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Study on barriers and opportunities for Smart Grid deployment (Lot 2)

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Acronyms and abbreviations

AD	Active Demand
AIM	Aggregator Implementation Model
APT	Advanced persistent threats
BIPV	Building-integrated Photovoltaics
BRP	Balancing Responsible Party
CAES	Compressed Air Energy Storage
CAPEX	Capital Expenditures
CEN	Comité Européen de Normalisation
CHP	Combined Heat and Power
CO2	Carbon Dioxide
ct/kWh	Cent/kilo-watt hour
DaaS	District as a Service
DCS	Distributed Control Systems (DCS)
DEN	Distributed Energy Network
DER	Distributed Energy Resources
DHC	District Heating and Cooling
DR	Demand Response
DS	Demand Side
DSM	Demand Side Management
DSO	Distribution System Operator
DSR	Demand Side Response
EASME	Executive Agency for Small and Medium-sized Enterprises
EC	European Commission
EdF	Électricité de France
EE	Energy Efficiency
EEA	European Environmental Agency
EEaaS	Energy efficiency as a service
EED	Energy Efficiency Directive
EEG	Renewable Energy Sources Act
EESC	European Economic and Social Committee
EFSI	European Fund for Strategic Investments
EHPA	European Heat Pump Association
EnMS	Energy Management Systems
EPC	Energy Performance Contract
ESCO	Energy Service Company
EU	European Union
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
EVSP	Electric Vehicle Service Provider
FCR	Frequency Containment Reserves
FCV	Fuel-Cell Vehicles
FIT	Feed-in-Tariff
FRR	Frequency Restoration Reserves
FRRa	Automated Frequency Restoration Reserves
FRRm	Manual Frequency Restoration Reserves
G2V	Grid to Vehicle
GHG	Greenhouse Gas

HV	High Voltage
HVAC	Heating, Ventilation and Air-conditioning
HVDC	high-voltage, direct current
IAN	Industrial Area Network
ICT	Information and Communications Technologies
IEA	International Energy Agency
IoT	Internet of Things
IREC	Interstate Renewable Energy Council
IRENA	International Renewable Energy Agency
JRC	Joint Research Centre
kW	Kilo Watt
kWh	Kilo-Watt-hour
Li-Ion	Lithium-Ion
LV	Low Voltage
MS	Member State
MV	Medium Voltage
MW	Mega-Watt
MWh	Mega-Watt-hour
NEM	Net Energy Metering
NIS	Network and information systems
NRA	National Regulating Authorities
NREL	National Renewable Energy Laboratory
OEM	Original Equipment Manufacturer
OPEX	Operating Expenditure
PCM	Phase Change Material
PLC	Programme Logic Controllers
PPP	Private Partnership Programme
PV	Photovoltaic
RCEF	Rural Community Energy Funds
RES	Renewable Energy Sources
RES-E	Renewable Electricity Sources
ROI	Return On Investment
SEDC	Smart Energy Demand Coalition
SER	Social and Economic Council of the Netherlands
SG	Smart Grid
SME	Small and Medium Enterprise
SO	System Operator
ToU	Time-of-Use
TSO	Transmission System Operator
UCEF	Urban Community Energy Fund
UPS	Uninterruptible Power Systems
USEF	Universal Smart Energy Framework
V2G	Vehicle to Grid
VPP	Virtual Power Plant
VPS	Virtual Power System

Glossary

KEY ACTORS IN SMART GRIDS	
Active consumers	'Active customer' means a customer or a group of jointly acting customers who consume, store or sell electricity generated on their premises, including through aggregators, or participate in demand response or energy efficiency schemes provided that these activities do not constitute their primary commercial or professional activity (European Commission, 2016).
Aggregator	An aggregator is defined as a market participant that combines multiple customer loads or supplied electricity for sale, for purchase or auction in any organised energy market (Danish Energy Association, 2016).
Consumers	Energy consumers can be grouped in industry (large, SME), households/residential, and commercial. The legislative package 'Clean Energy for all Europeans' establishes that consumers across the EU will be entitled to generate electricity for either their own consumption, store it, share it, and consume it or to sell it back to the market (European Commission, 2016a).
Consumer acceptance	Consumer acceptance is a precondition of consumer engagement; but (passive) acceptance of certain products or services does not necessarily imply an engagement.
Consumer engagement	Consumer engagement can be defined as an active relationship or commitment that a consumer enters with regard to an energy technology or service, for example, by installing PV rooftop systems, switching suppliers, or participating in a demand-response programme.
Distributed Energy Network (DEN) Manager	The DEN Manager is the agent in charge of managing a distributed energy network. The DEN needs significant knowledge and experience to identify the energy consumption and generation patterns of the DEN participants (often involving industries with specific technical assets and processes).
Distribution system operator (DSO)	'Distribution system operator' means a natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity (Articles 2 and 25 of 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).
Electric Vehicle Supply Equipment (EVSE) operators	According to the UK EVSE Trade Association, EVSE supply equipment for both electric vehicle (EV) charging points and the charging point management systems or 'back offices' that control electric vehicle recharging through e-mobility membership and payment services.
Energy prosumers	Energy prosumers are not only consumers that also produce energy, but also sellers of energy, and therefore active

KEY ACTORS IN SMART GRIDS	
	participants in the market (IMPROSUME project, Bremdal, 2014).
Energy Service Companies (ESCO)	ESCOs are companies providing energy services to final energy users, including the supply and installations of energy efficient equipment, and/or building refurbishment, and in many cases on a turnkey basis. The three main characteristics of an ESCO are: • ESCOs guarantee energy savings and/or provision of an energy service at lower cost; • The remuneration of ESCOs is directly tied to the energy savings achieved; • ESCOs can finance, or assist in arranging financing for the energy savings project by providing a savings guarantee. ESCOs accept some degree of risk for the achievement of improved energy efficiency in a user's facility and receive their payment for the services delivered based on the achievement of the energy efficiency improvements (either in whole or at least in part) (JRC website[1]).
Energy Service Provider Companies (ESPCs)	The JRC (Bertoldi et al., 2006) defines ESPCs as slightly different from ESCOs, explaining that these may be "consultants specialised in efficiency improvements, equipment manufacturers, or utilities. ESPCs provide a service for a fixed fee or as added value to the supply of equipment. ESPCs may have some incentives to reduce consumption, but these are not as clear as in the ESCO approach, since an "EPSC is paid a fee for their advice or equipment rather than being paid based on the results of their recommendations".
Local energy communities	'Local energy community' means: an association, a cooperative, a partnership, a non-profit organisation or other legal entity which is effectively controlled by local shareholders or members, generally value rather than profit-driven, involved in distributed generation and in performing activities of a distribution system operator, supplier or aggregator at local level, including across borders (European Commission, 2016).
Transmission system operator (TSO)	An entity entrusted with transporting electricity on the extra high or high voltage network with a view to its delivery to final customers or to distributors, and which is also responsible for cross border capacity and exchanges (ENTSOE-E glossary).

KEY TERMS AND CONCEPTS	
Aggregation	Aggregation is a commercial function of pooling de-centralised generation and/or consumption to provide energy and services to actors within the system (Eurelectric, 2014a).
Closed distribution network	Article 28 of Directive 2009/72/EC defines a Closed Distribution Network as a system, which distributes electricity within a geographically confined, industrial, commercial or shared services site and does not (without prejudice to a small number of

[1] https://ec.europa.eu/jrc/en/energy-efficiency

KEY TERMS AND CONCEPTS	
	households located within the area served by the system and with employment or similar associations with the owner of the system) supply household customers (ENTSOE-E Glossary).
Demand Response (DR)	Demand response means allowing consumers to adapt their energy usage to different energy prices throughout the day. This could mean receiving a payment for turning down the heating system in order to stabilise the grid during peak time. Alternatively, it could mean access to cheaper energy via dynamic price contracts and smart meters when wind farms and solar panels are producing plenty of electricity (European Commission, 2016g).
Distributed Energy Generation / Distributed Energy Network	Distributed generation assets are small devices, of less than 10 MW of capacity (US) - but in some definitions extended to 50 MW - which provide electricity or heat, produced from renewable sources or fossil fuels. These devices can be aggregated in a virtual or real network for optimisation of production and consumption.
Electrical Energy Storage	Several competing technologies are available for electricity storage. Distinctions are made between large- and small-scale storage systems, since the first are generally grid-connected, while smaller units are deployed on the customer side and not necessarily connected to the grid. Relevant applications related to SG are (IEC, 2011): • Industrial: storage applications installed in customer-side substations can control power flow and mitigate congestion, or maintain voltage in the appropriate range; • Transport: batteries for electric vehicles; • Residential and commercial: energy storage medium for energy management systems in homes and buildings.
Energy transfer	Energy transfer refers to an activation of demand-side flexibility that affects two different BRPs and/or suppliers.
Flexibility	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 characterise flexibility include the amount of power modulation, the duration, the rate of change, the response time, the location, etc. (Eurelectric, 2014a).
Reserve capacity	Reserve Capacity means the amount of Frequency Containment Reserve (FCR), Frequency Restoration Reserve (FRR), or Replacement Reserve (RR) that needs to be available to the TSO.
Rebound effect	The rebound effect refers to a compensatory increase in energy use after a peak shaving period.
Unbundling	Unbundling is the separation of energy supply and generation from the operation of transmission networks (European Commission website[2]).
Virtual Power Plant (VPP)	One distributed generation technology with significant growth potential is the Virtual Power Plant (VPP). In the VPP model, an

[2] https://ec.europa.eu/energy/en/topics/markets-and-consumers/market-legislation

KEY TERMS AND CONCEPTS	
	energy aggregator gathers a portfolio of smaller generators and operates them as a unified and flexible resource on the energy market or sells their power as system reserve. VPPs are designed to maximise the profits of the asset owners while also balancing the grid. They can match load fluctuations through forecasting, advance metering and computerised control, and can perform real-time optimisation of energy resources (Bayar, 2013).

KEY BUSINESS TERMS	
Business case	“Business case” refers to the argument defending the viability of a product, service, or line of business. The business case answers the question: "If we introduce this product or service, will it be successful, and if so, why?”
Business model	A business model describes the dynamic mechanics by which a company makes money from a product or service. The business model answers the question: "which is our strategy for making money?"
Business opportunity	Business opportunity refers to a newly identified need, want, or demand trend that a company can exploit.

0. Executive summary

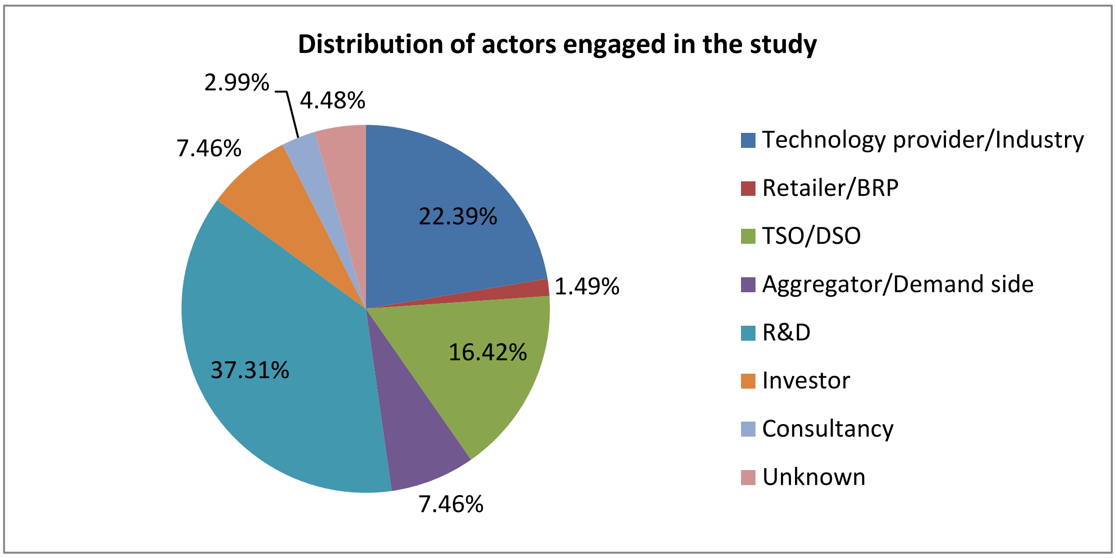
Objectives

EASME has entrusted this study to a consortium consisting of smart grid (SG) and forward-looking experts to identify legal, economic and other types of barriers that hinder the deployment of smart grid technologies at medium and low voltage levels. New business opportunities and new business models related to SGs and likely to benefit the European engineering industry were to be explored.

Methodology

The study takes a long-term view on developments related to Smart Grids, formulated by two scenarios considered highly plausible by the participating experts. Interaction with all stakeholders involved in SG deployment has been essential for developing the long-term market perspective and for refining the opportunities detected during the initial literature review and the in-depth assessment of 23 recent SG research projects. Figure 0-1 shows the type of experts that have contributed to this study and their relative weight:

Figure 0-1 Distribution of actors engaged in the study



Source: own elaboration

In two separate rounds of consultations, the experts chose six business opportunities enabled by SG deployment, which are discussed in detail in this report in the form of Strategic Action Plans (SAPs), showing desirable medium and long-term objectives and necessary short-term actions.

Long-term perspective

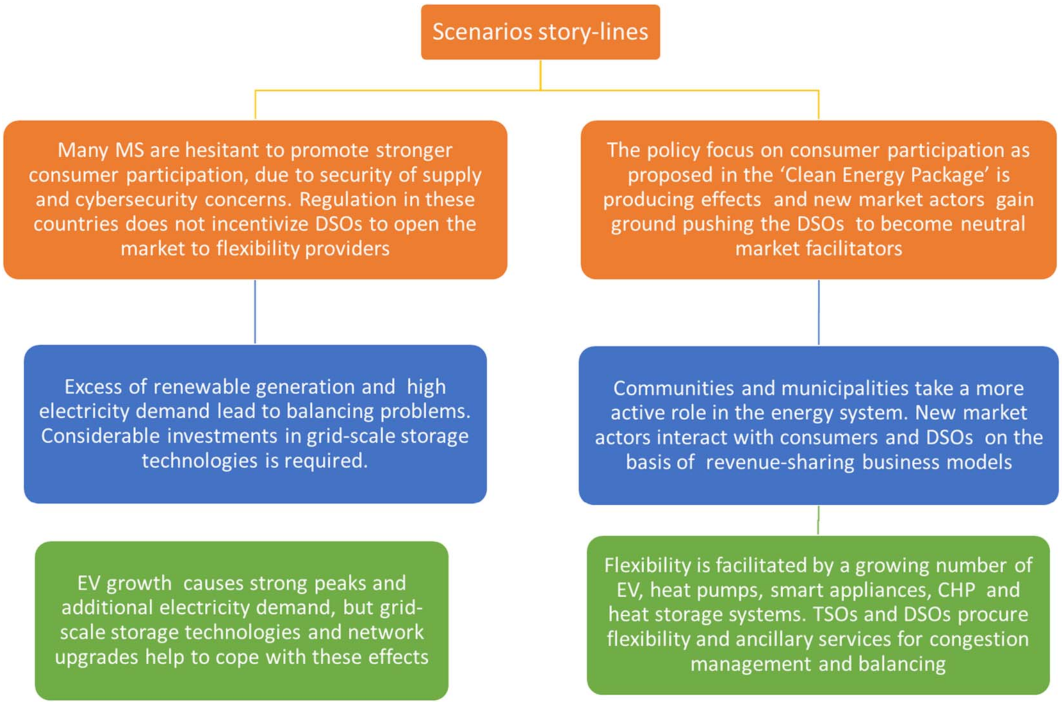
The two scenarios developed in the study provide insights on the possible framework conditions for SG deployment by 2030. By combining the possible evolution of five main drivers, two plausible scenarios can be envisaged:

- 'Networks in control', which is in fact a Business As Usual Scenario (BAU), in which smart grids are deployed through top-down action of network operators to increase the efficiency of network management and to cope with additional demand coming from electric vehicle (EV) deployment and new renewable supply-side resources, mainly in the form of large off-shore wind parks, but with limited benefits for consumers and new service providers

- 'People have the power' features a paradigm change, in which smart grids develop thanks to the full interaction of all actors in the electricity network, including consumers and new business actors. This scenario can unfold if the recently proposed changes to energy and electricity regulation ('Clean Energy for All Europeans Package': European Commission 2016, 2016a, 2016b, 2016f, 2016g, 2016i, 2016j, 2016k, 2016l, 2016r, 2016s, 2017, 2017a)[3] are approved and implemented with due diligence in the Member States (MS).

Figure 0-2 shows the key steps of the scenario pathways.

Figure 0-2 Key steps of the scenarios



Source: own elaboration

The impact of the scenarios on opportunities for industry is different. In "Network in Control", the digitalised grid guarantees an adequate level of service quality and efficiency and enables Transmission System Operators (TSOs) and Distribution System Operators (DSOs) to manage grid constraints, ensuring security of supply. The scenario implies notable investments in fixed capital assets (superconducting cables to reinforce the grid; solid-state transformers for high-density locations with increasing electricity consumption; ICTs and grid-scale energy storage systems) with limited possibilities to make use of the reserve capacity offered by demand side flexibility (except for electric vehicle storage capacity).

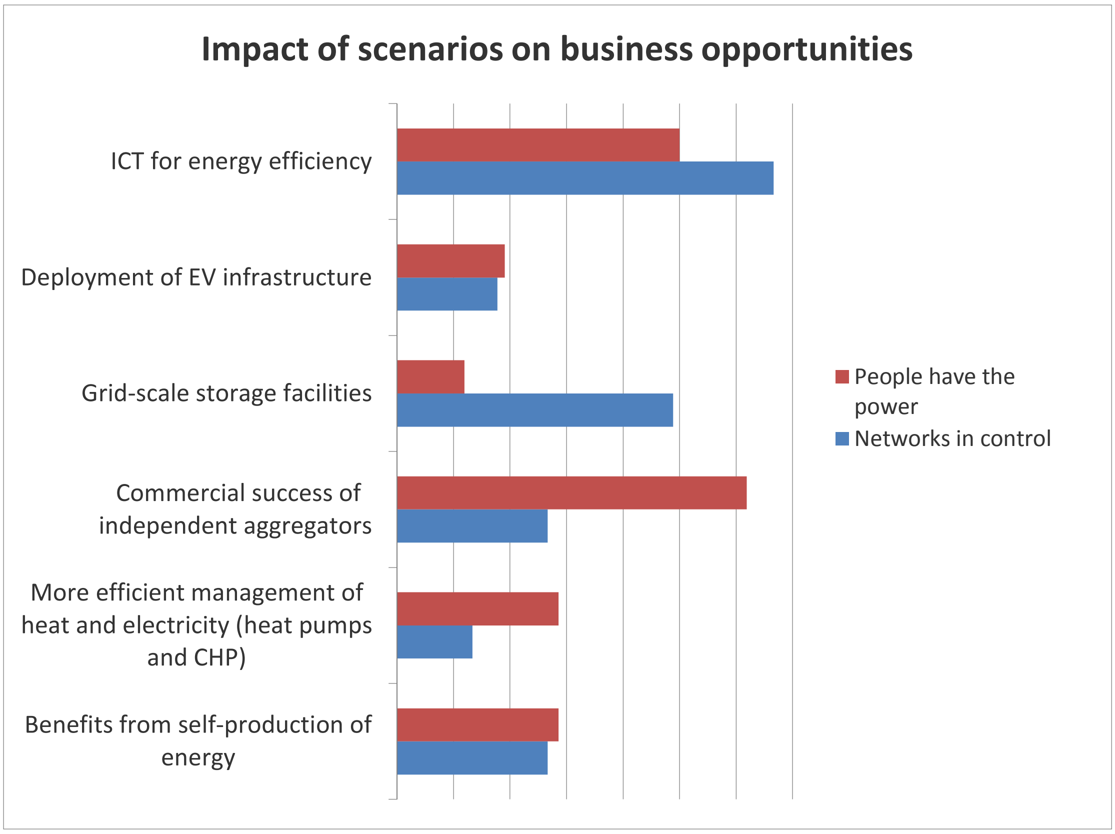
This scenario may unfold by 2030, given the limited systemic change needed for its realisation. Thanks to the leading role of TSOs and DSOs and the maturity of ICT-enabling technology, the infrastructure upgrade can take place in the medium term.

[3] The "Clean Energy for All Europeans Package" was released at the end of 2016, but the Commission has since published two corrigenda, one affecting the proposal for the internal market of electricity and a second one concerning the proposed directive on the promotion of renewable energy. The term "Clean Energy Package" has been used throughout the document for the combination of legislative measures proposed by the EC, including the two corrigenda.

The "people have the power" scenario has bigger benefits for producers of small-scale storage facilities, which are coupled to small RES power plants to increase the stability of micro-grids. The ICT industry benefits from investments in upgrades of the communication and data infrastructure and the smart appliances industry delivers the devices required to ease flexible demand and production of electricity at the residential level. Heat pumps improve their competitiveness with traditional heating solutions, thanks to additional income from participating in DR programmes. Business opportunities arise also in the field of electricity trade, especially for independent aggregators and Balancing Responsible Parties (BRPs).

The business opportunities related to SG deployment, which the experts selected as most promising during the surveys and the workshops, are likely to evolve differently in the two scenarios. Figure 0-3 shows that the "People have the power" scenario is clearly more supportive for three opportunities ("commercial success of independent aggregators", "more efficient management of heat and electricity", and "benefits from self-production of energy") than "networks in control". "ICT for energy efficiency" – understood by most experts as efficiency along the value chain of energy production and distribution –, and grid-scale storage facilities can blossom under "network in control", while the impact on the deployment of EV infrastructure is largely neutral.

Figure 0-3 Impact of the scenarios on business opportunities



Source: own elaboration based on results from 2nd expert survey

Discussion of business opportunities

Table 0-1 lists the six opportunities considered most promising by the participating experts, along with the associated long-term policy goals. For each opportunity, a Strategic Action Plans (SAP) is presented, which proposes short-term actions and medium-term objectives to reach the 2050 goals. The SAPs point the way to the accomplishment of the "People have the Power" scenario, which is broadly aligned with the proposals of the Clean Energy Package.

In some cases, 2050 objectives have not yet been defined for Europe. In these cases, information from other recognised sources, such as the International Energy Agency (IEA) and the World Energy Council, is cited, and gaps have been filled by extrapolating from 2030 objectives. In a few cases, the SAPs suggest new actions that are not yet included in policy documents, reflecting the opinions of industrial stakeholders and the findings of relevant research.

Table 0-1 List of business opportunities and long-term objectives

Business opportunities enabled by SG	Long-term objectives (2050)
Benefits from self-production of energy	25% - 30% of households and SMEs in Europe participate in individual or collective self-production schemes (own proposal)
More efficient management of heat and electricity	Decarbonisation of the heating and cooling sector (double the current RES share) Use of electrical heating appliances rises as much as five-fold (European Commission, 2015) High-efficiency CHP contributes at least 13.1% to overall electricity production in the EU (European Commission, 2016u) with renewables as the dominant fuel
Commercial success of independent aggregators	Customers at the heart of the system... all electricity markets are open for aggregation (own proposal based on Clean Energy Package)
Grid-scale storage	Limiting global warming to below 2°C means that globally installed energy storage capacity must increase from 140 GW in 2014 to 450 GW in 2050 (EASE/EERA, 2016, citing IEA 2014a).
Deployment of EV infrastructure	European Strategy for Low-Emission Mobility: Greenhouse gas emissions from transport will need to be at least 60% lower than in 1990 (European Commission, 2016c).
ICT for energy efficiency	Final energy demand of 729.6 MTOE by 2050 in EU 28. Sustained annual reduction rate of 1.5% (extrapolation of objectives formulated in the updated Energy Efficiency Directive (European Commission, 2016f))

Benefits from self-production of energy

According to the European Commission (2015a), self-production contributes significantly to financing the energy transitions, for example through private investments in small-scale PV systems. These systems are expected to increase their share in the electricity capacity mix from 6% in 2014 to 22% by 2040, according to estimates from Bloomberg New Energy Finance. The quickly falling cost of PV creates interesting options, especially for the commercial sector (e.g. department stores, office buildings, SMEs), which can attain high rates of renewable electricity self-consumption (e.g. 50%-80%), due primarily to the relatively good match between energy consumption profiles and onsite renewable generation curves. As a result, commercial self-consumption systems are increasingly viable in a growing number of MS, among them Germany and Italy (European Commission, 2015a).

The main discussion related to the regulation of self-production revolves around how the system operators remunerate excess production when fed into the grid (Donoso, no date). European regulators recommend avoiding net metering on the basis that this scheme does not induce the producers to engage actively with the market (CEER, 2016). Instead, metering schemes are to be designed in such a way that the prosumer participates in the balancing market and assumes its responsibility within the system. However, CEER does not address the issue of transaction costs (for participating in DR and balancing), nor, for example, time restraints for non-commercial prosumers. The European consumer organisation BEUC remarks in this context that "the simpler and the more reliable the rules, the lower the costs of renewable self-generation and the faster the market uptake" (BEUC, 2016).

SGs can contribute substantially to reducing the problem of excess energy and raising the level of self-consumption. Smart grid solutions in the form of demand response (DR), combined with storage, can help increase the level of self-production for a residential PV system from the present 30% to up to 65-75% (European Commission, 2015a). Furthermore, intelligent control of PV inverters by DSOs can increase the capacity of the network for hosting distributed generation by 50% (MetaPV, 2014).

Mühlenhoff (2016) states that the MS need to define and implement long-term strategies guaranteeing the return on investment for self-production. Since such strong policy signals are not yet in place, a discussion among the MS and the Commission about a quantified objective for self-production for 2050 could help clarify the long-term policy goal and support for self-producers.

25-30% of households and SMEs participating in self-production and consumption - as proposed in this Strategic Action Plan - is aligned with the IEA's expectation that self-consumption will obtain a share of 25 to 30 % in the coming decades (IEA-RTED, 2014). The slightly different indicator proposed here has the advantage of reflecting changes in behaviour, which is crucial for sustainable transition management.

More efficient management of heat and electricity (heat pumps and CHP)

As the European electricity mix moves towards a higher share of intermittently generated electricity, the combined management of heat[4] and electricity is gaining interest in research and policy. The combination of the two different energy carriers increases the flexibility of the electricity system, since heat can easily be stored for a limited time without interfering with the user's comfort. Research has also found that thermal storage is approximately 100 times cheaper than electric storage (Lund et al., 2016).

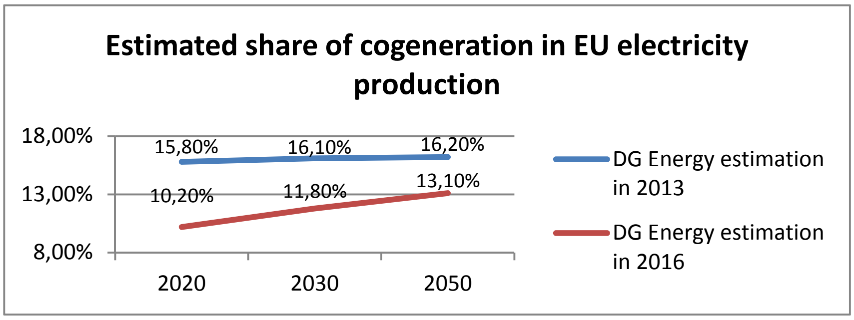
Cogeneration plants can fulfil a similar function in the system, although developments in this sector are not clear presently. The *Strategy for Heating and Cooling* (EC, 2016t) recognises that the potential of cogeneration (estimated at an additional 110-120 GWe by COGEN Europe, 2016) is not being fully exploited. Consequently, the EC lowered its expectations regarding CHP in 2016, as shown in

[4] Covers heating and cooling

Figure *0-4*.

Figure *0-4*.

Figure 0-4 Share of cogeneration in EU electricity production. Estimations for 2020, 2030, and 2050



Source: own elaboration based on data from DG Energy

On the other hand, residential CHP (used for district heating) is experiencing a renaissance in several countries, such as Italy, France, or the UK. Likewise, the opening of both the regulating power market and the primary reserve market has made it possible for small, distributed CHP plants to enter the market in countries like Germany, Belgium, Slovenia or Denmark.

Both the heat pump and the cogeneration markets offer strong opportunities for European industry. In the case of heat pumps, the sector's trade associations, such as SULPU in Finland, maintain that Europe retains technology leadership (Hirvonen, 2015). Among the key players in the market, we find EU-based companies such as Danfoss Group Global (DK), Viessmann Group (DE), Bosch (DE) and NIBE Group (Sweden).

CHP is another core competence of the European economy. The EU is a market leader and is currently exporting its skills and products globally. These skills and competencies are a valuable economic and knowledge base for Europe, contributing to GDP and jobs (CODE 2, 2015). A large number of the leading companies operating in the market, such as 2G Energy AG, Siemens AG, Edina Ltd., Wärtsilä Corporation and ENER-G Holdings, are European.

Regulatory uncertainty arising from significant changes in recent years in both the electricity market and the energy market make CHP investment high-risk (CODE 2, 2015). This is hampering the market diffusion of micro-CHP (Ezeamama, 2016).

SG deployment can help reduce this risk by providing additional income for the owners of CHP plants. Heat pumps can contribute flexibility to the grid if they are able to respond to control signals. Heat pumps installed in new housing already have the potential to create a link between the electricity network and heat storage by using a thermal buffer and a control system. Furthermore, the pooling of heat pumps via a Virtual Power Plant (VPP) and aggregated participation in the electricity market bring considerable benefits. The Danish trial, titled "READY" (Bang et al., 2014), found that "in a typical Danish house, the annual savings associated with intelligent control in accordance with hourly spot prices was roughly 300 DKK (EUR 40). By participating in the regulating power market, the annual savings are considerably higher, but also more uncertain. Even if the heat pump only contributes with down regulation, the increase in annual savings can easily be 500 DKK (EUR 67)".

Commercial success of independent aggregators

The increase in self-generation, small-scale renewable and intelligent appliances interacting with the grids, which are difficult to control centrally (NEXT Kraftwerke, 2016), has created a need for professional aggregators. Aggregation is not limited to the demand-side, but can integrate supply-side elements in distributed energy networks, neighbourhoods, or districts. The common element of these initiatives is the need for sophisticated ICT-tools, sometimes described as the "energy cloud" (de Heer et al., 2016).

According to the proposals included in the Clean Energy Package), consumers should be able to freely choose and change suppliers or aggregators and to engage in demand response, self-generation and self-consumption of electricity, so every consumer is entitled to request a smart meter equipped with a minimum set of functionalities. However, presently, the aggregation of flexible volumes is allowed only in six MS. Market development is hampered by the fact that the identification of flexible loads and the assessment of the exact potentials remain difficult and involve substantial effort and high costs due to the necessary audit process (Delnooz et al., 2012).

Most European countries that have opened up the market to DR (e.g. France, Belgium, Switzerland, and UK) have also enabled aggregated load participation. In the UK, for instance, the National Grid (responsible for matching of supply and demand on a second-by-second basis) would like to see 30-50% of capacity in the electricity-balancing market coming from demand-side response (DSR) by 2020, in comparison with just 4% now (Schaps et al., 2016).

Due to the lack of an appropriate regulatory framework in most of Europe, the business model of aggregators is not yet mature. Some experts representing the demand side and research pointed out that generation overcapacities in some national electricity markets presently block the 'sense of urgency' for integration of flexibility in the market. Business models for demand-side participation are especially complex, since access to a large number of household devices is needed before the residential DR business model becomes viable.

The Flex4RES project partners (Flex4RES, 2016) propose a set of additional measures to enable flexibility to participate in the market, such as trading as close as possible to real time and the assessment of resource adequacy on a regional basis to unlock the potential of flexibility. Special attention should be paid to tapping the flexibility potential related to cross-sectoral coupling, especially district heating. New flexibility products need to be adapted to the characteristics of the source of flexibility, and these sources should include the so far untapped potential of other energy carriers, for example, district heating systems, and smaller volumes of flexibility, which can be offered by residential consumers or SMEs through aggregators.

It is also necessary to consider that in a power system, in which a much greater number of assets interact with each other and with the network, the risk of disturbances increases. It may therefore be necessary to search for solutions to enhance the resilience of the grid (EASME expert workshop). Aggregation models, which combine demand and supply side resources, also require economies of scale. The size of the pools, i.e. the number of units participating in aggregation determines, for example, the value that PV adds to the pool, according to the INCREASE project (2017)

In order to create sound business opportunities for aggregators, the markets and regulatory frameworks should include wide range of actors, traded sizes, timeframes, and emerging products. Market requirements regarding the minimum bid size should not be prohibitive for small aggregated amounts (INCREASE project, 2017).

De Heer et al., (2016), representing USEF, propose the definition of an Aggregator Implementation Model (AIM), which describes the relation of the aggregator with the supplier and BRP and how balance responsibility, transfer of energy and information exchange are organised. This kind of model could help eliminate some of the regulators' concerns about aggregation.

Distributed and grid-scale storage facilities

In the new scenario of electricity production and distribution enabled by Smart Grids, storage can play a very relevant role in solving both grid uncertainty and grid instability issues in a system with a significantly increased share of renewable generation at any connection point on the grid.

It is likely that grid-scale storage deployment will occur in response to the plans for further deployment of renewable distributed energy resources (DER). The question was discussed during the first expert workshop and, although there was consensus on the need for storage to balance the grid, there were doubts about which type of technology is better suited, i.e. large facilities or small-scale options. One of the participating experts commented that “the need for grid-scale storage is determined by other developments in the network (use of smaller storage devices on the household level, existing overcapacities, etc.), so that a strong market uptake is not assured before 2030. There will be, however, niche markets, for example on the sites of large customers or as a solution to overcapacities in generation. But the outlook for this opportunity is more uncertain than for the other opportunities” discussed during the workshop.

During the interviews, it was stated that the further downstream a battery is located within the electricity system, the more services it can offer to the system at large. However, the applicable regulation framework could limit these services and the role of the participants.

To counter the uncertainty for investing in battery technologies, some TSOs are currently revising their ancillary services product definition and procurement rules. National Grid in UK, for example, will procure a new faster-acting service - Enhanced Frequency Response (EFR) - aimed predominantly at storage assets, including stationary batteries, to provide frequency response in 1 second or less (BATSTORM project, 2016). In this context it is important to notice that National Grid is considering 4 year term contracts and allowing aggregation of multiple smaller sites as long as the service provision is unaffected (National Grid, 2017). This kind of regulatory action will make the business case for battery storage much stronger

Also in other MS, i.e. Germany, Austria, and Italy, commercial parties are entering the residential market for battery storage. Sonnenbatterie, Lumenaza or Moixa are examples for innovative service providers in the residential storage market (Mayr, 2016). In the Netherlands, Eneco (one of the largest producers and suppliers of natural gas, electricity and heat in the Netherlands) is collaborating with Tesla Powerwall under the name of ‘CrowdNett’ to roll out 3.3 kW battery storage systems at an end-consumer investment cost of EUR 4,500, being EUR 2,200 below the market price (Eneco, 2017). Additionally, the project participants get a guaranteed CrowdNett-remuneration of EUR 450 during the first five years in return for 30 percent of each Powerwall’s capacity. CrowdNett offers this capacity as reserve service to TenneT, the Dutch TSO. This is a good example of creating win-win situations for all stakeholders involved.

When storage concepts are applied to district or neighbourhood level, potential savings in terms of energy range from 1.2 to 15.26%, depending on the system design and seasonal demand (summer / winter). The monetary savings are highest when storage is linked to heat consumption (CHP), according to the findings of the COOPERaTE project.

Europe’s engineering industry is slightly better positioned in the field of stationary storage, as compared to EV batteries, since ABB, Siemens, and Bosch are considered serious competitors (SBWire, 2017). EASE / EERA have analysed the competence level for different types of storage technologies in Europe. The results are shown in

Table *0-2*.

Table *0-2*.

Table 0-2: European competences in storage technologies

Storage Technology	Competence level
Chemical Storage	+++++
Electrochemical Storage	+++
Electrical Storage	++
Mechanical Storage (Hydro Pump)	+++++
Mechanical Storage (others)	+++

Source: own elaboration based on EASE/EERA, 2016

However, a clearer definition of energy storage at EU level is needed to unlock the market fully (EASE/EERA, 2016 and EUROBAT, 2016). A specific European Storage Framework is envisaged (ENTSO-E 2016) to clarify the role of storage in the different SG layers (equipment, communication, information, functions/services and business scenarios). The proposals in the Clean Energy Package provides the much needed definition of storage, although the concrete mechanisms for the remuneration of the different services that storage provides to generation, distribution and consumption are yet to be defined.

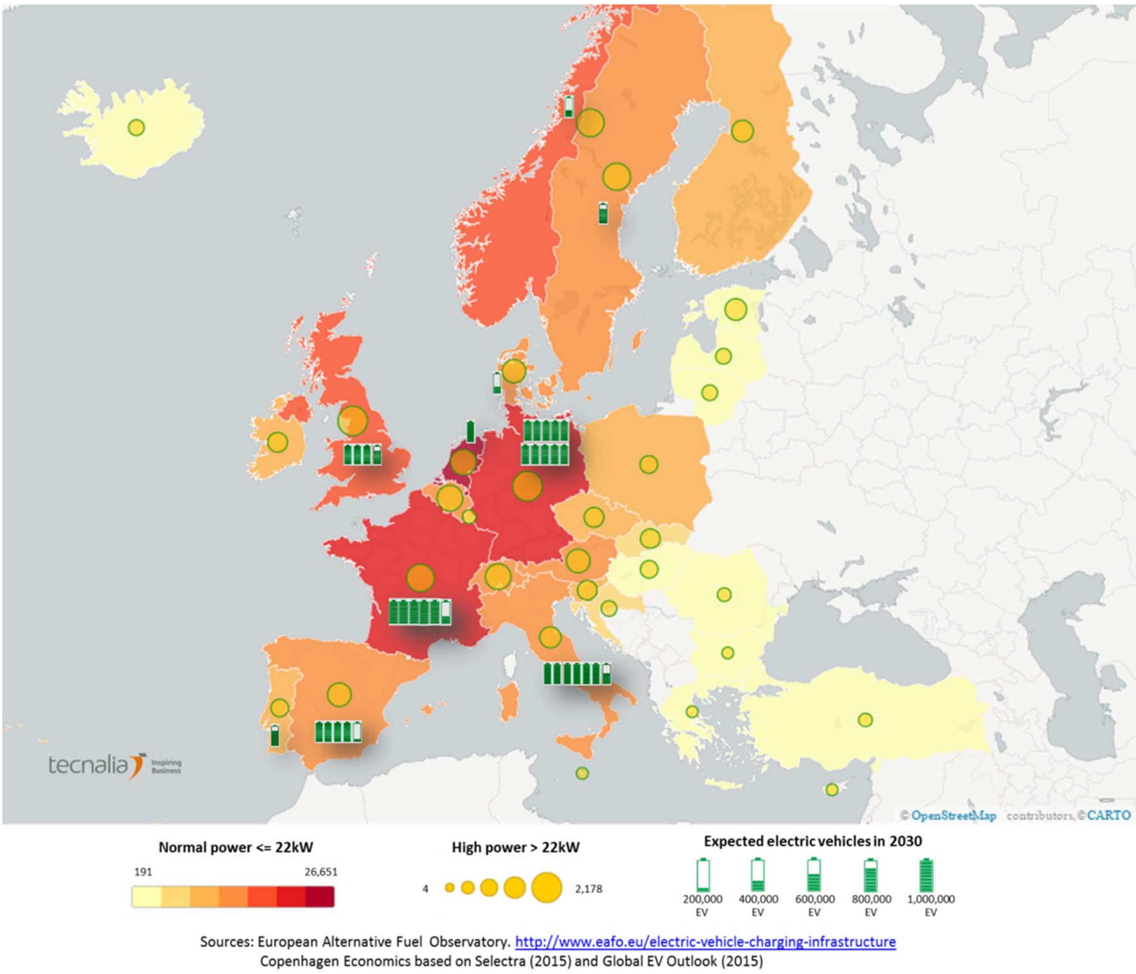
Regulatory action will help define the real market value of storage, which is largely determined by the concrete needs of customers and the characteristics of the transmission and distribution networks. The World Energy Council (2016) therefore recommends to "to examine storage through holistic case studies within a specific context, rather than place faith in generic cost estimations". If DSOs and TSOs facilitate the detection of market niches, market uptake of storage solutions could accelerate.

