SMART ENERGY SOLUTIONS IN THE EU: STATE OF PLAY AND MEASURING PROGRESS

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ABSTRACT

The European energy system is undergoing, and will continue to in the future, a transition towards a more sustainable energy system. An important part of this will be the deployment of smart energy solutions in the household sector, including smart meters, controls, appliances, and their integration in home networks. This study is in support of the Commission's work related to smart energy solutions in the framework of the SET plan, in particular in understanding methods to develop indicators that can be used to measure progress under the Declaration of Intent for the Action 3.1 on Initiative for Smart solutions for energy consumers. First, 'smart energy solutions' are defined and the type of technologies that this includes are detailed. Once the scope has been established, existing indicators that are able to monitor the levels of deployment of such technologies will be reviewed. This includes indicators being proposed or used by international and Member State level energy agencies and other organisations. It is not intended that this study will comprehensively assess the actual deployment of smart energy solutions across all EU Member States. Instead, selected countries who are more advanced in the deployment of such technologies are considered in more detail. These include France, Switzerland, Ireland, UK, and Sweden. Finally, we review estimates of the potential of demand response in Europe to achieve goals related to energy efficiency, cost savings, and renewable energy penetration.

Keywords: smart meters; demand side management; European Union;

1 INTRODUCTION

The EU's broad energy policy objectives - as defined in the *2030 Climate and Energy strategy* - are security of supply, environment, and competitiveness. In the electricity sector, this will require decarbonisation of electricity generation and reducing primary energy consumption. The increased use of smart energy solutions (SES) is one measure that can contribute to achieving those goals. "The widespread use of smart [energy] solutions should not be a goal itself, but rather be seen as a tool amongst many" [1] to achieve the overall objectives. SES are expected to support the ongoing shift on the supply side towards more renewable generation, both on the central grid system and also in distributed systems. SES could also provide consumers with ways to reduce costs in multiple ways: by shifting demand; through improved information and automation to optimize energy use; and through a move towards being prosumers.

From the policy maker's perspective, there needs to be a distinction between the technical feasibility - technical components installed, smart energy solutions technically possible - and the actual contribution of smart energy solutions to the wider electricity supply system - cost of installing and running smart energy solutions against savings achieved.

Accomplishing this will require a regulatory framework that promotes demand response and energy efficiency services, where the availability of real-time information and secure handling of data is guaranteed to consumers. It will also require an improved understanding of how consumers understand and view smart solutions.

In this paper, indicators relevant to smart energy solutions are identified and explained. In order to do so, smart energy solutions are first defined. Selected case studies are then presented to highlight successful measures related to the deployment of smart energy solutions. An overview of the current status of smart metering in the EU is provided. This is followed by a discussion of the demand response potential in the EU and how the estimation of this potential can be improved. Finally, a set of conclusions are provided.

2 DEFINITIONS AND SCOPE

Information and communication technologies (ICT) are increasingly applied in almost all technological areas. This trend towards 'smartness' [2] is usually driven by the goal to gain more control over technical processes, decisions and communication [3]. In accordance with [4], this paper does not employ the term 'smart' normatively as a desirable state, but it is rather understood as a description of a technical system with increased utilisation of ICT [5]. Laitner [6] describes smart energy solutions as follows: any energy solution that is described as "smart" [...] has semiconductor sensors to measure temperature or other variables; communications chip to receive and transmit data; memory chips to store the information; and microcontrollers, microprocessors, and power management chips to adjust energy loads". In this paper we focus on electricity loads that are either stored, generated or consumed. Smart energy solutions are generally applicable to all energy carriers. However due to the importance of the electricity supply system for the decarbonisation of the European energy system, we focus on electricity. We then classify the technical components of SES as storage, generation and consumption (Figure 1).

All technical components can either be influenced through a user interaction or automatically (active or passive end-users). By providing targeted information (e. g. about the consumption, the current electricity price, the current electricity generation) the behavioural pattern of the end user can be changed in the short- and the long-term. In the case of an automated influence of the system, the end user only defines the degrees of freedom to be used by the technical automation. This would allow, for instance, a dish washer or laundry machine to start within a defined time period or an air conditioning to operate within a range of temperature. As shown in Figure 1, the informational connection of the smart energy solution is the basis for both kinds of controls.

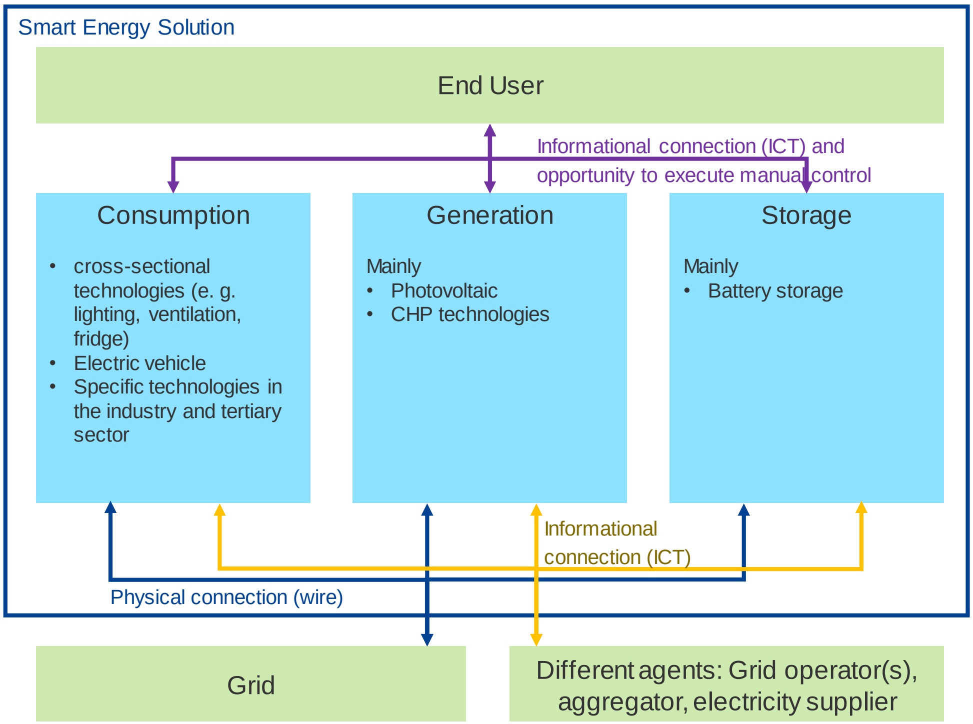

Figure 1 -Conceptual visualization of elements of a Smart Electricity Solution

3 CASE STUDIES

In this section, a set of country cases studies provide insights into the present levels of SES deployment, and what its implications for consumers are. Information on smart metering and its installation, the effect of smart meters in national electricity markets, and its impact in the wide electrical system is presented. In addition, other types of SES - that are in the early stage of development - are also described. The countries selected as case studies – Switzerland, France, UK, Ireland, and Sweden - are among the most advanced in Europe in terms of SES deployment.

3.1 Overview of smart metering in Europe

The Intelligent Energy Europe programme published a report on the European smart metering landscape in 2016 [7]. Based on this, Figure 2 provides an overview of the regulatory situation (horizontal axis) versus the progress in implementation (vertical axis) of smart metering. Several dimensions are considered for the classification of the countries. For the regulatory axis, four dimensions are considered:

1. cost benefit analysis and rollout plan,
2. timeline of rollout,
3. barriers from new regulations (privacy and data protection, measurement and calibrating meters),
4. legal minimum functional requirements.

For the progress of implementation axis, three dimensions are considered:

1. enabling infrastructure,
2. rollout status,
3. services already available for consumers.

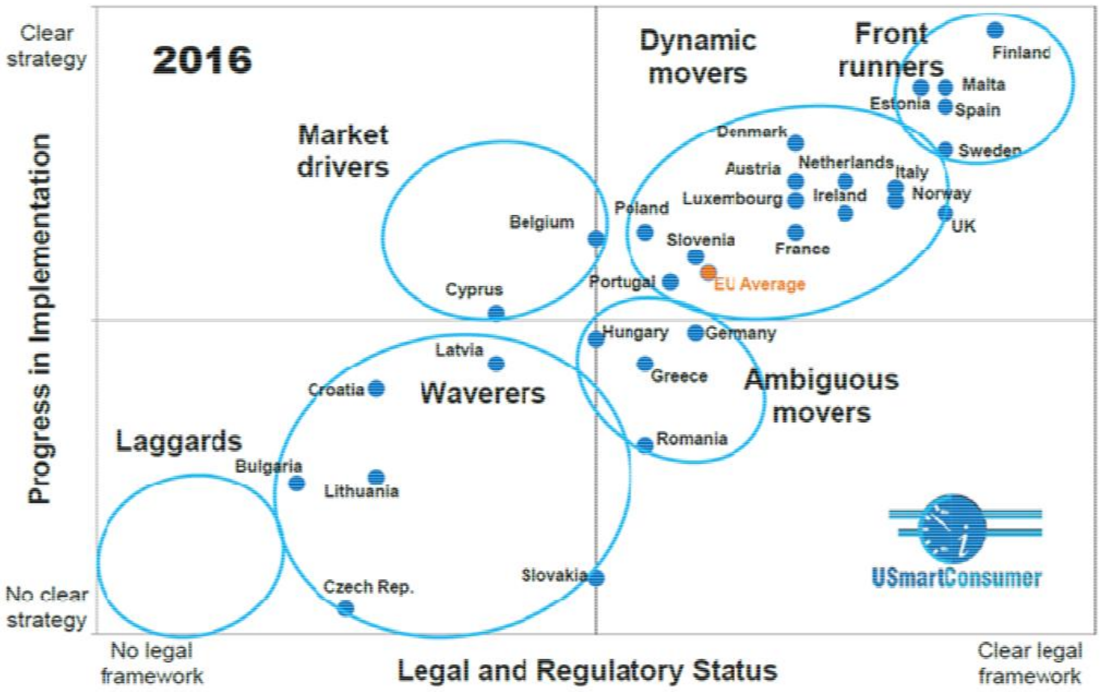

Figure 2 - Regulatory status versus implementation for smart metering [8]

By weighting the dimensions, the Member States[1] were clustered into five groups: *Dynamic movers*, *Ambiguous movers*, *Market drivers*, *Waverers,* and *Laggards*. The *dynamic movers* are characterised by a clear path towards a full rollout of smart metering. Either mandatory rollout is already decided, or there are major pilot projects that are paving the way for a subsequent decision. The *market drivers* are countries where there are no legal requirements for a rollout. Some Distribution System Operators (DSOs) or legally responsible metering companies nevertheless go ahead with installing electronic meters either because of internal synergistic effects or because of customer demands. *Ambiguous movers* represent a situation where a legal and/or regulatory framework has been established to some extent and the issue is high on the agenda of relevant stakeholders. However, due to lack of clarity within the framework, only some DSOs have decided to install smart meters. *Waverers* show some interest in smart metering through regulators, utilities or ministries. However, corresponding initiatives have either just started, are still in progress or have not yet resulted in a regulatory push towards smart metering implementation. Finally, *Laggards* are countries where smart metering is not yet being considered. All considered countries are roughly on the diagonal line from *no clear strategy, no legal framework* to the opposite. Hence, implementation progress is linked with a clear legal framework.

