EU ELECTRICITY REFORM

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May 2022

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PREFACE

Electrical experiments are, of all others, the cleanest, and the most elegant, that the compass of philosophy exhibits. They are performed with the least trouble, there is an amazing variety in them, they furnish the most pleasing and surprising appearances for the entertainment of one's friends, and the expense of instruments may well be supplied, by a proportionable deduction from the purchase of books, which are generally read and laid aside, without yielding half the entertainment.

Joseph Priestley
The history and present state of electricity: with original experiments
London, 1775

This text is neither a book, nor a conventional report. Before you read it (or just lay it aside…) let me explain why – and how you should read it.

I believe that the existing cross-border EU electricity market model (to which foundation I proudly contributed, together with so many like-minded colleagues and friends) needs deep structural reform. The required reform is not comparable to replacing one piece in a machine or even to replacing a machine through a new model of the same machine. Therefore, it is not my intention to prescribe how to repair the machine, or how to design a new one. This text is not a handbook.

The first goal of the present report is to substantiate the need for structural reform by highlighting key weaknesses of the current market design. Secondly, it addresses today's major difficulty about decarbonized and digitalized energy systems: how to think and to talk about them – in a certain sense, how to imagine them. Consequently, the present text has a fragmented structure, each part shedding light on some topics from different angles and suggesting a particular set of notions suitable for grasping the challenges ahead and appropriate for the design of new electricity architectures. It is a kind of a *thought experiment* for going forward – hopefully, a "pleasing and surprising" one.

ACKNOWLEDGEMENTS

The views expressed here reflect innumerous conversations with many friends and colleagues who have provided bright ideas, useful suggestions and straightforward criticism. In particular as regards the present text, I would like to thank David Newbery, Felix Matthes, Jean-Michel Glachant, Joísa Dutra, Leigh Hancher, Matthias Finger, Philipp Offenberg, Sami Andoura, Vicente López-Ibor Mayor and Zsuzsanna Pató. Maria Vasconcelos contributed to research and drafting of several Sections. However, the views and opinions expressed in this report are those of the author.

The author gratefully acknowledges financial support by Breakthrough Energy.

EXECUTIVE SUMMARY

EU electricity and natural gas markets were created in the 1990s to reduce energy costs. At that time, electricity was a mature sector and natural gas a fast-growing industry.

In the meantime, the EU has adopted ambitious climate and energy policies, requiring, i.a., full electricity decarbonization and electrification of the transport and heating sectors. The European Commission expects electricity demand to more than double by 2050, while natural gas demand is expected to halve by 2030 and to be phased out soon thereafter. Achieving the “Fit for 55” goal means doubling renewable energy sources by 2030. The future role of new fuels (e.g., green gas) is uncertain.

As a result of the Russian war against Ukraine, the EU decided to accelerate the “*reduction of our overall reliance on fossil fuels” and to speed up the development of renewable energy sources, also “improving energy efficiency and the management of energy consumption, and promoting a more circular approach to manufacturing and consumption patterns*” (Versailles Declaration of March 11, 2022).

Squaring the reduction of greenhouse gas emissions (55% by 2030, net zero by 2050) with efficient energy markets and revamped energy infrastructures is a difficult, yet unavoidable and urgent task. This requires a fresh look at how we manage both, designing new energy architectures, new legal frameworks and new regulatory policies that fulfil these multiple goals, supporting electricity expansion and phasing out natural gas.

How to imagine future – fully decarbonized and digitalized – energy systems and how to manage the EU energy transition? This report offers a set of suggestions:

1) Energy system integration

- **Energy system integration, including electricity market redesign, is the basic principle of energy system transformation**: *“Energy system integration – the coordinated planning and operation of the energy system ‘as a whole’, across multiple energy carriers, infrastructures, and consumption sectors – is the pathway towards an effective, affordable and deep decarbonisation of the European economy in line with the Paris Agreement and the UN’s 2030 Agenda for Sustainable Development.”* (EC, 2020). Nowadays, considering commercially available techniques and their respective costs, energy system integration can be best achieved through electrification of mobility and heating/cooling. Therefore, it takes place predominantly at local level.

- **Integration through electrification requires the existence of a suitable local “electricity platform”**: With the primary goal of facilitating “horizontal” energy system integration (as opposed to the traditional “vertical” role of just carrying electricity to end-users), electricity platforms will be the key integrative and transformative tool. Each local platform has two sides, a physical infrastructure and a transactional superstructure, and the two are inseparable like the two sides of a coin. They can support the deployment of new resources and devices, new transactions and new business models, as long as they are suitably built upon existing electricity distribution networks.

- **Overcoming the technical and institutional challenges of energy system integration requires skills and training usually not yet available at local level:** The development of electricity platforms performing energy system integration at local level requires all energy-related sectors to be treated simultaneously and consistently, the abolishment of organizational silos, cooperative co-design and extensive participation of numerous stakeholders.

2) New energy architectures

- **Multi-sector and multi-level energy architectures provide a coherent approach to all energy-related sectors (electricity, gas, heating and cooling, electrical transportation, waste-to-energy, etc.):** Energy-related sectors are increasingly coupled by climate policy and the rise of energy digitalization, requiring co-ordination of regulation, market, and system operation. Multi-sector and multi-level energy architectures must also ensure a dynamic balance between the "creative destruction" of market forces and technical innovation, on the one hand, and the intrinsic stringency of system reliability, on the other hand.

- **A new, multi-sector and multi-level EU energy architecture, builds upon the existing Internal Energy Market:**
  -First, through the establishment of robust and fast growing local, sector coupling electricity platforms, to manage energy system integration according to the respective local resources and institutional context. These platforms must combine competitive and cooperative features, putting consumers at the heart of the energy transition. Local architectures promote, by design, energy flows following a comprehensive "technical metabolism" pattern aimed at optimizing resource efficiency and minimizing waste, according to the circular approach.
  -Second, through the modification of the current EU electricity market regulatory framework to enable its transformation from a unified "single market" into a unifying platform of (local) platforms.

- **This report provides a conceptual framework for the design of multi-sector and multi-level energy architectures and for a corresponding electricity market reform:** The need for such a reform arises from the fact that many underlying assumptions of the 1990s do not hold anymore. For instance, in many EU Member States the amount of electricity generation capacity with State guaranteed remuneration already exceeds 50% of total installed capacity, with a fast-growing trend. A combination of increased network scarcity and rehabilitation of the long-term approach created a situation where practically all new electricity generation investments have a State guarantee. Moreover, integration of planned large-scale offshore wind plants with the existing continental European interconnected system also requires substantial amendments to operational and market rules.

- **Evolution:** The proposed EU electricity reform may be seen as the second wave of monopoly eradication: the first wave, in the 1990s, abolished national generation, supply and import/export de *jure* monopolies; now, it's time to end de facto wholesale market monopolies. Overall efficiency requires current wholesale electricity markets to be open up not just to new market actors, but also, and above all, to competition from alternative, local platforms. Decarbonization today, like liberalization yesterday, require structural, disruptive change through true competition and innovation.

Building new energy architectures and adapting the current electricity market model to them, instead of postulating the current (legacy) electricity market model as the only possible energy architecture's foundation, is the essence of a successful energy transition.

3) Networks and planning

- **Price signals from energy-only wholesale markets have been unable to promote the necessary network investments:** Empirical data collected over the first two decades of EU electricity liberalization show that price signals from energy-only wholesale markets were unable to promote the necessary network investments – between 1996 and 2015, the length of transmission lines (440 kV plus 220 kV) even decreased in Germany and Italy, while congestion and redispatching costs continuously increased across Europe. More recently, EU transmission network planning procedures and methodologies have substantially improved; hopefully, this progress will soon encompass distribution networks.

- **Network expansion to support a twofold increase of electricity demand by 2050, as required by the Green Deal, requires more than reliable price signals and a widened scope:** Expansion and digitalization of electricity networks are a sine qua non condition for achieving carbon neutrality, strategic energy autonomy and efficient competition. In the past, energy markets did not promote network development, but network development will promote efficient energy system integration and competitive, centralized and decentralized, markets. Network expansion thus requires some explicit and coherent planning, in addition to more reliable price signals than the ones provided by wholesale markets where 50% and more of total installed capacity enjoys a State guaranteed price.

- **New energy governance:** Regulation (EU) 2018/1999 was a first and very important step towards increased coherence of EU energy governance, but a second step is now needed to effectively support decentralization and energy system integration, also considering the need for additional elements of infrastructure planning and more stringent ex ante regulation.

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INTRODUCTION

Electricity and gas prices unexpected surges observed in the second half of 2021 led many decision-makers and public opinion in general to question the functioning of present-day electricity and gas markets in Europe. The fact that in 2020, in the EU, mainly as a consequence of Covid-19, electricity and gas prices had reached their lowest values ever, compounded the perception that excessive price volatility and excessive prices must be a symptom of EU energy markets dysfunction.

By the turn of the year, many observers expected that the 2021 price surge would vanish soon, similarly to the last energy price crisis, back in 2008, relieving energy consumers and policymakers alike. Unfortunately, the Russian invasion of Ukraine, in February 2022, put an end to such expectations. Daily natural gas prices (TTF) that had reached 50 €/MWh on August 31, 2021, were above 100 €/MWh on October 5, touched 180 €/MWh on December 21 and, following a period of relative stability in the ensuing weeks, around 80 €/MWh, reached 227 €/MWh on March 7, 2022. Futures for the current year trade above 100 €/MWh, for 2023 above 80 €/MWh and for 2024 above 60 €/MWh. Electricity prices experienced similar swings and baseload German futures trade currently at 200 €/MWh for 2023, 150 €/MWh for 2024 and above 120 €/MWh for 2025.

Many factors contribute to the current energy price crisis: some causes are transient and exogenous to EU energy markets, while other factors are intrinsic. The present study is mainly concerned with those structural, intrinsic features, namely with the growing mismatch between market structures and energy and climate public policies. This problem has been discussed for many years by some experts and it is analysed in detail in this report.

The main objective of the present report is to provide a comprehensive conceptual framework for discussing EU electricity reform and enabling large-scale deployment of clean technologies and energy digitalization, a prerequisite for economically and socially efficien decarbonization and strategic energy autonomy.

The present report is divided into four parts:

- Part I identifies the main challenges to the current market design, mainly resulting from new decarbonization and security of supply policies.

- Part II provides two brief excursus, both putting electricity into context: in the ongoing wider energy transformation process and historically. This background is not indispensable, but it helps understanding how to move forward.

- Part III is the core of the report, describing the proposed conceptual framework for EU electricity reform.

- Part IV includes several short notes on relevant topics for further development and implementation of the proposed conceptual framework.

The author takes sole responsibilty for the views expressed in this report, but he acknowledges the contribution of a large number of experts who kindly read previous drafts and made extremely useful suggestions.

PART I

Identifying the challenges

DECARBONIZATION AND ENERGY MARKETS

Long difficult to manufacture, and even more so to fix, green is not only the color of vegetation; it is also and above all that of destiny.

Michel Pastoureau, *Vert. Histoire d'une couleur*. 2013

Back in 2011, the European Council concluded that "*reducing greenhouse gas emissions by 80-95% by 2050 compared to 1990 as agreed in October 2009 will require a revolution in energy systems, which must start now*".

The candour and wisdom of this statement were not duly appreciated until the 2021/2022 energy price crisis. It is now obvious that without the required "*revolution in energy systems",* another revolution may well take to the streets again, multiplying and amplifying *gillets jaunes'* discontent.

According to successive polls, Europeans endorse the Green Deal. Moreover, investors have committed to finance it; they also actively support the establishment of new taxonomies, corporate codes, and innovative funding vehicles. However, if high energy prices persist, ad-hoc interventions proliferate, and decision-makers fail to provide a convincing and coherent explanation about the necessary structural transformation of our energy systems in general – and of the electricity system in particular – public opinion support may vanish and, deprived of social support, investors will shy away from the energy sector, leaving energy decarbonization half-way.

EU decarbonization goals have been and are ambitious and sharp, but until now the "energy transition" process lacks the same degree of clarity, in particular as regards EU electricity market reform. Now is time to reduce fuzziness and to provide more concrete guidelines to small and large investors alike. Short-term measures may be useful to address both vulnerable and energy intensive consumers' problems related to anomalous high energy prices, but they are not necessarily helpful to enhance medium-term clarity – on the contrary, unharmonized "quick-and-dirty" remedies tend to worsen structural problems.

Squaring the reduction of greenhouse gas emissions (55% by 2030, net zero by 2050) with efficient energy markets and revamped energy infrastructures is a difficult, yet unavoidable and urgent task. It requires a fresh look at how we manage both, going back to basics and designing new energy architectures, new legal frameworks and new regulatory policies that fulfil these multiple goals. **Decarbonization requires and digitalization enables the creation of new, multi-sector and multi-level energy architectures** oriented towards energy system integration. Building these new energy architectures to fulfil the above-mentioned goals, and adapting the current electricity market model to them, instead of postulating the current (legacy) electricity market model as the only possible energy architecture's foundation, is the essence of a successful energy transition.

This is an evolutionary process: new technical, business and institutional realities emerge, while old structures change and adapt to new boundary conditions and to new goals. It takes years to fully implement these changes. In this sense, energy transition is about accelerating evolution, not about revolutionary replacement of existing market structures overnight. Yet, a revolution is urgently needed *now*, concerning the way we *think* about energy systems. The "*revolution in energy systems"* is indeed a Copernican revolution - solar energy plays a central role in the renewable energy mix… - because the internal electricity market must be set into motion, instead of being seen as the static centre of a future decarbonized energy galaxy.

From a material point of view, reaching EU goals in 2030 and in 2050 requires the introduction and large-scale deployment of clean technologies and innovative solutions, regarding not only the renewable energy supply-side and the increasingly flexible demand-side, but also the disruptive "new entrant" in-between, i.e., storage – both decentralized and centralized, both short-term and seasonal. However, large-scale physical deployment of those new energy resources has been delayed and is only partially feasible within the current energy market arrangements and regulatory model; therefore, electricity market reform is a critical step and a *conditio sine qua non* towards energy decarbonization through large-scale innovative investments on both centralized and decentralized resources.

Although electrification plays a crucial role in the road to net zero, this does not imply that the current electricity model should be imposed upon all sectors, such as electrical mobility and heating. Coupling – also called integration – of all energy-related sectors requires due consideration being paid to all sectors and suitable interactions and interfaces being established within the energy system, around the new "electricity platform". Electrification is a practical and cost-effective way of decarbonizing most energy-related sectors, it is not an end in itself. The current electricity market model was designed to deliver a product (electricity, although this product is assembled from several sub-products such as base, peak, daily spot, futures, etc.); the new market model must deliver a basic service (i.e., using the so-called electricity platform – see Section *A new EU energy architecture*) that enables delivery of multiple end-user services (heating, cooling, mobility, etc.) and multiple types of energy (electrical, thermal).

Multi-sector integration must be the starting point for the new energy architecture, as clearly pointed out in the Commission's 2020 Communication "Powering a climate-neutral economy: An EU Strategy for Energy System Integration" :

*“**Energy system integration – the coordinated planning and operation of the energy system ‘as a whole’, across multiple energy carriers, infrastructures, and consumption sectors** – is the pathway towards an effective, affordable and deep decarbonisation of the European economy in line with the Paris Agreement and the UN’s 2030 Agenda for Sustainable Development.”*

Integration is feasible and potentially deeper at urban level, where the largest energy “consumption sectors” are located. Therefore, market (re)design must start at local level, to enable optimisation of all relevant distributed energy resources. At local level, where everything is or can be physically interconnected, everything needs to be invented: how to coordinate economic and physical transactions across sectors, how to ensure reliable operation of the electricity platform, governance, regulation, etc.. This is indeed a huge legal and institutional challenge. Moreover, at the same time, energy digitalization is changing the very nature of each and all “consumption sectors”. Understanding the challenges of energy digitalization, both from the digital perspective (e.g., cybersecurity, data science applications) and from the point of view of electrical systems (e.g., ensuring observability and stability under multiple control flows – see Section *The control flow problem*) is a daunting task.

Local energy systems will not be operated in geographical isolation: thanks to the existing interconnected electricity network, they will be able to cooperate and to compete with resources located in other geographical areas. However, this requires reforming the current governance and regulation of the internal electricity market, somehow extending its scope to the local level, introducing new functions (beyond enabling coupling of national daily and intra-daily markets) and ensuring multi-level coherence. The present rules must be changed to accommodate local energy systems diversity (among themselves, and as compared to the current centralized system), thus accomplishing energy system integration throughout Europe.

The necessary reforms concern not only the way energy systems are integrated and jointly operated, but also the way energy infrastructures are planned in order to enable their interaction and their qualitative transformation through the massive deployment of new, clean technologies, and digitalization.

There are several aspects involved here, such as energy planning methodologies (improving TYNDP (Ten-Year Network Development Plan) and facilitating the adoption of new planning methods at local level - neither deterministic nor probabilistic, but rather fuzzy), reviewing tariff setting, accommodating large-scale projects such as off-shore wind farms, etc..

At the same time that energy system integration takes place throughout Europe, leading to increased decentralization of energy resources, some Member States plan very large offshore wind power plants, sometimes crossing national borders. These hyper-centralized resources represent a different type of challenge, not only as regards their physical connection to the transmission network, but also in terms of their impact upon overall reliability and functioning of the interconnected system.

The existing electricity transmission system is under pressure from both sides: from below, where new interfaces with numerous, decentralized, locally integrated energy systems are urgently needed; from the top, where a few hyper-centralized supply centres could emerge in coming decades, bringing their own *ad-hoc* multi-jurisdictional governance and establishing their own integration paths, namely with different storage techniques.

"[T]he importance of an integrated approach to climate change, energy and competitiveness objectives"[1] has been recognized by the European Council since 2005. Now is time to act.

1 European Council presidency conclusions, Brussels 15 & 16 December 2005

SECURITY OF SUPPLY AND ENERGY MARKETS

"My support to Nord Stream 2 was clearly a mistake. We clung to bridges that Russia no longer believed in and that our partners warned us about." We have to "reconsider some things where we made mistakes."[2]

Frank-Walter Steinmeier, President of Germany, April 4th, 2022

Supposing that rhetoric bridges between new sustainability policies and existing energy markets will deliver the desired climate and competitiveness results, without deeply reforming energy markets (in particular electricity) is a mistake, as pointed out in the previous section. Likewise, imagining that commercial bridges (e.g., multi-billion euro pipelines) with an increasingly dominant primary energy supplier would deliver security of supply and competitiveness, was a mistake, as recently recognized, among others, by the President of Germany.

Leaving security of gas supply to "the market" and to "cost-benefit" analysis based on dubious assumptions and parameters, instead of following a common European approach, was another mistake, as illustrated, for example, by the 2019 rejection of the construction of new gas interconnectors between France and Spain by the respective energy regulators. The language of the French regulator's decision clearly reveals the dominant short-term national approach and the lack of a EU long-term strategic perspective:

"The MidCat project, which involves the development of additional firm capacity of 230 GWh/d in the Spain-France direction and 160 GWh/d in the France-Spain direction, would require, in addition to the new interconnection proper, the reinforcement of the French internal network, in particular through the implementation of the Eridan and Est Lyonnais projects. The total cost of the necessary investments on the French side has been estimated at more than 2 billion euros by the three TSOs (GRTgaz, Teréga, Enagás). The MidCat project was identified as a Project of Common Interest in 2015. The cost/benefit analysis carried out within the framework of the TYNDP 2017 shows benefits that are not sufficient to offset the cost of the project."[3]

The Iberian Peninsula hosts 7 operational LNG terminals (out of 22 in the whole EU) with a combined maximal technical physical capacity of 2 110 GWh/d. This figure

2 Frankfurter Allgemeine Zeitung, 5.4.2022, p. 3 : Am Montag sagte er dann: *„Mein Festhalten an Nord Stream 2, das war eindeutig ein Fehler. Wir haben an Brücken festgehalten, an die Russland nicht mehr geglaubt hat und vor denen unsere Partner uns gewarnt haben." Steinmeier ging weiter, wurde grundsätzlich. Die Verantwortung für den Krieg liege bei Putin, sagte er, die sollten wir „nicht auf uns ziehen". Das heiße aber nicht, „dass wir nicht einiges zu überdenken haben, wo es unsererseits Fehler gegeben hat".*

3 *CRE, Délibération de la Commission de régulation de l'énergie du 27 mars 2019 relative à l'examen des plans décennaux de développement de GRTgaz et Teréga*. https://www.cre.fr/Documents/Deliberations/Decision/Projet-d-interconnexion-gaziere-STEP (our translation).

compares with 1 742 GWh/d at the Russia/Germany entry point. However, the maximum pipeline capacity between Spain and France is just 224 GWh/d[4]…

Security of energy supply concerns are currently more acute in the natural gas sector than in the electricity sector. However, at operational level, blind reliance on market forces without proper monitoring and governance has been also responsible for several critical situations in the interconnected European electricity system over the last decades. Security of supply concerns in electricity related to the possibility of missing generating capacity in the future, due to insufficient generation investments, for whatever reasons[5], have been addressed through so-called Capacity Revenue Mechanisms. The impact of those mechanisms upon pre-existing wholesale electricity markets is not yet well understood[6]. Therefore, security of supply, considering the different time scales, the different elements involved in its definition, and the way it is translated into operational market features and infrastructure planning, regards both gas and electricity.

Moreover, gas-fired power plants played an essential role in electricity liberalization, as indicated by the figures in the next paragraphs, thus establishing a close relationship between natural gas and electricity markets. This link was critically exposed by the 2021/2022 energy price crisis and some Member States call for "delinking" as a means of mitigating electricity price increases.

In 1990, only 5 EU-27 Member States had installed combined cycle gas turbines (Belgium, Ireland, Spain, Hungary and the Netherlands), amounting to less than 2 GW altogether. This figure compares with 13 GW gas turbine power plants and 208 GW steam generators (mainly coal-fired power plants) in the same year. By 1996, when electricity liberalization started, circa 8 GW combined cycle power plants were present in 10 EU-27 Member States. In the year 2000, 25 GW were installed in 17 Member States. In 2020, 118 GW were installed in all but 4 EU-27 Member States (Estonia, Luxembourg, Romania and Slovenia), generating 560 TWh, i.e., 20% of total electricity generation. In the same year, other steam generators capacity was 151 GW and gas turbine power plants amounted to 17 GW[7].

The EU fleet of gas-fired power plants (both combined-cycle and open-cycle) is relatively new and plays as essential role in covering electricity demand in almost all EU Member States, although with different weights in different countries. For instance, in the period 2010 to 2020, gas-fired electricity generation represented roughly between 10% and 20% of total electricity generation in Germany, between 30% and 40% in

4 ENTSOG https://www.entsog.eu/sites/default/files/2021-11/ENTSOG_CAP_2021_A0_1189x841_FULL_066_FLAT.pdf

5 David Newbery, Missing Money and *Missing Markets: Reliability, Capacity Auctions and Interconnectors.* EPRG Working Paper 1508, Cambridge Working Paper in Economics 1513, 2015.

6 Francisco Moraiza and Dominic Scott, *The Impact of Capacity Market Auctions on Wholesale Electricity Prices*. The Energy Journal, Vol. 43, No. 1, 2022.

7 Data from Eurostat

Spain, between 40% and 50% in Italy, and between 50% and 60% in the Netherlands.

The expansion of natural gas demand in the EU, both for end-use and for electricity generation, was and remains constrained by EU climate policy and by EU decarbonization targets. The reduction of natural gas demand is not an accident: it was indeed, from the very beginning of EU climate policies, an explicit and quantified goal, a logical consequence of decarbonization.

The EU has taken the lead in combating climate change since the 1990s and in 2007 it set targets for 2020, namely to reduce greenhouse gas (GHG) emissions by 20% compared to 1990, which have since been replaced by more ambitious targets for 2030 (reducing GHG emissions by 55% compared to 1990) and for 2050 (carbon neutrality).

EU policies have been successful: GHG emissions in 2020 were 31% below the 1990 value[8] (in 2019, before the pandemic: 24%[9]). The total use of energy decreased, in the same period, by 8%[10], with different reductions for coal (65%) and oil and petroleum products (17%), contrasted by a 31% increase for natural gas. However, the increase (44%) in demand for natural gas was recorded in the period 1990 to 2005; then, between 2005 and 2010, the demand for natural gas stabilized and, between 2010 and 2020, it decreased by 10%.

Impact analyses of the 2020 targets, carried out in 2007 and published by the European Commission (EC) at the beginning of 2008, clearly indicated that this decarbonization policy would translate into a combined reduction in oil and gas imports of between 41 and 48 billion euros in 2020[11]. Also in 2008, the EC quantified the impact of new policies on the reduction of physical energy demand and energy imports, as part of a review of the EU's energy policy[12] - see Figure 1 showing a graph used in public presentations by EC officials at that time[13] describing the expected reduction of natural gas imports according to the 2020 objectives, called "New Energy Policy". However, this information was not internalized in market design and regulatory policies.

In reality, although total natural gas demand decreased 9.4% in the period 2005 to 2019, natural gas imports increased 25% in the same period[14].

8 https://www.eea.europa.eu/highlights/eu-achieves-20-20-20

9 https://ec.europa.eu/clima/eu-action/climate-strategies-targets/progress-made-cutting-emissions_en

10 https://ec.europa.eu/eurostat/web/energy/data/database

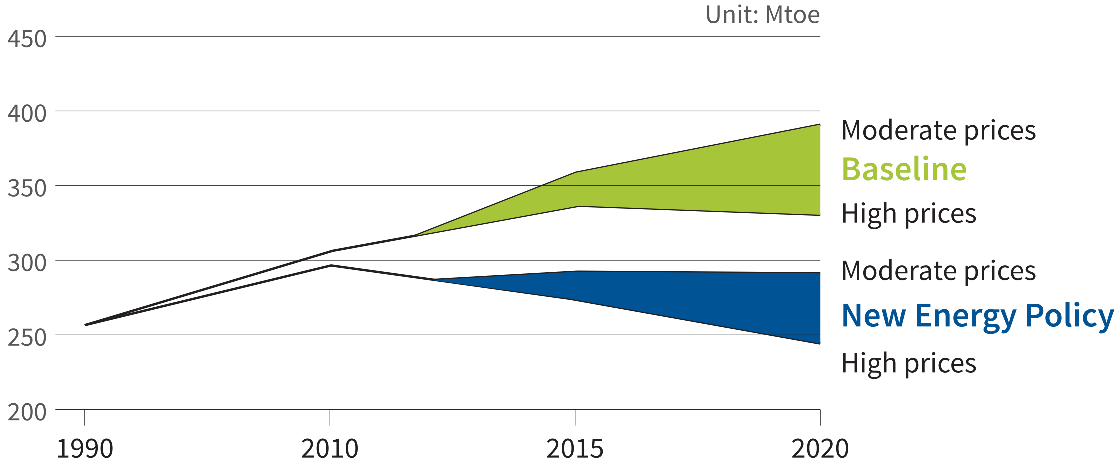
11 Commission staff working document SEC(2008) 85, Vol. II, of 27.02.2009, p. 210. https://ec.europa.eu/clima/system/files/2016-11/climate_package_ia_annex_en.pdf. Figures for EU-27 at that time, i.e., with United Kingdom and without Croatia.

12 Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Second Strategic Energy Review. An EU energy security and solidarity action plan. SEC(2008) 2794.

13 Presentation by Jean-Arnold Vinois at the United Nations Economic Commission for Europe special session on "Strategic alliances for Energy Security", Geneva, 19 November 2008. https://unece.org/fileadmin/DAM/energy/se/pp/EnCom17/19Nov/13_Vinois.pdf

14 All Eurostat figures relative to EU-27 2008, i.e., with United Kingdom and without Croatia.

Figure 1 | **Expected reduction of EU natural gas imports by 2020, computed in 2008**



Source: EC

Also in 2007, the EC presented proposals for new electricity and gas directives that led to the so-called 3rd energy package, approved in 2009. Nowhere, in the articles or in the explanatory memorandum, the expressions "reduction", "decrease" or similar ones can be found. This clearly shows how the (proposed and approved) new "common rules for the internal market in natural gas" ignored the "new energy policy", namely the goal to reduce fossil fuels demand by 2020.

In fact, the new common rules were just an upgrade of the previous rules, established by the 1998 and 2003 Directives, when gas demand dynamics was completely different: EU-28 natural gas demand increased 26% between 1990 and 1998 and a further 19% increase was witnessed between 1998 and 2005. Since then, natural gas demand is slowly decreasing.

The current wholesale natural gas market was designed to support fast growing gas demand, not to cope with decreasing demand. Implementing the Green Deal means accelerating fossil fuel demand reduction and this requires addressing new challenges in natural gas markets, changing paradigm from expansion to contraction, and managing phaseout instead of ramp-up.

The necessary changes concern not only market design and regulation, namely as regards issues such as stranded costs and the introduction of biogas and hydrogen, but also application of competition law to gas markets. To minimize overall transition costs and ensure security of supply throughout the energy transition process, cooperation must be reinforced, both among Member States and between the EU and major natural gas suppliers. These necessary long-term agreements are crucial for an orderly transition process, otherwise gas supply countries and gas supply undertakings will be reluctant to accomplish the required investments (both to replace outdated assets and to enable geographical import diversification) and to provide decreasing gas quantities to Europe at affordable prices.

The EU must be clear and transparent about the envisaged phasing out timetable and the main features of "managed competition" during this period. The use of fossil fuels in general and of natural gas in particular will be firmly and quickly reduced in the EU as a result of policy decisions, with competition playing a subsidiary, albeit relevant, role.

Phasing out natural gas will not be the outcome of either perfect competition or destructive competition – it will be the product of "managed competition" under the Green Deal.

The more explicit the political and regulatory meaning of "management" in this context is, the more "competition" can subsist during the transition, for the benefit of energy consumers. On the contrary, pretending that the "perfectly competitive" current EU natural gas market, either as it stands today or as an envisaged ideal type "target model", jealously preserved from political interference, will spontaneously lead to natural gas phaseout, paves the way for an expensive and disorderly transition through all kinds of collusion and market power abuse.

Given the importance of natural gas in electricity generation, as explained above, phasing out natural gas must be properly managed also in the internal electricity market. Since gas-fired power plants have higher costs than photovoltaic and onshore wind power plants, and because one urgent EU goal is now to accelerate *"the reduction of our overall reliance on fossil fuels"*, *"speeding up the development of renewables"* (Versailles declaration of 11 March 2022), utilization of gas-fired power plants will decrease in the coming years. However, their contribution to cover electricity demand is crucial, given the intermittent nature of renewable sources, the slow deployment of storage resources and the uncertain future contribution of new clean fuels.

The existing electricity market model assumed that power plants could participate in the market as long as they were competitive, potentially until the end of their technical lifetime. This assumption does not hold anymore for gas-fired power plants: according to EC forecasts[15], by 2030 natural gas electricity generation will be halved. In 2020, the average utilization factor of EU combined cycle gas turbine power plants was 54%; therefore, many such power plants will be below the profitability threshold well before they reach the end of their lifetimes, unless either a) they get extra

15 EC, Commission staff working document SWD(2020) 176 final of 17.9.2020, Part 2/2, Fig. 46 on pg. 58

revenues (e.g., some kind of capacity payment) or b) electricity prices are so high that they provide enough remuneration - in this case, keeping the current marginal price model means electricity consumers would have to bear these costs and some non gas-based generators would get windfall profits. Otherwise, gas-fired power plants will shutdown and security of electricity supply will be at risk[16]. Therefore, "managed competition" is the only way out of this dilemma - but it is not risk-free.

Different national decarbonization targets and different national generation profiles may lead to different strategies, but none will be risk-free. Clarity about natural gas phaseout is important not only vis-à-vis natural gas suppliers, but also with regard to gas network and to gas-fired power plant owners – and, ultimately, to gas and electricity consumers. The costs of security of energy supply are determined by political choices and internalized, one way or another, by market agents - but they are supported by energy consumers.

16 According to Carbon Tracker, in October 2021, "*More than a fifth of European gas-fired power plants and nearly a third of US units are lossmaking and surging fuel prices risk sending many more into the red*" https://www.energylivenews.com/2021/10/19/one-in-four-gas-power-plants-runs-at-a-loss/

WHY EU ELECTRICITY MARKET REFORM ?

Restlessness is discontent — and discontent is the first necessity of progress.
Show me a thoroughly satisfied man - and I will show you a failure.

Thomas A. Edison[17]

On October 13, 2021, the European Commission issued a Communication[18] expressing concern about energy prices and indicating that it would *"Investigate indications for any possible anti-competitive behaviour in the energy market"*, *"Ask ESMA to further enhance the monitoring of developments in the European carbon market"* and *"task the Agency for the Co-operation of Energy Regulators (ACER) to assess benefits and drawbacks of the current wholesale electricity market design, among other its capacity to address situations of extreme price volatility in the gas markets and available measures to reduce such situations, while ensuring a cost effective transition towards a net zero energy system, and to propose recommendations* [by April 2022] *which the Commission will assess for follow-up as appropriate"*, pointing out, however, that *"there is of yet no clear evidence that alternative market framework would provide cheaper prices and better incentives"* than the current wholesale electricity market.

On October 20/21, 2021, the European Council invited "*the Commission to study the functioning of the gas and electricity markets, as well as the EU ETS market, with the help of the European Securities and Markets Authority (ESMA). Subsequently, the Commission will assess whether certain trading behaviours require further regulatory action*". Furthermore, it invited *"the Commission and the Council to swiftly consider medium and long-term measures that would contribute to energy at a price that is affordable for households and companies, increase the resilience of the EU's energy system and the internal energy market, provide security of supply and support the transition to climate neutrality, taking into account the diversity and specificity of situations of Member States"*[19].

On March 8, 2022, the European Commission issued a Communication on "REPowerEU: Joint European Action for more affordable, secure and sustainable energy"[20], indicating that "*To address the current emergency, the Commission will look into all possible options*

17 Dagobert D. Runes (ed.), *The diary and observations of Thomas Alva Edison*. Philosophical Library, N. York, 1976. Pg. 110.

18 EC, COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Tackling rising energy prices: a toolbox for action and support, COM(2021) 660 final

19 Council Conclusions - European Council meeting 21 and 22 October 2021. https://www.consilium.europa.eu/media/52622/20211022-euco-conclusions-en.pdf

20 EC, COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS REPowerEU: Joint European Action for more affordable, secure and sustainable energy COM(2022) 108 final https://eur-lex.europa.eu/resource.html?uri=cellar:71767319-9f0a-11ec-83e1-01aa75ed71a1.0001.02/DOC_1&format=PDF

for emergency measures to limit the contagion effect of gas prices in electricity prices" and, furthermore, *"will also assess options to optimise the electricity market design to reap the benefits from low cost energy. It will take into account the final report of the European Union Agency for the Cooperation of Energy Regulators (ACER) and other contributions on the functioning of the electricity market on benefits and drawbacks of alternative electricity pricing mechanisms. It will follow up as appropriate to keep electricity affordable without disrupting supply and further investment in the green transition."*

The informal meeting of the Heads of State or Government on March 10/11, 2022, issued the Versailles Declaration[21], describing several actions aimed at reaching *"the objective of climate neutrality by 2050"* and at phasing out *"dependency on Russian gas, oil and coal imports as soon as possible"*. Moreover, the Council indicated that it continues working on *"monitoring and optimising the functioning of the electricity market"*.

Finally, the European Council on March 24/25, 2022, "*calls on the Commission to submit proposals that effectively address the problem of excessive electricity prices while preserving the integrity of the Single Market, maintaining incentives for the green transition, preserving the security of supply and avoiding disproportionate budgetary costs."*[22]

Clearly, the main concern expressed by the Council and by the Commission over the last months is the negative impact of current high energy prices upon households and industrial consumers. This concern led to ongoing investigations on both behavioural and structural factors. However, under pressure from extremely volatile and extremely high energy prices, discussions very often miss essential points. Therefore, it is useful looking at the reasons that *may* lead to electricity market reform, independently of the concrete present situation. The main reasons are indicated in the next figure.

The preliminary question is whether the basic assumptions (of perfectly competitive markets) underlying the initial choice of the existing Market Design (MD) are still valid.

