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ISGAN
INTERNATIONAL SMART GRID ACTION NETWORK

Power Transmission & Distribution Systems

System Efficiency

Discussion paper

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ISGAN Annex 6

January 2018

iea Energy Technology Network
CLEAN ENERGY MINISTERIAL

About ISGAN Discussion Papers

ISGAN discussion papers are meant as input documents to the global discussion about smart grids. Each is a statement by the author(s) regarding a topic of international interest. They reflect works in progress in the development of smart grids in the different regions of the world. Their aim is not to communicate a final outcome or to advise decision-makers, but rather to lay the ground work for further research and analysis.

Disclaimer

Acknowledgments

Acknowledgements go to Gianluigi Migliavacca, John Young, Ralf Eickhoff, Stefan Krengel, Kjetil Uhlen, Maarten Noeninckx, Antony Zegers, Rakesh Batra, Senja Nordström, Fredrik Lundström, Rish Ghatikar, Nick Singh, Oswald van Ginkel, Kejia Ren, Kazumi Ueda and Annex 6 participants for their valuable inputs and feedback and to Susanne Ackeby for her coordinative support.

Nomenclature or List of Acronyms

AMI	Advanced Metering Infrastructure
CAPEX	Capital Expenditures
CBA	Cost Benefit Analysis
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
DER	Distributed Energy Resources
DG	Diesel Generator
DOE	Department of Energy
DR	Demand Response
DSM	Demand Side Management
DSO	Distribution System Operator
EMS	Energy Management System
EU	European Union
EV	Electric Vehicle
GOI	Government of India
IPP	Independent Power Producer
ICE	Internal Combustion Engine
JESC	Japan Electrotechnical Standards and Codes Committee
M2M	Machine To Machine
NERSA	National Energy Regulator of South Africa
NRA	National Regulatory Authority
OMS	Open Metering System
OPEX	Operational Expenditures
PLC	Power Line Communications
R&D	Research and Development
RES	Renewable Energy Sources
SEA	Swedish Energy Agency
SIM	Subscriber Identity Module
SMS	Short Message System
TSO	Transmission System Operator

Abstract

In the era of deployment of a smarter and more sustainable energy system, an overall perspective of system efficiency becomes increasingly important. System efficiency is a multifaceted concept, which in the present document is broken down in the dimensions of carbon dioxide (CO_2) emissions, energy and economic efficiency.

In order to improve the efficiency of a given system there are a number of available solutions at the disposal of policymakers and market actors. In this work, five action areas have been chosen and defined – multi-energy systems, electric storage, electric mobility, demand side management and automation & sensor technologies - and a review of activities and initiatives currently underway in several countries has been presented.

The efficiency measures and indicators identified in this report are key for bringing about the vision of an environmentally friendly and economically profitable electrical energy system, although some alternatives are not yet at a stage where they could be readily deployed in a systematic or widespread manner. In these cases and depending on the specific circumstances, regulatory policies and support measures can provide guidance and sustenance to overcome the uncertainties of future developments and promote potentially promising solutions.

Executive Summary

The development and evolution of technologies, not only in the domain of energy infrastructure but also more broadly in the area of controls and communications, open the door to a number of potential innovations and improvements in terms of system performance. With respect to the latter in particular, one can formulate suitable dimensions with which to measure the achieved degree of efficiency. For the purpose of the present work, efficiency has been defined in relation to 3 dimensions, namely:

1. CO_2 emissions: greenhouse gas (especially CO_2) emissions are avoided, or at least minimised
2. Energy: energy, especially renewable energy, is not wasted
3. Costs: economic costs are reduced, or at least not increased

The above dimensions have been selected since they represent key concerns when evaluating a given approach or technology in the modern energy domain, given that technological factors have to be addressed and evaluated together with economic, political and environmental aspects.