In the medium term, there is a strong potential for cost improvement. EASE/EERA (2016) expects that by studying the potential of advanced battery systems, battery costs can be reduced by 40% between 2020 and 2030.

Deployment of EV infrastructure

Recent market trends related to EV indicate that market uptake is accelerating. IEA reports firm commitments from 14 countries for EV stock objectives, “aspiring to bring 13 million EVs on the road by 2020” (IEA 2016). The present level of penetration of charging stations in the MS is shown in Figure 0-5, distinguishing between normal and “high power” connections, as the latter constitute the main concern with regard to network impacts of EV uptake.

Figure 0-5 Number of EV charging stations in MS with high penetration of infrastructure



Source: own elaboration based on the indicated sources

Fast charging of 43 kW to 200 kW (and up to 350 – 400 kW in the future) represents the main challenge from the point of view of grid management and can create a need for grid reinforcements (EASME SG expert workshop). Grid absorption capacities may be insufficient to provide 150 GW of additional generation capacity, which would be needed if 80 % of cars were electric by 2050 (EEA, 2016).

The costs for grid integration of charging infrastructures can be significantly reduced using smart charging strategies controlling both charging time and power (Eurelectric, 2015a) and by car-sharing in urban environments. According to IEA estimates, slow charging can add flexibility to the system during hours of peak demand: 125,000 EVs could provide 300 MW of flexibility (IEA, 2016). Smart charging strategies require the type of intelligent interaction with the network that SGs can provide, but the EV technologies that are presently in the market are not prepared for this. These aspects should be taken into account in the EU’s mobility strategy, which proposes that emissions need to be at least 60% lower in 2050 than in 1990.

ICT for energy efficiency

The system benefits of the smartening of the energy system by incorporating ICT (smart management of production units and smart substations), in terms of avoided investments in network upgrade, are estimated at 20% of new investment per year in the case of Germany (Büchner et al., 2014). Distribution grid automation is presently attracting high levels of investment (USD 7.32 billion in 2014, estimated to reach USD 10.33 billion in 2018, according to Frost and Sullivan (2015)), in order to locate and automatically fix faults and to fine-tune supply/demand levels (Visser, 2014). Europe has several strong players competing successfully in this market (ABB, Siemens, Eaton Corp).

Eurelectric[5], however, considers that the highest savings potential in Europe can be reaped "downstream". According to an ICT provider interviewed in the study, many different 'smart energy services' for residential and commercial customers are conceivable:

- selling and servicing boilers (smart sensor data will allow to monitor the performance of these appliances from a distance)
- insurance packages, one-off repairs (smart sensors enabling a real-time detection of appliance failure)
- loyalty packages
- feedback on energy use (with our without comparison with peers, e.g. by coupling to social networks)
- home energy management (e.g. peak load management)
- contract optimisation, providing flexibility to energy markets, etc.

The bundling or "packaging" of services is an attractive option from the business perspective, since most energy consumers (even small industries) are not yet aware of the potential for contract optimisation, according to an expert form the research field. User motivation is essential for tapping this energy savings potential, but for residential consumers, installation costs may outweigh the benefits and payback times can be very long, according to the COOPERaTE project (2015). Energy management systems therefore aim at delivering other types of user satisfaction (comfort, control) and are presently quite successful in the market.

However, not all of these potential ICT services lead to energy savings. Shifting of consumption through DR or peak load management, for example, can deliver economic benefits for the user and the electricity system, but this does not necessarily mean that the actual energy consumption is reduced. Seven large-scale trials carried out during the E-Energy project found that the use of smart meters and Energy Management Systems lead to savings of 0% - 20% (2% on average). The evidence on achievable energy savings and their sustainability over time is, however, inconclusive, since the effects vary depending on the type of feedback and support given to the user during the trials.

Presently, the economic benefits from energy savings are highest in the commercial sector, which supports much higher tariffs than industry. Energy efficiency investments in commerce, industry, and buildings will support the growth of ESCOs. ESCOs offer energy as a service (EEaaS) and these services can increase the attractiveness of smart energy systems (Goldman et al., 2010). In Europe, the main revenue for ESCOs still comes from heat supply contracts, but the JRC (Bertoldi et al., 2013) refers to an expert interview with MPW Institute LLC indicating that the increasing use of smart appliances in buildings and facilities enables

[5] http://www.eurelectric.org/sustainability/energy-efficiency/

ESCOs to "*offer better services at lower cost*". Consumption forecasts and optimisation tools for selling flexibility to the market are valuable innovations for ESCOs, according to the findings of the I3RES project. Additionally, gateways with an associated sensor network, such as the DaaS (District as a Service) Platform, facilitate the work of ESCOs on city and district level (URBGRADE project[6]).

If household electricity demand followed a similar trajectory as the one envisaged for final energy demand, i.e. an annual reduction of 1.5%, households would use just 53.7 MTOE in 2030. This objective will be difficult to reach in view of the expected increase of electricity for heating and mobility, but in the coming years, SGs can deliver much more detailed information on electricity consumption. This data will make it possible to design new and targeted intervention strategies to promote energy savings.

Since improvements in energy efficiency are driven by the investments of consumers in energy savings measures and behavioural change, the majority of the interviewees and projects like ADVANCED believe that consumer engagement with SG solutions will crucially depend on the ease-of-use of the tools and interfaces deployed in homes. A relatively simple way of steering consumer behaviour, which is already applied by some manufacturers, is to establish the most energy-efficient use mode as "default". Psychological research on "choice architecture" (Velte, 2010 and Pichert, 2010) has shown that users can be induced to make the right, i.e. the most ecological choices, if the "default option", which does not require further action from the user, is the energy-saving mode.

Conclusions

The smartening of the European power grids is under way and SGs can unlock new business models based on pooling demand and supply sources, or even on direct interaction with individual customers. The stakeholders participating in the study have repeatedly pointed to the "resistance to change" as one of the main factors limiting potential business opportunities and hindering the implementation of new business models. The Clean Energy Package addresses most of the remaining regulatory challenges, but adapting the rules of the electricity system to a large number of different and sometimes not professional users and producers with time restraints and limited technical knowhow is a difficult task. As stated by the European Economic and Social Committee (2017), "strong governance" is necessary to accomplish the objectives of the Clean Energy Package, clarify the value of user interaction with the electricity system for operators and consumers and, by this, establish a secure operating field for new service providers.

[6] https://urb-grade.eu/

1. Introduction

This report presents in a comprehensive manner the main findings of the study on barriers and business opportunities for Smart Grid (SG) deployment. It starts with a description of the approach, the objectives and the methodology applied during the study, which relied on extensive interaction with a representative pool of diverse stakeholders to enhance the original findings from literature and the review of recent SG research projects.

The report starts out by presenting two potential scenarios for SG deployment by 2030 and 2050. The pathways described in these scenarios will greatly influence the unfolding of the six main business opportunities related to SG, discussed in detail in this report. For each of these opportunities, a Strategic Action Plan has been elaborated to show the existing barriers and ways of overcoming them by means of short-term actions. Key messages underline the main actions necessary to reach the long-term policy objectives. Most of these objectives, with the time horizon of 2050, derive from relevant policy documents. It is assumed that they can be met if the proposals brought forward by the EC in the recent 'Clean Energy for All Europeans' Package (hereinafter referred to as Clean Energy Package) are implemented in all MS with due diligence ("people have the power" scenario"). However, a different pathway can also be envisioned, in which SG deployment progresses, but does not benefit the new actors and trends in the energy system, such as small-scale renewable producers, aggregators, and demand-side participation of citizens and SMEs.

Chapter 2 tells the full storyline of the scenarios, elaborated by means of two expert surveys and two workshops. Chapter 3 describes the six main business opportunities, three of which strongly depend on developments in the overarching policy framework. This chapter also lists the barriers that were identified during the initial literature review, the in-depth project analysis, and the expert interviews. Chapter 4 presents the conclusions of one year of intensive work by the project team.

1.1 Objectives of the study

This study was entrusted by EASME to a consortium conformed of smart grid and forward-looking experts to identify legal, economic and other types of barriers that hinder the deployment of smart grid technologies at medium and low voltage levels. Based on this analysis, options for new business opportunities and new business models were to be explored, which are likely to benefit the European engineering industry. Finally, key messages were requested showing policy options, which will help address and overcome these barriers and facilitate the rise of new business opportunities.

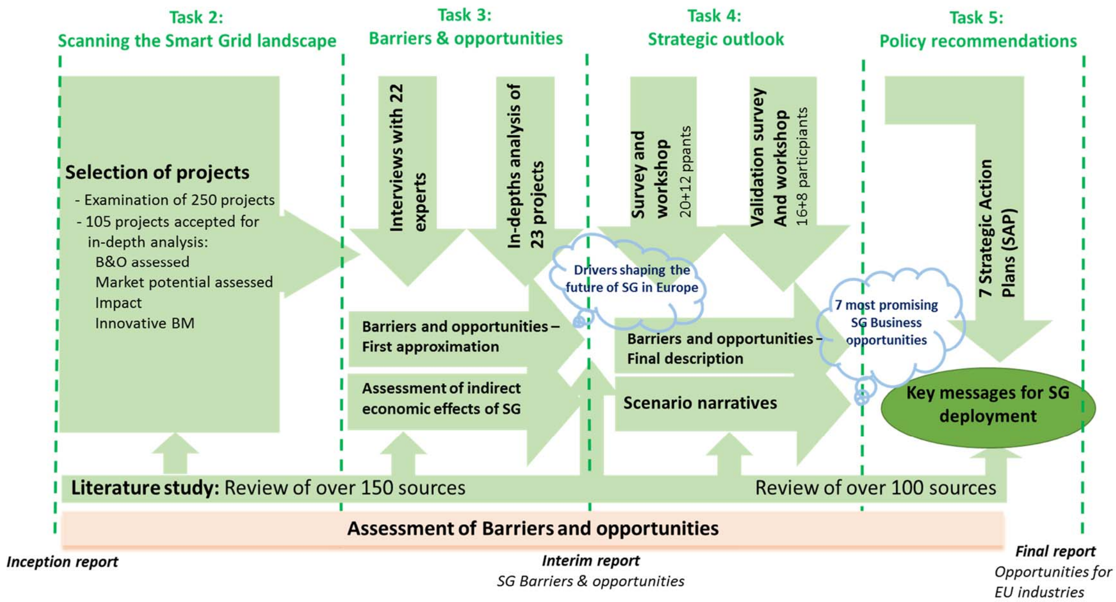
1.2 Approach and methodology

The study started out with a thorough review of more than 150 literature sources. This was followed by an in-depth assessment of 23 projects, which were selected using a diverse set of criteria. One of the main aspects for selecting the project for in-depth review was the interest of the business case addressed and the availability of information on novel business models (see 'Annex 2: The selection criteria applied and the full list of projects reviewed').

The business opportunities identified during this process were then discussed in interviews with 22 smart grid experts representing different points of view (academia, investors, DSOs, aggregators and SG technology providers). This exercise led to a preliminary assessment of business opportunities and barriers (see 'Annex 3: The interviewees and barriers, business opportunities, enabling assets and ICT'). This preliminary assessment was then further elaborated with two groups of experts: one participating in a physical workshop celebrated in December 2016 in Brussels, and an on-line validation workshop held in January 2017 (see Annex 1 for the full list of contributors to this study). Both workshops were prepared by means of an on-line survey launched prior to the workshop and the input received was very valuable for selecting and defining the possible future scenarios for SG deployment. The full methodological process applied in the project is shown in

Figure *1-1*.

Figure 1-1 Overview of the project



Source: Own elaboration

The scenarios described in this report were created by selecting five key drivers for SG deployment and determining their possible evolution over time (Table 1-1).

Table 1-1 Drivers and sub-factors of SG deployment

	Distribution grid and ICT infrastructure	Consumers participation and flexibility of demand	Market structure and dynamism	Variable RES in the energy supply mix	Regulatory Framework
RELATED FACTORS	- Decentralised electricity generation - Physical extension of the grid - ICT upgrade of the grid - Role of the DSOs in the transition - Storage Facilities - Electric Vehicles	- Factors for consumer acceptance (e.g. environmental awareness) - Instruments and initiatives that foster consumer participation - Policy and regulation on electrification, DR, tariffs and data security	- New actors in the electricity market - Business models New products and services for flexible demand Actors' responsibility and ownership in the market	- Decarbonisation roadmap and policy - Degree and pattern of integration of RES in the grid - Fair play for unsubsidised renewables	- Energy price regulation - Incentive mechanisms - Standards for electricity market and data handling

Source: own elaboration

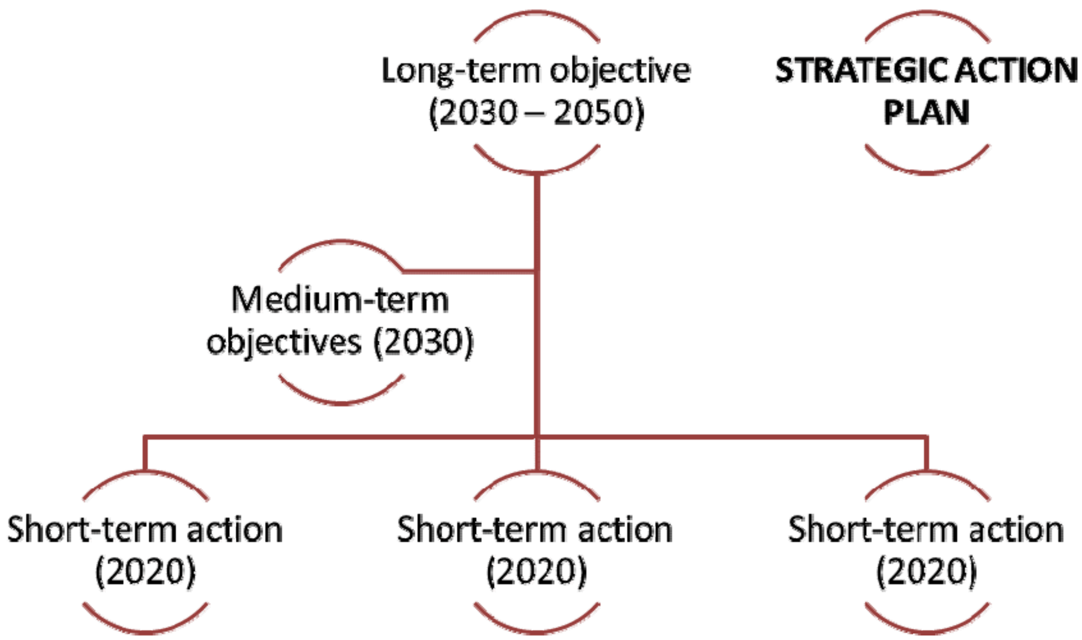
During the first workshop, the number of possible scenarios was reduced from the original four to those two, which the participating experts considered most likely to unfold between 2030 and 2050:

- 'Networks in control', which is in fact a Business As Usual Scenario (BAU), in which smart grids are deployed through top-down action of network operators;
- 'People have the power', which features a paradigm change where smart grids develop thanks to the full interaction of all the actors in the electricity network, including consumers and new business actors.

Chapter 2 explains these scenarios in detail.

Finally, a Strategic Action Plan (SAPs) was elaborated for each of the six business opportunities, which received the highest ratings from the participating experts. Looking at specific business opportunities made it possible to analyse the barriers identified in previous steps of the study in detail, and to incorporate the policy perspective. The basic structure of the SAPs is shown in Figure 1-2.

Figure 1-2 Elements and time horizon of the Strategic Action Plans



Source: own elaboration

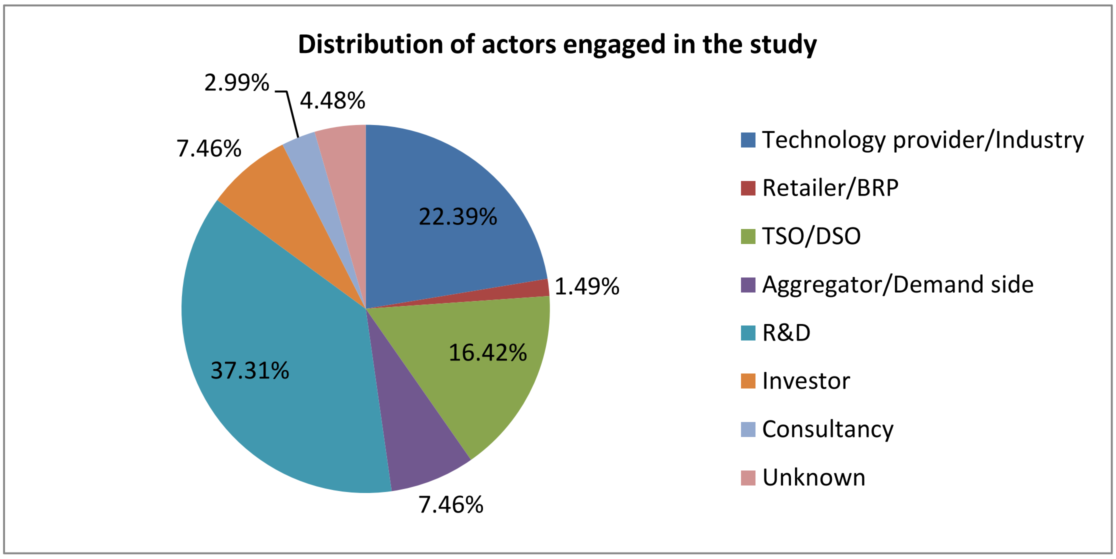
The SAPs identify actions that are necessary to create an appropriate environment for SG-related business opportunities. They also indicate, based on expert statements, which of these actions are most relevant to advance towards the "People have the power" scenario.

Literature sources and information provided by the experts throughout the study have been equally important to elaborate the SAPs. The SAPs take stock of the recent policy developments around the Clean Energy Package, especially those proposals that support the shift to smart grid and smart energy. Potential impacts on industry are indicated when information was available and in some cases best-practice examples in the MS are highlighted.

1.3. Interaction with SG experts and stakeholders

The outcomes of the study reflect the opinion of 67 experts, which are listed in 'Annex 1: List of experts who have contributed to this study'. The pool of experts consulted is well balanced among grid operators, retailers and industry, which represent 40.3% of the actors engaged in the study, and the R&D side (37.31%). The demand side and the investors are equally represented by 7.46% each (Figure 1-3).

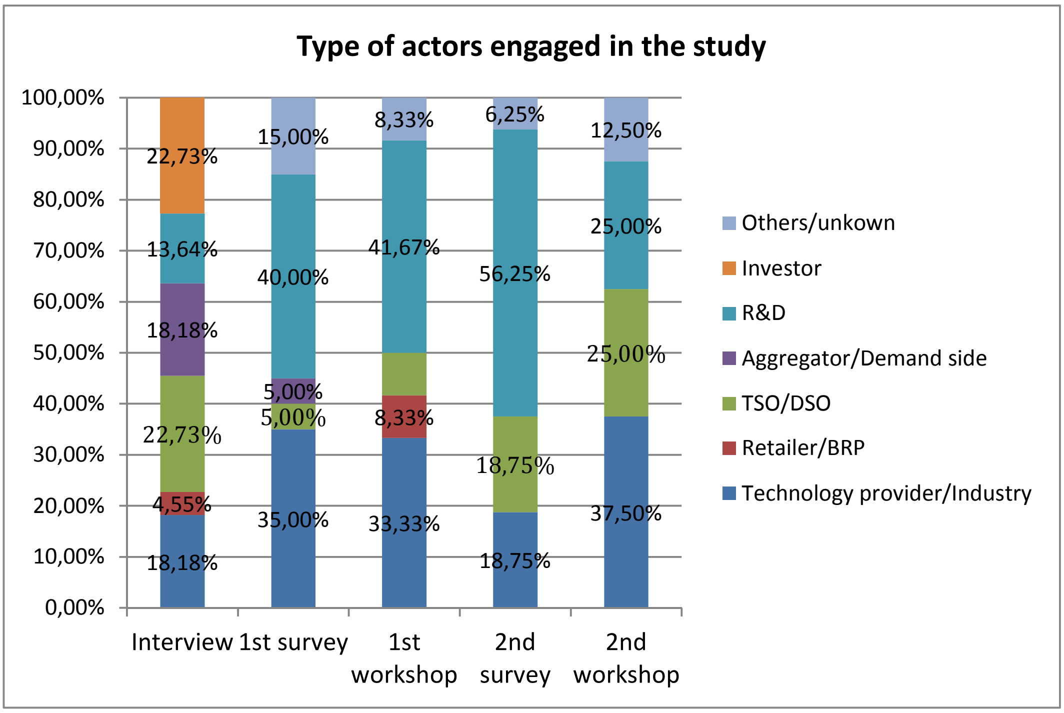
Figure 1-3 Distribution of actors engaged in the study



Source: own elaboration

Industry and grid operators gained in relevance as the study progressed, as shown in Figure 1-4. The high diversity of stakeholders in all phases of the study assured that all viewpoints were given due consideration.

Figure 1-4 Type of actors engaged in the study



Source: own elaboration

2. Scenarios for SG deployment in Europe

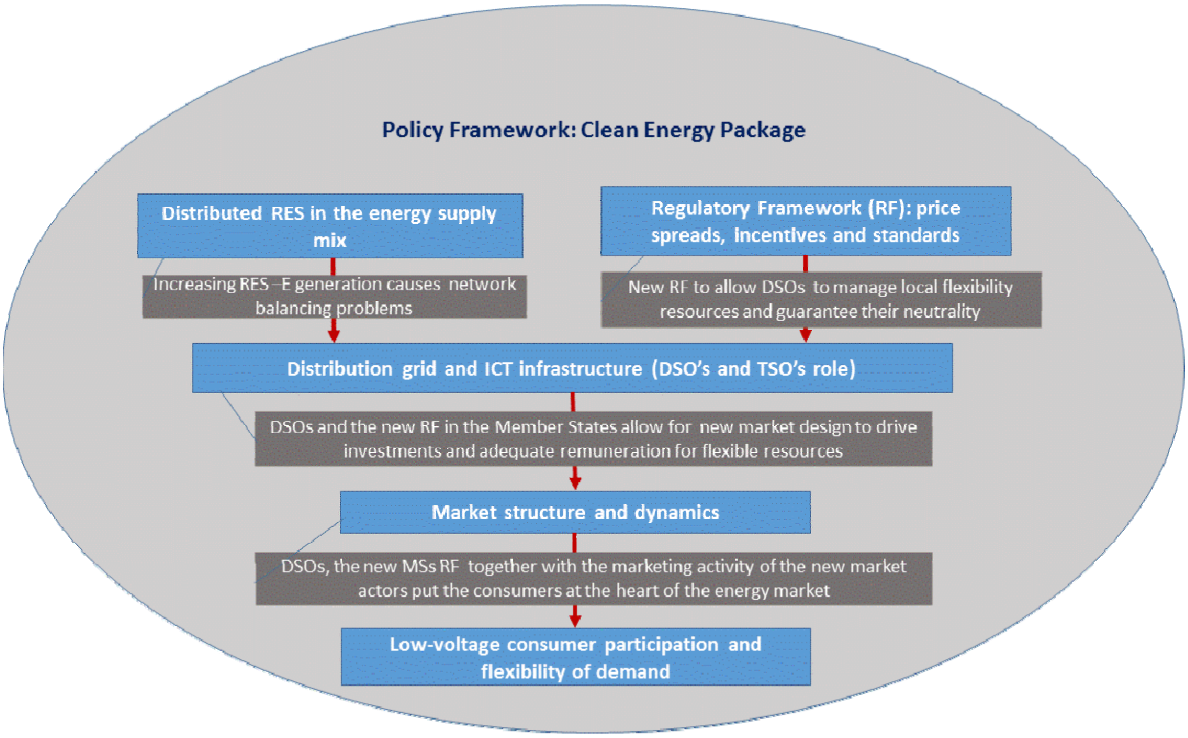
2.1. The selected scenarios in brief

The scenarios resulting from the outlook analysis were developed in three steps. A draft version of the scenarios was conceived based on the literature review and the outcomes of the project evaluation and the interviews. Then, this draft version was presented to a pool of experts involved in a first consultation round. Finally, a revised version underwent a validation round that involved additional experts and industrial stakeholders, leading to the final version of the scenarios with fully developed storylines.

Resulting from this process, the main findings of this outlook analysis are:

- There are five key drivers, which appear to be highly interrelated in a hierarchical way, with the regulatory framework at the top. Figure 2-1 shows this hierarchy and the relationship between the drivers in the case the new policy measures envisaged in the Clean Energy Package are successfully implemented (see the following paragraph).

Figure 2-1 Hierarchy of key drivers



Source: own elaboration

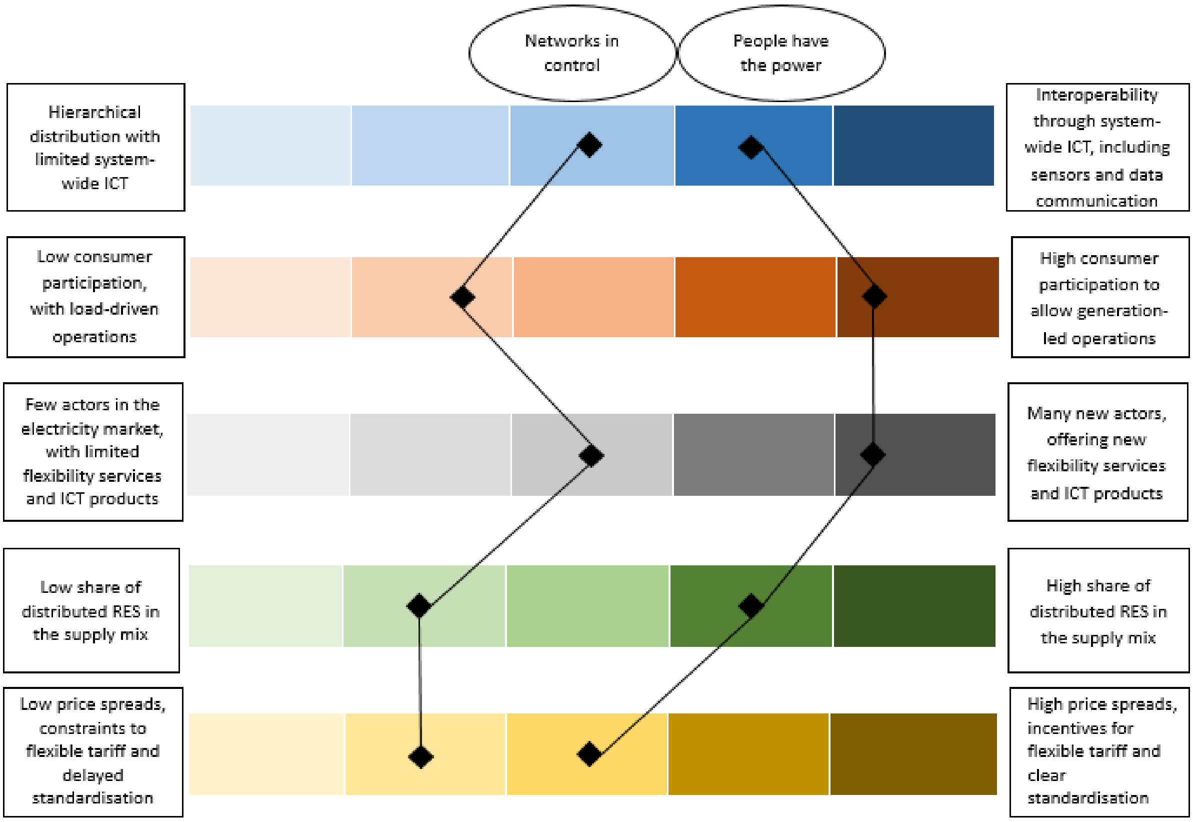
By combining the possible evolution of these drivers, two plausible scenarios can be envisaged:

- 'Networks in control', which is in fact a Business As Usual Scenario (BAU), in which smart grids are deployed through top-down action of network operators to increase the efficiency of network management and to cope with additional demand coming from EV deployment and new renewable supply-side resources, mainly in the form of large off-shore wind parks.

- ‘People have the power’, featuring a paradigm change, in which smart grids develop thanks to the full interaction of all actors in the electricity network, including consumers and new business actors.

The two scenarios are graphically represented in Figure 2-2, which depicts the so-called “scenario space”, according to the methodology applied in the scenario building process. The figure shows how the drivers evolve differently in the two scenarios forming two distinct configurations within the scenario space.

Figure 2-2 The scenario space



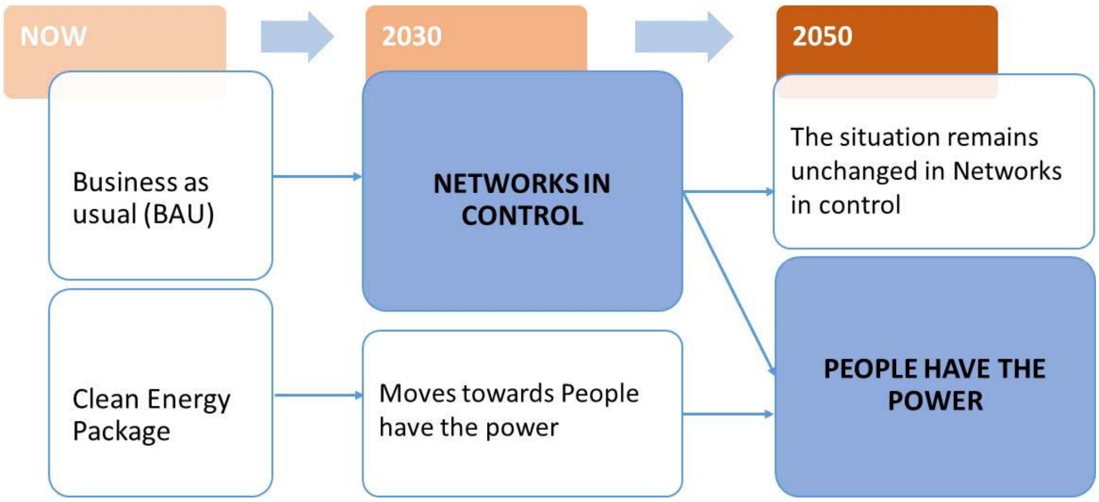
Source: own elaboration

These two scenarios have a different time horizon and are possibly, although not necessarily, **sequential** (see

Figure *2-3* below). While 'Networks in control' could unfold already by 2030, the major changes required for 'People have the power' make this scenario likely to unfold between 2030 and 2050, according to the expert discussions and the survey results. However, to trigger the paradigm shift required for 'People have the power', the EU and the MS need to initiate effective policies in the short term, as those envisaged in the Clean Energy Package.

A possibility is that, in the medium term (i.e. 2030), the Clean Energy Package fails to trigger the system-level and behavioural changes that are needed for 'People have the power' and thus the transition will lead to 'Networks in control'. In fact, this was the most probable situation, according to the experts and stakeholders involved in the study. From 2030 on, the smart grid environment may either remain unchanged and maintain the main features of 'Networks in control' or evolve towards 'People have the power', increasing the number of actors in the electricity market and fostering higher consumer participation.

Figure 2-3 Scenarios path in time



Source: own elaboration

While the scenarios may be complementary in time, it is not possible that both unfold simultaneously in space (i.e. at a given time in the same country). In fact, it is hard to imagine that both scenarios come into reality in one country, because the prevalent role of DSOs in 'Networks in control' is in contrast with the emergence of new multiple actors in the electricity market that would stimulate full consumer participation required for 'People have the power'. Indeed, these two situations result from alternative regulatory frameworks that shape the market environment.

What may happen is that some EU countries move towards 'Networks in control' and, at the same time, some others move towards 'People have the power'. In this sense, the two scenarios are complementary in Europe, but creating geographical 'patches' of the two different smart grid patterns. The two scenarios are therefore still alternative at geographical level within the same period.

The scenarios are also alternatives because the unfolding of one or the other depends on which actors lead the transition to smart grids (expert comment, second workshop). The role of DSOs is crucial in this context. In 'Networks in control', the transition is top-down, and the majority of the DSOs are reluctant to facilitate innovation. In 'People have the power', it is the new market actors and the consumers that drive progress, supported by empowering and enabling regulation. The realisation of 'People have the power' will happen only if the electricity market evolves towards a more flexible and 'horizontal' electricity generation and distribution model, which remunerates in a fair way consumer involvement on the supply and demand side. The higher price spreads and greater level of standardisation in "people have the power" create the necessary conditions for DR to bring benefits to active consumers and for new service providers to enter the market.

2.2. The impact of the new policy framework proposed by the Clean Energy Package on the evolution of the scenarios

Among the different opinions expressed by the experts that have participated in the consultation rounds, one of the most interesting remarks was that "Networks in control" could be regarded as Business as Usual (BAU), while "People have the power" foreshadows what should happen when smart grids can be finally implemented in an effective way. It is then important to better define what this BAU scenario actually implies in the context of this study. Generally, BAU scenarios illustrate what is expected to happen in a given timeframe if no new policy intervention is introduced in the same period of time (Forward Thinking

Platform and GFAR, 2014). The BAU scenario accordingly describes what might happen if the reference policy framework does not substantially change in the future, that is, if the Third Energy Package, especially for what concerns Directive 2009/72 on common rules for the internal market in electricity and associated regulation, is not modified.

However, the reference policy framework is going to change. In fact, the recent Clean Energy Package, presented on November 30, 2016, envisages a deep recast of the Third Energy Package, especially for what concerns the role of the consumers and the DSOs, the market development and the important role that renewable electricity will play in the future generation mix. In practice, it is as though EU policy makers have paved the way to the "People have the power" scenario, having realised that the policy framework provided by the Third Energy Package was no longer able to adequately support the MS in tackling the decarbonisation and climate change challenges effectively.

The Third Energy Package is therefore expected to be improved in the near future. However, at this time, it is not possible to foresee to which extent the new policy measures will be accepted and fully implemented on MS level, thus helping overcome the strong barriers that still hinder a smooth implementation of the new smart grids paradigm.

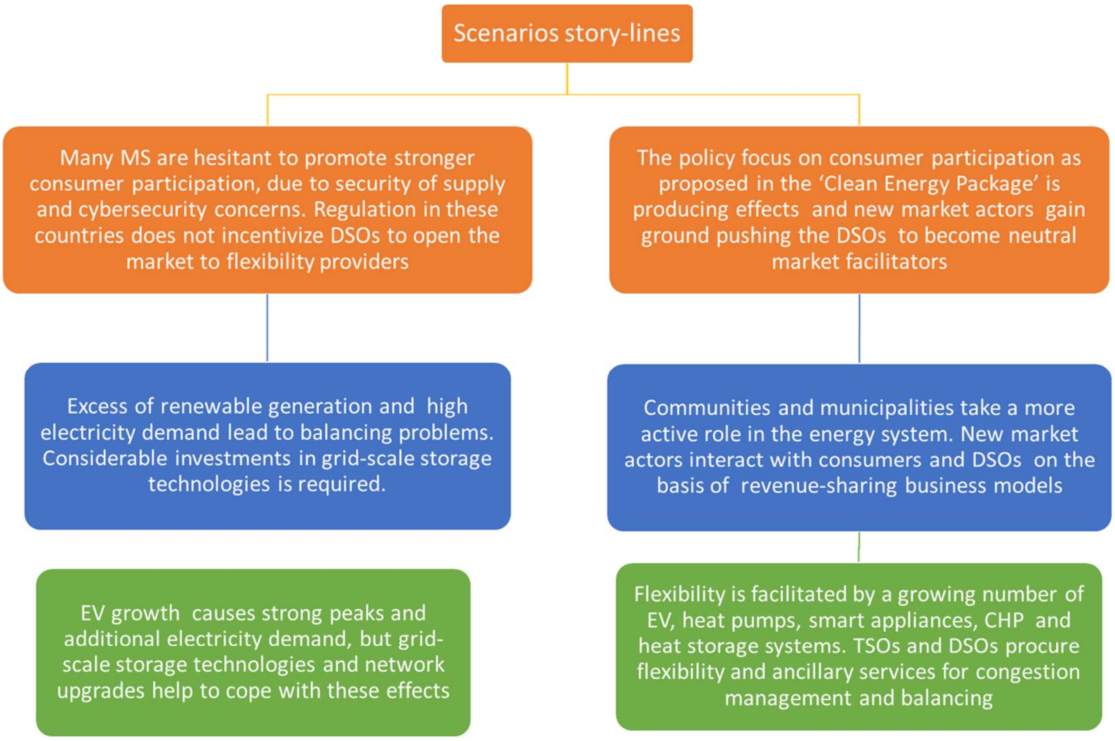
Overall, these new measures are designed to favour a deep paradigm change by ensuring flexibility to the electricity system through:

- the new role of the DSOs as "neutral market facilitator" (ACER/CEER, 2017), which includes procurement of network services, data management, support for the deployment of EV infrastructure and energy storage services (but not ownership of these assets), in full cooperation with consumers and the new market actors.
- the opening of the market to new actors
- consumer empowerment

Distribution operators, market actors and consumers interact in a highly interconnected system, in which DSOs play a pivotal role. Actually, the success of the challenging policy framework depicted by the Clean Energy Package, and consequently, the emergence of one of the two scenarios we have outlined, appears to be closely linked to the desired transformation of the distribution operators. If DSOs do not become real and neutral market facilitator, it is likely that the market will not evolve and the energy system will not focus primarily on the needs of the consumers. On the contrary, if the desired transformation of DSOs takes place, the chances that the consumers conquer their central role are high, as, most probably, the new market actors and the DSOs - under a different regulatory framework - are able to overcome the barriers that now hinder the opening up of the electricity market. At the same time, a more sophisticated market would strongly support the desired change in consumer behaviour towards a more active participation in the demand and the supply side.

