THE
Energy Transition. Enel's Solutions

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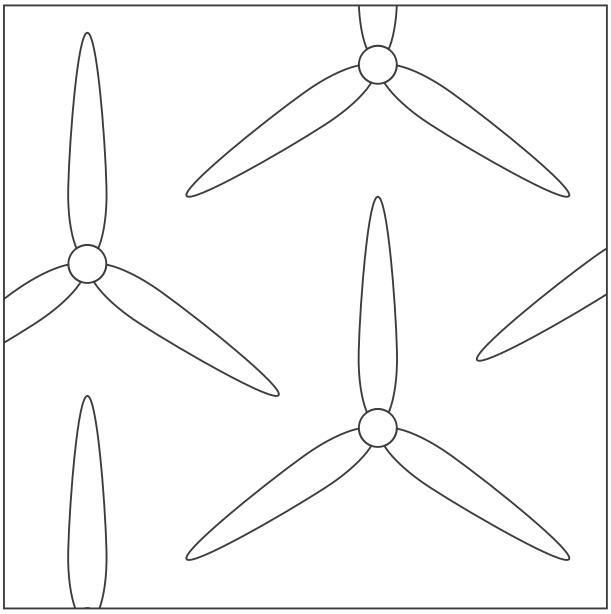
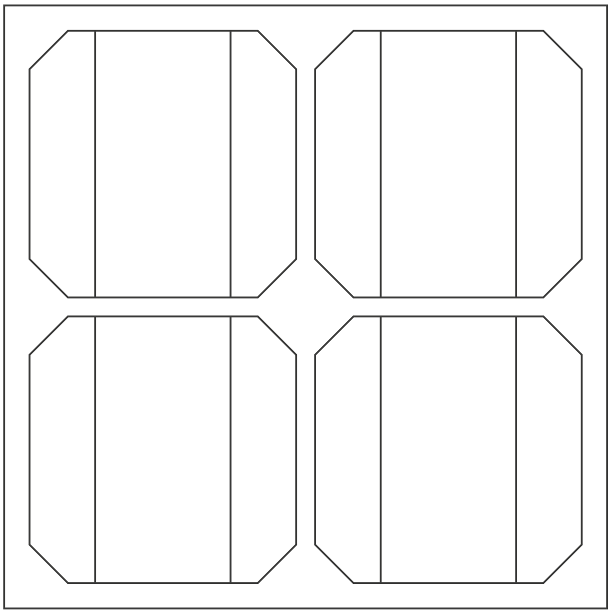
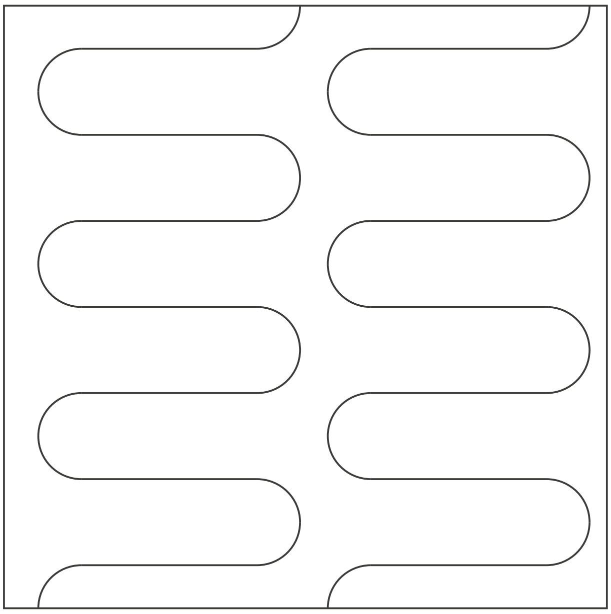
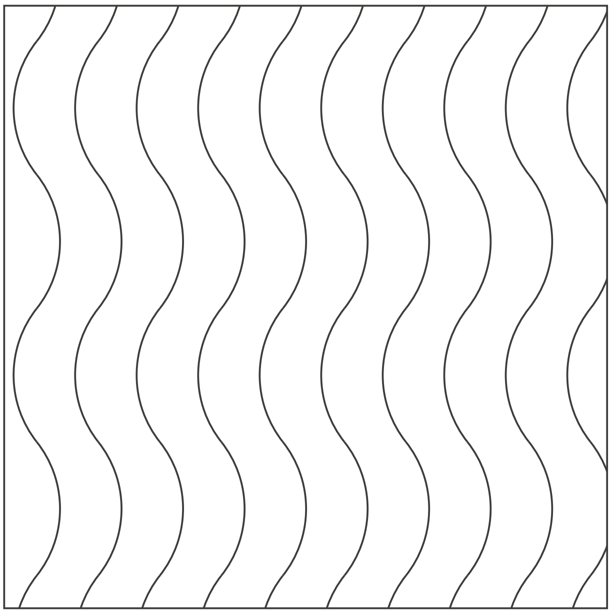

Index

Reading guide

This Handbook aims at providing an overview on the ongoing, dramatic changes taking place in electricity generation, as a result of the quick acceleration of the energy transition and of the fight against climate change in the past decade. This volume is addressed to readers with a limited familiarity with the energy sector and with Enel, who want to understand the energy transition. It aims at writing about the ongoing environmental changes and their impacts on the economy and the society. It is a tool to open up Enel's plan on how to guide and lead this energy transition, as driving the future of sustainable energy is indeed our key goal.

The Handbook thus focuses on power generation, also presenting information on other topics which are related to the important transformations the energy industry has been facing since recent years. Regarding topics such as electrification, we provided a synthetic, yet not exhaustive overview of what is taking place in the world and in Enel X in particular.

The Handbook is divided into seven different chapters, each detailing specific features of the energy transition and going further into the key concepts introduced in this introduction, and a glossary.

The structure is as follows:

1. Global warming and the transition: this chapter will discuss climate change as the main cause behind the energy transition, detailing the characteristics of the phenomenon, its origin, the global fight for emissions reduction and its social, political and technological drivers.

2. Actions for the energy transition: this chapter will provide a frame of reference for global trends and a perspective on the state of the art of main technologies. It will show a general overview of three key trends at the core of the Enel generation division's strategy: the growth of renewables, the phase out of coal, electrification and the supporting role of gas.

3. Leading technologies: this chapter will move on to a description of the more mature technologies leading the transition, providing a technical perspective over the state of the art of solar, wind, hydro and geothermal.

4. Emerging technologies: this chapter will explore the more experimental side of the process, discussing those technologies that, despite being key for the evolution of the transition, are still in a non-commercial state of development (marine, hydrogen) or just entered in the commercial stage but are not as mature as solar and wind (storage).

5. Complementary actions: this chapter will provide a description of the measures enabling and adding to the energy transition: assuming that the phenomenon is not a single technological shift, but a change involving the system as a whole, it will describe the main elements supporting this encompassing evolution, in particular services for the consumer, grids and digitalization.

6. Power sector framework: this chapter will complement the previous one with an analysis of the role of the regulatory framework. It will focus on how to favor renewables' diffusion and integration and on the differences in the design between pre-energy transition markets and future ones.

7. Socioeconomic impacts: this chapter will conclude the Handbook by discussing the impact of the energy transition and its interaction with society and consumers. It will highlight positive externalities of the transition towards the society as a whole (thus beyond the economic, industrial and environmental sectors), the issues at stake (job losses versus job recoveries, regions in transition, how to structure an inclusive transition) and the potential benefits for consumers.

Each chapter is divided into thematic sections, which are designed to be read also individually, and are introduced by a short presentation of their key message. In almost all sections, we provided a short list of challenges the sector will face, followed by a presentation of the solutions Enel is developing to address such issues. Considering that different topics concern different parts of Enel's organizational structure, we first provided a brief description of the company and of the business lines involved in the discussion of this Handbook.

About Enel

By distributing around 500 TWh of electricity across a network spanning approximately 2.2 mln km, Enel is the world's largest international and privately owned operator of power grids. Enel works in 32 countries across five continents, generating energy with a managed capacity of more than 89 GW. With more than 70 million customers around the world, Enel has the biggest customer base among our European competitors, and we are one of Europe's leading energy companies by installed capacity and reported EBITDA.

The Enel Group is made up of approximately 68,000 people from around the world whose brilliant work is based on our values of Responsibility, Innovation, Trust and Proactivity. Together we work towards the same goal. We are Open Power and our aim is to overcome some of the greatest challenges the world is facing. This is to be achieved through a new approach which combines attention to sustainability with the best in innovation.

Enel is dedicated to creating innovative solutions that meet society's changing needs. Through its openinnovability.com crowdsourcing platform, the company connects people and ideas from across the world, encouraging anyone to propose sustainable innovation projects and solutions that help develop local communities.

Enel is also committed to helping to achieve the UN's Sustainable Development Goals (SDGs).

THE GLOBAL GOALS
For Sustainable Development

Enel includes two sub-brands: Enel Green Power (which, in our internal organisation is part of Global Power Generation) and Enel X. In our communication, we refer to Global Power Generation when discussing topics related to thermal plants or in relation to issues such as decarbonization and the role of gas. Generally speaking, we speak of Global Power Generation in our internal communication to reinforce the cohesion of the new professional family. On the contrary, we use Enel Green Power for topics which exclusively relate to renewables or for commercial communication, where it is important to strengthen the visibility and the value of the brand.

Enel Green Power

Enel Green Power is the Enel Group's global brand focused on developing and managing renewable energy generation systems with a global presence in 28 countries in Europe, America, Asia, Africa and Oceania. Enel Green Power is a global leader in the green energy sector, operating more than 1,200 plants with a managed capacity of 49 GW across a generation mix which includes wind, solar, geothermal and hydropower, and is at the forefront of integrating innovative technologies into renewable power plants. Enel Green Power is a strategic partner that enables communities, companies and final consumers to move towards sustainable living, driving the shift towards a decarbonized society and actively contributing to the development and wellbeing of the territories where it operates.

Enel Green Power applies the CSV (Creating Shared Value) Model, finding new business opportunities by solving social problems, combining competitiveness with long-term, sustainable value creation. Thanks to its research, technological innovation, internationally renowned operational excellence, and the hard work of its people, Enel Green Power looks to the future fully aware of its potential for growth, both in terms of additional capacity and operational performance. Enel Green Power invests in new technologies to improve its flexibility

and performance, such as the combination of technologies and sources in the same plant (hybridization), the integration of renewables with other sectors (agrivoltaics, green building, new fabrics, etc.) and the research to give new life to end-of-life plant components. All these projects are conducted under the lens of Sustainability and Circular Economy. With its international experience, Enel Green Power also develops custom projects to offer companies the best solutions when it comes to energy generated by renewable sources. Clean energy and sustainable projects, competitive costs and tailor-made solutions are the main benefits of the Power Purchase Agreement (PPA), a tool capable of building strong, long-lasting partnerships with business and industrial clients.

Enel Green Power is also one of the founding members of the RES4Africa Foundation, founded in 2012 to promote renewable energies and the spread of know-how on the African continent.

Global Power Generation

Global Power Generation is a new Enel division, created on 1 October 2019. It comprises the two major streams of the Group's generation, i.e. thermal and renewables, and is meant to bring the company further in line with its strategy and to confirm its role of leader in the process of the energy transition. The division is key in our extended family to reconsider the role of energy producers and to be forerunners in the global process of the energy transition.

Enel X

Enel X, part of the Enel Group, is a global leader in the service sector and is dedicated to the development of high added-value products in industries where energy has the greatest potential for transformation.

Through a flexible platform that is open to digitalization, sustainability and innovation, Enel X creates an ecosystem of solutions that transform energy into new opportunities in various sectors: electric mobility, public and private energy efficiency, artificial intelligence and data analysis services, energy consulting and management, and financial services. The company manages services such as demand response for more than 6.3 GW of total capacity, 110 MW of storage capacity installed and around 100,000 public and private EV charging points at global level.

The energy transition in a nutshell

A definition of the current energy transition

Although definitions vary, the current energy transition could be considered as the global shift from a fossil fuels-based mix towards a low or zero carbon one. The phenomenon has been triggered by the need to reduce greenhouse gas emissions in order to mitigate climate change in the 1990s, but has boomed mostly in the past decade thanks to the dramatic and unprecedented fall of costs associated with technologies driving the transition, i.e. solar photovoltaic and wind generation. Thus, despite starting almost only due to environmental reasons (the fight against climate change), the energy transition has gained a strong industrial driver; repercussions are significant for global political and economic relations, due to the new role of actors such as China and Africa; for utilities, due to new possibilities being offered but also to the still significant uncertainty surrounding the phenomenon; and for the society as a whole, thanks to the interactions between the energy revolution and others, first and foremost the digital one.

New and old transitions

While the global energy mix is not new to transitioning to new equilibria, many are the elements of difference compared to the switch from wood to coal in the 19th century and coal to oil in the 20th century. Two are the most relevant: the reasons triggering the shift and the time horizon. While early transitions were prompted by the possibility to exploit new technologies and resources, the current one started from the need to protect the planet from the greatest threat it has faced so far – climate change. The reality of the menace and its already evident impact have pushed for changes at a much quicker pace than those usually applied to the energy sector – major global energy transitions have each taken 50 to 60 years. Long-term planning has been substituted by a significantly shorter time horizon, also to take into consideration the rapid and still ongoing fall in generation costs, which decreased by 80% for solar PV and by 60% for onshore wind in the last decade.

A varied geographical/time horizon

The current energy transition has also different impacts and features depending on the regions and countries involved. The EU is at the forefront of the transition, leading in terms of level of ambition for policies and technological know-how. China has also established itself as one of the leaders of the process through heavy investments inside and, mostly, outside the country, becoming the first global investor for renewables worldwide. The United States are another key player of the energy transition, living an important acceleration of renewables, even considering the historic importance in the country of the coal industry, in decline now, and the recent success of shale gas and oil after the homonymous Shale Revolution in the 2010s. Other actors are emerging, first and foremost Sub-Saharan Africa; in 2014 the region witnessed the first ever increase in its access to power rate in post-colonial history, mostly due to new utility scale renewables project and the diffusion of renewable-based mini-grid and off-grid systems. Renewable energies have brought landmark results in countries like Ethiopia and Kenya, which respectively doubled and tripled their access to power rate between 2009 and 2015, and the prospects are equally positive for many other countries in Sub-Saharan

Africa, even for utility scale; South Africa is leading the African transition in this sense, largely to compensate for the increase in energy demand following the country's high rate of urbanization.

A persistent uncertainty

There are still many undefined elements of the energy transition, including its final outcome; despite the need to aim for a zero-carbon energy mix, and to dramatically decrease the use of fossil fuels already in the medium term (between 2030 and 2050), the currently possible maximum renewable energy penetration is significantly lower than 100% and estimates largely vary between countries and institutions. Fossil fuels thus retain a role in the energy mix, although varied; while gas is considered a key resource as a bridge fuel, prospects for clean coal and CO_2 capture technologies have worsened due to their high costs and technical complexities, particularly when compared to the new cost levels of renewables. However, the cost curves for solar and wind are becoming increasingly flat – thus indicating further commercial maturity of the technology – and the urge to fight climate change is increasing – and so the push on governments by global movements; a much clearer vision on the time horizon of the energy transition is to be expected in the years to come, particularly if the current, extremely low oil price will not significantly rebound, further diverting investments towards renewables.

Changing the system

A key point for the phenomenon is that the change will not only concern energy generation, but will affect the global society and economy as a whole, as greening the power sector alone will not be enough, neither to stop global warming, nor to guarantee an effective penetration of renewables. Structural changes will be required and will take place as part of two main trends:

→ **Decarbonization**, which will mostly consist in the political and economic choices taken by governments to favor the decrease in emissions and will be directly impacted by the success of climate diplomacy. In this sense, governments and international institutions will need to support a restructuring of the whole energy sector, to cope with the intermittency and with the specific features of the two dominant technologies of the energy transition. It will be necessary to consolidate grids, improve and deepen the digitalization of the system. The regulatory framework and the design of energy markets will need to adapt to technologies whose marginal costs, one of their key structural components, is zero. Green finance will be required to lower the risk premium which, even if now smaller than in the past, remains high for renewables. It will be fundamental to design solutions for zero-carbon energy mixes combining storage, interconnections and other available solutions, particularly gas; the flexibility of the resource, the low start-up time, the much smaller amount of emissions when compared to coal (around 50%) make gas an ideal bridge-fuel for the short to medium term of the transition.

- **Electrification**, which will focus on consumers' choices, both domestic and industrial, towards the adoption of energy-efficient, electricity-fueled, low-emissions tools. Industrial consumers, including energy-intensive industries, will have to quickly abandon coal use in their processes and substitute it with electricity when possible. Domestic consumers will be an increasingly important actor in the transition, as the digitalization will allow for wider choices towards a greener and more suitable energy consumption. As utilities are pushing governments and policy makers for stable policies supporting the transition, more aware consumers are already requiring solid, climate-friendly reputations from energy companies. The development of electric transportation will finally allow for further penetration of electricity in the energy mix, while green hydrogen will open a wider array of possibilities to decarbonize hard-to-abate sectors.

A circular approach

The energy transition is however only part of a wider, more complete global search for sustainability. Indeed, the interdependence between the environmental, social and economic long-term stability is the basis for sustainable development, which aims at tackling the sources of environmental degradation – not just the symptoms – while providing opportunities and creating incentives for economic advancement. To achieve this goal, it will be then necessary to implement innovative models and methods for governance that integrate the social, economic and ecological dimensions of sustainability and provide cross-scale and cross-sectoral solutions. Circularity is key for this; the attitude by which new resources are extracted to produce new items should be substituted by a wider approach where an extended usage of goods will be matched by an increasing share of recycled materials along the supply chain. Five are the key pillars of such an approach:

- **New materials**, replacing current materials with new ones from renewable sources (e.g. wood instead of concrete) or from recycling.
- **Extended life**, designing assets and projects in a way that their useful life can be extended as far as possible (e.g. design for disassembly, modularity, repairing, flexibility or biodegradability, as well as for enabling reuse, remanufacturing, refurbishment or repowering).
- **Sharing**, increasing the load factor by sharing assets and/or resources (e.g. the diffusion of public transportation).
- **Product as a service**, selling the use, not the ownership (e.g. the diffusion of apps for the sharing mobility, such as bikes and electric mopeds).
- **New life cycles**, designing the end of life according to these priorities: first reuse, than remanufacture and as last option recycle.

This concerns the construction and management of renewable plants but also dismantling them; circular economy in the energy system consists of designs, processes and solutions that decouple resource consumption from energy production, addressing not only the fuel used but also all the other dimensions. Sustainable and circular dismantling will be indeed a key component for the energy transition, starting from the players who are fostering the transition – who still require the process of disposing exhausted fiberglass blades and solar panels to be fully developed – and reaching industries based on other technologies as well, considering for instance the potential environmental impact of exhausted batteries.

Finally, it is important to consider that the circular economy is not about adding a recycling phase to a linear model, but rather innovating the whole value chain in order to drive resource impact down to zero. This has to be done in an economically competitive way, because these applications have to affect the whole economic model and not only represent niche uses.


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Chapter 1

Global warming and the transition

1.1

Numbers and evidence

KEY MESSAGE

The scientific community has an almost unanimous consensus on the reality and anthropogenic origin of climate change. While its impact will significantly worsen in the decades to come, it is already visible in all regions of the world – with some areas being more susceptible, such as the Arctic and the Mediterranean Sea.

THE REALITY OF CLIMATE CHANGE

According to data collected by NASA, in 2019 we have reached a 0.98 Celsius degree increase for average global temperature when compared to pre-industrial levels. Temperatures have been rising since the second half of the 19th century, but this has remarkably increased since the 1970s-1980s. The impact of global warming is already evident: Arctic sea ice has decreased by an average 12.85% per decade, while coastal tide gauge records show a 3.3 millimeters rise of sea level per year since 1870. The past decade was the hottest on record and 2019 was the second-warmest year ever, just shy of the maximum set in 2016. In 2019, the global average surface temperature was nearly 1 degree higher than the average from the middle of last century. Wildfire seasons have become globally longer and more intense and so has happened for extreme weather events, which are increasingly more common and more devastating. Phenomena such as El Niño have become more erratic and have caused dangerous droughts in areas already threatened by chronic aridity, such as Eastern Africa. Generally speaking, global warming has been creating new problems and exacerbating old ones; while the Gulf Stream is slowing down and possibly changing its route, alien species are multiplying in ecosystems throughout the world, as in the case for instance of the growing presence of flamingos in the delta of the Po river in Italy.

THE ROLE OF MAN

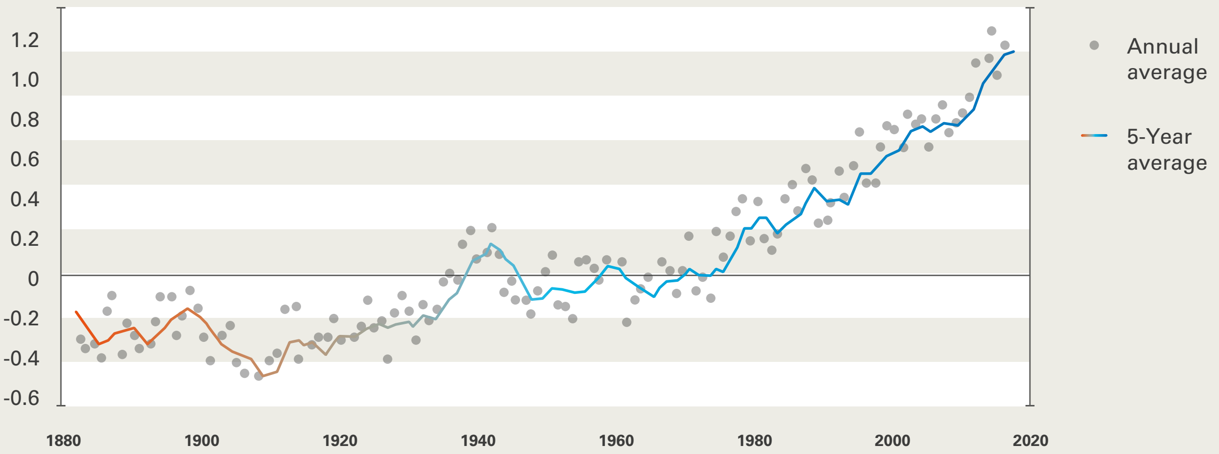
There is an almost unanimous consensus of the scientific community on the anthropic origin of climate change, since 97% of active climate researchers are shown to agree on the causal link between human greenhouse gas emissions and global warming. Such connection was established already in the 19th century thanks to the work of Nobel prize winner Svante Arrhenius, who proved the correlation between levels of carbon dioxide and temperature, and further confirmed by American scientist David Keeling in the 1960s.

