Electrify 2030

Electrification, industrial value chains and opportunities for a sustainable future in Europe and Italy

The European House Ambrosetti

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With the scientific contribution of

enel Foundation

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This study was prepared by The European House — Ambrosetti for Enel Foundation and Enel X.

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Preface

The energy sector is currently in the midst of profound change. Technological progress is revolutionizing the way we produce, distribute and consume energy, and it is opening the door to business models which, only a few years ago, were unimaginable. While globalization has extended the competitive arena across the globe, digitalization is creating new modes of interaction, both among different industrial sectors and within them, to generate combinations for value creation never seen before. The traditional energy paradigm based on fossil fuels as sources of energy is becoming increasingly unsustainable, not only for environmental reasons, but also economically.

Ten years ago, renewable sources were referred to as alternative forms of energy, characterized as unreliable and too expensive, and incapable of taking on a real role in the international energy paradigm. The economic crisis which began in 2008 and the subsequent collapse of oil prices led many to predict a hiatus in the development of renewable sources whose too-high costs were seen as being unable to compete with the decreased cost of fossil fuels. And yet, the story has been completely different. The installed capacity of renewables has continued to increase and investment has grown significantly.
In the span of a decade, the average cost of generating photovoltaic solar power and on-shore wind power has decreased by 80% and 60%, respectively. In some regions, electrical generation from renewable sources is currently more competitive than from their fossil fuel alternatives. Based purely on the economic advantages, renewables are set to gradually replace the other sources and, according to the IEA, in 2040, the share of renewable energy in the global electrical generation mix will rise from the current level of 24% to over 60%.

The first spin-off of the drop in the costs of renewable technologies is the reduction in the price of electricity which will lose its tendency towards volatility and gain long-term stability. In fact, unlike fossil fuels, renewables will not be affected by the instability of hydrocarbon prices. Therefore, electricity promises to become a low-cost energy source, gradually replacing conventional sources in the energy mix. As a result, increasingly sustainable and low-cost electrical energy is destined gradually to become the main energy source for end consumers. Given increasingly cleaner generation, the gradual penetration of the electric carrier will allow us to not only decarbonize those sectors of the economy that historically have been the highest polluters, but also best utilize the resources at our disposal. In fact, from an energy standpoint, electrical technologies are typically more efficient than traditional ones which allows for significant savings in those sectors (transport, residential and industrial) in which energy needs are generally met by fossil fuels. Take, for example, electric vehicles which are about three times more efficient than internal combustion vehicles if the entire energy cycle is considered. Or, in the residential sector, the case of heat pumps that make it possible to air-condition buildings while cutting consumption by half.
Not only does this study offer an opportunity to analyze the key role of electricity in the energy transition process, its value lies above all in focusing the spotlight on the role electrification could have in Italy overall, as an opportunity for the entire industrial supply chain, in the creation of new jobs and generating new investment.

Currently in Italy, about 21% of final consumption is electrified (2% in transport, 26% in residential and 35% in industrial). Therefore, there exists an ample margin in our system especially in the mobility sector — which could utilize the electric carrier to improve efficiency and reduce costs. An enormous potential to also develop a renewed production supply chain with a highly-innovative technological commitment. In this electrification process, 17,000 companies could be involved which employ over 320,000 people and with a turnover of €80 billion per year. In e-Mobility, the most ambitious scenario estimates that, to the year 2030, about €457 billion would be activated along the entire value chain.
The merit of this study is that of analyzing, for the first time, the entire value chain involved in electrification expected through 2030, while mapping the competencies of the country and its economy and analyzing its strong and weak points. It represents, therefore, a fundamental tool for both businessmen and policy-makers in order to provide a true picture of the potential connected with the energy transition process and consolidate efforts towards those sectors with the greatest opportunities for development.

Thanks to the growing competitiveness of renewable sources, advances in storage and increasingly-flexible systems, electricity could guide the decarbonization of Italy and its economy to render it cleaner and more competitive. As has been the case with renewable sources, we are not talking about something in the distant future, but a situation that could soon materialize before our very eyes.

Francesco Starace
Chief Executive Officer and General Manager, Enel

"I have been urging all sectors of society to choose wisely and invest in the low carbon pathway. Over the next 15 years, the world will make a massive investment in new infrastructures, in serious renewable energy. The transition to renewable energy is speeding up, as businesses became increasingly aware of the advances in technology."
Ban Ki-moon

The history of energy over the centuries has always been a very dynamic one. The decision to use one source of energy rather than another, with the gradual shift from coal to oil, then to gas and nuclear, has had a significant impact on society and the economy. And yet, the transformations seen in the energy sector in the past have never moved so rapidly and so explosively as the energy transition currently underway.
The most recent statistics from the United Nations Framework Convention on Climate Change show that greenhouse gas emissions worldwide continue to increase (58,710 million tons of CO_2 equivalent, +62% compared with 1990 levels), as is public awareness about their negative impact on human health. In Europe, it is estimated that there are 497 premature deaths connected with particle pollution per million inhabitants (564 per million inhabitants in Italy), with an overall cost of nearly €680 billion, of which €100 billion in Italy alone.

It is clear that the traditional energy paradigm, based on energy production from fossil fuels only, is no longer viable. The European Union is also in the front lines in supporting the development of sustainable energy policies. The political agreement reached in June 2018 among the European Commission, the European Council and European Parliament calls for — by the year 2030 — a reduction of at least 40% in greenhouse gas emissions compared with 1990 levels, a share of renewable energy sources of at least 32% and an improvement of at least 32.5% in energy efficiency.

Within this context, the electric carrier has the potential to become the energy carrier of the future. The consultants of The European House — Ambrosetti have identified five reasons why the electric vector could guide the energy transition currently underway through offering a significant contribution to the European Union's decarbonization goals.

When the mix of electrical energy generation is characterized by a significant share of renewables, electrification promotes decarbonization. The recent literature outlined that increasing the share of electricity on final energy consumption is environmentally convinient when CO_2 emissions are below 600 t/GWh. The European Union and Italy are already below this threshold, thus, for these economies, electrification is already a concrete opportunity to decarbonize. Electrical technologies are also more efficient from an energy standpoint compared with traditional technologies and this allows for significant savings in the transport, residential and industrial sectors. To give just an example of the attainable improvements from some technologies, our consultants have estimated an efficiency saving of around 50% for heat pumps used in building air conditioning, 85% lower consumption through the use of LED lighting in the private sector and 52% in the public sector, 40% greater efficiency through the use of electric motors compared with internal combustion motors and 12% energy savings through lithium ion batteries compared with other types of electrochemical batteries. In addition, digitalization combined with the electric vector optimizes the management of consumption and efficiency, thus reducing waste to a minimum. Thanks to its intrinsic versatility and efficiency, the electric vector also allows for improvement in the resilience of the energy system as a whole by improving its capacity to react in the face of external shocks. Finally, adopting the electric vector could offer major stimulus for innovation in lifestyles (for example, the new mobility paradigm offered by e-cars) and industrial processes (for which the electric vector guarantees greater precision during production).

But, above all, electrification represents an unprecedented opportunity for industry through the activation of new industrial supply chains, creation of new jobs and stimulus for investment. To assess the industrial impacts of electrification, The European House — Ambrosetti is the first to have reconstructed the e-Mobility supply chain (cars, two-wheel vehicles, buses, light commercial vehicles and trucks) and the supply chains of the main electrification technologies (heat pumps,

LED lamps, electric motors, batteries, power electronics and energy management systems), and has developed a number of scenarios for the various types of electric vehicles to the year 2030, as well as some “what if” scenarios involving the penetration of electrification technologies, again for the year 2030.
Considering the electric motor vehicle market as a whole and the turnover that can be generated at each stage of the relative supply chain (manufacturing, recharging infrastructures, services, recycling and second life), our consultants estimate that in the different development scenarios hypothesized, Italy could activate a cumulative turnover between €102.4 and €456.6 billion as of 2030.
This is a significant impact which had never been quantified until now, in which Italy could “capture” a major share in the component, bodywork and interiors, and electric charging equipment sectors, as well as the electricity grid, recycling and second life of vehicles.
In terms of electrification technologies, The European House — Ambrosetti simulations predict that the adoption of electric technologies could activate an overall turnover of between a minimum of €135 billion and a maximum of €326.5 billion.
I am pleased to note that all the impact analyses have received the scientific validation of the engineers of the Department of Engineering, ICT and Technologies for Energy and Transport of the CNR (National Research Council of Italy), to which go my most sincere thanks.

I would like to mention that, at the end of this report, there is also a “glossary of electrification technologies” that maps all the technologies which make electrification of energy consumption possible. We hope that business leaders and representatives of European and Italian government and institutions will find this to be a useful tool.
This ambitious study would not have been possible without the concerted efforts of the top management of Enel, the Enel Foundation and Enel X, starting with Francesco Starace, Carlo Papa, Francesco Venturini and Ernesto Ciorra, together with the Enel Working Group, in exploring a theme at the forefront of debate today, and without the invaluable contribution of the Scientific Committee — Francesco Profumo (President of the Compagnia di San Paolo; former Italian Minister of Education, Instruction and Research) and Raffaele Tiscar (former Head of Cabinet, Italian Ministry of the Environment) — and the International Energy Agency — Fatih Birol (Executive Director) and Laszlo Varro (Chief Economist) — to whom go my deepest thanks.

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Valerio De Molli
Managing Partner and Chief Executive Officer,
The European House — Ambrosetti

When the International Energy Agency was established in 1974, the world used 5,500 TWh of electricity and 55 million barrels per day of oil. Since then, global oil demand has grown by 80% and oil is still the number one primary energy source of the world economy. However, electricity use increased much faster — by a factor of 4 — and this is expected to continue.
In every IEA scenario, electricity is growing more rapidly than overall energy use, therefore increasing its role in the energy system. This process has been driven by providing electricity to the more than one billion people who still lack electricity access, the continuous expansion of the ownership of electric appliances and industrial electricity use, as well as the increasing use of electricity to replace fossil fuels in transport and building heating. With all of these changes, the 21st century is increasingly shaping up to be the age of electricity.

Electricity supply has also been transformed by new technologies, especially wind and solar PV. Both of these technologies have undergone disruptive technological development and cost declines over the past decade. Together, they now absorb the large majority of new investment into power generation.

The expanding role of electricity with an ever-increasing share of wind and solar creates major opportunities — for example, the electrification of personal vehicles and building heating which today are dominated by oil and gas respectively.
The inherent flexibility in the demand for charging electric cars and operating heat pumps will also promote the integration of the variability of wind and solar, creating powerful synergies. There are also important benefits in terms of the reduction in local air pollution and a reduction in dependency on oil and gas imports.

However, these benefits are not automatic: electrification solves old energy security problems associated with dependency on oil and gas but can also create new ones. For example, the uncoordinated use of renewables and electric cars could increase costs and capacity requirements and can even be destabilizing to the power system.

As such, policy and regulation remain essential to shape the industry's future. We will require thoughtful policies and regulation as well as close cooperation between the private sector and policymakers. Investment in renewables will need to be accelerated from its recent decline and a thorough modernization will be needed both for physical network infrastructure as well as for operations and system management.

At the IEA, we have declared 2018 as the "*Year of Electricity*," focusing some of our work program on this most important topic. In this respect, the initiative by The European House — Ambrosetti and Enel to undertake a comprehensive assessment of the opportunities and challenges presented by intense electrification is also timely. The analysis maps the investment and regulatory aspects of the further expansion of renewables, the unique opportunities unlocked by the application of digital technologies in the power system and the potentially transformative impact of electric vechicles. The research brought together a diverse set of leading experts from the private sector, academia as well as government institutions.

The analysis, which we were happy to contribute to, reflects the state of the art in both technological transformation as well as new regulatory and business model approaches and should serve as a solid foundation for strategic decisions in the energy industry and energy policy.

Fatih Birol
Executive Director, International Energy Agency

The Climate change in terms of global warming (affecting the growth of land and ocean temperature, the decrease of the Artic sea-ice extent and the increase in the mean sea level) is a global issue that cause considerable negative impacts on the environment and social-economic systems.
The causes are mainly related to the relevant growth in the anthropogenic Greenhouse Gas (GHG) emissions with respect to the pre-industrial era; CO_2 emissions play a crucial role, and the majority of them is related to the energy sector. Global CO_2 emissions from fossil fuels combustion in 2015 reached 32.3 Gt (57.5% higher than the 1990 value), and about 68.0% of these emissions are caused by six countries (China, the United States, the European Union, India, the Russian Federation and Japan).

Climate change is a global issue while at local scale (especially in urban areas) air pollutant emissions (SOX, NOX, PM, VOC, CO and NH_3) are relevant, due to their negative effects on health, economy and environment. The largest part of them — with exception of ammonia — is due to the energy sector.

Policy actions, aiming at mitigating both climate change and air pollution, are needed and environmental sustainability targets are set by international agreements. The achievement of those goals prompts for a deep restructuring of the global energy systems with a shift from an energy mix based on fossil fuels to one based on renewable energy sources, the so-called "energy transition".

One of the most effective pathways for the energy transition is the so-called "electric triangle": a wide electrification of final uses, coupled with power generation from renewables and exploitation of electricity as energy vector. This approach can be implemented at different spatial scales, by connecting world renewables production areas (e.g. the Arctic and the Equatorial regions) to main consumption areas through large-scale UHV interconnections, or by exploiting locally available resources through distributed power generation from renewables and smart energy systems at the distribution level.

In addition to what above, the electrification process can also be exploited as a major industrial opportunity. In order to assess the positive impacts that this could have on the Italian industrial value-chains, The European House — Ambrosetti in the study "Electrify 2030" has set out scenarios for the development of the electric motor vehicles, the infrastructure network for recharging them and the end-use electric technologies associated with the highest efficiency gains (heat pumps, LED lamps, electrochemical storage systems and electric drives). The overall potential industrial impact of electrification, which had never been quantified so thoroughly, is massive and Italy could capture a significant share of it thanks to its manufacturing and technological competences.

Electrification of final uses significantly involves all the end-use sectors: buildings, industry and transport. In concert with the study "Electrify 2030", the study "Electrify Italy", conducted by Politecnico di Torino, MIT and Enel Foundation, highlights the potential of end-uses electrification, the possible sectorial technological evolution and the related mid-/long-term benefits in different areas.

Electrification can lead to an increase in the overall efficiency, reducing the total final energy consumption. This reduction s supported by the penetration of electricity-based technology in the end-use sectors. Electrification strives for environmental sustainability reducing the global CO_2 emissions, thus showing positive effects on the ecological footprint, and the emissions of air pollutant, with local benefits in terms of air quality.

From an economic viewpoint, in the long-term the electrification scenario could become economically sustainable, especially in the case of a reduction in the electricity/gas price ratio and a decrease in the power generation costs from renewables. The reduction in GHG and air pollutant emissions can cause indirect economic benefits, like the avoided health costs (due to air pollution) and economic losses (related to the climate change phenomena).

Finally, electrification can enhance the energy security of energy supply (crucial for countries with high energy dependency, like Italy), reducing the needed quantity of fossil fuels to be imported and the exposure to geopolitical risks.

Electrification seems thus to be a proper and convenient pathway for the energy transition, but for being effectively implemented it will certainly require long-term investments, in research and technological development, infrastructure, new regulations, ad hoc supporting policy actions and proper communication strategies for increasing people's awareness on the positive impacts on their daily quality of life.

Francesco Profumo
Chairman, Compagnia di San Paolo; former Chairman, Iren;
former Italian Minister of Education, Universities and Research

From many points of view, the decarbonization of productive systems and economies represents an epoch-making challenge that will be the key to the 21st century.
It will force the economic players to change their investment priorities radically and it will orient their research and development sectors towards a perspective of greater social responsibility. But it will also impact on modes of consumption, on urban lifestyles and the development of mobility according to models which, only a few years ago, would have been unthinkable.

All this will require to policy makers new tools for assessing the impacts of actions taken to significantly accelerate energy production from renewable sources, reduce energy consumption and promote sustainable mobility—the three key sectors for meeting the ambitious goals set out in the Paris Agreement.

From the challenging threshold defined within the European context at 2030 (and even more in the light of the subsequent goals for 2040 and 2050), it is evident that the only compatible energy carrier is electricity, in respect of whom the use of gas fails to solve all the criticalities related to emissions.

In fact, it will be absolutely necessary to attain as soon as possible 100% of electricity production from renewable sources, implement housing policies in which heating and cooling systems use electricity and modify both public and private, urban and non-urban mobility systems through a significant component of electrical vehicles if we want to obtain the best-possible results.

The condition is that the infrastructure of a country such as Italy (and by this, I mean energy, digital and transport infrastructure) will see in the coming years major enlargement and improvement initiatives adequate to the level of the structural changes this challenge involves. And here is where the problems begin...

Unquestionably, to meet this "insane" challenge, government, industry and consumers must reach a social agreement to avoid that this sudden paradigm shift falls exclusively on consumers, with the risk of lowering consumer demand and failing to capitalize on the enormous opportunities for new jobs and value creation that these challenges could offer.

On the other hand, the international context is not helpful. The days have passed when belonging to a group automatically offered its members economic and political benefits. For years now we have been adrift in the sea of global competition on all sides. China has already decided what direction to take and, following the centralized control model typical of the Far East, it has already aligned consumers and producers, racking up records and goals with Olympic speed. Europe is floundering breathlessly behind the Asian giant, well-aware of how critical the climate question is and worried about how and when Trump's America will decide, on the basis of what's good for its trade, when to enter the game again.

In this global competitive challenge, the time factor is a strategic one, but also the most complicated one to manage in an era in which nothing will be the same again. And yet, we must try by simulating scenarios, sharing technological and industrial know-how, creating new synergies with the financial sector and, above all, attempting to "put ourselves in the shoes" of consumers.

We must do this, because of the opportunities decarbonization could offer for Italy, because of the new industries that could emerge and because of the high-quality human capital we have yet to utilize.

Raffaele Tiscar
Former Head of Cabinet, Italian Ministry of Environment;
former Vice Secretary General, Presidency of the Council of Ministers in Italy

Ten key points of the study

1. ***Decarbonization and resilience of economic systems are crucial features in reducing the overall human development footprint***

   Greenhouse Gas (GHG) emissions have been constantly increasing at global level, reaching 58,710 million of tons of CO_2 equivalent in 2016, i.e. +62% compared to 1990 levels, but general public awareness about the negative effects on human health and the overall ecosystem is also increasing worldwide. Yet, the need to decarbonize economic systems is going together with the necessity to address external shocks by exploiting a country's resilience, meaning the capacity of a country to bounce back quickly after a negative event. The concept of resilience refers to several intertwined aspects of the economic and environmental ecosystem, including the energy sector. Considered together, decarbonization and resilience positively contribute to reducing the overall ***human development footprint***. Hence policymakers, at both national and supra-national level, have increasingly embedded these concepts in the sustainability policies. For instance, at the European level, the recent political agreement among the EU Commission, the EU Council and the EU Parliament calls for a 40% reduction in GHG emissions compared to 1990 levels, a 32% share of renewable energy in final energy consumption and a 32.5% improvement in energy efficiency by 2030.

2. ***Five reasons underpin the claim of the electricity carrier being the energy carrier of the future***

   Within this context, there are five main dimensions allowing to claim that the electric carrier is the energy vector of the future:

   - it allows to reduce ***CO_2 emissions*** when electricity is generated through a balanced energy mix, that integrates a significant share of renewables, and it enables the reduction of pollutant emissions improving ***air quality*** in particularly in urban areas;
   - it offers several opportunities to improve the ***resilience*** of the overall energy system;
   - it promotes higher levels of energy efficiency, since end-use electric technologies reduces energy needs and relative CO_2 emissions compared to traditional ones;
   - it can be easily integrated with ***digitalization***, enabling more effective consumption management and higher efficiency, thus enhancing the role of the Distribution System Operator (DSO);
   - it stimulates innovation and sustainability in ***lifestyles*** and ***industrial*** processes, allowing for both energy savings and improvements in product quality.

3. ***Electrification has been growing in recent decades and several policy scenarios foresee continued growth to 2030***

   Increasing generation capacity from renewables, technological development of electricity-driven technologies, as well as decarbonization policies, are the key factors underpinning the growth of electrification, meaning the share of electricity consumption in total final energy consumption. In the period between 1990 and 2016, electrification has experienced a growing trend on both a European (from ***17%*** to ***22%***) and Italian level (from ***17%*** to ***21%***) and several policy scenarios outline a further electrification potential to be reached at 2030. This potential is quantified in a range between ***3 and 9 percentage points increase*** for both Europe (ranging from 25% and 31%) and Italy (ranging from 24% to 30%). In Italy, the relatively higher electrification potential is estimated in the ***transport sector*** that is projected to grow from the current 2% (primarily due to the almost complete electrification of railway lines) to a range comprised between ***5%*** and ***8%***. Electrification in ***buildings*** is also expected to show significant growth from ***26%*** to ***32%-34%***. The latter share would allow Italy to reach the building electrification levels currently seen at EU levels. The ***industrial sector*** has an electrification potential estimated to be ***2-4 additional percentage points*** (starting from the current level of a 35% electricity share in final energy consumption).

4. *e-Mobility in Italy is still in the take-off phase but the electrification of mobility is expanding*

Being transport the sector with the highest electrification potential in Italy to the year 2030, a comprehensive e-Mobility database has been developed to support this study. As of today, e-Mobility (Battery Electric Vehicles — BEV and Plug-in Hybrid Electric Vehicles — PHEV) in Italy involves ***14,647*** electric cars (0.04% of the existing stock), ***6,211*** electric two-wheelers (0.07% of the existing stock of motorcycles and mopeds), ***455*** electric urban buses (1% of the existing stock), and ***4,454*** electric Light Commercial Vehicles (0.1% of the existing stock). At the moment, e-Trucks (Medium Duty Vehicles and Heavy-Duty Vehicles) are still largely at the pilot stage and none are registered in Italy.

5. *The e-Mobility value chain involves multiple industrial and service supply chains, with significant potential in terms of turnover, employment and installed competences*

In order to assess the potential impact on Italian industry associated with the development of electric mobility, the ***extended e-Mobility supply chain*** has been reconstructed, considering both direct and associated chains: Research & Development, manufacturing, distribution and sales of vehicles, IT and energy platforms, use and aftermarket, "second life" and reuse of electric vehicle and charging infrastructure components. The joint analysis of all components reveals that, in Italy, there are about ***160,000 companies*** potentially involved in the extended e-Mobility value chain with more than ***820,000 employees*** and a turnover of more than ***€420 billion***. Yet, the competences present in Italy along the different phases of the extended value chain have also been evaluated, revealing both strengths and weaknesses. For instance, Italy hosts several excellences in the more traditional carmaker phases such as the components sector — in particular with regards to vehicle manufacture and use and aftermarket — and bodywork and interiors, but also in the electricity system. In 2001, Italy was indeed the first country in the world to launch a national plan of massive installation of electronic meters, which are the basis of current smart grid and the roll-out of the 2nd generation is currently taking place. Regarding competences that need to be developed it is important to highlight the current shortages in the storage system, in which Italy lags behind the international best performers (China, Japan and South Korea) but also in the production of electric and hybrid engines, in which there are activities only at the Research and Development phase.

6. *Evolutive scenarios to 2030 were developed for all forms of e-Mobility*

In order to build a framework within which estimating the achievable turnover in Italy along the extended e-Mobility industrial value chain by 2030, three alternative scenarios (baseline, intermediate and accelerated) have been developed for the penetration of all forms of mobility and charging infrastructures. The ranges correspond to:

- ***e-Cars***: ***2 to 9 million*** vehicles and 30,000 to 45,000 dedicated public charging stations;
- ***e-Two wheelers***: ***240,000 to 1.6 million*** units and 857 to 2,000 dedicated public charging stations;
- ***e-Buses***: ***3,307 to 10,188*** vehicles and 413 to 637 dedicated charging points;
- ***e-Light Commercial Vehicles***: ***202,763 to 630,478*** vehicles and 724 to 1,051 dedicated public charging stations;
- ***e-Trucks***: ***0 to 34,336*** vehicles and 0 to 8,584 dedicated charging points.

Merging the analysis of the vehicles and charging infrastructures prices, the assessment of the market value of ICT services and estimate of the turnover from recycling, these penetration scenarios result in a total potential turnover in Italy at 2030 that is estimated to be between ***€102.4*** and ***€456.6 billion***.

7. *Electrification technologies have the potential to activate an extended industrial value chain in Italy*

To identify the full array of electrification technologies and identify those which are more promising in terms of both technological maturity and deployment potential, an innovative model has been preliminarily built to capture all existing and investigational technologies related to the electrification. In this 360° map of electrification technologies, ***more than 60 technologies***, supporting direct and indirect electrification, have been analyzed by grouping them according to both their application in buildings, industry and transport and their final use (electricity generation on site, storage and utilization). The overall Italian industrial value chain of electrification technologies is potentially composed of about ***17,000 firms*** involving more than ***320,000 employees*** and with a total turnover of around ***€80 billion***.

8. ***Six electrification technologies were identified as having the highest deployment potential and providing the largest efficiency gains***

Among the 60 electrification technologies that were preliminary mapped, 6 of them were identified as having the highest deployment potential and efficiency gains. In detail, those technologies are:

- ***heat pumps*** (***~50%*** efficiency gain compared to traditional combustion heating and cooling systems such as the condensing boiler);
- ***LED lamps*** (up to ***80%–85%*** efficiency gain in the residential sector and ***~52%*** in public sector compared to standard filament lamps and 5%–10% compared to fluorescent lamps);
- ***electrochemical storage systems*** (***~12%*** efficiency gain generated by Lithium-Ion batteries vs. their electrochemical alternatives);
- ***electric drive*** (***~40%*** efficiency gain in electric cars vs. traditional combustion engines and ***~25%*** in industrial inverters);
- ***power electronics*** (***~73%*** efficiency gain in wide band-gap-devices employing semi-conductors such as silicon carbide or gallium nitride in place of silicon);
- ***Energy Management Systems*** (providing efficiency gains of ***~16%*** in buildings and ***14% –17%*** in heating, ventilation air conditioning).

For these six technologies a map of the extended value chains was developed by focusing on four macro-sectors: Research and Development, manufacturing, distribution sales and aftermarket, and recycling and second life. Yet, to complete the investigation of the Italian industrial value chains, the current Italian level of manufacturing and industrial competences has been assessed through a matrix of the six aforementioned technologies and the four macro sectors composing the value chains. The detailed analysis of Italian competences reveals a few critical issues regarding the recycling and reuse fields and the necessity to build industrial competences concerning electrochemical storage systems. However, a few competences of excellence exist for heat pumps and LED lights.

9. ***A "what if" analysis has been developed for the electrification technologies deployment scenario***

Building upon the efficiency gains that would be triggered by the given electrification technologies and the average market cost of any given technology, a ***"what if" analysis*** has been provided to estimate the attainable turnover from the deployment of four of those technologies until 2030. Scenarios for Energy Management Systems and power electronics were not developed because their cross-technology nature means they are typically coupled with other electricity-driven technologies and prevents them being identified with a single use. The "what if" analysis was built according to technology-specific deployment conditions and envisioning an evolutive scenario and a full-deployment scenario for any technology. The overall amount of turnover that can be originated from the four technologies ranges between ***€135 billion*** and ***€326.5 billion*** broken down as follows:

- heat pumps: €33.5 billion to €146.0 billion;
- LED lamps: €3.5 billion to €4.5 billion;
- electric drives: €17.0 billion to €30.5 billion;
- electrochemical storage systems: €81.0 billion to €145.5 billion

10. ***Integrated strategic action is needed to sustain the electrification process and reap all its benefits***

Fostering the electrification process requires to act across different sectors and fields making a multi-level strategy necessary to reap all the benefits and opportunities that can be activated for Italy and its industrial value chains. In detail, ***5 focus*** areas have been identified, within which different proposals have been grouped according to their basis:

- ***e-Mobility take up***, which implies the adoption of effective management of the e-Mobility transition by setting up a comprehensive strategic vision at national and local level, the enhancement of the installation process of public and private charging points by removing all the regulatory and legislative stumbling blocks and by setting ambitious targets for clean vehicle procurement by public authorities, whose newly purchased fleets shall be 100% clean, within a strict time frame, e.g., 2025.

- ***Energy efficiency deployment***, by giving continuity to incentive mechanisms, setting up a "Home Maintenance Leaflet" to increase stakeholder awareness of energy efficiency benefits and devising innovative financial schemes.
- ***Enhancing collaboration between corporate and research networks***, which entails the creation of a national Tech Transfer Lab focused on electrification technologies.
- ***Strengthening national capabilities in electric frontier technologies***, through the launching of national programs for R&D activity in companies operating in the electric technologies sector (while also relying on public-private partnership schemes and pre-procurement mechanisms) and the launching of "Technology Impact Bonds" to sustain research initiatives having both a social impact and an economic return.
- ***Diffusing awareness about the benefits of electrification***, with specific actions directed towards public opinion, policy-makers and institutional stakeholders and the business community.

The Distribution System Operator (DSO) can act as a key enabling factor, sustaining the technological evolution and the associated investment. The legislative and regulatory scenario should properly incentivize ***DSO necessary investment on its own network***, both in digitalization and renewal, with commitments to cope with the integration of an increasing amount of renewables, the spread of extensive network of charging infrastructure for electric vehicles and a higher share of electricity in final-user consumption. Furthermore, it is necessary to define rules and responsibilities of the various network operators (TSOs and DSOs) in line with the on-going European regulatory framework, especially concerning the coordination of distributed energy resources.

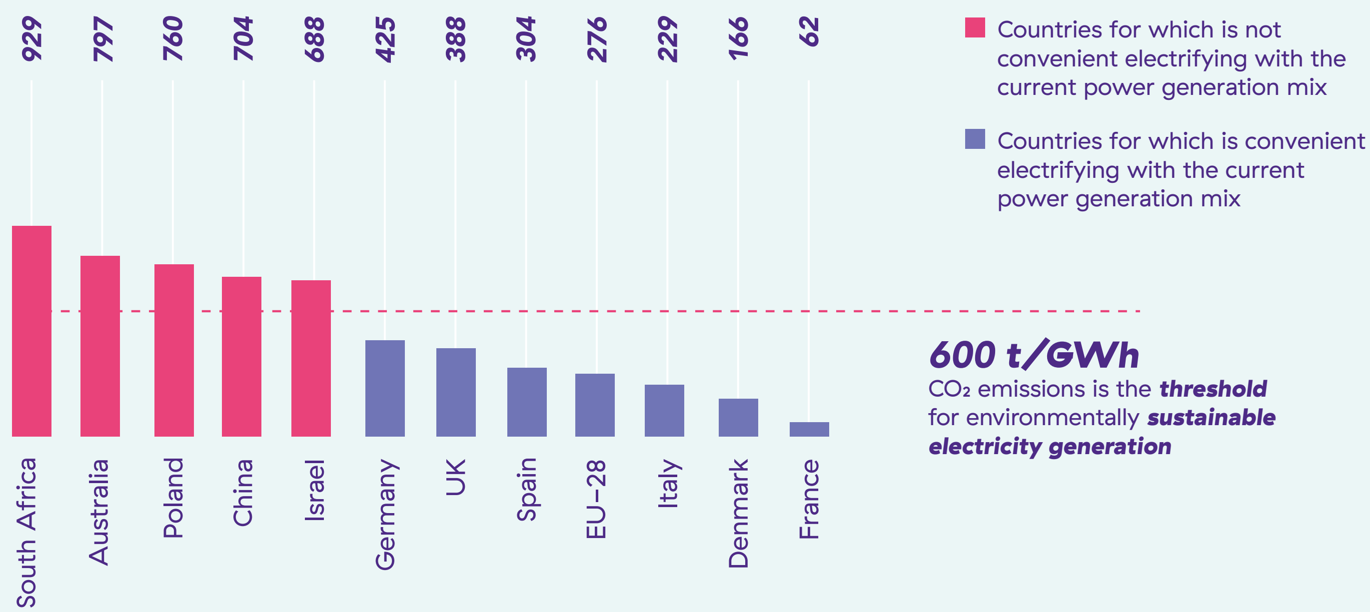
Executive Summary

The electric carrier is an enabler of sustainability, resilience and economic development

- Greenhouse Gas (GHG) emissions are steadily increasing at the global level and reached ***58,710 million tons of CO_2 equivalent*** in 2016 (***+62%*** compared to 1990 levels), with China, the United States, the European Union, India and Russia emitting more than 50% of total gases. Along with this phenomenon, public awareness about their negative effects on human health and the overall ecosystem is increasing worldwide. GHG emissions are indeed related to several negative externalities, like global warming, food insecurity, extreme poverty and disease.
- Since the world is increasingly exposed to external shocks, ***resilience*** is becoming a key concern in reference to the capability of a country or a population to adapt and bounce back quickly in response to events. Resilience refers to several economic and environmental ecosystems: economic system, energy system, IT infrastructure, mobility and water infrastructures, ecological ecosystem and the urban environment. When it comes to the power sector, resilience is strictly related to ***energy security***: increased power generation via renewables and integration of energy storage makes it possible to reduce the quantity of fossil fuels required, thus lowering geopolitical vulnerability. This is particularly relevant for countries, like Italy, characterized by high dependency on energy imports (77% in 2015).

FIG.1

CO_2 emissions from electricity production (t/GWh), 2014.
Source: The European House — Ambrosetti elaboration on C. Kennedy "Key threshold for electricity emissions", European Environment Agency (EEA) and Organization for Economic Cooperation and Development (OECD) data, 2018



N.B. Estimates provided by ISPRA for the Italian case foresees 325 t/GWh CO_2 emissions for gross electricity generation and 220 t/GWh CO_2 emissions for heat production in 2017.

- In this context, electricity is the energy carrier of the future as it enables sustainability, resilience and economic development. Firstly, the electric carrier makes a significant contribution to ***reducing CO_2 emissions*** when the electricity generation mix is balanced towards renewables, and it makes it possible to reduce pollutant emissions, thus improving air quality, in particular in urban areas. It has been analyzed that increasing the share of electricity in final energy consumption is convenient when emissions from electricity generation are ***lower than 600 t/GWh CO_2***. Italy is already below this threshold, thus it can fully exploit the environmental benefits of electrification by increasing its electricity production.
- The electric carrier also allows for higher levels of ***energy efficiency*** (which means using less energy to provide the same result), thus reducing energy needs and related GHG emissions. Electric technologies are able to guarantee higher levels of energy efficiency than their traditional counterparts:
  - heat pumps allow for ***up to a 50%*** reduction in energy use compared to other heating and cooling systems;
  - LED lamps are ***over 50%*** and ***80%*** more efficient than standard filament lamps, respectively in public and residential lighting;
  - electric drives for e-Cars are ***40%*** more efficient compared to combustion engines and electric drives for industrial uses are ***25%*** more efficient compared to traditional ones;
  - lithium ion batteries have an energy efficiency ***12%*** higher than alternative electrochemical storage systems.
- The electric carrier, thanks to its intrinsic versatility and efficiency, offers several opportunities to ***improve resilience*** of the energy system overall. The electric vector can contribute to the resilience of the overall system through:
  - ***renewable sources*** which allow for higher diversity of primary energy supply and generation mix, reducing dependency on a single source;
  - ***electricity storage systems***, which ensure continuity of supply in the event of breakdowns, allow for a deeper penetration of renewable sources and make the overall system less vulnerable to cyber-attacks;
  - ***electricity technologies*** that are more efficient than traditional ones (as described above), allowing for reduced energy intensity and thus lower energy supply and lower system vulnerability;
  - ***network digitalization*** and ***smart management systems*** that permit better management of power flows and prevent disruptions thanks to the collection and analysis of big data.
- Furthermore, the electric carrier can be easily integrated with ***digitalization***, enabling more effective consumption management and higher efficiency, thus enhancing the role of the Distribution System Operator (DSO). Indeed, digitalization in the power sector makes it possible to collect digital data about the state and performance of power sector assets, process the information and, ultimately, influence real-time actions. This, in turn, avoids excessive stress on the system and leads to improved efficiency and lower costs from power generation to utilization.
- Finally, electricity stimulates innovation and sustainability in ***lifestyles*** and ***industrial*** processes, allowing for both energy savings and improvements in product quality. Concerning the former, several new societal megatrends (ageing society, urbanization, sharing economy, smart mobility, energy efficiency and circular economy) find opportunities for innovation thanks to the electric carrier, which has a positive impact on overall sustainability. Concerning industrial processes, there are three aspects in which electricity plays a remarkable role:
  - ***Improved product quality***. Electricity is an extremely-precise energy source that makes it possible to minimize errors on final products.
  - ***Cost reduction***. Costs savings in industry are linked to reduced energy waste stemming from more precise processes, increased efficiency due to electricity technologies and indirect electrification enabled by technologies (power to hydrogen, power to fuel, etc.) which reduce the amount and cost of industrial inputs.
  - ***Sustainability***. Technologies supporting electrification — when substituting those for gas or fossil fuels — contribute to reducing emissions.
- To sum up, all these features make the electric carrier a key tool in ***reducing the overall human footprint*** generated by daily human activity. Population worldwide is growing, and this is considered as a threat to the entire biosphere, since it forces the environment to adapt to the increasing number of human needs. By reducing CO_2 emissions, allowing for higher level of energy efficiency, improving resilience of the overall energy system, fitting well with digitalization and enabling new lifestyles and more efficient industrial process, electricity can contribute to reduce the overall human footprint.

FIG.2

Human Development Footprint.

Source: The European House — Ambrosetti elaboration on European Environment Agency (EEA) and various sources, 2018

NEGATIVE EXTERNALITIES FROM HUMAN DEVELOPMENT

Human activities

Air pollution

- ***~ 90%*** of city dwellers in EU (***~ 70%*** in Italy) are exposed to very high and dangerous concentrations of ozone pollution and PM_{10} (European Environment Agency –EEA)
- In Europe premature deaths from ambient particular matter pollution can be estimated at 497 per 1 million inhabitants in 2016 (564 per 1 million inhabitants in Italy in the same year), that corresponds to an estimate of ***cost of $787.2 billion*** (***$116 billion*** in Italy) for the society, if we consider environmental and health damages (OECD)

Climate change

- In Europe there was a ***loss of $436.1 billion*** over the period 1980–2016 from climate-related extremes ($61.2 billion in Italy over the same period) (European Environment Agency — EEA)
- Heat-related mortality in Europe will increase by ***between 60,000 and 165,000 deaths per year*** by the 2080s compared with the present baseline, with the highest impacts in southern Europe, especially Italy, Spain and Greece (European Commission)
- Extreme cold can also significantly affect human health especially for people with cardiovascular and respiratory diseases and to elderlies, with deaths often occur several days or weeks after the coldest day of a cold period (European Environment Agency – EEA)

Ozone depletion

- European population living at around 45 degrees North can experience, by 2050, an approximate ***5% excess of total skin cancer incidence*** due to ozone depletion (World Health Organization — WHO)

Soil contamination

- There are almost ***340,000 sites*** in Europe and it has been estimated that managing them costs ***~€6.5 billion per year*** (European Environment Agency — EEA)
- There are ***40 polluted sites*** of national interest ***in Italy*** covering ***243,788 hectare of surface*** (Italian Ministry of Environment)

Sea/water pollution and consumption

- More than ***1.8 trillion pieces of plastic*** in the patch of the Pacific ocean that weigh ***~80,000 tonnes*** (The Ocean Cleanup)
- ***More than half*** of the surface water bodies in Europe and in Italy are in less than good ecological status (EEA)
- ***1.1 billion people*** worldwide lack access to water and ***2.7 billion*** find water scarce for one month per year (WWF)

Noise

- Noise pollution damages ***20 million Europeans*** and causes sleep distrubance for 8 million people in Europe (European Environment Agency — EEA)
- Noise pollution causes ***43,000 hospital admissions*** and ***10,000 premature deaths*** per year in Europe (European Environment Agency — EEA)
- In Italy, on average, ***52% of controls in cities*** reveals a surpassing of the tolerant limit of noise which varies according to the urban area and the hour of the day considered (from 40 to 70 dB) (ISPRA)

Deforestation and soil consumption

- The world is losing ***18.7 million acres*** of forests annually, equivalent to 27 soccer fields every minute (WWF)
- ***15% of worldwide greenhouse gas emissions*** are the result of deforestation (WWF)
- Between 2006 and 2012, the ***annual loss of farmland*** was approximately 107,000 ha/year in the European countries of which 5,800 ha/year in Italy (European Environment Agency — EEA)

N.B. Not all the negative externalities mapped in the Human Development Footprint have a corresponding benefit brought about by the electric vector.

BENEFITS FROM ELECTRIC VECTOR

- Innovative pathways for ***low-carbon industry*** (plastics, chemicals, paper, ceramics, cement, iron, steel, etc.)
  - Reduction of ***82%*** of CO_2 emissions with 100% electrical power-based iron production (Eurofer)
  - Reduction of ***ambient temperatures and improvement of air quality*** by replacing coke-fired cupolas with induction melting at iron foundries (EPRI)
  - Elimination of the need for open flame at foundries by using an electric ladle preheater resulting in the ***reduction of on-site emissions*** (EPRI)
  - ***Reduction of on-site emissions and less exposure to open flame*** using an electric alt bath furnace in place of a natural gas convection furnace for heat treating application in the metal fabrication industry (EPRI)
  - ***Decrease to 1% from 2-4% of material lost*** due to oxidation by using electric furnace instead of fossil burners (EPRI)
- Sustainability of ***power production***
  - ***Drop of CO_2*** emissions from electricity generation (gCO_2/KWh) by more than 25% in Europe and by more than 60% in Italy in the last 25 years, also thanks to the growth of renewable energy sources for electricity generation (EEA)
  - Reduction of ***water utilization*** due to use of renewable energy sources plants instead of fossil fueled plants* (EPRI)
- Decarbonization of end-use
  - Reduction between ***120 and 170 kg CO_2/MWh*** for each electric heat pump installed in residential buildings compared to thermic energy (ENEA, CNR and RSE)
  - Reduction of ***50% g CO_2 eq./km*** (well-to-wheel) generated by electric vehicles compared to fuel ones (RSE)
  - Lowering of ambient ***temperature*** by ***4.5° C*** using electric kitchen instead of gas-burning ones (EPRI)
  - Reduction of ***29%*** and ***81%*** of the average concentration of CO_2 and $PM_{2.5}$ in electric kitchens than gas-burning ones (EPRI)
  - ***Reduction of on-site emissions***, such as carbon monoxide (CO), by using electric forklifts as a replacement to internal combustion engine-driven (EPRI)
  - ***Emissions savings*** estimated at 705 tons per year for CO, 26 tons per year of total hydrocarbons, 25 tons per year of NOx, and 1.1 tons per year of PM by switching to electric baggage tractors, belt loaders, and pushback tractors in one airport (EPRI)
  - ***Removal of chlorine*** for treating water by using electric water treatment processes generating benefits for human health (EPRI)
- New lifestyles
  - ***Sharing mobility*** is enabled by e-Mobility and reduces private vehicles use with positive effects on air quality in cities* (National Observatory on Sharing mobility)
  - Better ***traffic management*** thanks to dedicated lanes and access to enlarged congestion zone for e-vehicles* (European Commission)

- Innovative pathways for ***low-carbon industry*** (plastics, chemicals, paper, ceramics, cement, iron, steel, etc.)
  - ***Reduction of ambient noise*** by replacing coke-fired cupolas with induction melting at iron foundries (EPRI)
  - ***Decrease of ambient noise*** by using an electric ladle preheater at foundries (EPRI)
- Decarbonization of end-use
  - ***Reduction of 100%*** of noise from e-vehicles compared to traditional ones (EPRI)
  - ***Lowering of noise by 9 dBA*** using electric kitchen instead of gas-burning ones (EPRI)
  - Reduction of noise pollution by using electric ground support equipment and gate ***electrification technologies in airports*** (EPRI)
  - Decrease of noise pollution by using ***electric forklifts*** (EPRI)

- Electrification technologies (for instance industrial ovens) are smaller than other technologies, taking up ***less space**** (EPRI)
- Reduced necessity to have larger plants thanks to ***decentralized generation*** of electricity* (EPA)

* Indirect effect.

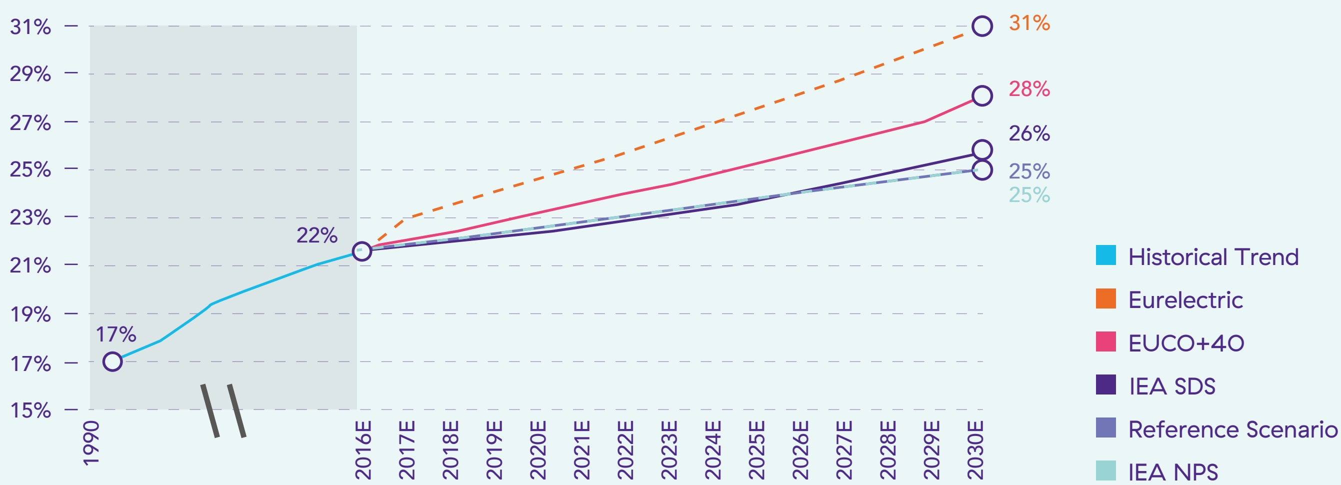
Electrification has a highly deployable potential in Europe and in Italy

- The term electrification refers to the share of electric consumption in total energy consumption. European electricity consumption has grown from 17% in 1990 to ***22%*** in 2016, making the European Union as a whole the 3rd largest electricity consumer worldwide, after China and the United States. Despite the different pace, the overall growth of electrification can also be seen in the EU Big-Five countries, among which the performance of the French and Spanish stands out. Looking at the 1990-2016 period, France and Spain fielded the largest increase, growing by 6.7 and 5.3 percentage points leading the two countries to reach 26% and 24%, respectively. During the same period, Italy showed a 4 percentage point rise (from 17% to 21%), followed by Germany with a 2.9 percentage point rise. Finally, the UK had an increase of 2.3 percentage points, that did not allow the country to surpass as yet the 20% threshold of electricity as a share of total final energy consumption.
- Although electrification has steadily grown in the last two decades, the current electricity share in final energy consumption must increase further to meet the policy targets set at the European and Italian levels. The recent political agreement among the EU Commission, the EU Council and the EU Parliament sets three strategic goals:
  - at least a ***40% cut in greenhouse gas emissions*** compared to 1990 levels;
  - at least a ***32% share of renewable energy*** in final energy consumption;
  - at least a ***32.5% improvement in energy efficiency***.

  Thus, in both Europe and Italy there is a notable potential for electrification to be deployed until 2030 and electrification, combined with a balanced energy generation mix, positively contributes to decarbonization.
- To identify the electrification levels that allows to reach these targets by 2030, several policy scenarios have been developed. Each scenario has different underlying assumptions leading to different levels of electricity share to be reached at the end of the given time period. Starting with the European case, electrification projections range between the ***25%*** envisioned by the EU Reference Scenario and the IEA-NPS and the ***31%*** derived from Eurelectric. Thus, the most prudential case predicts a ***growth of 3 percentage points compared to the current level***, while the highest one envisions an increase of 9 percentage points. The IEA-SDS and the EUCO+40 scenarios fall in the middle between the Reference Scenario and the Eurelectric ones, with an estimated electrification share of 26% (+4 p.p.) and 28% (+6 p.p.) respectively.

FIG.3

Electricity share in final energy consumption in Europe (%), 1990-2030E.
Source: The European House — Ambrosetti elaboration on Eurostat, European Commission, International Energy Agency and Eurelectric data, 2018

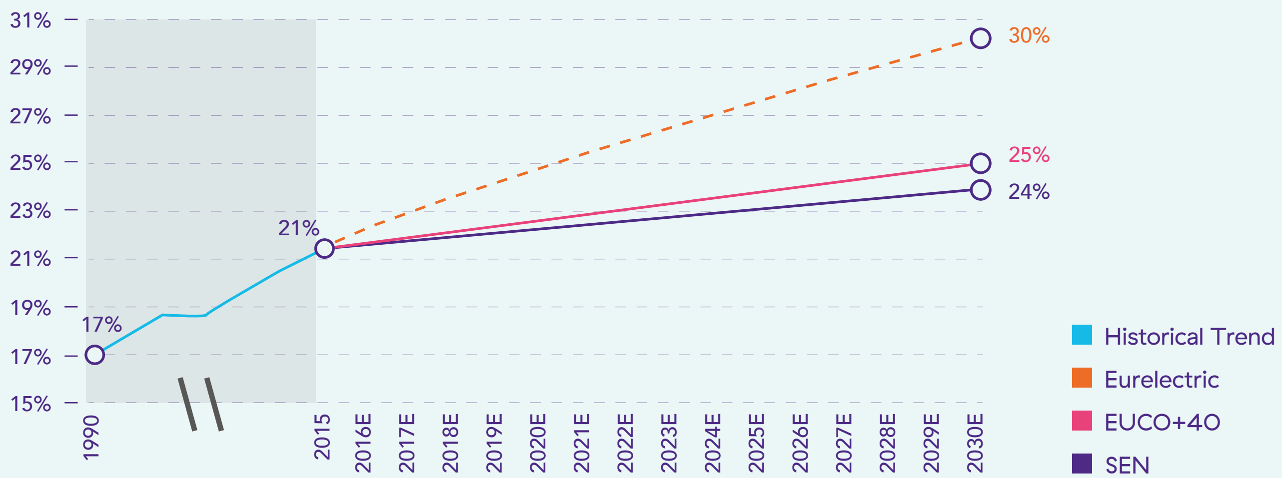


N.B. Scenarios that are not policy driven have a dotted line.

- In the Italian context, electrification potential ranges from the ***24%*** predicted by the National Energy Strategy (SEN) to the ***30%*** derived from the Eurelectric scenario, with the 25% set by EUCO+40 in the middle. Thus, the National Energy Strategy foresees an increase of 3 percentage points compared to the current share, while EUCO+40 envisions slightly higher growth (+4 percentage points). The highest prediction is for +9 percentage points, on a par with that for Europe. For Italy, there are no IEA scenarios because these were specifically designed at an aggregate European level only.

FIG.4

Electricity share in final energy consumption in Italy (%), 1990–2030E.
Source: The European House — Ambrosetti elaboration on Eurostat, National Energy Strategy (SEN) and Eurelectric data, 2018



N.B. Scenarios that are not policy driven have a dotted line.

Electrification stimulates industrial value chains and ecosystem of innovation

The transport sector has the highest potential for electrification

- In light of international sustainability trends, electric mobility ***is experiencing an unrelenting growth at the European level***, driven by both market dynamics and policy targets:
  - the ***e-Car*** market has experienced steady growth in recent years (+68.7% Compounded Annual Growth Rate — CAGR — between 2011 and 2017), bringing the number of electric cars circulating on European roads to over 300,000;
  - the European electric two-wheeler market (motorcycles and mopeds) is growing faster, especially the moped segment which grew by ***233% from 2011 to 2017*** in term of new registrations and recorded a market share of ***6.3%*** in 2017;
  - cities around Europe are introducing electric buses, as a signal of their intention to contribute to emissions reduction in urban environments. In Europe there were ***more than 2,100 urban e-Buses in 2017***, with full electric (Battery Electric Vehicles — BEV) making up the majority of the total with 1,560 electric units;
  - although electric light commercial vehicles are not very widespread in Europe, they represent an attractive alternative to traditional vehicles, particularly for those activities that ask for short-distance urban deliveries: almost ***0.6% of light commercial vehicles*** sold in Europe in 2017 were electric;
  - due to their weight and their need to travel for long distances, ***electrification in the truck sector is still at an experimental stage*** and there are no electric trucks on European roads.
- In Italy, e-Mobility stock is comprised of ***14,647*** electric cars (Battery Electric Vehicles — BEV — and Plug-in Hybrid Electric Vehicles — PHEV), ***6,211*** electric two-wheelers, ***455*** electric urban buses, ***4,454*** electric light commercial vehicles and ***zero*** electric trucks.

FIG.5

Electric mobility in Italy, 2017.
Source: The European House — Ambrosetti elaboration on European Alternative Fuel Observatory (EAFO), Associazione Nazionale Ciclo Motociclo e Accessori (ANCMA), Automobile Club d'Italia (ACI), Associazione Trasporti (ASSTRA) and European Association of Motorcycle Manufacturers (ACEM) data, 2018

14,647 electric cars (stock) out of a car fleet of ~37 mln (0.04%)

6,211 electric two-wheelers (stock) out of a total fleet of ~8.5 mln (0.07%)

455 electric urban buses (stock) out of a total fleet of ~50,000 (1%)

4,454 electric light commercial vehicles (stock) out of a fleet of ~4 mln (0.1%)

As of today, electrification in the ***truck*** sector is zero

- The spread of e-Mobility can enhance new development as well as the reinforcement of ***industrial value chains***, with a significant potential in terms of value added and employment. For the 2017 study, the "e-Mobility Revolution. Impacts on Italy and its industrial value chain: Italy's agenda", the ***e-Mobility extended value chain*** has been reconstructed, defined as all industrial sectors and services involved in the development of electric mobility, considering both direct and indirect supply chains. The framework of the analysis includes all types of road e-Vehicles (cars, two-wheelers, urban buses, light commercial vehicles and trucks), both full electric (BEV) and hybrid plug-in (PHEV). In this study, the analysis has been integrated and updated, in order to quantify the turnover potentially achievable from e-Mobility development.
- For the mapping of the supply chain, a ***matrix presentation*** of macro-sectors has been adopted: vehicles, on one side, and charging infrastructure and grid electricity, on the other, are the backbones along which ICT services for e-Mobility are inserted. These sectors are analysed along the entire value chain:
  - ***Research and Development***, which focuses on specific areas including energy efficiency and innovative intelligent vehicle charging systems, performance improvement solutions, the design and engineering of the management and reuse of energy storage systems, vehicle redesign, the development of software and self-driving systems.
  - ***Manufacturing***, which includes the manufacture of parts and accessories for vehicles and their motors as well as assembly operations. In the infrastructure and energy chain, this phase includes networks for electric energy and telecommunications, extending to service stations, electrical charging points and ICT systems for the latter.
  - ***Distribution and sale*** of vehicles, IT platforms and energy.
  - The ***use of electric vehicles and their aftermarket***, covering the maintenance, repair, sale of finished parts and spare parts, the provision of smart services and the management of electric vehicles, as well as services dedicated infrastructure and electricity network management or customer assistance.
  - ***"Second life" recycling and the reuse*** of electric vehicle and charging infrastructure components.
- In Italy, the e-Mobility extended value chain ***potentially involves*** about ***160,000 companies*** with more than ***820,000 workers*** and a turnover exceeding ***€420 billion***. The turnover generated from the sectors involved in the value chain increased by ***9.9%*** in one year only, compared to the entire Italian manufacturing sector that grew by only 2% over the same period.
- To fully understand the economic and business opportunities of the Italian industry in the electrical mobility development scenario, the phases of the extended e-Mobility value chain in which the Italian industry can acquire a competitive advantage in the international context based on its skill base have been identified. To this end, the assessment of skills and level of competitiveness of Italian industry for various phases of the value chain has been performed:
  - battery systems;
  - electric and hybrid motors;
  - inverters;
  - components;
  - bodywork and interior;
  - charging equipment;
  - ICT systems;
  - electric power distribution;
  - mobility services.

  For each of these outputs and services, the various top down phases were considered according to the "matrix" view of the extended e-Mobility value chain: Research and Development, manufacturing, use and aftermarket, recycling and second life.

  Thus, the Italian level of expertise has been evaluated according to three levels: high competences, medium competences and competences to be built.
- Italy shows both strengths and weaknesses along the extended value chain. On one side, the country boasts several excellences in the following sectors:
  - ***Components***: Italy is the ***2nd*** country in the world for trade balance of electric conductors with voltages greater than 80 V and ***3rd*** country in the world for trade balance of gears and gearing.
  - ***Bodywork and interior***: the country has experience in the design of vehicle interiors and the production of bodywork, also in the bicycle and motorcycle sectors as well as in the truck and light commercial vehicle sectors thanks to the Piedmont manufacturing district.
  - ***Power grid and charging infrastructures***: In 2001 Italy was the first country in the world to launch a national plan of massive installation of electronic meters, which are the basis of smart grid.
  - ***Mobility services***: Italy has a long-standing tradition in the production of light electrical vehicles, electric bicycles and motorcycles, and a framework is emerging of innovative companies specialized in the development of software, applications and technological solutions for managing mobility, including intermodal.

  With regard to inverters, storage systems and electric engines, Italy does not have a prominent position in the international scenario. In fact, in these sectors, Italian companies have to face the competitive advantage of other international players coming from China, Japan, South Korea and Germany.

FIG.6

Mapping of e-Mobility industrial value chains.

R&D *(new areas of research)* | **Manufacturing**

Vehicle

R&D (new areas of research)

- Fossil fuels°
- Sources of renewable energy
- Alternative fuels (e.g. biodiesel, hydrogen, methane°, etc.)
- Energy efficiency (e.g. cutting edge materials for energy storage, soundproofing, bodywork and components, etc.)
- Vehicle-to-Home
- Autonomous Vehicle
- Battery Management System (BMS)
- Electronic differential
- On-board energy flow management strategies
- Redesigning vehicle and its bodywork
- Electric drivetrain
- Design and engineering
- Software development
- Vehicle-to-Vehicle

Electrical systems

- Wires and wiring sets
- Windscreen wipers, heated rear windows and electrical anti-fogging devices for automobiles
- Starter motors°
- Aerial
- Conductive and inductive charging systems (static and dynamic)

Mechanical components

- Brakes and components (disk, pedal and calipers)
- Clutches
- Manual/automatic gear box°
- Front/rear differential
- Rims and wheels
- Pads
- Gas spring/absorbers
- Chassis
- Axles
- Suspension shock absorbers
- Radiators
- Silencers°
- Steering and columns
- Tank°
- Passenger access platform*
- Easel**
- Pedal**
- Fairing**

Audible systems

- Horn
- Loudspeakers
- Soundproofing°
- Audible indicator

After Treatment System

- Catalysts°
- Intakes°

Electronic systems of power

- Electronic capacitors
- Electronic resistors
- Electronic valves
- Spark plugs°
- Wiring for ignition systems°
- Ignition coils°
- Dodes

Electronic systems of control

- Dashboard
- Telematic systems
- Electric panel (electronic crystals, components for monitors, cathode tubes)
- Micro-processors
- Connectors
- Inducers
- Boards and printed circuits
- Electrical systems for windows and doors
- Panel instruments
- Voltage regulator
- Control units
- Diagnostics
- Vehicle Management System (VMS)

Lighting

- Headlights/LEDs
- Interior lighting
- Daytime running lamp adaptive lights

Air Conditioning

Bodywork

- Cab
- Bumpers
- Spraying and painting
- Front grill
- Doors
- Lining of trunk

Interior trims

- Windshields and windows
- Mirrors and steering wheel
- Handrails and buttons for stop request*
- Handlebar**
- Seats
- Saddle**
- Safety kit (fire extinguisher, first aid)
- Ticket punch*
- Safety belts and airbags
- Interior gadgets

Electrochemical storage systems

- Battery pack
- Battery charger
- Super-capacitors
- Accessories
- Battery Management System (BMS)

Software for vehicles

- Sensors
- Diagnostics systems
- Start&Stop Systems
- Safety Systems
- Navigation systems
- Tracking devices
- Integrated systems (ABS, EDS,...)
- Alarm system

Infrastructural and energy network

R&D (new areas of research)

- Energy efficiency
- Sources of renewable energy
- Energy transmission/distribution network
- Development of software for electrical energy flows
- Second-life for electric batteries
- Vehicle Grid Integration (VGI)
- Smart charging

Energy

- Electricity production, transmission and distribution grid and related infrastructures
- Installation of new energy transmission facilities for more widely distributed grids
- Public electricity grid
- Domestic grid
- Storage systems
- Smart grids
- Transformers (of electricity distribution, of fluorescent current, etc.)
- Substations of transformers for electricity distribution
- Transmission and distribution regulators

Telecommunications network

- Systems for connecting to Internet
- Vehicle-to-Vehicle
- Smart phones
- Telecommunication/transmission infrastructures (4G, 5G, etc.)

Software for charging points

- Integrated systems
- Sensors
- Diagnostic systems
- Navigation systems
- Tracking devices
- Payment/transaction systems for charging
- Software for vehicle interaction/recognition

Electrical charging points

- Exterior panels
- Displays
- Electrical cables
- Transformer
- Power converter
- Connectors for slow and fast charge
- Handle
- Energy/power gauge
- Protection and control device
- Hardware communication module
- Integrated storage systems
- Electrical safety check in residential setting
- Human Machine Interface (HMI)

N.B. The value chain outlined refers to the electric vehicle as a whole and does not include other indirect/external supply chains.

