THE ENERGY TRANSITION

ONGOING IN THE EUROPEAN UNION & EMERGING IN CHINA

中国华能集团公司技术经济研究院
CHINA HUANENG GROUP TECHNICAL ECONOMICS RESEARCH INSTITUTE

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Keywords
Decarbonisation; Paradigm shift; Electricity markets; Flexibility; Grids; Innovation; Knowledge sharing; Common public and private stakeholder vision.

Executive summary

This paper is a joint effort between the *Fondazione Centro Studi Enel* (Enel Foundation) and the *Huaneng Technical Economics Research Institute* (HTERI) within the framework of a Memorandum of Understanding signed by the two organizations in 2016 to collaborate in research activities on energy transition.

The paper aims at giving a first broad overview of the significance and implications of energy transition and its drivers in different contexts. Given also the variety of issues covered, a diverse team of authors has contributed to its drafting.

The paper **focuses on electricity**:

- how **grid infrastructures** can become the backbone of a decarbonised and decentralised system including integration of renewables;
- new approaches required to implement **flexible investment strategies** in a context of increasing share of capital components of energy, leading to reduced marginal energy prices and the consequent need for new pricing structures and long term arrangements;

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[1] *Fondazione Centro Studi Enel* (Enel Foundation): http://www.enelfoundation.org
[2] *China Huaneng Group Technical Economics Research Institute* (HTERI)
[3] Enel SpA

- the potential of **wholesale and retail markets** to facilitate the transition.

As for the latter, we discuss the crucial connection between the two markets with a focus on Europe where the largest number of liberalized retail customers are based. Retail markets are offered as key for the energy transition.

The essential **technological dimension** spans over an almost unlimited spectrum. We have chosen to address it through **three selected case studies**.

Finally, the paper reflects on the **implications of energy transition on power companies**, both those that have already produced tangible effects and those that will do so in the future.

What is an energy transition?

An energy transition is a process that leads to fundamental changes in the way energy is produced and consumed. As pointed out by a Saudi Arabian politician[4], such a process is generally not prompted by the availability of resources, rather by policy and technology.

In the last couple of decades environmental policy drivers have been dominant, at least in the industrialized world. Especially in the wake of the Kyoto Protocol, decarbonisation has been the lead focus for strategy evolution.

Recently, the picture has become more complex. New drivers, including consumer expectations, are emerging. Several different issues, often closely interrelated, have to be taken into account at the same time in new contexts in which new players – from innovation intensive companies to citizens who have become involved through small scale investments in renewables and other distributed facilities - come on stage and fragment the market structure. Moreover, national energy systems and economies are becoming increasingly interconnected.

[4] "*The Stone Age came to an end not for a lack of stones and the oil age will end, but not for a lack of oil*" Ahmed Zaki Yamani, 2000. Saudi *Minister of Oil (Petroleum) and Mineral Resources* from 1962 to 1986, and a minister in OPEC for 25 years.

An effective energy transition implies a difficult balance between sustainability, competitiveness, affordability, and security of supply. Such a balance is addressed, for example, by the “trilemma” goals heralded by the *World Energy Council*[5].

Electricity is at the centre of energy transition because of its role for economic and social development and its potential to support the decarbonisation agenda[6]. Electricity is in fact a primary link to the use of carbon-free energy sources such as renewables and nuclear, and its penetration in sectors such as transport and heating/cooling can facilitate their decarbonisation.

Significant challenges of the energy transition and relevant targets, result from technical issues but regulatory and market arrangements and macroeconomic costs remain critical.

The need for investments puts pressures on energy bills. Governments need to ensure a balanced distribution of burdens between different segments of society and should resist temptations to policy stop-and-go’s such as retroactive cuts on support schemes, which undermine investors’ confidence and tend to increase the overall costs of the transition, as shown for example by Eurelectric’s “lost decade” scenario[7].

A few elements are **essential for an effective energy transition**:

- pricing carbon in a stable and robust way is a condition for cost optimization, as explained by a number of leading economists including the Nobel Prize Jean Tirole[8];
- regulatory arrangements must guarantee that investments in renewables take place at the minimum cost. Measures to reduce risk premia help to drive these down, given the predominance of upfront capital components. Such

[5] http://www.worldenergy.org/publications/2016/world-energy-trilemma-2016-defining-measures-to-accelerate-the-energy-transition/
[6] Context and key issues *“Electricity generation is at the core of efforts to reduce carbon dioxide (CO2) emissions” p.21. ©OECD/IEA 2016 Re-powering Markets, IEA Publishing*
[7] http://www.eurelectric.org/media/79057/power_choices_2013_final-2013-030-0353-01-e.pdf
[8] http://www.chaireeconomieduclimat.org/en/evenement/call-for-an-ambitious-and-credible-climate-agreement-in-paris/

measures include long-term contracts awarded on a competitive base, as in the case of the UK's *Contracts for Difference* (CfD), where a significant price reduction has been achieved compared to *Feed-In Tariff* (FIT) administered prices[9];

- security of electricity supply must be considered as core. Electricity markets need to be redesigned to accommodate ever-larger shares of generation from fixed-cost installations. Capacity markets or tenders for long-term contracts are necessarily a part of the solution;
- simplified access to financing for energy efficiency[10];
- International cooperation and policy convergence, in particular between neighbouring countries, facilitates market integration and cost effectiveness.

Three European attempts at structural reform can help understand the meaning of energy transition. These are the UK's "**Electricity Market Reform**", the German "**Energy Transition**" ("*Energiewende*"), and the French "**Energy transition for green growth act**" ("*Loi de transition énergétique pour la croissance verte*"). Especially in Germany and the UK these can be seen as the latest steps of a long road started decades ago; designed by firm political will and governed by appropriate structures but which would have been impossible without technological advance and consumer acceptance.

Essential elements of the UK's "**Electricity Market Reform**" have been:

- a carbon price floor to guarantee a minimum trajectory over time;
- contracts for difference (CfDs), designed to pay low carbon generators a competitively awarded fixed price in order to stimulate cost efficiency and provide certainty over total revenue;
- a capacity market to address security of supply;

[9] See DECC "*Contract for Difference (CfD) Allocation Round One Outcome*", 26 February 2015

[10] "Building the European Energy Union – Proposals and policy recommendations to power European competitiveness", September 2015 by *The European House Ambrosetti*. The paper makes the following recommendations: (i) transparency, scalability and standardization of financing in the private sector to create a secondary market of energy efficiency financial products; (ii) improvement of the role of dedicated credit lines (concessional loans in particular), through public banks in order to increase the bankability of projects; (iii) sharing best practices regarding "On-Bill Repayment" mechanisms; (iv) better use of risk-sharing facilities by public banks and multilateral development banks; (v) allocation of incentives to service and product providers rather than only to customers, in order to benefit from economies of scale and learning; standardization and promotion of Energy Performance Contracting (EPC) programs.

- an emissions performance standard to limit emissions from new plants.

Also of note, the goal to improve financial predictability through long-term contracts. This recognizes that low-carbon investments are capital intensive and require regulatory stability for investments to take place.

The German “**Energy Transition**” is inspired by broad, often overlapping, energy policy targets, including measures to reduce consumption of: primary energy, gross electricity, final energy in the transport sector, and CO_2 emissions, whilst simultaneously increasing the share of renewables in final energy and gross electricity consumption. The instruments adopted to carry out this transformation have included:

- mechanisms to support renewables and integrate them into the market while controlling the amount of subsidies;
- standards and incentives to support energy efficiency and productivity;
- laws to guide nuclear phase-out;
- strategic reserves to address security of supply;
- streamlined permitting procedures for network development.

The burden sharing of the costs of the transition, in particular between households and energy-intensive industries, has been the object of heated debate, especially in relation to how the surcharge to support renewables is to be distributed across electricity tariffs.

The French “**Energy transition for green growth act**” includes targets on emissions, renewables, energy efficiency, energy consumption, and provides for a reduction of the shares of nuclear and fossil fuels, as well as broader environmental objectives. It relies on:

- diversifying electricity production and reducing the share of nuclear power to 50% by 2025;
- increasing the share of renewable energy in final energy consumption to 32% and to 40% of electricity production in 2030, with the support of: existing feed-in tariffs, new calls for tenders for photovoltaic installations and a new support scheme providing for a premium for electricity sold directly on the market;
- reducing final energy consumption by 50% in 2050 compared to 2012 through a government program for housing which facilitates investments with

tax credits and soft loans combined with the existing white certificate mechanism for energy efficiency;
- promoting clean transportation through measures such as obligations to equip new car parks with electric charging points, and traffic restriction in polluted areas;
- halving the amounts of waste disposed of in landfill sites by 2025 by promoting a more circular economy.

The overhaul of the electricity sector is completed by a decentralized capacity market for security of supply (implemented separately as an application of a former law).

Overview of energy transition drivers

OVERVIEW OF ENERGY TRANSITION DRIVERS IN THE EUROPEAN UNION

As shown by the UK, German and French examples drivers for energy transition in Europe are rooted in national context - both in terms of the issues to address and the instruments used to deal with them.

