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SMILE

Smart Island Energy Systems

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Abbreviations and Acronyms

RES	Renewable Energy Sources
EMS	Energy Management Systems
DSM	Demand Side Management
DRM	Demand Response Management
CAGR	Compound Annual Growth Rate
DR	Demand Response
DSO	Distribution System Operators
C&I	Commercial and Industrial
AMI	Advanced Metering Infrastructure
BTM	Behind The Meter
FTM	Front Of The Meter
BESS	Battery Energy Storage System
TES	Thermal Energy Storage
EV	Electric Vehicle

1 Introduction

The overall scope of SMILE project is to demonstrate, in real-life operational conditions, a set of both technological and non-technological solutions adapted to local circumstances targeting distribution grids to enable demand response schemes, smart grid functionalities, storage, and energy system integration with the final objective of paving the way for the introduction of the tested innovative solutions in the market in the near future. To this end, three large-scale demonstrators have been implemented in three island locations in different regions of Europe with similar topographic characteristics but different policies, regulations, and energy markets: Orkneys (UK), Samsø (DK) and Madeira (PT).

The present deliverable D6.5 has been developed in the framework of SMILE activities dealing with market analyses, business cases, financial mechanisms.

The main purpose of this deliverable is to provide a general, yet comprehensive, framework towards the evaluation of the market context. To this aim, the document has been divided into the following main parts:

1) An overview of the general context of the market, detailing the main trends and key figures with respect to Photovoltaic and Wind energy sectors, used as RES in the project use cases.

2) Detailed analysis of the two main segments identified in the context of the SMILE project:

- Demand-Side Management and Demand Response Management, detailing in particular demand response programs as well as smart electricity meters. In addition, in the section, it has been highlighted the energy management systems, aggregator and virtual power plant platforms role as well as the one played by electric vehicles charging algorithms.
- Energy storage systems, detailing both battery storage demand and supply, especially in relation to lithium-ion batteries, while insights have also been provided on heat and thermal storage technologies evolving market.

With respect to the above-mentioned market segments, activities have been focused on the definition of the market value, future projections, competitive landscape, main trends, and key figures.

2 The general context: key trends and main figures

This chapter outlines the main trends affecting the global energy market in the European context with the final aim to describe the general framework in which the technologies that are the most significant in the SMILE project were developed and implemented.

2.1 Key trends and main figures

According to International Energy Agency's 2019 World Energy Outlook[1], **electricity supply and demand are expected to increase worldwide**. The report data shows a projected increase of electricity demand (considering IEA's "Current policies" scenario representing a projection of a "business-as-usual" case where 2019's existing policies are not further updated and modified in time) of 32.6% in 2030 with respect to 2018 demand. A further 22.5% increase is expected by the year 2040. With regard to electricity generation, between the years 2018 and 2030, an increase of about 31.5% is expected while a further 22.4% growth is projected for the subsequent decade. This positive electric energy generation trend is coupled with an increase of the share of renewable energy over the total electricity supplied as highlighted in Figure 2.1.

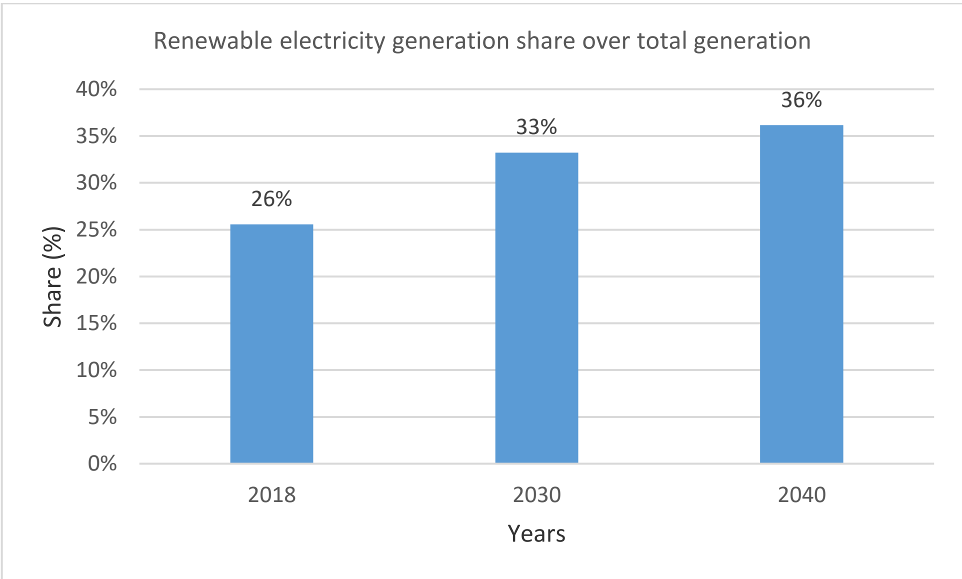

Figure 2.1: Renewable electricity generation share over total generation
Source: RINA Elaboration on IEA 2019 data[1].

It is worth reporting that the investigation of global and European IEA's "Sustainable Development" scenario (which represents the optimal situation that would allow the achievement of the Sustainable Development Goals) and "Stated Policies" scenario (representing the context where policymakers 2019's plans and new policies are implemented) show that an increase in electricity demand is expected in both projections (as it was the case for the "Current policies" one). The graph below shows the extent of the demand growth.

[1] IEA (2019), World Energy Outlook 2019. Available at: https://iea.blob.core.windows.net/assets/98909c1b-aabc-4797-9926-35307b418cdb/WEO2019-free.pdf

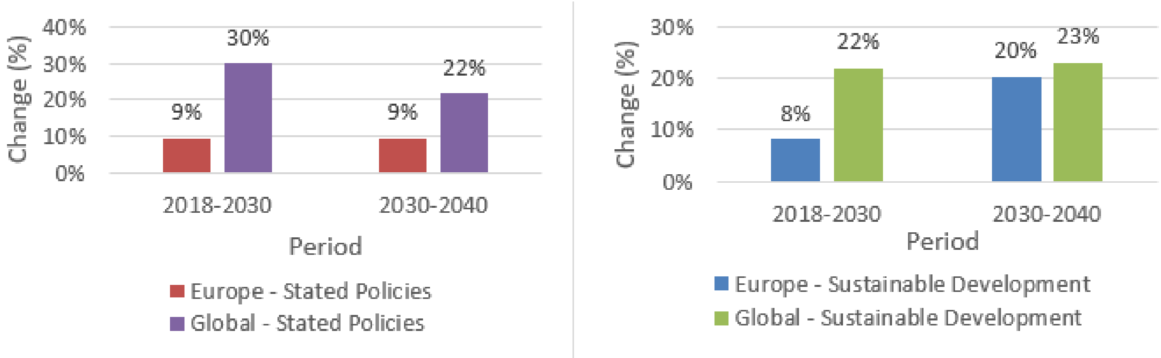

Figure 2.2: Scenarios of energy demand growth in the periods 2018-2030 and 2030-2040
Source: RINA elaboration of IEA data[1].

Once again considering as the base year 2018, either a 9% or 8% growth is projected in Europe by 2030. A larger variability is instead attached to the global context where the two scenarios differ of about 8 percentage points, with the "Stated Policies" one foreseeing a steeper growth. In the decade 2030-2040, while the "Stated Policies" scenario for Europe projects once again a growth of about 9%, the "Sustainable Development" one entails a much higher increase (about 20% in the ten-years' period). Globally, substantial increases are expected, differing solely of about one percentage point. The difference in trends visible in the comparison between the global and the European contexts relates to the fact that electricity demand in advanced economies is generally not expected to undergo steep growth paths despite the boost associated to increasing electrification. On the other hand, significant growths are expected in developing economies with dramatic increases, for example, in South-East Asia and Africa with changes in the two periods analyzed roughly ranging between 40% and 60%. Considering the European Union context (E.U. 27-related data[2]), in 2019, the share of energy arising from RES was almost 20% of the total, following nine years of steady growth starting from a 14.4% share in 2010. In the figure below, it is reported how the percentage share of renewables over the total energy sources has evolved in E.U. 27 and U.K; considering the SMILE project framework, it has been chosen to add Denmark and Portugal performances, as well as Sweden as a benchmark, being the most virtuous country in the Union with 56% share in 2019.

[2] Eurostat (2021), Share of energy from renewable sources (spreadsheet). Available at: https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/default/table?lang=en

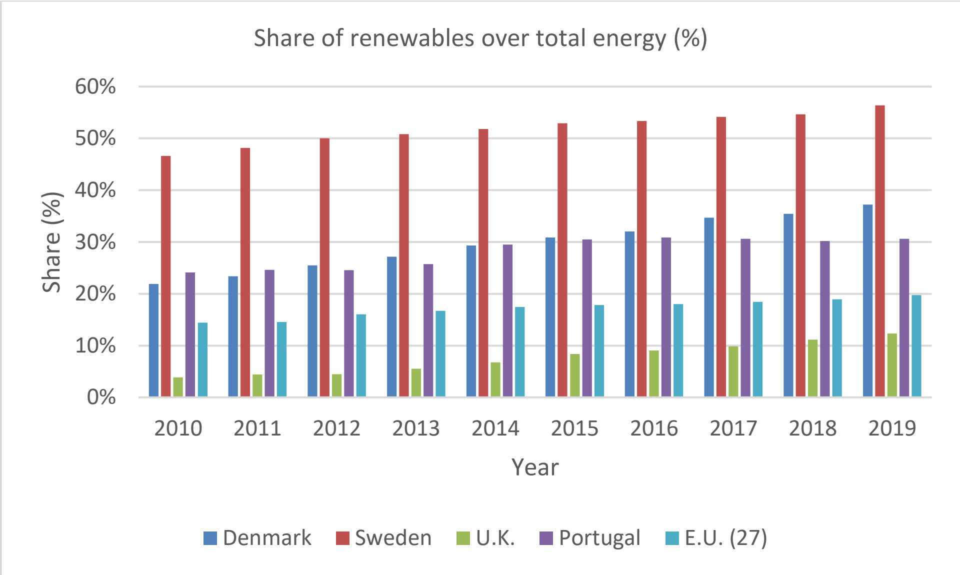

Figure 2.3: Share of renewables over total energy in Europe (2019)
Source: Eurostat[2].

It must be highlighted that the projections illustrated above do not reflect the last changes in the European policy framework currently under discussion in the so-called "Fit for 55 package[3]" which represent a further step towards the achievement of a 55% reduction in EU-wide emissions by the year 2030 (vis-à-vis 1990 levels), functional to the attainment of a full climate neutrality by 2050.

Considering the nature of the pilot projects implemented within SMILE, involving in particular wind-based and solar-based energy generation, it is crucial to address trends associated to these two renewable energy sources. In this context, it is worth to underline that EU Commission's proposed wide target which mostly affects the European energy generation industry, relates to a minimum share of renewables in the EU gross final consumption equal to 40% by the year 2030[4]. However, it should not be overlooked the effects of policies other than climate targets setting such as those related to market-based instruments, as for example the review of EU Emission Trading system and its enlargement to additional sectors[5]. These factors might indeed substantially affect the projections and estimates discussed and provided in this document.

[3] European Commission (webpage), Delivering the European Green Deal. Available at: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en

[4] European Commission (2021), Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652.

[5] Florence School of Regulation (2021), Fit for 55: EU rolls out largest ever legislative package in pursuit of climate goals. Available at: https://fsr.eui.eu/fit-for-55-eu-rolls-out-largest-ever-legislative-package-in-pursuit-of-climate-goals/

2.1.1 Photovoltaic

According to IRENA[6], **the global cumulative photovoltaic capacity is going to grow in the period 2019-2050 reflecting a CAGR equal to 8.9%**. At the end of 2020, the global capacity of PV plants was equal to over 700 GW[7]. Considering solely the European scenario, at the end of 2020, the total installed PV capacity reached 151.7 GW[8]. **In the European Union alone PV capacity increased in the same year of over 18 GW being the year recording the second-best growth (second only to the year 2011) and despite the pandemic that hit the global economy**[9]. The largest market in terms of PV installations within the Union is **Germany** with about 54.6 GW of installed capacity (that also recorded the largest capacity increase in E.U. in 2020 with about 4.8 GW of new installations), followed by **Italy** whose capacity did not grow substantially in 2020 and stands at over 21 GW; differently, **Spain** estimated capacities in 2020 increased by about 2.6 GW reaching a total installed capacity value of 13.2 GW. Considering once again **the overall European context, in the period 2018-2030, it is expected a further general growth of about 140% of the installed capacity; a further increase of more than 200% is instead projected for the subsequent two decades**.
Different PV modules technologies with diverse maturity levels experienced, since 2010, substantial cost decreases while increasing efficiency, improved manufacturing processes and systems design which are expected to drive prices further down (despite a slight increase at the beginning of 2021 due to growths in material prices). In addition, further cost decreases may be experienced due to growing investments and manufacturing located in regions benefitting from low labour cost[10]. A noticeable cost cut has already been recorded in the period 2010-2020 where the **global average LCOE for utility-scale PV plants has decreased of about 85% reaching the value, in 2020, of 0.057 $/kWh** (corresponding to about 0.050 €/kWh). **Europe**, during the last decade, **experienced a weighted average PV module price reduction of about 93%.**

2.1.2 Wind Energy

Considering wind-generated power, **about 93 additional GW have been installed on a global scale in 2020 reaching the total value of 743 GW**. The new installations can be further broken down into about 93.4% representing onshore installations and about 6.6% representing offshore ones. Those new installations reflect a noticeable increase in terms of additional capacity as during the previous year, the increase has been limited to 60.8 GW. 2020's positive trend appears even more remarkable considering the effect of Covid-19 pandemic on world economy.

[6] IRENA (2019), Future of Solar Photovoltaic: Deployment, investment, technology, grid integration and socio-economic aspects (A Global Energy Transformation: paper). Available at: https://irena.org/-/media/Files/IRENA/Agency/Publication/2019/Nov/IRENA_Future_of_Solar_PV_2019.pdf
[7] IRENA (2021), Renewable Power Generation, Costs in 2020.
Available at: https://www.irena.org/publications/2021/Jun/Renewable-Power-Costs-in-2020
[8] Power Electronics News (2021), Europe Solar Photovoltaic (PV) Power Market Outlook. Available at: https://www.powerelectronicsnews.com/europe-solar-photovoltaic-pv-power-market-outlook-by-segment-residential-commercial-and-utility-industry-analysis-growth-share-size-trends-and-forecast-2021-2030/
[9] SolarPower Europe (2020), EU Market Outlook for Solar Power 2020-2024.
Available at: https://www.solarpowereurope.org/wp-content/uploads/2020/12/3520-SPE-EMO-2020-report-11-mr.pdf?cf_id=23124
[10] Eero Vartiainen, Gaëtan Masson, Christian Breyer, David Moser, Eduardo R. Medina (2019), Impact of weighted average cost of capital, capital expenditure, and other parameters on future utility-scale PV levelised cost of electricity. Available at: https://onlinelibrary.wiley.com/doi/epdf/10.1002/pip.3189

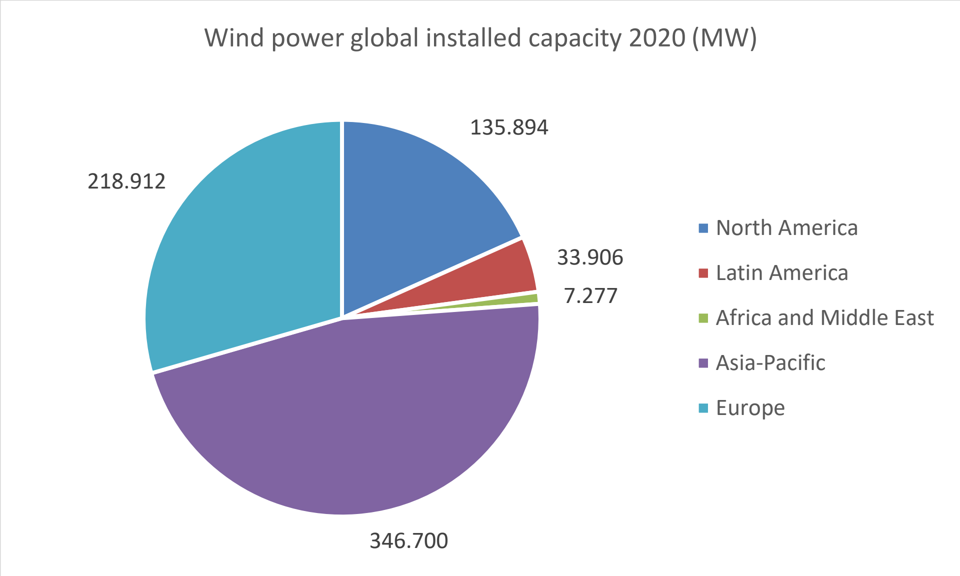

Figure 2.4: Wind power global installed capacity in 2020 (MW)
Source: RINA Elaboration on GWEC data[11].

The Asia-Pacific region leads the way in terms of wind capacity with about 47% of the global data. It is followed by Europe representing roughly 29.5% and by North America with about 18% of the whole capacity. **The recent rise in global wind installation has been so far led by China and the U.S. and the coming years are expected to confirm the primate of Asia-Pacific, Europe and North America as leading regions in terms of new installations.** At the same time, a more significant role is expected to be played by **offshore installations** with annual percentage increase reaching over 20% in 2025. In order to meet the decarbonization objectives set by the Paris Agreement, 2020's recorded newly installed capacity should double or even triple by the year 2030[11].
Considering wind energy generation at utility-scale, **its associated LCOE is falling since 2010** making wind the cheapest electricity generation source in specific areas of the world[12, 13]. Such sharp decrease is connected to turbines decrease in cost and increase in size (implying higher power generation) as well as to other advancements such as the higher height of the hub. In this sense, according to IRENA, onshore wind energy generation plants (at utility scale) commissioned in 2020 would show an **average global LCOE value equal to about 0.039 $/kWh (corresponding to about 0.034 €/kWh) while regarding offshore installation the value would be slightly higher and equal to 0.084 $/kWh (corresponding to about 0.074 €/kWh)**. 2020's commissioned plant LCOE for onshore and offshore installations decreased respectively by 56% and 48% compared to 2010's values. It is worth to highlight that onshore wind installations are already competitive with respect to all fossil fuel-based options[14].
The learning rates associated to wind LCOE are significant factors affecting the future of the energy industry; this appears especially true considering onshore installations that are affected by a 32% rate

[11] GWEC (2021), Global Wind Report 2021.
Available at: https://gwec.net/wp-content/uploads/2021/03/GWEC-Global-Wind-Report-2021.pdf
[12] Mike Scott (2020), Solar And Wind Costs Continue To Fall As Power Becomes Cleaner, Forbes.
Available at: https://www.forbes.com/sites/mikescott/2020/04/30/solar-and-wind-costs-continue-to-fall-as-power-becomes-cleaner/?sh=12ee80ff785f
[13] Wind Europe (2019), Wind energy is the cheapest source of electricity generation.
Available at: https://windeurope.org/policy/topics/economics/#
[14] IRENA (2019), Future of Wind, Deployment, investment, technology, grid integration and socio-economic aspects.

for the period 2010-2021; the rate related to offshore installations for the same period is lower corresponding to less than half its onshore counterpart.

2.1.3 RES Penetration

Resources for the Future recently published a report where key projections from energy institutions are put together and compared. In the context of the study, it is worth investigating whether the previously highlighted expected rise in renewables (taking into account especially wind and solar energy) will be matched by a decrease in fossil fuels demand. **Coal** is projected by most studies to experience mostly downward sloped demand in the coming thirty years; this is especially the case for western economies where an over 70% demand drop might be expected (while other world regions might still rely on coal in the coming thirty years). Europe and North America are likely to see a drop in natural gas demand by 2050 comprised between 40% and 50% but on a global scale natural gas demand, according to a number of projections, might remain stable or even increase (most probably in relation to demand originating from Africa and Asia). Differently, **oil demand** is projected to remain roughly stable by a set of institutions, but a number of others foresee significant demand contractions peaking to a remarkable 88% decrease by 2050[15]. **While wind and solar energy generation are forecasted to grow (as highlighted before) it must be highlighted that key barriers might be addressed and that some projections still foresee a significant competition from fossil fuel generated energy**. It should be recalled that Fit for 55 package might further affect E.U. fossil fuels market vis-à-vis renewables industry in the coming months when debates across the Union will take place.

Considering in particular solar and wind-based electricity generation, the issue connected to **intermittency**[16] of these energy sources makes the deployment of energy management solutions a primary requirement to accommodate the expected substantial penetration of RES. Intermittency makes the electricity generation profile variable and unpredictable and that is why **forecasting assumes an essential role in effective RES deployment**. An upper limit in terms of maximum production can be introduced through curtailment that essentially entails losing the generated energy, but no minimum production can be effectively granted[17]. In this sense, when systems are substantially dependent on RES, back-up capacity becomes essential and that might imply further investments. In addition, **RES exploitation is strongly location-dependent** (implying that plants shall be located in optimal sites where the energy source is available) and expenses might be required for the connection to the existing grid. In addition, policy and regulatory-related barriers as well as lack of suitable incentive schemes might represent additional obstacles to renewable deployment across various world regions[18].