* Typical components for bus ** Typical components for two-wheelers ° Output/services at risk in case of a total decarbonization of car fleet (100% BEV)

Exclusive inputs/outputs for electric vehicle

Energy supply chain

ICT services

Distribution/Sales

Use and aftermarket

Recycling and second life

Powertrain (electric and thermal motor)

- Thermal engine°
- Power generators
- Alternators°
- Engine generator sets (excluding turbine generating sets)
- Rotor and stator coils
- Generator sets°
- Cooling systems (water and air)
- Electronic power converters
- Permanent magnets
- Coupling system between thermal and electric engine°

Distribution

- Logistics
- Vehicle park

Sales

- Customer support services
- Financing services
- Training/technical updating services

Software

- Online Platforms for orders/sales management
- Integrated systems
- Integrated systems for transport
- ITS integrated systems
- Upgrading systems
- Management systems of electric car fleet
- Big Data analytics (electric battery status monitoring software)

Maintenance

- Maintenance/overhaul of vehicle and components
- Battery replacement and installation
- Conversion and retrofitting kits°
- Roadside assistance

Smart services

- Vehicle-to-Vehicle
- Vehicle-to-Home
- Vehicle-to-Grid
- Bidding/geolocation services, etc.
- Driving and parking assistance
- Wearable device/IoT
- Mobile App

Operating services

- Car sharing services
- Management of electric car fleet
- Ancillary services (geomarketing, ecc.)
- Integrated mobility services

New forms of vehicle use

- Car sharing
- Ride sharing
- Car pooling

Vehicle

- Recycling of conventional vehicle components (electronics, bodywork, glass,etc.)
- Recycling of electric vehicle components

Battery

- Recycling of components (copper, iron, etc.)
- Regeneration of battery for domestic/industrial use
- Storage of batteries for electric storage

Service stations

- Fuel service stations and infrastructures (gasoline pumps, etc.)°
- Charging stations (alternate current and fast direct current) and related infrastructures
- Service areas (catering, etc.)
- Parking for stops
- Electrification system along the motorway network
- Wireless charging pads and dynamic charging systems
- Solar panels
- Energy management systems

Energy

- Transmission
- Distribution
- Energy Community

Operating services

- Maintenance
- Replacement and installation
- Monitoring
- Energy demand management systems
- Vehicle-to-Grid for energy flows management in electricity grid
- Smart charging

Customer service

- Maintenance services
- Car sharing services
- Parking
- Wireless network communication

Infrastructure

- Recycling/reuse of charging stations component parts
- Conversion of service areas and industrial sites

N.B. This document is a proprietary model elaborated by The European House - Ambrosetti, in order to map the e-Mobility industrial value chains. The model has been validated by engineers affiliated to the "Engineering, ICT and Technologies for Energy and Transportation" department at Consiglio Nazionale delle Ricerche - CNR.

FIG.7

Mapping of Italian skills along the e-Mobility industrial value chains.

PHASES OF VALUE CHAINS	Storage systems (batteries)	Electric and hybrid engines	Inverters	Components	Bodywork and interiors
R&D, Design/ Engineering	R&D to date in Italy is under-developed	Excellences in the manufacture of components for engines; some initiatives in R&D field, with Magneti Marelli (leader in the Powertrain segment in Italy), Politecnico di Milano and PoMoS (Sapienza University); excellences in the motorcycle sector (Energica)	R&D driven above all by the development of technological solutions applied to the renewables sector and for industrial automation	The presence in Italy of numerous medium to large-sized players active in the design of mechanical components and systems in plastic and composite materials	Italian tradition (e.g. Pininfarina's agreement with Iran Khodro and Hybrid Kinetic; Zagato; Pininfarina); university courses and European level Masters in automotive design
Manufacturing	Segment that is still under-developed (among the majors there are Fiamm and Midac) when compared with China, Japan, South Korea, Germany and France, but in 2020 the market for battery energy storage from the energy and industrial sectors will hit €1.35 billion in Italy	The leading car manufacturer for the production of electric engines is Nissan, followed by Mitsubishi and GM	The presence of medium to large manufacturers of inverters for the photovoltaic and automotive (e.g. Elettronica Santerno) sector that is dominated by the Chinese, Germans, Japanese and South Koreans	Italy is the 2^{nd} country in the world for trade balance of electric conductors with voltages greater than 80 V and 3^{rd} country in the world for trade balance of gears and gearing; Magneti Marelli is among the top 100 OEMs (30^{th} in the world and 13^{th} in Europe in 2016)	Extensive experience in the design of vehicle interiors and the production of bodywork, also in the bicycle and motorcycle sectors; Pirelli is the 5^{th} producer of tyres in the world; far-reaching experience in the production of bodywork of trucks and light commercial vehicles in the Piedmont manufacturing district (IVECO)
Use and aftermarket	Aftermarket is still under-developed in Italy; experiences of the battery pack leasing service by some automotive operators, with its own scheduled replacement with new battery packs and updated technology	Aftermarket services (maintenance, support, etc.) of electric engines are still not very widespread in Italy when compared to other European countries (e.g. Germany) that are among the major manufacturers of such engines	Basic support services guaranteed by medium to large manufacturers and distributors of inverters	2,000 companies active in the component sector in Italy, with a turnover of €38.8 billion and ~€20 billion in exports (19% towards Germany); 71% of operators active in the aftermarket segment	Expertise in the aftermarket services is widespread for bodywork and interior components of thermal engine vehicles
Recycling and second life	COBAT's know how in the disposal of accumulators* (collaboration with CNR-National Research Council -on the recovery of lithium batteries); Central-Southern European countries at the forefront (in Germany, a pilot project for spent batteries in Smart ForTwos, for supplying renewable energy to the domestic grid)	COBAT expertise in the disposal of component parts in engines	Recovery projects for inverter electrical component parts (e.g. collaboration between COBAT and manufacturers)	Collaboration between steelworks, national demolition operators and SMEs: production of ~1.8 million tonnes per annum of ferrous scrap broken up in Italy; initiatives for the recovery/disposal of windscreen and side window glasses and plastic materials coming from the automotive sector	

Skill levels

- High
- Middle
- To be built

Italian excellences in the industrial value chain for electric cars

* COBAT (70 collection points and 26 specialist treatment and recycling plants) treats 51% of industrial and vehicle accumulators placed on the market for consumption

OUTPUT

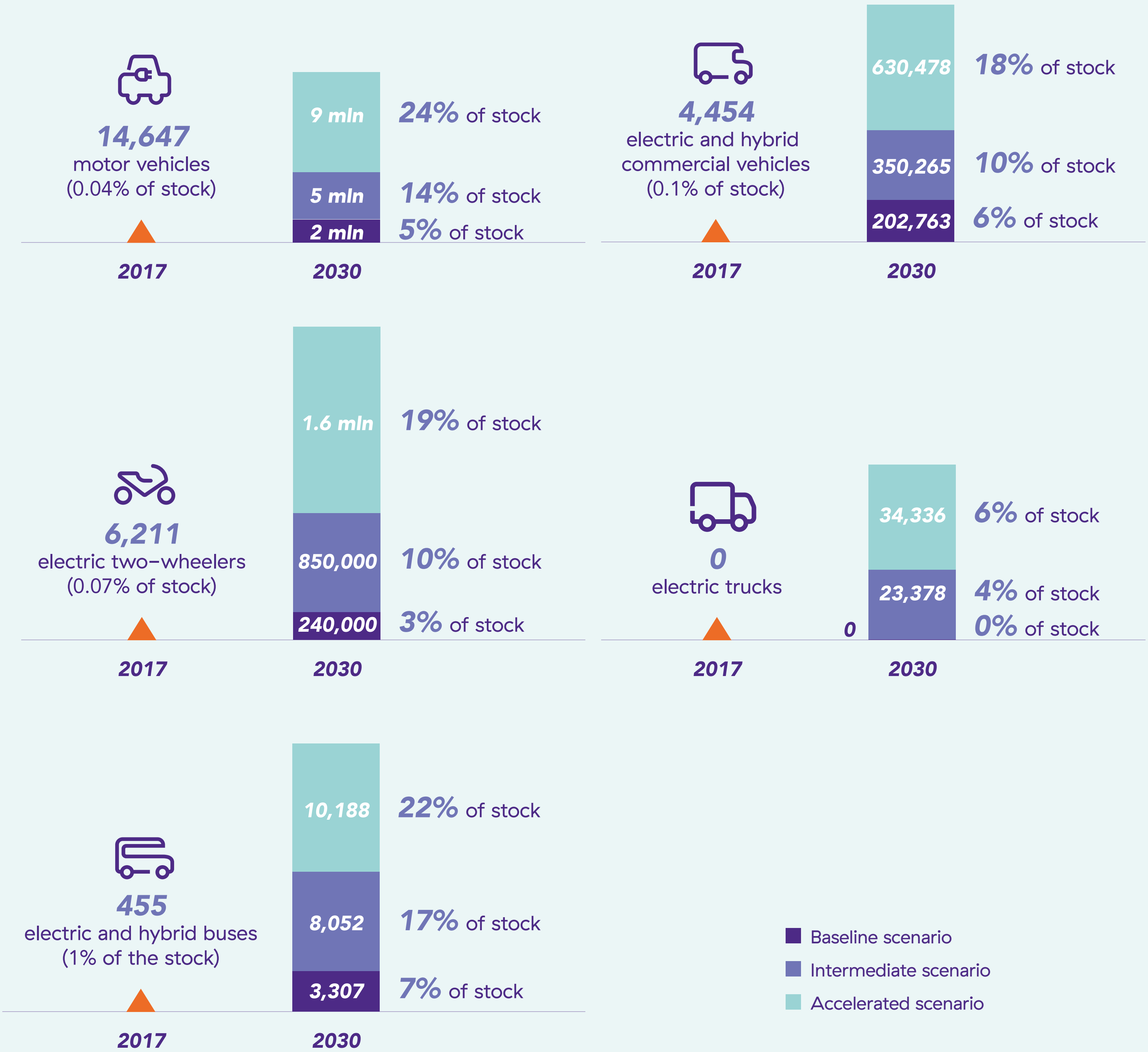
Electric charging infrastructures	***ICT Systems***	***Energy grid***	***Mobility services***
Japan and US specialization in R&D on infrastructures and standard (AC) and fast (DC) charging systems; tests on inductive charging in Northern Europe and in the Netherlands. Enel has expertise in EVSE solutions in both AC and DC charging, including ICT management platforms	Launch, in 2015, of the German ICT for Electric Mobility II plan for developing ICT solutions for e–Mobility; investments in the United Kingdom in R&D for driverless vehicles	Cutting edge R&D (e.g. agreement between Enel and Rosseti, Russian operator for the development of innovative smart grids, June 2017); experimentation on storage systems for integration into the electricity grid (Terna)	R&D for digital services and broadband solutions (Vetrya has developed an e–car with info–mobility and ITS services–driven by an onboard tablet which operates as a multimedia dashboard giving information about the vehicle status, recognized by the London Stock Exchange as one of the 1,000 EU most innovative companies)
Italy has excellences in the production of charging infrastructures (e.g. Enel, Bitron, Ducati Energia, Energy Resources, etc.)	STM among the world's leading companies for electronic circuits, batteries and (semi) autonomous driving systems; other EU countries have integration solutions between charging stations and domestic communications (e.g. Devolo – Germany); growing telematic segment (e.g. Octo Telematics)	Italy was the first country in the world to launch in 2001 a national plan of massive installation of electronic smart meters, which are the basis of smart grid; currently the roll–out of the 2nd generation of smart meters is on–going	Relocation of bicycle and mopeds production from China to Italy with Five, the first ultra green start–up dedicated to the electric mobility in Italy
Imminent boosting of the charging network infrastructure on a domestic level and associated opportunities	Development of value added ICT and software services associated with the creation of a network of infrastructures (Big Data, geolocation services of charging points via mobile networks, bidding services, etc.)	Technical possibility of offering services associated with Vehicle–to–Grid; the need to draft regulation on the offer and related pricing and uniform communication standards	Increasing diffusion of Mobility as a Service app providing integrated access to different mobility services (public transport, trains, car and bike sharing)
Italy is aligned with other countries; possibility of creating a network for the recovery of main quality materials (e.g. iron and copper plates)	Italy is aligned with other countries; possibility of creating a network for the recovery of component parts in copper, silicon and rare earth elements in the face of significant investments		

- In order to build a framework within which estimating the achievable turnover along the e-Mobility industrial value chain in Italy at 2030, ***three alternative scenarios for electric penetration at 2030 in Italy*** have been developed for all forms of mobility (e-Cars, e-Two-wheelers, e-Buses, e-Light commercial vehicles and e-Trucks): baseline, intermediate and accelerated scenario. The analysis produced the following results:

  - ***e-Cars***: 2 to 9 million vehicles;
  - ***e-Two-wheelers***: 240,000 to 1.6 million units;
  - ***e-Buses***: 3,307 to 10,188 vehicles;
  - ***e-Light commercial vehicles***: 202,763 to 630,478 vehicles;
  - ***e-Trucks***: 0 to 34,336 vehicles.

FIG.8

Evolutive scenarios of the spread of electric vehicles (cars, two-wheelers, buses, light commercial vehicles, trucks) in the Italian fleet as of 2030.
Source: The European House — Ambrosetti elaboration, 2018



- The analysis of the extended e-Mobility value chain and the development scenarios show great ***industrial and economic potential*** for Italy, which has been quantified in terms of potential revenue. The assessment was carried out for four macro-areas: vehicles, infrastructure, services, recycling and second life. The assessment focused on all the types of vehicles already analysed for scenarios: e-Cars, e-Two-wheelers, e-Buses, e-Light Commercial Vehicles and e-Trucks. Overall, the turnover achievable in Italy is estimated to be between ***€102.4 and €456.6 billion*** in 2030. From this analysis, it can be easily noticed that revenue coming from the e-Vehicles related supply chain accounts for more than 90% of total results. Italy has a long tradition in the automotive industry and thus it can exploit the opportunity of e-Mobility to innovate and stand as a leader in this sector, which would provide considerable economic results for market players.

FIG.9

Total turnover achievable in Italy along the e-Mobility value chain at 2030 (billion Euro).
Source: The European House - Ambrosetti data elaboration, 2018

Scenario	e-Vehicle	Infrastructure	Services	Recycling and second-life	Total turnover at 2030
Baseline	91.3	6	4	1.1	**102.4**
Intermediate	235.9	11	9	2.1	**258.0**
Accelerated	421.3	18	14	3.3	**456.6**

The electrification offers a relevant contribution to energy efficiency

To identify the full array of electrification technologies and discover the most promising ones in terms of both technological maturity and deployment potential, an ***innovative model*** has been built. The objectives of this model are:

- developing a comprehensive map — previously non-existent — of all ***current technologies and those being researched*** that are related to electrification;
- identifying a ***selection of technologies*** with applications that span a range of sectors and final uses;
- having a scientifically solid base to support the reconstruction of the industrial value chains for those most promising technologies.

In the 360° map of electrification technologies, ***more than 60 existing electrification technologies*** have been analyzed, by grouping them according to both their application in buildings, industry and transport and their final use (electricity generation on site, storage and utilization). As of today, considering only manufacturing activities, the industrial value chain of electrification technologies for energy efficiency ***potentially involves*** in Italy around ***17,000 firms*** and more than ***320,000 employees***, with a total turnover of around ***€80 billion*** per year.

FIG.10

Mapping of electrification technologies at 360°.

Electricity generation on site

Buildings & household consumption

Cogeneration System

- *High power (only for buildings with a power> 100 kW):*
  - Gas Turbine CHP plants
  - Gas engine CHP plants
  - Biofuel engine CHP plants
  - Combined cycle power plant
  - Molten-carbonate fuel cells and Solid fuel cells or Stream turbine CHP plants
  - Nuclear power plants
- *Small power*
  - Reciprocating engine or Stirling engine
  - Biomass
  - Municipal Solid waste

Photovoltaic system

Micro-wind system

Fuel cells*

Industry

Cogeneration System

- *High power*
  - Gas Turbine CHP plants
  - Gas engine CHP plants
  - Biofuel engine CHP plants
  - Combined cycle power plant
  - Molten-carbonate fuel cells and Solid fuel cells or Stream turbine CHP plants
  - Nuclear power plants
- *Small power*
  - Reciprocating engine or Stirling engine
  - Stirling engine
  - Biomass
  - Municipla Solid waste

Photovoltaic system

Micro-wind system

Fuel cells*

Transport

Photovoltaic system

Micro-wind system

Fuel cells*

Energy Management System (EMS): Integrated Technology used by electricity operators to monitor and optimize generation, distribution and utilization performances

Power electronics: electric-electronic appliance that modifies features of out-coming electricity from those of in-coming electricity

Energy Management System (EMS): Integrated

Power electronics: electric-electronic

LEGEND

- Cross-cutting Technologies
- Technologies enabling energy efficiency
- Technologies with the highest enabling potential for electrification
- Indirect electrification

* Investigational technologies are all the technologies that are currently under investigation and have the potential to be marketed in the near future (3 to 5 Years)

** Only energy-intensive household applicances have been considered

Storage	Utilization
Electrochemical storage system (batteries) **Electrostatic device (supercapacitors)*** **Electro-mechanical device (flywhells*, CAES=compressed air energy storage)** **Electromagnetic deviced (SMES- Superconducting Magnetic Energy Storage System)** **Thermal Storage system** **Solar fuel*** **Power to fuel** **Power to gas**	**Heat pumps** • Air source Heat Pumps • Ground Source Heat Pumps • Hybrid Heat Pumps • Ductless Mini-Spirit Heat Pumps • Absorption Heast Pumps **LED lamps** **Electric Divers** • 1-10 kW (elevator and freight elevators for residential use, washing machine, dishwasher, water pumps - single dwelling) • 10-100 kW (elevator and freight elevators for commerviale use water pumps for residential buildings) **OLED lamps (organic LED)*** **Efficient refrigerators**** **Efficient washing machines**** **Induction burners**** **Efficient dishwaters****
Electrochemical storage system (batteries) **Electrostatic device (supercapacitors)*** **Electro-mechanical device (flywhells*, CAES=compressed air energy storage)** **Electromagnetic deviced (SMES- Superconducting Magnetic Energy Storage System)** **Thermal Storage system** **Solar fuel*** **Power to fuel** **Power to gas**	**Heat Pumps** • Air source Heat Pumps • Ground Source Heat Pumps • Hybrid Heat Pumps • Ductless Mini-Spirit Heat Pumps • Absorption Heast Pumps **LED lamps** **Electric Divers** • 1-10 kW (HVAC - Heating, Ventilation Air Conditioning) • 10-100 kW (Washing machine, Plastic, HVAC - Heating, Ventilation and Air Conditioning) • 100 kW-1 MW (Oil-gas, cement, chemical, pulp-papers, metals) • 1 MW-100 MW (Oil-gas, cement, chemical, pulp-papers, metals) **OLED lamps (organic LED)*** **Induction oven (steel industry)** **Electrode oven (glass industry)** **Microwave oven (ceramics industry)** **Arc electric oven (steel industry)** **Pulse dryer (paper)** **Radio frequency and infrared dryer (texti** **Microwave dryer (chemical industry)** **Electrolysis (chemical industry)** **High pressure processing (food)** **Ultrasound dye (textile industry)**
Electrochemical storage system (batteries) **Electrostatic device (supercapacitors)*** **Electromagnetic deviced (SMES- Superconducting Magnetic Energy Storage System)** **Solar fuel*** **Power to fuel** **Power to gas**	**Heat Pumps** • Air source Heat Pumps • Water Source Heat Pumps **LED lamps** **Electric Divers** • 1-10 kW (Electric veihicle actuators) • 10-100 kW (Light duty electric car propulsion) • 100 kW-1 MW (Ship propulsion) • 1 MW-100 MW (Ship propulsion) **OLED lamps (organic LED)*** **Conductive and inductive recharging system**

Technology used by electricity operators to monitor and optimize generation, distribution and utilization performances

appliance that modifies features of out-coming electricity from those of in-coming electricity

N.B. This document is a proprietary model elaborated by The European House — Ambrosetti in order to map all Italian competences for electrification technologies. The model has been validated by engineers affiliated to the "Engineering, ICT and Technologies for Energy and Transportation" department at Consiglio Nazionale delle Ricerche - CNR.

N.B. We have considered only technologies strictly linked to the electrification process and energy efficiency enabled by electrification.

FIG.11

Mapping of industrial value chains of electrification technologies.

	Research and Development: Competences	Research and Development: Research areas	Manufacturing
Heat pumps	• Electronic engineering • Electric engineering • Chemical engineering • Environmental engineering • Computer science • Mechanical engineering • Physics • Mathematics	• Thermodynamics • Materials • Energy efficiency • Environmental impacts • Electric and electronic systems • Digital system • Mechanical systems • Sensors • Control systems	• Coolant • Evaporator • Compressor including electric motor • Condenser • Expansion valves • Throttling valves • Probe • Fan coil units • Coils • Duct connections
LED lamps	• Electronic engineering • Electric engineering • Chemical engineering • Physics • Mathematics	• Chemical compounds • Materials • Lighting • Optoelectronics • Energy efficiency	• Semiconductor devices (Silicon, Carbon, Germanium, Gallium Arsenide) • Chip • Electrical connections • Optical lenses • Protective cap • Light paths • Cooling plate (only in Power LED)
Electric drives	• Electronic engineering • Electric engineering • Mechanical engineering • Control system engineering • Computer science • Physics • Mathematics	• Energy efficiency • Power electronics • Electrical machines • Control systems • Embedded systems	**Electric Motor** *Direct Current (DC) Motor* Brush DC: • Shunt wound • Separately excited • Series wound • Compound wound • Permanent magnet • Servomotor Brushless DC: • Universal *High Power Converters* Direct Conversion: • Matrix converter • Cyclo converter Indirect Conversion: *Voltage source* • High power 2 VSI • Flying capacitor • Neutral point clamped • Cascade H bridge • Hybrid topologies
Electrochemical storage systems (batteries)	• Electronic engineering • Electric engineering • Chemical engineering • Chemistry • Physics • Mathematics	• Battery Management System • Hybrid batteries (supercapacitors + storage system) • Big Data analytics • Smart–grid • Power electronic converters	*Battery types* • NiCd cell • Lithium–ion cell • NiMH cell • Lead–acid battery
Power electronics	• Electronic engineering • Electric engineering • Physics • Mathematics	• Materials • Electrical circuit • Nano–technology • Control systems • Semiconductor devices • Thermal management • Electromagnetic compatibility • Energy efficiency	• Semiconductor power devices (power diode, power transistor, wide bandgap device, etc.) • PCBs (printed circuit boards) • High frequency transformers *A Power Electronics is an electric–electronic appliance that modifies features of out–coming electricity from those of in–coming electricity*
Energy Management Systems (EMSs)	• Electronic engineering • Information technology • Computer science • Energy engineering • Physics • Mathematics	• Computer software • Embedded programming • ICT • Operations research • Artificial intelligence • Sensor networks • Energy efficiency	*Hardware* • Smart meter • Sensors • Wearable device/IoT • Portable devices (PC, tablet, smartphone) • Embedded boards (DSP, microcontroller, FPGA, etc.) *An Energy Management System is an integrated hardware/software technology used by electricity operators to monitor, control and optimize generation, distribution and utilization performances*

N.B. This document is a proprietary model elaborated by The European House — Ambrosetti in order to map the industrial value chains of the six cross–cutting technologies that can play a key role for electrification.

Distribution, sale and aftermarket

Recycling and second life

- Logistics
- Deposit
- Sale
- Installation
- Post-sale assistance
- Maintenance
- System integrators

- Packaging
- Transportation
- Sale
- Installation

Alternating Current (AC) Motor

Induction Motor

Squirrel Cage
- Design A*
- Design B*
- Design C*
- Design D*
- Shaded Pole
- Split phase
- Capacitor start
- Capacitor run
- Resistance start

Wound Rotor
- Repulsion start
- Repulsion induction

Synchronous Motor
- Permanent magnet
- Synchronous reluctance
- Hysteresis
- Synchronous induction
- Reluctance
- Sub-synchronous reluctance
- Variable reluctance
- Stepper
- Hybrid

Linear
- Induction
- Synchronous

Current source
- PWM current source inverter
- Load commutated inverter

- Transportation
- Distribution
- Sale
- Installation
- Maintenance
- Substitution

Accessories
- Inverter
- Charger
- DC/DC converter

- Transportation
- Distribution
- Sale
- Installation
- Substitution and maintenance
- System integrators

- EMI filters
- Embedded control boards (DSP, microcontroller, FPGA, etc.)
- Capacitor
- Inductor

- Transportation
- Distribution
- Sale
- Installation
- Maintenance

Software
- Mobile app
- Diagnostic system
- Monitoring system
- Big Data analytics
- Energy management algorithms
- Cloud and Edge computing
- Automation systems

- Transportation
- Distribution
- Sale
- Installation
- Consulting services
- Maintenance
- System integrators

Recyclable materials and items:
- Iron
- Steel
- Aluminium
- Nickel
- Molybdenum
- Magnesium
- Copper
- Bronze
- Lithium
- Cobalt
- Nickel
- Graphite
- Glass
- Plastic
- Silicon
- Battery regeneration for residential and industrial use
- Permanent magnet materials

LEGEND

Detailed components of a single part.

* There are different standard types of squirrel cage. Design A: normal starting torque, normal starting current, normal slip; Design B: normal starting torque, low starting current, normal slip; Design C: high starting torque, low starting current, normal slip; Design D: high starting torque, low starting current, high slip.

The model has been validated by engineers affiliated to the “Engineering, ICT and Technologies for Energy and Transportation” department at Consiglio Nazionale delle ricerche – CNR.

- The 360° map of the electrification technologies allowed to identify ***six technologies*** in the three sectors and uses being particularly promising in terms of both efficiency gains stemming from their adoption and capability to activate an industrial value chain: heat pumps, LED (Light Emitting Diode) lamps, electric drives, electrochemical storage systems (batteries), power electronics and Energy Management Systems (EMSs).
- Further, relying on the 360° map of the electrification technologies, it has been elaborated an ***extended map of the industrial value-chain*** concerning the six aforementioned technologies. The value chain map adopts a matrix presentation in which four macro-sectors of the value chain are matched with the different technologies by also considering the different components of the technological appliances. In particular, the four macro sectors here considered to include the components of the electrification technologies' value chains are:
  - ***Research and Development***, which considers both the competences and skills that are necessary in the development of the given technologies and the research areas that are involved in research related to the technology.
  - ***Manufacturing***, which includes the manufacture of the constitutive parts of the various technologies. Given the substantial differences in the manufac-

PHASES OF VALUE CHAINS	***Heat pumps***	***LED lamps***	***Electric drives***
R&D, Design/ Engineering	Excellences in the research field with different actors involved (CNR, Politecnico di Milano, Firenze University, Robur and Ariston Thermo)	An excellence centre is constituted by the LUCE LAB located at the Politecnico di Milano and partnered by the Italian Design Association and the main industries in the field (Artemide, IGuzzini, Gewiss)	Excellences in the manufacture of components for motors, but R&D is lacking, with the exception of Magneti Marelli (leader in the Powertrain segment in Italy); excellences in the motorcycle sector (Energica)
Manufacturing	58 companies with more than 7,200 workers and a total turnover bigger than €1,550 million (with 64% share of export) but activity mostly related to assembly. One case of excellence is Ariston Thermo that created a platform for heat pumps sales	About 80 producers of equipment, components and LED lamps based in the Italian territory. Italy is the third exporter of LED lamps worldwide (following China and Germany). €1.5 billion is estimated for the LED market in Italy by 2020	Small producers of electric drives (between thousands W and dozens of kW), but major producers are multinationals such as General Electric, ABB, Siemens
Use and aftermarket	Services and aftermarket are relatively developed thanks to the widely spread network of installers	Installation and related services are already well developed for both residential and public lighting. A few cities have already switched to LED lights in all their streets (Milan is the most prominent case)	Aftermarket services (maintenance, support, etc.) of electric motors are still not very widespread in Italy when compared to other European countries (e.g. Germany) that are among the major manufacturers of such motors
Recycling and second life	Some recyclable materials and components can experience a growth in the near future	LED lamps need to be treated as special electric wastes. Ecolamp and Remedia are the largest consortium in charge. Application for re-use are not developed yet	COBAT expertise in the disposal of component parts in motors

* Electric/electronic appliance that modifies features of out-coming electricity from those of in-coming electricity.

** Integrated hardware/software technology used by electricity operators to monitor, control and optimize generation, distribution and utilization performances.

turing of the six technologies, their specific characteristics have been taken into account. For instance, the electric drive is divided into components for Direct Current (DC) Motors and Alternative Current (AC) Motors, batteries are classified by battery types and accessories that are common to all of them, and energy management systems are subdivided according to hardware and software components.

- ***Distribution sales and aftermarket***, which implies all the distribution, logistics and maintenance parts of the value chains. Included in this category are also the system integrator companies providing services in all the parts considered.
- ***Recycling and second life,*** including the recycling and reuse of materials and items as well as the possible usage for exhausted technologies as battery regeneration for residential and industrial use.

FIG.12

Mapping of Italian skills along the industrial value chains of electrification technologies.
Source: The European House — Ambrosetti elaboration, 2018

OUTPUT

Electrochemical storage systems (batteries)	Power electronics*	Energy Management System** (EMS)
R&D to date in Italy is under-developed	Some Italian companies (STMicroelectronics) are developing new forms of power electronics with Silicon Carbide, a compound of silicon and carbon, a type of wide bandgap (WBG) semiconductor, associated with higher energy efficiency. The US is at the forefront of this field of research	R&D in Italy is still underdeveloped and concentrated to university Labs
Segment that is still under-developed (among the majors are Fiamm and Midac) when compared with China, Japan, South Korea, Germany and France, but in 2020 the market for battery energy storage from the energy and industrial sectors will hit €1.35 billion in Italy	There are some companies specialized in the manufacturing of power electronics (EEI, Elettronica Santerno, Fimer, FRIEMM, Layer, Santerno, TDN Macno). Market leaders in this field are Siemens, ABB, General Electric, Danfoss, Nidec	There are a few companies working with system integration and most of them are concentrated in the building sector (Bticino, CAME Gewiss). The value of the smart home market in Italy in 2016 has overcome €250 million
Aftermarket is still under-developed in Italy; experiences of the battery pack leasing service by some automotive operators, with its own scheduled replacement with new battery packs and updated technology	Aftermarket services are present in Italy but they can be widened	Aftermarket services are present in Italy but they can further be widened with the growth of applications
COBAT know how in the disposal of accumulators (collaboration with CNR – National Research Council – on the recovery of lithium batteries); Central-Southern European countries at the forefront (e.g. in Germany, a pilot project for spent batteries in Smart ForTwos, for supplying renewable energy to the domestic grid)	This is a field that can experience further development in the near future	Not really affected given the software nature of the application

Skill levels High | Middle | To be built

- To complete the investigation of the Italian industrial value chains, the current ***Italian*** level of manufacturing and ***industrial competences*** was assessed. This additional map has been constructed by elaborating a matrix of:
  - the ***six different technologies*** having the highest potential of deployment (heat pumps, LED lamps, electric drives, electrochemical storage systems, power electronics, Energy Management Systems);
  - the ***four phases,*** that were identified as key components of the value chain (Research and Development, Manufacturing, Distribution sales and aftermarket, recycling and second life).
- The result is a complete picture of the Italian level of expertise for any technology and phase. To assess Italian competences three levels have been individuated: high, middle and competence to be built. Italy shows notable medium and high level competences for:
  - ***Heat pumps***: in which there are several excellences in R&D, with different actors involved such as Consiglio Nazionale delle Ricerche (CNR), Politecnico di Milano, Firenze University, and a few private companies.
  - ***LED lamps***: Italy is the third exporter of LED lamps worldwide (following China and Germany) and the LED market in Italy by 2020 is estimated to be €1.5 billion.
  - ***Electric drives***: even if, major producers are multinationals, there are several Italian producers of electric drives (with thousands W and dozens of kW).
  - ***Power electronics***: some Italian companies are at the forefront of research thanks to their positioning in the development of new forms of power electronics embedding Silicon Carbide (a compound of silicon and carbon), that is associated with higher energy efficiency.
  - ***Energy Management Systems (EMS)***: in the manufacturing phase, there are a few companies working with system integration and most of them are concentrated in the buildings' sector.

  By contrast, a first look to the distribution of competences in the map reveals a weaker situation in at least two regards: the recycling and second life phase — which has to be built from ground zero for all the given technologies — and electrochemical storage systems, whose competences are still underdeveloped compared to competitors.
- The six technologies that were individuated as the ones having the highest deployment potential allows for significant efficiency gains, making them a suitable option to move in the direction indicated by the EU policy targets and increase the efficiency of industry, buildings and transport. The energy ***efficiency gains*** associated with the six technologies can be summarized as follows:

FIG.13

Efficiency gains associated with the six technologies compared to the technological alternatives.
Source: The European House — Ambrosetti elaboration, 2018

	Efficiency gain (%)	Alternative technologies
Heat pump	**~50%** in the average air source heat pump	Heat pump average save in primary energy vs. traditional combustion heating and cooling systems (e.g. condensing boiler). Efficiency gains comprised between 50% and 60% are also visible in the high temperature industrial heat pump
LED lamps	**80%–85%** in the residential sector **~52%** in public ones	Average energy use save across the different lumens type and vs. the standard filament lamp (adaptive lighting can further increase efficiency of public lighting by 10% or even 30% in main roads). LED lamps have an efficiency gain ranging between 5% and 10% also compared to the fluorescent lamps
Electric drives	**~40%** in the electric cars **~25%** industrial inverter	Energy use save vs. internal combustion engine in the cars and energy save given by an inverter applied to the electrical drives in the industry
Electrochemical storage systems (Batteries)	**~12%** generated by Lithium-Ion batteries	Efficiency of the Lithium-Ion batteries vs. the alternative electrochemical ones (efficiency gain is here referred to Sodium Nickel Chloride, for lead-acid, sodium sulfur, redox flow is also higher)
Power electronics	**~73%** in wide band-gap-devices	Effects generates by employing semi-conductors such as silicon carbide or gallium nitride in place of silicon
Energy Management Systems (EMSs)	**~16%** in buildings and **14%–17%** in heating, ventilation air conditioning	Efficiency gains of the most recent system integration software compared to the past (advanced aggregation software allow to maximize usage of distributed storage and renewable generation and optimize the management of heating and cooling facilities)

- Building upon the efficiency gains that would be triggered by the given electrification technologies, a ***"what if" analysis*** has been provided to estimate the attainable turnover from the deployment of four of these technologies to 2030: heat pumps, LED lamps, electric drives and electrochemical storage systems. For each technology, different end uses have been considered and two scenarios have been developed for the analysis: ***a full deployment scenario*** (100% of installation of the specific technology) and an ***evolutive scenario*** (lower share of penetration differentiated by technology).
- The activation of the Italian industrial value chain for the electrification technologies reveals an attainable turnover ranging ***between €135 billion and €326.5 billion***. The hugest part of this turnover is generated by electrochemical storage systems and heat pumps which underscores the strategic value of the existing competences in these two fields.

FIG.14

Overall turnover attainable by 2030 in the full deployment and the evolutive scenarios (€ billion).
Source: The European House — Ambrosetti elaboration, 2018

EVOLUTIVE SCENARIO

	Turnover at 2030
Heat pumps	33.5
LED lamps	3.5
Electric drives	17.0
Electrochemical storage systems	81.0
TOTAL TURNOVER AT 2030	135.0

FULL DEPLOYMENT SCENARIO

	Turnover at 2030
Heat pumps	146.0
LED lamps	4.5
Electric drives	30.5
Electrochemical storage systems	145.5
TOTAL TURNOVER AT 2030	326.5

How to enhance the electrification process and reap its benefits

- The electrification process does not necessarily refer to a single policy realm but encompasses a few of them by engendering technological changes and triggering new consumer behaviour. As for this, a ***multi-level strategy*** needs to be adopted to reap all the benefits and opportunities that can be activated for Italy and its industrial value chains. ***Five focus areas have been identified***, among which different proposals are grouped according to their basis:
  - e-Mobility take up;
  - energy efficiency deployment;
  - enhancing collaboration between companies and research networks;
  - strengthening national capabilities in electric frontier technologies;
  - diffusing awareness about the benefits of electrification.
- In all this framework, the Distribution System Operator (DSO) can act as a key enabling factor, sustaining the technological evolution and the associated investment. The legislative and regulatory scenario should properly incentivize ***DSO necessary investment on its own network***, both in digitalization and renewal, with commitments to cope with the integration of an increasing amount of renewables, the spread of extensive network of charging infrastructure for electric vehicles and a higher share of electricity in final-user consumption. Furthermore it is necessary to define rules and responsibilities of the various network operators (TSOs and DSOs) in line with the on going European regulatory framework, especially concerning the coordination of distributed energy resources.

FIG.15

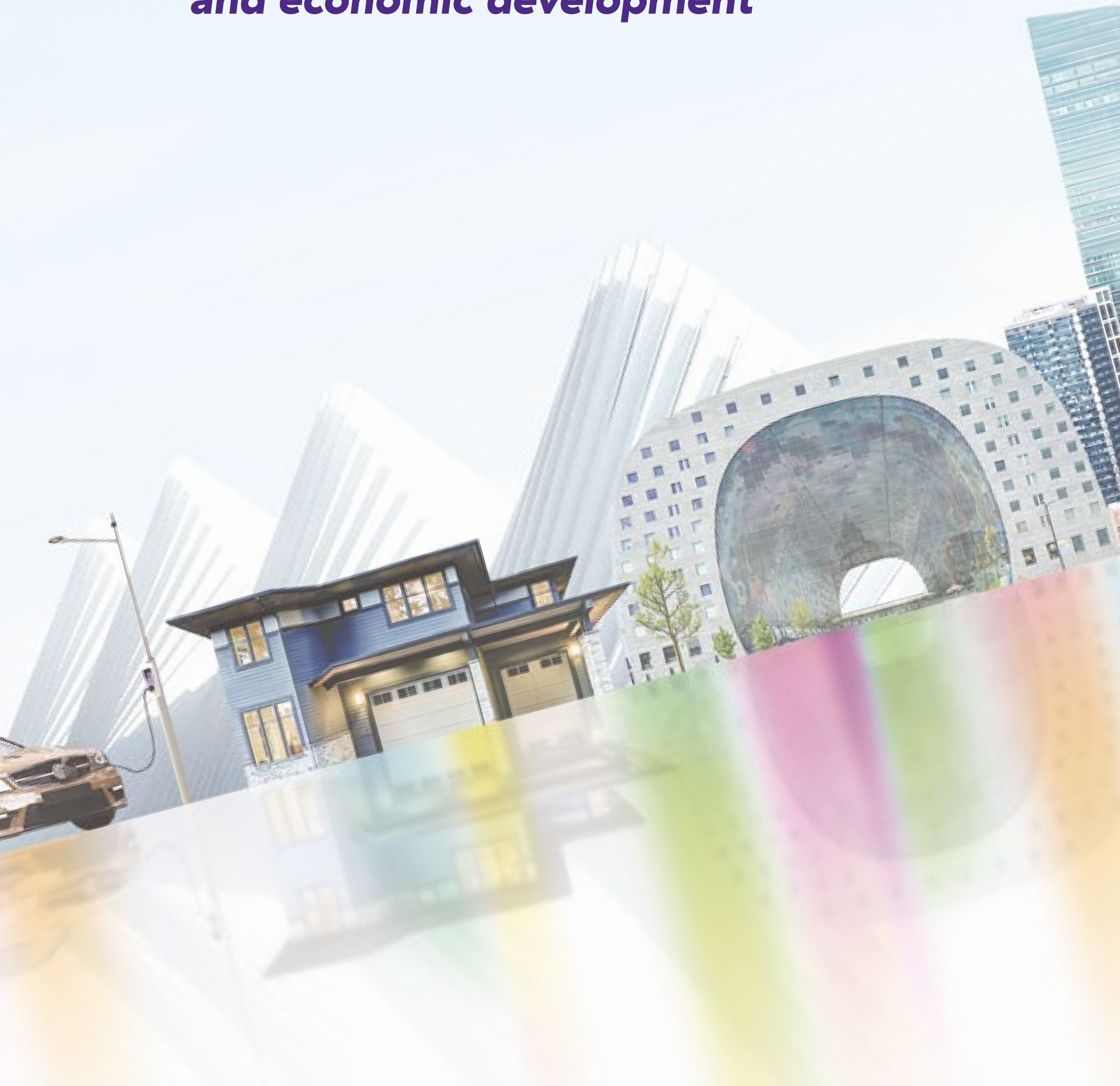
Synoptic view of the policies to support electrification in Italy.
Source: The European House — Ambrosetti elaboration

E-MOBILTY TAKE UP	• Adopting an effective management of the ***e-Mobility transition*** by promoting co-ordination among the institutional actors and elaborating a strategy involving precise targets and actions at national and local level • Enhancing the installation process of ***public and private charging points*** by removing all the regulatory and legislative stumbling blocks • Setting ambitious target for the ***clean vehicle procurement by public authorities***, whose new purchased fleet shall be 100% clean by 2025
ENERGY EFFICENCY DEPLOYMENT	• Giving ***continuity to the incentivizing mechanisms*** on a multi-annual base and optimizing the implementation procedures • Setting up the "***Home Maintenance Leaflet***" to increase the stakeholder awareness on energy efficency benefits and introduce a feature that can be priced by the market so increasing the value of the interventions made by householders • Devising ***innovative financial schemes***, e.g. combining traditional mortage with an ad hoc loan for energy efficiency technologies guaranteed by the financial institution under an agreement with an industrial player, to support technologies with medium-long payback period
ENHANCING COLLABORATION BETWEEN COMPANIES AND RESEARCH NETWORKS	• Creating a national ***Tech Transfer Lab*** focused on electrification technologies, empowering the role of the already existing research institutions and with the mission of acting as enabler of technological transfer between the research institutions and the private sector
STRENGTHENING NATIONAL CAPABILITIES ON ELECTRIC FRONTIER TECHNOLOGIES	• Launching national programs for the R&D activity of companies operating in the electric technologies sector, relying upon ***public-private partnership schemes*** and the ***pre-procurement tool*** • Launching a "***Technology Impact Bonds***" to sustain research initiatives with a social impact and economic return and with a supply mechanism that could favor the creation of consortium involving all the players along the value chains and guaranteeing all the steps from research to implementation
DIFFUSING AWARENESS ABOUT THE BENEFITS OF ELECTRIFICATION	• ***Increasing the awarness*** on the electrification benefits via specific action directed towards public opinion (via a national communication campaign based on recurring cycles), ***policy-makers and institutional stakeholders*** (via the definition of a function providing policy assessment in terms of a sustainable development in the energy sector) and the ***business community*** (through a permanent forum focused on electrification technologies)

The Distribution System Operator (DSO) can act as a key enabling factor, sustaining the technological evolution and the associated investment. The legislative and regulatory scenario should properly incentivize ***DSO necessary investment on its own network***, both in digitalization and renewal, with commitments to cope with the integration of an increasing amount of renewables, the spread of extensive network of charging infrastructure for electric vehicles and a higher share of electricity in final-user consumption. Furthermore it is necessary to define rules and responsibilities of the various network operators (TSO and DSOs) in line with the on going European regulatory framework, especially concerning the coordination of distributed energy resources.

Part 1

The electric carrier is an enabler of sustainability, resilience and economic development



Part 1

Key messages

- Greenhouse Gas (GHG) emissions are steadily increasing at the global level, reaching ***58,710 million of tons of CO_2 equivalent*** in 2016 (***+62%*** compared to 1990 levels) and public awareness about their ***negative effects*** on human health and ecosystem is increasing worldwide.

- Since the world is increasingly exposed to external shocks, ***resilience*** is becoming a key concern in reference to the capability of a country, an economic or an environmetal system adapt and bounce back quickly in response to the events. The concept of resilience refers to several intertwined aspects of the economic and environmental ecosystem, including the energy sector.

- Decarbonization and resilience are two sustainability policy objectives and considered together they contribute to reducing the overall human development footprint. At the European level, targets for decarbonization by 2030 call for a reduction of ***40%*** of GHG emissions compared to 1990 levels, a ***32%*** share of renewable energy in final energy consumption and a ***32.5%*** improvement in energy efficiency.

- Five features make the electric carrier particularly suitable to reach the European Union policy targets and reduce the overall ***human development footprint***:

  1. Electricity generated through a balanced energy mix, integrating a significant share of ***renewables***, allows to ***reduce CO_2*** emissions. The threshold to increase electricity production while decarbonizing is individuated at ***600 t/GWh CO_2*** emissions and Italy is already below the threshold. Yet, by enabling the reduction of pollutants' emissions, the electric carrier contributes to the ***improvement of air quality***, in particular in urban areas.

  2. End-use electric technologies, compared to traditional technologies, provide higher levels of ***energy efficiency***, thus reducing energy needs and related CO_2 emissions.

  3. The electric carrier can be easily integrated with ***digitalization***, enabling more effective consumption management and higher efficiency, thus enhancing the role of the Distribution System Operator (DSO).

  4. The electric carrier, thanks to its intrinsic features of versatility and efficiency, offers several opportunities for improving the ***resilience*** of the overall energy system.

  5. The electric carrier stimulates ***innovation*** and sustainability in ***lifestyles*** (i.e. new consumers' habits related to urbanization, the sharing economy and smart mobility) and ***industrial processes***, in which electricity propelled technologies allow for both energy savings and improvements in production processes.

1.1.

Decarbonization and resilience are a cornerstone of global sustainability policies and the electric carrier is pivotal for them

1.1.1. Decarbonization and resilience are at the centre stage in the international debate

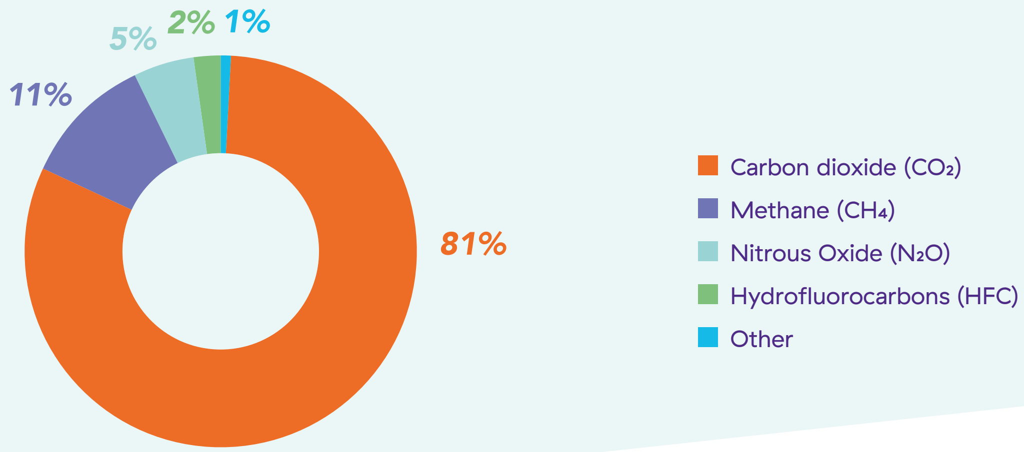
1. To introduce decarbonization, it might be useful to provide a definition of this phenomenon. Decarbonization refers to the ***reduction of Greenhouse Gas (GHG) release***, that is the emissions into the earth's atmosphere of various gases that contribute to the greenhouse effect.[1] Carbon dioxide (CO_2) is the GHG mostly emitted and it is commonly produced by human activities, like industrial processes, electricity generation, manufacturing and construction, transportation, heating and cooling systems, agriculture and land-use.

FIG.1

Air emissions by atmospheric components at global level (% values), 2017.

Source: The European House — Ambrosetti elaboration on United Nations Framework Convention on Climate Change (UNFCCC) data, 2018

58,710 million of tons of CO_2 equivalent

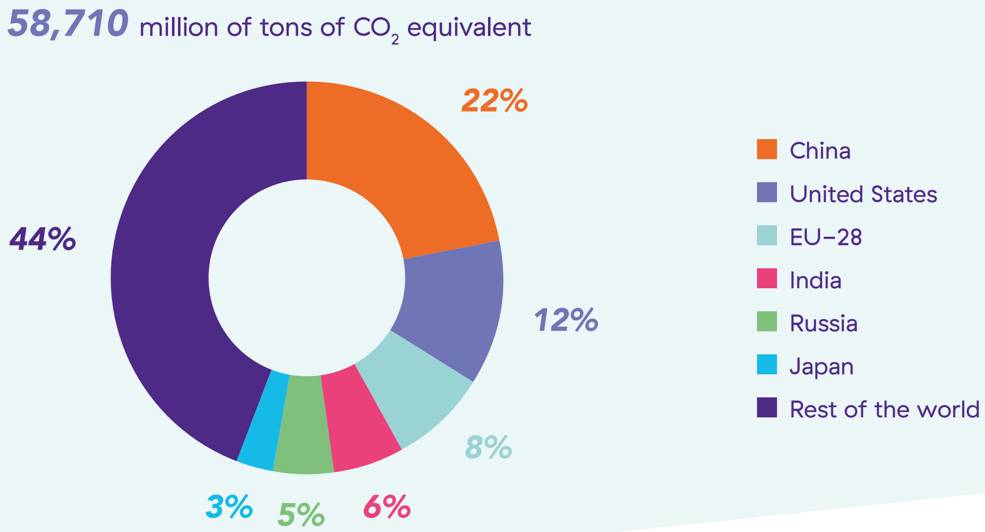


2. GHG emissions are steadily increasing at the global level and reached ***58,710 million of tons of CO_2 equivalent*** in 2016 (***+62%*** compared to 1990's levels), with China, the United States, the European Union, India and Russia emitting more than 50% of total gases. Narrowing the analysis only to European countries, Germany is the most polluting economy and it is responsible of 20.8% of total GHG emissions in Europe, followed by the United Kingdom (12.1%), France (10.7%), Italy (9.9%) and Poland (8.7%).

1 The greenhouse effect is the problem caused by increased quantities of gases such as carbon dioxide in the air. These gases trap the heat from the sun and cause a gradual rise in the temperature of the Earth's atmosphere.

FIG.2

Global emissions of CO_2 equivalent by country (% values), 2016.
Source: The European House — Ambrosetti elaboration on World Bank and Eurostat data, 2018



3. Awareness about GHG emissions is increasing worldwide since their ***negative effects*** on human health and the overall ecosystem have begun to emerge. GHG emissions are indeed related to several negative externalities:

- ***Global warming***. This phenomenon has reached its historical peak in the last years, with 2015, 2016 and 2017 confirmed as the three warmest years on record (the world temperature in 2017 was 1.1 degrees Celsius above the pre-industrial era). Beyond global warming itself, several natural disasters and cataclysms have occurred in the last years due to climate-related extremes: in Europe almost 90,000 climate-related fatalities have occurred from 1990 until today, causing more than €430 billion of losses.
- ***Food insecurity***. GHG emissions affect the quality and quantity of land and water resources available for production in agriculture and other climate-dependent sectors, such as forestry and fisheries. It has been estimated that prolonged droughts, especially in developing countries, can generate an increase of almost 30% in the number of people with difficult access to food.
- ***Extreme poverty.*** Extreme events caused by GHG emissions (flood, droughts, heavy rains, etc.) bring countries, especially the developing ones, to their knees: it has been estimated that 123 million people globally could face extreme poverty by 2030 due to GHG emissions.
- ***Health***. The direct costs of health diseases associated to GHG emissions is estimated to be between €1.8 and €3.6 billion by 2030 (see Part 1.3 for more details about health effects of pollution).

4. Since the world is increasingly exposed to external shocks, ***resilience*** is becoming a key topic in reference to the capability of a country or a population to adapt and to speedily recover from the shock.

HOW TO MEASURE RESILIENCE

Even if a unique indicator does not exist, there are some Key Performance Indicators (KPIs) that can be considered a good proxy for resilience. Regarding the financial market, the CBOE Volatility Index shows the market's expectation of 30-day volatility and gives an indication of market reactions to economic shocks. Looking at the evolution of the index in the last 10 years, the highest values have occurred during the most relevant economic shocks periods, like the liquidation of Lehman Brothers, the European Debt Crisis and Brexit. Mobility and water infrastructures resilience can be evaluated by analysing the effects of natural disasters in terms of people affected and economic losses: a resilient infrastructure system should be able to contain damages. Nevertheless, from 1960 to 2017, 13,735 natural disasters have occurred around the world, causing 5.4 million deaths, affecting 7.8 billion people and generating $3.3 trillion of damage, showing that there is a need of higher resilience. Finally, economic losses due to cyberattacks could be considered as a good proxy of the ability of infrastructures to protect IT systems from cybercrimes. Cyberattacks led to economic losses bigger than $400 billion in 2016, showing that contemporary IT infrastructures are very much in need of resilience.

Source: The European House — Ambrosetti elaboration on CBOE, EM-DAT and CSIS data, 2018.

5. The concept of resilience refers to several intertwined aspects of the economic and environmental ecosystem:

- ***Economic system***. Resilience refers to the ability of financial networks comprised of banks and firms to recover from a financial turmoil or the capability of the system to resist to an economic crisis and to recover quickly.
- ***Energy system***. Resilience is the capability of the system to identify and isolate breakdowns, guaranteeing continuity and reducing operational costs; it refers also to the reduction of dependency from foreign providers and to lower exposure to disruptions in their infrastructures.
- ***IT infrastructure***. Resilience consists of the ability to provide an acceptable level of service in the face of faults and challenges to normal operation and to isolate breakdowns reducing damages and related costs.
- ***Mobility and water infrastructures***. Resilience consists in the ability to absorb elastic deformation, to survive to natural disasters, limiting damages and to enhance reliability of water services under critical conditions.
- ***Ecological ecosystem***. Resilience refers to the capacity of an ecosystem to respond to a perturbation or climate changes and resources depletion.
- ***Urban environment***. Resilience is the ability to resist external shocks and to reduce dependency from other territories.

FIG.3

The different aspects of the concept of resilience.
Source: The European House — Ambrosetti elaboration on various sources, 2018

6. Strictly related to the resilience notion, electrification can originate positive effects by enhancing ***energy security*** too. An increased power generation via renewables, integrating energy storage, allows to reduce the needed quantity of fossil fuels, thus reducing the geopolitical exposure. This is particularly relevant for countries like Italy characterized by a high energy import dependency (77% in 2015). Thanks to the envisioned increase of electricity share in final energy consumption, Italy could reduce its energy import dependency by ***more than 22%*** by 2050.[2]

2 Source: Politecnico di Torino and MIT "Electrify Italy", 2018.

CLIMATE CHANGE AND RESILIENCE IN THE POWER SECTOR

Short term interruptions due to extreme weather events have often seriously threatened the electricity supply in all countries, especially in the developing ones. Moreover, the increasing demand of water due to global warming and population growth is a warning for power plants activities. ***Extreme climate-related events can intensify the stress on the power system*** in several ways:

- Transmission and distribution (T&D) networks are vulnerable, unless specifically designed interventions are made, to extreme weather events like high winds, falling trees, snow and ice accumulation, temperature-related equipment failures, lightning strikes, storm surges and floods, efficiency losses and sagging of lines.
- High ambient temperatures may reduce power plant efficiency and increase demand for electricity due to a growth of cooling systems use.
- Increased flooding, extreme precipitation and storms threaten power infrastructure located in flood-prone areas.

Water is an essential source for electricity production and its scarcity could compromise the electricity supply. For example, hydropower production may be impeded by prolonged and repeated droughts or seasonal changes in water availability. Moreover, cooling thermal-electric power plants, which rely on water availability, may reduce their cooling efficiency due to higher water temperatures and result in a proportional increase in the demand for cooling water.

Source: The European House — Ambrosetti elaboration on International Energy Agency (IEA) data, 2018.

7. For all these reasons, decarbonization and resilience have become a prerogative for international and national policy makers, which are looking for tools and ways to make economies more climate-friendly, less energy-consuming and resilient. Firstly, the United Nations has included targets about resilience and sustainability within 6 out of the ***17 Sustainable Development Goals***. Through them, the UN recognizes that ending poverty must go together with strategies that build economic growth and address a range of social needs, including education, health, social protection, and job opportunities, while tackling climate change and environmental protection. Although UN policy targets are not binding, countries are expected to take action to meet these goals and to regularly present a progress report of their initiatives.

FIG.4

UN SGDs that address the issues of GHG emissions and resilience.
Source: The European House — Ambrosetti elaboration on United Nations Framework Convention on Climate Change data, 2018

8. The world has recently agreed on more challenging policy targets. An example is provided by the Paris agreement, signed in December 2015 by 195 countries which adopted a universal global climate deal. The agreement aims at keeping the uprising of the temperatures below 2°C and, if possible, below 1.5°C compared with pre-industrial levels. The agreement has come into force in 2016 and requires all Parties to put forward their best efforts through "nationally determined contributions" (NDCs). This includes the requirement that all countries meet every 5 years to set more ambitious targets and report to each other and to the public their progress towards the achievement of commitments.

9. At the European level, the European Commission has launched the EU 2030 Climate & Energy Framework, as a milestone policy of the long term low-carbon economy roadmap for 2050[3] and in response to European Union's commitment to the Paris agreement. The policy, adopted by EU leaders in 2014 and revised upward in 2018,[4] sets three strategic goals:

- at least 40% cuts in greenhouse gas emissions compared to 1990 levels;
- at least a 32% share of renewable energy in final energy consumption;
- at least a 32.5% improvement in energy efficiency.

3 The low-carbon economy roadmap suggests that by 2050, the European Union should cut GHG emissions by at least 80% compared to 1990 levels. Milestones to achieve this target are 40% emissions cut by 2030 and 60% by 2040.

4 In June 2018, the European Commission, the European Parliament, and the Council reached a political agreement on new rules for improving energy efficiency and renewables in Europe which are higher than the previous ones (27% share of renewable energy in final energy consumption and 27% improvement in energy efficiency).

FIG.5

Transposition of COP21 goal by main countries worldwide.
Source: The European House — Ambrosetti elaboration on United Nations Framework Convention on Climate (UNFCCC) Change data, 2018

United Nations Climate Change

The 2016 Paris agreement commits the **177 signatories** to keep the uprising of the temperatures below **2°C** and, if possible, below **1.5°C** as to pre-industrial levels

Signatory country	Main NDC* target
China	• Reducing carbon intensity by 60%-65% compared to the 2005 levels before 2030 • Increasing the intensity of non-fossil fuels in the primary energy consumption by 20%
United States	• Reducing by 26%-28% greenhouse gas emissions compared to 2005 levels before 2025
EU & UK	• Reducing by at least 40% greenhouse gas emissions before 2030 (vs. 1990 levels)
India	• Reducing the carbon intensity by 33%-35% compared to 2005 levels before 2030 • Reaching 40% of non-fossil electric capacity before 2030
Russia	• Reducing by 25%-30% greenhouse gas emissions before 2030 (vs. 1990 levels)
Japan	• Reducing by 26% greenhouse gas emissions before 2030 (vs. 2013 levels)

* The ratification of the COP21 implied that the climate target presented to the UN evolved from Intended Nationally Determined Contribution (INDC) to Nationally Determined Contributions (NDC). Those are the objectives that any country has decided to fix in order to contribute to keeping global warming below the 2°Celsius.

10. To achieve the 40% target, the European Commission has set specific goals for different types of sectors. Emissions Trading Systems (ETS)[5] sectors should cut emissions by ***43%*** by 2030 compared to 2005 levels while non-ETS sectors should reduce emissions by ***30%*** compared to 2005 levels. For the latter case, each Member State has to transpose this directive in national binding targets.

11. Italy has defined a national strategy (***SEN — Strategia Energetica Nazionale***) in 2017 with the aim of making the national energy system more competitive, sustainable (in line with the European Commission and COP21 targets) and safer. Some of the national targets defined by the SEN are:

- cutting at least ***40%*** of greenhouse gas emissions by 2030 from 1990 levels (transposition of the EU Directive);
- improving energy efficiency by reducing final energy consumption ***from 118 to 108 Mtoe***[6] by 2030;
- ***28%*** share of renewables in final energy consumption by 2030;
- ***eliminating coal*** as source of electricity production by 2025.

5 This system works on the 'cap and trade' principle that applies to all power stations, industrial plants and airlines operating in 31 European countries, whose emissions account for 45% of the total. A cap is set on the total amount of GHG that companies are allowed to emit every year. Within the cap, companies receive or buy emission allowances which they can trade with one other as needed. After each year a company must have the right amount of allowances that cover all its emissions, otherwise heavy fines are imposed.

6 Mtoe stands for "million of tonnes of oil equivalent". The tonne of oil equivalent (Toe) is a unit of energy defined as the amount of energy released by burning one tonne of crude oil.

THE INVESTMENTS NEEDED IN THE ELECTRICITY SECTOR TO MEET EUROPEAN POLICY TARGETS

According to the European Commission's estimations within the EU 2030 Climate & Energy Framework, the annual average level of investments needed for 2011-2030 in the electricity sector amounts up to €1,333 billion, in the GHG40/EE/RES30 scenario which is almost in line with the current EU targets. The investments requirements for grids and generation and boilers represent a small share of total investments required (between 9% and 12%), while the biggest contribution is expected to be given by investments in the transport sector (about 80% of total investments).

		Annual investment expenditure (2011-2030)		
Scenario	**2030 Target**	**Grid**	**Generation and boilers**	**Total**
Reference	• GHG[1]: -32.4% • RES[2]: 24.4% • EE[3]: -21%	€37/41 billion	€50/59 billion	€816/949 billion
GHG40	• GHG[1]: -40% • RES[2]: 26.5% • EE[3]: -25.1%	€41/56 billion	€53/85 billion	€854/1,188 billion
GHG40/EE/RE30	• GHG[1]: -40% • RES[2]: 30% • EE[3]: -30%	€40/47 billion	€55/72 billion	€879/1,333 billion

(1) Greenhouse gas emission (GHG) reductions compared to 1990.
(2) Share of renewable energy sources (RES) in final energy consumption.
(3) Energy Efficiency (EE): primary energy savings compared to Baseline 2007.

Source: The European House — Ambrosetti elaboration on European Commission data, 2018.