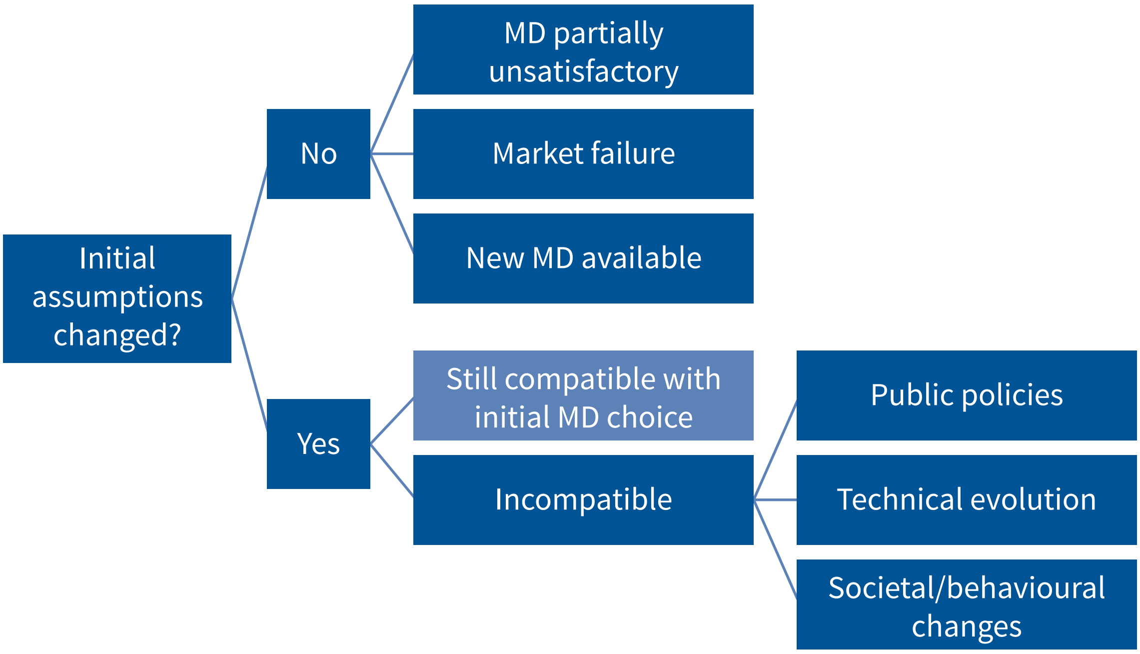
If this is the case, there may still be reasons for modifying the existing MD:

- The MD may be globally satisfactory but partially unsatisfactory, thus suggesting partial modifications.
- The MD may have failed to some extent (minor or fundamental failure), thus requiring substantial changes or even complete overhaul (e.g. California 2000).
- Independently of the existing MD past performance, there may be new MD models available now (not available when the initial choice was made) that offer better prospects.

21 https://www.consilium.europa.eu/media/54773/20220311-versailles-declaration-en.pdf

22 https://data.consilium.europa.eu/doc/document/ST-1-2022-INIT/en/pdf

Figure 2 | **Possible reasons for market design (MD) review**



If some initial assumptions have changed in the meantime, there are two cases: either the changes do not affect the MD choice (i.e., the initial choice is still valid) or they are incompatible with the initial MD choice. In the first case, there is no need for market redesign. In the second case, there may be several changes - acting individually or together - explaining the incompatibility, hence driving the market restructuring process. These factors are the following ones:

- Public policies (e.g., climate and energy policy)
- Technical evolution (e.g., energy storage)
- Societal/behavioural changes (e.g., the wish to be part of an energy community, sharing locally energy resources, instead of being supplied through the retail market).

The Internal Energy Market is a remarkable achievement in many respects:

- From the political viewpoint, it has contributed and still contributes to consolidation of the European Union project - economically, institutionally and even symbolically.
- Technically, there is no comparable electricity market in the world, in terms of scale , degree of cross-border integration and quality of service.

- The establishment of "common rules" and the dissemination of good practices has benefited all Member States, independently of their degree of physical and commercial connectedness with neighbouring Member States.

- Economically, it exhibits some economies of scale and it also enabled the creation of many innovative undertakings acting not only in several Member States, but in several continents.

It is true that integration of national markets is still incomplete and imperfect, due to lack of interconnection capacity at several borders, weak governance, institutional gaps, etc.. Nevertheless, the Internal Energy Market is part of our *acquis* and its fragmentation would mean a huge loss for all Europeans.

The Internal Energy Market needs to be improved and reinforced, it has an important role to play in the implementation of the EU Green Deal. However, 26 years after it was first launched, and 28 years away from EU carbon neutrality, it also needs to be revamped. The need was evident before the present energy price crisis, but this crisis may be the necessary opportunity to start the reform process.

Going back to the previous figure, I believe that all the reasons mentioned there recommend reform of the existing EU electricity market and I will provide some brief examples:

a) Although the Internal Energy Market works, it does not work very satisfactorily from the point of view of end-users: EU households have experienced increasing natural gas and electricity prices over the last 15 years; low energy demand (usually corresponding to low income) households suffered the largest energy price increases; energy-related costs as a percentage of EU-27 households total final consumption expenditure has also increased since the early days of energy liberalization; EU-27 households pay substantially more for electricity than G20 average households (see Section *Retail energy prices – did competition deliver ?*).

b) In some respects, the current MD failed - for instance, as regards coordination of generation and network investments (see Section *Networks: the missing arms of the invisible hand*).

c) Energy digitalization was a mirage 26 years ago and is a reality today. Although the EU is home of some pioneers and world leaders in energy digitalization, as a whole the EU electrical system is underdeveloped in this respect. Digitalization has the potential not only to substantially improve efficiency of electricity trade in general and cross-border trade in particular, as well as overall reliability, but also to enable the establishment of local electricity platforms, combining competitive and cooperative features, aimed at implementing energy system integration.

d) Public policies, in particular climate and energy policy, have changed dramatically the basic assumptions underlying the present MD. Just two examples: fossil fuel power plants, the backbone of electricity liberalization, are being phased out, one after the other; nowadays, in a growing number of Member States, more than 50% of installed generation capacity has a State guaranteed price (almost non-existant at the onset of liberalization).

e) Technical evolution, in part due to EU public policies, is impressive: for instance, electrical and thermal storage, both centralized and decentralized, are the new game changer, challenging the century-old assumption that electricity is different from other commodities because it cannot be stored… Energy digitalization, with the incredible granularity brought by the Internet of Things, is about to abolish another century-old mantra - that electricity demand is inelastic.

f) Society has changed significantly since the 1980s, when energy liberalization was first envisaged in the USA. The shared economy, powered by internet, is a new, powerful model waiting for legislators and regulators to enter massively in the energy landscape of our towns and villages.

Reinventing the Internal Energy Market is one of the most exciting challenges we face today. There is no lack of reasons to do so, and no deficit of good ideas to apply.

Many suggestions have been published concerning amendments to the existing electricity market model, namely as regards the use of long-term contracts of different types. Until recently, the Internal Electricity Market was almost entirely based on short-term price signals; as long as thermal generation overcapacity and limited intermittent generation characterized the European electricity system, this short-term approach worked just fine. However, developments over the last 5 years, as well as increased ambitions regarding future carbon neutrality and strategic energy autonomy, clearly indicate that short-termism is not any more a sound energy market foundation. Decision-makers, investors and experts realized that it was necessary to rehabilitate the concept of "competition for the market", namely through different types of auctions and contracts that have been recently introduced in many Member States.

A combination of increased network scarcity and rehabilitation of the long-term approach has led to the current situation where practically all new electricity generation investments have a State guarantee (the old-fashioned feed-in tariffs having been replaced by more sophisticated and less visible subsidies).

Most of the suggested (and partially implemented) long-term mechanisms are useful tools to overcome shortcomings of the legacy EU energy-only market model and they have been recently praised and promoted by the European Commission, namely in the October 2021 "toolbox". However, two points should be highlighted at this stage:

- It is not yet clear how the long-term mechanisms being widely adopted over the last years - and gaining traction –, both on the supply-side and on the demand-side (e.g. corporate PPA), will impact the functioning of the (increasingly residual) spot market.

- These mechanisms may solve some relevant and urgent issues (e.g. system adequacy or price stability) but they do not provide a satisfactory answer to the more structural challenges of energy decarbonization and digitalization that the present report addresses.

PART II

Excursus

EXCURSUS I : ELECTRICITY IN THE WIDER ENERGY CONTEXT

The notion of an industry is an idealization or a limit case.
Jean Tirole, The theory of industrial organization, 1988

This report discusses a very specific and, in a certain sense, very technical topic: electricity reform in the European Union. However, before addressing technicalities, it is important to set the discussion in a broader context. Zooming out, this Section provides three different view angles:

- the first encompasses the overall energy landscape, of which electricity is part;
- the second covers the ongoing decarbonization process, of which energy is part;
- the last one embraces the very idea of transformation.

Electricity reform is part of the so-called "energy transition" which aims mainly at:

1) reducing energy demand through sufficiency and efficiency measures, and
2) decarbonizing energy supply – thus eliminating greenhouse gas emissions currently associated with energy (intermediate) transformation and energy (final) use[23].

Consequently, this energy transition involves *all* energy vectors and *all* energy-related sectors: electricity is one of many - interrelated - energy vectors and it cannot be handled separately[24].

This holistic approach to "energy", abolishing old energy silos and establishing a kind of energy continuum based upon the carbon content of the different sources, is a major feature of the contemporary "energy transition". Although this approach involves many technical and regulatory aspects it is, primarily, a political process. For instance, a decision to electrify the transport sector has huge redistributive effects – it

23 Energy end use is just another type of energy transformation – transforming some kind of final energy (e.g. electricity) into useful energy (e.g. heat or light). Final energy use is carbon free if and only if all energy transformations involved in the energy chain are carbon free. However, it should be pointed out that manufacturing the devices required to transform energy usually requires energy on its own, hence the carbon content of this "secondary" energy should also be taken into account. Moreover, even if the carbon content of the energy used to manufacture energy transformation devices is carbon free, other environmental impacts should be considered – e.g., related to the use of materials and of space (on land or on sea).

24 Worldwide, electricity represents just 19.6 % of total final energy use; in the European Union, this ratio is 22.8 % (European Commission, *Statistical Pocketbook 2021. EU energy in figures*. Luxembourg, Publications Office of the European Union, 2021)

is a political, not a technical decision. Indeed, such a political decision has a strong impact upon electricity infrastructures and electricity markets and it requires suitable technical and regulatory decisions to follow. The move towards electric mobility was triggered by public policy and its success depends mainly upon changing consumer behaviour and huge investments by car manufacturers; it was not dictated by electricity markets. Since the transport sector represents 31% of total final energy demand in the EU and electricity currently just represents 23% of EU final energy demand[25], it is reasonable to expect that transport electrification will have a very substantial impact upon electricity networks and electricity markets. Pretending that current electricity networks and electricity markets are able to absorb electrical transportation without substantial quantitative and qualitative changes is unrealistic.

The fact that all energy-related sectors must contribute to decarbonization according to priorities, trade-offs and (technical and economic) choices dictated by the public policies of each State, within the Paris Agreement framework[26], somehow amalgamates those sectors, leading to a new kind of systemic "energy integration". This integration has both physical and institutional dimensions: the former is usually visible (for instance, electric vehicle charging stations are objects that couple mobility with electricity networks), while the latter includes regulatory and governance aspects (for instance, who is allowed to build and operate electric vehicle charging stations and how much should they pay for using the electricity network).

Electricity reform should not be discussed *before* discussing energy system integration; a coherent approach requires talking about electricity reform *after* agreeing on what energy system integration means and how it can be achieved in a given political context.

On the other hand, the energy transition is part of a broader societal transformation aimed at avoiding the destructive consequences of climate change. Therefore, it is important to be aware, not only of the multiple sources of greenhouse gases ("energy"[27] being just one of them, along with agriculture, waste management, etc.[28]), but also of the multiple dimensions (namely social and economic, besides technical and regulatory ones) of this ongoing transformation leading to a different, low-carbon future.

25 Ibid.

26 United Nations, *Paris Agreement*, 2015. Available at https://unfccc.int/sites/default/files/english_paris_agreement.pdf

27 "*Energy*" usually includes a broad spectrum of activities, all relevant from the viewpoint of greenhouse gas emissions: from coal mining and oil and gas production down to final energy use, through energy transport and several intermediate energy transformations (e.g.: oil> associated gas > LNG > gas > electricity > heat).

28 See, for instance: United Nations Environment Programme, E*missions Gap Report 2021: The Heat Is On – A World of Climate Promises Not Yet Delivered*. Nairobi, 2021.

A certain degree of interaction between "energy" and other economic sectors already exists – for instance, through biofuels or waste-to-energy dedicated facilities. From the circular economy point of view, these interactions must be fully exploited and all sectors must be "integrated" in terms of energy and materials flows[29]. Smooth interaction or integration between such diverse sectors requires not only a coherent conceptual framework, but also consistent policies and a certain degree of regulatory harmonization. For instance, the relative weights of gate fees levied upon a given quantity of waste received at different waste processing facilities clearly influences the cost of energy generated at waste-to-energy facilities – but it also has a substantial impact upon the overall societal cost of reaching certain waste management goals[30].

Social acceptance or rejection, not only of new technical devices and new services, but also of new regulatory incentives, constraints and economic signals (namely energy prices and regulated infrastructure tariffs), is critical for timely and cost-effective achievement of decarbonization targets.

Moreover, climate action is just one out of 17 Sustainable Development Goals[31] and the nexus across many of these goals is quite strong (for example, energy-water-food-health). For instance, countries experiencing substantial reduction of water flows, namely due to below-average precipitation, and extended drought periods, are exposed to unexpected shortages of electricity hydro-generation and must find appropriate social and environmental trade-offs among conflicting water uses.

Electricity reform and energy system integration should not be discussed *before* discussing the role of energy in a given Sustainable Development context; a coherent approach requires talking about electricity reform and energy system integration *after* agreeing on what are the relevant nexuses between energy and other related and relevant sectors.

In this wider context where highly political and highly sensitive decisions must be taken, any discussion about electricity reform implies some form of predictive

29 Cf. European Commission, *A new Circular Economy Action Plan For a cleaner and more competitive Europe*. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM (2020) 98 final of 11.3.2020. "*The transition to the circular economy will be systemic, deep and transformative, in the EU and beyond. It will be disruptive at times, so it has to be fair. It will require an alignment and cooperation of all stakeholders at all levels - EU, national, regional and local, and international.*"

30 For instance, according to Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste (the so-called Waste Framework directive - OJEU L/150 of 14.6.2018): *"Member States shall take the necessary measures to ensure that by 2035 the amount of municipal waste landfilled is reduced to 10 % or less of the total amount of municipal waste generated (by weight). (…) By 2030,the preparing for re-use and the recycling of municipal waste shall be increased to a minimum of 60 % by weight;"*

31 https://sdgs.un.org

judgements, weighing different technical, social and political options. In this respect, it is useful reflecting on the following warnings provided by two recent and remarkable books:

- *"(…) assuming that the future will be nothing but a superior version of the past accomplishments is highly imprudent. Accomplishments of the modern civilization inspire hope and instill confidence in our problem-solving abilities – but the recitals of advances should not ignore many fundamental limits and undesirable trends whose combined effects will make future grand transitions extraordinarily difficult."*[32]

- *"To be clear, personal values, individuality, and creativity are needed, even essential, in many phases of thinking and decision making, including the choice of goals, the formulation of novel ways to approach a problem, and the generation of options. But when it comes to making a judgement about these options, expressions of individuality are a source of noise. When the goal is accuracy and you expect others to agree with you, you should also consider what other competent judges would think if they were in your place."*[33]

These clear messages highlight the complexity of the challenges we currently face, the need for creative and innovative approaches to these difficult problems and the importance of avoiding biases, usually rooted in the past. The European gas and electricity markets were indeed formidable accomplishments that *"inspire hope and instill confidence"* in our ability to adapt them to the energy transition, but excessive reliance on past models is a *"source of noise"* when considering multiple options to design a suitable energy transition.

Finally, the present energy transition and the overarching decarbonization and sustainability programmes should be seen in a historical context of successive "grand transitions" and "great transformations". This applies both to the evolution of electricity systems as such (an issue to be discussed in Excursus II) and to the evolution of political and economic thinking.

One of the most influential and inspiring books on this topic is *"The great transformation"*[34], first published in 1944. The author carefully places the market economy as part of the economy at large, and the economy as part of society, condemning what he called *"market society"*, i.e., a model based upon the assumptions that *"nothing could be more normal than an economic system consisting of markets and under the sole control of market prices"* and that *"a human society based on such markets"* is *"the goal of all progress"*. *"On the contrary"*, Polanyi objects, *"the market has been the outcome*

32 Vaclav Smil, *Grand transitions: how the modern world was made*. New York, Oxford University Press, 2021. Pg. 244.

33 Daniel Kahneman et al., *Noise: a flaw in human judgement*. London, William Collins, 2021. Pg. 371.

34 Karl Polanyi, *The great transformation: the political and economic origins of our time*. Boston, Beacon Press, 2001 (originally published in 1944, New York, Farrar & Rinehart).

of a conscious and often violent intervention on the part of government which imposed the market organization on society for noneconomic ends." Therefore, *"the end of market society means in no way the absence of markets. These continue, in various fashions, to ensure the freedom of the consumers, to indicate the shifting of demand, to influence producers' income, and to serve as an instrument of accountancy, while ceasing altogether to be an organ of economic self-regulation."*

Writing at the end of WWII, Polanyi could observe how *"the institutional separation of politics and economics" "proved a deadly danger to the substance of society"* and how some degree of planning and control is necessary to ensure peace and freedom. He even points out that *"the victory of fascism was made practically unavoidable by the liberals' obstruction of any reform involving planning, regulation, or control".*

The recent invasion of Ukraine and several not-so-veiled threats delivered by the Russian government, including interruption of oil and natural gas supply, proved how right Polanyi's view was that the excessive institutional separation of politics and economics represents a *"deadly danger to the substance of society"*. It is striking how some of today's "liberals" seem to ignore the lessons of History and still obstruct much needed EU reforms, like electricity and gas markets reform - which shall indeed include some kind of "*planning, regulation,* [and] *control".* This is necessary for security of supply reasons, as the dramatic events of February 2022 have clearly revealed, but this is also necessary to achieve EU decarbonization goals.

Energy infrastructures and energy markets will not spontaneously transform themselves at the scale and at the pace required by EU policies; these public policies (namely climate and energy, circular economy) must be translated into suitable planning tools - e.g., infrastructure expansion in electricity, natural gas phasing out – and into appropriate regulatory policies able to provide the needed incentive and control mechanisms and to deliver outcomes aligned with those public policies.

EU electricity market reform is necessary to ensure security of energy supply and energy decarbonization; this reform must include some elements of planning and more stringent *ex ante* regulation.

EXCURSUS II : ELECTRICITY MARKETS IN HISTORICAL CONTEXT

You never know when you might need an old idea. It could rise again one day to enhance a perspective the present cannot imagine.

Ian McEwan, 2015[35]

Before discussing how EU electricity markets should support EU climate and energy policy, as well as adapting to energy digitalization and clean technologies, it is worth briefly recollecting the electricity business' origins. This preliminary excursus is instructive in two ways: on the one side, it shows that electricity business models evolve all the time, hence there is no such thing as "the" electricity market (i.e., a consolidated electricity market archetype); on the other side, and most interestingly, many of the issues discussed in the early days surface again in today's discussion about the future of energy systems.

The business of selling electricity started with self-generation – i.e., generators were installed in the client´s premises powering their own electrical appliances. Electric street lighting, using arc lamps and dedicated generators, starting in the late 1870s, was another example of decentralized generation and decentralized energy resources management.

The first "multi-client" electricity supplier, or retailer, based on centralized generation, started operation in 1882, in Manhattan. That company initially owned a few generators and a few kilometres of underground cables, supplying a few dozens of customers, powering a few hundreds of incandescent electrical lamps in their premises. In fact, the company was called Edison Electric Illuminating Company. After several years of fierce competition, electrical lighting successfully replaced gas lighting - which had been introduced, starting in the late 18th century, in many cities – not to mention the replacement of old lighting sources such as candles and oil lamps.

To beat incumbent gas lighting undertakings, electricity suppliers needed to find other uses than lighting for their "product", otherwise power plants remained idle during day hours, when lighting is not necessary, thus compromising their competitive advantage over gas lighting suppliers. The rescue came from electric public transportation: tramways and subways were built in many towns, providing a convenient complement to lighting, hence rising the utilization factor of electrical infrastructure (generators, cables, etc.). In 1891, long-distance commercial supply of large electrical motors started, thus further increasing diversification of electricity uses – and electricity suppliers' turnover.

35 In John Brockman (ed.), *This idea must die. Scientific theories that are blocking progress*. HarperCollins Publishers, N. York, 2015. Pg. 256

Edison's business model was copied around the world, with several companies building the necessary infrastructure to serve different geographical areas. However, in some cases, those companies also competed for customers within the same area, thus duplicating infrastructure. Initially, electricity undertakings adopted different technical solutions and a remarkable "war of the currents" (direct- versus alternating-current) took place between Edison and Westinghouse. Eventually, Westinghouse's alternating-current model won the contest thanks to its ability to serve broader areas (direct-current supply was limited to a radius of about 1 km around generation). The 1891 International Electrotechnical Exhibition, in Frankfurt-am-Main, proved the superiority of 3-phase alternating-current for long-distance electricity transmission, establishing a *de facto* international technical standard for electrification.

The development of long-distance transmission enabled the merger of local companies, serving just a few thousand customers each, into larger undertakings serving larger geographical areas and an increasing number of customers. It also enabled the beginning of cross-border electricity trade: in Europe, this started in 1921, between France and Italy, via Switzerland. That such long-distance transactions, involving several electricity undertakings located in different jurisdictions, required appropriate technical and institutional coordination, was recognized very early by the industry: as early as in 1929, the creation of a 400 kV "European network" was proposed. Although the Union of Producers and Distributors of Electrical Energy (UNIPEDE) was established in 1925, in Paris, this loose association of electricity undertakings had no mandate to coordinate network planning or operation. Only in 1951, within the Marshall Plan framework, the Union for the Coordination of Production and Transmission of Electricity (UCPTE) was established, as a kind of voluntary self-regulation body for planning and operation of the interconnected system.

Initially, local and regional high-voltage networks were connected to one another bilaterally; however, a multilateral approach to interconnections was adopted soon, making use not just of bilateral lines, but also of rings and close meshes, thus increasing the interconnected system's reliability, robustness – and complexity.

The electricity industry's initial development in Europe faced not just a problem of coordination, but also a problem of financing, given the large scale and the long construction and payback times involved. Therefore, many electrification projects in Europe were developed by consortia consisting of (mainly German) equipment manufacturers and (mainly Swiss) banks.

In Europe, after World War II, the electricity industry was nationalized in several countries (France in 1946, United Kingdom in 1948, Italy in 1962, etc.). National State-owned monopolies accelerated technical harmonization, for instance, establishing the same frequency (50 Hz) everywhere and standardizing voltage levels, which also facilitated the development of international interconnections and cross-border electricity exchanges (between national monopolies). In countries where private and mixed (public/private) electricity undertakings subsisted, each one was a monopoly within a specific geographical area.

In the 1990s, total or partial privatisation of electricity undertakings was adopted in most European countries. At the same time, under EU leadership, two converging processes were launched:

- ▷ Ending of electricity and natural gas monopolies regarding generation, imports and exports, trading and supply (transmission and distribution networks remain monopolies, but they are now regulated by independent national regulatory authorities).
- ▷ Construction of the European Internal Energy Market through implementation of successive legislative packages aimed at facilitating cross-border energy transactions through harmonisation and coordination of system operation, market coupling and regulation.

Liberalisation of EU energy markets over the last 30 years will be discussed later on, namely in the Section *Governance of EU electricity markets*.

In summary, history shows that:

- The electricity industry has a long tradition of managing both **decentralized** and **centralized** resources. From the very early days, self-generation, demand management and long-distance international electricity trade have been all successfully implemented.
- Very often, **social factors** (for instance, safety – incandescent lighting *versus* arc lighting) influence the choice of end-use **technical solutions**; those solutions, on the other hand, influence the choice of transmission and generation technical solutions. Later on, when extensive networks cover the whole territory and interconnect with neighbouring networks, it is infrastructure technology that influences the kind of end-user appliances and business models that may or may not be adopted.
- In the electricity industry, periods of tough **competition** and heterogeneity alternate with periods of dominant or even monopolistic positions, leading to increased homogeneity, vertical integration and reduced freedom of choice.
- Standardization and **coordination**, usually managed through self-regulation, play a central role in electricity industry's development, determining to a large extent the pace and direction of electricity business models' evolution.

PART III

Electricity reform: clean energy and strategic energy autonomy

A NEW EU ENERGY ARCHITECTURE

A building has at least two lives – the one imagined by its maker and the life it lives afterward – and they are never the same.

Rem Koolhaas, 2012[36]

From a technical point of view, several alternative roads may lead to carbon neutrality and to enhanced energy autonomy. This holds true for Europe and is valid worldwide. Each technical path presents different uncertainties, difficulties and potential benefits; requires different market structures and needs different governance; has different impacts upon neighbouring systems. Different paths require different actions by system operators, traditional undertakings, old and new market agents and regulators. Therefore, each technical path reflects specific political choices and may be assessed in terms of how fast or how efficiently it leads to the desired political objective(s) – i.e., how consistent it is with societal goals expressed in public policies. This dimension may be called external consistency.

Equally important is assessing the internal consistency of any given technical path. Technical systems have their own internal logic and if this logic is not respected the system will not function properly and may eventually collapse. Technically inconsistent paths lead nowhere. Assessing the internal consistency of any proposed path, hence its ability to deliver the envisaged goals, does not imply a judgement about the desirability of such goals or about the relative merits of alternative paths.

The roads to carbon neutrality are full of new technical apparatus (e.g. electrical and thermal storage, digital sensors and meters), new combinations of old and new devices (e.g. hybridization), new types of transactions (e.g. self-generation, renewable energy communities, EV charging) and new regulatory challenges. The growing diversity of “electrical objects” and interactions among them, as well as with end-users, is a novelty. During the liberalization process, and until recently, technical diversity was rather limited and electricity systems were technically similar throughout Europe. In spite of the previous high degree of technical homogeneity, agreeing on and implementing common rules for the Internal Electricity Market (IEM) has been a lengthy and arduous process.

This new diversity, which was not yet apparent ten years ago, is remarkable: for instance, in 2020, solar and wind represented more than 60% of total electricity generation in Denmark (and less than 5% in Slovakia - see Figure 27); in Norway, where petrol- and diesel-powered car sales will end by 2025, electric cars made up nearly two

36 In *Journal of International Affairs*, vol. 65, nr. 2, Spring/Summer 2012. Pg. 115

thirds of new sales in 2021[37]. As more Member States accelerate their energy transition processes, the more visible and relevant the growing heterogeneity of electricity systems will become and more intense centrifugal forces will act upon the current IEM model in order to relinquish several restrictions, enabling diversity to flourish.

Each Member State has the *"right to determine the conditions for exploiting its energy resources, its choice between different energy sources and the general structure of its energy supply"*[38]; hence, different national paths, fostering different political and technical options, may coexist. Member States must comply with common goals, common policies and common rules, but they also enjoy substantial freedom regarding the choice of energy resources – although constrained by decarbonization – and the organization of energy supply. This applies not only to the national level, but also to the local level, which is particularly relevant in the context of growing decentralization, a common feature to most energy transition paths.

Managing the expected and legitimate growing diversity of EU electricity systems during the energy transition process requires amendments to the IEM model. Energy is indeed an area of shared competence between the Union and Member States (Article 4 TFEU), and ensuring *"the functioning of the energy market"* is a Union task, but *"Such measures shall not affect a Member State's right to determine the conditions for exploiting its energy resources, its choice between different energy sources and the general structure of its energy supply."* (Article 194 TFEU).

IEM rules must be amended to take into account not only growing diversity of national energy policy choices, but also growing diversity and complexity of technical developments, in particular as regards energy decentralization. Preserving *"the functioning of the energy market"* requires changing some present market rules, adapting them to ongoing technical and policy changes. In other words: preserving a common electricity market, for the present and for the future, does not mean maintaining all the rules designed in the past, on the contrary.

Although full harmonization was not and is not a pre-condition for a well-functioning European electricity market, full consistency is:

a) each path must be intrinsically consistent and

b) consistent with the IEM and

c) the IEM itself must be inherently consistent.

In this context, consistency refers to the internal rules governing the energy transition,

37 Reuters 22.01.03 https://www.reuters.com/business/autos-transportation/electric-cars-take-two-thirds-norway-car-market-led-by-tesla-2022-01-03/

38 Article 194 of the Treaty on the Functioning of the EU (TFEU)

in particular market design, regulated infrastructure investments and system operation. External consistency – i.e., compliance with public policies, namely climate and energy policy – should also be regularly checked, both at national and at EU level.

As stated above, legislators are free to favour, endorse or even determine any given "feasible" technical path towards carbon neutrality and energy autonomy. However, once they have taken this primordial decision, their subsequent choices should be compatible with objective - and unfortunately complex - technical, economic and institutional constraints of electricity systems and markets. Any lack of internal consistency will make energy transition unnecessarily costly and protracted, as shown by several examples. California is probably the best known and the most expensive failure due to lack of internal consistency: in order to please all constituencies, the 1996 electricity market model, unanimously approved by the California Legislature, was inconsistent by design (e.g. prohibiting long-term contracting) and led to multiple large-scale blackouts and the ultimate market collapse in 2000.

Consistency must be provided at design phase, but it must also be effectively enforced, at local and at EU levels. Both require appropriate governance, and this proves difficult to achieve, for different reasons: at local level, mainly due to lack of experience and resources; at EU level, mainly due to lack of political will – see Section *Governance of EU electricity markets*.

This Section provides a conceptual framework for designing new, multi-sector and multi-level energy architectures, and for assessing their consistency. It is based on 5 fundamental assumptions:

1) Consistency must be granted at all levels and across all sectors.

2) Energy system integration must be achieved by design: resource flows should follow a comprehensive "technical metabolism" pattern aimed at optimizing efficiency and minimizing waste according to the "circular economy" model. In other words, all energy-related sectors must be treated simultaneously and consistently, old silos and barriers must be abolished.

3) Nowadays, taking into account commercially available techniques and their respective costs, energy system integration can be best achieved through electrification of mobility and heating/cooling.

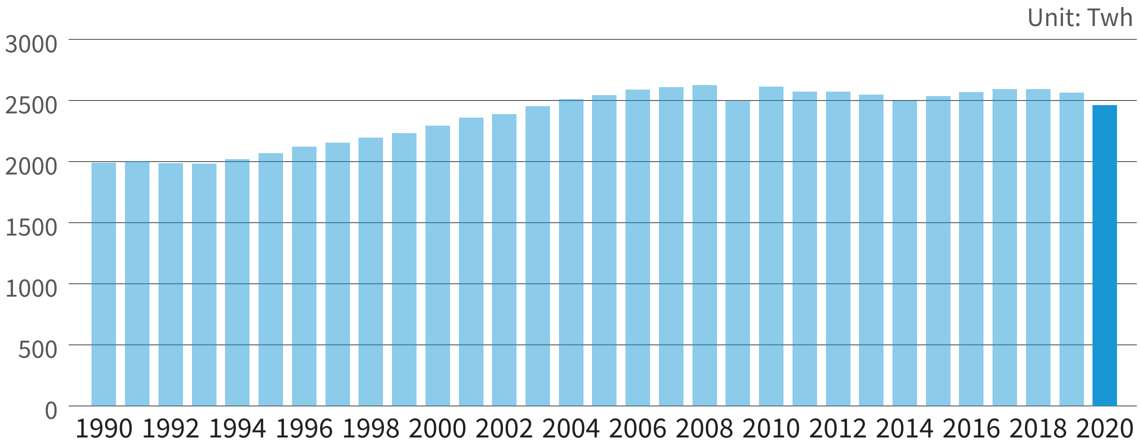
4) Integration through electrification requires the existence of a suitable local "electricity platform". Each local platform has two sides, a physical infrastructure and a transactional superstructure, and the two are inseparable like the two sides of a coin. The primary goal of this an electricity infrastructure is to facilitate "horizontal" energy system integration (as opposed to the "vertical", traditional role of just carrying electricity to end-users).

5) Deployment of new resources and devices (for example, batteries, advanced power electronics associated with small and large-scale intermittent generators, demand management "energy boxes", EV charging points, thermal storage, etc.), supported by appropriate new transactions and new (both competitive and cooperative) business models, shall be incentivized since they are crucial for any successful transition path.

Two relevant facts deserve special attention before introducing the proposed conceptual framework and discussing new energy architectures:

1) The energy transition follows a period of persistent decreasing primary energy demand and nearly stagnation of electricity demand – see Figure 3. Energy efficiency targets and security of supply goals reinforce the trend towards lower primary energy demand, while decarbonization through green electrification, mainly in the transport and heating sectors, will reverse the recent decline in electricity demand.

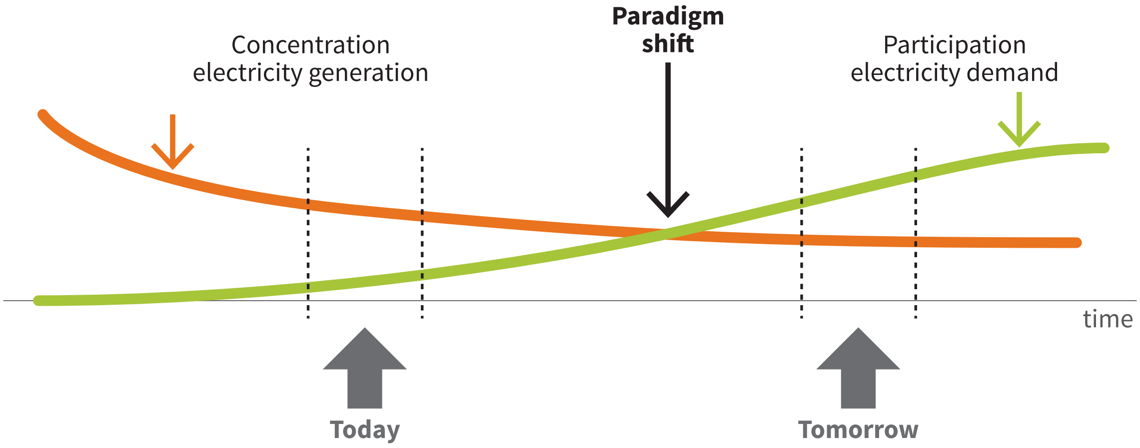
Figure 3 | **EU-27 yearly electricity demand**



Source: Own elaboration based on Eurostat

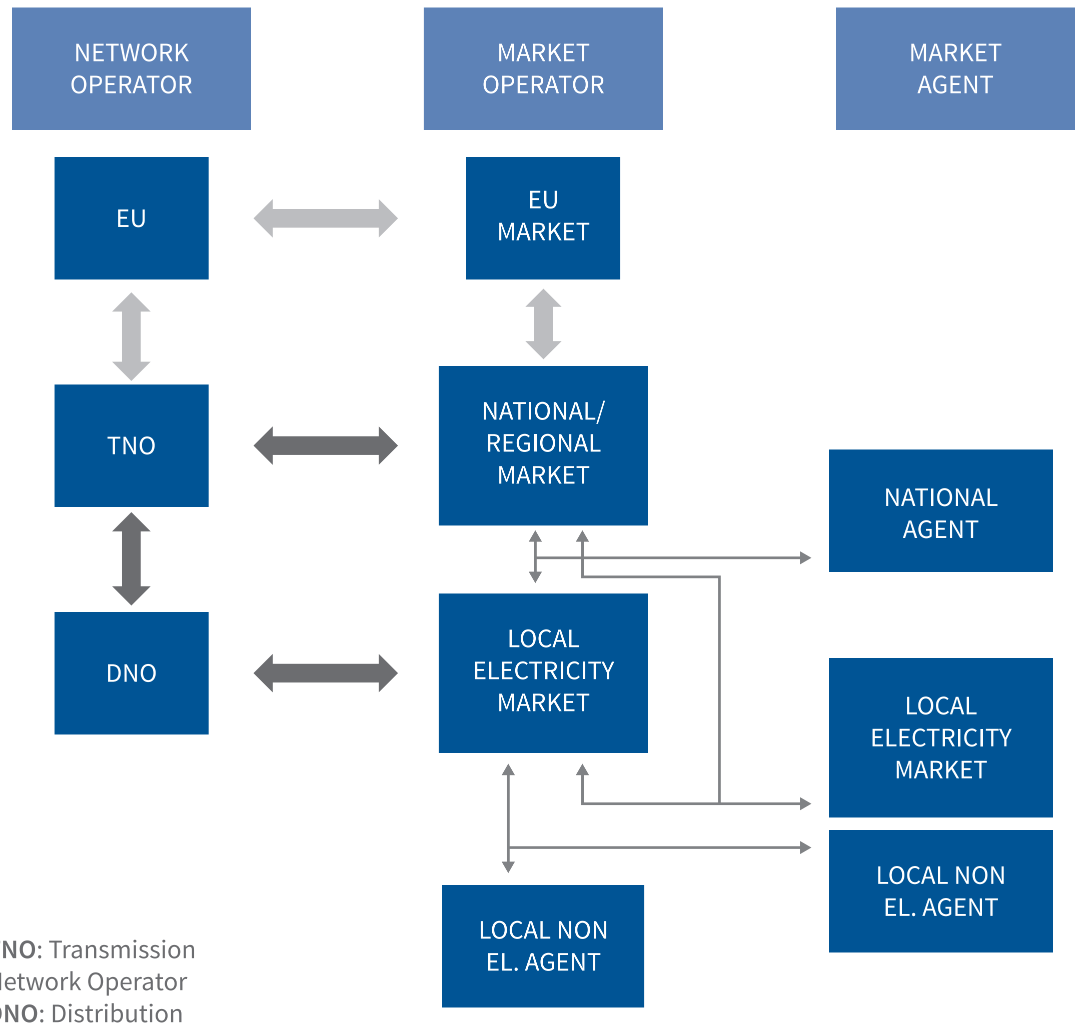
2) At the same time, concentration of electricity generation is decreasing, thanks to (mainly PV) decentralized generation, and demand becomes more active, thanks to digitalization through new information and communication technologies (ICT). The combination of these two concurrent trends produces a significant paradigm shift in the way electricity systems and electricity markets are operated – see Figure 4.