Figure 2-4 presents these key concepts and shows the importance of the roles of DSOs for the different development steps of the two scenarios. In the 'Networks in control' scenario, the evolution towards smart grids is led by grid operators and has a top-down character. In 'People have the power', smart grids are developed thanks to a new regulatory environment that, fixing new roles and responsibilities to incumbents and new entrants, paves the floor to the development of bottom-up actions undertaken by consumers and new market actors.

Figure 2-4 Key steps of the scenarios



Source: own elaboration

2.3. The scenario storylines

- ***Networks in control***

Networks in control – The scenario at a glance

The EU directives promoting consumer participation have mostly failed to provide a playing field for demand aggregation at the EU level. Some markets offer demand response options, but in the major part of the EU, individual residential consumers have few opportunities and low incentives to participate actively in demand-side management. This makes it difficult for new market actors to deploy innovative business models successfully. Current national regulatory frameworks prioritise network investments to guarantee security of supply. As a result, DSOs have few incentives to avoid network investments by unlocking flexibility and the number of flexibility providers remains limited. TSOs and DSOs are driving the smartening of the grid and investing in infrastructure upgrades required to integrate RES and additional demand from EV market uptake. Although the EU's objective of 27% renewables by 2030 is achieved in this scenario, the largest part of this production is covered by offshore wind and a limited number of large PV plants, while grid-connected distributed RES, and particularly rooftop solar, have experienced slower growth rates than expected.

Main scenario assumptions

As outlined in the previous paragraph, in 'Networks in control', the new measures envisaged in the Clean Energy Package, which aim at putting the consumers at the heart of the energy system, have largely failed in the majority of the MS. This means that despite the latest provisions in the Clean Energy Package, the use of DR remains limited in many countries. In those EU countries that, starting from the second decade of this century, have put in place a regulatory framework allowing for the development of Demand Response services, the demand side flexibility providers have enlarged their initial market niche and now contribute to the overall system balancing needs[7], although to a limited extent. Despite the promising situation in these countries, the overall number of DR users and self-producers is still low at the EU level. In general, the newly introduced capacity market does not place demand-side resources or storage solutions on an equal footing with generation assets. The regulatory cost treatment in some MS still favour investments by DSOs (CAPEX) over operative costs (OPEX), so that there are little incentives for DSO to procure flexibility services rather than to invest in network upgrades. Regulatory cost treatment also poses difficulties for SG investments that carry a high level of risk and therefore hamper innovation (Eurelectric, 2014).

One of the main reasons why DR programmes are absent in some countries is the fact that, despite the proposed new regulatory framework promoting an active role of consumers, some NRAs, in agreement with the DSOs, have been reluctant to open the market, due to technical challenges, disagreement over data ownership and cybersecurity concerns. The regulation on data access and ownership, as well as data privacy improved, following the implementation of the General Data Protection Regulation (GDPR) and of Directive (EU) 2016/1148 (NIS) on security of network and information systems on MS level, but combatting all risks related to cybersecurity still remains a challenge for the Energy Expert Cyber Security Platform (EECSP), due to the quickly changing IT environment.

IT technologies are the backbone of the grid smart, but also render the grid vulnerable to the fast-changing cyber-threats. The greater the use of ICT in power grids, the larger the cyber-threat surface (Langer et al., 2016). These attacks are present in four domains:

1. threats to the confidentiality, availability and integrity of data in the system
2. threats to the security and proper use of the infrastructure as a whole
3. threats to the environment of Smart Grid operations, and
4. inter-organisational threats

Confidentiality, Integrity and Availability (CIA triad) emerge as the major security concerns. **Confidentiality,** which is intrinsically linked to privacy aspects, sets measures to protect data against access by unauthorised parties. Although it is the least critical dimension when considering grid automation systems, it is very important for end consumers. **Integrity** focuses in identifying and preventing unauthorised modification of data. Data integrity concerns grid automation systems, as well as services that create benefit for consumers at their homes or businesses. **Availability** focuses on identifying and assuring data and services that need to be available for a specific purpose at a very precise time. It is critical for systems supporting grid automation, but less important for smart metering applications (ENISA, 2012).

[7] As for SEDC 2015, five EU countries already provide a regulatory framework allowing for the development of Demand Response services: Ireland, Great Britain, Belgium, France, and Finland. The Baltic countries and the Netherlands are partially opening this market and other three countries are in the preliminary phases: Denmark, Germany and Poland. This market is on the contrary closed in the Southern and Eastern MS.

Under this scenario, direct interactions with customers and service providers through ICT are necessarily limited and hierarchical. Consequently, cybersecurity threats are easier to control than in the "People have the power" scenario. However, the existence of multiple legacy systems entails significant vulnerability of the grid infrastructure in case of ever more sophisticated threats (US Department of Energy, 2009). Besides, "the combination of legacy and future technologies requires specific solutions in the energy system that cannot be replicated from other areas with different needs (e.g. the internet)" (European Commission, 2017b).

Tariffs and price spreads

The tariff structure has not substantially changed and weak or inconsistent price signals have failed to elicit wide-spread consumer interest in Demand Response and self-production of energy. Lack of appropriate feedback and administrative hurdles for consumers eventually hindered the development of an open electricity market. The situation is different in more advanced countries, but the unsolved challenge of connecting million of new intelligent devices to the network is still limiting DR options. Security of supply concerns and the fear of loss of guaranteed income for the established actors, as well as possible lower tax revenues for governments lead regulators to limit the participation of small-scale demand and supply-side solutions in the market. Problems such as a viable regulatory framework for measurement of DR, the technical difficulty of quantifying and evaluating flexibility, or network fees designed to incentivise a flattening of the demand and production curve, still have to be resolved.

Industrial and commercial customers provide a certain level of flexibility, but in most EU countries, SMEs and residential consumers have few opportunities and little interest in participating actively in demand-side management. This also means that the demand for smart appliances and solutions for home energy efficiency remains low, hindering the development of new business models based on pooling of demand and production sources.

The distributed RES situation

The share of distributed RES is lower than anticipated in the first decade of the century, since the development of small-scale, grid-connected renewable resources has slowed down, due to high charges for network use and, in some cases, taxes on self-generation, as well as complex requirements for grid connection. Levels of curtailment of renewable production increase in MS with a high base of conventional must-run capacity increasingly affect PV (Steurer et al., 2014) and render small-scale generation less and less viable. Nonetheless, the 27% target of renewable electricity production by 2030 is achieved in this scenario, with a large part of this production covered by offshore wind parks. This is possible thanks to ongoing policy support for large-scale RES and offshore engineering expertise in Europe.

The characteristics of the distribution system

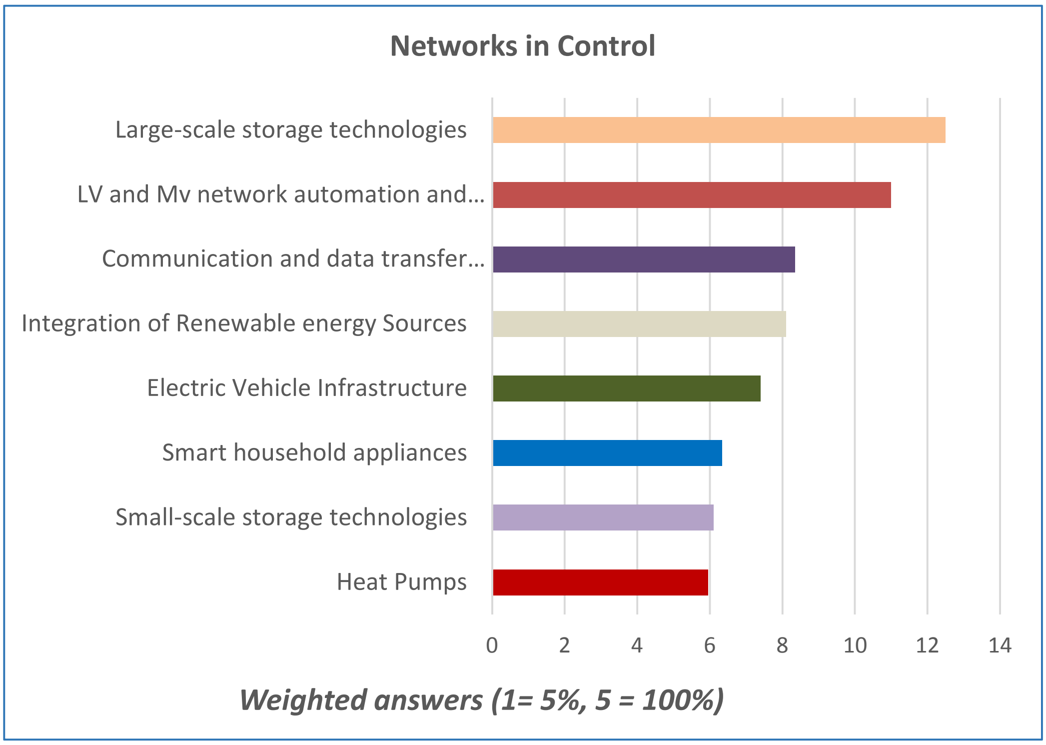
In this framework, the distribution system remains primarily hierarchical, with electricity flowing one way from generators to end consumers. Gas power plants remain the primary source for grid balancing, but there is growing concern about the difficulty of managing periods of low demand and high generation from wind parks and, at the same time, ensuring the security of supply (derived from UKERC, 2014 and Appelrath, 2012). To this end, the MV and HV grids have been widely equipped with ICT solutions improving grid management and control from the side of DSOs and TSOs, and widespread regional cooperation has been undertaken, thanks in part to the establishment of the "energy policy regions", as advocated by the European Network of Transmission of the System Operators (ENTSO-E, 2016). To enhance interconnection capacity and ensure the flexibility of the network by integrating variable RES, a reinforced grid infrastructure (including superconducting solutions) is able to manage data exchange and communications across countries in order to store and trade electricity. ICT devices and sensors are deployed in the grid at the low voltage level as well. However, their use is limited to the DSOs, to allow them to monitor the status of the grid and electricity consumption / injection. Advanced electronic meters have been installed in several MS and an adequate ICT infrastructure has been developed, but the meters presently mainly provide automatic feedback to the retailers and DSOs without actively involving the consumers (European Smart Grids Task Force Expert Group 1 – Standards and Interoperability, 2015). This facilitates investment planning, prediction, and maintenance scheduling by DSOs, but does not assist them in executing real time operations on customer sites.

Overall effect of the 'Networks in control' scenario on the engineering industry

As shown in

Figure *2-5* below, which describes the outcome of this scenario on the EU industry as assessed by experts and stakeholders, smart grid development in this scenario mainly benefits those sectors within the engineering industry that provide products and services to the DSOs, since solutions are required to balance the medium and high voltage grid. The developments result in strong support for the European wind-power industry, which competes successfully in global markets. In parallel, the impact is positive for industries producing large-scale storage facilities, which are needed to compensate for the lack of flexibility at the bottom level of the system. The impact is also high for those sectors providing solutions for the digitalisation and automation of the grid. Business opportunities arise for ICT solutions to balance the system and to manage data and grid constraints, as the strengthened DSOs invest in this area to monitor and regulate electricity flows. It can be expected that in the automotive industry, the EV segment will exceed the projected 5% of the total stock of Light Duty Vehicles by 2030 (European Commission, 2016f), providing business opportunities linked to the development of large-scale supporting infrastructures (charging stations and related ICT regulation and management devices). Moreover, these vehicles have started to contribute storage capacity to flatten the consumption curve (Pyper, 2016), since DR programmes for other types of appliances are not widespread enough to deliver this service to the grid.

Figure 2-5 Impact of the scenario 'Networks in Control'



Source: own elaboration based on results from the 2nd survey

Final remarks

In this scenario, the digitalised grid guarantees an adequate level of service quality and efficiency and allows TSOs and DSOs to manage grid constraints and ensure security of supply. According to the expert evaluation in the workshop, the scenario implies notable investments in fixed capital assets (superconducting cables to reinforce the grid; solid-state transformers for high-density locations with increasing electricity consumption; ICT and grid-scale energy storage systems). It presents limited possibilities to make use of the reserve capacity offered by demand side flexibility (except for electric vehicle storage capacity).

This scenario may unfold by 2030, given the limited systemic change needed for its realisation. Thanks to the leading role of TSOs and DSOs and the increasing maturity of ICT technology for grid automation, the utilities are able to deploy the required ICT layer on medium and low voltage level by 2030 across Europe. If these investments succeed in providing stability to the system and deliver the desired decarbonisation objectives, it will be easier for the established market players to ward off political pressures to open up the energy markets. However, if the still largely centralized system fails to deliver sustainable and affordable solutions for the integration of higher shares of RES in the energy mix and much improved levels of energy efficiency, public opposition could then force the MS to open to the market, as outlined in the 'People have the Power' scenario, albeit with some decades of delay. Furthermore, if the investment required for upgrading the transmission and distribution network causes a strong rise in electricity tariffs, utilities and regulators will face problems of social equity and energy poverty, on the one hand, and an increasing numbers of communities going off-grid, thus worsening the capacity imbalance between supply and demand.

- ***People have the power***

People have the power – The scenario at a glance

Thanks to the implementation of the EU directives championing active participation of consumers in the electricity network, demand response is an attractive option for both the residential and industrial customers, due to frequent and steep price peaks. Consumers and self-producers engage in the grid at low and medium voltage level providing the required flexibility both on the demand and on the supply side. The electricity market is well developed, with a large number of new actors, including aggregators, BRPs, renewable energy suppliers, prosumers and ICT developers of energy efficiency solutions. Given this evolution of the electricity market, the DSOs fulfil their role as neutral market facilitators, boosting the development of new services and enhancing demand response. Distributed RES reach high shares throughout Europe and contribute by 50-60% to total electricity demand, mainly thanks to distributed RES. generation plants, such as roof-top PV and micro-CHP.

Main scenario assumptions

The main assumption for the “People have the power” scenario is that the European stakeholders and policy makers have successfully implemented the new measures envisaged in the Clean Energy Package. This means that consumer empowerment has become a reality and their level of engagement in the grid operations is strong at low and medium voltage level. Driven by right price signals and by well-designed marketing initiatives, DR programmes become an attractive option for both residential and commercial customers, including SMEs. Many consumers engage in self-production, lowering their dependence from the grid and feeding electricity back into the grid. It is common to have PV roofs on individual houses and on shared roofs of commercial and public buildings, while wind power has proven competitive for industrial users. Self-production contributes 25-30% to electricity production and, combined with storage and SG solutions, provides the required flexibility both on the demand and on the supply-side.

Therefore, the demand for new products and services that allow for flexibility and consumer engagement is on the rise, creating business opportunities for providers of SG solutions. Business actors develop innovative products, mainly in the field of smart home appliances, which have become fashionable to some extent. EVs are able to interact with the grid and sales have been higher than expected. Independent operators provide and manage the enabling infrastructure (Eurelectric, 2016a). The new market design is accepted by the MS and regulators push traditional DSOs to become neutral market facilitators. In this system, local grid operators provide a common platform, managed by a neutral intermediary, on which trials with innovative service can be tested. This innovative environment permits a large number of new actors, including aggregators, BRPs, renewable energy suppliers, ICT developers of energy efficiency solutions and others to enter the market successfully. New business models appear in the market, including the involvement of the local communities through crowd-funding initiatives.

With the connection of millions of devices, the grid becomes more vulnerable, and, especially, social engineering attacks are increasing. This type of attack relies on the acquisition of information about computer systems by non-technical means. Social engineering is a technique that: (i) does not require any (advanced) technical tools, (ii) can be used by anyone, and (iii) is cheap (Beckers et al., 2015).

In this scenario, grid protection is crucial for the entire network, from pan-European large grids down to micro-grids in city neighbourhoods (Langer, 2016). Europe-wide concerted action is required to improve the capabilities to identify, detect, respond, and recover from a cyber-attack (Healey et al., 2016). Building on the work for the cyber-security, privacy of the Smart Metering Systems (European Commission, 2016t), and General Data Protection Regulation (European Commission, 2014b and 2016v), the Commission and the national authorities regularly update a common risk assessment for the entire SG architecture to properly understand and address the evolving threats to the energy system (EECSP, 2017). The MS implement the Directive (EU) 2016/1148 (NIS) and adopt national strategies to increase the security of network and information systems under the coordination of the Commission's Coordination Group. Due to these actions, technical security has increased, but the grid is still vulnerable to sophisticated cyber-attacks such as advanced persistent threats (APT), which render the existing defence mechanisms inapplicable (Hu, n.d.). To avoid major blackouts, intensive work is under way to increase resilience, i.e. the grid's ability to resist failure and rapidly recover from breakdown (Hertzog, 2012). Critical devices on the consumer side are increasingly enhanced or retrofitted with embedded storage capacity to reduce the effects of a possible blackout (EASME SG expert workshop).

This scenario unfolds thanks to a steady evolution of the regulatory framework and strong policies to trigger change at individual and market level. The MS promote flexible tariffs and DR, since these measures are convenient to deal with the intermittency of decentralised RES generation.

The characteristics of the distribution system

To allow the outlined deep behavioural and economic changes, the distribution grid has evolved considerably. A fully digitalised infrastructure allows for multidirectional flow of electricity. An extensive ICT layer enables high interoperability of network operators and devices, allowing for complete and real-time interaction among all actors in the system. Sensors are widespread and data communication and ownership are well regulated.

TSOs, through regional cooperation centres (expert comment, 2nd workshop), and DSOs – coordinated by the new EU DSO entity (European Commission, 2017, and Danish Energy Association, 2016) - assure the security and reliability of the service. In addition to the upgraded and smart main grid, micro-grids are deployed in many locations, with back-up connections to the local grid operators. Wherever and whenever this is convenient, the micro-grids are used as an alternative to the electricity supply from the grid operators. It is however worth noting here that this optimistic scenario could present a drawback because the increased flexibility assured by the demand side, together with the high share of distributed RES generation and the spread of micro-grids generation, could slow-down, or even hinder, the trans-border and regional cooperation between TSOs. This might cause even security problems in case of adverse weather conditions and high demand peaks.

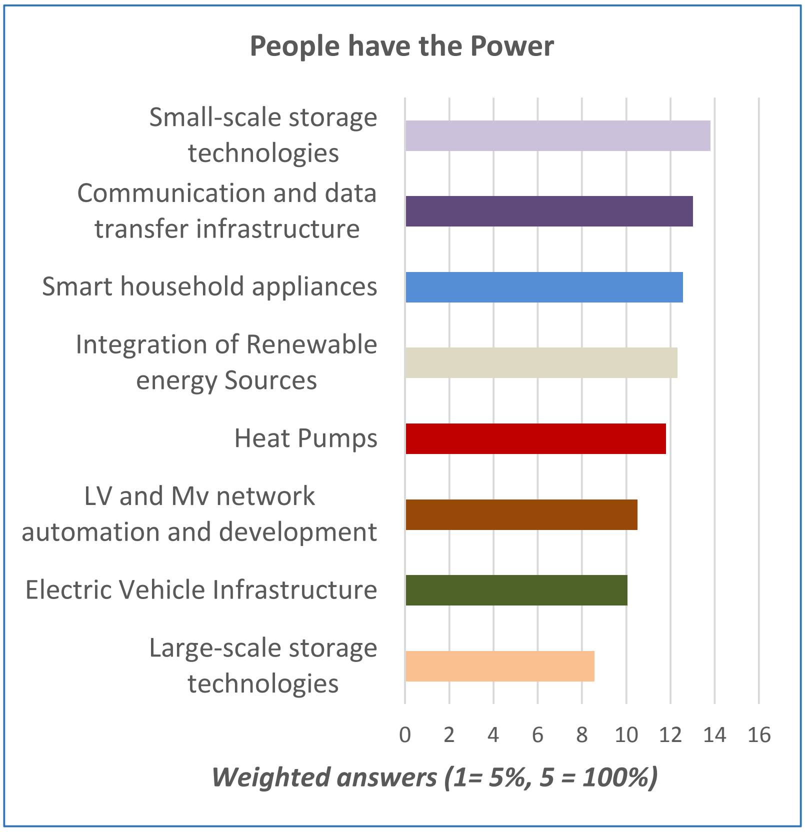
The distributed RES situation

Distributed RES reach high shares and contribute to the achievement of the EU decarbonisation objectives. Thanks to end-users engagement in self-production and maturity of enabling technology, especially storage, RES see strong market uptake.

Overall effects of the scenario 'People have the power' on the engineering industry

As shown in Figure 2-6 - which describes the impact of this scenario on the EU industry as assessed by experts and stakeholders - given the pronounced changes in the system, this scenario allows for the exploitation of business opportunities in several sectors. The strongest impact is on producers of small-scale storage facilities, which are coupled to small RES power plants to increase the stability of micro-grids. The ICT industry benefits from investments in upgrades of the communication and data infrastructure to allow for the full interoperability in the grid. The smart appliances industry also benefits considerably in this scenario, as these devices are needed to ease flexible demand and production of electricity at the residential level. Heat pumps improve their competitiveness with traditional heating solutions thanks to additional income from participating in DR programmes. Business opportunities arise also in the field of electricity trade, especially for independent aggregators and BRPs.

Figure 2-6 Impact of the scenario 'People have the power'



Source: own elaboration based on results from the 2nd survey

Final remarks

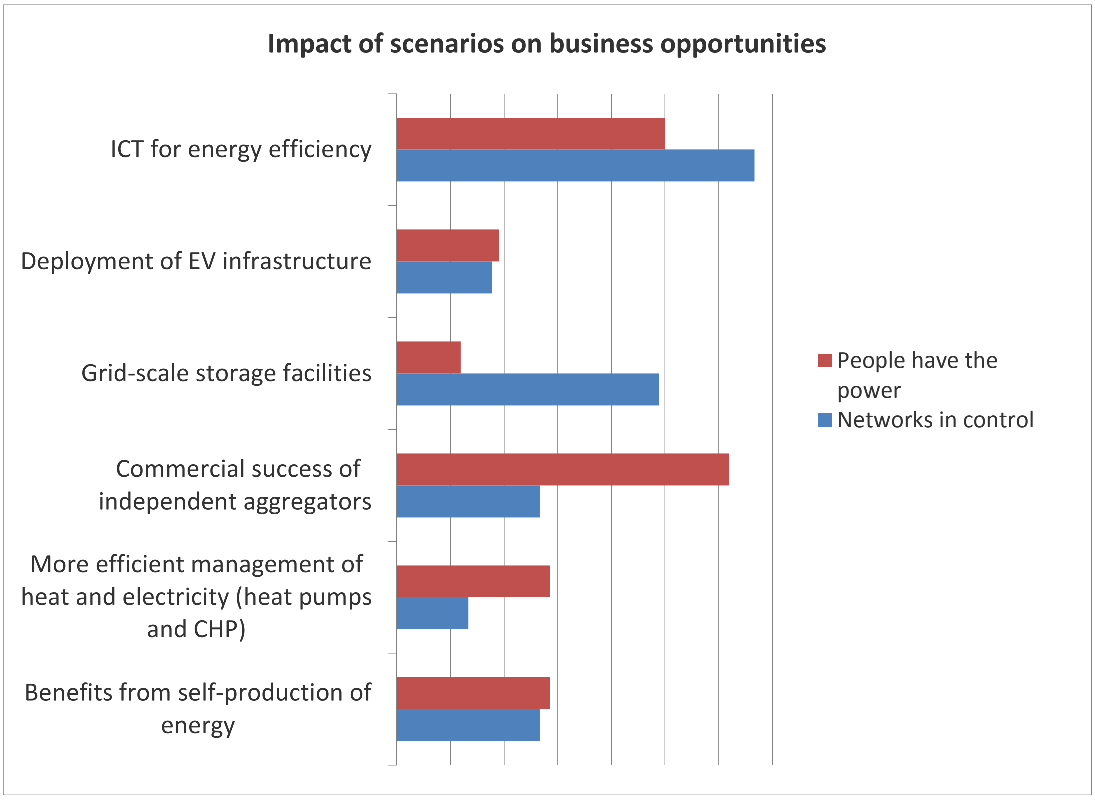
Since "People have the power" involves important structural changes in market and infrastructure, along with modifications in energy consumption, it is likely to come into reality in the long term, by 2050. However, the transition process towards greater consumer participation in the market could evolve much quicker once the NRAs start to implement the changes proposed by the Clean Energy Package and set the right incentives for consumer engagement, removing existing market barriers. By 2030, DR programmes may expand across Europe and the greater understanding of the benefit that these programmes create for the consumers strengthens their interest in energy efficiency measures.

Also in this desired scenario, attention must be paid to the issue of energy poverty, since the evidence on SG-induced energy savings is presently inconclusive. Although low-income households are just as interested in DR measures as the general population (Smart Grid Consumer Collaborative, 2012, Nicolson et al., 2017), they were found to have very limited information on smart meters and smart grids (Smart Grid Consumer Collaborative, 2014). Two surveys carried out in the US report documented "widespread suspicion" among low-income households that "smart grid technology raises household energy costs". The surveys document that the "age-based digital divide persists among the low-income population, threatening an "energy divide". However, trials with different types of customer feedback show a wide range of results – from 0% to 20% of savings (Buchanan et al., 2015), depending on the type of feedback and incentives offered to the customer. On the other hand, ACER's 2015 analysis demonstrated that the switch of suppliers alone can bring maximum annual savings that range from 425 euros (39%) in Germany to 9 euros (2%) in Hungary, so that the SG's facilitating effect could be more positive than found so far.

2.4. Business opportunities in each scenario

The second expert survey determined that the two scenarios affect the uptake of SG-related business opportunities differently. Figure 2-7 shows that the "people have the power" scenarios has clearly a stronger impact on three opportunities ("commercial success of independent aggregators", "more efficient management of heat and electricity", and "benefits from self-production of energy") than "networks in control".

Figure 2-7 Impact of the scenarios on business opportunities



Source: own elaboration

The discussion with the experts during the second workshop allowed analysing the reasoning behind these expectations, especially with regard to "ICT for energy efficiency", which was not included among the most relevant opportunities selected in the first workshop. The experts in the validation round understood ICT deployment in a wider sense, not only as ICT for energy efficiency. ICT will connect all technological solutions necessary to share information on how to produce, distribute, and use electricity. Thanks to ongoing investments in the replacement of grid components with smart architecture, the experts consider this an immediate business opportunity.

With regard to the relevance of ICT for energy efficiency, the experts maintained that the combination of ICT and SG enables more comprehensive solutions than ICT alone: while smart thermostats help control energy consumption at the home, their interaction with the grid through monitoring and control would contribute to improved grid management.

According to the experts, grid-scale storage would see stronger growth under “networks in control”, whereas the impact of both scenarios with regard to EV infrastructure is almost even. The experts participating in the first workshop were highly optimistic with regard to EV market uptake, interpreting that market growth in this case will not be heavily affected by the way SGs are deployed. The experts suggested, however, considering also small-scale storage, including community solutions, among the business opportunities, as storage is likely to be deployed in any part of the grid and behind the meter. For this reason, the business opportunity discussed in chapter 3.4 of this report looks at both, grid-scale and distributed storage.

2.5. Flexibility first – a glimpse of a very different future

“Flexibility first” describes a scenario with much higher levels of renewables of up to 100% of electricity demand in some MS during the major part of the year. The “digitisation” of society and economy (Orgalime, 2016) has accelerated the deployment of the required ICT infrastructure and this has had a profound effect on the energy production and distribution system. Smart Grids have largely eliminated the need for expensive, fossil fuel base-load power plants. High levels of RES shares, regulation and technical progress in the energy and the ICT fields have obliged energy service providers to prioritise investments in flexibility solutions. The function of the distribution grids is mostly limited to back-up for small area networks, with small and medium-sized storage devices taking care of balancing.

Most of the European citizens have access to demand-response services and own intelligent appliances capable of responding to price signals autonomously. Aggregation of electricity demand takes place on different levels (buildings, neighbourhoods, etc.), and across pools of appliances (Shah, 2017), whenever this brings a benefit for the final user and has a positive effect in terms of efficient use of energy. ESCOs, VPPs and other types of innovative service providers, many of them originating in the ICT field, have largely ousted traditional utilities from the market. Aggregators have successfully managed to activate the flexibility potential and market participation of SMEs and residential users. Energy markets in 2050 resemble “symphonies”, made up of “individual energy resources, like instruments in an orchestra”, which “can provide the most value to end customers. The sweetest symphonies integrate many instruments, at the right time, at the right volume. No instrument plays all the time, but the ensemble continuously creates beautiful music” (Dyson et al., 2017).

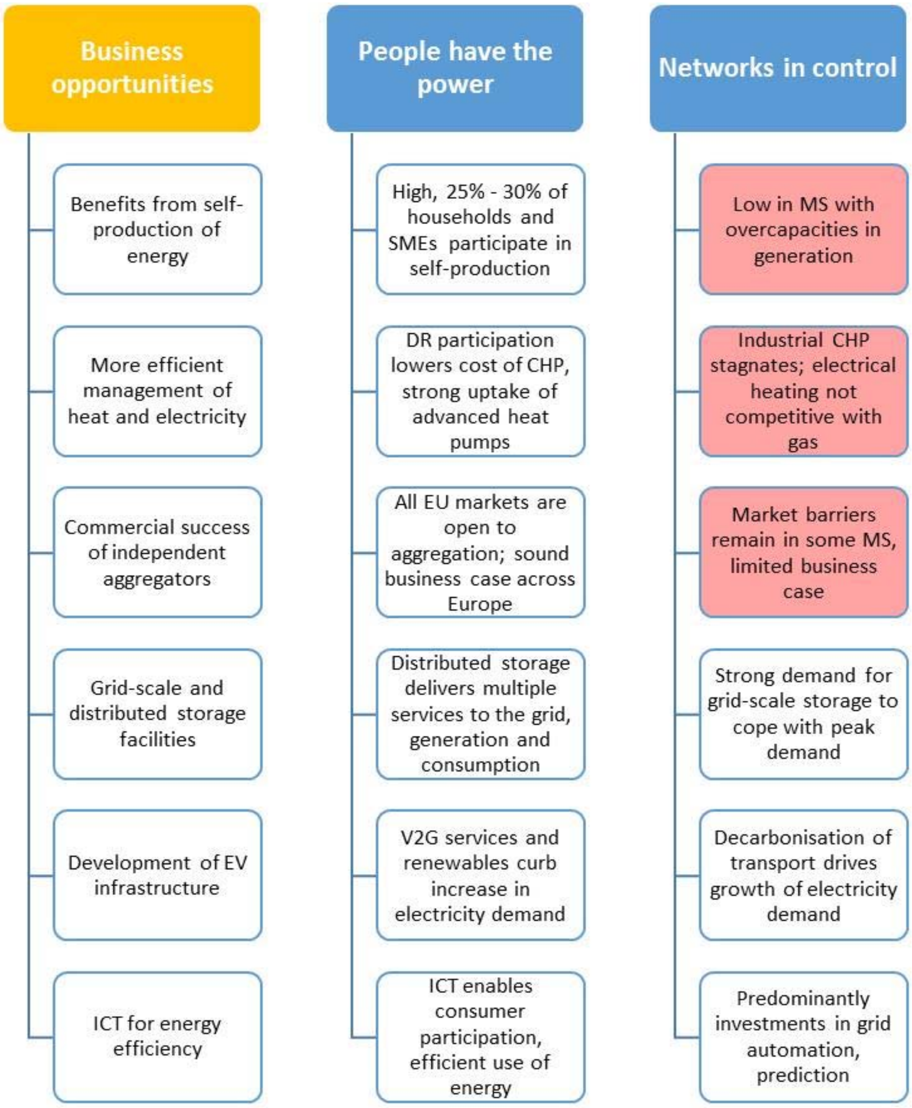
According to the first expert survey, the “flexibility first” scenario is consistent and plausible, but only in the very long term. Such an ideal scenario would require fully “harmonic and coordinated development” of all drivers, as expressed in one written comment to the survey, something that the experts participating in the workshop did not think was likely to happen.

3. Main opportunities related to SG deployment

This chapter discusses in detail the business opportunities related to SG deployment. The business opportunities were identified during the review of SG projects, in literature and interviews, and afterwards validated by the experts participating in the surveys and the workshops. The opportunities are strongly linked to the enabling effects of SG on emerging technologies, which would benefit from strong interaction with the electricity system. The information on each business opportunity is presented in a similar way by giving first a short description of the opportunity and its likely impact on industry. The text then discusses the main barriers and proposals for overcoming them by means of short and medium-term actions, which are presented in the form of a Strategic Action Plan (SAP).

The SAPs point the way to the accomplishment of the "People have the Power" scenario, which is broadly aligned with the proposals of the Clean Energy Package. Figure 3-1 below shows how each opportunity performs under each scenario. The first three opportunities are likely to blossom only under the "People have the power" scenario, whereas the last three would unfold differently in the two scenarios.

Figure 3-1 Likely development of business opportunities under each scenario



Source: own elaboration

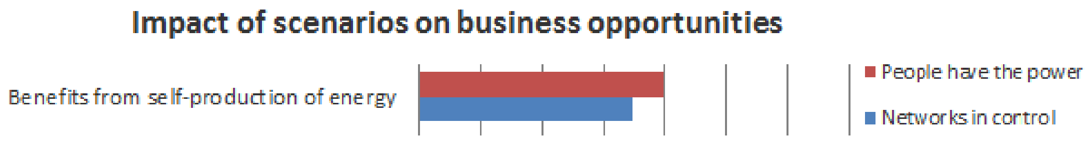
Most of the long-term objectives in the SAPs correlate with those defined in EU policy documents. In some cases, when 2050 objectives have not yet been defined for Europe, information from other recognised sources, such as the International Energy Agency (IEA) and the World Energy Council, is cited, and gaps have been filled by extrapolating from 2030 objectives. In a few cases, the SAPs suggest new actions that are not yet included in policy documents, reflecting the opinions of industrial stakeholders and the findings of relevant research.

3.1. Benefits from self-production of energy

According to the EC, future electricity markets will be characterised by more variable and decentralised production and increased interdependence between cross-border systems. Opportunities for consumers to participate in the market will unfold thanks to demand-side response, **self-production**, smart metering, and storage (Linklater's, 2016).

According to the second expert survey, benefits from self-production of energy will grow stronger under the "people have the power scenario" than under "networks in control".

Figure 3-2 Self-production of energy in the two scenarios



Source: own elaboration

As the experts participating in the first workshop remarked, "The plausibility of 'People have the power' depends very much on the profitability for the consumer", i.e. market actions to foster consumer participation.

3.1.1. Description of the opportunity

The majority of the SG projects (i.e. 70%) analysed for the purpose of this study dealt with contract optimisation for the energy user or self-consumption. Self-generation or consumption, enhanced by SG, can help balance the network by the following mechanisms:

- lowering the net peak offtake / injection
- compensating load peaks by producing mainly during peak hours
- improved demand response (DR)

Self-production can improve demand side flexibility if the self-generation site is able to control power injection in response to variable consumption levels (via e.g. storage, DR or smart inverters) and if the prosumer is reacting actively to price signals in order to provide flexibility. This can happen individually or through aggregators by adapting consumption (or production) behaviour in accordance with the needs of the system (CEER, 2016).

Self-generation already encompasses a large number of very different actors, ranging from individual households to neighbourhoods, energy communities, and industrial self-production. Trends such as peer-to-peer energy communities, prosumer VPPs with a focus on regional energy sharing, tenants buying the solar energy produced on the roofs of residential buildings and storage sharing among prosumers are on the rise. Some experts predict that these developments will change the energy system as we know it today (E-Energy, 2014).

The project review has shown that self-generation using wind energy can be highly profitable for industrial users. Verbeeck et al. (2012), for example, report that the Antwerp

Port Authority is currently investing in a big wind farm on the premises. Many Antwerp harbour companies are getting the opportunity to have one of the wind turbines on their company estate. They will have the possibility to buy electrical energy "directly" from the wind turbine without the intermediation of the DSO. In principle, this is financially interesting because:

- no distribution and transmission fees have to be paid for the wind energy.
- due to its intermittent character, the value of wind energy on the energy market is lower and thus cheaper for the companies

This results in an electricity price, which is 40% to 50% lower than the electricity tariffs applicable when buying electrical energy from a traditional supplier (Verbeeck et al., 2012).

Interaction between self-generation and the grid can also make the use of renewables more profitable. At the AMORAS facility, a company with large buffers and a large overcapacity of pump installation, also located in Antwerp, simulations showed that it was possible to operate the pump installation completely on wind energy. Without optimisation, only 60% of the produced wind energy can be used locally. In case the flexibility is employed in an optimal way, almost 80% of the wind energy can be used locally. This results in an overall energy cost reduction of almost 20% (e-harbours, 2012).

Although the project review has demonstrated the value of self-consumption for different types of users, it is important to understand that the underlying motivations and attitudes vary depending on the type of self-producer and that the motivations are not limited to monetary benefits.

Prosumers have a different attitude regarding energy exchange than professional owners of Distributed Energy Resources (DER): they just want to sell their energy surplus (PV owners usually in summer) and purchase energy in times of limited self-generation (for PV owners in winter) (Karg et al., 2013). "Neighbourhood electricity", a form of community of providers of distributed energy, often emerges because of the desire to become independent of big power plants or "monopolies" or to prevent the expansion of transmission grids. The communities are organised bottom-up via internet platforms and are not necessarily bound to regional communities, although there is often a direct link to regional initiatives.

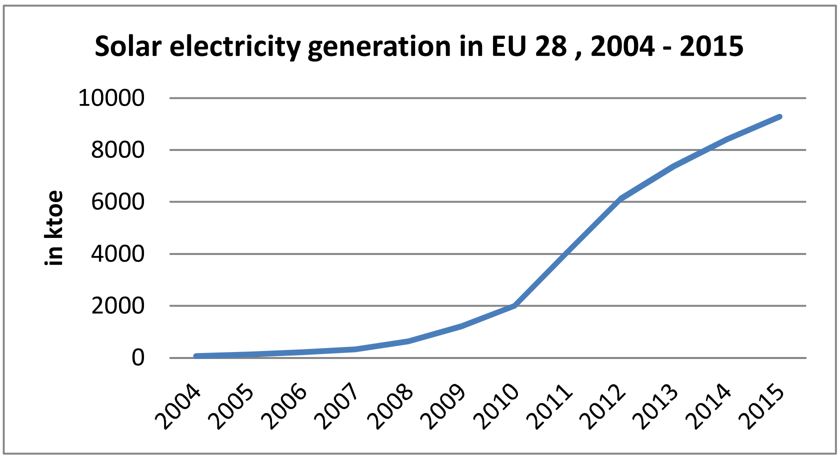
The political support for self-generation at EU level is strong. The Council of European Energy Regulators (CEER), for example, points to the benefits of self-generation for the electricity system in form of reduced network losses (CEER, 2016). By generating and consuming electricity locally, system losses produced during transport and distribution – mainly owing to the Joule effect - are eliminated. CEER cites a series of studies[8], showing that at low penetration rates (up to 10-15% of total production) distributed generation (either associated to self-production facilities or not) is likely to reduce distribution network losses.

