Electrification as a key tool for decarbonization and sustainable development

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Foreword

This document is based on data available on publicly available sources and on a set of studies conducted by Enel Foundation and its partners.

Publicly available sources:

- IEA World Energy Outlook 2018
- The World Bank, World Development Indicators, https://data.worldbank.org/indicator
- IEA, "IEA Statistics", https://www.iea.org/statistics/
- Eurostat, "Energy Statistical Database", http://ec.europa.eu/eurostat/web/energy/data/database
- IEA, "Headline", https://www.iea.org/media/statistics/IEA_HeadlineEnergyData.xlsx
- IEA WEO2017 Special Report on Energy Access Outlook
- https://www.eurelectric.org/decarbonisation-pathways/
- https://ec.europa.eu/clima/policies/strategies/progress_en

Enel Foundation studies

- https://www.ambrosetti.eu/wp-content/uploads/Electrify-2030_versione-online.pdf
- *Fuelling Italy's Future*, 2018 https://www.enelfoundation.org/en/news/Low-carbon_mobility_can_boost_economic_growth_in_Italy
- Electrify Italy 2018

A pressing set of challenges: meeting global energy demand growth, assuring reliable energy access for all, preserving the environment

The world demand for energy will keep growing. Mostly, if not completely, driven by developing economies, the IEA projects (new policies scenario) an increase by over 25% between 2017 and 2040.

Moreover, not only energy availability is very unequally distributed among different countries, but also a very large part of humanity still do not have access to electricity at all. In 2016 the world Total Final Energy Consumption (TFC) per capita was 53.9 GJ/person. At country level, the same indicator ranges from 1.9 GJ/person for South Sudan to 289.9 GJ/person for Qatar. African countries, in general, are characterized by very low level of energy consumptions, and the average for the whole continent is 20.3 GJ/person.

Moreover, notwithstanding the progress recently made, in 2017 about 1 billion people still lacked access to electricity.

At the same time, 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, an increase largely attributable to the still predominant role of fossil fuels (81% in 2017 according to IEA) in the global primary energy mix.

Climate change is already directly affecting people's lives. Frequent an intense rainfall causing serious and frequent flooding, droughts compromising some types of crops and allowing alien invasive species that may carry new diseases. These and other phenomena can have severe effects on humans and infrastructures. In Europe there was a loss of $436.1billion over the period 1980-2016 from climate-related extremes ($61.2 billion in Italy over the same period)[1]. Moreover, heat waves and extreme cold spells are associated with

[1] https://www.ambrosetti.eu/wp-content/uploads/Electrify-2030_versione-online.pdf

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[1].

In addition to that, pollutant emissions related to the combustion of fossil fuel and biomass are responsible of negative impacts on people's health.

Air pollution from different sources (e.g. fossil fuel combustion, agriculture and waste management) is recognized to harm human health and the environment. In the EU around 90% of city dwellers (70% in Italy) are exposed to pollutants (O3 and PM10) at concentrations higher than the acceptable threshold for health. Particulate matter (PM10 and PM2.5), nitrogen dioxide (NO2) and ground-level ozone (O3), 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 cost of mortality, morbidities and impacts on the environment, animal and plant health[1].

It is clear that trying to meet the increasing global energy demand adopting the same energy paradigm, based on large-scale utilization of fossil fuel is not a sustainable strategy.

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

A radical shift in the way energy is sourced, supplied and consumed is therefore a clear necessity. Moreover, the occurrence of negative events (e.g. severe weather conditions, fuel supply shortage or discontinuity), suggests the need to increase the resilience, the capacity to quickly recover after a negative event. The concept of resilience refers to several intertwined aspects of the economic and environmental ecosystem, including the energy sector.

It is no wonder how 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

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.

It is important to notice that the measures adopted by the EU for the reduction of GHG emissions are proving to be effective. The EU is today on track to meet the 20% target for 2020. EU emissions were reduced by 23% between 1990 and 2016, while the economy grew by 53% over the same period.

The "Transition Nexus": a viable, cost effective solution.

The "Transition Nexus", encompassing the relation among CO2 emissions, decarbonization pace and electrification of final uses which is connected to customers' choice. The successful reduction of CO_2 emissions calls for an accelerated decarbonization path and final customers purchasing choices play a key role also influencing corporates' commitment.

Power generation from renewables, electricity as the main energy vector and electrification of final uses in all sectors, represents a viable and cost effective solution to the current challenges.

This electrification paradigm has meaningful application in both centralized and decentralized energy systems.

The advantages of the adoption of this concept are multiple:

- it promotes higher levels of energy efficiency, since end-use electric technologies are more efficient than their non-electric equivalent, thus reducing energy needs and relative CO_2 emissions;
- the electric carrier offers a relevant contribution to reduce CO_2 emissions when the electricity generation mix is balanced towards renewables, that are already in the money and getting cheaper and cheaper;
- 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 (e.g. increase of energy security through reduction of dependency form import, exploit digitalization advantages in terms of O&M efficiency, reduced outages, asset lifetime extension, integration of decentralized production)
- through digitalization, it is possible i)to enable more effective consumption management and higher efficiency; ii) to unlock business opportunities providing value added services to customers.