1.1.2. The electric carrier will play a key role for the achievement of decarbonization and resilience goals

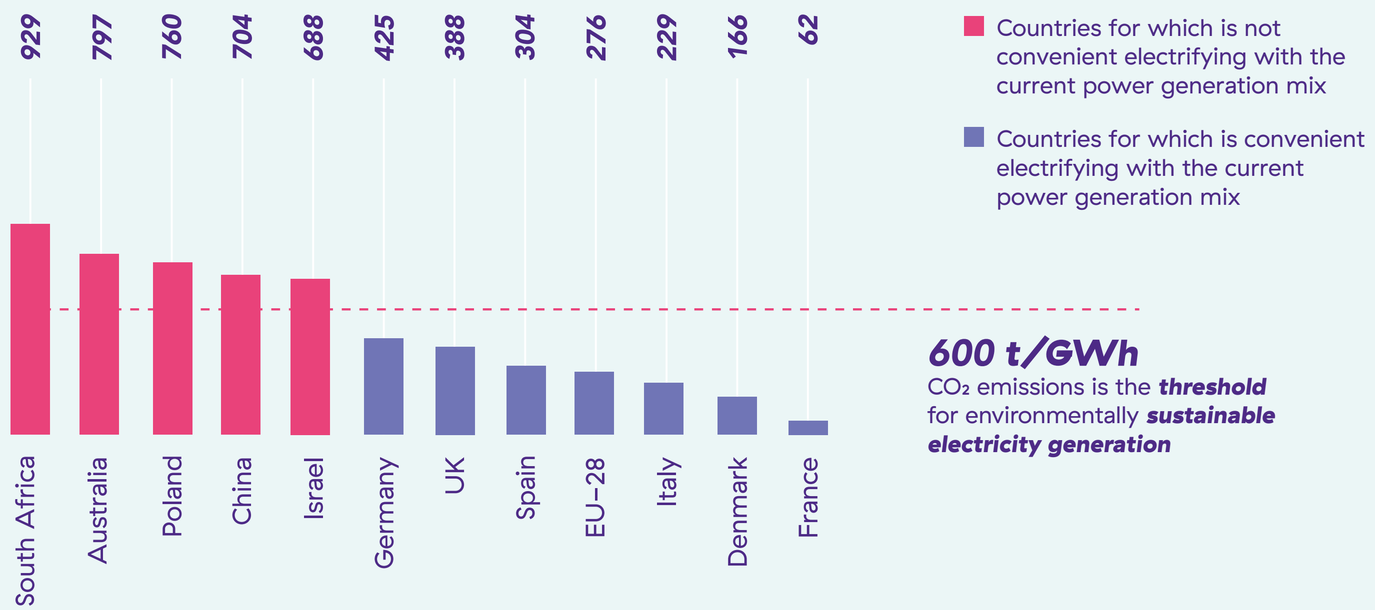
12. Electricity used as a source of final energy consumption has a great potential since it helps to meet international policy goals about decarbonization and resilience. Firstly, the electric carrier offers a relevant contribution to ***reduce CO_2 emissions*** when the electricity generation mix is balanced towards renewables. For the largest economies worldwide, the convenience to increase the share of electricity in final energy consumption has been evaluated. In order to do so, scientific literature on the importance of a balanced energy mix in electricity generation for future sustainability has been reviewed[7] and all the analyses have been validated by the electric engineers affiliated to Department of Engineering, ICT and Technologies for Energy and Transport of the National Research Council — CNR. The results of the analysis show that the threshold for environmentally sustainable electricity generation, based on experimental research on technology substitution[8], is equal to ***600 t/GWh CO_2 emissions*** meaning that:

- countries below this threshold can fully exploit the environmental benefits of electrification by increasing their electricity production;
- countries above the threshold need to preliminary rebalance their electricity generation mixes and then increase their electricity production to have a sustainable electrification.

7 See bibliography for detailed references.
8 For example, replacing diesel and gasoline automobiles in Europe and North America, respectively, with equivalent electric vehicles and the potential use of ground-source heat pumps in Canadian cities.

FIG.6

CO_2 emission from electricity production (t/GWh), 2014.
Source: The European House — Ambrosetti elaboration on C. Kennedy "Key threshold for electricity emissions", European Environment Agency (EEA) and Organization for Economic Cooperation and Development (OECD) data, 2018



N.B. Estimates provided by ISPRA for the Italian case foresees 325 t/GWh CO_2 emissions for gross electricity generation and 220 t/GWh CO_2 emissions for heat production in 2017.

13. In addition to this, the electric carrier allows for higher levels of ***energy efficiency*** thus reducing the energy needs and the related GHG emissions. Electric technologies, compared to traditional ones, are able to guarantee higher levels of energy efficiency than their traditional counterparts (see Part 3.2. dedicated to the efficiency gains that can be obtained from end-use electric technologies):

- heat pumps allow for ***up to 50%*** reduction in energy use compared to other heating and cooling systems[9];
- LED lamps are ***over 50%*** and ***80%*** more efficient than standard filament lamps, respectively in public[10] and residential lighting;
- electric drives for e-Cars are ***40%*** more efficient compared to combustion engines while an inverter applied to the electric drives in industry can engender a ***25%*** energy save;
- lithium ion batteries have an energy efficiency ***12%*** higher than alternative electrochemical storage systems.[11]

14. ***Digitalization***, when combined with the electric carrier, enables a further CO_2 reduction via a more effective consumption management in transport, buildings and industry, as well as a higher overall efficiency in the power sector. Indeed, digitalization in the power sector allows to collect digital data about the state and performance of power sector assets, to process the information and, ultimately, influence real-time actions. This, in turn, avoids excessive stress on the system and leads to improved efficiency and lower costs from power generation to utilization. Digital data and analytics can reduce power system costs and generates positive spill overs in at least four ways:

- ***Reducing Operation and Maintenance (O&M) costs***. Predictive maintenance can lower costs for the owner of plants and networks and consequently the price for final consumers.
- ***Improving power plant and network efficiency***. Digitalization allows for improving planning and efficiency of combustion in power plants, lowering loss rates in networks and leading to greater efficiencies as a result. Moreover, reducing losses in the supply of energy allows also for CO_2 reduction.
- ***Reducing unplanned outages and downtimes***. Better monitoring and predictive maintenance can reduce the frequency of unplanned outages and limit the duration of downtimes resulting in lower costs and more resilience for the system.
- ***Extending the operational lifetime of assets***. Improving maintenance and reducing the physical stresses on the equipment is likely to increase the operational lifetime of assets resulting in a greater stability and greater cost saving for owners.

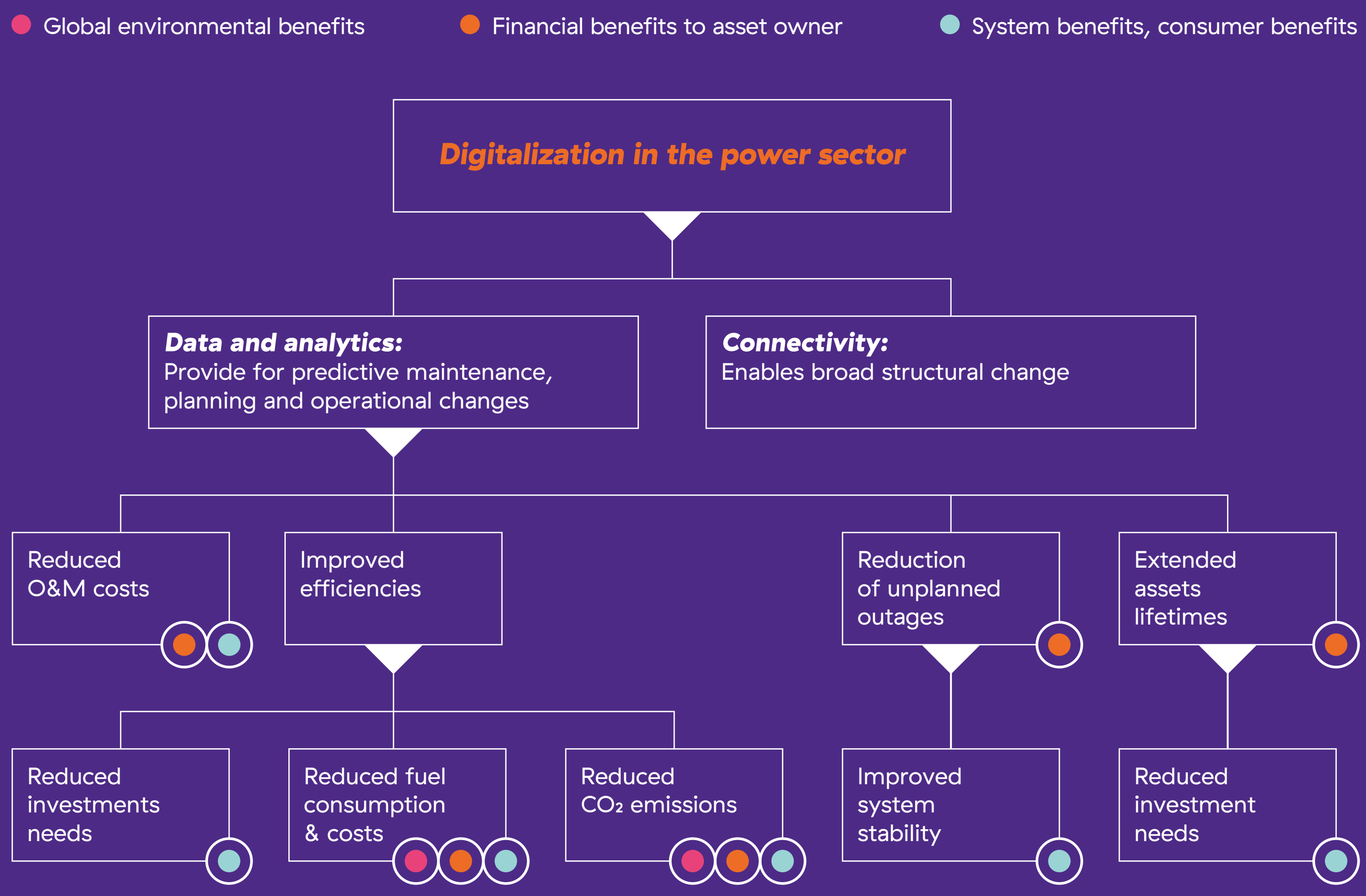
THERE ARE "VIRTUOUS" AND "VICIOUS" COUNTRIES IN TERMS OF ELECTRICITY GENERATION MIXES IN EUROPE

Among the European countries, there are several differences in terms of electricity generation mix. France produces the 76.7% of national electricity through nuclear plants, while Germany still relies on coal for the 42.1% of its mix. Italy is one of the most "virtuous" countries in Europe with regard to renewables, that have reached 39% of share in electricity generation mix, contributing to the achievement of renewable target before the policy 2020 deadline. ***Poland*** has the most polluting system since ***78.2%*** of electricity is generated with coal while ***Denmark*** is the cleanest country in Europe, with a share of renewables of ***60.5%***.

9 For heating and cooling systems, the substitution of traditional gas boilers and air-conditioner was considered.
10 Adaptive lighting can further increase efficiency of public lighting by 10% or even 30% in main roads.
11 Efficiency gain is referred to Sodium Nickel Chloride, for lead-acid, sodium sulphur, redox flow is also higher.

FIG.7

Positive effects of digitalization in the power sector.
Source: The European House — Ambrosetti elaboration on International Energy Agency (IEA) and various sources, 2018



15. Digitalization plays also a pivotal role in the ***transition from centralized to decentralized electricity production*** which in turn is able to increase power system resilience. Digitalization, indeed, has both a technical impact in enabling the decentralized production, through improvements in the management of transmission and distribution of electricity, and social impacts. These latter ones are related to the activation of technologies changing the consumer habits especially in urban areas (meaning that digitalization enables new paradigms such as the smart city and the relative changes in mobility and infrastructures)[12]. Centralized generation and one-way distribution of electricity make the power system less resilient to external events. Indeed, they can generate widespread disruptions due to extreme weather conditions as well as potential terrorist attacks and they are characterized by a high level of dependency from foreign suppliers and exposition to their disruptions. Moreover, a centralized generation system runs the risk of supply interruption, planned or unplanned, during demand peaks, due to over demand in respect to the infrastructure's capacity. The decentralized and digitalized power system can overcome these risks and generate positive spill overs for users. Indeed, a decentralized system utilizes smart sensors to monitor the functioning of the grid, permitting to prevent disruptions and breakdowns and to intervene rapidly in fixing them. Moreover, by utilizing electricity storage systems, it can ensure continuity of electricity provision in case of disruptions and it can enhance the development of

12 Source: Politecnico di Torino and MIT "Electrify Italy", 2018.

renewables sources, able to reduce dependency on foreign providers and exposure to disruptions in their infrastructures. Finally, smart meters identify demand peaks and connect to the grid when demand is low, reducing pressure on the infrastructure.

16. The electric carrier, thanks to its intrinsic features of versatility and efficiency, offers several opportunities to ***improve resilience of the overall energy system***. The electric vector can contribute to the resilience of the overall system through:

- ***renewable sources*** which allow for higher diversity of primary energy supply and generation mix, reducing the dependency from a single source. They can also lower the pressure on the grid and guarantee the ability to localize, providing a greater energy independence that protects systems from disruptions and blackouts;
- ***electricity storage systems***, which ensure the continuity of supply in the event of breakdowns, allow for a deeper penetration of renewable sources and make the overall system more flexible;
- ***electricity technologies*** that are more efficient than technologies powered by other fuels (see part 3.2.), allowing for a lower energy intensity and thus to lower energy supply and less vulnerability of the systems;
- ***network digitalization and smart management systems*** that permit a better management of power flows and to prevent disruptions thanks to the collection and analysis of big data, allowing for real-time interventions and predictive maintenance. These technologies are thus able to guarantee higher flexibility of the system, lower pressure on the grid and a faster capacity of intervention.

17. In light of the current energy transition trends, the role of Distribution System Operators (DSOs) is of increasingly importance. A relevant part of the new trend in the electricity industry is taking place within the distribution network, as well as the continuous technological innovation and the strong increase in both electrification and number of connected renewable power plants and storage systems. In this context, DSOs are fundamental players in supporting the energy transition while guaranteeing service continuity, quality of supply and the safety of the electricity system at the low and medium voltage level.

18. This scenario calls upon the DSO for an increased investment on its own network, with commitments to cope with the integration of an ever-increasing amount of renewables, the spread of an extensive network of charging infrastructure for electric vehicles and a higher share of electricity in final-user consumption.

19. To accomplish with these growing responsibilities, DSOs are investing in the digital transformation of former "fit & forget" networks through the implementation of intelligent technologies for remote control, network automation, monitoring of energy flows and metering. Thanks to this, their role of "neutral market facilitator" is even of upmost importance in fostering the integration of diffused energy resources and enabling the introduction of new models able to involve more actively the end-users in the management of the energy system, both through increased awareness and participation to the supply of network services (active demand response).

20. These innovative sources of services could be effective and efficient solutions to the challenges posed by the energy transition to network operators at all levels, so that DSOs seek to a more active role in the exploitation of such resources. In this context, it shall be pivotal to establish new cooperation models among network operators, in line with their own mission to pursuit integrated operations and cope with both cogent congestion management and long-term network development plans. In this aim, a coordinated and evolved dispatching market mechanism, allowing to acquire the resources needed to respond to transmission and distribution respective needs, will need to be devised with the aim of closely converging towards an overall "optimal system status" while guaranteeing the indispensable levels of security and quality of service at all levels of the network.

21. To this aim, while debate among stakeholders is currently ongoing, regulatory frameworks are evolving at the European and national level and institutional interlocutors will be claimed to define rules and responsibilities related to the coordination between the various network operators. The Clean Energy Package's proposal, that allow distributors to procure ancillary services with the aim of increasing efficiency in operations, will need to consider ways to coordinate properly local and system needs.

22. In this context, the regulatory framework will need to govern the range of flexibility services and the ways these are procured. Furthermore, a strong coordination and the exchange of information between network operators in the most efficient way will need to be pursued and exploited. It is not the aim of this study to deepen and propose technical, regulatory and operational solutions of future dispatching system, that will need to be settled at proper institutional level and would require an appropriate ad-hoc study.

23. There is an ongoing discussion at the European level and the direction that is emerging is that, as a first step toward full coordination, DSOs' and TSOs' supervision and coordination of the effects of the activation of flexibility resources connected to the distribution grid shall be reinforced. This entails the use of such resources also for local needs in order to avoid inefficient duplication of monitoring and control infrastructures, while guaranteeing the necessary security and quality of supply on medium and low voltage network.[13]

13 See Art. 32 of the (Proposal for a) Directive of the European Parliament and of the Council on "Common rules for the internal market in electricity".

1.2.

The electric carrier allows for innovation in lifestyles and industrial processes

24. All the aforementioned characteristics of the electric carrier allow for ***innovation in lifestyle and industrial processes***. Concerning the former, indeed, there are a few societal megatrends among which the electric carrier actively contributes to fostering innovation and boosting changes in consumer habits. In turn, innovation in industrial processes enabled by the electric carrier primarily concerns the adoption of electricity-driven technologies in energy intensive industries. In both fields, innovation brought about by the electric carrier has a positive impact on the overall sustainability.

FIG.8

Innovation fields enabled by the electric carrier.
Source: The European House — Ambrosetti elaboration, 2018

The ***electric carrier***, via an increase in the electricity share in final energy consumption, allows for ***innovation*** in consumer habits and industrial processes

a. *Societal megatrends*

- Ageing society and silver economy
- Urbanization
- Sharing economy
- Smart mobility
- Energy efficiency
- Circular economy

b. *Industrial processes*

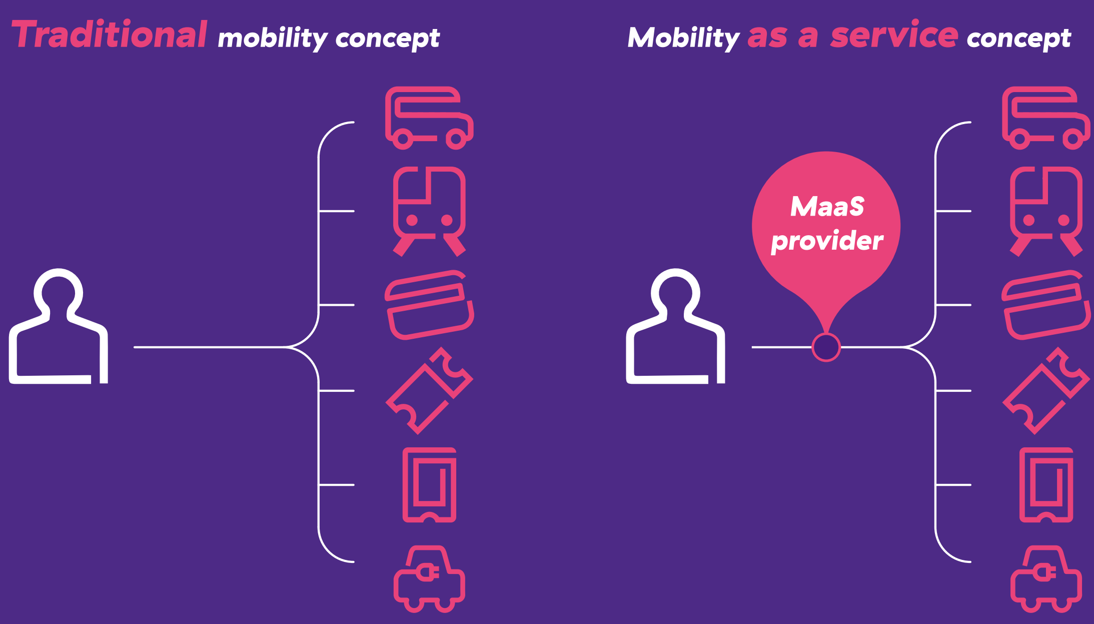
- Agrifood
- Ceramics
- Chemical industry
- Glass
- Machinery
- Paper
- Plastics
- Steel and aluminium
- Textile

25. In all the societal megatrends here individuated, the electric carrier is a contributor of the ongoing changes in consumers' habits and lifestyles. This is primarily occurring because of the intrinsic efficiency of several electricity-driven technologies and the better fit between the electric carrier and digital technologies.
26. Starting with the ***ageing society and silver economy***, the European Commission has estimated the value of the so-called silver economy being ***€3.7 trillion***[14] already in 2015. The electric carrier can contribute to its further development by propelling safer and more connected vehicles than the traditional ones and therefore enhancing fruition even by the eldest component of the population. This is especially sensitive in the Italian case where 22% of the current population has more than 65 years, placing Italy in the first position among all the EU countries. An additional point of innovation driven by electricity concerns the flexibility in energy management, allowing for an optimization of the energy use that fits the necessities of this component of the population.
27. ***Urbanization*** is a powerful global trend as the world population living in urban areas has overcome the rural one already in 2008. In mature economies, where the proportion of people living in urban areas is even larger (e.g. 69% in Italy and 75% in the EU28), urbanization engenders issues related to soil consumption and urban density making urban logistics and mobility more complex. In this regard, the electric carrier can contribute to improving traffic management through dedicated lanes and access to restricted driving zone for both electric cars and electric Light Commercial Vehicles (LCVs), as well as an improved air quality.
28. The spread of ***sharing economy*** platforms is another powerful driver of change in consumer habits and the electric carrier is better fitting them; for instance, a positive impact of the electric vector on sharing mobility can be individuated in the lower maintenance costs of electric vehicles. Thus, the spread of electric vehicles — having full access to the restricted driving zones — in public and corporate fleets can contribute to reduce individual car ownership.
29. The mobility field is arguably the one where the electric carrier has the highest potential to stimulate changes in lifestyles and a key component into it is the ***smart mobility.*** Urban mobility, indeed, is evolving towards increased inter-modality implying a better — and more efficient — combination of transport modes both on the collective side (bus, metro, trolley buses, etc.) and on the private one (cars, mopeds, etc.). A few cities have already reached a combination in which sustainable modes cover more than a half of urban travels. For instance, in Paris almost 70% of the urban trips are made via public transport or walking and cycling. In the urban mobility evolution, the electric carrier deploys its effect to the electrically powered public transport, in which e-buses are steadily growing and both metro and trolley buses are a constant feature. In addition to that, a turning point in the development of the so-called smart mobility is the growth of ***Mobility as a Service platforms***, integrating all the mobility functions (such as travel planning, ticketing, live monitoring etc.) in a single access point and reshaping the way in which citizens can rely upon different mobility services.

14 The silver economy as postulated by the European Commission comprises all the economic activities related to the ageing population (services, new products etc.) that can increasingly provide economic growth and jobs in the next decades. In the EU-28 already 19% of the population is aged 65+, a percentage estimated to grow to 28% by 2050.

FIG.9

The smart mobility paradigm enabled by the rise of Mobility as a Service.
Source: The European House — Ambrosetti elaboration, 2018



30. A further trend capable of triggering innovation in lifestyles is the increasing attention that consumers and industry are paying to ***energy efficiency***. This trend is therefore driven by both an increased awareness of the environmental effects of their consumption choices and the economic gains that can be associated to energetic efficient solution. In this field, the electricity-driven technologies — allowing a better calibrated regulation of the energy consumption — are a fundamental tool. For instance, in the new buildings those technologies do not only have a positive effect in regulating heating and cooling, but they are also a constitutive part of the so-called ***Nearly-Zero Emissions Buildings*** (***NZEB***).[15] Those buildings are characterized by an almost zero net energy consumption, meaning the total amount of energy used on an annual basis is roughly equal to the amount of renewable energy they create. To make this possible, a fundamental role is played by electricity powered energy management systems.

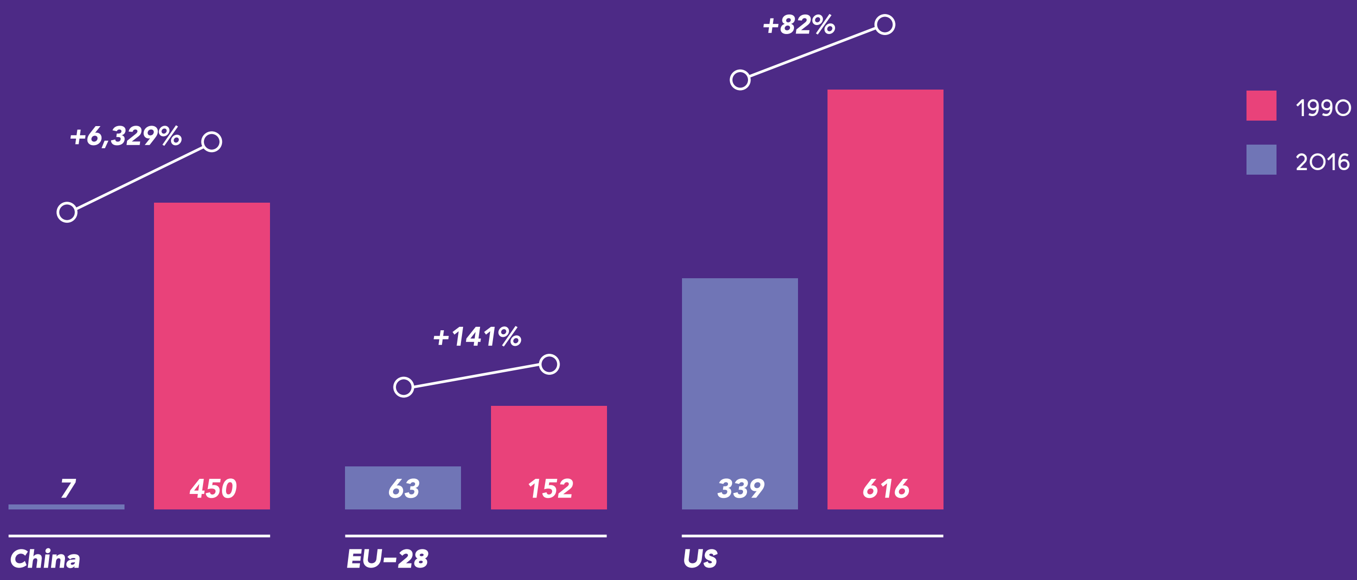
15 The EU Energy Performance of Buildings Directive (EPBD) requires all new buildings to be nearly zero-energy by the end of 2020; the term is anticipated to 2018 for new public buildings. The definition of the NZEB requirements is left to Member States.

BOOSTING ENERGY EFFICIENCY: THE ELECTRICITY ROLE IN SPACE COOLING

Concerning buildings and their energy consumption, there is a specific field in which electric technologies can play a critical role in promoting energy efficiency: ***space cooling***. On average, ***almost a fifth*** of all the electricity used in buildings is for cooling. Unlike heating technologies, in which diversity among countries is notable and where the share of electricity, natural gas or fuel oil powered systems varies, ***cooling is almost completely powered by electricity***. The share of natural gas, used almost entirely for thermally driven chillers or systems in commercial buildings, was limited to a share of about 1% in 2016. Yet, global sales of air conditioning (AC) systems have been growing steadily in the last decades: since 1990, annual sales of AC systems more than tripled to 135 million units per year. Most of them are packaged and split-systems for residential and smaller commercial buildings and about 53 million new units are sold each year in China alone (among which 41 million are in the residential sector). As a result of these trends, there are currently ***1.6 billion AC systems in use***, and over half are located in just two countries: China and the US. The hugest growth in the next years is expected to come from the emerging economies, with just three countries — India, China and Indonesia — contributing to half of global cooling energy demand that is forecast at the moment. Further, installed AC systems vary remarkably in energy efficiency and keeping them running consumes globally ***over 2,000 terawatt hours (TWh) of electricity per-year***, corresponding to roughly two and a half times the total electricity use in Africa. In this regard, new electric technologies (mostly heat pumps but also efficient energy management systems) allow to optimize energy consumption and foster a more environmentally sustainable consumers' behaviour.

FIG.10

Electricity consumption for space cooling in building (TW/h), 1990-2016.
Source: The European House — Ambrosetti elaboration on International Energy Agency (IEA) data, 2018



31. The last societal megatrend here considered is the spreading of the ***circular economy***. Even if the contribution of the electric carrier in this regard is still less defined than the previously mentioned ones, it has to be emphasised that electricity is an important factor in the maximization of the existing resources constituting the cornerstone of the circular economy paradigm. In other terms, according to the new consumption and production paradigms introduced by the circular economy, electricity is both a cost saving option for power distribution and an enabling factor behind the growth of renewables.

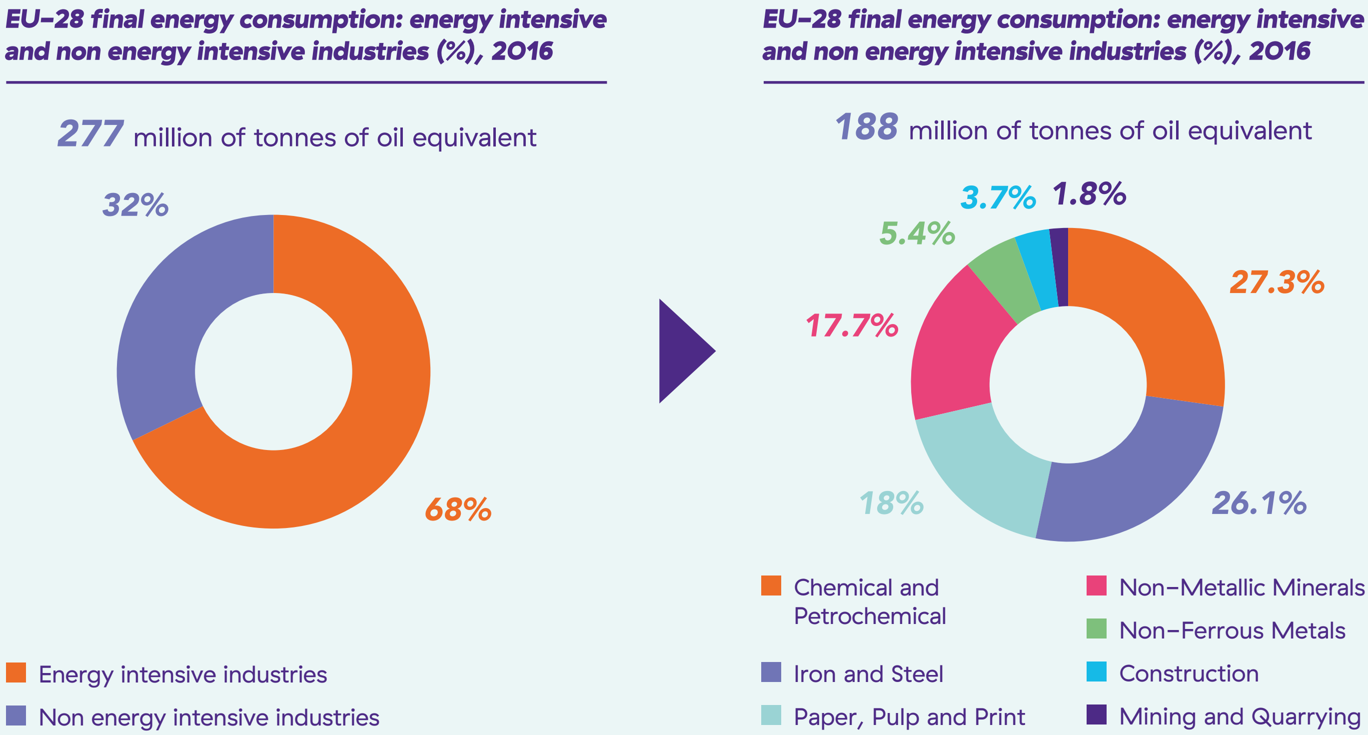
32. The other field in which the electric carrier is a powerful driver of innovation concerns the industrial sector among which the most promising field for electrification is ***industrial processes***, meaning the adoption of electricity-driven technologies having the potential to improving product quality, reducing energy costs, and increasing sustainability. In other words, innovation in industrial process is spurred by these three drivers in which electricity plays a remarkable role and that can be summarized as follows:

- ***improved product quality***. Electricity is an energy source extremely precise allowing to minimize energy waste and reaching the most efficient energy use. In other terms, an electricity-driven process allows to instantly adjust energy inputs according to varying conditions and therefore reducing energy waste;
- ***cost reduction***. Costs savings in industry are not limited to the reduced energy waste stemming from more precise processes but additional ones are related to the technologies supporting indirect electrification (i.e. power to hydrogen, power to fuel, etc.) reducing amount and cost of industrial inputs. Furthermore, cost reduction is obtained also via an increased productivity originating from electric technologies. For instance, allowing to reach higher temperature in a shorter time-span, electric technologies enable an increase in the hourly production of furnaces.
- ***sustainability***. Technologies supporting electrification — when substituting gas or fossil fuels ones — contribute to reduce the emissions, making easier to reach the Emissions Trading System (ETS) targets set at the EU level for the different industrial sectors. Moreover, by reducing material losses and energy waste, electricity improves the economic footprint of the industries.

33. The array of benefits depicted beforehand makes the case for energy intensive industries being the ones most affected by the innovation opportunities opened up by the electric carrier. Iron and steel, non-ferrous metals, chemical and petrochemical, non-metallic minerals, mining and quarrying, paper, construction are typically referred as energy intensive industries and account for ***67.9%*** of the industrial final energy consumption in Europe.

FIG.11

Final Energy Consumption share across the EU-28 industrial sectors.
Source: The European House — Ambrosetti elaboration on Eurostat data, 2018



34. The chemical and petrochemical industry, accounting for the largest component of the industrial final energy consumption in the EU28, offers a straightforward example of innovation driven by an increased relevance of the electric carrier in the final energy consumption. Further, at the global level, the chemicals and petrochemicals sector's share of global final energy consumption has grown from roughly 6% to 10% over the last four decades, so that it is currently the largest industrial energy user, accounting for almost ***30%*** of industrial final energy consumption[16]. An increasing proportion of that energy input (58% in 2014) is used as feedstock, implying this sector's growing prominence and an increase in process energy efficiency in which electric technologies have a notable role.

35. The innovation driven by electricity in the chemical industry, indeed, is going beyond the substitution of the existing pumps and valves with more technologically advanced electrical ones and affects a few types of industrial processes of the industry such as:

- ***power to heat***: the use of electricity to either directly produce heat or upgrade sources of waste heat to useable temperature levels;
- ***power to hydrogen***: the use of electricity to produce hydrogen through the electrolysis of water;
- ***power to specialties***: the direct electrochemical synthesis of high value fine and specialty chemical intermediates and products using conventional and biomass-derived feedstocks;
- ***power to commodities***: the direct electrochemical synthesis of large volume commodity chemicals using conventional and sustainable feedstocks, such as CO_2.

36. All these types of industrial processes specific to the chemical industry can be coupled with the drivers of innovation in which the electricity allegedly has a remarkable role that were described beforehand.

ELECTRIFICATION OF THE CHEMICAL INDUSTRY IN THE NETHERLANDS: THE VOLTACHEM PLATFORM

VoltaChem is a Shared Innovation Program set up in the Netherlands connecting several Dutch applied research centres (TU Delf, the Netherlands Organisation for Applied Scientific Research, the Energy Research Centre of the Netherlands, Twente University), the electricity and power sector (Aramco, Shell) and the chemical industry (Dow, Johnson Mattheys, Solvay, Umicore, Vopak). The overall aim is a ***joint strategy for the electrification of the chemical industry***, individuated as a key element to support the competitive position of the entire Dutch supply chain. The new technologies that are developed and implemented within the VoltaChem platform primarily focus on the conversion of renewable energy to heat, hydrogen and chemicals.

Source: The European House – Ambrosetti elaboration on VoltaChem data, 2018.

16 Source: International Energy Agency report "Energy Technology Perspective", 2017.

FIG.12

Type of Industrial processes of the chemical industry affected by the electric carrier and relative driver of innovation behind them.

Source: The European House — Ambrosetti elaboration on VoltaChem — TNO data, 2018

Type of processes	Key driver of innovation
Power-2-Heat: (heat pumps, Electric boiler, Electrode boiler)	Cost reduction, sustainability
Power-2-Hydrogen: Electrolysis	Sustainability
Power-2-Specialties: Electro synthesis, Electrolysis	Cost reduction, new products
Power-2-Commodities: Electro synthesis, Plasma polymerisation	Cost reduction, sustainability

37. On a smaller scale, in terms of energy consumption, another example of innovation driven by the electric carrier can be the ***ceramic industry*** in which electricity-driven technologies constitute an efficient choice to replace gas-driven ones in drying and cooking processes. In the Italian context, indeed, the Ceramic tiles and refractory materials production accounts for 1,500 mm^3 of natural gas per year. The yearly need of electricity accounts for 1,800 GW/h, among which only 500 GW/h are produced by cogeneration and overall energy impacts for 20% of the production costs[17]. The drying and cooking phase processes are technically possible to be electrified by substituting natural gas ovens with electricity powered ones (mostly through microwaves ovens and resistance heating), so that the overall energy efficiency of the process can be improved ***up to one third***. Microwave ovens, indeed, reduce both the thermical stress and the energy waste and improve the quality of the final products, through a higher precision in the production phases.

17 Source: Confindustria Ceramica, 2018.

1.3.

The electric carrier helps to reduce the human development footprint

38. Daily human activities can directly or indirectly cause negative externalities on environment and the overall ecosystem. Population worldwide is growing, and this is considered as a threat to the entire biosphere, because it forces the environment to fit the increasing number of human needs. To describe the human development footprint and to provide suggestions on how to reduce it, negative externalities from human development have been mapped and the role of electric carrier in reducing these effects has been assessed.

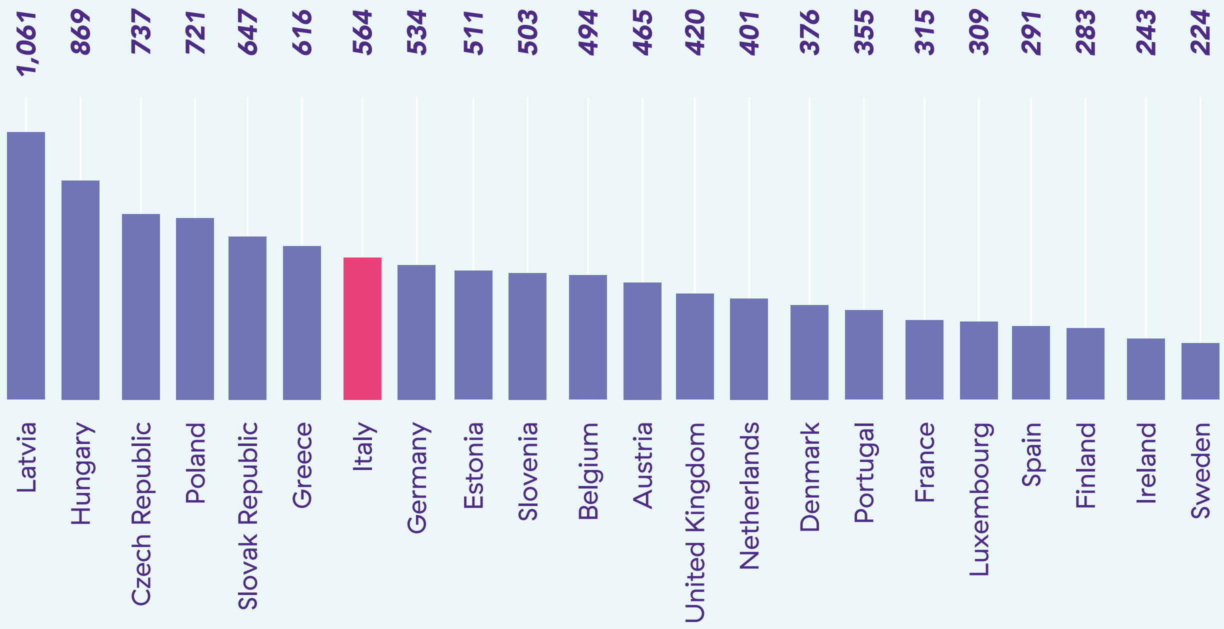
1.3.1. Human development can generate negative externalities on the ecosystem

39. ***Air pollution*** comes from different sources, like burning of fossil fuels in electricity generation, transport, industry and buildings, agriculture and waste management, and is recognized to harm human health and the environment. Although in Europe emissions have decreased in the last years, air pollutant concentrations are still too high in some areas. Around ***90%*** of city dwellers in the EU (***70%*** in Italy) are exposed to pollutants (O_3 and PM_{10}) at concentrations higher than the acceptable threshold for health. Particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2) and ground-level ozone (O_3), are now generally recognized as the three pollutants that most significantly affect human health. In Europe, premature deaths from ambient particular matter pollution alone can be estimated at ***497 per 1 million inhabitants*** in 2016 (***564 per 1 million inhabitants*** in Italy in the same year), generating a cost of ***$787.2 billion*** (***$116 billion*** only in Italy) estimated as the of cost of mortality, morbidities and impacts on the environment, animal and plant health.

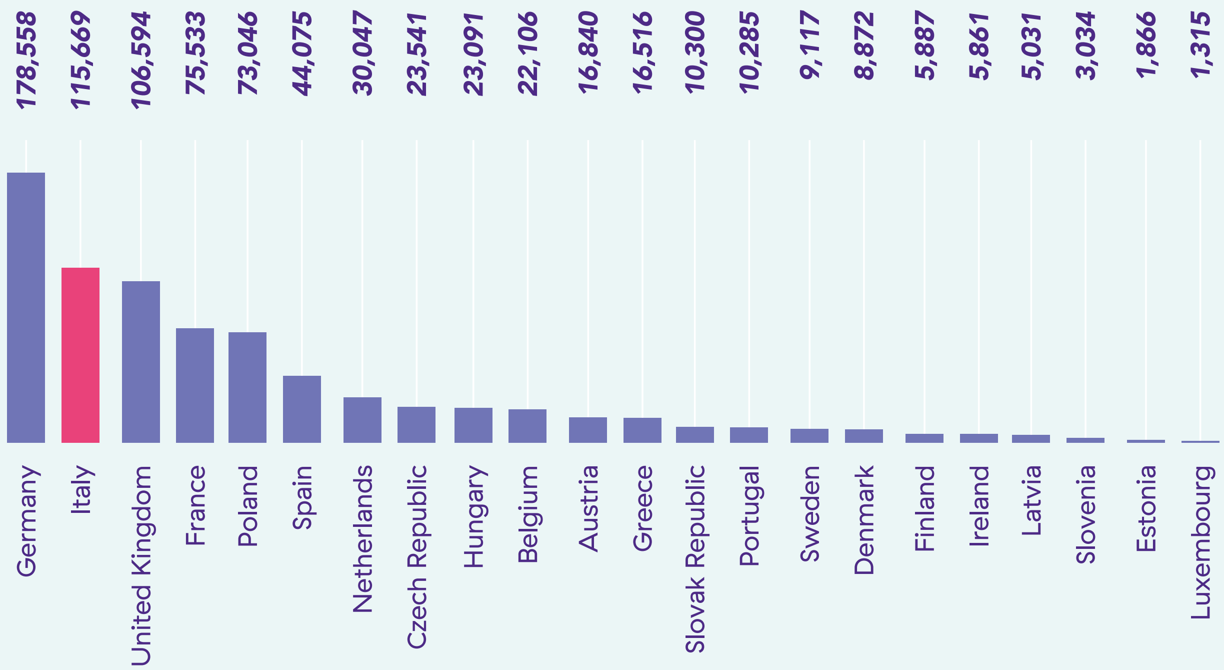
FIG.13

Premature deaths from ambient particular matter pollution and their cost in European OECD countries.
Source: The European House — Ambrosetti elaboration on Global Burden of Disease (GBD) and Organization for Economic Cooperation and Development (OECD) data, 2018

Premature deaths from APMP* per 1 million inhabitants, 2016



Cost of premature deaths from APMP* (million $), 2016



** Ambient particular matter pollution.*

40. Climate change is affecting people's lives across Europe. The increasing intensity and frequency of rainfall in many parts of Europe will lead to more serious and frequent flooding events in the future. Elsewhere in Europe, especially in Southern countries, high temperatures reduce rainfall and increase the probability to face droughts, compromising some types of crops and allowing alien invasive species that may carry new diseases. These phenomena can cause a range of natural disasters with severe effects on humans and infrastructures: in Europe there was a loss of ***$436.1 billion*** over the period 1980-2016 from climate-related extremes (***$61.2 billion*** in Italy over the same period). Moreover, heat waves and extreme cold spells are associated with decreases in general population well-being and with increases in mortality and morbidity, especially in vulnerable sectors of the population. The frequency of extreme heat has substantially increased across Europe in recent decades. Heat waves have caused tens of thousands of premature deaths in Europe since 2000 and it has been estimated that heat-related mortality in Europe will increase by ***between 60,000 and 165,000 deaths per year*** by the 2080s compared to the current baseline, with the highest impacts in southern Europe, especially Italy, Spain and Greece.

THE 2003 EUROPEAN HEAT WAVE

The 2003 European heat wave led to the hottest summer on record in Europe since at least 1540. The heat wave generated a health crisis and a crop shortfall due to a severe drought that hit all of Europe. The hottest months were July and August that recorded prolonged periods with temperatures higher than 40°C. This event was a clear example of the effects that extreme temperatures can have on human health: ***70,000*** people died due to high temperatures, 14,800 of whom in France only.

Source: The European House — Ambrosetti elaboration on European Environment Agency (EEA) data, 2018.

FIG.14

Economic losses from climate-related extremes over the period 1980-2016 in EU-28 countries (number of fatalities and economic loss).
Source: The European House — Ambrosetti elaboration on European Environment Agency data, 2018

N°	Countries	Fatalities	Loss (€ million)
1	France	23,404	60,043
2	Italy	20,629	61,778
3	Spain	14,602	34,458
4	Germany	9,829	92,144
5	United Kingdom	3,533	52,734
6	Portugal	2,995	6,102
7	Greece	2,405	7,168
8	Belgium	2,165	4,131
9	Netherlands	1,728	7,961
10	Romania	1,301	10,729
11	Poland	1,187	13,730
12	Croatia	721	2,744
13	Hungary	703	5,767
14	Austria	590	12,726
15	Slovenia	241	1,630
16	Czech Rep.	207	10,014
17	Bulgaria	192	2,414
18	Luxembourg	130	702
19	Slovakia	104	1,635
20	Latvia	92	356
21	Cyprus	75	390
22	Lithuania	69	933
23	Ireland	66	3,889
24	Sweden	44	4,242
25	Denmark	42	9,949
26	Estonia	9	103
27	Malta	7	61
28	Finland	4	1,873

41. As long as human activities release greenhouse gases into the atmosphere, ***ozone depletion*** will continue to worsen.[18] Ozone layer and hole have generated concern about the risk to contract skin cancer, sunburn and cataracts since humans are less protected from UVB wavelengths of ultraviolet light (UV light) passing through the Earth's atmosphere. It has indeed estimated that European population living at around 45 degrees North (Piemonte and Lombardia in Italy, Aquitaine and Provence-Alpes-Côte d'Azur in France, etc.) can experience, by 2050, an approximate ***5%*** rise in total skin cancer incidence due to ozone depletion.

42. Pollution caused by human activities is not only related to atmosphere but also to soil contamination, caused by the presence of chemicals or other alteration. There may be as many as ***2.5 million*** potentially contaminated sites across Europe today, which need to be investigated. Of these, approximately ***14%*** (340,000 sites) are expected to be contaminated and likely to require remediation with an estimated managing cost of ***€6.5 billion*** per year. Municipal and industrial waste disposal and treatment causes around a third of Europe's soil contamination problem and the most frequent contaminants are mineral oils and heavy metals. Soil contamination can generate negative effects on human health through accidental soil ingestion (for example children playing outside or adults that do not properly wash fruits and vegetables), inhalation (especially for workers in agriculture), skin contact and indirect contact (for example through contaminated drinking water).

43. Water is a precious resource for the environment and human activities put it under threat both in term of its contamination and its overconsumption. Water pollution refers to the spreading of harmful substances such as oil, plastic, industrial and agriculture waste and chemical particles into water bodies like lakes, rivers, oceans, aquifers and groundwater. In the Pacific Ocean alone there are more than ***1.8 trillion*** pieces of plastic that weigh almost 80,000 tons. On a smaller scale, contaminated water can be used also for drinking, bathing or irrigation leading to human deaths and diseases. In Europe, more than half of the surface water bodies are in less than good ecological status. Finally water scarcity is another water-related issue that inflicts our society nowadays. Indeed, freshwater (utilized for drinking, bathing and irrigating) is quite rare. Only ***3%*** of the world's water is fresh water, and two-thirds of that is tucked away in frozen glaciers or otherwise unavailable for our use. As a result, some ***1.1 billion*** people worldwide lack access to water, and a total of ***2.7 billion*** find water scarce for at least one month of the year.

THE GLOBAL SOIL PARTNERSHIP

The Global Soil Partnership for Food Security and Climate Change Mitigation and Adaptation (GSP) was launched by the Food and Agriculture Organization (FAO) of the United Nations in Rome on September 7, 2011, with the aim of implementing the guidelines of the 1982 World Soil Charter, which called for commitment by governments, international organizations and land users to ***manage the land for long-term advantage rather than short-term expediency***. The GSP brings together international, regional and national organizations that are working in the area of soil protection and sustainable management and wants to raise awareness among them on the importance of soils for food security and climate change adaptation and mitigation.

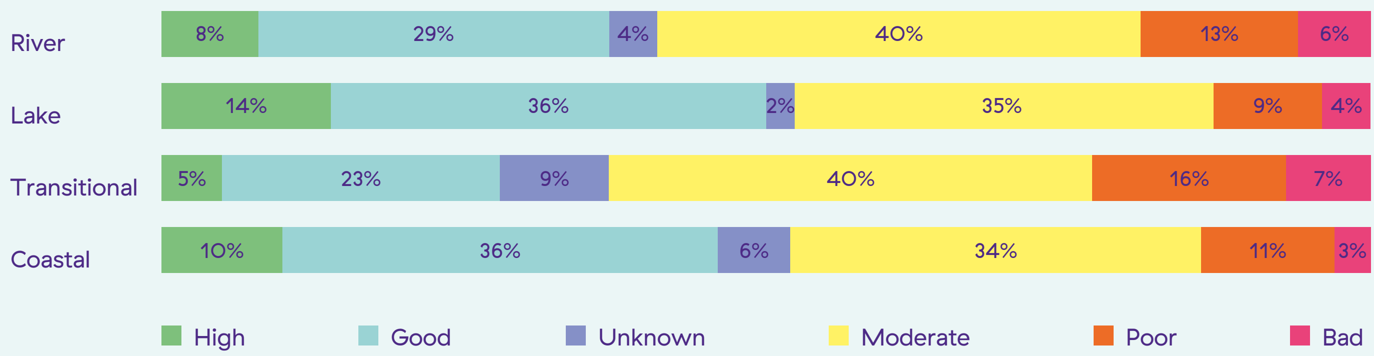
Source: The European House — Ambrosetti elaboration on FAO data, 2018.

18 In particular, the main ozone-depleting substances (ODSs) are chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). Source: United States Environmental Protection Agency, 2018.

FIG.15

Ecological status of surface water bodies in Europe (percentage values).

Source: The European House — Ambrosetti elaboration on European Environment Agency (EEA) data, 2018



44. Noise pollution is a growing environmental concern and it is generated by several sources like road and railways transport, airport and industrial processes. Most of outdoor noise comes from urban contexts, since road traffic is the first source of this disturbance[19] affecting almost ***125*** million people, one in four Europeans. Due to environmental noise, almost 20 million people are annoyed and at least 8 million people suffer sleep disturbance in Europe. However, noise pollution can lead also to more serious effects: it causes ***43,000*** hospital admissions and ***10,000*** premature deaths per year in Europe since it roots to hypertension and cardiovascular diseases.

45. The expansion of residential areas and construction sites is the first cause of land take in Europe. Agriculture zones, forests and natural areas are disappearing in favor of the development of artificial surfaces. Between 2006 and 2012, the annual land take was approximately 107,000 ha/year in the European countries. Looking at the cumulative result over the period, an average of ***46.2 %*** of all land areas in the European countries that changed to artificial surfaces was arable land or permanent crops. This phenomenon was particularly significant in Denmark (88%), the Slovak Republic (78%), Italy (76%) and the Czech Republic (71%).

THE ENVIRONMENTAL NOISE DIRECTIVE

The Environmental Noise Directive (END) is the main European Union tool through which policy makers monitor land-based noise emissions and decide actions to be developed. It obliges EU Member States to assess noise levels by elaborating strategic noise maps for all major roads, railways, airports and urban areas. After analysing the mapping results, Member States have to prepare action plans for those areas that have surpassed the END noise thresholds. Finally, Member States are required to select and preserve areas of good acoustic environmental quality, referred to as "quiet areas", in order to protect the European soundscape.

Source: The European House — Ambrosetti elaboration on European Environment Agency (EEA) data, 2018.

1.3.2. The electric vector can reduce the overall human development footprint

46. Electric technologies are capable of boosting energy efficiency, power system resilience, productivity of industrial processes and the overall product quality, while supporting emissions and pollution reduction, water savings and safety thus improving the overall ***human development footprint***. Potential benefits and opportunities of existing and emerging electric technologies refer to emissions reduction and greater resilience helping to tackle air pollution, climate change, ozone depletion, soil contamination and water pollution, noise lowering (solving noise pollution) and space saving contributing to reduce the soil consumption issue.

47. With regard to the industrial sector, electric technologies can provide innovative pathways for low-carbon industry (plastics, chemicals, paper, ceramics, cement, iron, steel, etc.). For example, steel production is responsible for a 6%-7% of total greenhouse gas emissions. Potential for GHG emission reductions can be found in the electric carrier: 100% electrical power-based iron production can lead to ***82%*** of CO_2 emissions cutting.

48. Replacing coke-fired cupolas with induction melting at iron foundries can reduce ambient temperature and noise and improve air quality. Coke fired cupolas are heavy emitters of health-hurting pollutants (CO, CO_2, PM, SO and NO_2) and their high temperatures negatively affect on workers' health. Moreover, using an electric ladle preheater at foundries eliminates the need for open flame, reducing on-site emissions and noise. Indeed, since the electric ladle does not need the combustion process, no off-gas is produced and air blowers for venting are not required, resulting in improvements in air quality and noise.

49. In the metal industry, using an electric resistance-based salt bath furnace in place of a natural gas convection furnace for heat treating applications reduces on-site emissions and exposure to open flame. Generally speaking, using electric furnaces in industry contributes to a circular economy, as they reduce material losses due to oxidation in traditional furnaces. Typically, 2%-4% of the material is lost in fossil burners while in electric furnaces this is ***below 1%***. Although the percentage difference may appear small, it should be considered the full lifecycle environmental impact of the material lost in the thermal process.

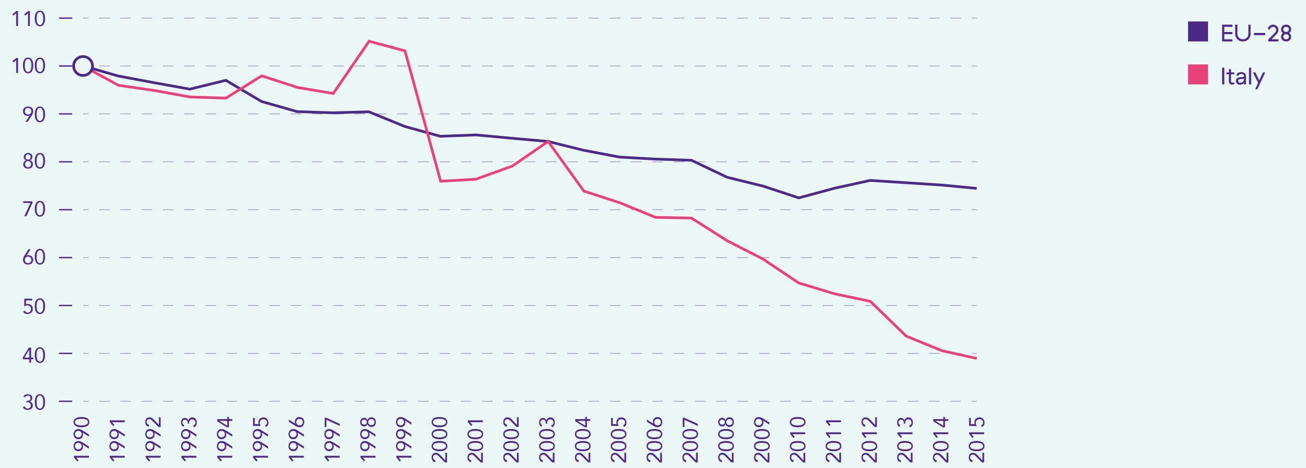
50. New electric technologies are also contributing to GHG emissions in electricity generation. In the last 25 years, CO_2 emissions from electricity generation have dropped by more than 25% in Europe and by more than 60% in Italy thanks both to a larger penetration of renewables and the EU-ETS mechanism. The 2018 revisions of the mechanism set the target of ***43%*** emissions' reduction in the involved sectors to be reached by 2030, then creating the conditions for further increasing efficiency and reducing CO_2 emissions in electricity generation. Utilization of renewable sources in electricity generation[20] helps also to reduce the dependency from water, which is highly used in thermal plants and to save land use, since large plants will be foregone in favor of a more decentralized and sustainable power production.

19 Source: European Environment Agency (EEA). Noise levels from road traffic are greater than 55 db Lden. This is a descriptor of noise level based on energy equivalent noise level (Leq) over a whole day with a penalty of 10 dB(A) for night time noise (from 10pm to 7am) and an additional penalty of 5 dB(A) for evening noise (i.e. from 7pm to 11pm).

20 The share of renewables in OECD Europe reached a new high in April 2018 – with 42.5% of total electricity production coming from renewables, as the latest detailed data provided by the International Energy Agency show. Source: Monthly electricity statistics for April 2018, International Energy Agency, July 2018.

FIG.16

CO_2 emission intensity of electricity generation (gCO_2/KWh, 1990=100), 1990-2015.
Source: The European House — Ambrosetti elaboration on European Environment Agency (EAA) data, 2018



51. Electric technologies allow for higher sustainability also in final uses. It has been evaluated that almost all the environmental impact of an electric heat pump comes from the energy consumption, which is typically lower than traditional heating and cooling systems. Moreover, also the amount of pollutants emitted is lower compared to traditional technologies. Overall, each electric heat pump installed in residential buildings emits between ***120 and 170 kg CO_2/MWh*** less compared to thermic energy systems.
52. In the residential context or in restaurants, using electric cooking equipment rather than direct combustion of natural gas, eliminates exposure to any combustion by-products and open flame and contributes to the decreasing of ambient temperatures. Indeed, gas cooking generates heavy amounts of particulate matter ($PM_{2.5}$), nitrogen monoxide (NO), Carbon Dioxide (CO_2), and Volatile Organic Compound (VOC), which can have negative impacts on people's health and well-being. Moreover, electric induction cooking is more efficient than gas cooking since induction ranges transfer ***up to 90%*** of their energy to the cookware. These units heat quickly, offer very precise temperature control, add a safety element by eliminating the need for an open flame and reduce indoor ambient pollution and temperatures.
53. Using electric forklifts as a replacement to internal combustion engine-driven ones can lead to a reduction of onsite emissions, such as carbon monoxide (CO), as well as of noise pollution. This brings to benefits in term of human health, since CO can lead to headaches, difficulty in breathing, and at severe levels can lead to nausea, dizziness, and eventually death. Moreover, in water treatments, removal of chlorine by using electric water treatment processes generates benefits for human health.
54. Finally, e-Mobility can help people to avoid suffering from road transport that is the main source of air and noise pollution. Electric vehicles can reduce by ***50%*** CO_2 emissions compared to petrol ones along their entire val-

THE POSITIVE EFFECTS OF ELECTRIC COOKING EQUIPMENT ON HEALTH: THE CHINESE CASE

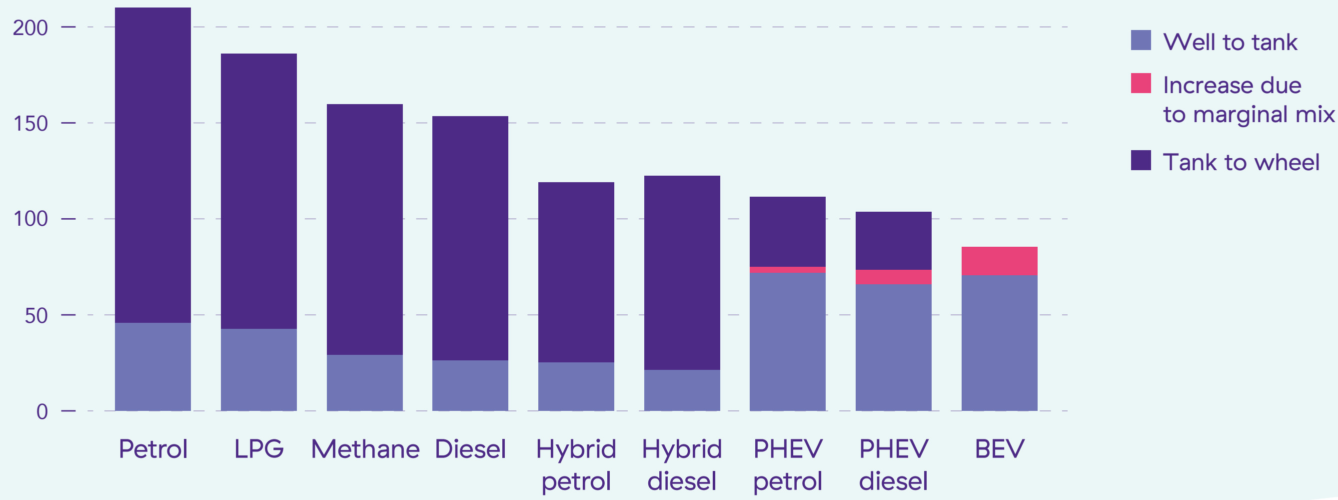
A 2011 study analysed a sample of 115 workers from 21 restaurants using only electric stoves and 278 workers from 32 restaurants using only gas stoves. This study found that median concentrations of NO, nitrogen dioxide (NO_2), and CO were 7.4, 1.5, and 1.6 times higher, respectively, in gas-fuelled kitchens than electric ones. Furthermore, the average concentrations of CO_2 and $PM_{2.5}$ in gas-burning commercial kitchens were 29% and 81% higher than electric kitchens. Workers in gas-burning kitchens successively reported health problem like sore throat, persistent cough, runny nose, wheezing, phlegm, eye pain, and decreased lung function. This study also indicated that kitchens using gas-burning cooking equipment were ***4.5°C*** warmer and ***9 dBA*** noisier than electricity run kitchens.

Source: The European House — Ambrosetti elaboration on Electric Power Research Institute data, 2018.

ue chains (well-to-wheels). Moreover, during their utilization, electric vehicles emit almost zero pollutants (CO_2, PM, NO_x and VOC) and generate no noise, allowing for noise pollution reduction, especially in cities. Moreover, electric mobility matches well with smart mobility and sharing economy, allowing for a better road and congestion management thus reducing pollution in urban environments.

FIG.17

Well-to-wheel emissions by technology in Italy (gCO_2/km), 2017.
Source: The European House — Ambrosetti elaboration on Ricerca sul Sistema Energetico (RSE) data, 2018



55. Other forms of e-Mobility can also contribute to the reduction of the human development footprint. For instance, at airports using electric ground support equipment (baggage tractors, pushback tractors, and belt loaders) reduces on-site emissions and noise pollution. It has been estimated that for one airport emissions savings are at ***705 tons per year*** for CO, ***26 tons per year*** of total hydrocarbons, ***25 tons per year*** of NO_x, and ***1.1 tons per year*** of PM by switching to electric baggage tractors, belt loaders, and pushback tractors.

FIG.18

Human Development Footprint.