Among the primary goals pursued in the context of SMILE project it appears to be included the reduction of wind and solar energy generation curtailment events that might be addressed by the introduction of Energy Management Systems (EMS) and load controllers (energy aggregators platforms), as well as initiatives designed to smarten the energy grid, the introduction of energy storage systems and by demand response programs and strategies. A further element that proved to

[15] Resources for the Future (2021), Global Energy Outlook 2021: Pathways from Paris.
Available at: https://www.rff.org/publications/reports/global-energy-outlook-2021-pathways-from-paris/

[16] S. Asiaban, N. Kayedpour, A. E. Samani, D. Bozalakov, J. D. M. De Kooning, G. Crevecoeur and L. Vandevelde (2021), Wind and Solar Intermittency and the Associated Integration Challenges: A Comprehensive Review Including the Status in the Belgian Power System, energies.

[17] E. Delarue, J. Morris (2015), Renewables Intermittency: Operational Limits and Implications for Long-Term Energy System Models. Available at: https://globalchange.mit.edu/sites/default/files/MITJPSPGC_Rpt277.pdf

[18] Seetharaman, K. Moorthy, N. Patwa, Saravanan, and Y. Gupta (2019), Breaking barriers in deployment of renewable energy. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6351575/pdf/main.pdf

be relevant within SMILE project refers to electric vehicles' integration into the grid, that might be also considered as further "energy storage" instruments.

Thus, the following chapters will focus on the above-mentioned elements providing an analysis of the related markets in terms of general overview, competitive landscape and future perspective. The analysis of markets for products/solutions investigated in this document are expected to provide a basis for the understanding of the potential future commercial opportunities for those key technologies developed and extensively tested in the context of the SMILE and for the technology providers which have been part of the consortium involved in the project.

3 Demand-side Management and Demand Response Management systems market overview

Demand Side Management (DSM) is a broad concept that encompasses a set of activities addressing the customer side of the electricity meter to lead energy demand to adapt to power generation and grid conditions. Such goal is pursued through energy efficiency strategies and control of the power factor. They include a set of arrangements to manage loads (load control and demand response), electrification and distributed generation[19,20]. The concept of Demand Response (DR) thus appears to be one of the arrangements encompassed by the concept of DSM and literature[21] refers to it both as a resource for electric system operators and an opportunity for energy consumers to support the achievement of a balance between demand and supply by adapting electricity consumption (shifting) in response to different schemes and incentives.
This section of the document especially addresses two key technologies developed and tested within the SMILE framework, in particular:

- The aggregator platform (Load Controller) provided by OVO enables energy consumers and producers to access the value of the latent flexibility in their energy consumption and production patterns. With intelligent control, flexible assets may be used to provide balancing or ancillary services to the power system, which in turn will facilitate the cost-effective integration of renewable energy and electric vehicles into the power system.

- PRSMA's energy management systems which represents the essential component linking together and centrally managing distributed generation and storage technologies, enabling data collection and analysis bringing visibility over energy production and consumption, unlocking implicit DR strategies and smart charging of EVs as well as peak-shaving actions for system operators (DSOs and TSOs).

While Demand Response (DR) essentially refers to programs where final users modify their "normal" energy consumption patterns following a set of inputs and/or incentives, for the sake of clarity, it is reported the difference[22,23] between Demand Response programs two main categories (that can

[19] Karin Arnold, Tomke Janssen (2016), Demand side management in industry – necessary for a sustainable energy system or a backward step in terms of improving efficiency? Wuppertal Institute for Climate, Environment and Energy gGmbH.
Available at: https://epub.wupperinst.org/frontdoor/deliver/index/docId/6940/file/6940_Arnold.pdf
[20] Xavier Lemaire, Energy efficiency and Demand Side Management (presentation), Sustainable Energy Regulation Network/REEEP. Available at: https://www.un.org/esa/sustdev/csd/csd15/lc/reep_eedsm.pdf
[21] U.S. Department of Energy Office of Electricity, Demand Response (Webpage).
Available at: https://www.energy.gov/oe/activities/technology-development/grid-modernization-and-smart-grid/demand-response
[22] European Commission JRC, Why Demand Response is not implemented in the EU? Status of Demand Response and recommendations to allow Demand Response to be fully integrated in Energy Markets.
[23] Smart Energy Demand Coalition (2016), Explicit and Implicit Demand-Side Flexibility: Complementary Approaches for an Efficient Energy System. Available at: https://www.smarten.eu/wp-content/uploads/2016/09/SEDC-Position-paper-Explicit-and-Implicit-DR-September-2016.pdf

coexist):

- Explicit DR refers to programs where flexibility offered by consumers can be contracted either directly or through aggregation (that may occur, depending on the regulatory framework, through energy suppliers and/or independent aggregators) and subsequently traded in the market. Flexibility might be purchased, in the market, for example, by system operators (and other parties) and resembles somehow generation. Long-term bilateral agreement for trading flexibility is also an available option[24]. Flexibility providers are compensated for their service. It must be added, in this context, that adaptation of consumption (energy demand from the site) might be either automatized or occur through manual intervention.

- **Implicit DR** refers to those programs where consumers adjust their consumption either manually or automatically to price signals in the presence of time-varying energy prices and/or network tariffs. No compensation from external party is foreseen but the financial incentive for consumers is, in principle, connected to the realization of energy savings.

DR programs involve a further market segmentation which relates to the categories of actors involved in the program whose distinction essentially relates to the generation (in case of prosumers) and consumption capacity of the sites as well as the extent of the flexibility that can be offered to the market or implicitly exploited by the user itself. Such categorization somehow reflects the sites' purpose (in terms of activities to which the site is devoted to). In this sense, the three different segments to which it is possible to generally refer are: residential sites and Commercial and Industrial ones (C&I). Residential sites tend to be characterized by a limited flexibility potential compared to C&I.

In this context, it appears reasonable to investigate the market for DSM and DR as integrated elements highlighting that DR and energy efficiency should be the main elements making up the DSM system market.
In general, it has been estimated that **the global revenues for DSM and the connected business models deployment will reach a value of over 60 million $ in 2028 following a growing demand**[25].
With regard to the **Demand Response Management system market**, considering insights from a set of market reports, it appears that its value **can be estimated as equal to about 8 billion $ in 2020**[26] while its value in 2027 might range between 14 billion $ to over 30 billion $[27]. The large extent of the reported range might arise from the large variability reported in terms of Compound Annual Growth Rate (CAGR), ranging, in turn, between 7%[28] and 31.70%. Additional variability might be associated to the

[24] Ö. Okur, P. Heijnen, Z. Lukszo (2021), Aggregator's business models in residential and service sectors: A review of operational and financial aspects, Renewable and Sustainable Energy Reviews.
[25] Smart Energy International (2019), Global demand-side management a $63.6 billion market. Available at: https://www.smart-energy.com/news/global-demand-side-management-a-63-6-billion-market/
[26] GlobeNewswire (2020), Global Demand Response Management Systems (DRMS) Industry, Report from ReporLinker. Available at: https://www.globenewswire.com/news-release/2020/09/04/2089316/0/en/Global-Demand-Response-Management-Systems-DRMS-Industry.html
[27] Market Data Forecast (2021), Demand Response Management System Market. Available at: https://www.marketdataforecast.com/market-reports/demand-response-management-system-market
[28] Mordor Intelligence, Demand Response Management System Market - Growth, Trends, Covid-19 Impact, and Forecasts (2021 - 2026). Available at: https://www.mordorintelligence.com/industry-reports/global-demand-response-management-systems-market-industry

initial market value considered (in the base year). To provide an overview on how the market for demand response management system might evolve between 2020 and 2027, it has been assumed a value of 8 billion $ for the starting year and three CAGR has been applied to the market value during the period: 7%, 16.40% and 31.70% respectively. These CAGR referred to different periods comprised between the years 2020 and 2027, respectively 2020-2025, 2020-2027, 2021-2026. For the sake of simplicity, in order to provide an initial market estimation such CAGRs have been applied to the whole period. The results of the reported assumption on DRM systems market value are reported in the figure below.

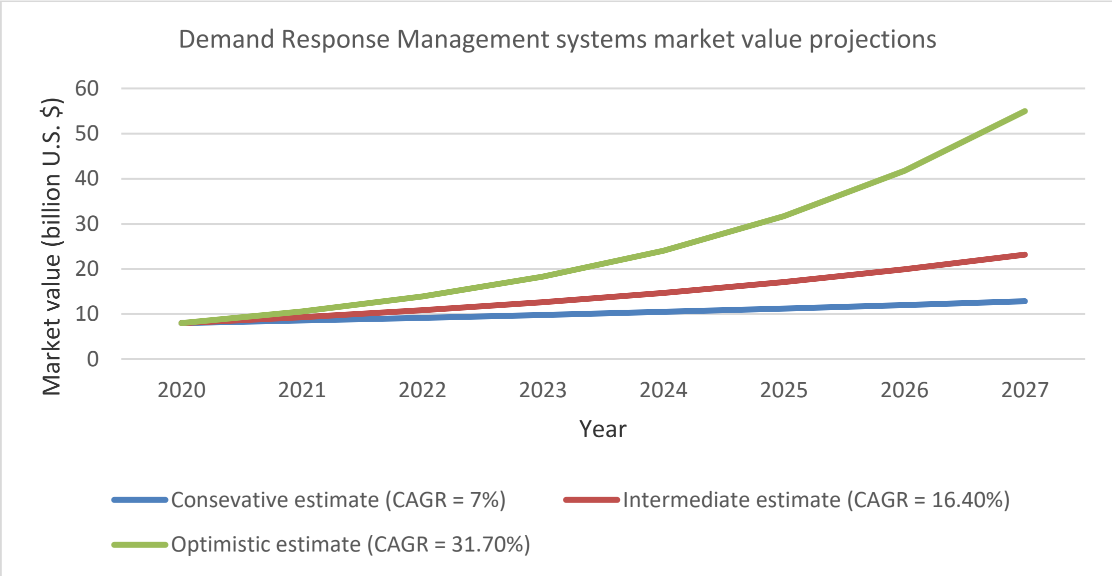

Figure 3.1: Demand Response Management systems market value projections
Source: RINA Elaboration on a set of market reports data.

Considering the most conservative estimate, in 2027 the market value is expected to reach almost 12.9 billion $ while the most optimistic one foresees as market value of about 55 billion $. The intermediate estimate indicates instead a market value of about 23 billion $ for the same year. Considering that a value equal to over 9.5 billion $ for the year 2024 is reported by another market report[29] and it is close to the DRM systems market value foreseen for the same year by the conservative estimate projection (almost 10.5 billion $), it has been chosen, in the context of this study, to adopt a prudential approach and rely primarily on the conservative estimate-provided results.
The considered market reports indicate a set of common crucial elements that are sustaining the projected market growths and that will be further investigated in this document. In particular:

- Growing interest for demand response programs from the residential sites segment.
- Growing penetration of smart electricity meters.

[29] Business Wire (2021), Demand Response Management Systems (DRMS) - Global Market Trajectory & Analytics, report from Research and Markets 2021.
Available at: https://www.businesswire.com/news/home/20210312005334/en/9.5-Billion-Demand-Response-Management-Systems-DRMS-Market---Global-Trajectory-Analytics-to-2027---ResearchAndMarkets.com

3.1.1 Growing interest for demand response programs from residential sites

A fairly recent study[30] has investigated DR deployments in countries across the E.U., evaluating the contexts of selected Member States. With regard to implicit DR at residential level, Finland as of 2019, for example, already experienced limited deployments of automatic DR programs in certain regions comprising the Helsinki area, while in relation to flexibility trading, and thus to explicit DR, enabling market conditions appear to be suitable for residential sites involvement and a number of pilot projects were being implemented. France is also unlocking DR potential both in terms of implicit and explicit strategies for households. In the former case, a key element is represented by the presence of time of use tariffs, while in the latter, independent energy aggregation is already being implemented as it will be further reported in the section devoted to the competitive landscape analysis in relation to DR programs. The internal contexts of other Member States will be further discussed in this section of the document.

Considering that the U.S. market appears to be the most advanced in terms of DR strategies deployments[31], to properly address the evolution of residential DR programs, it is worth to start looking at the number of enrolled DR programs customers in United States[32], considering such trend as a model that might be reflecting the scenario of other mature markets such as the E.U. one. Considering the number of customers enrolled in DR programs evolution in the period 2013-2019, it appears that **the only growing trend refers to residential customers while industrial and commercial ones tend to decrease**. In Figure 3.2 two trends are reported, representing respectively the changes recorded for the period 2013-2019 and for the period 2017-2019. The latter adopts 2017 as the starting year due to the fact that it represents the peak year for the number of commercial customers enrolled in DR programs (it is also the second largest data referring to industrial customers whose largest number has instead been recorded in 2013).

[30] M. de España Zaforteza (2019), Demand Response participation in different markets in Europe (Master's thesis).

[31] Demand Response Market Snapshot: US vs. Europe (webpage), RESPONSE project (Demand Response for all). Available at: http://project-respond.eu/demand-response-market-snapshot/

[32] U.S. Energy Information Administration (2020), Annual Electric Power Industry Report (extract). Available at: https://www.eia.gov/electricity/annual/html/epa_10_08.html

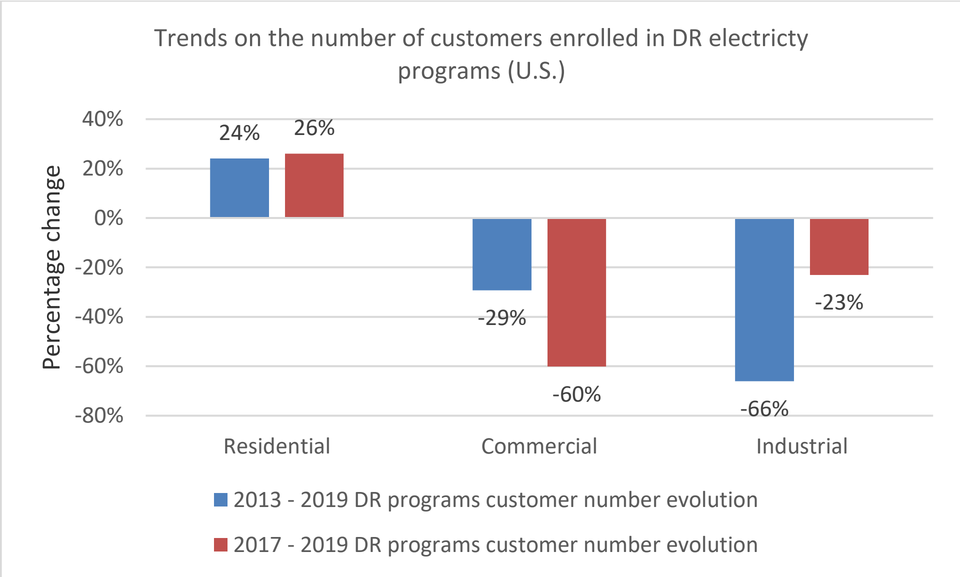

Figure 3.2: Trends on the number of customers enrolled in DR electricity programs (US)
Source: RINA Elaboration on a U.S. Energy Information Administration data.

To provide an additional visual representation of the trends described above, in Figure 3.3 it has been reported the percentage change in the number of customers per customer category (residential, commercial, industrial) for the whole period 2013-2019.

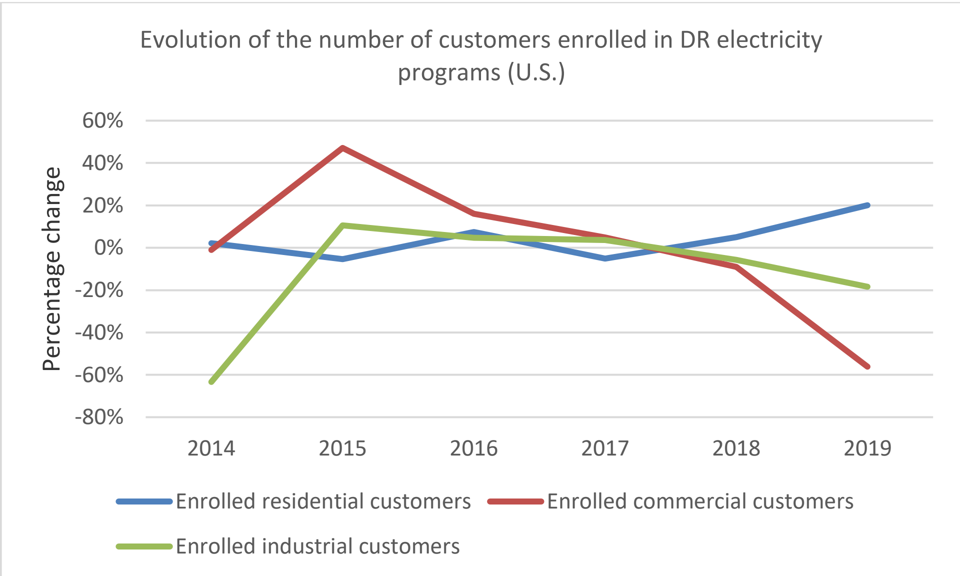

Figure 3.3: Evolution of the number of customers enrolled in DR electricity programs (US)
Source: RINA Elaboration on U.S. Energy Information Administration data[32].

As anticipated, it has been documented an increasing enrollment (in the U.S.) of residential customers in demand response programs and it is expected a similar growing interest across regions. A further elaboration of U.S. Energy Information Administration data shows that the average annual energy savings per customer category in U.S. (still referring to customers enrolled in electricity DR programs) are the following:

- About 103 kWh for residential customers.
- About 709 kWh for commercial customers.
- About 1,520 kWh for industrial customers.

In the context of this analysis, to provide additional elements highlighting the credibility of an increasing market value for DRM systems, it is worth considering the growing attractiveness that such DR programs might gain in a scenario affected by growing electricity prices. Still referring to residential consumers, a growing trend in terms of electric energy retail price has been recorded[33] since 2010 as shown in figure below.

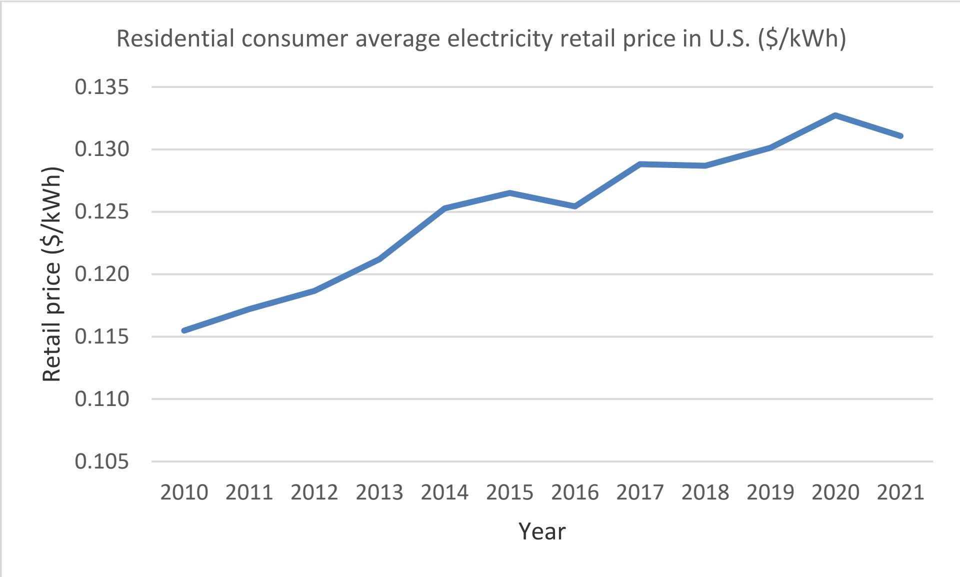

Figure 3.4: Residential consumer average electricity retail price in U.S.
Source: RINA Elaboration on U.S. Energy Information Administration[33].

Considering SMILE project framework, which is embedded in the European context, it is worth comparing the same figures reported for the U.S. with the European Union's ones. E.U. average retail price for household customers[34] tend to be higher with respect to U.S. average prices as shown in Figure 3.5. The comparison has been carried out considering average prices €/kWh in the period 2016-2020; the conversion of U.S. prices from $ to € has been performed using European Central Bank provided average exchange rate[35], for the period 4/01/2016 – 31/12/2020, equal to 0.8818. Prices in U.S. and E.U. include taxes.