AN UNCERTAIN FUTURE

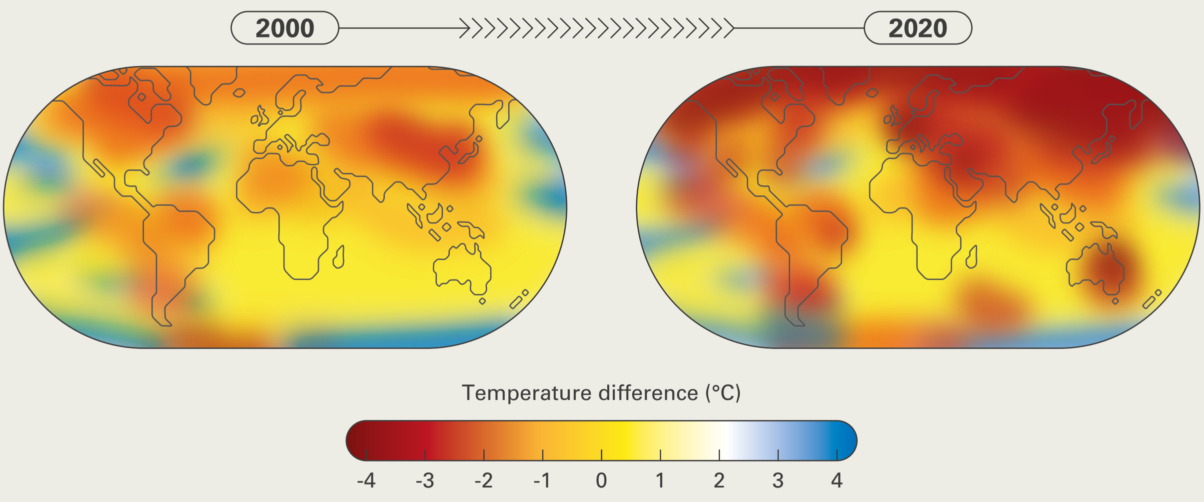
Although the picture for the upcoming impacts of climate change is not fully clear, the prospects are bleak. According to the International Panel for Climate Change (IPCC), a 2 degrees increase will result in exposing 37% of the world population to extreme heat waves at least once every five years, in the disappearance of 99% of the world's coral reefs and in a 13% decrease in global Gross Domestic Product (GDP). The impact will however be significant already in 2050 when, according to Professor Norman Myers of Oxford University, 200 million people will be displaced by desertification and extreme weather events. Even a 1.5 degree increase – the most ambitious target – will inflict significant damage to the planet, such as a 0.4 meters sea level increase and a -7% of world GDP by 2100, according to the IPCC. Yet, what scares the most is the uncertainty surrounding the evolution of many Earth natural processes under new climate conditions, which may lead to much more devasting impacts in the years to come. Above all, scientists are monitoring nine active "tipping points" – i.e. natural phenomena or ecosystems whose transformation will make irreversible changes to the planet: Arctic sea ice, Greenland ice sheet, boreal forests, the permafrost, the Atlantic Meridional Overturning Circulation (i.e. the Gulf Stream circulation system), the Amazon rainforest, warm-water corals, the West Antarctic Ice Sheet and the state of parts of East Antarctica.

01 Global warming is worsening and accelerating the pace of climate change

Global temperature index (°C)



Global temperature variation



Source: NASA

1.2

Climate change causes

KEY MESSAGE

Different human activities contribute to climate change, from farming to deforestation, but power generation and, in general, energy usage, is the single largest contributor to the phenomenon.

THE RISE OF EMISSIONS

According to the IPCC, anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in the last 800,000 years. Their effects, together with those of other anthropogenic drivers have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century.

CAUSES OF EMISSIONS

Humans are increasingly influencing the climate and the Earth's temperature by burning fossil fuels and cutting down rainforests. This adds enormous amounts of greenhouse gases to those naturally occurring in the atmosphere, increasing the greenhouse effect and global warming. More specifically the causes for rising emissions are:

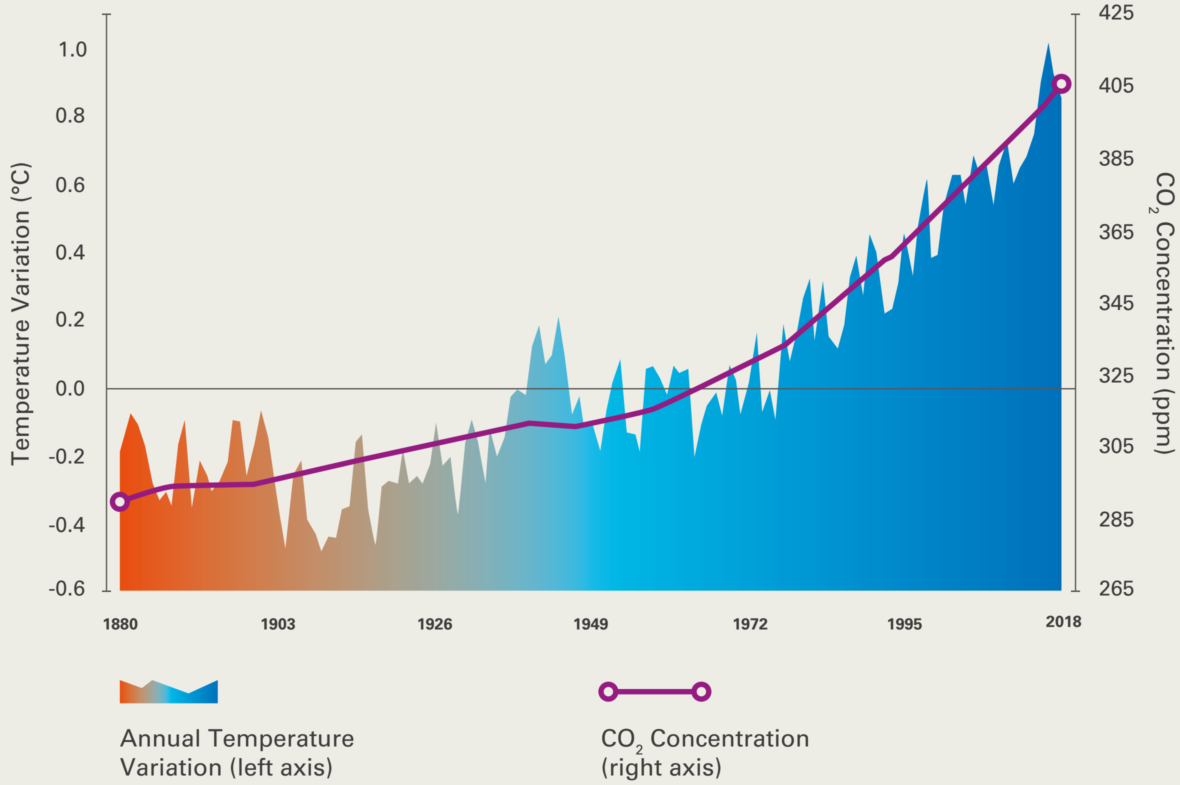
- Burning coal, oil and gas, which produces carbon dioxide and nitrous oxide, representing the majority of greenhouse emissions.
- Cutting down forests: trees help to regulate the climate by absorbing CO_2 from the atmosphere. Thus, when they are cut down, that beneficial effect is lost and the carbon stored in the trees is released into the atmosphere, adding to the greenhouse effect.
- Increasing livestock farming, as animals produce large amounts of methane when they digest their food.
- Fertilizers containing nitrogen, which produce nitrous oxide emissions.
- The use of fluorinated gases, which produce a very strong warming effect, up to 23,000 times greater than CO_2.

THE ROLE OF ENERGY AND POWER GENERATION

According to the International Energy Agency (IEA), energy is responsible for almost 90% of total CO_2 emissions, and coal-fired electricity generation alone is accountable for 30%. It has been estimated that the current trend of CO_2 emissions due to coal combustion is responsible for 0.3 °C of the 1 °C increase in global average annual surface temperatures above pre-industrial levels, making it the single biggest emitting source in human history. Fuel switching (from coal to gas) has however reduced the carbon intensity of global power generation by some 95 million tons between 2017 and 2018. Renewables too have already made a visible impact; thanks also to nuclear energy, in 2018 the growth of emissions has been 25% smaller than energy demand. Outside power generation, oil is the second largest source of emissions, having produced 11,446 million tons of CO_2 in 2018 (78% of coal's total of 14,664 million tons).

02 What are the causes of global warming?

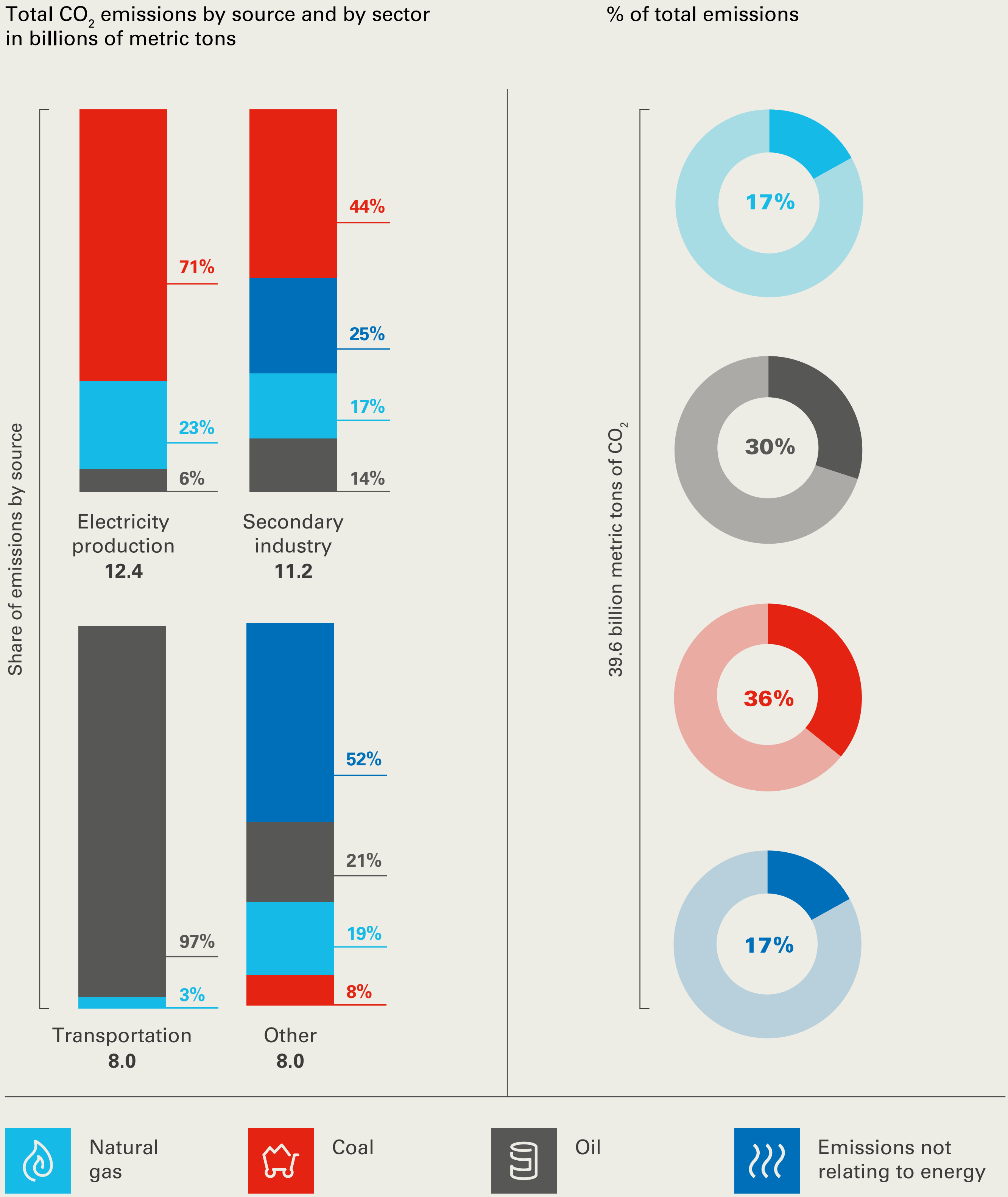
Greenhouse gases



The majority of CO_2 emissions are linked to energy production, but don't derive solely from the electric power industry

Source: NASA, NOAA, Morgan Stanley

03 Coal is the main source of CO_2 emissions



Source: Global Energy Perspective – Reference Case 2019, McKinsey

1.3

International agreements and regulatory targets

KEY MESSAGE

Despite the failure of the Kyoto Protocol and the many difficulties faced by climate diplomacy over the years, the success of the 2015 COP21 led to the signature and now ratification by almost all Member countries of the ambitious Paris Agreement. The main challenges lay now in its revision and implementation.

THE SUCCESS OF THE COP21

In December 2015, the 21st Conference of Parties (COP21) of the UN Framework Convention on Climate Change (UNFCCC) was successful in producing the long-awaited Paris Climate Change Agreement. The treaty provides a credible framework for pursuing decarbonization, after the failure of the 1998 Kyoto Protocol and more than a decade of unsuccessful negotiations throughout the different yearly COPs. The final legal text of the agreement incorporated clear long-term targets to tackle climate change and a flexible structure based on Nationally Determined Contributions (NDCs) made by governments. Climate financing commitments were upgraded by making clear that they will be additional, will not rely only on the private sector and will be an integral part of NDC plans made by governments. The role of the private sector was supported by clear reference in the agreement to market instruments similar to the ones implemented within the Kyoto framework.

THE TARGETS

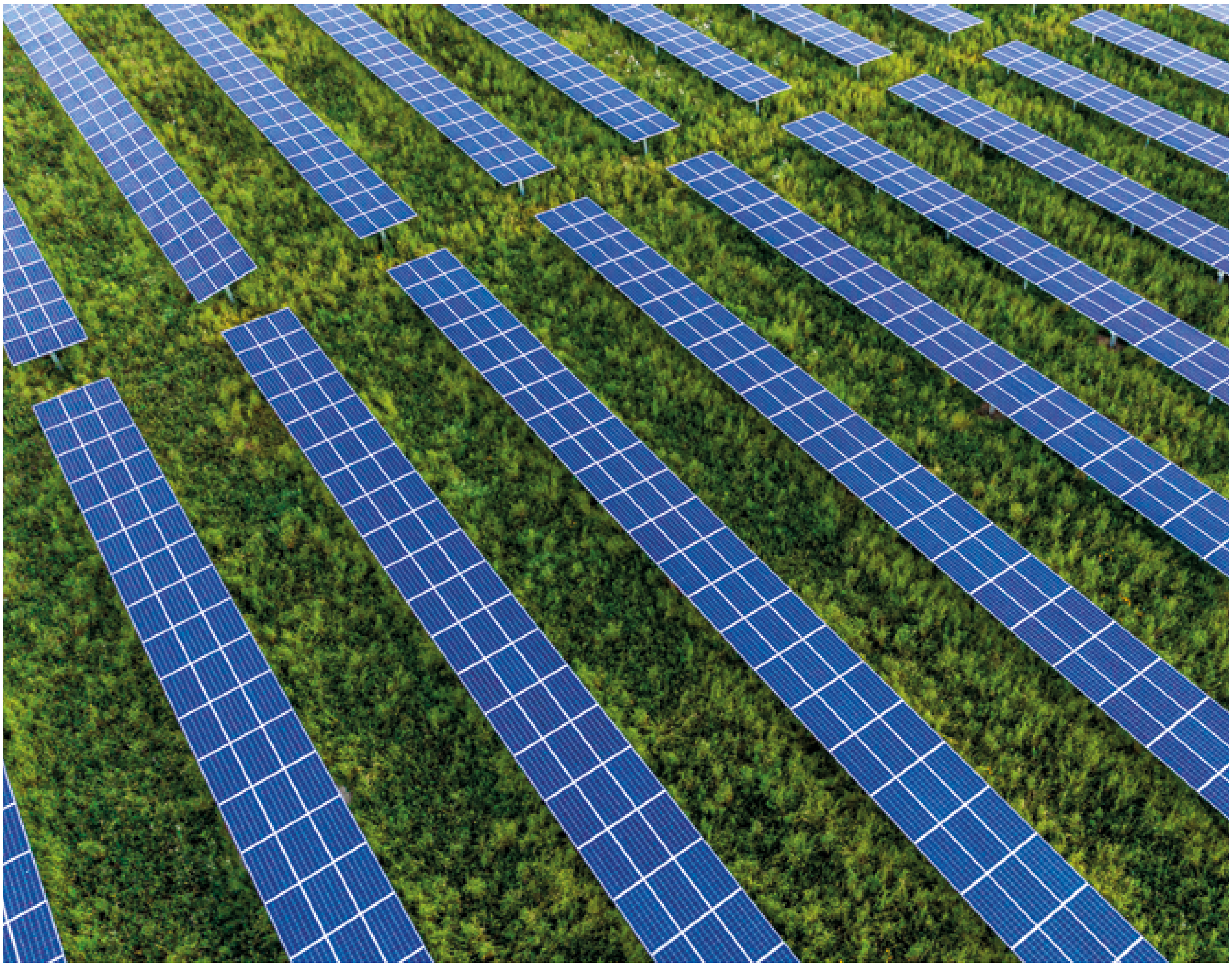
During the UNFCCC Paris Conference governments pledged to limit the rise in temperature well below 2 °C versus pre-industrial levels with efforts to stay within 1.5 °C, to cap emissions as soon as possible and achieve carbon neutrality in the second half of the century. However, even assuming the full achievement of the NDC national pledges presented in Paris, the global concentration of GHG emissions will lead to an expected rise in global average temperatures of 2.7 °C, well above the Paris goal of under 2 °C. It is therefore vital that the Paris Agreement framework is made operational as soon as possible and the updated NDCs that will be presented starting in 2020 by the Parties reflect the "highest possible ambition" that governments have committed to in the negotiations.

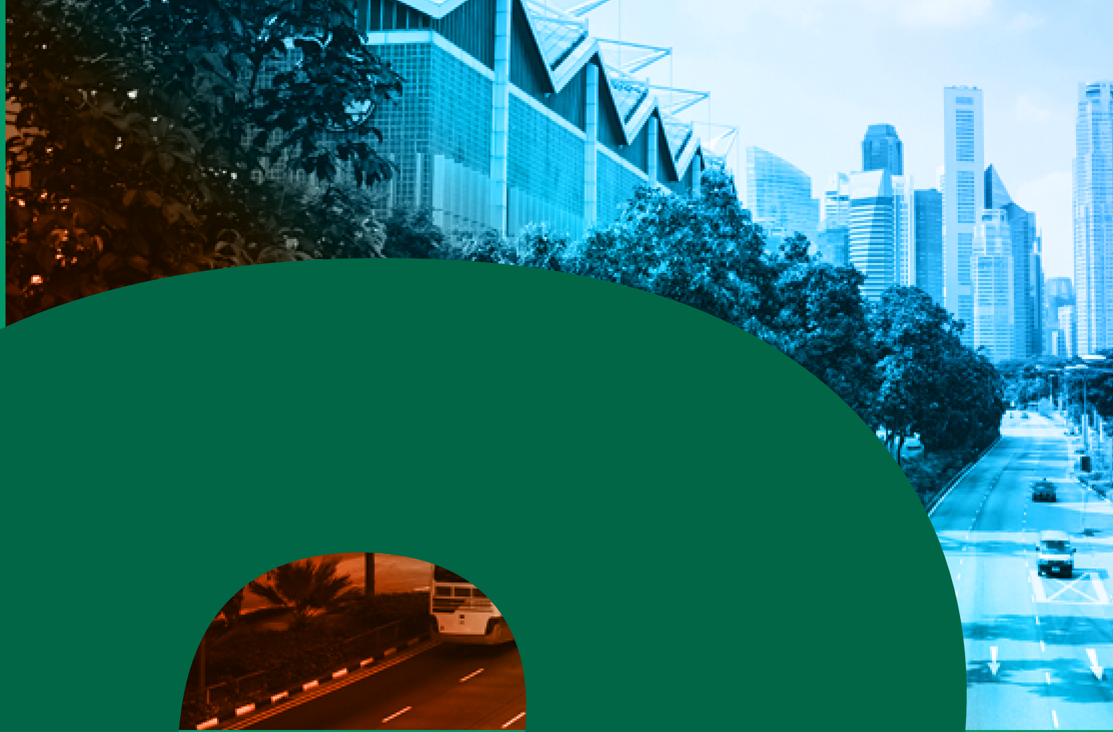
THE ISSUES AHEAD

Despite the success of the COP21, many are the questions left open by the Agreement. NDCs are determined individually and voluntarily by countries, and this does not guarantee that efforts will be adequate to the task; the latest UNEP report highlights that even if all current unconditional commitments under the Paris Agreement were implemented, global temperature would rise anyway by 3.2 °C, bringing even more serious and destructive climate impacts. Furthermore, many details are yet to be defined and negotiations in the COPs following the 21st have proceeded with limited success. In December 2018, the COP24 in Katowice ended positively approving the expected implementation rules of the Paris Agreement (the so-called "Paris Rulebook"). The result confirmed the willingness of governments to move forward despite the uncertainties of the economic cycle and the difficult geopolitical dynamics and provided very specific transparency provisions over the actions undertaken by governments, thus increasing the medium-long term political visibility and regulatory stability for investments. The results are however disappointing in terms of the ambition of the national objectives that determines the speed of decarbonization of the energy systems. The latest COP, number 25 and held in Spain in December 2019, has left most Parties unsatisfied and was labelled by UN secretary general António Guterres as a "lost opportunity." The cancellation of COP26 due to the COVID-19 pandemic is equally bad news, as the conference should have been the occasion to renegotiate the still inadequate NDC commitments.

THE WORLD ACTING

In the meantime, policy makers have started to adapt energy policies addressing challenges to ambitious decarbonization programs. Europe is at the forefront in committing to climate goals starting from the 20-20-20 targets and the now upgraded 2030 targets. In Italy the current PNIEC (Piano Nazionale Integrato per l'Energia e il Clima, i.e. the National Integrated Plan for Energy and Climate) plans to phase out coal by 2025. In Spain the government announced the closure of the national coal mines, in anticipation of the complete coal phase out by 2030. Chile also launched an ambitious decarbonization plan (Mesa de Descarbonización), aimed to completely phase out coal plants by 2040 and to achieve carbon neutrality by 2050. Additionally, regulators have introduced different types of carbon taxes in many countries, in order to charge carbon dioxide emissions.





Chapter 2

Actions for the energy transition

2.1

Renewables' acceleration

Key message

The extraordinary fall in generation costs for solar PV and wind is one of the key drivers of the energy transition, and has influenced and is influenced by the spike in installed capacity for the two, by booming investments and by the rise of emerging technologies with an unprecedented acceleration of innovation.

LEADING THE TRANSITION

The acceleration of the energy transition in the past decade has been mostly due to the expansion of the two leading technologies, solar PV and wind (onshore and, more recently, also offshore).

The two have witnessed an outstanding, unprecedented fall in costs, which is evident when looking at Levelized Costs of Energy (LCOE), i.e. the average cost to generate electricity over a plant's lifetime.

According to the International Renewable Energy Agency (IRENA), the LCOE for solar PV has fallen by 82% in the period 2010-2019, for wind onshore (already at a lower cost level than solar) by 60%, and for offshore by 29%.

Such reductions have brought renewable sources to be largely cost-competitive or cheaper than least expensive fossil fuel sources; 90% of new hydro projects commissioned in 2019, 75% of onshore wind and 40% of solar PV ones will generate electricity at a lower price than cheapest new fossil generation.

Thanks to such low costs, the capacity for these resources has spiked: global solar PV capacity rose from 40 to 580 GW between 2010 and 2019, while onshore wind power grew from 178 GW to 594 GW.