Source: The European House — Ambrosetti elaboration on European Environment Agency (EEA) and various sources, 2018

NEGATIVE EXTERNALITIES FROM HUMAN DEVELOPMENT

Human activities

Air pollution

- ***~ 90%*** of city dwellers in EU (***~ 70%*** in Italy) are exposed to very high and dangerous concentrations of ozone pollution and PM_{10} (European Environment Agency –EEA)
- In Europe premature deaths from ambient particular matter pollution can be estimated at 497 per 1 million inhabitants in 2016 (564 per 1 million inhabitants in Italy in the same year), that corresponds to an estimate of ***cost of $787.2 billion*** (***$116 billion*** in Italy) for the society, if we consider environmental and health damages (OECD)

Climate change

- In Europe there was a ***loss of $436.1 billion*** over the period 1980–2016 from climate–related extremes ($61.2 billion in Italy over the same period) (European Environment Agency — EEA)
- Heat–related mortality in Europe will increase by ***between 60,000 and 165,000 deaths per year*** by the 2080s compared with the present baseline, with the highest impacts in southern Europe, especially Italy, Spain and Greece (European Commission)
- Extreme cold can also significantly affect human health especially for people with cardiovascular and respiratory diseases and to elderlies, with deaths often occur several days or weeks after the coldest day of a cold period (European Environment Agency – EEA)

Ozone depletion

- European population living at around 45 degrees North can experience, by 2050, an approximate ***5% excess of total skin cancer incidence*** due to ozone depletion (World Health Organization — WHO)

Soil contamination

- There are almost ***340,000 sites*** in Europe and it has been estimated that managing them costs ***~€6.5 billion per year*** (European Environment Agency — EEA)
- There are ***40 polluted sites*** of national interest ***in Italy*** covering ***243,788 hectare of surface*** (Italian Ministry of Environment)

Sea/water pollution and consumption

- More than ***1.8 trillion pieces of plastic*** in the patch of the Pacific ocean that weigh ***~80,000 tonnes*** (The Ocean Cleanup)
- ***More than half*** of the surface water bodies in Europe and in Italy are in less than good ecological status (EEA)
- ***1.1 billion people*** worldwide lack access to water and ***2.7 billion*** find water scarce for one month per year (WWF)

Noise

- Noise pollution damages ***20 million Europeans*** and causes sleep distrubance for 8 million people in Europe (European Environment Agency — EEA)
- Noise pollution causes ***43,000 hospital admissions*** and ***10,000 premature deaths*** per year in Europe (European Environment Agency — EEA)
- In Italy, on average, ***52% of controls in cities*** reveals a surpassing of the tolerant limit of noise which varies according to the urban area and the hour of the day considered (from 40 to 70 dB) (ISPRA)

Deforestation and soil consumption

- The world is losing ***18.7 million acres*** of forests annually, equivalent to 27 soccer fields every minute (WWF)
- ***15% of worldwide greenhouse gas emissions*** are the result of deforestation (WWF)
- Between 2006 and 2012, the ***annual loss of farmland*** was approximately 107,000 ha/year in the European countries of which 5,800 ha/year in Italy (European Environment Agency — EEA)

N.B. Not all the negative externalities mapped in the Human Development Footprint have a corresponding benefit brought about by the electric vector.

BENEFITS FROM ELECTRIC VECTOR

- Innovative pathways for ***low-carbon industry*** (plastics, chemicals, paper, ceramics, cement, iron, steel, etc.)
  - Reduction of ***82%*** of CO_2 emissions with 100% electrical power-based iron production (Eurofer)
  - Reduction of ***ambient temperatures and improvement of air quality*** by replacing coke-fired cupolas with induction melting at iron foundries (EPRI)
  - Elimination of the need for open flame at foundries by using an electric ladle preheater resulting in the ***reduction of on-site emissions*** (EPRI)
  - ***Reduction of on-site emissions and less exposure to open flame*** using an electric alt bath furnace in place of a natural gas convection furnace for heat treating application in the metal fabrication industry (EPRI)
  - ***Decrease to 1% from 2-4% of material lost*** due to oxidation by using electric furnace instead of fossil burners (EPRI)
- Sustainability of ***power production***
  - ***Drop of*** CO_2 emissions from electricity generation (gCO_2/KWh) by more than 25% in Europe and by more than 60% in Italy in the last 25 years, also thanks to the growth of renewable energy sources for electricity generation (EEA)
  - Reduction of ***water utilization*** due to use of renewable energy sources plants instead of fossil fueled plants* (EPRI)
- Decarbonization of end-use
  - Reduction between ***120 and 170 kg*** CO_2/MWh for each electric heat pump installed in residential buildings compared to thermic energy (ENEA, CNR and RSE)
  - Reduction of ***50% g*** CO_2 ***eq./km*** (well-to-wheel) generated by electric vehicles compared to fuel ones (RSE)
  - Lowering of ambient ***temperature*** by ***4.5° C*** using electric kitchen instead of gas-burning ones (EPRI)
  - Reduction of ***29%*** and ***81%*** of the average concentration of CO_2 and $PM_{2.5}$ in electric kitchens than gas-burning ones (EPRI)
  - ***Reduction of on-site emissions***, such as carbon monoxide (CO), by using electric forklifts as a replacement to internal combustion engine-driven (EPRI)
  - ***Emissions savings*** estimated at 705 tons per year for CO, 26 tons per year of total hydrocarbons, 25 tons per year of NOx, and 1.1 tons per year of PM by switching to electric baggage tractors, belt loaders, and pushback tractors in one airport (EPRI)
  - ***Removal of chlorine*** for treating water by using electric water treatment processes generating benefits for human health (EPRI)
- New lifestyles
  - ***Sharing mobility*** is enabled by e-Mobility and reduces private vehicles use with positive effects on air quality in cities* (National Observatory on Sharing mobility)
  - Better ***traffic management*** thanks to dedicated lanes and access to enlarged congestion zone for e-vehicles* (European Commission)

- Innovative pathways for ***low-carbon industry*** (plastics, chemicals, paper, ceramics, cement, iron, steel, etc.)
  - ***Reduction of ambient noise*** by replacing coke-fired cupolas with induction melting at iron foundries (EPRI)
  - ***Decrease of ambient noise*** by using an electric ladle preheater at foundries (EPRI)
- Decarbonization of end-use
  - ***Reduction of 100%*** of noise from e-vehicles compared to traditional ones (EPRI)
  - ***Lowering of noise by 9 dBA*** using electric kitchen instead of gas-burning ones (EPRI)
  - Reduction of noise pollution by using electric ground support equipment and gate ***electrification technologies in airports*** (EPRI)
  - Decrease of noise pollution by using ***electric forklifts*** (EPRI)

- Electrification technologies (for instance industrial ovens) are smaller than other technologies, taking up ***less space**** (EPRI)
- Reduced necessity to have larger plants thanks to ***decentralized generation*** of electricity* (EPA)

* Indirect effect.

Part 2

Electrification has a highly deployable potential in Europe and in Italy

Part 2

Key messages

- Increasing generation capacity from renewables, technological development of electricity-driven technologies, as well as decarbonization policies and digitalization, are the key factors underpinning the ***growth of electrification*** the share of electricity consumption in total final energy consumption.

- Between 1990 and 2016, electrification has experienced a growing trend both a global (from ***13%*** to ***18%***) and European level (from ***17%*** to ***22%***). France currently has the highest electricity share in final energy consumption among the EU Big-5 (26%); Italy stands at ***21%***.

- Several policy scenarios have been conceived to identify ***electrification potential by 2030***. This potential ranges from a ***3*** to ***9 percentage point increase*** in both the European (25% to 31%) and the Italian case (24% to 30%).

- In Italy, the relatively higher electrification potential is estimated in the ***transport sector*** that is projected to grow from the current 2% (primarily due to the almost complete electrification of railway lines) to a range comprised between ***5%*** and ***8%***. Electrification in ***buildings*** is also expected to show significant growth from ***26%*** to ***32%-34%***. The latter share would allow Italy to reach electrification in buildings currently observable at EU levels. Finally, the ***industrial sector*** has an electrification potential estimated to be ***2-4 additional percentage points*** (starting from the current level of 35% electricity share in final energy consumption).

- Assessing the ongoing evolution trend towards the 2030 policy targets for renewables, Greenhouse gas emissions - GHG and energy efficiency in the major European economies (Italy, France, Germany, Spain and UK), a few shared aspects can be seen:

  1. All the countries are in line, or almost in line, with the EU policy target of ***32%*** in renewable energy sources by 2030.

  2. GHG emissions show an overall ***downward trend*** everywhere, even if the trend is occurring at different rates from country-to-country and with the partial exception of Spain in which the decrease starts later in time than the other countries.

  3. Energy efficiency is showing the ***slowest progress*** towards the policy targets with an improvement compared to trend of 32.5% by 2030 and revealing the necessity to push for further investments in this field.

2.1.

Electrification is an unrelenting growing trend worldwide

1. The term electrification refers to the share of electric consumption within overall energy consumption. Hence, analysing the growing trend of electrification at the global and the European level requires taking into account the overall composition of energy demand. In this regard, in 2016, global energy demand totalled 13,760 million tonnes of oil equivalent (Mtoe).[1] China was responsible for the largest share of this demand (22% of the total), followed by the United States (almost 16%), the European Union (12%) and India (6.5%).

2. Currently, global energy consumption is still largely satisfied by ***oil***, representing 32% of the total and among which transport is, by far, the largest intensive user, accounting for 55% of the global millions of barrels per day (mb/d). Despite decarbonization policy targets being in place, ***coal still*** represents 27% of current global energy consumption yet.[2] Power generation and industrial sectors are the largest consumers of coal (62% and 32% respectively) and China represents the lion's share with about half of worldwide coal consumption. The third largest component is represented by ***natural gas***, totaling 22% of global energy consumption in 2016. The largest share of natural gas is deployed in power generation (40%), while industry and buildings are consuming about 20% each.[3]

3. Fossil fuels (oil, coal and natural gas) amount therefore to 81% of overall energy consumption. The remaining shares include nuclear (5%), bioenergy (10%),[4] hydropower and other renewables (4%).

4. For energy consumption in final uses, however, electricity is becoming a primary choice driven by the development of renewable energy sources (RES) which makes electricity a vehicle for decarbonization, of innovative technologies (heat pumps, ovens, etc.), allowing for a notable increase in energy efficiency compared to those fueled by traditional energy sources as well as digitalization.

THE CHINESE COMMITMENT ON DEVELOPING RENEWABLES AND REDUCING COAL

Since 2013, China's coal consumption has steadily decreased by a few percentage points per year leading several scientists to claim that the global peak of coal consumption has been reached.

However, an increase of 5.7% in the Chinese energy demand in 2017 has led to an apparent reverse in this decreasing trend and has resulted in about a +0.4% growth in coal demand (in absolute terms). The rebound occurred despite China's reduced mining capacity that has recently ignited an upward trend in prices.

As of 2017, coal remains the ***largest source of energy in China*** at just ***over 60%*** of its energy mix, though it has dropped from 80 per cent in 2010. Under its Paris Agreement commitment, China has resolved to increase the share of renewables in the energy mix and to bring coal down to 58% by 2020.

Source: The European House – Ambrosetti elaboration on Bloomberg New Energy Finance (BNEF) and Nature Geoscience data, 2018.

1 The tonne of oil equivalent (toe) is a unit of energy defined as the amount of energy released by burning one tonne of crude oil. Multiples of the toe, in particular the Mtoe, are the typical unit of measure for the overall energy demand.

2 For electricity generation only, it must be specified that, in 2015, coal was responsible for 27.9% of electricity generation in mature economies (OECD countries), but the share was up to 47.1% in non-OECD countries (Source: International Energy Agency "Electricity Information 2017").

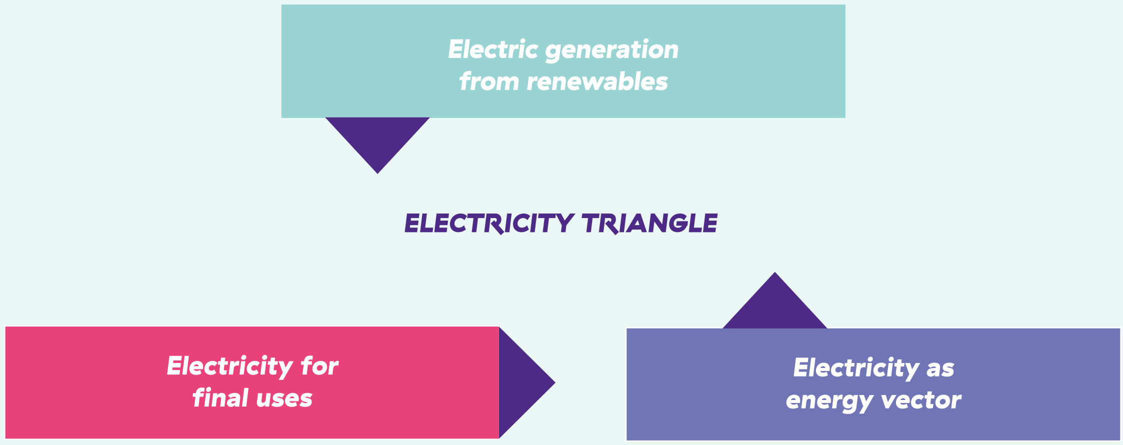
3 Source: International Energy Agency "World Energy Outlook 2017".

4 Bioenergy includes the traditional use of solid biomass and modern use of bioenergy. Source: International Energy Agency "World Energy Outlook 2017".

5. The growth of renewables, indeed, going together with the increased share of electricity in final uses and the versatility that electricity has compared to other energy sources makes decarbonization possible. In this regard, the contribution of electrification to the ongoing energy transition is clearly seen in the "electricity triangle" in which all the vertexes represent a key contribution of electricity to energy transition itself.

FIG.1

The Electricity Triangle.
Source: The European House — Ambrosetti elaboration on Politecnico di Torino and MIT and Enel Foundation "Electrify Italy", 2018



THE CONTRIBUTION OF RENEWABLE ENERGY SOURCES TO WORLDWIDE POWER CAPACITY

Renewable Energy Sources (RES) are increasingly playing a primary role in electricity generation, which enables the energy transition process together with reduced fossil fuel use in power generation.
Despite the overall positive trend, not all renewable sources are on the same growth path. In 2016, the most relevant RES were ***solar photovoltaics*** (PV) and ***wind power*** that together produced ***126 GW*** out of the 165 GW additional power from Renewable Energy Sources (RES) generated in the world. Yet, their total production was only 4 GW lower than the additional generation capacity stemming from coal, natural gas and oil during the same year. Solar PV alone contributed ***74 GW***, a quarter of the overall generation capacity added in 2016 and an increase of 50% compared to 2015. In this regard, China was the best performer by adding 34 GW of capacity from PV in the last year. However, also the United States had a solid performance increasing its PV capacity by 15 GW and almost doubling the 2015 result.
Wind power capacity equaled ***52 GW*** in 2016, down by 20% compared to 2015, but still the second highest result ever. As with PV, China also led in wind power (20 GW of additional power added to global power capacity). The European Union was also among the best performers in wind capacity with the addition of 13 GW in 2016 that were mostly concentrated in Germany and France.
On the flip side of the coin, in recent years, hydropower capacity has slowed and stabilized at a level of about one fourth compared to the peak in 2013. Again, this result is mostly driven by Chinese policies that have constantly reduced hydropower generation in favor of solar and wind sources.
Further, it has to be specified that all the previously mentioned data refer to the additional power added in the last available year. Considering, instead, the renewable energy generated by technology in the world, hydropower accounted for 4,144 TWh in 2016, preceding wind with 916 TWh and solar with 312 TWh. At the same time, fossil fuels (oil, coal and natural gas) had a cumulative electricity generation equal to ~16,000 TWh, and nuclear power was responsible for ~2,400 TWh.

Source: The European House – Ambrosetti elaboration on International Energy Agency data, 2018.

6. In other terms, the joint action of increased generation capacity stemming from renewables, technological development (the uptake of electricity-propelled technologies and the progressive reduction of costs related to storage systems), as well as decarbonization policies, underpinned the ***steady increase in electrification*** visible in recent decades at global and European levels.
7. Starting with the broader picture, electricity share in final energy consumption has grown a global level by ***5 percentage points*** between 1990 and 2016 (***13%*** to ***18%*** of total energy consumption). A notable factor behind this growth concerns the fact that rising electrification is mirrored also in the underlying dynamic of energy investments. In 2016, for the first time, investments in the electricity and power sector have exceeded those in oil and gas (***$720 billion*** and ***$650 billion***, respectively).

THE DECREASING COST OF RENEWABLES HAS A POSITIVE EFFECT ON THE ELECTRICITY PRICE

In the last decade, the average generation cost of solar photovoltaic and wind on-shore has gradually decreased (~-80% and ~-60%, respectively).
Thus, from the point of view of economic efficiency, renewables can progressively replace other energy sources, generating an increase in the share of renewables on global electricity generation mix, from the actual 24% to over 60% in 2040.
One of the first consequences of the lower cost of renewable energy sources is the reduction of electricity price.
In addition, electricity price will be much more stable over time, given that renewables are exempted from oil and gas price volatility.
Therefore, electricity has the potential to become a low-cost energy source, gradually substituting traditional energy sources in the energy mix, thus increasing its share on final energy consumption.

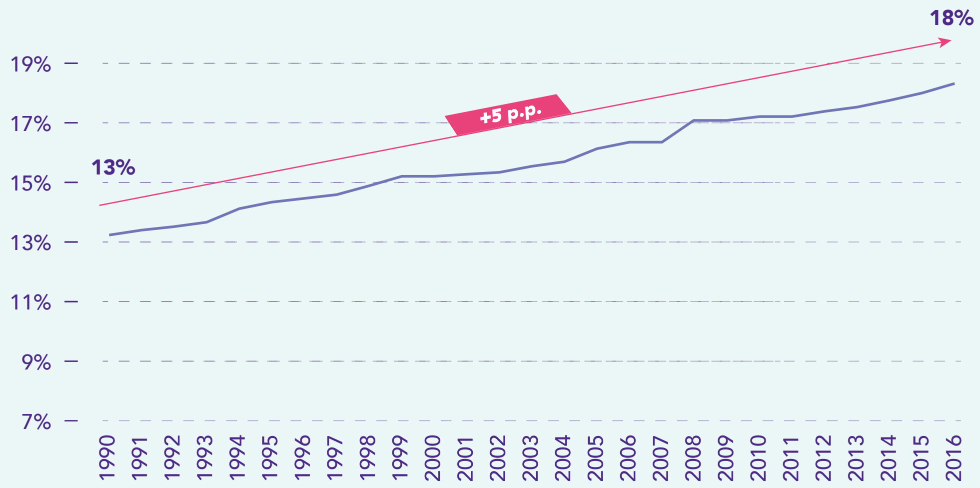
Source: International Energy Agency, 2018.

8. An important factor in the growing global electrification share was the steady increase of electricity consumption in emerging economies, where average yearly growth was up to 3%. In these countries, electrification had a baseload nature, meaning that it was largely conceived to provide electricity to people and companies that did not have access to it before. In other terms, baseload electrification primarily implied heavy investments in distribution infrastructures. Also, thanks to these investments, people without any access to electricity have decreased ***from 1.7 billion*** in 2000 to ***less than 1.1 billion*** in 2016.
9. By contrast, in mature economies, electrification primarily implies the substitution of other energy sources in end uses, mainly fossil fuels, with electricity-powered ones. In spite of this constitutive difference, the growing trend of electrification is visible also in these latter countries. Moreover, the rising trend in mature economies should also be weighed from the standpoint that technological improvements also partially contributed to flattening electricity demand. The use of efficient appliances makes it possible to reach the same performance with lower electricity intensity. Conversely, efficiency gains and substitution of appliances and technologies powered by the electric carrier (compared to those powered by fossil fuel) have a positive direct impact on the electrification share. However, despite this growing electrification trend and the opportunities stemming from new technologies for energy efficiency gains, there is still huge unlocked potential for electrification. Indeed, improvements in energy efficiency slowed down in 2017: global energy intensity improved by only 1.7% in 2017, compared with an average of 2.3% over the last three years.[5]
10. A detailed analysis of the overall structure of energy demand in the European Union indicates a notable difference compared to the global scenario: oil and gas still have a prominent role with 37% and 23% of the total energy demand, respectively, but coal consumption is considerably lower than it is at the global level (about ***5%*** vs. ***27%***).
11. However, similarly to the trend visible at the global level, European electricity consumption has grown from ***17%*** in 1990 to ***22%*** in 2016, making the EU as a whole the ***3rd electricity consumer worldwide***, after China and the US. The steady growth of electrification is mirrored also in the investment side. Over the decade 2000-2010, indeed, the hugest part of European investments in the energy sector were directed towards gas plants and infrastructures, whilst investments in renewables were covering only a limited part. In the 2011-2015 period, this trend was partially inverted and investments in solar and wind on-shore technologies have already outpaced those in natural gas.

5 Source: International Energy Agency, 2018

FIG.2

Electricity in final energy consumption in the world (% values) and change (percentage points), 1990–2016.
Source: The European House — Ambrosetti elaboration on International Energy Agency (IEA) data, 2018



BASELOAD ELECTRIFICATION IN EMERGING ECONOMIES: THE CASE OF INDIA

India is by far the most prominent energy consumer among emerging economies. Its energy demand (897 Mtoe, 6.5% of the world total) is higher than that of all the Southeast Asian countries (643 Mtoe, almost 5% of the world total), Brazil (290 Mtoe, 2% of the world total) and South Africa (139 Mtoe, 1% of the world total).

In recent years, India was also at the forefront in baseload electrification that allowed the country to reach an annual increase in electricity share in end uses of 6.8% in the 2000–2013 period and an even stronger 7.4% from 2014 onwards. This trend was the result of governmental policies oriented to pursue at the same time a broadening of the share of people having access to electricity and more sustainable energy production.

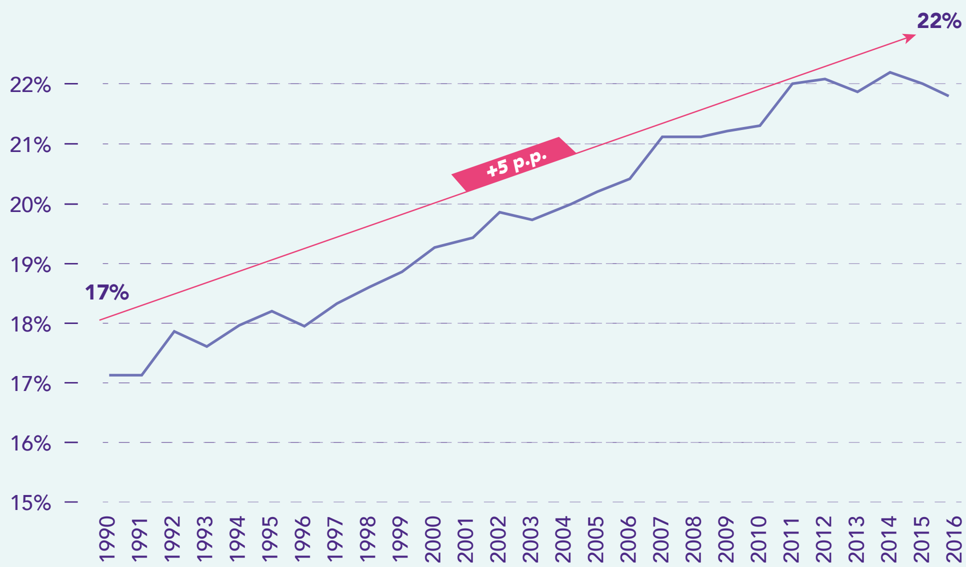
Among the most relevant targets of the national energy policy:

- universal “24x7” access to electricity by 2022;
- reduction of oil imports;
- 75 gigawatts (GW) of renewable capacity by 2022;
- NDC (Nationally Determined Contributions) commitments to reduce the emissions intensity of the economy by 33–35% by 2030 (compared to the 2005 baseline);
- NDC commitments to boost the share of non fossil–fuel capacity in the power sector to 40% over the same period.

Source: The European House – Ambrosetti elaboration on International Energy Agency and Energy Information Administration data, 2018.

FIG.3

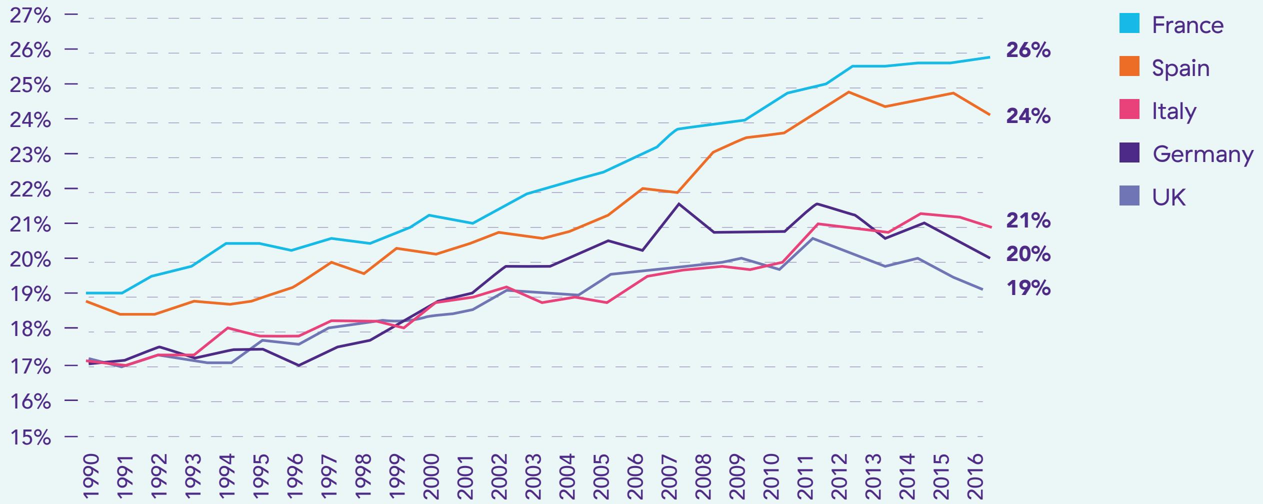
Electricity in final energy consumption in the EU28 (% values) and change (percentage points), 1990–2016.
Source: The European House — Ambrosetti elaboration on European Commission data, 2018



12. Despite the different pace, the overall growth of electrification is visible also when considering the EU Big-Five Countries among which the French and the Spanish performances stand out. Looking at the 1990–2016 period, ***France*** and ***Spain*** fielded the largest increase, growing by 6.7 and 5.3 percentage points allowing the two countries to reach ***26%*** and ***24%*** respectively. Moreover, while the French trend is the result of the highest share of nuclear in the electricity generation mix (about 75%), the Spanish one is currently underpinned by a more balanced power generation mix in which nuclear accounts for only 20%, natural gas 19%, and renewables 36%. In the same considered period, Italy fielded an increase of 4 percentage points (***17%*** to ***21%***), followed by Germany with a ***2.9 percentage point rise***. Finally, the UK had an increase of ***2.3 percentage points*** that did not allow the country to surpass as yet the 20% threshold of electricity as a share of total final energy consumption.

FIG.4

Electricity in final energy consumption in the EU Big Five (%), 1990–2016.
Source: The European House — Ambrosetti elaboration on European Commission data, 2018



THE CASE OF FRANCE

France is the European country where the percentage of electricity consumption in the final energy consumption is at the highest level and where the increase in the period between 1990 and 2016 was also the strongest. This result is underpinned by the longstanding huge nuclear production capacity (currently there are 58 reactors spread across the country), representing consistently more than 75% of electricity generation. France's decision to massively invest in nuclear plants traces back to 1974, immediately after the first oil shock. As a result of this policy, France currently has a considerable level of energy independence and among the lowest cost of electricity in Europe. Moreover, nuclear production also translates into a significant emissions reduction.

In 2015 the French electricity production was 568 TWh and nuclear provided 437 TWh of it. Production from hydroelectric accounted for 59 TWh, coal and gas 32 TWh, and solar and wind 29 TWh. After the net exports of 64 TWh, total electricity consumption came to 422 TWh, about 6,300 kWh per capita on average.

Thanks to the nuclear power installed, over the last decade, France has exported an average of 70 TWh net per year and Electricité de France (EDF) expects the net exports to continue at the pace of 55–70 TWh/yr in coming years. The primary destination of French electricity export are Italy, the UK, Switzerland, Belgium, Spain, and Germany.

Source: The European House — Ambrosetti elaboration on World Nuclear Association data, 2018.

2.2.

Some electrification scenarios can be envisaged for Europe and Italy at 2030

13. Although electrification has steadily grown in the last two decades, the current electricity share in final energy consumption requires a further increase to meet the policy targets set at European and Italian levels.

14. To identify the electrification levels that allows to reach those targets by 2030, several policy scenarios have been built. Each scenario has different underlying assumptions leading to different levels of electricity share to be reached at the end of the given time period. In order to individuate the electrification potential for both the EU and Italy a few scenarios have been considered:

- ***EU Reference Scenario***, which is in line with the EU 2030 Climate & Energy Framework targets: at least a ***40%*** cuts in greenhouse gas emissions (vs. 1990 levels), at least a ***27%*** share from renewable energy sources, and at least a ***27%*** improvement in energy efficiency (vs. 1990 levels).[6]
- ***EUCO+40***, which is another scenario developed in the impact assessment of the Climate & Energy Framework by the EU Commission (and available for both the EU28 and Italy) and introduce a more challenging objective for energy efficiency improvements to be obtained from now to 2030. In EUCO+40, indeed, an improvement of ***40%*** is expected in energy efficiency, instead of the 27% set by the Reference Scenario.[7]
- ***IEA New Policies Scenario (NPS)***, available only at the EU level and elaborated by the International Energy Agency to take into account energy policies already in place, as well as the expected targets and effects of those announced.
- ***IEA Sustainable Development Scenario (SDS)***, again available only at the EU level, it starts from the Sustainable Development Goals targets most closely related to the energy sector and provides an estimation of the necessary electricity share to achieve them.[8]
- ***Eurelectric scenario*** (available for both the EU28 and Italy), which is based on the evolution curve elaborated by Eurelectric in the 2018 study and originally referred to 2050. Therefore, the 2030 values here presented have been obtained through a re-elaboration of the intermediate scenario (Eurelectric-2) included in the study. The re-elaboration implied computing the compound annual growth rate (CAGR) up to 2050 and subsequently identifying the corresponding electrification share at 2030.
- ***SEN (Strategia Energetica Nazionale)*** is — of course — an Italian only scenario. Further, this is a policy scenario applying the European targets — embedded in the EU 2030 Climate & Energy Framework — within the Italian context in light also of a few specific national goals.[9]

15. Starting with the European case, electrification projections fall in the range between ***25%*** envisioned by EU Reference Scenario and the IEA-NPS and ***31%*** stemming from Eurelectric. Thus, the most conservative case predicts a ***growth of 3 percentage points compared to the current level***, while the highest one envisions an increase of 9 percentage points. The IEA-SDS and the EUCO+40 scenarios fall in the middle between the Reference Scenario and Eurelectric scenario, with an estimated electrification share of 26% (+4 percentage points) and 28% (+6 percentage points), respectively.

6 These are the targets originally proposed by the European Commission, which have been superseded by a political agreement among the EU Commission, the EU Council and the EU Parliament in 2018. This agreement sets a 32% level for renewables and 32.5% improvements in energy efficiency.

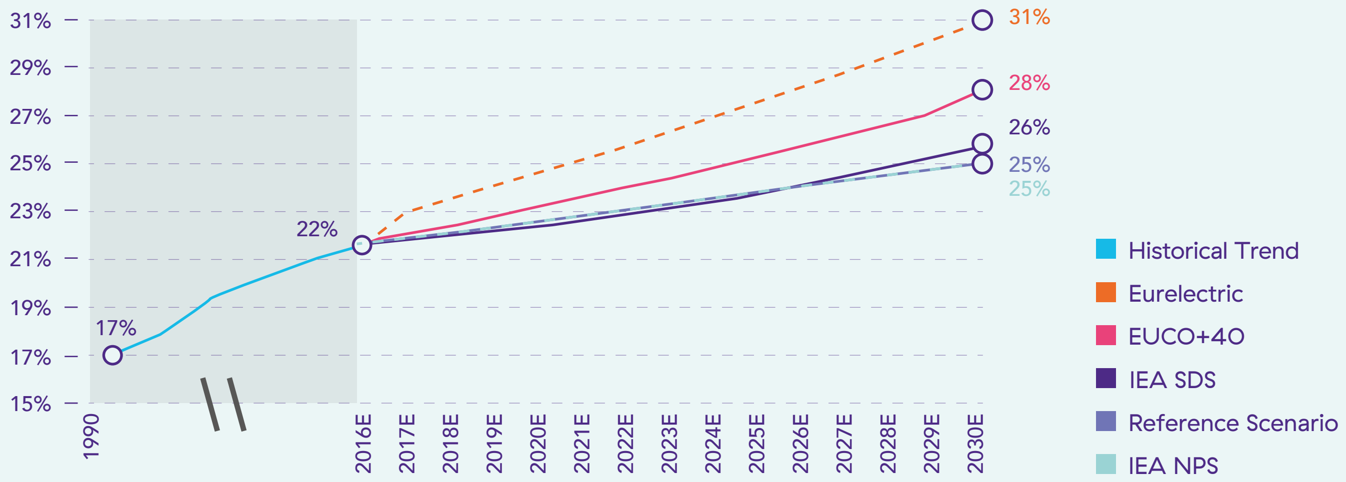
7 As the EUCO+40 is conceived to test a huge improvement in energy efficiency compared to the Reference Scenario also the other objectives overshoot compared to the Reference Scenario. In the EUCO+40, therefore, the overall reduction of GHG emissions would be 43% compared to 1990 levels and renewables would reach 28% share in the final energy consumption.

8 Specifically the SDGs considered include affordable and clean energy for all (SDG 7), action on climate change (SDG 13), as well as the efforts to reduce air pollution which are included under the goals for health (SDG 3) and cities and sustainable communities (SDG 11).

9 Reduction by 1.5% a year on the time span 2021-2030, compared to the average energy consumption of the period 2016-2018; renewable energy sources up to 28% of the gross final consumption ad 2030; phasing-out from coal at 2025.

FIG.5

Electricity share in final energy consumption in Europe (%), 1990–2030E.
Source: The European House — Ambrosetti elaboration on Eurostat, European Commission, International Energy Agency and Eurelectric data, 2018

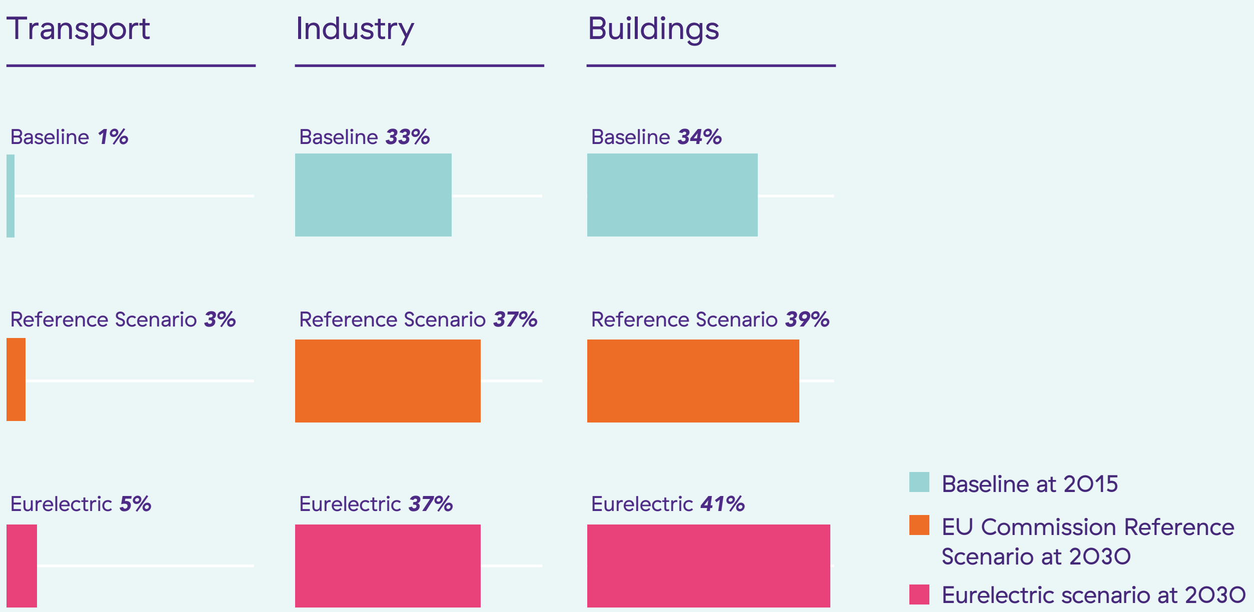


N.B. Scenarios that are not policy driven have a dotted line.

16. In selected scenarios the broader electrification potential can be declined also at the ***sectoral level*** in which the potential is going to be deployed by 2030. In the European context the sectoral analysis is based on the Reference Scenario and Eurelectric which provide a picture of the most conservative and the most challenging electrification scenarios.

FIG.6

Electricity share on final energy consumption by sector in Europe (% values), 2015 and 2030E.
Source: The European House — Ambrosetti elaboration on European Commission and Eurelectric data, 2018



17. Starting from very low level (1% of electricity share in overall transport energy consumption, which can be attributed to the trains) electrification in transport is expected to grow ***three-fold*** in the Reference Scenario and ***five-fold*** in the Eurelectric one. This growth is primarily obtained through the development of electric vehicles.

18. Industry consumption of electricity currently amounts to one third of the total (33%). However, the electrification potential is narrower, with both the scenarios forecasting a ***37%*** penetration at 2030 (***+4 percentage points***). The slower electrification is arguably due to the fact that industrial electric technologies, e.g. electric furnaces, despite being in an advanced state of technological development, are still not economically convenient to fully substitute the traditional combustion ones. Moreover, compared to buildings, significant improvements have already been obtained in energy intensive industries directly involved in the EU Emission Trading Scheme (ETS).[10]

19. Buildings have the highest share of electrification in the EU aggregate (34% of total energy consumption covered by electricity). This share is the result of important consumption factors that are already electrified (for instance, space cooling is almost completely powered by the electric carrier). Electrification scenarios for buildings envision around ***39%*** a share by 2030 in the EU Reference Scenario (+5 percentage points increase) and ***41%*** in the Eurelectric one. The expected increase of electrification is attributed mainly to the substitution of heating and cooling technologies powered through fossil fuels with electric ones (e.g. the heat pumps uptake).

THE CONTRIBUTION OF NEARLY ZERO ENERGY BUILDINGS (NZEBS)

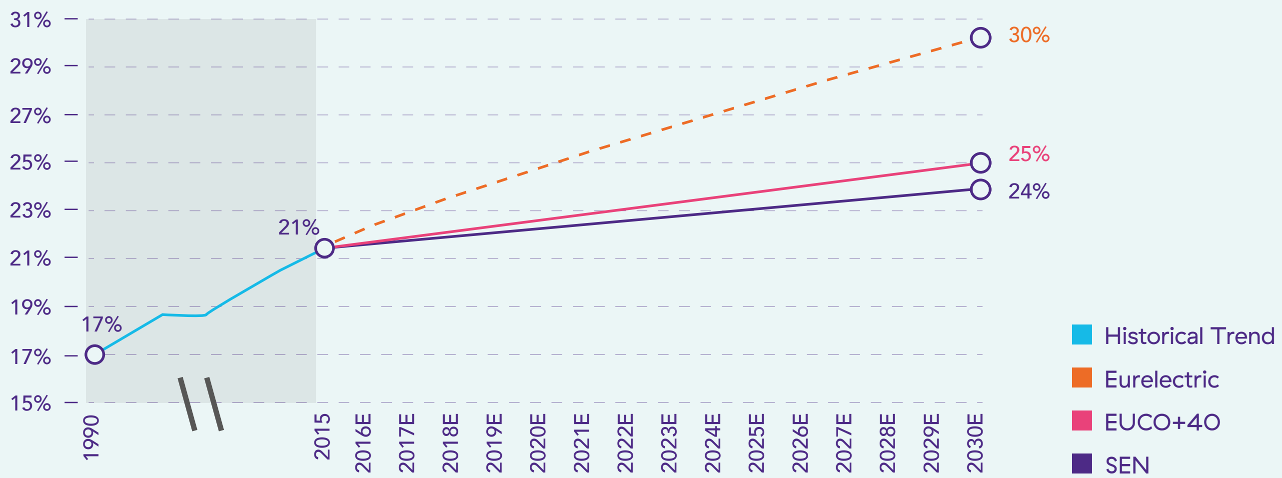
The EU Energy Performance of Buildings Directive (EPBD) highlights the need to reduce energy consumption and increase the use of energy from renewables in buildings. To do so, the EPBD defines a Nearly Zero Energy buildings standard to be in place for all new buildings. The NZEB is therefore a “building having a very high energy performance” and whose “nearly zero or very low amount of energy required should be covered to a very significant extent by energy from RES”. Therefore electricity technologies, both in terms of distributed generation via RES and of installation of energy management systems are a key elements in the NZEB standard. According to the EPBD, new buildings must be nearly zero-energy by ***2021*** and all new public buildings by ***2019*** and EU countries have to set national plans to meet these goals.

The European House – Ambrosetti elaboration on European Commission data, 2018.

10 The functioning of the European Trading scheme is described in Part 1 of the study.

FIG.7

Electricity share in final energy consumption in Italy (%), 1990-2030E.
Source: The European House — Ambrosetti elaboration on Eurostat, National Energy Strategy (SEN) and Eurelectric data, 2018



N.B. Scenarios that are not policy driven have a dotted line.

20. In the Italian context, electrification potential ranges from the ***24%*** predicted by the National Energy Strategy (SEN) to the ***30%*** derived from the Eurelectric scenario, with the 25% set by EUCO+40 in the middle. Thus, the National Energy Strategy foresees an increase of 3 percentage points compared to the current share, while EUCO+40 envisions slightly higher growth (+4 percentage points). The highest prediction is for +9 percentage points, on a par with that for Europe. For Italy, there are no IEA scenarios because these were specifically designed at an aggregate European level only.

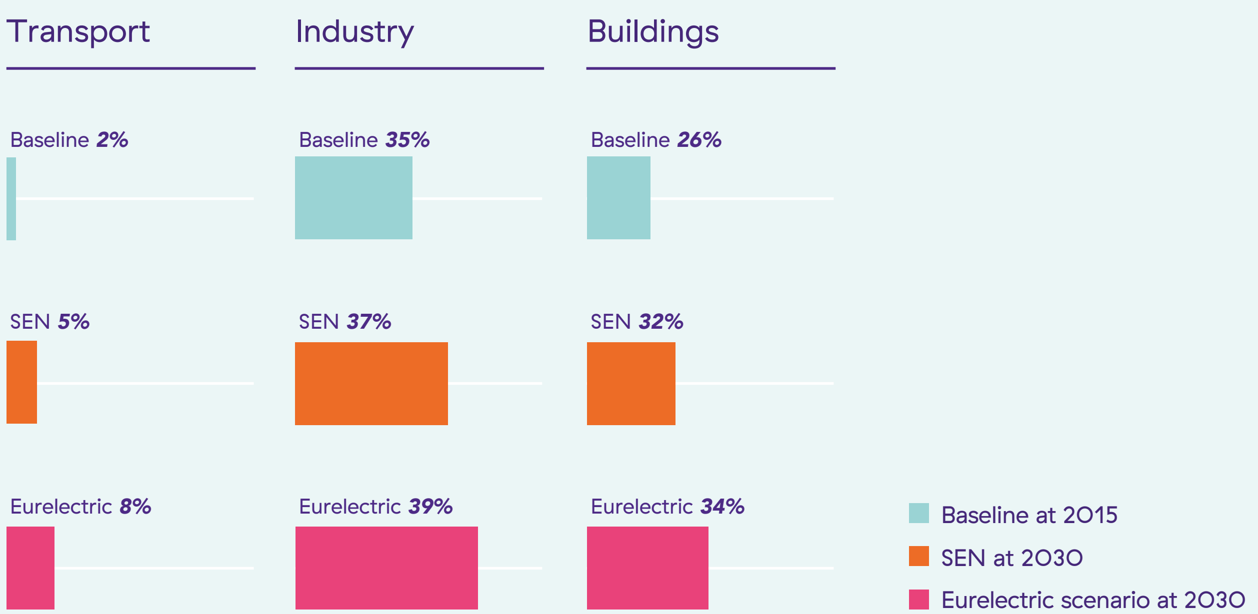
21. Looking at the sectoral level, the current Italian situation is similar to that of Europe, except for buildings falling behind the EU level by ***8 percentage points*** and totalling an electrification rate of ***26%***. This difference can be explained by the age of Italian housing stock. Three out of four residential buildings in Italy were built before 1980 and more than half (57%) before 1970. The age of residential buildings and the predominance of natural gas in heating (compared to northern European countries) contribute to explain the relatively lower level of electrification in Italian buildings.

22. The aforementioned issue affects also the electrification scenarios. The National Energy Strategy foresees a ***32%*** electricity share in total energy consumption for buildings in 2030. This would be a noticeable increase (+6 percentage points) but still insufficient to catch up with the current buildings electrification rate on the European level. Yet, the Eurelectric scenario that envisions a 34% share of electrification in buildings by 2030 (+8 percentage points), brings the sectoral electrification to the level that is currently visible in the European average.

23. Conversely both industry and transport have an electrification rate slightly higher than the European one. Electricity share in industry currently amounts to more than one third of total energy consumption (***35%***) and is expected to grow by ***2*** to ***4*** percentages points according to the SEN and Eurelectric scenarios respectively. This confirms the relatively lower growth of electrification in industry seen also in Europe as a whole. Yet, the present electrification rate in the transport sector is 2%, doubling the European level. What makes the difference for Italy is arguably the ***railways***, which are almost completely electrified. Starting from this point, the electrification scenarios foresee a growth rate even higher than the European one. The SEN scenario expects electricity share to grow 1.5 times compared to the current level, reaching ***5%*** (+3 percentage points). The Eurelectric scenario, on the other hand, envisions four-fold growth by 2030, with an electrification rate of 8% (+6 percentage points) by 2030.

FIG.8

Electricity share in final energy consumption by sector in Italy (%), 2015 and 2030E.
Source: The European House — Ambrosetti elaboration on National Energy Strategy (SEN) and Eurelectric data, 2018



2.3.

Fulfilling Europe's and Italy's policy targets on energy and climate requires a further increase of electrification powered by renewables

24. In both Europe and Italy there is a notable potential for electrification to be deployed until 2030 and — as demonstrated in Part 1 of this study — electrification combined with a balanced energy generation mix positively contributes to decarbonization. The growth of renewable energy sources in the generation mix is therefore a key variable to achieve both electrification and decarbonization. Further, a few electricity-driven technologies are more efficient than traditional ones that supports the claim that electrification has a positive impact on improving energy efficiency.[11]

25. As already mentioned in the study, the three pillars (Renewable Energy Sources — RES, Greenhouse gas emissions — GHG and energy efficiency) are the three indicators the EU has selected to monitor the advancement towards the macro-objectives of reaching decarbonization and keeping the uprising of the temperature under control. The 2020 Climate & Energy Package was the first policy package that brought together the three indicators. The 2020 targets were overcome by the new policy targets proposed by the European Commission in 2016 within the 2030 Climate & Energy Package. However, a political agreement among the main EU institutions (Council, Parliament and Commission), reached in ***June 2018***, has already updated the targets for renewables and energy efficiency fixing more challenging ones.

11 The efficiency gains of the electricity-driven technologies are extensively covered in Part 3 of the study.

FIG.9

Evolution of the EU targets for renewables, GHG emissions and energy efficiency.
Source: The European House — Ambrosetti elaboration on European Commission data, 2018

2009

2020 Climate & Energy Package

- ***20%*** cut in greenhouse gas emissions (vs. 1990 levels) by 2020
- ***20%*** of EU energy from renewables by 2020
- ***20%*** improvement in energy efficiency by 2020

2016

2030 Climate & Energy Framework (as proposed by the EU Commission)

- At least ***40%*** cuts in greenhouse gas emissions (vs. 1990 levels) by 2030
- At least ***27%*** share for renewable energy by 2030
- At least ***27%*** improvement in energy efficiency by 2030

2018 (14 JUNE)

Political agreement among the EU Commission, the European Parliament and the Council

- Sets a new target for renewables at ***32%*** by 2030
- Sets a new energy efficiency target for the EU for 2030 of ***32.5%***, with an upwards revision clause by 2023

26. To assess how the EU-28, Italy and other major European countries (Germany, France, UK and Spain) are performing with respect to these three policy objectives,[12] a few synthetic indicators valid for all the given countries are provided:

- As both GHG emissions and energy efficiency refer to 1990 as the baseline year to achieve a certain reduction, the ***historical trend from 1990 to 2016*** has been plotted (light blue line in the figures), based on available data from Eurostat and the European Environmental Agency.
- A ***policy target*** scenario has been set (orange line in the figures), assuming that all EU targets for 2030 are reached and scaling down through the Compound Annual Growth Rate (CAGR) for the period 2016-2030, to obtain the year-by-year progress that would be necessary to reach those targets.
- Then, a ***long-term trend*** has been identified (red dotted line in the figures), projecting at 2030 the Compound Annual Growth Rate (CAGR) over the period 2004-2016 for renewables and the longer period 1990-2016 for GHG emissions and energy efficiency. Starting from 2004 in the long term trend for renewables is meaningful because the first Renewable Energy Directive elaborated by the European Commission is dated late 2001 but the majority of the countries did not implemented a national plan until 2003.
- Finally, a ***short-term trend*** has been set (Violet dotted line in the figures), projecting at 2030 the Compound Annual Growth Rate (CAGR) for 2012-2016 in renewables (meaning when the technology reached market maturity) and the Compound Annual Growth Rate (CAGR) for the period 2010-2016 for GHG emissions and energy efficiency. The choice to have these two indicators starting from 2010 is conceived to minimize the impact of the economic crisis in the two trends.[13]

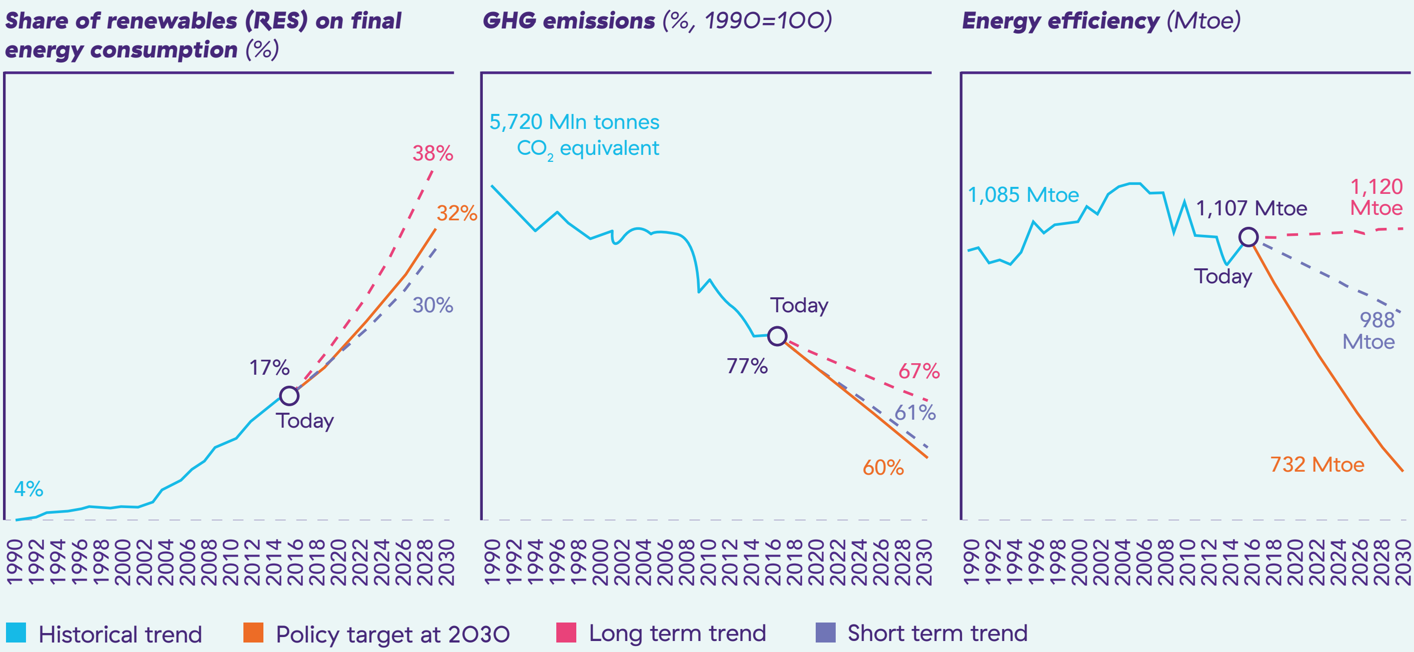
27. Starting from European Union aggregate data it is possible to notice that the EU is perfectly ***on track*** concerning renewables. The policy target trend is, indeed, mid-way between the short term trend and the long term one that embeds the peri-

12 Existing targets for renewables and energy efficiency were considered to be the ones resulting from the upward revision of the political agreement among the EU institutions of June 2018.

13 An additional trend concerning the period 2005-2016 was tested for GHG emissions and energy efficiency, but the results are not displayed in the figures because of the very narrow differences with the short-term scenario in the majority of cases. Additional information concerning the differentiated pace across the years and the countries is given in the description of the figures.

FIG.10

Historical trend and projected scenarios for renewables, GHG emissions and energy efficiency in the EU28 (%, Mtoe), 1990-2030E.
Source: The European House — Ambrosetti elaboration on Eurostat and European Environment Agency data, 2018



od during which the acceleration of renewables was stronger. However, the short term period — based on market maturity consideration — projects the EU with 3 percentage points above the previous threshold for RES set by the 2030 Climate & Energy Package (27%) and close to the existing target of 32%. Similar consideration is made for GHG emissions in which the short-term trend projects the EU in line with the policy target.

28. By contrast, the energy efficiency focus reveals a quite different picture in which the long-term trend would give a final energy consumption higher than the present one, and also slightly higher than it was in 1990. The short term trend reveals, instead, the progress that were made in the most recent years and in which energy consumption in the EU decreased from the peaks of the early 2000s. However, the same trend shows also that a noticeable ***acceleration in the energy efficiency field is necessary*** to approach the ambitious target set for 2030.[14]

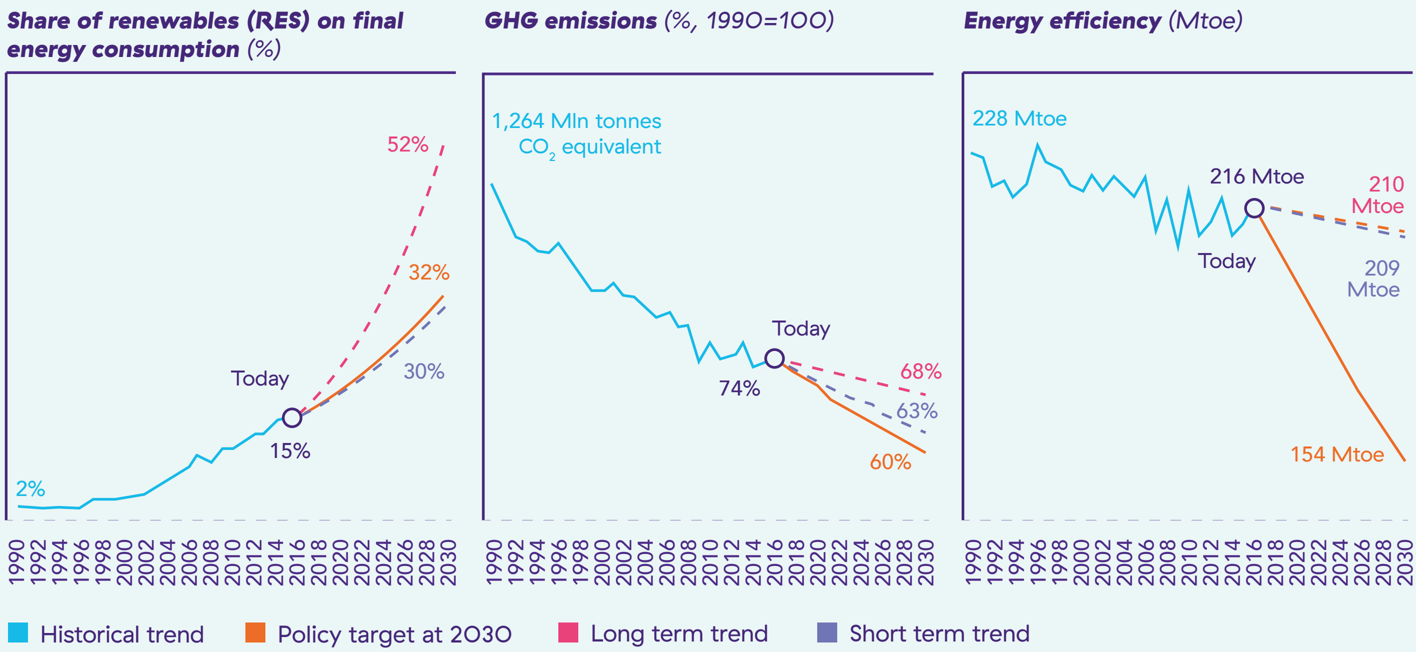
29. A very interesting picture is grasped once the same trends are assessed for Germany. ***Renewables*** share for 2030 is ***almost reachable*** by keeping the same pace of the short-term trend, while the long-term reference (projecting for Germany about half of its energy generated through renewables) is here useful to grasp the speed and the massive investment that the country kept since 2004 to reach the current level.

30. Concerning ***GHG emissions***, Germany has already overcome the target set for 2020 (-20% compared to 1990) and is perfectly ***on track*** to reach the 2030 target. In this regard, it is important to remark that reduction in GHG emissions does not imply that Germany has already completed a sort of "green transition". The 1990 level, indeed, embedded for Germany the emissions of the highly pollutant industrial sector of the former East Germany and the speed of the GHG reduction is strongly correlated to the conversion and closure of many of those plants occurred in immediate years following reunification. To give an idea of the East Germany burden in terms of GHG emissions it is useful reporting that German emissions in 1990 (1,264 million tonnes of CO_2 equivalent) were ***almost 22%*** of EU emissions overall and more than the emissions of France and Italy together. Indeed, the historical trend shows a steep downward trend in the 1990s and early 2000s and then leveling out in the last few years. Regarding ***energy efficiency***, Germany would eventually require an even stronger acceleration than the EU as both the projected trend fall ***far away from the policy target*** one.

14 Concerning the energy efficiency target it needs to be specified that 732 Mtoe corresponds to a reduction of 32.5% compared to 1990. However, given the not-binding nature of this target, the political agreement reached among EU institutions made public in June 2018 states also that final energy consumption in Europe at 2030 should not be above 956 Mtoe.

FIG.11

Historical trend and projected scenarios for renewables, GHG emissions and energy efficiency in Germany (%, Mtoe), 1990-2030E.
Source: The European House — Ambrosetti elaboration on Eurostat and European Environment Agency data, 2018

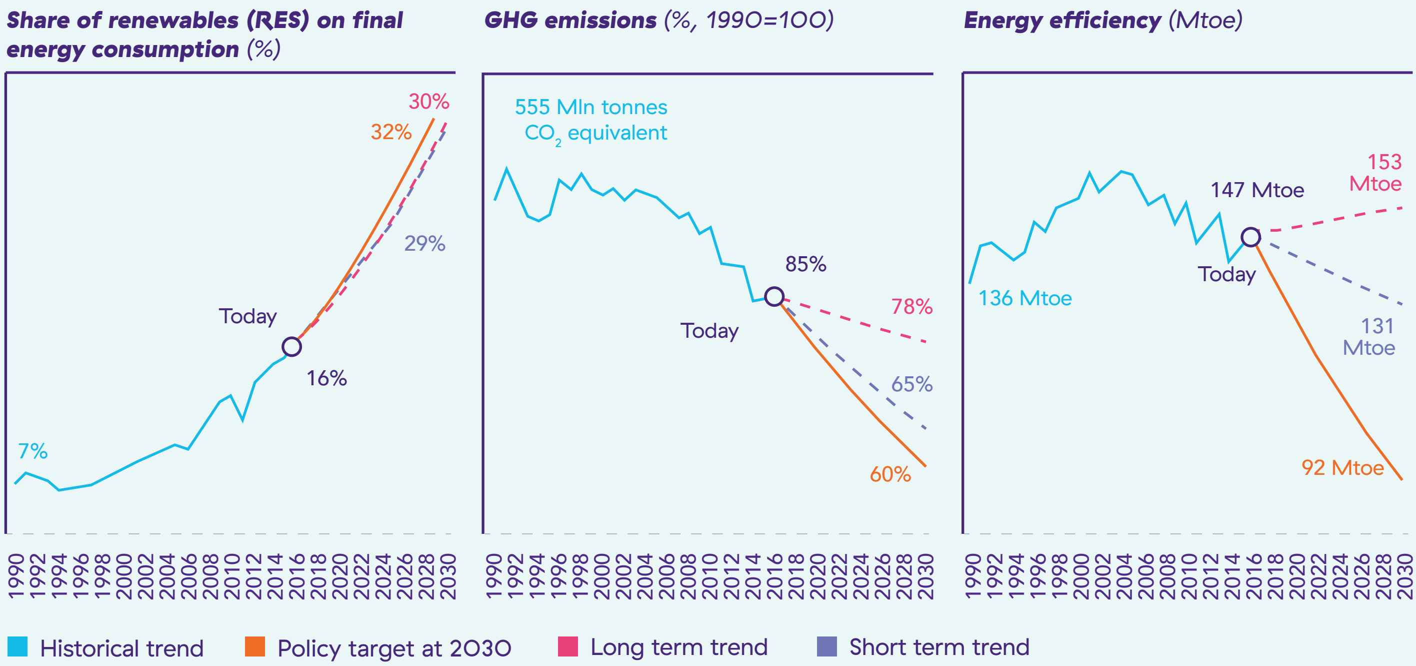


31. France has a longstanding tradition in the production of energy from biomasses and renewable wastes that allowed the country to have a 7% share of renewables as early as 1990, almost double the EU average level and more than three times that of Germany at the same time. The higher starting point (the less steep acceleration of RES than the counterparts) makes the case for ***France*** being ***slightly behind the policy target*** in both long-term and short-term trends.

32. Turning to GHG emissions, the short term trend is way closer to the policy target than the long term one, implying that recent years have seen a substantial improvement in this regard. Concerning ***energy efficiency***, on the other hand, a consideration fairly similar to those of the EU overall can be made: there has been ***slow progress*** in recent years, but it is still insufficient to catch up with the policy targets.

FIG.12

Historical trend and projected scenarios for renewables, GHG emissions and energy efficiency in France (%, Mtoe), 1990–2030E.
Source: The European House — Ambrosetti elaboration on Eurostat and European Environment Agency data, 2018



33. The United Kingdom is a very peculiar case in at least two respects: renewable energy sources and GHG emissions. As for ***renewables*** the UK is a ***latecomer in Europe***. Only 9% of final energy consumption in the country is currently generated from RES (vs. 17% on average in the EU). Yet, the percentage was still below 1% in 2004 making the case for the steep acceleration visible in the long-term trend that is projecting the UK to a quantum leap in renewables by 2030. Given the delay compared to the other countries — and the relative advantage of the latecomer — which implies that investments in research can be lower than the first movers — the growing trend is particularly steep and the UK is on track to reach the policy target by keeping the pace of the current short term trend[15].