The challenge consists then in determining how to attain significant improvements in the chosen key dimensions by way of appropriate solutions. Within the performed assessment 5 action areas have been chosen, specifically:

1. Multi-energy systems
2. Electric storage
3. Electric mobility
4. Demand side management (DSM)
5. Automation & sensor technologies

The key motivation behind this selection is that these action areas can be leveraged in order to generate efficiency improvements by exploiting the potential they offer in terms of novel infrastructural/technological/operational solutions, e.g. electrical storage units (batteries) can absorb excess renewable energy sources' (RES) generation and release it into the grid at a later point in time when it is required by physical consumption, thereby averting the need to curtail clean power generation and improving CO_2 efficiency.

The performed analysis consists in collecting and reviewing information from national ISGAN representatives in terms of activities that are underway or have been planned in the respective countries for each action area; the activities can be in the form of research and development (R&D), pilot and demonstration projects, incentives, subsidies, regulations, operating codes, best practices or other, depending on the given circumstances.

The aim is to utilise the acquired feedback to derive insights into the current status of work at an international level. Although a considerable number of the presented activities are R&D projects for which conclusive results have yet to be established and even if it is often difficult to adapt regulations or policies enacted in one nation to a country that might have a significantly different regulatory framework, electric market organisation, industrial background or economic sector composition, in view of the benefits to be achieved it is nevertheless of common interest to highlight relevant points, as featured below.

- Multi-energy systems: alternative fuels have benefited in the past from various forms of incentives and it would appear reasonable to presume that a similar approach would be viable for multi-energy systems, specifically with respect to gas and hydrogen, and more in general in terms of a closer coupling of the electricity and heating sectors. Suitable incentives have already led to a higher penetration of heat pumps in Germany and Sweden.

- Electric storage: incentives have succeeded in the past in fostering the deployment of RES generation, with one relevant case being residential photovoltaic (PV) units, and a similar path could be taken towards triggering the uptake of small-scale storage units, since the benefits stemming from the combination of these technologies are straightforward. Although costs for battery systems are still only marginal profitable, it is expected that they will decrease in the years to come, prompting the need for timely action.

- Electric mobility: admittedly still in its primordial stages and possibly with a relatively limited role to play in terms of storage services offered to the grid. Norway and Germany in Europe, and, driven by the federal and state initiatives, certain states in the USA such as California, stand out however as examples for increased presence of electric vehicles (EV) and could provide useful experience and insights to other countries to lower CO_2 from the transportation sector, reduce oil dependency, and improve air-quality. Countries such as India have aggressive EV deployment plans for the coming years.

- DSM: strategies such as demand response (DR) programs of various types have already been implemented in the past in a number of countries via e.g. dynamic electricity rate tariffs, and more recent initiatives and pilot projects in various countries (Ireland, South Africa, USA, Singapore, Germany, Austria) have shown that fully-fledged, automated DSM is a viable solution to address grid reliability and intermittency with RES generation. Commercial and industrial customers in particular have more to offer and to gain from such approaches since they often deploy control and automation systems, and energy and electricity costs can be a relatively large portion of their operational expenditures (OPEX). Relevant synergies with Automation and Sensor Technologies below.

- Automation and Sensor Technologies: federal initiatives in the USA have shown that systematic funding of novel technologies is successful in terms of enabling operating paradigms that achieve tangible improvements in system efficiency. This stands in contrast to experiences reported in Europe, where OPEX-related expenditures are under pressure to remain limited, inhibiting potential developments. Machine-to-machine (M2M) solutions could also provide substantial benefits and should be addressed.

Table of Content

1. Introduction

This discussion paper is part of Task 3 (Technology Development and Demonstration) within IEA ISGAN Annex 6 on Power Transmission and Distribution. The purpose of this task is to develop recommendations for the development of technologies and their application within future electrical systems current trends, market mechanisms, political objectives and environmental targets. Figure 1 positions this work in the ISGAN context.