Figure 4 | **Paradigm shift in electricity supply and demand**



Until the 1990s, electricity was a national issue, even in those Member States where instead of a single national vertically integrated monopoly there was a plurality of regional, more or less vertically integrated, monopolies. Some municipalities managed electricity distribution in their respective areas, but they depended upon national undertakings for the provision of ancillary services and energy (entirely or just in part). Liberalization and the construction of the IEM changed this figure, introducing a supra-national level where the most important "common rules" are defined and where some degree of planning and operational coordination takes place. Now, energy decentralization introduces a new and increasingly important layer of activity and decision-making. Figure 5 describes the new electricity functional relational map.

Figure 5 | **The new electricity functional relational map**

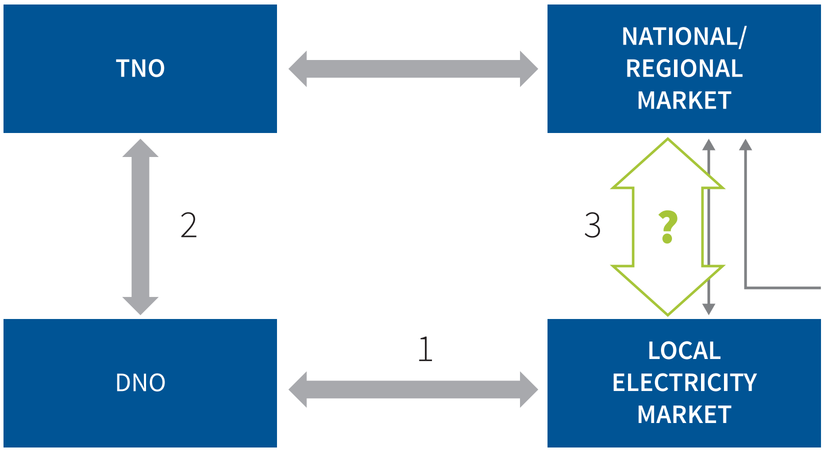


TNO: Transmission Network Operator
DNO: Distribution Network Operator

The EU level, as represented in Figure 5, consists of a set of increasingly complex rules, mainly defined in Network Codes, establishing coordination procedures: a) among system operators; b) among market operators and c) between system and market operators. There are no legal entities performing these functions – neither a EU independent system operator, nor a EU market operator. Likewise, there is no EU energy regulator.

The creation of “local electricity markets” (their scope and architecture will be discussed later in this Section), as a consequence of growing decentralization and energy systems integration, introduces new coordination needs, namely between local and national markets, as described in the following figure (interaction nr. 3).

Figure 6 | **The "critical square" of electricity market decentralization**



The development of local electricity markets also requires the implementation of suitable coordination mechanisms between local market operators and local distribution network operators (interaction nr. 1). The active involvement of DNO in energy resources management at local level, on the other hand, requires adjustments in the interface protocols between DNO and TNO (interaction nr. 2).

Figure 7 indicates the possibility of coexistence, at local level, of two types of markets, designated "local electricity market" and "local non-electricity market". Two different electric mobility scenarios illustrate the meaning of these two alternative realities:

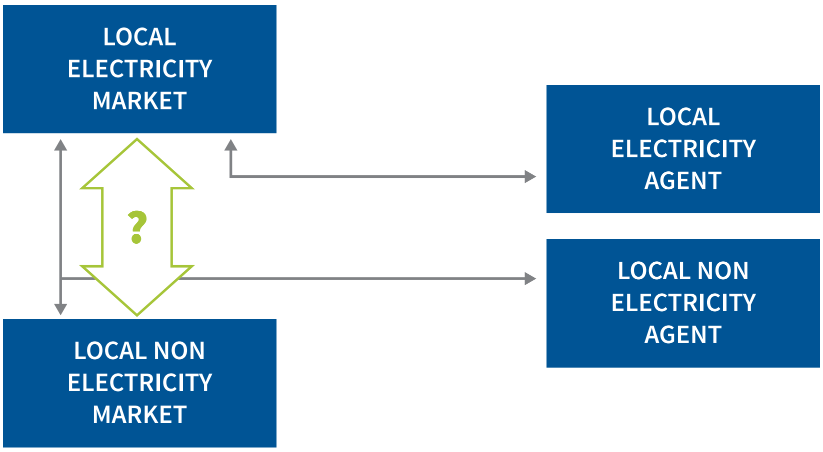
- If all electric vehicles (EV) are owned and operated by individuals, charging their batteries is just another kind of electricity use (i.e., another "individual load"). Electricity flows through the local distribution network will increase, in the same way individual electricity bills will also increase. Consumers will look for the best offers available in the electricity market. In this case, there is no local mobility market, the electricity market absorbed (electrified) mobility.

- If, on the contrary, electric vehicles are shared, instead of being individually owned, and there are several undertakings offering "mobility services", then there is some kind of local mobility market. Individuals have a contractual relationship with mobility service providers, not with electricity suppliers. Mobility service providers will implement their own charging strategies according to the size and characteristics of their respective fleets and they will establish contracts with electricity suppliers. Obviously, the volume - and the degree of flexibility - of their "aggregated load" is much superior to any individual load; their ability to influence electricity markets is much higher. Furthermore, they may develop their own electricity generation facilities.

It can be argued that in both scenarios the existence of a (new) local electricity market is optional, since the required electricity transactions can be carried out within existing wholesale and retail electricity markets. However, in the presence of massive deployment and use of electric vehicles, whatsoever business model being adopted, the local distribution network will be subject to severe congestion problems (especially if fast charging stations are numerous). Therefore, the existence of a local electricity market may be an useful tool to better manage local energy supply and demand resources, even if there are separated markets for newly electrified sectors - for example, mobility. Anyway, local electricity markets are the inevitable consequence of bottom-up decentralization of "conventional" household and services energy management, enabled by energy digitalization.

Figure 7 highlights the possibility of different types of interaction between local electricity and non-electricity markets, as explained above, and the need to define clear interfaces and clear roles, namely concerning local electricity agents.

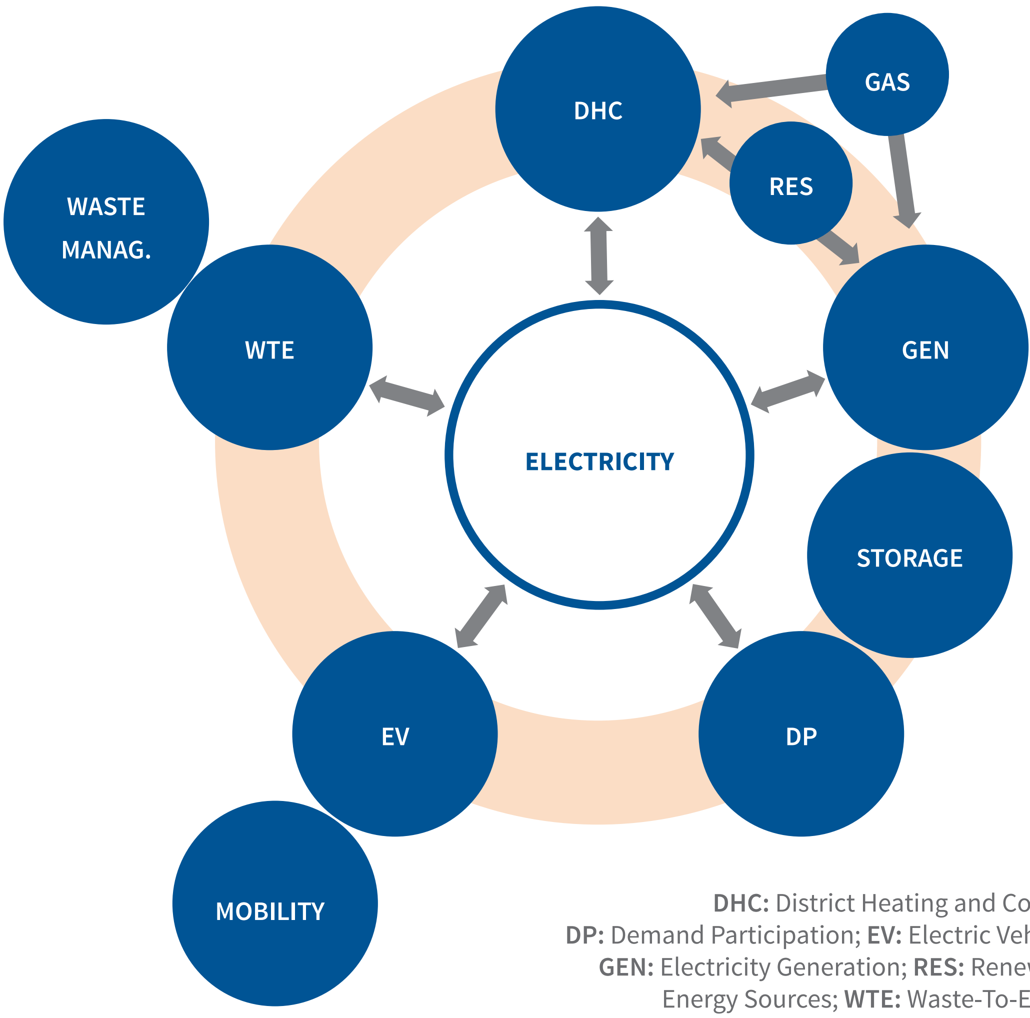
Figure 7 | **The "critical dipole" of local market integration**



The circular economy perspective leads to efficient energy system integration, providing a comprehensive approach to all energy-related sectors, as depicted in Figure 8. The centre stage is occupied by the electricity infrastructure, acting here as a platform for enabling interactions among all relevant energy-related sectors and not just as a link between "conventional" electricity generation and electricity demand.

The physical and commercial interactions that may take place through the "electricity platform" establish strong interactions amid multiple public policies (e.g. energy, mobility and waste management); vice versa, the kind and the intensity of transactions through the electricity platform depend upon policy coordination and harmonization, including regulation, taxes and subsidies in all energy-related concerned sectors.

Figure 8 | **Electricity as a platform for energy system integration**



DHC: District Heating and Cooling; **DP:** Demand Participation; **EV:** Electric Vehicles; **GEN:** Electricity Generation; **RES:** Renewable Energy Sources; **WTE:** Waste-To-Energy

The local electricity platform is the cornerstone of energy systems integration, thus of the current energy transition. Its main function is to enable the horizontal (i.e., local level) coordination of all relevant electricity transactions. The integrative force of the local electricity platform depends on its design and intrinsic efficiency, but also upon extent and density of the space of allowed transactions, i.e., upon the number of integrable sectors. This perspective means a radical departure from the old, top-down, vertically-integrated approach, where local electricity networks were just the "last mile" of a vertical chain of supply-to-demand infrastructure.

Two remarks should be underlined at this stage:

1) Vertical coordination between each local electricity platform and the "upper" electricity system is necessary, but this new, active, bi-directional interface, is quite different from the old, passive, uni-directional pass-through. Actually, the new interface is a combination of two coordination mechanisms, as shown in Figure 6 above: one operational, managed by network operators, concerning the coordination of control flows and power flows between the local electricity network and the upper network; the other one is commercial, concerning the coupling of both local, decentralized transactions performed in local coordination platforms (including market and non-market transactions) and centralized transactions carried out in currently existing electricity wholesale markets.

2) To perform their key integrative role, local electricity platforms must be built upon existing local electricity distribution networks. However, network topology, network branch (i.e. line) and node (i.e. substation) capacities, network protection and network supervisory control and data acquisition (SCADA) all must be substantially upgraded.

As indicated previously, electricity systems have been traditionally isolated from other energy-related systems like heating and cooling, transport and waste management (although remote control of water and space heating, as well as electric rail transportation, were and still are available in some countries). For decades, electricity generation resources (usually large power plants) have been deployed at high voltage level and control has been centralized (i.e., control was performed only at the top level, involving power plants and very high/high voltage networks). Therefore, the traditional architecture of electricity systems is insulated and hierarchical. This may be categorized as a Single-Sector/Single-Level (SSSL) architecture.

The Internal Energy Market introduced a multi-level approach, with an interplay between national and EU levels – i.e., a Single-Sector/Multi-Level (SSML) architecture.

Low-carbon energy systems, on the contrary, combine different sectors and different resource and control levels. Therefore, they require an integrated architecture - a Multi-Sector/Multi-Level (MSML) architecture.

The sectors concerned may include electricity, gas, district heating and cooling, mobility, waste management, etc. In each sector, several layers may be present, from “low-level” (“local”) to “high-level” (“EU”), as shown in the figure below.

Figure 9 | **Resource and control levels in energy and energy-related sectors**

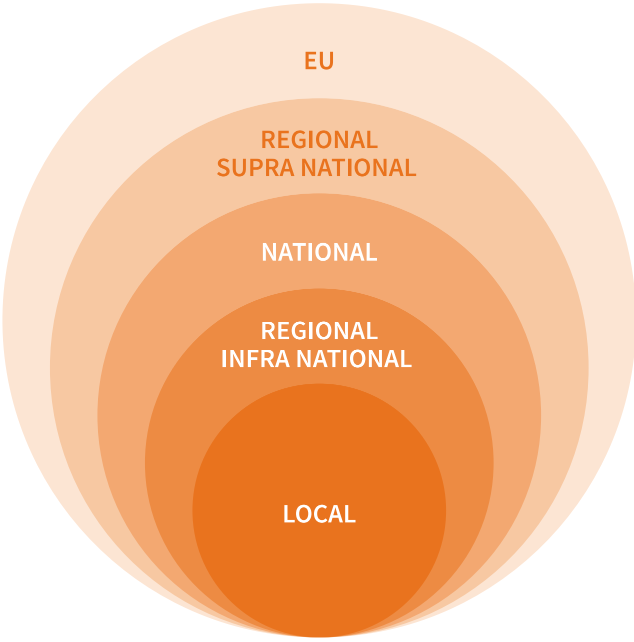
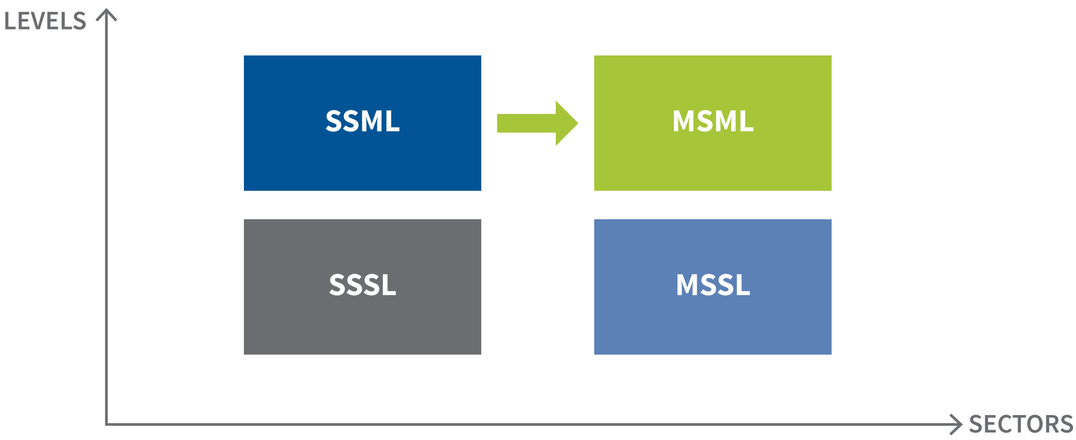


Figure 10 puts the MSML architecture into the context of possible electricity system architectures. Liberalization promoted the evolution SSSL > SSML, now the Green Deal and energy system integration require the step SSML > MSML.

Figure 10 | **Classification of electricity systems architectures**



SSML: Single Sector Multiple Level
MSML: Multiple Sector Multiple Level
SSSL: Single Sector Single Level
MSSL: Multiple Sector Single Level

Any MSML architecture supports different types of transactions. The transactions may be classified according to different criteria, such as space, time and nature:

- space (or location): within each layer, in each sector; across layers within the same sector or even across sectors;
- time: the moment in which a decision about the transaction is taken or the time-frame in which the transaction actually takes place;
- nature: "economic" (decided either bilaterally or through a market operator according to commercial interests; in both cases, they may concern either "physical" or "financial" products) or "technical" (managed through network or system operators according to specific operational requirements).

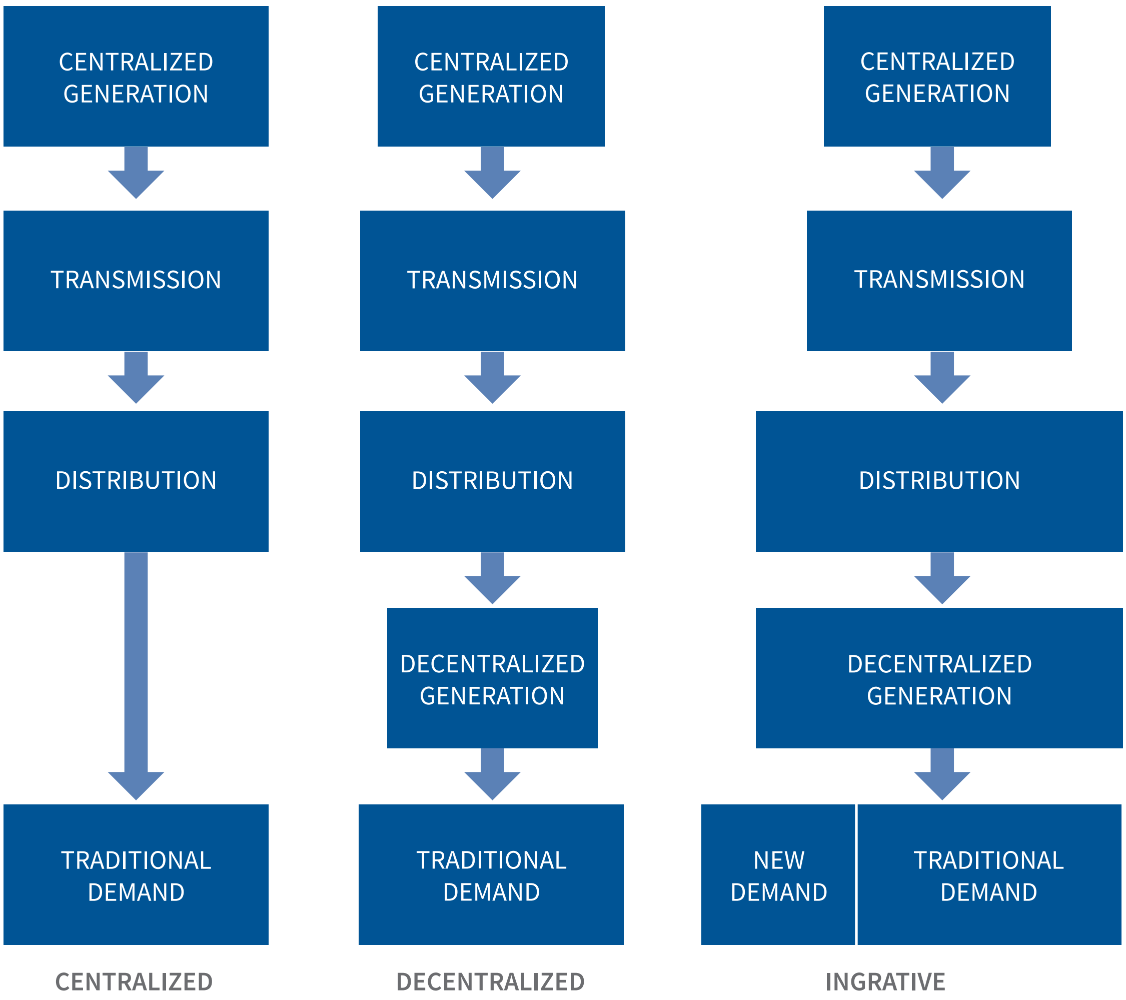
Leaving the silos and moving towards a MSML architecture is a complex process. In this context, optimization may assume different meanings: for example, it may lead to minimization of greenhouse gas emissions, to minimization of natural resources use, to minimization of energy use, to maximization of economic output, to maximization of sustainable growth, etc.. The design of local electricity platforms depends upon the hierarchy of those locally preferred goals, as well as upon the number and characteristics of the sectors to be integrated.

How local solutions will emerge and converge through a MSML architecture is not obvious, and there is no one-size-fits-all approach. This difficulty is not exclusive of electricity systems, but rather a diffuse challenge of our times, as clearly stated by the philosopher Philip Clayton: "*We recognize that simpler systems combine to produce new, more complex systems. But we don't currently have sufficiently general language to describe and quantify this process. This is one of the great scientific puzzles of our day.*"[39]

Fig. 11 summarizes the evolution of electrical systems in the 21st century, from the traditional, still conceptually and institutionally dominant, centralized model, through decentralization, towards the future energy system integration model, based on the MSML energy architectures described above.

39 Philip Clayton, *On the plurality of complexity-producing mechanisms*. In Charles H. Lineweaver, Paul C.W. Davies and Michael Ruse (eds.), *Complexity and the arrow of time*. Cambridge University Press, 2013. Pg. 333.

Figure 11 | **Evolution of electricity systems in the 21st century**

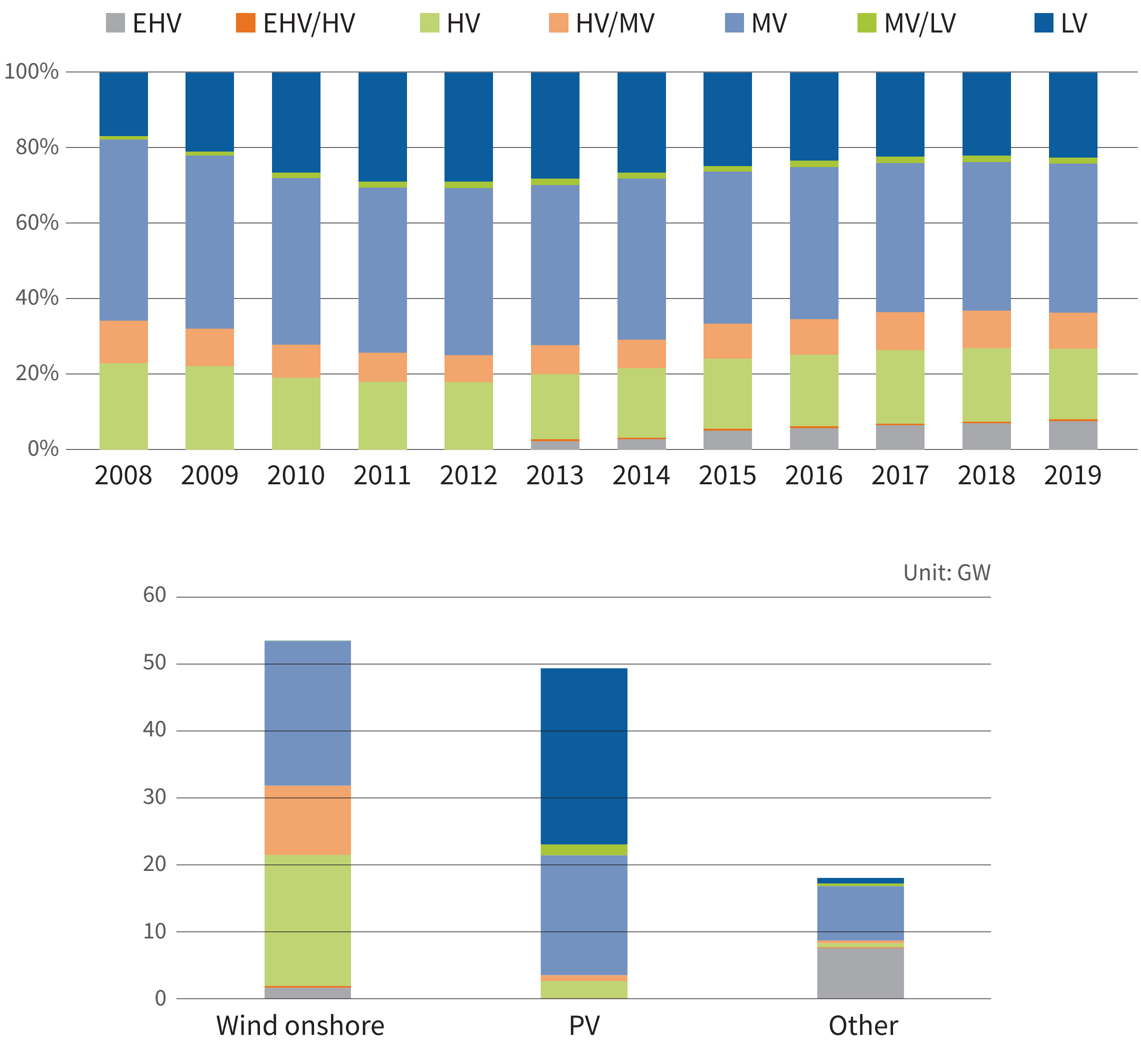


Decentralization is a worldwide trend, associated with the increase of renewable electricity generation. Worldwide, "*[s]ince 2011, renewables have accounted for more than half of all capacity additions in the power sector.*"[40] Basically, decentralization means that new renewable generation capacity is mainly connected at distribution level, both at low-voltage (small rooftop photovoltaic plants) and at medium-voltage level. Consequently, centralized generation covers a decreasing percentage of total electricity demand. However, because the new renewable generation is intermittent, centralized back-up capacity is still necessary; therefore, the increase of decentralized capacity does not translate into the same amount of centralized capacity decrease (see Fig. 11, "Decentralized" model). Moreover, large off-shore wind and hybrid plants are planned at certain coastal areas.

40 IRENA, *Renewable Energy Integration in Power Grids | Technology Brief*, 2015. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA-ETSAP_Tech_Brief_Power_Grid_Integration_2015.pdf

Decentralization started in some Member States at the turn of this century, simultaneously with the development of photovoltaic, wind and biomass power plants, having reached already a significant weight - see Fig. 12 In Europe, around 95% of new generation capacity is now connected to distribution networks[41]. For example, in Germany, 1.3 million generators are now connected at low-voltage level, corresponding to 23 GW or 10% of total national installed generation capacity, and 61 thousand generators are connected at medium-voltage level (51.7 GW, 23%)[42]. In Italy, 913 thousand photovoltaic generators (98% of all photovoltaic plants) are connected at low-voltage networks, corresponding to ca. 7% of total national installed generation[43].

Figure 12 | **Renewable electricity generation capacity by voltage level in Germany**



Source: Own elaboration based on data from Bundesnetzagentur

41 Similar figures can be found in many places, e.g. Alain Beltran, Michel Derdevet and Fabien Roques, Énergie, Descartes & Cie., Paris, 2017. Pg. 21

42 Bundesnetzagentur, *Bericht zum Zustand und Ausbau der Verteilernetze 2021*, 2022. Pg. 46

43 GSE, Solare fotovoltaico – rapporto statistico 2020, Pg. 11 https://www.gse.it/documenti_site/Documenti%20GSE/Rapporti%20statistici/Solare%20Fotovoltaico%20-%20Rapporto%20Statistico%20GSE%202020.pdf

One of the issues raised by decentralization is how much decentralized generation can be “absorbed” by existing distribution networks (i.e., without new investments on network reinforcement). For instance, a recent study found that “*with the capacity of the present grid Sweden can supply 24%, Germany 60% and UK 21% of their current annual net electricity consumption from residential solar photovoltaic.*”[44]

The decentralized model basically transfers generation assets from transmission to distribution networks, thus creating the need to a) manage those resources at distribution level and b) coordinate local management with centralized system operation.

Energy system integration goes a step further by creating new types of electricity demand (e.g. through electrification of heating/cooling and transportation) and augmenting the amount of distributed electricity generation. This model requires a new type of resource management, much more complex than in the decentralized model: both in mobility (“smart charging”, “V2G”) and in heating (“smart storage”) advanced demand management is crucial; this trend will inevitably lead to higher intensity and sophistication of traditional demand side management. The electricity distribution network is transformed into a (physical) electricity platform whose main function is to enable the efficient local integration (and decarbonization) of all energy-related sectors, through a (transactional) platform, requiring different algorithms and procedures for optimization, protection and control. The local platform has two sides, a physical infrastructure and a transactional superstructure, and the two are inseparable like the two sides of a coin.

44 Elias Hartvigsson et al., Estimating national and local low-voltage grid capacity for residential solar photovoltaic in Sweden, UK and Germany, Renewable Energy, Volume 171, 2021, Pages 915-926.

NETWORKS: THE MISSING ARMS BEYOND THE INVISIBLE HANDS

There continues to be a lack of adequate communication and understanding between economists focused on the design and evaluation of alternative market mechanisms and network engineers focused on the physical complexities of electric power networks and the constraints that these physical requirements may place on market mechanisms.

Paul Joskow and Jean Tirole, Reliability and competitive electricity markets, 2006

Lessons from the liberalization experience

In the old days of vertically integrated monopolies, electricity networks were designed to convey centralized generation to demand at least cost, for a given reliability level. Therefore, at the onset of electricity liberalization, the legacy network served legacy generation, putting incumbent generators at advantage compared to newcomers. Usually, each new generator connected to the grid further drove the legacy network away from its optimal operational point (as defined in the vertically integrated framework) and increased the amount of "congestion" in the existing network, thus ideally requiring some degree of network expansion to "re-optimize" the electrical system. The following paragraphs describe what happened in Europe in recent decades.

The quantity of combined cycle power plants connected to the grid, in the EU-27, following liberalization, is quite impressive, as indicated by the amount of their total installed capacity[45] in the following sample years:

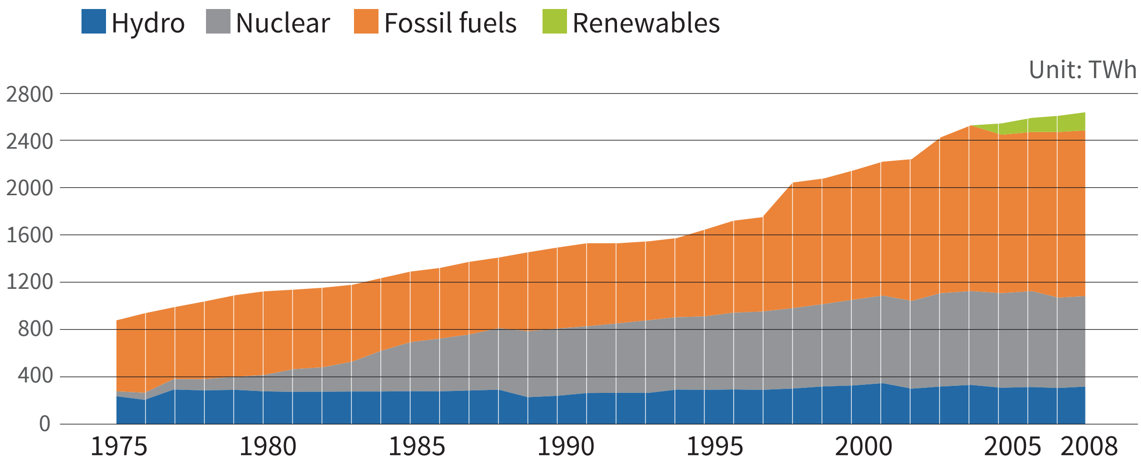
1990 .... **2 GW**
1996 (liberalization starts) .... **8 GW**
2003 (2nd liberalization package) .... **36 GW**
2009 (3rd liberalization package) .... **87 GW**
2020 .... **119 GW**

The new gas-fired electricity generation complemented coal-fired generation in the supply of EU electricity demand, as clearly illustrated in the following graph, corresponding to the interconnected system of continental Europe (the so-called UCTE countries) from 1975 until 2008[46].

45 Eurostat

46 UCTE Statistical Yearbook 2008, pg. 133.

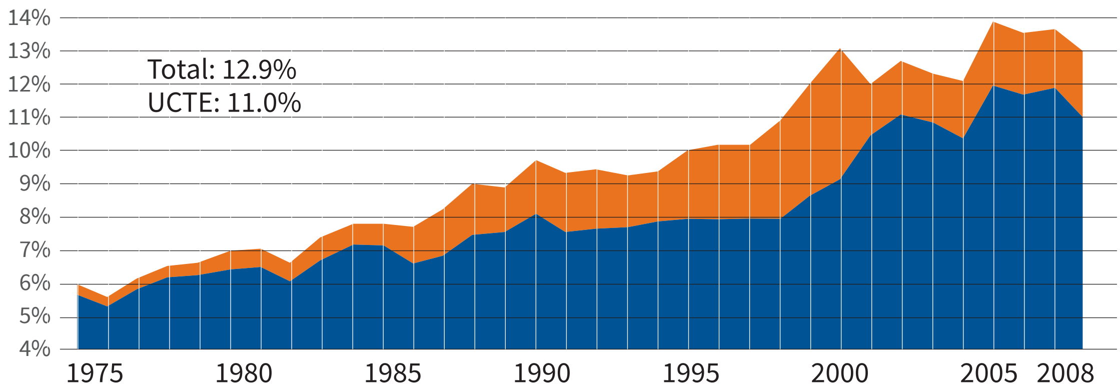
Figure 13 | **Net electricity generation in interconnected continental European countries (UCTE)**



Source: UCTE

As can be observed in the previous graph, thermal electricity from fossil fuels, mainly generated by large, centralized power plants, almost doubled from 1995 to 2004: it increased from 730 TWh in 1995 to 1386 TWh in 2004, remaining stable after that. In principle, such massive expansion of generation should lead to significant expansion of the transmission grid. Moreover, construction of the Internal Electricity Market required expansion of interconnection capacities, which at many borders are still extremely low. The ratio of electricity exchanges to electricity demand, in the original UCTE countries ("Western continental Europe"), increased from 5.7% in 1975 to 8.4% in 1995 (see Figure 14). In the year 2000 (four years after liberalization started), the ratio was just 8.5%. Thanks to the inclusion in UCTE of the four Central European countries, in 2000, the ratio jumped to 10.5%, in 2001; in the year 2008, it was just 11.0%, as indicated in the next figure[47].

Figure 14 | **Ratio of cross-border physical electricity exchanges to demand**

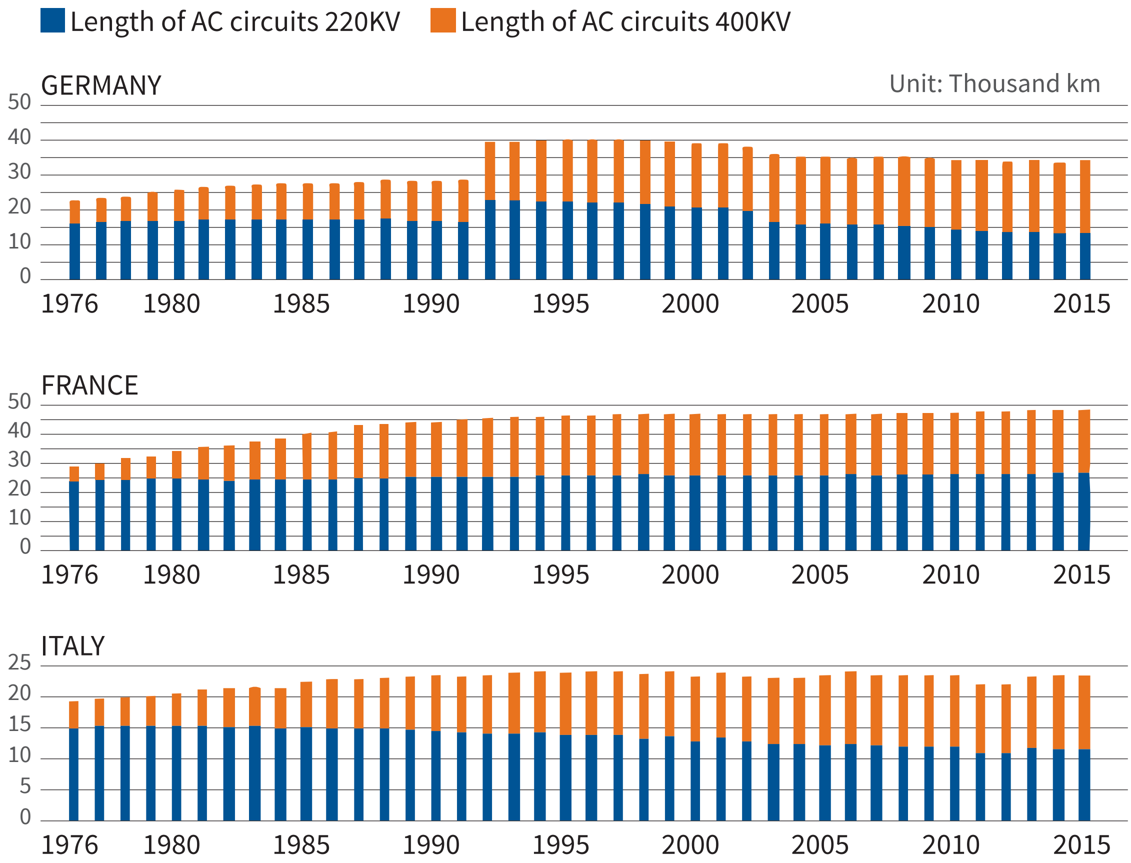


Source: UCTE

47 Ibid., pg. 138.

Therefore, there were two strong reasons for increasing electricity transmission capacity in Europe, both internally in each Member State, and across borders. Unfortunately, the opposite happened in the "core" network, as can be seen in the following graphs[48] showing reductions of transmission lines length (km) in the three major continental European countries: Germany (15% between 1996 and 2015), France (1998-2003) and Italy (3% between 1996 and 2015). The situation was better at the periphery of the continental interconnected system, as shown by the Spanish case (note that network expansion was almost entirely Iberian, since interconnections with France remain insufficient).