15 Given the instability of UK data for renewables that are currently experiencing the same acceleration rates that the other countries had more than 5 years ago (in UK from 2014 to 2016 the growth was about 2.2 percentage points), the short term trend is here projected by referring to the CAGR for the 2015–2016 period only.

34. Like Germany, a steep downward trend for ***GHG emissions*** is visible also in the UK making the current levels ***almost equal to the 40% reduction*** that must be obtained by 2030 according to the EU policy targets.
35. Even in this case it must be highlighted that the starting point was considerably higher than France and Italy (UK emissions in 1990 amounted to 14% of the overall EU ones, second only to Germany) and since 1990 the country underwent a structural transition from manufacturing-based economy to a service economy. Unlike the case of Germany the short term trend is revealing a considerably faster decrease than the long term one which implies that recent years have seen a constant improvement in GHG reduction. This difference can be partially explained by the persisting manufacturing economy of Germany as compared to the largely service-based of the UK.[16] Finally, ***energy efficiency is a critical point*** for the UK as well, the long term trend is projecting the country to a substantially stable position and the short term trend marks some improvements but without approaching the target.

THE DEVELOPMENT OF RENEWABLES IN THE UK

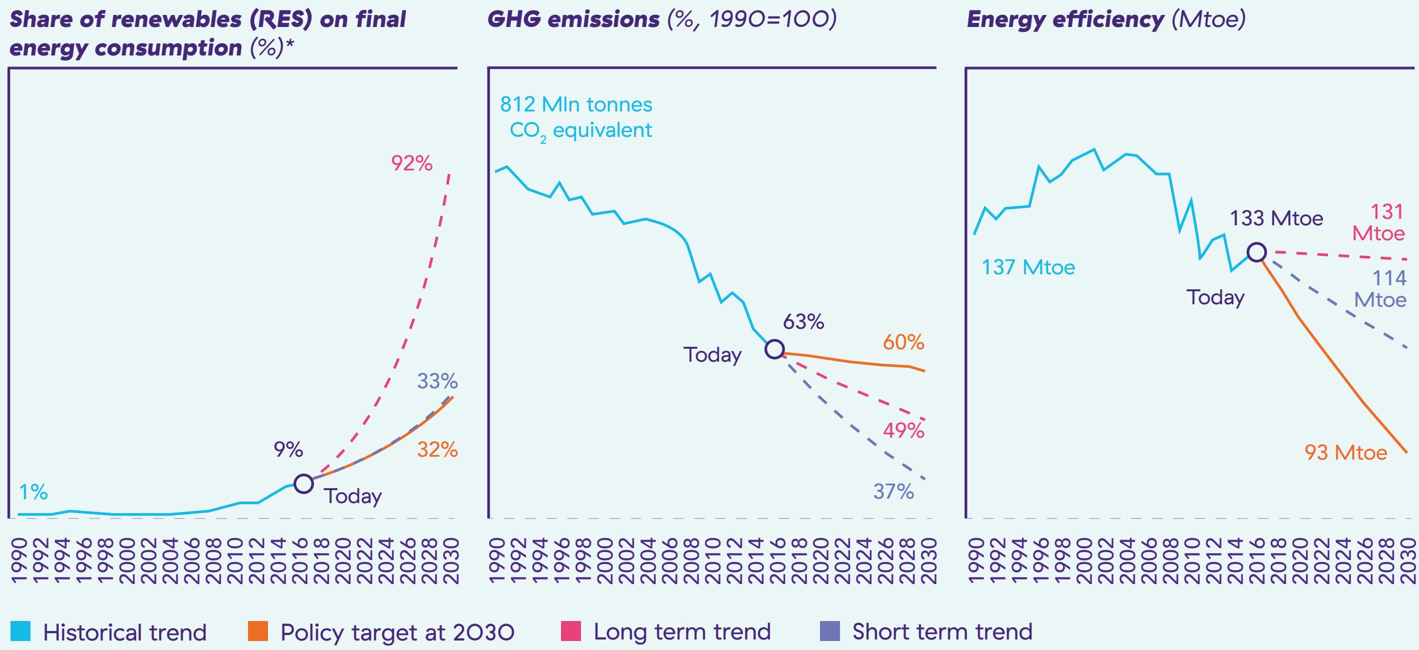
In the UK the Renewables share in final energy consumption in 2008 was lagging behind the EU average (2.7% vs. 11.1% at that time). Following the introduction of the ***Climate Change Act*** (2008) investments started to grow bringing the UK to become a world leader in renewables, and especially with regard to wind power.
In spite of this growth, the trend for the next years is hard to predict because of the recent (2016) government's decision to change the previous framework by ***banning onshore windmill subsides***. The result of the policy change is visible in the slump (-56%) of investment in wind, solar and other RES observable in 2017 making particularly hard to predict the evolving trend for renewables in the country.

Source: The European House - Ambrosetti elaboration on Bloomberg New Energy Finance (BNEF) data, 2018.

16 The service sector in the UK has almost doubled its revenues from 1990 to now (from £17,000 million to over £35,000 million in 2016), so that the current contribution of the services to the UK Gross Domestic Product is equal to 80%.

FIG.13

Historical trend and projected scenarios for renewables, GHG emissions and energy efficiency in the UK (%, Mtoe), 1990-2030E.
Source: The European House — Ambrosetti elaboration on Eurostat and European Environment Agency data, 2018



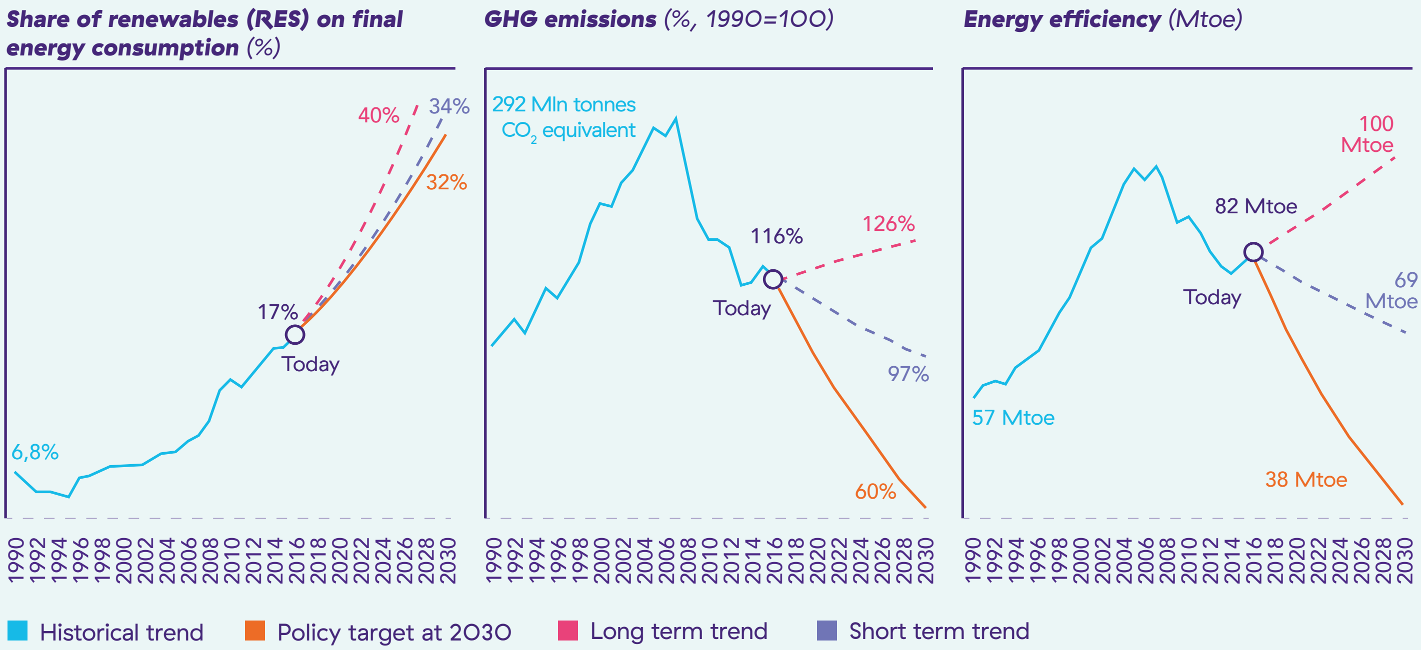
* Differently from the «Short term trend» for all the other countries, The European House — Ambrosetti has considered the 2015-2016 period Compound Annual Growth Rate

36. Differently from the other countries here depicted, Spain registered an increase in GHG emissions along all the 1990s and the early 2000s before reversing the trend almost in coincidence with the economic crisis and then pursuing along it. In other terms, looking at the historical trend, the ***reduction in GHG emissions*** is visible only in a ***later moment than the other countries*** and the EU average. However, this difference can be explained by the fact that Spain had in 1990 a relatively less developed industrial sector than all the other countries here considered — in which deindustrialization processes and transition to a service economy contributed also to the reduction of GHG emissions — while having an economic expansion phase that followed the entry in the EU occurred only in 1986. Given this country-specific caveat, making the case of a growing long-term trend too, it has to be highlighted that the decreasing trend of the most recent years is grasped by the short-term trend outlining a further decrease to be reached until 2030.

37. With regard to the ***renewables***, and similarly to the French case, ***Spain was an early mover*** and the growth has been steady along the years, projecting both the short-term and the long-term trends above the policy target at 2030. Finally, concerning energy efficiency, the historical trend of final energy consumption substantially mirrors the GHG emissions one, and similarly to the other countries an improvement is captured by the short-term trend only.

FIG.14

Historical trend and projected scenarios for renewables, GHG emissions and energy efficiency in Spain (%, Mtoe), 1990-2030E.
Source: The European House — Ambrosetti elaboration on Eurostat and European Environment Agency data, 2018



38. To a great extent, the Italian case is similar to the German one concerning the pattern of renewables' development. The long-term trend is here projected at about half of total final energy consumption mirroring the acceleration — and relative investments — that were directed towards ***renewables*** since the early 2000s. Yet, the short-term trend is ***substantially aligned with the previous policy target of 27%*** share of RES, but additional effort is required to reach the upgraded target of 32%.

39. Yet, concerning the Italian ***GHG emissions***, it needs to be emphasised that the short-term trend is substantially ***in line with the policy target*** and being 15 percentage points below the long term one implied that Italy has considerably accelerated the path towards GHG reduction in recent years compared to the situation during the 1990s.

40. As with the aggregate EU picture and the other countries here considered, a ***delay in energy efficiency improvements is visible also in the case of Italy***. The current levels of final energy consumption are higher than they were in 1990 and even the short term trend — which includes the recent improvements visible in the historical trend — does not allow for it to catch up with European policy target objectives.

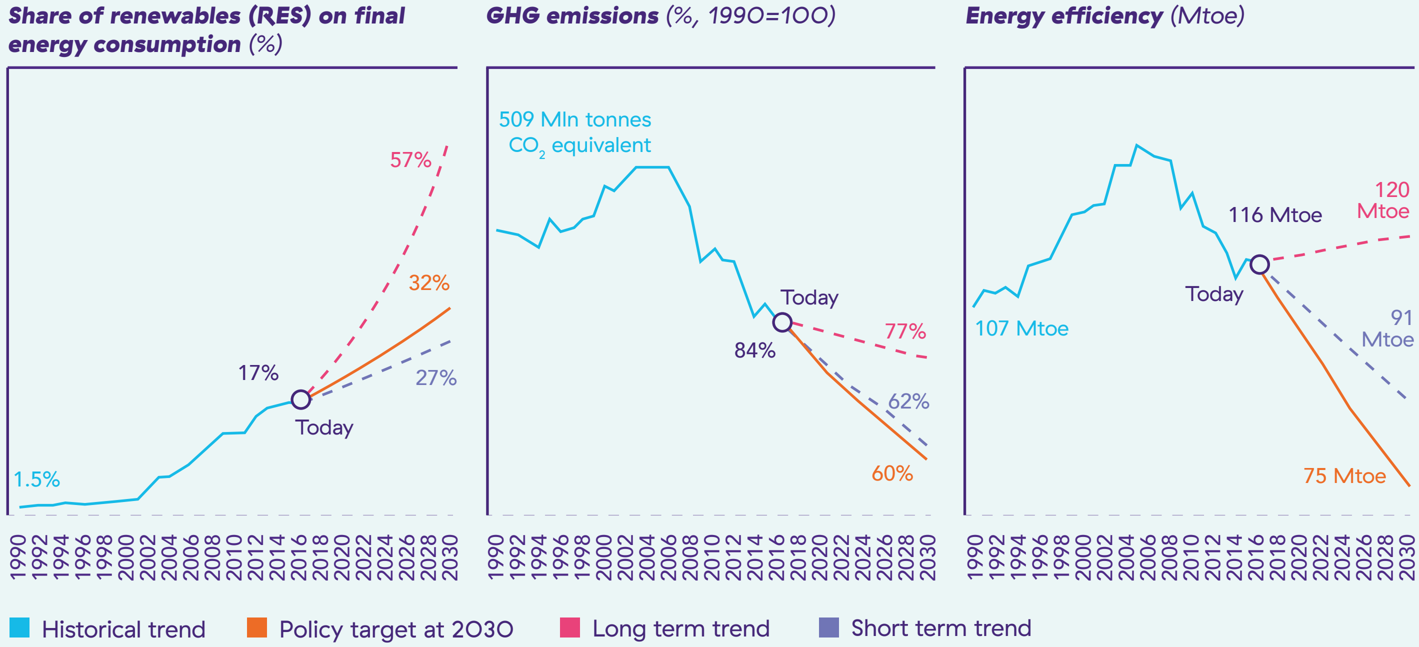
41. To give an idea of the effort required in the energy efficiency field the Italian National Energy Strategy (itself a policy scenario that includes the effects of a few policy measures) forecasts overall final energy consumption will be 108 Mtoe. This level would be a reduction of 8 Mtoe compared to the current consumption levels (and 12 Mtoe compared to the long term trend) but still 17 Mtoe higher than the projected short term that — in spite of recent acceleration — at the current speed does not allow Italy to reach the policy target by 2030.

42. In spite of country diversity in terms of emissions starting points and development of renewables, which were covered beforehand, a few common points stand out from the synthetic indicators that we developed. In particular:

- ***All countries are in line or almost in line to reach the EU policy target of a 32% share in renewable energy sources*** share by 2030. This evidence strengthens the evidence introduced in Part 1 of this study concerning the positive contribution of electrification to reach the decarbonization targets. Higher levels of renewables, indeed, enable a fossil fuels free energy transition making electrification a concrete tool to decarbonize.
- ***GHG emissions show an overall downward trend*** in all countries examined even if the trend is occurring at a very different pace across them and with the partial exception of Spain in which the decrease starts later in time than the other countries. Further, the countries experiencing a faster decrease of GHG are also the ones where structural changes occurred compared to the 1990 benchmark (the full absorption of the Eastern Lander in Germany and the transition towards a service-led economy in the UK).
- ***Energy efficiency is the weakest indicator at the EU level and in all the considered countries***. The short term trend only reveals recent improvements in the energy efficiency field but without bringing the countries close to the EU policy objective. In other terms, the energy efficiency indicator reveals the necessity to push for further investment. In this regard, the efficiency gains associated with electricity-driven technologies that can be deployed from here to 2030 are among the most important factors of acceleration currently available.

FIG.15

Historical trend and projected scenarios for renewables, GHG emissions and energy efficiency in Italy (%, Mtoe), 1990-2030E.
Source: The European House — Ambrosetti elaboration on Eurostat and European Environment Agency data, 2018



Part 3

Electrification stimulates industrial value chains and ecosystem of innovation

Part 3

Key messages

3.1. The transport sector has the highest potential for electrification

- In light of international sustainability trends, the electric mobility ***is experiencing an unrelenting growth at the European level***, driven by both market dynamics and policy targets:
  - the ***e-Car*** market has experienced a steady growth in recent years (+68.7% Compounded Annual Growth Rate — CAGR — between 2011 and 2017), bringing Europe to have more than 300,000 circulating electric cars on its roads;
  - the European e-Two-wheelers market (motorcycles and mopeds) is growing faster, especially with the moped segment which grew by ***233% from 2011 to 2017*** in terms of new registrations and recorded a market share ***of 6.3%*** in 2017;
  - cities around Europe are introducing electric buses, as a signal of their intention to contribute to emissions reduction in urban environments. In Europe there were ***more than 2,100 urban e-Buses in 2017***, with full electric (Battery Electric Vehicles — BEV) making up the majority of the total with 1,560 electric units;
  - although electric light commercial vehicles are not very widespread in Europe, they represent an attractive alternative to traditional vehicles, particularly for those activities involving short-distance urban deliveries: almost ***0.6% of light commercial vehicles*** sold in Europe in 2017 were electric;
  - due to their weight and their need to travel for long distances, the ***electrification in the truck sector is still at an experimental stage*** and there are no electric trucks on European roads.
- As of today, e-Mobility stock in Italy is comprised of ***14,647*** electric cars (Battery Electric Vehicles — BEV — and Plug-in Hybrid Electric Vehicles — PHEV), ***6,211*** electric two-wheelers, ***455*** electric urban buses, ***4,454*** electric light commercial vehicles and ***zero*** electric trucks.
- The Italian extended e-Mobility value chain involves several industrial and economic sectors linked to vehicles production, electricity grid infrastructure, ICT services and recycling. In Italy there are ***about 160,000 companies*** involved in the e-Mobility extended value chain with more than ***820,000 workers*** and a ***turnover exceeding €420 billion***.
- To build a framework within which to estimate the achievable turnover along the extended e-Mobility industrial value chain in Italy at 2030, ***three alternative scenarios*** have been developed (baseline, intermediate and accelerated) ***for electric penetration at 2030 in Italy*** for all the forms of mobility and charging infrastructures:
  - ***e-Cars***: 2 to 9 million vehicles and 30,000 to 45,000 dedicated public charging stations;
  - ***e-Two wheelers***: 240,000 to 1.6 million units and 857 to 2,000 dedicated public charging stations;
  - ***e-Buses***: 3,307 to 10,188 vehicles and 413 to 637 dedicated charging points;
  - ***e-Light commercial vehicles***: 202,763 to 630,478 vehicles and 724 to 1,051 dedicated public charging stations;
  - ***e-Trucks***: 0 to 34,336 vehicles and 0 to 8,584 dedicated charging points.
- Together with the analysis of the vehicle and charging infrastructure prices, the assessment of the market value of the ICT services and the estimation of the turnover from recycling, the analysis of the penetration scenarios results with a total potential turnover at 2030 in Italy was estimated to be between ***€102.4 and €456.6 billion in 2030***.

3.2. Electrification offers a relevant contribution to energy efficiency

- At both European and Italian level, there are some electrification technologies enabling the growth of electricity in final end uses to 2030.
- The comprehensive map of the electrification technologies at 360° — comprising ***over 60 technologies*** supporting direct and indirect electrification — reveals how six technologies are the key drivers behind the electrification of end uses until 2030. These technologies (***heat pumps, LED lamps, electrochemical storage systems, electric drives, power electronics and energy management systems***) are the most promising in terms of both efficiency gains and deployment potential.
- The overall Italian industrial value chain of the electrification technologies is currently composed of about ***17,000 firms*** and more than ***320,000 employees***, totaling a turnover of around ***€80 billion*** per year.
  - The detailed analysis of ***Italian competences*** reveals a few critical issues regarding the recycling and reuse fields and the necessity to build industrial competences concerning electrochemical storage systems. On the other hand, a few competences of excellence exist for heat pumps and LED lamps.
  - The activation of the Italian industrial value chain for the all electrification technologies — measured through a "what if" analysis that envisioned a full deployment and an evolutive scenario — reveals an overall actionable turnover ranging between ***€135 billion*** and ***€326.5 billion***.

3.1.

The transport sector has the highest potential for electrification

3.1.1. What is the state of the art of e-Mobility in Europe and in Italy

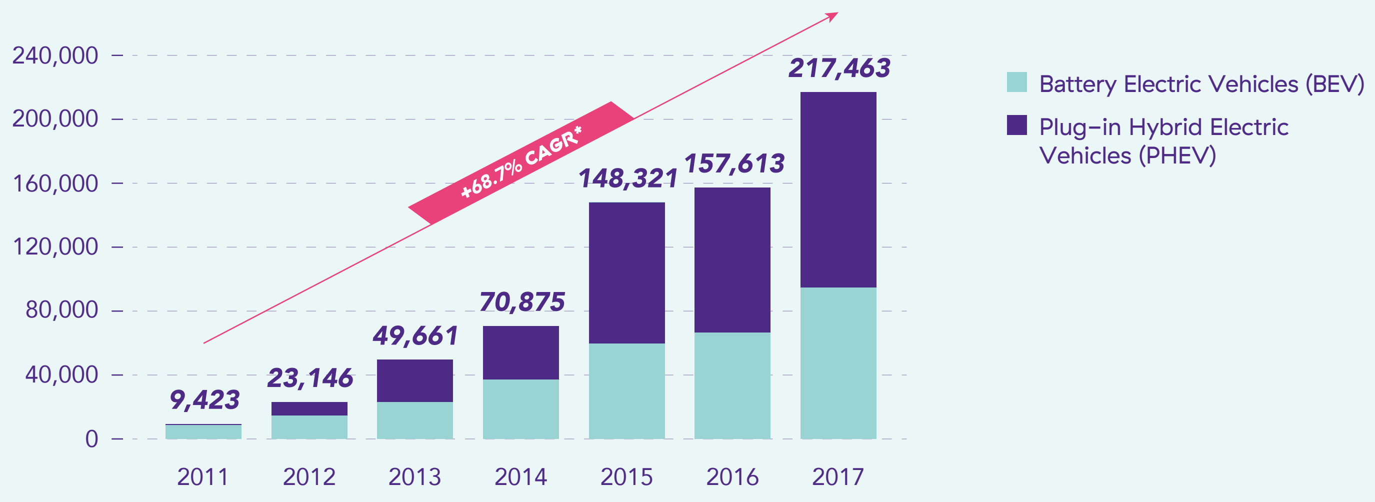
1. In light of the aforementioned sustainability trends and the negative impacts of road pollution, electric mobility is being increasingly identified as one of the cleanest and most valuable option for transport. For these reasons, e-Mobility is showing a growing trend at the European level, driven by both market dynamics and policy targets. In fact, since duty vehicles, cars and buses, represent the majority of transport emissions and are responsible for 15% of overall CO_2 emissions within the European Union, specific targets have been set by European Commission.[1] At the same time, benefits associated to e-Mobility (environmental sustainability, energy efficiency, technological content, accessibility and connectivity) are such that attention and interest of the various market players involved, both public and private, are increasing.

2. Starting from the e-Cars market, it has experienced steady growth in the last years (***+68.7%*** Compounded Annual Growth Rate — CAGR — between 2011 and 2017) and currently Europe has more than 300,000 circulating electric cars on its roads. The market share of new vehicles amounted to ***0.64%*** for Battery Electric Vehicles (BEV) and ***0.8%*** for Plug-in Hybrid Electric Vehicles (PHEV) in 2017.

1 For cars, manufacturers are obliged to ensure that their new car fleet does not emit more than an average of 130 g CO_2/km since 2015 and 95 g CO_2/km by 2021. For vans the mandatory target is 175 g CO_2/km by 2017 and 147 g by 2020. Moreover, the European Union adopted a Heavy-Duty-Vehicle strategy in May 2014 which is the EU's first initiative to tackle emissions caused by High Duty Vehicles. Measures for the certification of CO_2 emissions and fuel consumption of those vehicles and for the monitoring and reporting of the certified data are currently being prepared. Source: European Commission, 2017.

FIG.1

Market share of e-Cars in the European Union (Battery Electric Vehicles — BEV and Plug-in Hybrid Electric Vehicles — PHEV), 2011-2017.
Source: The European House — Ambrosetti elaboration on European Alternative Fuel Observatory (EAFO) data, 2018



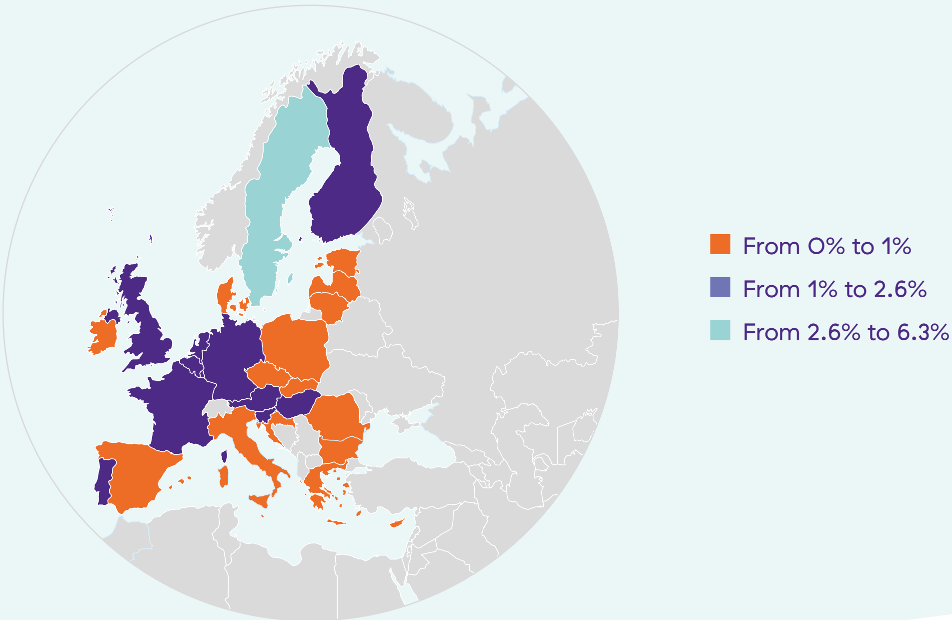
** Compound Annual Growth Rate.*

3. Although this growing trend, differences among European countries persist. Northern European economies affirm themselves as the best performers in terms of electric car market dynamics: Sweden registered an electric cars market share equal to ***6.3%*** in 2017, followed by the Netherlands (2.7%), Belgium (2.7%), Finland (2.6%) and Austria (2.1%). In Sweden, there are today almost ***50,000*** circulating electric vehicles (1.1% of the stock), a number that has grown by ***114% per year*** since 2012.

FIG.2

Market share of e-Cars in the European Union (Battery Electric Vehicles — BEV and Plug-in Hybrid Electric Vehicles — PHEV) by country, 2017.

Source: The European House — Ambrosetti elaboration on European Alternative Fuel Observatory (EAFO) and International Energy Agency (IEA) data, 2018



4. The European two-wheeler market (motorcycles and mopeds) is growing faster, especially with regard to the moped segment, because of its adaptability to the urban context. Moreover, as opposed to other types of transport, the price difference between an e-Moped and a traditional one is relatively small, and vehicles can be recharged at home without any tailored infrastructure. These features allowed the market to grow by ***233% from 2011 to 2017*** in terms of new registrations and to record a market share of ***6.3%*** in 2017. From the other side, although the e-Motorcycle market is less mature than the mopeds one (market share was 0.4% in 2017), it also grew by ***349% from 2011 to 2017*** in terms of new registrations.

5. Once again, there are differences among European countries, with Belgium acting as the best performer with 12.3% of two-wheeler new registrations being electric at 2017, followed by the Netherlands (6.9%) and France (3.2%).

The interesting feature of this analysis is that, although Italy is one of the most developed European markets for two-wheelers, (it accounts for ***17.3%*** of the overall European market), when it comes to electric vehicles, it is at the bottom of the league.

THE E-TWO-WHEELERS MARKET IN CHINA

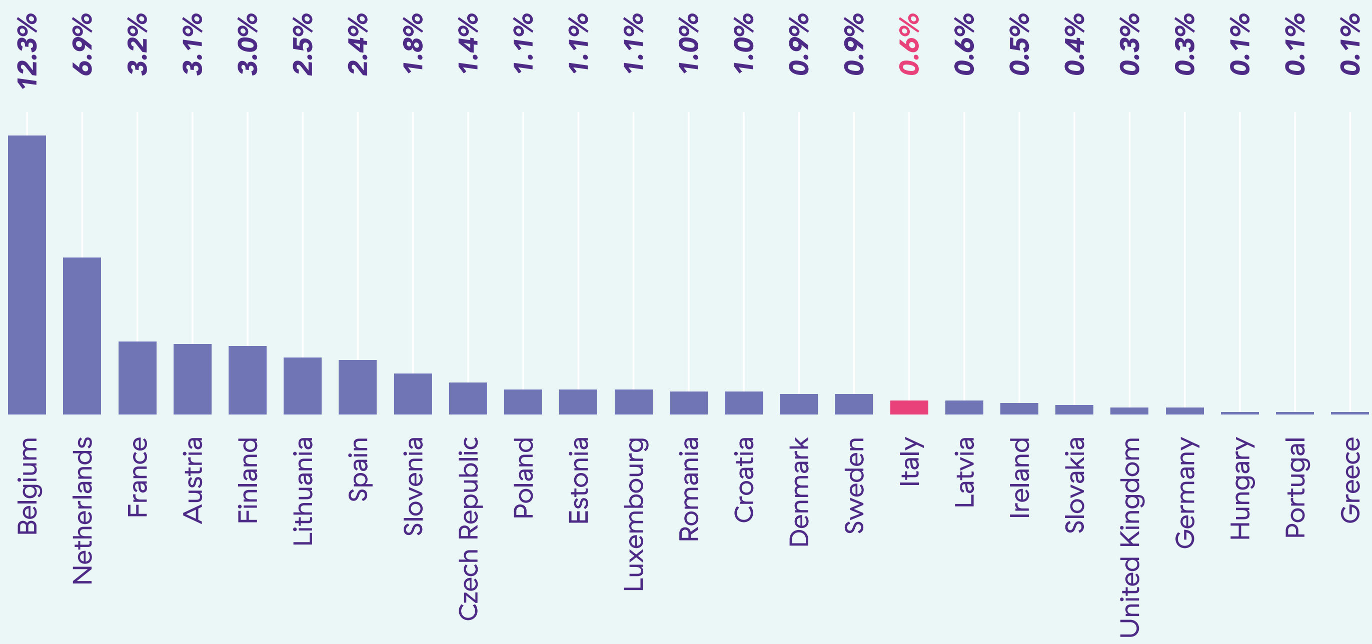
Nowadays, almost all the existing electric two-wheelers circulate in China: in 2017 there were around ***250 million*** units on Chinese roads, a number 100-times higher than the electric light duty vehicles in the world today. This phenomenon is still growing with sales amounting to almost 30 million e-Two-wheelers per year. Two main features have enhanced the widespread of e-Two-wheelers in China:

- policy targets: in 1999 the government designed certain types of electric two-wheelers as bicycles allowing citizens to drive them without a license and it introduced severe policy restrictions on the gasoline motorcycles circulation;
- vehicle characteristics: vehicles are sold at low costs, below that of an internal combustion engine scooters, because of their manufacturing and low battery requirements since there are limitations on maximum speed (20 km/hour).

Source: The European House — Ambrosetti elaboration on International Energy Agency (IEA) data, 2018.

FIG.3

Market share of e-Two-wheelers in the European Union by country, 2017.
Source: The European House — Ambrosetti elaboration on European Association of Motorcycle Manufacturers (ACEM) data, 2018



6. Cities around Europe are introducing electric buses, as a signal of their intention to contribute to emissions reduction in urban environments. Although one of the stumbling blocks of their widespread adoption is the higher cost compared to diesel ones, it is worth noting that e-Buses have lower Total Cost of Ownership (***€0.85/km***) than diesel (€0.90/km) and Compressed Natural Gas (€1.02/km). In Europe there were ***more than 2,100*** urban e-Buses in 2017, with full electric (BEV) making up the majority of the total with 1,560 electric units.

7. Electric light commercial vehicles are not very widespread, but manufacturers are slowly increasing the number of models they offer. As of today, there are only five available brands for electric light commercial vehicles, but they are expected to increase to 11 by 2023.[2] Electric light commercial vehicles are an attractive alternative to traditional vehicles, particularly for those activities involving short-distance urban deliveries. Almost 2 million light commercial vehicles were sold in Europe in 2017 and on average ***0.6%*** of them were electric.

MAJOR E-BUS MANUFACTURERS COME FROM CHINA BUT GLOBAL COMPETITION IS INCREASING

Chinese e-Bus manufacturers are world leaders and they doubled the units sold in China in a single year (from 50,000 in 2015 to 116,000 in 2016). The biggest producer is Yutong with 19% of the Chinese market, followed by BYD that alone has a 13% share of the e-Buses market and Zhontong (10%). BYD and Yutong have also gained success outside China, selling urban e-Buses to several European and United States cities, thanks, above all, to their lower costs compared to European and US manufactures. However, Chinese manufacturers are facing strong competition in Europe and the United States as the regions have several domestic bus manufacturers with a manufacturing tradition and growing expertise in e-Bus production. Bus producers like Solaris, Optare, VDL, Volvo or Proterra have been quick to recognize the opportunities of electric buses and offer models for sale. Their existing relationships with European cities and bus market players, as well as their expertise in the structure of the European public transport market, gives them an advantage over Chinese manufacturers.

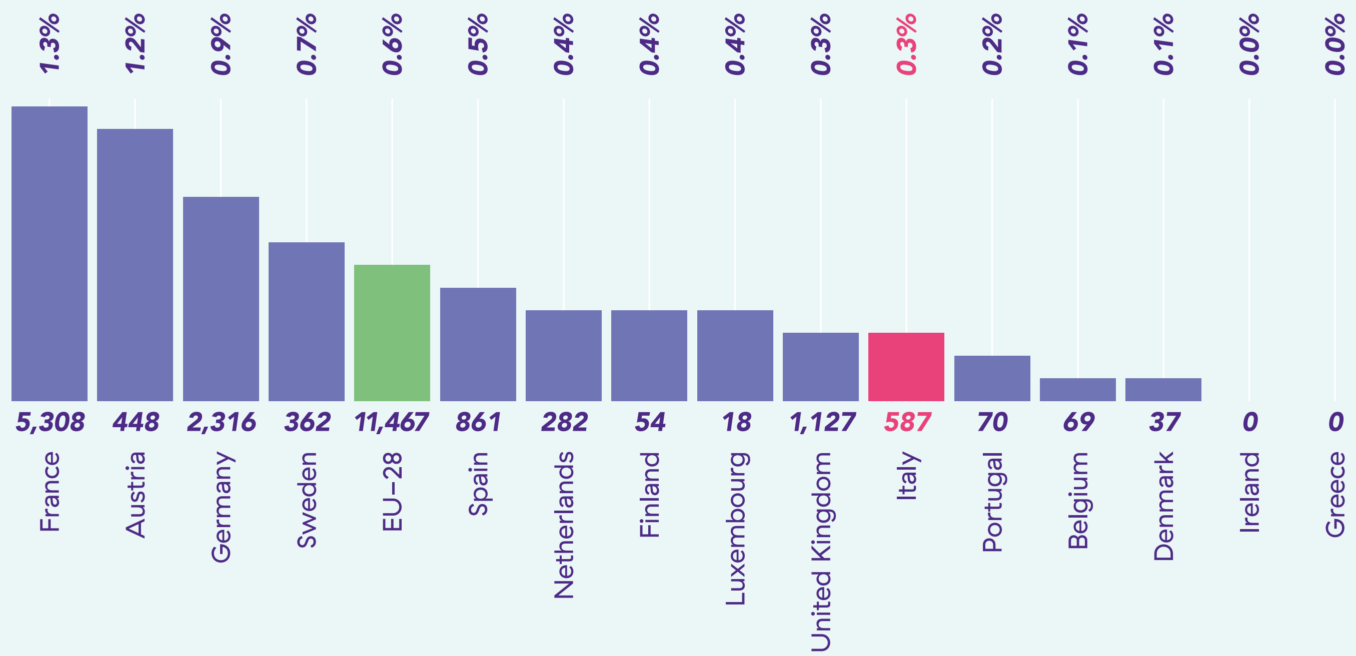
Source: The European House — Ambrosetti elaboration on Bloomberg New Energy Finance data, 2018.

2 The brands that will be involved are: Mercedes, Alke, Iveco, PSA, Renault, Volkswagen, Nissan and SAIC. Source: EV Volumes, 2017.

FIG.4

Annual sales of e-Light Commercial Vehicles in European countries (absolute numbers and as a percentage on total sales), 2016.

Source: The European House — Ambrosetti elaboration on the International Council on Clean Transportation (ICCT) data, 2018



8. Due to their weight and their need to travel for long distances, the electrification in the truck sector is still at an experimental stage. In Europe no e-Trucks have been sold, compared to 1,500 units in United States and 46,452 in China.[3] However, this market is expected to develop in the future both due to market dynamics and policy targets. The European Union has indeed proposed targets for reduction of truck CO_2 emissions for the first time ever: ***15%*** by 2025 and ***30%*** by 2030. Moreover, some solutions of electrified roads can pave the way for the development of e-Trucks market in Europe.

9. With regard to Italy, a comprehensive e-Mobility database has been developed, starting from 2005. As of today, e-Mobility (Battery Electric Vehicles — BEV and Plug-in Hybrid Electric Vehicles — PHEV) accounts for:

- ***14,647 electric cars*** out of a car fleet of almost 37 million (0.04%);
- ***6,211 electric two-wheelers*** out of a total fleet of almost 8.5 million (0.07%); [4]
- ***455 electric urban buses***[5] out of a total fleet of almost 50,000 (1%);
- ***4,454 electric light commercial vehicles*** out of a fleet of almost 4 million (0.1%).
- Zero e-Trucks as of today, as previously mentioned.

SOME RECENT EXAMPLES OF e-TRUCKS

Tesla has launched an electric truck called "Semi" that can travel 800 km with a charged battery and has operational costs 20% lower than diesel trucks. Moreover, the battery takes only 40 minutes to be charged and the vehicle has an automatic piloting system able to stop the vehicle in case of emergency and to alert the driver about the risk of collision. The truck will be available on market starting in 2019.

Daimler has recently unveiled the FUSO eCanter program, a small electric truck meant for urban routes with a range of only 100 kilometers (62 miles) and a load capacity up to three and a half tons, and a bigger all-electric truck, which has a 26 ton capacity, a massive 212 kWh battery pack, and ~125 miles of range. Now the company is launching a new unit called e-Mobility Group to consolidates its electric truck efforts.

Source: The European House — Ambrosetti elaboration on Tesla and Daimler data, 2018.

3 Values for United States and China refer to Medium and Heavy Trucks. Source: EV Volumes, 2017.

4 Since there is no database with the stock of electric two-wheelers circulating in Italy, an estimation has been made on the number of new registrations in Italy from 2011 until today.

5 Including trolleybuses.

FIG.5

Electric mobility in Italy, 2017.
Source: The European House — Ambrosetti elaboration on European Alternative Fuel Observatory (EAFO), Associazione Nazionale Ciclo Motociclo e Accessori (ANCMA), Automobile Club d'Italia (ACI), Associazione Trasporti (ASSTRA) and European Association of Motorcycle Manufacturers (ACEM) data, 2018

14,647 electric cars (stock) out of a car fleet of ~37 mln (0.04%)

6,211 electric two-wheelers (stock) out of a total fleet of ~8.5 mln (0.07%)

455 electric urban buses (stock) out of a total fleet of ~50,000 (1%)

4,454 electric light commercial vehicles (stock) out of a fleet of ~4 mln (0.1%)

As of today, electrification in the **truck** sector is zero

IN SWEDEN THERE IS THE WORLD'S FIRST ELECTRIFIED ROAD FOR CHARGING VEHICLES

The world's first electrified road has opened in Sweden under the name of "eRoadArlanda", allowing for cars and trucks to be recharged while travelling. The electrified road is about 2 km long and connects Stockholm Arlanda airport and one of its logistic sites. Energy is transferred from two tracks of rail in the road via a movable arm attached to the bottom of the vehicle helping the driver to overcome the problems of keeping the electric vehicles charged and the affordability of the batteries manufacture. For example, for a heavy truck to be 100% electric, it would need a battery weighting 40 tonnes but with this system the battery installed on an electric truck would be able to weigh only 600 kilograms. The system is powered only when the vehicle passes over it and when the vehicle stops the current is disconnected. It is also able to calculate the vehicle power consumption so that the cost can be debited per vehicle and user. This system will certainty enhance the achievement of the Government goal of a completely fossil fuel free vehicle fleet by 2030.

Source: The European House — Ambrosetti elaboration on Swedish Ministry of Transport data, 2018.

3.1.2. e-Mobility involves a relevant industrial value-chain

10. For the 2017 study, the "e-Mobility Revolution. Impacts on Italy and its industrial value chain: Italy's agenda", the ***extended value chain of the e-Mobility*** has been reconstructed. It is defined as all industrial sectors and services involved in the development of electric mobility, considering both direct and indirect supply chains. The framework of the analysis includes all types of road e-Vehicles (cars, two-wheelers, urban buses, light commercial vehicles and trucks), both full electric (BEV) and hybrid electric plug-in (PHEV). In this study, the analysis has been integrated and updated.

11. For the mapping of the supply chain, a ***matrix presentation*** of macro-sectors has been adopted: vehicles, from one side, and charging infrastructure and grid electricity, from the other side, are the backbones along which ICT services for e-Mobility are inserted. These sectors are analyzed along the entire value chain:

- ***Research and Development***, which focuses on specific areas including energy efficiency and innovative intelligent vehicle charging systems, performance improvement solutions, the design and engineering of the management and reuse of energy storage systems, vehicle redesign (e.g. engineering and design of bodywork, components, and innovative materials) in the context of electric vehicle characteristics, the development of software and self-driving systems.
- ***Manufacturing***, which includes the manufacture of parts and accessories for vehicles and their motors (in part in common with resources dedicated to internal combustion engines, in part addressing full electric and hybrid plug-in models) as well as assembly operations. In the infrastructure and energy chain, this phase includes networks for the electric energy (generation, transmission and distribution of electricity and related infrastructure, both public and residential) and telecommunications, extending to service stations, electrical charging points and ICT systems for the latter.
- ***Distribution and sale*** of vehicles, IT platforms and energy.
- The ***use of electric vehicles and their aftermarket***, covering the maintenance, repair, sale of finished parts and spare parts, the provision of smart services and the management of electric vehicles, as well as services dedicated infrastructure and electricity network management or customer assistance.
- ***"Second life" recycling and reuse*** of electric vehicle and charging infrastructure components.

12. In order to identify all the components relevant to each activity in the extended value chain, each phase involved a detailed quantitative census of existing or potential products and services, with recourse to multiple channels and sources of information:

- study of major technical reports and scientific literature;
- field interviews with active value chain industrial operators;
- expert reviews with the engineers affiliated to the Institute for Marine engineering (INM), Department of Engineering, ICT and Technologies for Energy and Transports (DIITET) of the National Research Council of Italy (CNR), who have validated the structure and individual activities/outputs of the e-Mobility extended chain.

FIG.6

Mapping of e-Mobility industrial value chains.

R&D (new areas of research) | **Manufacturing**

Vehicle

R&D (new areas of research)

- Fossil fuels°
- Sources of renewable energy
- Alternative fuels (e.g. biodiesel, hydrogen, methane°, etc.)
- Energy efficiency (e.g. cutting edge materials for energy storage, soundproofing, bodywork and components, etc.)
- Vehicle-to-Home
- Autonomous Vehicle
- Battery Management System (BMS)
- Electronic differential
- On-board energy flow management strategies
- Redesigning vehicle and its bodywork
- Electric drivetrain
- Design and engineering
- Software development
- Vehicle-to-Vehicle

Electrical systems

- Wires and wiring sets
- Windscreen wipers, heated rear windows and electrical anti-fogging devices for automobiles
- Starter motors°
- Aerial
- Conductive and inductive charging systems (static and dynamic)

Mechanical components

- Brakes and components (disk, pedal and calipers)
- Clutches
- Manual/automatic gear box°
- Front/rear differential
- Rims and wheels
- Pads
- Gas spring/absorbers
- Chassis
- Axles
- Suspension shock absorbers
- Radiators
- Silencers°
- Steering and columns
- Tank°
- Passenger access platform*
- Easel**
- Pedal**
- Fairing**

Audible systems

- Horn
- Loudspeakers
- Soundproofing°
- Audible indicator

After Treatment System

- Catalysts°
- Intakes°

Electronic systems of power

- Electronic capacitors
- Electronic resistors
- Electronic valves
- Spark plugs°
- Wiring for ignition systems°
- Ignition coils°
- Dodes

Electronic systems of control

- Dashboard
- Telematic systems
- Electric panel (electronic crystals, components for monitors, cathode tubes)
- Micro-processors
- Connectors
- Inducers
- Boards and printed circuits
- Electrical systems for windows and doors
- Panel instruments
- Voltage regulator
- Control units
- Diagnostics
- Vehicle Management System (VMS)

Lighting

- Headlights/LEDs
- Interior lighting
- Daytime running lamp adaptive lights

Air Conditioning

Bodywork

- Cab
- Bumpers
- Spraying and painting
- Front grill
- Doors
- Lining of trunk

Interior trims

- Windshields and windows
- Mirrors and steering wheel
- Handrails and buttons for stop request*
- Handlebar**
- Seats
- Saddle**
- Safety kit (fire extinguisher, first aid)
- Ticket punch*
- Safety belts and airbags
- Interior gadgets

Electrochemical storage systems

- Battery pack
- Battery charger
- Super-capacitors
- Accessories
- Battery Management System (BMS)

Software for vehicles

- Sensors
- Diagnostics systems
- Start&Stop Systems
- Safety Systems
- Navigation systems
- Tracking devices
- Integrated systems (ABS, EDS,...)
- Alarm system

Infrastructural and energy network

R&D (new areas of research)

- Energy efficiency
- Sources of renewable energy
- Energy transmission/distribution network
- Development of software for electrical energy flows
- Second-life for electric batteries
- Vehicle Grid Integration (VGI)
- Smart charging

Energy

- Electricity production, transmission and distribution grid and related infrastructures
- Installation of new energy transmission facilities for more widely distributed grids
- Public electricity grid
- Domestic grid
- Storage systems
- Smart grids
- Transformers (of electricity distribution, of fluorescent current, etc.)
- Substations of transformers for electricity distribution
- Transmission and distribution regulators

Telecommunications network

- Systems for connecting to Internet
- Vehicle-to-Vehicle
- Smart phones
- Telecommunication/transmission infrastructures (4G, 5G, etc.)

Software for charging points

- Integrated systems
- Sensors
- Diagnostic systems
- Navigation systems
- Tracking devices
- Payment/transaction systems for charging
- Software for vehicle interaction/recognition

Electrical charging points

- Exterior panels
- Displays
- Electrical cables
- Transformer
- Power converter
- Connectors for slow and fast charge
- Handle
- Energy/power gauge
- Protection and control device
- Hardware communication module
- Integrated storage systems
- Electrical safety check in residential setting
- Human Machine Interface (HMI)

N.B. The value chain outlined refers to the electric vehicle as a whole and does not include other indirect/external supply chains.

* Typical components for bus ** Typical components for two-wheelers ° Output/services at risk in case of a total decarbonization of car fleet (100% BEV)

Exclusive inputs/outputs for electric vehicle

Energy supply chain

ICT services

Distribution/Sales

Use and aftermarket

Recycling and second life

Powertrain (electric and thermal motor)

- Thermal engine°
- Power generators
- Alternators°
- Engine generator sets (excluding turbine generating sets)
- Rotor and stator coils
- Generator sets°
- Cooling systems (water and air)
- Electronic power converters
- Permanent magnets
- Coupling system between thermal and electric engine°

Distribution

- Logistics
- Vehicle park

Sales

- Customer support services
- Financing services
- Training/technical updating services

Software

- Online Platforms for orders/sales management
- Integrated systems
- Integrated systems for transport
- ITS integrated systems
- Upgrading systems
- Management systems of electric car fleet
- Big Data analytics (electric battery status monitoring software)

Maintenance

- Maintenance/overhaul of vehicle and components
- Battery replacement and installation
- Conversion and retrofitting kits°
- Roadside assistance

Smart services

- Vehicle-to-Vehicle
- Vehicle-to-Home
- Vehicle-to-Grid
- Bidding/geolocation services, etc.
- Driving and parking assistance
- Wearable device/IoT
- Mobile App

Operating services

- Car sharing services
- Management of electric car fleet
- Ancillary services (geomarketing, ecc.)
- Integrated mobility services

New forms of vehicle use

- Car sharing
- Ride sharing
- Car pooling

Vehicle

- Recycling of conventional vehicle components (electronics, bodywork, glass,etc.)
- Recycling of electric vehicle components

Battery

- Recycling of components (copper, iron, etc.)
- Regeneration of battery for domestic/industrial use
- Storage of batteries for electric storage

Service stations

- Fuel service stations and infrastructures (gasoline pumps, etc.)°
- Charging stations (alternate current and fast direct current) and related infrastructures
- Service areas (catering, etc.)
- Parking for stops
- Electrification system along the motorway network
- Wireless charging pads and dynamic charging systems
- Solar panels
- Energy management systems

Energy

- Transmission
- Distribution
- Energy Community

Operating services

- Maintenance
- Replacement and installation
- Monitoring
- Energy demand management systems
- Vehicle-to-Grid for energy flows management in electricity grid
- Smart charging

Customer service

- Maintenance services
- Car sharing services
- Parking
- Wireless network communication

Infrastructure

- Recycling/reuse of charging stations component parts
- Conversion of service areas and industrial sites

N.B. This document is a proprietary model elaborated by The European House - Ambrosetti, in order to map the e-Mobility industrial value chains. The model has been validated by engineers affiliated to the "Engineering, ICT and Technologies for Energy and Transportation" department at Consiglio Nazionale delle Ricerche - CNR.

13. A dimensional ***analysis on currently active industrial sectors*** and services and those that could potentially be involved in the development of electric mobility in Italy has been carried out, in order to quantify the industrial base already available today and understand the opportunities associated with e-Mobility for the country's production base. The analysis was conducted starting with the selection and segmentation of the various activities identified along the value chain, based on the Istat ATECO industrial sector codes[6] in order to quantify the number of enterprises, turnover and number of people employed in each sub-area at the deepest available level of analysis. All the value chain areas have been considered:

- manufacture (construction, assembly and components), distribution and sales, maintenance and aftermarket aspects related to cars, two-wheelers, buses, light commercial vehicles and trucks;
- recycling and second life handling of vehicles, charging points and their components;
- generation, transmission and distribution of electric power;
- construction of public utility structures for electricity and telecommunications;
- fuel sales (service stations).

14. Two types of activity, Research and Development and ICT Services, have not been included in the quantitative model for the electric mobility extended value chain in Italy. This is due to the impossibility of extrapolating the relevant data from the ATECO Istat statistics strictly related to the key automotive industry and e-Mobility sectors.

15. In Italy, the e-Mobility extended value chain ***potentially involves*** almost ***160,000 companies*** with more than ***820,000 workers*** and a turnover larger than ***€420 billion***. Although the total number of companies decreased slightly, the turnover generated from the sectors involved in the value chain increased by ***9.9%*** in one year only, compared to the entire Italian manufacturing sector that grew by only 2% over the same period.

6 Istat is the Italian national statistical database and classifies economic activities under statistical codes called "ATECO".

FIG.7

Number of companies, workers and turnover potentially involved in the e-Mobility extended value chain in Italy.
Source: The European House — Ambrosetti elaboration on Istat data, 2018

158,310 companies in 2015* (-0.7% compared to 2014)

827,587 workers in 2015* (+0.6% compared to 2014)

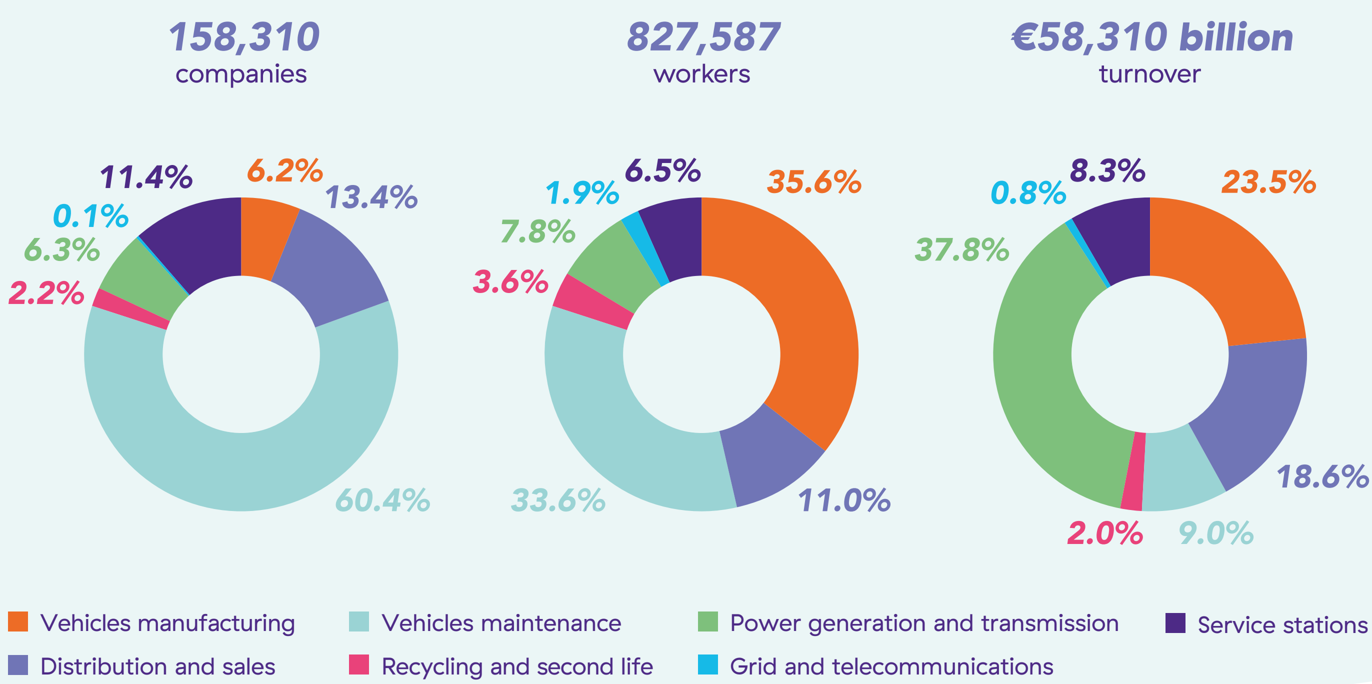
€426 billion of turnover in 2015* (+9.9% compared to 2014)

** Latest available data.*

16. More than half of the companies comes from the vehicles maintenance sector (95,761 companies), which includes the activities of maintenance and repair of vehicles, wholesale and retail of vehicles and rental services. The vehicles manufacturing sector is made of ***9,784*** companies, representing the ***2.5%*** of the total Italian manufacturing companies. These two sectors are the ones employing the greatest share of all the workers involved in the e-Mobility value chain. Indeed, in the manufacturing and maintenance sectors more than 294,000 and 278,000 people are employed, representing as a whole ***69%*** of the total value chain workers. With regards to turnover, the highest contribution to the e-Mobility value chain comes from the power generation and transmission sector that creates a turnover of more than ***€160 billion***, 82% of the overall turnover coming from the Italian energy supply sector.

FIG.8

Number of companies and workers and turnover along the e-Mobility value chain by sector (percentage values).
Source: The European House — Ambrosetti elaboration on Istat data, 2018



17. To fully understand the economic and business opportunities of the Italian industry in the electrical mobility development scenario, the phases of the extended e-Mobility value chain in which the Italian industry can acquire a competitive advantage in the international context based on its skill base have been identified. To this end, the assessment of skills and level of competitiveness of Italian industry for various phases of the value chain has been performed:

- battery systems;
- electric and hybrid motors;
- inverters;
- components;
- bodywork and interior;
- charging equipment;
- ICT systems;
- electric power distribution;
- mobility services.

For each of these outputs and services, the various top-down phases were considered according to the "matrix" view of the extended e-Mobility value chain:

- Research and Development;
- manufacturing;
- use and aftermarket;
- recycling and second life.

Thus, the Italian level of expertise has been evaluated through three levels: high competences, medium competences and competences to be built.

FIG.9

Mapping of Italian skills along the e-Mobility industrial value chains.

PHASES OF VALUE CHAINS	Storage systems (batteries)	Electric and hybrid engines	Inverters	Components	Bodywork and interiors
R&D, Design/ Engineering	R&D to date in Italy is under-developed	Excellences in the manufacture of components for engines; some initiatives in R&D field, with Magneti Marelli (leader in the Powertrain segment in Italy), Politecnico di Milano and PoMoS (Sapienza University); excellences in the motorcycle sector (Energica)	R&D driven above all by the development of technological solutions applied to the renewables sector and for industrial automation	The presence in Italy of numerous medium to large-sized players active in the design of mechanical components and systems in plastic and composite materials	Italian tradition (e.g. Pininfarina's agreement with Iran Khodro and Hybrid Kinetic; Zagato; Pininfarina); university courses and European level Masters in automotive design
Manufacturing	Segment that is still under-developed (among the majors there are Fiamm and Midac) when compared with China, Japan, South Korea, Germany and France, but in 2020 the market for battery energy storage from the energy and industrial sectors will hit €1.35 billion in Italy	The leading car manufacturer for the production of electric engines is Nissan, followed by Mitsubishi and GM	The presence of medium to large manufacturers of inverters for the photovoltaic and automotive (e.g. Elettronica Santerno) sector that is dominated by the Chinese, Germans, Japanese and South Koreans	Italy is the 2nd country in the world for trade balance of electric conductors with voltages greater than 80 V and 3rd country in the world for trade balance of gears and gearing; Magneti Marelli is among the top 100 OEMs (30th in the world and 13th in Europe in 2016)	Extensive experience in the design of vehicle interiors and the production of bodywork, also in the bicycle and motorcycle sectors; Pirelli is the 5th producer of tyres in the world; far-reaching experience in the production of bodywork of trucks and light commercial vehicles in the Piedmont manufacturing district (IVECO)
Use and aftermarket	Aftermarket is still under-developed in Italy; experiences of the battery pack leasing service by some automotive operators, with its own scheduled replacement with new battery packs and updated technology	Aftermarket services (maintenance, support, etc.) of electric engines are still not very widespread in Italy when compared to other European countries (e.g. Germany) that are among the major manufacturers of such engines	Basic support services guaranteed by medium to large manufacturers and distributors of inverters	2,000 companies active in the component sector in Italy, with a turnover of €38.8 billion and ~€20 billion in exports (19% towards Germany); 71% of operators active in the aftermarket segment	Expertise in the aftermarket services is widespread for bodywork and interior components of thermal engine vehicles
Recycling and second life	COBAT's know how in the disposal of accumulators* (collaboration with CNR-National Research Council -on the recovery of lithium batteries); Central-Southern European countries at the forefront (in Germany, a pilot project for spent batteries in Smart ForTwos, for supplying renewable energy to the domestic grid)	COBAT expertise in the disposal of component parts in engines	Recovery projects for inverter electrical component parts (e.g. collaboration between COBAT and manufacturers)	Collaboration between steelworks, national demolition operators and SMEs: production of ~1.8 million tonnes per annum of ferrous scrap broken up in Italy; initiatives for the recovery/disposal of windscreen and side window glasses and plastic materials coming from the automotive sector	

Skill levels

- High
- Middle
- To be built

Italian excellences in the industrial value chain for electric cars

* COBAT (70 collection points and 26 specialist treatment and recycling plants) treats 51% of industrial and vehicle accumulators placed on the market for consumption

OUTPUT

Electric charging infrastructures	ICT Systems	Energy grid	Mobility services
Japan and US specialization in R&D on infrastructures and standard (AC) and fast (DC) charging systems; tests on inductive charging in Northern Europe and in the Netherlands. Enel has expertise in EVSE solutions in both AC and DC charging, including ICT management platforms	Launch, in 2015, of the German ICT for Electric Mobility II plan for developing ICT solutions for e-Mobility; investments in the United Kingdom in R&D for driverless vehicles	Cutting edge R&D (e.g. agreement between Enel and Rosseti, Russian operator for the development of innovative smart grids, June 2017); experimentation on storage systems for integration into the electricity grid (Terna)	R&D for digital services and broadband solutions (Vetrya has developed an e-car with info-mobility and ITS services-driven by an onboard tablet which operates as a multimedia dashboard giving information about the vehicle status, recognized by the London Stock Exchange as one of the 1,000 EU most innovative companies)
Italy has excellences in the production of charging infrastructures (e.g. Enel, Bitron, Ducati Energia, Energy Resources, etc.)	STM among the world's leading companies for electronic circuits, batteries and (semi) autonomous driving systems; other EU countries have integration solutions between charging stations and domestic communications (e.g. Devolo - Germany); growing telematic segment (e.g. Octo Telematics)	Italy was the first country in the world to launch in 2001 a national plan of massive installation of electronic smart meters, which are the basis of smart grid; currently the roll-out of the 2nd generation of smart meters is on-going	Relocation of bicycle and mopeds production from China to Italy with Five, the first ultra green start-up dedicated to the electric mobility in Italy
Imminent boosting of the charging network infrastructure on a domestic level and associated opportunities	Development of value added ICT and software services associated with the creation of a network of infrastructures (Big Data, geolocation services of charging points via mobile networks, bidding services, etc.)	Technical possibility of offering services associated with Vehicle-to-Grid; the need to draft regulation on the offer and related pricing and uniform communication standards	Increasing diffusion of Mobility as a Service app providing integrated access to different mobility services (public transport, trains, car and bike sharing)
Italy is aligned with other countries; possibility of creating a network for the recovery of main quality materials (e.g. iron and copper plates)	Italy is aligned with other countries; possibility of creating a network for the recovery of component parts in copper, silicon and rare earth elements in the face of significant investments		

18. Italy shows both strengths and weaknesses along the extended value chain. The country boasts several excellences in the components sector, in particular with regards to vehicles manufacturing and use and aftermarket. Italy is, indeed, the 2nd country in the world for trade balance of electric conductors with voltages greater than 80 V and 3rd country in the world for trade balance of gears and gearing. Moreover, one Italian manufacturing company is among the top 100 Original Equipment Manufacturers (30th in the world and 13th in Europe in 2016). There are almost 2,000 companies active in the component sector in Italy, with a turnover of €38.8 billion and almost €20 billion in exports (19% of which towards Germany).