According to the European Commission (2015a), self-production contributes significantly to financing the energy transition, for example through private investments in small-scale PV systems. These systems are expected to increase their share in the electricity capacity mix from 6% in 2014 to 22% by 2040, according to estimates from Bloomberg New Energy

[8] "Identifying energy efficiency improvements and saving potential in energy networks", Tractebel and Ecofys for DG Energy (EC), December 2015. Also "Assessment of energy distribution losses for increasing penetration of distributed generation", Méndez-Quezada et al., 2006; "Energy losses in a distribution line with distributed generation based on stochastic power flow", Marinopoulos et al., 2011; "Fostering microgeneration in power systems: the effect of legislative limitations", Fidalgo et al., 2012; as cited by "Regulatory practices and distribution system cost impact studies for distributed generation: Considerations for South African distribution utilities and regulators", U.J. Minnaar, 2015.

Finance (European Commission, 2015a). Figure 3-3 shows the strong increase of solar electricity production in the EU-28 between 2004 and 2015.

Figure 3-3 Solar electricity generation in the EU 28



Source: own elaboration based on Eurostat's SHARES tool

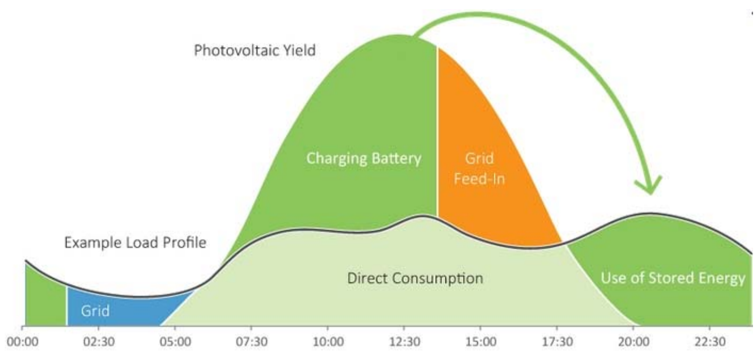
Self-production leads to savings on the energy bill (CEER, 2016), when socket parity[9] is achieved, i.e. when rooftop solar has the same price as electricity sourced from a utility (Barnard, 2015). A PV solar rooftop system can produce electricity at a price of EUR 95-100 MWh, which is less than retail electricity tariffs for commercial consumers (European Commission, 2015a).

The quickly falling cost of PV therefore creates interesting options for the commercial sector, (e.g. department stores, office buildings, SMEs), which can attain high rates of renewable electricity self-consumption (e.g. 50%-80%) due primarily to the relatively good match between the energy consumption profile and the onsite renewable generation curve. As a result, commercial self-consumption systems are increasingly viable in a growing number of MS, among them Germany and Italy (European Commission, 2015a). Finally, self-generation clearly contributes to achieve the policy goals related to the fight against climate change and the renewable energy objectives (CEER, 2016).

Opportunities for the European engineering industries

Self-production creates new business opportunities for the electrical storage industry, due to the intermittent character of renewable power generation. Figure 3-4 shows how storage helps to regulate power output of PV systems.

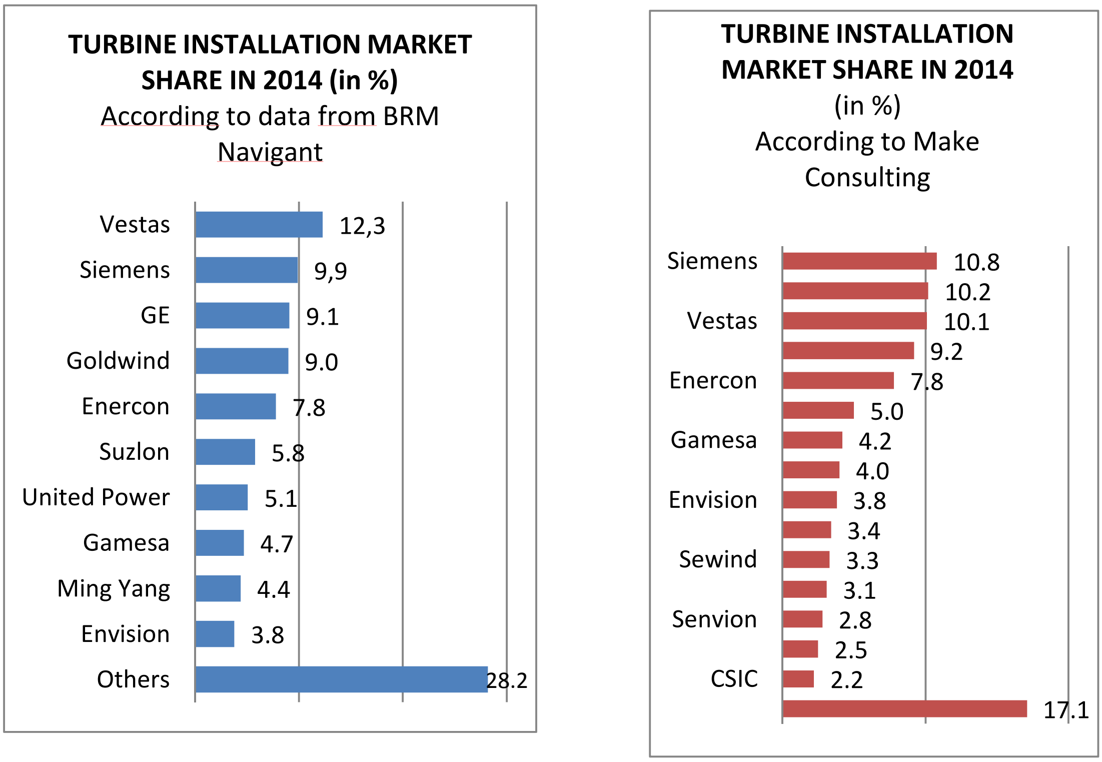
Figure 3-4 Storage use in combination with self-production



[9] Socket parity is slightly different from grid parity, which refers to renewable energy generation being able to compete in equal terms with traditional power plants in the wholesale market.

Manufacturers of renewable energy technologies also benefit from the trend towards self-production. For industrial self-production, wind is increasingly attractive and European companies maintain a strong position in the wind turbine sector. The top players are Siemens and Vestas (see Figure 3-5).

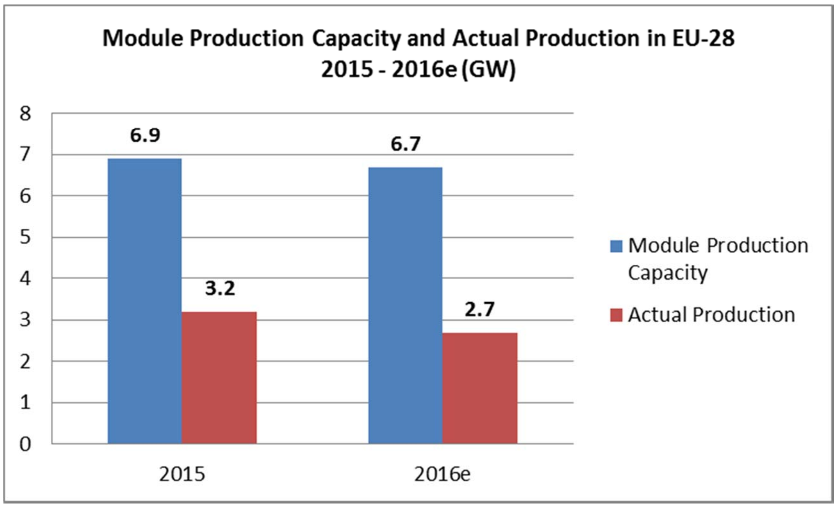
Figure 3-5 Market shares of European Wind Turbine Producers, 2014



Source: own elaboration based on Windpower Monthly (2015) and indicated sources[10]

The situation is more difficult in the PV sector, since solar module production in Europe continues to decrease and fell by 16% in 2016 (see Figure 3-6):

Figure 3-6 Modules Capacities & Actual Production in EU 28, 2015-2016e



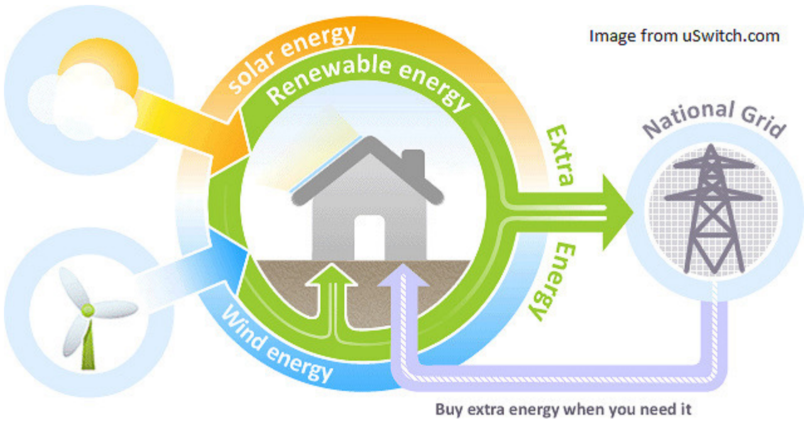
Source: own elaboration based on data from Schmela, Solar Power Europe, 2017

[10] http://www.windpowermonthly.com/article/1352888/ten-biggest-best-manufacturers

SolarWorld is presently the only remaining European company among the world leaders of PV panel producers, but SMA, along with ABB, remains a top player in the solar inverter business[11]. SMA achieved revenues of almost EUR 1 billion in 2015 (MEUR999.6). The newest product offered by SMA is the Sunny Boy Storage, an inverter enabling the connection of new and existing household PV systems to batteries (SMA, 2016).

Self-production also leads to new relational models between the consumer and the electrical system, such as net metering, which is currently under discussion. Net metering is a resource usage and payment scheme (billing mechanism) that allows electric customers to feed excess electricity generated by their self-generation systems into the grid. The owner then receives credits for the injected energy and these credits can be used to source electricity from the grid when needed. At the end of the billing period, customers are only billed for their "net" energy use (SEIA, no date).

Figure 3-7 Net metering scheme



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Source: Sulaiman, 2013

Smart grid solutions in the form of DR, combined with storage, can help increase the level of self-production for a residential PV system from the present 30% to up to 65-75% (European Commission, 2015a[12]) and therefore reduce the problem of excess electricity production substantially.

3.1.2. Main barriers to deployment

High CapEx and lack of space may be obstacles or impediments for small consumers

Access to capital and/or financing is a key determinant of whether or not residential consumers can enjoy the benefits of self-consumption (European Commission, 2015a).

In addition, in densely populated urban areas, an additional obstacle may exist regarding the physical location of the self-production facility, i.e. the place where the installation can be located. Available roof space has been considered a limiting factor for small-scale PV deployment, but researchers from NREL have recently been able to determine that rooftop solar could provide almost 40% of US electricity sales *if all types of buildings were used* for PV generation (Trinastic, 2016).

Opposition from utilities and policy to self-production and self-consumption

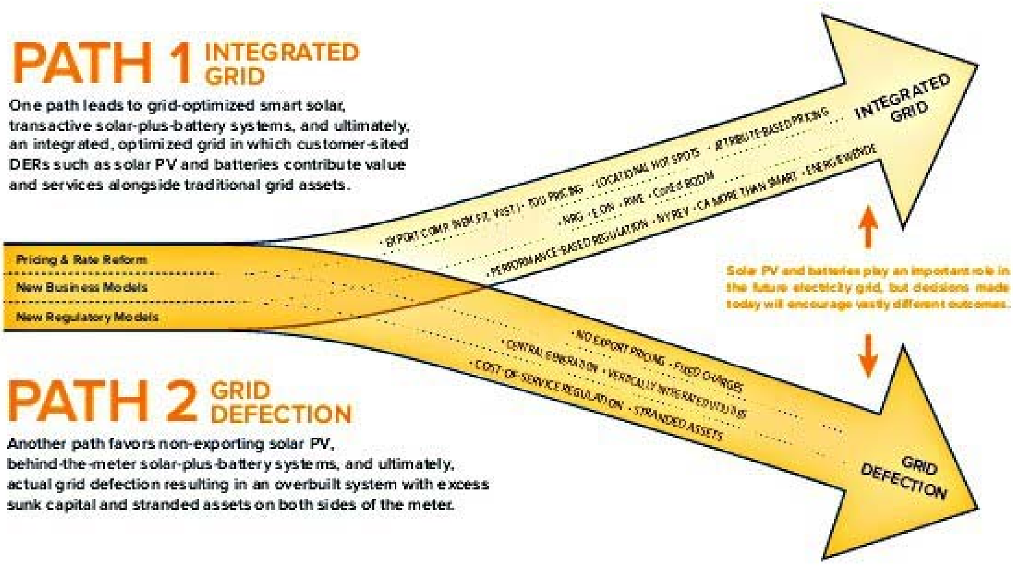
Increasing the capacity of distributed renewable electricity generation, as happens with self-production, can provoke the need for network reinforcement, if the hosting capacity of the

[11] ongoing research for DG RTD, will be cited when approved.
[12] This value has been determined for Central European households.

grid and the storage capacity of the prosumer are insufficient. In the absence of smart grid technologies and sufficient storage capacity, renewable energy sources and injections from self-generation can generate distortions in the network and increase operating costs (European Commission, 2015a).

In this context, DSOs have the responsibility to reinforce the network and may incur in higher operating costs. Consequently, the DSOs could present an opposing position to the implantation and massive deployment of self-generation facilities. Likewise, there is a risk of fiscal losses from energy sales for public authorities. Furthermore, with the uptake of residential batteries, self-consumption can lead to "grid defection" (RMI, 2014) and therefore to stranded assets for grid operators and conventional generators. Unless major changes are made to the established electricity markets, these costs would then have to be borne by the part of the consumers, which remain "captive", i.e. do not have the possibility of self-generation. Figure 3-8 shows two possible pathways for future self-consumption with solar generation, either integrated in a much more flexible network or disconnected from the grid.

Figure 3-8 Possible development paths for solar generation



The main discussion related to regulation of net metering as instrument to promote self-generation refers to the way the system operators remunerate excess production (Donoso, no date). The European regulators recommend avoiding net metering on the basis that this scheme does not induce the producers to engage actively with the market (CEER, 2016). Instead, metering schemes are to be designed in such a way that the prosumer participates in the balancing market and assumes its responsibility within the system. However, CEER does not address the issue of transaction costs (for participating in DR and balancing), nor, for example, time restraints for non-commercial prosumers. The European consumer organisation BEUC remarks in this context that "the simpler and the more reliable the rules, the lower the costs of renewable self-generation and the faster the market uptake" (BEUC, 2016).

Restrictive regulation

For the objective of the expansion of self-production to as many consumers as possible, restrictive regulations such as the caps on net energy metering (NEM) in California or the

Spanish solar tax, which penalises self-generation (Tsagas, 2015), are serious barriers presently. The PV Financing project (CREARA Energy Experts, 2016) has documented the sometimes very detailed specifications in national regulation that pose barriers to the expansion of solar self-generation, which not only affect the remuneration for excess energy, but also limitations to shared ownership in multi-family housing, for example.

Complex and burdensome administrative and authorisation procedures for small-scale self-consumption

Administrative and authorisation procedures are complex and burdensome for small-scale self-consumption projects and jeopardise the competiveness of these projects (European Commission, 2015a).

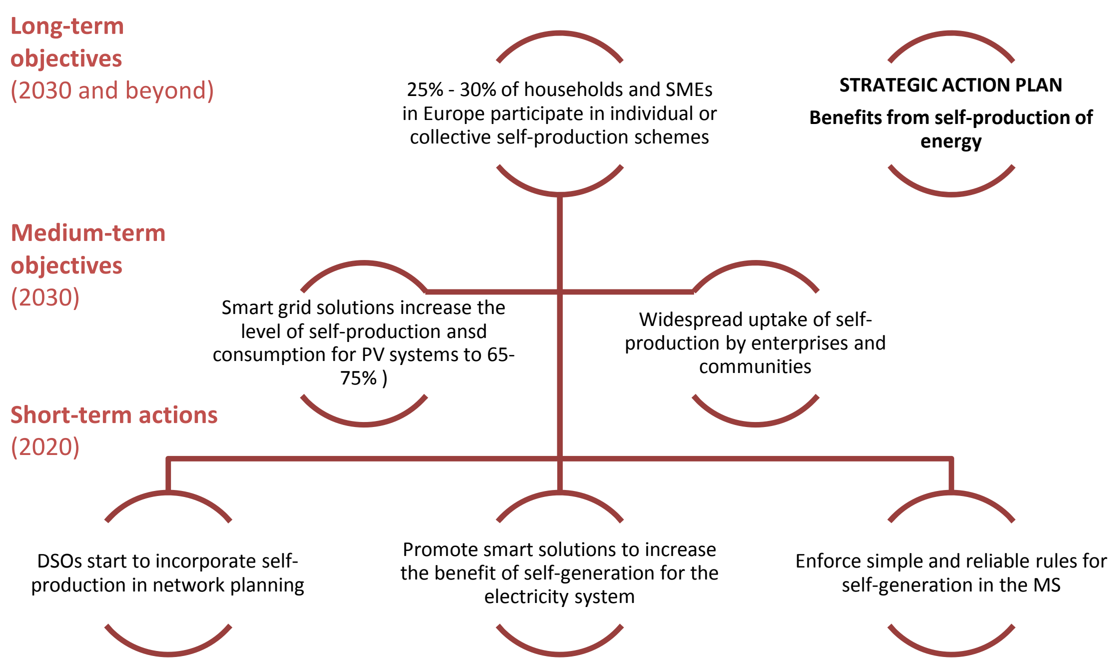
Legal limitations to closed distribution networks, which could make greater use of industrial and commercial self-production through onsite clustering of facilities

Closed distribution networks are market niches, in which self-generation and smart energy management could blossom, but there are presently legal barriers to the establishment of this type of networks in some countries (e.g. closed distribution networks can only be created under very specific circumstances). This was pointed out by a representative of the investor side and documented by other sources (Citiworks judgment, C-439/06; Deketelaere et al., 2011; e-harbours, 2012b). The Clean Energy Package assumes that closed distribution networks will exist for "industrial and commercial [enterprises] or shared services sites such as train station buildings, airports, hospitals, [and] large camping sites" (European Commission, 2016l). The proposal for the new renewable energy directive specifies that customers located in closed distribution sites "are allowed to jointly engage in self-consumption" (European Commission, 2017a).

3.1.3. Strategic action plan

Figure 3-9 summarises a proposal of the strategic action plan to achieve higher benefits from self-production of energy:

Figure 3-9 Strategic action plan for the opportunity "Benefits from self-production of energy"



Source: own elaboration

Long-term objectives (2030 and beyond)

➢ **25% - 30% of households and SMEs in Europe participate in individual or collective self-production schemes**

The study on the "Potential of Energy Citizens in the European Union" (Kampman et al., 2016) found that "264 million people could be producing 611 TWh of electricity by 2030 and 1,557 TWh by 2050. That would mean 19 % of the EU's electricity demand by 2030 and 45 % by 2050. Households would be particularly strong in the production of solar, and micro- and small enterprises in the production of wind power.

The study also underlines the important role of energy collectives, which "could contribute 37 % of the electricity produced by energy citizens". Micro-and small businesses could contribute 39 %, households 23 % and public entities 1%.

The numbers represent a maximum, taking into account the potential of renewables, assuming that "half of the households, around 113 million, may have the potential to produce energy". Reaching this objective would require a strongly supportive regulatory environment, for example by following Solar Power Europe's proposal of enshrining the "right to self- generate and consume … in the European Charter on the Rights of Energy Consumers" (SPE, 2015), an option that has not been considered in the revised renewable energy directive (European Commission, 2016a). Mühlenhoff (2016) states that the MS should define and implement long-term strategies to guarantee the return on investment for self-production. Since such strong policy signals are not yet in place, a discussion among the MS and the Commission about a quantified objective for self-production for 2050 could help clarify the long-term policy goal and support for self-producers.

25-30% of households and SMEs participating in self-production and consumption, as proposed in this Strategic Action Plan, are aligned with the IEA's expectation that self-consumption will obtain a share of 25 to 30 % in the coming decades (IEA-RTED, 2014), but the proposed indicator has the advantage of reflecting changes in behaviour, which is crucial for sustainable transition management.

Medium-term objectives (2030)

➢ ***Smart grid solutions increase the level of self-production and consumption for PV systems to 65-75%***

In order to increase self-consumption rates and avoid demand and production peaks, smart-grid solutions, coupled with storage and demand-side measures, can be applied to adjust demand and production curves for self-generation and to improve interaction with the grid. Smart grid solutions in the form of DR, combined with storage, can help increase the level of self-production for a residential PV system from the present 30% (De Boeck et al, 2016), to up to 65-75% (European Commission, 2015a) and therefore reduce the problem of excess electricity production substantially. Recent modelling results show that community projects, in which 40% of the members own a PV system and use peer-to-peer consumption combined with local storage, can already achieve a self-production rate of 28% on a sunny summer day in the Netherlands (Bellekom et al., 2016).

➢ ***Widespread uptake of self-production by enterprises and communities***

SG solutions and distributed storage systems installed on neighbourhood or community level can reduce the cost-per-kWh and allow individual regions to integrate higher volumes of distributed, consumer-driven renewable energy. "Community solar" is already a recognised driving force in the energy market and similar concepts can be beneficial for groups of SMEs or commercial establishments, which, as indicated before, pay high electricity prices and have a demand curve, which is highly compatible with PV. The recast of the renewable energy directives specifically supports the "renewable energy community" (European Commission, 2016a), since these collective efforts have the greatest potential for unlocking new business models.

Short-term actions (2020)

➢ ***Incorporate self-production into network planning***

The significant increase of self-generation, because of more residential PV adoption, tends to reduce electricity retail sales. As with sales, higher self-generation may also reduce the growth rate of the grid (California Energy Commission, 2015). In order to take into account and handle these impacts of self-production, it would be necessary to incorporate self-production into network planning.

To reap the expected benefits of self-production, regulatory frameworks need to allow TSOs and DSOs to account for self-production when assessing network expansion needs and system operation to avoid inefficient grid expansion and improve active system management (CEER, 2016).

Market mechanisms should be designed to identify and incentivise DG development in higher-value locations based on interconnection policy. Distributed generation procurement programmes have to be adjusted to align incentives for market participants (IREC, no date). This action is aligned with the requirement from the revised renewable energy directives to include "production of electricity from renewable self-consumers and energy communities in gross final consumption of electricity from renewable energy sources" (European Commission, 2016a). The regulators (ACER/CEER, 2017) also support the elaboration of network plans by DSOs, which include medium-term forecasts that improve the transparency of needs/service requirements and enable market participants to react and offer solutions.

➢ ***Promote smart solutions to increase the benefit of self-generation for the electricity system***

SG solutions enhancing the benefit of self-production for the electricity system at large are crucial for accelerating the deployment of small-scale renewables. Intelligent control of PV inverters by DSOs, for example, can increase the capacity of the network for hosting distributed generation by 50% (MetaPV, 2014).

Flexibility valuation mechanisms can support the market participation of self-production and improve system efficiency. The deployment of smart meters can enable this participation in the balancing markets (CEER, 2016), but a distinction needs to be made here between professional and private suppliers of flexibility, as their motivations and forms of interaction with the grid are different.

➢ ***Enforce simple and reliable rules for self-generation in the MS***

The renewable auto-producers may sell their excess production without losing their rights as consumers and they should also be entitled to remuneration for excess energy they feed into the grid (EC, 2017a). The consumer perspective requesting "simpler and more reliable rules" should be respected in national legislation.

It will be necessary to implement well-designed community-shared distributed generation programmes to benefit the entire electric system while promoting expansion of self-production (IREC, no date). To avoid negative impacts on social justice and to make self-consumption widely accessible to consumers from all income levels (European Commission, 2015), the participation of lower income consumers can be promoted through innovative business models and financial instruments. New cooperative business models, for example, allow for small-scale investments in self-production, and such investments in renewable energy should be accounted for as a contribution to the energy transition. One DSO interviewed during the study suggested to regard the grid as social asset, which should be paid by everyone regardless of the usage to avoid that fewer consumers will pay the bill for the grid.

Besides, in order to facilitate the administrative and authorisation procedures, it would be necessary to simplify current procedures, as some MS have done by introducing facilitated notification procedures for small renewable energy installations, or the on-line information platforms and applications used in a few MS (e.g. Portugal, Hungary, Italy, and Sweden) (European Commission, 2015).

3.1.4. Key messages

In the following bullet list, the key messages regarding self-consumption of energy and SG deployment are presented:

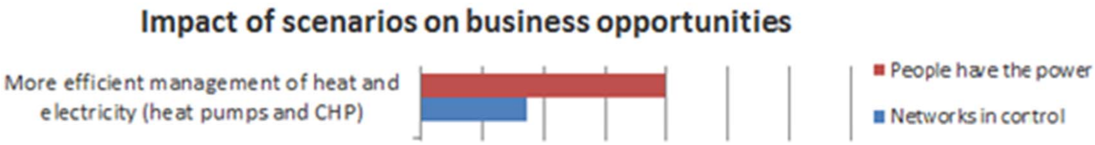
- Determine the individual and system-wide benefits of grid-delivered self-production in an objective way and set uniform guidelines with simple and reliable rules that maximise the benefits of self-production for the producer and for network operation. SG solutions, such as smart converters, increase the level of self-consumption and, at the same time, the hosting capacity of the distribution networks. User-friendly SG strategies increase the value of interaction with the grid for self-producers and help prevent "grid defection".
- Adjust regulation of self-production to the different types of actors emerging in the energy sector. Consider user-centred factors such as complexity of interaction with the electricity system and markets, time restraints and limited technical knowledge of non-professional energy producers.
- Support self-production schemes in the commercial sector, which shows a high fit of production and consumption curves and the greatest, unexploited economic potential.
- Energy communities and cooperatives are essential to unlock new business models, which allow the participation of lower income households in self-production schemes.

3.2. More efficient management of heat and electricity (heat pumps and CHP)

As the European electricity mix moves towards a higher share of intermittently generated electricity, the combined management of heat[13] and electricity is gaining interest in research and policy. The combination of the two different energy carriers increases the flexibility of the electricity system, since heat can easily be stored for a limited time without interfering with the user's comfort. Involving flexible heating technologies such as the simultaneous production of electricity and heat **(cogeneration - CHP, heat pumps, water boilers**, and possibly heat storage) in the grid stabilisation tasks is becoming crucial, especially with accelerated deployment of RES (Lund et al., 2012). Besides, linking heating and cooling with electricity networks reduces the cost of the energy system – to the benefit of consumers (European Commission, 2016t).

According to the expert survey, this opportunity will grow much stronger in the "people have the power" scenario.

Figure 3-10 Impact of scenarios on "more efficient management of heat and power"



Source: own elaboration

Since CHP and heat pumps are two different markets, two separate actions plans have been elaborated, after discussing each of the opportunities and the likely impact of SG.

3.2.1. Description of the opportunity

3.2.1.1. Heat pumps and water boilers

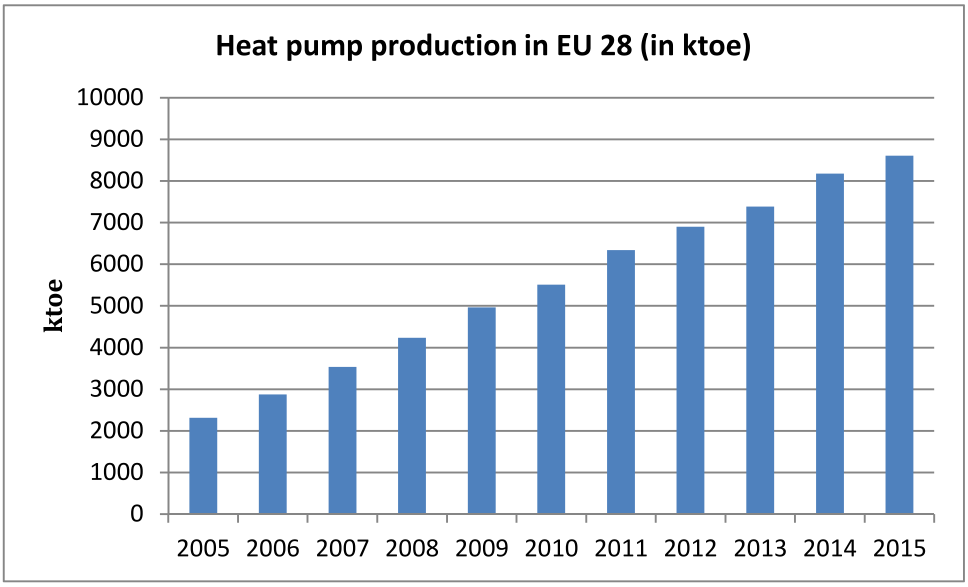
The so-called "thermostatically controlled" loads[14] are interesting candidates for Active Demand Response (Arteconi et al., 2016). In fact, **heat pumps and water boilers** are the most attractive applications for demand side solutions due to their high power and flexibility, although savings in operational cost and CO_2 emissions reductions are generally limited to about 7% (Patteeuw, 2016).

The newest generation of heat pumps works at 65 degrees and can deliver all energy required for heating and hot water, as well as refrigeration in summer.

SG deployment is expected to have an especially positive effect on the economies of heat pumps, which offer up to 2 hours of flexibility with the dwelling acting as a thermal storage. The European heat pump market has shown steady and strong growth during the last decade, as illustrated by Figure 3-11.

[13] Covers heating and cooling
[14] Boilers, heat pumps, refrigerators and air conditioners

Figure 3-11 Evolution of heat pump production 2004 – 2014 in EU-28



Source: own elaboration based on Eurostat's SHARES tool (Directive 2009/28/EC) and EHPA

The European Heat Pump Association estimates that more than 8.4 million pumps are currently installed, with almost 890,000 units sold in 2015 in the 21 EU countries covered in the association's annual report (EHPA, 2016). Heat pumps have contributed significantly to the overall growth of renewable heating and cooling (ECOFYS, 2014) and many countries are adopting stringent building codes (concerning thermal regulation), which are encouraging the installation of heat pumps.

The effects of pooling of heat pumps via a Virtual Power Plant (VPP) and aggregated participation in the electricity market have been analysed in a series of demonstration projects in recent years. The Danish trial, titled "READY"(Bang et al., 2014), found that "in a typical Danish house, the annual savings associated with intelligent control in accordance with hourly spot prices was roughly 300 DKK (EUR40). By participating in the regulating power market, the annual savings are considerably higher, but also more uncertain. Even if the heat pump only contributes with down regulation, the increase in annual savings can easily be 500 DKK (EUR67)".

3.2.1.2. Cogeneration (CHP)

High efficiency cogeneration[15] is one of the most important technologies identified in order to achieve European energy efficiency and greenhouse gas emissions 2020 targets (Comodi, et al., 2016). Small cogeneration facilities can also be an effective way to supply energy to remote areas without the need for expensive grid infrastructure (European Commission, webpage[16]).

Combination with thermal storage - which is approximately 100 times cheaper than electric storage according to Lund et al. (2016) - increases the efficiency of CHP, since there is no need for curtailment. Hence, CHP plants can be optimised to follow electricity prices and this

[15] High efficiency cogeneration is defined in the 2004/8/EC cogeneration directive [by the energy savings obtained by combined instead of separate production of heat and electricity). Energy savings of more than 10 % qualify for the term 'high-efficiency cogeneration'.

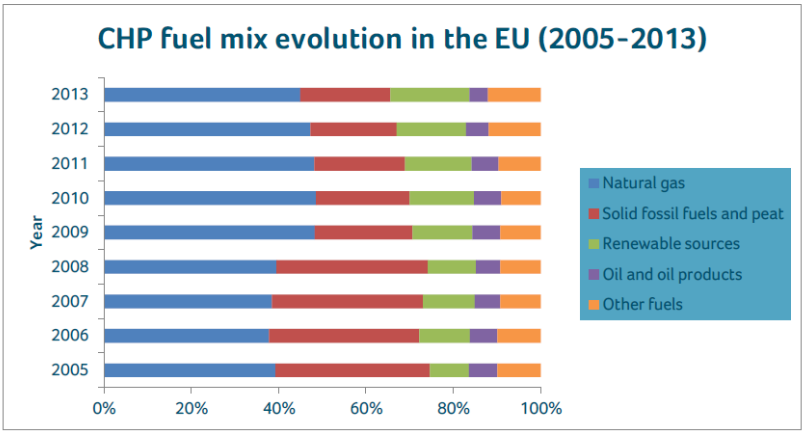
[16] https://ec.europa.eu/energy/en/topics/energy-efficiency/cogeneration-heat-and-power

makes CHP systems better suited (as compared to power-only systems) to address grid balancing issues caused by high penetration of intermittent RES (Rong, 2016).

CHP plants across Europe vary significantly in terms of size and application sector and the fuel and technology they use. Commercial CHP has taken off strongly in most European countries, while large industrial CHP remains steady. Residential CHP (used for district heating) is experiencing a renaissance in several countries, such as Italy, France, or the UK. Likewise, the opening of both the regulating power market and the primary reserve market has made it possible for distributed CHP plants to enter the market in countries like Germany, Belgium, Slovenia, or Denmark. The case of flexible operation of the Skagen CHP plant, which is equipped with CHP units, heat storage and electric boilers, illustrates how such small plants can provide valuable grid stabilisation at very low additional investment and operating costs (Lund et al., 2012).

According to Eurostat (2014), the use of natural gas for CHP has increased in the last years in Europe, representing 45% in 2013 (see Figure 3-12), and the use of renewable sources is also becoming more prominent, having reached 18% in 2013).

Figure 3-12 CHP fuel mix evolution in the EU (2005-2013)



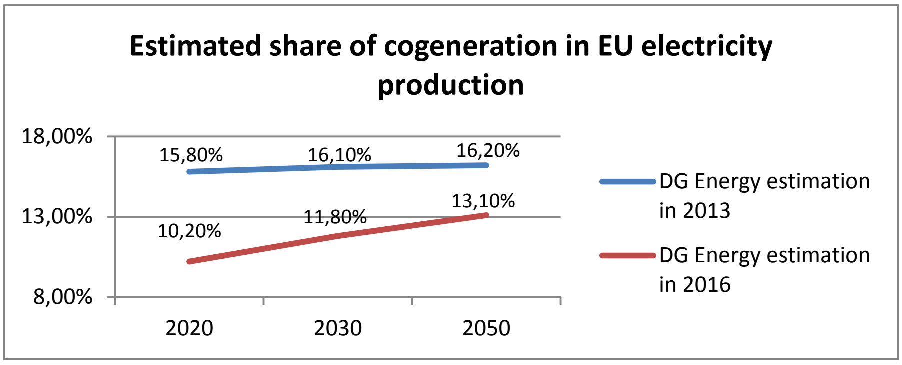
Source: Eurostat

The EC consistently supports CHP. However, the 2004/8/EC Directive on cogeneration (European Commission, 2004) failed to achieve the targeted efficiency gains (CODE 2, 2015). The current cumulative electrical capacity of CHP in EU-28 is 118.9 GW and represents 10.5 % of Europe's electricity (Eurostat, 2014 data), lower than the 11.1% it represented in 2004. The *Strategy for Heating and Cooling* (European Commission, 2016t) recognises that the potential of cogeneration (estimated at an additional 110-120 GWe) is not being fully exploited. The assessment of the potential for the application of high-efficiency cogeneration and efficient DHC performed in EU countries, pursuant to the requirements of Article 14 of the Energy Efficiency Directive (EED) (European Commission, 2012), points to the important role of cogeneration as a driving force of industrial competitiveness (Artiñano, 2017). For example, in Spain, a third of the more than 8,000 GWh of cogeneration potential, which could be implemented cost- efficiently (Ministerio de Industria, Energía y Turismo, 2016), corresponds to key industrial sectors, such as food, paper, and non-ferrous metals. Unfortunately, due to methodological differences in reporting under Article 14 of the EED, it is presently not possible to determine de Europe-wide cost efficient potential for cogeneration (Cornelis et al, 2017).

New technologies for cooling, polygeneration, and fuel cells are areas, in which the potential for cogeneration has yet to be fully realised (COGEN Europe, 2016a). However, DG Energy (European Commission, 2016u) has decreased significantly the estimations made in 2013

(European Commission, 2013) and now expects a rather moderate growth of CHP. Figure 3-13 shows the differences between the 2013 and the 2016 estimates for 2020, 2030, and 2050.

Figure 3-13 Share of cogeneration in EU electricity production. Estimations for 2020, 2030, and 2050



Source: own elaboration based on data from DG Energy

Opportunities for the European engineering industries

Heat pumps

The heat pump market is very interesting from the manufacturing perspective, since the sector's trade associations, such as SULPU in Finland, maintain that Europe retains technology leadership (Hirvonen, 2015). Among the key players in the market, we find EU-based companies such as Danfoss Group Global (DK), Viessmann Group (DE), Bosch (DE) and NIBE Group (Sweden).

Hybrid heat pumps are now common in the portfolios of all major heating equipment manufacturers, including Worcester Bosch, Daikin, BDR Thermea, Viessmann, Vaillant, and Ariston. The unit sales are to increase at least fourfold by 2020 (Delta-EE, 2015).

With hybrid products offering the potential to achieve A++ ratings on the new Energy Label and being able to open up the gas boiler replacement market (worth an estimated EUR 25 billion per year) for heat pumps, it is expected that heat pumps will perform well in this competition.

Cogeneration (CHP)

CHP is a core competence of the European economy. The EU is a market leader and is currently exporting its skills and products globally. These skills and competencies are a valuable economic and knowledge base for Europe contributing, to GDP and jobs (CODE 2, 2015). A large number of the leading companies operating in the market such as 2G Energy AG, Siemens AG, Edina Ltd., Wärtsilä Corporation and ENER-G Holdings Plc (ENER-G), are European (Transparency Market Research, 2016; JRC, 2011).