[1] EU27 and Norway

3.2 Switzerland

3.2.1 Smart meter roll-out and technical specifications

Since the liberalisation of the electricity market in 2009[2], the number of DSOs in Switzerland has increased. This is due to, for instance, municipalities creating their own DSO[3]. As of January 2016, there are 653 DSOs. To enhance liberalisation and market rules, the Swiss Federal Office of Energy (SFOE) issued minimal requirements for smart metering [9], which may be used as indicators of progress. The requirements target the following areas.

- Creation of a technical framework to allow profitable business models;
- Allow the consumer to change easily electricity suppliers. Thus, commercial barriers are avoided;
- Legal and investment security for DSOs;
- Facilitate the deployment of SES and other innovative power solutions.

Currently, there is no national Swiss policy roadmap for the implementation of smart metering. On the other hand, electricity suppliers and DSOs within the liberalisation of the Swiss electricity market drive local deployment of smart meters. Several pilot projects and case studies were launched in recent years, which may be used as an indicator.

Three major DSOs in Switzerland are currently operating smart meters: Elektrizitätswerke des Kantons Zürich (EKZ), Industrielle Werke Basel (IWB), and Elektrizitätswerk der Stadt Zürich (EWZ). Figure 3 shows the percentage of smart meters installed by the Smart Grid Swiss Association members (*Verein Smart Grid Schweiz – VSGS*). In 2014, already 64,000 smart meters (with remote readout) were installed [10], which can be clearly used as an indicator. It is important to note that the VSGS statistics do not distinguish between meters in household, SME, or large corporates. Some smaller DSOs have also launched minor smart meters projects (Smart Linth Region, SWG Grenchen, Abron Energie AG), for which official statistics are not available.

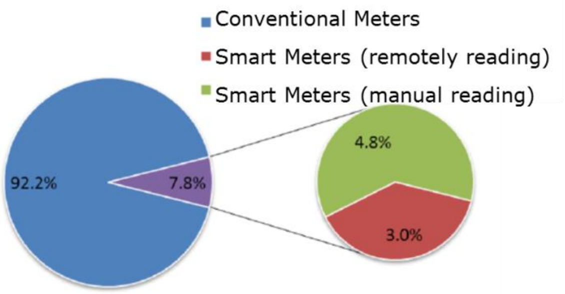

Figure 3 - Smart and conventional meters operated by VSGS members in 2014 (of a total of 64000); adapted from [10]

GWF MessSysteme AG (GWF) is the largest manufacturer for smart meters in Switzerland (producing also water, gas and heat meters). They produce an upgraded conventional meter that has additionally a wireless device allowing “drive-by” readout. However, this enhanced meter cannot be considered as fully smart for use in SES. As a second

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[2] The liberalisation of the Swiss electricity market started in 2009, and is currently restricted to large electricity consumers, who can freely choose their power suppliers. Free choice for smaller consumers is expected in 2018. http://www.frenergie.ch/fre-bulletin/louverture-du-marche-de-lelectricite-en-suisse/

[3] Swissgrid: https://www.swissgrid.ch/swissgrid/fr/home/reliability/griddata/distribution.html

product, their more advanced meter fulfils the minimal requirements for smart metering systems by the SFOE (as discussed in the previous section, ‘Smart meter roll-out and technical specifications’). The communication is by electrical signals following the RS-485 standard and allows up to 30 devices to be connected to a single collector [11]. According to GWF, such smart meters are ready for a “Smart Grid” in Switzerland.

3.2.2 Types of load management

3.2.2.1 Indirect load management

Time-of-use (ToU) tariffs - without explicit feedback - are available in Switzerland since several years [12]. Conventional power meters are already offering the possibility to record the consumption split into two tariff steps. With smart meters, such contracts can be improved with more steps, which could allow to increase the load shifting potential between 2.5% and 5% compared with a two-step tariff [13]. CPP (critical peak pricing) and RTP (real time pricing) are demand response tools not yet available for small consumers, and could serve with ToU tariffs deployment as an indicator.

3.2.2.2 Direct load management

Apart from ToU tariffs, direct load management through controlled electric appliances are already available and deployed in Switzerland (SVE, 2016, 1). However, the remote controls are simple, that is, no information about the live-characteristics of the appliance is transmitted; it is just switched off or on, and currently mainly used only for water heaters (usually combined with water storage and electric heating). In Figure 4, the flexibility potential of categories of electric appliances is shown. The appliance category offering the best flexibility potential is the hot water, offering a potential of 75% when the flexibility duration goes beyond 4 hours. These estimates are however highly dependent on the specific technology used for each application.

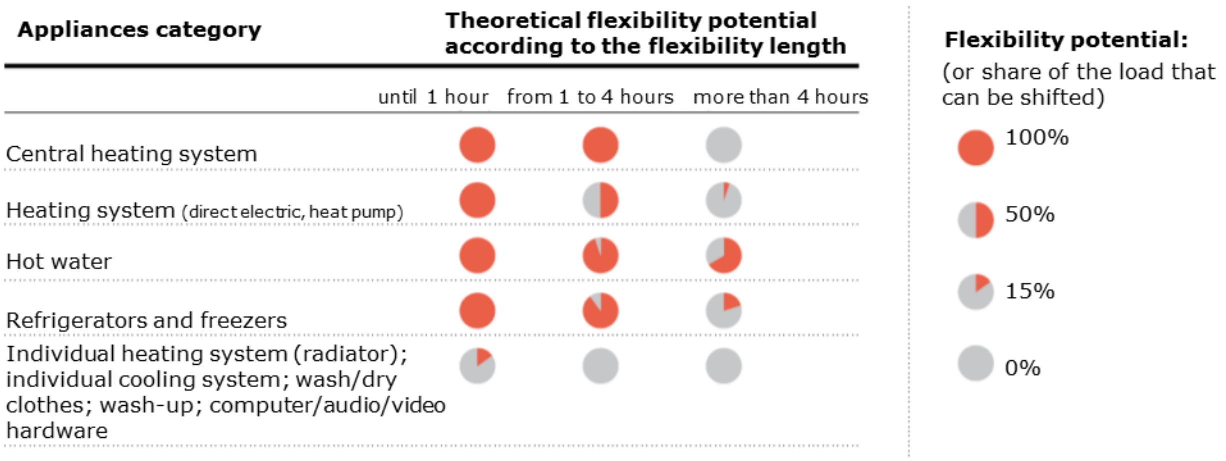

Figure 4 - Theoretical flexibility potential of load management; adapted from [12]

3.2.3 Other system component of SES

Batteries of electric vehicles (EV) –while not being used but connected to loading stations– can be used as a buffer at the household scale or even at the regional scale [14], [15]. This *vehicle to grid* (V2G) concept is not yet implemented in Switzerland [16]. Nevertheless, the number of EVs could be an indicator for SES. The number of EVs in Switzerland rose by almost 70% between 2014 and 2015. In 2015, 7,531 EVs were on the roads. However, they represent still only 0.2% of the car fleet.

Figure 5 shows a possible evolution of the EV fleet in Switzerland. These projections were calculated using the *Swiss TIMES energy system model* (STEM) developed by the PSI. By 2040, plug-in hybrid electric vehicles (PHEVs) together with battery electric vehicles are the majority. The share of the latter increases to 95% in 2050 to around five million vehicles [17]

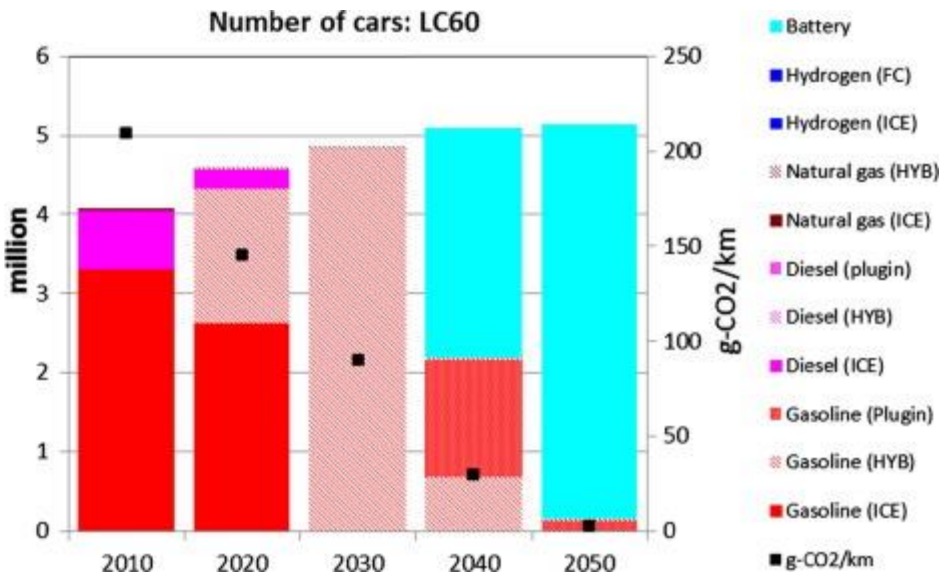

Figure 5 - Evolution of number of electric vehicles in Switzerland

3.2.4 System level impacts (ToU tariffs)

The major Swiss electricity suppliers are currently not providing ToU tariffs together with feedback to end-users, likely because the number of smart meters is still negligible. However, small pilot projects linked with feedbacks programs have already been implemented in the smaller cities (e.g. in Arbon and Dietikon), which could be used as indicators. As of today, no exhaustive data statistics or impact reports are available of these still marginal efforts for ToU tariffs.

3.3 France

3.3.1 Smart meter roll-out and technical specifications

In France, most of the smart meters are installed by ENEDIS, which is the largest DSO covering 95% of power distribution [18]. The interface of *Linky*, a smart meter, is still simple and allows the consumer to monitor the current electricity tariff, actual load, and maximal subscribed load. The guidelines for minimal requirements of the Swiss government for smart meters (see 3.2.1) are roughly comparable to those of French authorities.