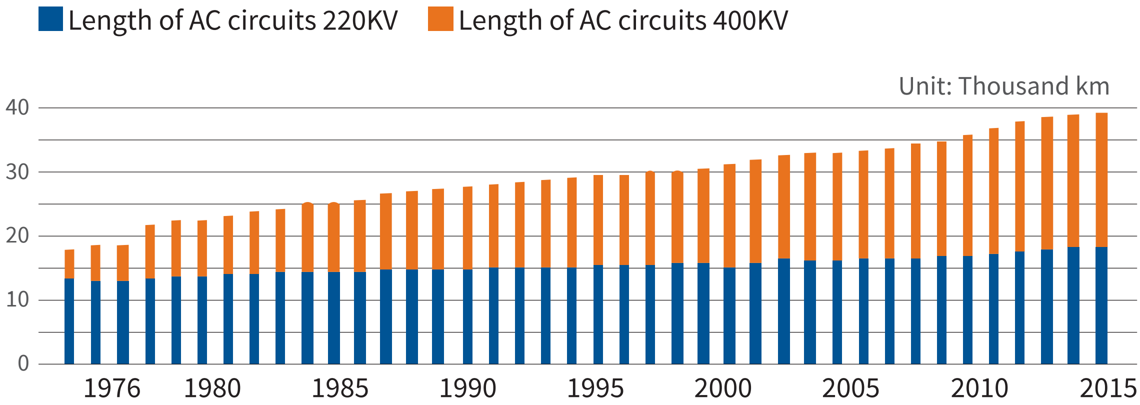
Figure 15 | **Evolution of the length of electricity transmission lines in Germany, France and Italy**



Source: ENTSO-E

48 Own elaboration based on data ENTSO-E, Inventory of Transmission 1975-2015, https://www.entsoe.eu/data/power-stats/.

Figure 16 | **Evolution of the length of electricity transmission lines in Spain**



Source: ENTSO-E

The lack of transmission investment since liberalization started, in 1996, explains the persistence of wholesale price differentials across Member States, and the increasing amounts of congestion management costs and loop flows, as shown in the following figures.

Figure 17 | **Evolution of spot electricity prices in selected markets**[49]

Yearly summary - average price (€/MWh)

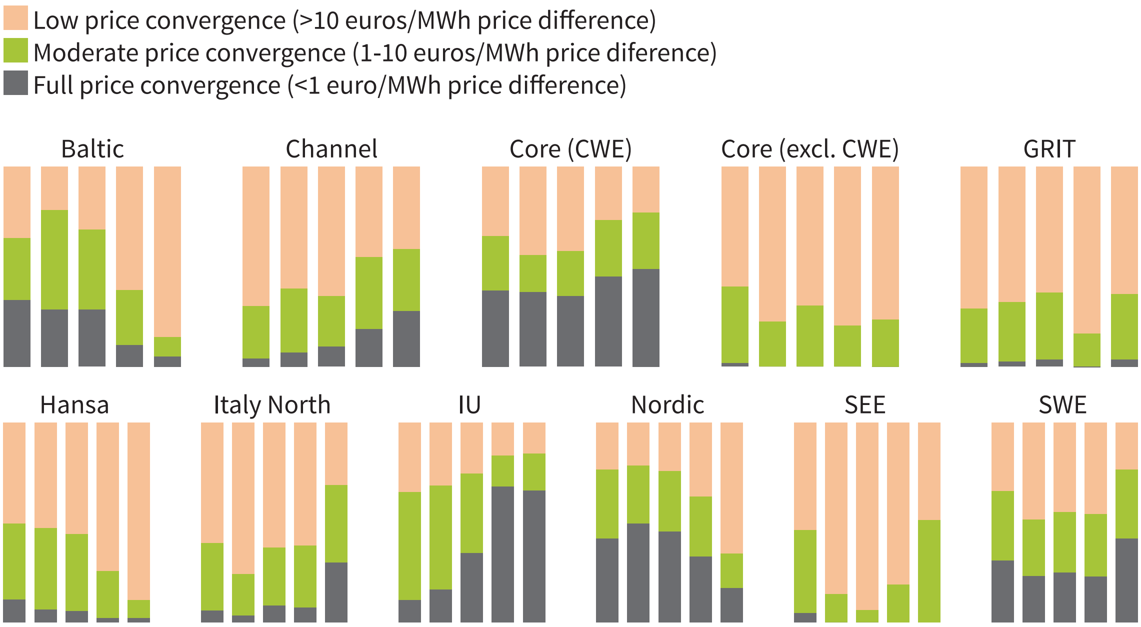
Period	Italy	Germany	Scandinavian Area	Spain	France
2004*	51,60	28,52	28,91	27,93	28,13
2005	58,59	45,97	29,33	53,67	46,67
2006	74,75	50,78	48,59	50,53	49,29
2007	70,99	37,99	27,93	39,35	40,88
2008	86,99	65,76	44,73	64,44	69,15
2009	63,72	38,85	35,02	36,96	43,01
2010	64,12	44,49	53,06	37,01	47,50
2011	72,23	51,12	47,05	49,93	48,89
2012	75,48	42,60	31,20	47,23	46,94
2013	62,99	37,78	38,35	44,26	43,24
2014	52,08	32,76	29,61	42,13	34,63
2015	52,31	31,63	20,96	50,32	38,48
2016	42,78	28,98	26,91	39.67	36,75
2017	53,95	34,19	29,41	52,24	44,97
2018	61,31	44,47	43,99	57,29	50,20
2019	52,32	37,67	38,94	47,68	39,45
2020	38,92	30,47	10,93	33,95	32,20
2021	125,46	96,85	62,87	111,93	109,17

* The data refer to the nine months from 1 Apr. 2004 to 31 Dec. 2004

Source: Refinitiv/GME

49 GME https://www.mercatoelettrico.org/en/Statistiche/ME/BorseEuropee.aspx

Figure 18 | Day-ahead price convergence in selected regions[50]



Note: Full price convergence: <1 euros/MWh difference. Moderate price convergence: 1-10 euros/MWh difference. Low price convergence: >10 euros/MWh difference. The number of bidding zones varies among CCRs; full price convergence is more complex to achieve in CCRs with a higher number of zones.

Source: ACER calculations based on ENTSO-E data

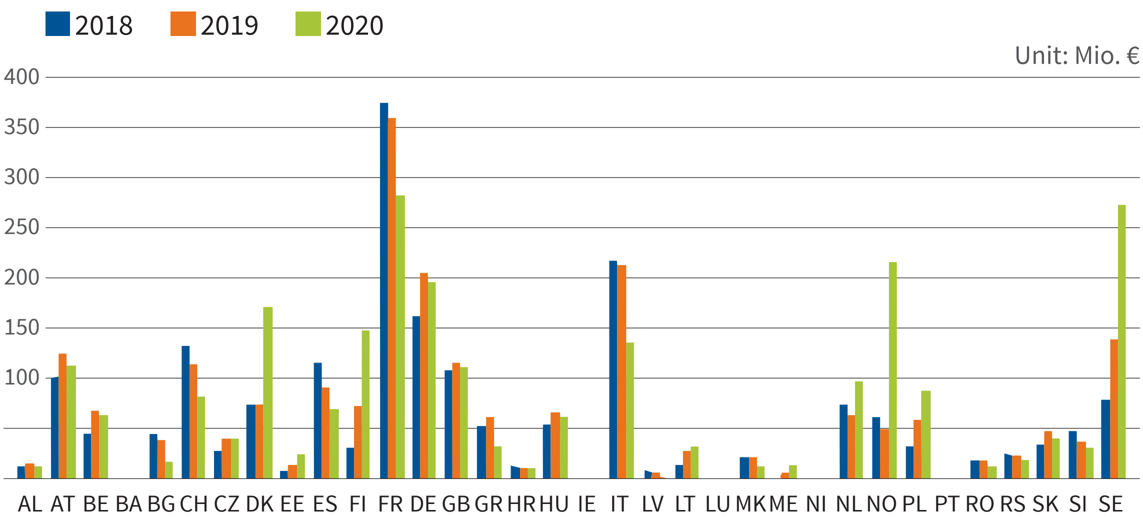
50 ACER/CEER, Annual report on the results of monitoring the internal electricity markets in 2020, pg. 39.

Figure 19 | **Cost of remedial actions for congestion management; loop flows**[51]

Country	Percentage of time when the 70% min. target is met (%)	Cost of remedial actions used for congestion management per unit demand (average 2018-2020, euro/MWh demand)	Loop flows vs. thermal capacity on interconnectors (%) (average 2018-2020)	Loop flows vs. thermal capacity on interconnectors (%) (worst border, average 2018-2020)
AT	34%	2.08	22%	57%
BE	1%	0.04	20%	20%
BG	0%	0.00	9%	14%
CZ	46%	0.01	36%	57%
DE	5%	2.13	24%	77%
DK	21%	0.00		
ES	55%	0.74	0%	1%
FR	33%	0.00	11%	34%
GR	67%	0.00	5%	14%
HR	1%	0.00	25%	25%
HU	0%	0.01	14%	25%
IT	44%	3.82	35%	49%
NL	1%	0.61	17%	20%
PL	18%	0.72	41%	77%
PT	47%	0.12	0%	0%
RO	2%	0.00	7%	11%
SI	3%	0.00	33%	49%
SK	22%	0.00	20%	30%

Source: ACER/CEER

Figure 20 | **Congestion income by country 2018 - 2020**[52]



Source: ENTSO-E

51 Ibid., pg. 117.

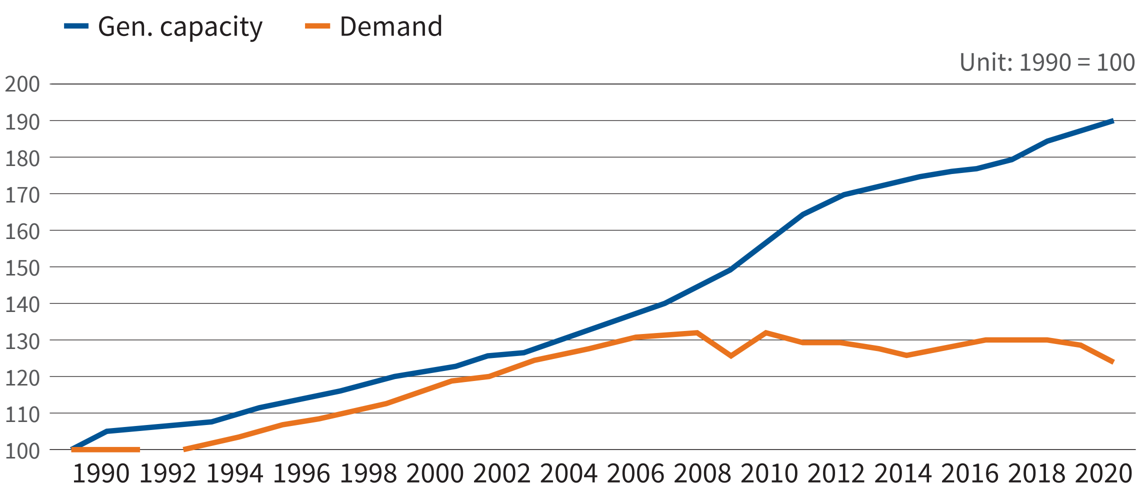
52 ENTSO-E, *Bidding Zone Configuration Technical Report 2021*, December 2021, pg. 84.

As regards congestion revenues in general, and interconnection rents in particular, it is worth recalling how much they have increased; in 2020, congestion incomes in France and in Sweden (see figure above) were higher than the total, EU-wide, volume of inter-TSO compensation payments. It is also worth recalling the following statement by the Norwegian TSO on November 17, 2021[53]:

"In total, the congestion revenues so far this year have been close to NOK 3.9 billion. It is expected that the total congestion revenues in 2021 will cover over 40% of the costs for the transmission grid Statnett is responsible for."

Figure 21 reveals that although electricity demand has increased, in the 1990s and until 2006 (45% in Italy, 38% in France and 13% in Germany[54]), transmission capacity (taking circuit length as a proxy) did not increase during this period. On the other hand, EU-27 installed electricity generation capacity increased proportionally to demand, as expected, in line with past experience, as shown in Figure 21[55]. Figure 21 reveals another interesting fact, namely the disconnect between electricity installed generation capacity and demand, starting in 2006: while demand stabilized around 30% above the 1990 level, installed capacity increased 90% compared to 1990.

Figure 21 | **Evolution of electricity demand and installed generation capacity, EU-27**



Source: Own elaboration based on Eurostat

53 https://www.statnett.no/en/about-statnett/news-and-press-releases/news-archive-2021/record-high-revenues-from-the-interconnectors-will-reduce-the-grid-tariff/

54 Eurostat

55 Own elaboration based on Eurostat. 1990 values taken as 100.

The impressive increase of new capacity, mainly as a result of subsidized renewable electricity generation, requires an urgent increase of transmission capacity, as recently acknowledged by transmission system operators[56]:

"The study finds needs everywhere in Europe, with a total of 50 GW of needs on close to 40 borders in 2030 and 43 additional GW on more than 55 borders in 2040. Addressing system needs would put Europe on track to realize the Green Deal, with 110 TWh of curtailed energy saved each year and 55 Mtons of CO2 emissions avoided each year until 2040. Market integration would progress, with price convergence increasing between bidding zones thanks to an additional 467 TWh / year of cross border exchanges by 2040. Investing 1.3 bn € each year between 2025 and 2030 translates into a decrease of generation costs of 4 bn € per year, while investing 3.4 bn € each year between 2025 and 2040 decreases generation costs by 10 bn € per year."

As shown above, price signals coming out of wholesale electricity markets were unable to promote the necessary network investments, contrary to some naif beliefs[57]. The gap between these beliefs and reality was well illustrated by Eurelectric, back in 2016, when answering the question *"Can you provide any concrete example or experience where price signals were/are inappropriate/appropriate for short-term utilisation or long-term development of the power system?"*; their answer was as follows[58]:

"Today, there are various interventions leading to a lack of trust in the market prices. For instance:

- *Implicit price caps*
- *Strategic reserve dispatch*
- *Remedial actions usage*
- *Regulated prices*

As an example, EURELECTRIC would like to refer to the day-ahead price observed in Belgium on 22-23 September 2015. The price cleared around 450 €/MWh on the 22nd and around 50 €/MWh on the 23rd. Around 1000 MW additional import capacity was available for Belgium on the 23rd. CWE TSOs explained during the Flow Based Consultative group

56 ENTSO-E, Ten-Year Network Development Plan 2020, Completing the map · Power system needs in 2030 and 2040, August 2021, pg. 8 https://eepublicdownloads.blob.core.windows.net/public-cdn-container/tyndp-documents/TYNDP2020/FINAL/entso-e_TYNDP2020_IoSN_Main-Report_2108.pdf

57 However, several experts had warned against such naif expectations. For instance, in 2006, based on their research work, Joskow and Tirole pointed out that *"Taken together, these results suggest that the combination of the unusual physical attributes of electricity and electric power networks and associated reliability considerations, limitations on metering of real time consumer demand and responsiveness to real time prices, restrictions on the ability to ration individual consumers, discretionary behavior by system operators, makes achieving an efficient allocation of resources with competitive wholesale and retail market mechanisms a very challenging task."* (Paul Joskow and Jean Tirole, *Reliability and competitive electricity markets*, 2006).

58 EURELECTRIC, A EURELECTRIC Response paper to ENTSO-E survey on market efficiency with regard to bidding zone configuration, August 2016, pg. 5

of March 30th that extra remedial actions were taken on the 23rd and that this kind of remedial action can be taken in case of extreme market prices. EURELECTRIC thinks that no price information should be taken into account when doing capacity calculation. This kind of intervention is preventing the market to trust the prices and hence, to rely on it to make decisions (being dispatch or investments).

A second example, which is detailed in our paper "Optimal use of the transmission network: a regional approach" (June 2016), is the capacity allocation on the Danish-German border. Cross-border capacity limitations/restrictions are often used as a non-costly way to deal preventively with potential congestions. This will generate inefficient use of the grid and hence, incorrect price signal."

The European Federation of Energy Traders (EFET) provided the following answer to the same question[59], adding more detail to EURELECTRIC's diagnosis:

"A pure energy-only market provides undistorted price signals. However, the European energy landscape is far from an energy-only market, and energy prices are being distorted by non market-based measures such as those described below:

- *Politically driven interventions in the market:*
  - *Subsidies of all sorts, including to RES-E generators*
  - *Grid privileges awarded to certain RES-E generators (priority access and dispatch, lack of balancing responsibility)*
  - *Unnecessary and/or poorly designed capacity remuneration mechanisms (CRMs)*
- *Taxes, such as carbon taxes introduced in parallel to the EU ETS*
- *Different treatment of auto-generation and auto-storage (behind the meter)*
- *Market splitting*
- *Financial regulation – MiFID, EMIR, CRD, MAD/MAR*
- *Lack of competition (volumes, market parties, vertical integration)."*
- *In this context, EFET also provided the following candid statement [60]:*

"there is no such thing as a "correct" price signal. Price signals always reflect the state of the market, taking account of all the design features of the said market. As such, they will always be "correct"."

This means, by other words, that energy traders are agnostic about the "state of the market" – as long as there is an open market where traders can trade, they will trade, playing by the rules and maximizing their benefit. As long as market rules enable

59 EFET, EFET comments on ENTSO-E survey on market efficiency with regard to bidding zone configuration, August 2016, pg. 13

60 Ibid.

trade, prices – and profits – are considered “correct”. Correct means consistent with a specific market design, assuming that everybody plays by these specific rules. This does not mean, however, either that these “correct” prices lead to efficient generation and network investments, or that the profits are fair.

The lack of transmission network investment over the first two decades of electricity liberalization has severely obstructed the development of efficient competition. “Price signals” were unable to promote the necessary network investments – for example, between 1996 and 2015, the length of transmission lines (440 kV plus 220 kV) even decreased in Germany and Italy, while congestion income and redispatching costs continuously increased.

Network expansion to support a twofold increase of electricity demand by 2050, as required by the Green Deal, cannot rely on “price signals” provided by wholesale markets where 50% and more of total installed capacity enjoys a State guaranteed price[61]. Reaching the Green Deal objectives requires speeding up expansion of electricity networks – not only transmission, but also distribution networks – and this requires a new approach to network planning.

Networks for the energy transition

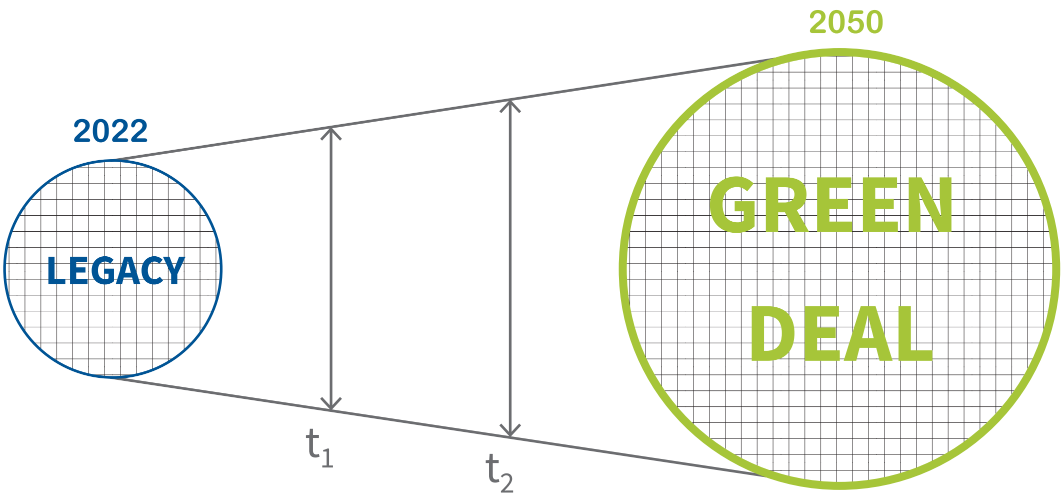
Network operators usually apply some kind of cost-benefit analysis to justify the proposed investment plans and regulators sometimes apply their own methodologies to check and approve or reject them. Network operators are interested on network expansion since this means enlarging their regulated asset base, hence their allowed revenues. Politicians and some energy regulators are reluctant to incentivize network expansion because the associated costs emerge immediately, through increased network tariffs, while the benefits will materialize many years later, when they will not be in office anymore. Moreover, the hidden costs of no action, i.e., keeping the legacy network unchanged, are usually not quantified at all, or not properly quantified. Besides this absence of interest alignment, difficulties in permitting and licensing of new network infrastructures, especially if overhead, also contributed to the lack of network expansion described in the previous pages.

The road to carbon neutrality requires augmented electricity networks – the European Commission estimates a twofold electricity demand increase by 2050. When

61 In 2021, in Germany, out of 232,7 GW total installed capacity, 134 GW receive a subsidy under the EEG law – i.e., 58% of total installed capacity is subsidized
https://www.bundesnetzagentur.de/DE/Fachthemen/ElektrizitaetundGas/Versorgungssicherheit/Erzeugungskapazitaeten/Kraftwerksliste/start.html

moving from the legacy network towards the future Green Deal network, at each point in time – see t_1 and t_2 in Figure 20 - there will always be some degree of inadequacy between the actual network and the necessary network to fully meet users' and public policy needs.

Figure 22 | **From the legacy network to the Green Deal electricity network**



In fact, whenever a substantial change occurs in the relevant public policy framework, such as the Green Deal, or in the basic technical or economic conditions of a given network industry (e.g. through the irruption of Internet of Things), the respective network infrastructure becomes – to some extent - inadequate to the new reality. Inadequacy may relate to any network feature, namely:

- **Topology** - a suitable network must connect the "right" dots (i.e., producers/sellers/senders with consumers/buyers/receivers); if some actors are left "off-grid", they cannot benefit from the advantages provided by the network.

- **Capacity** - the branches connecting the dots (nodes) must exhibit the "right" physical characteristics (namely capacity), i.e., they must enable the required flows between nodes; insufficient capacity leads to congestion, latency or similar phenomena, while overcapacity means idle assets – both cases causing economic inefficiency.

- **Regulation** - the technical and commercial rules governing infrastructure access and use should enable all legally acceptable transactions to take place in the most efficient way, be it along traditional or new business models.

At one extreme of the inadequacy scale, infrastructure may be just slightly misadapted to the new reality, thus requiring only minor, incremental changes in some rules, not implying new investments; at the other extreme, infrastructure may become obsolete, hence requiring major infrastructure overhaul and substantial investments. In some cases, as in mobile phones, totally new, competing networks are built that coexist with the old networks. Sometimes, the obsolete infrastructure is dismantled (e.g. when a subway replaces a tram in urban transportation systems; could happen with natural gas infrastructure). Between these two extreme situations, infrastructure usually needs to be somehow adapted to change.

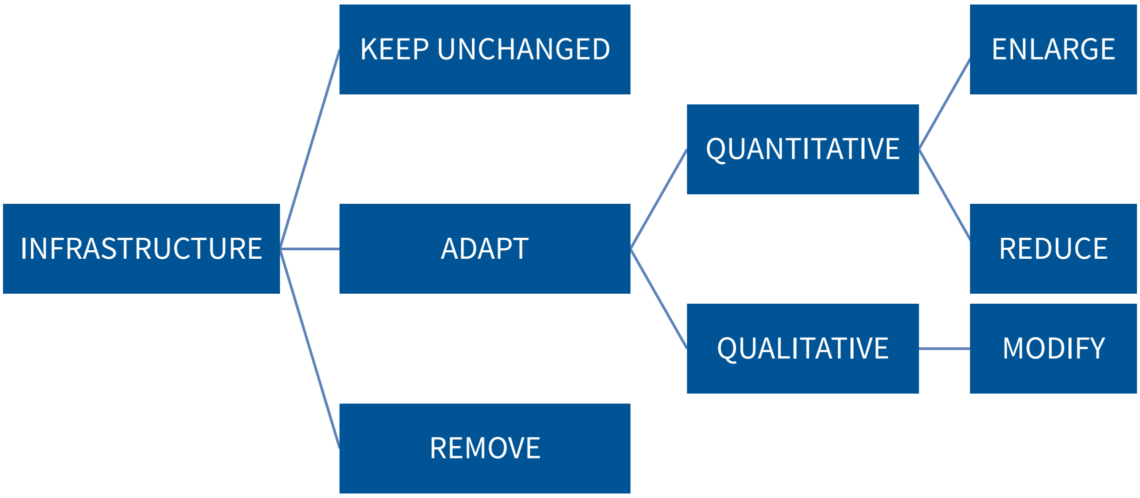
Network inadequacy may arise instantaneously at the very moment that a new public policy enters into force defining new goals and new roles that cannot be fulfilled within the existing network. From that moment on, the legacy infrastructure becomes an obstacle to the effective fruition of some rights and to the achievement of some policy targets.

Infrastructure inadequacy creates difficulties to the development of the emerging reality and it prevents some transactions from materializing, totally or partially – for instance, due to congestion. Therefore, inadequacy causes costs that would not exist if the infrastructure was perfectly adapted to the new requirements/conditions. On the other hand, changing the infrastructure and the way it is used usually requires new investments that will increase the costs supported by network users. Moreover, some past investments may become useless under the new conditions. This problem is known in the literature as "stranded costs".

Although inadequacy may arise suddenly, (re)establishing adequacy may take a long time, due to the complex technical and administrative procedures usually involved.

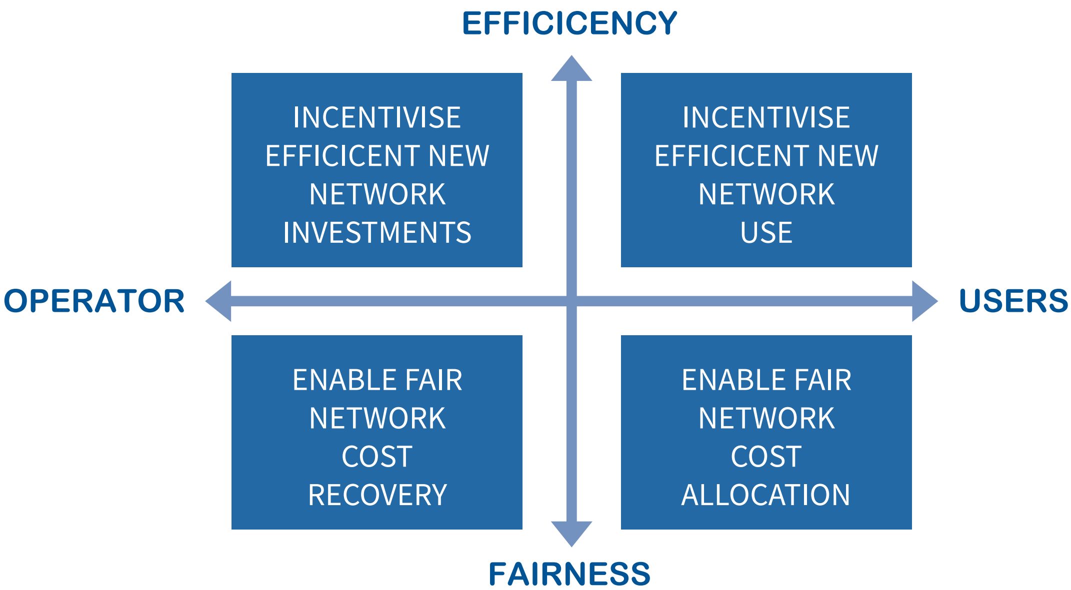
Adaptation may be more of "quantitative" nature (adding new elements, upgrading others or removing some parts of the network) or more "qualitative" (e.g. changing existing rules or adding new rules concerning access and/or use of the infrastructure, at technical and/or business level), as indicated in the next figure. Each case requires a different regulatory approach, both in the short-term (i.e., during the transitional phase) and in the long-term (i.e., in the new state corresponding to the Green Deal 2050 scenario).

Figure 23 | **How to handle legacy infrastructure following structural changes**



Regulation must promote the necessary infrastructure adaptation, providing appropriate signals both to infrastructure owners/operators and to infrastructure users. In other words, some kind of "re-regulation" becomes necessary and must be properly designed and implemented. Re-regulation must address four symmetric issues, as described in Figure 24: on the one hand, incentivise new investments and enable fair past cost recovery for network operators; on the other hand, promote efficient use of the available infrastructure and provide fair allocation of costs among consumers (network users) along the road.

Figure 24 | **Re-regulation of legacy networks during the energy transition**



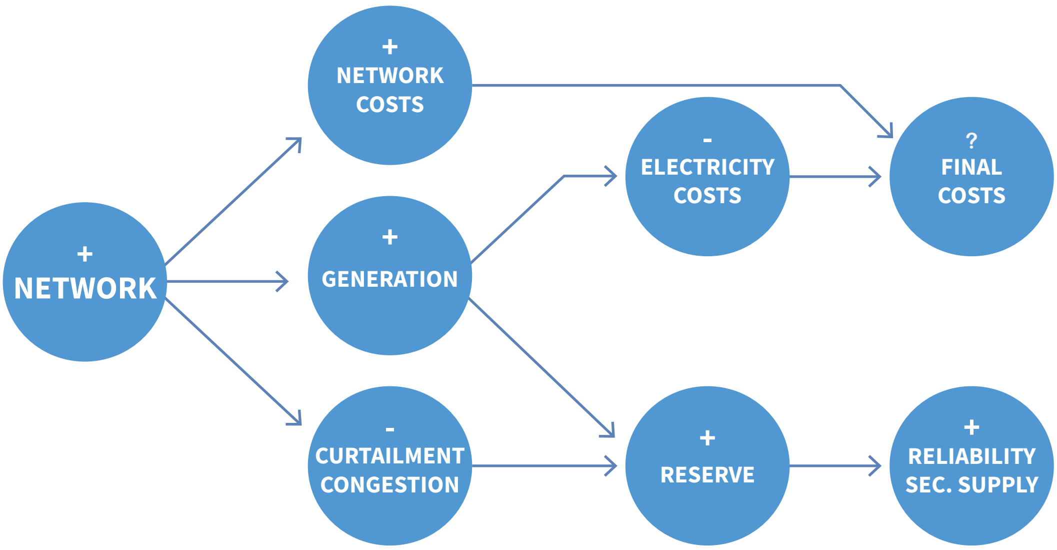
Re-regulation requires complex and, to a large extent, subjective, trade-offs among, i.a., efficiency, fairness, celerity and adaptability. Adaptability involves two different dimensions:

- On the one hand, it is a matter of "timing" – establishing the right timing to allow stakeholders (all or at least a significant majority) to adapt to the new rules in such a way that extreme situations of inefficiency and/or unfairness are avoided. Conversely, this dimension can be seen as the degree of inefficiency and/or unfairness that regulation considers acceptable in order to implement all required regulatory modifications within a certain time horizon; the deadline may be externally prescribed (for example, through legislation) or self-determined by regulation.

- On the other hand, it is a matter of "flexibility" – providing enough latitude to allow for unexpected and/or unintended developments to be appropriately handled within the new "regulatory contract", thus avoiding too frequent *ad hoc* regulatory amendments.

Figure 25 describes the expected major impacts of any electricity network expansion.

Figure 25 | **Main impacts of network expansion to meet Green Deal objectives**



More network means, obviously, more network costs to be supported by network users. On the other hand, more network capacity means that more generators can be connected to the network and compete with other generators, thus lowering wholesale electricity prices. The impact upon end-user retail prices will result from the algebraic sum of electricity cost reductions and network cost increases; potential net direct price benefits depend on the amount of network costs involved, i.e., on the degree of network reinforcement.

Furthermore, network expansion means less curtailment of renewable energy sources and less congestions[62] in the network, thus also increasing available generation capacity and reserve margins. This leads to increased reliability and security of electricity supply, besides reducing lost energy by curtailment, thus inducing an indirect price benefit.

In the past 25 post-liberalization years, networks have been analyzed mainly from the short-run perspective. However, *"transmission management has also important implications in the long run when generation and transmission expansion are taken into account"*, namely because *"welfare optimal line investment is crucially affected by the investment in generation capacity anticipated by the transmission operator."* [63]

The issue of coordination between generation and transmission investments within electricity markets has always been one of toughest ones. As well summarized by Léautier, *"If competition, regulation, and foresight were perfect, if capacity increments could be positive and negative and made arbitrarily small, this dynamic* [generation and transmission] *investment process would converge to the optimal long-term equilibrium"*[64]. The theory is based upon the existence of perfect competition at each node; the problem, as pointed out by Cretì and Fontini, is that there are many reasons why market prices are distorted, imperfect – such as *"market power, regulatory interventions like the imposition of price caps, the absence of a complete representation of consumer demand in the wholesale market, the discretionary behavior of SOs* [System Operators], *or randomness in the load and or the costs."* [65]

The fact that between 1996 and 2015, in the EU-27, electricity generation from natural gas increased 72% and combined-cycle installed capacity increased by almost 100 GW, while transmission capacity did not increase (and even decreased in some large Member States), clearly confirms that market-based coordination of generation and transmission investments is problematic.

Theory, as well as the post-liberalization context, are based on the assumption that structrural price differences may lead to new transmission investments, namely interconnection capacities between countries or "zones" with different price levels. However, this vision of networks as highways for unidirectional bulk power transactions belongs to the past. Renewable generation is mainly connected to low- and medium-voltage distribution networks and distribution networks become local platforms for energy system integration, changing not only size, but also purpose.

62 Although the notion of network congestion seems rather intuitive, it is technically complex. ENTSO-E points out that *"the definition of a structural congestion in Article 2 of CACM does not provide clear technical criteria to identify such congestions"* - ENTSO-E, *Bidding Zone Configuration Technical Report 2021*, December 2021, pg. 11.

63 Veronika Grimm et al., *Transmission and generation investment in electricity markets: The effects of market splitting and network fee regimes*, IWQW Discussion Papers, No. 04/2014, pg. 29 https://www.econstor.eu/handle/10419/95860

64 Thomas-Olivier Léautier, *Imperfect markets and imperfect regulation,* MIT Press, Cambridge (MA), 2019. Pg. 216/7

65 Anna Cretì and Fulvio Fontini, *Economics of electricity*, Cambridge University Press, Cambridge, 2019. Pg. 222.

Market-based coordination of centralized generation and transmission network investments did not work in the past, when, in theory, it could have worked. Market-based coordination of decentralized resources and distribution network investments will for sure not work in the future, for the simple reason that, given existing differences in regulation, taxation and subsidies, across the many sectors involved, energy system integration cannot be achieved through processing of electricity market signals – it will be the outcome of political negotiations or it will not be…

Approving distribution network investments, aimed at transforming local networks into local platforms, will necessarily be the task of - hopefully benevolent - social planners.

Decarbonization and decentralization require a pragmatic approach to distribution network investments, taking into account the practical impossibility of establishing a perfect level playing field across all energy-related sectors. This "original sin" (from the point of view of market purists) does not preclude, however, the design of efficient and competitive exchange platforms - and their implementation upon transformed and transformative distribution networks. These new local networks, if properly designed, will offer huge new opportunities for innovative transactional and business models.