19. Italian competences are strong also in the bodywork and interiors sector of the e-Mobility value chain, since the country boasts extensive experience in the design of vehicle interiors and the production of bodywork, also in the bicycle and motorcycle sectors. Moreover, Italy has far-reaching experience in the production of bodywork of trucks and light commercial vehicles in the Piedmont manufacturing district.

20. The Italian electricity system, including its grid, is at the frontier of innovation. This allows Italy to be on track for the renewable targets for final energy consumption and to invest in other grid forefront technologies and services. Italy was indeed the ***first country in the world*** to launch in 2001 a national plan of massive installation of ***electronic meters***, which are the basis of smart grid and the roll-out of the 2nd generation is currently taking place.

21. When it comes to competences that need to be developed, Italy can find opportunities in the ***inverter*** and ***mobility services*** sectors. In the former, Italy has competences in the Research and Development phase, especially with regards to the renewable segment. However, the manufacturing of these components is in the hands of China, Germany, Japan and South Korea. In the latter sector, the R&D for digital services and broadband solutions needs to be empowered although there is an Italian company which has developed an e-Car with info-mobility and ITS services. These services are driven by an on-board tablet which operates as a multimedia dashboard giving information about the vehicle status, increasing the ease and the safety of driving. With regards to the manufacturing of mobility services, it is noteworthy to notice that several start-ups and companies are showing up in Italy providing integrated mobility services and developing hardware and software systems supporting them.

22. Regarding the ***storage systems***, Italy does not have a prominent position within the international scenario. Research and Development must be developed and manufacturing appears at a very early stage when compared with China, Japan, South Korea, Germany and France. Some progresses can be seen in the recycling and second life segment with Cobat that is striving to combine electric mobility (and thus its batteries) with circular economy needs.

23. The same is true for ***electric and hybrid engines***, where Italy has some initiatives in the Research and Development field, both from the business side and the university side. However, with regard to manufacturing, the leading car manufacturer for the production of electric engines is Nissan, followed by Mitsubishi and General Motors, none of these being Italian.

24. Finally, Italy should put more effort into the development of ***ICT systems***, where the country must face some international leaders such as United States and Germany. Italy could exploit its current competences in electronic networks and semi-autonomous systems to further develop ICT services and software for charging infrastructures.

THE ENEL INNOVATION HUB&LAB

On May 11, 2018, the Enel Innovation Hub&Lab opened in Pisa to promote the evolution of thermo-electric generation. The new space is a meeting point for technological partners and start-ups with the aim of testing and implementing innovative technology for the sector, like the Industrial Internet of Things, Big Data, Artificial Intelligence and robotics, including technology for promoting safety and protecting the environment. The Normale University of Pisa acts as a leader of this initiative which has already supported several start-ups, like Athonet, Nozomi Networks, Amber Kinetics, Convexum and Percepto.

Source: The European House — Ambrosetti elaboration on Enel data, 2018.

THE CHALLENGE OF COBAT FOR THE FUTURE OF E-MOBILITY IN ITALY

During its annual meeting on recycling, Cobat launched a challenge for Italy: e-Vehicles fully recyclable in all their components, including lithium batteries, by utilizing them as a storage system for renewable energy. Cobat is indeed conducting research, together with Enel, Class Onlus, CNR and Politecnico di Milano, to develop a technology able to convert the exhausted vehicle batteries in storage systems for renewable electricity.

Source: The European House — Ambrosetti elaboration on Cobat data, 2018.

3.1.3. The projected scenarios for e-Vehicles at 2030 show a potential for electrification of transport

25. In order to build a framework within which estimating the achievable turnover along the e-Mobility industrial value chain in Italy at 2030 (see Part 3.1.2.), ***alternative scenarios for electric penetration at 2030 in Italy*** were developed for all forms of mobility (e-Cars, e-Two-wheelers, e-Buses, e-Light commercial vehicles and e-Trucks) and for charging infrastructures. Three scenarios — baseline, intermediate and accelerated — have been analysed by following a detailed methodology:

- study and critical assessment of the development scenarios — when available — elaborated by major reference institutions and associations: Associazione Trasporti (ASSTRA), Union Internationale des Transports Publics (UITP), local public transport systems, Unione Nazionale dei Rappresentanti degli Autoveicoli Esteri (UNRAE), Associazione Nazionale Filiera Industria Automobilistica (ANFIA), European Association of Motorcycle Manufacturers (ACEM), Automobile Club d'Italia (ACI), etc.;
- analysis of the technical literature and in-depth study of the expected technological curve for any transport mode;
- estimation of the annual registration rate of the electric vehicles;
- evaluation of the yearly replacement rates (historical trends) in the national market by transport mode;
- estimation (when possible) of the effects of sustainable mobility policies by different form of mobility;
- evaluation of the e-Vehicles' stock and sales at 2030;
- market check with business leaders for each sector of interest (more than 30 business leaders in the transport sector)[7];
- technical check with the engineers affiliated to the Institute for Marine engineering (INM), Department of Engineering, ICT and Technologies for Energy and Transports (DIITET) of the National Research Council of Italy (CNR).

26. With regards to ***e-Cars***, the scenarios elaborated for the 2017 study, "e-Mobility Revolution. Impacts on Italy and its industrial value chain: Italy's agenda" were taken into consideration. Scenarios at 2030 were estimated by studying the e-Cars penetration curve under the assumption that 2025 will be the year in which combustion engine cars and electric cars will reach economic parity and analysing the alternative propulsion fuels available at 2030 together with their technical and economic development. Moreover, the scenarios elaborated by other Italian Institutions and Research centres[8] were studied and the market trends of benchmark countries for e-Cars development (China, Norway, the Netherlands and Sweden) were considered. The assumptions that the total car fleet (37 million) will not change by 2030 and the replacement rate will remain stable at 2% have been taken into account.

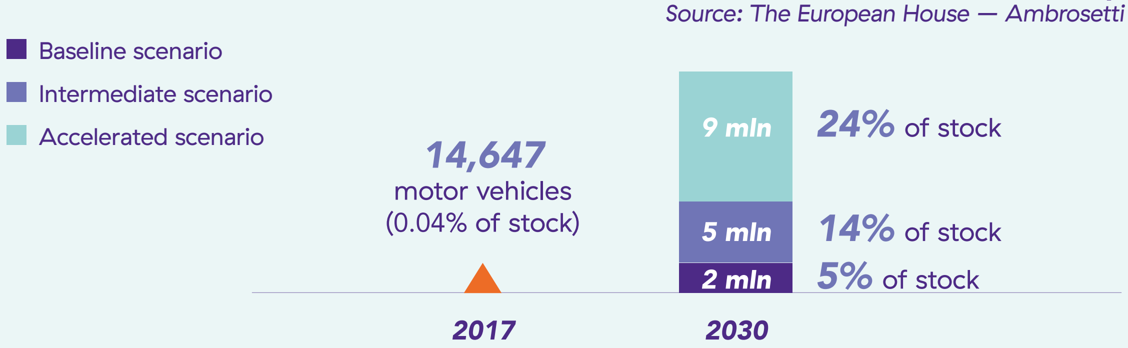
27. Three scenarios for e-Cars in Italy at 2030 were elaborated:

- ***Baseline scenario***: based on the scenario delineated by Associazione Nazionale Filiera Industria Automobilistica (ANFIA), which envisages a 19% share of electric cars on total sales at 2030. The obtained result is ***2 million*** e-Cars at 2030 (***5%*** of stock).
- ***Intermediate scenario***: based on the scenario delineated by the National Energy Strategy (SEN) in 2017 that indicates ***5 million*** e-Cars in Italy at 2030 (***14%*** of stock).
- ***Accelerated scenario***: based on the declaration of business leaders announcing half of their production to be electric by 2022. This scenario could lead to ***9 million*** e-Cars at 2030 (***24%*** of stock).

7 Including also business leaders interviewed for the study, the "e-Mobility Revolution. Impacts on Italy and its industrial value chain: Italy's agenda", in 2017.
8 Italian Government, Politecnico di Milano, Ricerca sul Sistema Energetico (RSE), Associazione Nazionale Filiera Industria Automobilistica (ANFIA), Unione Nazionale Rappresentanti Autoveicoli Esteri (UNRAE), Automobile Club d'Italia (ACI), Università Bocconi.

FIG.10

Evolutive scenarios of the spread of electric cars (Battery Electric Vehicles — BEV and Plug-in Hybrid Electric Vehicles — PHEV) in the Italian car fleet as of 2030 (absolute number and as a percentage of stock).
Source: The European House — Ambrosetti data elaboration, 2018



28. Starting from the investigation of the current electric two-wheelers fleet and sales in Italy (from Associazione Nazionale Ciclo Motociclo e Accessori — ANCMA, Unione Nazionale Rappresentanti Autoveicoli Esteri — UNRAE — and European Association of Motorcycle Manufacturers — ACEM — databases) and the study of international literature about the current market and its expected evolution, scenarios for ***electric two-wheelers in Italy*** at 2030 were developed. In doing so, the hypothesis of invariance of the two-wheelers fleet at 2030 (8.6 million) and of the ratio between motorcycles and mopeds on total annual sales (2.7%) have been considered. The assumption of slower evolution of the existing stock than cars was used: the relative share of new registration of two wheelers on the existing stock is indeed equal to 2.7% and lower than for cars (4.9%). Finally, the market trend of the benchmark country for electric two-wheelers (China) and the alternative fuels available at 2030 (for two-wheelers, gas and liquified natural gas are not a viable option) were fully analysed.

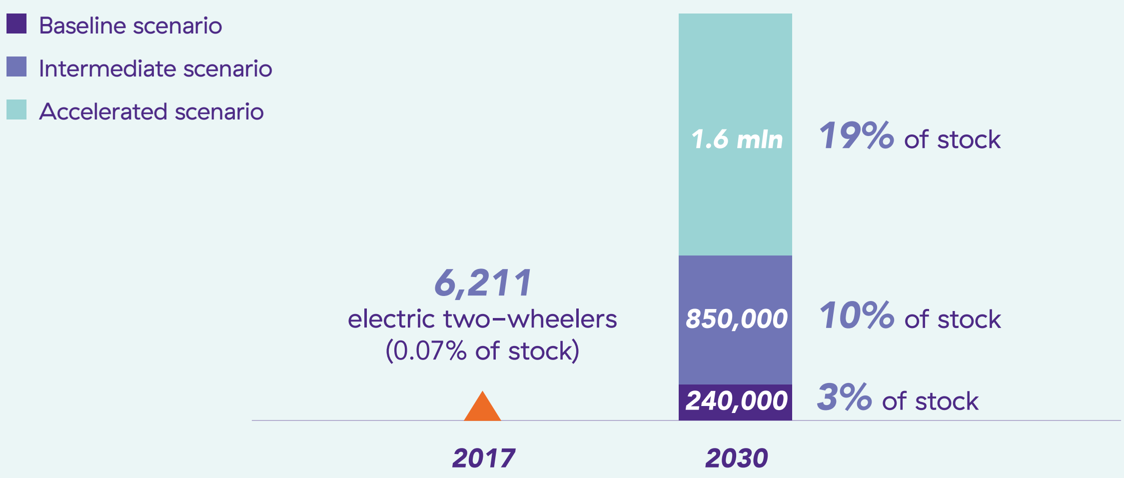
29. Three scenarios for electric two-wheelers in Italy at 2030 were built:

- ***Baseline scenario***: based on the minimum expectation formulated by market players and resulting in ***240,000*** e-Two-wheelers at 2030 (***3%*** of stock).
- ***Intermediate scenario***: based on the reference expectations of Italian business leaders operating in the two-wheelers sector. This scenario indicates ***850,000*** e-Two-wheelers circulating at 2030 (***10%*** of stock).
- ***Accelerated scenario***: based on benchmark analysis of two-wheelers increase in China embedding the effects of European Union policies (Euro 5 at 2020)[9] on electric two-wheelers sales. As a result, ***1.6 million*** e-Two-wheelers at 2030 (***19%*** of stock) were estimated.

9 Euro 5 (less polluting and noisy vehicles) is set to apply to newly-type-approved motorcycle models going on sale on or after 1 January 2020 and to be adopted across existing type-approved vehicles 12 months after that.

FIG.11

Evolutive scenarios of the spread of electric two-wheelers (Battery Electric Vehicles — BEV and Plug-in Hybrid Electric Vehicles — PHEV) in the Italian fleet as of 2030 (absolute number and as a percentage of stock).
Source: The European House — Ambrosetti data elaboration, 2018



30. Scenarios for ***e-Buses*** has been developed, at the urban level only, since in the evolving regulatory framework (emissions' standards, charges, etc.) they have the highest likelihood to be electrified, while long-distance buses follow the same pattern of medium and heavy-duty vehicles. Thus, starting from the analysis of the exogenous conditions making e-Buses a viable option, it was considered, on one side, there are regulatory policies, imposing that 5,782 Euro 0 buses still existing in the public bus fleet can no longer circulate starting from January 1st, 2019. On the other side, technological conditions are such that market maturity is estimated to be reached at 2023 and Total Cost of Ownership will be lower than diesel fuelled vehicles in 11 years. The current bus fleets in the Metropolitan Cities were, because they are considered key areas for mobility policies, and the funding programmes available for public transport companies to renew the bus fleet were analysed. In the elaboration of scenarios, a comparison with existing studies on e-Buses uptake (Bloomberg New Energy Finance, International Energy Agency, Union Internationale des Transports Publics and European Environmental Agency) was made and the alternative fuels available at 2030 (natural gas could be a competitor of the electric carrier) were considered.

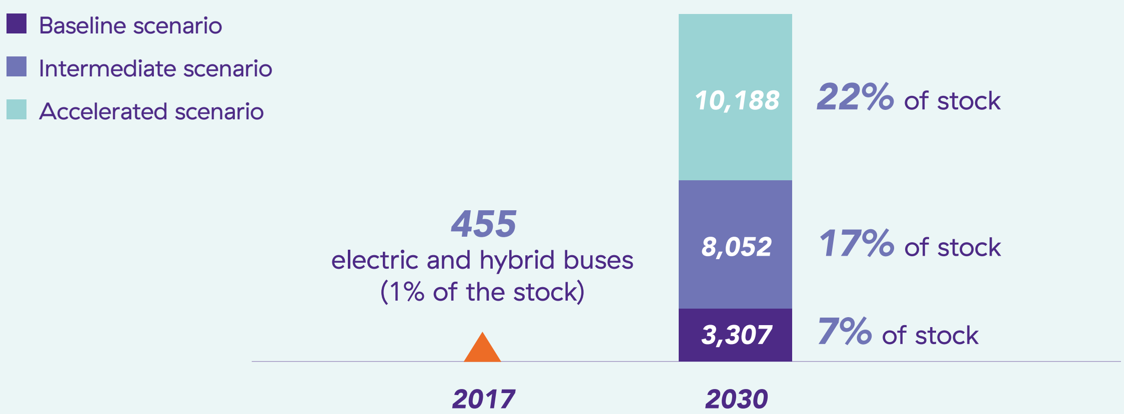
31. Three scenarios for e-Buses in Italy at 2030 were built:

- ***Baseline scenario***: based on 84% of electric vehicles share in new sales in 2030 and assuming a replacement rate of 3% (i.e. the average rate of the last 5 years). ***3,307*** e-Buses at 2030 (***7%*** of stock) were obtained from the analysis.
- ***Intermediate scenario***: based on 84% of electric vehicles share in new sales in 2030 and assuming a replacement rate of 6.5%. In this case, the analysis showed ***8,052*** e-Buses at 2030 (***17%*** of stock).
- ***Accelerated scenario***: based on 70% of e-Buses stock in Metropolitan Cities bus fleets and 10% in all the other public transport company' fleets. The results of this analysis bring to ***10,188*** e-Buses at 2030 (***22%*** of stock).

32. In building scenarios for ***electric light commercial vehicles***, the hypothesis that their market conditions for electrification are similar but more promising than cars was considered. Firstly, as for e-Cars, electric light commercial vehicles' technology is estimated to reach technological parity by 2025 and cost parity by 2030. Then, an adoption curve steeper than the e-Cars one was utilized because e-Light commercial vehicles are heavily affected by urban mobility policies concerning the last mile of the logistics supply chain and thus they fit better with the electric carrier. As for e-Cars, the size of the Italian light commercial vehicle fleet as of 2030 was assumed to remain stable with the hypothesis of 2% replacement rate and all the alternative fuels available at 2030 were analysed.

FIG.12

Evolutive scenarios of the spread of electric urban buses (Battery Electric Vehicles — BEV and Plug-in Hybrid Electric Vehicles — PHEV) in the Italian fleet as of 2030 (absolute number and as a percentage of stock).
Source: The European House — Ambrosetti data elaboration, 2018



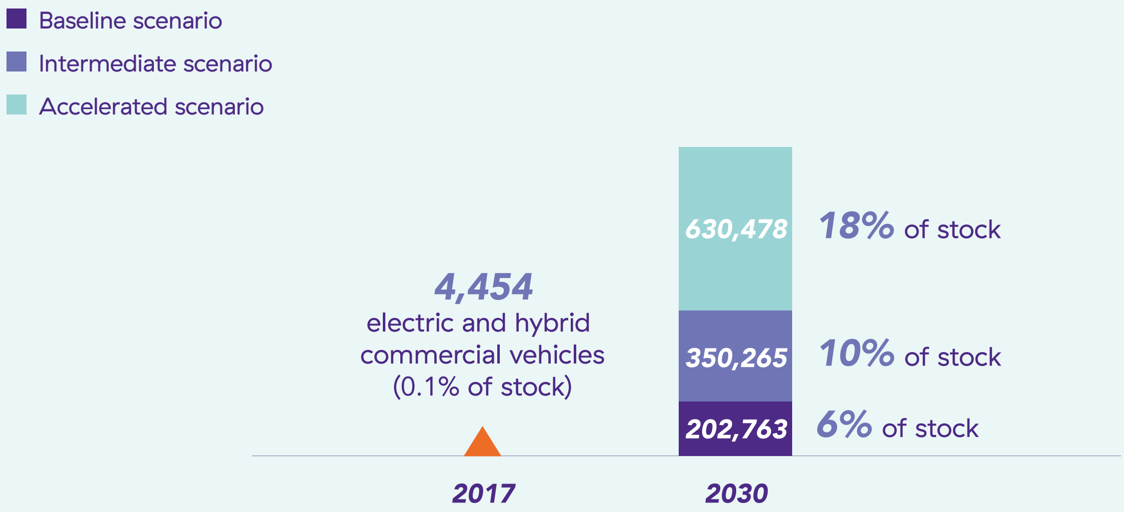
At the end, a benchmarking analysis with existing studies on e–Light commercial vehicles uptake was performed.

33. The resulting scenarios for e–Light commercial vehicles in Italy at 2030 are:

- ***Baseline scenario***: based on the same baseline scenario penetration curve delineated for e–Cars, leading to ***202,763*** e–Light commercial vehicles at 2030 (***6%*** of stock).
- ***Intermediate scenario***: based on the penetration curve delineated by international literature for the European e–Light commercial vehicles annual sales and parametrized on the Italian market. The result of the analysis shows ***350,265*** e–Light commercial vehicles at 2030 (***10%*** of stock).
- ***Accelerated scenario***: based on the expectation formulated by the main market players and resulting in ***630,478*** e–Light commercial vehicles at 2030 (***18%*** of stock).

FIG.13

Evolutive scenarios of the spread of electric light commercial vehicles (Battery Electric Vehicles — BEV and Plug–in Hybrid Electric Vehicles — PHEV) in the Italian fleet as of 2030 (absolute number and as a percentage of stock).
Source: The European House — Ambrosetti data elaboration, 2018



34. Finally, scenarios for ***e–Trucks*** (medium and high–duty vehicles) were elaborated considering the hypothesis that, given their size and long distance covered, the transition from diesel to alternative powertrains will happen at a very different pace than light–duty vehicles. Indeed, currently, e–Trucks are largely at the pilot stage and technological parity is expected to be reached no earlier than 2027. For the construction of scenarios, the current trucks fleet and sales in Italy were investigated using Automobile Club d'Italia (ACI) databases and intelligence over the evolution of the market was made through sectoral studies (International Energy Agency — IEA — and Unione Nazionale Rappresentanti Autoveicoli Esteri — UNRAE). Then, the current experimental strategy[10] and declarations of the leading market players were examined. As with the other forms of mobility, the size of the Italian truck fleet was assumed to remain stable at approx–

10 The most notable one being the one promoted by the California Air Resources Board providing incentives for truck manufacturers to develop zero–emissions and hybrid trucks. Source: California Air Resources Board (CARB), 2018.

imately 580,000 and all the alternative fuels available at 2030 were analysed.

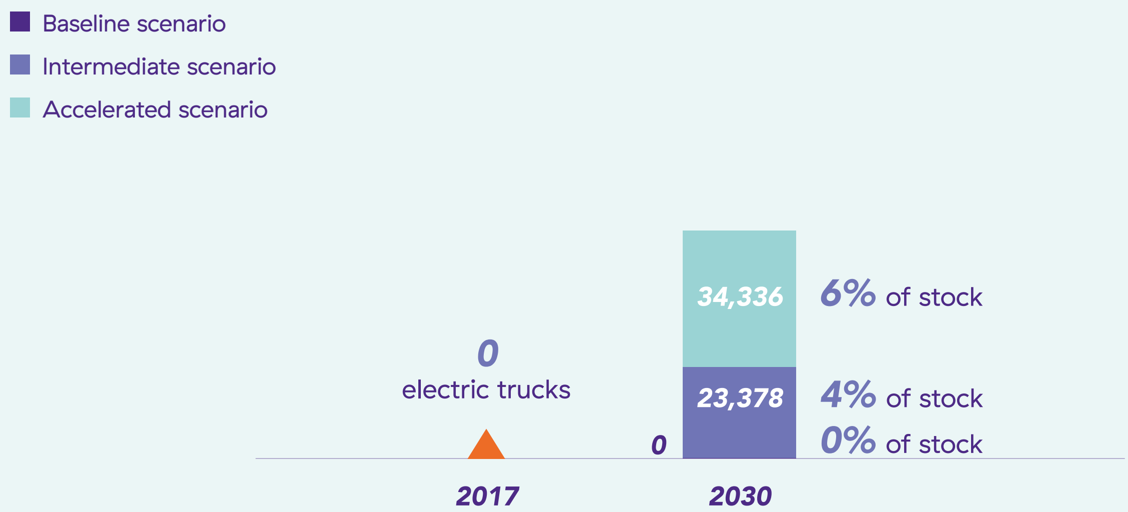
35. Three scenarios for e–Trucks (medium and heavy–duty vehicles) in Italy at 2030 were elaborated:

- ***Baseline scenario***: based on the assumption that Total Cost of Ownership will not decrease, and electric trucks will remain at pilot stage with ***no vehicles*** on roads at 2030.
- ***Intermediate scenario***: based on the hypothesis that technological parity and Total Cost of Ownership equal to diesel vehicles are reached by 2027. This scenario envisages ***23,378*** circulating e–Trucks at 2030 (***4%*** of stock).
- ***Accelerated scenario***: based on technological parity in 2027 and steeper curve than the intermediate one after that moment. The results of this analysis show a circulating park made of ***34,336*** e–Trucks at 2030 (***6%*** of stock).

FIG.14

Evolutive scenarios of the spread of electric trucks (Battery Electric Vehicles — BEV and Plug–in Hybrid Electric Vehicles — PHEV) in the Italian fleet as of 2030 (absolute number and as a percentage of stock).

Source: The European House — Ambrosetti data elaboration, 2018



36. Finally, to assess the alignment of the analysis on vehicle units with the SEN electrification scenarios in the transport sector, the projected e–Mobility scenarios at 2030 into electrification potential were transposed. Thus, the bottom–up analysis for projected e–Mobility scenarios was converted using the electrification potential at 2030 through the following steps:

- estimating the average consumption of a medium Battery Electric Vehicle[11] — BEV— (kWh/km) and converting it into Million Tonnes of Oil Equivalent (Mtoe)/km;
- evaluating the average number of kilometres of an Italian car per year (11,200 km);[12]
- estimating the energy consumption (in Million Tonnes of Oil Equivalent — Mtoe) of all electric cars in Italy in the three different projected scenarios at 2030 (baseline, intermediate and accelerated);
- assessing, from Eurostat data, the final energy consumption in the transport sector (in Million Tonnes of Oil Equivalent — Mtoe), assuming that total energy consumption at 2030 will not vary, after deducting the energy consumption of traditional cars that will be replaced by e–Cars at a 1:1 replacement rate;

11 A Nissan Leaf model has been considered.
12 Source: Quattruote, 2018.

- estimating the electrification potential in the transport sector, measured as the electricity share on final energy consumption in the transport sector in Italy;
- assuming the share of electrified trains in the overall rail fleet remains invariable (currently electrification is over 90%).

The results of the analysis show that in the intermediate scenario, the e-Mobility estimates are totally in line with the electrification scenario of the Italian National Energy Strategy (SEN) at 2030, equal to ***5%*** asking for an increase in the share of electricity in final energy consumption of 150% compared to the current value.

FIG.15

The electrification potential in the Italian transport sector (share of electricity on final energy consumption).
Source: The European House – Ambrosetti data elaboration, 2018

Electrification potential* in the transport sector**		e-Cars***	e-Two wheelers***	e-Buses***	e-LCV***	e-Trucks***	e-Train****
2017	~2%	14,647	6,211	455	4,454	0	1,418
Baseline Scenario 2030	3.2% (+60% vs. 2015)	2 mln	240,000	3,307	202,763	0	1,418
Intermediate Scenario 2030	5% (+150% vs. 2015)	5 mln	850,000	8,052	350,265	23,378	1,418
Accelerated Scenario 2030	9.1% (+355% vs. 2015)	9 mln	1.6 mln	10,188	630,478	34,336	1,418

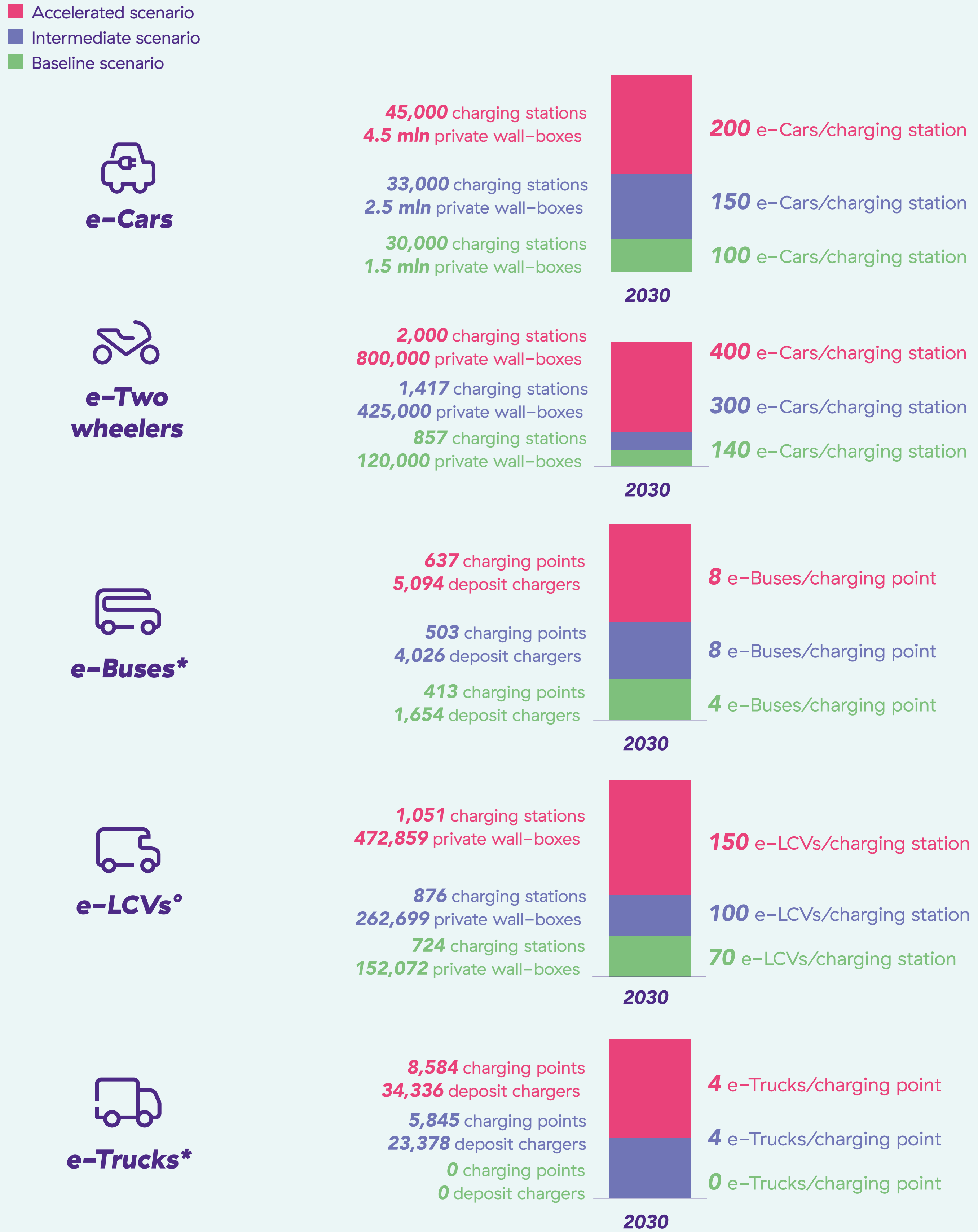
** Electricity share on final energy consumption of the transport sector; ** It includes cars, two-wheelers, buses, trucks light commercial vehicles and railways; *** Battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV); **** The number refers to the electrified rail fleet of the FSI Group; scenarios have not been developed for e-Train, assumption of units' number stability has been considered.*

37. With the support of market operators, similar scenarios for charging infrastructures were developed taking into account the type of infrastructure most appropriate to each vehicle analysed. As a result, public charging stations and private wall-boxes were considered for e-Cars, e-Two-wheelers and e-Light Commercial Vehicles with deposit chargers and charging points (High Power Charging — HPC) for e-Buses and e-Trucks. These scenarios were developed considering two initial hypotheses:

- no account is taken of disruption technology in the infrastructure sector, considering incremental innovation to be the dominant trend;
- given the likelihood of incremental innovation, there is no explicit breakdown between quick, fast or ultrafast electric charging stations, since by 2030 the current quick and fast charging technologies will be superseded by technological evolution, also considering the increasing electric car battery life.

FIG.16

Scenarios for charging infrastructures at 2030 for e-Cars, e-Two-wheelers, e-Buses, e-Light commercial vehicles and e-Trucks in Italy.
Source: The European House — Ambrosetti elaboration on Enel data, 2018



* Charging points for e-Buses and e-Trucks are High Power Charging (HPC) types with a charging power of 150kW. ° LCV: Light Commercial Vehicles.

3.1.4. Electrification in the transport sector has a significant industrial impact

38. The electrification scenarios and the analysis of the extended e-Mobility value chain show a great ***industrial and economic potential*** for Italy, which was quantified in terms of potential revenue. The assessment was carried out for four macro-areas: vehicles, infrastructure, services, recycling and second life. The assessment focused on all the types of vehicles already analysed for the scenarios: e-Cars, e-Two-wheelers, e-Buses, e-Light Commercial Vehicles and e-Trucks.

39. In order to quantify the turnover induced by the electric vehicles sector, from Research and Development to sales, the ***price*** of different forms of e-Vehicles was identified:

- e-Cars: ***€40,000***, resulting from the average price of a "small battery electric vehicle" and the average price of a "medium-large battery electric vehicle". We also simulated the average price of the circulating e-Cars fleet at 2030, assuming that the foreseeable lower costs of batteries will not be translated directly into the car prices;[13]
- e-Two wheelers: in a range from ***€3,000*** (list price of a medium model of e-Moped) to ***€20,000*** (average list price of a medium-premium model of e-Motorcycle);
- e-Buses: ***€450,000*** is the average price indicated by business leaders in their declarations;
- e-Light Commercial Vehicles: ***€30,000*** based on the estimate of the average price of an e-Bus based on business leaders' declarations;
- e-Trucks: ***€350,000*** resulting from the sum of the current price of a medium truck (~€150,000) and the price of the battery (~€200,000).

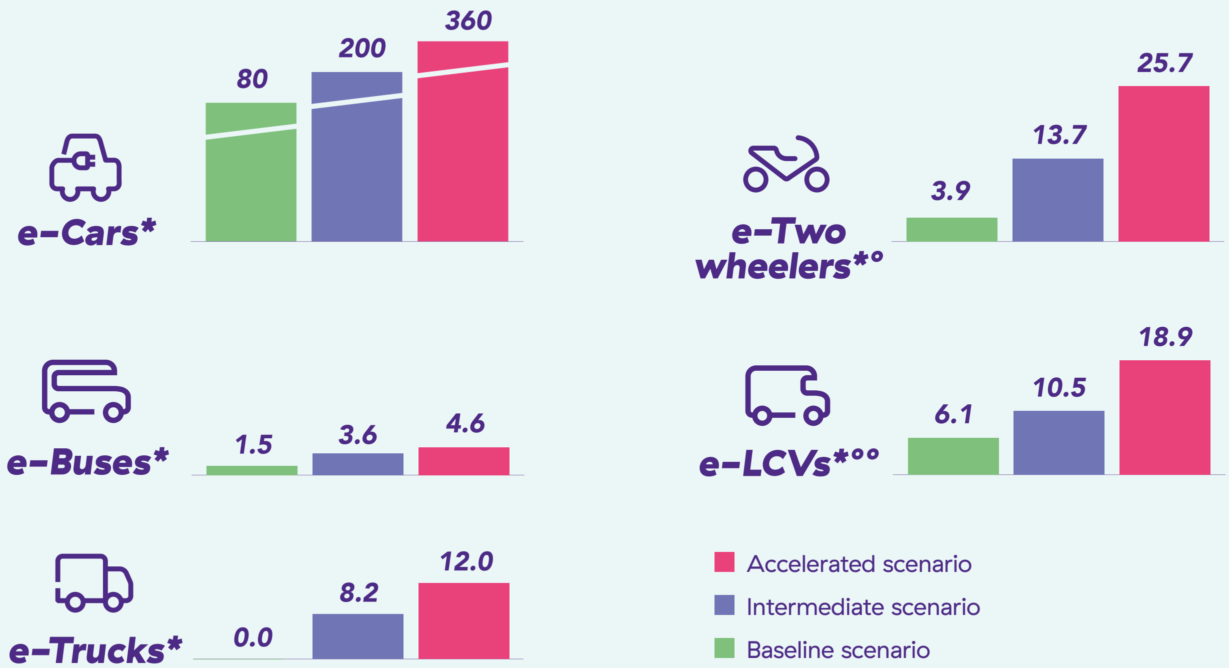
40. Once the various prices were individuated, the ***electric vehicles turnover*** generated by 2030 was quantified, by combining the unitary costs with the penetration scenarios at 2030. The range obtained, according to the expected levels of spread of electric vehicles in Italy, is estimated to be:

- ***€80*** to ***€360 billion*** for e-Cars;
- ***€3.9*** to ***€25.7 billion*** for e-Two-wheelers;
- ***€1.5*** to ***€4.6 billion*** for e-Buses;
- ***€6.1*** to ***€18.9 billion*** for e-Light commercial vehicles;
- ***€0*** to ***€12 billion*** for e-Trucks.

13 Despite decreasing costs of technology and production, the price of a medium car (e.g. Golf Volkswagen) has increased over the last 10 years (from ~$8.000 to ~$20.450, +156%).

FIG.17

Total achievable turnover from e-Vehicles in Italy in the extended industrial value chain from R&D to distribution in the three different projected scenarios at 2030 (Euro billion).
Source: The European House — Ambrosetti data elaboration, 2018



* Battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV) ° Mopeds and Motorcycles (turnover is the weighted average of the two)
°° LCV: Light Commercial Vehicles

41. The second area of the analysis consists in the ***electric recharging infrastructures***. In order to estimate the achievable turnover of recharging equipment for public and private use, the extended industrial value chain from manufacturing to aftermarket was reconstructed and interviews with industry operators were conducted to estimate the price. The price embedding the costs of the following segments was considered:

- manufacturing, with reference to the finished charging station or wall box;
- operational services, including installation services, fixed network connection costs and costs related to system connectivity;
- maintenance, including relevant costs for one year of operation.

Thus, different prices for each type of charging infrastructure were estimated on the basis of interviews with market players:

- Wall-boxes: ***€2,400*** (considering only manufacture and installation costs without additional charges due to dedicated grid connection the cost is equal to ~€1,200);
- Fast public station: ***€39,600*** (of which 57% are manufacture costs, 37% are costs related to installation and connection to the grid and 6% for maintenance);
- Deposit chargers (for e-Buses and e-Trucks): ***€39,600***;
- Charging point (High Power Charging, for e-Buses and e-Trucks): ***€70,000***.[14]

As a result, the total achievable turnover from charging infrastructures in the extended value chain, related to the projected scenarios developed (see part 3.1.3) ranges ***from €6 to €18 billion by 2030***.

14 This number refers to High Power Charging with a charging power of 150kW. The cost is composed by electronic power components (~70%), electronic and electromechanical components (~15%), case (~10%) and connectors (~5%). There exists another type of High Power Charging (HPC), with a charging power of 350kW, whose cost is above €500.000, not included in the analysis.

FIG.18

Total activatable turnover in Italy from charging infrastructures in the extended value chain in the three different projected scenarios at 2030 (Euro billion).
Source: The European House – Ambrosetti data elaboration, 2018

	Cars	Two-wheelers	Buses	Light Commercial Vehicles	Trucks	Total e-Vehicles*
Baseline	4.8	0.3	0.1	0.4	0.0	**6**
Intermediate	7.3	1.1	0.2	0.7	1.3	**11**
Accelerated	12.6	2.0	0.2	1.2	2.0	**18**

* Values rounded to the upper value.

42. The electric carrier can be easily integrated with digitalization, enabling more effective consumption management and higher efficiency, thus enhancing the role of the Distribution System Operator (DSO). New digital services will be further developed for different purposes, like improving vehicle driving and management (vehicle-to-vehicle, guide assistance, geo-marketing, etc.), allowing for better city logistic (vehicles sharing, integrated urban mobility services, fleet management, etc.) and making the electricity grid more stable (vehicle-to-home, vehicle-to-grid, etc.). Given its role in the future, the ***turnover generated from the service sector*** in Italy at 2030 was estimated. In order to do so, the estimation made last year in the study, "e-Mobility Revolution. Impacts on Italy and its industrial value chain: Italy's agenda" for the car sector, was consulted which consists of:

- study of international literature[15] on economic impact of the development of car services worldwide and estimates of revenues from digital sector revenue;
- focus on three specific types of service: ***sharing mobility, digital services*** and ***supply of new technologies***[16];
- parameterization of the results for the Italian case by using the share of Italian circulating park in the global stock (3.9%);
- estimate of the future market value of digital services for cars and assessment of the share of it going to the e-Cars sector according to development scenarios.

43. ***The analysis was extended*** to other forms of e-Mobility (e-Two-wheelers, e-Buses, e-Light commercial vehicles and e-Trucks) by considering the share of the circulating park of each type of vehicle on the overall stock of vehicles in Italy. In doing so, sharing services were assumed to be deployed only for cars and two-wheelers, since they are not applicable to buses, light commercial vehicles and trucks. Finally, the turnover achievable in Italy by services related to e-Mobility has been estimated, according to the three scenarios (baseline, intermediate and accelerated) and it was found that it could range ***from €5 to €14 billion*** at 2030 in Italy.

15 Among others: IHS; Autofacts; Frost & Sullivan; Harvard Business Review; NHTSA; Technavio; Thomson Reuters; Gartner; Oxford Economics; see bibliography for the detailed list.

16 The estimate calculations excluded the hardware component of such services as it had already been included in the computations related to motor vehicle components and charging equipment.

FIG.19

Total achievable turnover in Italy from services for e-Vehicles in the three different projected scenarios at 2030 (Euro billion).
Source: The European House - Ambrosetti data elaboration, 2018

	Cars	Two-wheelers	Buses	Light Commercial Vehicles	Trucks	Total e-Vehicles*
Baseline	4.00	0.70	0.00	0.17	0.00	**5**
Intermediate	7.00	1.39	0.01	0.28	0.02	**9**
Accelerated	11.00	2.65	0.01	0.51	0.03	**14**

* Values rounded to the upper value.

44. The last stage of the extended e-Mobility value chain is the reuse and recycling sector whose achievable turnover at 2030 was estimated according to a double methodology. Firstly, the turnover generated from the ***recycling of the vehicle components*** was estimated by:

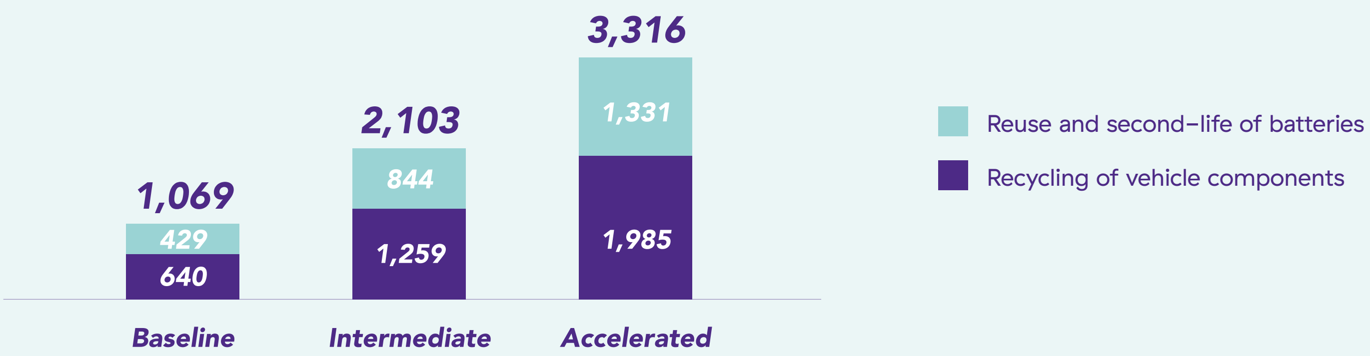
- analysing the lifespan of each type of e-Vehicle, considering an average value of 10 years for motorcycles, buses and trucks and 8 years for cars, mopeds and light commercial vehicles;
- calculating the number of each type of e-Vehicle (cars, two-wheelers, buses, light commercial vehicles and trucks) circulating in Italy at 2022 and 2020 according to the estimated lifespan and based on e-Mobility scenarios at 2030, in order to quantify the number of electric vehicles scrapped by 2030;
- identifying the price for the recycling and recovery of the components of each type of vehicle, equal to almost 5% of the sale price.

45. Then, with regard to the revenue realizable from the ***reuse and second life of batteries***, the estimates of Bloomberg New Energy Finance (BNEF) about the reuse costs of e-Vehicles batteries (€832 to regenerate a vehicle battery of 24 KWh) were considered, parameterizing the cost according to the power of each type of battery. The resulting values have been linked to the expected number of e-Vehicles scrapped by 2030. The results of these two combined analysis give the estimate of the possible turnover from recycling and reuse of e-Vehicles which could reach ***up to €3.3 billion*** at 2030 in Italy.[17]

17 This is a conservative estimate since it does not consider the growth that the recycling parts will experience due to an increase of the electric vehicles stock.

FIG.20

Turnover generated in Italy by the recycling of e-Vehicles components and the reuse of batteries by 2030 (Euro million).
Source: The European House – Ambrosetti data elaboration, 2018



46. From the estimated turnover generated in each segment of the extended e-Mobility supply chain, the total potential turnover at 2030 in Italy can be estimated resulting from the vehicles sub-value chains and infrastructure related to charging, ICT services, recycling and second life. Overall, the turnover achievable in Italy is estimated to be between ***€102.4 and €456.6 billion*** by 2030. From this analysis, it can be seen clearly that revenues coming from the e-Vehicles related supply chain accounts for more than 90% of total results. Italy has a long tradition in the automotive industry and thus it can exploit the opportunity of the e-Mobility to innovate and stand as a leader in this sector, achieving considerable economic results for market players.

FIG.21

Total turnover achievable in Italy along the e-Mobility value chain at 2030 (billion Euro).
Source: The European House – Ambrosetti data elaboration, 2018

Scenario	e-Vehicle	Infrastructure	Services	Recycling and second-life	Total turnover at 2030
Baseline	91.3	6	4	1.1	**102.4**
Intermediate	235.9	11	9	2.1	**258.0**
Accelerated	421.3	18	14	3.3	**456.6**

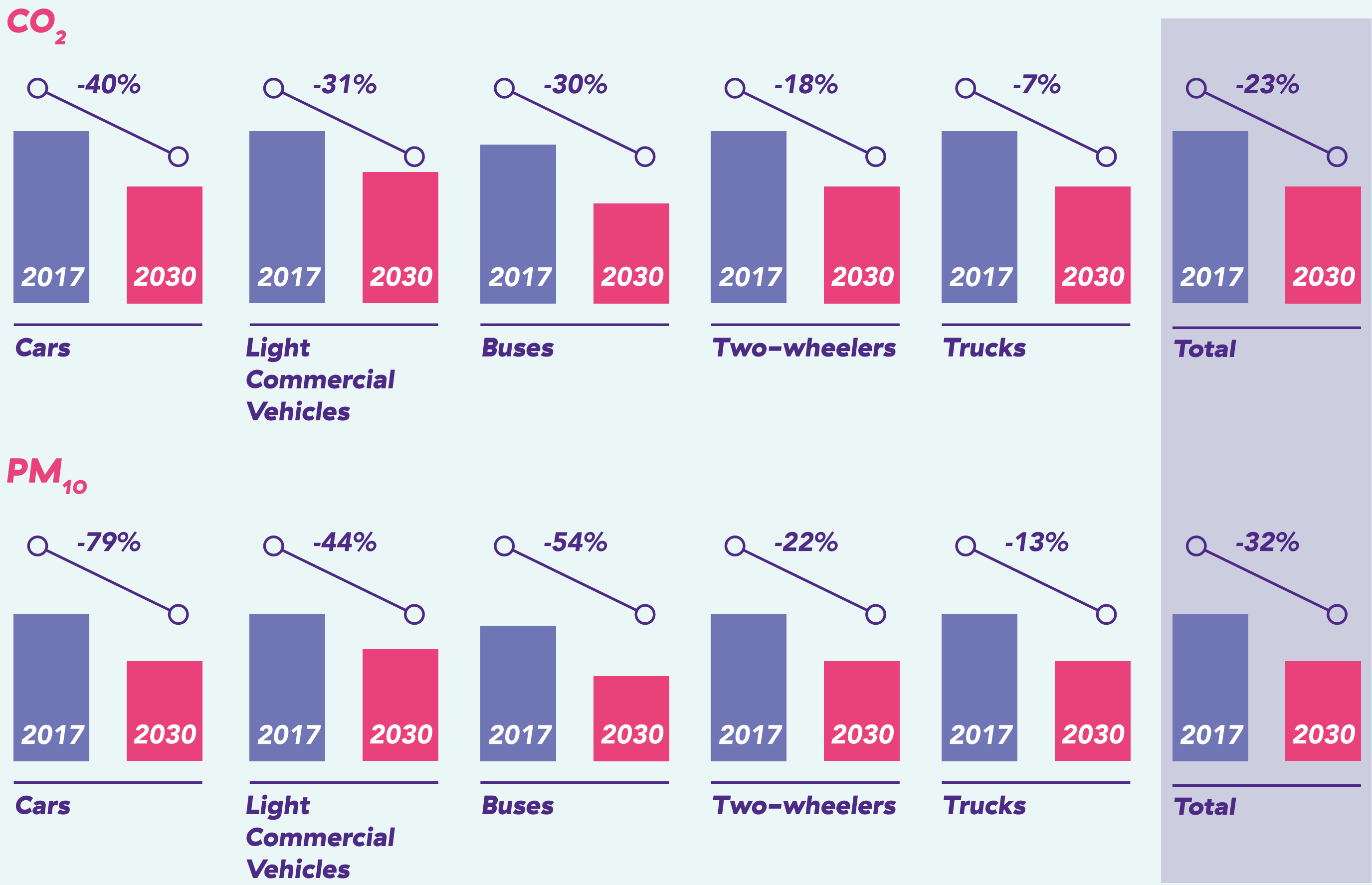
47. In addition to the effects related to turnover, the development of e-Mobility according to our scenarios can contribute to the reduction of road pollution and health-related diseases. In order to assess this potential, an analysis about the impact of e-Mobility on sustainability was conducted with the aim of quantifying the potential reduction of emissions originating from its development. The following methodological steps were followed:

- identification, using the Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA) dataset, of the ***emission levels*** (CO_2, PM_{10}, NO_x, NMVOC) for all the transport modes (cars, two-wheelers, buses, light commercial vehicles and trucks);
- analysis of the Automobile Club d'Italia (ACI) database, where the ***fuel type and emission standard*** (from Euro-0 to Euro-6) of all relative fleets were extrapolated;
- estimate of the average km-per-year for any transport mode, identified as ***11,200 km*** for cars and light commercial vehicles, ***3,500 km*** for two-wheelers, ***70,000 km*** for buses and ***120,000 km*** for trucks;
- identification of the ***aggregate emissions*** by transport mode and pollutant at 2017;
- estimate of the same aggregate emissions at 2030 by considering the accelerated scenario in all the transport modes and with the replacement of the oldest vehicles with the electric ones in different sectors.

The results of the analysis show a reduction in emissions from ***23%*** to ***45%*** depending on the type of pollutant with the highest contribution coming from e-Cars.

FIG.22

Emissions reduction in the accelerated e-Mobility scenario (CO_2, PM_{10}, NO_x and NMVOC).
Source: The European House – Ambrosetti elaboration on Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA) and Automobile Club d'Italia (ACI) data, 2018



3.2.

Electrification offers a relevant contribution to energy efficiency

3.2.1. There are some technologies that enable energy efficiency through electrification

49. Reaching the EU policy targets for energy efficiency requires a consistent acceleration in this field over the next years.[18] Yet, Italy and Germany share first place in the International Energy Efficiency Scorecard elaborated by the American Council for an Energy-Efficient Economy (ACEEE) thus revealing an even stronger case for improvement.[19] In this regard, the electricity-driven technologies can ensure notable efficiency gains and contribute to the overall policy objectives. Some of these technologies, indeed, can be conceived as proper alternatives to those powered by fossil fuels — meaning their adoption entails a direct switch from fossil fuels to electricity — while others can substitute already existing electric technologies providing important energy savings.

50. To identify the full array of electrification technologies and individuate the ones being more promising in terms of both technological maturity and deployment potential an ***original model*** was built. Further, the model was validated by engineers affiliated with the "Institute for Marine engineering (INM) and the Department of Engineering, ICT and technologies for the Energy and Transports (DIITET)" at Consiglio Nazionale delle Ricerche (CNR).

51. The objectives of this model are:

- developing a comprehensive map — previously non-existent — of all the ***current and investigational technologies***[20] related to the electrification;
- identifying a ***selection of technologies*** with applications that span a range of sectors and final uses;
- having a scientifically solid base to support the reconstruction of the industrial value chains for the most promising technologies.

52. In the 360° map concerning electrification technologies ***more than 60 existing electrification technologies*** were analyzed and grouped according to both their application in buildings, industry and transport and their final use (electricity generation on site, storage and utilization[21]). Further, being a technological assessment, the potential impact of these electrification technologies is not limited to Italy but can be extended to the overall European Union.

53. Moreover, the map already included all the appliances and technologies that can enable ***direct or indirect electrification***. Direct electrification, indeed, refers to the direct use of electricity as an energy carrier (power consumption by households, road transport, etc.). Indirect electrification, instead, refers to the power demand to produce hydrogen, gas and other synthetic fuels that can contribute to decarbonizing several industrial processes (for instance, steel-production, chemical processes, etc.).

54. Through the matrix view, ***two cross-cutting technologies*** affecting the three sectors of interest and final uses have been identified: power electronics and energy management systems (EMSs) in addition to the ***four technologies having the highest enabling potential for electrification*** in terms of both efficiency gains and deployment opportunities: heat pumps, LED lamps, electric drive and electrochemical storage systems. All these technologies have the greatest potential to be deployed in the next years and constitute the basis for the estimation of the industrial value chain.

55. To further complete the technologies mapping, a comprehensive ***glossary*** of all the electrification technologies was prepared and is also included at the end of this study.

18 In the second part of the study, the gap between the estimated trend for energy efficiency at 2030 (based on the CAGR for 2010 and 2016) and the objectives set by the policy target (-32.5% compared to 1990 levels) was estimated in 16 Mtoe in Italy and 256 Mtoe in the overall EU28.

19 American Council for an Energy-Efficient Economy, "International Energy Efficiency Scoreboard 2016".

20 Investigational technologies refer to all the technologies that are currently under investigation but have the potential to be marketed in the near future (3 to 5 years).

21 Concerning home appliances, only energy-intensive household appliances — having a high potential to increase energy efficiency — have been considered in the map (i.e. washing machines, dishwashers, refrigerators and induction burners).

THE MATRIX OF THE MAP: SECTORS AND FINAL USES

In order to include all the relevant technologies that are already available or likely to hit the market over the next few years, a matrix aimed at recomprising all the electrification technologies by sector of application and by final use was set up.
In this regard, on the vertical axis are positioned the sectors in which the technologies are deployed:

- ***Transport***: entailing all forms of private and public transportation (air, sea and road transport);
- ***Buldings***: covering all the different kind of structures (private households' buildings, private commercial buildings and public buildings);
- ***Industry***: implying all the processes to produce intermediate and final goods.

On the horizontal axis, are shown the three final uses in which electrification technologies may find an important application:

- ***Electricity generation***: implying the process of generating electric power. Carried out in power plants, it is the first stage in the delivery of electricity to end users;
- ***Storage***: entailing the capture of energy produced at one time for later use. It involves converting energy from forms that are difficult to store to more conveniently or economically storable ones;
- ***Utilization***: meaning the electricity usage to generate output from electrical and electronic devices, with the final aim of producing mechanical or thermal energy.

Source: The European House — Ambrosetti elaboration, 2018.

FIG.23

Mapping of electrification technologies at 360°.

Electricity generation on site

Buildings & household consumption

Energy Management System (EMS): Integrated Technology used by electricity operators to monitor and optimize generation, distribution and utilization performances

Power electronics: electric-electronic appliance that modifies features of out-coming electricity from those of in-coming electricity

Cogeneration System

- *High power (only for buildings with a power> 100 kW):*
  - Gas Turbine CHP plants
  - Gas engine CHP plants
  - Biofuel engine CHP plants
  - Combined cycle power plant
  - Molten-carbonate fuel cells and Solid fuel cells or Stream turbine CHP plants
  - Nuclear power plants
- *Small power*
  - Reciprocating engine or Stirling engine
  - Biomass
  - Municipal Solid waste

Photovoltaic system

Micro-wind system

Fuel cells*

Industry

Cogeneration System

- *High power*
  - Gas Turbine CHP plants
  - Gas engine CHP plants
  - Biofuel engine CHP plants
  - Combined cycle power plant
  - Molten-carbonate fuel cells and Solid fuel cells or Stream turbine CHP plants
  - Nuclear power plants
- *Small power*
  - Reciprocating engine or Stirling engine
  - Stirling engine
  - Biomass
  - Municipla Solid waste

Photovoltaic system

Micro-wind system

Fuel cells*

Transport

Photovoltaic system

Micro-wind system

Fuel cells*

Energy Management System (EMS): Integrated

Power electronics: electric-electronic

LEGEND

- Cross-cutting Technologies
- Technologies enabling energy efficiency
- Technologies with the highest enabling potential for electrification
- Indirect electrification

* Investigational technologies are all the technologies that are currently under investigation and have the potential to be marketed in the near future (3 to 5 Years)

** Only energy-intensive household applicances have been considered

Storage	Utilization
Electrochemical storage system (batteries) **Electrostatic device (supercapacitors)*** **Electro-mechanical device (flywhells*, CAES=compressed air energy storage)** **Electromagnetic deviced (SMES- Superconducting Magnetic Energy Storage System)** **Thermal Storage system** **Solar fuel*** **Power to fuel** **Power to gas**	**Heat pumps** • Air source Heat Pumps • Ground Source Heat Pumps • Hybrid Heat Pumps • Ductless Mini-Spirit Heat Pumps • Absorption Heast Pumps **LED lamps** **Electric Divers** • 1-10 kW (elevator and freight elevators for residential use, washing machine, dishwasher, water pumps - single dwelling) • 10-100 kW (elevator and freight elevators for commerviale use water pumps for residential buildings) **OLED lamps (organic LED)*** **Efficient refrigerators**** **Efficient washing machines**** **Induction burners**** **Efficient dishwaters****
Electrochemical storage system (batteries) **Electrostatic device (supercapacitors)*** **Electro-mechanical device (flywhells*, CAES=compressed air energy storage)** **Electromagnetic deviced (SMES- Superconducting Magnetic Energy Storage System)** **Thermal Storage system** **Solar fuel*** **Power to fuel** **Power to gas**	**Heat Pumps** • Air source Heat Pumps • Ground Source Heat Pumps • Hybrid Heat Pumps • Ductless Mini-Spirit Heat Pumps • Absorption Heast Pumps • 10-100 kW (Washing machine, Plastic, HVAC - Heating, Ventilation and Air Conditioning) • 100 kW-1 MW (Oil-gas, cement, chemical, pulp-papers, metals) • 1 MW-100 MW (Oil-gas, cement, chemical, pulp-papers, metals) **LED lamps** **Electric Divers** • 1-10 kW (HVAC - Heating, Ventilation Air Conditioning) **OLED lamps (organic LED)*** **Induction oven (steel industry)** **Electrode oven (glass industry)** **Microwave oven (ceramics industry)** **Arc electric oven (steel industry)** **Pulse dryer (paper)** **Radio frequency and infrared dryer (texti** **Microwave dryer (chemical industry)** **Electrolysis (chemical industry)** **High pressure processing (food)** **Ultrasound dye (textile industry)**
Electrochemical storage system (batteries) **Electrostatic device (supercapacitors)*** **Electromagnetic deviced (SMES- Superconducting Magnetic Energy Storage System)** **Solar fuel*** **Power to fuel** **Power to gas**	**Heat Pumps** • Air source Heat Pumps • Water Source Heat Pumps **LED lamps** **Electric Divers** • 1-10 kW (Electric veihicle actuators) • 10-100 kW (Light duty electric car propulsion) • 100 kW-1 MW (Ship propulsion) • 1 MW-100 MW (Ship propulsion) **OLED lamps (organic LED)*** **Conductive and inductive recharging system**

Technology used by electricity operators to monitor and optimize generation, distribution and utilization performances

appliance that modifies features of out-coming electricity from those of in-coming electricity

N.B. This document is a proprietary model elaborated by The European House — Ambrosetti in order to map all Italian competences for electrification technologies. The model has been validated by engineers affiliated to the "Engineering, ICT and Technologies for Energy and Transportation" department at Consiglio Nazionale delle Ricerche - CNR.
N.B. We have considered only technologies strictly linked to the electrification process and energy efficiency enabled by electrification.

56. In a nutshell, the 360° map of the electrification technologies allowed to identify ***six technologies*** in the three sectors and uses being particularly promising in terms of both efficiency gains stemming from their adoption and capability to activate an industrial value chain. These technologies can be defined as follows:[22]

- ***Heat pump***: a device transferring heat energy from a source of heat to what is called a "heat sink". Therefore, a heat pump moves thermal energy in the opposite direction of spontaneous heat transfer, by absorbing heat from a cold space and releasing it into a warmer one. A heat pump uses a small amount of external power to accomplish the work of transferring energy from the heat source to the heat sink. In this regard, the efficiency of a heat pump is measured by a Coefficient of Performance (COP), determined by the ratio between energy usage of the compressor and the amount of useful heat extracted from the condenser. A high COP value represents a high efficiency; for instance, a COP value of 4[23] implies that by any kilowatt of electricity consumed, the heat pump would engender 4 thermal kilowatt in the environment. Thus, a heat pump with COP equal to 4 can almost halve the primary energy consumption compared to a condensing boiler.
- ***LED (Light Emitting Diode) lamp***: a light source that uses semiconductors and electroluminescence to create light. Instead of heating a filament to create light, electricity passes through a chemical compound that generates light once excited. LED lamps allow to reach 80%-85% of efficiency gains as compared to the traditional incandescent lamps and also a 5%-10% compared to the fluorescent ones.
- ***Electric drive***: the combination of an electric engine, an electronic power converter necessary for the drive's powering, a control system implemented on an appropriate programmable hardware platform and a group of sensors.
- ***Electrochemical storage systems (batteries)***: accumulators useful to directly transform chemical energy into electricity. The core part of this system is the electrochemical cell that generates direct current power.
- ***Power electronics***: the application of solid-state electronics conceived for the control and conversion of electric power. The conversion is performed with semiconductor switching devices such as diodes, thyristors and transistors. An AC/DC converter (rectifier) is the most typical power electronics device found in many consumer electronic devices.
- ***Energy management systems (EMSs)***: system of computer-aided tools used by operators of electric utility grids to monitor, control, and optimize the performance of the generation and/or transmission system. In addition, EMSs could be used in small-scale systems like micro grids and have an increasing number of applications also in the Commercial and Industrial sector, in which they allow for improved monitoring, management, optimization and automation of the energy uses.[24]

22 The definition here provided comes from the glossary of all the electrification technologies elaborated by The European House — Ambrosetti that has has been validated from the engineers affiliated at the "Institute for Marine engineering (INM) and the Department of Engineering, ICT and technologies for the Energy and Transports (DIITET)" at Consiglio Nazionale delle Ricerche (CNR).

23 An air source heat pump for residential use has an average COP of 3 or 4. This is an indicative dimension only as those differences in COP are affected by the external temperature, the installation in new or existing buildings and the specific type of heat pump.

24 In the case of adoption of Energy Management Systems in companies, an important factor is constituted by the compliancy with the ISO 50000 standards' series as defined by the International Standardization Organization (ISO). In this broader series, for instance, the ISO 50001, standard was specifically launched in 2011 to provide organizations with a recognized framework for integrating energy performance into management practices, provided a framework for companies willing to develop a policy for more efficient use of energy, fixing internal targets and objectives to meet the policy ones, measuring the results and improve energy management. An update of the ISO 50001 is awaited by the end of 2018.

ONE TECHNOLOGY SEVERAL AVAILABLE OPTIONS: HEAT PUMPS AND ELECTROCHEMICAL STORAGE SYSTEMS

Both heat pumps and electrochemical storage systems are among the six most promising technologies related to the electrification in Italy and Europe. As they are quite complex technologies, a few additional specifications to the general definition given above are required.