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[33] U.S. Energy Information Administration (2021), June 2021 Monthly Energy Review (Ms Excel spreadsheet). Available at: https://www.eia.gov/totalenergy/data/monthly/
[34] Eurostat (2021), Electricity prices for household consumers (Ms Excel spreadsheet). Available at: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_204&lang=en
[35] ECB, USD/EUR exchange rate. Available at: https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html

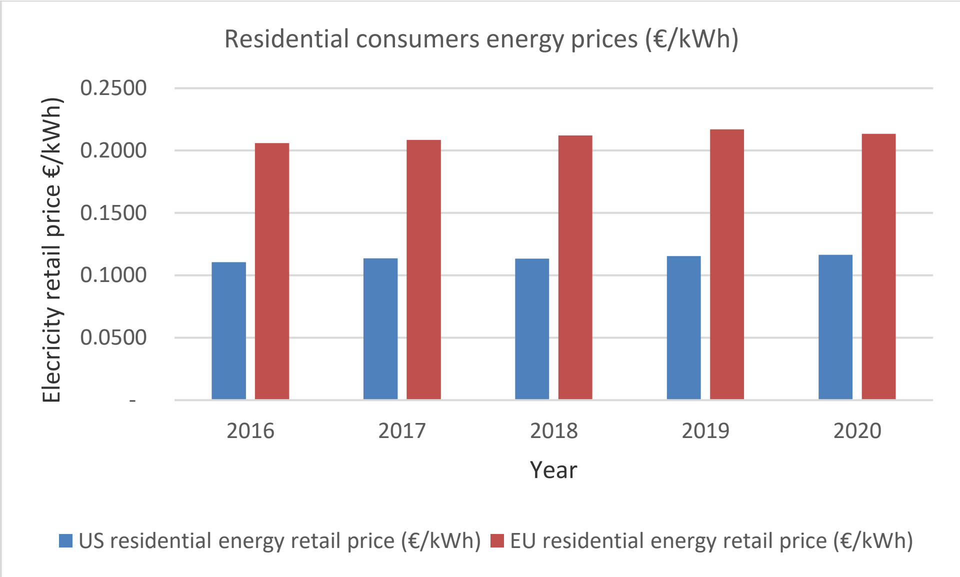

Figure 3.5: Residential consumers energy prices

Source: RINA Elaboration on U.S. Energy Information Administration and Eurostat data.

In Figure 3.6, it is also reported the trend recorded for household electricity retail prices in the European Union for the period 2016-2020.

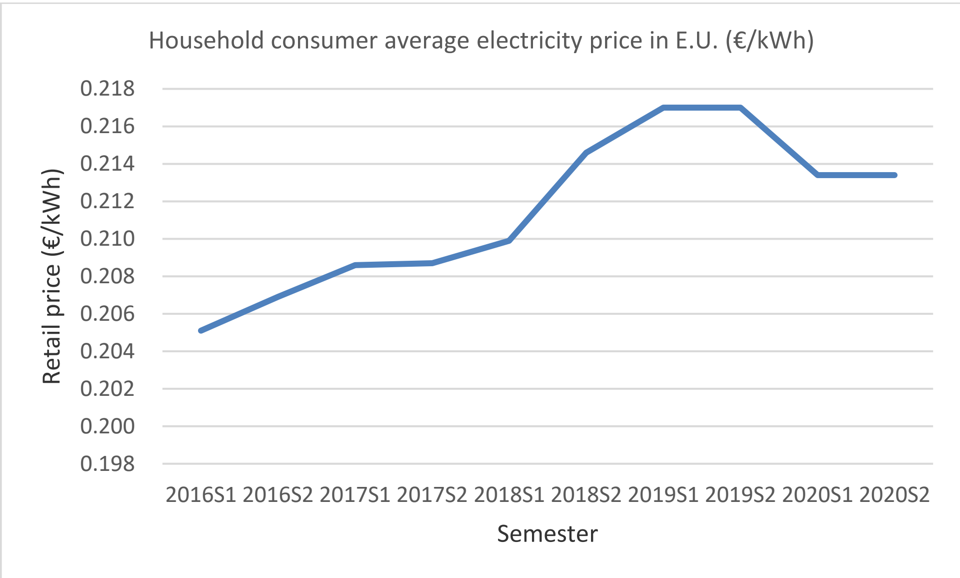

Figure 3.6: Household consumer average electricity price in E.U.

Source: RINA Elaboration on Eurostat data[34].

Considering the growing trend of prices shown in figures above (except for the recent decrease recorded starting from the second semester of 2019), **it is reasonable to assume that European households might be somehow motivated to enroll in DR programs (despite DR deployment in Europe is not as developed as it currently is in the U.S.). The rationale behind this push does not solely refer to realizing energy and monetary savings by shifting consumption to non-peak periods (in scenarios where electricity has different price rates at different times of the day, i.e. dynamic pricing) but it also might involve counterbalancing possible energy price increase with compensations and incentives (financial incentives from utilities, aggregators and other energy system stakeholders).**

It is essential to investigate households' electricity prices across the European Union to assess where financial incentives to enroll in DR programs (given that an enabling regulatory framework is or is being established) might be more relevant for residential sites. A map based on electricity prices[36] for households that exceeded the annual consumption of 2,500 kWh is provided in Figure 3.7.

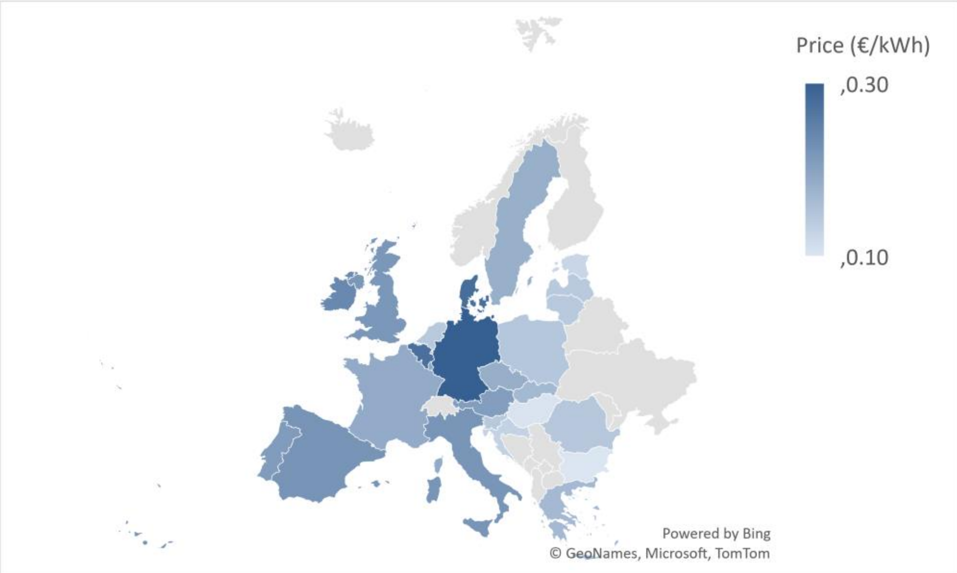

Figure 3.7: Electricity prices for households in E.U.
Source: RINA Elaboration on Statista data[36].

The countries where electricity prices for households appear to be the highest are, in descending order: **Germany** with over 0.30 €/kWh, **Denmark** and **Belgium** where prices are close to 0.28 €/kWh, Ireland follows with a price per kWh that slightly exceeds 24 cents, while Spain and Italy stand at about 0.22 €/kWh. The United Kingdom shows a rate slightly below the Italian one. Financial-related motivations are also inducing European consumers in turning into prosumers, especially through the installation of PV modules in sites rooftops[37]. As discussed at the beginning of this document, Fit for 55 package might further change the projected scenarios triggering a further boost in PV modules deployment across the Union. Furthermore, the Clean Energy for all Europeans package in 2019, aimed at creating a suitable framework for households (consumers) to invest in renewables generation and recover the expense through a reasonable payback period[38]. Moreover, the E.U. Directive 2019/944[39] clarifies the role and the rights of energy communities which might unlock further savings or revenue creation opportunities for prosumers and consumers in the Union. The European Commission reported in 2019 that by 2030 energy communities might own 21% of solar energy generation capacity[38]. Finally, the

[36] Statista (2021), Prices of electricity for households with an annual consumption greater than 2,500 kilowatt hour in the European Union in 2020, by country. Available at: https://www.statista.com/statistics/1046505/household-electricity-prices-european-union-eu28-country/
[37] Smart Energy Europe (2020), The smartEn Map, Prosumers. Available at: https://smarten.eu/wp-content/uploads/2020/12/the_smarten_map_2020_DIGITAL.pdf
[38] European Commission (2019), Clean Energy for all Europeans. Available at: https://op.europa.eu/en/publication-detail/-/publication/b4e46873-7528-11e9-9f05-01aa75ed71a1/language-en?WT.mc_id=Searchresult&WT.ria_c=null&WT.ria_f=3608&WT.ria_ev=search
[39] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU.

above-mentioned Directive also specifies that "customers" have "the right to produce, consume, store and sell electricity, individually or through an aggregator" as well as the right to access aggregation contracts. In this sense, investigating DR and households' access to flexibility trade appears essential.

Flexibility is obviously an invaluable alternative for those local frameworks where injecting generated electricity into the grid is subject to limitations or where export of renewables towards the public grid does not provide notable financial gains; it appears thus relevant to assess whether in those countries where electricity prices are particularly high, prosumers and households in particular, have access to energy flexibility options. In **Germany**, where electricity prices are the highest within the European Union, the legal framework appears to prevent households to access explicit demand response which is instead mostly available for commercial and industrial sites[37]. At the same time, for those households which are prosumers, a feed-in tariff up to about 0.10 €/kWh is available (representing one third of the electricity consumption price highlighted above). As a consequence, also in presence of financial benefits for households for avoiding the use of the grid, maximizing self-consumption appears a suitable solution to face German high electricity prices. **Danish** consumers pay the highest electricity taxes (66% of electricity bill) in Europe and high electricity prices are a driving force for further decentralized energy resources installation. Residential sites can market their flexibility through aggregators in the context of existing pilot projects while obstacles limiting aggregators exist. Implicit DR is a feasible and growing solution as differently from the German context, smart meters experienced a substantial penetration rate (smart meters penetration rates in European countries are further discussed later in this document). The market for flexibility in **Belgium** shows only a limited openness to residential sites and most importantly business cases proved to be financially not sustainable so far[40], thus hampering widespread adoption. **Spain** is undergoing regulatory changes that are expected to boost the introduction of explicit DR programs through independent aggregators; in addition, changes on electricity time-based tariffs might have positive effects on implicit DR initiatives. Finally, in **Italy**, by the end on the year 2020, less than 15% of residential sites were subject to dynamic tariffs, despite smart meters penetration rate is higher than most European countries. In this sense, the room for further implicit DR is still wide. The market of explicit DR for small prosumers appears still limited providing instead opportunities and diverse options for industrial consumers[37].

At this point, having addressed the financial incentives fostering flexibility exploitation at residential level, it is significant to explore a further key motivation that might influence energy consumers to enroll into DR programs: environmental-related benefits. In this sense, a study[41] conducted in the U.S. that proposed DR programs coupled with "Automated Emissions Reduction (AER) environmental messaging" instead of economic incentives, showed that such alternative stressing on environmental benefits within the value proposition, may lead to enhanced customer engagement with lower expenses for utilities and aggregators. Moreover, the incremental involvement of environmental related benefits within the value proposition for DR programs might strengthen customer retention and boost organizational reputation.

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[40] R. Gheuens (2020), Barriers to residential demand response in Belgium and the Netherlands. Available at: https://upcommons.upc.edu/bitstream/handle/2117/334218/masterthesis-gheuensraf.pdf?sequence=1&isAllowed=y

[41] WattTime (2020), Customer Response to Demand Response, How Automated Emissions Reduction (AER) environmental messaging and traditional economic incentives influence customer reactions and program enrollment. Available at: https://www.watttime.org/app/uploads/2020/12/WattTime-GLPF_Environmental_Residential_Demand_Response-Report-202012-vFinal.pdf

3.1.1.1 Competitive landscape

Explicit DR programs, except for cases in which single industrial or commercial sites are able to provide a large enough load, require the presence of aggregators (also identified as balancing service providers). Aggregators essentially pool together energy consumption and generation capabilities of a set of actors (either generators, especially dealing with distributed energy resources, consumers or prosumers). The aggregator can act on those actors' energy consumption/available flexibility temporarily reducing or increasing demand. Aggregators engage with the above-mentioned actors through a contract that generally entails compensating them for the flexibility provided. Hence, a parallel contract with respect to the energy supply one exists in the case aggregation service is provided by an independent third party and not by the energy supplier[42]. Aggregators appear thus essential in the development and consolidation of explicit DR programs in the residential segment being it mostly made up of small consumers and prosumers whose maximum load would not qualify to individually offer their potential flexibility in the market.
Despite the previously discussed growing interest in residential demand-response, it still represents a limited phenomenon[43] (a study on European main aggregators found that 90% of DR involves commercial and industrial customers[44]) a but a set of initiatives is opening up opportunities to further develop the residential segment[45].

Table 3.1: Companies active in the residential demand-response

Company	Key information
Voltalis	One of the European pioneers in the field appears to be the French-based Voltalis, the leading organization, in Europe, in the flexibility management market for residential sites. The company developed a device that is provided, free of charge, to residential sites with installed electric heating. An app is provided to the householder where consumption can be monitored and eventually remotely managed, but, most importantly, when imbalances are detected on the grid, Voltalis can intervene in real time managing a pool of residential and commercial sites consumption and thus balancing the load. Voltalis value-proposition appears to combine grid safety and stability, and environmental benefits (associated to the enablement of energy savings) which both appeal to consumers, with a financial argumentation consisting in a maximum 15% energy saving ("jusqu'à 15% d'économies d'énergie[46]"). Voltalis initiative has been boosted by Meridiam (a large independent benefit corporation investing in long-term public infrastructure projects) support that

[42] European Consumer Organisation (2018), Electricity Aggregators: Starting off on the right foot with consumers. Available at: https://www.beuc.eu/publications/beuc-x-2018-010_electricity_aggregators_starting_off_on_the_right_foot_with_consumers.pdf
[43] J. Hughes (2019), Residential demand response: releasing great potential in the next 5 years, Delta-EE. Available at: https://www.delta-ee.com/delta-ee-blog/residential-demand-response-releasing-great-potential-in-the-next-5-years.html
[44] P. Poplavskaya, L. de Vries (2020), Aggregators today and tomorrow: From intermediaries to local orchestrators? in Behind and Beyond the Meter: Digitalization, Aggregation, Optimization, Monetization.
[45] Connected Energy Solutions (2021), Residential demand response: Pilot to profitability. Available at: http://connectedenergysolutions.co.uk/residential-demand-response-pilot-to-profitability/
[46] Voltalis (Webpage). Available at: https://www.voltalis.com/particuliers/notre-solution

	acquired its majority stake[47] and by a 20 million loans issued by the European Central Bank[48]. Voltalis is currently managing over 100,000 residential sites in France and is committed to reach the number of 1 million sites in Europe by 2024 (reaching 500,000 homes in France).
tiko	Another European-headquartered initiative, the Swiss start-up Tiko, is addressing residential sites and small businesses. The company brings into the segment the concept of Virtual Power Plant (VPP) which is essentially an interconnected but decentralized network of independent generators and consumers; a central control allows load management and eventually the interaction with wholesale energy and ancillary service markets. Tiko combines this concept that allows customers to generate revenues from wholesale markets access with the retrofitting and the installation of hardware components at the consumer premises that together with the EMS provide visibility and control over consumption. In addition, solutions for prosumers (PV modules) are available. Even in this case a larger organization, the multinational utility company Engie, acquired the majority share of the initiative potentially boosting the further development and expansion of Tiko in Europe[49,50]. Outside Switzerland the company has already created partnerships in France, Germany and Austria[51].
LichtBlick	A further European operator, a renewable energy provider offering also aggregation services, that is dealing with the residential segment is the German LichtBlick. It launched the "SchwarmEnergie" concept, coupled with the platform "SchwarmDirigent" that enables the bundling of decentralized energy consumption, generation and storage[52]. The company has also been involved in the installation of small-scale heat and power plants units in residential sites whose flexibility capacity is to be offered as a control reserve to TSOs[53,54].

[47] Meridiam (2020), Meridiam becomes the majority shareholder of Voltalis, the European leader in Demand Response for residential and commercial end-users.
Available at: https://www.meridiam.com/en/news/article/meridiam-becomes-the-majority-shareholder-of-voltalis-the-european-leader-in-demand-response-for-residential-and-commercial-end-users
[48] European Central Bank (2020), France: EIB, with the support of the European Commission, is financing the deployment of 150 000 smart boxes to actively manage electricity demand (press release).
Available at: https://www.eib.org/en/press/all/2020-016-eib-with-the-support-of-the-european-commission-is-financing-the-deployment-of-150-000-smart-boxes-to-actively-manage-electricity-demand
[49] Tiko (website). Available at: https://tiko.energy/
[50] Engie (2019), Tiko: Energy aggregation for householders (press release). Available at: https://innovation.engie.com/en/news/news/new-energies/tiko-energy-aggregation-for-householders/12868
[51] RePower (2019), Prosegue l'espansione all'estero di tiko con un nuovo partner.
Available at: https://www.repower.com/en-us/tiko_2019_ita
[52] C. D. Ahrens (2017), Transition to Very High Share of Renewables in Germany.
Available at: https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7874617
[53] Reuters (2015), German firms turn batteries into power plants to aid grid control.
Available at: https://www.reutersevents.com/renewables/energy-storage/german-firms-turn-batteries-power-plants-aid-grid-control
[54] Power Engineering International (2017), Lichtblick aims to take advantage of German CHP law.
Available at: https://www.powerengineeringint.com/decentralized-energy/district-energy/lichtblick-aims-to-take-advantage-of-german-chp-law/

sonnen	The German battery manufacturer Sonnen has launched a Virtual Power Plant initiative that links together Sonnen batteries owners. Pooling distributed home-installed batteries capacities, brought together in the sonnenCommunity, allows the company to offer ancillary services to the grid[55]. In this context, Sonnen is not solely providing battery-based aggregation services to households but it is aiming to compete directly with utilities becoming an energy supplier. The sonnenFlat 1500 service, for example, provides Italian customers who purchased a Sonnen battery and have installed PV modules, with 1500 kWh of electric energy, free-of-charge, to meet the average 25% of yearly energy need that is not covered by PV generation and storage system integration. In the case the household exceeds the 1500 kWh provided, an energy supply rate is charged by Sonnen which effectively plays the role of the energy supplier. The contract provides Sonnen with the control over the home-installed batteries to provide balancing services to the national grid[56]. In March 2019, Sonnen has been fully acquired by the multinational oil and gas corporation Shell which is operating since 2016 a new division focused on the electric energy value chain[57].

Other independent aggregators not focused on the residential segment are currently operating in Europe.

Table 3.2: Main independent aggregators

Company	Key information
Actility	Actility is a French-based IoT solution provider which is also engaged in enabling demand-response services for customers in the industrial and tertiary segment through its platform ThingPark Energy. The platform optimizes sites consumption and manages the load allowing the sites to participate in DR programs and generating revenues, as shown in the scheme reported below[58].