There is also a strong micro-CHP design and manufacturing competence in Europe. Micro-CHP products are now available from most boiler manufacturers in Europe and the sector is investing heavily (CODE 2, 2015). Some of the leading players in micro CHP market include Vaillant Group, Viessmann Group, Ceres Power Holdings Plc, BDR Thermea Group and Solid Power, among others (MarketsAndMarkets, 2015).

3.2.2. Main barriers to deployment

Due to a number of reasons, progress in highly efficient or renewable heating and cooling solutions is slower than progress in implementing highly efficient or renewable electricity generation options (Öko-Institut et al., 2017):

- Ownership and decision-making for heating and cooling are more distributed than in the electricity sector.
- Heating and cooling has received less attention from the policy side up to now.
- Compared to renewable electricity, zero- or low-carbon options for heating and cooling are still relatively more expensive, leading to higher carbon abatement costs (as compared to options in the electricity sector).

The following are the main barriers to a more efficient management of heat and electricity:

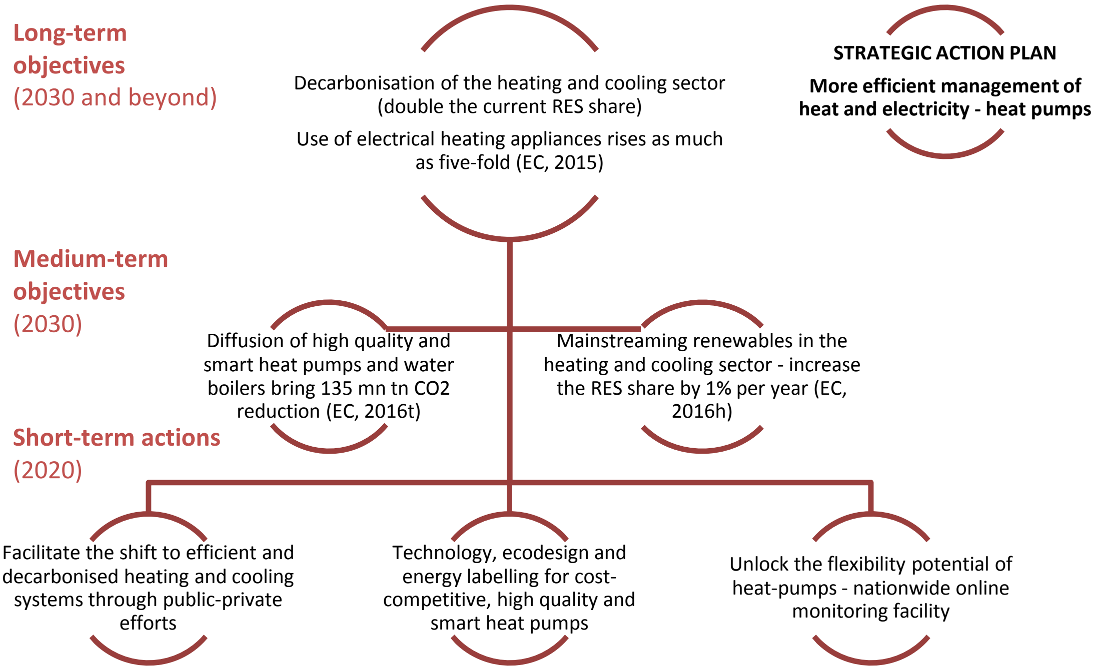
- A thorough quantification of the benefits associated with DR involving heat pumps is still a challenge. The problem relates to the establishment of clear baselines ("what would have happened if the DR option would not have been activated"). Besides, the deployment of DR in the residential or commercial sector requires substantial investment in grid infrastructure (Patteeuw, 2016). Domestic energy savings do not provide a very strong incentive to individual households to undertake DR with their micro-CHP unit. Houwing et al. (2011) concluded that, with DR variable, energy costs are between 1–14 % lower than with heat-led control (equivalent to 9-112 Euro per year/per household). Cost savings with DR strongly depend on the structure of the real-time electricity tariffs: with stronger-fluctuating tariff structures, savings are higher. In Germany or the Netherlands, fuel bill savings by using micro-CHP are between 26% and 34% (Delta-EE, 2015a).
- Due to the recently low price of natural gas, the operational costs of electrical heat pumps are not competitive when compared to traditional gas-fired boilers in some countries like Belgium. This problem is greater in those countries, in which the societal costs of renewable electricity support schemes (e.g. green certificates) are financed by a surcharge on electricity tariffs.
- For CHP, there is a complex need to comply with electricity and heat supply, as well as energy efficiency regulations (European Commission, 2016t). Regulatory uncertainty arising from the significant changes in recent years in both the electricity market and the heat markets make CHP investment high-risk (CODE 2, 2015). This is especially hampering the market diffusion of micro-CHP (Ezeamama, 2016).
- Small CHP operators tend to be new players with small portfolios and less ability to control risks, which leaves them often at a disadvantaged position compared to established utility players in charge of large industrial CHP (JRC, 2011). Besides, grid connection and grid access barriers (slow processes for granting permits and high charges) are higher in the case of smaller units (European Commission, 2016t; IEA, 2008, CODE 2, 2015).

- The lack of adequate, consistent, and stable support schemes (COGEN Europe, 2016) is not contributing to address the aforementioned uncertainty.
    - In the case of heat pumps and water boilers, there are few attractive financial products for building renovation (European Commission, 2016t) and this is hampering the deployment of the market.
    - These support schemes are crucial in the case of cogeneration, which involve higher upfront investments compared to conventional generation and distribution systems (OECD/IEA, 2014).

3.2.3. Strategic action plan

3.2.3.1. Heat pumps and water boilers

Figure 3-14 Strategic Action Plan for the opportunity "More efficient management of heat and electricity – Heat pumps and water boilers"



Source: own elaboration

Long term objectives (2030 and beyond)

- **Decarbonisation of the heating and cooling sector (double the current RES share)**
- **Use of electrical heating appliances rises as much as five-fold**

According to Thomas Nowak, secretary general of the European Heat Pump Association, "Solutions that are not '2050 ready' should not be promoted anymore. Instead, renewable and highly efficient solutions must be phased-in quickly. The industry is ready for this but requests clearer goals" (Fletcher, 2016). "The decarbonisation of the heating sector will play a fundamental role in achieving the ambitious Energy Union goals and meeting the EU's climate targets" (European Commission, 2016t). According to the EC (2015), "the heating and cooling sector will see a significant increase in the use of renewables, in particular in the household sector and in particular towards the use of biomass or biogas". Renewable energy share in the heating and cooling sector was estimated to be 17.7% in 2014, and this amount is supposed to almost double by 2050 (European Commission, 2015). The EC also expects the use of electrical heating appliances to rise as much as five-fold.

Medium-term objectives (2030)

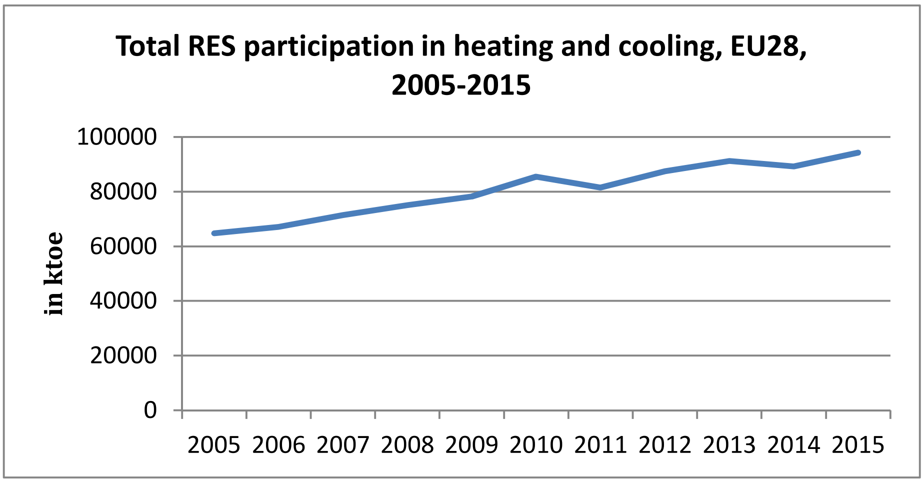
- **Diffusion of high quality and smart heat pumps and water boilers bring 135 MT of CO_2 reduction**

Much larger amounts of high quality heat pumps and water boilers (including hybrid heat pumps[17] and thermally driven heat pumps or 'sorption cooling systems'[18]) are to be introduced in all sectors. Collective heat supply will play a significant role in some Member States (MS). For example, in the Netherlands, collective heating solutions are expected to supply over 30% of heating demand by 2030 (Netherlands Enterprise Agency, 2015).

- **Mainstreaming renewables in the heating and cooling sector - increase the RES share by 1% per year**

The EC (European Commission, 2016t) proposes to increase the share of renewable energy in heating and cooling by 1 percentage point per year until 2030. This proposed rate seems rather low when considering the historical increase of RES of 32% in heating and cooling over the last decade.

Figure 3-15 Total RES participation in heating and cooling, EU 28, 2005-2015



Source: own elaboration based on Eurostat's Shares tool

The low rate may reflect the fact that developments in this field are highly dependent on support actions in the MS and determined by the historical configuration of heating solutions in the building stock, which makes it necessary to ensure flexibility in choosing adequate strategy solutions (European Parliament, 2016). The Parliament therefore proposes to combine "the most advanced technologies with smart energy management, for example through home automation and smart heating control systems, especially in a connected world where the appliance can easily adapt to weather conditions and electricity price signals and contribute to the stabilisation of the grid by shifting demand". By providing flexibility to the electricity market, advanced heating systems can become easier to finance by private entities, since they provide additional revenues, which older, inefficient systems cannot obtain.

Smart strategies for controlling Heating, Ventilation and Air-Conditioning (HVAC) units should receive greater attention from policy makers, since they account for 40% - 60% of peak loads in commercial and residential buildings (Alhaider, 2016). In this context smart grid solutions, combined with solar and smart thermostats (Lombardo, 2016), can help to cope with increasing demand for air-conditioning in Europe, which stems from the desire for comfort and climate change effects, i.e. longer periods of high temperature.

[17]The technology combines air source heat pumps and gas boilers (PHAM News, 2015)

[18] While the majority of heat pumps today use electric compression units, thermally driven heat pumps using the sorption cycle are a promising technology for heating, and can also provide cooling. These so called 'sorption cooling systems' are regarded as one of the most efficient technologies to convert RES and excess heat into cooling (European Technology Platform on Renewable Heating and Cooling, 2014).

Short-term actions (2020)

➢ **Facilitate the shift to efficient and decarbonised heating and cooling systems through public-private efforts**

Almost half of the EU's buildings have individual boilers installed before 1992 with efficiency of 60% or less. 22% of individual gas boilers, 34% of direct electric heaters, 47% of oil boilers, and 58% of coal boilers are older than their technical lifetime. Building refurbishment is a good moment to undertake the renewal of heating systems. However, the rate of building renovation is low (0.4 to 1.2% per year) (European Commission, 2016t).

Attractive financial products can accelerate building renovation. The EU strategy on heating and cooling establishes that a share of energy efficiency funding should be dedicated to invest in energy-efficient heating and cooling equipment in energy-poor households or in the most deprived areas (European Commission, 2016t). Over the period 2014-2020, the European Regional Development Fund and the Cohesion Fund will invest EUR 17 billion in energy efficiency in public and residential buildings and in enterprises. Besides, financial incentives provided by public funds will have to be linked to the energy savings achieved, as suggested by the legislative proposal on the Energy Performance of Buildings Directive (European Commission, 2016s).

Empowering communities to contribute to a diverse, low carbon energy mix has been a successful option in the UK, through the Community Energy Funds. Under this programme, urban and rural communities received £10m and £15m, respectively, between 2013 and 2015. Through these funds, community groups can receive grants for technical feasibility studies, and loans for the later, more complex stages of project development. The funding help groups overcome the riskier stages of renewable development and attract commercial finance, or raise money through a community share offer (Department of Energy and Climate Change-UK, 2015).

Effectiveness of public funds must increase, but **private investors** have to be mobilised as well. The European Fund for Strategic Investments (EFSI) 2.0 is a key element for unlocking private financing for energy efficiency and renewables in buildings at a greater scale (European Commission, 2016q). The Commission is launching a European Buildings Initiative with a "smart financing for smart buildings" component. This new initiative, carried out in close co-operation with the European Investment Bank (EIB) and the Member States, can unlock additional EUR 10 billion of public and private funds until 2020 to develop a large-scale pipeline of bankable projects and establish an energy efficiency platform in every MS (European Commission, 2016r).

The SER Energy agreement's[19] advice on buildings, in the Netherlands (Netherlands Enterprise Agency, 2015) suggests:

- the elimination of inequalities in the tax on gas and electricity, to promote applications of renewable heat
- creating financial investment support for small-scale renewable heat options that offer a fair level playing field if compared to other options such as PV
- lowering the VAT rate for decentralised renewable options

[19] More than 40 organisations, large companies, provinces and NGO's have signed in 2013 the 'SER Energy Agreement' on:
Final energy savings of 1,5% per year
Final energy savings of 100PJ in 2020 compared with 2012
14% renewable energy in 2020, 16% in 2023;
15.000 full time job creation in the energy savings sector

- use of tax instruments around property tax rates, transfer tax, etc. based on level of use of renewable energy or energy performance of the building
- new positioning for hybrid heating networks and lower temperature systems.

➢ Technology, eco-design and energy labelling for cost-competitive, high quality and smart heat pumps

Heat pump technology still needs to improve in order to offer cost-competitive heat pump kits for houses with existing non-electrical boilers (European Technology Platform on Renewable Heating and Cooling, 2014).

Heat pumps (particularly the ones installed in new housing) already have the potential to create a link between the electricity network and heat storage (using a thermal buffer and a control system). The heat pump will, however, need to be given a smarter control so that it can determine when to start and when not to. In addition, the control must take into account the consumer's behaviour, climate data, and the thermal inertia of the building (Mosterd, 2016). Industrial heat pumps research should aim to deliver heat at medium pressure steam levels (around 200°C) by exploring alternative thermodynamic cycles for heat-pumping and heat-transforming (European Technology Platform on Renewable Heating and Cooling, 2014). In addition, much research is being done on phase changing materials (PCMs) and thermochemical storage as storage medium that can further increase the energy density (more heat stored in less volume) or make summer heat available in winter (Mosterd, 2016). Other studies point to liquid water heat pumps as preferred technologies (Flex4RES project, 2017).

Investment incentive for preferred technologies in the form of low-interest loans (FlexRES project, 2017), Eco-design and energy labelling requirements are crucial to enhance the market diffusion of advanced heat pumps, which can contribute to standardised control and communication solutions. The implementation of eco-design and energy labelling requirements is expected to bring annual energy savings of 600 TWh (European Commission, 2016t).

Eco-design and energy labelling requirements for space and water heaters came into force in 2015 and the sale of inefficient boilers is now banned (European Commission, 2016t). The CEN Heat Pump Keymark, coordinated by EHPA, lays the groundwork for a single certificate valid across all MS, which is fully compatible with the requirements of the Eco-design regulation. Companies that use other accepted certification schemes already benefit from a transition period (until 30 September 2017) (EHPA, 2017).

➢ Unlock the flexibility potential of heat-pumps - nationwide online monitoring facility

The heat pump can only contribute flexibility to the grid if it is able to respond to one of the following control signals: electricity price signals, availability of renewable power generation, scheduled periods with anticipated high demand, continuous one way signal from an aggregator, two way communications, or even frequency and voltage control. In fact, the heat pumps' contribution of flexibility to the grid depends much more on how the pump is able to respond to these signals than on the building or heat pump type, storage size and the number of systems installed (Mosterd, 2016). Economic investment incentives for flexible technologies can be enhanced in four ways (Flex4RES, 2017):

1. Decreasing the variable costs of flexible technologies: reduction in levies on electricity
2. Increasing the variable costs of inflexible technologies

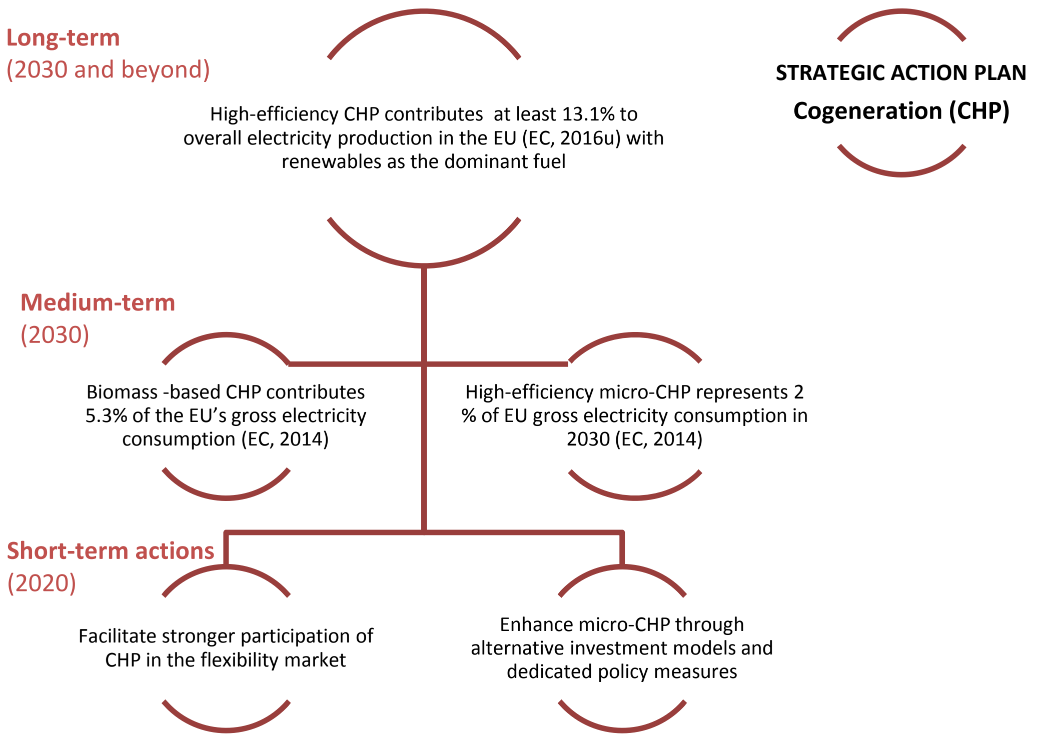
3. Decreasing the fixed cost for flexible technologies: address high capital costs of flexible technologies by subsidising or providing low or no interest loans
4. Increasing the fixed cost for inflexible technologies: adding levies on the investment cost of fossil fuel-based technologies.

A nationwide online facility for heat monitoring operated by a neutral independent party in cooperation with the grid administrators could offer benefit (by means of aggregating functions) for all stakeholders in the process of unlocking flexibility potential of heat pump (Mosterd, 2016):

- many functionalities are available for a large group of people involved at various authorisation levels
- monitoring electricity consumption offers the possibility of building up general profiles, based on which end users can offer smart energy concepts
- based on the historical performance curve, the consumer knows beforehand how to manage participation in demand-response. Monitoring also provides insight on the effect of user behaviour and the resulting energy consumption
- measured consumption offers valuable information that is useful for “peak-shaving” and “load balancing” and helps grid operators to better dimension new grid investments

3.2.3.2. Cogeneration (CHP)

Figure 3-16 Strategic Action Plan for the opportunity “More efficient management of heat and electricity – CHP”



Source: own elaboration

Long term objectives (2030 and beyond)

- **High-efficiency CHP contributes at least 13.1% to overall electricity production in the EU with renewables as the dominant fuel**

DG Energy (European Commission, 2016u) expects a moderate growth of CHP from the current 10.5% share in EU's electricity production to 11.8% and 13.1% in 2030 and 2050, respectively. The roadmap developed by CODE 2 (2015) foresees a more significant growth of CHP (20%), and expects RES to become the dominant fuel in 2050, if a rigorous implementation of the EED (European Commission, 2012) takes place at national level after the full assessment of the economically feasible potential in all MS. The more ambitious objective can be achieved if industry is guaranteed a secure planning horizon of 25 years to undertake the renovation of older and less efficient plants and the construction of additional cogeneration capacity (Artiñano, 2017).

Medium-term objectives (2030)

- **Biomass based CHP contributes 5.3% of the EU's gross electricity consumption**

The transition to a RES-based energy mix is slowly displacing fossil fuel based CHP plants (Morán, 2017). As a fuel, natural gas dominates the European CHP market, but renewable fuels, mainly biomass, are becoming increasingly important (European Commission, 2014). Biomass-based CHP is predicted to show significant growth, mainly in DHC systems, but also in industrial cogeneration. It is estimated that the installed capacity of biomass CHP in the EU-27 could grow to 52 GWe by 2030, contributing 5.3 % of the EU's projected gross electricity consumption. A decrease of at least 10% in capital expenditure for biomass CHP systems by 2030 will support this growth (European Commission, 2014).

- **High-efficiency micro-CHP represents 2 % of EU gross electricity consumption in 2030**

Micro-CHP will play a predominant role in domestic heating systems (Pehnt, 2006; Beith, 2004; DELTA EE, no date). Excluding fuel cell-based CHP and assuming mainly natural gas fuelled units, the estimated maximum potential for such CHPs in the EU-28 could reach 9 GWe by 2020 and 15 GWe by 2030. This represents about 1 % and 2 % of projected EU gross electricity consumption by 2020 and 2030 respectively (European Commission, 2014).

The market adoption of micro-CHP will vary across the EU. In 2014, between 62% and 71% of homeowners in Germany, the UK and the Netherlands found micro-CHP "appealing", when presented with product information and details of running costs (DELTA EE, no date).

Short-term actions (2020)

Real CHP growth in countries like Germany or Denmark is achieved by means of a well-designed governance structure, with a market- or subsidy-based support scheme implemented in the wider context of an overall energy efficiency or energy and climate plan (CODE 2, 2015). The new strategy on heating and cooling (European Commission, 2016t) calls for specific sustainable heating and cooling strategies to be developed at national level, giving special attention to combined heat and power, cogeneration, district heating and cooling (DHC), preferably based on renewables. These strategies should support new technologies, such as cooling, polygeneration, fuel cells, storage of high-temperature heat, etc., and also foster flexible CHP production for grid support, promote DR in CHP and facilitate cost competitiveness of CHP (see the following two measures).

➢ **Facilitate stronger participation of CHP in the flexibility market**

Flexible CHP production can play a significant role in the electricity balancing and grid stabilisation (Lund et al., 2012), but there is a lack of business models that reward energy flexibility and sustainability. Ensuring streamlined and clear grid interconnection standards to facilitate the exploitation of the flexibility potential of co-generation technologies is of utmost importance (OECD/IEA, 2014).

An example of the use of the flexibility of CHPs for grid support can be found in the Netherlands. The Dutch grid operator Westland Infra encountered grid congestion issues due to a massive growth of CHPs (Energeia, 2009). From 2008 until 2010, a successful mechanism was in place. After clearing of the day-ahead market, all CHP owners received their planning as if there were no grid issues. Based on that planning, CHP owners could bid how much they were prepared to pay to the grid operator for not delivering (ECW, 2014).

The Dutch TSO TenneT has adopted exactly the same principle in the Rotterdam Maasvlakte harbour area since April 2011 (Energeia, 2009). In both cases, the mechanism is a temporary measure until grid reinforcements are in place.

In Germany, the new CHP-Act (KWKG, 2016) gives an incentive to CHP plants to operate when they are needed, i.e. at times of higher electricity demand. This is because they will only receive the fixed premium for a limited number of operating hours (so-called full load operating hours). Therefore, the plants have an incentive to operate when the market price is higher. In line with the guidelines of the new regulation, CHP plants will not receive any support when electricity prices are negative, i.e. when supply exceeds demand.

➢ **Enhance micro-CHP through alternative investment models and dedicated policy measures**

In order to overcome the disadvantaged position compared to large utilities and electricity-only generation, alternative investment models that engage with individual households and minimise investment risks will be needed (JRC, 2011). Application of DR to clusters of micro-CHP in virtual power plants (VPP) could be another option (Houwing et al., 2011).

However, only a supportive policy framework at EU and MS levels can accelerate the transition of the micro-CHP sector from emerging technology to full-scale commercialisation. Delta-EE (2015a) suggests, among others, the following measures:

- reinforcing the position of micro-CHP as part of the supply-side measures that can help MS meet the building efficiency requirements
- clarifying the energy labelling methodology to fully reflect the primary energy savings of both heat and electricity produced by micro-CHP
- market uptake support for micro-CHP technologies: a sustained commitment to support field trials for emerging high efficiency technologies like fuel cell micro-CHP with the goal to reach market-readiness by 2020
- ambitious implementation of the energy efficiency directive (and the proposals suggested in its revision)

3.2.4. Key messages

- The challenge of integrating fluctuating power from RES in the electricity grid calls requires shifting from electricity-only smart grids to smart integration of multiple energy streams. Electricity smart grids must be coordinated with the utilisation of renewable energy and its conversion into other energy carriers other than electricity (Rong, et al., 2016). Seeing the electricity sector as part of a complete sustainable energy system paves the way for better and more cost-effective solutions to smart grid applications compared to looking at the electricity sector as a separate part of the energy system (Lund et al., 2012).

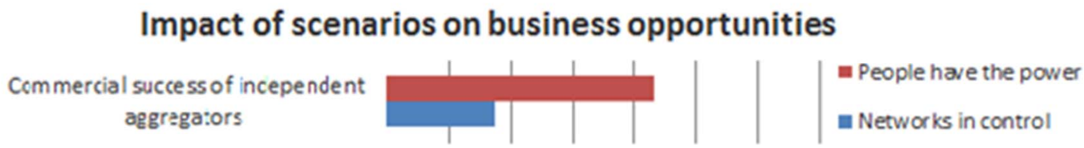
- More advanced CHP systems incorporating different types of storages and committed to achieve high utilisation of RES (Rong et al., 2016), as well as high quality heat pumps and water boilers, with automated demand-side control are crucial for achieving an optimised combined management of heat and power.
- The ambitious implementation of the 'Clean Energy for All Europeans' legislative proposals is crucial to allow a favourable and stable policy environment for a more efficient management of heat and electricity. Strategic local, regional and national heating and cooling planning, based on mapping of demand and source points to identify cost-effective opportunities, is crucial.
- However, the implementation of EU legislation at MS level is slow, selective, and heavily driven by the country's energy history. The lesson from the original 2004 Directive is that it will take considerable effort from all - industry, market and policy actors - if the EED is to receive rigorous and thoughtful implementation (CODE 2, 2015). Some MS, such as Denmark or the United Kingdom, are moving forward faster than others., but the range of regulatory arrangements in Europe hampers the replicability of project results in other countries (Mosterd, 2016).
- The expected savings from DR in VPP do not provide a very strong incentive to individual households to undertake DR. Pooling heat pumps or setting up clusters of micro-CHP via Virtual Power Plants (VPP) seems an interesting alternative, because it can increase the value that the heat pumps can deliver to the system.

3.3. Commercial success of independent aggregators

This opportunity contemplates the widening of business opportunities for independent aggregators in a liberalised and flexible European electricity market.

The survey results show that this opportunity is highly influenced by the different assumptions in the scenarios. The experts participating in the second survey commented that "regulation plays a fundamental role in removing barriers for solutions for smart grids that already exist", for example, independent aggregators.

Figure 3-17 Impact of scenarios on "commercial success for independent aggregators""



Source: own elaboration

3.3.1. Description of the opportunity

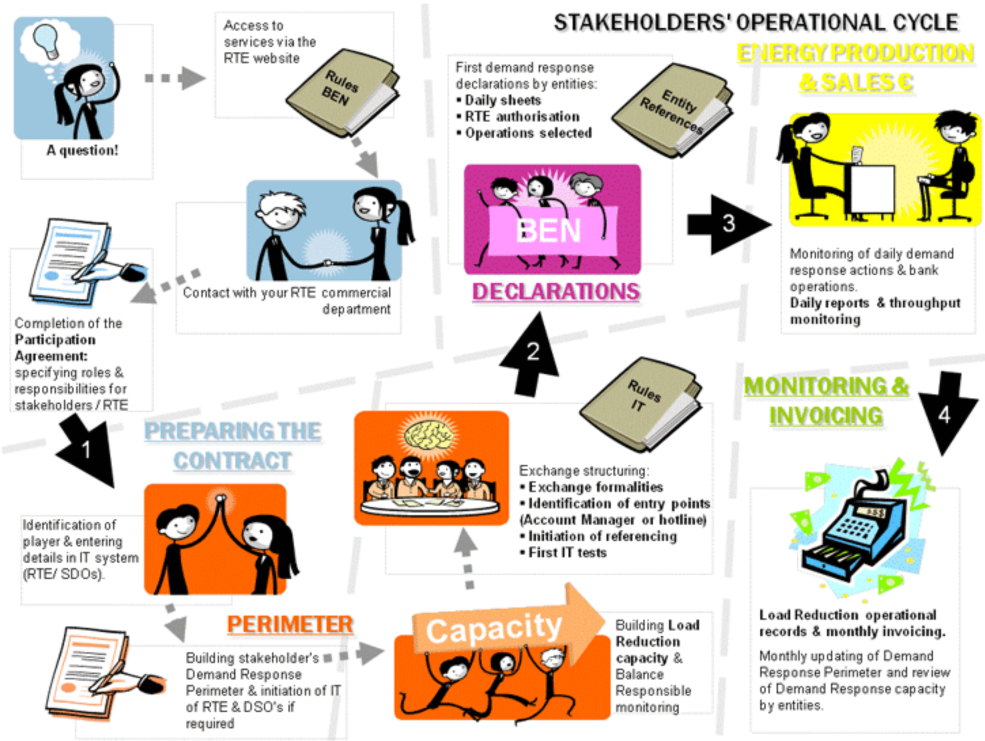
Europe is in the midst of a far-reaching transition in the energy sector, moving from a system based on fossil energy to a system based on sustainable energy and shifting from a system hinging on a few large-scale producers to a system with many decentralised, small-scale producers. These small-scale assets are more difficult to control centrally (NEXT Kraftwerke, 2016), so that aggregation starts to play a key role in network management.

Aggregation makes the flexibility potential of smaller customers available to the market, providing better market access for these customers and benefits from lower energy bills.

Aggregators are new entities in the electricity market that act as mediators / brokers between users (small consumers and distributed generation) and the utility operator / BRP. Aggregators possess the technology to perform DR services, as well as the pooling of small-scale generation units (Gkatzikis et al., 2013).

France is one of the MS, which has modified the regulation of the electricity sector to accommodate aggregated demand. Figure 3-18 shows the process for the incorporation of individual customers:

Figure 3-18 RTE description of operational stages involved in electricity load reduction



Aggregation is not limited to the demand-side, but can integrate supply-side elements in distributed energy networks, neighbourhoods or districts. The common element of these initiatives is the need for sophisticated ICT-tools, sometimes described as the "energy cloud" (de Heer et al., 2016).

Aggregators can combine resources from DR and distributed generation in Virtual Power Plants (VPPs).

The VPP concept was introduced in Europe after the liberalisation of the energy market, with the aim of enabling smaller DER to participate in larger markets (Dethlefs et al., 2015). VPPs are able to match load fluctuations through forecasting, advance metering and computerised control, and can perform real-time optimization of energy resources (Bayar, 2013). VPPs aggregate decentralised producers and demand-side flexibility (demand Response, storage) and help maintain a stable grid, ensuring the alignment of power demand and supply (NEXT Kraftwerke, 2016).

Flexibility can be activated for multiple purposes, with widely varying timing and technical requirements, but the use of flexibility always boils down to efficiently maintaining the energy balance while guarding the grid capacity constraints to prevent and/or mitigate emergency situations. Flexibility represents a way to better manage and decrease costs for the BRP, i.e. flexibility is an alternative for production by costly generation units or a purchase of electricity on the exchange during hours with high prices. While large industries can sell their flexibility directly to the BRP, aggregators collect flexibilities from different sources and provide access to the wholesale market for energy consumers with smaller loads.

The business of aggregation

There is some theoretical discussion going on for the long-term need of aggregators in a more sophisticated energy system. Some experts argue that aggregation may only create value temporarily, due to the present limitations of the power sector (i.e. incomplete information, imperfect coordination of responses of all agents to economic signals, and lack of response to price signals). Burger et al. (2016) identify three broad categories of aggregation:

1. Aggregations with "fundamental" or "intrinsic" value, i.e. not depending on regulations, market conditions or technologies advances, and permanent or near permanent in time

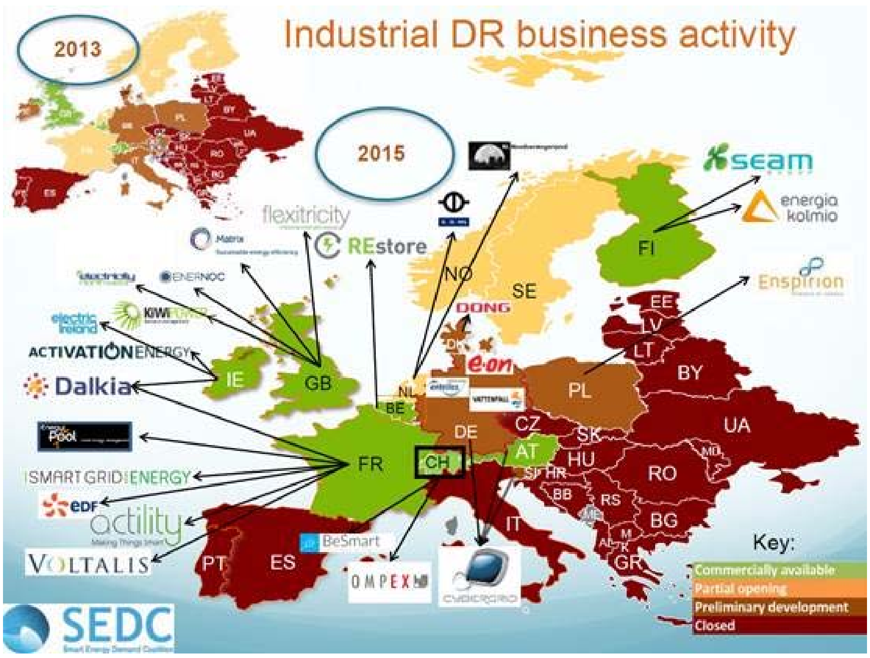
2. Aggregations with "transitory" value, contributing to the better functioning of the power system under the present and near-future conditions, but the value may decrease due to an improvement of the technical, managerial or regulatory conditions

3. Aggregations with only "opportunistic" value, emerged to take advantage of regulatory or market design "flaws"

Burger et al. (2016) propose that regulators and policy makers should take steps to encourage aggregation that creates fundamental or transitory value, while limiting aggregation that creates private opportunistic value.

This discussion will gain importance as markets in the MS open up for aggregation, as has happened in the UK, Belgium and France, which now offer attractive opportunities for commercial players.

Figure 3-19 Industrial DR service providers across Europe



In the UK, for instance, the National Grid (responsible of the matching of supply and demand on a second-by-second basis) would like to see 30-50% of capacity in the electricity-balancing market coming from DSR by 2020, in comparison with just 4% now (Schaps et al., 2016).

Aggregation at the residential level is less developed than aggregation services for industrial users. In the industry oriented business model, the revenue stream indicates that the TSO is the responsible party remunerating the industrial companies (potentially via the aggregator as intermediate party) (DRIP project). Aggregators can underpin the business model by offering smaller scale industrial stakeholders access to the energy market. The ADDRESS project identified a list of criteria, which a long-term strategy of an aggregator has to consider in order to be successful in the market, among them the need to establish a relevant portfolio and adapt it in the long term to the needs of flexibility requestors.

The INCREASE project (2017) has confirmed that the determination of the pool size and composition is especially relevant for a viable business model incorporating PV. The business model also has to consider factors such as energy price, the share of the profit that the aggregator receives from PV, income from flexible energy sales related to DR, and the software costs.

Bearing in mind that the calculations of the INCREASE project represent a simplistic energy system and that they investigated only one of many possible configurations that could be applied in the smart grid environment, these are the main conclusions obtained in the project:

– For small aggregators with small DR pools, including PV in their pool can make their business profitable.
– DR will most likely be accompanied by different storage options and the services will be sold on different markets.

Opportunities for the European engineering industries

Since there is presently no standardised model in Europe, relevant quantitative indicators on the market size of the emerging aggregator industry are not available. This situation is likely to change as the work on Smart Grid standards, including those applicable to aggregation and VPPs, is progressing (CEN-CENELEC-ETSI Smart Grid Coordination Group, 2017). Insights on the aggregator market were gained in an interview with Actility, a pioneer of the Internet of Things (IoT). Actility has customers all around the world, in Europe, China, Australia, Japan, and the US. Actility's partners and investors include important communication companies such as Orange, KPN, Swisscom, and Inmarsat, and technology giants like Cisco, Foxconn and Softbank (Actility, 2017).

3.3.2. Main barriers to deployment

Aggregators are "new players" in the electricity system and there are market barriers affecting the entry and market operation, along with competition between new entrants and existing market actors. The success of the implementation of the SG concept depends on the design of the legislative and regulatory framework and the market structure.

Relationship between the Balancing Responsible Party and the aggregator

The role of the BRPs is fundamental for the unfolding of the aggregator market. Presently, there is a lack of clarification of the rules, conditions, etc. of the relationship between the BRP as established provider of services to the grid, and the aggregator enabling the participation of consumers.

Most countries that have opened their product requirements to DR (e.g. France, Belgium, Switzerland, and UK) have also enabled aggregated load participation. However, the problem of "transfer of energy" (defined as the activation of demand-side flexibility that affects two different BRPs and/or suppliers), led different MS to limit the aggregation possibilities and allow DR participation in the market exclusively via the retailer/BRP. Thereby, the aggregator is reduced to a service provider for retailers rather than an independent party providing flexibility services.

Difficulty to identify, quantify and evaluate flexibility

Goldberg et al. (2013) discuss the difficulties related to determining the value of flexibility in the system. As a first step, a baseline calculation model needs to be defined in order to assess how a switched-off plant / facility would have continued running without the activation of flexibility, as mentioned in chapter 3.2.2. This DR baseline is an estimate of the electricity that would have been consumed by a customer in the absence of a DR event. This estimate is important because it allows the verification of a DR contribution compared to its contractual obligations and the compensation for participation or price settlement.

Stromback (2015) explains the current approaches for calculating this baseline reach from flat extrapolation of the last value for an event of limited duration to "more elaborate extrapolations based on the curve of the last 8 from 10 days". Baselines can also be calculated by creating a pool of customers with a similar load profile (Energyville, own research). Yet, the identification of flexible loads and the assessment of the exact potentials remain difficult and involve substantial efforts and high costs due to the necessary audit process (Delnooz et al., 2012).