A continental perspective is however still extremely relevant because of EU legislation on the environment, climate change and energy markets and EU funding for projects of regional significance. EU legislative intervention tends to cover cross border issues such as interconnections and market integration. Furthermore, EU state aid rules apply to many of the mechanisms chosen by Member States to implement the energy transition. The *Energy Union Project* launched by the European Commission in 2015[11] is just the latest step of a path begun twenty years ago to implement trans-national energy policy through legislative activity initially distinct from but now fully integrated with climate and environmental objectives (***fig.1***).

Stakeholder needs are diverse and not always complementary: final consumers

[11] http://eur-lex.europa.eu/resource.html?uri=cellar:1bd46c90-bdd4-11e4-bbe101aa75ed71a1.0001.03 /DOC_1& format=PDF

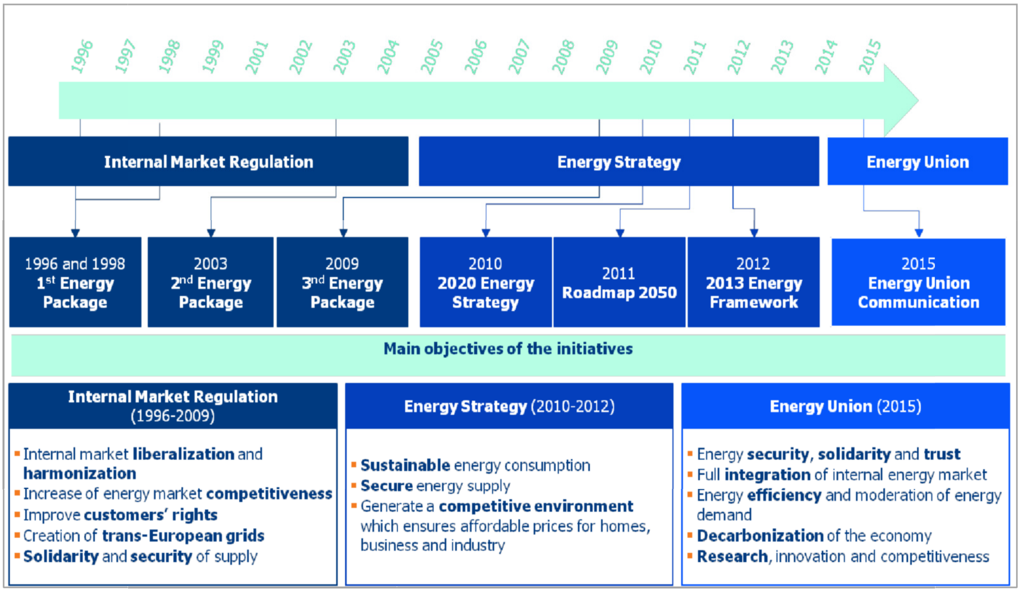

Fig.1 *The path towards progressive integration of EU energy and climate policies (**Source**: European House - Ambrosetti)*

are looking for a more active role; utility companies call for regulatory frameworks capable of facilitating investments; new entrants such as ICT companies, new service providers and aggregators are pushing to enter the energy sector with new business models; and Member States want to preserve their prerogatives on energy policymaking.
As detailed below, three drivers stand out as instigators of dramatic discontinuities: **decarbonisation**, **customer empowerment** and **innovation**.

- **Decarbonisation of the electricity sector** requires massive investments for a radical transition to new generation assets and grids. Conventional generation will shift from baseload power to backup capacity and distribution grids will have to manage distributed resources. *"In 2014, renewables made up an estimated 58.5% of net additions to global power capacity and represented far higher shares of capacity added in several countries around the world. By year's end, renewables comprised an estimated 27.7% of the world's power generating capacity. This was enough to supply an estimated 22.8% of global electricity ...".*[12]

[12] REN21: Renewables 2015 "Global Status Report" p.30

Overview of current EU-level power sector innovation policy levers

		Main EU-level examples
R&D and demonstration funding	Direct R&D grants	• FP7 & Horizon 2020, Structural funds, Intelligent Energy Europe, Euratom, CIP
	R&D risk-sharing and loans	• EIB Risk Sharing Finance Facility (RSSF)
	R&D tax credits	• Implemented at Member State level (typically not energy-specific)
	Demonstration funding	• Ad-hoc / one-off programmes including NER 300, European Energy Programme for Recovery • More systematic support through FP7, European Industrial Initiatives (SET plan)
Support for commerciali-sation and deployment	Public VC function	• Intelligent Energy Europe start-up / SME support, EIT VC functions in InnoEnergy
	Product-to-market support	• No significant use in EU energy policy, but cf US biofuels support programmes
	Patents	• Standard patent provisions; no special provisions for energy sector
	Prizes	• (No significant use in EU energy policy)
	End-use support[1]	• Policies to create market demand, including implementations of RES directive, EU ETS, EE directive
	Public procurement	• Selected Member State initiatives (e.g., Spain 3% quota for innovative products)
Enabling market framework	Infrastructure	• E.g., connecting Europe Facility (TEN, EIB, Structural Funds, Cohesion funds)
	Competition	• Third Internal Energy Market Package
	Regulation and incentives	• Market design, undertaken at Member State level
	Legal framework	• EU coordination of various applicable legislation (bankruptcy, IP, etc.)
Collaboration and learning	Education and training	• Fit European Research Area, various Member States
	Coordination and publication	• SET Plan and Energy Technology Platforms, European Industrial Initiatives, Zero Emissions Platform
	Technical standards	• Range of specific initiatives, including product energy efficiency standards, grid standards, etc.
	Networks and outreach	• European Research Area, EIT, technology-specific collaborations

1 Includes subsidies, mandates, tax credits, and rebates for end-users of innovative products

Fig.2 Overview of EU innovation policy levers
(***Source***: *Eurelectric elaboration on European Commission data*)

Although questioned for its distributional and competitiveness effects the decarbonisation driver is still powerful because of international commitments in the wake of the agreement struck at COP21 in Paris in 2015, and because of its ability to stimulate modernization. The critical issue is to identify and balance cost effective instruments including long-term price signals to incentivize investments, a stronger ETS to deliver meaningful CO_2 prices, competitive mechanisms to add capacity from renewables and a revised market design to reflect the characteristics of a decarbonised electricity sector.

- **Customer empowerment** means awareness and freedom of choice, access to a broad spectrum of services, the opportunity to sell self-produced energy on the market and system flexibility. The consequences of choice are potentially disruptive and pose threats to traditional power business models. A markedly distributed system implies the need to handle a massive amount of data to both manage it securely and stay in business. Providing a favourable framework to the development of smart grids is essential to enable distributed resources and customer empowerment.
- **Innovation** is at the heart of the energy transition and is a powerful enabler. A number of technologies - both supply and demand side - have proven to be game changers: innovative power generation from renewables, storage, efficient elec-

tro-technologies for transport, heating & cooling or technologies enabling peer-to-peer trading are just a few examples. Innovation is also instrumental to guaranteeing energy security and reducing energy, technology and system costs.

The European Union is making considerable efforts to create a favourable environment to foster innovation. Key initiatives[13] address the knowledge base, how to get ideas to market, regional and social benefits, partnerships, international cooperation, *etc*. As for the power sector specifically, a number of innovation policy levers are being used, such as those shown in ***fig.2***.

With tens of millions of smart meters installed and comprehensive rollouts planned in over two thirds of EU Member States, the foundations for smart grids have been laid.

As a result, fuel and technology substitutions are occurring at ever faster rates, forcing utilities to rethink their role and to take into account new players and business models from outside the industry. A decline in the value of merchant generation, an increase in the value of transmission and distribution networks, renewables and downstream activities, the increasing importance of information flows as compared to power flows all highlight the importance of innovation.

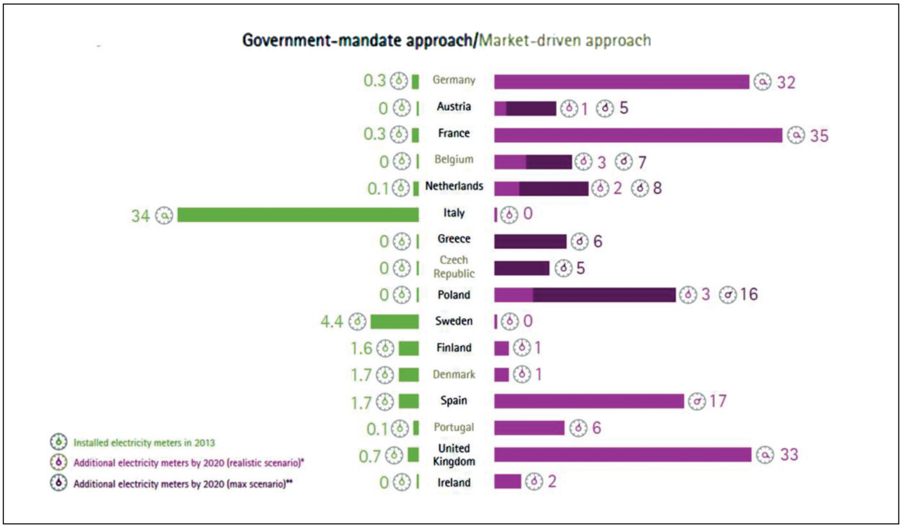

Fig.3 Estimation of the total number of *smart meter*s (mln) installed in Europe by 2020. (***Source***: "*Realizing the Full Potential of Smart Metering*", Accenture 2013)

[13] http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=key

Overview of energy transition drivers in China

Energy demand in China remains huge and growing

China is the world's largest consumer of energy, and has been the biggest source (over 40%) of global energy demand growth over the past 30 years. However, the growth of energy demand slows to a more sustainable rate as China adjusts its economic structure. In 2015, Chinese consumption reached 3,014 Mtoe (Million tonnes oil equivalent), grew 1.5% on yearly basis, still recorded the world's largest volume and increment in primary energy consumption[14]. The extent of adjustment in economic structure will have a major bearing on the future energy demand. According to a research conducted by *China Energy Research Association*, the energy demand in China is expected to grow by 1.4% p.a. from 2016 to 2030 and reach 3,710 Mtoe in 2030.