The role of electrification in achieving decarbonization goals is crucial. Eurelectric estimated that in Europe decarbonization up to 95% is achievable by 2050 through strong electrification, energy efficiency, and support from other non-emitting fuels.

Moreover, the EU published in November 2018 its "Strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050"[2]. The strategy includes various electrification scenarios. In all of them electricity becomes the dominant energy carrier and its shares grows strongly in all scenarios, from 22% in 2015 to 29% in 2030 and then in 2050 ranging from 41% (P2X) to 53% (ELEC).

The recently released IEA WEO 2018 dedicates a special focus to electrification. At the global level, it anticipates an increasing role of electricity in the future. In all the scenarios the share of electricity in total final consumption grows, with a share in 2040 that ranges from 24% of the "new policies scenario" up to 31% in the "future is electric" scenario.

Impact of electrification on air quality and human health

As an example of the positive impact of electrification, the relation between air quality and impact on human health and healthcare system, related to the evolution of new low carbon vehicle sales, can be measured. Low-carbon mobility can help cut air pollution by decreasing substantially NOx and PM

[2] https://ec.europa.eu/clima/policies/strategies/2050_en#tab-0-0

emissions from cars. The Fuelling Italy's Future study3, shows that such emissions can be reduced in 2025 respectively by 50% and 63% compared to 2017 levels, moving close to zero in 2050. Thanks to the reduction of air pollution due to tailpipe emissions, the central scenario shows that in 2050, about 114,644 life years will be gained, for an equivalent of almost 1,400 lives. Around 2,000 cases of lung cancer and 12,600 cases of chronic bronchitis will be also prevented in the same period. The total monetary value of the improvements is estimated to be €8.5 billion in 2025, increasing to €10.5 billion in 2030 and up to €13.5 billion in 2050.

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

Increasing generation capacity from renewables supported by significant cost reductions, 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%). At global level, between 1990 and 2016 electrification grew from 13% to 19% and is expected to increase up to 21% - 24%, in 2030 depending on the considered scenario[4].

Recent Enel Foundation studies have focused on Italy. In this country, 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).

As far as renewable generation in Italy is concerned, shares between 56-65% in 2030 and between 84-90% in 2050 can be achieved depending on the level of CO_2 prices. This projection indicates that Italy's electricity supply is likely to be shaped by RES in the near future. The pace of transition from fossil fuels to RES is affected by different variables such as technology cost reduction, innovation and carbon policies. Still, the economic expansion analysis indicates that by 2030 56% (more than 80% in 2050) of the electricity will be provided by RES even in the absence of a CO_2 price. This share can even go above 90% if CO_2 emission reduction measures such as a CO2 price are applied. With these high penetrations of RES, it is possible to reduce the CO_2 emissions from the electricity sector up to 80%.

e-Mobility is the sector with the highest potential for electrification, and affects a large part of the economic system

Electric mobility is experiencing an unrelenting growth at the European level, driven by both market dynamics and policy targets. Between 2011 and 2017 the e-Car market grew at an astounding +68.7% Compounded Annual Growth Rate – CAGR – bringing Europe to have more than 300,000 circulating electric cars on its roads. The e-Two-wheelers market is growing even faster, especially with the moped segment which grew by 233% from 2011 to 2017;

[3] *Fuelling Italy's Future*, 2018 https://www.enelfoundation.org/en/news/Low-carbon_mobility_can_boost_economic_growth_in_Italy

[4] Source: IEA statistics, IEA WEO 2018

In Italy, the e-mobility sector is still in the take-off phase. As of August 2018, 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 development of electric mobility has a potential impact on a substantial part of the economic system, as shown by an analysis of the Italian *extended e-Mobility supply chain*, 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. 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.

e-mobility: estimating the growth potential in Italy and its impact on the economic system

To estimate the achievable turnover in Italy along the extended e-mobility 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*.

Electrification technologies have the potential to activate an extended industrial value chain in Italy and provide substantial efficiency gains

To identify the full array of electrification technologies and identify those which are more promising in terms of both technological maturity and deployment potential, the Electrify 2030 study has built an innovative model 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 currently composed of about *17,000 firms* involving more than *320,000 employees* and with a total turnover of around *€80 billion*.

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

• *heat pumps* (*~50%* efficiency gain compared to traditional combustion heating and cooling systems such as the condensing boiler); It is worth noticing that heat pumps, besides the advantages in terms of energy savings and reduced CO2eq emissions would guarantee a better air quality since they do not emit particulate at local level. Conversely, biomass boilers are the largest particulate emitters, followed by oil and gas boilers.

• *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 siliconcarbide 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. 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, revealing 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.

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 performed 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