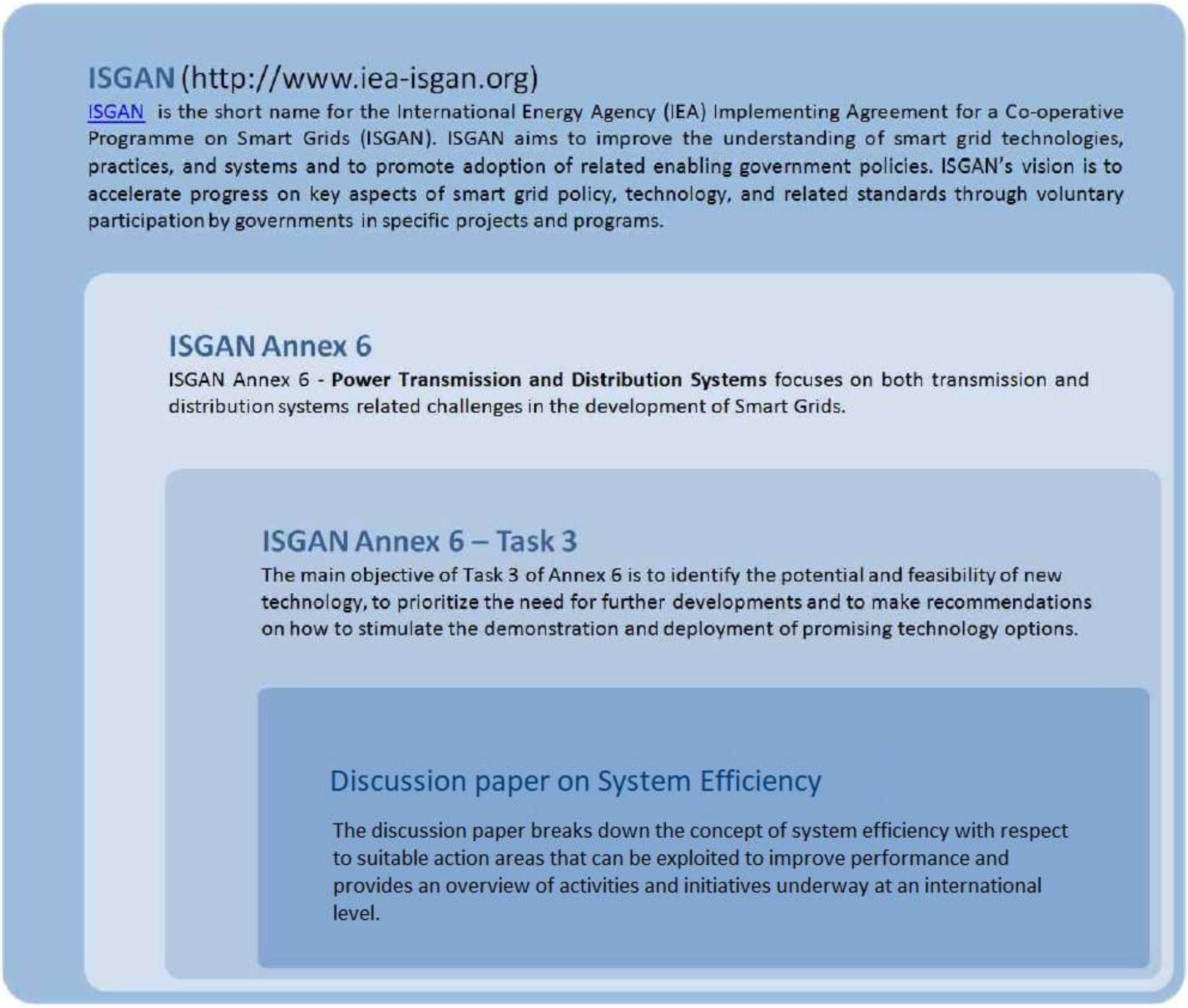

Figure 1 Position of this discussion paper wthin ISGAN

In general, the recent past has witnessed an increasing penetration of generation at the distribution grid level, often based on renewable and non-controllable energy sources. Since production and demand must be matched at all times in electricity networks, this prompts the need for novel technologies, processes and regulations to ensure that this new generation can be put to use and the resulting generated energy consumed in a manner that does not jeopardize grid stability. Indeed, the simplest alternative would be to simply curtail this supplemental production, resulting in a however in a waste of "free" and clean generation that would be detrimental in terms of overall efficiency with respect to both energy spillage and CO_2 emissions. Furthermore, any proposed solution should also be economically efficient, since costly technologies and operating procedures are unlikely to be adopted in a competitive market environment and thus will only have a limited impact.