Smart metering implementation in France started officially in December 2015 [19]. By October 2016, 1,751,200 smart meters were installed[4]. The next implementation period is from 2016 to 2021, which should result in a smart meter coverage of 90%. It may be interesting to compare with the more ambitious roll-out plan in 2014 reported the European Commission: Figure 6 shows that the French government had committed to have an implementation period finished in 2020, and the objective for 2016 was to have three million smart meters installed, which could be used as an indicator.

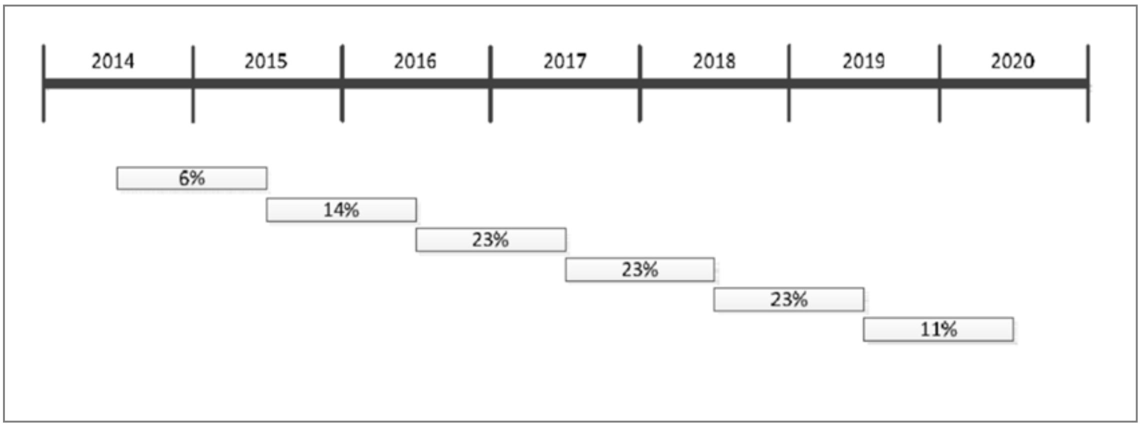

Figure 6 - Projected roll-out of smart meter in France (2014-2020) [20]

3.3.2 Types of load management present

Already ten of the eleven electricity suppliers in France are offering ToU tariffs to small consumers. The exception is Enercoop offering only a fixed tariff; Enercoop's power is 100% renewable and they follow the "Negawatt" approach[5], which results in electricity tariffs that are 15% more expensive than those of competitors. In Figure 7 the price components are shown for Enercoop, which may constitute also useful alternative information for consumers.

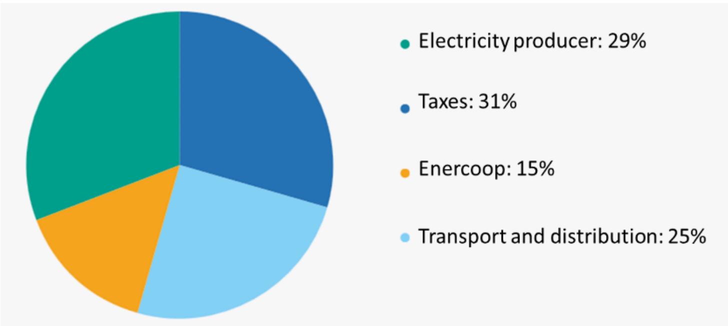

Figure 7 - Price components of Enercoop [21]

[4] personal communication with ENEDIS
[5] Negawatt means "power that is saved"

3.3.3 Other system components of SES

Over the past years, EV deployment grew constantly. In 2016, 13,516 licences were issued as of the time this study was conducted (the monthly statistics indicate that 2016 will continue to exceed previous years). Number of EVs could be used as an indicator, as well as the governmental grants.

3.3.4 System level impacts

The feedback loop of information proposed by *Electricité de France*[6] (EDF) is shown in Figure 8. The central element is the smart meter *Linky*. In a first step, the electricity consumption is recorded by the smart meter with a period of minimal 10 minutes. The French legislation has recommended this lower boundary of 10 minutes to protect consumer privacy [23] . The consumer has to agree on the recording periodicity with the supplier and can usually choose between 10, 30 or 60 minutes. In a second step, the smart meter transmits daily the data to ENEDIS who transfers the data to the electricity supplier. The customer can monitor the electricity consumption of the previous day and get feedback and advices.

Small consumers can choose between eleven electricity suppliers as of today. However, none of them are providing in their contracts such feedback yet. EDF offers a contract called *e.quilibre* where the user can monitor the electricity consumption on a monthly basis only. With more nation-wide deployment of smart metering in the future more flexible feedback contracts may emerge (currently it seems that the almost two million smart meters installed are below the threshold for such contracts). Moreover, a consumer having a Linky smart meter can already monitor consumption, but only at the online platform of ENEDIS, which may be still too inconvenient as a major downside.

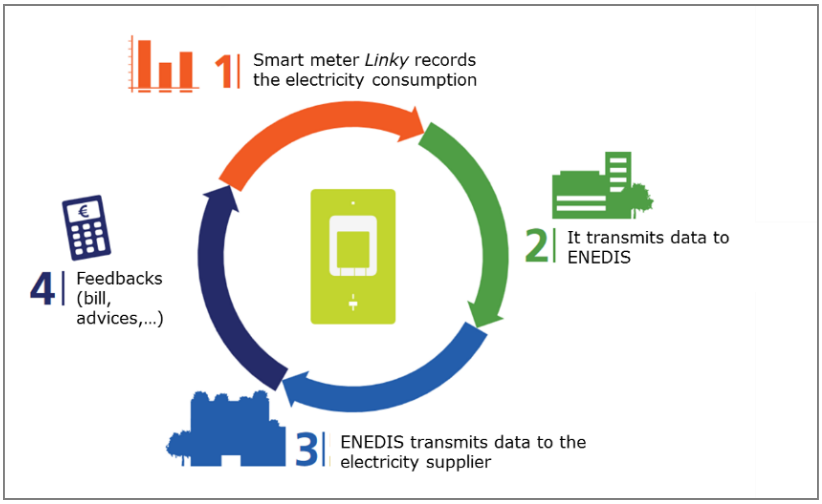

Figure 8 - Information loop using the Linky smart meter (Source: [24])

[6] EDF is the largest power producer in France; in 2014, 92.6% of the electricity of small consumers was provided by EDF [18]

3.4 UK

3.4.1 Smart meter roll-out and technical specifications

The fundamental requirement for any home SES is a smart meter, which provides additional information and/or the ability to control use, to either increase or decrease demand to meet the mutual aims of both the consumer, supplier and network operator. Therefore, indicators for smart meters are critical.

3.4.1.1 Smart meter roll-out: physical installation

The UK Government's Smart Metering Implementation Programme aims to roll out 53 million smart meters to all domestic consumers and smaller non-domestic premises[7] in Great Britain by the end of 2020 [27]. Suppliers need to take all possible steps to get full coverage, although smart meters are not compulsory for households i.e. they are not obliged to agree to an installation, and could refuse a supplier's request.

As part of the roll-out, installation will include both a smart electricity meter, a smart gas meter, and a communications hub. Consumers are also offered an In-home Display at no upfront cost. Data will be used by energy suppliers (for billing) and energy network operators (to help manage load and enable improved planning). Use of data by other organisations will be subject to agreement by consumers. A Data and Communications Company (DCC), overseen by the regulator, will put in place communications to allow for information to be sent from smart meters to energy suppliers, energy network operators and energy service companies.

Indicators used to monitor progress on the roll-out are provided in a quarterly statistical publication [26][8]. The following indicators of installation are used –

- No. of smart meters installed by large energy suppliers in domestic properties, by fuel type (quarterly)
- No. of smart meters installed by small energy suppliers in domestic properties, by fuel type (annual)
- No. of domestic gas and electricity meters operated by the large energy suppliers by meter type (quarterly), distinguished by fuel type
- No. of domestic gas and electricity meters operated by small energy suppliers by meter type (annual)

An important distinction is made between installation (first two bullet points) and operation (second two bullet points). Operation means those meters which the energy suppliers are operating in 'smart mode' [28]. This may differ from 'installations' for the following reasons; i) customers with smart meters who are in the process of switching to a smaller supplier whose data is currently not collected; ii) as per i), but where the new supplier is currently unable to operate the installed smart meter in smart mode; iii) technical issues preventing smart mode operation, and therefore is operating in a traditional mode.

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[7] These are business or public sector customers whose sites use low to medium amounts of electricity (defined as a smaller non-domestic site falling within Balancing and Settlement Code Profile Classes6 1, 2, 3 or 4) or gas (defined as a smaller non-domestic site using less than 732MWh of gas per annum). The sites therefore range from individual micro- and small businesses to the smaller sites of private and public sector organisations [26].

[8] BEIS states - Currently these data are considered to be Experimental Statistics; this means they are new statistics and have not undergone the full evaluation process that is required for National Statistics.

It is worth highlighting that in the 'meter type' indicators, traditional and 'smart-type' categories are also included. 'Smart-type' do not have the full functionality of smart meters[9], and are therefore not included in the roll out numbers. The above indicators are repeated for non-domestic sites; for these indicators, 'smart' and 'advanced'[10] meters are distinguished but both count towards the roll-out targets.

Some of the indicator information for both households and non-domestic sites is presented below (Figure 9 and Figure 10).

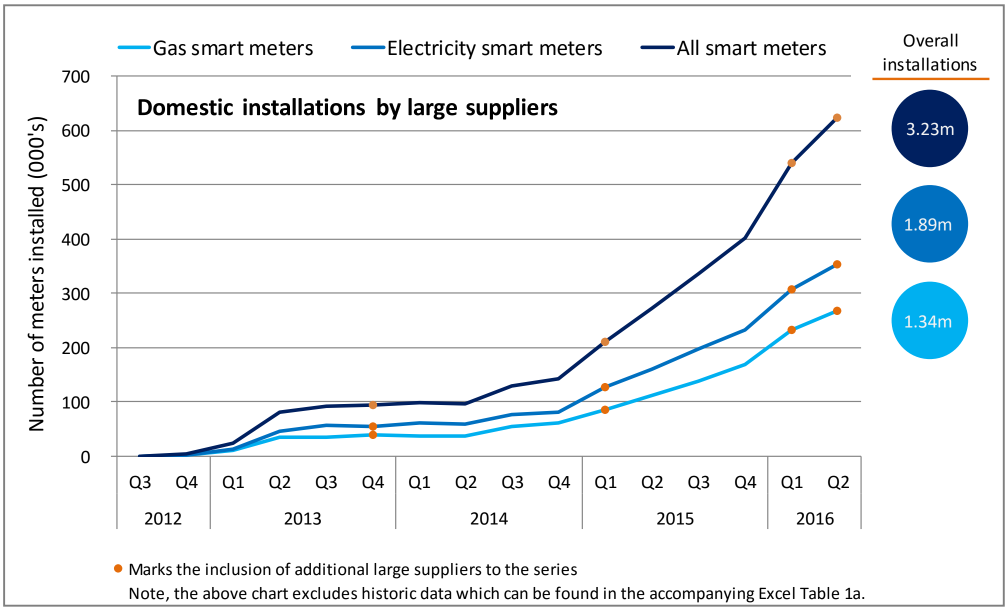

Figure 9 - Quarterly domestic installation activity for large energy suppliers (Source: [26])

As the regulator, Ofgem [30] has an obligation to monitor the roll out of smart meters, and has stated a range of indicators. This includes numbers of installations, consumers declining installations, problems with equipment, primarily In-Home Displays, and coverage of PSR consumers[11].