[55] GTM (2017), Sonnen Tries Different Virtual Power Plant Models in Germany, Australia and America. Available at: https://www.greentechmedia.com/articles/read/sonnens-new-virtual-power-plant-model-differs-by-country

[56] Sonnen (website). Available at: https://sonnen.it/sonnencommunity/

[57] Shell (2019), Shell completes acquisition of Sonnen (press release). Available at: https://www.shell.com/energy-and-innovation/new-energies/new-energies-media-releases/shell-completes-acquisition-of-sonnen.html

[58] Actility (website). Available at: https://www.actility.com/energy/

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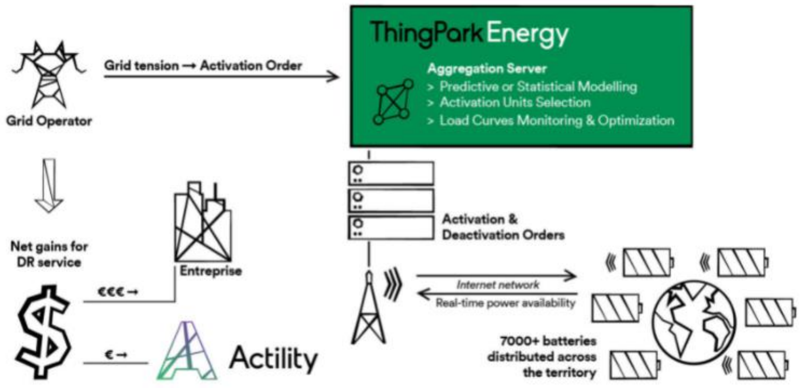
<tr><td></td><td>

Figure 3.8: Actility platform functioning

The company effectively expanded to the aggregation service field especially through the acquisition, in 2017, of Noodvermogenpool, the largest DR aggregator in the Netherlands[59]. The acquisition led to the creation of one of the leading organizations competing in the expanding energy aggregation market in Europe.</td></tr>
<tr><td>BayWa r.e.</td><td>BayWa r.e. is a German organization engaged in the development and management of renewable energy-related projects being simultaneously a green energy supplier. It is part of a larger international group operating also in other industries and it is currently present in 28 countries[60]. It is also an aggregator of green energy (the company operates 100% carbon neutral) through a VPP model. Infact, BayWa r.e. centrally manages a dispersed network of generators, consumers and storage systems allowing the trading of flexibility into energy markets (automatically). In particular, the company VPP model leverages on the integrated functioning of two software components: a remote control system allowing the monitoring and remote control of customers' assets (for generation, consumption and storage) and an optimisation software which combines data from external sources (as for example market prices) and information coming from managed sites to deploy effective DR strategies[61].</td></tr>
<tr><td>ecotricity</td><td>Ecotricity is a U.K.-based green electricity supplier that recently entered the aggregation market in 2018, adopting Kraftwerke Next VPP platform. Kraftwerke run a VPP-as-a-service model allowing the pooling of DER assets as well as the access to European energy markets. Its solution will allow Ecotricity to monitor generation and consumption of its controlled assets and the automatic identification of those assets that can deliver</td></tr>
</table>

[59] Actility (2017), Actility acquires NL Noodvermogenpool, taking the lead in European demand response (press release). Available at: https://www.actility.com/actility-acquires-nl-noodvermogenpool-taking-the-lead-in-european-demand-response/

[60] BayWa r.e. (website). Available at: https://www.baywa-re.com/en/about-baywa-re/company-information

[61] SmartEN (2018), Smart Energy in practice: Collection of use cases on digital decentralised solutions. Available at: https://www.smarten.eu/wp-content/uploads/2018/10/LAST_use-cases-publication_low-resolution.pdf

	tradable flexibility in the market[62]. Ecotricity objective relates to managing not solely its own green-energy production portfolio (wind, solar and green gas) but to broaden operations scope involving energy-supply customers offering them revenues from DR[63].
NEXT KRAFTWERKE	The Cologne-based Next Kraftwerke operates one of the largest VPP in Europe pooling renewable energy generators (wind, solar, biogas), consumers and storage facilities. The company focuses on the industrial and commercial sites segment trading their flexibility resources in the wholesale market and mainly providing ancillary services to TSOs across Europe (reserves). By June 2021, the company pooled capacity exceeded 9,000 MW with a network of over 11,000 energy producing and energy consuming units. In 2019, after just ten years from its foundation, Next became the leading PV aggregator in Germany[64] and it currently operates in multiple European countries. Next Kraftwerke has been fully acquired by Shell in August 2021[65], further strengthening the multinational corporation position in the electric energy value chain. Next platform (NEMOCS) is also offered as a scalable software-as-a-service solution to VPP operators.
e2m	Another Germany-based relevant player is E2m. It is an aggregator and energy trading operator with a network of about 4,500 total managed units including about 3,500 dispersed generation units. The network generation capacity reaches 3.7 GW. The company has established subsidiaries across Europe, in Finland, Poland, Austria, the Netherlands, Belgium, Italy and U.K. The set of services provided is summarized in the image below[66].

[62] Next Kraftwerke (2018), Ecotricity selects Next Kraftwerke's NEMOCS to build Virtual Power Plant (press release).
Available at: https://www.next-kraftwerke.com/news/ecotricity-selects-next-kraftwerkes-nemocs-to-build-virtual-power-plant

[63] The Energyst (2019), VPP: Why Ecotricity has entered the flexibility market.
Available at: https://theenergyst.com/ecotricity-enters-flexibility-market/

[64] Next Krafwerke (website). Available at: https://www.next-kraftwerke.com/company

[65] Next Krafwerke (2021), Shell completes acquisition of Next Kraftwerke (press release). Available at: https://www.next-kraftwerke.com/news/shell-completes-acquisition-of-next-kraftwerke

[66] E2M (website). Available at: https://www.e2m.energy/en/

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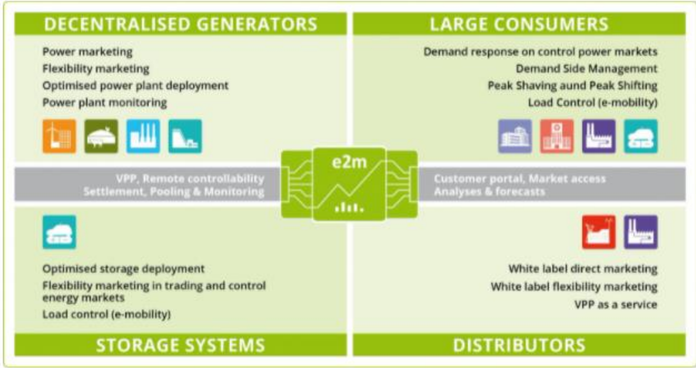
<tr><td></td><td>

Figure 3.9: Services for customers

The French multinational utility corporation EDF acquired, in 2019, 100% of E2m[67] strengthening its aggregation capacity in the German market and complementing its aggregation services business provided in France through the subsidiary Agregio.</td></tr>
<tr><td>agregio
GROUPE EDF</td><td>Agregio is the subsidiary of the French utility giant EDF. It manages a portfolio of over 4 GW of flexibility capacity from commercial and industrial generators and producers. The company implemented the VPP concept through the development of a proprietary technology[68]. In 2018, Agregio was aiming at capturing a market share comprised between 20% and 30%, in France, by the year 2020[69].</td></tr>
<tr><td>Energy Pool
Smart energy management</td><td>Energy Pool is the company that pioneered the DR aggregation business in France, in 2009. It automatically interacts with its industrial and commercial sites as well as with generators through a DR box which is installed at customers’ premises generating revenues through flexibility trading[70]. In Europe Energy Pool also operates in U.K., Belgium, Germany and Turkey. In its global portfolio the company manages about 6 GW of flexibility capacity[71].</td></tr>
<tr><td>enel x</td><td>Enel X is an Italian-based aggregator dealing with commercial and industrial loads managing a flexibility capacity, across fifteen countries of about 6 GW in 2020 (6.3 GW in 2019). In Europe, Enel X is operating in Italy, Romania, Poland, Germany, France, Ireland, Spain, Norway, U.K. and Russia. In 2021, the company confirmed its leading positioning in the Irish DR market controlling about 36% of the overall DR capacity in the</td></tr>
</table>

[67] Actu-Environnement (2019), Feu vert de la Commission européenne à l'acquisition d'E2M par EDF. Available at: https://www.actu-environnement.com/ae/news/E2M-EDF-acquisition-approbation-Commission-europenne-concentration-energie-renouvelable-agregateur-33902.php4
[68] Agregio (website). Available at: https://www.agregio.com/
[69] S&P Global (2018), EDF subsidiary Agregio inks contract to optimize 350 MW of French renewables. Available at: https://www.spglobal.com/marketintelligence/en/news-insights/trending/mrjiepg8ccbgnda0vuhy_g2
[70] Energy Pool (website). Available at: https://www.energy-pool.eu/fr/
[71] Industry Wired (2020), Energy Pool: Optimizing Energy Consumption with Smart Energy Management Solutions. Available at: https://industrywired.com/energy-pool-optimizing-energy-consumption-with-smart-energy-management-solutions/

	country[72]. Enel X currently leads the Polish DR market managing a 70% of the country DR capacity[73] and it remains the major aggregator in Italy with about 350 MW capacity managed in 2020[74].
	The largest DR aggregator in the U.K. is Flexitricity with over 500 MW of managed flexibility capacity. The company operates with commercial and industrial sites and also interacts with the public sector. In addition, Flexitricity partners with energy suppliers providing them with the opportunity to offer DR services to their customers. The company in addition to trading flexibility in different markets is also an energy supplier since 2018. Flexitricity has been acquired by the Swiss energy company Alpiq, in 2014, and since 2020 it is owned by the British investment fund Quinbrook Infrastructure Partners[75] which operates in the renewable energy field.
	Centrica Business Solutions is part of the British multinational and service company Centrica. It competes in the distributed energy market in Europe, in particular in U.K., Ireland, Germany, France, Belgium, the Netherlands and Hungary. Outside Europe, Centrica Business Solutions operates in North America and Mexico. The company developed its own DR software, a cloud-based solution, and it appears to focus on commercial and industrial customers and the public sector. It manages a global flexibility capacity of about 2.3 GW. In addition, the company indicates that through its solution "52% more revenue" are generated. Centrica's solution entails the installation of hardware components at customers' premises and flexible financing options are offered[76]. Centrica effectively strengthened its positioning in the DR market through the acquisition, in 2017, of the Belgian aggregator Restore which was managing at the time about 1.7 GW capacity from sites located in Belgium, France, Germany and U.K.[77]
	Another European player, Sympower has been founded in the Netherlands in 2015. It currently operates, in addition to the Dutch market, in Finland and Sweden. It appears to be mostly working with industrial customers from typical energy-intensive sectors. It is attracting investments to boost its growth (5.2 million only in March 2021). It does

[72] Energy (2021), Enel X achieves a 36% market share of demand response in Irish capacity market. Available at: https://energydigital.com/sustainability/enel-x-achieves-36-market-share-demand-response-irish-capacity-market

[73] Enel X (2020), Enel X strengthens demand response leadership in Poland with new award (press release). Available at: https://www.enel.com/media/explore/search-press-releases/press/2020/02/enel-x-strengthens-demand-response-leadership-in-poland-with-new-award

[74] Enel X (2020), Demand Response, l'energia che rende protagonista. Available at: https://www.enelx.com/it/it/news/2020/02/progetto-terna-demand-response

[75] The Herald (2020), Scottish energy demand response pioneer sold for £15m to investment firm. Available at: https://www.heraldscotland.com/business_hq/18720901.scottish-energy-demand-response-pioneer-sold-15m-investment-firm/

[76] Centrica Business Solutions (website). Available at: https://www.centricabusinesssolutions.com/

[77] Green Tech Media (2017), European Grid Edge M&A Alert: Centrica Buys REstore for $81M. Available at: https://www.greentechmedia.com/articles/read/european-grid-edge-ma-alert-centrica-buys-restore-for-81m

	not install proprietary hardware components, but it relies on off-the-shelf solutions, maintaining the company focus on the software component[78].
	Grupo ASE is the major electric demand aggregator in Spain. It is an independent player focusing on industrial loads.

Other players in addition to those reported are obviously operating in the European and global DR segment. The two technology providers involved in SMILE project especially in relation to DSM, are, as mentioned earlier in the document, OVO and PRSMA.

- OVO Energy[79], part of OVO Group, is a U.K.-based energy supplier which started operations in 2009. The company offers consumers 100% renewable energy supply contracts together with a set of additional services connected to residential energy storage, zero carbon heating, EVs charging and energy smart metering. Within OVO controlled companies, a cloud-based SaaS platform transforming energy retail and enabling decarbonization has been developed. In particular, the "Kaluza" platform, which has been deployed in the SMILE Orkney demonstration site, connects with a number of distributed smart devices measuring in real time their available demand flexibility to provide services to the grid.
- PRSMA[80] is a Madeira-based company born from the joint efforts of M-ITI (Madeira Interactive Technology Institute) and an entrepreneur operating in the electronics sector. It developed and commercializes a cost-effective sensing system capable of disaggregating residential sites consumption, providing visibility to occupants and insights on potential faults as well as on tariffs. In the context of the SMILE project, PRSMA developed the EMS which collects residential and commercial UPACs generation and consumption information which are integrated with the ones from EVs and data from the distribution grid, to enable DR and smart grid applications.

As shown from the identification of the various actors involved in the market, **large corporations such as Engie, EDF and Shell, in the past years, invested in the aggregation field, highlighting the strategic relevance of the market**. Some actors play a relevant role in a set of national markets as in the case of Enel X for the Irish, Polish and Italian markets, Grupo ASE leads the Spanish market and Flexitricity the British one. Actility, after the acquisition of Noodvermogenpoo should be holding a significant share of the Dutch market. However, a clear and reliable breakdown is hard to establish considering that most players operate in multiple countries and the market has been dynamic in recent years. The investigation of market players led to the interesting conclusion that **most operators offering aggregation services and managing VPPs are often involved in providing other services especially related to sites energy efficiency and energy consulting**. In addition, in-house developed energy management and aggregator platforms (enabling DR) are often licensed to other operators (sometimes as white-label products), especially utilities, willing to provide directly DR services. There exist also major players focusing on the provision of VPP solutions and partnering with major energy industry actors such as the British Kiwi Power (which is also an aggregator).

[78] Tech.eu (2021), Less than a second to react: How Sympower brings flexibility to the energy transition. Available at: https://tech.eu/features/34871/less-than-a-second-to-react-how-sympower-brings-flexibility-to-the-energy-transition/
[79] OVO Energy (website). Available at: https://www.ovoenergy.com/
[80] PRSMA (website). Available at: https://www.prsma.com/

Aggregators, in portraying their value proposition addressed to industrial, commercial and residential sites tend to refer to three key elements:

- Additional revenue generation with limited impact on customer operations;
- Grid stability and safety support;
- Contribution to decarbonization and efficiency, and realization of environmental benefits.

However, aggregators' customers are not solely energy consumers and prosumers but the set of grid operators which represent relevant revenue streams as clearly summarized in P. Poplavskaya and L. de Vries' 2020 study[44]. The "B2B" semicircle, refers in fact to utilities and grid operators such as TSOs, DSOs and Balance Responsible Parties.

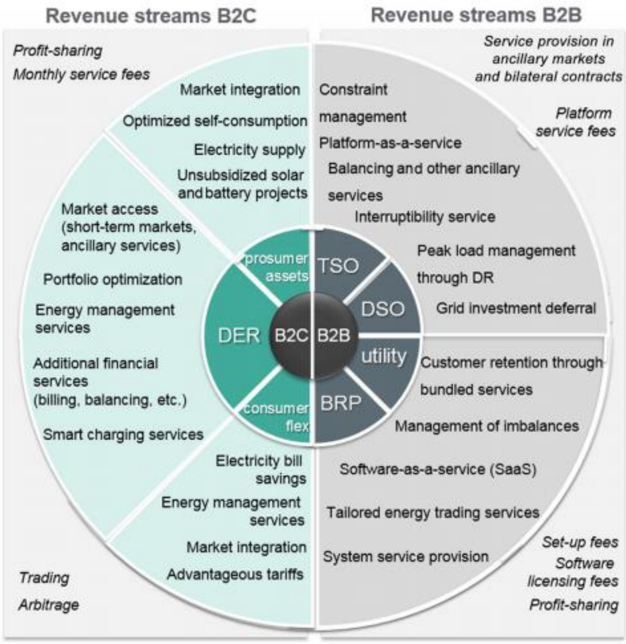


Figure 3.10: Potential customers for aggregators
Source: P. Poplavskaya and L. de Vries'[44] (2020).

The flexibility offered, exploited to generate revenues, tends to be employed for the provision of reserve services (primary, secondary, tertiary), frequency response services, in the capacity market and in the energy wholesale one.

Apart from explicit demand response which entails the need for aggregating solutions, implicit demand response, in addition to the need to a widespread smart meter installation might be boosted by market players. To mention one, Peek, which essentially eases customers' non-automatic participation into implicit demand-response programs. It provides visibility to households over the times during the day where electricity rates are the lowest, higher or the highest, through a plugged-in device and/or through an application. The company directly partners with utilities[81].
As highlighted within Table 3.1 and Table 3.2 in which several companies providing VPPs services have been mentioned (Ecotricity, NEXT, BayWa.re., etc.) and as also confirmed by the transformation of the electricity sector, based on the digitalization of the power system, VPP platforms are more and more emerging as key technologies enabling higher security and quality levels for energy supply and demand given the growing introduction of renewable energy.

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[81] Peek (website). Available at: https://peek.energy/

Europe, which is considered the birthplace of the VPP concept, is experiencing an evolution of the enabling platforms enriching the set of ancillary services offered to the energy markets[82] as well as flexibility trading schemes. While the VPP concept was traditionally working on the supply side of the market in relation to the boost in renewable energy sources highlighted in the first section of this document, the focus is now shifting towards the demand side that, as extensively investigated in the context of the SMILE project, relates not solely to large consumers (such as energy intensive industries) but to smaller energy customers, prosumers, EVs, etc. The market for VPP in Europe is indeed aligning with this evolution already recorded in other regions such as Canada, Australia and Japan[82].
Europe lags behind the U.S., being the latter a major VPP market, as with respect to DR, as mentioned at the beginning of this section. But, as already reported, due to the increasing dependence of energy systems on energy sources with variable load profiles, stakeholders in the market are investigating and testing technologies to source flexibility and subsequently match the grids balancing needs. As suggested by Guidehouse Insights, the demand side flexibility can be cost-effectively exploited through the adoption of suitable software solutions. In addition, it has been estimated, as reported in the image below, that market revenues for the European VPP market might reach the value of 3 billion in the year 2028.

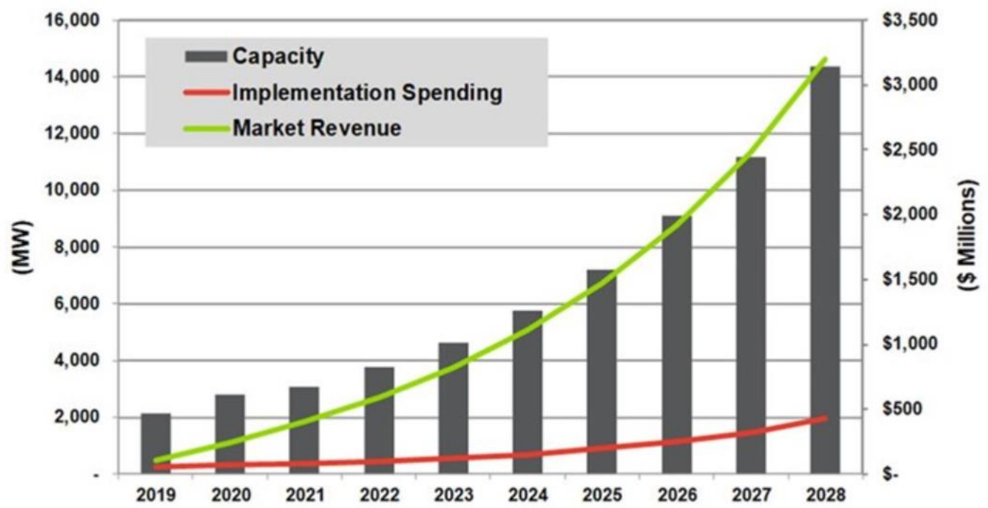

Figure 3.11: Annual total VPP capacity, implementation spending and market revenues (Europe, 2019-2028).
Source: Guidehouse Insights, 2019[82].

Another study, forecasts that the European VPP market will experience a growth in the period 2019-2028 reflecting a CAGR equal to 20.98%. The two driving forces indicated to support this growth relates to: the rising popularity of the VPP concept and the growth in DER embedded in a "decentralized power generation model[83]".
A dominant market share in the Europe region is contributed by Germany, the U.K., and France, and the market in these countries is expected to increase during the forecast years. The demand for virtual power plant has been increasing since 2015 in these regions.

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[82] Guidehouse Insights (2019), The European Take on Virtual Power Plants. Available at: https://guidehouseinsights.com/news-and-views/the-european-take-on-virtual-power-plants
[83] Inkwood Research (2020), Europe Virtual Power Plant Market Forecast 2019-2028 . Available at: https://inkwoodresearch.com/reports/europe-virtual-power-plant-market/#:~:text=Report%20Summary-,The%20Europe%20virtual%20power%20plant%20market%20is%20estimated%20to%20grow,a%20decentralized%20power%20generation%20model.

Nevertheless, structural reforms shall be put in place to accelerate VPP markets throughout Europe. Anyhow the VPP market concept already appears as a relevant option for smaller consumers/prosumers willing to access savings realization/revenues generation opportunities (as for example in the case of Tiko or Sonnen described earlier). Seeing the interest of large organizations in the energy sector, demonstrated by their investments in VPP initiatives, the market for the enabling software platforms is expected to experience substantial growths in the coming years.

3.1.1.2 EVs charging solutions in DSM

The relevance of EVs future role in European and global energy systems has been substantially highlighted by the development and testing activities carried out within SMILE project environment. In particular, in the Orkney Islands scenario, it has been proved that EVs charging stations are technically feasible devices capable of providing demand flexibility which might benefit other stakeholders in the local energy system, such as generators affected by curtailment events. In Madeira island, instead, it has been tested the concept of smart charging enabled by the EMS provided insights on individual and aggregated energy consumption/generation levels, renewables share, market prices and forecasts. Indeed, EVs charging strategy algorithms have been integrated in the SMILE solution and complemented the role of the EMS and the load controllers described earlier in the present document. Two SMILE technology providers, in particular, developed and tested solutions dealing with EVs smart charging: OVO and Route Monkey.
Route Monkey is a U.K.-based transportation software company controlled by the parent organization Trakm8. The latter is a technology solutions provider involving products related to fleet management, route optimization, vehicles cameras, insurance and automotive telematics[84]. In the context of the SMILE project, Route Monkey developed and tested algorithms which can deploy charging strategies for EVs basing on a set of internal (such as drivers' behaviors, information on EVs fleet) and external variables (such as electricity prices, local energy consumption and production levels, renewables generation, etc.). The relevance and the future business opportunities associated to fleet management and charging software and algorithms, is inevitably connected to the growing adoption of EVs, especially in Europe. Fortune[85] highlighted the primate of Europe over U.S. in relation to EVs sales, especially associated to widespread adoption in Northern European countries (as shown in the figure below).

