe / ton

**Oil products:** fixed coefficient for all countries – same as EUROSTAT or IEA

**Natural gas:** national coefficients for key countries and fixed coefficients for the other countries (0.82 toe / 1000 m³); the national coefficients are indicated in the database

**Coal, Lignite:** fixed coefficient for coke; national coefficient for production, imports and exports for key producers or importers; the national coefficients are indicated in the database.

**Electricity:**

- nuclear: 1 TWh = 0.26 Mtoe
- hydroelectricity: 1 TWh = 0.086 Mtoe
- geothermal: 1 TWh = 0.86 Mtoe
- total production: 1 TWh = 0.086 Mtoe
- imports, exports: 1 TWh = 0.086 Mtoe
- consumption: 1 TWh = 0.086 Mtoe

# Geographical scope of the sources

| Enerdata | |
|---|---|
| **Europe region** | |
| Europe | European Union (27), Albania, Bosnia-Herzegovina, Croatia, Iceland, Macedonia, Norway, Serbia and Montenegro, Switzerland, Turkey. |
| UE-28 | European Union (25), Bulgaria, Romania, Croatia. |
| **America region** | |
| America | North America, Mexico, Central America, South America, Caribbeanv |
| Latin America | Central America, Mexico, South America, Caribbean. |
| North America | Canada, USA. |
| Central America and Mexico | Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama. |
| South America | Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela. |
| Caribbean | Bahamas, Barbados, Bermuda, Cuba, Dominica, Dominican Republic, Grenada, Haiti, Jamaica, Netherlands Antilles and Aruba, Saint Vincent and the Grenadines, Saint Lucia, Trinidad and Tobago. |
| **Asia region** | |
| Asia | ASEAN, Afghanistan, China, Hong Kong, Japan, Macao, Mongolia, North Korea, South Asia (Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka), Soth Korea, Taiwan. |
| ASEAN | Association of Southeast Asian Nations (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam). |
| **Pacific region** | |
| Pacific | Australia, Pacific Islands, New Zealand. |

| Enerdata | |
|---|---|
| **Africa region** | |
| Africa | North Africa, Sub-Saharan Africa. |
| North Africa | Algeria, Egype, Libya, Morocco, Tunisia. |
| Sub-Saharan Africa | Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, DR Congo, Ivory Coast, Djibouti, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Equatorial Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe. |
| **Middle East region** | |
| GCC | Gulf Cooperation Council (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates). |
| OPEC Middle East | Iran, Iraq, Kuwait, Qatar, Saudi Arabia, UAE. |
| OAPEC | Organization of Arab Petroleum Exporting Countries (Algeria, Bahrain, Egypt, Iraq, Kuwait, Libya, Qatar, Saudi Arabia, Syria, Tunisia, UAE). |
| **CIS region** | |
| CIS | Commonwealth of Indiapendent States (former USSR, excluding Baltic countries). |
| Soviet Union (former) | Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan. |

*Source: Enerdata*

# Geographical scope of the sources

| International Energy Agency | |
|---|---|
| **Europe region** | |
| European Union | EU28 |
| Eastern Europe / Eurasia | Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, the former Yugoslav, Republic of Macedonia, the Republic of Moldova, Romania, Russian Federation, Serbia (incl Montenegro until 2004 and Kosovo until 1999, Slovenia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan. For statistical reasons, this region also includes Cyprus, Gibraltar and Malta. |
| OECD Europe | Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom. |
| **America region** | |
| OECD North America | Canada, Mexico and the United States. |
| OECD Latin America | Chile. |
| Latin America | Antigua and Barbuda, Aruba, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, the British Virgin Islands, the Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, the Dominican Republic, Ecuador, El Salvador, the Falkland Islands, French Guyana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Montserrat, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, Saint Lucia, Saint Pierre et Miquelon, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, the Turks and Caicos Islands, Uruguay and Venezuela. |
| **Asia-Pacific region** | |
| China | Refers to the People's Republic of China, including Hong Kong. |
| ASEAN | Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam. |
| OECD Asia | Japan and Korea. |
| Non-OECD Asia | Afghanistan, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Chinase Taipei, the Cook Islands, East Timor, Fiji, French Polynesia, India, Indonesia, Kiribati, the Democratic People's Republic of Korea, Laos, Macau, Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, Pakistan, Papua New Guinea, the Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Tonga, Vietnam and Vanuatu. |
| Other Asia | Non-OECD Asia regional grouping excluding China and India. |
| OECD Oceania | Australia and New Zealand. |
| OECD Pacific | Includes OECD Asia and Oceania. |