BEHIND THE BOOM

The causes for such transformations are multiple, and not only technological. Solar panels have become increasingly more efficient, achieving a global weighted capacity factor of about 18% in 2019, according to IRENA. Similarly, the cost of crystalline silicon modules has globally abated by between 87% and 92% in the period 2010-2019; production costs across the world have also become similar, closing the wide gap that existed between Chinese and European production a decade ago. Wind turbines have benefited from a boost in the capacity factor through the increase in the average size of the turbine, but also by more efficient global supply chains – the latter a factor which is now positively and largely impacting offshore wind farms. Such technologies have also experienced a particularly high learning rate – i.e. the average cost reduction compared to the increase in global installed capacity – such as the remarkable 23% of onshore wind and the impressive 36% for offshore. This translated into evident changes, such as the massive reduction of curtailment in countries like China and Germany in the past decade. The financial side has also brightened; risk premiums for renewables have decreased in most countries, particularly concerning the resource, the technology, the curtailment and the price risks. Investments in renewables are now six times the 2004 amount and are three times greater than those for fossil fuels.

WHAT'S NEXT

Despite such a bright outlook, many are the obstacles faced by the development of renewables. According to IRENA, in order to limit the temperature increase to 1.5 degrees it will be necessary to invest 110 trillion dollars in the energy system in the period 2016-2050, which will translate into a doubling of current direct investments in renewable energy. This will also require new sources of funding and an expansion of current risk mitigation tools, such as green bonds, sustainability linked bonds or investments backed by institutions. Stable regulatory and political frameworks on the national level will be fundamental to support the role of the private sector in the transition, both in the OECD Countries and in developing countries (particularly in Sub-Saharan Africa). Above all, countries and international institutions will have to quickly design solutions fit for zero-carbon energy systems holding a significant, if not dominant, share of intermittent renewables: grids and the penetration of digital measures must be strengthened. Interconnections among countries, gas generation for peak hours demand and storage solutions will need to be coherently implemented to compensate for intermittency.

THE DIGITAL TRANSFORMATION

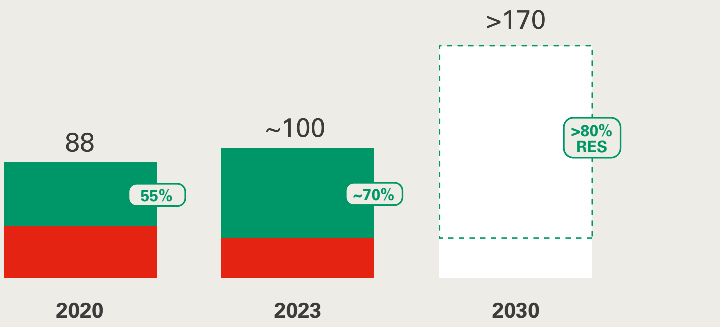
Generally speaking, the energy transition will strongly benefit from the ongoing changes brought in by the so-called Industry 4.0 – i.e. the diffusion of automation, of digitalization and machine-to-machine communication (particularly the Internet of Things). This transformation could help the diffusion of renewables in several different ways: it could improve the coordination between generation and energy demand, increase the efficiency of production, reduce risks via the robotization of dangerous activities, enhance the predictability of intermittent resources, better manage the grid and address issues in the planning of energy systems (regarding, for instance, storage and decentralized solutions).

CHALLENGES

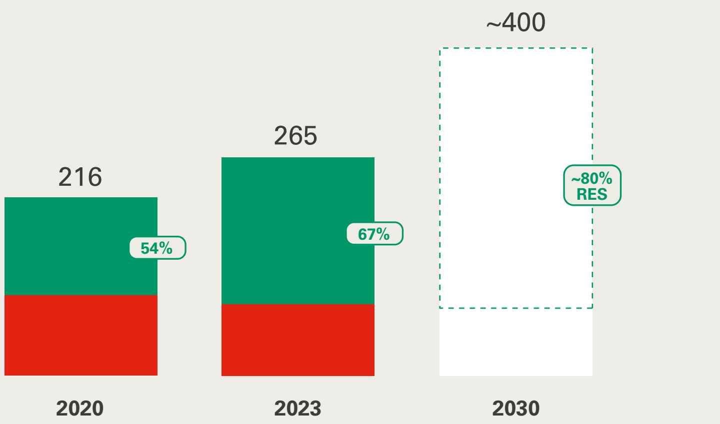
- Need to speed up the transition.
- Need to cope with the intermittence of mainstream renewables and to empower and stabilize energy infrastructures.

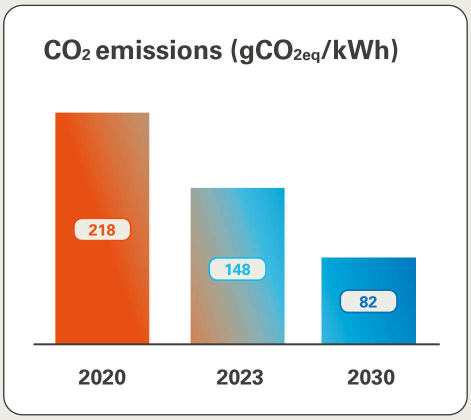
04 Enel's plan to accelerate renewables

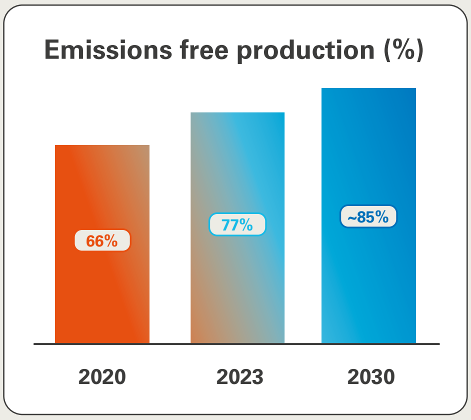
Capacity evolution[1] (GW)



Production evolution[2] (TWh)







Enel's plan to accelerate renewables

- The average annual built capacity is expected to increase to some 6.5 GW, up by around 40% versus the previous plan, gearing up to the average 9.6 GW per year targeted throughout the decade.
- In the period, the Group will significantly decarbonize its generation mix, with additional renewable capacity more than offsetting the closure of coal plants. Production is set to follow the same path, with an overall growth expected to be around 50 TWh, driven by renewables, which will account in 2023 for around 67% of total production.
- As a result, the Group's Scope 1 CO_2 emissions are set to decrease by over 30% between 2020 and 2023, positioning the Group well on track to achieve its science-based decarbonization target of 80% GHG emission reduction in 2030 versus 2017 levels as well as its 2050 full decarbonization target.

Renewables   Conventional Generation

1. It includes renewable managed capacity and nuclear capacity.
2. It includes renewable managed production and nuclear production.

2.2

Decoal and fuel switching

KEY MESSAGE

The major transformations imposed by the energy transition to global energy systems, mostly in terms of improved flexibility, will require a progressive and well-designed coal phase out. Gas will play a transitory role in this process.

THE TRANSITION'S IMPACT ON ENERGY SYSTEMS

The acceleration towards the energy transition and thus the diffusion of renewable, variable technologies for power generation, replacing the current fossil, is also determining physical and technical changes in the energy systems, with the following challenges for electricity supplies:

- Maintaining stability of electrical grids due to the reduction of programmable generation.
- Not increase of likelihood of electrical failures like disconnections and black outs.
- Need of sources providing ancillary services (reactive power supply and frequency regulation mainly).

NEW REQUIREMENTS

The energy transition must be able to overcome all these challenges, in order to ensure adequacy, flexibility and resiliency of the electrical systems, considering that:

- The system is adequate if it is provided with resources (generation, storage, demand response and transmission and distribution) apt to satisfy the demand while respecting the prerequisites of operability and quality.
- The system is flexible and secure if it can compensate quick variations in energy demand or supply.
- The system is resilient if it can tolerate acute stress while maintaining the ability to go back to its normal status in a short time. The system anticipates, absorbs, adapts and recovers.

The programmable sources (traditionally fossil fuels and, in part, hydro) have been able to satisfy all these safety requirements, whereas the renewable non-programmable technologies (mainly wind and solar) can create some imbalances between power demand and supply.

HOW TO PHASE OUT COAL

Considering this, the phase out of coal's synchronous capacity cannot jeopardize the grid's safety and, in the mid-term scenario, the new paradigm for energy security will require even more flexibility in the system through for example:

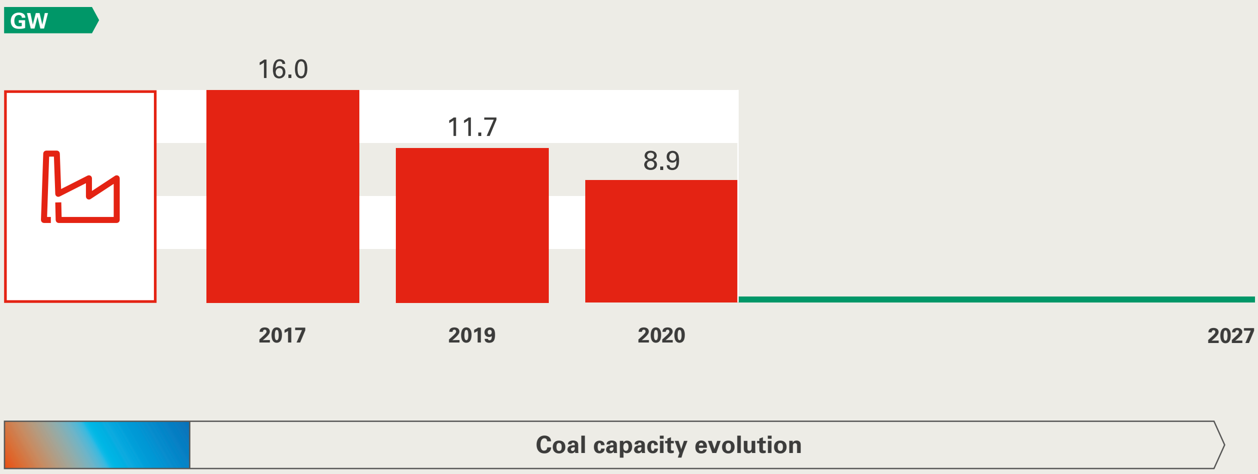
- Additional capacity and production from gas generation for peak hours demand, replacing coal's phased out capacity (fuel switching coal to gas), to guarantee quick supply of power and services (frequency regulation).
- Energy storage installations (batteries) to satisfy the need of ancillary services.

This is particularly true in Italy, where today the reserve margin (generation capacity exceeding the peak power demand, which can be promptly activated in case of need) is lower than 10% and electric generation from fossil fuel is about 60% on the total generation.

CHALLENGES

- Time horizon of fossil fuels phase out.
- Environmental impacts of decommissioning.
- Maintain a stable and affordable supply of electricity during the transition.
- Need to improve efficiency of gas plants.

05 Accelerating exit from coal to 2027



ENEL'S TARGET

In this context, Enel Global Power Generation has set targets to accelerate the energy transition through boosting the renewables growth, the decarbonization of our fleet and the promotion of a sustainable transition supported by an adequate role of gas.

ENEL'S PLAN

Enel's strategy toward a full decarbonization is based on the so called "repurposing" of the thermal power plants meaning reconversion of existing sites with new renewable capacity or various hybrid sources (combination of more than one source on the same site) with gas power plants where there is a need of ensuring stability of the system during the transition towards a fully decarbonized economy. Circular economy and CSV (Creating Shared Value) are principles embedded in our strategy and guiding all our sustainable investments to meet the needs of communities hosting our power plants, our clients and all our stakeholders.
In all the assets that are about to be decommissioned, Enel is pursuing a strategy for their repurposing according to the following fundamental principles, all equally essential:

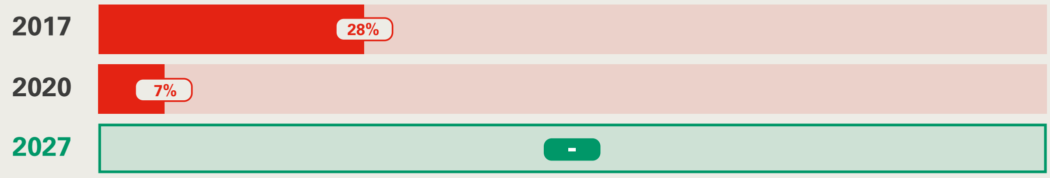
- Requalification projects must be a chance to write new stories of energy reconversion, sustainable growth and development of innovative ideas enhancing creative thinking and fostering entrepreneurship.
- Maximizing reuse of decommissioned assets, such as roads, infrastructures, HV grid connections, buildings, etc., for new functions according to the principles of Circular Economy.
- Contribute to Enel Group's goals by cooperating with other business lines for the realization of projects such as BESS, e-mobility, digitalization, network stability, etc.
- During the whole project, from preliminary interviews to the decision on the requalification project, Enel works in cooperation with local communities through a multi-stakeholders approach to foster creating shared value. Ensure environmental protection: land remediation is performed by Enel with the best standards.
- Open up our sites to new ideas coming from the society has proven successful in Italy (starting with Futur-e project launched in 2015) and it has therefore been extended to countries where the Group will be managing thermal power plants through the energy transition, such as Spain and Chile. This will aim at setting an international best practice for end-of-life management of dismissed industrial plants.

CREATING SHARED VALUE FOR LOCAL COMMUNITIES

Decommissioning and regeneration can coincide. Used materials, equipment and plants in general have no longer to be considered as a burden but as a resource able to generate significant returns for all the stakeholders involved: energy companies, investors and local communities. Establishing positive and synergic relationships with communities in which Enel operates is a key aspect to be pursued in any requalification process, as well as activating virtuous collaborations between stakeholders and generating shared value for the communities.

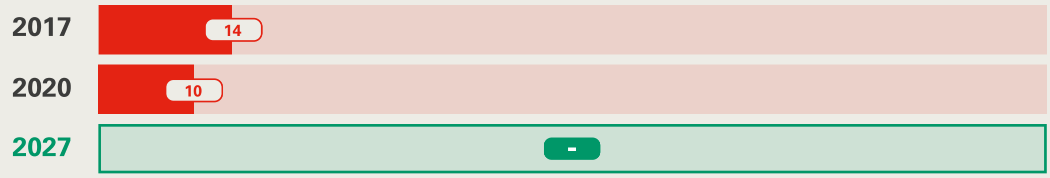
Coal production (TWh)

Coal production on total



Coal emissions (mn ton)

Plants (no.)



2.3

The role of gas

KEY MESSAGE

Gas generation will keep playing an important role in the energy transition thanks to its flexibility, its ability to match intermittent renewables balancing energy systems in the years to come and its reliability in supplying base load power for countries with growing energy needs.

THE ROLE OF GAS

Compared to coal, gas technologies are more flexible and therefore more suitable for balancing RES penetration. In addition, the resource produces less pollutants and CO_2. According to the IEA (The Role of Gas in Today's Energy Transitions – 2019), in 2018 gas on average resulted in 50% fewer emissions than coal per unit of electricity generated, due to the following reasons:

- Greater average efficiency of gas technology compared to coal (efficiencies lower than 40% for coal plants, compared to values greater than 50% for gas-fired plants, with peaks of over 60% for the latest technologies).
- The combustion of natural gas generated a lower emission of CO_2 per single calorie compared to the combustion of coal because, according to the different chemical compositions, coal has a higher carbon specific content than natural gas.

Coal-to-gas switching is therefore necessary to reach emission and CO_2 reduction goals without affecting grid stability, improving adequacy and flexibility of the system.

THE IMPORTANCE OF GAS IN THE TRANSITION

The impelling necessity of fighting climate change puts gas at the center of the short and medium-term planning. Indeed, gas is at the moment the only solution (even if perhaps only transitory) to guarantee the stability of the electrical system while renewable capacity is being built and storage solutions are evolving, thanks to its advantages in terms of output, availability and affordability. Gas capacity will thus continue to be necessary and it is expected to grow with a Compound Annual Growth Rate (CAGR) of 2% at global level, driven by emerging regions like China, MENA and Indonesia but also by some mature markets such as Canada and Germany (according to Bloomberg New Energy Finance data). Gas generation outlook at global level is stable with a CAGR of 0.4%, driven by emerging regions such as China, Malaysia, MENA, Sub-Saharan Africa and mature markets like the USA and Canada.

A DOUBLE ROLE

In mature markets, gas generation will be required mainly to play a double role:

- Replacement of coal generation on base load operation with highly efficient gas generation power plants, mainly Combined Cycle Gas Turbine (CCGT), because of the significantly lower emissions level of the resource than solid fossil fuels. Despite not being an emission-free technology, gas generation – also through an efficiency close to 63% in Closed Cycle Gas Turbine (CCGT) mode and over 40% in Open Cycle Gas Turbine (OCGT) mode – is able to contribute to a very important CO_2 emissions reduction. In the first case, the gas fluid is recirculated again and again, in the second a new charge is added to each cycle as the previous is discarded in the atmosphere – thus reducing its efficiency in terms of emissions. In Italy, for example, the CO_2 specific emissions will reduce by 2/3 in case of replacement of coal with CCGT generation and by half in case of replacement of coal with OCGT generation.

- Provision of flexible capacity on peak load operation in open cycle configuration (OCGT), being able to provide the required capacity during the programmed daily events of renewable intermittency and in the non-programmable accidental events of sudden lack of capacity in the system. Due to gas turbine characteristics, gas generation indeed is characterized by very fast ramp rates: that is from 50 MW/min achievable with existing Class E/F gas turbines, to 100 MW/min with new Class H gas turbines.

THE REQUIRED INNOVATION

In order to provide system operators with the required services to match booming RES development, the existing gas generation plants will invest on performance enhancement programs, mainly aimed to:

- Improve the efficiency.
- Reduce the minimum environmental load.
- Increase the ramp up.
- Augment the maximum available capacity.
- Reduce the environmental impact, thanks to CO_2 catalyzer and denitrification systems.

2.4

Electrification

KEY MESSAGE

Electrification is key for the decarbonization of the economy and the success of the energy transition, as the process will promote energy efficiency and decrease the use of fossil fuels. The quick spread of a variety of innovative technologies, in every sector from transportation to manufacturing, is fundamental for its success.

THE ROLE OF ELECTRIFICATION

Electrification – i.e. the increasing use of electricity in several sectors, from transportation to manufacturing – is one of the main pillars of the energy transition to decarbonize the economy, along with energy efficiency and the reduction of fossil fuel use in the energy mix. Electricity has many advantages over other sources of energy: it is efficient and flexible, thereby making it the easiest energy vector to manage, can provide a significant reduction in overall energy consumption, it is efficient and flexible – thereby making it the easiest energy vector to manage – and can provide a significant reduction in overall energy consumption. Electrification is progressing, but at rates that need to double if we are to meet the Paris Agreement objectives. To make an example, all scenarios developed by the European Commission's long-term vision for a fully decarbonized EU economy by 2050 confirm that electricity will play an increasingly greater role, by more than doubling its current share in final energy demand to a 41-53% penetration by 2050.

THE ADDITIONAL BENEFITS

Electro-technologies are mature in a number of sectors (residential, tertiary, industrial and transportation). Some of them will contribute more than others, such as heat pumps and electric vehicles. Indeed, electrification can bring forward a set of benefits that go beyond decarbonization, such

as improved energy efficiency, improved urban air quality and security of supply. Local air pollution and related health effects in the urban environment can be reduced by using electricity in transportation and heating. Exposure to traffic noise levels, which endangers human health and degrades quality of life, could experience a strong reduction through electrification, particularly in mobility. In addition to this, switching to electricity provides an opportunity for reducing fuel dependency while contributing to the strategic planning of the diversification of energy supply.

THE TECHNOLOGIES AT STAKE

Innovations in EV batteries, heat pumps, and green hydrogen technologies, among others, will be critical for this energy transition. The good news is that in recent years there have been significative steps forward in many electrification technologies. Today's heat pump technology can easily provide 200% to 300% more thermal energy than the electricity input in the residential sector, and the value is even greater in the industrial and services sectors, even in cold countries such as Norway or Finland, where heat pumps are already widespread. Running costs of heat pumps are lower than oil heating solutions and comparable to gas heating ones. Electric vehicles are already competitive with conventional vehicles in some countries from a total cost of ownership perspective, and manufacturers are reaching now about 500 km ranges in several car models, thanks to improved battery technologies with higher energy density. Battery costs have dropped by 60% in the last five years and are expected to decrease by an additional 25-30% by 2020. As highlighted by a number of sound studies, full lifecycle GHG emissions of EVs – including manufacturing and disposal – are significantly lower than conventional vehicles in balanced electric systems. Other emerging electrification technologies include electrification of low-grade heat in industry, electrification of ports and vessels and hybrid systems such as micro-grids that combine storage and on-site renewables. However, it is important to note that not all processes can be electrified – at least in the medium or short term – and thus storage solutions (hydrogen in particular) will be required.

CHALLENGES

- Disposal of batteries and electric devices.
- Efficiency of some electric devices compared to those powered by fossil fuels (particularly in the industrial sector).
- Upfront cost of electric cars and buses.
- Commercial immaturity of several electric options (ships, industry, etc.).

Actions for the energy transition

Electrification

Enel's Solutions

ENEL'S COMMITMENT

Enel X supports customers in their decarbonization process and in using energy more efficiently, levering electrification and digitalization through the offer of new value-accretive solutions.

B2G

In Business to Government (B2G), Enel X offers municipalities the opportunity to upgrade and manage public building energy assets in a more efficient way while at the same time providing more technologically and digitally advanced services (data analytics, public electric mobility), when necessary, also relying on the expertise developed with Business to Business (B2B) customers.

B2B

In B2B, electrification for Enel X means developing end-to-end solutions tailored to customers' need for distributed energy assets (PV) that may include battery storage and HVAC. These, while enhancing the customers' resilience and optimizing their energy spending through self-production may also turn into revenue-generating assets thanks to demand-side participation to network flexibility services through Enel X's role as aggregator.

B2C

In Business to Consumer (B2C), Enel X is promoting efficient HVAC technologies (so-called green products) as well as distributed energy resources (PV and storage).

THE TECHNOLOGIES INVOLVED

e-Mobility is active in innovative technologies, like vehicle-to-grid (V2G), that exploit smart hardware coupled with algorithms to provide a bi-directional flow of electricity (EVs can inject back into the grid the electricity stored in their battery, or they can reduce their charging rate) to help balance the network in case of need, thus providing flexibility services. These services are remunerated by the local transmission or independent systems operators, which represents an additional incentive towards EVs deployment.

BALANCING THE NETWORK

Furthermore, with a higher number of variable resources in the energy mix, EV adoption will become especially relevant as it could help solve network imbalances by reducing the need for RES curtailment by charging, for instance, during times of high RES production and low energy demand.

Electrification also increases the key role of the distribution grid as enabler of other sectors like Industry, C&I, Transportation, etc. making the grids an enabling platform for ecosystems.

Enel is keeping on innovating and digitalizing networks and distribution infrastructures, to make them more resilient and open to new market players participating to the energy transition.

Energy infrastructure needs to evolve so that the capacity for electricity can expand. Investments in infrastructures must focus on efficiency and quality of service. Meanwhile, we need to think about climate-proofing our infrastructures.

Digitization of our technologies and processes increases the renewables host capacity, alongside improving communications between primary and secondary substations and the distributed assets. Moreover, it fosters the capacity and integration of electric-vehicle charging stations.

Flexible technologies help to integrate larger volumes of renewable generation by shifting high levels of energy demand to periods of high renewable production, or by storing the exceeding renewable generation to be used during periods of high consumption.

The integration of distributed assets, such as electric cars, batteries and electrolysers will promote new business models and create a new role for the DSO as the enabler of new network services.