It is precisely with respect to the aforementioned issues that the present discussion paper attempts to identify and assess ongoing initiatives, regulatory policies and research and development (R&D) work worldwide that tackle and address efficiency-related aspects in future electricity grids. Specifically, 3 efficiency dimensions have been selected:

1. CO_2: greenhouse gas (especially CO_2) emissions are avoided, or at least minimised
2. Energy: energy, especially from renewable energy sources (RES), is not wasted
3. Costs: economic costs are reduced, or at least not increased

Proposed solutions should aim at achieving an amelioration in at least one of these dimensions, ideally while not worsening any of the others, or at least not in any excessive way, although a precise quantification of the overall effects might be difficult to determine or might at best depend on a case-by-case analysis. The following action areas have been selected for the deployment of technologies and methods targeted at system efficiency improvement:

1. Multi-energy systems
2. Electric storage
3. Electric mobility
4. Demand side management (DSM)
5. Automation & sensor technologies

Each action area presents both a set of opportunities and challenges that must be simultaneously taken into account if any possible increase in efficiency is realistically to be achieved within the foreseeable future.

National representatives have been contacted in order to acquire information concerning activities in each partner country, resulting in an overview of current trends/initiatives and providing input for the discussion about how the latter ought to evolve in the coming years, accounting for technical, economic and regulatory aspects. Input was acquired from the following countries:

- United States of America
- South Africa
- Germany
- Austria
- Belgium
- Norway
- Italy
- Ireland
- Sweden
- Singapore
- India
- Japan.

It should be borne in mind however that only a limited number of experts have been asked for input for each nation: since the scope of the aforementioned action areas is considerably large, even within a single country, it cannot be guaranteed that the information provided on the following pages is fully exhaustive. Additionally, although the objective is to employ the obtained input to gain insights into the current status of activities and attempt to formulate recommendations for further work it should be mentioned that a number of the presented activities are research projects for which definitive results have yet to be derived, or country-specific initiatives that it is not always possible to export or adapt to other national settings.

The following Chapters 2 to 6 present an explanation of the action areas listed above, an overview of country activities and an outline of relevant discussion points based on the salient findings from the latter. Conclusions are briefly drawn in Chapter 7.

2. Multi-Energy Systems

2.1. Definition of action area

Converting energy from one form to another affords the possibility of storing it more easily, for example by employing power-to-gas or power-to-heat devices, so that a surplus of RES production does not have to be curtailed. Furthermore, couplings between the energy grids allow for an increased deployment of combined heat and power (CHP) units that increase overall efficiency by utilizing waste heat to serve the load. Lastly, renewable electricity-fed heat pumps have the potential to replace other more inefficient types of heating devices, so that emphasizing the link between the electrical grid and the heating load can lead to an improved efficiency in terms of CO_2 emissions.

Notice that relying on coupled multi-carrier systems automatically implies some conversion process that will be inherently lossy, but this is still often a better solution than altogether discarding “free" RES energy.

2.2. Overview of country activities

The table Table 1 in Appendix gives an overview of country initiatives, obtained results and relevant insights & remarks in the area of multi-energy systems.

2.3. Discussion points

Heating networks, in the form of either gas grids or district heating, are an existing reality and the related transport and storage technologies are in many cases already installed and operational. The construction, commissioning, deployment and targeted operation of the necessary links between this infrastructure and the electrical grid is, on the other hand, still an ongoing process, but one that seems to have attracted a considerable degree of attention. Specifically, the relative ease with which electrical power can be converted to heat energy, and the existence of technologically proven and economically viable storage facilities for the latter, render the conversion coupling in this direction of specific interest when dealing with non-controllable RES generation. Admittedly, a certain amount of energy is wasted due to conversion losses, yet this could still be preferable to altogether curtailing the surplus RES injection, provided that the outlays associated with the required infrastructure are not excessively high. Some highlights from the initiatives listed in Table 1 are featured below.