Energy supply in China faces four essential challenges

Firstly, the security of energy supply has to be safeguarded. China has been in a condition of persistently high level of dependence on foreign oil (reached 60.6% in 2015) compounded by insufficient oil reserve capacity. Efforts have been made to expand domestic oil production and reserve simultaneously.

Secondly, CO_2 emissions have to be reduced dramatically to guarantee the sustainability of energy supply. Accelerating the shift in energy mix away from coal towards natural gas, nuclear and renewable energy is becoming more and more prominent and urgent nowadays in China.

Thirdly, energy efficiency must be ensured to guarantee the affordability of energy supply. It is crucial for China to develop advanced energy technologies as well as innovative capabilities to improve the comprehensive energy efficiency, thus to reduce the cost of energy supply, especially of clean energy.

Last but not least, the regulation of energy supply needs reform to adapt to changes brought by three challenges mentioned above. Effective supervision and market mechanisms have to be established in China to tackle problems

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[14] BP Statistical Review of World Energy, June 2016

such as overcapacity[15], massive renewable power curtailment, and unreasonable distribution of resources as well as hampered competition. To sum up, energy supply in China is facing challenges for security, sustainability, affordability and regulation.

Extensive and inefficient way of energy exploitation and utilization in China has seriously damaged the environment

In 2015, coal accounted for 64% of primary energy consumption and fuelled 67% of power generation in China. In the same year, the amount of coal exploitation in China has exceeded 4 billion tonnes, which is twice the sustainable supply capacity of the domestic coal resource[16]. Consequently, severe coalmine subsidence emerged in many coal-producing provinces with annual additional area of more than 400 square kilometres, and billions of tonnes of groundwater damaged every year in China according to a research conducted by the *Chinese Academy of Engineering*. In addition, more than 0.8 billion tonnes of coal, about 20% of total consumption, is utilized via dispersed combustion directly without any emission reduction or pollution control measures, which is deemed as the major cause of noxious haze over central and eastern China in recent years. The latest data released in "2015 China Environmental Status Bulletin" show that only 21.6% of the cities in China have met the new environmental protection standards. In summary, extensive and inefficient way of carbon-intensive energy exploitation and utilization has already caused harmful impact on people's health and ecological environment in China.

Energy Revolution - national strategy for promoting energy transition in China

Proposed by Chinese President Xi Jinping in mid-2014, the Energy Revolution Strategy aims to promote energy consumption revolution to curb unreasonable energy consumption and boost energy efficiency; promote energy supply revolution to establish a diversified, clean and low carbon energy supply system; promote energy technology revolution to upgrade energy industries with innovation of technology, value chain and business model; promote energy dereg-

[15] According to a report by *China National Development and Reform Commission* in 2015, the over capacity of coal production exceeded 1.7 billion tonnes, .and the installed capacity of power generation was more than 80% higher than the peak load in 2015

[16] About 2 billion tonnes per year according to a research conducted by the *Chinese Academy of Engineering*

ulation and market reform to restructure energy markets with effective competition and regulation; strengthen international cooperation in all aspects to safeguard energy security in the global context.

The long-term goal of Energy Revolution Strategy is to build a clean, low-carbon, secure and efficient energy system. By 2020, China will increase the share of non-fossil energy in primary energy consumption to 15% and cut its CO_2 emissions per unit of GDP by 40-45% below 2005 level. By 2030, non-fossil energy consumption share will grow further to 20% and China's CO_2 emissions will peak. Stage goals, priority tasks as well as schedules and timetables for China's Energy Revolution Strategy will be promulgated specifically in the imminent "2030 National Energy Production and Consumption Revolution Strategy" by *China National Development and Reform Commission*. In general, Energy Revolution Strategy is China's action to ensure affordable and sustainable energy for the people's livelihood and national development.

Energy transition of China will be a long and more complicated course. As mentioned above, China's CO_2 emissions will continue to grow until 2030. That means, China's energy transition process is governed largely by National Strategy of Combating Climate Change, which might last throughout this century. The complexity is determined by the fact that China's energy revolution involves transitions in energy consumption, supply, technology innovation, regulation and market reform, and international cooperation, which are interrelated and interact with one another. For instance, energy supply revolution involves energy diversification and decarbonisation, which resembles the two successive stages of energy transition in EU since the oil crisis in 1970s. The power sector of China will be confronted simultaneously with issues of deregulation, competitive electricity and carbon market construction, evolution of renewable energy supporting schemes etc. In conclusion, during this long and complicated course, care must be taken at different stages to ensure the coordination and consistency of policy development and market reform to avoid inconsistency and conflicts.

Implications for grid infrastructures

The drivers and trends of the energy transition described in previous sections clearly indicate an enhanced role for grid infrastructure and an urgent need for it to incorporate new features towards:

- accommodating larger renewable capacity through strengthened interconnections capable of integrating areas endowed with significant resources into power systems;
- assimilating variable resources into existing networks;
- managing distributed resources through active distribution grids capable of dispatching distributed generation and enable demand response.

Integrating variability[17] is a major challenge - context, source and grid-specific - and depends on multiple factors among which: predictability of resources[18]; operational flexibility and technological and regulatory maturity of the receiving power grid; distribution of renewable energy sources in relation to demand centres and existing energy mixes. Each system consequently requires a specific combination of tools to reach politically set targets in terms of costs, social benefits and security of supply[19]. For example:

1. **investments in technology** including: smart transmission & distribution; system monitoring and control; holistic forecasting; extended interconnectivity; storage capacity and to enable effective demand response solutions[20];
2. **clear rules of governance and engagement for all stakeholders** through transparent grid coding and market mechanisms;
3. **sustainable remuneration schemes** including energy pricing, capacity payments, transmission tariffs, demand response compensation.

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[17] Measured on scale of difficulty going from geothermal (low) to wind (high) - via biomass, reservoir hydro, run-of-river and solar.
[18] Correlated to the adequacy of forecasting and monitoring tools and the availability of historical data
[19] For examples of differing levels of national autonomy versus trans-frontier interconnections see the **Baltic Energy Market Interconnection Plan** or, the 4 GW REM (France, UK & IRE) interconnection grouping as examples.
[20] To a system operator a **dispatchable decrement of demand can be equivalent to an increment of supply**. For example, within the PJM regional transmission system in the United States demand response resources presently provide a capacity contribution of 13 GW (corresponding to approximately 10% of peak demand).

Technological development, increased inter-nodal connectivity and advanced dispatch and congestion management tools make it possible to assimilate more than 100% of a given system's needs from variable renewables, even for short bursts of time[21], without negative implications.

Within the EU, studies and cooperation on network evolution, including massive integration of variable renewables, are ongoing. Examples of such cooperation are the *European Electricity Grid Initiative*[22] illustrated below and the *European Technology Platform (ETP) SmartGrids*[23]. These initiatives act not only as platforms for technology and policy development but also as project aggregators under the umbrella of the *European Strategic Energy Technology (SET)-Plan*[24].

However, out of the 195 projects of common interest (PCIs) earmarked for the completion of the Single Energy Market and financed with 5.35 billion euro from the Connecting Europe Facility (CEF), only three are specifically dedicated to smart grid R&D[25]:

- **SINCRO.GRID** (Slovenia, Croatia)[26];
- **Green-Me** (France, Italy)[27];
- **North Atlantic Green Zone Project** (Ireland, United Kingdom/N. Ireland)[28].