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[9] They do not meet the criteria under the Smart Meter Equipment Technical Specification (SMETS). A full overview of required smart meter specifications can be found in [29].
[10] Advanced meters must, at minimum, be able to store half-hourly electricity and hourly gas data, to which the customer can have timely access and the supplier has remote access. In smaller non-domestic sites, advanced meters may be installed as an alternative to SMETS-compliant smart meters until April 2017, in the case of large suppliers, and August 2017 in the case of small suppliers. These meters will not have to be replaced with SMETS meters in non-domestic sites before 2020 and therefore count towards the supplier's roll-out obligation [26].
[11] PSR customers i.e. those on the Priority Services Register are a list of vulnerable customers who may have additional needs in relation to energy.

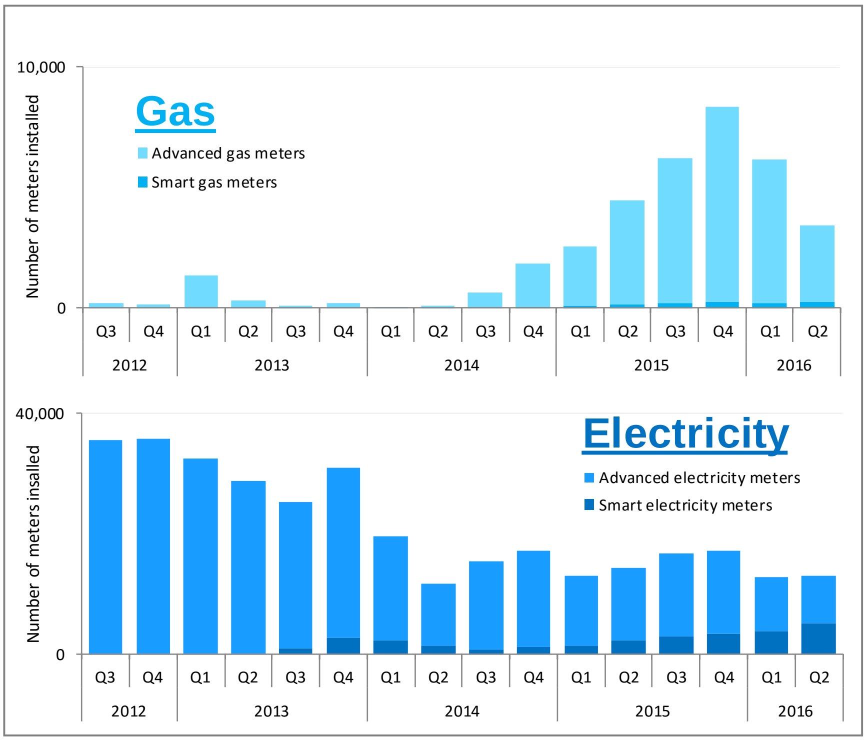

Figure 10 - Number of smart and advanced meters installed by large energy suppliers in smaller non-domestic sites, by fuel type and quarter (Source: [26])

3.4.1.2 Smart meter roll-out: mode of operation

Smart meters in the UK are primarily being installed and operated so that they feed back the information to energy suppliers and network operators, via the DCC. It is important to recognise that they are not yet being exploited to realise their full functionality (automations, links to smart devices). However, they do have the necessary functionality to (in the future) reflect real-time prices and allow either direct consumer responses or automated services via third parties [31]. In fact, the Roadmap [27] does not envisage this 'smarter' role until the late 2020s and into the 2030s (see Figure 11 below). In part this is due to the lack of integrated systems in households, absence of time-of-use tariffs to provide incentives, and the fact that a stronger potential will be seen as the technology mix changes e.g. move to heat pumps (hybrid-based or with storage, EVs etc.) [32]. Such technologies are therefore considered to have strong option value (if they have the necessary functionality), with a strong current use now but with greater potential in years to come [33].

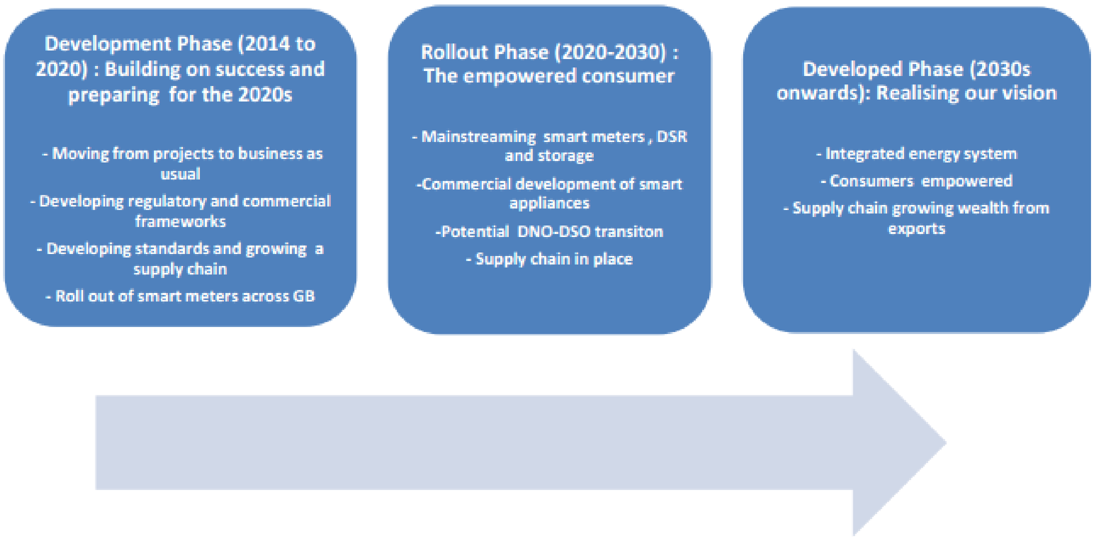

Figure 11 - Stages in the development of the UK smart grid (Source: [27])

Future indicators will need to consider how the smart meter is being used, to better understand the additional potential. A number of indicators could be foreseen that provided information on the level of automation of the household system (uptake of smart appliance systems[12]), through types of agreements with suppliers on handing over some control for automation, the uptake of time-of-use tariffs, and other key elements of smart energy solutions that might further the role of the smart meter e.g. home power storage systems, electric vehicle ownership etc.

3.4.2 Types of load management present

The National Infrastructure Commission made a range of recommendations about the UK's move to increasing power system flexibility [34]. It states that in order for these consumers to directly engage with and benefit from demand flexibility, Ofgem [the regulator] needs to ensure that the regulatory framework incentivises suppliers to offer 'smart tariffs', so that the prices people pay can reflect the cost of providing electricity over time (e.g. on a half-hourly basis).

ToU tariffs incentivise consumers to shift demand away from higher tariff periods to lower tariff periods. These are largely absent from the UK, with the exception of Economy 7, where customers benefit from cheaper electricity at night. Economy 7 tariffs tend to be used by consumers who use electricity rather than gas for heating, and have hot water storage tanks and electric storage heaters, and can therefore utilise electricity at night. This is estimated to encourage two million household customers to shift electricity use to the night, resulting in a shift of 20% of annual household demand from the day [35][13].

[12] A number of tech giants are developing hub systems that allow for control of smart appliances, such as Samsung (SmartThings), LG, Sony (Life Space UX) and Google (NEST).

[13] Of consumers with Economy 7, 38% were recently found not to have a storage heater or run any of their appliances at night, therefore paying more than they need to, to the advantage of no one but the energy companies [36]

In [37], the UK's first residential dynamic time of use tariff has been trialled under Ofgem's Low Carbon Network Fund, by UK Power Networks, EDF Energy and partners. Over 1,100 households participated to explore response to variable price signals. The result was reduced demand in response to network constraint events by approximately 10% as well as increasing their demand during supply demand balancing events. This was based on manual response, which could be enhanced with automated smart appliances. A review of previous demand side response trials with a range of different tariffs (e.g. Time of Use, Critical Peak Pricing) found that peak energy demand reductions are 60-200% greater with automation and / or control by other parties (e.g. suppliers, Distribution Network Operators) than without. There are moves afoot to see how half hourly settlement could work, an important precursor to allowing for ToU pricing[14].

There are two types of indicators that should be considered in the future. The first relates to the uptake of ToU tariffs, and the second to the impact. On impact, this could include indicators that measure the expenditure and consumption under ToU tariffs by ToU period (available via aggregated smart meter data). This could then be compared to household consumption without ToU tariffs.

It is also worth noting that there might be other tariffs that are available that do not necessarily focus on price as a means of incentivising consumers. In addition to being price-based, contracts with a supplier could also be volume-based or control-based. Volume-based impose some *cap or constraint on electrical power consumption* while control-based see *customers cede some level of control over specified appliances to the DSR operator* [39]. Therefore, indicators could track the type and level of consumer contracts in the future – and their subsequent effectiveness. This is vital for learning how to maximise potential; [39] notes that the evidence is limited in respect of how consumers will respond to ToU pricing, and therefore learning of effectiveness via indicators will be crucial for decision makers.

3.4.3 Other system components of SES

There are a number of key elements of further developing smart energy solutions. These include the stronger integration of energy using appliances into building level communication systems (energy management systems & smart appliances), and opportunities for increased electricity storage, either through electric vehicles or dedicated building level storage solutions e.g. Tesla Powerwall.

On smart appliances, [40] states that potential is large; however, this will take some time to feed through to the domestic appliance stock, with consumers reluctant to switch until a new appliance is required. No formal statistics on smart appliances or energy management systems is available in the UK, although a number of market research companies have made estimates.