One example of our commitment towards a clean energy future is our Puglia Active Network project, improving system efficiency and network losses management, therefore contributing directly to CO_2 reduction. Through this project, our environmental commitment in terms of hosting capacity for renewable energy integration is to reach about 19 terawatt-hours of cumulative renewables production for the five-year monitoring period, from 2020 to 2024. PAN key data: 102 HV/MV Primary substations, 100 MV/MV Primary substations, 8,000 MV/LV secondary substations, 74 EV charging points, 2,230 million customer, 44,500 producers, 29,300 km MV lines.

Chapter

3

Leading technologies

3.1

Solar

KEY MESSAGE

Solar photovoltaic (PV) is one of the two leading technologies of the energy transition, having benefited from a cost decrease curve even steeper than wind energy, and outpacing others, such as concentrated solar power (CSP).

SOLAR MODULES

Whereas modules efficiency will increase, costs will fall thanks to the introduction of new technologies and materials that will allow to overcome the physical limits of actual PV technology, reaching efficiencies higher than 30% and increasing productivity above 20%. More specifically, main technology trends will be the following:

- → Increase the share of high-efficiency cells (such as PERC, i.e. Passivated Emitter and Rear Cell).
- → Adoption of a new higher efficiency technology like HJT or IBC (Interdigitated Back Contact) and then Tandem technology.
- → Increase energy production (e.g. bifacial solution, specific process on the cells, smart electrical solution).
- → Costs reduction (efficiently decrease processing cost, wafer cost reduction).
- → Reliability in any climate condition (desert area, wet climate), also through the development of ad hoc technologies.
- → New cell configurations and bigger size of modules will be able to simplify circuits and increase module's electrical efficiency.

The actual structure of solar modules is 40 years old. New concepts are emerging and are presently in the research phase such as a plastic module with a simplified structure and production process that uses less materials, leveraging the circularity concept for plastic use. Thanks to the flexible use of plastic it could be possible to rethink the internal structure of the module, integrating electronics components making it smarter and flexible for different kinds of application.

CONVERSION UNIT

The present inverter technology will undergo a noticeable change in the next five years due to the introduction of new active materials (e.g. silicon carbide) with a significant reduction of the cost and increase in performance. Also, inverters will be able to manage and integrate different layout architectures and electrical configurations or integrate storage systems at DC (Direct Current) level. This will also allow for new scenarios to open, enabling PV technology to provide services to the grid.

ELECTRICAL ARCHITECTURE

New conversion unit concepts (e.g. Maximum Power Point Tracker – MPPT – at string or module level, high voltage conversion units, etc.) will make it possible to define new plant electrical architectures, leading to a reduction of Balance Of Plant (BOP) costs and plant losses along with an increase of the overall system’s sustainability.

TRACKERS AND STRUCTURES

New materials (e.g. composite materials) will allow for lighter, stronger and cheaper structures. Integration of active components (e.g. inverter, monitoring systems) with the tracker management system will allow us to optimize the performance of the tracker according to the site specificities. New tracker (1x and 2x) and fixed structure designs based on circular models will be developed, fostering a reduction of environmental footprint and better sustainability. New solutions to maximize the radiation available for square meter will be designed and implemented.

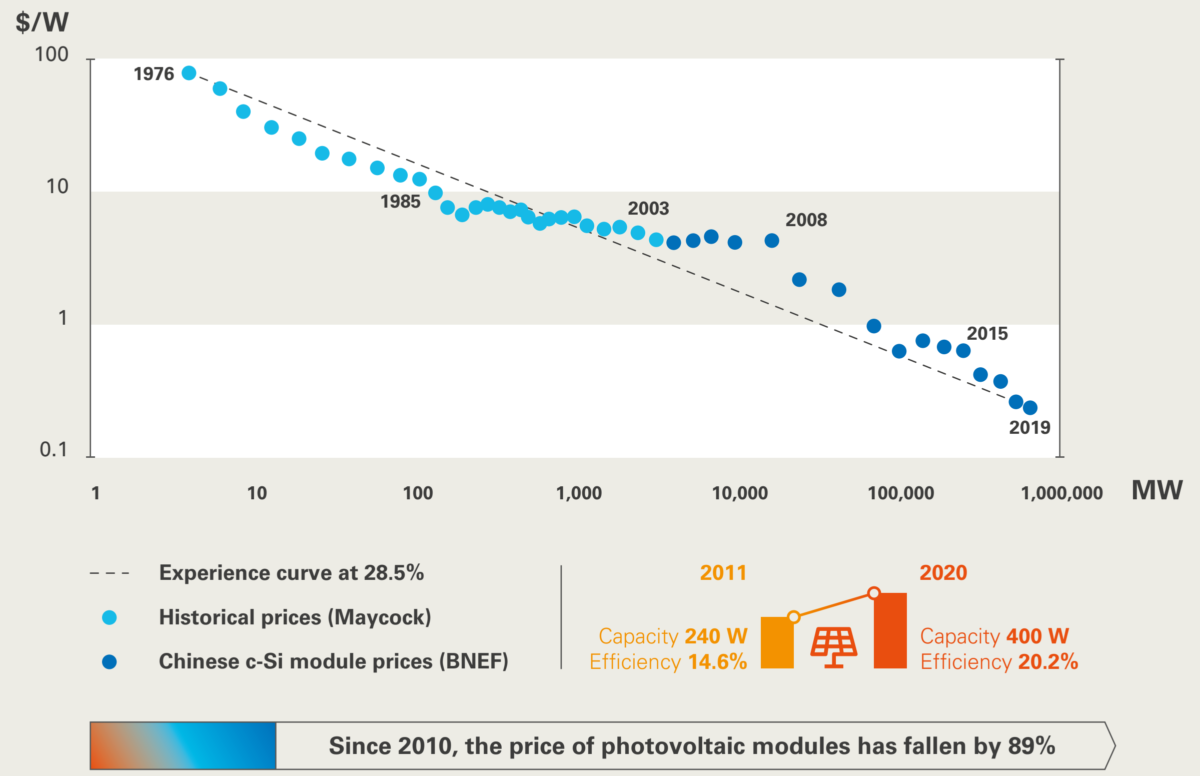
IMPACTS MITIGATION

Land occupation reduction will be possible thanks to the increase in technology efficiency, new plant layout concepts and integration with other production activities (i.e. integration of PV with agriculture) aiming at better land utilization and at employing PV modules, structures and other materials for multiple complementary uses (i.e. building materials, agrivoltaics and grid services, feeding load) in consideration of the limited number of hours during which such materials are used (typically 25% of time).

END-OF-USE MANAGEMENT

Increases in photovoltaic production have triggered the development of photovoltaic recycling technology in order to recover as much value as possible. To date, while the percentage recovery of the panels is around 90% of the weight, there are joint initiatives amongst European companies and research institutes, aiming to enhance the recovery and recycling of the materials that make up the remaining 10% of the panel weight, such as cells that contain the most precious materials (silver, copper and high-quality silicon). A possible reuse, as a second life, of modules that have a low degradation is also being studied.

06 Photovoltaic modules



CHALLENGES

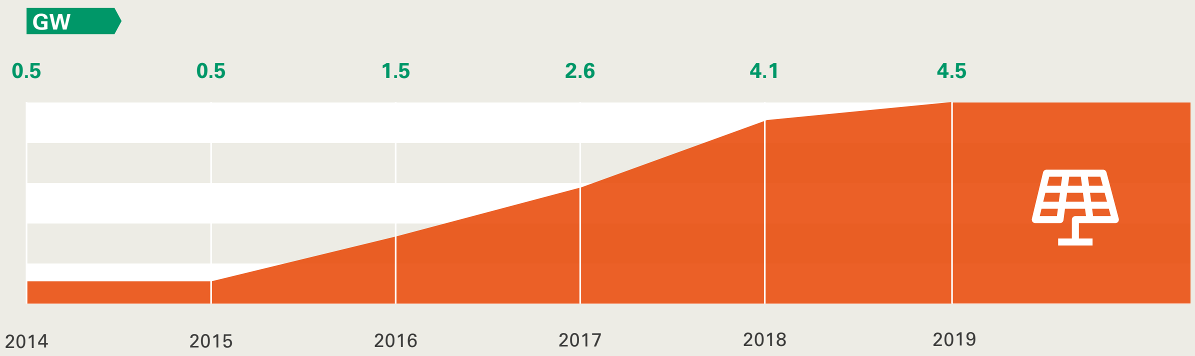
- Value chain low availability to invest in innovation and sustainability improvement of modules and PV components due to low margin in the EBITDA.
- Supply chain sustainability.
- Need to improve efficiency and lower costs of modules.
- Projects evaluation approach not fully based on LCOE criteria.
- Land use for utility scale solar panels, competition between agricultural and energy use.


enel
Green Power

Leading technologies

Solar

Enel's Solutions



Solar: our growth from 2014 to 2019. Since 2015, we have moved from small plants mostly in Europe to big and technologically advanced ones in Brazil, Mexico and South Africa

THE BULK OF THE TRANSITION

Solar energy, together with wind, is globally leading the energy transition thanks to price competitiveness (PV module costs have decreased by 89% since 2010), to module power increase (which increased from 240W in 2011 to 400W in 2020), to efficiency (which improved from 14.6% to 20.2%) and to the evolution of the business model in relation to market evolution (from feed-in-tariffs to tenders and then to an integrated model, focused on the customer).

EGP'S 3SUN SOLAR FACTORY AND THE EFFICIENCY RECORD IN SOLAR CELLS

Enel Green Power's 3SUN factory in Catania is the only place in the world producing cutting-edge bifacial photovoltaic modules with amorphous crystalline silicon heterojunction technology (HJT). HJT technology guarantees solar cells higher

performance than other commercially available cells and even higher efficiency levels. In February 2020, the 3SUN EGP PV Innovation Group demonstrated that the efficiency of the solar cell on an industrial scale can reach and exceed 24.5% (cell area of 244.3 cm^2, industrial standard size). This result brings the company close to the world efficiency records of HJT bifacial modules.

NEW PV PLASTIC MODULES

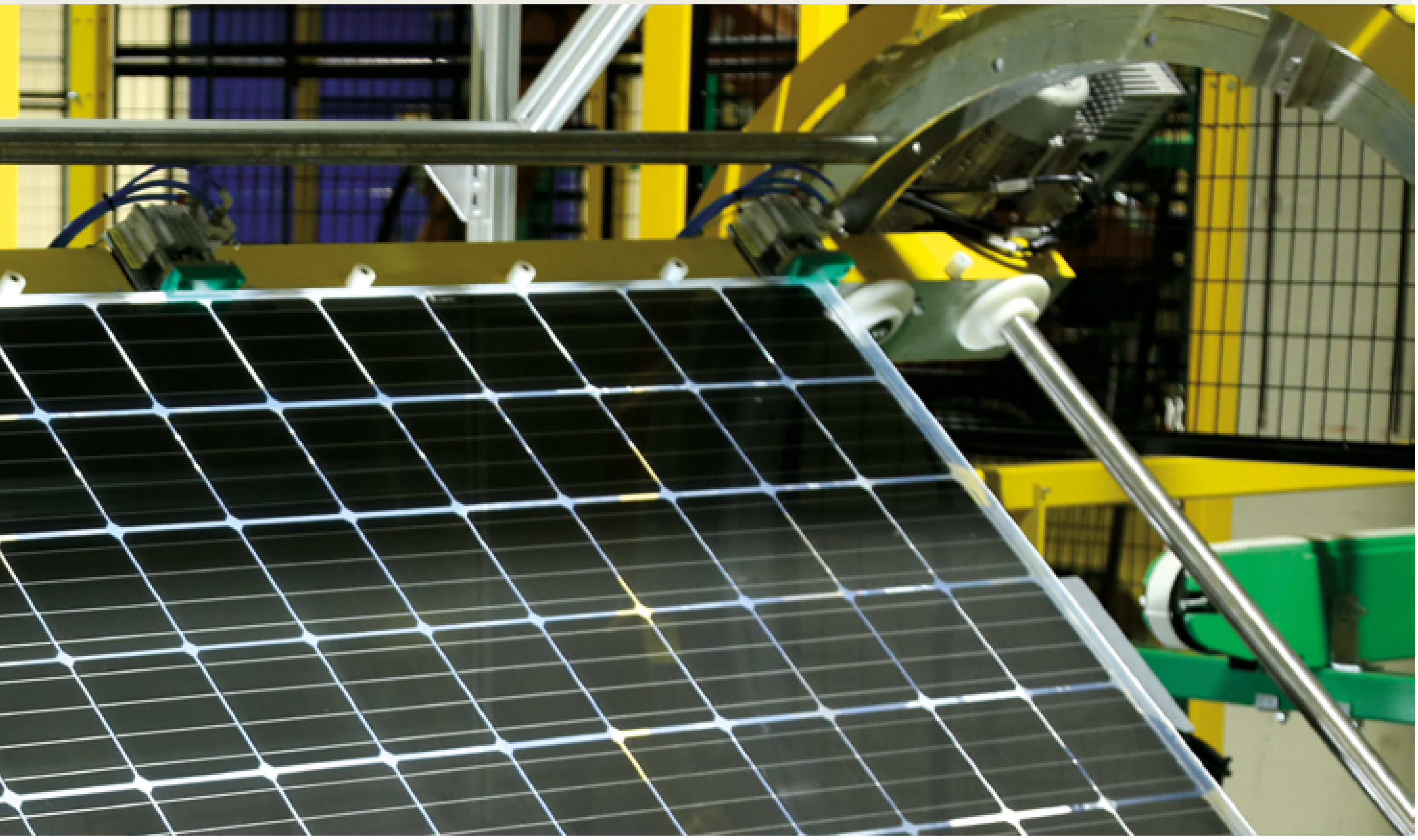
Enel Green Power is developing a new PV panel concept based on the use of recycled plastic in substitution of glass. This will allow promoting a superior product while significantly contributing to solve the problem of short-lived plastic products' accumulation in the environment.

SUSTAINABILITY & WATER SAVING IN PV CLEANING

Water saving is a fundamental step in the path of sustainable growth of photovoltaic power plants. With the rise of an increasing number of photovoltaic fields installed in the most remote areas of the world and often subject to drought, Enel Green Power takes advantage of the most innovative technologies that guarantee the sustainable use and saving of water resources during operation and maintenance activities, including PV cleaning assets. For this purpose, EGP's innovation is at work to test the most advanced autonomous robotic solutions capable of cleaning the panels through zero-water methods, which are a remarkable improvement compared to the invasive traditional techniques. Moreover, EGP has demonstrated that it is possible to produce water from air thanks to an innovative thermal machine capable of extracting water from the humidity present in the air, based on the inversion cycle of compression for in situ production. The water thus generated will be available for panel cleaning activities, for the operations during construction phases, as well as for use by local communities.

INTEGRATION OF SOLAR ENERGY WITH OTHER SECTORS AND AGRIVOLTAICS

Enel Green Power is committed to enhance the areas where photovoltaic power plants are located, seeking new technologies and operational strategies that allow the sustainable growth of PV systems. To this aim, new solutions in the agrivoltaic sector are being explored, focusing on the the co-localization of agro-zoological activities and photovoltaic systems which will create new opportunities for local communities and markets through an efficient and sustainable land use, capable of preserving biodiversity. For the scouting phase, Enel Green Power has also launched a challenge by means of the Enel Open Innovability Platform to find innovative solutions for the integration of agro-zoological activities within ground-mounted photovoltaic bifacial power plants, not requiring any plant layout modification, enhancing the ecosystem and preserving the wildlife habitat.



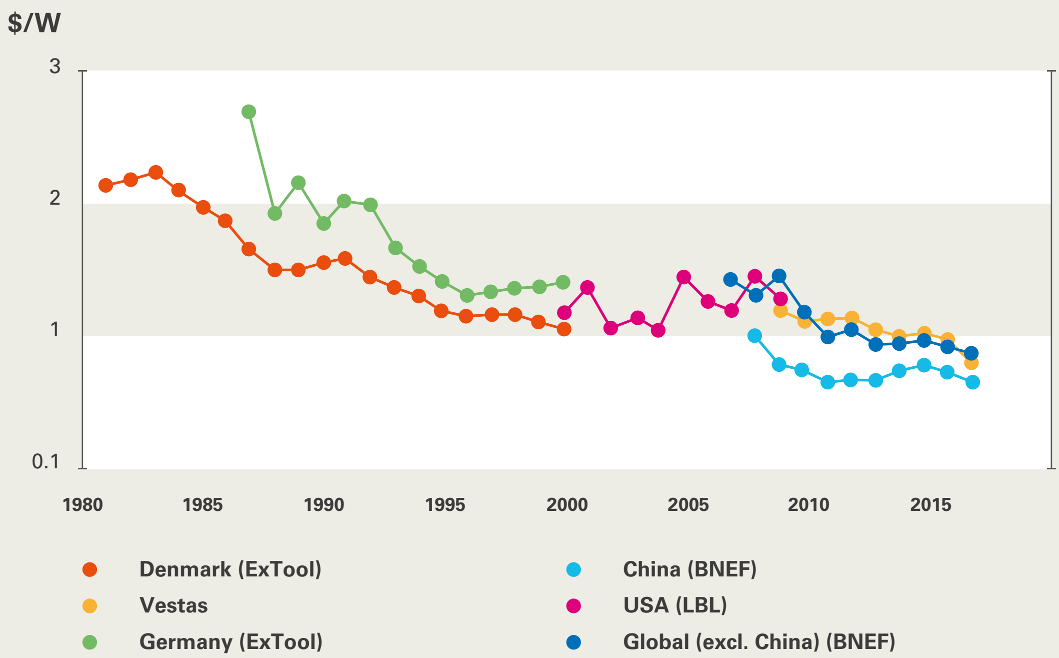
3.2

Wind

KEY MESSAGE

Onshore wind is the other leading technology of the energy transition, with cost levels similar to those of solar. It is benefiting from an ongoing technological evolution involving both onshore and offshore wind farms and leading to significantly larger turbines. While the growth trend for wind energy is here to stay, there is a number of challenges that this technology will have to face in the next few years.

07 Wind turbines



Since 2010, the price of wind turbines has fallen by 40%

BIGGER WIND TURBINES, BLADES AND TOWERS

The biggest wind turbines worldwide have rotor diameters of 158 meters, towers over 160 meters tall – and the average size is expected to keep on growing. This brings a need for the industry to re-think these major components in order to reduce weight and cost, but also to make transportation still possible and relatively easy to be handled from a logistics point of view. Towers won't only be tubular steel, like conventional ones today, but there will be more and more hybrid towers with different structures and different materials. Moreover, blades will need to get longer but still maintain a reasonable weight; further development in advanced materials will be key to keep blades robust but light, easy to manufacture and to recycle at the same time.

OFFSHORE WIND

On a global scale, offshore wind is expected to grow significantly in the coming years, but onshore installation will still keep the lion's share. Onshore wind is indeed more widely available worldwide and far cheaper than offshore, which requires not only much higher investments (per MW of installed capacity) but also longer construction times. Experiments, such as those for floating turbines, could however further reduce costs and increase efficiency for offshore wind.

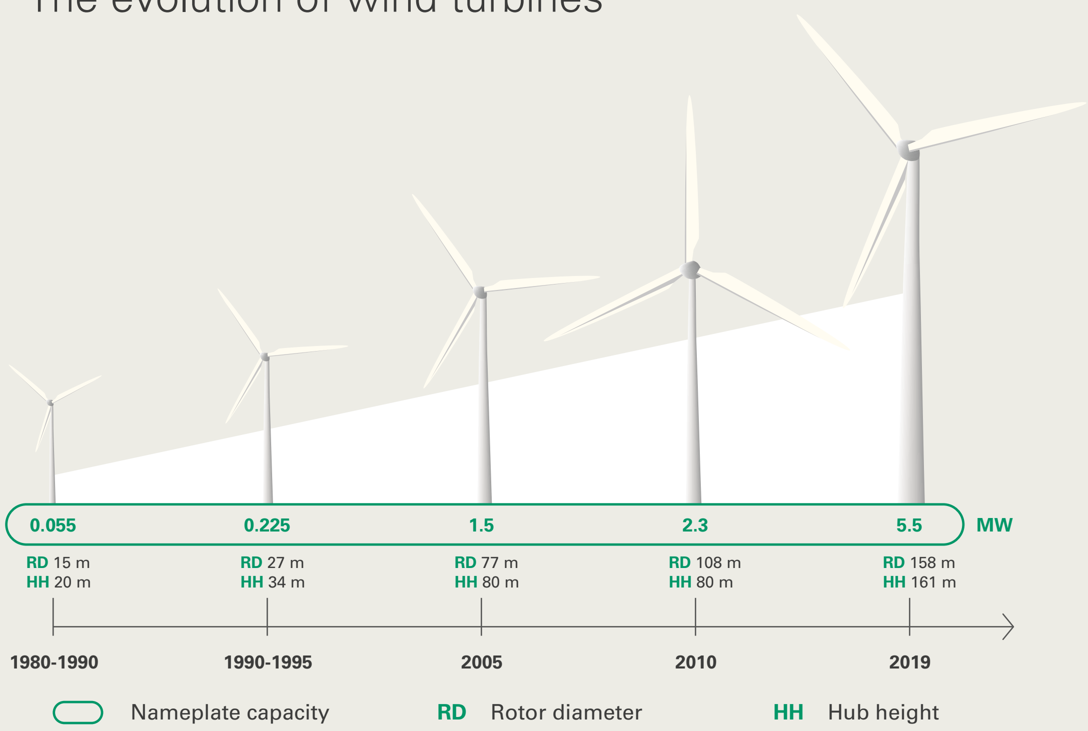
NEW DESIGN TO USE AND EFFICIENCY

The general trend of performance improvement for wind turbines will continue for the years to come and will be fostered by improved blade aerodynamics, enhanced component reliability and reduced overall failure rate. To that extent, advanced materials will be pivotal for all the components to deliver increased performance, allowing high return on investment in a reduced asset lifecycle. New manufacturing techniques will spread to keep up with these new materials and bigger dimensions. Not only mechanical and structural components, but generators and power electronics will be improving as well.

GRID AND SYSTEM INTEGRATION

Wind turbines and wind farms will have to increasingly provide ancillary services and grid stabilization. Improvement in power electronics will be key, as well as control software systems to blend and better dispatch energy from different

08 The evolution of wind turbines



Sources: IEA

renewable power plants. A further improvement in forecasting systems is also envisaged to deliver reliable wind energy-yield predictions and to match production and market demand in the best possible way.

NEW MATERIALS FOR BLADES

Although wind energy is by definition green and sustainable, there's a further commitment for it to be even more environmentally friendly. While around 90% of the materials that make up a wind turbine is easily recyclable, the blades are actually a challenge because of the composite materials they are made of. Innovative recycling techniques need to be developed and new advanced materials will be engineered and set up to further improve the circularity and the environmental footprint of wind energy.

WIND BLADES NEW LIFE

Most wind turbine components are quite easy to recycle (i.e. metal parts), but there is a small non-metallic portion of components that is less easy to recycle, namely the blades of the wind turbines. These are mostly made of composite materials (tipically a combination of glass/carbon fibers and epoxy matrix), plus some other minor components/materials (e.g. glue and gelcoat), making this task particularly challenging. In this framework, several initiatives have been set up in order to define a feasible value chain to be more and more sustainable, under a circular economy perspective.