Worthy of note is that the falling cost of renewables, advances in utility & resi-

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[21] *i.e.* Portugal, Scotland, Costa Rica & Denmark.
[22] http://www.gridplus.eu/eegi
[23] http://www.smartgrids.eu/
[24] https://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan
[25] http://ec.europa.eu/energy/infrastructure/transparency_platform/map-viewer/. Smart Grid: "*an electricity network that can integrate in a cost efficient manner the behaviour and actions of all users connected to it, including generators, consumers and those that both generate and consume, in order to ensure an economically efficient and sustainable power system with low losses and high levels of quality, security of supply and safety*."
[26] Aims at solving network voltage, frequency control and congestion issues enabling further deployment of renewables and displacement of conventional generation by integrating new active elements in the transmission and distribution grids into the virtual cross-border control centre based on advanced data management, common system optimisation and forecasting involving two neighbouring TSOs and the two neighbouring DSOs
[27] Aims at enhancing RES integration by implementing automation, control and monitoring systems in HV and HV/MV substations, including communication with the renewable generators and storage in primary substations, as well as new data exchange to allow for a better cross-border interconnection management
[28] Aims at lowering wind curtailment by implementing communication infrastructure, enhanced grid control and interconnection and establishing (cross-border) protocols for Demand Side Management

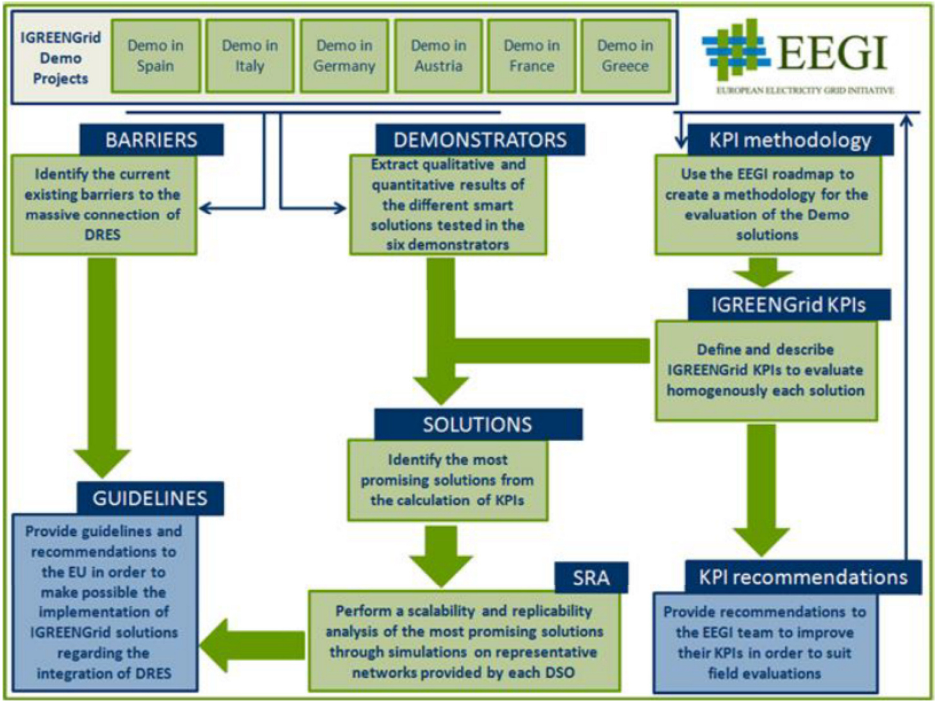

Fig.4 *European Electricity Grid Initiative (**Source**: EEGI).* Demo projects & methodology for the formulation of common EU guidelines for grid innovation. Enel participates in the IGreen-Grid initiative in Isernia[29] with the following objective, to increase the MV network hosting capacity of distibuted generation whilst maintaining power quality. "*Expected principal innovations are advanced control and protection systems, innovative charging stations for electric vehicles, electric energy storage system and provisions for "smart info" devices*."

dential scale storage and the development of smart meters, have opened the market to new players – profoundly affecting the role of incumbents (*i.e.* DSOs and retail suppliers). The *prosumer*[30], the market aggregator and the digital entrepreneur leverage technology to create new business models, contracts and services for trading energy and localising or micro-sizing supply and demand. With the possible assimilation of blockchain technologies in peer-to-peer networks, there is an explicit effort to "cut-out the intermediary" - distributors and financial institutions - whilst other forms of credit/debit may substitute payments in currency.

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[29] http://www.igreengrid-fp7.eu/italy
[30] Term used to define an energy consumer who also generates beyond self-consumption and sells back into the grid. The prosumer usually generates with renewable energies and uses a bidirectional meter and grid to participate in the energy market.

These dynamics will see roles, services and remuneration evolve ever further away from centralised models, a threat but also an opportunity for present-day market participants and a core enabler will be the further development of network infrastructure: smart, multimodal and distributed.

Case study: Wind generation to cover network ancillary services in Spain

Study supported by ***Santiago Dominguez*** *&* ***Vanesa Pellon***
of ***Enel Renewable Energies Iberia****.*

The Spanish electricity market has three main peculiarities:

1) a large share of variable renewable generation - approximately 18% of annual consumption is generated by wind (approximately equivalent to the shares of coal or nuclear within the country's generation mix);
2) low interconnectivity outside of national borders (restricted to limited capacity from France and Morocco);
3) recurring negative margins on energy distribution due to overcapacity and waves of variable energy generation.

With a view to reducing service costs and eliminating an unjustified inequality versus traditional generation, in 2014 the Spanish government decided a world first regulatory innovation allowing wind plants to provide "ancillary services" to the network - until 2014 this was prohibited. Regulation was finalised in late 2015 for services deliverable from the beginning of 2016.

On December 18th, 2015 the Ministry of Energy published a resolution: "*for which are defined the criteria for participation in the ancillary services, and certain testing and operating procedures are approved for adjusting to meet the Royal Decree 413/2014, of June 6, by which is regulated the activity of electric power production from renewable energy sources, cogeneration and waste*".
Enel was the first to take advantage of the opportunity:

- December 31st, 2015 Enel's Spanish Control Room requested permission to start with the tests for enabling participation in ancillary services: markets deviation management and tertiary regulation;
- February 26th, 2016 the TSO agreed to allow Enel to make its first tests;
- March 21st, Enel received its first letters of acceptance, enabling participation in ancillary service markets;
- April 1st, Enel's Energy Management office sent out its first offers and generated its first specific revenues from four plants offering a combined 117 MW.

The tests and information required by the regulator (REE) include:

- in-depth revision of project technical information and electrodynamic models, detailed component lists and precise KPIs;
- real life remote power control simulations including: testing the capability to step down to zero production and step up back to initial production in short periods of time (<15 minutes);
- capacity to sustain a given set point with minimal deviation (<10%) for a period to be defined by the TSO during tests.

By October 2016 Enel had qualified 18 wind plants for more than 500 MW of installed capacity to participate in the Ancillary Services market and will have qualified almost all, if not all, its plants by year-end 2016 (70+ plants and 1,600 MW). An enormous amount of work was done to render Enel's renewable plants and control rooms technologically compliant and capable of overcoming tests imposed by the Regulator and valid for all technologies. Where networks allow, Enel is also competitive because able to offer a diverse geographical and technological mix of wind plants which can be combined to meet service standards in a "virtual plant" configuration.

Enel's Energy Management unit has subsequently developed its business models and IT systems both to enable for an effective participation on the ancillary market (*i.e.* with automated bidding) and to provide the smart/real-time feedback required by O&M to run its plants in accordance to both market and maintenance paradigms.

Systems and tools

Several activities were implemented to facilitate participation in the ancillary services market; mainly within Enel's Control Systems:

- enhanced linkage between Energy Management and Control Room systems;
- configuration of coordinated power control;
- dispatching of maximum producible power for expected hourly production for h+1, h+2, h+3 & h+4;
- optimization of downtime/start-up of wind farms by agreeing changes to the configurations of local regulators;
- automation of the systems used to distribute real time power curtailments submitted by the TSO and to enable the agile start/stop of generating units dependent on energy price margins.

To be able to bid for ancillary services Enel systems have been configured to comply with the set-point-per-offer-unit defined by Enel Energy Management. If one of two offered units matches a tertiary regulation bid, the Control Room is able to apply the power set point to supply the matched bid exactly.

Enel's success within a complex market context can be attributed to a number of factors: in-depth understanding of local market dynamics; in-house innovation; close coordination between functions and with the regulator; a focus on operational excellence (meaning optimal plant availability) and the ability to team up with vendors (*i.e*. to fine tune & test start/stop algorithms). Enel's size and geographically distributed wind generation portfolio also matter – the possibility of offering multiple options means being able to make up for local shortcomings in natural resources with abundance elsewhere.