The existing electricity distribution network is the "starting point" for any energy transition and it limits what can be done, i.e., it restricts the space of possible transactions both in the merely decentralized and in the integrative model. The problem of choosing the "right" – physical - network is one of making choices that will affect the – economic - choices of network users. In fact, "*What people choose often depends on the starting point, and hence the starting point cannot be selected by asking what people choose. (…) the majority's choices might themselves be a function of the starting point or the default rule. If so, the problem of circularity dooms the market-mimicking approach*"[66] . The goal of distribution network planning supporting the development of local exchange platforms "*should be to avoid random, arbitrary, or harmful effects and to produce a situation that is likely to promote people's welfare, suitably defined.*" [67]

In recent years, in some Member States, coordination of renewable generation and transmission networks is being challenged by developers paying, in renewable auctions, not only the associated network connection costs, but also an extra MW or MWh fee to grant them the right to inject electricity into the grid for 15 or more years. In many Member States, the total amount of requested network capacity for the connection of renewable power plants (without subsidies or any type of State guaranteed

66 Richard H. Thaler and Cass R. Sunstein, *Libertarian Paternalism*, The American Economic Review, vol. 93, Nr. 2, May 2003. Pg. 178.

67 Ibid., pg. 179.

price) is larger than the total amount of installed generation capacity in the respective country. Criteria for granting or rejecting these requests are not always very clear, but the practical consequence of these projects is a much more "chaotic" network development.

Competition for network access is becoming more significant than competition in energy markets – and is increasingly becoming a synonym for "competition for the (energy) market".

Finally, hybridization (connecting more than one type of power plant at the same point, e.g., solar and wind) and combined renewable generation/storage introduce new flow patterns and new flexibility degrees into the electrical system, challenging the way network congestions are managed and valued.

Network planning and network tariffs

Electricity networks are often deemed the unhelpful monopoly between vibrant markets and smart consumers, a tedious link between competitive generation and customer choice. In the old days of vertically integrated monopolies, transmission was treated as a kind of embedded generation cost and distribution was the realm of less-skilled engineers. Except for some visible design enhancements in the shape of poles and invisible insulation improvements in cables and circuit breakers, innovation was not frequent in networks, as opposed to power plants. When liberalization was introduced in the European Union, the major concern regarding networks was to ensure that system operators do *"not discriminate between system users or classes of system users, particularly in favour of its subsidiaries or shareholders"* and therefore *"Unless the transmission system is already independent from generation and distribution activities, the system operator shall be independent at least in management terms from other activities not relating to the transmission system."*[68] This independence (through "unbundling") was reinforced in successive Directives and Regulations and it was extended to distribution system operators in 2003; at the same time, the duties of system operators have been expanded and increasingly detailed.

The first liberalization electricity Directive did not address the issue of network tariff setting. The second Directive, in 2003, stated that *"national regulatory authorities should ensure that transmission and distribution tariffs are non-discriminatory and cost-reflective, and should take account of the long-term, marginal, avoided network*

68 Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity. Official Journal L 027, 30/01/1997.

costs from distributed generation and demand-side management measures."[69]. The accompanying Regulation[70], dealing with cross-border transactions, established furthermore that *"The costs incurred as a result of hosting cross-border flows shall be established on the basis of the forward looking long-run average incremental costs, taking into account losses, investment in new infrastructure, and an appropriate proportion of the cost of existing infrastructure, as far as infrastructure is used for the transmission of cross-border flows, in particular taking into account the need to guarantee security of supply. When establishing the costs incurred, recognised standard-costing methodologies shall be used. Benefits that a network incurs as a result of hosting cross-border flows shall be taken into account to reduce the compensation received."*

Network tariffs have been and still are established in many different ways and according to many different regulatory approaches in the different Member States. At least since 2003, this diversity has not been a serious obstacle to liberalization and cross-border trade.

As regards network planning, it was initially "tolerated", in conjunction with generation planning, in the following terms: *" 'long-term planning ` shall mean the planning of the need for investment in generation and transmission capacity on a long-term basis, with a view to meeting the demand for electricity of the system and securing supplies to customers"*; *"As a means of carrying out the abovementioned public service obligations, Member States which so wish may introduce the implementation of* [generation] *long-term planning."*[71] The 2003 Directive introduces some guidelines concerning distribution (but not transmission) network planning: *"When planning the development of the distribution network, energy efficiency/demand-side management measures and/or distributed generation that might supplant the need to upgrade or replace electricity capacity shall be considered by the distribution system operator."*[72] However, the 2003 Regulation recognized that *"It is important to avoid distortion of competition resulting from different safety, operational and planning standards used by transmission system operators in Member States. Moreover, there should be transparency for market participants concerning available transfer capacities and the security, planning and operational standards that affect the available transfer capacities."*[73]

The 2009 Directive enhances the importance of network planning, namely through

69 Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in electricity and repealing Directive 96/92/EC**.** Official Journal L 176, 15/07/2003.

70 Regulation (EC) No 1228/2003 of the European Parliament and of the Council of 26 June 2003 on conditions for access to the network for cross-border exchanges in electricity. Official Journal *L 176, 15/07/2003.*

71 Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity. Official Journal L 027, 30/01/1997.

72 Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in electricity and repealing Directive 96/92/EC. Official Journal L 176, 15/07/2003.

73 Regulation (EC) No 1228/2003 of the European Parliament and of the Council of 26 June 2003 on conditions for access to the network for cross-border exchanges in electricity. Official Journal L 176, 15/07/2003.

the introduction of a specific article (Article 22) on *"Network development and powers to make investment decisions"* establishing that *"Every year, transmission system operators shall submit to the regulatory authority a ten-year network development plan based on existing and forecast supply and demand after having consulted all the relevant stakeholders. That network development plan shall contain efficient measures in order to guarantee the adequacy of the system and the security of supply."*[74] The accompanying Regulation[75] amplifies and enacts network planning through the creation of several network codes, justified in the following terms: *"In particular, increased cooperation and coordination among transmission system operators is required to create network codes for providing and managing effective and transparent access to the transmission networks across borders, and to ensure coordinated and sufficiently forward-looking planning and sound technical evolution of the transmission system in the Community, including the creation of interconnection capacities, with due regard to the environment. Those network codes should be in line with framework guidelines, which are non-binding in nature (framework guidelines) and which are developed by the Agency for the Cooperation of Energy Regulators".* The network codes (several hundreds of pages) and their respective implementation progress reports can be easily accessed[76].

In a certain way, the 2009 detailed prescription of network planning tools and network regulation through EU approved network codes (confirmed and enlarged in 2019[77]) was a reaction to the lack of action by national regulatory authorities. In fact, the 2003 Directive had introduced an important article on monitoring of security of supply (Article 4):

"Member States shall ensure the monitoring of security of supply issues. Where Member States consider it appropriate they may delegate this task to the regulatory authorities referred to in Article 23(1). This monitoring shall, in particular, cover the supply/demand balance on the national market, the level of expected future demand and envisaged additional capacity being planned or under construction, and the quality and level of maintenance of the networks, as well as measures to cover peak demand and to deal with shortfalls of one or more suppliers. The competent authorities shall publish every two years, by 31 July at the latest, a report outlining the findings resulting from the monitoring of these issues, as well as any measures taken or envisaged to address them and shall forward this report to the Commission forthwith."

74 Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC. Official Journal L 211, 14/08/2009.

75 Regulation (EC) No 714/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) No 1228/2003. Official Journal L 211, 14/08/2009.

76 https://www.entsoe.eu/network_codes/.

77 Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity. Official Journal L 158, 14/06/2019.

Most national regulatory authorities, impressed by the fast deployment of combined-cycle gas-fired power plants, believed that wholesale markets would automatically provide suitable levels of security of supply and did not see the need to address reliability issues, either at national or at EU level. Where they were empowered by national legislators with this task, they usually considered it a bureaucratic, useless duty. Had they taken this responsibility seriously and voluntarily harmonized network planning methodologies and adequacy and reliability criteria across Member States, the exponential increase in EU-led regulation should not have taken place or, at least, should have been much more limited in scope.

The current top-down approach, aiming at improving integration of national markets into a single European electricity market (although via regional structures[78]) through increasingly detailed regulation, tends to sideline decentralization: paradoxically, regionalization, supposed to speed-up integration at EU level (which turned out to be an illusion), has been a powerful obstacle to decentralization, i.e., to the emergence of local markets.

Decentralization is key to meet 2030 and 2050 decarbonization goals. Therefore, the current regionalization approach must be urgently reviewed and complemented by a bottom-up approach. It is up to national regulatory authorities to promote coordination and harmonization of these two complementary approaches, striking the right balance between local and EU governance and regulatory procedures.

The brief historical background provided in the previous paragraphs shows that the logical implications of liberalization upon network planning and network tariff setting were never properly addressed. A first phase of complete omission and lack of regulation (1996-2009) was followed by a phase of overregulation, materialized in successive plans and multiple codes, often overlapping and lacking clarity (e.g., the introduction of lists of so-called projects of common interest, subsidized with taxpayers' money according to political criteria, in parallel with the introduction of ten-year network development plans approved by regulatory authorities). The current over-regulatory trend unfolds while new policy goals are established (e.g., Green Deal) that add new challenges to electricity systems, also regarding network planning and network tariff setting. These two areas require urgent reform by legislators and regulators, respectively.

78 The 2019 electricity Regulation mentions the word "regional" more than 200 times; this word was indeed absent from the 1996 and from the 2003 Directives - which were concerned with the establishment of "common rules", not with the creation and management of a fragmented regional patchwork – and appears only once in the 2003 Regulation.

GOVERNANCE OF EU ELECTRICITY MARKETS

It has often been said that modern democracies are becoming more complex, fragmented and multi-layered. In recent decades we have witnessed decentralization in many organizations (…) with these changes power has slipped away from the political centre (the government) in several directions: upwards to international organizations (not least the European Union), downwards to local authorities and municipalities, inwards to semi-autonomous state agencies, and outwards to private organizations.

Göran Sundström et al., *Democracy, governance and the problem of the modern actor,* 2009 [79]

Introduction

From a political and legal perspective, the roots of the Internal Energy Market are located at the very beginning of the European project, in the 1950s, namely in the three European Communities[80] that preceeded the European Union[81], as well as in the 1986 Single European Act. Therefore, from political, legal, and institutional viewpoints, the Internal Energy Market (also called Single Energy Market) is a typical product of the European project, and its governance reflects the European Union *'Eigendynamik'*. However, its (transnational) governance has been also influenced by more general trends, going beyond the European continent and the European project, in particular those related to the governance of global common goods such as oceans and climate. These trends act like inter-subjective soft links inducing common conceptual flows and organizational patterns in different fields and should not be equated with hard legal and/or political prescriptions - or restrictions - embodied in international treaties and passively transposed by the EU.

Identifying the major internal and external factors shaping the dynamics of EU energy market governance is important, not only to better understand "why we are where we are", but also to realize "where we can go from here", in particular as regards the governance of decentralized energy systems and its impact upon overall EU energy system governance. Before addressing the governance of decentralized energy systems from an internal perspective – i.e., both from the viewpoint of (new and innovative) decentralized energy systems and from the perspective of the (old) Internal Energy Market where those new, decentralized systems are supposed to be embedded – it is worth

79 In Göran Sundström et al. (eds.), *Organizing democracy*. Edward Elgar Publishing, Cheltenham, UK, 2010. Pg. 1

80 The European Coal and Steel Community (ECSC), the European Atomic Energy Community (EAEC or Euratom), and the European Economic Community (EEC) – renamed European Community in 1993 by the Treaty of Maastricht.

81 The European Union was created by the Treaty of Maastricht, in 1993, and "upgraded" by the Treaty of Lisbon, in 2009.

discussing some fundamental, overarching notions and how they can be applied both to describe and to reimagine EU energy governance.

A certain parallelism between EU governance developments and global, international developments can be illustrated through the following example: in 1997, the Kyoto Protocol (which entered into force in 2005) set in its Annex B binding emission reduction targets for 37 industrialized countries and economies in transition and the European Union; in 2009, the EU renewables directive[82] set in its Annex I national binding targets for the share of energy from renewable sources in gross final consumption of energy in 2020. In 2015, the Paris Agreement (which entered into force in 2016), set a global emission reduction target, but no national binding targets (countries just submit their plans for climate action known as nationally determined contributions); in 2018, the new EU renewables Directive[83] set a binding Union target of 32% for the overall share of energy from renewable sources in the Union's gross final consumption of energy in 2030, but no national binding targets (*"Member States should establish their contribution to the achievement of that target as part of their integrated national energy and climate plans pursuant to the governance process laid down in Regulation (EU) 2018/1999 of the European Parliament and of the Council"* [84]).

In the example above, there is no direct legal connection between international treaties under the United Nations Framework Convention on Climate Change, on the one side, and European Union Directives on renewable energy, on the other side. For instance, the European Union could have kept national binding renewable energy targets despite the absence of emission reduction national targets in the Paris Agreement. Although there is no legal causation, i.e., no necessary formal connection at all between the different UN and EU laws mentioned above, there is, beyond an obvious policy nexus (reducing greenhouse gas emissions requires, *inter alia*, replacing fossil fuels with renewable energy sources), a certain "cultural" link which is explained by the evolution of the "culture of political negotiations" among a large number of States (196 at the United Nations, 27 in the European Union). As a matter of fact, once a consensus-building scheme proves successful, politicians and diplomats involved in complex and lengthy negotiations tend to replicate it elsewhere, as long as the political, social and cultural context allow for "copy/paste".

The role of epistemic authorities and the subsidiarity blackout

To start with, it is important to recognize that *"inter- and transnational authority comes not only in the form of political authority – as in the case of the UNSC* [United

82 DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. OJEU L 140 of 05.06.2009.

83 DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources (recast). OJEU L 328 of 21.12.2018.

84 Ibid., whereas (8).

Nations Security Council] – *but most frequently in the form of epistemic authorities that mainly produce interpretations with behavioral implications, but not necessarily decisions to which actors defer directly"*[85]. As pointed out by Michael Zürn, *"Empirical assessment of patterns of authority in the global governance system shows that both political and epistemic authority beyond the nation state has risen generally over time since 1945, and rose especially steeply in the 1990s. At the same time, a specific type of public authority in the global governance system has gained especial relevance: politically assigned epistemic authorities (PAEAs). These are bodies to which states delegate the competence to gather and interpret politically relevant information. (…) Deference to these interpretations does not mean following a direct request or a command, but taking on an expectation that one will follow the recommendations implicit in these assessments"*[86].

Governance of the Single Market in general, and of the Internal Energy Market in particular, is indeed characterized by the creation of several "epistemic authorities" charged with the task of gathering and interpreting relevant information, as illustrated by the following list:

- In 1998, the Florence Forum (also known as European Electricity Regulatory Forum) was launched by invitation of the European Commission. Since then, it regularly publishes Conclusions, Recommendations, Guidelines for Good Practice and similar non-binding documents.

- In 1999, the Madrid Forum (also known as European Gas Regulatory Forum) was launched by invitation of the European Commission, following the Florence Forum model.

- In 2003, the European Commission established the "European Regulators Group for Electricity and Gas" (ERGEG)[87], composed by *"the heads of the national regulatory authorities or their representatives"* who elected a chairperson *"from among its members"*. According to this Decision, *"The Group, at its own initiative or at the request of the Commission, shall advise and assist the Commission in consolidating the internal energy market, in particular with respect to the preparation of draft implementing measures in the field of electricity and gas, and on any matters related to the internal market for gas and electricity. The Group shall facilitate consultation, coordination and cooperation of national regulatory authorities, contributing to a consistent application, in all Member States, of the provisions set out in Directive 2003/54/EC, Directive 2003/55/EC and Regulation (EC) No 1228/2003, as well as of possible future Community legislation in the field of electricity and gas."*

85 Michael Zürn, *A theory of global governance: authority, legitimacy, and contestation*. Oxford University Press, 2018. Pg. 9.

86 Op. cit, pg. 251.

87 COMMISSION DECISION of 11 November 2003 on establishing the European Regulators Group for Electricity and Gas. OJEU L/296 of 14.11.2003

- ERGEG was replaced in 2009 by ACER (Agency for the Cooperation of Energy Regulators)[88] on the grounds that *"The work undertaken by the ERGEG since its establishment has made a positive contribution to the internal markets in electricity and natural gas. However, it is widely recognised by the sector, and has been proposed by the ERGEG itself, that voluntary cooperation between national regulatory authorities should now take place within a Community structure with clear competences and with the power to adopt individual regulatory decisions in a number of specific cases."*[89] These *"individual regulatory decisions"* assigned to ACER were restricted to: a) the establishment of *"the terms and conditions for access to and operational security of electricity and gas infrastructure connecting or that might connect at least two Member States" "where the competent national regulatory authorities have not been able to reach an agreement"* or *"upon a joint request from the competent national regulatory authorities"*, subject to Guidelines issued by the European Commission *"on the situations in which the Agency becomes competent to decide"*; b) the concession of exemptions related to major new gas infrastructure or to the allocation of congestion management revenues from new direct current interconnectors (again, just in case the concerned national regulatory authorities are not able to reach an agreement or jointly request such a decision). Deprived of significant powers[90], ACER's role is mainly to provide opinions and recommendations *"upon a request of the European Parliament, the Council or the Commission, or on its own initiative"* – i.e., the typical tasks of "*politically assigned epistemic authorities".* In other words, ACER is not (yet ?) an independent supra-national authority in charge of regulating interstate energy facilities and interstate energy trade, like the Federal Energy Regulatory Commission in the United States of America. Maybe one day "pragmatic federalism" will prevail in the EU.

- In 2009, European Networks of Transmission System Operators for Electricity[91] and Gas[92], respectively ENTSO-E for electricity and ENTSO-G for gas, were established by law *"In order to ensure optimal management of"* transmission networks, and in particular to *"elaborate network codes"* and to adopt both *"common network operation tools"* and *"a non-binding Community-wide ten-year network development plan"* [93]. Back in 2009, these associations of transmission system operators

88 REGULATION (EC) No 713/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 July 2009 establishing an Agency for the Cooperation of Energy Regulators. OJEU L 211 of 14.08.2019

89 Ibid., Whereas (3)

90 ACER's mandate has been enlarged since 2009, namely through REGULATION (EU) 2019/942 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 establishing a European Union Agency for the Cooperation of Energy Regulators (recast). OJEU L 158 of 14.06.2019. However, the enlargement mainly concerns the scope of recommendations and coordination tasks, not the depth of regulatory action.

91 REGULATION (EC) No 714/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 July 2009 on conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) No 1228/2003. OJEU L 211 of 14.08.2009.

92 REGULATION (EC) No 715/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 July 2009 on conditions for access to the natural gas transmission networks and repealing Regulation (EC) No 1775/2005. OJEU L 211 of 14.08.2009.

93 Ibid.

were requested to propose to the European Commission, for approval, *"the draft statutes, a list of members and draft rules of procedure"*, thus enjoying remarkable freedom as regards their internal organization.

- In 2019, new members were added to the growing family of "epistemic authorities" in the energy realm, namely the "European entity for distribution system operators" (EU DSO) and electricity NEMOs (nominated electricity market operators)[94]. *"Transmission system operators and NEMOs shall cooperate at Union level or, where more appropriate, at a regional level in order to maximise the efficiency and effectiveness of Union electricity day-ahead and intraday trading"*; *"The EU DSO entity should closely cooperate with the ENTSO for Electricity on the preparation and implementation of the network codes where applicable and should work on providing guidance on the integration inter alia of distributed generation and energy storage in distribution networks or other areas which relate to the management of distribution networks"*[95]. This time, the legislator was much more prescriptive concerning the new bodies' organization than it was in 2009, now establishing, for instance, that *"The EU DSO entity shall consist of, at least, a general assembly, a board of directors, a strategic advisor group, expert groups and a secretary-general"* and that *"decisions of the general assembly are adopted"* if *"65 % of the votes attributed to the members are cast; and (iii) the decision is adopted by a majority of 55 % of the members"*[96].

Similar institutional arrangements (i.e., many *"epistemic authorities",* no EU regulatory authority, bundling in the European Commission legislative and regulatory functions) have been introduced in other industries in the EU, namely in network industries (e.g., telecommunications[97]) and in financial services (European Supervisory Authorities for banking, insurance, and securities[98]). Only the European Central Bank, established by the Treaty of Maastricht, enjoys the independence and powers of a supra-national EU regulatory authority, subjected to clear accountability procedures - and not surrounded by a myriad of "epistemic authorities".

The proliferation of "epistemic authorities" in EU regulated sectors, over the last decades, not only could not fix fundamental – technical and economic - coordination problems left unanswered by successive "legislative packages", but also added new – institutional - coordination needs. It is no surprise that the increasing number of those authorities goes hand in hand with increasing litigation, involving both sector specific appeal boards and the Court of Justice of the European Union[99].

94 REGULATION (EU) 2019/943 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on the internal market for electricity (recast). OJEU L 158 of 14.06.2019

95 Ibid.

96 Ibid.

97 https://berec.europa.eu/

98 https://ec.europa.eu/info/business-economy-euro/banking-and-finance/financial-supervision-and-risk-management/european-system-financial-supervision_en

99 Increased litigation is due not only to this expansive institutional universe, but also to the quasi exponential growth of norms and delegatd acts.

In the electricity sector, a peculiar attempt of circumventing the creation of indispensable EU coordination instances, was "regionalization", further rising coordination requirements.

In 2017, energy governance innovation at operational level was introduced by a Commission Regulation in the following terms: *"While there are currently a number of voluntary regional cooperation initiatives in system operations promoted by TSOs, formalised coordination between TSOs is necessary for operating the Union transmission system in order to address the transformation of the Union electricity market. The rules for system operation provided for in this Regulation require an institutional framework for enhanced coordination between TSOs, including the mandatory participation of TSOs in regional security coordinators ('RSCs'). The common requirements for the establishment of RSCs and for their tasks set out in this Regulation constitute a first step towards further regional coordination and integration of system operation and should facilitate the achievement of the aims of Regulation (EC) No 714/2009 and ensure higher security of supply standards in the Union."*[100] The Commission Regulation requested TSOs to *"jointly develop a proposal for common provisions for regional operational security coordination, to be applied by the regional security coordinators and the TSOs of the capacity calculation region."*[101]

This new regional approach was boosted in 2019: *"Coordination between transmission system operators at regional level has been formalised with the mandatory participation of transmission system operators in regional security coordinators. The regional coordination of transmission system operators should be further developed with an enhanced institutional framework via the establishment of regional coordination centres. The establishment of regional coordination centres should take into account existing or planned regional coordination initiatives and should support the increasingly integrated operation of electricity systems across the Union, thereby ensuring their efficient and secure performance. For that reason, it is necessary to ensure that the coordination of transmission system operators through regional coordination centres takes place across the Union."* [102] Annex I of Regulation (EU) 2019/943, comprising four pages, establishes the "Tasks of Regional Coordination Centres".

The idea that *"European regions have always been the natural place for TSOs to cooperate"*[103] is historically accurate. The EU interconnected system was developed bottom-up, starting with a small group of core networks that was enlarged step-by-step. At that time, communication technologies and computer power did not allow for real-time, full-scale monitoring and simulation of the European interconnected electricity

100 COMMISSION REGULATION (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation. OJEU L 220 of 25.08.2017. Whereas (6).

101 Ibid., Article 76.

102 REGULATION (EU) 2019/943 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on the internal market for electricity (recast). Whereas (53).

103 ENTSO-E https://eepublicdownloads.entsoe.eu/clean-documents/SOC%20documents/rscis_short_final.pdf

system; therefore, it was sensible to keep monitoring and control functions at regional level, introducing simple but effective "firewalls" at each region borders to avoid the undesired propagation of unexpected disruptive events. Moreover, there has always been a certain distrust (usually unjustified) from the "old club members" towards newcomers, considered to be less strict in terms of common rules enforcement and less technically advanced; ringfencing the core region and regionalization of system operation was a logical corollary of this self-protective viewpoint.

Today, a real-time unified view of electricity networks and electricity markets in Europe is feasible and several platforms offer day-ahead and quasi-real-time information. Nowadays, "full observability" is granted, and it would be logical to implement "full control", going beyond just "security coordination", in order to optimize operation of existing transmission assets, enhancing economic efficiency and reliability. However, such optimization requires harmonization of "congestion management" rules, i.e., deciding about how to overcome the gap between new generation and trading patterns, on the one hand, and old network infrastructures, on the other hand. These decisions involve both short-term (operational) and long-term (investment) issues with stark redistributive effects; moreover, these decisions usually also involve assumptions about spillover effects upon adjacent interconnected networks. Therefore, the idea of a single independent system operator in charge of monitoring and controlling the whole interconnected European electricity system, which is coherent with the Internal Electricity Market and has been proposed by several experts since the very beginning of EU energy liberalization, has been always rejected by Member States who are consistently averse to any explicit definition of rules with visible redistributive impacts[104]. This aversion is the main reason for not applying the principle of subsidiarity[105], which requires allocating the ultimate competence for supervision and control of the interconnected electricity system to the *only* level where it can be properly achieved, i.e., *"at Union level"*.

The first and second EU energy legislative packages basically ignored the need to build a suitable governance for transmission system operation in the Internal Energy Market; as a result, a patchwork of legacy procedures and *ad hoc* solutions has endured.

104 The existing inter-transmission system operator compensation mechanism, established by the "COMMISSION REGULATION (EU) No 838/2010 of 23 September 2010 on laying down guidelines relating to the inter-transmission system operator compensation mechanism and a common regulatory approach to transmission charging" (OJEU L 250 of 24.09.2010), improves the mechanism initially established by "REGULATION (EC) No 1228/2003 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 June 2003 on conditions for access to the network for cross-border exchanges in electricity" (OJEU L 176 of 15.07.2003). This is the only visible redistributive mechanism in the Internal Electricity Market – however, it was originally negotiated, in 2000, not by Member States, but by the European Commission and national regulatory authorities, on the one hand, and transmission system operators and the German government (there was no German regulator at that time), on the other hand, in the Florence Forum. This voluntary agreement was then adopted by Regulation (EC) N.° 1228/2003. The mechanism started with a volume of 200 M€ and reached 352 M€ in 2020 (cf. ACER, *Report on the implementation of the ITC mechanism in 2020*, 15.11.2021).

105 Article 5(3) of the TEU: *"the Union shall act only if and in so far as the objectives of the proposed action cannot be sufficiently achieved by the Member States, either at central level or at regional and local level, but can rather, by reason of the scale or effects of the proposed action, be better achieved at Union level".*

Network codes and regionalization, introduced respectively by the third and fourth packages, together with an inflation of epistemic authorities, substantially increased complexity without necessarily improving effectiveness of the Internal Electricity Market governance. The lack of robust and clear governance has high economic costs and is responsible for a few incidents since liberalization started.

Electricity liberalization – even without proper governance - did not lead to frequent blackouts and impoverished quality of supply, as feared by some of its opponents; however, as regards application of the principle of subsidiarity to Internal Electricity Market governance, a persistent blackout could be observed over the last 25 years. Now that energy systems enter a new phase of structural change, namely through decentralization of energy resources, application of the principle of subsidiarity is required in a different context, pointing into a different direction: not upwards, as previously, but downwards (relatively to the national level). A second subsidiarity blackout can be feared. As well as a new wave of epistemic authorities, this time at local level, as a kind of *Ersatz* for proper and efficient governance… The EU could play a relevant role here, providing tools for efficient decentralized energy resources planning and management and supporting training and exchanges among local leaders and experts.

Preserving – and further enhancing – the Internal Electricity Market, while at the same time enabling and fostering decentralization, requires robust governance mechanisms, especially at system operation level. Energy digitalization provides the necessary tools and can deliver a suitable information infrastructure. However, only appropriate institutional arrangements can transform raw data into useful operational flows that enable new types of energy transactions and enhance overall reliability. The required multi-level institutional architectures must fit different decentralized realities, characterized not only by different demand patterns and different available resources, but also by different cultures and different legal frameworks.

Electricity decarbonization, digitalization and decentralization – entangled legalities

The so-called fourth energy package brought electricity and gas, hitherto neatly demarcated silos, into a broader political and legal framework, due to the reinforced association between energy and climate policies. Suddenly, the carefully delimited Internal Electricity Market got new “interconnectors” to buildings and mobility, two sectors with strong traditions of robust regulation (for instance, safety and energy efficiency standards have been enforced for several decades in each of these two sectors).

Electrification of heating/cooling and mobility not only challenges the traditional meaning of “household” in electricity statistics and energy policies, but also substantially changes the electricity system architecture, thus requiring new control strategies and a new governance. This was clearly recognized by EU policy makers and legislators, leading to the approval, within the framework of the fourth energy package, of Regulation (EU) 2018/1999 "on the Governance of the Energy Union and Climate Action"[106].

Energy system integration (namely through electrification of heating/cooling and mobility) takes place mainly at local level and local means, in the EU, mainly urban (urban population represents 75 percent of the whole population). Therefore, decarbonization leads to decentralization and brings to the forefront municipalities and other relevant actors who did not play a major role during the previous transition from monopolies to fully liberalized markets. The new energy governance must take into account and "accommodate" different "legal orders" at play and this requires a departure from the previous perspective that guided the legal construction of the Internal Energy Market.

Energy liberalization was triggered by a single Directive (actually, one for electricity and one for gas), followed by the usual transposition into the legal framework of each Member State. The fact that more and more Directives, Regulations and, lately, Delegated Acts, have been regularly issued does not change the basic assumption that the construction of the Internal Energy Market resulted from the straightforward application of EU law. This simplistic linear view may be criticized because legal orders are always entangled, as nicely described by Nico Krisch:

"Entanglement was, by all accounts, a defining feature of many legal orders before the emergence and consolidation of the modern state. Even Roman law, often associated with system and coherence, is an impressive example of multiple fora, rules and practices, between which litigants and dispute settlers navigated their way. (…)

Yet perhaps the most prominent expression of entangled legalities is to be found in medieval Europe. From the eleventh century onwards, law became increasingly systematized through legislation and codification, but the corpus iuris of much secular law was still made up of rules drawn ('received') from a wide variety of sources (…) Scholars have described the resulting structure as a 'patchwork of accomodations', in stark contrast with the idea of an integrated order or system. (…)

With the consolidation of the modern state, complexity and entanglement were reduced but not entirely supressed. (…) 'Negotiations' between state and non-state law, traced in pluralist scholarship, persisted both in Europe and elsewhere (…)

The rise of transnational and international legalities over the past few decades has exacerbated the perceived multiplicity of legal orders and has helped to remove legal

106 REGULATION (EU) 2018/1999 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and 2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/EC and (EU) 2015/652 and repealing Regulation (EU) No 525/2013 of the European Parliament and of the Council. OJEU L 328 of 21.12.2018

pluralism from the obscurity it long suffered in many mainstream accounts of law. (…) One important aspect of the new 'global legal pluralism' has been the broader focus on different kinds of legalities, - formal and informal, public and private. (…)

Legal multiplicity can, of course, just mean that different legal orders exist side by side, with occasional contact, as in the traditional conflict-of-laws paradigm between national legal orders. But where interactions are more frequent and intense, the relations between different legal orders (and, more broadly, different bodies of norms) move to the centre of attention. The legal order as such can then no longer be understood without an account of the ways in which its different parts are entangled."[107]

It must be acknowledged that energy decarbonization and decentralization, involving so many and so different bodies of norms, inevitably entangles the 25 years old Internal Energy Market legal order with other, namely local bodies of norms. The governance of a multi-sector and multi-level energy architecture, where interactions between energy-related sectors and decision-making levels are "frequent and intense", requires moving the relations between different legal orders "to the centre of attention".

Regulation (EU) 2018/1999 was a first and very important step towards increased coherence of EU energy governance, but a second step is needed to effectively support decentralization and energy system integration.

As a final note, it should be pointed out that even before energy system integration became the cornerstone of energy transition, an integrated approach to regulation and governance of network industries had been proposed and justified by several authors. For example, Matthias Finger advocated that "*the future European model of network industry regulation will have to evolve by taking better into account the technical nature of network industries, as this will better reflect the coevolution between the technical systems, on the one hand, and their institutional governance, on the other.*"[108]

107 Nico Krisch, *Framing entangled legalities beyond the State*. In Nico Krisch (ed.), *Entangled legalities beyond the Stat*e. Cambridge University Press, 2022.

108 Matthias Finger and Frédéric Varone, *Regulatory practices and the role of technology in network industries: the case of Europe*. In Rolf W. Künnecke et al., *The governance of network industries*. Edward Elgar Publishing, Cheltenham, UK, 2009. Pg. 87.

PART IV

Further reflections

WHAT IS A "FAIR TRANSITION" ?

Justice is the first virtue of social institutions, as truth is of systems of thought. A theory however elegant and economical must be rejected or revised if it is untrue; likewise laws and institutions no matter how efficient and well-arranged must be reformed or abolished if they are unjust.

John Rawls, A theory of justice. Harvard, 1971

"A theory of justice" [109], published 50 years ago and one of the most important 20th century books on political philosophy, elaborates the concept of "justice as fairness", previously introduced by the same author in 1958. John Rawls invented a thought experiment, the so-called "original position", where representatives of all citizens meet to discuss and try to agree on the principles of justice that should shape a liberal society. Because representatives don't know whom they represent (the so-called "veil of ignorance"), the original position is a fair situation where each citizen is represented simply as a free and equal citizen interested in building a just social system. In fact, each representative ignores both the individual characteristics of the citizen it represents (race, gender, social class, income group, etc.) and the political and economic characteristics of the society where they actually live.

When discussing the shape of a low-carbon future energy landscape, the veil of ignorance cannot be activated: we are where we are, our original - individual and collective - position is known to everybody, hence our preferences, advantages, restrictions and interests cannot be hidden. This handicap emerges before our eyes at every COP meeting…

The following figure describes three possible energy transition paths towards the low-carbon future, according to three different original positions. The plane where these paths are depicted is defined by two axes: one represents time, the other represents the evolution of energy policy complexity. The three starting points can be briefly described as follows:

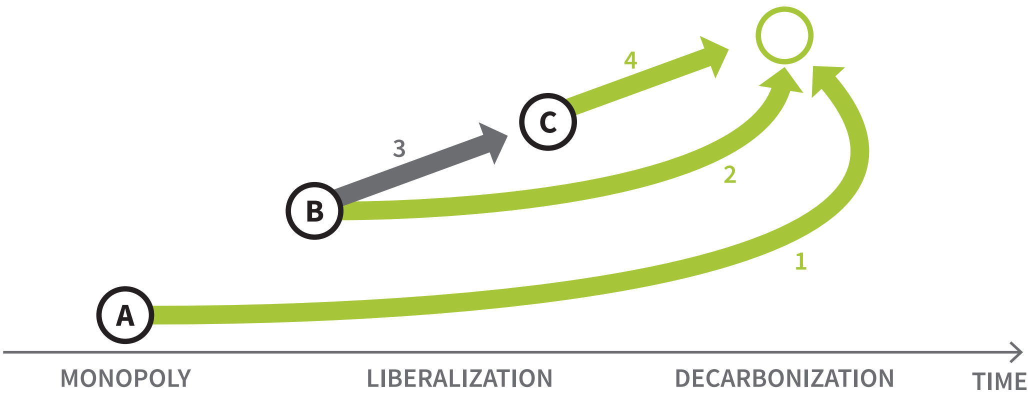
a) Traditional vertically integrated energy monopoly.

b) Imperfect and partially cross-border integrated energy markets.

c) Full liberalized and integrated "perfect" energy markets.

109 John Rawls, *A theory of justice*. London, Oxford University Press, 1985 (originally published by Harvard University Press in 1971).

Figure 26 | **Possible energy transition paths towards a low-carbon future**



Path nr. 1 corresponds to the transition from a vertically integrated monopoly (or, more generally, from a system where no wholesale market was introduced) to a decarbonized system. Many - mainly developing - countries around the world, as well as some States in the United Sates of America, are in this position.

Path nr. 2 corresponds to a starting point of liberalized markets. This is the case in the European Union, where legislation was introduced in 1996, different national and regional wholesale markets have been implemented since then, and full retail competition was achieved in 2007. In the European Union, liberalization of national electricity (and natural gas) markets was launched simultaneously with the project of building a single supra-national electricity (and natural gas) market thanks to the adoption of “common rules”. Legislation did not mandate any kind of particular market design – neither at national, nor at European Union level – and the 1996 list of “common rules” proved to be too short. As a consequence, Member States created their own national markets and, sometimes, incompatibility between neighbouring wholesale rules was such that cross-border interconnectors remained idle for several months, until a certain degree of bilateral harmonization enabled the execution of cross-border transactions.

Instead of adopting a top-down approach, agreeing on a specific common market model and creating a regulatory agency at European level, Member States decided to act bottom-up, mandating increased coordination among system operators. In the meantime, market operators enhanced transnational market coordination and some market platforms decided to merge. Cooperation between system operators, on the one hand, and market operators, on the other hand, together with relevant market agents, led to growing compatibility, increased coordination and improved coupling of national and regional electricity markets through dedicated algorithms and procedures. Although this bottom-up approach has delivered significant benefits as compared to the previous, more fragmented situation, many problems remain unsolved, in particular as regards congestion management and reliability.