| International Energy Agency | |
|---|---|
| **Zone Africa** | |
| Africa | Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo, Côte d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, United Republic of Tanzania, Togo, Tunisia, Uganda, Zambia and Zimbabwe. |
| North Africa | Algeria, Egypt, Libyan Arab Jamahiriya, Morocco and Tunisia. |
| Sub-Saharan Africa | Africa regional grouping excluding South Africa and North Africa regional grouping. |
| **Zone Moyen-Orient** | |
| Middle East | Bahrain, the Islamic Republic of Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, the United Arab Émirates and Yemen. It includes the neutral zone between Saudi Arabia and Iraq. |
| **Autres zones spécifiques** | |
| OECD | Includes OECD Europe, OECD Latin and North America and OECD Pacific regional groupings. |
| OECD+ | OECD regional grouping and those countries that are members of the European Union but not of the OECD. |
| Other Major Economies | Comprises all countries not included in OECD+ and Other Major Economies regional groupings, including India, Indonesia, the African countries (excluding South Africa), the countries of Latin America (excluding Brazil), and the countries of non-OECD Asia, (excluding China) and the countries of Eastern Europe/Eurasia (excluding Russia). |
| Other Countries | Algeria, Angola, Ecuador, the Islamic Republic of Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Émirates and Venezuela. |

*Source: Enerdata*

# Geographical scope of the sources

| BP Statistical Review | |
|---|---|
| North America | US (excluding Puerto Rico), Canada, Mexico. |
| South and Central America | Caribbean (including Puerto Rico), Central and South America. |
| Europe | European members of the OECD plus Albania, Bosnia-Herzegovina, Bulgaria, Croatia, Cyprus, Former Yugoslav Republic of Macedonia, Gibraltar, Malta, Romania, Serbia and Montenegro, Slovenia. |
| Former Soviet Union | Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, Uzbekistan. |
| Europe and Eurasia | All countries listed above under the headings Europe and Former Soviet Union. |
| Middle East | Arabian Peninsula, Iran, Iraq, Israel, Jordan, Lebanon, Syria. |
| North Africa | Territories on the north coast of Africa from Egypt to western Sahara. |
| West Africa | Territories on the west coast of Africa from Mauritania to Angola, including Cape Verde, Chad. |
| East and Southern Africa | Territories on the east coast of Africa from Sudan to Republic of South Africa. Also Botswana, Madagascar, Malawi, Namibia, Uganda, Zambia, Zimbabwe. |
| Asia Pacific | Brunei, Cambodia, China, China Hong Kong SAR *, Indonesia, Japan, Laos, Malaysia, Mongolia, North Korea, Philippines, Singapore, South Asia (Afghanistan, Bangladesh, India, Myanmar, Nepal, Pakistan, Sri Lanka), South Korea, Taïwan, Thailand, Vietnam, Australia, New Zealand, Papua New Guinea, Oceania.* Special Administrative Region. |
| Australasia | Australia, New Zealand. |
| OECD members | Europe: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Republic of Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, UK.<br>Other member countries: Australia, Canada, Israel, Japan, Mexico, New Zealand, South Korea, US. |
| OPEC members | Middle East: Iran, Iraq, Kuwait, Qatar, Saudi Arabia, United Arab Émirates.<br>North Africa: Algeria, Libya.<br>West Africa: Angola, Nigeria.<br>South America: Ecuador, Venezuela. |

| BP Statistical Review | |
|---|---|
| European Union members | Austria, Belgium, Bulgaria, Cyprus, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Republic of Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, UK. |
| Other EMEs (Emerging Market Economies) | South and Central America, Africa, Middle East, non-OECD Asia, non-OECD Europe. |
| Methodology | The primary energy values of both nuclear and hydroelectric power generation have been derived by calculating the equivalent amount of fossil fuel required to generate the same volume of electricity in a thermal power station, assuming a conversion efficiency of 38% (the average for OECD thermal power generation). |
| Percentages | Calculated before rounding of actuals. All annual changes and shares of totals are on a weight basis except on pages 6, 14, 18, 20 and 22. |
| Rounding differences | Because of rounding, some totals may not agree exactly with the sum of their component parts. |
| Tonnes | Metric equivalent of tons. |
| Disclosure | Statistics published in this Review are taken from government sources and published data. No use is made of confidential information obtained by BP in the course of its business. |

**Country groupings are made purely for statistical purposes and are not intended to imply any judgement about political or economic standings.**