Furthermore, the "rebound effect" has to be taken into account. As pointed out by the DRIP project (2015), load peaks may be generated during the recovery period of a previous interruption (activation of negative capacity), with the subsequent costs and negative effects for the customer and an increment in the system power losses. In addition, as indicated by experts active in the aggregator business, the BRP can be impacted by the rebound effect as the activation of flexibility and the load peaks during the recovery period influence the balancing schedule.

Overcapacities in generation present a barrier for the business case of independent aggregators

It is necessary that the price spreads in the market make DR profitable for the aggregator and the provider of flexibility. Some experts representing the demand side and research pointed to national markets characterised by generation overcapacities, which block the 'sense of urgency' for integration of flexibility in the market.

In some countries, such as Belgium and UK, this barrier does not exist, but in Germany, for example, it is still relevant and blocking large-scale demonstration projects. At the same time, a trend towards higher price spreads has been observed in some markets, for example, the Netherlands.

Regulatory acceptance and inclusion within the system of the new players is advancing slowly

Many MS do not yet officially authorise aggregation of flexible volumes. In the Spanish electricity system for example, no commercial aggregator is active in the market (IndustRE project, 2016). Regulators in Portugal, Spain, Italy, Croatia, the Czech Republic, Bulgaria, Cyprus and Malta have not yet enabled DR or aggregation (Bertoldi et al., 2016). As in different energy markets, certain requirements on minimum volume are applicable, the inability to aggregate volumes hampers the market participation of small flexibility volumes (Stromback, 2015).

Market dominance of traditional players will continue and aggregators will need to build relationships with consumers from scratch

For customers connected to the LV or MV grid, an aggregator interviewed in the study indicated that the traditional players (e.g. electricity retailers) will likely remain the key partner for offering DR services and products, thanks to well-established customer interaction channels. On the contrary, the aggregator will have to build the customer base from scratch, since access to a large number of household devices is needed before the residential DR business model becomes interesting. Nevertheless, there are examples for successful operation in the market. VOLTALIS in France, for example, is a thriving example of demand-side aggregation, since the company already has 100,000 members participating in their DR programme, according to information displayed on the company website. Energy Pool[20] is another relatively new company (founded in 2009), which offers energy management & DR for industrial and commercial electricity end-users in France (Smart Grid Today, 2014).

Risk of using flexibility on balancing markets

In some European countries, for example the Netherlands, passive balancing can be used to trade energy: purchasing energy through long-term contracts or day ahead markets and sell abundance (created through postponing processes) of energy on the balancing market. When the imbalance price exceeds the day ahead price, profits can be made, but only if this energy can be re-purchased on a later moment for a lower price (DRIP Project). If not, the flexibility provider incurs the risk of facing higher costs.

Due to the unpredictability of the spot market - currently comparable with derivatives of shares -, there is a significant risk involved using flexibility on balancing markets. The risk is especially high for postponed processes that have a limited time window before they need

[20] http://www.energy-pool.eu/

to restart, since the potential gains / losses are related to the variations of the energy price (DRIP Project).

To address this risk, flexibility providers can sign bilateral agreements with BRPs and/or aggregators, or trade platforms and so avoid the payment of high imbalance costs (SGTF-EG3, 2015).

Need for investments in the resilience of the grid

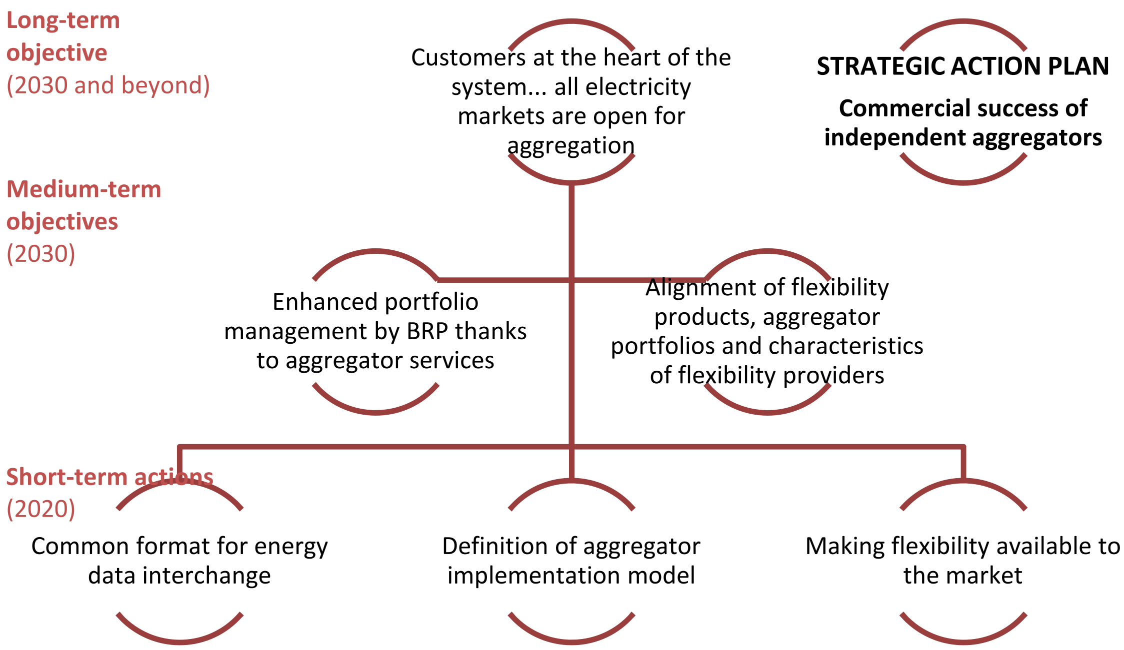
In an electricity system, in which a large number of actors and devices interact to increase flexibility, the risk of disturbances increases and it may therefore be necessary to search for solutions to enhance the resilience of the grid (EASME expert workshop). Resilience refers to the ability of a system to recover and to reduce the magnitude and/or duration of disruptive events (Alexander, 2013).

Resilience also gains importance in the context of potential climate change impacts. As extreme weather and other natural disasters will continue occurring and threaten or even devastate electric utilities' generation, transmission, and distribution systems, the electricity industry is developing innovative technologies to respond to these challenges (EPRI, 2017).

3.3.3. Strategic action plan

The following figure proposes a strategic action plan to facilitate the commercial success of independent aggregators.

Figure 3-20 Strategic Action Plan for the opportunity "Commercial success of independent aggregators"



Source: own elaboration

Long-term objectives (2030 and beyond)

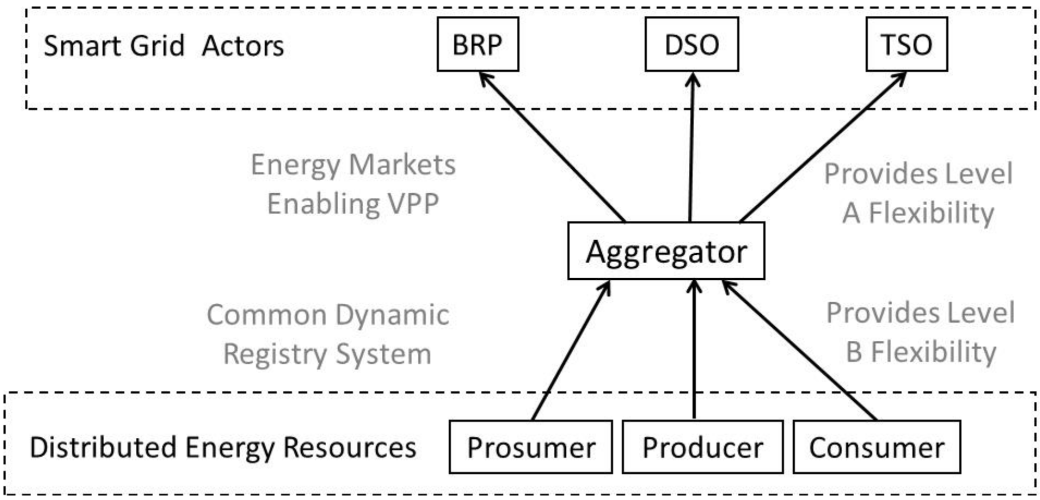
- **Customers at the heart of the system... all electricity markets are open for aggregation**

The recent proposals from the Clean Energy Package (European Commission, 2017) support the role of aggregation, stating that "market participation of consumers and small businesses shall be enabled by aggregation of generation from multiple generation facilities or load from multiple demand facilities to provide joint offers on the electricity market and be jointly operated in the electricity system, subject to compliance with EU treaty rules on competition".

Commercial success can be assured by a combination of "push and pull" strategies to help unlock the demand-side flexibility resource and to enable its overall market-based monetisation. This implies putting consumers at the heart of demand management and to allow them to become central participants in the electricity market, which benefit from different service offers that best suit their own needs and preferences (SEDC, 2016).

As shown in Figure 3-21, the proposal for a new market scheme from Dethlefs et al. (2015), distinguishes between aggregated flexibility (level A flexibility), which the aggregator offers to the SG market actors, including VPPs, and additional, B-level flexibility, which the aggregator draws form distributed energy resources (DER). The authors propose to create different registries to empower DER owners, who could sell their resources to different aggregators. The registries are to use common standards, as proposed by USEF (see below), but extend this idea to include the actors on the DER level.

Figure 3-21 Role of the aggregator in future energy markets as intermediate actor between large actors and DERs



Source: reproduced from Dethlefs et al., (2015)

Medium-term objectives (2030)

- **Enhanced portfolio management by BRP thanks to aggregator services**

According to a research representative, who participated in the first workshop, it is likely that SMEs, with the help of an independent aggregator, will participate in the balancing market. This view is supported by a demand-side expert, who perceives a "large untapped potential for flexibility in the residential and the SME sector".

The Linear project found that the potential of providing balancing services with residential flexibility sources is very effective in some short-time variations in the production of wind energy. Overall, the imbalance volume can be reduced up to 25.5% in ideal circumstances (Muhajir et al., 2012).

Smaller consumers could opt for a dynamic pricing formula in their energy contract when the BRP establishes price incentives in order to incentivise consumers to modify their energy consumption in real-time. Another special sub-model is "neighbourhood electricity", which can be facilitated by BRPs or aggregators[21]. They stimulate the creation of communities of prosumers and providers of distributed energy trying to balance supply and demand within these communities.

Alignment of flexibility products, aggregator portfolios, and characteristics of flexibility providers

By 2030, flexibility products have to be adapted for smaller loads and the characteristics of the flexibility sources to promote stronger participation by SMEs and citizens. The markets and regulatory frameworks will then include a wide range of actors, traded sizes, timeframes, and emerging products. Market requirements regarding the minimum bid size should not be prohibitive for small aggregated amounts (INCREASE project, 2017).

Likewise, new flexibility products need to be adapted to the characteristics of the source of flexibility, and these sources should include the so far untapped potential of other energy carriers, for example district heating systems and smaller volumes of flexibility, which residential consumers or SMEs can offer through aggregators. When defining these products, the BRP should also take into account the limitations of potential flexibility sources, such as CHP, storage technologies or environmentally dependent DER. i.e. wind and solar (Dethlefs et al., 2015).

Short-term actions (2020)

Common formats for energy data interchange

According to the proposals included in the Clean Energy Package (European Commission, 2017), consumers should be able to freely choose and change suppliers or aggregators and to engage in DR, self-generation and self-consumption of electricity, so every consumer is entitled to request a smart meter equipped with a minimum set of functionalities. De Heer et al. (2016) add that the measuring and validation processes should ensure correct and trustworthy data.

To implement this right, it will be necessary to define the rules on data sharing between the consumers, the suppliers and other service providers by clarifying the role of the parties responsible for data management and by setting a common European data format to be developed by the EC in an implementing act (European Commission, 2017). In line with this, information exchange and confidentiality rules should be defined, looking for the balance between transparency and confidentiality (de Heer et al., 2016).

The EC also foresees the creation of integrated short-term markets in order to deal with the regional level variability in an economically responsible way for both the consumers and the system as a whole (European Commission, 2017). Such integrated markets need common formats for energy data interchange, both in terms of data availability and access, and interconnection at European level, to deliver potential benefits for the system, but also for the European industry.

[21] See, for example, www.jurenergie-strom.de; www.regiostrom-altbayern-schwaben.de ; www.fichtelgebirgsstrom.de

A recent report by an ad-hoc group under the European Smart Grids Taskforce (European Smart Grids Task Force Expert Group 1, 2016) argues that an industrial initiative may allow achieving this approach, while looking for compatibility or alignment with existing systems and always ensuring compliance with European and national legislation. Industry can support the definition of energy services based on technical specifications in terms of interactive functionality, protocols, and data formats on European level.

➢ Definition of aggregator implementation models

MS are required to define frameworks for independent aggregators and for DR along principles that enable their full participation in the market. To stimulate consumer participation (either individually or through aggregation), more transparent real time price signals will be necessary (European Commission, 2017).

To better define the rules of the game for aggregators, USEF, the Dutch Foundation Universal Smart Energy Framework, has initiated a working group with representatives from the relevant stakeholders, i.e. TSOs, DSOs, suppliers, aggregators and balance responsible parties (BRPs). USEF propose the definition of an Aggregator Implementation Model (AIM), which describes the relation of the aggregator with the supplier and the BRP, and how balance responsibility, transfer of energy and information exchange are organised. The working group discusses aggregation models with an initial focus on four markets – Belgium, Denmark, Germany, and the Netherlands – and on industrial customers (de Heer et al., 2016).

USEF suggest taking into account the following considerations when defining AIMs:

- Flexibility is separated from the underlying energy supply, as the aggregator takes responsibility for the activation of flexibility and the supplier for the energy supply. In line with this, isolating the controllable asset used for DR from the other assets at the prosumer's site may help removing the responsibility of the aggregator for the uncontrollable load
- In case more than one supplier is allowed in the same connection point, balance responsibilities need to be clearly defined for the relation with dual supply models

Different business models for aggregation have been described in literature. For Denmark, Biegel et al. (2014) propose an architecture that permits an aggregator to control residential heat pumps and utilise them as portfolio for a VPP. The BESTRES project (Verhaegen et al., 2016) has identified the possible business models for aggregation, as shown in table 3-1.

Table 3-1 Business models for aggregators

Business model	Explanation
Combined aggregator - supplier	Supply and aggregation are offered as a package and there will be one BRP per connection point
Combined aggregator - BRP	There are 2 BRPS on the same connection point, the BRP (independent aggregator) and the BR (supplier). The supplier is compensated for imbalances.
Combined aggregator - DSO	Not tackled: regulated and unregulated roles should not be combined.
Independent aggregator as service provider	The aggregator is a service provider for one of the other market actors, but does not sell at own risk to potential buyers.
Independent delegated aggregator	The aggregator sells at own risk to potential buyers such as the TSO, the BRP and the

	wholesale electricity market
Prosumer as aggregator	Large-scale prosumers choose to adopt the role of aggregators for their own portfolios.

Source: reproduced from Verhaegen et al., 2016

➢ Making flexibility available to the market

To assure the commercial success of independent aggregators, the potential of flexible resources (which are disperse by nature) has to be identified, and must then be made available to the market through smart appliances or a fully Flexible Home (SEDC, 2016).

- From the market side, consumers should have some options to manage their own electricity consumption, and therefore their own electricity bill. For instance, customers should be able to self-generate electricity if they wish (SEDC, 2016)
- should be allowed to participate in the markets as "Flexibility Service Provider" independently from their supplier / BRP (Ranchere, 2014),
- should have the chance to choose the service offer most suitable for them (SEDC, 2016)

Regarding this third option, dynamic retail electricity tariff may enable consumers to make the best use of their local flexibility (SEDC, 2016). Dynamic pricing involves challenges such as the availability of sufficiently granular and frequent data for flexible rate deployment and absence of accepted standards for interoperability. Advanced communication channels are required and the customers must be guaranteed that the electricity bill will never be higher than the otherwise applicable tariffs (Cognizant 20-20 Insights, 2012).

SEDC (2016) proposes a series of measures to make flexibility available to the system and to enable the system for this flexibility, without negative effects on the consumer's lifestyle:

- introduction of a Smart Building Certificate to complement the European Energy Efficiency Certificate for buildings that offers a recognisable and marketable identification of the available Demand Flexibility (SEDC, 2016)
- complementation of the existing European Energy Efficiency Label for appliances with a smartness indicator, to show the potential of appliances to respond to external signals and to adjust electricity consumption (SEDC, 2016). The idea of a smartness indicator for buildings has been included in the proposal for a revised Directive on energy efficiency of buildings (European Commission, 2016s)
- programmes or plans at national level to renovate the oldest appliances by a new range of smart and efficient appliances (e.g. "Plan Renove" in Spain)
- training consumers to manage their own energy consumption in a more efficient way. For this, consumers need access to all data related to their own use of electricity at all time
- adaptation of standard market products to DR, suiting to technical requirements and including measurement and verification procedures, in order to enlarge flexibility participation in open balancing, reserves, capacity and wholesale markets to DR (Ranchere, 2014)

3.3.4. Key messages

In the following bullets, some ideas and key issues related to the opportunity of commercial success of independent aggregators are stated:

- Rules should be adapted on the one hand to make consumers´ flexibility (industrial, SMEs, tertiary, residential) available for the market and on the other hand to establish how market could use this flexibility in an optimised way, both technically and economically, to provide benefits to consumers and to the electricity system as a whole. The amounts of flexibility that can be offered to the system need to be small enough to allow for the participation of a wide range of consumers.
- Common data sharing and exchanging formats and protocols should be defined to expand the flexibility markets from national level to European level, as a key step to empower consumers, individually and collectively through aggregators, and to maximise the exploitation of the available resources in the grid on European level.
- Aggregator implementation models should be clearly defined, in order to determine the relationship between different parties and to ensure that the responsible parties support the operation requirements of the electricity system and the market rules.

3.4. Grid-scale and distributed storage facilities

3.4.1. Description of the opportunity

The term "Grid-scale Storage" comprises energy storage resources - usually with relevant capability - that are connected to the electricity grid for two main purposes:

- next to large generation plants, supporting energy storage backup and stability of grid parameters
- in the transport and distribution grid sections, supporting grid parameters stability functions (frequency and voltage, basically)

Alternatively, the term "Distributed Storage" applies to smaller scale energy storage resources connected to the distribution grid section and belonging to the grid end-user (consumer, producer or prosumer).

The survey results only discuss the role of grid-scale storage facilities, since the inclusion of distributed storage was one of the corrections introduced later on during the expert workshop. However, it is very clear that the "network in control" scenario would undoubtedly be more beneficial for large grid-scale facilities, whereas distributed storage would flourish in "people have the power" (see also Figure 2-6 in chapter 2 of this report). In a written contribution to the survey, one expert pointed out that further decentralisation of the grid, including a possible disconnection of distribution grids from the main grid, "strongly depends on the availability of small-scale storage facilities".

Figure 3-22 Impact of scenarios on "grid-scale storage facilities"

Source: own elaboration

Options for grid-scale storage were first considered when large amounts of production from RES started to enter the network: "Grid-scale storage sites are national infrastructure facilities able to absorb the output of entire wind or solar farms, and sustain level output for hours at a time before requiring recharging" (Holmes et al., 2015).

In the new scenario of electricity production and distribution enabled by Smart Grids (SG), grid-scale storage can play a very relevant role in solving both grid uncertainty and grid instability issues in a system with a significantly increased share of renewable generation at any connection point on the grid.

Storage is promoted as the "game-changer", which could contribute to solving three challenges in the electricity sector:

- the increasing need of resources contributing to the power and energy balance stability control of the Smart Grid in a scenario with a large deployment of Distributed Energy Resources (DER) and Demand Side Management (DSM)
- the volatility challenge of renewable energy resources connected to all grid segments (transmission and MV/LV distribution), especially for electricity generation from wind and solar
- the progress of self-consumption and in the prosumer role behind the Smart Meters

It is likely that grid-scale storage deployment will grow in response to the plans for further deployment of renewable distributed energy resources (DER). The question was discussed during the first expert workshop and, although there was consensus on the need for storage to balance the grid, there were doubts about which type of technology is better suited, i.e. large facilities or small-scale options. One of the participating experts commented that "the need for grid-scale storage is determined by other developments in the network (use of smaller storage devices on the household level, existing overcapacities, etc.), so that a strong market uptake is not assured before 2030. There will be, however, niche markets, for example on the sites of large customers or as a solution to overcapacities in generation. But the outlook for this opportunity is more uncertain than for the other opportunities" discussed during the workshop.

The costs of storage technology - traditionally considered not viable - are now affordable due to the improvement of the performance of some technologies and the public policy commitment to a low carbon energy system, significantly increasing Renewable Energy Sources (RES)-based DER as a share of electricity generation (EASE/EERA, 2016).

On the other hand, SG enables storage to embrace several applications and to provide different services to the grid (Table 3-2). Depending on the specific regulation, possible different owners or actors in the energy market could be considered, i.e. TSO/DSOs, producers, consumers, and prosumers. Aggregators can play a relevant role by giving visibility and dimension to the storage systems distributed in the premises of the small and medium producers, consumers, and prosumers. In this sense, it is possible to talk about "Virtual Storage Plants", similar to "Virtual Power Plants".

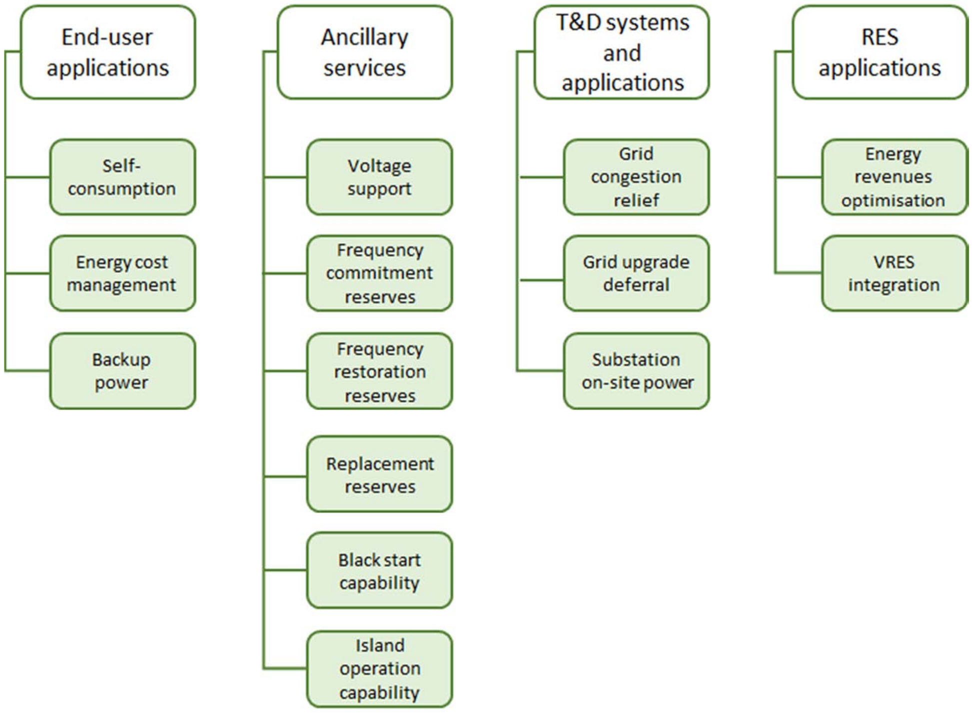
Table 3-2 Overview of energy storage applications

Generation/Bulk Services	Ancillary Services	Transmission Infrastructure Services	Distribution Infrastructure Services	Customer Energy Management Services
Arbitrage	Primary frequency control	Transmission investment deferral	Capacity support	End-user peak shaving
Electric supply capacity	Secondary frequency control	Angular stability	Contingency grid support	Time-of-use energy cost management
Support to conventional generation	Tertiary frequency control	Transmission support	Distribution investment deferral	Particular requirements in power quality
Ancillary services RES support	Frequency stability of weak grids		Distribution power quality	Maximising self-production & self-consumption of electricity
Capacity firming	Black start		Dynamic, local voltage control	Demand charge management
Curtailment minimisation	Voltage support		Intentional islanding	Continuity of energy supply
	New ancillary services		Limitation of upstream disturbances	Limitation of upstream disturbances
			Reactive power compensation	Reactive power compensation
				EV integration

Source: EASE/EERA, 2016

From the set of services listed in Table 3-2, the BATSTORM project identified applications for which stationary battery storage appeared to be most suitable within the European energy system (BATSTORM project, 2016). The established overview, depicted in Figure 3-23, can serve as a good indicator of the business opportunities for stationary battery technologies. The different applications were divided into four main categories, being end-user applications, ancillary services, transmission and distribution applications and applications supporting RES. Batteries are well suited for applications, which range from minutes to multiple hours and technologies are available, which cover power ranges from 1kW until about 100MW. Moreover, batteries are typically very reliable and responsive with response times of seconds or even less.

Figure 3-23 Potential applications for stationary battery technology



Source: reproduced from BATSTORM project, 2016

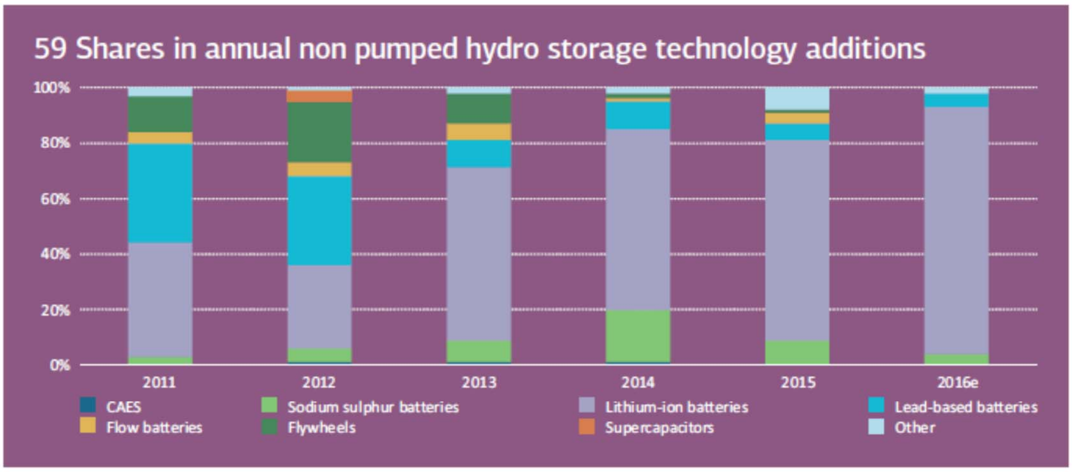
As indicated by the experts, the potential business opportunities for batteries and the energy services they can deliver within the system depend significantly on where the battery is deployed within the energy system. Depending on the specific location of the battery (i.e. transmission grid connected, distribution grid connected or behind the meter at a RES or consumer site) certain business models become impossible. The experts stated during the interviews that the further downstream a battery is located within the electricity system, the more services it can offer to the system at large. However, the applicable regulation framework could limit these services and the role of the participants.

Investors are now paying attention to large-scale storage options. The expert representative of investment fond SUSI indicated that ENGIE and SUSI Partners signed a Memorandum of Understanding (March 2016) to promote grid-scale power storage projects. As an initial stage, SUSI will contribute EUR 50 million in equity for projects that ENGIE intends to develop. From the point of view of investment funds, grid-scale storage is the most interesting case, as it allows for large-scale investments, but returns on investments of more than one year are presently nowhere secured.

To counter the uncertainty for investing in battery technologies, some TSOs are currently revising their ancillary services product definition and procurement rules. National Grid in the UK, for example, will procure a new faster-acting service - Enhanced Frequency Response (EFR) - aimed predominantly at storage assets, including stationary batteries, to provide frequency response in 1 second or less (BATSTORM project, 2016). In this context it is important to notice that National Grid is considering 4 year term contracts and allowing aggregation of multiple smaller sites as long as the service provision is unaffected (National Grid, 2017). This kind of regulatory action will make the business case for battery storage much stronger.

Figure 3-24 shows the development of installed energy storage capacity in recent years worldwide. It can be observed that pumped hydro storage is still clearly the dominating technology. Among the new solutions, thermal storage and large-scale batteries seem to be growing slightly faster than CAES (Compressed Air Energy Storage) and hydrogen solutions (IEA, 2016a).

Figure 3-24 Worldwide installed energy storage capacity

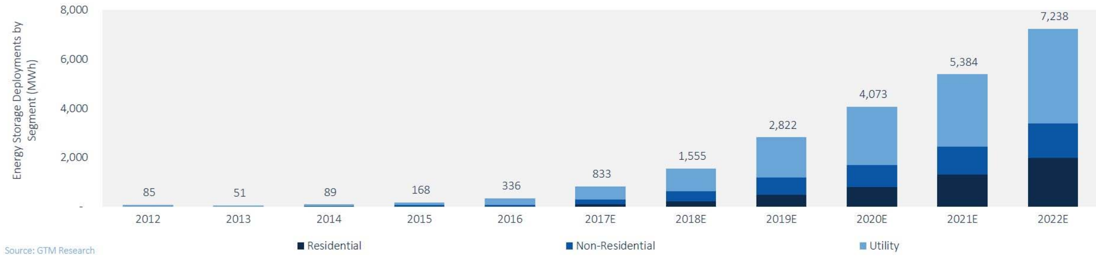


The Smart Grid, with its natural capability to integrate intelligent supervision and control systems (adaptive, estimative, predictive, autonomous, etc.), boosts the flexibility that storage can provide to the network. In that sense, SG opens the opportunity of technological activity and business niches in the domain of Storage-To-Grid integration applications, in the same way as the already recognised Vehicle-To-Grid (V2G) domain.

Most regulatory bodies are paying attention to grid storage issues and are aware of their relevance. The US Department of Energy (2013) states: “energy storage systems and the services they provide can be used in regulated and deregulated markets. However, for energy storage technologies used on the grid, regulatory policies and rules provide the framework for the business case and economics of storage systems. Other incentives, such as tax structures and asset depreciation rates significantly affect the economics for storage projects. All electrical grid-connected storage services, market opportunities, cost-recovery methods, cost-effectiveness criteria, incentives, and rebates are governed by a well-established regulatory oversight”.

The tendency in the US seems to be that, with the convenient regulation and promotion framework, distributed battery storage will overtake grid-scale storage as shown in Figure 3-25. “By the end of the decade, however, distributed batteries will edge out centralised systems in front of the meter. Behind-the-meter batteries in homes and commercial sites will amount to 841 megawatts of capacity; front-of-the-meter storage will amount to 821 megawatts of capacity. In energy terms, utility-scale projects will still represent 54 percent of the market, giving that sector a bit of an edge" (Lacey, 2016).

Figure 3-25 Evolution of storage sector applications in the US



Source: GTM Research and Energy Storage Association (2017)

There is clear evidence for the support to the deployment of distributed storage "behind the smart meter", not only in the regulatory, but also in the economic domain.

At the residential level, the business opportunities for battery technologies are sprouting and the consulted experts provided several examples for this. Currently some markets and/or regulations stimulate the integration of battery storage systems in the energy system. In Germany, for example, the combination of decreasing feed-in tariffs for solar PV, support schemes for batteries and high electricity prices have created particularly attractive conditions for battery deployment at the residential level combined with PV (Normark et al., 2014). In addition, as storage has been allowed to bid into the balancing market in Germany via pooling, the business case can be enhanced by aggregating these residential battery units into a large virtual storage to offer reserve services in the balancing market (BATSTORM project, 2016).

Sonnenbatterie is another successful newcomer, which operates in the German and the US market. The company uses a marketing strategy that bets on creating a community of people striving for independence and safe power supply in case of extreme weather events. Sonnenbatterie offers this community not only services related to the battery itself, such as sharing energy, but also energy efficiency services[22].

Lumenaza, also in Germany, is a new software provider, founded by former Siemens employees, which targets a similar market as Sonnenbatterie, i.e. the 1.4 million roof top PV owners and the owners of small storage devices. The newcomer cooperates with utility ENBW in the creation of energy communities and regional energy markets, in which the small prosumers can trade surplus electricity at more attractive prices and sell it directly to other consumers[23].

Also in other MS, commercial parties are entering the residential market for battery storage. In the Netherlands, Eneco (one of the largest producers and suppliers of natural gas, electricity and heat in the country) is collaborating with Tesla Powerwall under the name of 'CrowdNett' to roll out 3.3 kW battery storage systems at an end-consumer investment cost of EUR 4,500, being EUR 2,200 below the market price (Eneco, 2017). Additionally, the project participants get a guaranteed CrowdNett-remuneration of EUR 450 during the first five years in return for 30 percent of each Powerwall's capacity. CrowdNett offers this

[22] Information obtained from Sonnenbatterie's website https://www.sonnen-batterie.com/

[23] http://energypost.eu/lumenaza-creates-regional-electricity-markets-want-connect-1-4-million-solar-pv-producers-germany-consumers-locally/

capacity as reserve service to TenneT, the Dutch TSO. This is a good example of creating win-win situations for all stakeholders involved.

The Austrian, Italian, and UK markets are also opening up to distributed storage and market newcomers. First mover Sonnenbatterie has created several communities in these MS, but there are also local start-ups, such as Moixa[24] in the UK, who offers a battery sharing option for households and commercial enterprises. The Italian market is heading towards growth, with sales of 5,000 units expected by the end 2016 (Mayr, 2016). The key drivers for development of the storage market are the uptake of rooftop PV, subsidy schemes, and regulation. Mayr (2016) explains that the net-metering scheme in Italy worked again the uptake of storage, but the main barrier was regulation: "Until April 2015, PV system owners were at risk of losing their right to incentives when installing battery storage. Now that this issue has been resolved and along with a tax deduction scheme subsidising 50% of the costs in place, the Italian residential storage market is finally making significant progress." In the case of Italy, the main players in the distributed storage market are Sonnenbatterie and Tesla

This increase of distributed generation could call for additional grid stability resources, probably based on storage and in a cyclical process. However, with the improvement of the capabilities, costs and flexibility of storage technologies, in parallel with a favourable regulation framework and the intelligent control and automation mechanisms provided by Smart Grids, the distinction between grid-scale and distributed storage is likely to become blurred.

Opportunities for the European engineering industries

The experts collaborating with the study confirmed that, even in the present situation, there are niche markets for grid-scale storage related to industries with high and sudden consumption peaks (investor interviews). This creates a playing field for energy service companies, which provide the required expertise for interaction with the electricity market and for combination with other facilities, such as CHP. When storage concepts are applied to district or neighbourhood level potential savings in terms of energy range from 1.2 to 15.26%, depending on the system design and seasonal demand (summer / winter). The monetary savings are highest when storage is linked to heat consumption (CHP), according to the findings of the COOPERaTE project.

Europe's engineering industry is slightly better positioned in the field of stationary storage, as compared to EV batteries, since ABB, Siemens, and Bosch are considered serious competitors (SBWire, 2017).

The wide range of storage alternatives enables the following economic activities:

- the design, development, installation and maintenance of storage systems supporting volatile generation in large RES (wind, PV) plants and the stability control of the grid
- system integration, especially in hybrid RE generation systems, at micro-grid level
- the design, development, integration and maintenance of smart supervision and control systems of the grid-scale storage capability and grid regulation stability

Storage can contribute to self-adaptive automatically processing, load state control, and forecasting, taking into account the conditions of the grid assets or the energy prices in the electricity market.

With respect to storage systems, EASE has carried out a study on the industry competences available in Europe for different storage technologies (EASE/EERA, 2016). Table 3-3 summarises the findings.

[24] http://www.moixa.com/

Table 3-3 European competences in storage technologies

Storage Technology	Competence level	Comments
Chemical Storage	+++++	• Rapid development in Europe in the recent years with vibrant developments in hydrogen technology
Electrochemical Storage	+++	• Strong in the most mature electrochemical storage technologies, such as Lead-Acid & Ni-Cd batteries. • Li-ion batteries, dominated by Asian actors and considered a one of the main drivers for electrochemical energy storage • Most NaS projects located in USA and Japan and some in France, Germany and UK • Alternative technologies to Li-ion in the term of 10-15 years (M Air, Na-ion, Li-S) could be an opportunity to Europe once significant improvements in cyclability.
Electrical Storage	++	• Ultracapacitors with larger producers in Asia. Main European producers in Germany and France • No European commercial supplier for Superconducting Magnetic Energy Storage (SMES), although some demonstrators and prototypes con be found in France, Germany, Italy and Spain
Mechanical Storage (Hydro Pump)	+++++	• Pumped Hydro Storage (PHS) is the largest storage technology in Europe and worldwide, but with a still relevant potential for growth. The eStorage project (eStorage 2015) estimates that 2,291 GWh of sites with existing reservoirs for new pumped hydro energy storage plants in the EU 15, Norway, and Switzerland) is ready for development. Led by Europe, with two thirds of the world market accounted for by European equipment manufacturers • R&D opportunities specially focused on mountain regions in Austria, Germany, Portugal, Spain, and Switzerland
Mechanical Storage (others)	+++	• Compressed Air Energy Storage (CAES) development led by the US. Adiabatic CAES, at demonstration process, is not yet commercially available although it has the potential to provide a large part of European storage need depending on geological characteristics. • Flywheel industry mainly located in the US although several projects are installed in France, Germany, Ireland, the Portuguese islands, Spain, and UK • Liquid Air Energy Storage (LAES) technology is basically led by the United Kingdom.

Source: own elaboration based on EASE/EERA, 2016

3.4.2. Main barriers to deployment

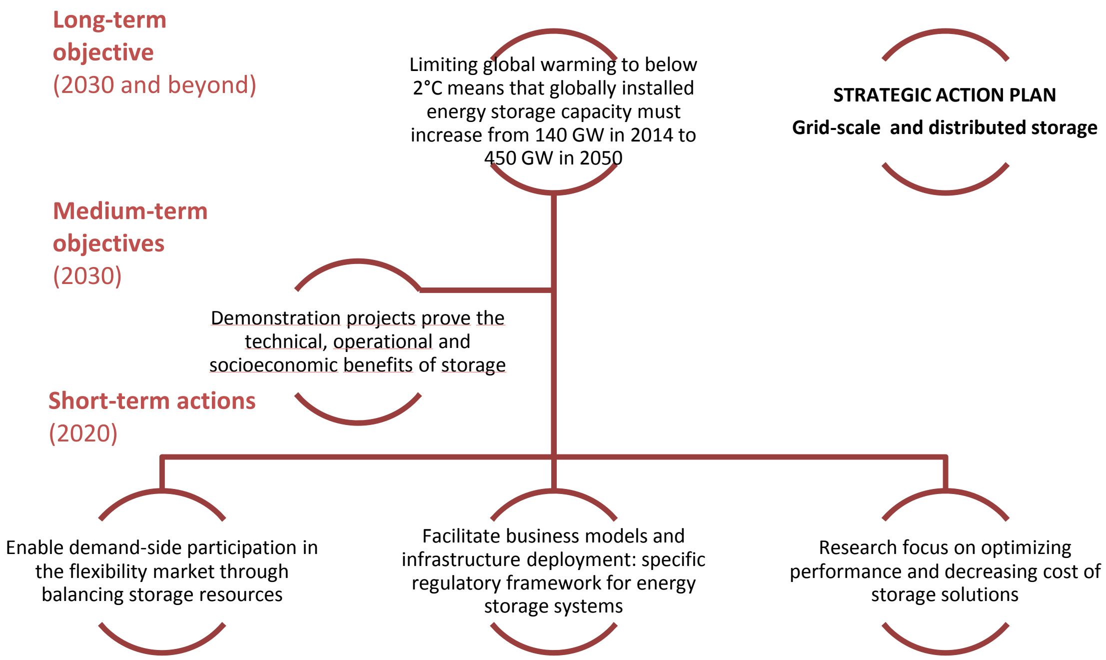
The main barriers considered for a relevant deployment of storage resources in the grid are listed in the following:

- Traditional Business As Usual (BAU) cost benefit analysis is not applicable to storage adoption given its versatility and flexible applicability. Holistic analysis has to be carried out considering technical features (functionalities, services, performance, etc.) and investment resources but also socioeconomic, environmental, and regulatory factors.