Starting the transition towards a low-carbon electricity system from the current situation of still fragmented and imperfect markets with many unsolved critical issues is challenging.

This is the reason why some stakeholders advocated an alternative to path nr. 2, namely, the sequential combination of paths nr. 3 (achieving first a fully integrated European electricity market, solving the many pending technical and institutional coordination issues) and nr. 4 (decarbonization). Until recently, they succeeded in delaying a serious debate about the transition towards a low-carbon future (i.e., path nr. 4), focussing legislative action on improving the current situation and achieving full implementation of the so-called “target model” by 2030 (path nr. 3). This success was very clear in 2018/2019, when the so-called 4th energy legislative package (also known as the Clean energy for all Europeans package) was approved. However, the growing ambition expressed politically by the “Green Deal” (launched in December 2019[110]) and legally by the 2021 “European Climate Law”[111] is incompatible with further delays. Although the European Union is still moving along path nr. 3, implementing the 2018/2019 legal framework, politically and *de facto* it has already started moving along path nr. 2. Of course, the increasing gap between path nr. 2, driven by political will, societal expectations and some actors’ behaviour, and path nr. 3, framed by the legal compact and regulatory policies, is a source of costly delays and inefficiencies.

A fair question is whether transition nr. 2 is more or less difficult than transition 3 + 4. Advocates of the latter believe that starting from a well-organized and well-integrated European market makes the transition easier and less costly. Incompleteness, they believe, implies paying a high(er) price for decarbonization. This reasoning assumes that it is easier and less expensive to build decarbonization upon sophisticated, well-functioning integrated markets, than upon less mature, less integrated markets – and, by extension, upon monopolies. This hypothesis, however, is far from being universally accepted – and reality seems to disprove it. Richard Schmalensee, one of the fathers of electricity liberalization in the USA, recently expressed his conclusions from empirical observations in the following way, where “traditional” and

110 See https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en#timeline

111 REGULATION (EU) 2021/1119 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 (‘European Climate Law’) Official Journal L 243, 07/09/2021. *“The European Climate Law writes into law the goal set out in the European Green Deal for Europe’s economy and society to become climate-neutral by 2050. The law also sets the intermediate target of reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels.”* https://ec.europa.eu/clima/eu-action/european-green-deal/european-climate-law_en

"emerging" systems mean, respectively, non-liberalized and increasingly decarbonized (intermittent generation) systems:

"traditional systems have more flexibility, at least in principle, to meet the new challenges of the emerging regime in a timely fashion, since utilities and their regulators can engage in classic integrated resource planning and project-by-project decision-making without needing to devise, adopt and modify complex new market designs. On the other hand, in the new terrain of the emerging regime, the information advantage of utilities over regulators is likely to be substantial, regulatory processes are rarely speedy, and the flip side of greater flexibility may be higher cost rates than could be attained under competition."[112]

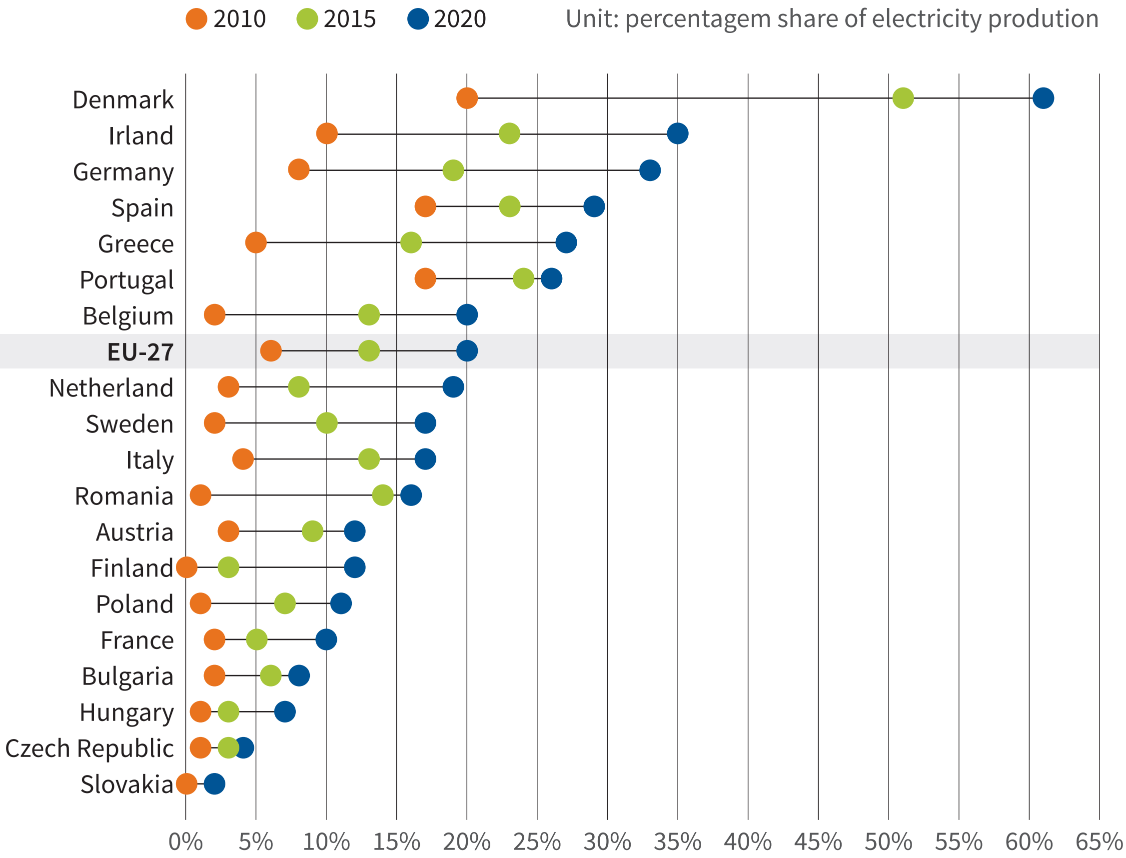
Although all European Union Member States are subject to the same energy legal framework and the same climate and energy policy, i.e., they are all around position B in the figure above, structural changes towards decarbonization vary from country to country. This is particularly true as regards penetration of wind and solar sources of electricity generation, as can be observed in the following figure [113]. Denmark is a clear front runner, with a combined penetration of wind and solar in total electricity generation of 61% in 2020, up from 20% in 2010; a group of 5 countries falls in the interval between 25% and 35%, while another group of 10 countries lies between 10% and 20%; finally, 4 laggards have a combined penetration rate lower than 10%. Some countries exhibit a regular growth pattern over time, while other countries excelled either in the period 2010-2015 or in the period 2015-2020.

Denmark and Slovakia generated about the same amount of electricity in 2019 (29.5 TWh vs. 28.4 TWh), but electricity generation capacity installed in Denmark (15.2 GW) is almost twice that in Slovakia (7.7 GW). Denmark is well advanced along path nr. 2, while Slovakia is at the beginning of the decarbonization journey and could go either along path nr. 2 or through 3 + 4.

112 Richard Schmalensee, *Strengths and weaknesses of traditional arrangements for electricity supply*. In Glachant, Joskow and Pollitt (eds.), *Handbook on electricity markets*. Cheltenham (UK), Edward Elgar Publishing, 2021. Pg. 28.

113 https://ember-climate.org/project/eu-power-sector-2020/

Figure 27 | **Wind and solar shares of electricity generation**



Europe's Power Sector in 2020, published by Ember and Agora Energiewende on 25th January 2021. The 19 countries displayed account for 97% of EU-27 electricity consumption

Source: EMBER, 2021

Considering the – observed and expected - acceleration of renewables deployment in several Member States, the European Union needs to review its electricity market legal framework, advancing decarbonization and supra-national integration at the same time. This review will be a compromise among different viewpoints, industry structures and social dynamics – prone to the introduction of new inconsistencies and the perpetuation of old ones. Given the complexity of this task and the diversity of original positions, as exemplary displayed in the previous figure, and also looking back to the long and often frustrating liberalization journey (moving from position A to position B, not represented in Figure 26), no easy transition should be expected on the road to 2030 and beyond. Markets and competition can be used to promote efficiency in general and cost-efficient compliance with public climate and energy policies in particular, but there is no "just add magic cookbook" available. Sticking to the old energy-only market models of the 2010s, ignoring that their "essence" has been diluted through parallel, uncoordinated policy interventions, into a *"patchwork of* *hybrid market approaches"*[114] is not helpful. Neither is denying the usefulness – or even the possibility – of applying market instruments in a decarbonized electricity system, thus reverting to central planning and industry nationalization.

When considering different possible compromise models, it is important to assess their consistency:

- On the one hand, the external consistency with public policies and available technical solutions. Any model that prevents the deployment of clean technologies, delays energy digitalization or fails to comply with public climate and energy policy should be rejected.

- On the other hand, internal consistency is crucial. The 2000/2001 California debacle is the most explosive example of internal inconsistency ("failure by design"), but many little Californias pop up everywhere, every time electricity reform is discussed.

Consistency is, above all, a matter of efficiency and democratic legitimacy. Inconsistencies in energy transition and in electricity systems are a waste of natural, financial and social capital; they lead, inevitably, to unfair outcomes. Unfortunately, the reverse does not hold: consistency is a necessary, but not a sufficient condition of fairness.

Defining what a fair energy transition is, deprived of Rawl's veil of ignorance, is overwhelming. By comparison, checking consistency of transition models should be a fairly simple task.

114 Fabien Roques, *The evolution of the European model for electricity markets*. In Glachant, Joskow and Pollitt (eds.), *Handbook on electricity markets*. Cheltenham (UK), Edward Elgar Publishing, 2021. Pg. 309.

FINANCING THE EU ENERGY TRANSITION

The best understanding of a liberal, open society relies on the concept of a marketplace of ideas. Debate becomes a testing ground, in which approval raises the price or value of ideas, and makes them more attractive and compelling, while confusion or contradiction lowers their acceptance and worth. (…)
An increasing obvious feature [of 21st century] is that debate – which is essential to the marketplace concept – has become impossible. In deeply polarized discussions in many countries (…) there is no room for any nuanced exchange of ideas. There is simple antagonism. (…)
The marketplace does not work because there are no prices at which exchange can take place. The price is the meaning, but the meanings of each term aren't clear.

Harold James, *The war of words*. Yale University Press, New Haven and London, 2021

The recent political discussions on the Taxonomy Complementary Delegated Act covering certain gas and nuclear activities [115] clearly shows the importance of *"meanings"* and also how *"wars of words"* can be politically and legally pregnant. While Regulation (EU) 2020/852[116] establishing *"the criteria for determining whether an economic activity qualifies as environmentally sustainable for the purposes of establishing the degree to which an investment is environmentally sustainable"* [117], as well as the first Delegated Regulation[118] *"specifying the content and presentation of information to be disclosed by undertakings"* were widely accepted, the second Delegated Act faces fierce opposition from several Member States and many sectors. As Flaubert allegedly said, *"Le bon Dieu est dans les détails"*…

Confusion concerns not only the characterisation of what is sustainable, but also the real value of "sustainable" financial products such as "green bonds", "green loans", "transition bonds", "sustainability-linked bonds", "SDG-linked bonds", "sustainability-linked loans", etc., etc….

115 https://ec.europa.eu/commission/presscorner/detail/en/ip_22_2

116 REGULATION (EU) 2020/852 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088. OJEU L 198 of 22.06.2020.

117 Ibid., Article 1.

118 COMMISSION DELEGATED REGULATION (EU) 2021/2178 of 6 July 2021 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by specifying the content and presentation of information to be disclosed by undertakings subject to Articles 19a or 29a of Directive 2013/34/EU concerning environmentally sustainable economic activities, and specifying the methodology to comply with that disclosure obligation. OJEU L 443 of 10.12.2021.

The first basic question in this Section is who actually promotes the energy transition and who invests in the energy transition.

Many citizens and many communities are active agents of this transformation and very often they are not motivated by economic returns on investment. Quantitative goals – financial or other – are not always the driving force moving people in local communities. As Rob Hopkins, founder of the *Transition Network*[119], points out about *"Transition Town Totnes"* (a small town in Devon, England), *"More important than any of the actual projects was the sense of connection, of feeling part of something, of the underlying story starting to shift"*[120].

This "sense of connection", or "sense of belonging", a moral obligation to "do one's part", is socially and culturally relevant, but has limited environmental impact, as highlighted by César Dugast and Alexia Soyeux in the French case: *"In total, the combination of a "realistic" posture in terms of individual gestures (approximately -10%) and investments at the individual level (approximately -10%), would induce a reduction of approximately -20% of the personal carbon footprint, i.e. a quarter of the effort required to achieve the 2°C objective."*[121] Even what the authors call *"heroic"* behaviour – i.e., if every day all citizens took the most extreme measures in their hands to minimize their carbon footprint (e.g., changing food and mobility patterns) – the total reduction of French greenhouse gas emissions would be around 25%, far from the 80% reduction implied in the Paris Agreement. Behavioural changes (not requiring new investments) and local - individual or community - investments are important, for several reasons, but reduction of (*per capita* as well as total) greenhouse gas emissions to achieve Paris Agreement targets requires a substantial "systemic transformation", going beyond the local level, which in turn requires substantial systemic investments.

Clearly, local and systemic investors act at different investment scales and therefore under different regulatory and economic conditions; not only their goals, but also their risk profiles, their expected returns and the financial products at their disposal are very different. However, the categories of investment needs concerning electricity supply[122] are the same at local and at systemic level: on the one hand, infrastructure (usually regulated, with access tariffs and rate of return established by an independent regulatory authority); on the other hand, (small or large) power plants and other asset classes (e.g., storage) that guarantee continuous supply under appropriate technical and economic conditions, competing in the market or cooperating within certain platforms. Figure 28 indicates the main investor groups according to where they act

119 Rob Hopkins, *The Transition Handbook - From Oil Dependency to Local Resilience*. Green Books, Cambridge, UK , 2008.

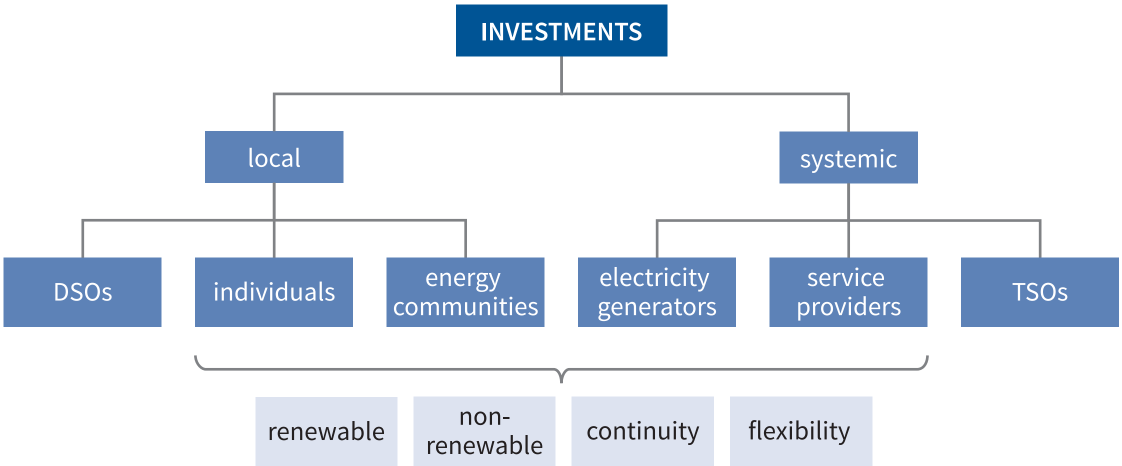
120 Rob Hopkins, *From what is to what if*. Chelsea Green Publishing, USA, 2019. Pg. 7.

121 César Dugast and Alexia Soyeux, *Faire sa part ? Pouvoir et responsabilite´des individus, des entreprises et de l'État face à l'urgence climatique*. Carbone 4, June 2019 (my translation). https://www.carbone4.com/wp-content/uploads/2019/06/Publication-Carbone-4-Faire-sa-part-pouvoir-responsabilite-climat.pdf

122 Energy transition is (much) more than electricity, although green electrification is key for decarbonization. In this Section only electricity investments will be discussed.

(local or systemic level) and who they are, also showing different supply asset classes (renewable and non-renewable electricity generation, storage aimed at providing continuity of supply and flexibility, as well as other flexibility means such as aggregated demand management).

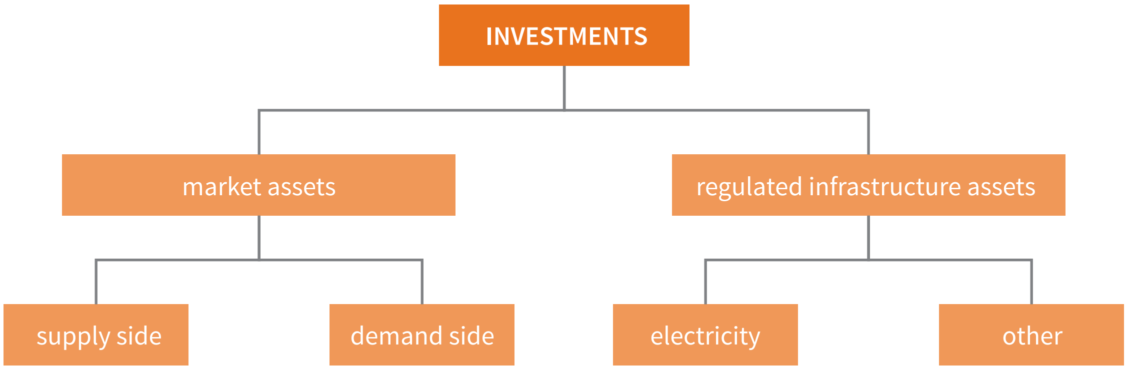
Figure 28 | **Investors on electricity supply transition**



The figure above addresses the electricity system supply side to show the present – and increasingly important in the future - diversity of players, as opposed to the old days of vertically integrated monopolies. Demand side investments depend, as always, on choices of individual electricity users; however, energy digitalization and electrification of heating/cooling and mobility increasingly blurs the border between supply and demand, both at individual and at systemic levels.

The previous figure already anticipates the **second basic question**: investing on what ? DSOs and TSOs obviously invest, respectively, on distribution and transmission infrastructures (both regulated assets); today, this basically means electricity and natural gas networks, in the future it may include other energy carriers (e.g., hydrogen). Other investors focus on non-regulated assets, not only on the supply side, but also on the demand side - since the two become increasingly intertwined -, that may compete in different marketplaces. The next figure provides a simple description according to this reasoning.

Figure 29 | **Investment types for the energy transition**



Investment on regulated assets ultimately depends on the kind of incentives and prescriptions applied by regulators to the regulated activities. This issue will be discussed in a separate Section.

As regards investments on assets that compete in energy markets, the following questions arise:

- The **third basic question** is: What are the necessary (enabling) conditions for those investments ?
- The **fourth basic question** is: How to assess the sufficiency of those market-based investments ?

The figure below helps answering both questions.

Figure 30 | **Non-regulated investments for the energy transition: conditions and results**

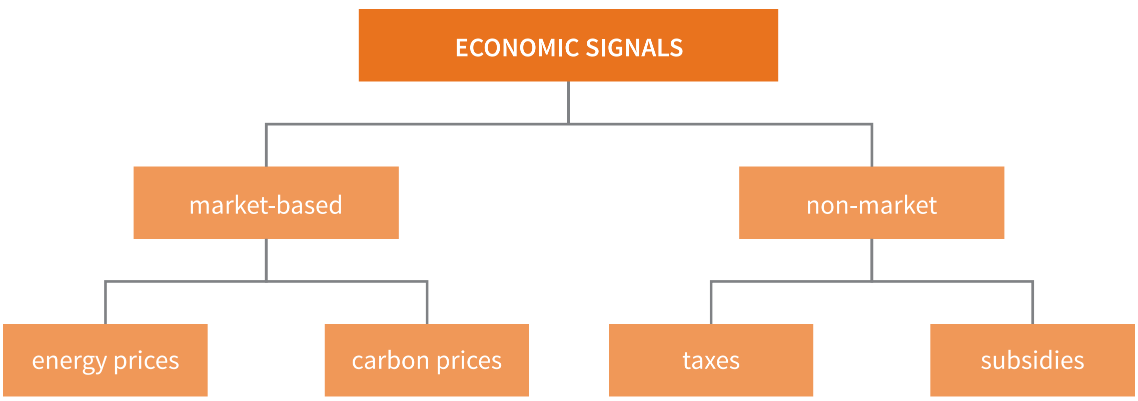
Starting from the right-hand side, there are two major ways of "measuring" investment results, namely, to assess whether the investment level is sufficient to meet pre-established goals. The outputs are easily measurable: how many MW of electricity generation were installed in one year, how many MVA of transmission capacity were added to the grid, how many km of new transmission lines by voltage level were built, etc. Measuring these outputs and relating them to the associated investments enables the calculation of performance indicators (e.g., unit cost of generation capacity by technology). However, outputs do not necessarily ensure the expected outcomes: for instance, if all new generation capacity corresponds to coal-fired power plants the yearly amount of GHG emissions will increase. Therefore, it is important to quantify and to monitor outcomes – e.g., the yearly reduction of GHG emissions, continuity of supply (e.g., number of minutes not supplied per year, etc.).

In a market economy, there are two main pre-conditions for investments to happen in the electricity transition (see left-hand side in the previous figure):

- Firstly, the investment needs must be revealed, and the expected value of these investments should be revealed through price signals. Electricity market prices must consider other related prices, such as carbon prices, where carbon markets exist, as well as relevant non-market economic signals like subsidies and taxes (see Figure 31 below). Electricity markets represent the "demand-side" of long-term decarbonization investments.

- Secondly, investors must perceive the benefits of these investment opportunities and appropriate financial products must be available to finance the required projects, matching investment needs and investor expectations. Financial markets represent the "supply-side" of long-term decarbonization investments.

Figure 31 | **Relevant economic signals for energy transition investments**



Energy markets and financial markets are coupled through both financial and informational flows. Information is a key enabler of energy transition investments, as clearly recognized by Marc Carney in his seminal 2015 speech as Governor of the Bank of England and Chairman of the Financial Stability Board:

"*The right information allows sceptics and evangelists alike to back their convictions with their capital.*

It will reveal how the valuations of companies that produce and use fossil fuels might change over time.

It will expose the likely future cost of doing business, paying for emissions, changing processes to avoid those charges, and tighter regulation.

It will help smooth price adjustments as opinions change, rather than concentrating them at a single climate "Minsky moment".

Crucially, it would also allow feedback between the market and policymaking, making climate policy a bit more like monetary policy."[123]

Although the *"right information"* results from a combination of several sources of information, electricity markets, carbon markets and financial markets play a central role (see Figure 31 above) and will be briefly addressed in the following paragraphs.

Electricity markets are discussed in different sections. It is worth recalling that electricity market structures have evolved since the beginning of electrification (see Section Excursus I), ensuing technical evolution, and will further evolve as a consequence of new technical developments, as well as of new individual and societal needs. In fact, *"Electricity markets that were designed around 20th-century technologies often put 21st-century technologies at a disadvantage"*[124], thus hindering decarbonization. When revising electricity market design, it is crucial to keep in mind the goal of carbon neutrality by 2050 and to avoid path dependencies that might arise from the hasty introduction of quick fixes aimed at achieving intermediate targets by, say, 2030, *"Because the things we'd do to get small reductions by 2030 are radically different from the things we'd do to get zero by 2050"*[125].

As regards carbon markets, the following statements provide a brief yet authoritative summary of the state-of-the-art:

123 Marc Carney, *Breaking the Tragedy of the Horizon – climate change and financial stability*. 29 September 2015 at the Lloyd's of London. Available at https://www.bankofengland.co.uk/-/media/boe/files/speech/2015/breaking-the-tragedy-of-the-horizon-climate-change-and-financial-stability.pdf?la=en&hash=7C67E785651862457D99511147C7424FF5EA0C1A

124 Bill Gates, *How to avoid climate disaster*. Allen Lane, UK, 2021. Pg. 205

125 Ibid., pg. 196

"Carbon prices alone will not be enough, for four reasons. (…)

Despite these four drawbacks, carbon pricing is a very useful, indeed essential, lever for most countries because it can achieve a great deal at low cost and high efficiency. (…)

Implicit carbon prices can also be designed to be inversely correlated to international oil prices, smoothing out prices faced by consumers. (…)

shadow prices of carbon may be different across time, over space, and with different uses. This may appear to be a departure from the "conventional wisdom" – i.e. that the first-best carbon price is globally uniform, applying to all sectors, in all countries and at all times. However, Stiglitz shows that his seemingly iconoclastic conclusion actually lies within the mainstream of modern public finance theory once concerns about distribution, innovation, and uncertainty are properly accounted for."[126]

Carbon pricing can be a powerful means to create a level playing field for clean, green technologies, turning investments aimed at decarbonization financially attractive (as compared to similar investments on fossil alternatives). Present-day carbon prices in the European Union have indeed reduced and, in some cases, even reversed, the cost gap between "green" and "brown" alternatives. However, existing carbon prices are insufficient – both as regards their intensity and their geographical coverage – to trigger the investment volumes needed to meet Paris Agreement targets. Moreover, carbon markets are exposed to speculative transactions, like similar markets, and, whenever market price volatility is excessively high, the price doesn't convey any information, as Nicolas Bouleau has shown[127].

Until now, and in spite of several major initiatives launched, over the last 15 years, by international financial institutions (World Bank, European Investment Bank, etc.) and by the financial industry itself, green financial products have had limited impact. Some authors argue that green finance is "an illusion"[128]. The difference between "green" and "standard" financial products is very often ambiguous and this difficulty also reflects different views about the appropriate discount rate for decarbonization projects[129].

The current volume of investments aimed at decarbonizing the economy are insufficient to meet Paris Agreement targets, not only in the European Union, but worldwide.

126 Cameron Hepburn, Nicholas Stern and Joseph E. Stiglitz, *Editorial "Carbon pricing" special issue in the European economic review,* Elsevier, 2020, https://doi.org/10.1016/j.euroecorev.2020.103440

127 Nicolas Bouleau*, Le Mensonge de la finance. Les mathématiques, le signal-prix et la planète*, Les Éditions de l'Atelier, France, 2018. Short summary: Nicolas Bouleau, *Les marchés financiers et la planèt*e, in Esprit, March 2020.

128 For instance: Alain Grandjean and Julien Lefournier, *L'illusion de la finance verte*. Les Éditions de l'Atelier, France, 2021.

129 This was a central theme in the dispute between William Nordhaus and Nicholas Stern following publication in 2007 of *The Economics of Climate Change: The Stern Review*. Cambridge University Press, Cambridge, UK.

As long as decarbonization projects are more expensive than "business-as-usual" projects, neither electricity markets provide long-term price signals, nor financial markets provide capital to support such projects. Given the scale and the urgency of decarbonization, the State is encouraged to intervene in order to promote the necessary investments – not only by academics, like Mariana Mazzucato (*"only government has the capacity to bring about transformation on the scale needed"*[130]), but also by investors (e.g., Chapter 10 *"Why government policies matter"* in Bill Gates, *op. cit.*). However, given recent massive State interventions worldwide, first to tackle the 2007 financial crisis, then to manage the coronavirus pandemic, the call for more State intervention, this time in climate policy, is not universally shared[131]. Of course, this is not a new debate (see end of Section Excursus I : *electricity in the wider energy context*) and it should be pointed out that deciding about State intervention – or non-intervention – in markets always implies a certain idea about the role (and the meaning…) of rationality in markets, as well as about the degree of (im)perfect knowledge available[132].

State intervention is usually designed to enable or to speed-up decarbonization investments on green assets related to competitive activities if their costs are higher than functionally equivalent brown assets (e.g., electricity generation). However, these policies and interventions inevitably impact upon the development of electricity networks and all regulated, monopolistic energy infrastructure. The link between direct and indirect impacts, i.e., between State financial support, on the one hand, and regulatory incentives for infrastructure, on the other hand, is not always explicitly addressed, although it is crucial from a systemic perspective.

130 Mariana Mazzucato, *Mission economy*. Allen Lane, UK, 2021. Pg. 205

131 Concerns were recently expressed by The Economist (January 15th 2022 edition) in the following terms: *"This newspaper believes that the state should intervene to make markets work better, through, for example, carbon taxes to shift capital towards climate-friendly technologies; R&D to fund science that firms will not; and a benefits system that protects workers and the poor. But the new style of bossy government goes far beyond this. Its adherents hope for prosperity, fairness and security. They are more likely to end up with inefficiency, vested interests and insularity."*

132 For a recent description of different approaches and schools of thought see Roman Frydman and Michael D. Goldberg, *Beyond mechanical markets: asset price swings, risk and the role of the state*. Princeton University Press, 2011.

RETAIL ENERGY PRICES – DID COMPETITION DELIVER ?

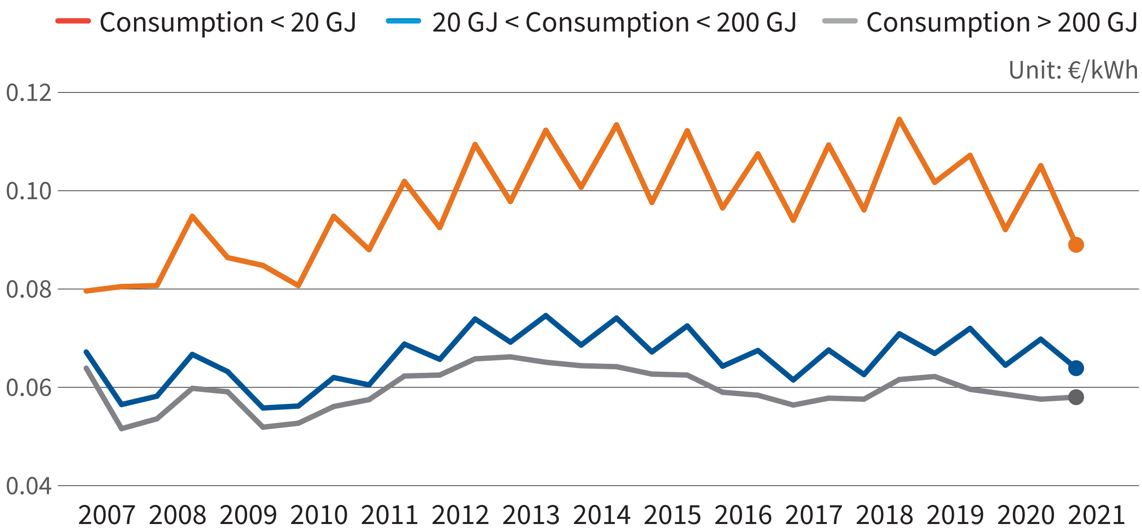
It is a limitless information system, without constraints of time and place, which specifies the turbo-consumer era.

Gilles Lipotvetsky, *Le bonheur paradoxal.* 2006

There are several ways of assessing the evolution of energy prices from the consumer point of view. The most obvious approach is to display the evolution of retail prices along time, either in nominal value (current prices) or in real value (constant prices in relation to a reference datum).

The figure below shows the evolution of nominal gas prices for average EU-27 household consumers, from 2007 until the first semester of 2021[133]. Small consumers (Band D1) have experienced an increase from around 80 €/MWh (2007 - 2010) up to around 100 €/MWh (since 2011). Medium size consumers (Band D2) have experienced lesser price increases and large household consumers (Band D3) have enjoyed stable prices.

Figure 32 | **EU-27 average gas prices for household consumers, all taxes included**



Source: Eurostat

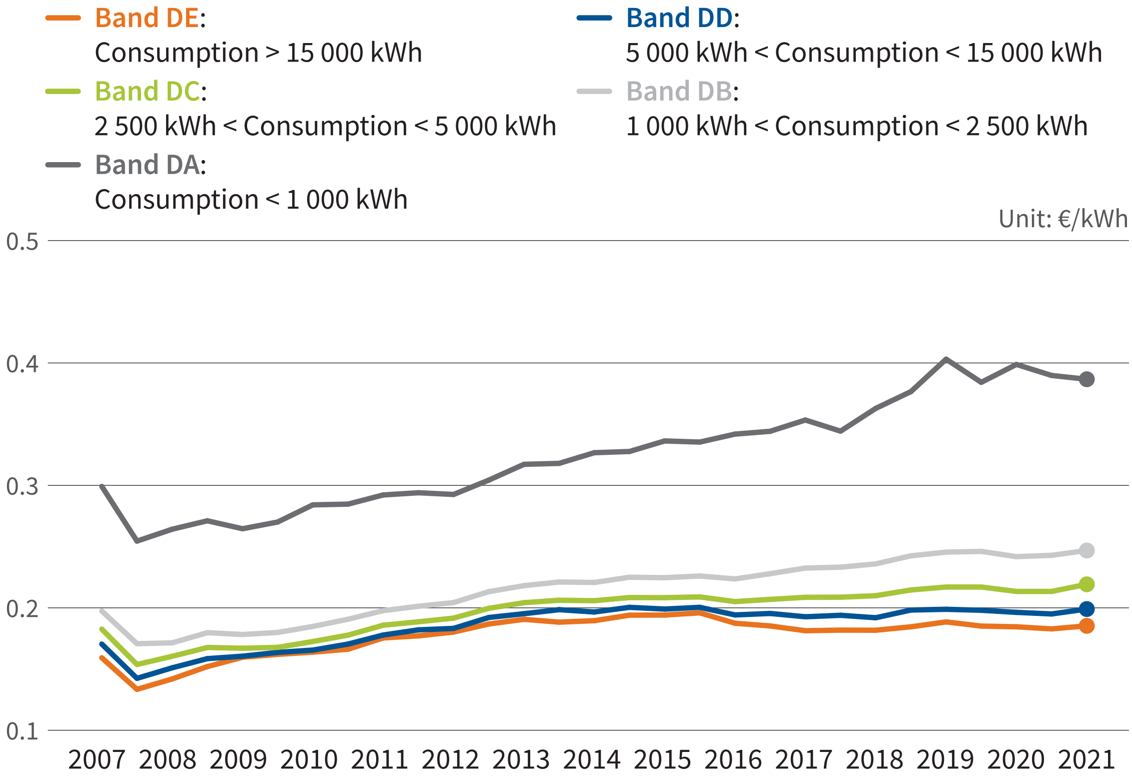
The next figure shows the evolution of nominal electricity prices for average EU-27 household consumers, from 2007 until the first semester of 2021[134]. Small consumers

133 Data from Eurostat: https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_202/default/table?lang=en

134 Data from Eurostat: https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_204/default/table?lang=en

(Band DA) have experienced an increase from 250 €/MWh (2007) to more than 350 €/MWh (since 2017). All other consumers have experienced smaller, yet substantial price increases.

Figure 33 | **EU-27 average electricity prices for household consumers, all taxes included**

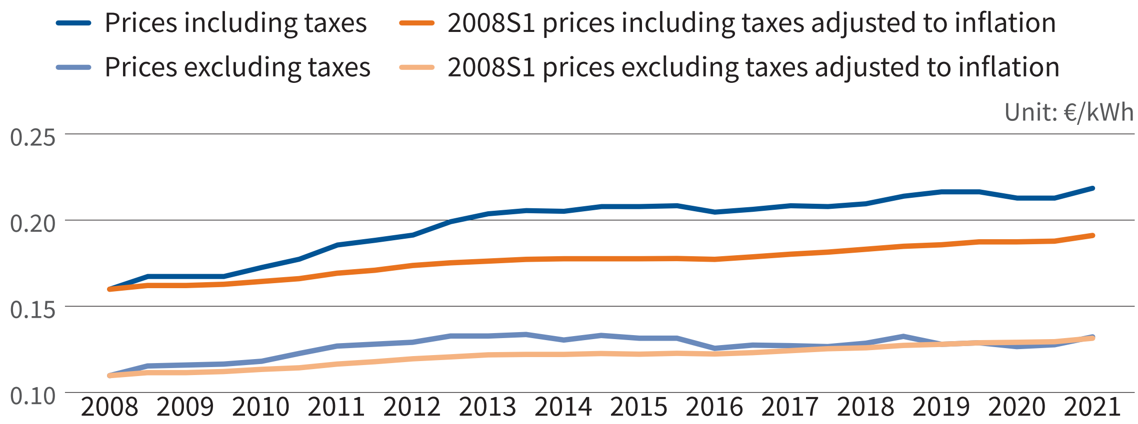


Source: Eurostat

The following figure, from Eurostat[135], compares the development of average EU-27 nominal and real (2008 based) electricity prices for household consumers in the period 2008 to 2021, with and without taxes. Price increases can be observed in all four cases.