Heat pumps are among the most promising technologies in terms of energy efficiency gains because of their capacity to provide an amount of energy (i.e. heat) superior to the amount of electricity used for their functioning by extracting heat from a cold space and releasing it into a warmer one. Due to the possibility to reverse their cycle of heat tranfer, they can be used for space and water heating as well as for space coooling. Heat pumps are cross-sectoral technologies, suitable to be employed in residential, industry and transport.

Further, there is not a single type of heat pump but rather several ones depending on the energy source employed and the heat source used. The first relevant distinction is between electric heat pumps and gas heat pumps, depending on whether they function using electricity or natural gas. Currently, there is only a limited amount of heat pumps propelled by natual gas available in the market. These pumps, in spite of their still limited market share, could constitute a useful substitute for natural gas boilers, and further pilot projects are being conducted by a few companies to extend their application in the next years. However, given the existing proportion in the market, heat pumps can be substantially considered an electricity-driven technology.

Depending on the heat source, heat pumps can be distinguished among:

- ***Air source heat pumps (ASHP)***: system that transfers heat from outside air to inside a building, or vice versa; depending on the external temperature, which could affect the performances of those pumps, the Coefficient of Perfomance (COP) can reach, in average, a level up to 3 or 4.
- ***Water source heat pumps (WSHP)***: system that moves heat from a source of water, such as a river or a small stream, to inside a building or vice versa; the Coefficient of Performance (COP) of those pumps is not affected by the external temperature and could reach a level of about 6.
- ***Ground Source heat pumps***: central heating and/or cooling system that transfers heat to or from the ground; again in these pumps the Coefficient of Performance is not affected by the external temperature so that it could reach a level up to 8.

As it is the case for heat pumps, there are several kinds of ***electrochemical storage systems*** as well. These technologies differ among each other for the two electrochemical materials used to produce the reaction, the type of electrolyte and the design characteristics.

The main types are:

- ***accumulators with watery electrolyte***, such as lead-acid batteries, nickelcadmium batteries and nickel-metal hydride batteries;
- ***batteries with electrolyte circulation***;
- ***batteries with high temperature*** (sodium-sulphur, sodium-nickel chloride);
- ***lithium-ion batteries***.

Among all those types, the most promising one is commonly considered to be the lithium-ion one. This battery has a relatively long life expectancy (up to 10,000 load-unload cycles) and can guarantee very high performance (more than 90%). They are suitable to be employed in every application and, crucial point for their expected uptake, they are currently the most used for electric traction.

Eventually, at the present stage of research, the lithium-ion battery is also considered the most economically viable with regard to the operation and manteinance costs. Indeed, fixed costs amount to €10 per kWh a year and variable costs to €0.023 per kWh unload a year.

Source: The European House — Ambrosetti elaboration on Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (ENEA), “Catalogo delle tecnologie energetiche, 2017”, data, 2018.

3.2.2. Energy efficiency enabled by electrification involves a significant industrial value-chain

57. While the technological assessment of the electrification technologies has a twofold relevance on both the Italian and the European level, the analysis of the industrial value chain is strictly focused on the effects that can be triggered in Italy. Yet, starting from the 360° map of the electrification technologies, the Italian companies that are potentially involved in the value chain were assessed. In this regard, all the electrification technologies were considered according to their sector and final use (generation on site, storage and utilization) and connected to the ***Ateco codes*** from Istat at the lowest available level (5^{th} level).
58. Only manufacturing activities have been considered because the Ateco codes do not allow to circumscribe the installers activities to the type of technology for which provide support. Yet, the installation is an important component of the value chain but it is rather neutral to the type of technology they provide to consumers, while the value added of those electrification technologies is going to be captured mostly by the manufacturing. At any rate, it is important to highlight that the figures given below concern the ***industrial value chain*** only.
59. As of today, therefore, the industrial value chain of the electrification technologies for energy efficiency ***potentially involves*** in Italy around ***17,000 firms*** and more than ***320,000 employees***, totaling a turnover of around ***€80 billion*** per year.[25]

25 Data refers to 2015, the latest available year for industrial production in the Istat database.

FIG.24

The potential dimensioning of the industrial value chain of the electrification technologies (generation on site, storage and utilization) in Italy.
Source: The European House — Ambrosetti elaboration on Istat data, 2018

17,000 companies

322,375 employees

€80 billion of turnover

60. Further, relying on the 360° map of the electrification technologies, an ***extended map of the industrial value-chain*** concerning the six aforementioned technologies was elaborated. The value chain map adopts a matrix presentation in which four macro-sectors of the value chain are matched with the different technologies by considering the different components of the technological appliances too. In particular, the four macro sectors here considered to include the components of the electrification technologies value chains are:

- ***Research and Development***, which considers both the competences and skills that are necessary in the development of the given technologies (for instance, mechanical engineering, physics etc.) and the research areas that are involved in research related to that technology (for example, thermodynamics, control systems, materials, etc.).

- ***Manufacturing***, which includes the manufacture of the constitutive parts of the different technologies. Given the substantial differences in the manufacturing of the six technologies, the specific distinction of any of them has been kept into account. For instance, the electric drive is divided into components for Direct Current (DC) Motor and Alternative Current (AC) Motor, batteries are classified between battery types and accessories that are common to all of them, and the energy management systems are subdivided between the hardware components and the software ones.
- ***Distribution sales and aftermarket***, which implies all the distribution, logistics and maintenance parts of the value chains. In this category are included also the system integrator companies providing services in all the considered parts.
- ***Recycling and second life***, including the recycling and reuse of materials and items (aluminium, nickel, cobalt, molybdenum, etc.) as well as the possible usage for exhausted technologies like the battery regeneration for residential and industrial use.

61. In order to identify all the components relevant to each activity in the extended value chain, each phase involved a detailed quantitative census of existing or potential products and services, with recourse to multiple channels and sources of information:

- analysis of major ***technical reports*** and scientific literature from: Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile — (ENEA), Ricerca sul Sistema Energetico (RSE), Politecnico di Milano etc.;
- ***interviews*** with industrial operators and academic experts in this field;
- ***expert reviews*** of the technological profile undertaken with the "Institute for Marine engineering (INM) and the Department of Engineering, ICT and technologies for the Energy and Transports (DIITET)" — CNR of Palermo, whose experts have validated the structure and individual activities/outputs of the electrification technologies value chain.

FIG.25

Mapping of industrial value chains of electrification technologies.

	Research and Development: Competences	Research and Development: Research areas	Manufacturing
Heat pumps	• Electronic engineering • Electric engineering • Chemical engineering • Environmental engineering • Computer science • Mechanical engineering • Physics • Mathematics	• Thermodynamics • Materials • Energy efficiency • Environmental impacts • Electric and electronic systems • Digital system • Mechanical systems • Sensors • Control systems	• Coolant • Evaporator • Compressor including electric motor • Condenser • Expansion valves • Throttling valves • Probe • Fan coil units • Coils • Duct connections
LED lamps	• Electronic engineering • Electric engineering • Chemical engineering • Physics • Mathematics	• Chemical compounds • Materials • Lighting • Optoelectronics • Energy efficiency	• Semiconductor devices (Silicon, Carbon, Germanium, Gallium Arsenide) • Chip • Electrical connections • Optical lenses • Protective cap • Light paths • Cooling plate (only in Power LED)
Electric drives	• Electronic engineering • Electric engineering • Mechanical engineering • Control system engineering • Computer science • Physics • Mathematics	• Energy efficiency • Power electronics • Electrical machines • Control systems • Embedded systems	**Electric Motor** **Direct Current (DC) Motor** *Brush DC*: • Shunt wound • Separately excited • Series wound • Compound wound • Permanent magnet • Servomotor *Brushless DC*: • Universal **High Power Converters** *Direct Conversion*: • Matrix converter • Cyclo converter *Indirect Conversion* – **Voltage source**: • High power 2 VSI • Flying capacitor • Neutral point clamped • Cascade H bridge • Hybrid topologies
Electrochemical storage systems (batteries)	• Electronic engineering • Electric engineering • Chemical engineering • Chemistry • Physics • Mathematics	• Battery Management System • Hybrid batteries (supercapacitors + storage system) • Big Data analytics • Smart-grid • Power electronic converters	**Battery types** • NiCd cell • Lithium-ion cell • NiMH cell • Lead-acid battery
Power electronics	• Electronic engineering • Electric engineering • Physics • Mathematics	• Materials • Electrical circuit • Nano-technology • Control systems • Semiconductor devices • Thermal management • Electromagnetic compatibility • Energy efficiency	• Semiconductor power devices (power diode, power transistor, wide bandgap device, etc.) • PCBs (printed circuit boards) • High frequency transformers *A Power Electronics is an electric-electronic appliance that modifies features of out-coming electricity from those of in-coming electricity*
Energy Management Systems (EMSs)	• Electronic engineering • Information technology • Computer science • Energy engineering • Physics • Mathematics	• Computer software • Embedded programming • ICT • Operations research • Artificial intelligence • Sensor networks • Energy efficiency	**Hardware** • Smart meter • Sensors • Wearable device/IoT • Portable devices (PC, tablet, smartphone) • Embedded boards (DSP, microcontroller, FPGA, etc.) *An Energy Management System is an integrated hardware/software technology used by electricity operators to monitor, control and optimize generation, distribution and utilization performances*

N.B. This document is a proprietary model elaborated by The European House — Ambrosetti in order to map the industrial value chains of the six cross-cutting technologies that can play a key role for electrification.

Distribution, sale and aftermarket

Recycling and second life

- Logistics
- Deposit
- Sale
- Installation
- Post–sale assistance
- Maintenance
- System integrators

- Packaging
- Transportation
- Sale
- Installation

Alternating Current (AC) Motor

Induction Motor

Squirrel Cage
- Design A*
- Design B*
- Design C*
- Design D*
- Shaded Pole
- Split phase
- Capacitor start
- Capacitor run
- Resistance start

Wound Rotor
- Repulsion start
- Repulsion induction

Synchronous Motor
- Permanent magnet
- Synchronous reluctance
- Hysteresis
- Synchronous induction
- Reluctance
- Sub–synchronous reluctance
- Variable reluctance
- Stepper
- Hybrid

Current source
- PWM current source inverter
- Load commutated inverter

Linear
- Induction
- Synchronous

- Transportation
- Distribution
- Sale
- Installation
- Maintenance
- Substitution

Accessories
- Inverter
- Charger
- DC/DC converter

- Transportation
- Distribution
- Sale
- Installation
- Substitution and maintenance
- System integrators

- EMI filters
- Embedded control boards (DSP, microcontroller, FPGA, etc.)
- Capacitor
- Inductor

- Transportation
- Distribution
- Sale
- Installation
- Maintenance

Software
- Mobile app
- Diagnostic system
- Monitoring system
- Big Data analytics
- Energy management algorithms
- Cloud and Edge computing
- Automation systems

- Transportation
- Distribution
- Sale
- Installation
- Consulting services
- Maintenance
- System integrators

Recyclable materials and items:
- Iron
- Steel
- Aluminium
- Nickel
- Molybdenum
- Magnesium
- Copper
- Bronze
- Lithium
- Cobalt
- Nickel
- Graphite
- Glass
- Plastic
- Silicon
- Battery regeneration for residential and industrial use
- Permanent magnet materials

LEGEND
Detailed components of a single part.

* There are different standard types of squirrel cage. Design A: normal starting torque, normal starting current, normal slip; Design B: normal starting torque, low starting current, normal slip; Design C: high starting torque, low starting current, normal slip; Design D: high starting torque, low starting current, high slip.

The model has been validated by engineers affiliated to the "Engineering, ICT and Technologies for Energy and Transportation" department at Consiglio Nazionale delle ricerche – CNR.

62. To complete the investigation of the ***Italian*** industrial value chains, the current Italian level of manufacturing and ***industrial competences*** were evaluated. This further map was constructed by elaborating a matrix of:

- the ***six different technologies*** having the highest potential of deployment (heat pumps, LED lamps, electric drives, electrochemical storage systems, power electronics, Energy Management Systems);
- the ***four phases***, that were identified as key components of the value chain (Research and Development, Manufacturing, Distribution sales and aftermarket, Recycle and second life).

PHASES OF VALUE CHAINS	***Heat pumps***	***LED lamps***	***Electric drives***
R&D, Design/ Engineering	Excellences in the research field with different actors involved (CNR, Politecnico di Milano, Firenze University, Robur and Ariston Thermo)	An excellence centre is constituted by the LUCE LAB located at the Politecnico di Milano and partnered by the Italian Design Association and the main industries in the field (Artemide, IGuzzini, Gewiss)	Excellences in the manufacture of components for motors, but R&D is lacking, with the exception of Magneti Marelli (leader in the Powertrain segment in Italy); excellences in the motorcycle sector (Energica)
Manufacturing	58 companies with more than 7,200 workers and a total turnover bigger than €1,550 million (with 64% share of export) but activity mostly related to assembly. One case of excellence is Ariston Thermo that created a platform for heat pumps sales	About 80 producers of equipment, components and LED lamps based in the Italian territory. Italy is the third exporter of LED lamps worldwide (following China and Germany). €1.5 billion is estimated for the LED market in Italy by 2020	Small producers of electric drives (between thousands W and dozens of kW), but major producers are multinationals such as General Electric, ABB, Siemens
Use and aftermarket	Services and aftermarket are relatively developed thanks to the widely spread network of installers	Installation and related services are already well developed for both residential and public lighting. A few cities have already switched to LED lights in all their streets (Milan is the most prominent case)	Aftermarket services (maintenance, support, etc.) of electric motors are still not very widespread in Italy when compared to other European countries (e.g. Germany) that are among the major manufacturers of such motors
Recycling and second life	Some recyclable materials and components can experience a growth in the near future	LED lamps need to be treated as special electric wastes. Ecolamp and Remedia are the largest consortium in charge. Application for re-use are not developed yet	COBAT expertise in the disposal of component parts in motors

FIG.26

Mapping of Italian skills along the industrial value chains of electrification technologies.
Source: The European House — Ambrosetti elaboration, 2018

OUTPUT

Electrochemical storage systems (batteries)	Power electronics*	Energy Management System** (EMS)
R&D to date in Italy is under-developed	Some Italian companies (STMicroelectronics) are developing new forms of power electronics with Silicon Carbide, a compound of silicon and carbon, a type of wide bandgap (WBG) semiconductor, associated with higher energy efficiency. The US is at the forefront of this field of research	R&D in Italy is still underdeveloped and concentrated to university Labs
Segment that is still under-developed (among the majors are Fiamm and Midac) when compared with China, Japan, South Korea, Germany and France, but in 2020 the market for battery energy storage from the energy and industrial sectors will hit €1.35 billion in Italy	There are some companies specialized in the manufacturing of power electronics (EEI, Elettronica Santerno, Fimer, FRIEMM, Layer, Santerno, TDN Macno). Market leaders in this field are Siemens, ABB, General Electric, Danfoss, Nidec	There are a few companies working with system integration and most of them are concentrated in the building sector (Bticino, CAME Gewiss). The value of the smart home market in Italy in 2016 has overcome €250 million
Aftermarket is still under-developed in Italy; experiences of the battery pack leasing service by some automotive operators, with its own scheduled replacement with new battery packs and updated technology	Aftermarket services are present in Italy but they can be widened	Aftermarket services are present in Italy but they can further be widened with the growth of applications
COBAT know how in the disposal of accumulators (collaboration with CNR – National Research Council – on the recovery of lithium batteries); Central-Southern European countries at the forefront (e.g. in Germany, a pilot project for spent batteries in Smart ForTwos, for supplying renewable energy to the domestic grid)	This is a field that can experience further development in the near future	Not really affected given the software nature of the application

Skill levels

- High
- Middle
- To be built

* Electric/electronic appliance that modifies features of out-coming electricity from those of in-coming electricity.

** Integrated hardware/software technology used by electricity operators to monitor, control and optimize generation, distribution and utilization performances.

63. The result is a complete picture of the Italian level of expertise for any technology and phase. To assess the Italian competences three levels were identified: high, middle and competence to be built. A first look to the distribution of competences in the map reveals a critical situation in at least two regards:

- ***the recycling and second life*** phase has to be built completely for all the given technologies (also due of the recent development of some technologies);
- the competences concerning ***electrochemical storage systems are still underdeveloped*** compared to the competitors and given the importance of batteries in the value chain this is an issue that requires to be addressed.

BRIDGING THE EUROPEAN GAP FOR ELECTROCHEMICAL STORAGE SYSTEMS: THE EUROPEAN BATTERY ALLIANCE (EBA)

The shortage in competences concerning electrochemical storage systems is not only an Italian issue but rather an European one. The largest producers of lithium-ion batteries are located in Japan (Panasonic), South Korea (Samsung, LG), and foremost in China (several producers among which the main ones are CATL and BYD).

To address this issue, the EU Commission Vice President Šefčovič has brokered the launch of the ***European Battery Alliance***. The European Battery Alliance is a ***cooperative platform***, gathering the EU Commission, interested EU countries, European Investment Bank, key industrial stakeholders and any sort of innovation actors. EBA's objective is "to create a competitive manufacturing value chain in Europe with sustainable battery cells at its core". Indeed, the EU Commission's aim is to prevent technological dependence.

Forecasts predict a battery market of up to ***€250 billion a year from 2025*** onwards. To cover this demand, the EU requires at least 10 to 20 "gigafactories", namely large scale cell production facilities. To pursue this goal, the Commission adopted the Strategic Action Plan for Batteries, based on seven measures intended to:

- secure access to raw materials for batteries;
- support scaled European battery cell manufacturing and a full competitive value chain in Europe;
- strengthen industrial leadership through accelerated research and innovation;
- develop and strengthen a highly skilled workforce along the whole value chain;
- support the sustainability of the EU battery cell manufacturing industry;
- ensure consistency with the broader EU regulatory and enabling framework.

Source: The European House - Ambrosetti elaboration on European Commission "European Battery Allieance 2017" data, 2018.

64. By contrast, Italy shows notable medium and high level of competences for:

- ***Heat pumps***: in which there are several excellences in R&D, with different players involved such as Consiglio Nazionale delle Ricerche (CNR), Politecnico di Milano, Firenze University, and a few private companies.
- ***LED lamps***: in the R&D field an excellence center is the LUCE LAB, installed at the Politecnico di Milano and partnered by the Italian Design Association and the main companies in the field. As regards the manufacturing activity, about 80 producers of equipment, components

EUROPEAN HEAT PUMPS MARKET

The European heat pumps market has grown in the time span 2007-2016, from 589,000 to 988,000 of sales. The current amount of heat pumps is equal to 9.5 million of units installed.

As of 2016, the European heat pump value chain employs ***53,155 full time workers***. 36% of the total jobs (19,000) are in manufacturing, 30% (16,000) in installation, 18% (10,000) in components manufacturing and 16% (9,000) in service and maintenance.

Italy is the ***second largest market by sales volumes***, with 181,000 units, after France (220,000). Sweden is the third market, with 101,000 units.

Source: The European House - Ambrosetti elaboration on European Heat Pump Association (EHPA) data, 2018.

and LED lamps are based in the Italian territory. Yet, Italy is the third exporter of LED lamps worldwide (following China and Germany). A total of €1.5 billion is estimated for the LED market in Italy by 2020.

- ***Electric drives***: even if major producers are multinationals, there are several Italian producers of electric drives (from thousands of W and dozens of kW).
- ***Power electronics***: in R&D, a few Italian companies are at the forefront of the research thanks to their positioning in the development of new forms of power electronics embedding Silicon Carbide (a compound of silicon and carbon) meaning a sort of wide bandgap (WBG) semiconductor, associated to higher energy efficiency. Moreover, there are additional companies specialized also in the manufacturing of power electronics.
- ***Energy Management Systems (EMSs)***: in the manufacturing phase, there are a few companies working with system integration and most of them are concentrated in the buildings sector. A possible reason behind this concentration could be the growth of the smart home market that in Italy reached the value of €250 million in 2016.[26]

26 Source: Politecnico di Milano, "Osservatorio IoT 2018".

3.2.3. Italy can obtain large industrial and economic advantages from energy efficiency enabled by electrification

65. The six technologies that were individuated as the ones having the highest deployment potential allow for significant efficiency gains, making them a suitable option to move in the direction indicated by the EU policy targets and increase the efficiency of industry, buildings and transport.

66. To quantify the benefits, in terms of ***energy efficiency gains***, of the six end-use electrification technologies previously identified with respect to their more traditional counterparts the following activities have been provided:

- analysis of the ***existing literature*** and database on energy efficiency from: Assoclima, Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (ENEA), Ricerca sul Sistema Energetico (RSE), Istituto Superiore per la Ricerca e Sviluppo Ambientale (ISPRA), International Renewable Energy Agency, Politecnico di Milano, etc.;
- identification of a ***representative type/power for each technology*** and estimation of the efficiency gains at the current technological stage;
- ***expert reviews*** of the technological profile undertaken with the "Institute for Marine engineering (INM) and the Department of Engineering, ICT and technologies for the Energy and Transports (DIITET)" — CNR.

67. The energy ***efficiency gains*** associated with the six technologies here individuated and compared with the alternative technologies available on the market can be summarized as follows:

FIG.27

Efficiency gains associated with the six technologies compared to the technological alternatives.
Source: The European House — Ambrosetti elaboration, 2018

	Efficiency gain (%)	Alternative technologies
Heat pump	~50% in the average air source heat pump	Heat pump average save in primary energy vs. traditional combustion heating and cooling systems (e.g. condensing boiler). Efficiency gains comprised between 50% and 60% are also visible in the high temperature industrial heat pump
LED lamps	80% – 85% in the residential sector ~52% in public ones	Average energy use save across the different lumens type and vs. the standard filament lamp (adaptive lighting can further increase efficiency of public lighting by 10% or even 30% in main roads). LED lamps have an efficiency gain ranging between 5% and 10% also compared to the fluorescent lamps
Electric drives	~40% in the electric cars ~25% industrial inverter	Energy use save vs. internal combustion engine in the cars and energy save given by an inverter applied to the electrical drives in the industry
Electrochemical storage systems (Batteries)	~12% generated by Lithium-Ion batteries	Efficiency of the Lithium-Ion batteries vs. the alternative electrochemical ones (efficiency gain is here referred to Sodium Nickel Chloride, for lead-acid, sodium sulfur, redox flow is also higher)
Power electronics	~73% in wide band-gap-devices	Effects generates by employing semi-conductors such as silicon carbide or gallium nitride in place of silicon
Energy Management System	~16% in buildings and 14% – 17% in heating, ventilation air conditioning	Efficiency gains of the most recent system integration software compared to the past (advanced aggregation software allow to maximize usage of distributed storage and renewable generation and optimize the management of heating and cooling facilities)

68. Building upon the efficiency gains that would be triggered by the given electrification technologies a ***"what if" analysis*** has been provided to estimate the attainable turnover from the deployment of four of these technologies to 2030[27]. To give consistency to the "what if" analysis the average market cost of any given technology — that could enable the afore-mentioned efficiency gains — was identified relying upon the technical literature and selecting the representative and average case for any option. In detail, the underlying prices considered in the following scenario are:

- €5,970 for small heat pumps (air-water technology, 6.7 kW) to be adopted in the residential sector;
- €11,956 for heat pumps (air-water technology, 21 kW) for apartment blocks and tertiary sector buildings;
- €100 to upgrade an average house with LED lamps;[28]
- €260 for substituting LED lamps in a single public lighting point;
- €2,625 for an electric drive (65 kW) fitting the need of an average electric car;
- €4,300 for an efficient inverter (55 kW) to be applied to an average electric drive in the industrial sector;
- €16,159 for an electrochemical battery of an average electric car.

69. On the basis of these prices, the scenarios developed for the "what if" analyses consider both ***a full deployment scenario*** (100% of installation of the specific technology) and ***an evolutive scenario*** (lower share of penetration differentiated by technology)[29]. Moreover, the quantification of those scenarios required a few additional steps:

- analysis of the existing housing stock based on the information of the current residential buildings subdivided by type of housing solution (single house, terraced house, apartment blocks etc.). Yet, the estimation of the new buildings to be built by 2030 was based on the average rate of the last 5 years (2013-2017);
- investigation of the overall amount of public lighting points currently installed in Italy and identification of the benchmark case among the Municipalities that have already introduced LED lamps (i.e. Milan) to calculate the unit cost of upgrading the public lighting to LED lamps solutions;
- identification of the composition of the electric drives currently installed in the industry among which an inverter can be applied;
- reconstruction of the cost incidence of electric drives and batteries in the overall cost of an electric car.

70. The reconstruction of the existing buildings in Italy and the estimate of the corresponding ***residential housing stock*** (useful in evaluating the type of pumps to be installed) and ***tertiary sector buildings*** (schools, offices and hotels) have been prerequisites for elaborating the scenarios for heat pumps. The new residential housing by 2030 are estimated on the basis of the 2013-2017 average and are equal to the cumulated figure of 570,108 assigned to the different house types according to the current composition share. The number of tertiary sector building is left unchanged compared to the current one.

71. Given the efficiency gains mentioned above, an electric heat pump can be considered an efficient solution for all the Italian existing buildings to substitute both traditional and condensing boilers. However, in the definition of the evolutive scenario the increasing amount of natural gas heat pumps that would hit the market over the next years have already been included. These pumps, indeed, are likely to find a market niche in the time span until 2030 especially because of their capability to efficiently function even when external temperature is close or lower than 0°.

AIR QUALITY EFFECTS OF THE ELECTRIC HEAT PUMPS

The deployment of electric heat pumps, as compared to the technological alternative (primarily condensing gas boilers and biomass boilers), has an additional positive effect to be considered along the energy efficiency gains. Electric heat pumps, indeed, reduce at the same time both Greenhouse gas (GHG) emission, measured in CO_2 equivalent, and PM_{10} ones while biomass boilers produces comparatively higher PM_{10} emissions and condensing gas boilers higher CO_2 equivalent ones. Being effective in reducing PM_{10} emissions, therefore, electric heat pumps contribute to the improvement of air quality in urban centres.

Source: The European House - Ambrosetti elaboration on Enel Foundation, Politecnico di Torino and MIT "Electrify Italy" data, 2018.

27 It has not been provided any deployment scenario for Energy Management System and Power electronics as their cross-cutting nature make them typically going together with other electricity-driven technologies and prevents from finding a single usage.

28 Given the absence of unitary numbers of lighting points installed in the Italian houses, likewise the existing literature, this price has been reconstructed on the basis of the estimated cost for upgrading with LED lamps an average apartment.

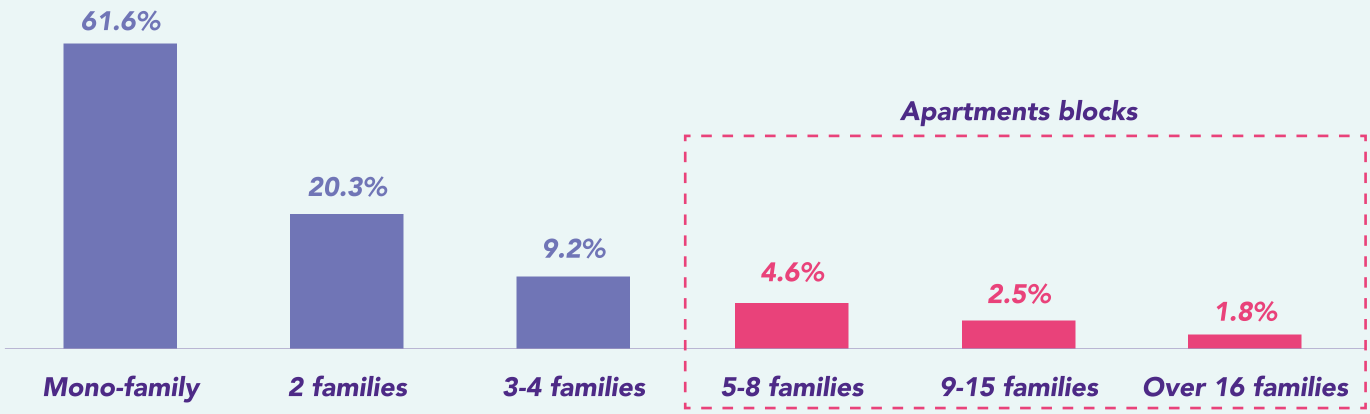
29 All the aggregate scenarios have been rounded to 0 or 5 as second decimal place.

71. In addition, concerning the adoption of electric heat pumps in the existing Italian buildings, it has to be specified that their combination with the envelope retrofit — the most typical one being the substitution of windows and shutters — engenders a particularly positive effect in terms of decreasing energy demand (increased energy efficiency) and reducing CO_2 emissions making the electric heat pump a technological option even more convenient in terms of global cost of the intervention[30].

30 The global cost of the intervention is defined as the total cost of a system over its lifetime embedding the initial investment cost of the intervention and the annual operating costs (including maintenance and energy costs). Source: Enel Foundation, Politecnico di Torino and MIT "Electrify Italy", 2018.

FIG.28

Residential buildings stock in Italy in 2018 (% values).
Source: The European House — Ambrosetti elaboration on Politecnico di Milano and Istat data, 2018



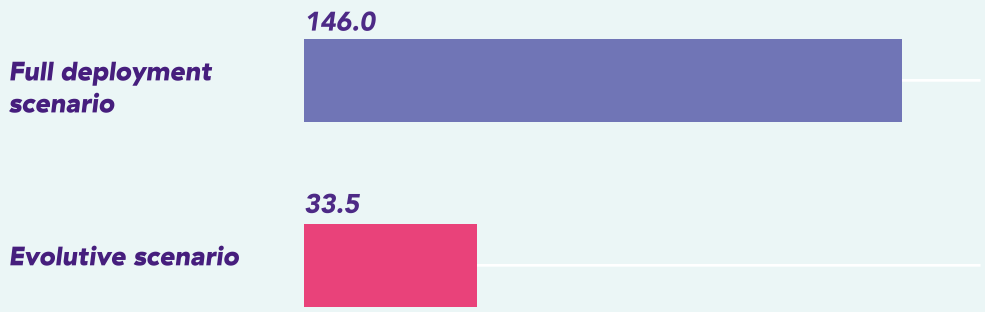
72. Following this, the turnover that can be activated in both the full deployment and the evolutive scenario for heat pumps at 2030 was defined as follows:

- ***Evolutive scenario***: installation of a heat pump in ***20% of the existing residential sector*** by differentiating for terraced houses and apartment blocks and discounting for the ones that already have a heat pump installed. Installation of a heat pump in ***all the new buildings to be built until 2030***. Installation of a heat pump in ***20% of tertiary sector buildings*** (schools, offices and hotels).[31]
- ***Full-deployment scenario***: installation of a heat pump in ***all the existing residential sector*** by differentiating for terraced houses and apartment blocks and discounting for the ones that already have a heat pump installed. Installation of a heat pump in ***all the new buildings to be built until 2030***. Installation of an heat pump in ***all tertiary sector buildings*** (schools, offices and hotels).

31 Given the current building renovation rate being about 0.7% (in France is 1.1% and in Germany 2%) even the evolutive scenario would require an acceleration in buildings' renewal to reach the target number of heat pumps. (Source: European Commission).

FIG.29

Turnover actionable by 2030 in the full deployment and the evolutive scenarios for heat pumps (€ billion).
Source: The European House — Ambrosetti elaboration, 2018



73. As for the LED lamps two fields have been considered. On the one hand, the installation of LED lamps in all (or in part of) the residential and tertiary buildings that were also involved in the previous scenario. On the other hand, the turnover that can be activated from installation of LED lamps in the public lighting.

LED LAMPS IN THE ITALIAN PUBLIC LIGHTING

In Italy there are ***~9 million lighting points*** accounting for ***6,000 GWh*** of electricity consumption in 2017 (i.e. 100 kWh per inhabitant, almost doubling the EU average of 51 kWh per inhabitant).
To improve energy efficiency a few cities have already started to replace the lighting system with LED lamps and obtaining energy gains of ~50%. Leaving aside small towns, remarkable cases are:

- Ravenna that replaced 37,000 lighting points with LED lamps, reducing energy consumption by 50%;
- Bergamo substituting 15,000 lighting points with LED lamps;
- Brescia substituting 43,000 lighting points with LED lamps.

The benchmark case for large-scale replacement is constituted by ***Milan*** that in 2015 replaced 140,000 lighting points with LED lights, for a total investment of ***€38 million***, which reduced energy consumption by 52%. Dividing the total investment by the number of lighting points, it results a unitary cost of €270 that includes the single lamp and the installation cost. This is the reference for the costs for public lighting renewal in the what if analysis.

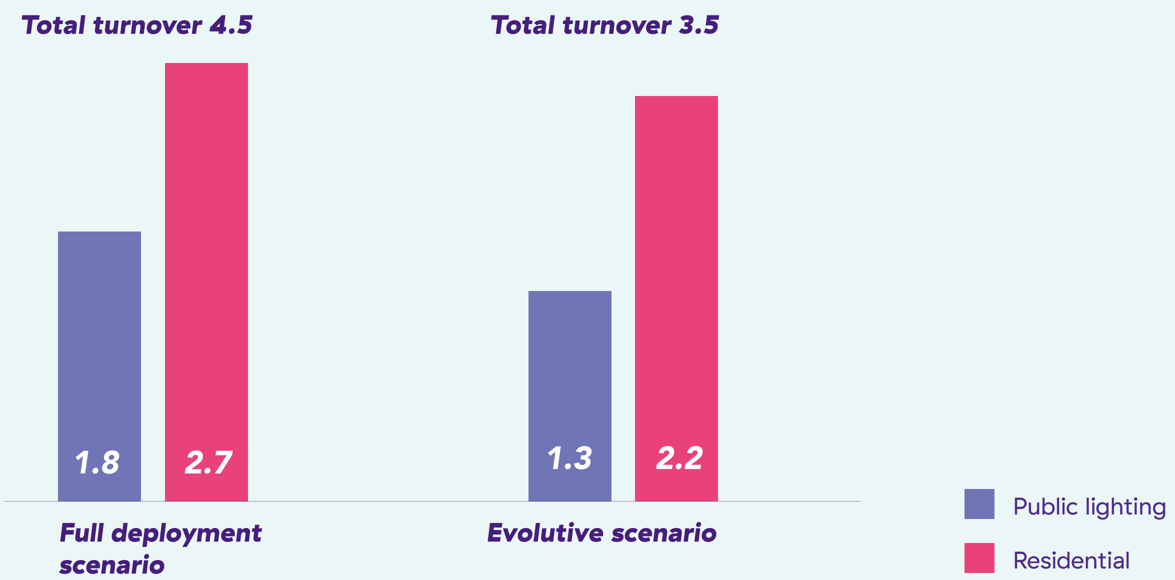
Source:The European House — Ambrosetti elaboration on Istituto Superiore per la Protezione Ambientale (ISPRA) and Comune di Milano data, 2018.

74. The turnover that can be activated for LED lamps at 2030 was therefore estimated on the basis of the following conditions:

- ***Evolutive scenario***: installation of LED lamps in ***70% of the existing houses*** and in all the new ones to be built until 2030. Installation of LED lamps in ***60% all public lighting***.
- ***Full-deployment scenario***: installation of LED lamps in ***all the existing and new houses*** and installation of LED lamps in ***all public lighting***.

FIG.30

Turnover actionable by 2030 in the full deployment and the evolutive scenarios for LED lamps (€ billion).
Source: The European House — Ambrosetti elaboration, 2018

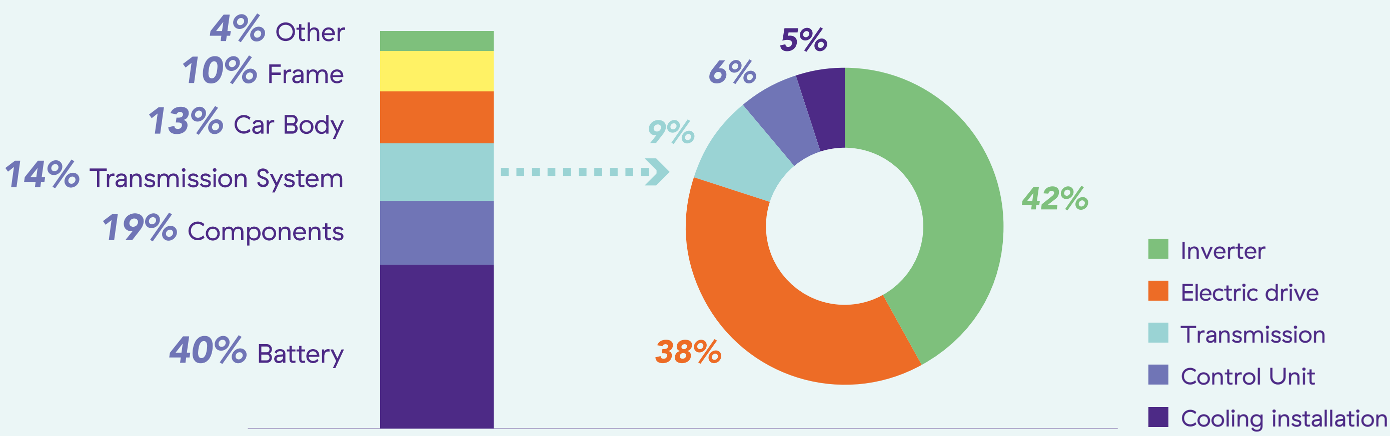


75. Concerning the electric drive two sub-fields were considered: the electric drive in e-Cars and the efficient inverters to be applied in industrial motors. Regarding electric vehicles, the deployment scenarios were based on the penetration curve outlined earlier in the study so that the turnover here depicted cosists in the revenues strictly related to the electric drive technology.[32] In the industrial sector, 74% of the total electricity consumption (equal to 112,000 GWh) is originated by electric drives. The application of an efficient inverter — guaranteeing an efficiency gain of 25% — has been considered for all the industrial electric drives consuming more than 22 kWh (~1.5 mln).

32 Concerning both the electric drive and the electrochemical storage systems, the turnover achievable in the «what if» analysis partially overlaps with the turnover outlined in the previous e-Mobility scenario. Electric drive and batteries are, indeed, key features in the cost structure of the e-Vehicle (see subsequent figure 31). Given the deployment scenario of any technology — underpinning the «what if» analysis — and the importance of e-Mobility for these specific technologies, the component concerning e-Cars was maintained also in this part (given also the role that Italy can play, especially for electric drives). Moreover, developing the «what if» analysis from the e-Mobility penetration scenarios allows to maintain consistency between the two parts.

FIG.31

Cost composition of the e-Car.
Source: The European House — Ambrosetti elaboration on The European House – Ambrosetti 2017 study "e-Mobility Revolution. Impacts on Italy and its industrial value chain: Italy's agenda" data, 2018

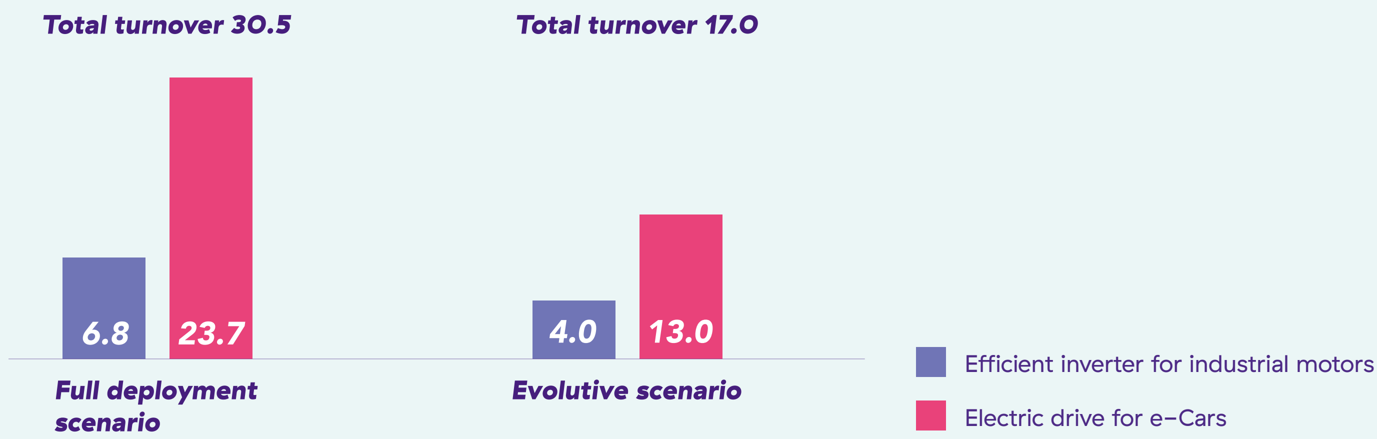


76. On the basis of these two fields, the actionable turnover concerning the electric drive at 2030 was estimated as follows:

- ***Evolutive scenario***: deployment of an electric drive in all the electric vehicles to be sold until 2030 according to the intermediate scenario pointed out early in the study (***5 million cars***). Deployment of an efficient inverter in ***60% of the largest electric drives*** (above 22kW) currently installed in the industrial sector.
- ***Full-deployment scenario***: deployment of an electric drive in all the electric vehicles to be sold until 2030 according to the accelerate scenario pointed out early in the study (***9 million cars***). Deployment of an efficient inverter in ***all the largest electric drives*** (above 22kW) currently installed in the industrial sector.

FIG.32

Turnover actionable by 2030 in the full deployment and the evolutive scenarios for electric drive (€ billion).
Source: The European House — Ambrosetti elaboration, 2018



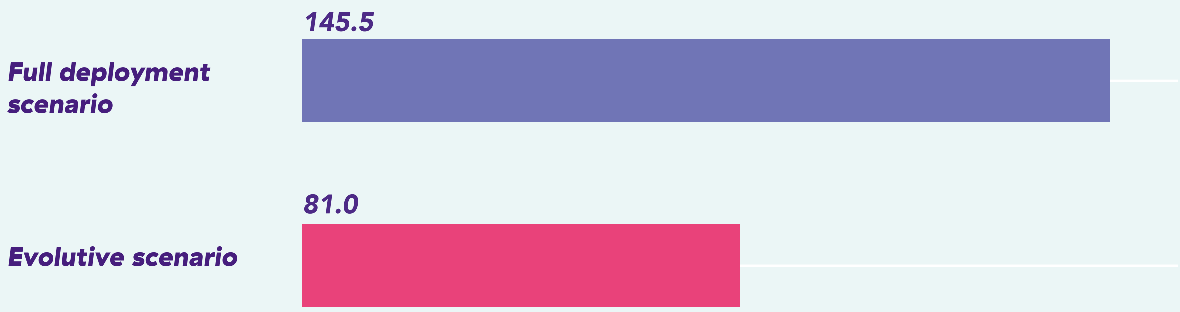
77. Finally considering the electrochemical storage systems, it has been considered the possible deployment of lithium-ion batteries in the e-Cars, among which they account for about 40% of the overall cost[33]. Therefore, the actionable turnover considers those case:

- ***Evolutive scenario***: deployment of the electrochemical battery in all the electric vehicles to be sold in Italy until 2030 according to the intermediate scenario described in this study (***5 million cars***).
- ***Full-deployment scenario***: deployment of the electrochemical battery in all the electric vehicles to be sold in Italy until 2030 according to the accelerate scenario described in this study (***9 million cars***).

33 See the cost structure of the electric vehicle presented above.

FIG.33

Turnover actionable by 2030 in the full deployment and the evolutive scenarios for electrochemical storage systems (€ billion).
Source: The European House — Ambrosetti elaboration, 2018



78. To summarize, the activation of the Italian industrial value chain for the electrification technologies, whose components and existing Italian competences have been described above, reveals an actionable turnover ranging ***between €135 billion and €326.5 billion***. The largest part of this turnover is generated by electrochemical storage systems and heat pumps making the case of the strategic value of the installed competences for those two fields.

FIG.34

Overall turnover actionable by 2030 in the full deployment and the evolutive scenarios (€ billion).
Source: The European House — Ambrosetti elaboration, 2018

EVOLUTIVE SCENARIO

	Turnover at 2030
Heat pumps	33.5
LED lamps	3.5
Electric drives	17.0
Electrochemical storage systems	81.0
TOTAL TURNOVER AT 2030	135.0

FULL DEPLOYMENT SCENARIO

	Turnover at 2030
Heat pumps	146.0
LED lamps	4.5
Electric drives	30.5
Electrochemical storage systems	145.5
TOTAL TURNOVER AT 2030	326.5

Part 4

How to enhance the electrification process and reap its benefits

Part 4

Key messages

- Fostering the electrification process requires action across different sectors and fields making a ***multi-level strategy*** necessary to reap all the benefits and opportunities that can be activated for Italy and its industrial value chains.

- ***5 focus areas have been identified***, among which different proposals are grouped according to their foundations:
  - ***e-Mobility take up***
    - Adopting an effective management of the e-Mobility transition by setting up a comprehensive strategic vision at national and local level, along with shared targets of development (in terms of number of e-Vehicles, charging infrastructure, etc.) and related operational roadmaps, including deadlines for phasing out of the most polluting vehicles, with guidelines for Regions.
    - Enhancing the installation process of public and private charging points by removing all the regulatory and legislative stumbling blocks.
    - Setting ambitious targets for clean vehicle procurement by public authorities, whose new purchased fleets shall be 100% clean, defining a rigourous time frame, e.g. 2025.

  - ***Energy efficiency deployment***
    - Giving continuity to the incentivizing mechanisms, foremost the Eco-Bonus, on a multi-annual base and optimizing their implementation procedures.
    - Setting up a "Home Maintenance Leaflet" to increase stakeholder awareness — primarily but not exclusively householders — on energy efficiency benefits via the introduction of an instrument with the potential to be priced by the market and consequently increase the value of the interventions made by householders over time.
    - Devising innovative financial schemes, e.g. combining traditional mortgage with an *ad hoc* loan for energy efficiency technologies guaranteed by the financial institution under an agreement with an industrial player, to support the uptake of energy efficiency technologies with medium-long payback period.

  - ***Enhancing collaboration betweeen companies and research networks***
    - Creating a national Tech Transfer Lab focused on electrification technologies, by empowering the role of the already existing research institutions having activities in closely related fields (for instance, the RSE, etc.), and with the mission of acting as enabler of technological transfer between research institutions and the private sector, easing the "go-to-market" mechanisms of electrification technologies (starting from the ones with the highest potential, e.g. heat pumps, LED lamps, electric drives and electrochemical storage systems).

  - ***Strengthening national capabilities on electric frontier technologies***
    - Launching national programs for the R&D activity of companies operating in the electric technologies sector, relying upon public-private partnership schemes and the pre-procurement tool.
    - Launching a "Technology Impact Bonds" to sustain research initiatives with a social impact and economic return and with a supply mechanism that favors the creation of consortium involving all the players along the value chains and guaranteeing all the phases from research to implementation.

  - ***Diffusing awareness about the benefits of electrification***
    - Increasing the awareness about the electrification benefits via specific action directed towards public opinion (via a national communication campaign based on recurring cycles), policy-makers and institutional stakeholders (via the definition of a function providing policy assessment in terms of sustainable development in the energy sector) and the business community (through a permanent forum focused on electrification technologies).

- The Distribution System Operator (DSO) can act as a key enabling factor, sustaining the technological evolution and the associated investment. The legislative and regulatory scenario should properly incentivize ***DSO necessary investment on its own network***, both in digitalization and renewal, with commitments to cope with the integration of an increasing amount of renewables, the spread of extensive network of charging infrastructure for electric vehicles and a higher share of electricity in final-user consumption. Furthermore, it is necessary to define rules and responsibilities of the various network operators (TSO and DSOs) in line with the on-going European regulatory framework, especially concerning the coordination of distributed energy resources.

4.1.

A multi-level strategy is needed to enhance the electrification process

1. The electrification process does not necessarily refer to a single policy realm but encompasses a few of them by engendering technological changes and triggering new consumers behavior. As for this, a ***multi-level strategy*** needs to be adopted. The multi-level word refers, therefore, to both the plurality of policy fields affected (e-Mobility, energy efficiency, etc.) and the different rationales behind the recommendations outlined here, which comprise the needs to elaborate strategic plans, diversify existing financing tools and enhance the awareness of both Italian citizens and stakeholders about the benefits and opportunities that the electrification process is opening.

2. To make the objects of the multi-level strategy clearer, all the policy recommendations here formulated have been clustered in ***five focus areas***:

- e-Mobility take up;
- energy efficiency deployment;
- enhancing collaboration betweeen companies and research networks;
- strengthening national capabilities on electric frontier technologies;
- diffusing awareness about the benefits of electrification.

3. In particular, all the recommendations concerning e-Mobility are consistent with and integrate the proposals set out in the 2017 study "*e-Mobility Revolution. Impacts on Italy and its industrial value chain: Italy's Agenda*".[1]

4. To summarize all the recommendations formulated in this part, a ***synoptic view*** has been elaborated to pair the five focus areas, meaning the clusters of the proposals, with the individual recommendation. Further, this synoptic view constitutes a proper tool-kit to support the electrification growth in Italy.

1 The study is available at: https://www.ambrosetti.eu/ricerche-e-presentazioni/e-mobility-revolution/. In 2017 study, it was emphasized that, in order to enhance the opportunity for e-Mobility and derive the maximum benefits from it, an integrated countrywide strategy was required based on six building blocks: 1) formulating, at the level of the Italian national economy, an incisive, all-round vision for the national development of e-Mobility (vehicles - private and public, two and four wheeled and "slow mobility"); 2) establishing a leadership role for Italy in the area of Research and Development through the launch of programs of research at a national level and the creation of a national cluster on e-Mobility; 3) promoting policies based on incentives of a non-economic nature in order to accelerate the spread, on a vast scale, of electric mobility, in the short-term, with particular reference to urban settings; 4) promoting pilot supply chain projects involving companies, universities and research centres; 5) accelerating the infrastructure process of the electric charging points network; 6) promoting a nationwide awareness and information strategy on e-Mobility.

FIG.1

Synoptic view of the policies to support electrification in Italy.
Source: The European House — Ambrosetti elaboration

E-MOBILTY TAKE UP

- Adopting an effective management of the ***e-Mobility transition*** by promoting co-ordination among the institutional actors and elaborating a strategy involving precise targets and actions at national and local level
- Enhancing the installation process of ***public and private charging points*** by removing all the regulatory and legislative stumbling blocks
- Setting ambitious target for the ***clean vehicle procurement by public authorities***, whose new purchased fleet shall be 100% clean by 2025

ENERGY EFFICENCY DEPLOYMENT

- Giving ***continuity to the incentivizing mechanisms*** on a multi-annual base and optimizing the implementation procedures
- Setting up the "***Home Maintenance Leaflet***" to increase the stakeholder awareness on energy efficency benefits and introduce a feature that can be priced by the market so increasing the value of the interventions made by householders
- Devising ***innovative financial schemes***, e.g. combining traditional mortage with an ad hoc loan for energy efficiency technologies guaranteed by the financial institution under an agreement with an industrial player, to support technologies with medium-long payback period

ENHANCING COLLABORATION BETWEEN COMPANIES AND RESEARCH NETWORKS

- Creating a national ***Tech Transfer Lab*** focused on electrification technologies, empowering the role of the already existing research institutions and with the mission of acting as enabler of technological transfer between the research institutions and the private sector

STRENGTHENING NATIONAL CAPABILITIES ON ELECTRIC FRONTIER TECHNOLOGIES

- Launching national programs for the R&D activity of companies operating in the electric technologies sector, relying upon ***public-private partnership schemes*** and the ***pre-procurement tool***
- Launching a "***Technology Impact Bonds***" to sustain research initiatives with a social impact and economic return and with a supply mechanism that could favor the creation of consortium involving all the players along the value chains and guaranteeing all the steps from research to implementation

DIFFUSING AWARENESS ABOUT THE BENEFITS OF ELECTRIFICATION

- ***Increasing the awarness*** on the electrification benefits via specific action directed towards public opinion (via a national communication campaign based on recurring cycles), ***policy-makers and institutional stakeholders*** (via the definition of a function providing policy assessment in terms of a sustainable development in the energy sector) and the ***business community*** (through a permanent forum focused on electrification technologies)

The Distribution System Operator (DSO) can act as a key enabling factor, sustaining the technological evolution and the associated investment. The legislative and regulatory scenario should properly incentivize ***DSO necessary investment on its own network***, both in digitalization and renewal, with commitments to cope with the integration of an increasing amount of renewables, the spread of extensive network of charging infrastructure for electric vehicles and a higher share of electricity in final-user consumption. Furthermore it is necessary to define rules and responsibilities of the various network operators (TSO and DSOs) in line with the on going European regulatory framework.

4.1.1. e-Mobility take up

PROPOSAL: VISION AND OPERATIONAL ROADMAP ON E-MOBILITY

OUR RECOMMENDATION:

Adopting an effective management of the e-Mobility transition by:

- Setting up, at national and local level, targets of development (in terms of number of e-Vehicles, infrastructure, etc.) and related operational roadmaps, that include deadlines for phasing out of the most polluting vehicles, with guidelines for Regions.
- Coordinating policies and actions among relevant Ministries (Transport, Economic Development and Environment) and local governments, aligning Italy with the international best practices in terms of policies, frameworks, tools, etc.
- Bringing together the energy and automotive industries as well as the other relevant players to define and plan the growing demand of infrastructures and other key components that will result from the rise in e-Vehicle use.

5. As demonstrated in the previous parts of the study, the e-Mobility uptake represents a historical turn for the entire transport sector, enhancing the environmental sustainability and efficiency of the entire sector and requiring to be governed via an action involving interrelated levels: infrastructural, market and legislative.

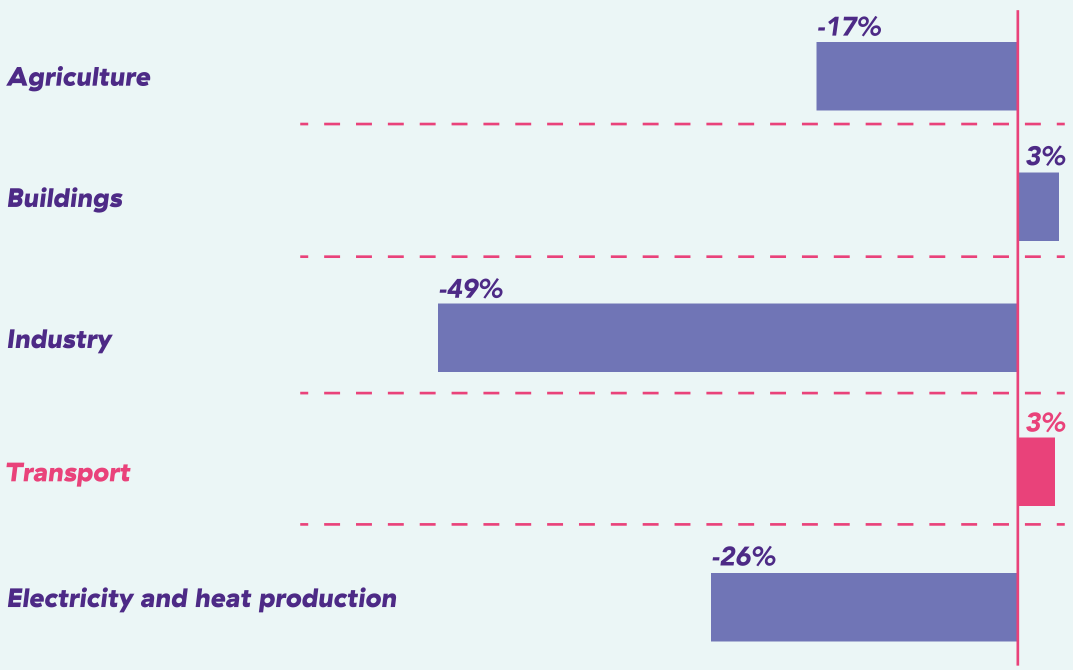
6. Italy has one of the highest motorization rates in Europe — 625 cars per 1,000 inhabitants, followed by Germany (546), Spain (492) and France (479) — and the Italian fleet is also among the ***largest and oldest fleet in the EU***, with 51 million vehicles. Yet, considering the car fleet only, 15% of Italian cars are more than 20 years old, way more than its European counterparts, such as Germany (5.4%) and the UK (1.8%).

7. The transport sector accounts for almost a quarter of the total European greenhouse gas (GHG) emissions and is the primary cause of air pollution in cities. Among the different types of transport, road transport is the largest responsible of GHG emissions, totaling more than 70% of total transport emissions. The size of the road transport fleet and its relatively high age explain why, in Italy, emissions related to transport have been increasing since 1990. Yet, due to the recurring violations of emissions thresholds in urban areas, Italy is currently under two infringements procedures at the EU level for excessive PM_{10} and NO_2 levels.[2]

2 The infringement procedure is currently in the first stage of appeal for non-compliance with the EU Directive 2008/50/CE concerning emissions levels in urban contexts.

FIG.2

Changes in CO_2 emissions by sector in Italy (% values), 1990-2015.
Source: The European House — Ambrosetti elaboration on European Environment Agency (EEA) data, 2018



8. Thus, this proposal aims to align Italy with the international best practices, in terms of strategies and policies aimed at promoting low and zero emissions vehicles. Indeed, several countries have already issued policy commitments to reduce transport related emissions:

- Norway will ban internal combustion engines by 2025;
- France and the United Kingdom will end sale of cars emitting greenhouse gas by 2040;
- The Netherlands will ban sale of all non-emission free vehicles by 2030;
- India aims at 100% e-Vehicles by 2030.

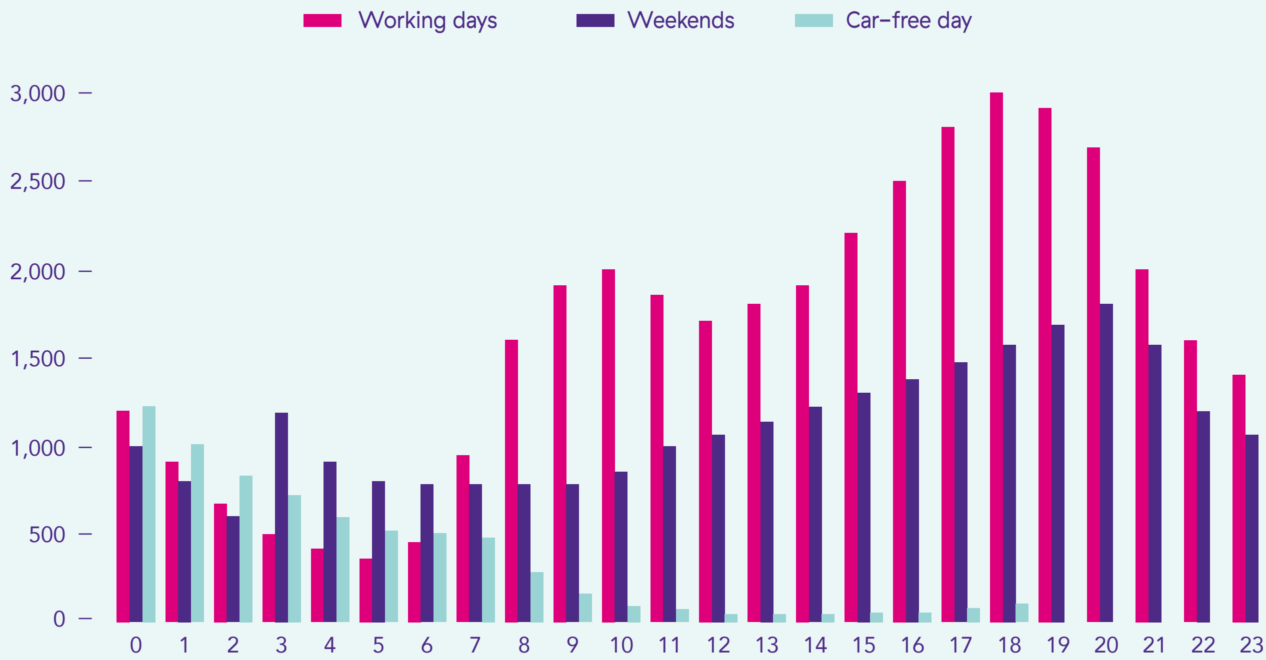
9. Given that electric vehicles reduce CO_2 emissions by ***55%*** over the lifecycle in respect to a diesel one, the uptake of e-Mobility can positively affect air quality in urban centers by cutting PM_{10} and NO_2[3], which levels violations are responsible for the infringement procedure mentioned before.

3 In the accelerated e-Mobility scenario (see Part 3), PM_{10} can be decreased by 32% from 2017 to 2030.

FIG.3

Effects of car-free day in Brussels, 17 September 2017 (concentration of microorganisms — m³).

Source: The European House — Ambrosetti elaboration on European Commission data, 2018



10. A fundamental part of the integrated plan should be the definition of a ***long-term perspective***, articulated in short and medium-term goals, implying the definition of clearly defined policy targets that allow a precise monitoring and permit effective management of the transition period. For instance, the UK has recently released a ***comprehensive strategy***[4] in which long-term perspectives on emission reduction and development of the e-Mobility are matched with short-medium term objectives concerning the industrial value chain, investments in the charging infrastructure and measures to support the key competences installed in the country. For instance, this strategy envisions both targets for sales of ultra-low emission vehicles by 2030 (50%-70% for cars, up to 40% for vans, and 100% for the central government fleet) and for infrastructural upgrade. This latter objective is outlined via the financing for innovative and publicly accessible charging stations — meaning that this measure could open the way for deployment of lamp posts having

4 Source: HM Government, "The Road to Zero: next steps towards cleaner road transport and delivering our Industrial Strategy 2018".

an embedded charging station — the expected mandatory inclusion of charging stations in all new dwellings and the mandatory smart charging functionality for all charging points to be sold and installed in the country. Such an integrated plan for e-Mobility would also have the positive spill-over of guaranteeing a prominent Italian role on the international scenario as one of the key players of e-Mobility, leveraging on Italian technological competences outlined in the previous Part (see Part 3) and then activating the technological potential.

11. Furthermore, in a broader context in which urban areas are increasing their extension, in 2011 there were 27 megacities having metropolitan areas equal or larger than 10 million inhabitants but at least 10 more are expected by 2020, ***urban planning*** is a fundamental aspect. A few studies have already attempted to establish the positive effects of electric mobility, energy efficiency, and integrated infrastructure solutions in urban mobility and in quality of life[5]. Hence, it has an increasing importance integrating and reconciling all the normative instruments originally devised to address mobility issues (pollution, traffic management, etc.) with the ones that, instead, were conceived to tackle urban planning at-large (land use plans, building permits, etc.).

12. In this regard, the e-Mobility development represents an occasion to pursue with this necessary integration among the available instruments. However, Italy has only recently approached a vision on e-Mobility[6] and it still lacks an integrated strategic plan setting targets and actions needed to reach the objectives (as the most advanced European countries in terms of e-Mobility have[7]). Yet, Italian legislation for sustainable urban mobility is scarce and fragmented, as highlighted by the fact that only 11 municipalities, out of 7,954, have approved an Urban Plan for Sustainable Mobility.