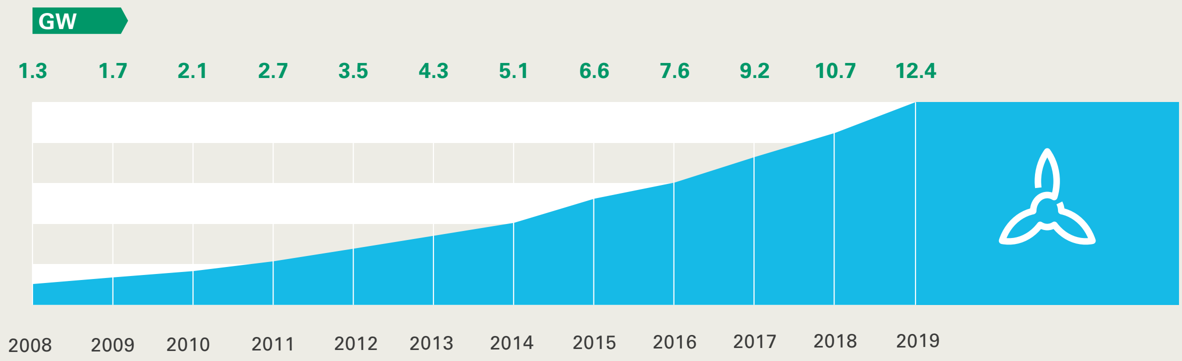
CHALLENGES

- Maintenance cost of wind farms.
- Lack of a supply chain for sustainable disposal of exhausted blades, and new recycable materials.
- Potential damage to birds, particularly migratory species, and impact on landscape.

Leading technologies

Wind

Enel's Solutions



We witnessed a constant geographical expansion from the Americas to India, catching new opportunities to extend the lifetime of wind farms in mature markets

A CONVENIENT SOLUTION

Wind, together with solar, is the technology driving the energy transition, proving that renewables are the most convenient solutions. Nowadays, at least two thirds of the global population live in a country where onshore wind and/or utility-scale PV are the cheapest option for electric generation. The LCOE for wind and solar is currently lower than coal and gas. Since 2010, the price for turbines has decreased by 40%, while their power and size has exponentially grown: the average 44 meters of height in 2009 have become 161 in 2019.

NEW EFFECTIVE AND SAFE APPROACHES FOR WIND MAINTENANCE

In order to become increasingly competitive and efficient in a stimulating market such as the wind industry, Enel Green Power takes advantage of the most innovative solutions for the maintenance activities of wind power plants. Self-hoisting crane technology is certainly among the most innovative solutions and is already being used in North American wind farms. The complete system including the self-hoisting crane can be shipped by containers and can be easily and safely installed on the wind turbine nacelle, with an almost fully automated process able to reduce man-machine interactions. Self-hoisting cranes offer a visible reduction of times, costs and, above all, of the safety risks that maintenance operations generally entail.

NEW MATERIALS AND WIND NEW LIFE

Enel Green Power is strongly committed to the selection and development of new materials for the wind industry, with the dual objective of guiding the development process of the new wind turbines generation and promoting the culture of sustainability and the circular economy in the whole sector. For this purpose EGP is working synergistically with the main original equipment manufacturers of wind turbines (so-called OEMs) and with the ecosystem of companies and research centers selected by the Enel Open Innovability Platform and the Enel Innovation Hubs operating worldwide. The main focus is on the blades which, due to current technology, are made of composite materials that are difficult to recycle. The goal is to develop innovative materials capable of facilitating the recycling process once the end of life is reached and contextually to improve the performance in order to make wind energy increasingly competitive. At the same time, key actors are being involved to cover the entire value chain to evaluate the joint development of integrated business models, looking at different sectors that could exploit the recycled materials from the wind blades to differentiate their product offerings. For example, the recycled fiber of wind blades finds many applications that can range from the nautical sector to the world of building insulators, to sports applications or to the use of blades as inert materials for the construction of asphalt and building materials with advanced and superior features.

SUSTAINABILITY FIRST

Enel Green Power lives with nature on a daily basis, to produce renewable energy and power a sustainable development path; every day it puts in practice a series of actions for the safeguard of ecosystems and of natural habitats in the territories where the company operates. Through constant monitoring, for instance, it leads studies on where certain bird species nest. By planning concrete and immediate solutions for their conservation, it builds them a safer habitat for their future.

PROTECTING THE LANDSCAPE

Concerning the impact on landscape, the company is now studying new materials and new designs for wind turbines, which could match the surrounding scenery.

3.3

Hydro

KEY MESSAGE

Hydro power is the most diffused, economic and reliable renewable energy source in the world, mostly because of its consolidated status. Despite the limited potential due to the current level of exploitation of water resources, its flexibility will be fundamental for the energy transition.

A MATURE SOURCE

Compared to other clean energy sources (e.g. wind and solar) hydropower has achieved high levels of technological maturity due to its protracted use. Accordingly, there exist fewer possibilities to identify and implement concepts that revolutionize the way hydro operates, and in continents such as Europe there is little space left for further capacity installation. However, a significant potential for novel approaches in the planning, design and operation of a hydropower station still exists. This potential partially derives from the evolving role of hydropower in the transforming electricity systems. Being an important source of grid flexibility and the main bulk of storage technology, hydropower needs to adapt to opportunities and challenges dictated by the changing conditions.

MORE FLEXIBILITY AND EFFICIENCY

Hydroelectric power is one of the most flexible sources of energy, since hydroelectric plants can adjust rapidly to meet changing demands. As long as there is enough water in the reservoir, power generation can be turned up within minutes if necessary. Pumped-storage plants can absorb large amounts of excess electricity, thereby reducing the stress on electricity grids and preventing energy from being wasted. In an increasingly volatile scenario, flexibility will be one of the key parameters of future hydro power plants, jointly with the capability to optimize water usage (thus increasing efficiency). Grid balancing and regulation will become important services in the near future, that pumped or storage hydro plants will be able to perform efficiently and at competitive prices. Indeed, especially Pumped Hydropower Storage (PHS) will have a crucial role in enabling higher levels of variable wind and solar penetration, by adding wide-ranging flexibility services across multiple timescales. Changes in the management of electricity markets would also create more opportunities for hydropower. According to the scenario described

above, technology will evolve as follows:

- Advanced multi-generation unit optimizer.
- New technologies to extend the range of operation of hydro power plants.
- Advanced seasonal and sub seasonal forecast.
- Hybrid systems with integration of PHS and batteries.

MORE RELIABILITY

The hydropower fleet is ageing: one third of today's installed capacity is more than 40 years old and in the future hydro power plants will be increasingly stressed to meet new energy scenario requirements. In this context, fostering digitalization would enable to gather and elaborate real-world data on the actual working conditions of the turbines to enhance the capacity of hydropower plants, to provide advanced grid supporting services without compromising their safety and reliability. In addition, new innovative solutions are mandatory to minimize the outages and malfunctions. According to the scenario described above, technology is expected to evolve as follows:

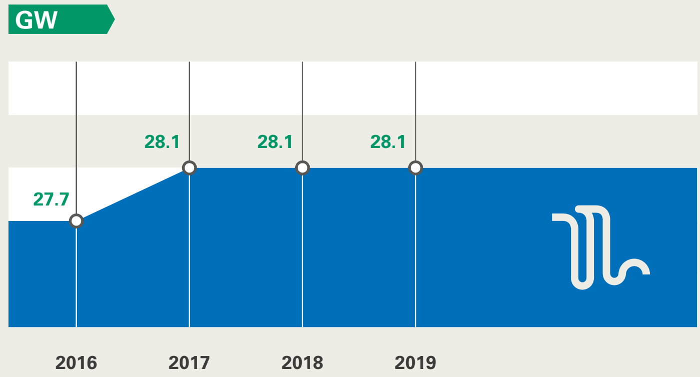
- New solution for cheaper and easier-to-install sensors to increase the data quantity and quality from electromechanical devices and hydraulic/civil works (e.g. fiber optics sensors).
- New and intelligent models to support the decision making process both in operation and maintenance (e.g. predictive models) also coupling data coming from different kinds of sensors (electromechanical, acoustic, etc.).
- Advanced tools and unmanned devices to replace low-value actions by operators (e.g. monitoring, checks, inspections, etc.).

HYDRO AND THE ENVIRONMENT

The development of new large-scale hydropower plants is challenging mainly due to the environmental impacts of dam construction and to the relevant cost of construction and operation. Small-scale and run-of-river hydropower is generally more eco-friendly and can potentially offer an alternative clean energy solution in unexploited scenarios with low head differences (few meters) available in rivers, irrigation canals and other sites. Finally, such solutions could be cost-effective for rural electrification. New turbine solutions will be developed in order to deploy such a concept.

CHALLENGES

- Repowering and updating the hydro sector.
- Impact on the landscape, the territory and the ecosystems.
- Barrage to migratory fish because of the presence of dams.



Hydro: our growth from 2016 to 2019. In 2016, large hydro was integrated into Enel Green Power, increasing its hydro capacity from 27.7 to 28.1 GW

EGP'S PORTFOLIO

EGP is now managing one of the major hydroelectric parks in the world, counting 800 plants and including facilities using a reservoir, run-of-the-river plants and more than 400 dams, mostly located in Italy, Spain and Latin America. The operativity of plants and dams is supported by a continuous program of investments, renovations and revamping of existing facilities, which covered 700 MW between 2008 and 2011, 850 MW between 2012 and 2015 and 1,400 MW in 2016-2019.

HYDRO POWER PLANTS' ASSET DIGITALIZATION

The path towards the assets' digitization involves the entire hydroelectric Enel Green Power fleet. The increasing number and reliability of sensors installed in hydroelectric power plants for the monitoring of temperature and vibrations of machinery as well as dams, ducts and channels, have allowed great progress in the field of anomalies detection and predictive maintenance. The amount of data collected by the sensors is processed by artificial intelligence and big data analytics systems to provide high-quality information in order to reduce maintenance operations' times and costs, avoiding risks for people and machinery failures.

SAFE APPROACHES FOR HYDRO INSPECTION AND THE CLOSER PROJECT

EGP's daily commitment of safeguarding health and safety is well represented by the Closer project, an innovative device that has already been deployed in many hydro power plants during inspection activities. Before the development of Closer, workers used to carry out the inspections in branch tunnels – courses that could even exceed 10 km – only provided with horns and audible warning devices. No active communication was possible during the many hours needed to complete the course. To date, Closer is able to create an effective and stable communication channel inside the tunnel or in other spaces having no signal, to allow workers to communicate with each other, exchange information with colleagues inside the tunnels and, if necessary, quickly activate the rescue team ready to intervene. Awarded at the National Wireless Expo 2019 in Lucca, the system – born from an open innovation challenge and developed by the Innovation Hydro team – is already in use in Italy, Spain and Latin America.

CONTINUOUS DESEDIMENTATION OF HYDRO POWER PLANT RESERVOIRS

Enel Green Power is committed to integrating innovation and sustainability within a continuously renewing historical source: hydroelectric power. A new solution, based on the continuous de-sedimentation technology, is being tested to demonstrate its capability of restoring the natural course of sediments from the mountain to the sea, a process that any barrier or dam on a river inevitably interrupts. The system consists of a boat which, equipped with a small pump and a "proboscis" immersed in the lake with adjustable depth, is able to break up the sediments with a jet of pressurized water and then suck to transfer them over the dam through a flexible conduit that will remain submerged, thus minimizing the visual impact of the entire system. The system also guarantees operational flexibility and low water consumption, not interfering with the management of hydroelectric plants or with the ecosystem, acting without noise and in a completely automated way.

HYDRO AND FISH MIGRATIONS

Enel is also experimenting with success a series of advanced solutions to favor the passage of wildlife through dams and basins. An example of this is the "fish ladder" recently opened in Enel Green Power's Isola Serafini, the largest hydro power plant on the Po river. The series of connected pools now allows migratory species to cross the barrage and come back to the breeding areas that have been precluded since the building of the dam in the 1960s. Recently, this infrastructure has witnessed the arrival of the first sturgeon – a species which many believed had disappeared from the Po river.

3.4

Geothermal

KEY MESSAGE

Although it is an old energy source and despite its potential, the diffusion capacity of geothermal energy is lower compared to that of other renewable sources. The need for dispatchable renewable generation and some technological changes are however increasing development opportunities, especially in areas with high geothermal potential.

AN OLD YET NICHE RESOURCE

Geothermal power production has been traditionally used as base load capacity, though it has a significant potential to both meet the needs of a changing flexible power system as well as stabilize energy grids. Electricity production using geothermal resources started in Larderello, Tuscany, in the first decade of the 20^{th} century, while geothermal district heating dates back to the 1930s. Yet, the resource has not spread globally, partially due to the concentration in specific areas of geothermal resources, and to the still high costs for exploration and to exploit sites with medium to low geothermal potential.

FUTURE PROSPECTS

The following technology evolutions are expected in the next decade:

- Unlocking the potential of new geothermal resources as affordable, sustainable and secure sources of energy through the development of new efficient technologies, such as high-enthalpy binary cycle technology and large-scale electrical submersible pumps (ESP), which are used for the extraction of geothermal fluid and enhanced geothermal systems. New countries are now joining the few that used the resource in the past decades, as great potential is being revealed for most of East Africa and South East Asia, particularly Indonesia.
- Enhancing the prediction and assessment of geothermal resources to reduce the costs of exploration technologies and increase the probability of success prior to drilling and during geothermal development, improving also the reservoir performance.
- Reducing the costs of the development and maintenance for geothermal projects by developing new energy conversion processes and improving the performance of technologies, including drilling and monitoring technologies. This will involve also the development of remote diagnostics projects using data processing with machine learning and Bayesian networks.
- Improving the lifetime of the equipment reducing the impact of scaling and corrosion by promoting also the exploitation of minerals from geothermal brines.
- Improving the environmental performance and mitigation of side effects like emissions into the environment by applying adequate technologies for the capture, use and abatement of non-condensable gases, and by combining with other renewable technologies, such as solar photovoltaic and hydrogen systems.
- Increasing the social acceptance of geothermal energy and improving the quality of life of the local communities, sharing the value created and responding to environmental concerns while highlighting the benefits of geothermal energy.

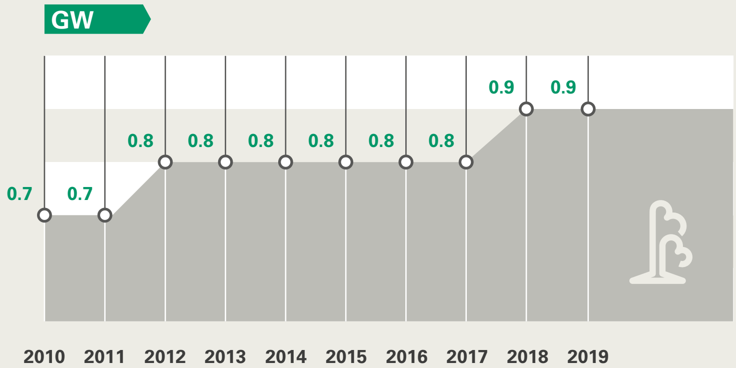
CHALLENGES

- Need to expand current geothermal resources.
- Evaporative losses.
- Need to improve drilling operations in terms of performance.

Leading technologies

Geothermal

Enel's Solutions



Geothermal: our growth in the last decade. We moved from state-of-the-art geothermal generation in Tuscany to binary cycle plants and to the first South American geothermal facility in Chile

GEOTHERMAL ACROSS THE WORLD

Geothermal generation is supported by a non-stop program of investments over the 40 sites we have in Italy, Chile and the USA; this is aimed at maintaining the existing plants and at perforation and re-injection activities, guaranteeing the continuity of the use of geothermal reservoirs.

MATCHING PROJECT TO SAVE EVAPORATIVE LOSSES

With the Matching project, funded by the EU within Horizon 2020, Enel Green Power has demonstrated an overall saving of evaporative losses up to 15% in the geothermal sector, through the replacement of wet cooling towers with hybrid ones equipped with advanced materials with improved robustness. Besides saving evaporative losses, a reduction of the visual impact was also possible, through the reduction of the visibility of the plume that is seen in evaporation from the towers.

THE LOCAL ECONOMIC IMPACT OF GEOTHERMAL GAS

The most significant environmental aspect that characterizes the operation of open cycle geothermal power plants is represented by the emission into the atmosphere of part of the endogenous fluids, consisting of incondensable gases, mainly CO_2 emissions from geothermal power plants, measured and registered for inventory purposes both by Enel and Control Authority, are not accounted as anthropic emissions as they would naturally happen from natural emissions from the ground. Enel is thus committed to improve the environmental impact of its activities, developing projects for the reuse geothermal CO_2. Two initiatives have been launched regarding the production of microalgae and the enhancement of the production in greenhouses. The process of growing spirulina alga using geothermal heat and CO_2 was validated in a specific project in 2018. EGP is now starting a new project to validate the use of geothermal CO_2 to improve the production of cultivation of basil in greenhouses already in operation close to geothermal power plants. This will allow both reducing the environmental impact and improving the efficiency of the activities related to geothermal areas with positive effects on social impacts, increasing the opportunity of job creation. Additional reuse options in chemical industries are under validation.

DRILLING IN DEEP SUPERCRITICAL CONDITIONS IN CONTINENTAL EUROPE

The Horizon 2020 project Descramble, led by EGP together with an international consortium of research partners, has developed novel drilling technologies for a proof-of-concept test of reaching deep geothermal supercritical resources. The project allowed to safely drill the continental-crust to demonstrate novel drilling techniques and the feasibility to control the high temperature and pressure conditions expected from the deep target. The test site was an existing 2.2-km-deep well in the area of Larderello (Italy), which was deepened to 2.9 km reaching supercritical conditions, although without the evidence of geothermal fluids, with a measured temperature exceeding 500 °C.

Chapter

4

Emerging technologies

4.1

Storage

Key message

The need for flexibility brought in by the energy transition already requires utility scale solutions for energy storage. Due to the cost and limited availability of pumped storage, we see the rise of new technologies, primarily the lithium-ion batteries.

A TECHNOLOGY ON THE RISE

Due to the massive deployment of renewables and the emerging need for flexibility, energy storage installations are expected to grow up to 1,095 GW by 2040, attracting 662 billion dollars in investment. Indeed, batteries contribute to the flexibility of electric systems in many ways:

- As intermittent generation's share increases, the demand of frequency regulation services is expected to grow, especially when the output of conventional power plants is low. The ability of Battery Energy Storage Systems (BESS) to react with fast and accurate response enables this technology to provide synthetic inertia to the system, taking the role that had been of the conventional generators being phased out from the system.
- The power system will run almost on 100% renewables during an increasing number of hours, especially during the daytime when the energy produced in excess (over generation) will have to be shifted to after the sunset.

THE ROLE OF ENERGY STORAGE IN ELECTRIC SYSTEMS

Historically, traditional power plants, grids and pumped storage hydropower have been the primary sources of flexibility for energy systems. While pumped hydro has been so far the most broadly deployed storage option, BESS are going to play a larger role as additional sources of flexibility. In fact, while the potential sites for installing a pumped hydro are few, or none in many countries, and their development requires several years, the modularity of BESS technology allows for fast deployment with minimal requirements in terms of siting. Moreover, the steep decline of technology cost– driven by the growing sales of battery electric vehicles (BEVs) and new technology improvements – is accelerating BESS deployment at global level.

STORAGE AND RENEWABLES

Battery deployments are mostly expected to be co-located with power plants like PV and wind farms in order to dispatch their production when needed and allowing the plant to stack revenues from different applications. In fact, plants combining RES and storage are becoming more and more common in many countries; for instance, they are securing their revenues by participating in the wholesale markets in the USA and Australia, while large hybrid auctions with long-term PPAs are being put in place in several markets like India, Morocco, Portugal, South Africa and the USA. Moreover, other countries like South Korea are deploying remuneration schemes specifically designed around the characteristics of wind and solar integrated with storage. Furthermore, long-term storage solutions will likely be required in the near future due to the increasing need of energy shifting in countries with high solar penetration.

THE TECHNOLOGIES AT STAKE

Energy storage comes in a multitude of different technologies, both based on electrochemistry (including lithium batteries and flow batteries) or another physical principles, like compressed or liquid air, thermal storage, gravitational storage, and more. BESS based on Lithium-Ion (Li-Ion) have established themselves as the most versatile technology. The market convergence around this technology is being driven by the growth of electric vehicles and their stage of technology development shows the highest potential of cost reduction with a higher reliability compared to other technologies still in demo phase.

LITHIUM AND ITS LIMITATIONS

Despite several factors which will allow Li-Ion technology play a significant role in the power system, their intrinsic technical limitations still represent a challenge. These limitations are mainly attributable to the batteries' lifetime consumption and degradation. The lifetime consumption can be directly or indirectly affected by factors like the number of cycles, calendar life and the depth of discharge (the deeper a battery is discharged, the shorter is the expected lifetime). The battery degradation over time reduces the battery's capability to store energy and its efficiency in doing so.

Moreover, when Li-Ion batteries are not operated or designed properly, they are subject to rapid heating, fires and even explosions posing a risk for safety. Proper safety management of a BESS project requires multiple actions (ranging from the design and manufacturing of the equipment to the integration, installation and operation of the system) that should safeguard the battery and the surrounding area even in the case of external events (e.g. earthquake).

MAXIMIZING VALUE

The key in creating value through storage deployment is to optimize design, in order to maximize opportunities for "stacking services" and synergies with other elements of whole project. The optimal structuring of storage applications is a complex process, which requires a deep knowledge of the project as well as of the market in which it is supposed to be.

CHALLENGES

- High cost of the technologies.
- Bottlenecks in the supply chain of lithium, cobalt, nickel. Social and environmental impact of their extraction.
- End-of-life management of electrochemical batteries.
- Need for long-term storage technologies.

Storage

HOW ENEL CONCEIVES STORAGE

Enel conceives storage as an ancillary and highly complementary technology for renewables, which allows to reduce their intrinsic limitations in terms of flexibility and dispatchability; at the same time it is able to reduce the risk profile of investments and to increase their profitability, by offering new and valuable services to the grid and customers.

With this vision, Enel is adding storage on a significant portion of its pipeline of projects under development in most geographic areas where it is present. Indeed, at the moment the storage projects' pipeline amounts to more than 7 GW in 14 countries (with this number increasing every day).

In the near future, the technological advancements, cost reduction and the evolution of regulatory frameworks are making adding storage a natural choice for plants generating energy from renewables.

A SOLUTION IN THE MAKING, COUPLING SUSTAINABILITY AND THE CIRCULAR ECONOMY

Enel is currently examining the feasibility of integrating exhausted EV batteries in renewable power plants in order to provide grid services, in a virtuous process also known as "circular economy". Our "Second Life Melilla" project is an example of this, and has been selected by the World Economic Forum (WEF) as a member initiative. The system will support the grid's stability by harnessing power from former Nissan Leaf battery packs.

At the same time, Enel is considering possible "green" engineering solutions to define future storage systems, driven by a solid commitment and partnerships with some of the leading suppliers in the business. Among the latest cutting-edge operations Enel will test on its power stations, is a thermal storage system developed by Brenmiller – an Israeli energy startup – and designed to stockpile high-temperature energy by using crushed rocks as a means to conserve energy in the form of extreme heat.

These innovative solutions are key to help suppliers adapt their infrastructure as much as possible to the specific needs entailed by the energy transition, while setting the stage for widespread use of these technologies to improve Enel's future competitiveness.