135 https://ec.europa.eu/eurostat/statistics-explained/images/c/c0/Development_of_electricity_prices_for_household_consumers%2C_EU%2C_2008-2021_%28EUR_per_kWh%29.png

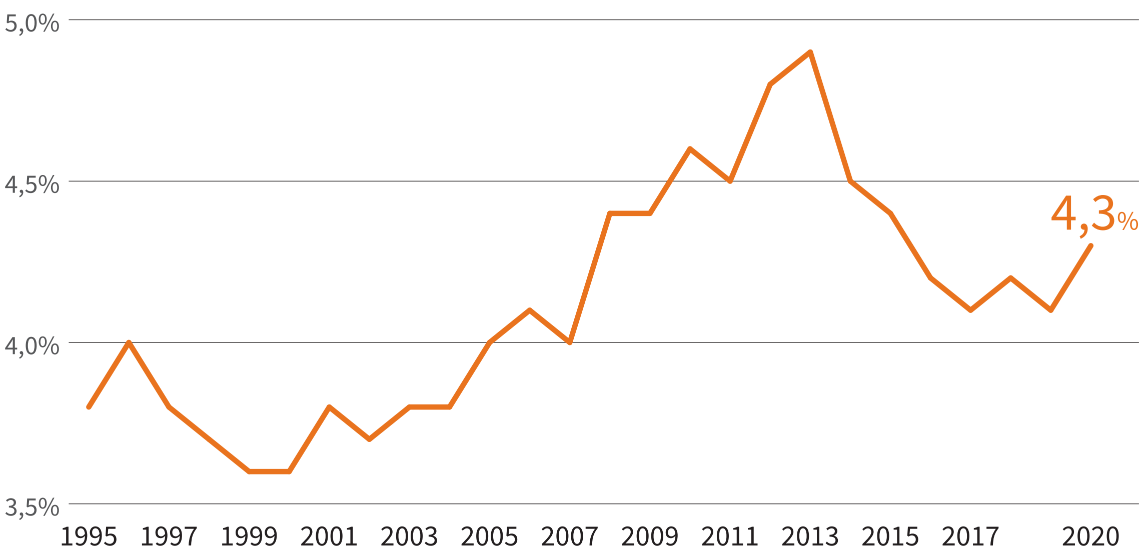
Figure 34 | **EU-27 average electricity prices for households, all taxes included (nominal and real)**



Source: Eurostat

A better way of assessing the impact of energy costs upon households is expressing them as percentage of households total final consumption expenditure, as shown in the next figure[136]. While in the period 1995-2005 this ratio was always below 4.0%, since 2007 it has always been above 4.0%. Interestingly, households' energy burden increased more intensely following full retail liberalization, in 2007.

Figure 35 | **"Electricity, gas and other fuels" as % of EU-27 households average final consumption expenditure**



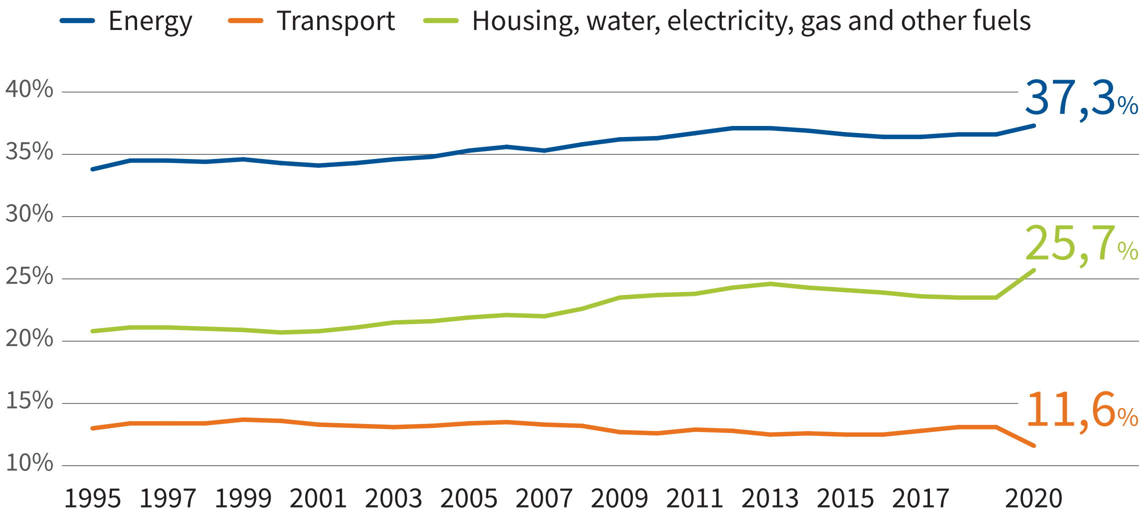
Source: Eurostat

136 Eurostat: https://ec.europa.eu/eurostat/databrowser/view/NAMA_10_CO3_P3__custom_2362212/default/table?lang=en

The following figure[137], describes the evolution of costs related to "transport" and to "housing, water, electricity, gas and other fuels", as well as the sum of these two energy-related categories. In this case, not only the "variable costs" ("Electricity, gas and other fuels" in dwellings, fuels in transport) are considered, but also the "fixed costs" (vehicles and housing). The quality of vehicles and houses, in particular their size and energy efficiency, determine, to a large extent, the amount of energy (i.e., variable costs) needed to satisfy users' needs.

The figure clearly reveals the impact of Covid-19 in 2020: transport costs decreased by 1.5 pp while in house costs increased by 2.7 pp. Disregarding 2020, the figure shows that transport expenditure remains stable since 1995, at around 13% of total final consumption expenditure. On the other hand, the category housing, water, electricity, gas and other fuels increased from about 21%, in the period 1995-2005, to about 24% in the period 2009-2019. The weight of all energy-related expenditure increased from 33.8%, in 1995, to 36.6% in 2019 - a sizeable 8% increase. In other words: in the period 1995-2019, households lost 2.8% of their income to cover energy-related costs.

Figure 36 | **EU-27 average household energy-related expeditures**
Final consumption expenditure of households, by consumption purpose (%)



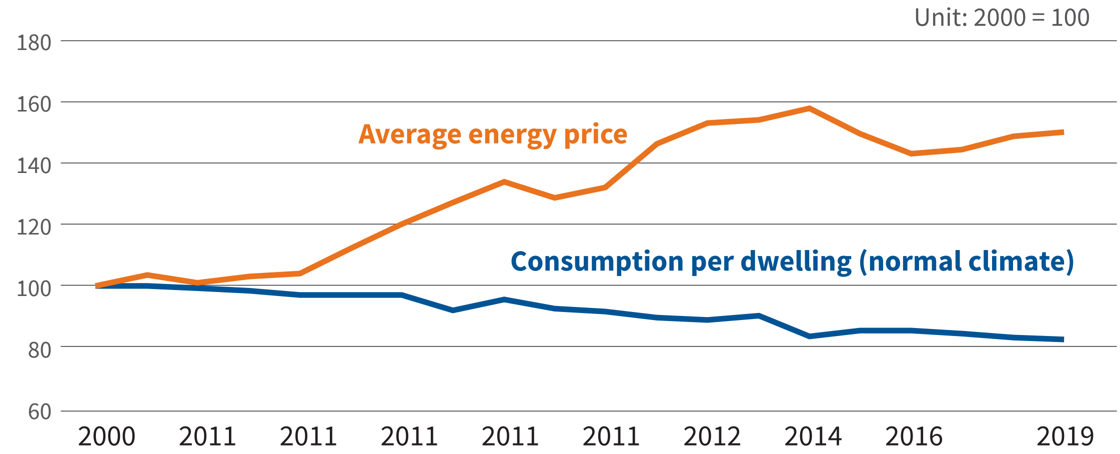
Source: Eurostat

Figure 37 helps explaining the two previous figures by showing how the potential benefits of households energy demand reduction was offset by energy price increases[138].

137 Eurostat: https://ec.europa.eu/eurostat/databrowser/view/tec00134/default/table?lang=en

138 https://www.odyssee-mure.eu/publications/efficiency-by-sector/households/consumption-dwelling-energy-price-income.html

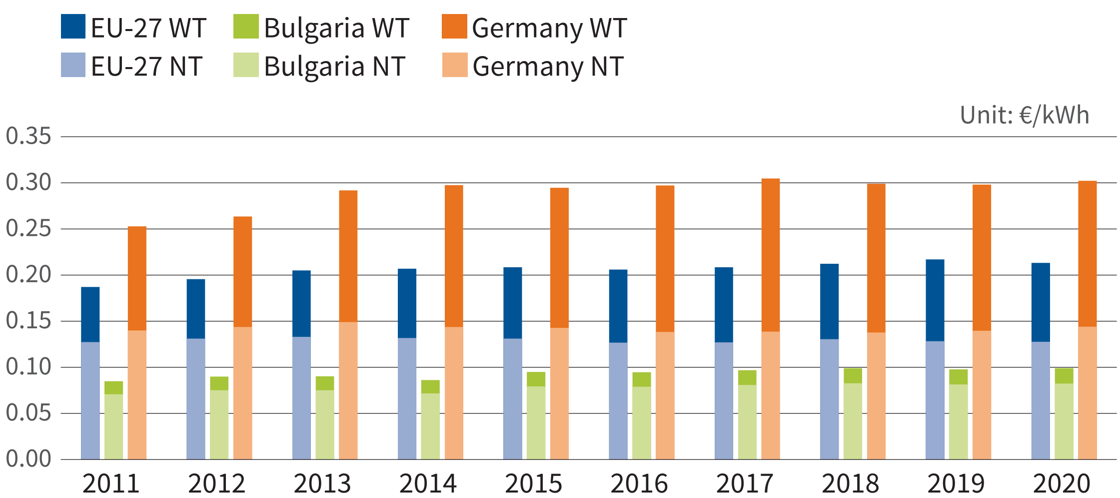
Figure 37 | **EU-27 average household energy demand and energy price**



Source: Eurostat

As indicated above, average EU-27 retail electricity prices have experienced steady growth over the last decades. While EU-27 average price increased by 14 %, between 2011 and 2020, this figure almost reached 20 % in Germany. Price differences between countries are significant, with German households paying about three times the price paid by Bulgarian households[139], on average, in the most representative market segment (yearly demand between 2 500 kWh and 5 000 kWh - see Figure 38[140]).

Figure 38 | **Retail electricity prices - households Band DC: 2.500 kWh < Consumption < 5.000 kWh - excluding all taxes and levies (NT) and including all taxes and levies (WT)**



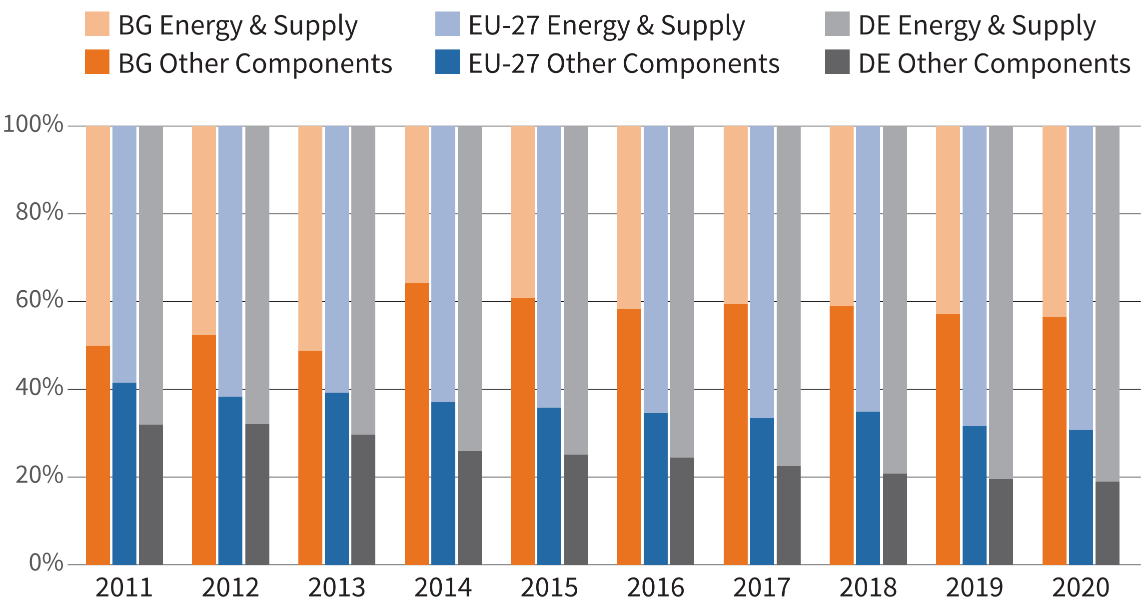
Source: Eurostat

139 Bulgaria exhibits the lowest household electricity prices in the EU. Germany has been at the top or close to it.

140 http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_204

Retail electricity prices consist of several components, which include energy costs, network charges, charges for renewable energy, value added tax (VAT), other taxes and charges, etc.. The final price composition varies significantly among European countries. In 2020, in the EU-27, the competitive price component - corresponding to energy and supply costs - amounted on average to just 31 % of the total price; this figure varies from 57 % in Bulgaria to 19 % in Germany. Furthermore, the weight of this price component has decreased in most European countries over the last decade, with few exceptions such as Bulgaria (see Figure 39).

Figure 39 | **Energy & supply costs' share of the final electricity price**



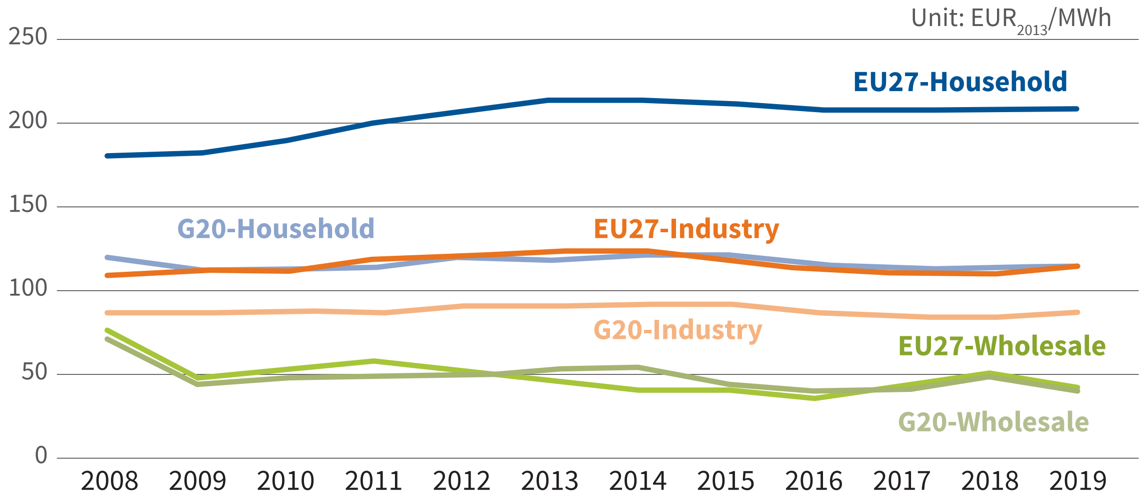
Source: Eurostat

EU households pay substantially more for electricity than G20 average households, as shown in the following figure[141], although wholesale prices are similar across regions. The main reasons for the difference are "*Relatively high consumer taxes and levies in the EU and price regulation/subsidies in the G20*"[142].

141 Trinomics et al. for the EC, *Study on energy prices, costs and their impact on industry and households. Final report*. October 2020. P. 11. https://op.europa.eu/pt/publication-detail/-/publication/16e7f212-0dc5-11eb-bc07-01aa75ed71a1/language-en

142 Ibid.

Figure 40 | **EU-27 / G20 average electricity price comparison**



Source: Eurostat

EU households have experienced increasing natural gas and electricity prices over the last 15 years.

Low energy demand (usually corresponding to low income) households suffered the largest energy price increases.

Energy-related costs as a percentage of EU-27 households total final consumption expenditure has also increased since the early days of energy liberalization.

EU-27 households pay substantially more for electricity than G20 average households.

Ceteris paribus, efficient competition in electricity and natural gas markets, combined with efficient regulation of their respective networks, should yield lower retail energy prices than unregulated monopolies. Unfortunately for consumers, many other things have not been held constant in world energy markets and this possibility had not been timely and properly communicated to them. The promise of lower energy prices did not materialize, and it could not materialize because in energy industries "all other things" tend to be different. This was true in the early phase of energy liberalization[143], and it is true in the current energy transition.

Full retail competition, providing all EU energy consumers the right to choose their electricity and natural gas suppliers, was introduced on the 1st of July 2007, following

143 At that time, there was a strong link between oil, natural gas and electicity prices. Inflation adjusted oil price reached an all-time low in 1998. However, ten years later, in June 2008, oil prices were at the all time monthly high in real inflation adjusted terms.

a period of step-by-step expansion of eligibility criteria, starting with the first liberalization directive in 1996.

The following indicators are commonly used in combination for evaluating the performance of retail electricity markets:

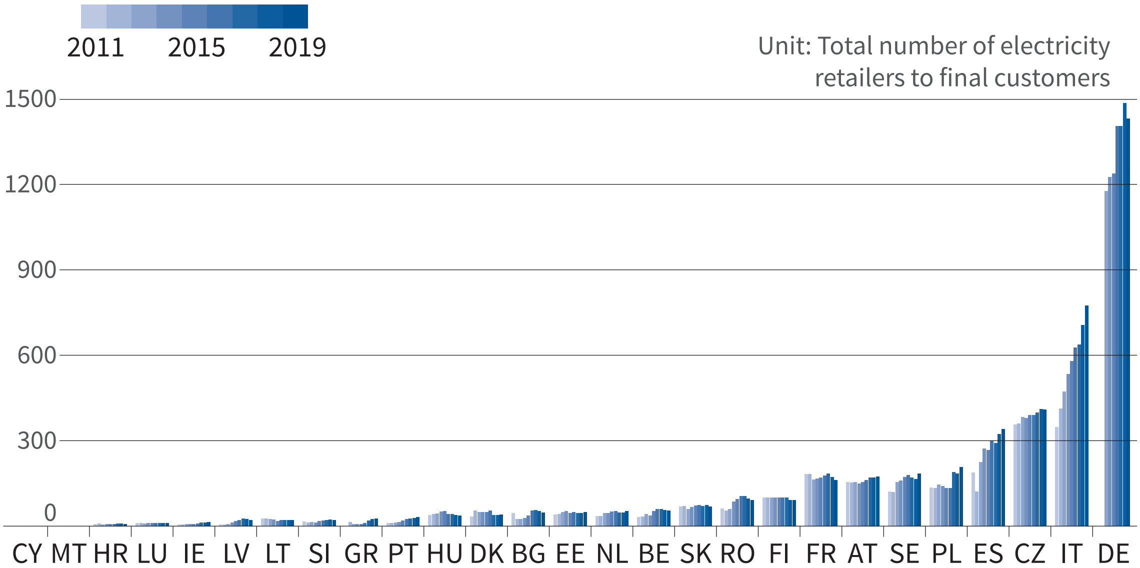
- Number of suppliers: Indicator of low entry barriers for suppliers
- Market concentration: Indicator of competition intensity
- Switching rate: Indicator of low exit barriers for consumers
- Public price interventions: Indicator of market distortion and/or consumer protection
- Correlation with wholesale electricity markets: Indirect indicator of competition level

In 2020 the EU average number of active nationwide electricity suppliers was 47, compared to 41 in 2019. Differences between countries are very significant, with smaller countries generally having less suppliers (e.g. 7 in Croatia) than large countries (e.g. 252 in Spain) (see Figure 41). Over the last decade the number of suppliers has increased in almost all Member States[144].

A distinction is generally made between the number of total active suppliers in a country and the number of suppliers that are active nationwide. In France, for instance, out of the 151 active suppliers in 2020, only 35 were active in the whole country, while the others were active in a specific geographical area only.

144 ACER (2021): "ACER Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2020 - Energy Retail Markets and Consumer Protection Volume", 2021

Figure 41 | **Total number of electricity suppliers in 2020**



Source: ACER

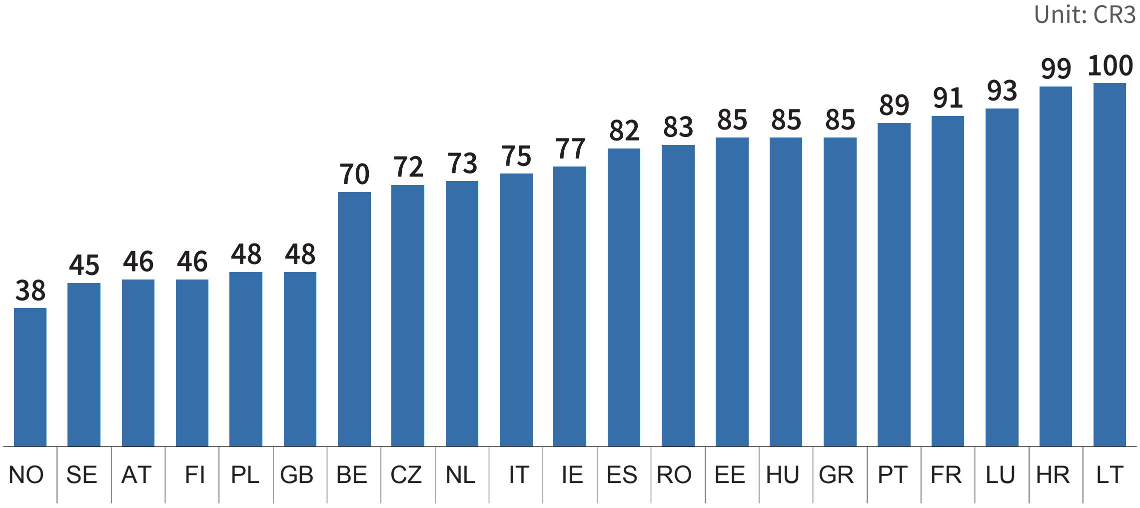
In 2020, ACER and CEER found[145] that only a third of the Member States that monitor the HHI index (8 out of 24) recorded a HHI of under 2000 – i.e. 16 Member States have "highly concentrated" retail electricity markets.

The Herfindahl–Hirschman Index (HHI) is calculated by squaring the market share, expressed in points, of each competing firm in the industry, and then summing the resulting numbers. An alternative index is CR3 – it represents the sum of the market share of the 3 largest firms in the respective national market. In 2020, the CR3 of 16 out of the 25 European countries using that index was in the "highly concentrated" (i.e., CR3 > 70%) range, as can be observed in the following figure[146].

145 Ibid.

146 Ibid.

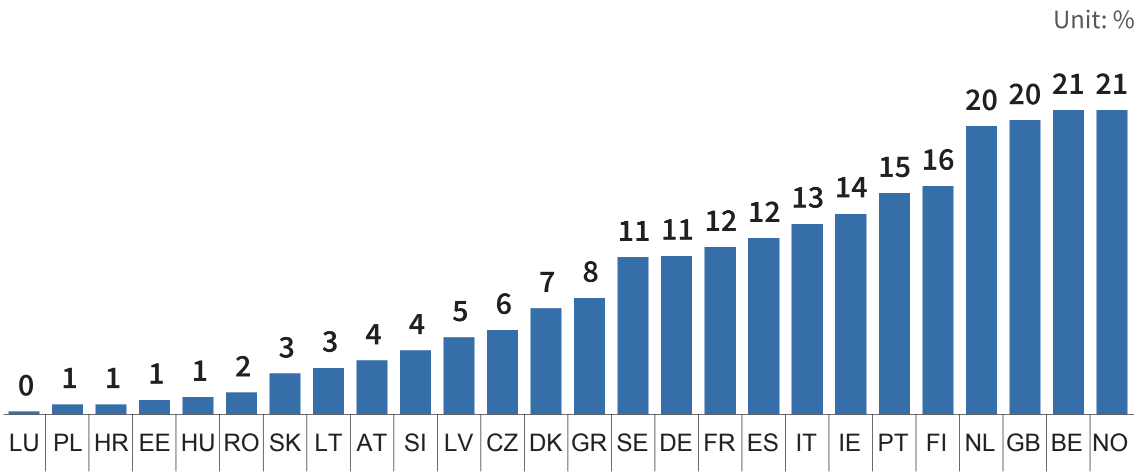
Figure 42 | **CR3 in 2020 for selected European countries**



Source: ACER

As the key indicator for the well-functioning of retail electricity markets from the demand perspective, switching rates reflect the possibility and the adoption level of consumer active mar-ket participation. However, a case-specific evaluation should complement the quantitative analysis in order to exclude the possibility that the switching is primarily driven by dissatisfaction with the supplier instead of by the willingness of an active market participation. The following figure indicates the switching rates observed in 26 European countries in 2020[147].

Figure 43 | **Switching rates of electricity suppliers in 2020 in selected European countries**



Source: ACER

147 Ibid.

Directive (EU) 2019/944 improved key legislative aspects regarding retail markets and customer protection as compared to the previous Directive 2009/72/EC. Among other things, it defines requirements for switching supplier:

- Duration: Legal limit 3 weeks[148] (from 2026 on, 24 h for the technical process[149])
- Costs: Termination fees are prohibited except in very specific circumstances.
- Comparison tools: Consumers with a yearly consumption of up to 100 MWh must have free access to at least one comparison tool[150].

Directive (EU) 2019/944 distinguishes between two goals of public intervention measures:

- Ensure the protection of *"energy poor and vulnerable household customers"* with measures that shall not go beyond the pursuit of *"a general economic interest"*.
- *"For the purpose of a transition period to establish effective competition for electricity supply contracts between suppliers, and to achieve fully effective market-based retail pricing of electricity"*.

Retail competition exists since July 2007 and thousands of suppliers are active in the EU. Switching rates vary from country to country and tend to be higher where market concentration is lower, i.e., where competition is more effective.

Retail electricity markets are highly concentrated in two thirds of EU Member States.

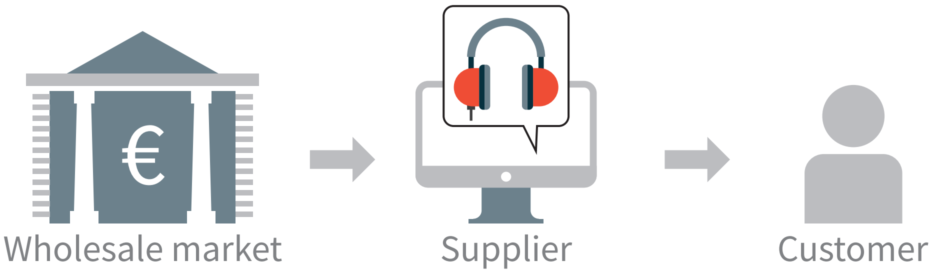
When full retail competition was introduced in electricity markets, back in 2007, the interaction model between consumer and markets was rather linear, with suppliers playing the key role, as described in Figure 44.

148 Directive 2009/72/EC, Art. 3.5

149 Directive (EU) 2019/944, Art. 12

150 Directive (EU) 2019/944, Art. 14

Figure 44 | **Suppliers at the centre of retail electricity markets**

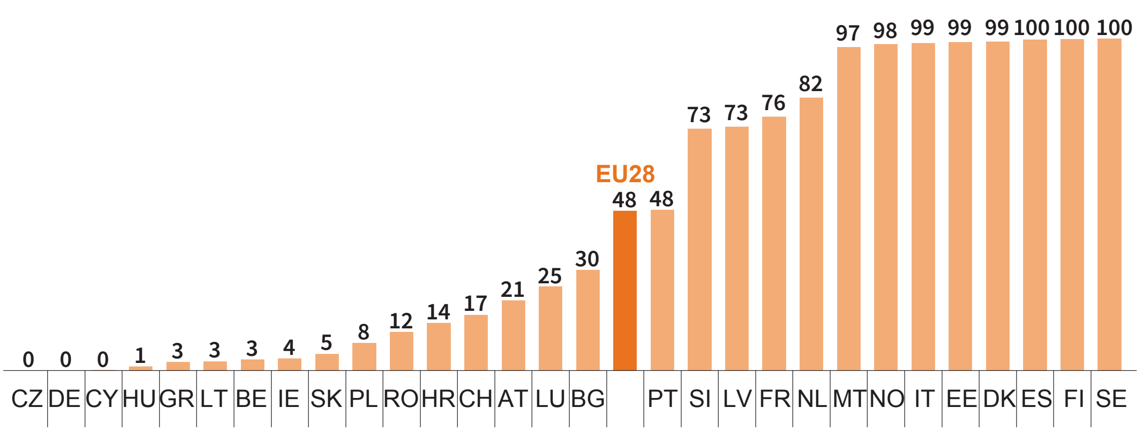


Since then, many new and unrelated developments have taken place, such as energy digitalization (including, but not limited to smart metering roll out), decentralized self-generation, increasingly including local storage, both individually and within energy communities, electric vehicles in urban mobility, etc..

According to the EC, *"by 2024, it is expected that almost 77% of European consumers will have a smart meter for electricity. About 44% will have one for gas."*[151] Currently, the penetration rate of smart meters varies strongly across Member States, as indicated in Figure *45*[152], with several countries having reached full smart metering deployment.

Figure 45 | **Current penetration rate of smart meters in EU-27**

Unit: %



Source: Eurelectric

As regards electric car registrations in Europe (EU-27, Iceland, Norway and the United Kingdom), they increased from 700 in 2010 to 1.325 million in 2020, representing 11%

151 EC https://energy.ec.europa.eu/topics/markets-and-consumers/smart-grids-and-meters_en

152 Eurelectric (2021): "Smart Grids. Prospects and Challenges - Yerevan International Energy Charter Forum"

of newly registered passenger cars in that year. In 2020, almost 30,000 electric vans were sold, representing a 2.2% market share.[153] "Overall in 2021, hybrid electric vehicles accounted for 19.6% of all new passenger cars registered across the EU, compared to 11.9% in 2020. Electrically-chargeable vehicles also saw a strong increase in sales, making up 18.0% of total car registrations, up from a 10.5% share in 2020."[154]

Directive (EU) 2019/944 promotes the development of aggregators, new entities pooling several end consumers in order to market their flexibility. A recent study monitoring markets for Demand Side Flexibility reveals that aggregators are the dominant players in these markets, although their number and activity is still rather limited[155].

Based on the new available digital technologies, manageable consumption patterns, decentralized generation resources and flexibility options, new business models arise, such as demand side aggregation, energy communities, local market platforms and multi-service provision.

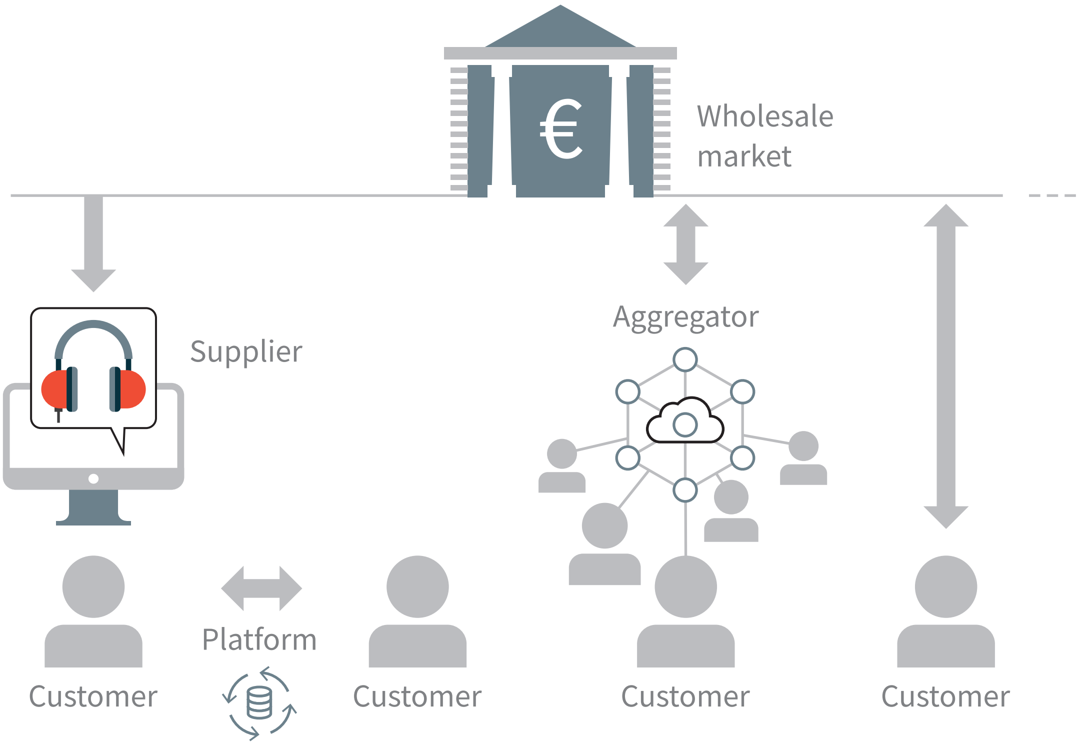
These recent developments, among others, lead to a wider scope of retail markets, to the entrance of new actors and to the establishment of new transactional interactions, as described in Figure 46. End consumers assume a new role and new players challenge the (former) exclusive intermediary role of traditional suppliers, requiring clear definitions of duties and responsibilities. Within this new framework, energy consumers may face new cost streams, as well as new revenue streams. The very notion of "energy price" may be split into several different components and synthetized in a much more complex way than the previous energy/networks/taxes triplet.

153 EEA https://www.eea.europa.eu/ims/new-registrations-of-electric-vehicles

154 ACEA https://www.acea.auto/fuel-pc/fuel-types-of-new-cars-battery-electric-9-1-hybrid-19-6-and-petrol-40-0-market-share-full-year-2021/

155 Delta-EE and smartEn (2022): "European Market Monitor for Demand Side Flexibility 2021"

Figure 46 | **Widened scope of retail electricity markets**



The old retail electricity market model, where suppliers could compete against each other for market share basically through lower margins, is over. New market models are needed, also at retail level, and not just at wholesale level.

In the new electricity retail markets, price will remain an important issue, and quality of service will remain a must. However, in a future configuration dominated by prosumers and aggregated partners, other performance indicators will become equally important, namely the ability to efficiently combine different types of energy resources and different types of transactions of both competitive and cooperative nature.

FLEXIBILITY – WHY, WHAT, HOW ?

[W]ith the most recent technical progress, in automation on the one hand and in computer science on the other hand, we could access another institutional model, self-adaptable institutions, where decentralized initiative and centralized synthesis would be combined.(…) But how would this happen in a system that so far has eliminated decision and choice?

Jacques Ellul, *Le système technician,* 1977

Flexibility is one of the most expended buzzwords when talking about energy transitions. Why? Flexibility has always been an important feature of electricity systems, meaning the ability to ensure reliability and stability through adequate (in terms of amplitude and timing) changes in the functioning of some electrical devices connected to the system – for instance, to compensate for unexpected changes in other devices. The importance of this feature is not new, and its prominence will increase with decarbonization and decentralization.

There are three main reasons why "flexibility" is intensely discussed nowadays:

1) Most traditional big providers of flexibility (i.e., fossil fuel power plants) are deemed to exit electricity systems soon as a consequence of decarbonization. Who will replace them, namely as regards balancing and transmission grid congestion management ? To cover future conventional flexibility needs, system operators will have to employ a high number of distributed resources, relying more on intelligent asset scheduling and control than on asset-based redundancy, as done in the past.

2) Future electricity systems exhibit new flexibility needs, e.g. deriving from inverted power flows or new load peaks at distribution grid level, for which suitable flexibility sources, procurement and remuneration methods must be developed. Most of these new needs arise at local level, while flexibility is traditionally managed in a centralized way. Failing to provide the needed extra balancing services can lead to the curtailment of renewable generation and delay the displacement of conventional fossil fuel plants, which would potentially incur significant compensation costs and counteract ongoing decarbonization efforts. Furthermore, failing to reduce or shift the expected surge in peak demand would lead to significant electricity system cost increases due to the reinforcement of generation and network infrastructures.

3) Future electricity systems include new resources (e.g. electrical and thermal storage) that may contribute significantly to flexibility. Energy digitalization enables this potential of mainly decentralized resources (including demand) to be bundled and usefully used, both at local and at central level. However, this requires, not only extensive and deep energy digitalization, but also new institutional arrangements[156].

What is flexibility ?

Interestingly, neither Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (recast), nor Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast), do provide a definition of flexibility, although the latter establishes that (Article 32):

"Member States shall provide the necessary regulatory framework to allow and provide incentives to distribution system operators to procure flexibility services, including congestion management in their areas, in order to improve efficiencies in the operation and development of the distribution system. (…)

Distribution system operators, subject to approval by the regulatory authority, or the regulatory authority itself, shall, in a transparent and participatory process that includes all relevant system users and transmission system operators, establish the specifications for the flexibility services procured and, where appropriate, standardised market products for such services at least at national level. (…)

The [distribution] *network development plan shall provide transparency on the medium and long-term flexibility services needed, and shall set out the planned investments for the next five-to-ten years".*

As usual in EU legislation, the lack of semantic clarity reveals a lack of procedural clarity, caused either by lack of political consensus or because the EU legislator decided to allow for "flexibility" in subsequent implementation steps. In the present case, the point is well summarized by L. Meeus *et al*. in the following diplomatic terms: *"How congestion management in balancing markets, redispatching markets and flexibility markets will evolve is very much an open issue"*[157].