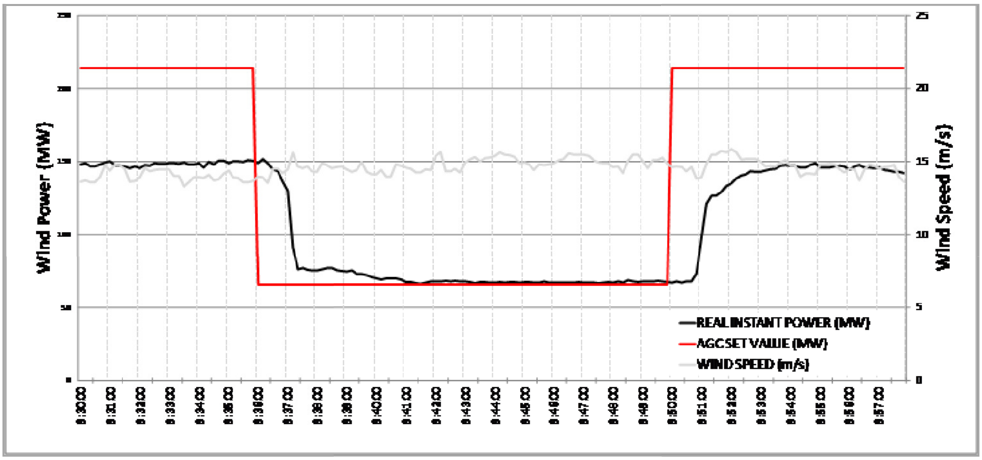

Fig.5 Example of a set point applied in a knot of four wind farms

That a *Variable Renewable Resource* such as wind could provide network ancillary services seemed unlikely only a few years ago but innovation in technology, monitoring & control, networks, weather forecasting, regulation, business processes and an ever expanding provision of renewable generation have led to what could quickly become another revolution in electricity markets. Also probable is that with diffuse storage and the potential end of intermittency on the near horizon, will come further disruption and opportunity, a wave that Enel is ready to ride.

Implications on the type and life of investments

The aggressive policy objectives set out by the EU Climate Energy policies are having important repercussions also on the investment cycles of power generating assets. For example, the accelerated deployment of RES generating assets is leading to the creation of stranded assets on the conventional generation side. In countries like Germany and Italy the increase in RES installed capacity (+135% and +98% respectively between 2008 and 2015) have led to a reduction in the number of operating hours of conventional plants in the order of 25% to 35%. Such effect has coincided with a marked reduction of electricity demand driven on one side by the economic cycle and on the other by the impact of energy efficiency policies.

Although the current impact of such factors on the short term is quite clear, uncertainty often permeates their impact in the medium to long term:

- **RES deployment**: the rapid deployment of RES generating assets in the years leading up to 2014 has been followed by a slow down of the penetration rate. The latter has been determined by: economic recession, the difficulty of some governments to maintain existing incentive schemes and the relatively slower rate of evolution of the infrastructure needed to service the new RES plants. Consequently, the growth rate may be slowing down and uncertainty remains about its levels over the 2020-30 horizon.
- **Economic cycle**: The recovery of the economic cycle is lagging against most expectations and there is an intense, ongoing debate over to what extent the reduction of economic activity in Europe may be structural rather than cycli-

cal. The impacts on electricity demand in 2020 range could be in the order of 5-15%, leading to the need to carefully assess its impacts on installed capacity requirements.

- **Energy efficiency**: Energy efficiency policies are often driven by *command&control* regulation characterized by significant uncertainty in the actual delivery of electricity savings. To-date such uncertainties make it difficult to assess the extent to which energy efficiency policies will affect electricity demand and whether these effects are to be transient or structural.

Uncertainty over the medium term evolution of electricity demand delays decisions to decommission power generation plants. In some cases, operators will continue operating assets that may be economically unsustainable in the short term with the view that they may become sustainable in the medium to long term due to a potential recovery of electricity demand or the exit of the operating assets of competitors. In some cases, the decision to decommission is postponed due to the social impacts this may entail *i.e.* in terms of employment. Examples of such instances have been debated vehemently in Spain and Germany - where the impact of a reduction in solid fuel conventional assets is bound to have significant impacts on the mining industry.

The decommissioning of conventional plants with long investment cycles has been matched by the rapid deployment of RES assets characterized by much faster implementation (in the order of one to five years) and shorter investment lifetimes (20 years). The narrower timeframes allow such assets to respond more quickly to changes in market demand and in the regulatory context. Very low levels of variable costs will however require a drastic review of the EU's Electricity Market.

The consequences of major uncertainties associated with electricity demand, industrial strategies and regulatory intervention are making predicting medium to long-term power indicators particularly challenging. A lack of a long-term price signal is keeping operators from investing in the EU power market - they will be tempted to do so only in the case of significant risk premia and reduced capital costs.

Case study: Decommissioning of fossil-fuelled plants in Italy - Enel’s Future-E project

*Study supported by **Marco Fragale** & **Andrea Biasotto** of **Enel**.*

The supranational dimension of the energy market requires Italy to define an energy strategy in line with the European Union’s policies, namely to: decarbonise, participate in the Single Market, focus on energy security and reduce energy costs. Strengthening security of supply signifies diversifying the energy mix to include all available technologies, multiplying supply routes and concentrating policy to promote the efficient use of energy. The Italian electricity industry must subsequently reduce emissions, develop renewable sources, innovate business models and increase energy efficiency. Further, following years of economic growth in Italy, demand trends and energy prices have fallen steeply since their peak in 2007; with a consistently stagnant economy and stakeholders shifting investments towards renewables, there is now a marked overcapacity in thermal generation. Today, there are 23 thermoelectric power plants in Italy that Enel considers marginal for a total of 13 GW to be decommissioned. In 2014 these collectively vaunted a sorry record of only 57 working hours and a 1% load factor. In order to guarantee a sustainable and innovative reconversion process for each plant, in 2015 Enel launched the Futur-E program - a novel approach to lead a process of change that affects not only the company’s generation mix but also local value chains and the environment.

***Fig.6** Main figures of the Futur-E project*

The Futur-E project is focused on the three pillars of sustainable development: environmental, economic and social. All efforts are made to protect direct employment and to identify projects directed towards generating shared value with territories and communities. Wherever possible, the industrial vocation of each area is to be maintained by means of conversion into productive sites with a different technology or with an inclusive functional transformation fostering reconversion to activities not pertaining to the energy sector. Whenever conditions do not allow for industrial development, all other options aiming at enhancing these areas through alternative uses are assessed.

Meetings, workshops and institutional tables are scheduled across the country – aiming to identify tailor-made solutions for each context. Enel is collecting local needs, ideas and objectives across the communities affected by the requalification of its facilities and sounding for innovative concepts in Italy and abroad.

A number of facilities and benefits render the Enel sites practically unique within the Italian real estate panorama:

- direct connection to power networks (grid/gas pipelines);
- high capacity data transmission capabilities;
- access to industrial scale water & cooling facilities;
- high safety standards of building infrastructure.

Futur-E incites redevelopment proposals by promoting international "*Calls for projects*". Interested parties (companies or consortia) are invited to present a project proposal for site reconversion, including a detailed business plan and a binding offer for the site. The projects are then evaluated by a technical committee, which includes representatives of the local administration. The aim of the appraisal is to identify the projects most suitable for the area by evaluating them through the three pillars of sustainability. Proposals have come from a number of diverse sources, presenting a positively heterogeneous mix of solutions: sports facilities, algae production plants, gas storage, data centres, resorts, *etc*.

To-date two plants have been successfully reconverted within the scope of the project: **Porto Marghera "Giuseppe Volpi" Power Plant** near Venice as a Logistics Centre and the **Assemini Power Plant** in Sardinia as an operating centre for grid stability support.

Enel's Futur-E project is made unique by a strategic overall vision, not limited to the redevelopment of individual plants but rather of a whole group of facilities, and for its model, involving dialogue and cooperation with the assets' local stakeholders. The Futur-E experience shows that a common purpose is key to transform a problem - the changing energy paradigm - into an opportunity for all interested parties.

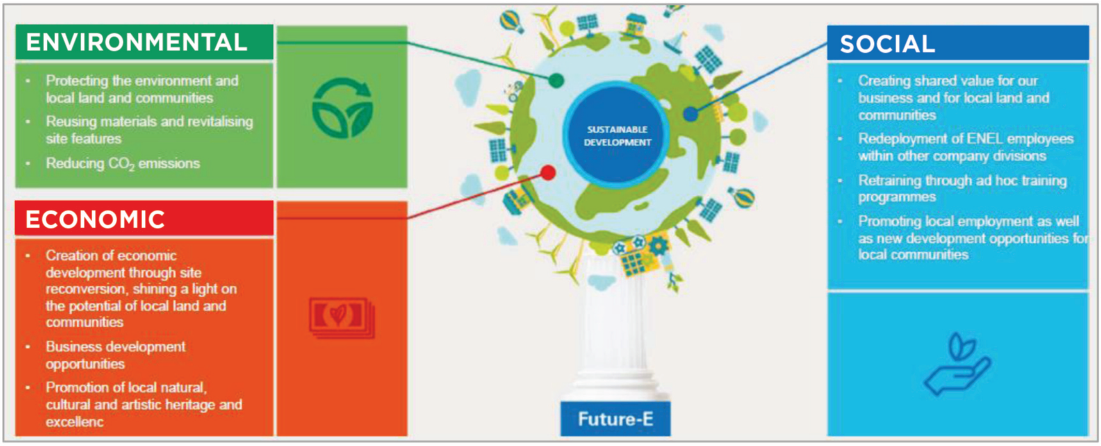

Fig.7 *The Futur-E program and the three pillars of sustainable development*

Implications on wholesale price formation

Wholesale price formation has historically been dominated by spot markets and short-term electricity price signals and, till now, policy makers have mainly focused on the integration of short-term electricity markets (*i.e.* day-ahead, intraday and balancing) giving little attention to the liquidity of long-term markets. European trading platforms for electricity generally offer contracts with delivery up to five years, but enough liquidity is available only for contracts with delivery below three years. For example, during 2014 only 1TWh was traded in German electricity markets with delivery in 2019.