13. By bringing together all public and private stakeholders (institutions and other public bodies, companies, workers and consumers), it is possible to define shared objectives on e-Mobility and plan the necessary investments over time. Involving all the relevant stakeholders, would allow to have a coordinated industrial activity going in parallel with the institutional regulatory interventions and ultimately to have in place a comprehensive and integrated plan considering each actor instances. For example, in the UK the government has promoted the Automotive Sector Deal, through which joint investment and long-term commitments between government and industry are secured in areas including the Research and Development of battery technology and the manufacture of ultra-low and zero emission vehicles.

THE GERMAN CASE: THE JOINT AGENCY FOR ELECTRIC MOBILITY (GGEMO)

The Joint Agency for Electric Mobility (GGEMO) was set up by the Federal Ministry of Economics and Technology (BMWi) in February 2010, to coordinate all federal government electro-mobility activities.
The agency supports the Federal government and the National Electric Mobility Platform to implement and develop the National Electromobility Development Plan.

Source: The European House – Ambrosetti elaboration on Germany Trade and Invest (2016) data, 2018.

5 Source: Enel Foundation, "Urban metabolism in Megacities".
6 The first "Piano Strategico Nazionale per la Mobilità Sostenibile", and the relative funds dedicated to it, was envisioned by the Budget Law 2018.
7 In addition to the UK Strategy mentioned above, it is worth making explicit the vision of the Netherlands to be synthetized as "Making all new cars emission-free by 2030, banning petrol- and diesel-powered cars in favor of battery-powered vehicles".

A EUROPEAN EXAMPLE: PLATFORM FOR ELECTRO MOBILITY

A few European-wide stakeholders belonging to civil society, industry, and transport modes have already joined their forces to ask for integrated action at the EU level in promoting integration between electric mobility and the consolidated transport modes.
The Platform's mission is to create a multimodal transport system powered by sustainable electricity. To accomplish this vision, the Platform sets four main objectives:

1. providing a forum in which likeminded organization effectively collaborate to develop the market for electro-mobility;
2. collectively inputing to EU policy making processes and other relevant forums;
3. developing practical policy interventions that address barriers and develop solutions which accelerate electro-mobility;
4. actively promoting electro-mobility to key decision makers and influencers in EU institutions and member states.

Source: The European House – Ambrosetti elaboration on Platform for Electric Mobility: Momerandum of Understanding data, 2018.

PROPOSAL: CHARGING INFRASTRUCTURE EMPOWERMENT

OUR RECOMMENDATION:

Enhancing the installation process of public and private charging points by removing all regulatory, legislative and operational stumbling blocks:

- Going beyond the Energy Performance of Buildings Directive[8] minimum requirements on charging infrastructure deployment in buildings when transposing the Directive and ensure the "right to plug" for condo owners and tenants.
- In the transposition of the REDII (Renewable Energy Directive)[9], setting up a market for "clean fuel credits" that fuel suppliers can trade to meet obligations under renewable energy targets in transport, so that overachievers can monetize exceeding credits (a charge point operator selling a higher renewable electricity share than required could use revenues to cover part of the charging infrastructure cost).
- Implementing a legislative action aimed at reducing regulated tariffs applied to private (private box/garage with dedicated POD — Point of Delivery, different from the POD of the main house) and public charging points.
- Fostering incentive schemes for the installation of charging points and wall boxes in private contexts (offices, residential buildings).
- Enhancing partnerships between public and private players to place private charging positions for public use close to private commercial activities (shopping malls, restaurants, hotels, public offices, etc.), exploiting the scheme offered by innovative public procurement.
- Need to provide proper follow-up to simplification procedures already foreseen by Italian legislation[10] while ensuring compliance by local institutions (Regions, Municipalities) with national guidelines (guidelines on Sustainable Urban Mobility Plans-PUMS, Decree on certified notice of commencement of works-S.C.I.A.).
- Adopting homogeneous rules for granting permissions (land occupancy, type of road signs etc.) for installing public charging points, starting from the 14 Metropolitan Cities.

14. Charging infrastructures are an essential enabling factor behind the e-Mobility uptake. Without their homogenous deployment across the country the positive dynamics on both the supply side (car producers investing to increase available electric models) and the demand side (consumers deciding to purchase an electric vehicle) are significantly weakened.

15. For this reason, leading countries in e-Mobility have set-up regulatory frameworks and incentive schemes to enhance the installation of charging points and stations, while Italy lags behind the best-in-class countries in terms of public and private charging positions due to the uncertainty of the legislative system and bureaucratic red tape. Currently, in Italy there are about ***3,000 public charging positions*** compared to 34,832 in the Netherlands, 25,431 in Germany and 16,657 in the United Kingdom[11] and ***7,500 private wall-boxes*** compared to 15,000 in Denmark and 14,000 in Germany. Although some interventions are planned, more effort is required: after the implementation of the Enel plan, there will be ***0.03*** charging positions per km in Italy in 2020, still far behind the current European best performers (the Netherlands, the EU's best performer, has 0.225 charging stations per km, followed by Norway, with 0.093 charging stations per km). Moreover, to meet the e-Vehicle intermediate development scenarios for e-Cars, e-Two-wheelers and e-Light commercial vehicles only (see Part 3.1.3.), reducing by almost one third PM_{10} emissions, Italy has to install over ***35,000*** public chargers (20 times current numbers) and ***3.2 million*** of private wall-boxes (427 times current numbers) by 2030.

8 The Energy Performance of Buildings Directive (EPBD) is the European Union's main legislative instrument aimed at promoting the improvement of the energy performance of buildings within the Community.

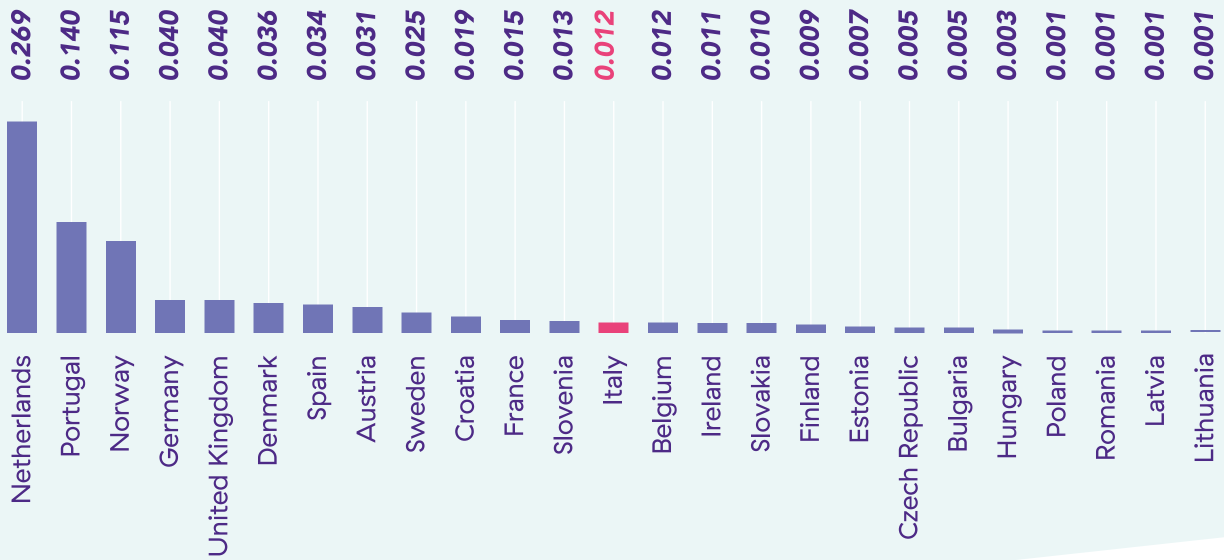
9 The Renewable Energy Directive establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfill at least 20% of its total energy needs with renewables by 2020 — to be achieved through the attainment of individual national targets. All EU countries must also ensure that at least 10% of their transport fuels come from renewable sources by 2020.

10 The European Energy Performance of Buildings Directive requires Member States to adopt an action plan for the installation of a minimum number of charging points, for all non-residential buildings with more than 20 parking spaces, by 1 January 2025, and to simplify the deployment of recharging points in buildings. Italy had recognized the need of actions and transposed the European Union Directive in legislative decree that entered into force from January 1st, 2018.

11 Source: European Alternative Fuel Observatory (EAFO), 2018.

FIG.4

Number of charging positions per km (state, provincial and communal roads) in European Union by country, 2017.
Source: The European House — Ambrosetti elaboration on European Alternative Fuel Observatory (EAFO) and Eurostat data, 2018



16. The existing delay in the charging infrastructure is particularly penalizing for the current development of e-Mobility because the charging infrastructure is also an enabling factor of the overall process and its underdevelopment is, in fact, curbing the deployment potential of e-Mobility in Italy. As a consequence, this proposal aims at enhancing the installation process of charging infrastructure in Italy, both in public and private contexts, in view of the future e-Mobility growth by removing all the regulatory and legislative stumbling blocks.

17. To address this issue, some initiatives could stem from the transposition of the European Union Directives. The European Commission has launched the Energy Performance of Buildings Directive[12] in which precise indications are set up for charging infrastructure in buildings:

- New buildings or buildings undergoing major renovations with more than ten parking spaces should be equipped with the dedicated infrastructure to allow for the installation of a recharging point for all parking spaces.
- New and major renovated non-residential buildings with more than 10 parking spaces, have to be equipped with the dedicated infrastructure to allow for the installation of a recharging point in at least 20% of parking spaces.

18. The directive requires Member States to adopt an action plan for the installation of a minimum number of charging points, for all non-residential buildings with more than 20 parking spaces, by January 1st 2025, and to simplify the deployment of recharging points in buildings.

19. Italy had recognized the need for action and transposed the European Union Directive in a legislative decree that entered into force on January 1st, 2018. However, something more can be done: Italy could introduce a more challenging regulatory framework, by simplifying the existing procedures for installing charging points in buildings (not only new ones) and ensuring the "***right to plug***" for condo owners and tenants.

20. Still on the subject of charging points in buildings, some incentive schemes can be deployed at national levels (for instance, tax reduction on investments, tax waiver on land occupation, subsidized loans for infrastructure construction),

12 EU Energy Performance of Buildings Directive (EPBD) highlights the need to reduce energy consumption and increase the use of energy from renewables in buildings. The most recent revision — which entered into force on July 9, 2018 and to be transposed within two years — reiterates support for electro-mobility infrastructure deployment in buildings' parking spaces and introduces new provisions to enhance smart technologies and technical building systems, including automation.

taking a leaf out of the best performers in Europe. For example, in France, private persons deciding to install charging points enjoy a 30% tax relief, in Denmark households are subject to reduced taxation for installation of home charging points (up to €2,500), in the Netherlands there are fiscal incentives up to 36% for investments in private charging infrastructures and in the UK incentives up to €560 were conceived for installing private charging points.

21. Another possibility worth to be evaluated at national level, refers to building partnerships between public and private players to install private charging points in public spaces. Indeed, a widespread distribution of charging points in public areas and commercial establishments (hotels, restaurants, shopping centers, post offices, etc.) would improve the service to citizens, customers, and foreign tourists, with pay-backs for those providing this option (representing therefore an incentive for their installation).

22. One of the main stumbling blocks to the widespread distribution of charging points in public areas, involves ***uncertainty about the rules and procedures*** to be undertaken in Municipalities. In order to overcome this factor, Italy would need to:

- define a binding document containing a set of rules for all municipal administrations in order to clearly know the "operational steps" when starting infrastructure construction;
- establish a time limit for issuing installation permits for public charging stations;
- adopt uniform guidelines, tax exemption mechanisms and/or simplified authorisation procedures for granting permissions for land occupation.

23. Actions should be undertaken starting from the 14 Italian Metropolitan cities[13], heart of the Italian innovation system and home of the new societal megatrends, including e-Mobility.

THE CHARGEPLACE IN SCOTLAND

In Scotland there is a comprehensive network of charging station guaranteed by "ChargePlace Scotland". Initially created from an agreement between the United Kingdom government and the Scottish government, ChargePlace Scotland is a network of electric vehicle charging points developed in partnership with all 32 Scottish local authorities, and through the Energy Saving Trust, with local businesses. There are currently more than 800 publicly available charging points on the network, including over 175 rapid charge points. Electric Vehicle drivers need just one access card for utilizing all the network's charging stations across Scotland.

Source: The European House — Ambrosetti elaboration on United Kingdom Government data, 2018.

24. Eventually, an additional element having the potential to positively contribute to the deployment of the charging infrastructure in Italy is the new approach adopted by the European Investment Bank (EIB) in which investments in charging infrastructure have been recognized as strategic as other infrastructural investments. In this regard, the first financing line of the EIB was directed to Italy where the infrastructural plan of Enel X Mobility (14,000 charging points to be installed by 2022) will receive from the EIB a 10-years loan of €115 million covering 50% of total investment.

13 The 14 Italian Metropolitan Cities are: Rome, Milan, Naples, Turin, Palermo, Bari, Catania, Florence, Bologna, Genoa, Venice, Messina, Reggio Calabria and Cagliari.

PROPOSAL: CLEAN VEHICLES PROCUREMENT BY PUBLIC AUTHORITIES

OUR RECOMMENDATION:

In the light of the Commission proposal to amend the Directive 2009/33/EU on the promotion of clean and energy-efficient road vehicles in public procurement (so-called Clean Vehicles Directive), setting ambitious targets for vehicle procurement by public authorities. In particular, all new fleet purchases shall be 100% clean by 2025.

25. This proposal aims at positioning Italy as a leading country in the transposition of the Clean Vehicles Directive concerning the procurement by public authorities. In particular, a promising field of action is represented by urban buses whose new purchase shall be 100% clean at 2025[14]. Public procurement – indeed – accounts for about 75% of the overall new buses purchases in the EU28 and almost the entirety of bus fleet for urban transport, making this segment a key element in the transposition of the Clean Vehicles Directive.

THE EU CLEAN VEHICLES DIRECTIVE

The revision of the Clean Vehicles Directive, as part of the Commission's second mobility package, aims at promoting clean mobility solutions in public procurement tenders and raise the demand for clean vehicles. In detail, the proposal provides a definition for clean light-duty vehicles based on a combined CO_2 and air-pollutant emissions threshold (PM_{10} and NO_X), while introducing a definition based on different types of propulsion systems for heavy duty vehicles.

Source: The European House – Ambrosetti elaboration on European Commission data, 2018.

26. One of the main problems concerning the existing Directive identified by the European Commission is the plurality of options chosen to transpose the directive across national frameworks. Yet, the current monetization methodology, with its strong emphasis on fuel consumption rather than fuel type, provides counterincentives to purchasing cleaner vehicles.[15]

27. To overcome these problems, and specifically concerning heavy-duty vehicles like buses, the new proposal of the European Commission envisions a clean fuel definition based on alternative fuel type (electricity, hydrogen and natural gas including biomethane) rather than on fuel consumption.

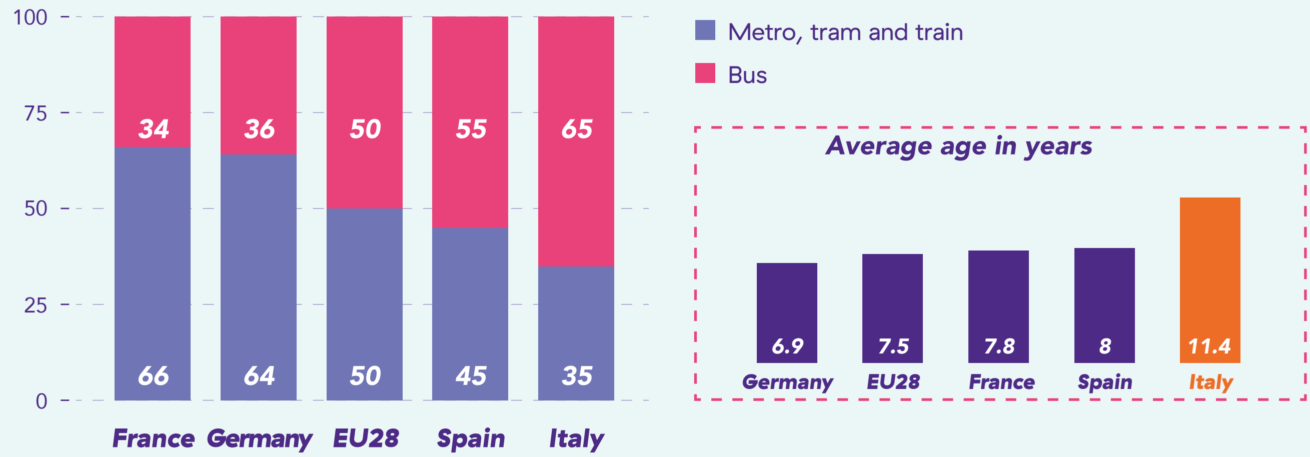
28. In addition to the European-wide considerations, Italy has a necessity to renew its bus fleet. Among the EU major countries, Italian transport companies have both the highest share of public transfer made via bus (***65%*** vs. 50% of the EU average), and the oldest buses (over ***11 years***) making the case for fleets renewal. In pursuing this renewal, incentives towards the clean fuels are already in place: following the implementation of the EU Directive 2014/194 from July 1st 2018 transport companies in highly polluted areas are obliged to buy at least ***25%*** of alternative fuel buses (Liquified Natural Gas – LNG, electric or hybrid) and by 2019, approximately 5.000 Euro 0 urban buses can no longer circulate.

14 This objective should be reached by guaranteeing the long-term stability and adequacy of funds allocated for the renewal of public bus fleets to ensure the standards of the service agreements. The target proposed in this study (100% at 2025) is very aggressive, given that the European one – which will be set by the Clean Fuel Directive that has still to be transposed by Member States – set a share of clean buses between 43% and 75% by 2030.

15 In other terms, the current monetization scheme tends to favor diesel vehicles that have efficient standards for fuel consumption but higher emission of NOx.

FIG.5

Urban transport mode (%) and average age of the bus fleet (years) in Italy and in the major European countries in 2015.
Source: The European House — Ambrosetti elaboration on ASSTRA and Cassa Depositi e Prestiti data, 2018



29. Yet, given the available funds across the different funding streams (***€1.4*** billion until 2022)[16], the Italian Transport Ministry expects up to ***6,000*** new buses by the end of 2019 and about ***2,000*** new buses per year to be added from 2020 to 2030 (40% more than the average of the last 5 years). Yet, the Budget Law 2017 — by envisioning the formulation of a Nation Plan for the Sustainable Mobility — increased the endowment (***up to €250 million*** each year between 2020 and 2033) of the Fund specifically conceived for purchases, electric reconversion and rental of public transport buses. In addition, those specific funds can also be allocated to enhance the technological infrastructure required to support the upgrade.

30. Setting the ground for an ambitious transposition of the Directive — ***up to 100% clean at 2025*** — would align Italy with the best international experiences concerning the e-Buses uptake. Some examples of international best practices are:

- China: leading country in the World for e-Bus uptake. Among the 385,000 e-Buses (Battery Electric Vehicles and Plug-in Hybrid Electric Vehicles) on the roads globally in 2017, ***99%*** were in China.[17]
- The Netherlands: being the country in which e-Buses, comprising also trolley buses, are expected to have a massive increase in the next few years following the decision of the Dutch government, taken already in 2016, to have new public transport buses as zero-emissions vehicles by 2025. The City of Eindhoven has almost ***50*** Battery Electric Vehicles (BEV) buses currently in operation making it one of the largest e-buses fleet already on the road in European cities.
- The UK: currently having ***344*** Battery Electric Vehicles and Plug-in Hybrid Electric Vehicles on the roads with a further increase to be expected over the next couple of years as a result of important orders made by Transport for London that is going to reach 240 electric buses in 2019.[18]

31. In this evolving context, ***e-Buses are already a viable option*** and with the significant potential to be even more central over the next years because of:

- Lower Total Cost of Ownership (***€0.85/km***) compared to diesel (€0.90/km) and Compressed Natural Gas (€1.02/km), which is largely related to the maintenance costs. Yet, a reduction of the battery costs —i.e. the most expensive component of e-Buses — to be

16 These are the funds that the Stability Law has explicitly allocated for bus renewal (€1.4 billion until 2022, with the perspective to reach €4 billion by 2033).
17 Source: Bloomberg New Energy Finance, "Electric Buses in Cities 2018".
18 Source: Transport for London, 2018.

obtained in the next years would contribute to further reducing the Total Cost of Ownership of the electric buses.

- Reduced pollutants emissions making e-Buses the most competitive contributor to the policy targets set for urban areas (e-Buses have no emissions of PM_{10} and NO_x while the alternative clean fuel, natural gas, still has 0,08 g/km for PM_{10} and 5,14 g/km of NO_x);
- Possibility to exploit the large e-buses battery packs as a stabilizing tool of the transmission grid. The stabilizing function is, indeed, relatively stronger than e-Cars because of the huge dimension of the battery pack and the relatively predictable usage of the buses during the day. As a result, in the evolution towards a smart grid, the e-Buses battery packs could allow to better accommodate the daily demand peaks.

4.1.2. Energy efficiency deployment

PROPOSAL: SUPPORTING ENERGY EFFICIENCY INTERVENTIONS

OUR RECOMMENDATION:

Addressing the shortcomings concerning energy efficiency in Italian buildings by:

a. Giving continuity to the incentivizing mechanisms, starting from the Eco-Bonus, overcoming the year-by-year renewal and optimizing implementation procedures.
b. Setting up a "Home Maintenance Leaflet" having the objective of going beyond the definition of energy category of the buildings and allowing to increase the consumer awareness about the possible energy gains through a tool that can be priced by the market in the housing transactions. Yet, this measure could be the starting point to address the broader issue concerning the absence of structured energy management in Italy.
c. Devising innovative financial schemes such as combining traditional mortgage with an ad hoc loan for energy efficiency technologies guaranteed by the financial institution under an agreement with an industrial player.

32. The importance of energy efficiency in buildings is supported by the fact that in Italy there are ***more than 14.5 million buildings*** among which 84% belong to the residential sector and account for 28% of Italian final energy consumption. Furthermore, in the last decade, Italy was the only country among the EU major ones to register an increase of energy consumption in the residential sector.

33. Incentivizing measures for householders, foremost through the so-called Eco-bonus, were conceived over the years to trigger investments in energy efficiency. However, the overall investments covered by the Eco-bonus during the years 2014-2017, in which approximately ***1.5 million of interventions*** were financed[19], were largely directed towards small-scale interventions such as the replacement of windows and shutters or insulation (***66%*** of the total) rather than towards the adoption of electrification-driven technologies or broader intervention of energy management requiring a huger initial investment.

34. To promote a better distribution of the investments via the Eco-Bonus, the preliminary condition is to provide continuity to the incentivizing measures. In other terms, to facilitate a multi-annual investment plan for households, it is necessary to overcome the year-by-year renewal in favor of a ***multi-annual planning***. Another condition related to the Eco-bonus is the optimization of the implementation procedures. For instance, the credit transfer mechanism, introduced in the 2018 Budget Law, which can contribute to reducing the initial amount of the expenditure so that facilitating the adoption of electrification technologies having a payback in the medium-long run, is not optimized yet. With this regard, indeed, the May 2018 Bulletin from the Revenue Agency clarified that the entire procedure is possible

19 Source: Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (ENEA), "Rapporto Annuale sull'Efficienza Energetica 2018".

FIG.6

Variation of final energy consumption in the residential sector (% values), 2006–2015.
Source: The European House — Ambrosetti elaboration on Eurostat data, 2018

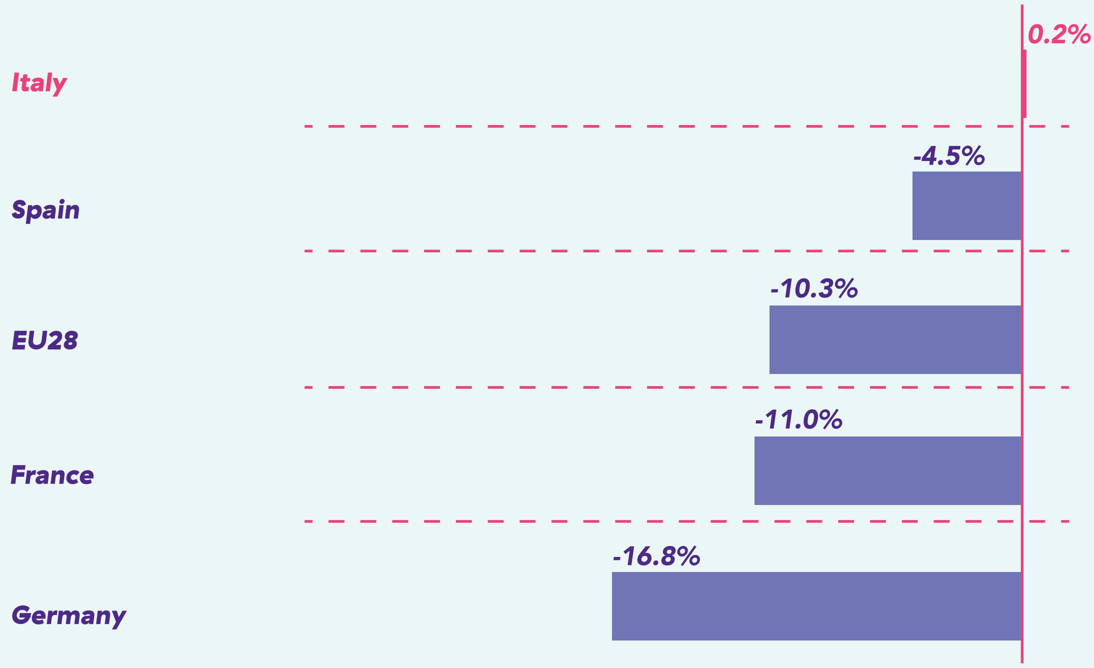
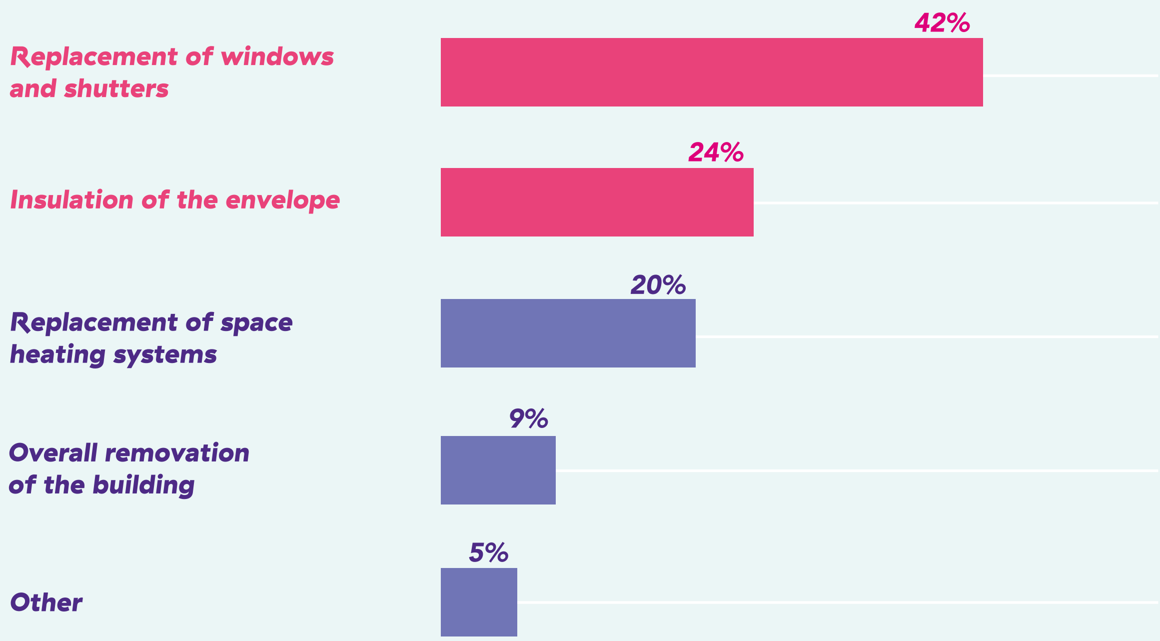


FIG.7

Type of investment activated in the Eco-bonus scheme (%), 2014–2017.
Source: The European House — Ambrosetti elaboration on Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo sostenibile (ENEA) data, 2018



only for citizens falling in the no-tax area and being therefore exempt from personal income tax (IRPEF). Furthermore, the credit transfer is only possible towards other private parties that were connected to the intervention (the suppliers) so that banks and financial institutions are still excluded.

THE ECOBONUS INCENTIVE RATES

The Ecobonus is the main financial instrument regarding energy efficiency in the residential sector. The 2018 Budget Law has confirmed the 65% incentive rate for technologies like heat pump, building management systems, etc. while reducing it to 50% rate for the replacement of windows and shutters and installation of envelope.

Source: The European House — Ambrosetti elaboration on European Commission data, 2018.

35. Another aspect to be highlighted is that Italy has a leading position in the ***smart meter technology*** deployment[20], especially with the roll-out of the second generation of smart meters undertaken by Enel. The 2G meters interface with smart home appliances through a dedicated communication channel, thus increasing customer awareness. In addition in combination with energy management systems, the development of new market services will be possible.

36. Despite the basis of smart meter deployed, in Italy, ***energy management at-large*** is not tackled in systemic terms yet, with electricity-driven technologies being the most penalized for several concurrent factors affecting the entire value chain:

- persisting gap in both citizen and stakeholder knowledge about the efficiency gains that electrification technologies can engender;
- existing fragmentation along the entire value chains that is related to buildings (planning, construction, installers, etc.) that has not yet made an upgrade in industrial terms, thus resulting in an approach towards energy management that is not sufficiently structured (for instance, not providing integrated solutions between electrification technologies and envelope retrofit, etc.);
- underdevelopment of financial schemes explicitly targeting energy efficiency interventions with mid-long-term payback period that results from both the limited knowledge mentioned above and the difficulties that financial institutions have in including them within their risks assessment models;
- delays in upgrading the Italian condorules to the new requirements set by the intervention in energy management at large.

37. The ***household maintenance leaflet*** is therefore conceived to promote a systemic approach to the energy management. This measure (totally new in the policy framework, also because of the peculiar features of Italian housing stock), has the aim of increasing the awareness on the benefits actionable from energy efficiency, foremost among the households but indirectly also among intermediaries, installers, and financial institutions, by helping them in including electrification technologies in their risk models, etc. In synthesis, the leaflet can help in:

- increasing ***consumer awareness*** about the benefits of energy efficiency by providing the owners with a synthetic information on savings obtainable from the energy efficiency investment and their returns as well as the glossary of the technologies involved in energy efficiency of the buildings;
- introducing a mechanism, by keeping track of all the interventions made by the owners, with the potential to be "***priced by the market***", to increase the value of energy efficiency investments in the housing market and then increasing the awareness about energy efficiency throughout the building-related value chain.[21] Hence, despite the main targets are householders, the leaflet can be an awareness arising tool for the broader system related to the buildings' value chain and contribute to addressing the critical issues for a systemic deployment of energy management that were mentioned above.

38. Finally, to complete the array of instruments to be deployed, ***innovative financial schemes*** such as combining traditional mortgage with an *ad hoc* loan for energy efficiency technologies guaranteed by the financial institution under an agreement with an industrial player can serve as triggers for mature technologies able to deliver high energy efficiency gains with medium-long-term payback period.[22] The overall objective of this recommendation, the first of its kind also due to the specificities of Italian housing stock, is to widen the array of financial instruments available in the residential sector by specifically targeting the necessities of those technologies, like the electrification-driven ones, that have already reached market maturity but which require an important initial investment and needing the medium-long term to realize the full returns.

20 Italy was the first country to deploy smart meter technologies on a wide scale (starting in 2001) and still has the hugest amount of smart meter in operation (more than 35 million). Source: Autorità di Regolazione per Energia, Reti Ambiente — ARERA, 2018.

21 The value chain related to the buildings comprises companies active in the design and planning phase (i.e. architects, engineers), installers, the extended construction sector and the financial sector.

22 For further details see also: "Studies on Energy Efficiency, Enel Foundation".

4.1.3. Enhancing collaboration between companies and research networks

PROPOSAL: COLLABORATION AMONG COMPANIES AND WITH THE NATIONAL RESEARCH NETWORK

OUR RECOMMENDATION:

Creating a national Tech Transfer Lab on electrification technologies with the specific mission of acting as enabler of technological transfer in collaboration and synergy with existing tech transfer offices and research institutions, easing the "go-to-market" mechanisms.

39. In Italy, coordination mechanisms and technology transfers between research institutions and industry need to be optimized to grasp all the innovation opportunities, and fully exploiting the globally recognized Italian researchers' skills. Regarding Italian competences, it is worth to mention the fact that Italy was one of the first countries to develop a prototype of e-Vehicle at the beginning of the 1990s, which however has not been marketed thereafter.

40. Despite the relevant Italian potential in research, there is a persisting shortage of coordination between the research sector and the industrial one, mainly due to personnel under-sizing, scarcity of financial resources and poor sensitivity to patenting activity. These critical areas are at the base of the Italian significant gap in terms of technological transfer, compared with European benchmarks, both in terms of ***company-specific initiatives*** and ***systemic coordination mechanisms*** that allow to electrification technologies to be marketed.

EUROPEAN BENCHMARKS FOR COMPANY SPECIFIC AND SYSTEMIC INITIATIVES: THE DYSON INSTITUTE OF TECHNOLOGY AND THE FRAUNHOFER GESELLSCHAFT

The collaborative schemes to promote technological transfer between companies and research institutions may largely differ in European benchmark cases. Two archetypical models of cooperation can be, therefore, individuated in the systemic coordination mechanism, in which the public component is emphasized, as opposed to the company specific initiatives. The common denominator of those initiatives is the overall objective of optimizing technological transfer.

For instance, the German ***Fraunhofer Gesellschaft***, is a clear example of ***systemic coordination mechanisms***. The Fraunhofer Gesellschaft is a research organization pooling together 69 institutes, each focusing on different fields of applied science and contributing to companies' innovation, through research on new products and technologies. Specific operations are classified into the following five categories:

- contract research from industry;
- licensing of patents acquired as research output;
- return of new inventions and services to society through business start-ups;
- supply of researchers to industry;
- provision of cutting-edge facilities to private enterprises.

The Institute employs around 24,000 researchers and engineers and has a yearly budget above €2 billion, funded by public finances for 30% and for the remaining 70% through contracts with industry or specific government projects with technological transfer occurring within this framework.

On the other hand, the British ***Dyson Institute of Technology***, a private institution of tertiary education founded by James Dyson, a British inventor and industrial design engineer, is a clear-cut example of a ***company-specific initiative***. The Institute, fully inserted in the city where Dyson Group is headquartered, offers joint programs with the University of Warwick and the Warwick Manufacturing Group (WMG), that have a long-standing expertise in bridging the gap between industry and academia, through their links with global engineering companies.

In the joint engineering programme set together witht the Warwick University, the Dyson Institute students can effectively alternate work and study experiences, working alongside Dyson's Global Engineering team four days a week, receiving a salary and having their university tuition fees paid.

Source: The European House — Ambrosetti elaboration on Dyson Institute of Technology and Fraunhofer Gesellschaft data, 2018.

41. Thus, the proposal of creating a Tech Transfer Lab aims at empowering the already existing Italian research centers, by stimulating them to focus on innovative electric technologies and strengthening technological transfer between research institutions (universities, research labs, etc.) and industry. Given the already existing centers, there is no need to create new bodies but rather the necessity to enhance effectiveness and efficiency of the existing ones.

42. In this regard, the new institute envisioned in the proposal, the Tech Transfer Lab, needs to be conceived as a ***facilitator of technological transfer***. To provide these solutions an effective plan could be empowering the already existing research institutions having activities in closely related fields to the electrification technologies in object (an example would be the RSE[23]). Then, the Transfer Lab would not act directly in the research phase, but rather as a pivotal actor carrying out the role of reference point for academics, institutions and private players. The overall aim is to ease the transfer of knowledge from universities/research networks to companies, to provide an enriched environment, suitable for career opportunities for national and international researchers and thus contributing to reduce the outflow of talented researchers towards other countries too and to sustain the "***go-to-market***" ***mechanisms*** of the most promising end-use electric technologies.

43. More precisely, the Lab should link universities and the private sector, undertaking a wide range of activities such as:

- reviewing the existing technology transfer procedures and adopting consolidated best practices;
- supporting communication between researchers and investors;
- undertaking specific consulting activity on the most promising projects;
- identifying opportunities, with analysis and evaluation of the entrepreneurial risk;
- elaborating business plans and providing support in all the different phases, focusing on the most valuable technologies from the market perspective, in order to select the ones with the highest potential to be marketed hereafter.

44. Fostering new technology transfer would also allow companies to rely on external Research and Development structures. Instead of creating an internal division, firms could outsource, at least partially, this functions to the existing research center. Firms could then propose their instances and ideas to the Tech Transfer Lab that would stimulate and support their realization, thus filling the communication gap between research and industry.

23 The RSE, i.e. Ricerca sul Sistema Energetico, is an entirely publicly owned joint stock company, part of the GSE Group (Gestore dei Servizi Energetici) and it is supervised by the Italian Ministry for Economic Development. The RSE carries out research into the field of electrical energy with special focus on national strategic projects funded through the Fund for Research into Electrical Systems.

4.1.4. Strengthening national capabilities on electric frontier technologies

PROPOSAL: LAUNCHING NATIONAL PROGRAMS FOR THE R&D ACTIVITY AND A "TECHNOLOGY IMPACT BOND"

OUR RECOMMENDATION:

Enhancing national capabilities on electric frontier technologies through two closely intertwined lines of action:

a. Launching national programs for the R&D activity of companies operating in the electric technologies sector, relying upon public-private partnership schemes and the pre-procurement tool.
b. Launching a "Technology Impact Bond" to sustain research initiatives with a social impact and economic return and with a supply mechanism that could favor the creation of consortium involving all players along the value chains and guaranteeing all the steps from research to implementation.

45. The electrification process can lead to new technological opportunities related to the expected evolution of the electricity sector (e-Mobility, digitalization, distributed generation, renewable sources, electrification of industrial processes, etc.). In the electric sector, given the ample margins for evolution, Research & Development is a strategic issue because it allows, on one hand, for the emergence of technologies to be used as inputs for launching new types of manufactured product and, on the other, for the identification of innovative solutions to meet sustainability goals regarding energy efficiency, transport security and the safeguarding of public health.[24]

46. Italy hosts important industrial players with international reach, small specialized and high-quality companies and highly qualified research system that can be even more competitive in meeting technology revolution challenges. As previously men-

24 Examples of investigational electric technologies having a huge potential of deployment can be considered: Flywheel, Solar fuel, Supercapacitors, OLED — organic LED, Fuel cells, Micro-CAES, SMES cryogen free, High temperature thermal storage systems, Domestic thermal storage systems.

tioned, Italy was one of the first countries to develop a prototype of e-vehicle at the beginning of 1990s, which however has not been marketed thereafter. Today there are excellent research centers with expertise in the electrification field in Italy, starting from the Engineering, ICT and technologies for energy and transportation department within the National Research Council (Consiglio Nazionale delle Ricerche — CNR) and Italian polytechnics.

47. Thus, Italy must aim at a ***position of leadership*** in a number of cutting-edge technologies which represent breakthroughs for the future. A first mechanism that can be put in place in order to pursue this objective is the launch of ***national programs for R&D activities*** of companies operating in the electric technologies sector, from a pre-competitive approach with subsequent industrial development, with public/private collaboration and partnership models in selected areas of scientific and technological specialization[25] and leveraging on the Pre-Commercial Procurement (PCP) tool[26]. In order to facilitate the adoption of end-use electric technologies at scale, it is also fundamental to develop ***appropriate regulatory frameworks*** and ***market mechanisms*** (such as remuneration schemes for the provision of flexibility services and lower barrier to entries for new technologies including small scale distributed systems such as vehicle to grid and commercial battery storage). These national programs for R&D activities should also aim at proving the commercial benefits that these technologies would bring to both the overall energy systems and end users.

48. Furthermore, in order to sustain the R&D activities of Italian companies on electrification technologies, sustaining capital inflows, it is of paramount importance to create innovative ways for fundraising, that match the peculiarities of research in the electric sector (high level of initial investments needed, mid-long-term return, etc.) with the expectations of private investors. With this respect, Italy could usefully take inspiration from the Social Impact Bond (SIB) scheme to launch a ***Technology Impact Bond (TIB)*** to sustain research initiatives with a social impact and economic return. The recipient should be a consortium that groups together key players of the research network on electrification technologies (i.e., universities, manufacturing companies, Energy Service Companies — ESCOs, etc.), which should guarantee coverage of all research phases.

THE FIRST EXAMPLE OF SOCIAL IMPACT BOND: THE CASE OF PRISONER REHABILITATION IN UK

The first Social impact bond was announced in the UK on 18 March 2010 by then Justice Secretary Jack Straw, to finance a prisoner rehabilitation program. This was a six-year scheme involving around 3,000 short term prisoners from Peterborough prison, serving less than 12 months, receiving intensive interventions both in prison and in the community. Funding from investors outside government were initially used to pay for the services, delivered by Third Sector providers with a proven track record of working with offenders. If reoffending had not been reduced by at least 7.5% the investors would have received no recompense.

Source: The European House — Ambrosetti elaboration on UK government data, 2018.

25 In particular, battery life and storage systems (including recycling and second life); systems for the management of energy flows through Smart Charging, Vehicle-to-Grid (V2G) and Vehicle-to-Home (V2H) technologies—for example, for managing and foreseeing demand peaks and regulating the grid; development of software and algorithm systems for public and private fleet management; planning of services connected with the development of shared vehicles that are digitally connected or self-driving; investigation of high temperature thermal storage systems and domestic thermal storage systems.

26 The Pre-Commercial Procurement (PCP) tool can be used when there are no near-to-the-market solutions yet and new R&D is needed. It can then compare the pros and cons of alternative competing solutions approaches. This will in turn enable de-risking the most promising innovations step-by-step via solution design, prototyping, development and first product testing.

4.1.5. Diffusing awareness about the benefits of electrification

PROPOSAL: CITIZEN AND STAKEHOLDER AWARENESS ON THE BENEFITS RELATED TO ELECTRIFICATION

OUR RECOMMENDATION:

Increasing the overall awareness about electrification benefits by addressing three different intertwined levels:

a. Public opinion: launching a national communication campaign ("Pubblicità Progresso") on traditional and social media, in line with international best practices such as UK's Go Ultra Low (GUL) campaign.
b. Institutional stakeholders: institutionalizing a public function that specifically provides policy assessment in terms of sustainable development in the energy sector (monitoring the advancements of SDGs and realizing impact assessment for specific issues).
c. Business community: Setting up a permanent national Forum where business leaders, along with institutions and experts (RSE, CNR, ENEA, etc.), can discuss about industrial opportunities stemming from electrification, agree on shared development targets and secure investments and lighthouse initiatives at country level.

49. As already mentioned in this study, electric technologies have several environmental and economic benefits in terms of:

- allowing to reduce CO_2 emissions when electricity is generated through a balanced energy mix;
- reducing transport related pollutant emissions and ameliorating the air quality in urban areas;
- offering several opportunities to improve the resilience of the overall energy system;
- promoting higher levels of energy efficiency;
- allowing for enhanced integration with digitalization, enabling more effective consumption management and higher efficiency;
- stimulating innovation and sustainability in lifestyles and industrial processes, allowing for both energy savings and improvements in products' quality;
- supporting the extended industrial value chains.

50. Despite these features, there is a ***systemic lack of awareness*** of the achievable benefits involving all levels: public opinion, policy makers and business leaders. Each of these three groups does not seem to be fully aware of their own potential gains as well as the overall gains for the national economic system, stemming from the development of national competences and production capacities. Hence, this recommendation aims at increasing the overall awareness in the three groups via differentiated and targeted actions.

51. The ***national communication campaign's*** target is ***public opinion***, to inform citizens about the advantages of all electrification solutions and highlight their contribution to pollution reduction. The campaign should communicate the environmental and economic gains resulting from a higher share of electric technologies in end uses, thus enhancing people's social responsibility towards air pollution as well as their interest for efficient energy solutions. In this way, people should become more prone to use electric technologies, increasing their take-up rate. Given the objective, it is very important that the campaign is conceived with a recurring cycle any few months to maintain the attention and convey new messages and upgrades on the obtained results.

THE BRITISH AWARENESS CAMPAIGN: GO ULTRA LOW (GUL)

Launched in 2014, Go Ultra Low is a marketing campaign ***jointly designed by government and industry*** to foster the adoption of ultra-low emission vehicles in the United Kingdom. Through a series of videos and other contents, in 2017/2018 the GUL campaign has been set to demonstrate how electric cars fit into people's driving habits and general lifestyles, addressing issues such as cost, range anxiety and charging. In the GUL initiative ***four tools*** were developed to allow consumers to calculate the benefits of owning an electric vehicle: a journey cost saving calculator, a car tax calculator, a journey range calculator and a home charging calculator.

The GUL website, launched in October 2017, has recorded more than ***600,000*** visits, with over 115,000 using the tools. Videos on stories of e-vehicle owners have been viewed more than 19 million times. Moreover, a survey has been carried out on a sample group and 96% of this group revealed it felt more positive towards electric vehicles. The same group showed an increase, after the campaign, of 13% of people who consider electric vehicle a credible alternative to fossil-powered vehicles and by 19% of people willing to purchase an e-Vehicle.

Source: The European House - Ambrosetti on HM government, "The Road to Zero strategy" data, 2018.

52. Creating a ***policy assessment function*** attached to a public authority, aligning it with the international best practices such as the "Sustainable Development Advisory Group (SDAG)"[27], aims to increase institutional stakeholder awareness and indirectly to improve policy activities. This branch would provide impact evaluation useful to better design policies and thus to improve the environmental and economic effects. Moreover, this advisory activity would impact on policy makers sensitivity about the energy sector's sustainable development, fostering their engagement on undertaking interventions aimed at environmental safeguarding and at activating the Italian potential in research and industry. To avoid the proliferation of institutions, the ultimate implementation of the public function in object should give priority, as a matter of principle, to the already existing structures/agencies and follow an evaluation process of the involved institutional actors in strict cooperation with the relevant private stakeholders.

THE SUSTAINABLE DEVELOPMENT ADVISORY GROUP (SDAG)

The SDAG is an independent panel of experts that helps the UK regulatory energy agency (Office of Gas and Electricity Markets – Ofgem) on environmental and consumer issues. The group is made up of policy experts from Government, industry and interest groups, who advise Ofgem on priorities related to sustainable development. Members of the Group participate as individuals and not as representatives of organizations.

Source: The European House — Ambrosetti elaboration on Ofgem data, 2018.

53. The ***permanent national Forum*** aims at involving business leaders, acting on two related aspects. At first, it would provide them with the opportunity to present their instances and ideas on potential development of energy related appliances, with the aim of activating all the stakeholders towards the empowerment of the national supply chain. In addition, it would constitute a context where institutions and experts can sensitize business leaders to focus on electrification technology development, envisaging their potential economic benefits.

54. The overall outcome would be the promotion of an alignment of interests and views among the different actors, in order to design a comprehensive national strategy.

55. Enhancing the electrification process requires acting across several aspects, making the multi-level strategy described in this part of the study necessary to reap all the benefits and opportunities that can be activated for Italy and its industrial value chains. Within this framework, the Distribution System Operator (DSO) can act as a key enabling factor, sustaining the technological evolution and the associated investment. The legislative and regulatory scenario should properly incentivize DSO necessary investment in its own network, both in digitalization and renewal, with commitments to cope with the integration of an ever-increasing amount of renewables, the spread of extensive network of charging infrastructure for electric vehicles and an higher share of electricity in final-user consumption. Furthermore, it is necessary to define rules and responsibilities of the various network operators (TSO and DSOs) in line with the on-going European regulatory framework, especially concerning the coordination of distributed energy resources.

THE GERMAN "ELECTROMOBILITY ON SITE" PROGRAMME

With the "Electromobility On Site" programme, the Federal Ministry of Transport and Digital Infrastructure (BMVI) supports the cross-sector cooperation of industry, science and the public sector in order to advance the integration of electromobility. Within this framework, and thanks to the involvement of other institutions (such as the National Organisation for Hydrogen and Fuel Cell Technology – NOW) a few cycles of workshops at national universities have been organized for business leaders focused on specific technological applications.

Source: The European House — Ambrosetti elaboration on Federal Ministry of Transport and Digital Infrastructure (BMVI) data, 2018.

27 Independent panel of experts that helps to guide the UK regulatory energy agency (Ofgem) on environmental and consumer issues. The group is made up of policy experts from Government, industry and interest groups, who advise on priorities related to sustainable development. Members of the Group participate as individuals and not as representatives of organizations.

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Glossary of electrification technologies

- ***Arc electric oven***: a furnace that heats charged material through an electric arc. Arc furnaces differ from induction furnaces because the charge material is directly exposed to an electric arc and the power in the furnace terminals passes through the charged material.
- ***Cogeneration system or combined heat and power (CHP)***: the use of a heat engine or power station to generate simultaneously electricity and heat. The combustion of gas releases mechanical energy that a generator converts into power. The heat produced in the engine can be used with the help of heat exchangers.
- ***Gas turbine CHP plants***: exploit the waste heat in the flue gas of gas turbines. The fuel used to propel these plants is typically natural gas.
- ***Gas engine CHP plants***: gas engine CHP plants exploit a reciprocating gas engine that is generally more competitive than a gas turbine up to about 5 Mw. The gaseous fuel used is normally natural gas. These plants are generally manufactured as fully packaged units that can be installed within a plantroom or external plant compound with simple connections to the site's gas supply, electrical distribution network and heating systems.
- ***Biofuel engine CHP plants***: exploit an adapted reciprocating gas engine or diesel engine, depending upon which biofuel is used, and are very similar in design to a Gas engine CHP plant. The advantage of using a biofuel is reducing hydrocarbon fuel consumption and thus reducing carbon emissions. These plants are generally manufactured as fully packaged units that can be installed within a plantroom or external plant compound with simple connections to the site's electrical distribution. Another variant is the wood gasifier CHP plant whereby a wood pellet or wood chip biofuel is gasified in a zero oxygen high temperature environment; the resulting gas is used to power the gas engine.
- ***Combined cycle power plant***: an assembly of heat engines that work in tandem with the same source of heat, converting it into mechanical energy, which in turn usually drives electrical generators. The principle is that after completing its cycle (in the first engine), the temperature of the working fluid engine is still high enough that a second heat engine may extract energy from the waste heat that the first engine produced.
- ***Molten-carbonate fuel cells***: high-temperature fuel cells that use an electrolyte composed of a molten carbonate salt mixture suspended in a porous, chemically inert ceramic matrix of beta-alumina solid electrolyte (BASE). These cells operate at extremely high temperatures of 650 °C.
- ***Solid oxide fuel cells***: electrochemical conversion device, with a solid oxide or ceramic electrolyte that produces electricity directly from oxidizing a fuel. Advantages of this type of fuel cells include high efficiency, long-term stability, fuel flexibility, low emissions, and relatively low cost.
- ***Steam turbine CHP plants***: device that extracts thermal energy from pressurized steam and uses it to do mechanical work on a rotating output shaft. The functioning is still similar to the one invented by Sir Charles Parsons in 1884.
- ***Nuclear power plants***: thermal power station in which the heat source is a nuclear reactor. As it is typical of thermal power stations, heat is exploited to generate steam that drives a steam turbine connected to a generator producing electricity.
- ***Reciprocating engine***: often referred as a piston engine, it is commonly a heat engine (despite the existence of pneumatic and hydraulic reciprocating engines too) using one or more reciprocating pistons to convert pressure into a rotating motion.
- ***Stirling engine***: heat engine that operates by cyclic compression and expansion of air or other gas (the working fluid) at different temperatures, implying that there is a net conversion of heat energy to mechanical work. More specifically, the Stirling engine is a closed-cycle regenerative heat engine with a permanently gaseous working fluid. Closed-cycle, in this context, means a thermodynamic system in which the working fluid is permanently contained within the system. The word regenerative refers to the use of a specific type of internal heat exchanger and thermal store, known as the regenerator.
- ***Biomass***: industry term for getting energy by burning wood, and other organic matter. Burning biomass releases carbon emissions, but has been classified as a renewable energy source in the EU and UN legal frameworks, because plant stocks can be replaced. It has become popular among coal power stations to switch from coal to biomass in order to

convert to renewable energy generation without wasting existing generating plant and infrastructure. Biomass most often refers to plants or plant-based materials that are not used for food or feed and are specifically called lignocellulosic biomass. As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel. Conversion of biomass to biofuel can be achieved by different methods that are broadly classified into thermal, chemical, and biochemical. Some chemical constituents of plant biomass include lignin, cellulose, and hemicellulose.

- ***Municipal solid waste***: can be used to generate energy. A few technologies have been developed making the processing of Municipal solid waste for energy generation cleaner and cheaper than ever before, including landfill gas capture, combustion, pyrolysis, gasification, and plasma arc gasification. While older waste incineration plants emitted a lot of pollutants, recent regulatory changes and new technologies have significantly reduced this concern.
- ***Compressed Air Energy Storage (CAES)***: an energy generation technology, where compressed air is accumulated in a geological disposal. After having been heated, air explodes in a gas turbine, connected to a generator.
- ***Conductive wireless charging system***: uses conductive power transfer to eliminate wires between the charger and the charging device. It requires the use of a charging board as the power transmitter to deliver the power, and a charging device, with a built-in receiver, to receive the power. Once the charging board recognizes the valid receiver, the charging begins.
- ***Direct Current motor***: any of a class of rotary electrical machines that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields.
- ***Electrochemical storage systems***: accumulators useful to directly transform chemical energy into electricity. The core part of this system is the electrochemical cell that generates direct current power.
- ***Electrostatic devices***: a type of capacitor that can store a large amount of energy. It employs electrochemical cells and large surface-area electrodes with double-layer capacitance.
- ***Efficient dishwasher***: mechanical device for cleaning dishware and cutlery. A mix of water and dishwasher detergent is pumped to one or more rotating spray arms, which blast the dishes with the cleaning mixture. Once the wash is finished, the water is drained, more hot water enters the tub by means of an electro-mechanical solenoid, and the rinse cycle begins. After the rinse cycle finishes and the water is drained, and the dishes are dried using one of several drying methods. Typically, a rinse-aid, a chemical to reduce surface tension of the water, is used to reduce water spots from hard water or other reasons.
- ***Efficient refrigerators***: household appliance that consists of a thermally insulated compartment and a heat pump (mechanical, electronic or chemical) transferring heat from the inside of the fridge to its external environment so that the internal part of the fridge is cooled to a temperature below the ambient temperature of the room.
- ***Efficient washing machine***: an open basin or sealed container with paddles or fingers to automatically agitate the clothing.
- ***Electrolysis***: a technique that uses a direct electric current (DC) to drive an otherwise non-spontaneous chemical reaction. Electrolysis is commercially important as a stage in the separation of elements from naturally occurring sources such as ores using an electrolytic cell.
- ***Electric drive***: is the combination of an electric engine, an electronic power converter necessary for the drive's powering, a control system implemented on an appropriate programmable hardware platform and a group of sensors.
- ***Energy management system (EMS)***: system of computer-aided tools used by operators of electric utility grids to monitor, control, and optimize the performance of the generation and/or transmission system. Also, it could be used in small scale systems like micro grids.
- ***Electrode oven***: is exploited as preheating ovens or for post-heating. Commonly heated items include ship bearings, cylinder heads, castings, welded joints, plates, aluminium, carbon steel joints, and pumps. Industries includes: aerospace, shipbuilding, oil, and construction.
- ***Fuel cell***: electrochemical cell that converts chemical energy from a fuel into electricity through an electrochemical reaction of hydrogen fuel with oxygen or another oxidizing agent. It requires a continuous source of fuel and oxygen (usually from air) to sustain the chemical reaction and can produce electricity continuously as long as fuel and oxygen are supplied. A solid oxide fuel cell (or SOFC) produces electricity directly from oxidizing a fuel; Molten-carbonate fuel cells (MCFCs) are high-temperature fuel cells that operate at temperatures of 600 °C and above.

- ***Flywheels***: storage system based on kinetic energy. Usually has a cylindrical shape, made of two mechanical parts, a fixed one, a rotating one and an electric one. The latter act both as generator and as engine. The main flywheels' feature is an enormous moment of inertia of the rotating masses.
- ***Heat Pumps***: device that transfers heat energy from a source of heat to what is called a "heat sink". Heat pumps move thermal energy in the opposite direction of spontaneous heat transfer, by absorbing heat from a cold space and releasing it to a warmer one. A heat pump uses a small amount of external power to accomplish the work of transferring energy from the heat source to the heat sink.
- ***Air source heat pumps (ASHP)***: system that transfers heat from outside to inside a building, or vice versa. In domestic heating use, an ASHP absorbs heat from outside air and releases it inside the building, as hot air, hot water-filled radiators, underfloor heating and/or domestic hot water supply. The same system can often do the reverse in summer, cooling the inside of the house. When correctly specified, an ASHP can offer a full central heating solution and domestic hot water up to 80 °.
- ***Ground Source Heat Pumps***: central heating and/or cooling system that transfers heat to or from the ground. It uses the earth as a heat source (in the winter) or a heat sink (in the summer). This design takes advantage of the moderate temperatures in the ground to boost efficiency and reduce the operational costs of heating and cooling systems and may be combined with solar heating to form a geosolar system with even greater efficiency.
- ***Hybrid Heat Pumps***: A hybrid heat pump system integrates an air-to-water heat pump with another non-renewable heat source, such as a condensing gas boiler, to create a highly energy efficient domestic heating and hot water system ideal for boiler replacement in homes.
- ***Ductless Mini-Split Heat Pumps***: comprised of two main components. A compressor or condenser is placed outside, while an air-handling unit is outfitted indoor. The separate components are linked via a conduit, consisting of a power cable, condensate drain, refrigerant and suction tubing. If there are more air-handling units, each of them will contain a thermostat.
- ***Absorption Heat Pumps***: an air-source heat pump driven not by electricity, but by a heat source such as solar-heated water, or geothermal-heated water.
- ***Water source heat pumps (WSHP)***: Water source heat pumps move heat from a source of water, such as a river or a small stream, to inside a building or vice versa.
- ***High pressure processing***: method of preserving and sterilizing food, in which a product is processed under very high pressure, leading to the sterilization of certain microorganisms and enzymes in the food.
- ***Induction burner***: heats a cooking vessel by magnetic induction, instead of by thermal conduction from a flame. In an induction cooktop, a coil of copper wire is placed under the cooking pot and an alternating electric current is passed through it. The resulting oscillating magnetic field induces a magnetic flux which repeatedly magnetizes the pot, treating it like the magnetic core of a transformer. This flux produces large eddy currents in the pot, which because of the resistance of the pot, heats it.
- ***Induction oven***: similarly to the induction burner, the induction oven uses electromagnetic induction to heat.
- ***Infrared dryer***: body with a higher temperature which transfers energy to a body with a lower temperature through electromagnetic radiation.
- ***Inductive Recharging System***: exploits an electromagnetic field to transfer energy between two objects through electromagnetic induction. This is usually done with a charging station. Energy is then sent through an inductive coupling to an electrical device, which can use that energy to charge batteries or run the device.
- ***LED (Light Emitting Diode)***: a light source that uses semiconductors and electroluminescence to create light. Instead of heating a filament to create light, electricity passes through a chemical compound that is excited and generates light.
- ***Micro-wind system***: the small-scale generation of electrical power, through means of wind power. Wind power is the use of air flow through wind turbines to mechanically power generators for electricity. Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity.
- ***Microwave oven***: an electric oven that heats and cooks food by exposing it to electromagnetic radiation in the microwave frequency range. This induces polar molecules in the food to rotate and produce thermal energy in a process known as dielectric heating.

- ***Microwave dryer***: produces heat by vibrating water molecules, almost a billion times per second. The resulting friction converts the radio energy to heat energy and vaporizes the water. Molecules of other substances, such as protein, fat, and fibre, do not readily absorb microwave energy so they do not heat up as much. This effect, plus evaporation of surrounding water, keeps the product much cooler than in conventional gas fired dryers.
- ***Organic Light Emitting Diode (OLED)***: organic light-emitting diode is a light-emitting diode (LED) in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current.
- ***Power electronics***: Power electronics is the application of solid-state electronics to the control and conversion of electric power. The conversion is performed with semiconductor switching devices such as diodes, thyristors and transistors. An AC/DC converter (rectifier) is the most typical power electronics device found in many consumer electronic devices.
- ***Photovoltaic system (PV system)***: it consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity, a solar inverter to change the electric current from DC to AC, as well as mounting, cabling, and other electrical accessories to set up a working system.
- ***Power to fuel/Power to Gas (PtG)***: Conversion systems based on electrochemical processes for electricity storage, in the way of fuels such as Synthetic Natural Gas, Hydrogen or Methanol.
- ***Pulse Dryer***: in this technology, very hot drying gases are accelerated to about 300 mph in a resonating pulse combustion engine, while the liquid is pumped into this gas stream at low pressure (about 1 psi) and very low speed.
- ***Radiofrequency dryer***: drying and thermal processing technology based on the dissipation of electromagnetic energy within the product. Unlike conventional techniques, where heat is transferred to the product through its surface from an external heat source by conduction, convection or irradiation, a Radio Frequency field generates heat directly inside the entire product mass – that is why the related mechanism is called "endogenous" or "volumetric". The heat generation is instantaneous and allows a rapid, uniform and perfectly controlled process, thus delivering outstanding results in terms of product quality, operational flexibility and energy savings.
- ***Sensor***: device, module, or subsystem whose purpose is to detect information on energy production and consumption and send the information to other electronics, frequently a computer processor.
- ***Smart Meter***: electronic device that records consumption of electric energy and communicates the information to the electricity supplier for monitoring and billing. Smart meters typically record energy hourly or more frequently, and report at least daily.
- ***Solar Fuels***: technology that captures solar energy in conversion systems. Electricity is generated and stored through the CO_2 direct reduction as well as through CO_2 activation and catalytic conversion.
- ***Superconducting Magnetic Energy Storage System (SMES)***: allows the storage of large quantities of energy as electromagnetic field in a winding. A typical SMES system includes three parts: superconducting coil, power conditioning system and cryogenically cooled refrigerator. Once the superconducting coil is charged, the power will not decay and the magnetic energy can be stored indefinitely.
- ***Thermal Storage Systems (TES)***: technology that stocks thermal energy by heating or cooling a storage medium so that the stored energy can be used in a second moment for heating and cooling applications and power generation.
- ***Ultrasound Dye***: ultrasound dyers alter the fibre structure to increase adsorption and significant enhancements in diffusion coefficient of the chemical molecules. They are mainly used in the textile industry.

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