156 EnTEC - Energy Transition Expertise Centre for the European Commission, Terms of Reference - Digital Flexible Solutions for the Energy System, November 2021, pg. 4: *"One important and very beneficial field of digital energy services consists in the provision of flexi-bility services (i.e. generation flexibility, demand side flexibility, storage flexibility). (…) Thus, digital infrastructure is needed to facilitate data exchange at application levels and between different players along the energy value chain. Providing infrastructure involves governments, regulators and stakeholders as well as consumers, and addresses (IT)-technical, or-ganisational, legal, economic and behavioural aspects of data exchange (or sharing1) and use."* See the final report at https://op.europa.eu/en/publication-detail/-/publication/c230dd32-a5a2-11ec-83e1-01aa75ed71a1/language-en

157 Leonardo Meeus et al., *Who is responsible for balancing the system ?*, chapter 5, pg. 95 in Leonardo Meeus, *The evolution of electricity markets in Europe*, Edward Elgar Publishing, 2020.

Flexibility is a generic term rather than a uniform, universal definition of a system- or use-case specific resource. The following is a non-exhaustive selection of commonly used definitions:

- "Flexibility is the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) in order to provide a service within the energy system." – German Regulatory Agency (BNetzA)[158]
- "On an individual level, flexibility is the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) in order to provide a service within the energy system. The parameters used to characterize flexibility in electricity include: the amount of power modulation, the duration, the rate of change, the response time, the location etc." – VDE adapted from BNetzA[159]
- "The ability to manage variability and volatility in order to balance supply and demand within the constraints of infrastructure" – Eurelectric (1)[160]
- "Flexibility: Any modification of generation and/or consumption levels in reaction to an external price or activation signal, aimed at providing a service within the energy system. The flexibility provided by consumers is called demand-side flexibility or demand response." – Eurelectric (2)[161]
- "Flexibility is the ability to purposely deviate from a planned / normal generation or consumption pattern. This ability can be deployed either directly, by an external signal, or indirectly as a response to a financial incentive such as energy prices and tariffs" – USEF[162]
- "Power System Flexibility – the ability to respond in a timely manner to variations in electricity supply and demand" – IEA[163]

Besides attempts to define the generic term, numerous definitions exist for more specific flexibility concepts, such as demand side flexibility.

Current discussions on flexibility are commonly introduced by an explanation of

158 https://www.bundesnetzagentur.de/EN/Areas/Energy/Companies/GridDevelopment/Flexibility/Flexibility_node.html

159 https://www.vde.com/de/fnn/dokumente/glossar

160 https://www.eurelectric.org/news/flexibility-bringing-the-european-power-sector-closer-to-reaching-its-climate-goals/

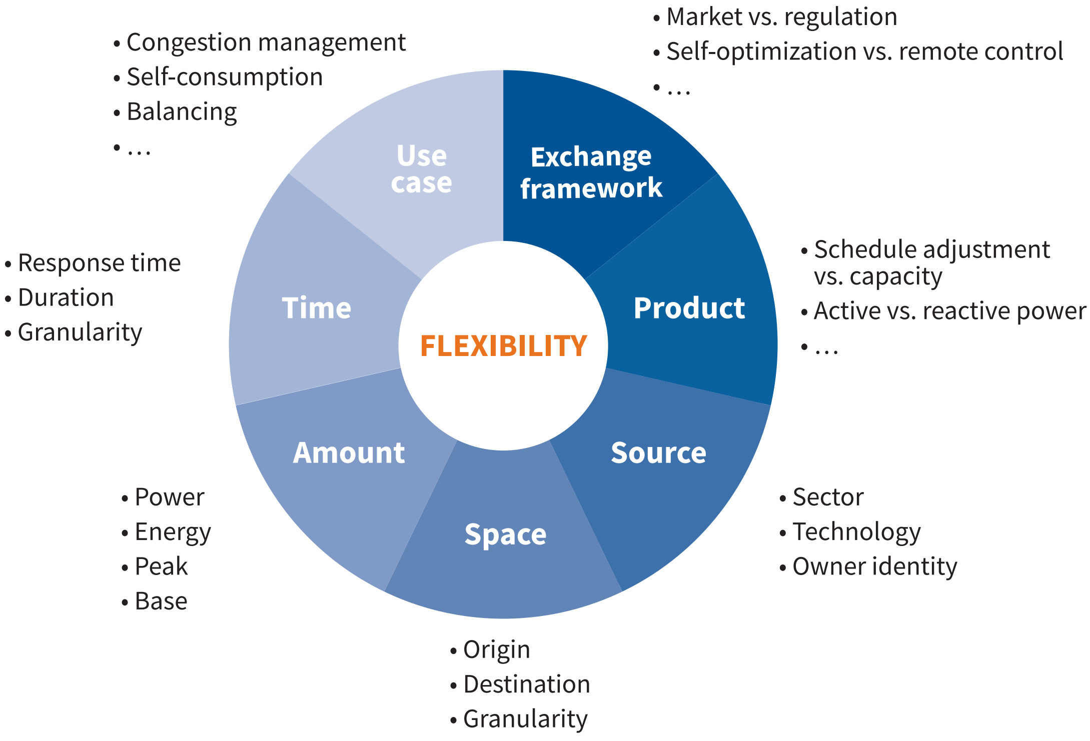
161 https://cdn.eurelectric.org/media/1940/demand-response-brochure-11-05-final-lr-2015-2501-0002-01-e-h-C783EC17.pdf

162 https://www.usef.energy/app/uploads/2018/11/USEF-White-Paper-Flexibility-Platforms-version-1.0_Nov2018.pdf

163 https://www.iea.org/commentaries/the-who-and-how-of-power-system-flexibility

the need or the envisaged flexibility use case: flexibility is either needed as a solution to an existing problem, e.g., for balancing supply and demand, or as an instrument to exploit profitable business opportunities, e.g., revenues from participating in aggregation schemes. The initial description of the regarded flexibility use case is then used as a basis to identify or justify certain configurations of the remaining dimensions (see 1) Time: Each specific use case has different impacts upon the time-related requirements for the provision and procurement of flexibility. The requirements differ mainly in terms of required response time (When and how fast is flexibility available?), granularity (seconds, hours, months, …) and duration (Is flexibility needed for a short or long period of time?). Additionally, flexibility is differentiated based on whether it is used at operational level (i.e., the use of resources to ensure efficient and secure system operation) or at capacity level (i.e., for maintaining the long-term capacity requirement of the system).). The following list identifies several dimensions typically used to characterize flexibility in electricity systems.

Figure 47 | **Flexibility dimensions**



1) *Time*: Each specific use case has different impacts upon the time-related requirements for the provision and procurement of flexibility. The requirements differ mainly in terms of required response time (When and how fast is flexibility available?), granularity (seconds, hours, months, …) and duration (Is flexibility needed for a short or long period of time?). Additionally, flexibility is differentiated based on whether it is used at operational level (i.e., the use of resources to ensure efficient and secure system operation) or at capacity level (i.e., for maintaining the long-term capacity requirement of the system).

2) *Amount*: Each use case further determines whether the needed or available amount of flexibility is expressed in terms of power or energy and if it is constant or time-variant (e.g. Peak / Base).

3) *Space*: Spatial features mainly relate to the origin (where is the flexibility provider physically located?), the destination (where is the flexibility recipient physically located?) and the granularity (is it possible and / or necessary to know whether a specific amount of flexibility was provided by a specific asset, consumer, distribution grid, etc.?). The space dimension is crucial in ongoing discussions around centralized vs. decentralized systems, including questions such as "How and by whom should flexibility resources located at distribution grid level be coordinated for use across voltage levels?".

4) *Source*: The origin of the flexibility provision is further categorized in terms of source sector (power, heat, gas), technological source (generation units, (cross-border) interconnections, demand side flexibility, energy storage) and owner identity (end consumer, aggregator, etc.), thus specifying the technical and commercial nature of potential flexibility providers.

5) *Product*: As soon as the dimensions time, amount, space and source are specified in line with the regarded use case, a viable product definition can be carried out. The complexity of this task is evident from the broad range of resulting configurations (schedule adjustments, reservation mechanisms, etc.).

6) *Exchange framework*: The peak of the issue's complexity is reached by the final dimension, which includes all aspects relating not to the "what" but rather the "how" of the issue at hand: in which fundamental framework is the flexibility transaction embedded (e.g., P2P market, centralized market, regulated bilateral agreement, etc.)? How is the available flexibility announced (e.g., daily bid, long-term capacity, …)? How is the flexibility retrieved (active control by the provider vs. remote control by the recipient, etc.)? etc.

In addition to the individual flexibility dimensions included in the simplified breakdown above, the implications resulting from some strong interdependencies between the different dimensions, as well as from external influencing factors (e.g. the impact of the regulatory framework on the use case or the availability of a suitable digital infrastructure to implement a certain configuration), must be considered in order to avoid over- or underestimation of flexibility needs and resources. A holistic perspective, even if only simplified, is therefore needed to enable the efficient realization of the numerous flexibility use cases.

Some current efforts in this sense envisage the introduction of a central "hub" containing all relevant information needed to provide and procure flexibility for multiple use cases and which is designated as "flexibility registry", "flexibility database", "flexibility platform", etc. (e.g. (ENSTSO-E2021[164])). However, even in the rare occasions when these suggestions include a standardization framework for the stored data that is compatible with different flexibility use cases, certain aspects crucial to the efficient utilization of the "hub" remain unanswered. For instance, who carries the responsibility for safely storing the data and granting legally compliant data access rights; or how should the system boundaries be defined – should the central "hub" contain data on distributed flexibility of a distribution grid area only, of a balancing zone, of the entire national energy system or of the whole European system?

How much flexibility is needed ?

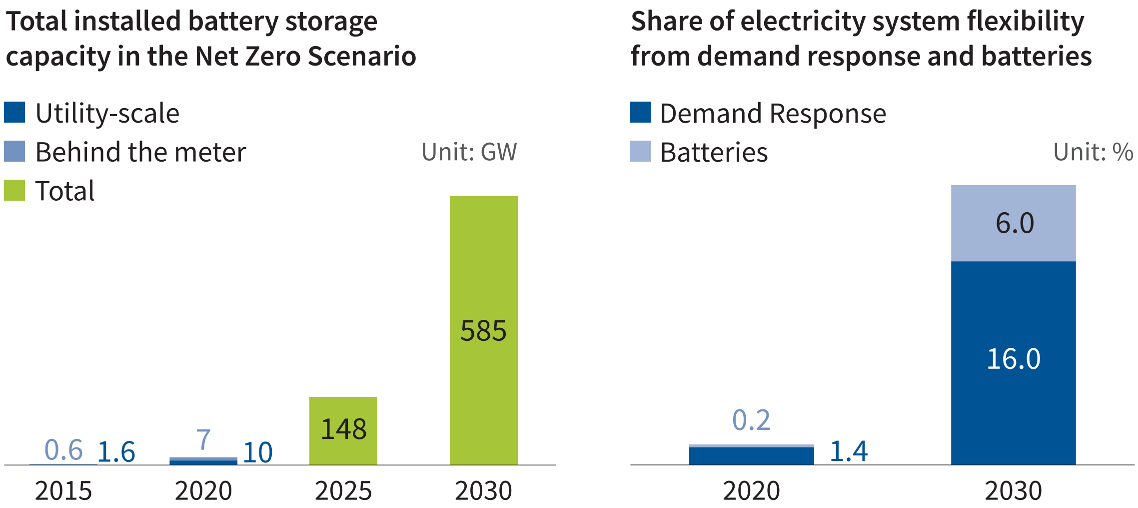
Notwithstanding the lack of clear definitions and the complexity of accurately estimating future flexibility needs or resources, many future energy system scenarios include estimates on the amount of available flexibility. Common to these scenarios is the statement that the deployment of flexibility resources has lagged behind, compared to the deployment of renewable energy sources.

The IEA Net Zero Emissions by 2050 Scenario, for instance, contains assumptions on both total installed battery storage capacity and on the share of electricity system flexibility from demand response and batteries by 2030, at global scale (see IRENA estimates global growth of battery electricity storage energy capacity in stationary applications, between 2017 and 2030, including a breakdown of the corresponding sectors (see Figure 47). While absolute differences between the various scenarios are significant, the absolute increase of battery electricity storage capacity between 2017 and 2030 is overall very high (9-15-fold increase in the REmap Reference Case and 17-38-fold increase in the REmap Doubling Case).). The IEA states that reaching these high shares implies increasing the efforts to incentivize battery storage capacity additions beyond the new policies and projects in place[165].

164 ENTSO-E, E.DSO et al. (2021): "Roadmap on the Evolution of the Regulatory Framework for Distributed Flexibility"

165 https://www.iea.org/reports/energy-storage

Figure 48 | **IEA 2030 flexibility forecast**

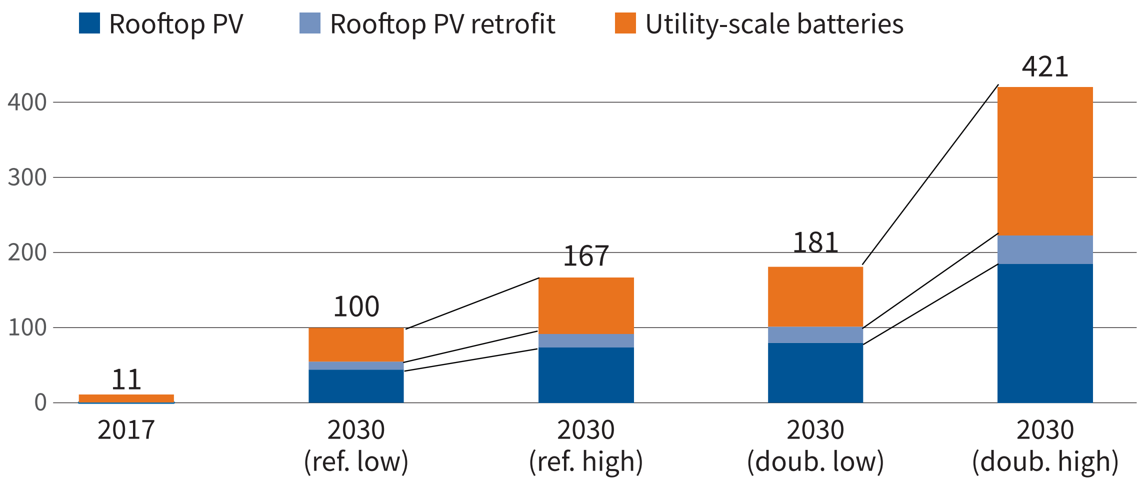


Source: IEA

IRENA[166] estimates global growth of battery electricity storage energy capacity in stationary applications, between 2017 and 2030, including a breakdown of the corresponding sectors (see Figure 49). While absolute differences between the various scenarios are significant, the absolute increase of battery electricity storage capacity between 2017 and 2030 is overall very high (9-15-fold increase in the REmap Reference Case and 17-38-fold increase in the REmap Doubling Case).

Figure 49 | **IRENA 2030 flexibility forecasts**

Battery electricity storage energy capacity growth in stationary applications by sector [GWh]

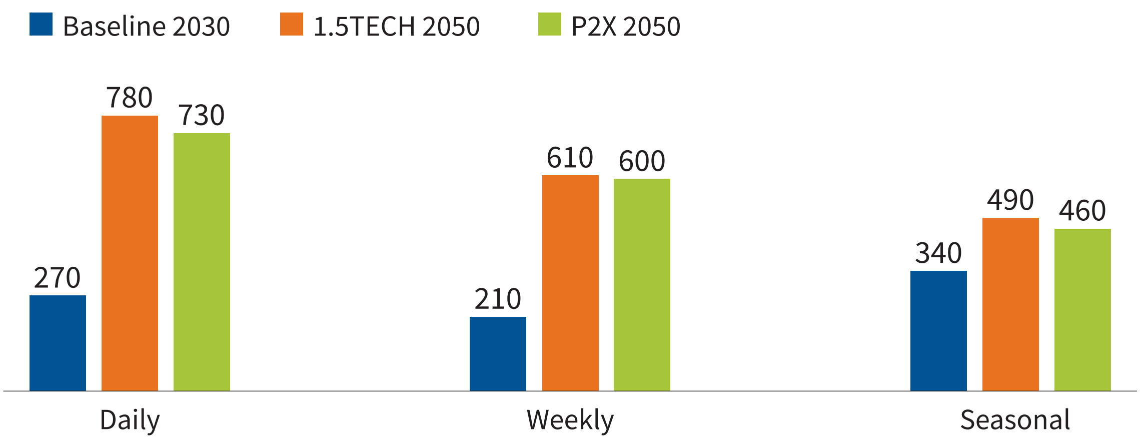


Source: IRENA

166 IRENA (2017): "Electricity storage and renewables: Costs and markets to 2030"

The 2020 European Commission report analysing the contribution of energy storage to security of electricity supply in Europe[167] estimates daily, weekly and seasonal future flexibility needs in the European Union for three scenarios: the Baseline 2030 scenario, containing the recently agreed policies, the 1.5TECH 2050 scenario, containing a path towards carbon-neutrality by 2050 with relatively conservative assumptions with regard to behavioural change and the P2X 2050 scenario, which also leads to carbon-neutrality by 2050 but with more ambitious assumptions in terms of storage deployment.

Figure 50 | **EC 2050 flexibility forecasts**
Flexibility needs at EU-28 level [TWh]



Source: EC

The larger differences between the 2030 and the two 2050 scenarios in the daily and weekly flexibility needs, compared to the seasonal needs, are explained in the report by the fact that while solar PV and wind power shares are the clear drivers of flexibility need increase in the shorter term, seasonal flexibility needs are influenced by other factors that might have opposing impacts on its value, such as the thermo-sensitivity of electricity demand.

A recent McKinsey report on Europe's decarbonization pathways[168] describes the most cost-optimal flexibility solutions for different timeframes. It states that short-term flexibility needs (between now and 2030) mainly relate to periods of less than six hours and that battery storage could provide the needed balancing. Increasing the installed capacity to 25 GW by 2030 and to 170 GW by 2050, as well as steeply reducing battery storage costs (to half of the current cost by 2030, followed by further reductions until 2050) would be the prerequisites. The report also indicates that the cost-optimal flexibility solutions to cover medium- to long-term flexibility needs, relating to periods lasting from days to months, are gas plants, hydrogen production

167 European Commission, *Study on energy storage - Contribution to the security of the electricity supply in Europe*, March 2020

168 McKinsey & Company, *Net-Zero Europe. Decarbonization pathways and socioeconomic implications*, 2020

via electrolysis and zero-emissions technologies such as natural gas power stations with carbon capture.

How is flexibility provided ?

Flexibility in electricity systems can be provided by any of the following four approaches:

a) Dispatchable generation (e.g. fossil fuel and biomass power plants).

b) Demand side management.

c) Network infrastructure expansion (electrical distribution and transmission grids, including cross-border capacity).

d) Energy storage.

In the following paragraphs provision of distributed flexibility is briefly discussed.

Thanks to energy digitalization and to the so-called Internet of Things, demand side flexibility can be easily exploited; however, progress has been slow. According to the latest DeltaEE and smartEN's "European Market Monitor for Demand Side Flexibility"[169], progress towards opening up markets and levelling the playing field for demand side flexibility has been driven by the Clean Energy Package but is not sufficient to help reach the 2030 targets defined by the EU's Fit for 55 package. The report states that only around half of European countries allow demand side flexibility and fewer still allow participation from aggregated assets. Great Britain is named as an example of a very active country in terms of exploiting distributed ("local") flexibility. However, while all six distribution network operators there have mechanisms in place to procure distributed flexibility, solutions enabling collective self-consumption are only allowed within regulatory sandboxes.

Flexibility markets have mainly been driven by Article 32 of EU Directive 2019/944, which requires regulatory framework adjustments by Member States to accommodate market-based flexibility procurement mechanisms for distribution system operators. Initial discussions have turned into a wide landscape of conceptual frameworks and pilots. In a comprehensive analysis[170] evaluating market-based approaches of over 170 DSOs with over 100.000 customers across Europe, Accenture identified the following major trends:

169 DeltaEE, smartEn (2022): "European Market Monitor for Demand Side Flexibility"

170 Accenture (2021): „An overview of local European flexibility markets" https://www.accenture.com/_acnmedia/PDF-166/Accenture-Flexibility-Benchmarking-Executive-Summary.pdf#zoom=50

- DSOs driving innovative flexibility procurement approaches are mostly driven by one out of two reasons:
  - To cover the DSO's own flexibility needs.
  - To help solve congestions in the overlying voltage levels (mostly high voltage) generally caused by a lack of transmission capacity.

- Five key use cases are currently covered by DSO local flexibility markets:
  - Investment deferral
  - Permanent embedded solution
  - Demand congestion
  - HV injection congestion
  - Outage management

- Time-related market design configuration is mainly influenced by the network visibility level and the specific grid congestion risks of a given DSO:
  - Short-term markets cover day-ahead or intraday flexibility needs (low visibility level, local flexibility excluded from plannings tasks).
  - Long-term markets consist of long-term capacity tenders and short-term activation notices (high visibility level, local flexibility integrated in grid planning tasks).

In another report[171] analysing flexibility platforms "identified as being at implementation stage at the time of research", Frontier Economics distinguishes between two different categories of distributed flexibility activities:

- Platforms that enable the exchange of standardised balancing and congestion management products between system operators and aggregators.
- Marketplace platforms that enable the procurement of local congestion management services by DSOs.

Common to the reviewed platforms in the report are the functions that they perform:

- Asset registration and prequalification
- Notification of flexibility requirements and submission of offers
- Coordinated grid impact assessment and priority of access
- Matching
- Price formation

171 Frontier Economics (2021): "Review of Flexibility Platforms", report for ENTSO-E

- Issuing dispatching instructions and activation
- Validation and settlement

The in depth analysis of the flexibility platforms was further used as a basis to identify current policy issues, namely three major challenges: to DER integration (due to the high entry costs and the potentially higher risks of contracting distributed rather than utility-scale resources potentially perceived by system operators), to DSO-TSO coordination and to market design (in particular with regard to the alignment of different markets and products).

How to assess flexibility's value ?

Closely linked to the discussion on how to define flexibility is the question how to determine its value. Due to the generic nature of the term, *"[f]lexibility is an ability; its actual value is only determined when it is applied in a specific product. For example, flexibility traded in wholesale markets takes the form of an energy block; flexibility used for Frequency Containment Reserves (FCR) transforms into regulating power. Flexibility is always sold in the context of a specific product rather than as a separate commodity."* [172]

Flexibility has different values to different parties and for different functions that it fulfils. Additionally, the value of individual flexibility sources can be significantly impacted by the interactions between flexibility products or services (e.g. using flexibility for increasing self-consumption can positively or negatively impact flexibility demand by grid congestion management) and by the fact that some sources of flexibility can reallocate the flexibility need in time or to another flexibility use case. Another aspect influencing the value of flexibility is potential competition between flexibility sources. The benefits of energy storage for the system depend not only on the system' state and expected developments (e.g. share of volatile generation) but also on the availability of other flexibility sources that are able to substitute – at least in part – energy storage. Overall, the value of a flexibility can differ on whether it is based on the estimated need (for a use case / a user), on the beneficiary's willingness to pay or on the resulting business case.

Despite these complicating influencing factors, establishing the value of flexibility is key to ensure a suitable compensation for the flexibility provider that reflects the value that flexibility brings to system and, in the longer term, to ensure that there are sufficient incentives for potential providers to invest in flexibility sources. While the lack of certainty in determining the optimal deployment path or target energy system might have a paralysing effect on the deployment of flexibility sources, inaction might represent the 'highest regret pathway'.

172 USEF (2018): "White paper: Flexiiblity Platforms"

There is a wide range of approaches used to evaluate the value of flexibility, among which are cost-benefit analyses in the broader sense and levelized cost of storage (LCOS) for the particular case of energy storage as a flexibility source. While the former is more widespread in energy system or use case analyses, the latter is more commonly used as a sort of economic lifecycle analysis for storage technologies. Within the CBA category, the value estimations can be further categorized into flexible technologies CBAs (e.g. CBA of energy storage deployment) and flexibility services CBAs (e.g. CBA of demand side management).

A high share of flexible technologies CBAs are focussed on energy storage, although, in the past couple of years, hydrogen technologies have been increasingly considered as well. IRENA, for instance, published an "Electricity Storage Valuation Framework" which *"can be used to compare costs and benefits of electricity storage against other flexibility alternatives at a system level"* [173]. At the core of the electricity storage suitability assessment are techno-economic parameters, such as efficiency, maximum depth of discharge, CAPEX and operating costs, weighted according to their relevance for the given storage application.

173 IRENA (2020): „Electricity Storage Valuation Framework: Assessing system value and ensuring project viability"

THE CONTROL FLOW PROBLEM

[P]roduction, as a mechanical part of the human, is destined for automation, while consumption, as a properly human fact, is that which cannot be automated in any way, not for ethical, but for ontological reasons.

Maurizio Ferraris, *Documanità. Filosofia del mondo nuovo.* 2021

Energy digitalization has the potential to improve electricity system performance in many ways, technically and economically, for instance increasing the number and volume of flexibility sources (see previous Section). Moreover, it enables implementation of new types of transactions and new business models, thus enhancing contractual freedom. However, it also brings new risks. Some of those risks are inherent to digitalization (e.g. cyberattacks), while others are specific to electricity systems. The problem described in this Section – the so-called control flow problem – belongs to the second category. Basically, it arises when multiple agents are entitled to remotely access a specific device; this may lead, for instance, to situations where contradictory control signals (e.g., switch on or off) are applied simultaneously to the same device.

To avoid the kind of risks mentioned in the previous paragraph, both operational and transactional ex ante rules are needed; they must be embedded in any consistent market design, somehow limiting the almost infinite transactional possibilities offered by digitalization to a set of transactions compatible with reliability.

At the onset of liberalization the "parallel flow" (or "loop flow") problem, i.e. the fact that between a generator and a customer electricity flows through all lines connecting them and not only along the shortest path between the two points, was considered by incumbent utilities an insurmountable obstacle. However, conceptually and practically this problem could be solved and solutions were quickly implemented, enabling free trade both within and across national borders[174]. The "control flow" problem electricity systems face nowadays is much more complex and requires much more sophisticated solutions.

174 It should be pointed out, however, that the persisting lack of tight operational coordination at EU level means that transmission assets remain underutilized, loop flows still cause heavy costs and the risk of further blackouts increases. Modern information and communication technologies can provide cost-effective optimization of physical flows throughout European energy systems, as well as increased reliability, but these technologies have not been systematically deployed yet because their adoption would induce new governance models (e.g., redefining the bidding zone concept), thus reducing the large autonomy system operators enjoy under the current loose operational coordination scheme and incidentally increasing their liability. From the economic and technical viewpoints tight operational coordination is the *conditio sine qua non* for efficient markets in any network industry. However, as I have indicated some years ago, <<in political weighing scales, the highly visible symbolic capital of national system operators is usually more valued than the invisible "costs of non-Europe" >>.

In the past, the costs of collecting, transmitting, processing and storing information were prohibitively high. Consequently, energy systems were only partially observable and partially controllable. Therefore, planning and operation of energy systems was based on many so-called “educated guesses”, combining a few analytical tools with statistics, practical experience and engineering judgment.

Optimization of investment costs, operational costs and reliability, all suffered from the lack of complete information. This information deficit was a problem also for traders and suppliers whose knowledge about the actual behavior of their respective end-user clients was approximative; moreover, they could not interact with clients in real-time.

Modern information and communication technologies enable full monitoring and full control of energy systems at affordable cost (using general-purpose infrastructures such as internet; dedicated communication infrastructures are more expensive). Therefore, old hierarchical, centralized control systems based on many guesses may be easily replaced by decentralized, cooperative control systems based on real-time information. Nowadays, individual appliances may be remotely controlled, not only in factories and large offices, but also in households, and in all kinds of electricity demand, storage and generation points. Moreover, in terms of information and control flows, appliances may be effortlessly aggregated according to ownership, type, geographical location or any other criterion, thus enabling the introduction of innovative business models and more sophisticated optimization algorithms.

In the meantime, distributed generation became very popular in many areas where some energy consumers are simultaneously electricity producers or even combined heat and power producers. Sales of electric drive vehicles are also growing very fast (“*Fuel types of new cars: battery electric 10.0%, hybrid 25.1% and petrol 36.0% market share in Q1 2022*”[175]). Distributed generation, as well as charging of electric vehicles, are usually monitored and remotely controlled.

Coming from a long period of “information deficit” it seems that the energy industry is now entering a period of “information surplus” and concerns about “big data” management have surfaced. However, the main challenge is not how to handle so much data, but how to guarantee that energy systems will be “under control” - i.e. how to ensure system integrity and reliability while allowing market participants as much freedom as possible; in other words, how to avoid that multiple, parallel uses of large amounts of data exposes the system to hazardous conflict or latency situations.

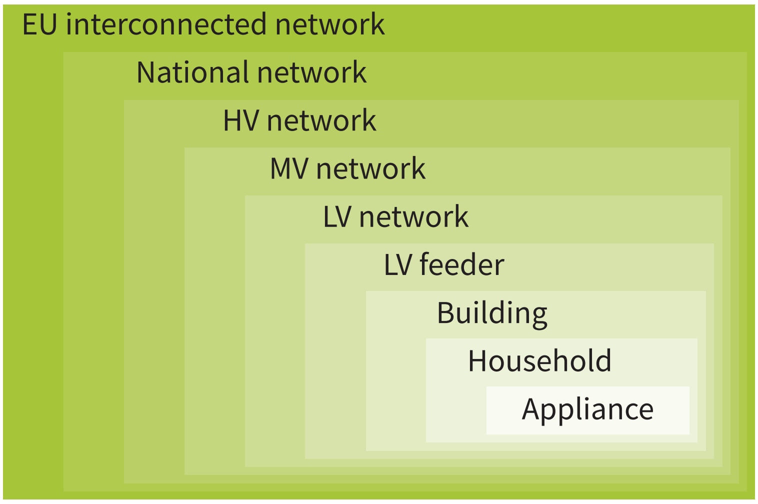
Control and communication devices are the same all over the world, but the way they are applied to energy systems (i.e., how they are interconnected and how information and control flows are organized) may differ, as well as the reliability of communication

175 ACEA Press Release May 5, 2022 https://www.acea.auto/fuel-pc/fuel-types-of-new-cars-battery-electric-10-0-hybrid-25-1-and-petrol-36-0-market-share-in-q1-2022/

channels (internet vs. utility owned dedicated infrastructure), thus enabling implementation of different market structures, contractual arrangements and control strategies.

The following figure describes several physical layers of electricity systems, from the single appliance to the interconnected European very-high voltage network.

Figure 51 | **The physical layers of EU electricity systems**



Modern information and communication technologies, if properly applied and complemented by appropriate software, enable the autonomous control of each individual layer. This possibility raises three basic questions:

1) How to ensure control at each level ?
Within each layer, different control policies can be implemented, from a highly centralized approach, more or less replicating at each level the current national hierarchical structure, down to a fully decentralized structure.

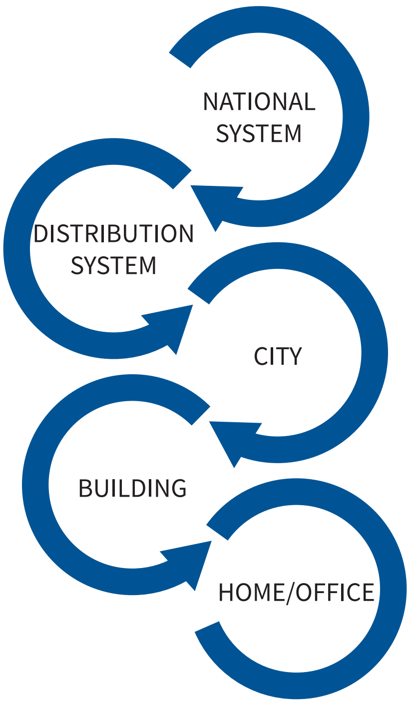
2) How to define the functional interfaces between layers ?
In order to ensure effective coordination of the whole system it is necessary to exchange information between layers and to establish clear communication and control procedures. Protocols must be implemented both for normal and for abnormal operational conditions.

3) Who is the “controller of the controllers” and “controller of last resort” ?
“Control of energy systems” does not consist of just one function – it includes a large array of functions and variables associated with different physical resources. In the past, provision of the necessary “system services” was limited to a relatively small number of resources, mainly concentrated at the higher voltage levels. New technologies,

both internal to energy systems (e.g. storage, fuel cells, heat pumps, wind and photovoltaic electricity generation) and external (namely information and communication technologies), enable the provision of system services by lower levels (see previous Section), thus expanding the control space.

If not properly managed, the multiplication and superposition of control loops (see next figure) may create stability and security problems. Therefore, decision-making and coordination roles must be (re)assigned in order to ensure that the whole system remains stable in spite of the multiplication of new types of transactions related both to the supply of "energy" (commodity and service) to end-users and to the supply of "system services".

Figure 52 | **Control flows**



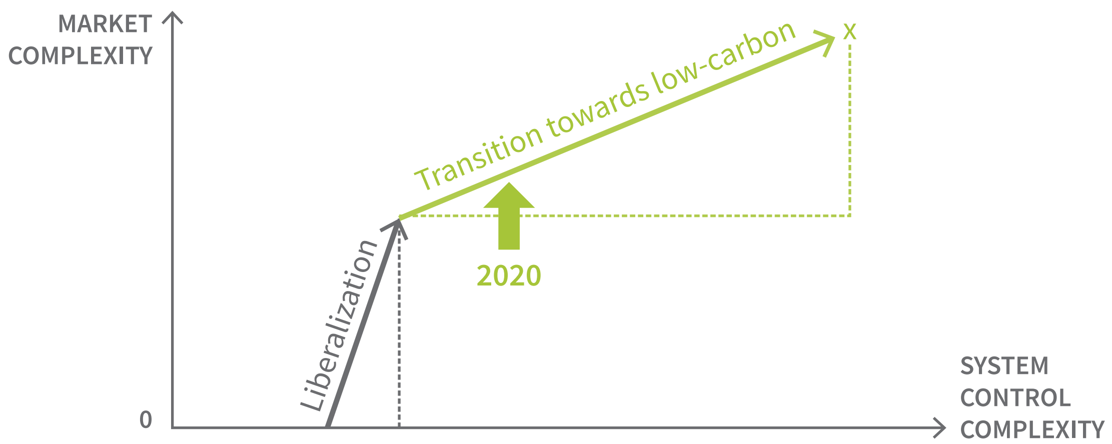
A clear definition of roles and control flows is a pre-condition for a successful and orderly transition towards low-carbon energy systems. Policy-makers and regulators should be aware that:

1) Whatever technological path they select or incentivize, a "control flow" question immediately arises that needs to be answered.

2) Snubbing this basic question on the grounds of its "technicality" will lead to a catastrophic combination of delays and over costs.

Control complexity, more and above market complexity, is the major problem in the near future (cf. next figure). Market redesign cannot be performed independently of system control redesign and this task, in turn, requires a full revaluation of the functioning of each layer of the whole electricity system.

Figure 53 | **Evolution of market and system control complexity**



Electricity systems are complex, non-linear dynamic systems. It is well known from systems theory that under these circumstances some control strategies keep the system within stability boundaries, while other control strategies lead the system to instability and collapse. Therefore, the control flow problem basically consists in identifying both acceptable and unacceptable control strategies. This knowledge must be obtained with the abstract tools of systems theory; however, in order to yield useful results, it must be translated into:

a) concrete rules about acceptable and unacceptable business models and behaviour of market agents;

b) clear roles for both network operators and market operators.

About the author

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First chairman of the Portuguese Energy Regulatory Authority (1996 / 2006). Co-founder and first chairman of the Council of European Energy Regulators (2000 / 2005). First chairman of the European Regulators' Group for Electricity and Gas (2003 / 2005). Co-founder of the Ibero-American Association of Energy Regulatory Authorities (ARIAE). Founder and member of the Executive Committee of the Florence School of Regulation.

Graduation in power systems from Porto University and Dr.-Ing. degree from the University of Erlangen-Nuremberg.

My current views on energy markets and energy regulation reflect a combination of different professional involvements over the last 40 years, namely:

- 40 years of academic experience;
- 4 years in the power systems equipment industry (networks);
- 7 years with the European utilities association when liberalisation started and interconnections with Eastern Europe were established;
- 10 years' energy regulation;
- 15 years of entrepreneurial involvement with renewable energy, energy efficiency and energy digitalization;
- many years of experience advising policy makers, regulators, financial institutions and undertakings on energy topics in several countries, spread over four continents.