[14] [38]

Ultra low emission vehicle (ULEV) statistics now account for 1.1% of new registrations, showing strong growth from previous periods [41]. In 2015, the share was 0.8%, and in 2014, it was 0.2%. However, in the current data, distinction between vehicle types is not provided; ULEVs are those with pure electric engines, plug-in hybrid engines or cars with CO_2 emissions below 75 g/km at tailpipe.

3.4.4 System level impacts

This section focuses on ex ante analysis of how broader system response based on smarter control of supply and demand could impact the broader system, and the potential economic benefits. Much of this analysis is based on modelled simulations, to better understand future potential, which is crucial for system planning. Therefore, these are not indicators of existing activity and progress towards such systems, but do provide evidence of future system potential.

3.4.4.1 System level peak demand shift

In the UK, there is a recognition that many of the building level SES will contribute to system level demand response. Strbac et al. [33] state that the demand side reduction (DSR) potential of industry[15] and commercial consumers in the UK has been estimated to be between 4% and 30% of their corresponding peak demand. The importance of DSR from I&C consumers is expected to grow greatly in importance and may constitute as much as 15% of flexible demand resources by 2030.

A DECC report in 2015 [37] cites two studies assessing the overall potential of DSR; firstly, non-domestic buildings (excluding industry) could contribute 1.2 – 4.4 GW (winter week day, Great Britain) to peak energy demands (by Element Energy and De Montfort University [42]). Secondly, another study on domestic and SME[16] sectors concludes peak reduction in 2030 could be up to 2.5 GW in the domestic sector and up to 2 GW for SMEs (by Redpoint/Baringa [43]). Other reports, such as one by Frontier Economics [32], also consider future potential across different appliance types, and assess DSR in a modelling framework.

3.4.4.2 Economic benefits

In addition to the physical system effects, a number of analyses have also estimated the potential economic benefits of DSR[17]. There is reduction in costs associated with energy systems that integrate flexible technologies, of which DSR is one, in addition to storage, interconnection, and flexible generation. Analysis by Strbac et al. [33] for the National Infrastructure Commission (NIC) estimated avoided investment due to flexible technologies to range between £2.9bn and £8.1bn per year in 2030. It is quite difficult, however, to pinpoint the savings from building level SESs specifically, due to the consideration of a range of technologies working together in an integrated system.

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[15] Note that DSR is already being used in industry, through schemes such as Frequency Control by Demand Management (FCDM), demand interruption to safeguard system stability, and Triad, where incentivizes are in place to reduce demand at highest peak times of the year.
[16] Small and Medium Enterprise
[17] DSR defined by Ofgem as 'customers responding to a signal to change the amount of energy they consume from the grid at a particular time', and its basic purpose is to inject a degree of flexibility into the electricity system [36].

The NIC [34] also highlights the economic benefits for growth and UK firms, another potential way of monitoring the efforts in relation to SES. DECC/Ofgem [27] highlight an E&Y analysis (for SmartGrid GB) that estimates that the development of smart grids *could lead to approximately £13bn of Gross Value Added between now and 2050; export earnings of £5bn to 2050 and jobs could be boosted by an average of 8,000 during the 2020s rising to 9,000 during the 2030s if sufficient investment is made.* Developing an indicator that measures impact on wider economy is potentially difficult because many of the firms involved in software development and systems operation apply their skills in many different sectors.

In a Consumer Futures paper on DSR and the domestic consumer, it was estimated that with the correct regulatory framework, smart solutions including DSR could save between £2 billion and £4 billion throughout the value chain to 2050, compared to conventional grid upgrades [27]. A report by the Citizen's Advice Bureau [36] states that the overall financial benefit from DSR is hard to estimate. One model commissioned by DECC, suggests savings from DSR between 2025 and 2030 are likely amount to roughly £10 per household per year if evenly shared. Alternatively, if not shared, participants could benefit in the region of £90 per year[18]. This analysis focuses on DSR, a specific outcomes of SES, and is based on modelled future outcomes.

Furthermore, R&D levels are also a possible indicator of future commercial benefits. A JRC report *Smart Grid Projects in Europe – Lessons Learned and Current Developments* put UK levels investment in smart grid technologies at some of the highest in the EU [27].

3.5 Ireland

3.5.1 Smart meter roll-out and technical specifications

The Commission for Energy Regulation (CER), the Irish energy regulator, in conjunction with the relevant government ministry (DCENR) established the National Smart Metering Programme (NSMP). This programme will aim to upgrade approximately 2.2 million electricity meters. The programme has 5 phases (Figure 12), and is currently in Phase 3, having published the High Level Design in October 2014 [44]. Phase 3 is focused on a range of activities around changes to consumer policy (regulatory changes, switching to time of use tariffs), developing consumer engagement activities and network activities, including procurement by operators for smart meter solutions and required network changes [45]. The rollout of electricity smart meters for all residential and small and medium sized businesses is planned to commence in 2018 (Phase 5 Deployment), subject to the successful completion of Phases 3 & 4.

[18] [43]

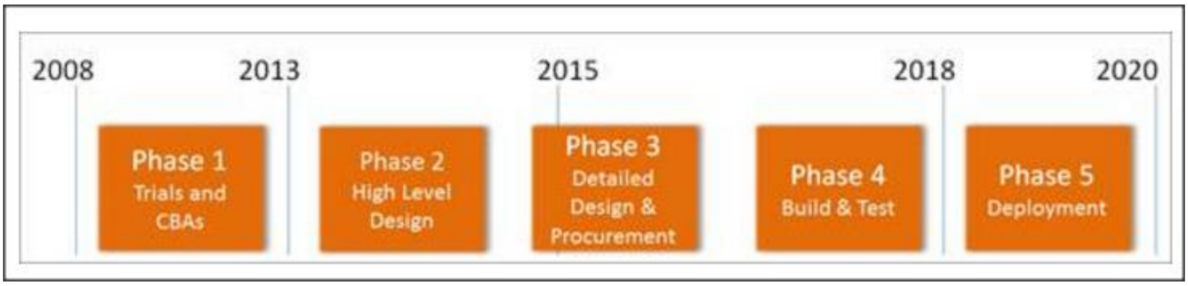

Figure 12 - Phases of the NSMP

In the High Level Design [44], the key features include –

- Limiting functionality of smart meters, with most of the data processing being done centrally (back office), and data on half hourly consumption, ToU tariffs etc. being passed to the consumer via non-AMI (automated meter infrastructure) such as online, apps, and mobiles.
- Introduction of ToU tariffs, to maximise the benefit of roll out
- Minimum information requirements through in-home display, smart bill and downloadable data file.
- Allow for switching between Pay As You Go (PAYG) and credit payment.

3.5.2 Types of load management present

As stated above, an important feature of the Irish smart metering programme is the introduction of ToU tariffs alongside smart meter roll-out. A decision document by CER [46] sets out the approach to ToU tariffs. Key features include – Suppliers to take reasonable effort to offer and migrate all (in a timely manner) residential and smaller business customers to a ToU tariff in a timely manner.

- Suppliers may offer a customer such a tariff from a date when relevant readiness criteria to that customer have been met (known as "TOU Go-Active").
- Suppliers must make available such a tariff for any customer for whom more than 12 months has elapsed since their "ToU Go Active" date. For residential customers, one of the tariffs choices must be its simplest ToU Standard Smart Tariff.
- Suppliers must provide, at least once annually, a prompt to each customer not on a Time-of-Use Tariff for the purpose of encouraging sign-up.
- The CER will, subject to progress on rollout, set out a date by which other (no ToU) tariffs will need to start being removed from the market.

Monitoring of the uptake of ToU tariffs by CER will be critical for providing insights into consumer acceptance, and in estimating the potential effect (in combination with the smart meter data).

Under Phase 1 of the NSMP, a range of trials were undertaken to explore technical and operational issues associated with smart meter roll out, as well as behavioural response. The residential behaviour trial, one of the largest of its kind (5000 homes), found that ToU tariffs, in combination with other informational stimuli (web access to information, detailed billing, in-home displays, reduction target incentives) led to average overall electricity usage reductions of 2.5% and 8.8% for peak usage [47][19].

Current ToU tariffs for electricity, which have limited customer reach, only extend to a day-night tariff, known as Nightsaver, which differentiate unit charges between the day and night periods. The lower charge period at night is from 11 p.m. to 8 a.m. in wintertime (late October to late March) and from 12 midnight to 9 a.m. in summertime (late March to late October).

3.5.3 Other system components of SES

Ireland has ambitious plans for electric vehicle roll out. The electric vehicle roadmap [48] describes how the passenger car stock is set to increase by 57% from 2011, with 2.9 million vehicles on the road by 2050. By 2020, the ambition is for the EV contribution to this fleet to be 10% (as set out in current policy), growing to 60% by 2050 under a medium scenario. Currently, new EV sales represent much less than 1% of all new sales, based on statistics produced by the CSO.[20]

Electric and plug-in electric vehicles are being encouraged through a grants scheme, with a maximum grant of €5,000 available for qualifying electric vehicles when purchased privately[21]. In addition to the grant, there is also substantial relief on Vehicle Registration Tax (VRT) for these vehicles, as the VRT is tied to the emission level of the vehicle.

There is also progress on the infrastructure to facilitate electric vehicle take-up. Ecars, set up by the Electricity Supply Board, operate the infrastructure network and have over 1,200 public standard and fast charge points across the country. This includes over 300 public charge points in Northern Ireland. Fast charge points number around 70.[22]

Key indicators to capture these elements of smart energy solutions could include:

- No. of EVs
- Establishment of charging infrastructure (no. of charge points)
- Policies to incentivise take up, such as vehicle grants, differentiated road duty etc.

3.5.4 System level impacts

The opportunities for developing a smart grid, in which smart energy solutions in building will make an important contribution, are outlined in the Smart Grid Roadmap [49]. This is very much tied to the requirement to decarbonise, and the need for smarter grids to cope with the increasing renewable generation. A headline finding of the roadmap is that decarbonisation of the electricity system will result in a 13 Mt CO_2 saving by 2050. 8 $MtCO_2$ will be directly

[19] A smart meter trial for gas was also undertaken, with 2000 households (CER, 2011b). This found average overall reductions, based on the use of variable seasonal tariffs, and similar stimuli to those in the electricity trial, to be 2.9%.
[20] 124 electric vehicles in class A/B were sold in January-February 2016, out of a total of 45,000. http://www.cso.ie/en/releasesandpublications/er/vlftm/vehicleslicensedforthefirsttimefebruary2016/
[21] Electric Vehicles Grant Scheme, http://www.seai.ie/Grants/Electric_Vehicle_Grant_Scheme/
[22] ecars description, https://www.esb.ie/our-businesses/ecars/

from the implementation of smart grid, while the rest will be due to the displacement of fossil fuels due to the electrification in end use sectors. Some other key findings from this road map relevant to smart energy solutions include:

- Strong electrification of the transport system, predominately in the domestic sector, with an expected annual demand close to 8,000 GWh by 2050.
- Increased interconnection, of 1.6 GW by 2040.
- 10,000 Irish jobs created through implementation of smart grid infrastructure and its associated technologies.