SUSTAINABILITY STANDARDS IN PROCUREMENT

In order to line up the supply chain with the highest sustainability standards, Enel has been among the first operators to introduce sustainability K factors in its procurement process, favoring suppliers a) which use renewable energy to fuel their production processes; b) which adopt CSR practices certified by international standards and c) which commit to collecting and recycling batteries at the end of their useful life.

NEW STORAGE TECHNOLOGY: THE BALEARIC ISLANDS CASE

Year after year, new materials and cutting-edge technological solutions are introduced in the market, leading to greater efficiency, lower costs and more sustainable products. Enel Green Power is proactively contributing to this revolution, by developing innovative projects aimed at improving the performance and sustainability of the technologies available, responding to the needs of an electrical system in constant evolution. In 2019, another important milestone has been reached.

EGP won a tender in the Balearic Islands, in Spain, and will be able to integrate two new technologies for long-term storage into the Son Juny and Son Orlandis photovoltaic plants in Mallorca: solid state lithium batteries and vanadium flow batteries.

These two technological solutions go beyond the most evolved energy storage systems and will be tested to ascertain their actual storage potential in real operating conditions.

Both technologies, each with its own specific features, promise to fill some of the most significant gaps in the current "standard" – Li-Ion batteries. The technologies feature greater stability and safety with regard to flammability, lower performance degradation – following repeated cycles of operation – and the absence of critical materials from the perspective of supply and sustainability (such as cobalt). The two innovative storage systems are currently in the development phase. Once operational, their performance will be analyzed to validate their actual operating efficiency.

4.2

Marine

KEY MESSAGE

Marine energy is still at an earlier stage than solar or wind and cannot be considered as having reached commercial maturity. Yet, its role in balancing the intermittence of the other technologies, untapped potential and latest developments could lead to a change in the next five to ten years.

THE TECHNOLOGIES INVOLVED

The power of sea and ocean can be exploited thanks to five physical principles, each one with its own peculiarities.

- → **Waves**: superficial motion of water, the most widespread and available, but with a lack of technology convergence and hampered by intermittence.
- → **Tidal stream**: horizontal currents associated with the vertical rise and fall of the tide, the most predictable and mature from a technological point a view yet limited by resource concentration.
- → **Tidal range**: the difference between high and low tide, it is applicable only where a basin is present.
- → **Ocean thermal energy conversion and salinity gradient:** the principle used is respectively the difference in temperature between deep and superficial water and the potential difference in salt concentration between two masses of water; these two technologies are the less mature.

THE POTENTIAL

There is a very big potential coming from marine energy. Tidal stream has 200 GW of theoretical installable power and 20 GW are located in Europe; wave energy has 700 GW of theoretical installable power and 80 GW are located in Europe. Many steps forward have been taken in the last few years; from 2011 to 2018 installed capacity went from 1 MW to more than 25 MW for tidal stream, with an annual generated capacity of 35 GWh, and from 500 kW to more than 11 MW for wave energy.

THE DRAWBACKS

Despite these progresses, marine energy converters are still far from industrial competitiveness. Ocean energies are, first of all, capital intensive; the cost of the device, infrastructure and installation is estimated at 60-80% of the final cost of energy. This means that developers need access to high levels of funding upfront, before any electricity – and therefore revenue – is generated. Strong geographic concentration

of some technologies and the technological immaturity of others have further limited the spread of the resource.

THE WAY FORWARD

The EU SET-Plan declaration of intent for ocean energy has set ambitious targets for wave and tidal energy technologies, setting the bar for future prospects. Tidal technologies are expected to reach an LCOE of 0.15 €/kWh by 2025 and of 10 €/kWh by 2030. Wave energy technologies are expected to reach the same targets with a five-year delay, 15 €/kWh in 2030 and 10 €/kWh by 2035. In order to meet these targets, technology costs need to be reduced by about 75% compared to 2016 values; utilities and countries interested in developing the technology should narrow the many options still available, ideally focusing on non-intermittent sources and on those which are already using parts produced for other technologies (for instance tidal stream), to match nearby intermittent renewable plants (e.g. offshore wind) and form a single, aggregated generation fleet.

CHALLENGES

- High cost and still low maturity of the technologies.
- International standards development for performance assessments.
- Scale up, industrialization and cost optimization of validated marine technology.

Emerging technologies
Marine

Enel's Solutions

NEW MARINE ENERGY DEVELOPMENTS IN CHILE

Enel Green Power is committed to drive forward marine renewable energy development in Chile. This is why, thanks to the Chilean government and along with other international partners, EGP has promoted the Meric R&D Program. Besides being a partner, EGP is owner of the Open Sea Lab (OSL) project, an innovative offshore oceanographic system, fed by the energy of the waves and connected wirelessly to onshore bases for data sharing in real time. The OSL's main goal is to propose a holistic approach toward the study of interactions between the wave energy generation systems and the ocean environment. Currently, around 40 professionals and researchers work in Meric, including permanent and associated staff, in order to continuously improve our knowledge and analysis of marine energy resources, since Chile has one of the greatest potential for marine energy worldwide.

BOOSTING THE MARINE TECHNOLOGY

Marine technology is still on the innovation path but it can be the solution to the struggling competition of the main energy transition drivers by obtaining REN installation permits in territories with many natural reserves and low terrain availability.
EGP innovation technology assessment process selected different wave energy converter solutions which demonstrated power generation and survivability in the harsh Atlantic Ocean sea and a number of Partnerships have been activated with different technology providers aimed at supporting demonstration programs in Europe (including the Mediterranean area) and in other regions of the world with high resource availability.
In this way EGP is gaining visibility and confidence with the most promising technologies while fostering their industrial development and is keeping ready for their adoption once they will be commercially available.
In addition to monitoring and supporting different marine technology providers, in order to evaluate the deploy of demonstrative projects and be ready for keeping playing the role of project developer also in marine energy, EGP is participating to EU funded projects, like DTOcean+ (aimed at developing an advanced design tool for Ocean Technology Array deployment) and is active in issuing ocean sector achievements and outlook through its membership in Italian (Blue Italian Growth – Technology Cluster) and European (Ocean Energy Europe) associations.

4.3

Green hydrogen

Key message

Hydrogen is one of the most quickly evolving technologies and could soon be key to match the growth of renewables. Although it has not yet reached full commercial maturity, hydrogen could shortly become one of the key solutions to reach a full decarbonization.

HYDROGEN IS HIGH ON POLITICAL AGENDA

Hydrogen is receiving growing attention by global policy makers; the March 2020 new industrial strategy for Europe, launched by the EU, already proposes a Clean Hydrogen Alliance, while the resource has a central role in the R&D plans of countries such as the UK, Norway and Japan. This was followed in July 2020 by the EU Hydrogen Strategy.

THE IMPACT OF THE CURRENT PRODUCTION

The bulk of the current production of hydrogen is far from being decarbonized. In fact, according to the IEA, the production of hydrogen, mostly from natural gas and coal, emits as much carbon into the atmosphere as the UK and Indonesia combined.

A DEFINITION

While hydrogen is present in nature almost everywhere, it is always bound to other element and it is impossible to find it freely in nature on its own. This means that, in order to have it in its pure form, it is necessary to separate it from the other elements using some other from of energy. For this reason, hydrogen is called an energy carrier and not an energy source.

Depending on the process used to separate it from the other elements, hydrogen is labeled with a different color:

- grey hydrogen, i.e. generated through fossil fuels, with the emissions of CO_2;
- blue hydrogen, obtained from fossil fuels but capturing CO_2 with carbon capture, utilization and storage systems (CCUS);

and

- green hydrogen, produced from renewable power the latter the only one being zero-emission renewable hydrogen.

Indeed, hydrogen is not attractive per se, it is all about how it is produced (like electricity).

HYDROGEN IS A COMPLEMENT TO ELECTRIFICATION, AND NOT AS A COMPETITOR

Since electrification offers the cheapest and simplest route to decarbonize large portions of total final energy uses, hydrogen will be a cost-effective and energy-efficient solution only to decarbonize those sectors of the economy that cannot be technically or economically electrified, i.e. the hard-to-abate sectors, such as heavy industry, aviation, shipping and long-haul as well as heavy-duty road transportation.

SUSTAINABLE HYDROGEN

Hydrogen needs to be renewable, i.e. produced via electrolysis fed by 100% renewable power. It is in fact the only truly sustainable production pathway, at zero greenhouse gas emissions and fed by renewable sources. There is no other production method which boasts comparable sustainability features. Blue hydrogen emits Green House Gases for the share of CO_2 it cannot capture and for methane leaks from the upstream natural gas value chain.

THE CONTRIBUTION TO FLEXIBLE GENERATION

A solar or wind project coupled with an onsite electrolyzer is similar, in terms of those services that can be provided to the grid, to a renewable plant combined with a battery. As renewable penetration grows, more flexible generation will be required and a hybrid power plant composed of a renewable technology coupled with an electrolyzer, alongside generating hydrogen, is much more flexible than a standalone renewable plant.

THE NEXT FUTURE

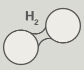
The domestic production of green hydrogen has the potential to create a new value chain, bringing value and jobs in the coming years, and can effectively improve security of supplies. The success of hydrogen will be achieved through the combination of further research, increase in application and exploitation of synergies with renewable energies. A clear understanding of the infrastructural needs for the diffusion of hydrogen is needed on both the European and the global level, since the still limited delivery of hydrogen infrastructures one of the main barriers to the development of the resource. IRENA estimates 700 GW of installed electrolysis for the production of hydrogen by 2030 and 1,700 by 2050 in order to exploit its full potential. This will in turn require a much more ambitious inclusion of hydrogen in the global fight against climate change and in the energy transition; this could translate into market stimuli, such as mandatory targets for clean hydrogen production, in a role for the hydrogen economy in the NDCs, and in a global, coordinated effort for the expansion of uses for the resource and for the economically sustainable development of the necessary infrastructures.

CHALLENGES

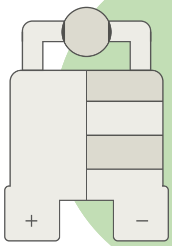
- Commercial immaturity and high cost of the technology.
- Lack of an international market.
- Lack of regulatory framework for the promotion of green hydrogen.

09 Green hydrogen: the business value chain

Operative **renewable plants** or plants in the development phase

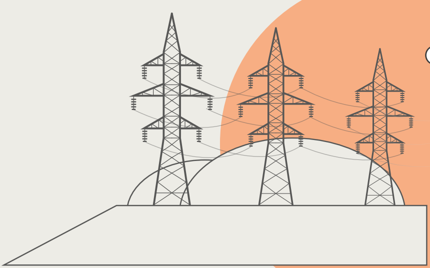


Green hydrogen to accelerate the energy transition



Adding an electrolyzer that uses **renewable energy to separate water (H_2O)** into its constituent parts: hydrogen and oxygen

Sale of the commodity to an industrial off-taker, thereby making production more sustainable



Production of **green hydrogen** and, at the same time, a more flexible plant that can provide ancillary services to the grid

ENEL'S PORTFOLIO WILL BE FURTHER ENLARGED WITH RENEWABLE PLANTS COUPLED WITH ELECTROLYZERS
Enel Green Power is working to create a pipeline of hybrid power plants composed of a renewable technology coupled with electrolyzers. This pipeline will include the possibility of retrofitting our existing PV and wind plants with such devices. The general idea is to make our plants more flexible and at the same time to produce hydrogen next to possible off-takers, relying on short pipeline connections or by using small sections of the existing gas network in an island-mode configuration. The bottom line is that we want renewable hydrogen: when it comes to decarbonizing the hard-to-abate sectors – such as some heavy industry, long-haul road transportation, aviation, and shipping – hydrogen produced via electrolyzers powered by 100% renewable electricity will play a key role as the most cost-effective and sustainable solution.

MATURITY
We are not looking for pilot or demo projects, but for commercially viable ones. Green hydrogen is still at the beginning and we will tailor the investments in line with customer needs in terms of hydrogen and with power grid needs in terms of flexibility. The basic concept is to create value by combining two or more technologies, like wind and an electrolyzer, so that the integrated plant can leverage more revenue sources: electricity sale to off-takers, sale of flexibility services to the grid operator or in the market thanks to the electrolyzer and, of course, sale of hydrogen to the "hard-to-abate" off-taker.

SYNERGIES WITH SOLAR AND WIND FOR THE INTERNATIONAL MARKET
We are actively looking for opportunities to co-locate electrolyzers with our wind and solar fleet, to produce hydrogen. The ideal renewable project capacity would be between 300 and 400 MW, with an electrolyzer of 100 MW. This is in line with what we do with batteries, a 20-25% ratio between hydrolysis or storage with power generation capacity. Any of the markets in which we are active could, in principle, be considered for a wind or solar plus electrolyzer plant but we expect the first likely locations to be Chile, the USA or Spain, where there are excellent renewable resources, big potential markets to be served through PPAs and favorable regulatory conditions.

THE CONTRIBUTION TO DECARBONIZATION
The use of hydrogen as an energy vector for decarbonization is within reach, but its production must be decarbonized, and the easiest way to do so is through electrolysis. The true challenge is to reduce the cost of producing hydrogen from renewables through improved economies of scale and technological evolution of the electrolysers. However we are sure that green hydrogen will become very competitive and that is why we are very serious about promoting this initiative.

Chapter

5 Complementary actions

enel

5.1

Services for the final consumer

Key message

Energy consumers are being directly affected by the energy transition, and the support and development of certain measures can accelerate the process. Utility bill management, energy management systems, smart cities and public lighting are among the most efficient tools in this sense.

DIGITALIZATION AND THE ENERGY CONSUMER

Commercial and industrial customers are often unaware of how energy is used on their premises during their production processes. Solutions that leverage digitalization comprise adaptable and tailor-made services like flexibility (demand response and storage), energy efficiency, distributed generation, electric mobility and energy advisory. These services empower consumers by helping them understand, optimize and manage their energy consumption in a way that is efficient and sustainable. Energy advisory services can help businesses to reduce energy supply costs, identify opportunities to increase efficiency and adopt a more aware approach in consumption. Furthermore, they can also support utilities in monitoring clients' consumption in real time, so they can become aware of the level of energy intensity they use and take corrective measures.

UTILITY BILL MANAGEMENT (UBM)

UBM is a comprehensive service for managing all utility use. Consumption trends are monitored through a software solution which comes with a user-friendly interface accessible from any type of device. In addition to efficient centralized bill management, the platform provides a multitude of different functionalities, including summaries of consumption at each of the client's sites. The company providing the UBM service can receive the bills directly from the suppliers of electricity, water, gas and waste collection. It then verifies their accuracy and carries out checks to identify any errors, before submitting the payment to the suppliers. Once the invoice is received, it is processed through a meticulous audit that verifies every piece of information. The added value of this type of platform is the marked benefits in terms of management and administration. UBM generates benchmark analyses and reports comparing costs at each site, both for internal and external use. This solution provides greater visibility and transparency concerning the client's use of utilities and identifies opportunities for energy cost reduction.

ENERGY MANAGEMENT SYSTEM (EMS)

Energy Management System software is able to gather consumption data from a client's equipment, processing it to produce benchmark analyses and identify actions to optimize energy use. EMS offers constant real-time monitoring of multiple sites, generating in-depth reports on the problems encountered and the underlying causes, as well as any examples of inefficient consumption. The software is capable of automatically identifying and suggesting corrective actions to optimize consumption and the related energy costs.

RESIDENTIAL

Digitalization and home appliance connectivity are the key drivers for residential customers, leveraging solutions such as renewable generation (e.g. solar photovoltaic or solar thermal) and demand electrification, with a special focus on electrification of transportation through electric vehicles, electrification of heating systems through heat pumps, energy efficient appliances and maintenance services to ensure the optimal performance of the appliances. Smart-home solutions help families save energy and simplify their life by allowing for easy, and even remote, management of heating, security, lighting and all other devices in the smart home ecosystem.

SMART PUBLIC LIGHTING

Nowadays, many urban public lighting systems still rely on traditional lights that offer poor lighting quality, high light pollution, frequent breakdowns and high consumption levels if compared to currently available advanced technologies (including LED) for efficient operation, monitoring, and management of street lighting. The technological and digital upgrade of the lighting infrastructure enables Public Administrations to transform it into a more valuable asset ready to integrate future applications that can make urban areas more accessible and safer. This could be achieved, for instance, by adding control sensors for real-time monitoring, by using adaptive lighting able to adjust to different traffic conditions and, generally speaking, by collecting information which will be fundamental for future planning on congestion management. Technological integration, such as the combination of lighting with chargers for electric vehicles, is another way to further expand the use of such tools.

CHALLENGES

- Need to develop differentiated solutions for governments, businesses and consumers.

Complementary actions

Services for the final consumers

Enel's Solutions

ENEL AND B2G

B2G means offering municipalities the opportunity to reduce energy spending on key urban services, such as street lighting, urban infrastructure and public transportation and assist them in transitioning to a smart and sustainable environment, also through the utilization of new digital solutions to plan/monitor mobility flows, interact with citizens, ensure cities' resiliency, and more. Enel X is levering the Enel Group's long-standing position as a street lighting O&M and electricity provider to evolve to a platform-based ecosystem that supports the "smartification of cities". This translates into a combination of remotely-connected lighting assets (once "dumb"), that reside in and are managed through a digital platform, which can accommodate also previously installed third-party hardware. The platform supports a combination of smart lighting services, such as adaptive lighting (automatic adjustment of light intensity based on the traffic intensity around the light poles), city analytics services (analysis of mobility flows through cameras installed on the light poles both for emergencies, including COVID-19, and routinary situations, such as flow planning during events), video surveillance. This positioning derives from the fact that cities are a core element of decarbonization given that i) they account for 70% of worldwide emissions mainly through buildings; ii) urbanization is progressing rapidly given that cities are home to more than half of the world's population and by 2050 they are expected to add another 2.5 billion new residents (source: McKinsey).

ENEL AND B2B

B2B means offering commercial and industrial customers the opportunity to become more aware of their consumption patterns, their spending, and ways they can reduce their utility bills), to comply with local regulations in terms of sustainability impacts mostly through digitally-based services, and to drill-down energy services' complexity across multiple sites, in the case of global customers, thanks to digitalization. Indeed, Enel X offers cost-efficient (UBM) and energy-efficient (EMS) solutions, monetization of customers' assets through the participation into demand-side flexibility programs which are now burgeoning across many countries thanks to the infinite possibilities opened by AI-based softwares and/or optimization engines for storage, and energy management systems to optimize consumptions according to the customers' production profile.

ENEL AND B2C

B2C means offering residential customers the opportunity to become aware of consumption patterns and reduce energy intensity. Besides offering home assistance services, Enel X offers home smartification products like Homix, a smart thermostat with integrated Amazon Alexa voice control that – also through the associated smartphone app – may act as a hub to control other smart devices, such as security cameras and lights.

5.2

The role of electric grids and DSOs

Key message

Different features of the energy transition, from the expansion of intermittent renewables to the electrification of new sectors, will require grid infrastructure reinforcement and digitalization to drive system level synergies. A greater development of existing infrastructures and a wider role for Distribution System Operators are needed. Consumers' growing awareness of sustainability issues will also be crucial to boost the shift in global energy markets.

THE SMARTNESS FACTOR

The capacity and the "smartness factor" of the grid must grow significantly, in order to increase the grid's intrinsic resilience and to lower its carbon footprint, while offering ever more flexible services – such as TSOs, DSOs, aggregators and flexibility exchange platforms – to retailers and Citizen Energy Communities. New market players – such as managers of so-called DERs (Distributed Energy Resources), prosumers, aggregators and active consumers – and, above all, the rise of intermittent capacity and generation assets connected to distribution grids pose new needs and require third-party business models being introduced to empower DERs to provide flexibility services and guarantee the success of the energy transition.

BOOSTING INVESTMENTS IN THE GRID

Investments in the Transmission and Distribution (T&D) sectors at global level are increasing and are estimated to have highly relevant growth in the next decades. The increase in electricity demand will be the reason for the majority of the expenditure changes. Additional expenditure will be needed to create connections to new generation and storage assets. Finally, the expenditure due to RES-related grid reinforcement will make up about 17% of total expenditure globally. Within T&D, distribution represents the highest share with 60-70% of the total, according to different sources, and is foreseen to increase this share. The estimated relevant share of investment in distribution grid digitalization has to be highlighted (i.e. network automation, monitor and control devices). Smart grids are actually the key enablers of DERs' flexibility services.

When talking about energy transition, we need to take into account also the role of policy makers in incentivizing the investments in energy infrastructure. The power sector can be completely decarbonized provided that the investment frameworks for RES and flexibility solutions are appropriately designed, providing signals to accelerate investment.

Regulators should encourage DSOs to develop innovative and digital solutions through a new/flexible regulatory framework capable of rewarding DSOs solutions that prove to be more performing and sustainable.

A greater coordination between TSOs and DSOs is essential for enabling both parties to fulfill their missions in a manner that minimizes social costs and maximizes sustainability and security of supply of power systems. DSOs, as defined also in the recast of Electricity Directive, shall act as neutral market facilitators and therefore foresee and oversee the impact of flexibility operations on their networks.

The TSO-DSO coordination will be formally reinforced starting Q1 2021 by the establishment of the EU DSO entity, which will serve as a technical and representing body at EU level, like ENTSO-E for European TSOs.

On this note, several guiding principles and recommendations have surfaced from European Institutions, reaffirming the evolving role of DSO and TSO as key market enablers in EU markets in the context of the energy transition.

One more area which deserves attention is securing and developing core competencies that will be critical to innovate, operate and maintain the energy system in an efficient way. This aspect of infrastructure future is based on: stronger support of on-going research and capability building programs; development of specific academies at EU level focusing on core capabilities with a long term and dynamic vision (e.g. electrical engineers, IT skills and data science, cybersecurity): promotion of the experimentation right of DSO on new business models and technologies to accelerate on the e-curve for these competencies to test their skills on real pilot cases and emerging technologies.

A NEW IMPORTANCE FOR DSOs

DSOs will need to adjust – and expand – their current role, which is pivotal in the energy transition and key to enable new value creation opportunities. This role transformation needs to be based in a proactive way on four intertwined dimensions:

- → Futurability. Different scenarios with new system paradigms in electrification, technology and sustainable resources, local energy communities and culture preference will require a new mindset in designing future energy systems having as stakeholder the society and legislative framework.
- → Grid Edge Transformation. Electrification, increased penetration of distributed energy resources, pervasive digitalization, and new business and societal technologies are shaping a grid edge transformation. This progression unlocks value creation and opportunities for innovation and technological development that will benefit the various stakeholders.
- → Innovative Resilience. Ever intensifying market dynamics, cybersecurity, large-scale social events, climate change and related force majeure phenomena will affect the energy sector, requiring disruptive solutions to guarantee a higher degree of reliability, adaptation and flexibility of power grids. All this will challenge DSO operations and require new business and regulatory models and new types of governance for the new energy architecture.
- → Evolutionary Customers and DSOs. Customer's behavior is evolving driven by new technologies, market, societal and environmental stimuli, more flexibility and affordability. New customer expectations will impact the evolution of DSO models and contribute to affordability as well as greater flexibility and simplicity.