Our group is a global reference in low-carbon energy and services. Our purpose ("raison d'être") is to act to accelerate the transition towards a carbon-neutral world, through reduced energy consumption and more environmentally-friendly solutions, reconciling economic performance with a positive impact on people and the planet. We rely on our key businesses (gas, renewable energy, services) to offer competitive solutions to our customers. With our 171,000 employees, our customers, partners and stakeholders, we are a community of Imaginative Builders, committed every day to more harmonious progress.
Turnover in 2019: 60.1 billion euros. The Group is listed on the Paris and Brussels stock exchanges (ENGI) and is represented in the main financial indices (CAC 40, DJ Euro Stoxx 50, Euronext 100, FTSE Eurotop 100, MSCI Europe) and non-financial indices (DJSI World, DJSI Europe and Euronext Vigeo Eiris - World 120, Eurozone 120, Europe 120, France 20, CAC 40 Governance).

# ENGIE in brief

**171,000**
employees throughout the world

**€60 billion** in 2019 revenues

**€12 billion** of investments planned between now and 2021, including about **€5 billion** in customer solutions, nearly **€2.5 billion** in renewable energies and close to **€3 billion** in gas and electricity networks

**IN 2019, WE INVEST FOR THE FUTURE:**
**€189 million** in research and development
**€182 million** in innovative start-ups

**9 GW**
of additional renewable capacity between 2019 and 2021

**2** drivers of growth:
customer solutions (**€21 billion** in 2019 revenues) and renewables (**€3 billion** in 2019 revenues)

An investment fund of **€34 million** to support energy access (ENGIE Rassembleurs d'Energies fund) for **4 million** beneficiaries.

**WE COMMIT TO GREEN FINANCING:**
**€3.4 billion**
green bonds emitted in 2019

**Publishing Director:** Jean-Marc Leroy

**Editors-in-chief:**
**ENGIE Renewable Energy Sources Outlook:** Audrey Quehen
**Dashboard of Energy Transition:** Pierre-Laurent Lucille

**Main authors:**
**ENGIE Renewable Energy Sources Outlook:** Séverine Allano, Eliott Joseph, Peter Verwee (ENGIE Impact)

**Dashboard of Energy Transition:** Brigitte Cottet

**Editorial reviewer:** Amélie Aubin

**Design and layout:** gayacom.fr

We thank for their contribution the Renewables Global Business Line, the Strategy Department, and all ENGIE contributors who have been involved in the development and revision of this publication.

**Photo credits:**
AdobeStock: Cover, p. 3, 10, 13, 18, 19, 29, 35, 42, 43, 50, 57, 61, 72, 73. ENGIE / Breton Vincent: p. 2, 33. GettyImages: p. 3, 59, 60, 66. ENGIE / Dureuil Philippe: p. 3, 4, 5. ENGIE/Brunet Arnaud: p. 6. ENGIE / Sipa Press / Salom-Gomis Sebastien: p. 9, 15, 35, 36, 38, 55. ENGIE / Capa Pictures / Blondeau Manuel: p. 12. ENGIE / Miro / Meyssonnier Antoine: p. 16, 24, 31, 37, 46, 54, 63. ENGIE / Capa Pictures / Lubroth Adam: p. 20. Energy Observer Production / Drancey Antoine: p. 21. ENGIE / Abacapress / Ribas Ricardo: p. 22. ENGIE / Moirenc Camille: p. 23. ENGIE / Scope Production / Meyssonnier Antoine: p. 25. ENGIE / Abacapress / Blondeau Manuel: p. 26. ENGIE / Capa Pictures / Avril Annabelle: p. 27. ENGIE Electrabel / De Villenfagne Arnaud: p. 28. ENGIE / Fevrier Arnaud: p. 32. ENGIE / Interlinks Image / Leimdorfer Gilles: p. 34. Energy Observer Production / Drancey Antoine: p. 39. ENGIE / Havas / Diaz Laurie: p. 40, 53. Aubin Amélie: p. 41, 64. ENGIE / Stella & Cadente: p. 44. ENGIE / Plas David: p. 45. ENGIE / Matarazzo Salvatore: p. 49.

# ENGIE Renewable Energy Sources Outlook

2020 Edition

ENGIE

ENGIE - SA with a capital of 2 435 285 011 euros - RCS Nanterre 542 107 651
Tour T1 – 1 place Samuel de Champlain – Faubourg de l'Arche – 92930 Paris La Défense cedex - France