3.6 Sweden

3.6.1 Smart meter roll-out and technical specifications

Sweden is a country with 100% smart meter roll out - completed in 2009. The roll out was one of the first to be completed, alongside Italy. This case study gives us a different perspective from the previous case studies above, one where the state of play on smart meters is much more advanced. The responsibility of the roll out was charged to the distribution system operators, who benefited from distribution tariffs to fund the smart meter installation [50].

All smart meters installed have hourly reading technology and remote load control of customer equipment. Automated Meter Reading (AMR) 3 has all 10 functionalities required by the European Commission, AMR 2 has 4 full and 1 partial functionality, AMR1 only 4. Surprisingly, AMR3 has the least service and investment costs. AMR systems gives improved control of non-technical network losses caused by broken meters, thefts, faults in data quality, faults and missing meter values, etc. [50]

From the 1st of July 2006 hourly metering was introduced to customers with main fuses of 63A (large-customers) and from the 1st July 2009 monthly metering was introduced to customers with main fuses at most 63 ampere (small-customers). Measures are being taken to improve the meter data management systems, which in 2010 only had capacity to process 30% of the hourly information [51].

After 2012, hourly metering was widened to all small-consumers in Sweden. This meant that they could have hourly metering upon request, if their contract with the supplier accorded this. Hourly metering for large-consumption customers is mandatory since the installation of the smart meter [51].

As the metering is the DSO responsibility and there are over 120 DSO in Sweden, the actual number of smart meters installed is difficult to determine.

3.6.2 Types of load management present

There are roughly 5.3 million electricity consumers in Sweden, of which approximately 4.6 million are domestic consumers. At the end of 2014 there were 123 electricity supply companies (according to Elpriskollen). Price regulation in Sweden doesn’t exist and the most common form of electricity contract is a variable price contract. The long-term trend is that more people are moving from fixed price to variable price contracts. The website elpriskollen.se is a state-owned price comparison platform for customers to compare electricity contracts, and choose which option suits them best, based on geography, consumption and preferences. As there are a big number of retailers in Sweden there isn't a standard practice in terms of tariffs or prices, but time-of-use tariffs have been in place for several years now. For all large-consumers (with a fuse above 80A) ToU tariffs are mandatory. There are some suppliers that offer the ToU option to small-consumers, but it is up to the end-user to decide which contract to go for. Other contracts can be arranged in a way that no ToU is considered, like for example, spot price contracts that charge the customers the Elspot price (day-ahead market) plus a fixed mark-up. From a demand response perspective, hourly prices are the pre-condition for the customers to shift consumption. Fixed price and variable (but not related to ToU) contracts offer no incentives for shifting consumption.

From the data gathered by the Swedish Energi Market Inspectorate (Ei), time-of-use tariffs are used both for grid tariffs and power tariffs – being grid tariffs related to the energy consumed and power tariffs related to the power required for each consumer. For power tariffs the proportion of time-of-use tariffs in the price of power is around 60% of the total price of electricity paid by the end-user.

3.6.3 Other system components of SES

The electric vehicle market share in Sweden was 2.4% in 2015. It increased from the share of the previous year, but at a lower rate than the year before. In what concerns taxes and incentives related to EV's, Sweden is trying to push EV's into the market. For EV buyers, there are rebates on the purchase of the car worth 4100€ (40000SEK), and there is also an exemption from the road circulation tax. VAT (value added tax) is 25%, which still holds the base price of the EV's quite high for a bigger demand. However, the way that the incentives and policies are designed pushes buyers more towards plug-in hybrid electric vehicles PHEV rather than battery electric vehicles BEV. All in all, the total incentive provided by the government in a BEV is 5600€ for a company and 7500€ for a private buyer, as for the PHEV is 8400€ for a company car and 12200€ for a private buyer. This value is gathered combining the rebate and the road tax exemption [52].

Advances are also being made concerning larger vehicles. In the city of Gothenburg they are already operating as normal route city busses [53]. New projects studying the electrification of the roads for truck transportation to be viable are being done, especially in cooperation with Scania and Siemens. The first eHighway was inaugurated in north of Stockholm, where Siemens is testing a 2 km stretch. With the goal of having totally de-carbonised transport sector by 2030, this is a step ahead in that direction [54].

3.6.4 System level impacts

Vattenfall's analysis estimates show the impact of smart metering installation in the following results: more than €1 million a year in reduced costs with AMR related to monthly billing, supplier change, move out/in and customer support; almost €7 million a year related to avoided technical network losses (broken meters, thefts, faults in data quality, etc.); generated financial benefits from extended business cases of around €2.5 million a year [50].

The Swedish government decided Ei should propose a general framework for an information management model to suit future use of electricity data in Sweden. The outcome was a service hub based on a holistic approach where information is gathered and available in a simple way for all parties to assess it. This would mean access to historic data for customers and significantly lower costs of data handling for DSO's. This also addressed the problem stated above around the lack of capability of present data systems to process all of the hourly data provided by the smart meters. The study evaluates the average economic benefit to be of €198 million in a 10-year span (for different scenarios), when compared to a system without data management hubs [55].

Still, there are still some barriers that delay the development of the market at the initial stages. For aggregators, market entry can have its challenges and obstacles. Information retrieved from the SEDC report [56] shows that a BRP (Balancing Regulating Party) has to first sign a contract with the consumer's supplier. Then, it has to pay an annual fee of 2500€ and have an electronic reporting system installed and connected to EDIEL (Electronic Data Interchange for the electricity industry). Plus, as the suppliers also work as a BRP, the contract between both parties is unlikely to occur right from the start.

From the report of the SEDC, there is no market size value for demand response concerning wholesale markets in the Nord Pool Spot [56].

4 POTENTIAL OF DEMAND RESPONSE AS A SMART ENERGY SOLUTION IN EUROPE

The rollout of smart meters in EU Member States is not homogeneous. The Third Energy Package's target of 80% roll-out being complete in all Member States with a positive Cost-Benefit Analysis (CBA) by 2020 is forecasted to be achieved (see Figure 13) (European Commission, 2014). The case studies in the previous section are of countries with positive CBA results. But it is also relevant to assess the potential of demand response (DR) in negative CBA countries. Gils [58] shows that in Germany, a country with a reportedly negative CBA, the potential of DR is mostly related with industry, as it is especially energy-intensive. DR in the industrial sector can thus help avoid costs on new medium- and peak-load power plants. However, DR in Germany's residential sector still needs to show more economical benefits to become viable.

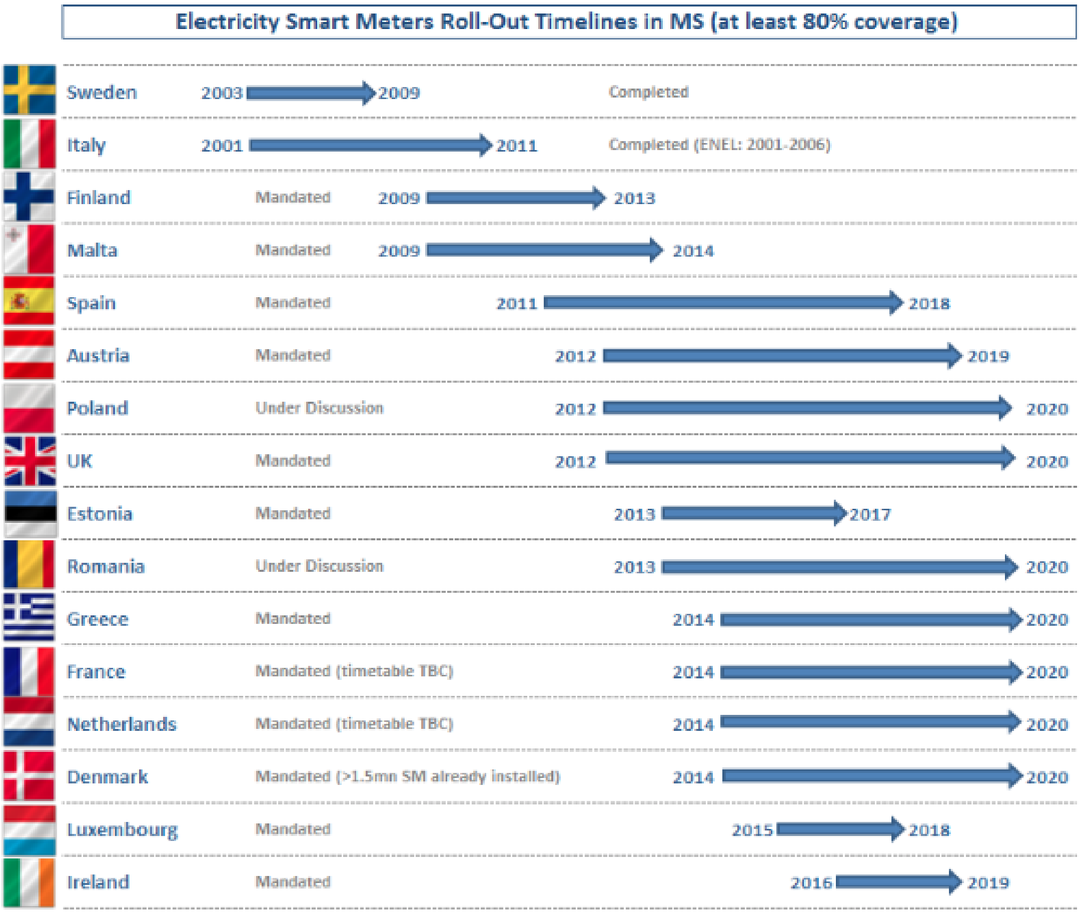

Figure 13 - Evolution of Smart-Meter roll-out in Member States (Source: European Commission)

Several EU Member States have had variable electricity pricing in the industrial sector for year; Torriti et al. [59] describe examples in the UK, Spain and Italy, described in further detail in the next section. However, its implementation in the residential and tertiary sectors is essential to achieve energy efficiency goals. For instance, commercial ventilation and household appliances - representing 15% and 17% of the annual average residential load, respectively - are predicted to have a big role to play in reducing peak-load demand in the future. In this part of the study we focus on key indicators that can help measure the implementation and impact that the deployment of SES can have on Europe's future electricity system.