DESIGNING THE GRIDS OF THE FUTURE

To make to transition faster, we need the grids to become:

- → **Participatory**. They need to empower the participation of new actors between demand and supply in the energy transition. This is a challenge at the core of the combined efforts of government and the private sectors.
- → **Resilient**. Energy platforms will become even more critical infrastructures and technological developments in the sector, characterized by increased automation, digitization, deployment of smart grids and interdependencies with ICTs can help us become more resilient and flexible at the same time.
- → **Sustainable**. Cooperation with all stakeholders is needed due to the fact that electricity is vital for societies and the economy to run smoothly, especially given that many other critical sectors depend highly on power supply (e.g. telecommunications, water, transportation). Also, the concept of the Circular Economy is going to change the way we look at our processes. Energy platforms are aligning more and more.

DSOs AND THE MARKET

In this regard, DSOs can act as the neutral market facilitator of local flexibility services (for congestion and voltage control management through RES and EV integration, deployment of storage), not only by performing their core activities related to secure and stable electricity supply and the distribution system, but also by applying flexibilty market-based procurement, using incentivizing network tariffs or connection agreements, to promote an efficient use of resources and services, involving the market players that own such flexibility assets. This will enable the solutions and business models promoting and accelerating the energy transition, for the benefit of all stakeholders.The enhancement of the role of DSOs will require a set of changes, such as:

- → Greater visibility to DSOs, advanced monitoring and control over the electricity flowing across their networks, via smart grids and smart metering infrastructures.
- → Modernization of the distribution system, including the deployment of new technologies and digitalization of the grid, to allow the utilization of flexibilities that are currently available or that will become available in the future.
- → Empowering the customer to play an active role in the energy transition.
- → Enhancing the dialogue between TSOs and DSOs that have the need and responsibility to cooperate in order to rethink the energy system, through innovation and digitalization.

5.3

Digitalization: large plant management

KEY MESSAGE

Utility-scale generation is significantly benefiting from digitalization in a number of areas: data analysis, scheduling maintenance, enhancing a plant's life and boosting workers' safety.

THE IMPACT ON LARGE POWER PLANTS

Digitalization and automation of business processes will have a huge impact on the construction, operation and management of large power plants. Rapid advances in telecommunications, sensors, Industrial Control Systems (ICSs), and industrial software are opening ways of driving efficiency gains from existing operations and are enabling new, more flexible business models offering extensive opportunities for growth. These advances result in reducing operation and maintenance costs, improving power plant and network efficiency, reducing unplanned outages and downtime, extending the operational lifetime of assets, enhancing health and safety measures for the operators and controlling environmental impacts.

MERGING INFORMATION AND OPERATIONAL TECHNOLOGIES

Not so long ago, the management of industrial technology was traditionally separated into two fields: Information Technology (IT) and Operational Technology (OT). IT works from the top down, deploying and maintaining data-driven infrastructures largely to the management side of business, and OT is built from the ground up, starting with equipment and assets and moving up to monitoring and control systems. With smart equipment, big data, and the Industrial Internet of Things (IIoT), the worlds of IT and OT suddenly collided, and so the prerogative of IT is now ubiquitous on operations. Due to the maturity of ICSs, the enhancement of connectivity services and the contamination of IT principles in OT processes (cloud solutions, IP-based protocols, etc.) the operating model of large power plants is evolving from a local control model to a fully unmanned and remotely controlled model.

A NEW DATA-DRIVEN APPROACH TO MAINTENANCE

The increasing availability of data coming from the field implies that the monitoring and control systems are continuously gathering endless pieces of information at a more rapid pace than ever before, typically funnelling massive amounts of data into a control room or historical data hub for analysis and response. Operators are tasked with sifting through signals and alarms working around the clock to manage anomalies or recognize potential threats. That means an increasing load of tasks and processes that humans can hardly manage or fully maintain. The introduction of AI powered by computer vision and machine learning solutions opens new horizons that will allow fast detection of critical events. In the long term, an important benefit of digitalization in the energy sector is the possibility to extend the operational lifetime of power plants and network components leveraging predictive and prescriptive maintenance. Conversely, monitoring the stress of power plants over their life cycle, is central not only for lifetime extension but also for the maximization of power plants' profit in relation to market opportunities, for example in the replacement of existing equipment with newer, more technologically advanced options. Both scenarios would increase revenues while reducing future investment requirements. This would ultimately lower prices for end users, also providing new digital services to external parties and capturing new market opportunities.

ROBOTIZATION

Robotization also contributes strongly to the digitalization framework because it brings a balanced usage of automation, like operating drones and robots, within the digital value chain. This allows companies to ensure higher value for their workforce in terms of safety and sustainability, guaranteeing fully functional operations. New technologies are enabling the combined use of drones and AI to perform thermographic analysis on solar power plants, for instance. Robotized boats are also used to perform bathymetries on basins and rivers eliminating environmental impact while ensuring the workforce's safety. Integrating the enormous potential of robotics within Operations and Maintenance (O&M) processes can lead to a reduction of costs and an increase of data quality which in turn allows for better and faster decision making and actions to reach the best results. From a strategic perspective, focusing investments in the 4.0 industry (AR/VR, edge-computing, robots, drones) can yield the highest returns due to a reduction in workforce costs, as well as an increase of worker safety.
Furthermore, the decrease in operational and capital costs (opex and capex) will allow an increase in the number of projects in which companies will invest; this will in turn increase jobs, balancing or even surpassing those lost because of the automation of processes.

CHALLENGES

- Need to invest in flexibility and education so reskilling can match workers' competences with the rapid evolution of energy systems.

Complementary actions

Digitalization: large plant management

Enel's Solutions

LIFE-LONG LEARNING

Enel is focusing much of its strategy on innovation, digitalization and the development of renewable sources, and these choices are dictated by a changing situation, but also by the need to facilitate an increasingly sustainable economy. In this situation and to respond to these stimuli from the outside world, significant upskilling and reskilling programs have been planned. While these are sometimes used as synonyms, they have different connotations and consequences: *upskilling* is focused on the development of existing professional skills, adding new competences dictated by technology or innovative processes; *reskilling* instead aims at creating new job profiles, substituting skills which are becoming obsolete or no longer sought after, and to enable the individual to handle new activities. In this field, Enel places great importance on reskilling and training programs related to digital transformation processes and the energy transition, aimed at acquiring new skills characterized by a high level of innovation. Examples are the training of technical staff to become drone pilots for the inspection of power lines or plants, or to qualify them as maintenance operators for conventional generation plants, so they can also work effectively on renewable plants.

DIGITAL CULTURE, A CHANGE IN MENTALITY

Enel's commitment extends from digital technical skills and is focused on increasing know-how and fostering digital culture with experiential learning initiatives and continual openness to and dialogue with the outside world, in addition to technical and operational training programs.

EXPERIENTIAL LEARNING

Some of the most efficient learning programs consist of job shadowing, i.e. an opportunity to "step into the shoes" of other colleagues, get to know the context in which they operate and the approaches adopted in a kind of joint workout. There are training programs to contribute to the development of technical and managerial skills for the benefit of departments and business lines, realized in collaboration with leading academic partners. We also support educational platforms; we recently launched a 2.0 version of eDucation, the Group's global training platform, enhanced with new content, renewed in its style and function and including a mobile version. In this platform anyone can become a content promoter, having the chance to suggest books, courses, articles, videos, links, documents and reports, also and perhaps mostly from the outside world, through learning playlists and with comments and followers.

5.4

Carbon offset

KEY MESSAGE

Carbon offsetting represents an important tool for companies, agencies, governments, individuals and any kind of entity willing to decrease their CO_2 emissions impact. This is obtained through the compensation of their own emissions via projects (delivered through certificates) reducing the amount of CO_2 going into the atmosphere.

A DEFINITION

Carbon offset means compensating for emitting one ton of CO_2 into the atmosphere by preventing a ton of CO_2 from entering the atmosphere elsewhere on Earth (for example, by investing in renewable energy) or by removing a ton of CO_2 that's already up there (by supporting something like tree planting – since trees absorb CO_2 from the air when they grow). It allows governments, companies and individuals to indirectly reduce their emissions by investing in projects with environmental, social and economic benefits all over the world.

THE PATH

The process of carbon offsetting consists of two main steps:

- **Carbon footprint calculation**. A carbon footprint is defined as the total emissions caused by an individual, event, organization, or product, expressed as carbon dioxide equivalent, in a specific period of time. The carbon footprint calculation is carried out by using models (verified or audited by competent authorities), which usually input all the features inherent to the entity whose carbon footprint is under investigation (e.g. for an event, the list of all the flights taken by attendees, or its total energy consumption). Then, those models output the overall quantity of CO_2 equivalent associated to it. Based on the number calculated by the model, the emissions are then neutralized.
- **CO_2 emissions neutralization**. Operationally, neutralization entails the purchase of special certificates, each one equivalent to a ton of CO_2 avoided. The money employed for such purchases is redirected towards projects aiming at reducing GHG emissions all over the world (especially in developing countries). Neutralization also represents a clear effort toward the Sustainable Development Goals. Certificates are purchased according to the quantity calculated in the previous step: then, they are redeemed in specific registries. Once the certificates have been cancelled, they cannot be used anymore. Carbon offsetting can be performed for compliance (the entity's activities are subject to constraint on emissions) or voluntary reasons (the entity is willing to make its activities more sustainable, even if its emissions aren't legally impacted).

CO_2 CERTIFICATES

There are two types of certificates that can be traded and cancelled for voluntary purposes:

- **VERs (Verified Emission Reductions)**. These are issued by independent parties and subject to some standards (VCS, Gold Standard, CCBS, others).
- **CERs (Certified Emission Reductions)**. These are issued by the UN's Framework Convention on Climate Change (UNFCCC) and derived from projects developed within the Clean

Development Mechanism with possibility of extra labels (e.g. Gold Standard).

CERTIFICATE FEATURES

The main features that characterize CO_2 certificates are:

- **Category**. This feature expresses the type of project the certificate is generated from. The main categories are Forestry and Land Use (projects focused on afforestation, reforestation and preservation of natural zones; the most famous sub-category is REDD/REDD+, which stands for "Reducing emissions from deforestation and forest degradation"), Renewable Energy (solar, wind, small hydro, biomass etc.), Waste disposal, Household Devices, Chemical/Industrial processes, Energy Efficiency etc.
- **Country of origin.** This is particularly relevant, as typically these certificates come from projects in developing countries.
- **Standard**. This feature focuses on expressing the type of benefits the project brings (environmental, economic, social benefits). The main standards are Verified Carbon Standard (VCS), Climate, Community and Biodiversity Standard (CCBS) and Gold Standard, assigned by independent organizations.

CHALLENGES

- Match the advancement of the energy transition with other environmental issues (e.g. biodiversity and forest protection).
- Need for a sustainable impact on the regions surrounding the energy infrastructures.

Complementary actions

Carbon offset

Enel's Solutions

OUR COMMITMENT

EGP is committed first of all to achieve 100% of renewables production by 2050 avoiding completely CO_2 emissions. At the same time, it is working to be more focused on forestry plantation with an innovative approach that could guarantee environmental and social benefits not only during the forestation period, but also assuring carbon sequestration for an unlimited period and encouraging the development of wood as a sustainable material substitute for concrete.

PRESERVE BIODIVERSITY AS A PRIORITY

Enel is committed to maintaining biodiversity and assuring ecosystem conservation in the development of projects up to operation and decommissioning involving local communities and respecting the environmental requirement of the territory. A wide range of actions was put in place by Enel worldwide with a particular focus on forests.

THE FORESTRY PROGRAM AS A NEW APPROACH

As part of this commitment, GPG is now interested in exploring and evaluating the opportunities to promote an innovative concept on reforestation program. It is not only pure reforestation, but also wood production through sustainable forest management, aiming at feeding the green building sector. The forestry sector could not only guarantee CO_2 storage, but also support actions oriented to biodiversity and ecosystem conservation and the engagement of local communities, creating shared value. The strategy on forestry plantation is oriented on multiple and complementary approaches, ranging from large-scale projects (focused on big countries with significant availability of land) and small-scale projects (focused on limited countries with a strong Enel presence, such as Italy and Spain, preferably nearby the company's operations).

RECENT EXAMPLES

An example of such commitment concerns Fortuna, one of our large hydroelectric plants in Panama, which includes a natural reserve of 20,000 hectares. EGP maintains not only the basin that is used for our electricity generation, but also the entire natural reserve. Another one is the El Quimbo hydroelectric power station area in Colombia, which has been contributing to the great reforestation process of the Colombian tropical dry forest. EGP has already planted hundreds of thousands of trees, and has contributed to the construction of a research center open to the public and to the creation of the "Cerro Matambo" nature reserve. Another example is the RENACE forest, a sustainability initiative for the restoration and protection of 690 hectares of high Andean forest, developed by companies including EGP, which has contributed to the planting of over 23,000 trees (also including native species such as alder and myrtle).

Chapter

6

Power sector evolution

6.1

Current regulatory framework

Key message

The current regulatory framework varies from country to country, but the definition of the cost of electricity generally follows either System Marginal Price or Pay-As-Bid schemes. While a regime of exceptions and market rules exists, service markets also exist, which are able to supply electricity in case of emergencies.

DEFINING THE COST OF ELECTRICITY

Apart from emerging markets, the way each country determines the cost of electricity is through market competition. The the main objective is to supply electricity to most of demand in the cheapest way possible. A least-cost mechanism is then followed.
Market competition is usually obtained through repeated auctions. There are two main schemes to determine the price of the market. The first one is called "System Marginal Price" and defines a unique power price for all players acting in the market. The second market scheme is "Pay-As-Bid" and defines one price for each seller. For the energy market, the scheme usually used is the "System Marginal Price".

SYSTEM MARGINAL PRICE

Under this scheme, for each market session, all the operators provide their own bids (potentially multiple) in terms of generation and price required for that generation. All these offers are sorted from low to high and a Merit Order Curve is built. The cheapest offers which meet energy demand are accepted, and the most expensive ones are rejected. The highest accepted bid sets the energy price for all participants. Additional constraints (such as per network) may be taken into account if required by the network structure.

PAY-AS-BID

Under this scheme, for each market session, all the operators provide their own bids (potentially multiple) in terms of generation and price required for that generation. All these offers are sorted from low to high, and the Merit Order Curve is built. The cheapest offers which meet energy demand are accepted, and the most expensive ones are rejected. Unlike System Marginal Price, each producer will receive exactly the price requested in its bid. For this reason, it not possible to speak about market price in the way it is commonly intended. Additional constraints (such as per network) may be taken into account, if required, also in this case.

MARKET RULES AND BIDDING DRIVERS

Despite the logic being the same almost everywhere, each market may consider some specific rule in terms of segmentations of the bids, timing, delivery and additional constraints, in particular price cap and floor. These are two specific constraints on prices which have to be fulfilled by the bids; they are included to avoid the final price will reach too high values (against consumers) and too low values (against producers), and the bid is usually free to be set between these two values. Not all the producers have to bid their energy in the market. Some kinds of operators (generally RES power producers) have a sort of "priority" in dispatching; this means that their energy is sold through the market, regard-less of other bids. For thermal power plants, the main driver for the bid is represented by fuel and variable costs. On top of this, if allowed by market rules, they can add an additional bid-up to recover additional costs (fixed cost, investment cost, extra margins and others). The possibility to add an extra-revenue is ruled out in some markets; in this case, the cost to produce energy for each power plant is subject to audit by an external Authority and the players are not allowed to bid at prices higher than such costs. The market will then cover all the variable costs of the marginal player. In these markets, all the additional revenues needed to cover fixed, investment and other costs, are usually obtained through alternative schemes or markets, such as Capacity Payment, Capacity Market, PPA, and others. This kind of mechanism is applied for example in Chile, Russia, South Korea and India.

SPOT MARKET

Through spot markets, producers and consumers can sell and buy energy for a very short time period (one hour or less) and very close to the delivery. As a general rule, the energy is sold on a one hour delivery in the day after the market session. Therefore, this kind of markets are often called "Day-Ahead-Markets". In reality, some markets may shorten the time to delivery and the settlement period (30 minutes or even 5). Subsequent additional market sessions may take place to adjust the production schedule and better fit technical constraints of each power plant. In these sections, each player can re-sell or re-buy the volume awarded in the previous section. These markets are operating in the Americas, Europe, Russia, Australia, and the Far East. In all these markets there is the possibility to sell and buy energy both through "spot" markets and according to "future" mechanisms.

FUTURE MECHANISMS

Through future mechanisms, producers and consumers can sell and buy energy for a variable period in the future at a fixed price or according to predefined rules. The delivery period may vary from a few days to several years (in some cases, like India, the delivery may cover up to 20 years). Through such products, producers and consumers are able to protect themselves against fluctuation in power prices and volume sold or purchased. Indeed they freeze, or at least reduce the volatility, of future revenues. Pricing mechanisms may be different according to each country. In Europe or North America, for example, forward markets are quite advanced and the price is set mainly through market clearing competition. In other areas, such as Latin America or India, bilateral contracts are preferred, also driven by action mechanisms. In such cases, the dependence on one or more external parameters (fuel costs, CPI, etc.) is usually taken into consideration.

SERVICE MARKETS

In case of a shock in the network (e.g. an increase of power generation or demand, the failure of a transmission line, etc.) some deviations in voltage and frequency may arise in respect to normal operating conditions. If such deviations surpass predefined thresholds, the stability of the network is put under pressure or even put at risk. To avoid critical conditions, the Network Operator has to restore the levels of voltage and frequencies within their own tolerance bands. To do this, the equilibrium between production and consumption has to be guaranteed instant-by-instant and continuous real-time adjustments are needed. To maintain the equilibrium between demand and consumption, the System Operator has to be able to increase or decrease the production of each power plant or reduce the load from pre-identified consumers. Then, the possibility to deviate from scheduled production is needed. Since a deviation in any point of the network has an impact on the whole system, the real-time management is managed at centralized level. Despite that, the way

the System Operator gets all the flexible resources needed may change across countries. An example of how it may achieve this goal is by modifying scheduled production and consumption through market logics, with specific products. Under the definition of "service market", we can include all those markets where the Network Operator is able to get all the flexibility it needs to properly manage the network operations, guaranteeing the stability of the grid.Unlike energy markets, service markets may change a lot across countries in terms of both available products and market rules for price determination and payments. In a way, only some general figures are identifiable as common to all the markets, and derive directly from the need to safely operate the network. In particular, each product exchanged in these markets may be included in one of these classes:

- → To provide a sudden and rough reaction to the shock.
- → To restore the capability to provide reaction to the shock in a longer time frame.
- → To restore the previous response capabilities and to ensure an adequate level of safety in case of prolonged failure or plant outages.

All previous capabilities operate at different timescales for different periods. In Italy, they are called respectively Primary Regulation, Secondary and Tertiary Services.

STRUCTURE OF ENERGY MARKETS

As already stated, to fulfil all the requirements above, each market has defined its own rules, with the timing each operator has to comply with and the products that can be exchanged. Due to the peculiarity of each market, providing an exhaustive list of exchanged products is almost impossible, especially because some of them are strictly related to the market structure. Despite that, we can divide markets in two classes:

- → Markets paying enablement.
- → Markets paying energy movements.

In the first class, markets pay the enablement to all the awarded offers, whether the service is actually provided or not. It is as if they paid for the availability to provide the service. On top of this, energy revenues/costs may be added according to the volume actually provided in real-time operations. Usually, in this case, the clearing of the service markets is simultaneous to energy markets according to co-optimization logics. Australia and the USA (Ercot) are two examples of this kind of market.

In the second class, we find the markets where the enablement to provide the service does not automatically guarantee revenues. In this case, revenues are directly linked to the energy delta actually provided for the service. The payments are then guaranteed only when a deviation from the DAM production plan is forced. For this reason, the clearing of these markets is subsequent to the energy results. The Italian power market represents an example of this kind of markets. Service markets are usually spot market only. In this sense it is not possible to exchange products beyond the day after the market sessions. Unique deviations from this exist in the UK, where some auctions for structured products (FFR) are available. It is to be noticed that, despite network operations being needed in all electric power systems, service markets are not operating in all countries even if an energy market is in place. In other words, real-time operation is guaranteed, while flexibility resources are not supplied through market logics, but through a centralized top-down approach. This happens in Latin America, India and South Korea, for instance.

6.2

Future regulatory framework

Key message

The current structure has been defined by the technologies available and by the cheapest resources. Previously disregarded environmental concerns and low RES costs are now changing both the structure of markets and the role of players.

HOW WE REACHED THE CURRENT STRUCTURE

Current electric power systems across the world are a consequence of the path followed by almost all economies during the last few decades. In particular, what mainly contributed to defining the current situation are systematic increase in power demand, energy policies and neighbor relationships, technological improvements and cost evolution. The current electric system is more or less the same worldwide, mainly based on thermal power generation, since fossil fuels represented a cheap, stable and easy-to-transport source of primary energy to support the development of any country across the world. Furthermore, the technology needed to convert fossil fuels into electricity has been mature enough for decades. Going in depth, the mix of technologies developed in each country reflects the most available energy resources both at local level and through commercial exchanges. This is the reason why in those countries where hydro resources represent a stable source of energy, these are largely exploited (e.g. Chile, Colombia, Brazil, Ethiopia, etc.), while in countries like Russia the electric industry is based on nuclear energy and natural gas. Looking at electric power systems worldwide, they are well represented by a few large power stations providing large amounts of energy to the national transmission lines to supply points of consumption. It is important to remark that past development in electric power systems was guaranteed by particular conditions, which are currently dropping. Among the most important, it is worth mentioning:

- → Constant increase of energy demand.
- → No concerns about environmental consequences.
- → Non-mature and high RES costs.
- → Cheap and easy-to-access fossil fuels.

According to this, the least-cost developments were clearly represented by hydro, nuclear and fossil fuel power plants. This general picture is nowadays rapidly changing according to the boom of RES installations, which usually operate directly at distribution level. This U-turn is guaranteed by a set of new conditions which are ruling out the current technology mix, in particular the need for a more sustainable growth from a regulatory point of view and a constant reduction in costs of sustainable technologies.

PLAYERS

Given a similar evolution worldwide, the structure of the power system and the players on the scene are more or less the same. It is possible to identify four or five main actors:

- → **Producers**, who have to produce high volumes of energy.
- → **Grid High-Voltage Operator (TSOs) and distributors (DSOs)**, responsible for the delivery of produced energy to consumption points. TSOs and DSOs have the burden to properly manage grid operations to ensure the network properly works.
- → **Retailers**, who can sign economic contracts with final consumers. They are able to link producers with retail and domestic customers. In some countries (like Chile) these

activities are managed by DSOs. In this case the two actors coincide.

- **Consumers**, who can be either domestic or C&I, and represent the final point of the chain.

In addition to these actors, an emerging kind of player is gaining importance, due to its ability to provide the flexibility the system needs: aggregators, who can modulate power consumption from consumers' side. It is important to notice that the increase of non-programmable technologies is going to require more flexibility to properly manage network operation and guarantee the stability of the grid. In particular, in order to maintain a stable network status, equilibrium between production and consumption has to be maintained. For this reason, there is the need for continuous real-time adjustments, mainly in production. Increasing production from non-programmable technologies increases the risk of facing strong deviation from scheduled production. A higher level of flexibility has to be guaranteed.

Chapter

7

Socioeconomic impacts

7.1

A just transition

Key message

The significant impact of the energy transition in all dimensions of human life will require policies to ensure that the phenomenon will be globally fair, both across and within countries. The current tools however already allow for a win-win outcome.