[84] Trakm8 (website). Available at: https://www.trakm8.com/
[85] Fortune (2021), EV sales are booming just about everywhere-except in the U.S.. Available at: https://fortune.com/2021/08/09/ev-sales-booming-europe-china-not-in-united-states/

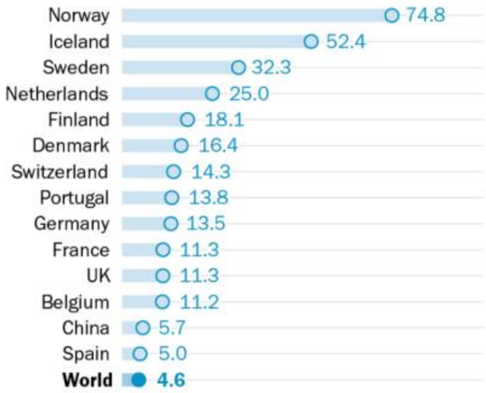

Figure 3.12: EVs share over total automobile sales in selected countries (2020).
Source: extracted from a figure in Fortune article[85], 2021.

Since EVs widespread adoption might eventually cause further challenges to public grids as, for example, there might be no match between demand from automobiles and RES peak generations time (indeed, it is probable that a large number of EVs will be connected to the charging infrastructure during the night, while it potentially matches high wind energy production, no solar power is available), the adoption of smart charging strategies and the exploitation of vehicles to unlock flexibility represent essential factors affecting future energy systems. In this context, IRENA [86] estimated that the employment of smart charging might limit the increase of peak load associated to growing EVs adoption to 5% with respect to a situation in which EVs charging is uncontrolled to which it is associated a 9% increase. The simulation was based on an assumed isolated system with a realistic (27%) solar power share of the energy mix and the electrification involved half of the electric vehicles in the scenario. It has also been estimated that smart charging might reach maturity by 2025 when it will become a default functionality for EVs charging. This factor, together with others, such a larger sizes of vehicles batteries and longer electric ranges will unlock further flexibility provision potential from individual EVs thus enabling the integration of growing RES penetration.
The central role of EVs charging software in the coming decade is confirmed by the steep growth projected for the smart charger market. Indeed, from a 2020 value of over 1.5 billion $, this market is expected to reach a size of about 38.4 billion $ by the year 2031. This forecasted remarkable growth arises from a wider adoption of EVs which is also driven by governments policies including subsidies for vehicles purchase and tax exemptions[87].

3.1.2 Smart meters rollout

This section focuses on the other key element, highlighted before in the document, affecting the growth of DRM systems market in the next years, namely the growing penetration of smart electricity meters. **The smart meters market can be effectively investigated starting from the related shipment volumes recorded and foreseen for the coming years**. According to Statista[88], the **worldwide shipping**

[86] IRENA (2019), Innovation outlook: Smart charging for electric vehicles. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/May/IRENA_EV_smart_charging_2019_summary.pdf
[87] Transparency Market Research (2021), Smart EV Charger Market. Available at: https://www.transparencymarketresearch.com/smart-ev-charger-market.html
[88] Statista (2020), Smart meter shipments worldwide from 2018 to 2024, by region (spreadsheet). Available at: https://www.statista.com/statistics/1097889/smart-meter-shipment-volume-worldwide-by-region/

volumes of smart meters are going to reach 1.16 billion units in 2024. **Asia Pacific is leading the way** with a total volume, in the same year, of about 122 million units, representing about 60% of the world volume. **Europe, during the period 2018-2024, represents instead about 21% of the worldwide shipping volume**. It is worthwhile highlighting, concerning Figure 3.13, that the European relative share of worldwide shipping volume is the one expected to record the highest increase (it is projected to gain about one percentage point in the period 2018-2024).

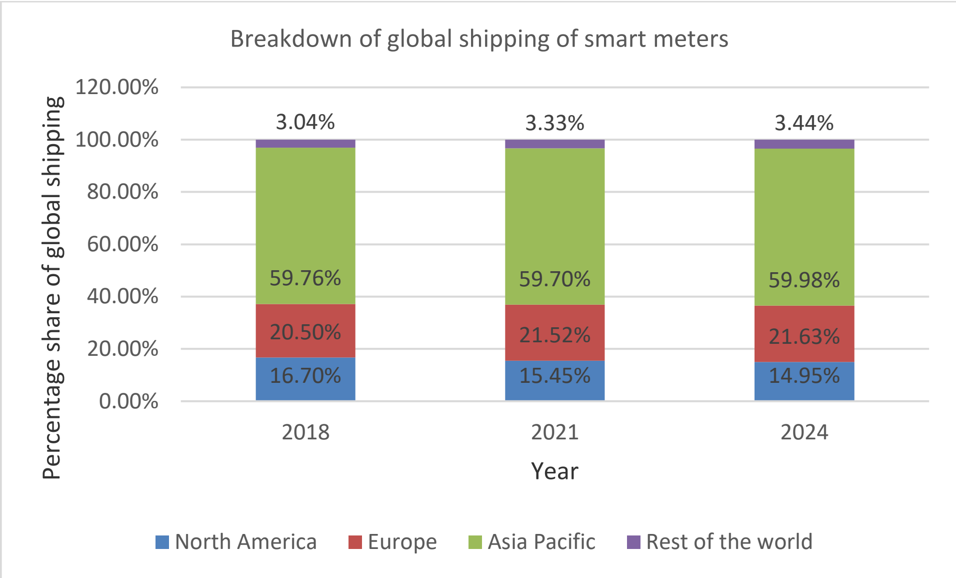

Figure 3.13: Breakdown of global shipping of smart meters
Source: RINA- Elaboration on Statista data[88].

The overall shipping volume is projected to increase until the year 2024 reflecting a sustained pace (an average yearly **7.5% growth rate**). Interestingly, **the European context** is expected to record an even more substantial growth **of about 8.5% yearly**. The European shipping volume is projected to experience a growth from 27 million units in 2018 to about 44 million in 2024. According to these figures it is reasonable to expect a general growth of the size of the smart meters market in the coming years with the Asia Pacific region representing the biggest share.

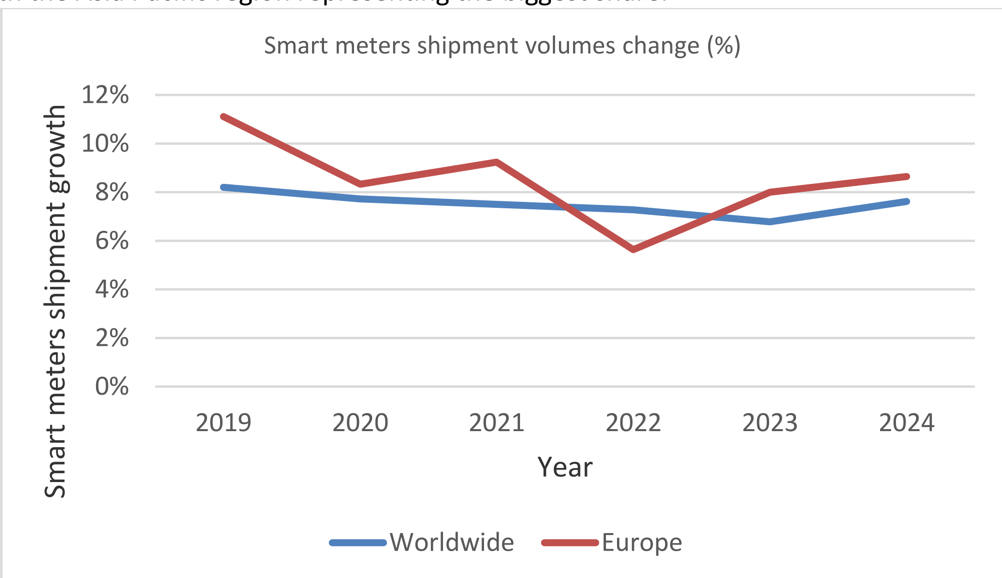

Figure 3.14: Smart meters shipment volumes change (%)
Source: RINA Elaboration on Statista data[88].

Smart meters market has been estimated to worth about 21 billion $ in the year 2020 and it is expected to reach a value in the range of 39-41 billion $ in the subsequent seven years[89,90]. Starting from 2020's market value, corresponding to about 18.41 billion € and, basing on the previously mentioned estimate, assuming a market value of about 35.01 billion € in 2027, a CAGR equal to 9.64% has been extracted and applied until 2030, leading to a market valuation of 46.23 billion € for the same year. Even in presence of a lower CAGR for the period 2027-2030, due to a possible decline, over years, of analog meters that are being substituted, **the growth in the smart meters market would still be noticeable and it could represent a potential significant boost for the DRM system market in the coming decade**. By considering the global shipping breakdown for the year 2021 as a proxy for global market value distribution it has been possible to roughly estimate Europe's smart meters market size for the same year, corresponding to about 4.34 billion €. The European market value might increase in the coming years to reach the value of almost 10 billion € in 2030. In Europe, smart meters demand has been substantially legislation-driven with policies backing the rollout of smart metering solutions and essentially "enforcing" the demand; a challenge might be represented by the shift from this enforced demand to an "organic" demand[91] which might be needed to sustain smart meters markets once legislation stops to back their deployment. In this regard, the relationship between utilities and costumers becomes increasingly relevant for further smart meters deployment as utilities require to engage their clients and promote the shift to smart meters (focusing on fostering consumers' acceptance when smart meters rollout is suppliers-led and its deployment is indirectly financed through energy bills payment). In this respect, the adoption of smart meters might be promoted not solely presenting the opportunity to participate in DR programs but also highlighting the advantage for businesses and householders to gain further visibility on consumption[92], enhanced accuracy of energy bills and faster recognition of potential issues and anomalies eventually leading to a rapid resolution. The growth in acceptance must inevitably go through an increasing awareness of the concept of smart meters in the European population as for example a recent study conducted in Poland highlighted an overall low level of awareness[93]. A 2017 report[94] from Telefonica indicated the forecasted penetration rates of smart meters for electricity in various world-regions, showing Europe and North America at the forefront of smart meters deployment with over 80% rates. Interestingly, the forecast shows that between 2021 and 2022, the European penetration rate should slightly exceed the North American one while, since 2012, the latter has always been substantially higher. Such outlook most probably

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[89] Allied Market Research (2020), Smart Meter Market by Product (Smart Electricity Meter, Smart Gas Meter, and Smart Water Meter), and End Use (Residential, Commercial, and Industrial): Global Opportunity Analysis and Industry Forecast, 2020-2027. Available at: https://www.alliedmarketresearch.com/smart-meters-market

[90] Market Research Future (2020), Smart Meters Market Research Report by Type (Electric Meters, Gas Meters and Water Meters), By Technology (Automatic Meter Reading (AMR) and Advanced Metering Infrastructure (AMI)), By Application (Residential, Commercial and Industrial) - Forecast to 2027. Available at: https://www.marketresearchfuture.com/reports/smart-meters-market-4569

[91] Smart Energy International (2019), Interview with David Green (IHS Markit). Available at: https://www.smart-energy.com/industry-sectors/smart-meters/understanding-the-rollout-of-smart-meters-in-europe/

[92] J. Susser (2020), Advanced Metering Infrastructure Is Unlocking Opportunities for Utilities and Their Customers, Advanced Energy. Available at: https://www.advancedenergy.org/2020/09/07/advanced-metering-infrastructure-is-unlocking-opportunities-for-utilities-and-their-customers/

[93] Y. Chawla, A. Kowalska-Pyzalska (2019) Public Awareness and Consumer Acceptance of Smart Meters among Polish Social Media Users, Energies.

[94] Telefonica (2017), The Smart Meter Revolution, Towards a Smarter Futurez. Available at: https://iot.telefonica.de/wp-content/uploads/2017/07/Telefonica_Whitepaper_The_SmartMeter_Revolution.pdf

reflects a policy-led steep acceleration in the European Union following the Directive 2009/72/EC[95] establishing that Member States were expected to "Ensure the implementation of intelligent metering systems" and that the roll-out of smart meters would be positively assessed in the case where, by 2020, 80% of consumers have "Intelligent metering systems" installed. In 2014, a few years after the directive has been issued, the European Commission[96] estimated that by 2020, considering the announced pledges, smart meters for electricity would cover about 72% of total consumers in Europe (with about 200 million units), thus forecasting that the achievement of the 80% goal would not have been feasible. The European Commission also reported the cost of smart metering systems as comprised between 200 € and 250 € per customer. Actual data[97] from 2019 showed a very fragmented scenario in Europe, with countries such as Spain, Italy and Malta, in the Mediterranean area, with over 97% penetration rates, Scandinavian countries (Norway, Sweden, Finland and Denmark) together with Estonia, show similarly high rates. In addition, the Netherlands recorded a relevant 82.2% rate. The remaining European countries had much lower penetration rates (except from France, Slovenia and Latvia with values exceeding at least 70%).
Special attention has been paid to smart metering also in the EU Directive 2019/944 on common rules for the internal market for electricity and amending Directive 2012/27/EU.
By 2020, about 120 million smart meter units have been installed in Europe[97] while around 107 million were deployed in U.S.; interestingly, the U.S. figure can be broken down: 26% of the total units are owned by "Public Power Utilities and Electric Cooperatives" while the most part is owned by electric companies[98]. In most European Union Member States (24 out of 27) smart meters are directly owned and installed by DSOs while in the case of Germany, France and Cyprus exceptions applies with either third party meters operators, local municipalities or the distribution system owner are involved; in the U.K., energy suppliers directly install and retain the ownership of smart meters[99].
Apart from Europe and North America, the forecasted penetration rate in 2021-2022, reported in Telefonica study[94], show values comprised between 60% and 70% for Asia Pacific and between 20% and 30% for Latin America. Africa and Middle East rate was below 10%.
In the context of the analysis of the smart meters market, considerations also on the so-called Advanced Metering Infrastructure (AMI) must be drawn, representing a key element for the deployment of DR programs and for the path towards increasing energy efficiency.
DR programs deployed introducing either real-time pricing tariffs or a time-of-use tariffs, or even following other frameworks, need utilities to collect information on consumers' energy consumptions[100]. This is essentially where AMIs are involved, as the integration of "smart meters,

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[95] European Parliament and Council of Europe (2009), DIRECTIVE 2009/72/EC.
Available at: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:211:0055:0093:EN:PDF
[96] European Commission (2014), Report from the Commission, Benchmarking smart metering deployment in the EU-27. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0356&from=EN
with a focus on electricity
[97] Eurelectric (2020), Distribution Grids in Europe, Facts and Figures 2020.
Available at: https://cdn.eurelectric.org/media/5089/dso-facts-and-figures-11122020-compressed-2020-030-0721-01-e-h-6BF237D8.pdf
[98] The Edison Foundation (2021), Electric Company Smart Meter Deployments: Foundation for a Smart Grid (2021 Update). Available at: https://www.edisonfoundation.net/-/media/Files/IEI/publications/IEI_Smart_Meter_Report_April_2021.ashx
[99] Tractebel, Engie (2019), European smart metering benchmark.
Available at: https://www.vert.lt/SiteAssets/teises-aktai/EU28%20Smart%20Metering%20Benchmark%20Revised%20Final%20Report.pdf
[100] M. Daneshvar. M. Pesaran, B. Mohammadi-ivatloo (2019), Transactive energy in future smart homes, The Energy Internet. Available at: https://www.sciencedirect.com/science/article/pii/B9780081022078000072

communication networks and data-management systems" essentially enabling the information flows between utilities and their customers[101]. AMI and smart meters (thus comprised within the elements enabling the deployment of AMI) are becoming increasingly relevant systems for utilities as the growing connection to grids of renewable energy sources characterized by intermittent load profiles and decentralized and distributed localization, as well as the adoption of electric vehicles, are profoundly affecting both energy demand and supply curves; AMI indeed allows to perform or schedule automatic energy readings (the manual upload of data is no more required), monitor the system load, detect and solve issues and outages, and, most importantly when dealing with DR programs, allow remote connection-disconnection[102]. In this scenario, utilities are required to provide prompt responses to signals that must be produced by the rapid (real-time or close to real-time) collection of data on consumption, and that is where AMI and smart meters are expected to play a central role in enabling the smooth running of utilities operations in a changing environment.

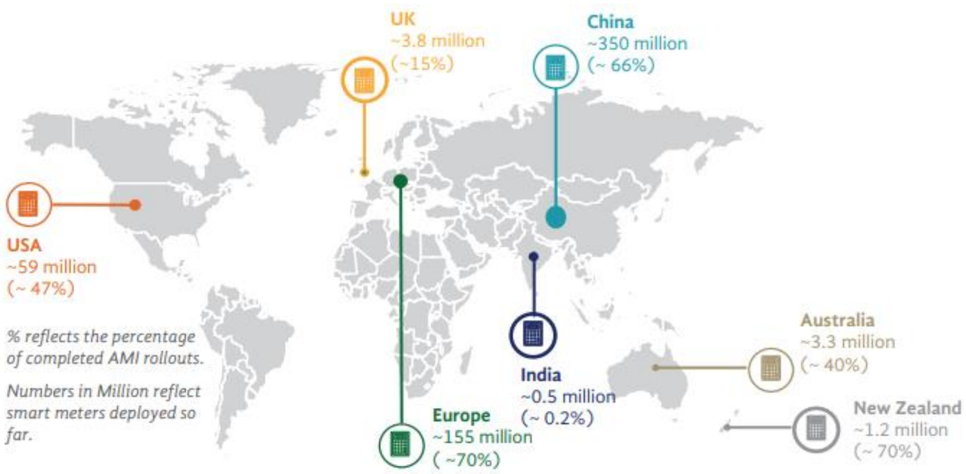

Figure 3.15: % of AMI rollouts and numbers (in millions) of smart meters deployed so far

Source: World Bank 2018[102].

A recent report[103] that indicates the revenues recorded for the advanced metering infrastructure market for the period 2011-2020, worldwide, shows that their value exceeded 16 billion $ corresponding to about 14.15 billion € (considering 2020 average $/€ exchange rate). It is worth recalling that the Advanced Metering Infrastructure concept encompasses, together with smart meters, hardware and software components for communication networks and data management functions. From the same report it is possible to extract a 11.02% CAGR (period 2011-2020). By assuming that such rate would be reflected by the AMI market for the subsequent period 2020-2030, it is obtained the trend shown in the figure below.

[101] U.S. Department of Energy (2016), Advanced Metering Infrastructure and Customer Systems, Results from the Smart Grid Investment Grant Program. Available at: https://www.energy.gov/sites/prod/files/2016/12/f34/AMI%20Summary%20Report_09-26-16.pdf

[102] World Bank (2018), Survey of International Experience in Advanced Metering Infrastructure and its Implementation. Available at: file:///C:/Users/ear01/Downloads/Survey-of-International-Experience-in-Advanced-Metering-Infrastructure-and-its-Implementation.pdf

[103] Advanced Energy Economy (2021), Advanced Energy Now 2021 Market Report. Available at: https://www.aee.net/aee-reports/advanced-energy-now-2021-market-report

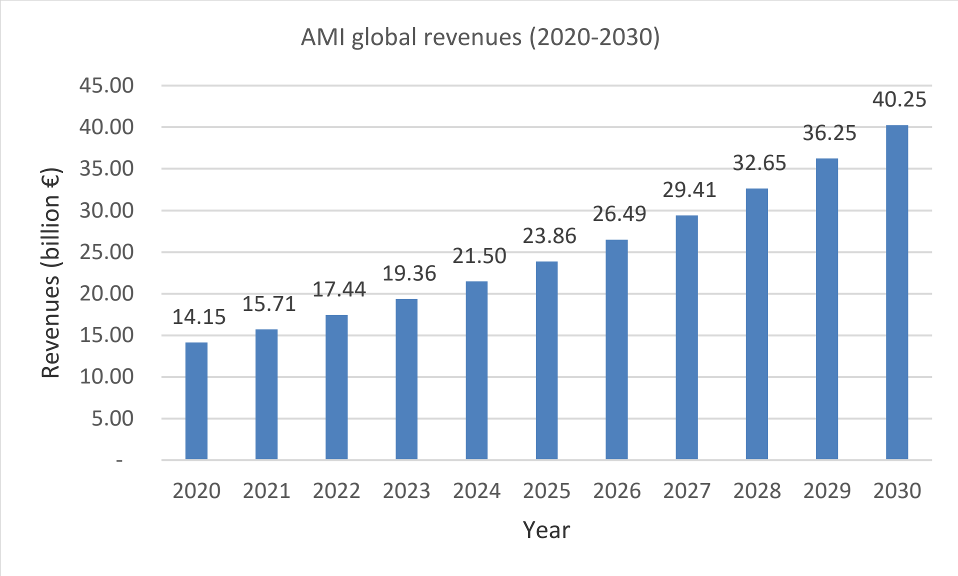

Figure 3.16: AMI global revenues

Source: RINA Elaboration.