The role of spot markets in wholesale price formation however is challenged by a number of factors, including: **decarbonisation**, the rapid penetration of RES assets characterized by low variable costs; **non market incentives**, a growing share of generating fleet subsidized by public programs and **divestments in end-of-lifetime of assets** whose fixed costs have been amortized.

Some further detail should help understand the challenge posed by these elements:

- **Decarbonisation investments** can be driven only by an adequate market design in which long-term price signals play a major role. The ambitious EU decarbonisation targets up to 2030 (and beyond) will require significant investments in new renewable capacity. These investments are in most cases characterized by high fixed costs and very low variable costs; indeed RES are infra-marginal technologies not naturally hedged against short-term price variations. If this risk is not mitigated by the development of long-term signals/agreements, it will result in increasing the financing cost of renewable projects and thus the cost of decarbonisation for final customers. In order to deploy more RES, the market design has to be fit for RES (i.e. allowing them to participate in all timeframes with a level playing field, and providing long-term price signals).
- **Non market incentives** are increasingly undermining the efficiency of spot market mechanisms by distorting their incentive structure. Early energy efficiency and renewable energy programs have led operators of plants benefiting from such incentives to become insensitive to market price signals. This has become especially critical in situations of oversupply, which have on one hand led to

over-remuneration of subsidized technologies and on the other to increased losses from non-subsidized sources. Furthermore, the long-term nature of many of the agreements and contracts underlying subsidies for promoted technologies, guarantee a reduction in uncertainty and market risk not enjoyed by market technologies. The latter is particularly significant and calls for a review of the balance between the role of short and long-term price signals in wholesale price formation.

- **Efficient divestment plans** in installed electricity capacity require a greater role for long-term price signals in the wholesale price formation process. These signals are particularly critical in meeting the adequacy issue, and to face the flexibility challenge brought about by the development of intermittent RES. Currently, European countries show both over-capacity (e.g. Italy) and under-capacity (e.g. the United Kingdom). These circumstances have been partly determined by the absence of long-term price signals. On one hand, investors are unwilling to put resources into markets with capacity deficits, on the other, without long-term price signals, investors are loath to divest assets in markets with capacity surplus and tend to wait for competitors to yield first. Finally, there are markets (*i.e.* Spain) where investments are urgently needed to avoid transforming the current condition of short-term apparent overcapacity in situations of future under-capacity. This behaviour could bring about an unordered closure of power plants moving the electricity system from over- to under-capacity. In addition, it is important to assure sufficient programmable power plants; able to maintain the instantaneous and continuous equilibrium between production and consumption of electricity. With long-term price signals, system adequacy is possible and the flexibility challenge can be met – *boom & bust* cycles are avoided with programmable capacity.

The wholesale market design needs to evolve and adapt to the new reality brought about by the low carbon energy transition. The current market concept was conceived at a time when electricity systems were characterized by large-scale, centralized conventional generation with high variable costs and relatively low fixed costs. Electricity systems are now moving away from this traditional scheme - towards a decentralized structure with a high and growing share of variable renewable energy sources. This historic transition is bringing about a shift in the cost structure of generation fleets, as the bulk of new plants coming online is characterized by high fixed costs and very low variable costs.

In a low carbon context, long-term price signals need to play a major role in the new market design. In order to achieve ambitious decarbonisation targets, markets need to deliver efficient price signals in all timeframes. The new market design paradigm should rely upon fully functioning and integrated day-ahead, intraday and balancing markets. It should also be complemented with long-term price signals and competitive schemes, which play a major role in allowing private investors to hedge the price risks of investments in new renewable capacity, reducing their financing costs and ultimately the cost of decarbonisation. Long-term price signals will also support the definition of efficient investment/divestment plans in conventional generation.

In order to provide these signals to all market participants the market design should be open to arrangements to procure long-term contracts with regulated counterparties. Long-term contracts can be for energy and firm capacity; the former offering a market-based remuneration allocated through a competitive auction. Without excluding other designs, the UK's *Contracts for Difference for RES scheme*, as approved by the Commission's Decision of 23 July 2014, can serve as a useful example. Long-term contracts for capacity could take the form of well-defined reliability options, *i.e.* one-way contracts for differences between generators and a TSO with proper lead and delivery periods and ensuring a level playing field for the participation of all sources. Such long-term contracts with regulated counterparties would minimize decarbonisation costs and define efficient investment/divestment plans for conventional capacity. It is of key importance to note that long-term contracts with a regulated counterparty for both firm capacity and energy, are meant as complementary to existing energy markets (*i.e.* forward, day-ahead, intraday and balancing) and not substitutes.

The greater role of long-term price signals in wholesale price formation should decrease volatility reducing uncertainty and investment risk premium. Such dynamics do not imply that variability associated with scarcity signals should be removed. Quite the contrary. In order to develop investments, prices must reflect actual situations of scarcity in the short and long-term markets. When capacity is not able to cover peak demand, maximum bidding prices should reflect the *Value of Lost Load* (VOLL). Allowing price spikes provides an incentive to invest in peak generating units and demand side management. Secondly, in order to avoid inefficient electricity flows during scarcity situations it is important to harmonize maximum and minimum prices between bidding areas. Thirdly, prices must signal situations of scarcity of flexible capacity. In fact, high prices during these situations incentivize conventional operators, RES producers and demand to improve the amount of flexibility they are able to provide to the system. Finally, prices must reflect situations of scarcity in transmission capacity.

Connection between wholesale and retail markets

Free the bill!

Since electricity is both a carbon-free energy vector and potentially generated from carbon-free energy sources, electrification is presently the fundamental answer to the objective of decarbonising economies both within electricity's traditional uses and as a substitute for other energy sources. In order to be competitive in areas such as transport[31] or *heating&cooling*, electricity bills need to be unchained from all the economic burdens not strictly associated to electricity's generation, transportation and service - an unburdening that would allow consumers to fully express their potential for power demand flexibility.

In Europe "… *between 2008 and 2014, policy support costs (levies) have increased on average by 170% for households. In 2014, the weight of the taxes & PSCs component almost equates the energy & supply component for the average residential consumer*" [32]. For example, the Italian electricity bill shows several policy driven liabilities to nominally cover: nuclear plant decommissioning; incentives for renewables, efficiency and R&D; tariff support to small island operators, railway operators, low income families, *etc.* These measures significantly affect mean electricity bills and translate into high, cost unreflective prices for several categories of consumers, including price sensitive industry.

As evidenced by Eurelectric[33], the paradox needing to be overcome across Europe, is the progressive divergence between wholesale prices, which are decreasing, and retail prices, which are generally increasing. This evident inefficiency leaves little room to provide consumers with efficient price signals based on authentic market dynamics and must be redressed.

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[31] IEA "*Key Facts*" 2016: *oil products' share of final energy consumption for transport is 93%, making the sector the least diversified. Transport energy and CO_2 emissions have increased by 28% since 2000.*

[32] Eurelectric "*Drivers of Electricity Bills: Supporting graphs …*" 2016.

[33] http://www.eurelectric.org/media/282159/retail_pricing_for_a_cost-effective_transition-lr-2016-2500-0008-01-e.pdf

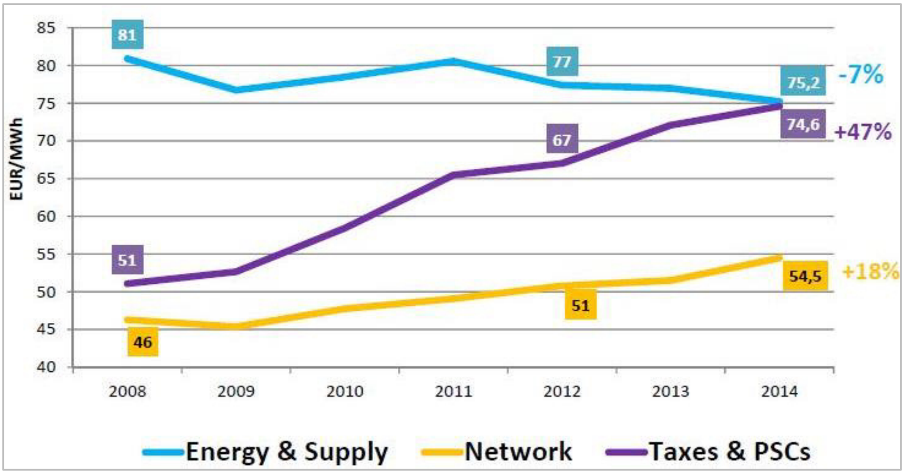

Fig.8 Increasing incidence of taxation & policy support costs on European residential bills (***Source***: Eurelectric)

Holistic infrastructure investment

The second element linking retail to wholesale is in the holistic infrastructure investment needed to imbed systemic efficiency, security and flexibility into and between the different voltage systems: "*system operators, TSOs and DSOs, must coordinate more on a day to day basis to keep the whole electric system reliable at affordable costs. This paradigm change triggers a mutation for both TSOs and DSOs and a joint new vision to give more flexibility to electricity networks*"[34]. Coordination will entail investment in infrastructure solidity, ICT, regulation and trading platforms/protocols.