- EASE/EERA (2016) and EUROBAT (2016) claim that the regulatory framework has not yet evolved to support cost-efficient deployment of energy storage. The interviewed experts stated that it is not possible to regulate storage without having a definition of what storage is and the role it plays within the energy system and this leads to uncertainty about how energy storage devices should be treated under current regulations. The recast of the Electricity Directive (European Commission, 2017) solves this partially with the following definition of storage "energy storage means, in the electricity system, deferring an amount of the electricity that was generated to the moment of use, either as final energy or converted into another energy carrier". However, the definition does not clarify how to remunerate the different services that a storage device can deliver to the grid - for example frequency and voltage control - and to generation and consumption assets. EASE (2017) specifically highlights the need for harmonizing grid charges across the EU and raises the question of how storage's contribution to avoided grid investments is to be recognised.
- The present fiscal treatment, i.e. double taxation (BATSTORM project, 2016): "as end - consumption electricity taxes and fees were designed to charge every unit of electric energy, battery-based storage systems connected to the grid risk being charged twice, once when stored in the storage facility and once when consumed by the final consumer" (EUROBAT, 2016).
- The lack of suitable investment frameworks for a technology with a very high initial cost in applications causes long return periods for investments. Rapid technology improvement aggravates this factor, causing uncertainty among investors and the fear to invest in technology, which will become obsolete before the owner recovers the investment.
- Possible investments in storage by large industry users are often hampered by the fact that energy is not the core business of these industries.

3.4.3. Strategic action plan

Figure 3-26 Strategic Action Plan for the opportunity "Grid-scale and distributed storage facilities"



Source: own elaboration

Long-term objectives (2030 and beyond)

- **Limiting global warming to below 2°C will mean that globally installed energy storage capacity must increase from 140 GW in 2014 to 450 GW in 2050**

- "Alongside other flexibility options, energy storage will play a crucial role in the transition to a low-carbon energy system. The IEA estimates that limiting global warming to below 2°C means that globally installed energy storage capacity must increase from 140 GW in 2014 to 450 GW in 2050" (EASE/EERA, 2016, citing IEA 2014a).
- The EU's long-term policy objectives also clearly recognise and state the relevance of storage resources: "Cumulative grid investments costs alone could amount to EUR1.5 to EUR2.2 trillion, between 2011 and 2050, with the higher range corresponding to greater investment in RES. This investment is not only required for RES but also for the technologies that can support an increased share of RES in the system, including energy storage, interconnections, and smart grids" (European Commission, 2011).
- According to EASE/ EERA, this threefold increase is necessary because, as the EC underlines, "energy storage can support the EU's plans for Energy Union by helping to ensure energy security, a well-functioning internal market and bring more carbon-cutting renewables online". By using more energy storage, the EU can decrease its energy imports, improve the efficiency of the energy system, and keep prices low by better integrating variable renewable energy sources (European Commission, 2016h).

Medium-term objectives (2030)

- **Demonstration projects prove the technical, operational and socioeconomic benefits of storage**

To ensure de availability of storage technologies at affordable costs and with suitable functionalities and performance in different points of the transmission and distribution networks, R&D support, demonstration, deployment and financing programmes have to continue, with a holistic approach covering also the environmental and socioeconomic domains to avoid, for example, potential problems with critical raw materials.

Short-term actions (2020)

- **Enable demand-side participation in the flexibility market through balancing storage resources**

The EC has addressed the role of storage in the Clean Energy Package and proposes rules for effective participation of DR, with minimum bid sizes of one MW or less, which will benefit storage devices and small-scale RES (European Commission, 2017). Small-scale storage will also play a role in the empowerment of consumers and communities and support aggregation, enabling the consumers to respond to dynamic energy pricing.

The non-discriminatory charges for access to networks proposed by the Commission will benefit all types of storage technologies. DSOs are encouraged to use distributed energy resources, among them storage, to avoid costly network expansions. Network tariffs should not discriminate between production connected at the distribution level and production connected at the transmission level.

The dispositions on DSOs and TSOs have impact on the deployment of grid-scale storage. In general, utilities are not to "own, develop, manage, or operate energy storage facilities" (article 36). Under certain, although very limited circumstances there is the possibility of economies of scale, for example by aggregating utility-owned storage resources on the distribution level. The dispositions severely limit utility-owned storage, which "may be the cheapest option to meet system needs if opened up to a competitive bidding process" (O'Boyle et al., 2015).

Dispositions regarding TSOs are similar and their obligation is to facilitate the "effective participation of all market participants", including RES, DR, *energy storage facilities* and aggregators through a transparent design of the balancing market.

These proposals from the Commission clearly aim at creating, open, and competitive market for storage, although the concrete support mechanisms are yet to be determined.

- **Facilitate business models and infrastructure deployment: specific regulatory framework for energy storage systems**

A specific European Storage Framework is envisaged (ENTSO-E 2016) to clarify the role of storage in the different SG layers (equipment, communication, information, functions/services, and business scenarios).

The World Energy Council (2016) has published relevant recommendations for policymakers:

- to focus less on an investment cost only approach for storage technology assessment, which only rewards technologies with the lowest levelised cost of storage (LCOS). Cheapest is not always best, or possible
- to examine storage through holistic case studies within a specific context, rather than place faith in generic cost estimations
- to accelerate the development of flexible markets, working with transmission and distribution system operators and regulators to help quantify and realise the true potential value of increasing system flexibility
- to consider storage as a key component when planning for grid expansion or extension

The market value of storage is determined by the characteristics of the transmission and distribution networks and the concrete needs of customers. An investor interviewed in the course of the study pointed to one niche market: cold start of equipment with high energy demand. If DSOs and TSOs facilitate the detection of market niches, market uptake of storage solutions could accelerate.

The barrier of rapid obsoleteness of storage technologies can be addressed by business models, in which ownership remains with the supplier of technology (i.e. leasing or similar), services that are already being offered by some battery suppliers (Cichon, 2015), also for small and residential systems (BRE, 2016).

- ***Research focus on optimising performance and decreasing cost of storage solutions***

Research efforts will have to be extended to determine the actual value of storage for different types of solutions, in combination with SG solutions for DR and types of production units, such as CHP. EASE/EERA (2016) proposes that research should study "intelligent battery management, including the electronics and systems for quality control and battery "smartness"". After studying the potential of advanced battery systems, the association considers that battery costs can be reduced by 40% between 2020 and 2030.

3.4.4. Key messages

- There is a need for harmonization of national regulations on energy storage in the MS to ensure that this regulation does not hamper the full deployment of the services and applications that storage technologies can provide. Regulators have to define the value and remuneration of the different type of services that storage can deliver to the grids, generators, and consumers. Unwarranted double taxing - in particular the application of final consumption fees to energy storage - has to be eliminated, given that storage does not constitute final use of the energy (EASE/EERA, 2016).
- Large-scale storage will follow naturally the deployment of large (wind, solar) RE plants. Distributed storage, in coordination and/or integration with DER, will have an impact on the development of grid-scale storage. With the improvement of storage technologies, combined with SG management capabilities and adequate regulation, advanced storage systems, including distributed devices, will be able to deliver a larger variety of services to the storage owner and the grid than the technologies presently in the market. Although there was no clear consensus among the experts on this particular question, the developments in the most advanced markets, such as the US and Germany, point to the increasing competitiveness of small-scale storage.
- Support measures should aim at maximising the functionalities that a given storage installation can deliver to the grid, such as stability (frequency, voltage, etc.), energy balancing or RES penetration, independently of the owner of the installation.

3.5. Deployment of EV infrastructure

3.5.1. Description of the opportunity

There is a strong political will in the EU to advance towards much lower GHG emission levels in the transport sector. The EU's 2016 *Strategy for Low-Emission Mobility* (European Commission, 2016c) foresees that these emissions need to be at least 60% lower than in 1990. To reach this objective, decisive measures to foster the use of alternative fuels and electric mobility are required, since the EU reference scenario (European Commission, 2016f) indicates that, without any additional measures, EV and hybrid vehicles would only represent 5% of the total stock of Light Duty Vehicles by 2030 and 12% by 2050.

The experts expect that the deployment of the EV infrastructure will not be heavily influenced by the scenario assumptions, as shown in Figure 3-27.

Figure 3-27 Impact of scenarios on the deployment of EV infrastructure

Source: own elaboration

Recent market trends related to EV indicate that market uptake is accelerating. IEA reports firm commitments from 14 countries for EV stock objectives, "aspiring to bring 13 million EVs on the road by 2020" (IEA, 2016). Table 3-4 shows he commitments assumed by European countries, which add up to 5.8 million vehicles in 2020.

Table 3-4 EV stock objectives for 2020 in selected MS

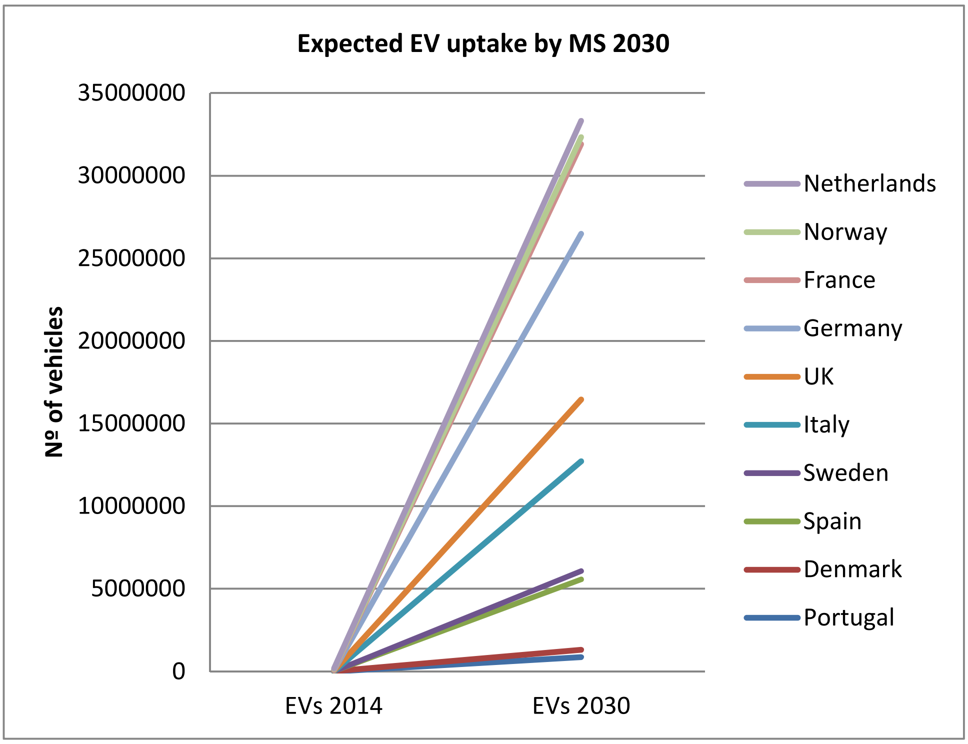
Country	EV stock 2015 (1,000)	2020 EV stock target (million)	Quantified objective 2020
Austria	5.3	0.2	4%
Denmark	8.1	0.2	9%
France	54.3	2.0	6%
Germany	49.2	1.0	2%
Ireland	2.0	0.1	3%
The Netherlands*	87.5	0.3	4%
Portugal	2.0	0.2	5%
Spain	6.0	0.2	1%
United Kingdom	49.7	1.6	5%
Total	264.1	5.8	

**Estimate based on a 10% market share target by 2020*

Source: own elaboration based on data from IEA 2016

Copenhagen Economics & VVA Europe (2016) present estimates for the development of this market by 2030, also for selected MS, corresponding to approximately 33.3 million vehicles (Figure 3-28).

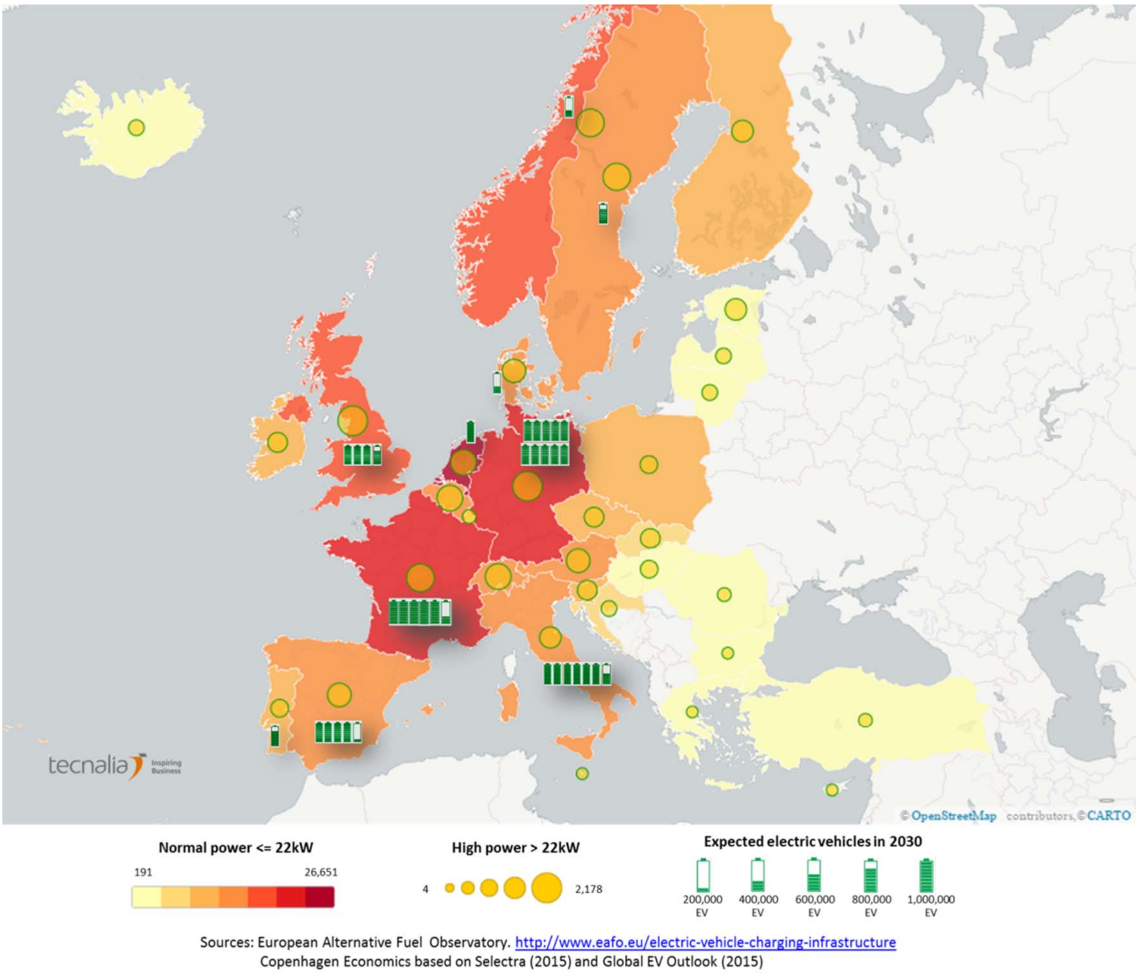
Figure 3-28 Expected EV market uptake 2030 for selected MS



Source: own elaboration based on Copenhagen Economics & VVA Europe (2016)

The basic condition for a quicker market uptake of EVs and hybrid vehicles – and the main challenge for the operators of the electric grid - is the deployment of the charging infrastructure. Figure 3-29 shows the present number of charging stations, distinguishing between normal and high power connections. High power connections (indicated in circles in the map) are those causing concerns in the distribution grid and their number tends to grow in the countries with the highest level of EV infrastructure deployment.

Figure 3-29 Number of EV charging stations in MS with high penetration of infrastructure



Source: own elaboration based on the indicated sources

The map shows the exceptional situation in Estonia, where high-power charging stations almost equal normal power chargers. This is due to the fact that the country deployed a network of 165 standard fast chargers[25], along with three different service packages and IT solutions for payment. The project was implemented as a turnkey solution by a consortium led by ABB[26].

The map also reflects the results of policy measures supporting EV deployment introduced in recent years – mostly in the form of purchase incentives and tax rebates - in some MS, namely France, Norway, the Netherlands, Norway, Portugal, Sweden, and UK (IEA, 2016).

[25] http://elmo.ee/estonia-becomes-the-first-in-the-world-to-open-a-nationwide-ev-fast-charging-network/
[26]http://www.eltis.org/discover/case-studies/elmo-estonias-innovative-national-quick-charging-ev-network

Opportunities for the European engineering industries

Opportunities for the European industries related to EV in an SG environment can be summarised as follows:

- Smart charging controlling both, charging time and power, to avoid grid congestion and investments in grid reinforcement
- The integration of volatile generation from RES such as solar and wind will be enhanced by aggregating and controlling the power demand for so-called load areas. This is especially relevant for urban areas, in which high concentration of loads is expected to occur, namely "residential neighbourhoods; at high-density locations such as campuses, shopping centres, and military bases; and at hubs for mobility-as-a-service businesses and fleets" (Gold et al., 2016).
- ICT applications for the management of EV fleets and new business models related to car sharing. It is estimated that the participation of a car-sharing operator in DR programmes leads to savings of EUR 206.50 per car and year i.e. cost savings of at least 42% in comparison to a simple plug-and-charge approach (reference Germany, Schmidt et al., 2015).

The direct impact on the European manufacturers is considered minor, because Japanese and Chinese companies presently dominate the EV vehicle battery market (Ayre, 2015). The engineering and service sector can obtain larger benefits from investments in the charging infrastructure: the cost of installing a charging station oscillates between EUR 2,600 for a 22 kW connection and EUR 15,250 for a 44 kW connection. The cost of fast charging stations is considerably higher (around EUR 90,000), to which another EUR 40,000 to EUR 100,000[27] has to be added in case that a new transformer and connection to the medium voltage network is required.

3.5.2. Main barriers to deployment

The main barriers to a quicker market uptake of EVs are described as follows:

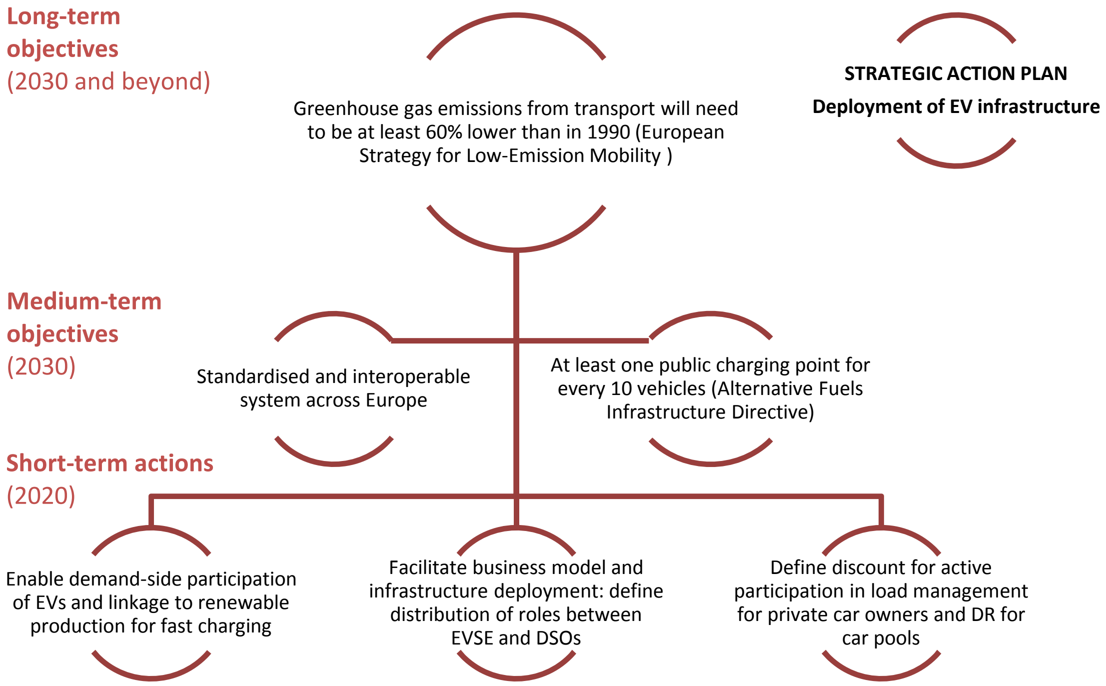
- IEA (2016) considers that the availability of charging points is still a key component hampering large scale market penetration
- Fast charging represents the main challenge from the point of view of grid management and can create a need for grid reinforcements (EASME SG expert workshop and Schäuble, 2016). Grid absorption capacities may be insufficient to provide 150 GW of additional generation capacity, which would be needed if 80 % of cars were electric by 2050 (EEA, 2016)
- The rules for the relationship between independent EVSE operator and the DSO for load management are not yet defined, rendering the business case for the former risky (Green e-motion project). Art.33 of proposal for common rules for the internal market in electricity (Recast Electricity Directive, European Commission, 2017) clarifies the basic principles of this relationship so that "any undertaking that owns, develops, operates, or manages recharging points for electric vehicles" can cooperate on a non-discriminatory basis with the DSOs. DSOs are allowed to fulfil the functions of an EVSE operator only if no commercial party is interested in providing this service and only for a transitory period.
- Interoperability between different charging service providers is not yet guaranteed (European Commission, 2016c and Green e-motion project)

[27] Information obtained from E.ON, cited by Hacker et al, and contrasted in personal communication with Iberdrola. The actual cost varies considerably depending on network characteristics and location.

3.5.3. Strategic action plan

Figure 3-30 summarises the short, medium, and long-term actions required for smooth deployment of EV infrastructure.

Figure 3-30 Strategic action plan for the opportunity "Deployment of EV infrastructure"



Source: own elaboration

Long-term objectives (2030 and beyond)

- **Greenhouse gas emissions from transport will need to be at least 60% lower than in 1990**

The European Strategy for Low-Emission Mobility (European Commission, 2016c) established the long-term objective for decarbonising the European transport sector. Decarbonisation is to be achieved through a combination of measures, including an accelerated transition towards low- and zero-emission vehicles and car-sharing concepts. The strategy foresees that, in the long term, EVs will interact with the electricity system and contribute to grid management. The short- and medium-term measures proposed here will help avoid or at least to mitigate negative impacts in term of increased electricity demand for transport, which EEA (EEA, 2016) has estimated in 150 GW, in case 80% of cars were electric in 2050. The strategy also mentions the problem of increased demand, which is to be "counter-balanced by lower demand in other sectors due to energy efficiency improvements" (European Commission, 2016c).

Medium-term objectives (2030)

- **Standardised and interoperable system across Europe**

Efforts to promote standardisation and interoperability are already under way. The EC has inaugurated a dedicated laboratory to ensure that "the next generation of electric cars and smart grids are fully interoperable, based on harmonised standards, technology validation, and testing methods" (European Commission, 2016c). However, technical standardisation has to be accompanied by Europe-wide standardised billing systems, as well as user information about charging point availability, characteristics, and costs. Information in GPS systems will have to be updated to inform about urban areas open to EVs only and local parking policies, if they promote the use of EVs. The need for a combination of infrastructure plus service is behind the recently created alliance of E.ON and e-mobility specialist CLEVER, which will roll out several hundred ultra-fast charging stations in Europe (E.ON, 2017).

- **At least one public charging point for every 10 vehicles**

The Alternative Fuels Infrastructure Directive recommends this ratio of charging points and vehicles and contains a reference to regulation on electricity, but does not mention the potential use of renewable energy in high-density areas. In order to be aligned with the renewable energy objective of 27% by 2030 and to avoid costly network expansion, the feeding in of renewables in appropriate charging sites could be considered. The full integration of PV for EV-charging in the grid requires improved interfaces and power control strategies, while the use of wind energy is necessarily limited in urban spaces (Ashique et al., 2017). Yet, field trials are under way: ČEZ Electromobility is running such a trial in the Czech Republic to test the integration of charging stations, an energy storage system, and a renewable energy source (ČEZ Group, 2016).

Short-term actions (2020)

- **Enable demand-side participation of EVs and linkage to renewable production for fast charging**

Strains on the distribution grid in densely populated urban areas, in which fast charging stations are likely to be deployed, can be alleviated by injection of electricity from renewable sources. Space could be a limiting factor here, but the possibility should be explored with support from the responsible DSO when authorisation for the installation of a charging station is requested. Even if electricity grids are not yet fully prepared for the interaction of renewables, EVs and batteries, examples for innovative business offers already exist in Europe. Fastned in the Netherlands is a fast-charging service provider of EV, which already offers 100% renewable energy in its nation-wide network[28]. Part of this energy is generated by PV modules on the roofs of the charging stations. The Dutch city of Utrecht has successfully implemented a solar charging system for EVs, using technology supplied by Nissan. In the case of Utrecht, solar energy is stored in the batteries of EV and can be activated for quick loading[29].

- **Facilitate business model and infrastructure deployment: define distribution of roles between EVSE and DSOs**

Electric mobility is a promising business opportunity for retailers – often associated to DSOs - and new market actors such as EVSE, according to the expert interviews. National legislation is in place in many MS to promote the use of EVs, but the role of specialised service providers needs to be further defined to allow for secure growth of this business opportunity. According to Schäuble (2016), careful planning of EV infrastructure deployment is required to overcome technical challenges of fast charging, but reinforcements of the distribution grid may be unavoidable. Time signals in electricity pricing, along with active monitoring and control, ease the impact on the network and reduce the risk of curtailment for the EVSE. If SG functions establishing a high level of communication between the DSO and the EVSE, and optimum interaction with the network are not deployed, there is the risk of the DSO disconnecting the EVSE in emergency situations - with or without consent (Übermasser, 2015). The Irish utility, ESB, points to another option, which would also

[28] See https://fastned.nl/en/locations
[29] See http://smartsolarcharging.eu/en/category/news/

interfere with an EVSE's business case: "it is likely that Load Control will be developed commercially for use in the market, but will be operated with DSO & TSO 'override' to ensure that it is not operated in such a way so as to breach standards or endanger the safe and secure operation of the system" (ESB, 2015)

The combination of active DR, aggregation of demand and storage can help to overcome these difficulties and enable innovative business models, as a pioneer example from Denmark is demonstrating[30].

- **Define discount for active participation in load management for private car owners and DR for car pools**

Subjecting the use of the car to electricity prices in a given hour could be detrimental to market uptake of EV. For this reason, the rules and benefits of participation in load management should be clearly defined and the benefits quantified in order to create an incentive for the vehicle owner to adapt charging patterns to the needs of the electricity systems. Trials by EdF and by the local energy supplier in San Diego (US) have shown that, with ToU, 70 to 80% of the EV owners predominantly charge their vehicle at off-peak times, even if the incentive is moderate (ICF, 2016).

3.5.4. Key messages

- Smart charging strategies controlling both charging time and power can significantly reduce the costs for grid integration of charging infrastructures (Eurelectric, 2015a). Smart charging, along with car sharing in urban environments, also helps to curb additional electricity demand derived from electrification of transport. According to IEA estimates, slow charging can add flexibility to the system during hours of peak demand: 125,000 EVs could provide 300 MW of flexibility (IEA, 2016), so that the impact on the LV grid would be limited, if the charging infrastructure and the accompanying IT components support the interaction with the network.
- Fast charging of 43 kW to 200 kW (and up to 350 – 400 kW in the future) will create strains on the distribution networks, so careful planning and siting is required, which takes into account the characteristics of the local network. The electricity market design initiative (MDI) aims at increasing the consumers' ability to use self-generated electricity from PV for charging vehicles, and similar concepts - also including small-scale wind power - should be implemented in high density locations and car pools.

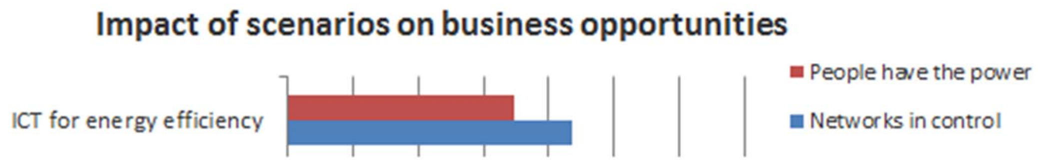
[30] See http://nuvve.com/

3.6. ICT for energy efficiency

3.6.1. Description of the opportunity

According to the survey results, DSOs are likely to adopt ICT solutions leading to greater efficiency in the production and distribution chain under "Network in Control" (see Figure 3-31). One of the experts, who participated in the first workshop, explained the different evolutions in the scenarios as follows: "if RES are high in the scenario 'Networks in control', the grid has to be equipped with more ICT related to prediction rather than connecting devices".

Figure 3-31 Impact of scenarios on "ICT for energy efficiency"



Source: own elaboration

The smartening of the electricity system through the incorporation of ICT devices can have a positive impact in terms of efficiency along the entire value chain of electricity production and distribution. The most important and documented effect is the avoidance of new network investments through smart management of production units and smart substations, which is estimated at 20% of new investment per year in the case of Germany. The effects are cumulative, so that by 2032, about 60% of new network investments could be avoided (Büchner et al., 2014). The study also found that supply side management has a stronger impact on system efficiency than demand-side management, although a combination of both can be highly beneficial. An early analysis from the US on the effect of voltage control in distribution grids estimated that for every 1% reduction in voltage levels during times of high peak demand, utilities expect to see 1% reductions in electricity consumption (US Department of Energy, 2012).

Distribution grid automation is presently attracting high levels of investment ($7.32 billion in 2014 and estimated to reach $10.33 billion in 2018, according to Frost and Sullivan (2015) in order to locate and automatically fix faults and to fine-tune supply/demand levels (Visser, 2014). In this sector, European companies (ABB, Siemens, Eaton Corp) operate successfully.

Eurelectric[31], however, considers that the highest savings potential in Europe can be reaped "downstream", so that this chapter focuses on energy savings options on the consumption side.

The strategies for activating the energy efficiency potential in the residential, commercial and public sectors have common characteristics, whereas energy efficiency measures in industry are more complex, as they have to consider the impact on the manufacturing process. For this reason, the industrial sector is discussed separately in this chapter.

SG- enabled energy efficiency solutions in the residential, commercial and public sectors

According to an ICT provider interviewed for this study, many different 'smart energy services' for residential and commercial customers are conceivable:

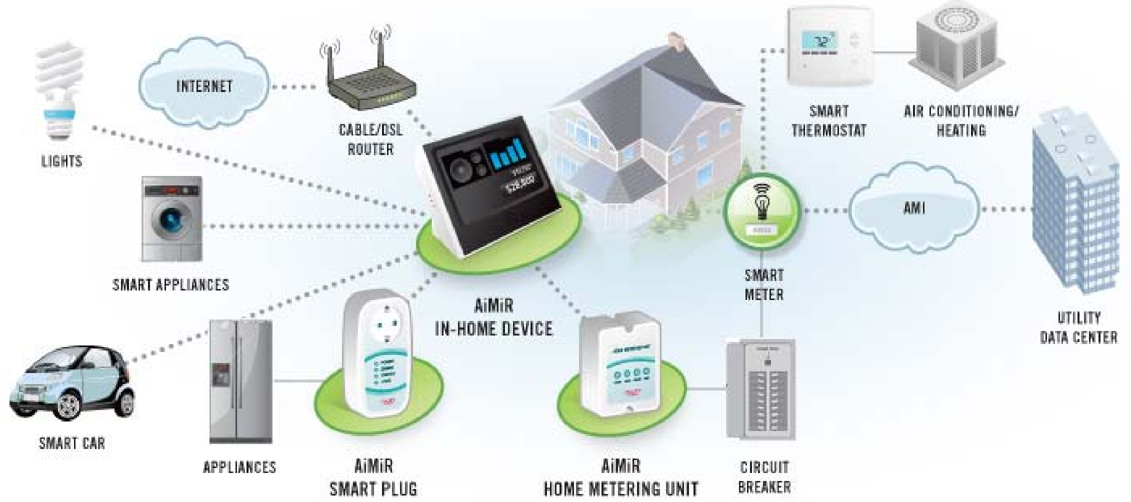
- selling and servicing boilers (smart sensor data will allow to monitor the performance of these appliances from a distance)
- insurance packages

[31] http://www.eurelectric.org/sustainability/energy-efficiency/

- one-off repairs (smart sensors enabling a real-time detection of appliance failure)
- loyalty packages
- feedback on energy use (with our without comparison with peers, e.g. by coupling to social networks)
- contract optimisation, providing flexibility to energy markets
- home energy management (e.g. peak load management).

The components of a home energy management system are shown below.

Figure 3-32 Example of a home energy management system



© 2010 Nuri Telecom - Al rights reserved[32]

The bundling or "packaging" of services is an attractive option from the business perspective, since most energy consumers (even small industries) are not yet aware of the potential for contract optimisation, according to an expert form the research field. Companies entering the business segment of home energy management are therefore looking for opportunities that go beyond energy savings to market these devices, such as improving home comfort or the status of the residents (Ayres et al., 2009, Beaware, 2013, Breukers and Mourik, 2013, Buchanan et al., 2014, Buchanan et al., 2015, Darby, 2010, Ehrhardt-Martinez, 2010, eSesh, 2013, Nachreiner et al., 2015, Staats et al., 2004, Waide Strategic Efficiency, 2014). An ICT provider considers that "simple business offers will make smart grid solutions attractive to residential customers, even if only a few Euro can be saved per month". The optimistic view sustained by one interviewee was that by 2020, 70% of EU households will make use of smart energy offerings on the market.

However, not all of these potential ICT services lead to energy savings. Shifting of consumption through DR or peak load management, for example, can deliver economic benefits for the user and the electricity system, but this does not necessarily mean that the actual energy consumption is reduced[33]. Seven large-scale trials carried out during the E-Energy project found that the use of smart meters and Energy Management Systems lead to savings of 0%-20% (2% on average). According to the E-Energy ancillary research consortium (2014), the energy savings effect is more pronounced at the initial stage of energy management and is not necessarily sustained over time. BEAMA and VaasaETT report savings of about 9% per year, based on a large set of trials carried out in Europe and the UK. Their findings indicate that the savings effect is sustained and even increased over time if

[32] http://www.nuritelecom.com/products/aimir-home-energy-management-system-hems.html

[33] There is some evidence that awareness-raising during participation in DR has a small effect in terms of energ savings, but the evidence is rather weak (Baatz 2017).

the user of In-House Displays receives pre-feedback and pre-technology education, as well as continuous guidance (Lewis et al., 2014). As discussed in chapter 2.3 and according to the results of the SG projects analysed in this study, the effects of residential energy savings programmes are determined by the kind of interaction with the user.

Furthermore, the ICT components and infrastructure required for delivering these services, such as data centres, broadband communication networks, Uninterruptible Power Systems (UPS), consumption in stand-by mode and more create additional electricity demand, which will offset part of the potential savings. Electricity consumption associated to broadband equipment alone is estimated in 50 TWh per year in Europe (reference year 2015[34]).

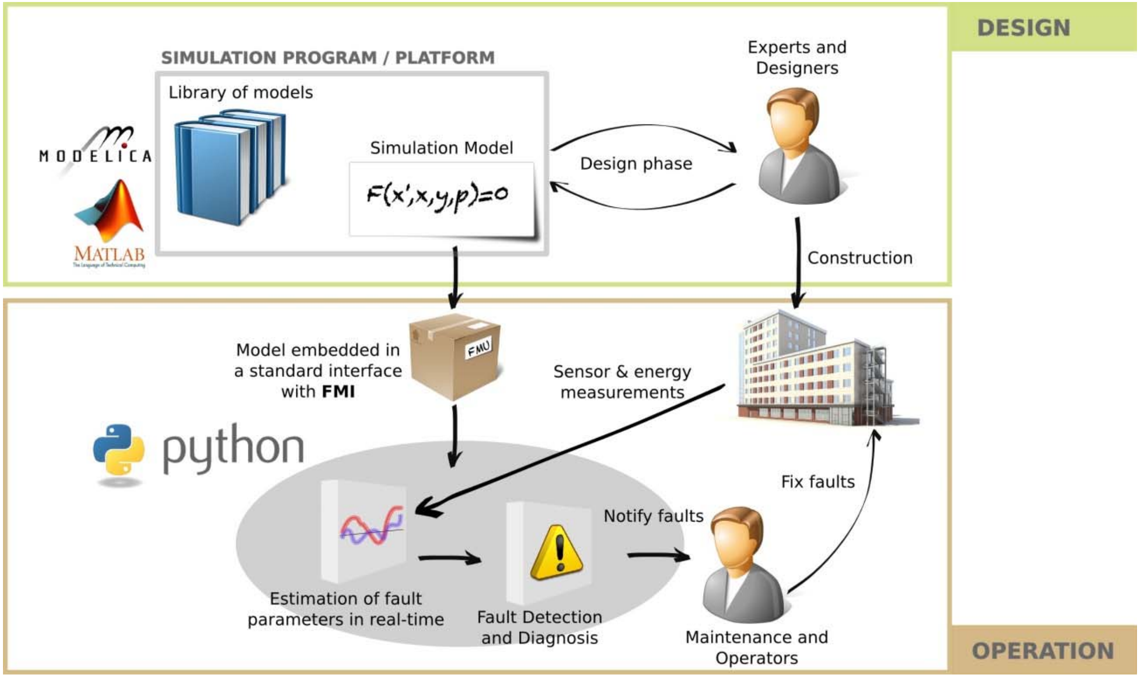
Typical examples of ICT solutions bringing about actual savings are:

- sensors to switch off lighting when not needed
- smart thermostats to control the ambient temperature and lower heating and cooling demand
- non-invasive load monitoring to provide device-specific consumption data to tenants (BECA project)
- development of energy maps of buildings to detect the need for energy efficiency investments (Sunshine project)
- optimisation of energy consumption of heating/cooling systems based on localised weather forecasts and energy modelling of buildings (Sunshine project)
- optimisation of power consumption through remote control of public illumination levels (Sunshine project)
- automatic fault detection (BECA project)

Fault detection for buildings and appliances is an especially interesting field of SG applications. Based on sensor measurements and self-learning algorithms, these applications are able to detect, for example, suboptimal operation of heating, ventilation and cooling systems (HVAC), or a higher than average energy consumption of single household appliances. Figure 3-33 shows a recent research project from the US, in which such an algorithm has been developed for building monitoring.