The AMI market is thus expected to roughly double its 2020 value by the year 2027, reaching about 29.4 billion €, a to further increase (reflecting a substantial CAGR) to reach over 40 billion in 2030.

3.1.2.1 Advanced Metering Infrastructure competitive landscape

Seeing the relevant figures associated to smart meters market and to AMI context, it appears worth to investigate the main players competing in this scenario. In particular, a Frost & Sullivan report[104] from 2019, indicates the 2018 breakdown of the global AMI market (excluding China, being extremely difficult to be addressed by foreign suppliers) reporting that Landis+Gyr, a Swiss-based multinational corporation, was holding about 18% of the global market. Itron (U.S.-based) and Sagemcom (headquartered in France) followed the largest player with market shares of about 12% and 11% respectively. The sixth position was interestingly hold by another European player, Enel, which is an Italian-based organization operating in the energy utility sector (it deals with both with electricity and natural gas distribution) but that is also providing its own smart-meters. The European market, in 2018, recorded the primacy of Sagemcom with a share corresponding to about a quarter of the whole market while Landis+Gyr was holding the second largest share of about one-fifth of the total. Itron and Enel followed the two leading players with market shares of about 14% and 10% respectively. Other key organizations competing in the European landscape include: Iskraemeco, Karmstrup, ZIV, Honeywell, Aidon and Aclara with decreasing shares comprised between 2% and 5%.

[104] Frost & Sullivan (2019), Electricity Metering Update 2019.
Available at: https://www.frost.com/frost-perspectives/electricity-metering-update-2019/

4 Energy storage systems

The other factor that is gaining increasing importance in relation to the growing RES penetration that has been discussed earlier in this document, and that has been indicated as a viable solution to RES associated limitations (intermittency, curtailment events, etc.), relates to the deployment of energy storage systems. This section of the document has been specifically developed in relation to the deployment within the SMILE framework of energy storage solution providers such as:

- Lithium Balance whose lithium-ion batteries have been developed and installed in all three SMILE demonstration sites in the Orkney Islands, Samsø and Madeira. Lithium Balance batteries deployed during the project responded to different needs such as flexibility provision from residential energy consumers, renewables self-consumption maximization, implicit DR strategies adoption for households and commercial sites and peak-shaving at system operators level.
- SunAmp whose heat batteries based on PCM technologies have been deployed in the Orkney to substitute the existing oil-based heating systems and, at the same time, enable flexibility provision to address curtailment events affecting renewables generation in the island.

The analysis of a set of recent market studies[105,106,107] led to the definition of the **battery energy storage system market value in 2021, corresponding to about 2.92 billion €.** The figure has been obtained considering the studies projections over a period spanning from 2020 and 2027. By further processing those data and including another projection[108] in the analysis, **a market value just over 9 billion $ for the year 2025 has been identified**. The CAGR extracted from the five-year's period is equal to about 32.6% reflecting a significant market expansion in a limited time period. The market value projected evolution is shown in Figure 4.1.

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105 Market Data Forecast (2021), Battery Energy Storage Systems Market. Available at: https://www.marketdataforecast.com/market-reports/battery-energy-storage-systems-market

106 MarketsandMarkets (2020), Battery Energy Storage System Market. Available at: https://www.marketsandmarkets.com/Market-Reports/battery-energy-storage-system-market-112809494.html

107 Industry Research (2021), Global and United States Energy Storage Systems (ESS) market insights, forecast to 2027. Available at: https://www.industryresearch.biz/global-and-united-state-energy-storage-systems-ess-market-18668835

108 Power Technology (2021), Global battery energy storage market to reach $11.04bn in 2025, says GlobalData. Available at: https://www.power-technology.com/comment/global-battery-energy-storage-market/

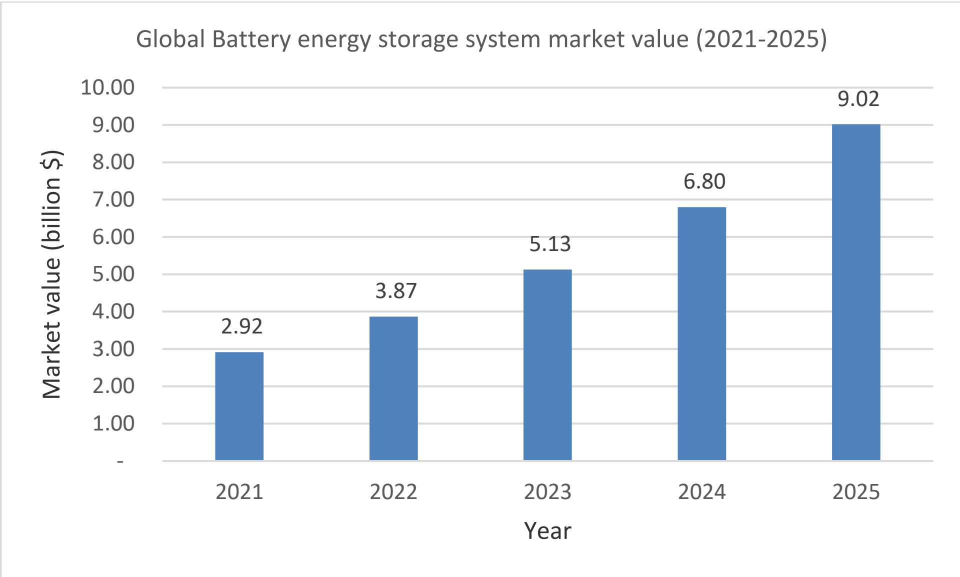

Figure 4.1: Global battery energy storage system market value (2021-2025)
Source: RINA Elaboration on a set of market studies.

4.1 Battery storage demand

Battery storage demand might be roughly represented by projections on future global installed capacity. In 2017, the total energy storage capacity was estimated at being about 4,670 GWh (it must be highlighted that precise figures might be hard to be established in this context) with pumped hydro storage representing roughly 96% of the total stationary storage capacity (energy storage applications might be broken down into stationery and electric vehicles-related ones). Pumped hydro storage differs from battery storage systems as it requires specific locations where water is available, generally larger investments, longer development time and no room for scalability. The share represented by technologies other than pumped hydro storage for those countries with the highest energy storage capacity is reported in the figure below where it is worthwhile noticing that batteries consist in a limited fraction of the total capacity. Countries with percentage shares very close to 0% have been excluded from the graph.

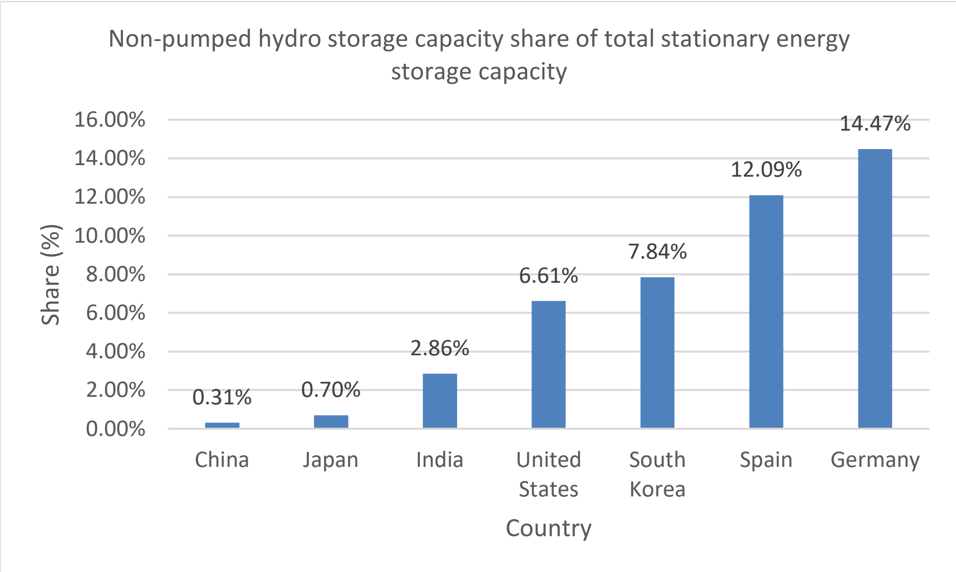

Figure 4.2: Non-pumped hydro storage capacity share of total stationary energy storage capacity
Source: RINA Elaboration on IRENA 2017 data[109].

The share of pumped hydro storage on total capacity is expected to be almost halved by the year 2030. The remaining 2017 capacity, corresponding to about 169 GWh, is projected to grow between 30 and 50 times during the subsequent 23 years. Battery storage systems (excluding thus pumped hydro storage from the analysis), according to IRENA projections, are expected to grow from 2017's 11 GWh to a minimum of 100 GWh in 2030[109]. Wood Mackenzie[110], in 2021, indicated that **capacity has reached about 27 GWh in 2020 and forecasted a significant growth until 2030 to 729 GWh**. Ten years later, in 2040, battery storage (still excluding pumped hydro storage) might even reach 2,850 GWh. **The figure would increase further, to 4,584 GWh, in the case the electric transportation share is included in the**

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[109] IRENA (2017), Electricity Storage and Renewables: Costs and Markets to 2030.
Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct/IRENA_Electricity_Storage_Costs_2017.ashx
[110] Wood Mackenzie (2021), Americas to lead global energy storage market by 2025. Available at: https://www.woodmac.com/press-releases/americas-to-lead-global-energy-storage-market-by-2025/

projection[111]. Europe is estimated to reach an installed capacity corresponding to about 9 GWh in 2021.
As it will be further discussed later along this document, major drivers underpinning the growing deployment appears to be associated to energy storage systems cost reduction, financial motives, opportunities associated to the exploitation of energy flexibility and developments at grid level (enhancing safety and further RES integration).

The battery energy storage market can be further broken-down according to battery technologies. In this sense, the largest share, both in stationery and EVs installations, is hold by **lithium-ion batteries**. In 2019, this technology was dominating grid battery storage system market with a share exceeding 90%[112]. Lithium-ion battery has a set of advantages with respect to competing technologies, including high energy density, low discharge rate, no memory effect on capacity; being relatively lightweight and compact makes the technology suitable for EVs. Finally, low maintenance is a significant advantage both in relation to stationery and transportation applications. Except from high investments required, lithium-ion batteries have a major limitation associated to safety risks due to a relevant tendency to overheating and they are characterized by a limited lifespan[113]. The mentioned substantial investment associated to lithium-ion batteries has experienced a notable decrease in the period 2012-2020 (about 82%). IHS Markit expects a further decrease that will bring the price below the 100 $/kWh threshold by 2023, to reach, by 2030, the price of 73 $/kWh[114]. However, such average low price does not represent a small-scale battery system scenario (for example a home storage installation) whose price to the household can be over 1000 $/kWh[115] (in the U.S.). In Europe, considering for example Germany, prices for medium-sized residential installations might be purchased for a minimum of 700 €/kWh while on average installations prices revolve around 1100 €/kWh[116].
The other typical technology other than lithium-ion one is represented by **lead-acid batteries**. This technology is available for both transportation and stationary applications, but despite increasing renewables penetration has a positive impact on the latter application market, the declining price for lithium-ion cells undermines a substantial market expansion[117]. Lead-acid technology offers a lower cost compared to lithium-ion batteries, but it is outperformed in terms of energy density, lifespan and

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[111] BlombergNEF (2019), Energy Storage Investments Boom As Battery Costs Halve in the Next Decade. Available at: https://about.bnef.com/blog/energy-storage-investments-boom-battery-costs-halve-next-decade/#_ftn1
[112] Environmental and Energy Study Institute (2019), Fact Sheet | Energy Storage (2019). Available at: https://www.eesi.org/papers/view/energy-storage-2019
[113] Clean Energy Institute (webpage), Lithium-ion battery. Available at: https://www.cei.washington.edu/education/science-of-solar/battery-technology/
[114] IHS Markit (2020), Milestone: Average Cost of Lithium-ion Battery Cell to Fall Below $100 Per Kilowatt Hour in 2023, According to IHS Markit (press release). Available at: https://news.ihsmarkit.com/prviewer/release_only/slug/2020-09-23-milestone-average-cost-of-lithium-ion-battery-cell-to-fall-below-100-per-kilowatt-hour-in-2023
[115] Nearby Engineers (2021), Tesla Battery Day 2020: How Affordable Batteries Benefit Renewables. Available at: https://www.ny-engineers.com/blog/tesla-battery-day-2020-how-affordable-batteries-benefit-renewables
[116] Energy Storage News (2020), Germany: Growth in home and industrial sectors but large-scale battery storage slowed down in 2019. Available at: https://www.energy-storage.news/germany-growth-in-home-and-industrial-sectors-but-large-scale-battery-storage-slowed-down-in-2019/
[117] Cision (2021), Lead-acid Battery Market to grow by $ 6.33 bn in Renewable Electricity Industry during 2021-2025 | Technavio (press release). Available at: https://www.prnewswire.com/news-releases/lead-acid-battery-market-to-grow-by--6-33-bn-in-renewable-electricity-industry-during-2021-2025--technavio-301345027.html

efficiency[118]. For this reason, also in the context of EVs, lithium-ion batteries are preferred to lead-acid ones.
Another alternative technology to lithium-ion one for stationery applications is represented by **nickel-based batteries**. They tend to be more expensive than lead-acid ones, but their deployment is still limited. Two major advantages can be identified with regard to Nickel-Cadmium batteries: they can be operated in harsh climate conditions and the two components can be recycled and used respectively for the manufacturing of industrial products and in the production of new batteries. Low energy density, and memory effect are major limitations. Batteries employing **sodium-based technologies** offer instead high energy density, efficiency and long cycle life but remain expensive and their operation requires high temperatures obtained through heating and insulation[119,120].
The key conclusion is that lithium-ion batteries are expected to dominate the market until other technologies will reach maturity and their manufacturing will scale-up.

Still considering lithium-ion batteries, a further segmentation can be implemented, it partially mirrors the one applied to DR programs, the market for battery storage can in fact be broken down into: Behind The Meter (BTM) installations with residential, commercial and industrial storage systems and in-Front Of The Meter (FTM) installations that refer to utility-scale systems. The following chapters investigate key information on each of these main segments of the battery storage market.

4.1.1 Commercial and industrial segment

The C&I or non-residential segment has reached a limited development when compared to its residential counterparts and FTM installations. At the end of 2020, it also experienced a 3% contraction while the other segments both continued growing. C&I delay might be related to high market complexity (due to the limited feasibility to provide standardized solutions to customers leading to higher required investments[121]), limited available financing and “good return on investment” as the driving consideration behind investment decision, leading to the need to match energy savings (reducing costs) with the opportunity to employ BTM batteries in rendering rewarded ancillary services to the grid[122]. Despite the current situation, IHS Markit expects **the C&I segment to overtake the residential one by 2030**.

4.1.2 Residential segment

Solar Power Europe indicated that the European residential Battery Energy Storage System (BESS) overall capacity, in 2019, was just below 2 GWh following annual double digits percentage growths (exceeding 60% annual increase since 2016). **Germany** which pioneered the European market since 2013, is at the forefront of such growing trend with 66% of the total capacity additions deployed in 2019 (496 MWh out of 745 MWh), followed by **Italy** (89 MWh corresponding to about 12% of the

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118 Energysage (2020), Lithium-ion vs. lead acid batteries. Available at: https://news.energysage.com/lithium-ion-vs-lead-acid-batteries/
119 EUROBAT (2016), Battery energy storage in the EU. Available at: https://www.eurobat.org/images/news/publications/eurobat_batteryenergystorage_web.pdf
120 X. Fan et al. (2020), Battery Technologies for Grid-Level Large-Scale Electrical Energy Storage. Available at: https://link.springer.com/article/10.1007/s12209-019-00231-w
121 PV Magazine (2021), Strong growth ahead for battery storage. Available at: https://www.pv-magazine.com/2021/04/13/strong-growth-ahead-for-battery-storage/
122 Solar Power World (2021), We’re optimistic about the C&I energy storage market in 2021. Available at: https://www.solarpowerworldonline.com/2021/01/commercial-energy-storage-market-2021/

total), while the **U.K.** and **Austria** contributed each about 5% of the continental increase (respectively, 38 MWh and 37 MWh of new installations)[123].

The growth in Germany was mainly driven by new 2019 PV installations that in two thirds of cases were coupled with storage systems while retrofitting represented a limited growth factor (only about 10% of new residential energy storage systems have been connected to previously installed PV modules). The German market context thus confirms the close relationships between increasing RES penetration and the growing installation of storage capacity that has been discussed in Chapter 2. Figure 4.3, extracted from IRENA 2017's study[109] on electricity storage and renewables markets, appears to reflect the German case on a global scale; it is in fact foreseen that **retrofitting will remain a limited phenomenon** while the majority of BTM energy storage installations associated to roof-top PV modules will be driven by additions in solar generation capacity.

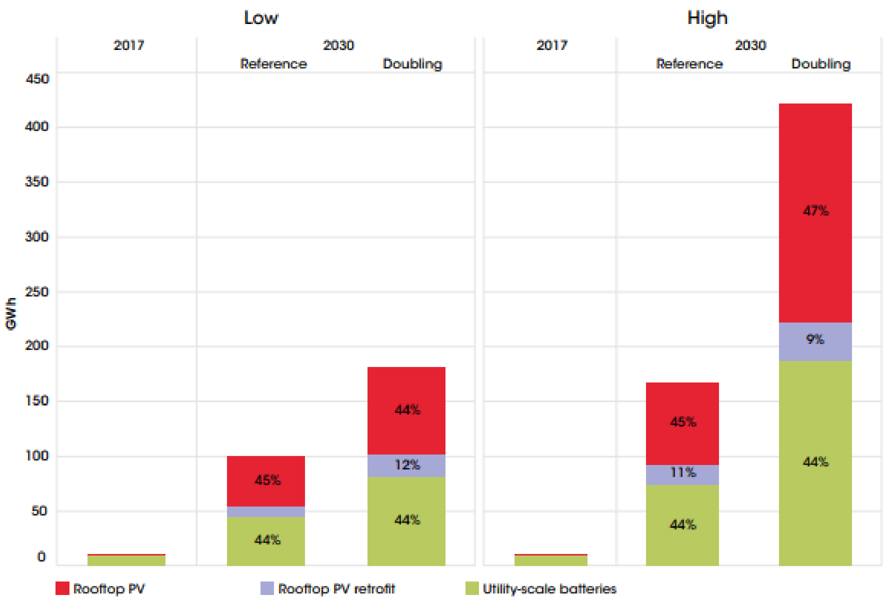

Figure 4.3: Germany installations of PV and batteries

Source: IRENA 2017[109].

The new residential installations discussed above were interestingly mainly driven by (in decreasing order of importance): the willingness to limit the exposure to electricity price-related risks (it is worth recalling that Germany has the highest electricity prices in Europe, as reported earlier in this document), the possibility to contribute to the country energy transformation process, the interest in the technology, the need to protect the house from power failures and finally the perception of the installation as a safe investment[124]. The participation in DR programs is not included in the list of drivers as the regulatory framework and the limited smart meters penetration in Germany tend to favor self-consumption. A pre-pandemic estimate from Wood Mackenzie[125] forecasted the achievement of

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[123] Solar Power Europe (2020), European Market Outlook for Residential Battery Storage 2020-2024. Available at: https://resource-platform.eu/wp-content/uploads/files/statements/2820-SPE-EU-Residential-Market-Outlook-07-mr.pdf

[124] J. Figgener et Al. (2021), The development of stationary battery storage systems in Germany – status 2020. Journal of Energy Storage. Available at: https://www.sciencedirect.com/science/article/pii/S2352152X2031817X?via%3Dihub

[125] PV Magazine (2019), Residential storage in Europe to grow 500% by 2024. Available at: https://www.pv-magazine.com/2019/08/09/residential-storage-in-europe-to-increase-500-by-2024/

sustainable business cases with positive net present value for residential battery installation, in Germany, by 2022 (with Italy expected to reach such target one year in advance).
In 2020, the residential segment BESS capacity was expected to reach a value between 2.6 GWh and 3 GWh (following a maximum expected addition of 1 GWh in the most optimistic scenario). Additions distribution per country was very similar to 2019's one with Germany once again leading the way.
Projections to 2024 indicates that the European market might even reach a 9 GWh capacity.