This paradigm change has generated another - the entrance of new stakeholders and the changing role of traditional incumbents. As argued earlier in this paper regulatory unbundling, innovation, bidirectional energy flows, demand-side capacity response solutions, *etc*. have permitted a number of new players to enter the market: technologists, traders, supply/demand integrators and *pro-*

[34] EEGI Research and Innovation Roadmap 2013-2022

sumers. In a recent report, OFGEM[35] notes: "*A key development in the domestic retail markets over the previous year has been the continued growth of the independent suppliers[36]. These suppliers now account for around 10% of all customers … with 13 new independent suppliers entering the domestic markets since 2012, many using novel business models*".

It is therefore overall market design subject to these new paradigms, which regulators and other key stakeholders need confront, such as to optimise the competitive market mechanisms and investments that will guarantee an optimally distributed, price reflective and secure supply of electricity within given constraints (environmental, geographical or political).

Market Innovation

From an international perspective, there is an evident impulse to innovative technical standards and transparent policy instruments. Example initiatives covering trading, investments, regulation and integrated energy management include:

- **Bid-based markets (USA)**: ISOs *(Independent System Operators*) and RTOs *(Regional Transmission Organizations*) use bid-based markets to determine economic dispatch. Two-thirds of the nation's electricity load is now served in RTO regions as the FERC[37] pushes for matchmaking consolidation in what was previously a highly fragmented market;
- **SmartNet (Europe)**[38]: this Horizon 2020 funded project aims at comparing different architectures for optimized interaction between member TSOs and DSOs (*n.b.* 41 TSOs connected to over 2400 DSOs) in managing ancillary services (reserve and balancing, voltage regulation, congestion management) from subjects located in the distribution segment across Europe;
- **Grid Code development (Central America)**: the "*Sistema de Interconexión Eléctrica de los Países de América Central*" (SIEPAC) links six Central American countries and 37 million consumers. Development of a regional grid code

[35] UK *Office of Gas and Electricity Markets* (OFGEM): "*Retail Energy Markets in 2015*" report
[36] *sic*: suppliers entering markets since liberalisation
[37] FERC Order n.2000
[38] http://smartnet-project.eu/

system to regulate access and exchanges on the network is a priority towards supporting the creation of a single electricity market between Central America, Mexico and Colombia[39]. Similar initiatives are ongoing in Asia and Africa - many reflecting the Nordic Grid or ENTSO-E Network Codes;

- **Demand Response**: the European *Smart Energy Demand Coalition* (SEDC) & the California based *OpenADR Alliance* are just two examples of efforts to standardize different aspects of demand response across a large number of stakeholders and countries. *SEDC* promotes load shedding awareness and solution friendly legislation in Europe; whilst *OpenADR* is mainly about open technical and communication protocols and certifications both within the core US market and internationally.

Case study: Smart Meters & Smart Grids

*Study supported by **Alessio Montone** of **Enel**.*

Enel started to deploy its *Automated Metering Infrastructure* (AMI), also named *Telegestore project*, in 2001 and was the first DSO in Europe to adopt Smart Metering massively. Enel has installed 34 million smart meters on its distribution network in Italy and sold more than four million smart meters to other Italian distribution system operators. By exploiting the experience gained on AMI, Endesa, Enel Group's Spanish utility, is presently deploying a next generation metering infrastructure in Spain with seven million smart meters installed and a commitment to install more than 13 million by 2018. Shortly, Enel will start deploying its second generation *Smart Metering Solution* in Italy, replacing all 32 million meters within 5 years. Enel's *Meters and More* technology is becoming a *de-facto standard* in Europe.

The original "Telegestore" project had a budget of 2.1 billion euro and a five-year plan. Thanks to the remote management infrastructure, Enel in Italy can perform bidirectional, real-time communications with its meters remotely and

[39] http://www.eprsiepac.com/contenido/

automatically. In particular, the solution allows operators to remotely manage practically all contractual operations and measure consumed and (eventually) produced energy. At the same time, it can gather relevant data on the quality of electricity supplies while monitoring real time service continuity - intervening promptly in case of a network malfunction. Enel also manages the grid integra-

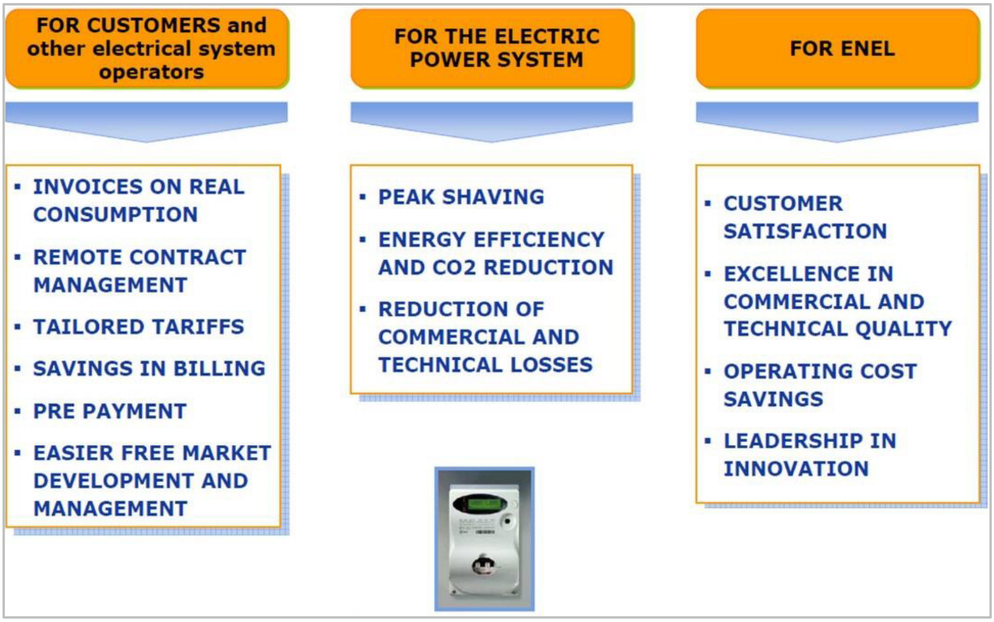

Fig.9 *Original benefits of Telegestore Project for its various stakeholders*

tion of more than 16GW of renewable energy generation with over 550.000 connections.

The revolution in digital technologies has been a springboard for a series of initiatives such as the remote control and automation of the network. Furthermore, Enel is making rapid progress in the field of electric mobility and has developed a complete, in-house infrastructure and systems for recharging electric vehicles with a view to supporting the development of ubiquitous e-mobility in its reference markets. Innovation is also allowing Enel to test cutting-edge solutions such as vehicle-to-grid; using electric cars as distributed storage to provide regulation services to grid operators.

Leveraging on its European experience, the Group is testing smart metering technologies in the Latin American countries where it has a significant presence

- Brazil, Chile, Colombia, Peru and Argentina – aiming thus to bring a tangible contribution to the development of innovative energy networks in these countries. In Chile, Colombia and Peru there are presently pilot projects involving more than 100,000 customers.

When it comes to measureable outcomes, AMI has enabled the liberalization of the Italian electricity market by allowing more than 10 million customers to subscribe to energy offers on the free market and 250,000 customers to change their energy supplier each month. The system takes almost 480 million remote readings and nine million remote operations per year. Since full rollout in 2007, savings have reached 450M€/year, compared to the 2001 baseline. Telegestore has brought customers substantial benefits including multi-tariff systems, flexible pricing and remote management of commercial operations.

Smart metering is just the beginning of the continuous improvement needed to render grids “smart”. Enel has developed an integrated system with hardware and software components for remote monitoring and automation of the network: real-time monitoring; selective fault detection logic; load shedding; optimization of network configurations; protection, coordination and integration of distributed generation. In Italy there are more than 150,000 secondary substations (one third of the total) and 2,100 HV/MV substations (100%) remotely controlled from 28 control centres: every control centre has its own SCADA (*Supervisory Control and Data Acquisition*) and manages more than 1 million LV customers.

All these investment have brought Enel’s Italian network to be a benchmark in terms of “*Quality of service improvement*” and “*Opex reduction per customer*”. Since 2001 interruptions have been reduced by 68% (128 to 39 min./yr/customer) and Opex by 35% (80 to 52€/yr/customer).