Gils [60] assesses that the potential of DR in Europe can be as high as 26% of load reduction to annual peak load and 172 GW of power decrease due to deferring or shedding loads (with an average of 93GW). These numbers are comparable with the 73 GW predicted by Capgemini in their 'moderate' scenario [61]. The Gils study [60] further shows that the figures for each sector are as follows: 25GW in industry, 31GW in tertiary sector, and 37GW in the residential sector. It is important to note that that in PV-dominated regions, DR partially substitutes short-term energy storage when the PV generation is at its peak. This allows for even more RE penetration that is not wind-related.

In Ireland a study was carried for its residential sector. It was estimated that the DR potential for interruptible loads is 147MW on average for 2020 [62]. In France, where Energy Pool is an aggregator, demand response represents

1,000MW of flexible capacity in the form of load reduction. In Sweden - a country with 100% smart meter roll-out - the town of Sala implemented ToU prices for the electricity distribution service and showed an average reduction of 8.4% to 15.6% during the peaks in the distribution system [63].

Although prospects are good, accurate assessments for all EU Member States is still missing. Gils [60] suggests that "a consumer and country-specific analysis of the flexible loads on the European continent is missing so far". This is important to accurately assess the techno-economic potential of SES in the EU, given the diversity of energy systems within its Member States.

4.1 Prices and tariffs

Electricity prices and tariffs for DR services at the Member State level is still in the development phase. A lot of studies in this area describe voluntary and non-voluntary pilots done in the US and in Europe. Eid et al. [63] provide an overview of various tariffs and their mode of operation (Figure 14). Flexible hourly prices are shown to be key for demand side response, but the method of its application is still up for debate. The frequency of price variations and time of notification given to consumers after the price change is as important.

A study by Torriti et al. [64] for Northern Italy found that mandatory ToU tariffs increased consumption by 13.69% and electricity bills reduced by 2.21%. This supports the idea of Steen *et al.* that tariffs need to be combined [65]. Using the study of the city of Gothenburg in Sweden, the authors suggest, "RTP (real time pricing) seems to be the most suitable choice to increase the possible amount of renewable energy generation". However, in order to avoid peak demand locally, RTP needs to be combined with other tariffs, such as Location Marginal Price – that reflects the real marginal price of electricity in a given region or location of a country. They further suggest that Critical Peak Price (CPP) can be advantageous for the consumer, but is limited to few hours per year.

In California, a state wide pricing pilot concluded that when TOU rates were used, consumer-responsiveness resulted in a 5% decrease in peak demand load. But, when consumers were signalled with CPP the results showed a decrease in peak load demand 8-15% with no enabling technology, and 25-30% with an enabling technology [66].

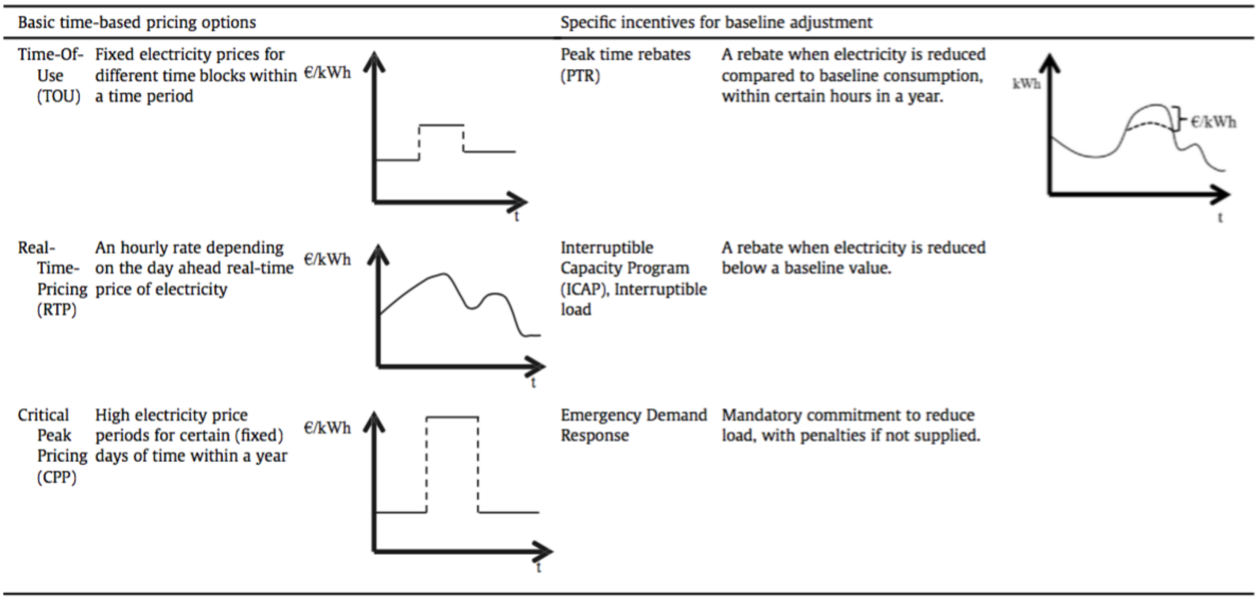

Figure 14 - Explanation of pricing schemes

Katz et al. [67] provides another perspective. From the results of their model, RTP is the most economically efficient type of dynamic pricing, but possibly not from the starting point. If consumers are targeted with highly complex dynamic pricing schemes from the start, they are more likely to be overwhelmed and therefore not willing to give up their comfort in order to have some economic benefit. Rather, mixed and more complex price tariffs can be implemented in a second stage. By this point, consumers are already familiar with dynamic pricing and TOU alone is able to provide the economic efficiency that other tariffs can. Figure 15 explains what this means in a simple way, comparing the complexity of the rates against its economic potential.

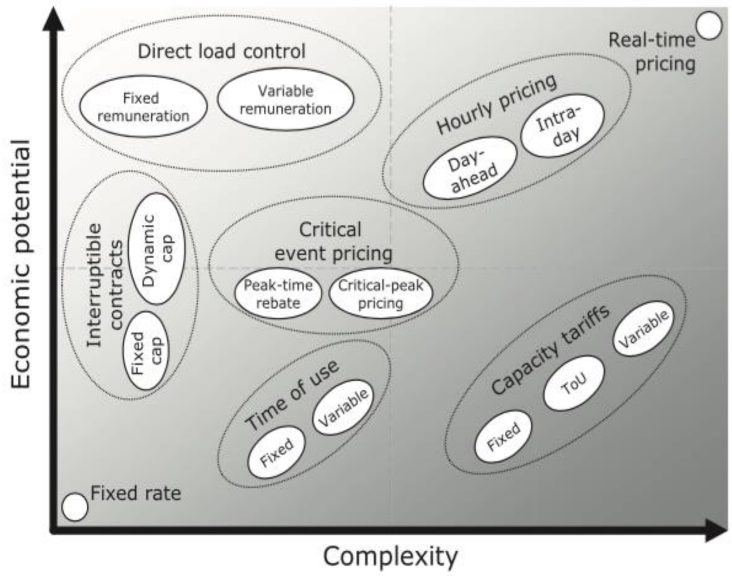

Figure 15 - Economic potential and complexity of dynamic tariffs Source: Katz et al. [67]

In France, a combination of CPP and TOU is used for customers that apply for the '*Tempo Tariff*' and it resulted on average in a reduction of consumption of 15% on normal days and 45% on peak days. Further, it led to consumers to save, on average, 10% of their electricity bill. (Eid et al. [63]).

4.2 Load profiles

Demand side management relies a lot on smart-meters and the information they provide. The principle behind dynamic pricing tariffs is that electricity prices fluctuate in the same proportion as demand fluctuates away from its baseline. Since generation capacity is managed in order to meet demand, the marginal cost of electricity increases as the demand increases. This happens due to the fact that generation technologies (e.g. natural gas fuelled power plants) to meet peak demand are in most cases more expensive – considering operating costs related to ramp up and rapid dispatch - than low and medium demand generation technologies, like renewables. This approach leads to one key issue related to electricity markets: how is the consumer baseline defined in order to determine the fluctuation of the demand? For the aggregator perspective, it can be useful to under-predict the available capacity in order to increase the demand fluctuation, meaning higher prices [68]. From the consumer perspective, if the high prices happen when a big fluctuation happens, it can be useful to simply inflate the baseline so that the fluctuations are smaller [69], [70]. This can also be addressed as asymmetry of information, which contributes to oscillatory behaviour on the demand side. As N. O'Connell et al. [71] state, "it occurs when there is a delay between price setting and consumption, so a prediction of the response is required, that is, the operator must predict information which the end-user already knows".

Several member states have no regulation concerning baseline measurement yet, and this is especially important when evaluating TSO and DSO's products in the consumer perspective. Countries like Denmark, Sweden and Ireland have no public or standardized methodology. In the Netherlands and in Germany and this is agreed by contractor and consumer [56]. For example, EnerNOC, a US company that recently acquired German and Irish market leader companies [72], uses two approaches to calculate the baseline [70].

As markets evolve and competition gets tighter, these methodologies will eventually become more transparent and beneficial for the end-consumer, but regulation could help speed up this evolution and facilitate market entry for new customers.

4.3 Economic benefits

In previous sections we have discussed the potential of this way of balancing energy demand in terms of power shifted, energy stored and saved, but now we focus on what those numbers reflect in terms of economic benefits. Some of those benefits have been discussed previously with some % of the savings in electricity bills in the end-consumers' perspective.

From the Capgemini report [61], we can see an estimated €20 billion of avoided investment and €25 billion savings in electricity bills for customers (moderate scenario). In the US, over €3.5 billion are annually earned by the local economy through DR [73].

Faruqui et al. [74] estimate that the total cost of smart meter implementation in the EU to be €51 billion. And apart from the operational savings - that are worth something like €26 to €41 billion - the benefits that come from dynamic pricing alone would cover the implementation costs. In the paper it says that "overcoming barriers to the adoption of dynamic tariffs could be worth as much as €53 billion".

From a Member State perspective, we have already seen the prospects for the UK in section 3.4. We can have a further look at other examples. Conchado et al. [75] provide results on the economic benefit DR could have in Spain: assuming a 0.5% in annual demand growth for 10-year period, total savings could add up to €270 million (0.4% of system costs) for a 25% DR system or to €1080 million (1.7% of system costs) for a 100% DR system. The surprising fact is that none of these savings are realised in avoided investments, because Spanish generation capacity can cope with the rate growth for the study period. What this means in reality is that, on average, we would see a reduction of 10€ to 20€/year per residential customer with a 400€/year electricity bill, which the authors classify as "quite low". In line with the authors point of view, Prüggler [76] suggests that household savings would have to be around 65€-120€/year for consumers to engage in DR programs. However, the high penetration of renewables can be a very important issue to the topic. Gils [58] studied the economic potential of demand response in Germany with an assumption of 70% share of VER in the energy power system and concluded that "the reductions in annual power supply costs achieved add up to several hundreds of millions of Euros".