4.1.3 Utility segment

In the context of stationery applications, lithium-ion batteries (the technology dominating the market growth also in this segment) at utility scale are contributing to the transformation of the energy sector providing support to the electric grid through a set of services[126,127]:

- *Frequency regulation* which allows to bring frequency value back within limit levels when deviations occur due to electricity demand/supply drops or sudden growths.
- *Flexible ramping* which allows the flattening of the load curve that can be especially relevant when significant intermittent renewable energy sources are connected to the grid (with steep peaks and valleys reflecting solar and wind energy generation).
- *Black start service* that allows the restoration of the grid normal functioning after it experienced a shutdown; in this sense, batteries can provide the initial power necessary to large generators to restart operating and to bring the grid back to operation.
- *Energy shifting and capacity investment deferral* relate to the possibility to employ the stored energy to deal with demand peaks that would otherwise require the installation of additional generation capacity.
- *Transmission and distribution congestion relief* relates to the situation in which energy supply is constrained by transmission and distribution network capacity that to deal with period of overload or to accommodate further generation capacity would require investments in strengthening the grid. Batteries at utility scale can contribute to manage congestion and delay the reinforcement of the network.
- *Reduced curtailment* relates to reducing curtailment events that are a direct consequence of the previous point in the scenario where no energy storage capacity is available and the network is overloaded.
- *Capacity firming* allows to renewable energy generators that are subject to intermittency to provide a more linear energy output to the grid as battery presence can support the offsetting of oscillations.

The above-mentioned services provision is not, in principle, mutually exclusive as the optimal exploitation of a single utility-scale battery installation might be achieved through offering a subset of services. Such option depends on the grid characteristics as well as on a set of barriers to FTM batteries installation. Typical barriers, in addition to the obvious high capital investment required, relates to lack of clarity of national regulatory frameworks on the services batteries can deliver or established limitations to battery potential exploitation[128]. In addition, the absence of markets or schemes that

[126] U.N. DESA (2021), Frontier Technology Issues: Lithium-ion batteries: a pillar for a fossil fuel-free economy? Available at: https://www.un.org/development/desa/dpad/publication/frontier-technology-issues-lithium-ion-batteries-a-pillar-for-a-fossil-fuel-free-economy/
[127] IRENA (2019), Utility-Scale Batteries Innovation Landscape Brief. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Utility-scale-batteries_2019.pdf
[128] NREL (2019), Grid-Scale Battery Storage. Available at: https://www.nrel.gov/docs/fy19osti/74426.pdf

provide a financially sustainable business case for battery installation might deter energy storage deployment. Finally, NREL indicates a less straightforward barrier to utility-scale battery deployments that is connected to the relative newness and rapid development of this system; the introduction of utility-scale batteries requires the adaptation of analytical software that were conceived for the scenarios where grid congestion, frequency imbalances and overload are managed through other strategies. In this sense, current analytical tools might not be suitable to capture the true potential of energy storage.

Looking at IRENA's 2017 projection[109] (reported in the Paragraph 4.1.2) it is clear that utility-scale batteries are expected to hold almost half of the overall storage capacity (44% of the total) by 2030 independently from the forecast scenario considered. In this sense FTM storage installations are expected to grow substantially during the current decade. Such foreseen increase could be pushed by the establishment of viable business case as demonstrated by Neoen and Tesla's recent large-scale installation in South Australia. The region experienced a RES penetration surge reaching a rate close to 50% in 2017 and projected to grow at 73% by 2021. Such high rates imply variable load profile due to intermittency of solar and wind energy generation by enabling energy export to neighboring regions. Renewables curtailment and substantial use of interconnection with other regions were the solutions employed, while frequency deviations threatened grid safety and a black out occurred in 2016. The Hornsdale Power Reserve installed in 2017 (with a total storage capacity equal to 129 MWh) enabled the "Fast Frequency Response" service which allows the system to react proportionally to grid frequency deviations. In addition to safety related benefits, energy storage installation affected the Frequency Control Ancillary Services market (FCAS). For safety reasons, prior Neoen project, the South Australian 35 MW FCAS constraint was established, causing prices in the market to increase dramatically in specific periods. The Hornsdale Power Reserve allows to respond to frequency deviations much faster than traditional ancillary services supplier keeping prices down and realizing savings for generators and consumers[129].

Neoen which owns and operates the power reserve has largely benefitted from the project as demonstrated by an increase by about 14% of 2019's revenues from its battery storage segment with respect to the previous year (mainly through the provision of frequency related ancillary services to the grid)[130]. In addition, in January 2020 an extreme climate event isolated the South Australia network from the rest of Australia leading the Hornsdale Power Reserve to play an even more critical role and to generate dramatically high revenues in the first quarter of the year[131]. Despite the exceptional event that boosted Neoen revenues, the installation of grid-scale batteries proved to be a sustainable business case with a limited payback period.

In Europe, the segment might experience similar major developments. In October 2020, Lithuania Energy Minister announced the construction by the end of 2021 of a large-scale battery storage system to enable the country network disconnection from the grid controlled by Russia. The plan foresees 200 MW of installed battery capacity[132]. The biggest utility-scale battery storage project in Belgium was planned to be opened in mid-2021; it is located in Wallonia and it has a storage capacity equal to 20

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[129] Aurecon (2018), Hornsdale Power Reserve Year 1 Technical and Market Impact Case Study.

[130] Renew Economy (2020), Tesla big battery at Hornsdale gets big jump in revenues, more to come. Available at: https://reneweconomy.com.au/tesla-big-battery-at-hornsdale-gets-big-jump-in-revenues-more-to-come-65622/

[131] PV Magazine (2020), Hornsdale and its big Tesla battery exceed expectations as storage revenue surges. Available at: https://pv-magazine-usa.com/2020/05/20/hornsdale-and-its-big-tesla-battery-exceed-expectations-as-neoens-storage-revenue-surgesneoen-reports-strong-revenue-increase-teslas-hornsdale-big-battery-exceeding-expectations/

[132] Yahoo!Finance (2020), Lithuania to build one of the largest battery parks in the world. Available at: https://uk.finance.yahoo.com/finance/news/lithuania-build-one-largest-battery-104052345.html

MWh. The project has been developed by Centrica Business Solution (please see the chapter devoted to discussing the competitive landscape of energy aggregators) that announced the battery park will be included in a VPP involving industrial sites[133]. Europe's largest battery has instead recently started operations (August 2021) in South-Western England with a storage capacity of about 100 MWh and with a plan to further increase it. Shell already committed to purchase power from the site[134].

4.2 Battery supply

Currently **lithium-ion battery manufacturing is dominated by China with almost 80% of the capacity** (about 525 GWh[135]). A shrink in China manufacturing capacity share is foreseen by 2025 (losing about 12 percentage points) while Europe is expected to emerge as a relevant production hub, with an increase of over three times its 2020's share (from 28 GWh to 368 GWh led by Germany, Poland, Hungary and France). Europe is in fact the only world region which is foreseen to increase its share (the only exception is represented by Australasia which is expected to reach a 1% share by 2025, from about 0% in 2020). The manufacturing capacity shares change for the period 2020-2025 based on S&P Global's projections[136] is reported in Figure 4.4.

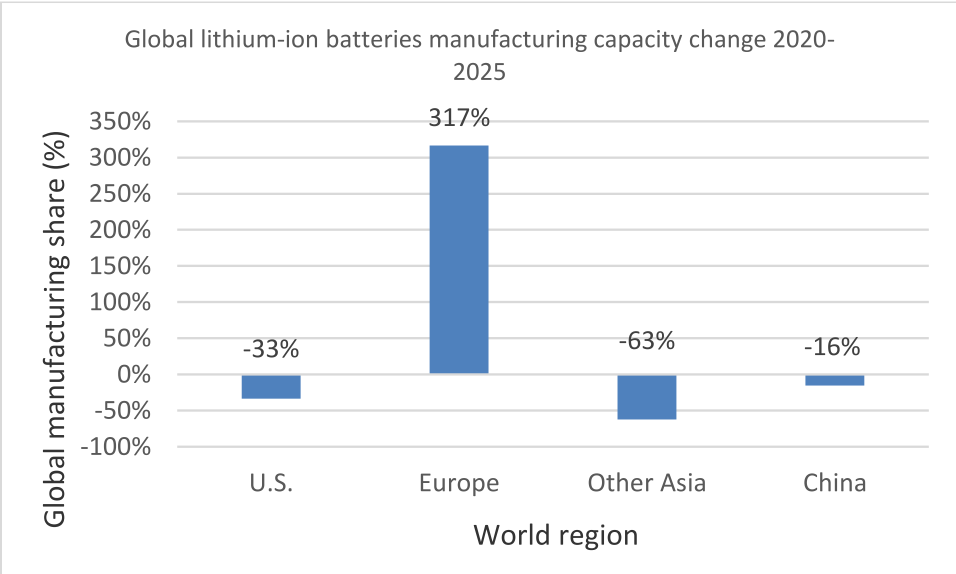

Figure 4.4: Global lithium-ion batteries manufacturing capacity change 2020-2025
Source: RINA Elaboration on S&P Global 2021 data[136].

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[133] Battery Industry (2021), Centrica and EStor-Lux announce Belgium's largest battery storage project. Available at: https://batteryindustry.tech/centrica-and-estor-lux-announce-belgiums-largest-battery-storage-project/

[134] Renewables Now (2021), Europe's largest battery of 100 MW/100 MWh goes online in UK. Available at: https://renewablesnow.com/news/europes-largest-battery-of-100-mw100-mwh-goes-online-in-uk-749940/

[135] U.S. Department of Energy (2020), Energy Storage Grand Challenge: Energy Storage Market Report. Available at: https://www.energy.gov/sites/prod/files/2020/12/f81/Energy%20Storage%20Market%20Report%202020_0.pdf

[136] S&P Global (2021), Top electric vehicle markets dominate lithium-ion battery capacity growth. Available at: https://www.spglobal.com/marketintelligence/en/news-insights/blog/top-electric-vehicle-markets-dominate-lithium-ion-battery-capacity-growth

4.2.1 The case for lithium

Lithium is a key component in the manufacturing of transportation and stationery batteries. Meeting the increasing demand for these batteries represented by the expected additional capacity deployments forecasted for the decade (in 2030, 90% of lithium demand will be associated to battery manufacturing)[137]. The largest lithium reserves are located in Bolivia with about 21 million tonnes subject to limited exploitation due to geo-political reasons. Argentina and Chile follow with about 17 and 9 million tonnes. The former faces similar barriers to development as Bolivia does while the latter has been the second largest lithium producer in 2019. Even in the U.S. lithium industry is underdeveloped despite the 6.8 million tonnes of estimated reserves. Australia, even though it has lower estimated reserves is the largest producer with more than double Chile production. China, being the major global consumer[138] dominates the material refining industry (80% share) and the battery components production (60% share). Even Japan and Korea hold strong positions in the latter market and in the general battery manufacturing one, but they depend for material supply on other countries[139].
Lithium reserves are also present with limited extent in Europe, in particular in Germany with about 2.5 million tonnes and in the neighboring Czech Republic with about 1.3 million tonnes[140].

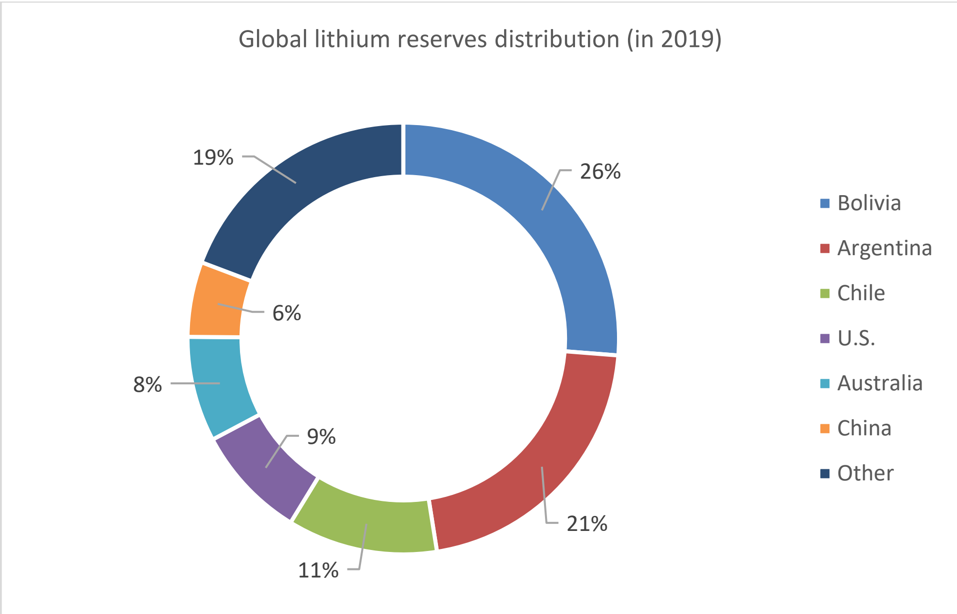

Figure 4.5: Global lithium reserves distribution (in 2019)
Source: RINA Elaboration on NS Energy 2020 data[138].

Not surprisingly the largest company engaged in lithium mining is headquartered in China. Jiangxi Ganfeng Lithium is the leading lithium supplier with operation in China, Australia, Argentina, Mexico

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[137] Global X (2020), Lithium, Explained. Available at: https://www.globalxetfs.com/lithium-explained/
[138] NS Energy (2020), Top six countries with the largest lithium reserves in the world. Available at: https://www.nsenergybusiness.com/features/six-largest-lithium-reserves-world/
[139] BloombergNEF (2020), China Dominates the Lithium-ion Battery Supply Chain, but Europe is on the Rise. Available at: https://about.bnef.com/blog/china-dominates-the-lithium-ion-battery-supply-chain-but-europe-is-on-the-rise/
[140] U.S. Geological Survey (2020), Mineral Commodity Summaries 2020. Available at: https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-lithium.pdf

and Ireland. The U.S.-based Albemarle holds the second position while the third is once again controlled by a Chinese company, Tianqi Lithium[141].

The investigation of the lithium mining and refining industries as well as the battery components one indicates that despite Europe is expected to capture a significant share of energy storage supply by 2025, currently, the downstream part of the battery value-chain is in the hand of Eastern-Asian players (in addition to battery final products manufacturing). Seeing the rapidly increasing batteries demand, investments in those countries where resources are almost untapped or were subject to limited exploitation are fairly reasonable to be expected. By the middle of the decade, Global X estimates[137] that a supply shortage might occur leading to price increase but the effect on batteries cost might be limited due to the fact that lithium represents a very limited fraction of battery prices and manufacturing processes improvements might offset the resulting price increase. However, a supply deficit of this resource, considering that extraction sites require several years before being operational, might be more significant after 2026 (with lithium price rising further[142]).

4.2.2 Battery manufacturing Europe competitive landscape

Considering the lithium-ion technology is currently dominating and it is expected to continue to dominate the battery manufacturing market in the coming years, it is worth investigating major manufacturers, while considering the scope of the SMILE project, the European manufacturing scenario has been chosen. Considering that the same technology is employed both in the stationery and the transportation segments, no differentiation is done in this context with respect to lithium-ion battery producers. S&P Global reports also the major manufacturers that are forecasted to make up the European lithium-ion production ecosystem, in 2025, whose capacity share is distributed as reported in Figure 4.6.

[141] NS Energy (2021), Profiling the top five largest lithium mining companies in the world. Available at: https://www.nsenergybusiness.com/features/largest-lithium-mining-companies/

[142] Forbes (2021), Lithium Price Tipped To Rise After Warning Of ‘Perpetual Deficit’. Available at: https://www.forbes.com/sites/timtreadgold/2021/07/02/lithium-price-tipped-to-rise-after-warning-of-perpetual-deficit/?sh=3bc37f5e4ab7

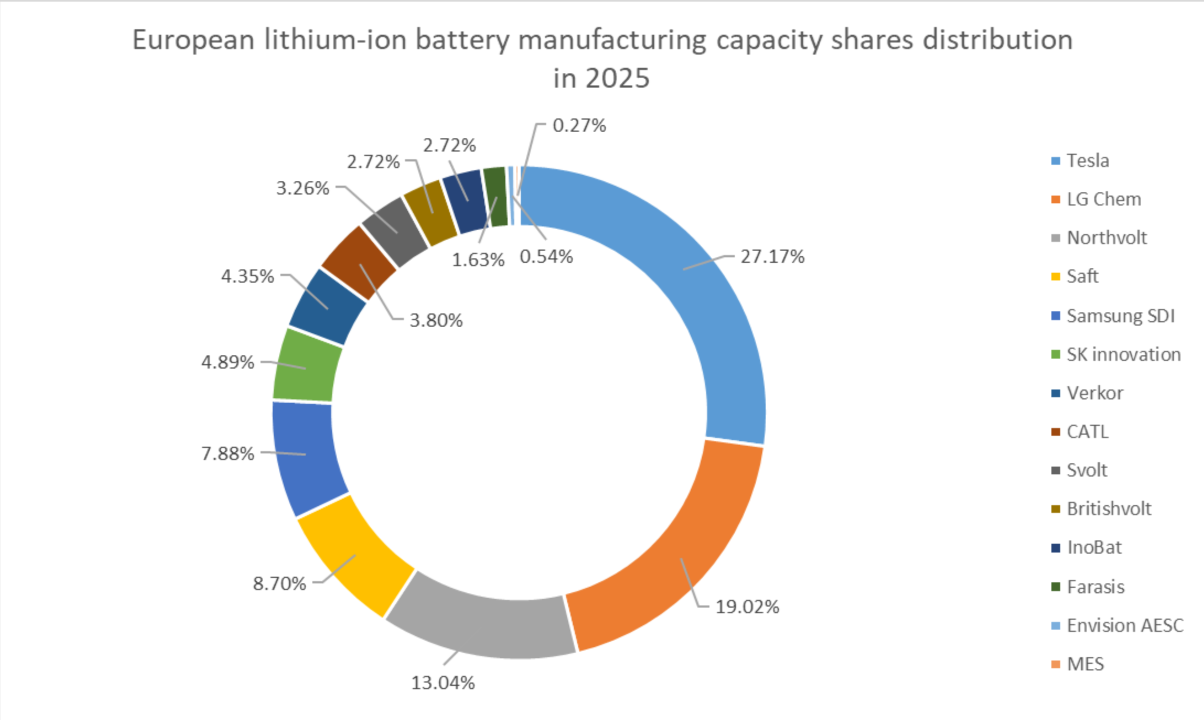

Figure 4.6: European lithium-ion battery manufacturing capacity shares distribution in 2025

Source: RINA Elaboration of S&P Global 2021 data[136].

Given that a set of other global players are operating in the battery manufacturing and commercialization segment, such as ABB which is not included in the graph above, as well as other companies such as Sonnen (mentioned in the section of this document addressing aggregators competitive landscape analysis) and Altairnano, it has been proposed below, in Table 4.1,a brief contextualization of the main manufacturers with Europe-located production facilities.

Table 4.1: Main manufacturers with Europe-located production facilities

Company	Key information
TESLA	Tesla operates both in the stationery and EVs segments. The latter represents its main market but in the second quarter of 2021 the energy storage and solar business experiences a 116% revenues growth compared to the same quarter in 2020. Demand for Tesla small-scale and utility-scale energy storage products is rising with supply struggling to meet it[143]. By May 2021, Tesla announced having installed 200,000 residential storage systems (named "Powerwall"). Moreover, it added that Tesla PV installations will be coupled with energy storage and PV, hence PV modules will not be available without a Powerwall[144]. This strategic choice is consistent with the market direction that sees (as discussed earlier in this document) the growth of the residential energy

[143] TechCrunch (2021), Tesla's solar and energy storage business rakes in $810M, finally exceeds cost of revenue. Available at: https://techcrunch.com/2021/07/26/teslas-solar-and-energy-storage-business-rakes-in-810m-finally-exceeds-cost-of-revenue/

[144] TechCruch (2021), Tesla has installed 200,000 Powerwalls around the world so far. Available at: https://techcrunch.com/2021/05/26/tesla-has-installed-200000-powerwalls-around-the-world-so-far/

	storage market dependent upon rooftop solar panels installations. Powerwall product consists in a 13.5 kWh indoor/outdoor installed battery with remote monitoring and control capabilities. The cost for the solution should be about 7,500 $[145]. For the commercial and utility segment Tesla offering relies on “Powerpack”, a battery with a maximum capacity of 232 kWh. It is described as a scalable solution that allows “Peak shaving”, “Load shifting”, “Emergency backup” and “Demand response” as well as ancillary services to the grid. A larger version of the product is “Megapack” designed for giga-scale installations[146].
LG Chem	LG Chem, an LG company, is a South Korea-based chemical company which has a business line devoted to energy solutions. The company, in addition to manufacturing batteries for EVs, produces also energy storage systems for various applications (residential, commercial and industrial and grid-scale projects). The residential product “RESU” offers a maximum energy storage capacity that is larger than Tesla competing solution, with about 16 kWh of usable energy capacity. A set of LG installed residential energy storage systems manufactured before 2019 that are subject to fire risk are currently undergoing a free replacement program[147]. 10,000 units in the U.S. are being substituted and their selling price for the period 2017-2019 was about 8,000 $[148]. The C&I and grid-scale segment is described as able to offer the peak-shifting and frequency regulation services as well as renewables integration. Moreover, solutions for UPS (installed at data centers and IT facilities) is provided, focusing on emergency power backup[149]. Considering European manufacturing capacity, in 2020, LG Chem obtained a loan from the European Investment Bank to expand its production facility in Poland[150] (the plant will be devoted to EVs batteries).