DEFINING THE JUST TRANSITION

The concept of a "just transition" captures the idea that we should not just decarbonize today's economy, but also build the sustainable and just economy of tomorrow, thus reinstating – through the lens of distributive justice – the traditional adagio of the interdependency among environmental, social and economic sustainability. Policies will need to guarantee that the most fragile part of the population and hard-hit regions (such as coal producing ones) will also benefit from the transition. It is necessary then to manage the resulting job losses, increasing new employment opportunities, implementing reskilling and upskilling programs. Indeed, a just transition must create alternatives for people and regions trapped in fossil fuel dynamics through new economic opportunities, education and skills trainings and adequate social safety systems. Governments and local authorities have to engineer new job opportunities for job losses caused by replacing fossil fuels with climate-safe power sources.

ADDRESSING ENERGY POVERTY

In the EU, roughly 45 million people live in conditions of energy poverty – definitions vary, but it is generally referred to a level of income which is inadequate to guarantee proper heating and/or energy services to a household. This is clearly even more evident in countries lacking universal access to power – in particular all Sub-Saharan Africa where more than 600 million people are not connected to the electricity grid. This has a major impact on health, on mental conditions and on the wellbeing of people, as well as on the environment, as energy poverty is associated both with high costs and with low efficiency. The energy transition could be the opportunity to address these issues, as the change in the energy system also implies a restructuring of the cost structure, which should include benefits for equality and society as a whole. This, in turn, will boost the transition itself, as the electrification of the system will depend on the adoption of new solutions (from transportation to heating) by consumers. Addressing the issue of energy poverty through the transition will require a series of different policy measures, depending on the region and even the country, which will include finding a shared definition of the issue, supporting the promotion of efficiency, particularly for buildings, and using social tariffs targeted to low-income households.

EQUALITY AMONG REGIONS AND COUNTRIES

The overall impact of the energy transition is already proving to be positive, and forecasts show that the new income brought by the electrification of sectors will be significantly higher than any losses caused by the substitution of thermal technologies. Estimates for the EU range from 47 to 80 billion euros of net addition for the period 2017-2030. Yet, this increase will not always be evenly distributed, as coal or carbon-intensive regions could suffer from job losses; EU Commission estimates indicate a potential 78,000 lost jobs in the Polish Silesian region alone. Negative impacts of the transition could also affect other areas, such as Lapland, where new wind projects could impact the lifestyle of indigenous Sami communities. Redistributive policies could smooth the burden of the transition for these regions, by providing direct assistance or by promoting sustainable investments. In this sense, the newly launched Just Transition fund by the European Commission, part of the wider European Green Deal, is perhaps the most ambitious measure, providing for the time being at least 100 billion euros to promote a fair transition in the EU.

7.2

New consumption trends

Key message

While the energy transition has an industrial drive, it is also strongly promoted by consumers' and citizens' growing awareness. Companies have to take this into consideration to fully engage in the transition, also regarding their stakeholders.

A NEW CONSUMER AWARENESS

Beyond policy targets set at international, European and national level, people are more and more concerned about sustainability and resilience, thus creating a favorable economic and societal context for the energy transition. The evolution of consumers' preferences and the rise of new lifestyles impacting the energy transition can be attributed to visible negative impacts of non-decarbonized and not-sustainable economies. Citizens are increasingly concerned about climate change, being the most commonly cited threat in many countries around the world. Focusing on European countries, climate change is perceived as the second threat after ISIS, except for Spain, where it is the first one. Overall, in Europe climate-related extreme events caused a loss of 452.6 billion euros and 90,325 fatalities over the 1980-2017 period. Along with this, other concerns like poor air quality, soil pollution and increasing traffic noise in urban centers have brought citizens across Europe to be more and more careful towards the sustainability of their choices. As a result, people have started to behave in a more sustainable way by providing their homes with in-house renewable energy sources, smart meters, energy efficiency technologies and by preferring more sustainable products, starting from the purchase of cars. In this context, young people are the most sensitive to the urgency of the energy transition.

FOCUS: EUROPE AND YOUTH

A survey made by the European Commission shows that young generations believe that protecting the environment and fighting climate change should be a priority for the European Union in the upcoming years (67% of respondents put the issue in the first place). Sustainability is a priority also in youths' everyday life, affecting consumption and investment decisions: 73% of European Millennials are indeed willing to pay more for sustainable goods. At the same time, younger generations pay attention to the sustainability of their working environment, taking into account companies' commitment towards sustainability when they are looking for a job. For all these reasons, post-Millennials have been called the "Green Generation" and are able to drive companies and institutions towards a more accelerated process of sustainable energy transition with their everyday life choices.

THE PRIVATE SECTOR

Over the last few years, also companies' approach towards sustainability has changed in order not only to meet targets set by national and international institutions and company duties but also to reap all benefits stemming from sustainability practices. Nowadays, companies are becoming aware that sustainability is fundamental for success in the market, since it is associated with tangible economic benefits.

This can translate in a number of new measures and attitudes:

- **Gaining competitive advantage through stakeholder engagement**. Sustainable businesses pursue an approach based on creating value for all stakeholders and not only shareholders, including employees, players along the extended supply chains, civil society. This approach implies a regular dialogue with stakeholders which could be valuable for companies, being better positioned to anticipate and react to economic, social, environmental and regulatory changes as they arise.
- **Improving risk management**. Sustainability practices help companies to better deal with natural disasters and civil conflict, which could significantly impact operations, revenues or expenditures. Being prepared to such events makes companies more resilient and less vulnerable, by decreasing their costs.
- **Fostering innovation**. Investing in sustainability can also drive innovation by redesigning products to meet environmental standards and social needs, such as changes in consumers' preferences in favor of more sustainable products and services.
- **Improving financial performance**. In addition to financial benefits related to innovation, better risk management and competitive advantage, companies can achieve significant cost savings through the deployment of energy-saving technologies and facilities. Moreover, investors are even more attracted by sustainable assets, since they have assessed that better financial performance is correlated with better Environmental, Social and Governance (ESG) performance. As a result, 39% of companies consider revenue growth as the first motivation to take action on sustainability.
- **Increasing productivity**. It has been demonstrated that companies having sustainable activities are 7.9% more productive than non-sustainable companies. The differential increases to 10.2% when companies are highly inclined towards sustainability. Furthermore, it has been assessed that companies operating in the energy sector are the ones paying more attention to the social dimension of sustainability.
- **Building customer loyalty**. To date, consumers expect more sustainability in goods and are more attracted by brands that declare to pay more attention to sustainability: it is not only Millennials, but 66% of global consumers who are willing to pay more for sustainable goods. As consumers ask for more sustainability, companies start to take action towards this direction. Indeed, 77.6% of companies believe that improving corporate image is the first reason to develop a sustainable attitude.
- **Attracting and engaging employees**. Companies engaged in sustainability practices are able to create a more comprehensive and inclusive work environment, where employees are critical stakeholders. This translates into reduced absenteeism and improved productivity. Firms that adopted environmental and sustainability standards see a 16% increase in productivity and a 25-50% reduction of employee turnover compared to firms that do not adopt sustainability practices.
- **Interesting investors**. Also, financial investors are increasingly conscious of the social and environmental consequences of human activities in business and politics. They are able to exclude from their portfolio companies that do not respect societal and environmental sustainability, while including the ones that follow practices in line with the ESG criteria. As a result, sustainable investment assets are steadily increasing globally, with some regions demonstrating stronger growth than others, setting a favorable context also towards a zero-carbon economy. The largest increase was in Japan, where sustainably managed assets grew more than 300 times over the period 2014-2018.

CHALLENGES

- Need to trigger a virtuous cycle of sustainability, involving the power sector, C&I companies and consumers.
- Need to raise awareness among companies regarding the social and economic value of their green reputation.

Socioeconomic impacts

New consumption trends

Enel's Solutions

ENEL AND ITS BUSINESS CLIENTS

This increasing concern about the future of our planet is driving major corporations across the Countries to go green by setting significant sustainability goals. Enel Green Power helps its partners fulfill those commitments through renewable energy purchases from projects across North America. Power Purchase Agreements are one of the main tools: they are tailor-made, long-term contracts designed to reduce emissions and accompany businesses towards a sustainable future. Enel Green Power's business model is fully sustainable in all its phases, including planning (i.e. project development and commercial structuring), implementation (financing and engineering and construction), and management (operation and management, and energy management):

- **Project development**. Becoming an EGP partner means leveraging high-quality projects and strategic partnerships. We are present in all the 5 continents, where we are also increasing the renewable capacity we manage from our current 46 GW to 60 GW by 2022.
- **Commercial structuring**. As an EGP partner, it is possible to secure access to tailored solutions for all your sustainability needs. Over 5 GW of PPAs are already operating.
- **Financing**. Our finance team and unique business strategies will determine the most suitable PPA price for your business. As a matter of fact, in 2018 we were awarded the PFI award as "Global sponsor of the year".
- **Engineering and construction**. From the blueprint to construction, we will get your energy supply up and running on schedule. In 2019 alone, more than 45 new renewable projects and around 3 GW of renewable capacity worldwide were successfully brought online.
- **Operation & Management**. 100 TWh generated since we started operations is an impeccable track record that will ensure a reliable supply. Furthermore, we'll provide a constant data flow attesting to the amount of supplied energy and emissions offset.
- **Energy management**. An integrated portfolio of energy generation, retail and trading mitigating corporate risks through predictive and big data management tools.

Glossary

Additional capacity: capacity relating to new plants, both consolidated or managed, or increase in the capacity of existing plants via technological development work. Additional capacity is declared when the first circuit of a plant is connected to the grid and begins producing energy and all the components of the plant are electromechanically complete. In the case of Enel-built plants, we use the term "additional built capacity"

Alternator: a device that converts the mechanical energy created by the rotating element of a turbine into electric power

BESS (Battery Energy Storage Systems): a group of devices, equipment and control logics capable of storing electric power so that it can later be fed into the grid. It allows solar and wind power plants to overcome their intrinsic flexibility and dispatchability limitations

Capacity auction or Capacity market: a new market created to guarantee long-term price signals and sufficient reliable capacity consistent with decarbonization goals. The mechanism introduces supplementary payment for suppliers of capacity who commit to maintaining and to making their capacity available to the electricity system, if required

Capex coverage ratio: ratio in percentage between the discounted positive margin generated by the investment in a regulated or risk-free system and the total investment made; it provides a measure of the investment's exposure to risk on returns relating to fluctuations in market prices

Carbon policy: a group of policies designed to support the changes the energy sector must make to achieve carbon dioxide emissions reduction targets, while simultaneously guaranteeing affordable, reliable energy to consumers. The most commonly adopted market mechanisms are emissions trading schemes (ETS) and carbon taxes

Coal phase out evolution: indicator representing the evolution of the installed capacity of coal-powered stations and providing evidence of their gradual decommissioning. When they cease operations, the corresponding capacity is subtracted from the balance sheet

COD (Commercial Operating Date): during the process of building a power station, this is the date in which the latter starts being paid for the electricity it produces

Closed Cycle or Combined Cycle Gas Turbine (CCGT) and Open Cycle Gas Turbine or Turbogas (OCGT) station: a plant that converts the chemical energy of natural gas into electricity. This is known as open cycle (OCGT) when it consists only of gas turbines, draws in mainly fresh atmospheric air from outside and the hot exhaust is discharged into the atmosphere. A closed or combined cycle gas turbine (CCGT) plant, on the other hand, sends the heat in the exhaust fumes coming out of the gas turbine into a steam generator to drive a steam turbine. Generally speaking, combined cycle plants are more efficient and environmentally-friendly than open cycle ones in terms of specific CO_2 emissions (lower atmospheric emissions), but are, however, less flexible

Commercial & Industrial (C&I) customers: companies, such as Heineken and Google, targeted by Enel Green Power's commercial program developed by the Commercial Office (CO) and offered long-term power purchase agreements (PPAs)

Commissioning: process at the end of the construction of a power station which includes activities necessary to guarantee that all the station's components, machinery and systems are working correctly and are capable of doing so safely and efficiently under normal operating conditions

Consolidated installed capacity: the maximum power deliverable by the generation plants over which Enel has control (de jure or de facto) and which it thus consolidates from an economic and financial perspective

Consolidated net production: the electricity generated by the plants net of grid losses and consumption relative to auxiliary services within the perimeter of companies whole or partially consolidated by the Enel Group

Consolidated renewable capacity/total capacity: the ratio of the installed capacity of power plants that produce energy from renewables (hydroelectric, wind, solar, geothermal) to the total installed capacity of renewable, thermoelectric and nuclear power stations. The trend provides evidence of a gradual shift in the asset portfolio towards a predominance of renewable sources

Control room: a room from which one or more plants spread over an area are centrally monitored and controlled

Conventional coal plant (or power station): a power plant that converts the chemical energy of coal into electricity, by producing high-pressure steam that drives a complex of steam turbines

Corrective maintenance: maintenance based on repairing faults when they happen. It cannot be planned but depends on when the fault that needs to be repaired occurs. Depending on the component involved, it may be necessary to shut down the plant, thereby causing production losses

CO_2 footprint: the average amount of CO_2 that power stations emit into the atmosphere to produce one unit of energy (1 kWh)

CSV (Creating Shared Value): a business model through which it is possible to create economic value for both the business and its stakeholders by producing a benefit for society and the environment

Data-driven asset: indicator representing the percentage of total installed capacity of stations with sensors and software that use data for the digitalized, remote or automated management of the station

Development capex (Asset development): the funds invested by Enel in building new power stations, increasing installed capacity or improving the efficiency of existing stations

Decommissioning: a set of operations that remediate, dismantle and remove the structures and components of a power station at the end of its working life

Dispatchable or Plannable generation: sources of electricity that can be used on demand and dispatched at the request of grid operators to meet market needs. Plannable generators can be turned on or off or can adjust their power output according to an order

Distribution: the final phase of the process of delivering electricity to the end user after generation and transmission

EBITDA/capex: ratio of average EBITDA generated by an investment project in the first five years after final delivery, and the relevant investment involved. It provides evidence of profitability of the investment in the short/medium term

EBITDA Growth: EBITDA relating to generation plants that went into operation as part of the plan

Electrolysis: a chemical process that uses electricity to break down water into its constituent elements: i.e. hydrogen and oxygen. Electrolysis can be used to produce green hydrogen by coupling an electrolyzer with a renewables plant

Enel Group Investment Committee: Enel Group-level committee set up to evaluate and approve investments authorized by individual business line committees. In the case of GPG, this involves investments of over 50 million euros in capex (or enterprise value) or relative entries in new countries

Energy transition: an energy paradigm revolution. In the case of the current energy transition, this means the transition from non-renewable energy sources to renewable sources, and is part of the wider transition to sustainable economies through the use of renewables, and the adoption of energy saving and sustainable development techniques

Engineering Procurement & Construction (EPC) contract: a contract regulating the relationship with a single supplier that provides engineering, procurement of materials and construction services, required to build a power station

Futur-e: process of renewal and energy upgrading of stations that fall within the scope of the Group’s decarbonization plan. Paying attention to the local area, innovation, sustainability and the circular economy are the main pillars of the project

Gasification: one of the main traditional processes capable of producing hydrogen by transforming a solid or liquid fuel into gas. This is done at high temperatures (of over 1,000 °C) and results in the creation of a fuel gas mixture known as syngas or synthesis gas, consisting primarily of carbon monoxide and hydrogen

Gas turbine or Turbogas: a mechanical device used to turn the chemical energy of gas into mechanical energy. In an Open Cycle Gas Turbine (OCGT) plant, the motion of the turbine is used to generate electricity using a current generator and an alternator. In a Combined Cycle Gas Turbine (CCGT) plant, a gas turbine is coupled with a steam turbine

Geothermal plant: a plant that converts the natural heat from deep inside the earth into electricity. Geothermal energy was first used to produce electricity on 4 July 1904 in Italy by Prince Piero Ginori Conti. He tested the first geothermal generator at Lardarello in Tuscany and actual power plants soon followed

Global Power Generation Investments Committee: a business line-level committee that evaluates and approves investments. The committee consists of the Head of GPG, as Chairman, and the heads of the AFC, BD, E&C, O&M, and Procurement, as well as all Country Managers. For investments in excess of 50 million euro capex (enterprise value) or relating to entering new countries, approval from the Enel Group Investments Committee is also required

Greenfield development: a way of developing projects in which all the stages involved in obtaining land rights, interconnection rights, permits, feasibility and engineering studies are managed directly by Enel with outside professional support (engineering firms, etc.)

Handover to E&C: process through which Business Development (BD) hands over all of the information and documentation on a project authorized by the Investment Committee, to Engineering & Construction (E&C). At the end of this process, which is formalized by the signing of the Handover Report. At this point, E&C officially takes control of the project to commence the opening of the building site and the subsequent building of the power plant and adjacent structures

Hetero Junction Technology (HJT): a technology that creates a photovoltaic cell using crystalline silica and amorphous silica. The resulting cell exploits the best characteristics of both materials

Hydraulic turbine: mechanical device that converts the kinetic and potential energy of a liquid into mechanical power

Inverter: a device that converts direct current (DC) to alternating current (AC). For instance, it is used to convert direct current from photovoltaic panels to alternating current to be fed into the grid

Installed capacity: the authorized maximum amount of power a power plant can produce

IRR (Internal Rate of Return): a discount rate that makes the net present value (NPV) of an investment equal to zero. It provides a measure of the profitability of an investment compared to internal cost of capital

LCA (Life-Changing Accident): an accident with permanent consequences that interferes with the day-to-day life of the victim or reduces their life expectancy

LCOE (Levelized Cost of Energy): cost of producing 1 MWh of electricity, a competitiveness index for generation plants

Managed installed capacity: maximum authorized power from both consolidated and unconsolidated generation plants, which are managed/operated by Enel through partnership agreements or asset management contracts

Non-dispatchable or Non-plannable generation: electricity sources that cannot be turned on or off to meet fluctuating energy requirements. This type of generation is often highly intermittent which means that it is not continuously available because of non-controllable factors (e.g. weather)

Onshore/offshore wind power: a plant that turns the kinetic energy of the wind into electricity. The term onshore refers to wind farms on land while offshore means wind farms built in the open water, generally at sea or in the ocean

Opex (operating expense): costs involved in running a business

Payback period: the number of years it will take for positive flows from an investment to compensate for outgoings sustained. It indicates the riskiness of a project solely in terms of time

Organic growth investment (or organic growth capex): the funds Enel invests in building new plants, increasing capacity or improving the efficiency of existing plants on the perimeter of its consolidated assets

Photovoltaic panel: a device made up of photovoltaic modules, which in turn are made of photovoltaic cells. The cells convert solar radiation into electric power using the photoelectric effect and are the basic components of a photovoltaic power plant. The most common type of cell in made from crystalline material with a layer of semiconductor material, most often silicon. There are also amorphous silicon cells

Photovoltaic (PV) plant: a plant that converts solar energy into electricity using the photovoltaic effect

Pipeline: a group of projects that have been authorized by the Screening Committee and satisfy the project's set of maturity criteria which are defined according to technology and country. The pipeline is different from "phase zero" in that Enel has certain real rights to the project (e.g. exclusivity, land agreements, co-development agreements, preliminary permission to connect to the electricity grid, permit requests made to local authorities). Furthermore, the projects in the pipeline are also subdivided according to their maturity status in terms of permits, feasibility studies and sales strategy for the electricity; these three sub-groupings are called:
a) Potential – low probability of success
b) Likely – average probability of success
c) Highly confident – high probability of success

Power Purchase Agreement (PPA): a contract between an electricity user and an electricity producer for the sale of electricity at a pre-established price and for a pre-established period of time. The contract lays out the commercial conditions for the sale of electricity: duration of the contract, delivery point, date/time of delivery, volume, price and energy source

Predictive maintenance: the group of operations that can predict when a particular machine or piece of equipment is developing a defect before it results in a fault. It requires a good knowledge of the machinery, techniques and instruments used for this task. It enables the early prediction of faults thereby reducing related production losses and avoiding unnecessary corrective and/or preventative operations

Preventative/planned maintenance: planned maintenance activities to review, replace or repair machinery or equipment at the plants before faults develop. The schedule is designed to minimize production losses arising from any halts in generation

Pumped storage system: a type of hydroelectric power station with a lower as well as an upper storage pool or reservoir: the water that generated electricity during the day is stored in the lower storage pool or reservoir and then can be pumped back up to the upper storage pool at a time of day when energy demand is lower (for instance, at night). This means the water that is pumped back up using power can be reused to generate energy at peak demand times. This enables users to take advantage of price differences and provide services grid stabilization services

Regulated energy auctions: auctions for sale and purchase of long-term electric power, typically developed by distribution companies who purchase electricity on behalf of regulated users. In some cases, they can also extend to C&I or even individual customers

Screening Committee: a monthly meeting held at geographical area level, at which developers request the BD (Business Development) Manager's formal approval to proceed with the initiatives presented to the Screening Committee. The BD Manager, the Head of the BD Area, developers and departments that support BD during the development stage (E&C, AFC, Regulatory, etc.) all attend

Start of Construction (SoC): in the process of building a plant, this is the date that the building site formally opens for construction work

Station availability: the percentage of time during which a power station is capable of generating electricity in the reference period analyzed

Steam reforming: one of the main traditional processes capable of producing hydrogen from fossil fuels. It involves causing natural gas and steam to react at temperatures of around 700-1,100 °C to produce syngas, which is essentially a mixture of carbon monoxide and hydrogen

Steam turbine: a mechanical device that exploits steam power, produced by a steam generator, by converting it into mechanical energy. Steam turbines are used in coal-powered power stations and gas combined-cycle power plants where the motion of the turbine is used to generate electricity via an alternator

Storage or flowing water hydroelectric plant: a plant that converts the potential and kinetic energy of water into electric power using a hydraulic turbine. The power of the plant depends essentially on two factors: the amount of water and the so-called drop or height difference between two levels in a water course. Storage hydropower is generated by a plant which has an upper storage reservoir that allows the flow of water – and the electrical power produced by it – to be regulated. A "flowing water plant" is a plant that uses the natural power of a water course and thus its electric power production cannot be planned

Tango: a type of technology used in the production of photovoltaic panels that pairs two different simple photovoltaic cells capable of turning solar radiation of different wave lengths into electricity: e.g. HJT and thin-film perovskite

Thin film: in photovoltaic panel production, thin film modules are made by depositing a thin layer of semiconductor material on a glass or plastic substrate

Tracker: an automatic mechanical device that reduces the angle of incidence between a photovoltaic panel and the oncoming sunlight, thereby increasing the power of the solar radiation picked up by the panel and the amount of energy produced by it

Transformer: an electric device used to transfer electric power at different voltage levels

Transmission: the act of transporting electric power on a high and very high voltage interconnected transmission network with the aim of delivering it to end users in high voltage form and to distributors

Unitary energy gross margin: ratio of gross margin (proceeds from energy production and other proceeds from non-core activities net of variable costs) and consolidated net production

Watt (W): International System unit of measurement of power. Multiples of Watts are kW (103 W), MW (106 W), GW (109 W) and TW (1,012 W)

Watt-hour (Wh): a unit of measure commonly used to measurement electricity and defined as the total power supplied when one Watt of power is maintained for an hour. Multiples of Watt-hours are kWh (103 Wh), MWh (106 Wh), GWh (109 Wh) and TWh (1,012 Wh)

Wind turbine: electromechanical device capable of converting the kinetic energy of the wind (wind power) into electricity

Zero phase: preliminary phase for projects after formal approval by the Screening Committee. During said phase, Enel has no real rights to such projects

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