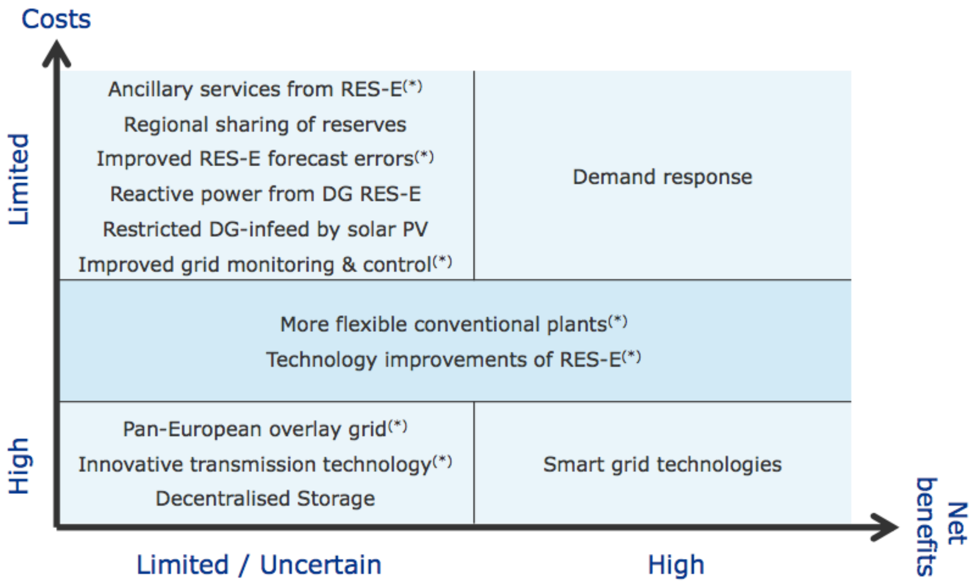

Figure 16 - Economic benefits and costs of different available technologies (Source: [77])

From the report of GNV GL to the EC, focusing on renewable energy systems expansion between 2020 and 2030, it results the following: “a cost-efficient integration of a high share of RES-E, demand response stands out as particularly promising. The analysis in this study suggests that an effective use of DR may yield annual savings in the order of € 60 to 100 billion” [77]. However, these savings don’t account for the deployment costs - from which the biggest part is from smart meter costs - but these are already being spent in the rollout programs of several member states. We can see in Figure 16 that demand response provides the highest net benefits with the least cost, in a high share RES perspective. It is important to explain that smart grid technologies include smart-meters and other devices. It is with the use of these devices that demand response is possible. In other words, demand response is an application of the smart grid technologies. However, smart grid technologies go beyond the smart-meters and expand to the wider range of the electrical grid.

4.4 Barriers

Until the EU implements a common, internal energy market, it may be premature to talk of harmonized DR programmes at the EU level [59]. It is possible that this may still be true when such an EU wide energy market exists. Due to the heterogeneity of EU countries, different DR programs may target different sectors (or even demographic groups) in each Member in order to exploit maximum economic benefit. Standardized regulation, especially for countries with more than one TSO (e.g. Germany) is needed [56]. Further, the initial investment cost - around 250€/smart meter (European Commission, 2014)- should be divided in the same way that benefits are (between provider, distributor, aggregator, retailer and consumer). But apart from investment and benefits, there has to be a clear regulatory framework in order to prevent imbalanced market power on any side. As Eid et al. [63] reports, "The value of DR should be distributed along the supply chain, together with incentives for participation for each agent under clearly elaborated business models".

As we can see from SEDC report, other barriers can cause a scarce entry in the market, such as surpassed communications systems (telephone bidding) and inappropriate minimum bid sizes (50MW). In Germany, for example, the pre-qualification process can take up to one year [56].

Aggregation services need to be considered as a resource so that market entry happens on an equal footing as capacity, balancing and storage resources do. However, improvements have been made in a few countries leading the DR revolution. Great Britain already enables independent aggregators and both France and Switzerland already have restructured roles and responsibilities of market participants, especially in order to enable independent aggregators [56].

Further, fragmentation of DR markets due to the early development phase and also to widely regulations and participation rules at the Member State-level. For example, there can be different markets (intra-day, day-ahead, feeding, etc.) with different participation rules for each. As long as the rules do not have a technical basis to be different, these should all be standardized at the Member State level, or ideally at the EU level.

The real technical and economic potential of smart energy solutions in Europe is as yet unknown. Many of the studies available do not address some important aspects. Suggestions for the parameters that should be addressed in further studies include the high penetration of smart meters at the EU level (ideally 80%-90%), combined with the penetration of storage capacity in households/SME, and the adoption of Battery Electric vehicles (BEV) across Europe. With so many unknown variables, the studies are more theoretical and can be translated into reliable estimations only when smart meter data, variable price data, and appliance load profiles are gathered.

5 CONCLUSIONS

Analysing the case studies from Switzerland, France, Ireland, UK and Sweden presented in section 3, the main conclusions are presented below.

Apart from Sweden, that has a complete smart-meter rollout, all the other countries are still ongoing or starting this stage. Switzerland does not have a planned rollout so far. Ireland will start in 2018. In both France and the UK roll outs are ongoing, with shares of 9% and 4%, respectively.

ToU are widespread in Sweden, Switzerland and France. In Ireland there is a strong push in favour of it, but not in the UK. Apart from ToU, that in some cases are wide and free of choice to consumers, no price or tariffs reflect real electricity marginal costs that vary with generation. ToU are contracts that have different prices for different hours of the day, separating the day in blocks of, for instance, peak and off-peak hours. However, it doesn’t reflect the variation in the real cost of electricity or in the increase of demand.

In all the case studies it was clear that, apart from Sweden, no real-time access to data on consumption was available as a type of feedback to consumption. Easy access to real time consumption and prices is key for the development of the smart grid. However, the Swedish example of the application for smartphones from the energy company E.ON goes against the tide. Also in Sweden, there is a think tank in place to understand the best way to develop an information hub of consumption data that can be accessed by all in the easiest way possible. In France there is a platform that is being set up so the consumers can be have access to it through the DSO's website, but an important communication barrier between the suppliers and consumers is then created.

Sweden, having a complete rollout of smart-meters still doesn't have dynamic tariffs. This can be explained by the complexity of the implementation and usage of these tariffs, the potential low impact of these in the Swedish reality due to district heating – providing more than 60% of the energetic needs to commercial and residential consumers– and given that flat tariffs are still present and when combined with lack of consumer interest and knowledge, still become very popular.

In the majority of the countries assessed there is free choice for the supplier of electricity to end-consumers. When ToU were introduced, it resulted in a relevant amount of consumers changing supplier of electricity. In Sweden, there is a state web site that provides free-of-charge comparison services for consumers to choose the option that fits better their needs.

In Switzerland, it is expected that by 2050 the share of EVs to reach 95% of the total vehicle fleet. In France there is a slower transition, and the number show a decrease in the number of EV licenses from 2015 to 2016. In Ireland and UK, there is a small uptake to date and a very strong commitment to push EVs forward. Sweden has one of the highest share rates of EV in the world, while offering incentives from tax and rebates. However, for the national goal of decarbonising the transport sector in 2030, this share is increasing at a slow pace.

It is important to state that SES need to be looked at as valuable assets to balance the supply and demand of energy. They can help Europe achieve its energy efficiency goals, emission reduction targets and more importantly and directly related, it will help increase the share of energy generation that comes from renewable sources.

As mentioned earlier, future indicators will need to consider how the smart meter is being used, to better understand the additional potential. A number of indicators could be foreseen that provided information on the level of automation of the household system (uptake of smart appliance systems), through types of agreements with suppliers on handing over some control for automation, the uptake of time-of-use tariffs, and other key elements of smart energy solutions that might further the role of the smart meter e.g. home power storage systems, electric vehicle ownership etc.

Table 1 - Summary of case studies

Summary	% Roll Out	Presence of ToU	Feedback on Consumption	Share of EV's (%)
Switzerland	Not planned**	Yes	No feedback	0,2
France	9%	Yes	No feedback	1,2
UK	4%	First trials	No feedback	1
Ireland	Start in 2018	Yes	No feedback	*
Sweden	Complete	Yes	Possibility of Real time	2,4

* Not available

** Country outside the EU

It is clear from the report that there is space for tackling barriers on information. Flows of information on consumption and prices need to be clear and standard for the market players. The concept of information hubs, countrywide or EU wide is very appealing to this problem. ICT can have the answer, providing cost-effective and innovative solutions.

As mentioned above, one of the most pressing and evident challenges once dynamic tariffs are put in place will be the marketing and information campaigning for consumer engagement to be exploited to its full potential. The role companies and organizations will play can be maximised through incentives for the initial deployment phase. It is important that campaigns and clarifying sessions provide the information for end-consumers to associate their knowledge to changes in prices. New market design, fair distributed costs (e.g. smart meters and O&M of the grid) and benefits for players throughout the supply chain that provide an added value to the system.

Market entry should be facilitated as much as it can so that the markets are vibrant and profitable for those who populate them – so that there can be progress. Key features for this require first facilitating regulatory bureaucracy needed. Also, it is required the minimum bids downsize to allow small producers to participate.

It is relevant to continue to fund future studies that focus on the impact of voluntary change to programs that attain a real-time pricing of electricity, as well as some events of critical peak prices. On some occasions, the years that can be predicted to have a large load demand for a certain period of time, and that these events are treated differently than the normal status of things so that the consumers are aware of it, not only by high prices.

In terms of policies, it is important to understand which barriers exist, and from these, which are delaying the evolution of technology and growth. These comprise legal, economic and social barriers. From what it was gathered there is space for intervention in order for a better integration of the end-users into the energy system, acting actively as players. The main barriers to be addressed in the near future are the following:

- Over-bureaucratic market entry for new players
- Lack of regulatory frameworks to implement demand side management strategies
- Lack of incentives or policies to deploy dynamic tariffs for countries with liberalised markets
- Lack of public interest and knowledge that leads to low levels of participation

There is a need for further studies concerning types of smart energy solutions that are only mentioned in surface in this report. These comprise mainly batteries and penetration of EV's and their influence in the future smart grid, taking into account systems that enable V2G technologies and their impact in balancing the electricity load.

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