[145] Electrek (2021), Tesla increases the price of Powerwall again. Available at: https://electrek.co/2021/01/17/tesla-increases-price-powerwall/

[146] Tesla (website). Available at: https://www.tesla.com/en_eu/

[147] LG Energy Solution (2021), LG Energy Solution Announces Plan for Free Replacement of Certain Energy Storage System (ESS) Home Batteries (press release). Available at: https://www.lgessbattery.com/eu/home-battery/news-view.lg?blcSn=1257&devonTargetRow=1&devonOrderBy=&searchType=all&searchKey=

[148] Energy Storage News (2021), Fire hazard leads to further product recall for LG residential battery storage systems. Available at: https://www.energy-storage.news/fire-hazard-leads-to-further-product-recall-for-lg-residential-battery-storage-systems/

[149] LG Energy Solution (website). Available at: https://www.lgessbattery.com/eu/main/main.lg

[150] EIB (2020), Poland: Electric vehicle battery production in Europe gets boost thanks to EIB loan of €480 million to LG Chem Wroclaw Energy (press release). Available at: https://www.eib.org/en/press/all/2020-088-electric-vehicle-battery-production-in-europe-gets-boost-thanks-to-eib-loan-of-eur480-million-to-lg-chem-wroclaw-energy-in-poland

northvolt	The Sweden-based battery manufacturer Northvolt just as the other players previously investigated operates both in the stationery and EVs segments. Concerning the former, the company offering appears to be limited to industrial and grid-scale applications, while the domestic segment is not served. The stationery service product, named Voltpack Mobile System, is a scalable solution (whose capacity ranges from a minimum 281 kWh to 1,405 kWh). Its employment primarily relates to grids and microgrids support as well as the provision of services such as peaks shaving, reserves and capacity provision, renewables integration and black start (consisting in a green alternative to diesel generators with lower maintenance requirements). Interestingly, Northvolt relies on a power-as-a-service business model where the company retains the management of the batteries installed at customers' premises[151]. Such choice appears consistent with the exclusion of the residential segment which might instead imply the management of tens of thousands dispersed small storage systems. Among the industrial fields potentially served it is included: construction, mining, material handling, agriculture, marine and aviation[152]. In relation to industrial and grid-scale solutions, Northvolt is building Europe's largest manufacturing plant, in the north of Poland, to meet the demand from the segments (production is foreseen to start in 2022[153]). Two additional major Northvolt battery manufacturing facilities are planned to become operational in Europe, one in Sweden, by 2021 and another in Germany by 2024. In the context of EVs, Northvolt is a key partner of Volkswagen for the implementation of its electrification strategy[154]. It is worth highlighting that despite the large expansion the company has been funded recently, in 2015, by a former Tesla executive[154].
saft	Saft is a French battery manufacturer owned, since 2016, by TotalEnergies (the French multinational oil and gas company). Just as Northvolt, Saft appears to exclude the residential segment from its products offering, rather focusing instead, considering stationery applications, on data centers, hospital buildings, utilities, defense sector and others. In Europe, it owns various manufacturing facilities: three in France, one in the U.K., one in Germany, one in Czech Republic and one in Sweden[155]. Regarding the EVs battery market, Saft parent company, Total, recently created a joint venture with PSA to create a new leading player, entailing the construction of two manufacturing facilities in

[151] Vattenfall (2020), Northvolt and Vattenfall launch battery energy storage system (press release). Available at: https://group.vattenfall.com/press-and-media/newsroom/2020/vattenfall-and-northvolt-launch-battery-energy-storage-solution

[152] Northvolt (website). Available at: https://northvolt.com/

[153] Northvolt, Northvolt expands in Poland to establish Europe's largest factory for energy storage solutions. Available at: https://northvolt.com/articles/systems-poland/

[154] Energy Storage News (2021), VW's US$14 billion Northvolt order is 'significant' for battery storage as well as electric vehicles. Available at: https://www.energy-storage.news/vws-us14-billion-northvolt-order-is-significant-for-battery-storage-as-well-as-electric-vehicles/

[155] Saft (website). Available at: https://www.saftbatteries.com/

	Germany and France [156] (the strategic relevance of the venture is confirmed by the fact that both the German and French governments committed funds to the project realization).
SAMSUNG SAMSUNG SDI	Samsung SDI, a subsidiary of the South-Korean multinational Samsung Group, established in 1970, operates both in the automotive and in the energy storage system markets. The company addresses the residential, commercial and industrial, UPS segments as well as utilities[157]. Samsung SDI has two manufacturing sites for batteries in Europe, located in Hungary and Austria, both focused on EVs batteries production. It has been recently announced that the Hungarian site will undergo a capacity expansion[158].

As mentioned earlier, Lithium Balance is the organization which has been involved in SMILE project development and testing activities of lithium-ion energy storage systems in the three demonstration sites. Lithium Balance, established in Denmark, operates since 2006 in the development and manufacturing of Energy Management Systems [159]. It has been acquired in 2021 by Sensata Technologies[160], the U.S.-based industrial technology player developing sensors-related solutions. Lithium Balance division devoted to BESS market is Xolta, it provides lithium-ion based solutions to a variety of customers ranging from households to commercial and industrial players as well as systems addressing microgrids (connected or independent) and solutions enabling voltage and frequency control and peak shaving. Lithium Balance BESS are modular and scalable solutions built with top-tier components. Residential customers are provided with access to an app where battery state of charge, energy generation and consumption levels as well as energy import from the public grid can be monitored. Visibility over monetary savings and on emission cuts is also provided[161].

4.3 Thermal Energy Storage

Thermal Energy Storage (TES) is an additional solution that can accommodate the expected further deployment of RES of the coming years, as together with photovoltaics and wind, concentrated solar power (CSP) is on the rise reaching 15.6 TWh of generation globally in 2019 and with IEA projected sustainable development scenario requiring a generation of almost 54 TWh in 2025[162] (more than three times 2019's value). Irena indicated that about half of the global final energy consumption is due to space and industrial heating. The energy use of space cooling is also increasing significantly in the

[156] Il Sole 24 Ore (2020), Automotive Cell Company, joint venture Psa-Total per produrre batterie in Europa. Available at: https://www.ilsole24ore.com/art/automotive-cell-company-joint-venture-psa-total-produrre-batterie-europa-ADfiDzn
[157] Samsun SDI (website). Available at: https://www.samsungsdi.com/
[158] Reuters (2021), Samsung SDI to invest $849 mln to expand EV battery plant in Hungary. Available at: https://www.reuters.com/article/samsung-sdi-batteries-hungary-idUSL4N2KU0FS
[159] Lithium Balance (webpage). Available at: https://lithiumbalance.com/about-us/
[160] Sensata Technologies (2021), Sensata Technologies Furthers Electrification Strategy with Acquisition of Lithium Balance. Available at: https://investors.sensata.com/investors/news-releases/press-release-details/2021/Sensata-Technologies-Furthers-Electrification-Strategy-with-Acquisition-of-Lithium-Balance/default.aspx
[161] Xolta (webpage). Available at: https://xolta.com/
[162] IEA (2020), Concentrating Solar Power (CSP), Tracking report. Available at: https://www.iea.org/reports/concentrating-solar-power-csp

last decades with electricity remaining the main form of energy employed for this purpose. In terms of impact, the electricity consumption for cooling can contribute to stress grids leading to demand peaks not solely in areas with extremely hot climates but in Europe too, especially during heatwaves. IEA estimates that the use of energy for space cooling across the world is going to reach, by 2050, 6,200 TWh representing an increase of over 200% of 2016's values. Such consumption will consist in about 16% of the global electricity consumption in the year. The growth key drivers will be the increasing number of AC units installed across the globe which is boosted by the increasing number of buildings that are going to be constructed due to population growth and climate change associated to global warming. Most of the growth of energy consumption for cooling needs will come from China, India and Indonesia[163]. Global cooling demand for energy is expected to be overshadowed by energy needs for heating purposes. In fact, while in 2020, heat demand was about 50,000 TWh, in 2050 it can rise to 56,600 TWh in 2050. The main driving force of the increase will be the growing need for heat for industrial purposes (whose demand increase will come mostly from South Asia and Africa[164]).
The notable energy needs for heating purposes is clearly represented by the average household consumption in the E.U. (reported by Eurostat in 2019) where the following breakdown has been observed: 63.6% of energy is required for space heating which together with water heating make up a remarkable share (78.4% of the total consumption), space cooling, as anticipated, covers just a fraction of the total (about 0.4%); lighting and appliances represent about 14.1% and the remaining share is associated to cooking and other purposes[165]. It is also worth to report that in the European Union, in the same year, households' consumptions represented about 26.3% of the overall final energy consumption, meaning that space and water heating where together representing almost 21% of the total[166]. At the same time, heating and cooling needs in the E.U. (not solely considering households', but also industrial and other sectors requirements) are only partially addressed by RES generation (22.1% of the total in 2019). Sweden leads the way with the highest percentage (66.1%) followed by Latvia and Finland (57.8% and 57.5%). Considering those countries where SMILE demonstration sites are located: Denmark and Portugal show both notable results compared to the E.U. average, respectively 48.0% and 41.6%, while U.K. lags behind with a limited share over the total energy consumption for heating and cooling of about 7.8%[167]. Increasing the share of renewables to meet heating and cooling demands might go through two major strategies: the conversion of electricity generated from RES to heat that can be stored and subsequently used or the generation of heat via heat pumps and electric boilers activation[168]. The former solution consists in the deployment of Thermal Energy Storage (TES) devices which employ a storage medium (either cooling or heating it) to store energy that can be subsequently released for heating, cooling or power generation purposes. Within TES technologies, the exploitation of Phase Change Materials (PCM) storage appears especially relevant in the context of the SMILE project. Such technology exploits specific materials property to

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[163] IEA (2018), The Future of Cooling Opportunities for energy-efficient air conditioning. Available at: https://iea.blob.core.windows.net/assets/0bb45525-277f-4c9c-8d0c-9c0cb5e7d525/The_Future_of_Cooling.pdf
[164] D. Keiner et al. (2021), Global-Local Heat Demand Development for the Energy Transition Time Frame Up to 2050, Energies.
[165] Eurostat (2021), Energy consumption in households. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_consumption_in_households
[166] Eurostat (2021), Energy statistics - an overview. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_statistics_-_an_overview
[167] Eurostat (2020), Just over 20% of energy used for heating and cooling is renewable. Available at: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20201229-1
[168] IRENA (2019), Renewable Power-To-Heat, Innovation Landscape Brief. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Power-to-heat_2019.pdf?la=en&hash=524C1BFD59EC03FD44508F8D7CFB84CEC317A299

release/adsorb energy during the change in physical state. The most relevant advantage associated to the use of PCM refer to their high energy density (which represents the amount of energy that can be stored in a volume unit). PCM exploitation represent a viable solution for residential application due to their energy-shifting potential and the opportunities they open up for demand-side management[169]. They become especially interesting coupled, in residential sites, with solar applications, enabling the conversion of energy into heat during the day where solar energy is available, but heating needs might be limited and allowing its release during nights when the temperature is cooler.
One of the opportunities for the exploitation of PCM in residential sites is actually developed by one of the technology providers involved in the SMILE project consortium, SunAmp.
Sunamp is a U.K.-based company which patented a heat battery energy storage technology which exploit PCM property. The solution addresses both the residential segment and the C&I one. In the former segment it is offered a heat battery promoted as an ideal substitution for old hot water cylinders (with a more compact, easier to install solution not requiring routine maintenance). Different solutions integrating with various electricity sources have been developed, allowing the connection of the battery eventually with PV modules, heat pumps, boilers and the grid (or integrations of them). Some solutions enable implicit DR. Different battery sizes are available and the products offering encompasses solutions for large-scale projects. A 10-years' warranty is expected to be offered. The C&I segment is addressed with a modular and scalable solution adapting to various industries (farming, leisure, public sector, etc.). The product enables cost savings through DR and through the provision of flexibility and ensures energy security; in addition, the battery can be employed for energy transportation via different means.[170]

A set of other players which are developing the heat and thermal battery market are reported below.

Table 4.2: Set of players in the heat and thermal battery market development

Company	Key information
Caldera The Heat Battery Company	Caldera is a start-up company headquartered in the U.K. which is working on the commercialization of a large-scale heat battery for residential sites named "Warmstone". The product is intended to substitute the boiler and it is designed to be installed outdoor (seeing its size, 1 m diameter and height equal to 1.7 m). The logic of the solution refers to the possibility to store electricity purchased during off-peak periods (at low cost) or own-generated energy via PV modules. The charge command can be connected to a signal from the utility[171], allowing implicit DR programs deployment (the solution needs smart meters presence to enable DR). Energy is converted into heat and stored for future use. The product is promoted as a viable solution also for off-grid installations. It is described as being produced using "recycled and natural materials", and as fully recyclable after its minimum 20 years' lifespan. The solution price (including installation and ancillary components) will be 12,000 £, corresponding to almost 14,000 €. In addition, the company recommends an annual check on the battery with an approximate cost of 100 £[172] (about 117 €). From the delivery of the battery, it takes two days to

[169] I. Sarbu, C. Sebarchievici (2018), A Comprehensive Review of Thermal Energy Storage, Sustainability.
[170] Sunamp (website). Available at: https://sunamp.com/
[171] Catapult Energy Systems (webpage), Caldera. Available at: https://es.catapult.org.uk/impact/projects/caldera/
[172] Caldera (website). Available at: https://www.caldera.co.uk/

	complete the commissioning. The company value proposition stresses on the opportunity for householders to reduce their carbon footprint decarbonizing their home heating. The German multinational group König Metall, a producer of metal components for the automotive industry, has recently invested in Caldera.
TEXEL ENERGY STORAGE	Another innovative solution is provided by the U.S.-based Texel Energy Storage which is finalizing the development and commercialization of its hybrid battery (which combines a thermal battery with a Stirling Converter). It is described as providing a performance level similar to that of lithium-ion batteries at a lower cost. Moreover, the technology appears to have further room for development, and it might already present a significantly low levelized cost of storage[173]. The extent of the storage capacity is described to be over 100 years with limited energy losses. In addition, the technology is fully recyclable, and it does not require rare materials for its production. The product will address different segments from households to large-scale applications (it is scalable to grid-size projects). The stack size is 30 kW[174].
[cellcius]	An additional heat battery technology is being developed in Europe by the Dutch start-up Cellcius (a spin-off organization from the independent research organization TNO and the Eindhoven University of Technology). The battery technology relies mainly on potassium carbonate (as a basis of a developed salt composite) and its interaction with water. It is going to be tested in residential sites across Europe, in 2022, specifically in the Netherlands, Poland and France, in order to assess the functioning under different weather conditions. It has been foreseen that the first industrial application will be implemented by the end of 2022.[175] The technology is designed to be suitable for residential applications as the device size might resembles the one of a washing machine. Its size might vary to reflect the site energy needs and being a scalable solution, the technology can be used to serve other segments such as the industrial one[176]. The solution is described as being capable to store energy in the form of heat, safely and loss-free. Furthermore, it is described as "inexpensive" and the product value proposition appears to rely substantially on the sustainability aspect of the technology whose active material is reusable[175].
EnergyNest The Thermal Battery company™	A further provider of thermal storage technology located in Europe is the Norwegian EnergyNest. The company already commercializes thermal batteries applicable to a set of segments (mainly power plants, industrial sites and in support of renewables generation sites) but it appears it is

[173] SolarPACES (2020), TEXEL Explores US Market for 2-Cent Thermal Energy Storage in Metal Hydrides. Available at: https://www.solarpaces.org/texel-explores-us-market-for-2-cent-thermal-energy-storage-in-metal-hydrides/
[174] TEXEL Energy Storage (website). Available at: https://www.texeles.com/
[175] Cellcius (webpage). Available at: https://cellcius.com/en/
[176] Innovation Origins (2021), The salt battery that drags a family through the sunless and windless periods. Available at: https://innovationorigins.com/en/coal-merchants-new-style-heat-merchants-will-soon-drop-by-your-home-with-charged-salt-batteries-salt-batteries/

	currently not serving the residential one. Multiple benefits are offered to the different segments, ranging from unlocking DR-related revenues to peak-shaving and cost savings. The technology relies on low-cost, common and reusable materials such as steel and a concrete-like material. The solution is described as requiring limited CAPEX and negligible OPEX, it is associated with a lifespan ranging between 30 and 50 years. Moreover, low limited losses are foreseen. In July 2021, the global investment manager company M&G, through its European infrastructure division, Infracapital, acquired the majority stake of EnergyNest. The 110 million € investment should allow EnergyNest to boost its international growth[177].

[177] EnergyNest (2021), EnergyNest secures €110m investment from M&G-backed Infracapital (press release). Available at: https://energy-nest.com/energynest-secures-e110m-investment-from-mg-backed-infracapital/

5 Conclusions

This document has been produced in the context of SMILE project which addressed the development and testing of a set of solutions involving DR, energy storage and smart grid implementation in scenarios constrained by a number of challenges associated to renewables intermittent load profiles, grid congestion, fuel poverty, energy wastage and others.
The document is expected to provide an informative and useful picture of the market contexts associated to the main technologies and solutions implemented in SMILE demonstration sites, as well as of those trends which are significantly affecting their future commercialization strategies and potential developments. The extended market analysis has been conducted with a global perspective but in every section substantial insights and reflections on the European context has been provided so as to ensure consistency with the SMILE project embeddedness in the European Union framework.

Firstly, it has been investigated the current and future scenario of technologies at generation level to which SMILE solutions have been integrated: PV panels and wind turbines. Research has shown that with regard to both technologies, energy production capacities are rising globally and notable cost declines have been reached during the last decade. RES penetration appears to be a growing trend worldwide and, at European level, thanks to the recent Fit for 55 package, a further boost can reasonably be expected for the decade 2020-2030. The DSM market has been extensively investigated especially in relation to the DR segment. Its global value has been prudentially estimated to reach 12.9 billion $ in 2027 and two key trends have been identified as driving forces for its growth: growing residential sites involvement in DR programs and smart meters rollout. The former element has been analysed starting from trends affecting the U.S. market which appears to have reached relevant progress in recent years and thus a subsequent comparison has been carried out with the European context for which it has been considered the evolution of householders' electricity price and the current legal framework for a number of countries to provide a picture of its current status. The competitive landscape for aggregators has been explored, indicating the leading players in a number of European markets, such as Flexitricity, Agregio, Enel X and Grupo ASE. The analysis also reported that many of the leading and emerging players are developing and implementing the VPP concept confirming the relevance of the associated enabling software platforms. In addition, it has been reported how EVs projected widespread adoption, especially in Europe, unlock key opportunities for fleet management and charging software that, at the same time, appear to become essential tools supporting the energy system integration of further demand from transportation and supply from RES. The second element associated to DSM market growth, smart meters rollout, has been analysed starting from global shipping volumes and it has been concluded that the European market might reach a value of almost 10 billion € in 2030. Smart meters adoption across Europe are key enablers of implicit DR strategies, hence, it has been shown how Europe presents different penetration rates of this technology. Finally, considerations on AMI have been drawn and the global market value has been projected to reach 40 billion € in 2030.

The second main section of the document addressed the energy storage systems market. The relevance of lithium-ion based solutions has been highlighted seeing the current advantage over other technologies but it has not been excluded that the latter will eventually reach maturity and play a significant role in the coming years. The residential battery segment has been found to be experiencing relevant growth rates with Germany, Italy, U.K. and Austria leading the way in Europe. Battery deployments in European utility segment is growing as well, with a number of projects either under implementation or planned. Europe is also expected to experience a growth in its battery manufacturing capacity while China is retaining its dominant role in lithium extraction and refining. The battery manufacturing competitive landscape analysis has been executed considering leading players with European-based manufacturing, providing insights on the four largest players: Tesla, LG

Chem, Northvolt and Saft. Finally, to ensure consistency with the set of key technologies developed and deployed in SMILE project, insights on players in the thermal and heat batteries technologies market have been outlined, both in relation to initiatives under development and to already commercially available products.

From the extended market analysis, it emerged that significant business opportunities are being unlocked in Europe for SMILE technology providers and for their competitors. At the same time recent European regulatory framework developments might further trigger markets growth while additional testing activities proving the technical feasibility and the economic advantages brought by the developed solutions might accelerate their adoption.