Implications for power companies (observed and foreseeable)

Implications for power companies in the European Union

Two defining traits of the low carbon energy transition have been:

- rapid technological change throughout the power value chain. Generation technology is being transformed by the fall in both industrial and deployment costs of RES technologies. Transmission and distribution technologies are evolving at unprecedented speeds driven by the penetration of digital technologies. The retail part of the value chain is transforming itself with offerings that are expanding well beyond the classical immaterial/commodity type product (electricity) and including services (*e.g.* energy management, energy audits) and new technological products (*e.g.* efficient appliances, electric vehicles); and
- increasingly flexible, dynamic and nimble investment sizes. As for the previous point, the entire value chain is affected. In generation the 40-50 years lifetime of conventional plants with deployment timeframes of five to ten years are being replaced by RES with 15-20 years lifetime investments deployable in one to five years. In transmission and distribution, network building timeframes of ten years and lifetimes of 40-50 years are increasingly leaving centre stage to digitalization projects with deployment timeframes of a couple of years and technologies that often become obsolete well within a decade.

To respond to such challenges, utilities in Europe have had to build consensus on the right equilibrium in terms of organizational disruption and to maintain the benefits delivered by their economies of scale. Patterns are emerging showing three different phases of organizational evolution:

1) **slow realization**: in the early phases utilities based on traditional business models and long life assets struggle to fully realize the full implications of the decarbonisation phenomena. The end-point of the process may be clear but perplexities and uncertainties exist as to the actual rate of decarbonisation to adopt. Such attitudes are often stimulated and/or reinforced by policy debates polarized between aggressive environmental agendas and conservative policies resisting change. Similarly, within utilities, it is often small groups from within the company that engage in raising awareness of the changing context;

2) **exploring**: in the second stage, the utility has fully realized the entity of the change and enters exploration mode. Different strategic lines are drawn and explored - be they in the renewable energy or in the energy efficiency space. To do so more effectively, management will usually free strategic new business lines from the existing core business processes; where traditional business model may hinder the development of new ideas. Independence is achieved through the creation of new divisions/business lines reporting directly to CEOs. As the new business lines become successful, they may be spun-off into separate legal entities in order to provide them with freedom of manoeuvre on both the industrial and financing fronts. Examples of such phase-two operators have been EON, EDF Energie Nouvelle and NRWE.
3) ***Upscaling***: once new business models have been consolidated they need to be up-scaled to take full advantage of the economies of scale enjoyed by the utility. Having grown in size, these separate legal entities are reabsorbed into the utility - both transforming the latter and benefitting from existing business processes. The old industrial processes are revised in order to be matched to the new reality and the utility renews. Example of such third phase utilities in Europe are Enel and Iberderola.

The new utility is now ready to operate effectively in what has become a drastically changed energy context brought on by the low carbon transition. A context made of constraints, which can become opportunities:

- ***Stakeholder engagement***: the low carbon transition brings enhanced stakeholder action - on one hand this signifies increased pressure and scrutiny, on the other opportunities to evolve virtuous, new ideas, engaging more effectively with the local communities in which the utility operates. Example of the latter are the CSV (Create Shared Value) approach adopted by the Enel Group with the local communities in which it operates.
- ***Increasingly ambitious mitigation***: existing assets are under continuous regulatory pressure to improve performance in terms of emission abatement and energy efficiency. Although such pressure may lead to costly investments, it can also increase the operational efficiency of plants.
- ***increasingly focus on customers:*** more and more customers expect higher quality and variety of services. This process is complemented by the increasing amount of client data delivered by the digitalization of the energy sector. Constraints such as privacy and development of compatible standards are matched by the opportunities delivered by new value-added services that

can complement a traditional energy offering characterized by ever falling margins.
- ***Highly competitive environment***: as already mentioned, the new low carbon transition market space is dominated by investments that are more nimble, flexible and smaller. Barriers to entry are lower in these market segments exposing utilities to increased competition by other industrial players in the area of both manufacturing and services. As a consequence, utilities will need to become more competitive in order to survive. At the same time, the business diversification brought by such transformation, makes utilities more resilient to changes in their core business.

The increasing number of competitors can be particularly significant, especially because such competition may come from extra-sectorial breed companies, forcing the utility to develop new business models and strategies. Competitors can include:

- data providers focusing on the digital side of the transition, namely monitoring consumption patterns and optimizing these through remote management of appliances
- aggregators exploiting the increasing value of flexibility on the power markets
- equipment manufacturers increasingly providing energy efficiency services complementing their product offering.

Even in this case risks can rapidly become opportunities when utilities adopt an "open innovation" approach exploring partnerships with operators active in adjacent and complementary market spaces. An example of such approach is the V2G (vehicle-to-grid) partnership between the Enel Group and Nissan/Renault as well as project partnerships developed by the Enel Group with RES equipment providers. The latter have allowed Enel Group to deliver competitive bids within public tender programs worldwide.

IMPLICATIONS FOR POWER COMPANIES IN CHINA

During the Thirteenth Five-Year Plan period, China's power generation companies are confronted with challenging circumstances. Tough and complicated international and domestic environment will drive the economy pursue a sustainable "new norm" growth model, and Chinese economy is projected to grow by about 6.5 percent annually[40]. Demand and supply situation of energy market will become more complex during this period, due to structural transition of Chinese economy. Electricity demand will maintain mid- or low-growth rate, about 3-4% per year, and even lower rate has appeared in 2015[41]. Coal consumption is now strictly limited by air pollution control especially in eastern provinces, and the government commitment of carbon emission peak by 2030 demands that coal consumption in China should reach peak around 2020. Also, today's severe overcapacity of coal-fired power plants will hinder new investment. China's Energy Revolution Strategy claims low-carbon, clean and smart development of power system. Moreover, market restructuring and reform of state-owned assets and enterprises will reshape the management and development systems of China's power companies.

In response to the volatile strategic environment and tough situation, China's power companies should promote and accelerate four strategic transformations: deepen the diversification of power sources away from coal dominant power mix; speed up the transformation to provider of more energy public goods; promote the strategic transformation to provider of energy service solutions and energy products; strengthen international cooperation and accelerate overseas development.

Firstly, China's power companies should continue the diversification of power sources away from coal-dominant power mix, which means that efforts to develop low carbon, clean and renewable energy sources should be intensified. Coal-fired power accounts for about 70%~80% of power generation of China's major power companies, which is a huge risk during China's energy transition to a green and low-carbon energy system. In early 2016, Chinese government announced that by 2020 electricity from non-hydro renewables should reach more than 9% of total electricity generated by power companies[42]. Therefore,

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[40] The thirteenth five-year plan for national economic and social development of the People's Republic of China.
[41] In 2015, the growth rate of electricity consumption in China is only 0.5%.
[42] The government document on the establishment of renewable energy development and utilization objective guidance system.

China's major power companies should accelerate the development of wind, solar, and other renewables. Preliminary analyses show that in order to deal with this structural risk, power companies should increase the capacity share of clean energy sources to more than 40% by 2020.

Secondly, China's power companies should speed up the transformation from electricity generator to provider of more energy public goods, including heat, cooling, steam, coal and natural gas. Electricity has always been the main product and also the largest source of turnover (over 80%) since China's power companies were founded. With the implementation of China's Energy Revolution Strategy, more and more energy market segments will be open to competition, which means great opportunity for China's power companies to expand their business and provide more energy public goods. Meanwhile, the integration of electricity and other energy public goods, such as heat, cooling, steam, coal and natural gas, should be strengthened to ensure more cost-efficient fuel supply and lower operational risk.

Thirdly, China's power companies should promote the strategic transformation to providers of energy service solutions and energy products, meaning that energy distribution and retail services, integrated energy finance services, energy technology services, energy trade and logistics services should be vigorously developed with corresponding energy market restructuring. Due to historical reasons, China's power companies own no transmission and distribution grid assets, and State Grid and Southern Grid Company are the only two buyers in China. With the further deregulation of energy markets, energy distribution and retail services will be open, which means that they could conduct face-to-face transactions with final customers and provide more services based on their own advantages, such as energy saving and pollution control services, energy management contract services, carbon asset management services, demand side response services and financial services for customers.

Finally, China's power companies should strengthen international cooperation and accelerate their overseas development. To strengthen international cooperation is one of the five aspects of China's Energy Revolution Strategy. In the past thirty years, China's power companies focused their development on domestic market and did their best to meet the rapid growth of national electricity demand. Nowadays, the problem of power supply shortage in China has been settled. They should put more resources on internationalization, as the government is promoting international cooperation under the Silk Road Economic Belt and the 21st-Century Maritime Silk Road initiatives. Along with more and more countries note that infrastructure and its connectivity is key to achieving sustainable development and shared prosperity[43], it's a good chance for China's power companies to invest power infrastructure in overseas, especially in the countries along the Belt and Road.

Conclusions

The energy transition represents a major and welcome paradigm shift.

The drivers and trends of the transition are global. Depending on local context, so too are the solutions to guarantee its goals. Operators, given continuously evolving scenarios, require regulatory and political institutions to share a strategic vision. Greater effort is needed to enable cross-border cooperation, render electricity supply and demand more flexible, rethink market remuneration and standards, eradicate carbon emissions across industries and systematically motivate market stakeholders to assume their relative obligations.

[43] G20 Leaders' Communique Hangzhou Summit 2016

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