[34] http://iet.jrc.ec.europa.eu/energyefficiency/tags/ict-codes-conduct

Figure 3-33 Fault detection in buildings



The BECA project found an energy savings potential in residential buildings of 15% for heating, 11% for cold water and 17% for hot water. It also found that most stakeholders achieve this financial pay-off during the first 3 years and almost all stakeholders after ten years across the seven pilot sites in seven countries that participated in the project. The socio-economic benefit for the pilot buildings, if extrapolated to 10 years, is estimated at EUR 1.7 million.

User motivation is essential for tapping this energy savings potential. Energy management solutions tend to satisfy a combination of user needs: i.e. more control over the energy consumption, security ("have I switched off my heating system?"), comfort (e.g. automated window shading), and entertainment (e.g. efficiency competition among neighbours). The business opportunity here is to offer appealing applications on app shops, easy to download, and plug-and-play solutions for smart appliances. The key element is that the service offered is running on top of a standardised ICT platform and has a user-friendly predefined interface. ICT offers a large variety of options for feedback, which, along with economic benefits and user-friendly technologies, is a crucial element for the success of the service offered. The encouraging news is that the smart home area has already entered the consumer market and follows the rules of trends, fashion, and marketing (S3C, 2013).

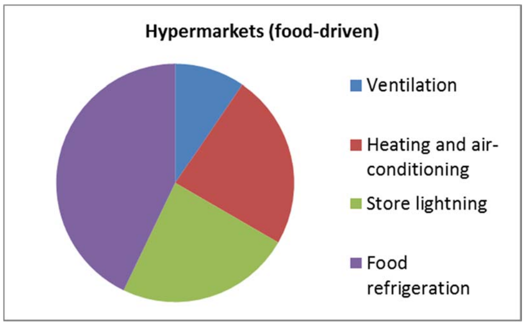
Energy efficiency services to the **public sector**, which can be delivered with the help of smart grids, are, for example, energy management in public housing or illumination. "Adaptive lighting" refers to a smart city environment, in which lights are switched on when required, for example, to illuminate a parking spot when the sensor detects movements. EPEC, the European PPP Expertise Centre (2013) estimates that "for a number of municipalities which have outdated systems, street lighting can account for as much as 30-50% of their entire power consumption". The same source affirms that intelligent control strategies, in combination with LED, are the most efficient solutions, since "LED lights … can be controlled

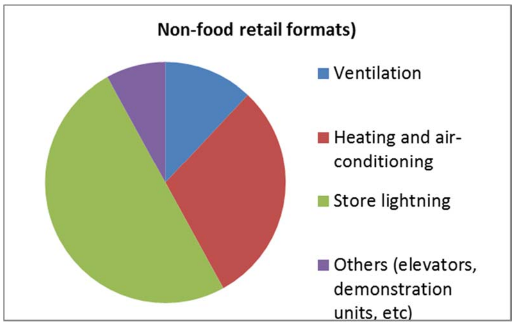
[35] https://eetd.lbl.gov/news/article/58903/if-buildings-could-tell-us-what

with high precision, dimmed rapidly, and adjusted continuously to create the level of visibility and sense of safety required".

Many of the solutions available for residents and the public administration are also relevant for the commercial sector, which is characterised by a large number of SMEs (95% of the 6 million companies, according to the European Retail Forum (2009). The basic features of energy consumption in commercial establishments are shown in Figure 3-34, distinguishing between those offering food products and those, which do not have the same need for cooling products. The figure shows that in the case of non-food commercial establishment, the largest part of energy demand is electrical and therefore suitable for interacting with DR programmes.

Figure 3-34 Energy consumption features in commercial establishments with and without food products

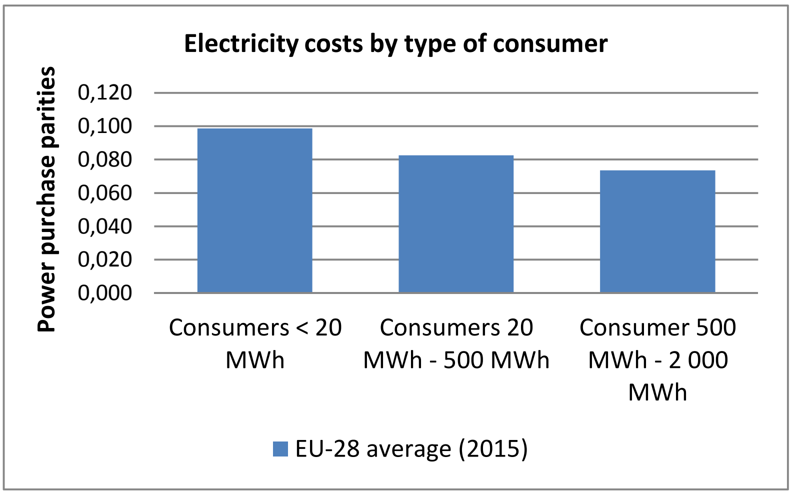




Source: reproduced from European Retail Forum (2009)

The service sector, which includes commercial establishments, consumed 147,234.3 MTOE of energy in 2015 (Eurostat, tsdpc320), about half of the energy consumed in the industrial sector (273,859.8 MTOE). However, electricity prices are generally higher for commercial than for industrial users, so that payback times are shorter for the former type of customers.

Figure 3-35 Cost of electricity for different types of companies



Source: own elaboration based on Eurostat data

SG- enabled energy efficiency solutions for the industrial sector

As indicated before, energy savings measures in industry are complex and require the support of specialised service providers, for example, ESCOs. ICF (2015) has analysed the energy use of eight key industry sectors (shown in Table 3-5) and has also detailed the economically viable energy savings opportunities for these sectors.

Table 3-5 Energy use in key industry sectors (2013)

Sector group	Final energy consumption in 2013 [ktoe]	% energy for process heating [%]	% energy for process cooling [%]	% energy for electrical [%]
Pulp, paper and print	34,265	59%	0.3%	31%
Iron and steel	50,815	75%	0.4%	19%
Non-metallic mineral	34,249	74%	0.2%	17%
Chemical and pharmaceutical	51,485	58%	0.6%	30%
Non-ferrous metal	9,381	32%	-	57%
Petroleum refineries	44,657	84%	0.6%	7%
Food and beverage	28,353	62%	10.0%	34%
Machinery	19,282	40%	1.0%	53%
Total	**272,487**	**66%**	**1%**	**26%**

Source: own elaboration based on ICF 2015

The measures related to electric grid management are listed below, along with the overall savings potential that can be achieved by 2030.

Table 3-6 Economically viable energy savings measures in industry

Energy Savings Measure	Total savings potential (%)
Integrated control system	17.3%
Sub-Metering and Interval Metering	13.8%
Implementation of Energy Management Systems (EnMS)	4.9%
Premium efficiency controls with automatic speed drives (pumps, fans and other motors)	5.7%
High efficiency non-packaged HVAC equipment	1.3%
Advanced boiler control	0.9%
Optimisation of pumping system	0.6%

Source: own elaboration based on ICF 2015

SG can contribute to the implementation of these measures by facilitating information to the Industrial Area Network (IAN) at the company's premises. Mattioli et al. (2015) define an IAN as "the communication infrastructure that allows the interconnection and support of all machines and devices needed in a particular industry, including regular ICT hardware and software (i.e. computers, printers and servers), and Industrial Control Systems (i.e. SCADA, Distributed Control Systems (DCS), Programme Logic Controllers (PLC's))." The most likely beneficiaries of these measures are specialised ESCOs, which are also able to tackle the considerable industrial efficiency potential related to heating and cooling.

Opportunities for the European engineering industries

The trend in Internet-connected appliances is positive. For example, sales of smart thermostats, which allow automatic control for heating and cooling demand (Albadi et al., 2008), have drastically increased their market share in recent years (Grand View Research, 2015). Apart from improving energy efficiency (Lu et al., 2010), some of these internet-connected smart thermostats "already perform peak shaving while maintaining thermal comfort", according to Lawrence et al. (2016).

For every 1.2 million Euro spent on energy efficiency, approximately 23 jobs are directly supported in the energy efficiency industry (European Commission 2016e). This industry presently contributes over EUR 150 billion annually to GDP and helps other European industries to maintain competitiveness, according to the sector association EEIF (Energy Efficiency Industrial Forum)[36].

Due to the need for specific expertise, energy efficiency investments in industry and buildings will also support the growth of ESCOs. ESCOs offer energy efficiency as a service (EEaaS) and these services can increase the attractiveness of smart energy systems (Goldman et al., 2010). The sector obtained revenues of $6 billion in 2013 in the US, a number, which is expected to climb to $11–$15 billion by 2020 (Stuart et al., 2014). The information on the European ESCO sector is patchy, but Bertoldi et al. (2013) consider that the overall trend is that of growth. In Europe, the main revenue for ESCOs still comes from heat supply contracts, but the JRC refers to an expert interview with MPW Institute LLC indicating that the increasing use of smart appliances in buildings and facilities enables ESCOs to "*offer better services at lower cost*". Consumption forecasts and optimisation tools for selling flexibility to the market are valuable innovations for ESCOs, according to the findings of the I3RES project. Additionally, gateways with an associated sensor network, such as the DaaS (District as a Service) Platform, facilitate the work of ESCOs on city and district level (URBGRADE project[37]).

3.6.2. Main barriers to deployment

The following barriers have been identified during the project review and interactions with experts:

- ICT providers, who have collaborated in the study, expressed their doubts about the timely deployment of ICT infrastructure to accommodate millions of smart devices.
- The drivers of innovation are unclear in this market: start-ups will have difficulties to compete with established service providers (utilities, telecom).
- There are difficulties to determine the optimum level of standardisation. Standardisation is required for plug-in solutions, but smart features of the products are an element of innovation and competitiveness, which companies should be able to pursue freely.
- In the case of residential consumers, the BECA project highlighted the challenges related to rental agreements, which include energy and water bills and therefore do not provide an incentive for energy saving by the tenant.
- In the case of industrial companies, energy efficiency is normally not the core competence, so that support from a specialised service provider is required (interview with investor). Furthermore, options for energy savings in industrial

[36] http://www.eeif.eu/
[37] https://urb-grade.eu/

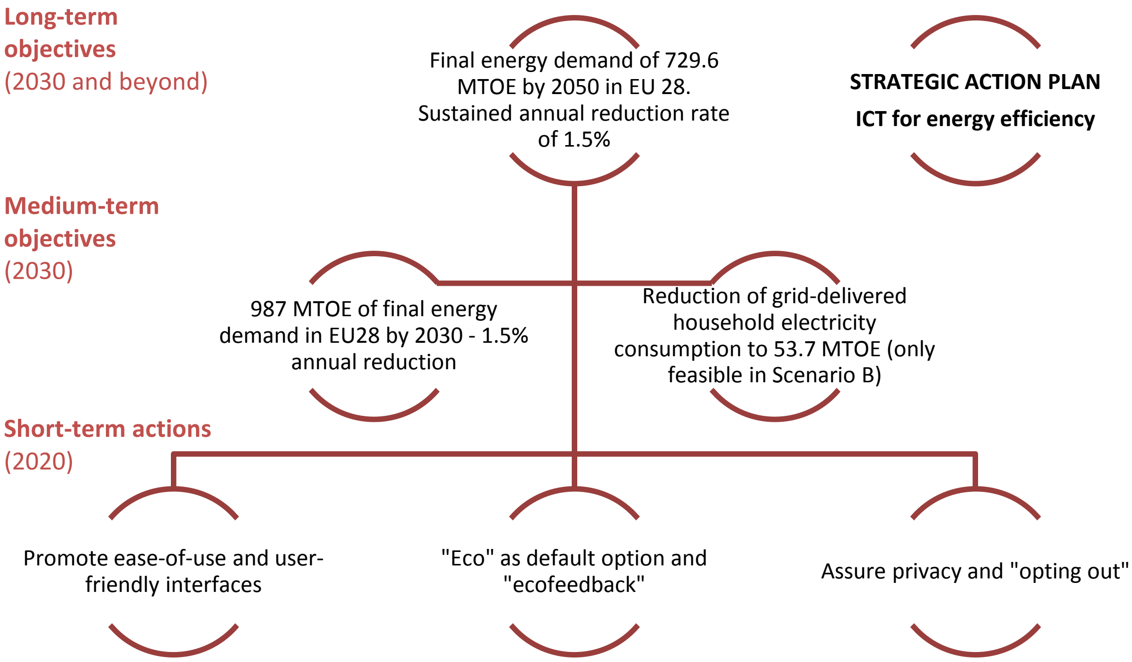
processes may have to be discarded, due to the cost of adapting these processes (e-harbour project)[38].

- Financing is a key bottleneck for ICT applications supporting energy efficiency improvements. For residential consumers, installation costs may outweigh the benefits and payback times can be very long. According to the COOPERaTE project (2015), the degree to which access to capital is a barrier to the consumer will vary depending on the degree of investment required (which may be small, if the flexible infrastructure is largely already present).
- Consumer behaviour is essential for obtaining actual energy savings, since even highly energy-efficient appliances that fulfil the criteria for energy efficiency labelling, can underperform during the use phase.

3.6.3. Strategic action plan

Figure 3-36 summarises the strategic actions required to enhance SG contributions to progress in the field of energy efficiency.

Figure 3-36 Strategic action plan for the opportunity "ICT for energy efficiency"



Source: own elaboration

Long-term objectives (2030 and beyond)

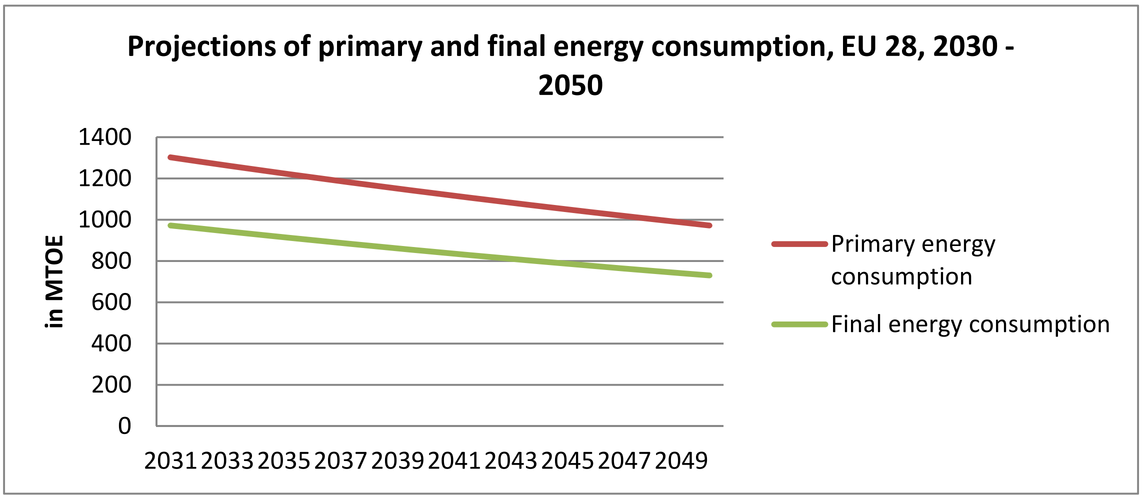
➢ **Final energy demand of 729.6 MTOE by 2050 in EU 28**

The EC has proposed a series of measures to achieve considerably higher levels of efficiency by 2030. The updated Energy Efficiency Directive (European Commission, 2016f) sets a 30% energy efficiency target for 2030, which translates into 1,321 MTOE of primary energy and no more than 987 MTOE of final energy. The MS have to deliver an annual reduction of 1.5% in national energy sales. If this progress in energy efficiency is maintained until 2050, the

[38] A comprehensive overview of energy savings potential and barriers in energy- intensive sector in Europe can be found in ICF (2015)

EU's final energy consumption in 2050 would be lowered to 972 MTOE of primary energy consumption and 729.6 MTOE of final energy demand, as shown in Figure 3-37.

Figure 3-37 Projections of efficiency improvements in primary and final energy demand, EU 28, 2030- 2050



Source: own elaboration

Smart grid effects improving the efficiency of the electricity value chain will probably occur earlier (before 2030), as described in the "Networks in Control" scenario, whereas SG-induced efficiency gains in final consumption may unfold when a higher consumer participation in the market is achieved (Scenario "people have the power).

Medium-term objectives (2030)

➢ **987 MTOE of final energy demand in EU28 by 2030 - 1.5% annual reduction**

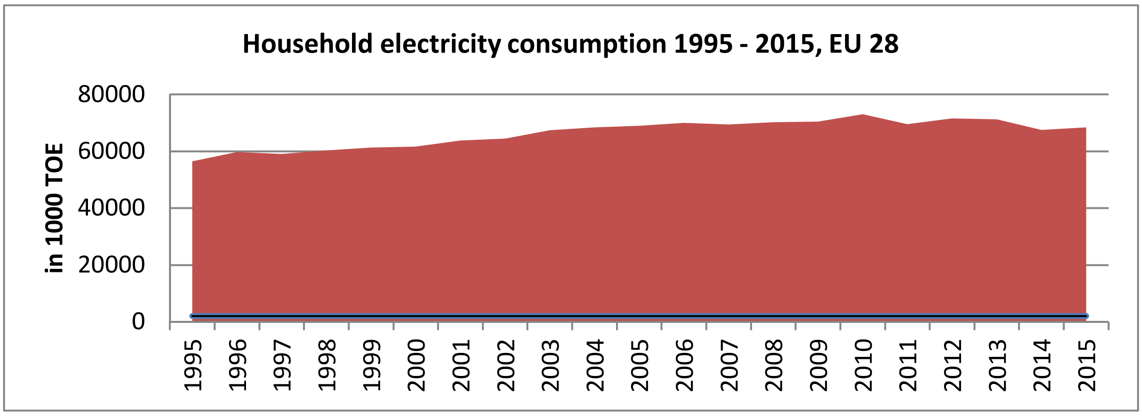
In order to achieve the 2030 energy efficiency objectives, the Commission (European Commission (2016f) proposes enhancements to the regulation on energy performance of buildings by:

- encouraging the use of ICT and smart technologies and introducing a smartness indicator
- establishing minimum energy efficiency requirements for air heating and cooling products
- enabling financing from the European Fund for Strategic investments through the development of flexible energy efficiency and renewable financing platforms at national level (with a possible regional dimension).

➢ **Reduction of grid-delivered household electricity consumption to 53.7 MTOE (Scenario B)**

SG deployment will be essential to exploit the full potential of smart technologies on building level and to curb the continuous growth in demand for electrical energy in households, which has only stagnated in recent years and only in some MS (Figure 3-38).

Figure 3-38 Household electricity consumption



Source: own elaboration based on Eurostat data

If household electricity demand followed a similar trajectory as the one envisaged for final energy demand, i.e. an annual reduction of 1.5%, households would use just 53.7 MTOE 2030. This objective will be difficult to reach in view of the expected increase of electricity for mobility, but in the coming years, SG can deliver much more detailed information on electricity consumption than presently available. This data will make it possible to design new and targeted intervention strategies to promote energy savings. Another relevant indicator for understanding trends in electricity production and consumption is the distinction between self-produced electricity and those delivered by the grid, since the energy efficiency objectives should focus on reducing fossil fuel consumption, not self-consumed renewable energy.

Short-term actions (2020)

- **Promote ease-of-use and user-friendly interfaces**

Since improvements in energy efficiency are driven by the investments of consumers in energy savings measures and behavioural change, the majority of the interviewees and projects like ADVANCED believe that consumer engagement with SG solutions will crucially depend on the ease-of-use of the tools and interfaces deployed in homes. It was also stressed that assuring that the user has ultimate control over their energy consumption is key to increase consumer acceptance. For these reasons, the interaction between the user and energy–consuming appliances during the use phase should be given more thought in eco-design initiatives.

- **“Eco” as default option and “Eco feedback”**

A relatively simple way of steering consumer behaviour is to establish the most energy-efficient use mode as “default” (see Figure 3-39 below). Psychological research on “choice architecture” (Velte, 2010 and Pichert 2010) has shown that users can be induced to make the right, i.e. the most ecological choices, if the “default option”, which does not require further action from the user, is the energy-saving mode.

Figure 3-39 Eco as default in dishwasher

Source: own picture

Some manufacturers are already implementing similar features. For example, the German domestic appliance producer Miele, whose international product line includes approximately 400 network-capable domestic appliances, offers an “Eco feedback function” to the customer[39].

- **Assure privacy and “opting out”**

An ICT provider remarked that in order to avoid privacy concerns, some essential principles need to be respected: customers should be the owners of their data, and use of the data for commercial purposes should only be made possible based on an agreement from these customers. The DSO representatives interviewed were of the opinion that the DSOs should be the ‘trusted partner’ for managing data on energy consumption for the end users connected to their grids. However, other, more business - oriented experts stress that the role of data manager should preferably be taken up by an independent actor in order to avoid market disturbance.

To address these concerns on data protection and privacy, the EC has provisioned a comprehensive reform of the data protection rules (General Data Protection Regulation – GDPR, European Commission, 2016v) that is applicable to all sectors. The EC has also proceeded with the sector specific actions through the Data Protection Impact Assessment (DPIA) Template for smart grid and smart metering systems (European Commission, 2014b), which offers guidance on data protection and privacy for data controllers and investors in SG. Besides, the EC has recently tabled (European Commission, 2017b, Art. 23 on data management) new rules on the exchange of data to allow market players to access vital market information, while guaranteeing a high level of data protection, privacy and security.

In this context, the ADVANCED project proposes an opt-out option (or opt-in for programmes requiring granular data use) as a potentially effective approach for managing consumers’ concerns to the use/exchange of personal and consumption data with third parties for technical and scientific purposes. This proposal is now covered by the consent

[39] https://www.miele.com/en/com/consumption-and-efficiency-3015.htm

provision in the GDPR. The GDPR protects the personal data of an identifiable natural person. Non-personal or "attribute data" is not affected by the directive, unless it is possible to track this type of data proceeding from IoT or SG applications back to the owner or the customer (Spindler et al, 2017).

3.6.4. Key messages

Demonstrate the capacity of SG to curb electricity consumption

The project review and the expert interviews indicate that there is still a strong and untapped potential for energy savings measures in households and small enterprises, including commercial establishments, which can be unlocked by SG solutions, such as home area networks. But presently little evidence is available on the patterns of electricity consumption in the different economic sectors and improving this through data delivered by SG applications will be fundamental to design enhanced and targeted energy efficiency strategies. Once these strategies are defined, the EC could consider establishing a separate energy savings objective for electricity, which should focus on grid-delivered electricity, excluding self-production and self-consumption.

Solutions must focus on the user / consumer and tackle privacy concerns

User motivation has been identified as a key element for the successful deployment of SG solutions and for participation in energy efficiency measures. Ease-of-use, user-friendly design and the incorporation of "eco-feedback-functions" and "eco-default" options should become the norm in electrical appliances and SG solutions. Opt-out and opt-in solutions that leave the final control of applications and of generated data to the consumer have to be assured, as provisioned by the principle of 'consent' of the GDPR (European Commission, 2016v).

4. Conclusions

The smartening of the European power grids is under way, but the unfolding of potential business opportunities depends largely on market design and to a lesser extent on the technology itself. The scenario analysis shows that SGs can enable new relational models between energy production and consumption, if both sides of the energy system open up to a much larger number of actors. SG can also unlock new business models based on pooling demand and supply sources, or even on direct interaction with individual customers.

However, it is also possibly that these opportunities are largely blocked by established market actors and regulators fearing a negative impact on income and/or taxes and negative consequences for security of supply. Opening up the electricity network to millions and millions of smart devices entails risks that need to be addressed, for example by increasing the resilience of the system. Again, in this field, SG can make important contributions, since distribution grid automation – which is already under way in some MS - permits to locate and automatically fix faults and to fine-tune supply/demand levels.

Regulatory action aiming to put the "consumer at the heart of the energy system" is complex, since it has to consider not only the role of different types of consumers on the supply and on the demand-side, but also the interaction with other parts of the energy system, for example heat supply or cogeneration. There is evidence that benefits of SG functionalities are greater for the customer and the electricity system at large when the storage potential of heat is included in demand-side management. CHP, heat pumps, hot water boilers, and district heating are cornerstones of "smart energy" and their chances to compete with traditional heating technologies increase with additional income from flexibility provision. The positive impacts on the well-positioned European heat pump industry and environmentally friendly cogeneration should also be considered in this context. The mapping of demand and source points for heat to identify cost-effective opportunities is crucial for advancing toward the smarter energy system of the future.

Similar arguments can be found supporting the interaction of electric vehicles with the grid. However, in the case of EV, action is even more urgent, since the increase of the number of fast charging stations is likely to provoke the need for network upgrades in densely populated areas hosting these charging stations. With possibly as much as 150 GW of additional electricity demand possibly coming from electric mobility in 2050, strategies must be implemented to promote the participation of car pools in network management and to reinforce distribution networks, preferably with renewable on-site generation.

Another very relevant challenge is that of adapting the rules of the electricity system to a large number of different and sometimes not professional users and producers with time restraints and limited technical knowhow. User-centred factors need to be considered in the formulation of simple and reliable rules for self-generation, for example, or in the design of intelligent household appliances. The IEA estimates of 25-30% of self-production by 2050 are realistic and so is the active participation of at least 25-30% of the European population in network management, whether as suppliers or as consumers, or both. In this context, the importance of joint actions through communities or professional aggregators must be stressed, along with the pooling of resources in Virtual Power Plants. Such entities have a special importance during times of transition, because they are an essential part of empowerment and facilitate engagement in the energy field of lower-income households. Network operators and BRPs have a central role in enabling demand-side participation in the market and, through this, increase the flexibility of the system. It is important that BRPs around Europe start offering flexibility products that are adapted to the often-limited possibilities of the flexibility providers.

With regard to self-production combined with PV, the immediate potential to be addressed is that of the commercial sector, which is exposed to much higher electricity prices than industry and has a consumption curve that matches largely the times of high PV production. SG solutions, such as smart converters can increase the level of self-consumption of PV and the hosting capacity of the distribution networks by 50%. Community projects, in which 40% of the members own a PV system and use peer-to-peer consumption combined with local storage, can already achieve a self-production rate of 28% on a sunny summer day in the Netherlands.

Unfortunately, the value of user interaction with the electricity system is often not clear, neither for the operator nor for the user. Standardised and objective mechanisms are needed to quantify and value the flexibility that distributed generation and demand management add to the grid. This is also true for the contribution of storage systems. Although it is not yet clear if larger or smaller scale storage systems will bring the greatest benefit for grid management, there is consensus among the experts that much greater storage capacities are needed to deal with intermittent RES production. 450 GW of smarter (and cheaper) storage will be required globally by 2050 to meet the climate goals, according to the IEA. The European engineering industry has strong players and a high level of expertise in chemical and electrochemical storage technologies that can push technology development. This sector would clearly benefit from to the harmonisation of the regulatory network in the MS creating the conditions for fair competition. The market is almost ready to embrace storage technologies, which can already compete in certain market niches when combined with innovative business models that reduce the risk of rapid obsoleteness of the chosen technology on the investor side.

The enabling function of smart grid has been evidenced for all developments described above, but in the case of enhanced energy efficiency, the SG contribution still needs to be demonstrated. Establishing a separate objective for efficiency gains in household electricity consumption could be a first step to understand if efficiency improvements can offset the additional demand for electricity required by SG solutions. Some evidence has been found for efficiency improvements along the value chain of electricity production due to SG deployment, but, in order to positively impact final energy consumption, the use of smart functions, combined with eco-default design and eco-feedback, needs to be extended. SG can help shed light on the still very opaque trends in electricity consumption and deliver the data necessary for better-targeted energy efficiency measures.

The measures proposed in the Clean Energy Package address many of the actions that need to be implemented to reach the “people have the power” scenario. The starting point in the MS, however, varies considerably, since only Ireland, Belgium, France, Finland, and UK have so far opened the market to demand response and aggregation. Fading support and retroactive changes to subsidy schemes for renewables, especially PV, are further signs for the plausibility of the “networks in control” scenario. These contradictions are typical in a transition process, which aims at far-going changes in a sector that is as essential for industrial competitiveness and the well-being of citizens as energy. Smart grids can make a difference in this transition, but political will and citizen engagement are the real elements inclining the balance towards the “people have the power” scenario. The European Economic and Social Committee warns in this context that “without a strong governance process it is no exaggeration to say that the Energy Union will fall apart and the chances of the EU meeting its own commitments and those under the Paris Agreement will be greatly reduced. Essential to the success of this process is the involvement and engagement of civil society, the cooperation and support of Member States and the agreement and commitment of the social partners” (EESC, 2017).

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6. Annexes

6.1 Annex 1: List of experts who have contributed to this study

Name	Organisation	Organisation type	INTERVIEW	1ST SURVEY	1ST WORKSHOP	2ND SURVEY	2ND WORKSHOP
Jessica Stromback	SEDC	INV	X				
Johan Reynaert	EIF/EIB investment fund	INV	X				
Gerard Reid	Alexa captial	INV	X				
MA Sanz	SUSI	INV	X				
Stefan Smets	KIC	INV	X				
Stefan Erbacher	buzzn, BRP	DEM	X				
Cedric de Jonghe	Actility, ICT and aggregator	DEM	X				
Frauke Thies	SEDC	DEM	X				
Tom Schulz	former CEO Entelios	DEM	X				
Damien Ernst	University of Liege	RD	X				
Pier Nabuurs	IIW former KEMA	RD	X				
Venizelos Efthymiou	DSO - university	RD	X				
Jochen Kreusel	Market innovation manager ABB	TECH	X		X		
Maher Chebbo	President Esmig, SAP	TECH	X				
Thierry Pollet	Landys &Gyr	TECH	X				
Wolfram Kr	Younicos	TECH	X				
Mark Daly	ESB Innovation	BRP	X	X			
Peter de Pauw	Eandis	SO	X				
Blanca Losada	Gas natural Fenosa	DSO	X				
MA Sánchez Forli	Iberdrola	DSO	X				

Name	Organisation	Organisation type	INTERVIEW	1ST SURVEY	1ST WORKSHOP	2ND SURVEY	2ND WORKSHOP
Vera Nunes	EDP	SO	X				
João Filipe Nuñes	EDP	SO	X				
Tim Cayford	GERG / Eurogas	TECH (IND)		X			
Ilaria Losa	RSE	RD		X			
Luciano Martini	RSE	RD		X			
Iva Maria Gianinoni	RSE	RD		X			
Holger Ihssen	Helmholtz Association	RD		X	X		
Carmen Gimeno	Geode	TECH (IND)		X			
Peter Söderström	Vattenfall	SO		X			
Roland Tual	Smart energy demand	DEM		X			
Unidentified	Unidentified	unknown		X			
Ingo Wagner	DHC+Technology platform	RD		X			
Monica Salvia	CNR-IMAA	RD		X			
Eduardo Garcia	Tecnalia	RD		X			
Carmelina Cosmi	CNR-IMAA	RD		X			
Jure RATEJ	ETREL d.o.o	IND		X			
Stryi-Hipp, Gerhard	Fraunhofer ISE	RD		X			
Alexandre Oudalov	ABB Switzerland	TECH		X	X		
Unidentified	Unidentified	unkown		X			
Jochen Kreusel	ABB	TECH		X			
Sonia Clarena Baron	EUturbines	TECH (IND)		X			
Unidentified	Unidentified	unknown		X			
Norela Constantinescu	ENTSOE	SO			X		X

Name	Organisation	Organisation type	INTERVIEW	1ST SURVEY	1ST WORKSHOP	2ND SURVEY	2ND WORKSHOP
Sanne Goosens	CECED	TECH			X		
Klaus Kubeczo	AIT	RD			X		
Erik Laes	VITO	RD			X		
Alexander von Jagwitz	BAUM	OTHERS			X		
Marko Cavar	DHC and Technology Platform	TECH			X		
Valerio Abbadessa	ENEA	RD			X		
Rachele Nocera	ENEA	RD			X		
Thibaut Richert	DTU – ESOM	RD				X	
Hellmut Frey	ENBW	SO				X	
Stephen McPhail	ENEA	RD				X	
Pieter Valkerihg	VITO - Energyville	RD				X	
Frank Meinke-Hubeny	VITO - Energyville	RD				X	
Unidentified	AIT	RD					
Unidentified	EDF	SO					
Cristina Gomez	ENTSOE	SO				X	X
Bradley Eck	IBM	TECH				X	X
Konstantinos Oureilidis	University of Cyprus	RD				X	X
Juan Rico	Atos	TECH				X	X

Name	Organisation	Organisation type	INTERVIEW	1ST SURVEY	1ST WORKSHOP	2ND SURVEY	2ND WORKSHOP
Kleineidam	University of Bayreuth ZET	RD				X	
Paul Raats	DNV GL	OTHERS (consultancy)				X	X
Torben	Aalborg University	RD				X	
Frank Graf	DVGW-EBI	TECH (IND)				X	X
Takis Ktenidis	PAUS TEI PIRAEUS SEALAB	RD				X	
Daniel Iglhaut	TUV	TECH (IND)					X
Cristina Gomez	ENTSOE	SO					

INV: Investor
SO: System Operator (TSO/DSO)
DEM: Demand side/aggregator
RD: R&D
TECH: Technology provider
IND: Industry

6.2. Annex 2: The selection criteria applied and the full list of projects reviewed

The selection criteria applied

The project selection process was made up by an exclusion phase and a selection phase.

The following criteria were used to **exclude** the projects from further analysis:

- The project is only targeting innovation >10kV (out of scope according to the Terms of Reference).
- The project information is missing or not available[40]. This criterion is for instance applicable to projects, which already removed their website, or projects ending in 2017-2018 that have not yet achieved full results.

The **selection or scoring phase** looked at the completeness of the assessment of *business opportunities*, the extent to which barriers for deployment of SGs were analysed by the project, as well as the *consortium*.

- **The project developed innovative products or services**. The following questions are essential:
  - New and promising services are developed
  - New and promising business models are investigated
  - New type of products are developed
  - Existing products or services are improved

- A **study on barriers and opportunities for smart grid business deployment** is included. This is essential for the scalability and replicability of the developed solutions in the project:
  - A study regarding regulatory barriers is included
  - A comprehensive summary of market acceptance, user acceptance and socio-political acceptance of the developed projects/services is included

- **Large and diverse consortium**. For this topic, if a variety of partners is working on the project will be examined, in terms of both number and type of partners.

The full list of reviewed projects

The application of the above listed criteria led to selection of the following projects:

[40] All publicly available information was included in the analysis, and not only the information that is easily accessible by the consortium.


ADDRESS
evolvDSO
M2RES
Green eMotion
ADVANCED
REservices
IRENE
I3RES
FINSENY
SUNSHINE
IGREENGrid
CIVIS
S3C
STEP-UP
EPIC-HUB
smartCEM
IoE
INGRID
BECA
COOPERaTE
LINEAR
DRIP
AlpStore
e-harbours
URB-GRADE
RENEWIT
Grid4EU
PV-NET

6.3. Annex 3: The interviewees and barriers, business opportunities, enabling assets and ICT

INV: Investor

DEM: Aggregator/Demand side

RD: R&D

SO: TSO/DSO

BRP: Retailer/BRP

TECH: Technology provider and industry

Barriers for Smart Grids	INV	INV	INV	INV	INV	DEM	DEM	DEM	DEM	RD	RD	RD	TECH	TECH	TECH	TECH	BRP	SO	SO	SO	SO	Total
Inadequate energy markets	1				1	1	1	1					1					1	1			8
Inadequate energy markets: Incomplete unbundling of activities																			1			1
Inadequate energy markets: Regulatory treatment of grid costs						1										1						2
Acceptance market actors: Prequalification process by DSO	1	1	1						1			1				1	1					7
Acceptance market actors: Disinclination of TSO to facilitate DR			1				1	1	1								1					5
Restricted access: Stringent requirements for BRP acknowledgement	1	1			1		1		1			1					1					7
Restricted access: Limitations for small scale DR					1	1	1						1				1					5
Asymmetric information							1															1
Overcapacity of generation							1	1														2
Limited consumer acceptance/engagement: Feedback and incentives						1																1
Limited consumer acceptance/engagement: privacy, security and confidentiality	1																					1
Limited consumer acceptance/engagement: Access to capital		1			1							1			1					1		5
Complexity to identify, quantify and evaluate flexibility							1	1			1		1					1				5
Lack of standardisation of enabling technologies											1		1			1						3

Opportunities for Smart grids	INV	INV	INV	INV	INV	DEM	DEM	DEM	DEM	RD	RD	RD	TECH	TECH	TECH	TECH	BRP	SO	SO	SO	SO	**Total**
Contract optimization		1		1	1			1		1	1			1								7
Trading wholesale market					1	1	1	1					1							1		6
Portfolio management		1	1		1	1	1		1	1				1			1			1	1	11
Reserve capacity		1			1		1		1							1	1					6
Smart Asset Management						1										1				1		3
Other grid services to the TSO					-							1	1	1		1					1	5
Grid services to the DSO								1		1		1					1				1	5
Assets																						**Total**
Sensors										1	1			1				1			1	5
WAMS										1			1	1				1				4
Asset management		1										1	1					1		1	1	6
Grid control technology								1		1			1		1				1	1		6
FACTS/Power electronics					1			1		1		1	1	1	1				1			8
Batteries, CHP…									1	1		1			1	1		1				6
ICT																						**Total**
Big data platforms							1		1	1	1		1	1				1	1			8
Forecasting														1		1				1		3
Smart appliances					1		1			1	1								1		1	6
VPP					1								1			1						3
Smart meters												1		1	1	1				1	1	6
ICT connectivity							1			1	1		1	1		1		1	1	1		9
Integration technology							1			1			1	1		1		1	1	1		8
Security																1		1		1	1	4
Plant control modules							1									1						2
DER asset management																				1		1
EV charging					1		1			1		1					1				1	6
Energy management systems							1				1		1	1					1			5
DR applications							1				1		1	1		1				1		6
Energy market platforms							1				1			1								3
Trade control systems							1						1	1								3
Business services							1				1	1										3