- A number of R&D projects are underway in Europe and incentives have been formulated to support multi energy systems and related technologies. One tangible outcome already now is the increase of heat pump installations in Germany and Sweden, and in Belgium a national plan has been devised promoting the use of the gas grid for bio-methane; proposals have also been discussed for the construction of hydrogen infrastructure.
- In South Africa the deployment of heat recovery processes appears to be well established and numerically significant, also due to the impact of its mining and pulp & paper industries, already leading to lower losses and CO_2 emissions. Further liberalization of such load-based generation (allowing IPPs below 100 MW to sell energy to the market) could lead to further reduction of fossil fuel employment.
- In general there are already now relevant technologies that could be put to use, but one issue to be addressed remains their long-term operational and economic viability, and some solutions, such as e.g. the utilization of hydrogen infrastructure, is more innovative in outlook and would have to be scientifically assessed and validated. On the other hand costs are projected to decrease in the

coming years and incentives could provide a useful tool to kick-start funding and investments in this domain.

3. Electric Storage

3.1. Definition of action area

Batteries have the potential to effectively absorb excess RES production, avoiding spillage, and inject energy back into the grid when there is an unexpected shortage, so that e.g. reserve units such as gas plants don't have to be activated. In this manner production stemming from fluctuating RES can be stored and later put to use in a timely manner, by providing reserve energy on the electricity market, avoiding any additional CO_2 emissions and enabling a potentially profitable business model for battery owners and operators.

Batteries can also be used for buying and storing electricity during "cheap" hours and using it either for self-consumption, or potentially even by selling it, when it becomes more expensive, so that end-user costs can also be reduced, provided that the initial outlay for the battery unit is not exceedingly high and that the latter's degradation rate is sufficiently slow to ensure a satisfactory degree of performance over several years of operation.

3.2. Overview of country activities

The table Table 2 in Appendix gives an overview of country initiatives, obtained results and relevant insights & remarks in the area of electric storage.

3.3. Discussion points

A distinguishing challenge of electrical grids has always been the necessity to instantaneously balance generation with demand, so it is to some extent natural that the most intuitively direct evolution would consist in seeking some way to directly store electrical energy in order to overcome this issue. Through batteries it is indeed possible to store electrical, or rather electrochemical energy, but grid-suitable battery technologies and designs have not been available at reasonably competitive prices up until the relatively recent past. Furthermore, cost viability for widespread deployment is still only marginal, and an informed understanding of the potential future costs of electricity storage technologies is essential to quantify their uptake as well as that of low-carbon technologies that would benefit from their usage. This can increase investor confidence and enable policymakers to design effective and timely deployment strategies, since costs are anyhow ultimately expected to decrease one way or the other. Some highlights from the initiatives listed in Table 2 are featured below.

- Various activities appear to be well underway at an international level, e.g. in Italy and Ireland, especially with respect to pilot or demonstration projects aimed at understanding what would be the specific interaction with grid dynamics. Final results are still pending.

- One specific incentive for the deployment of small-scale batteries could be residential PV units, which are present in some countries with a significant degree of penetration and which could prompt end-users to look into storage possibilities in the near future. One such programme exists in Germany.

- South Africa already has field experience with electrical storage, also due to the need to provide energy to settlements and industry in remote or even non-accessible areas. This is often in connection with RES, which feature a high overall capacity (>200 MW).

- Lastly, one concern that has been voiced by the national representatives addresses the need to assess and if possible improve the entire battery production/usage/disposal cycle in an integrated manner in order to understand what the overall impact on the environment would be. Sweden has a substantial number of activities dealing with the development and production of battery technologies.

4. Electric Mobility

4.1. Definition of action area

Although they still constitute only a small fraction of cars sold worldwide, electric vehicles offer the potential to significantly diminish CO_2 emissions in comparison to traditional combustion engines, provided that clean electricity generation be made available. Furthermore, when connected to the grid they can act in a similar way as batteries. Electric vehicles are not necessarily considered only, as only an additional load, since they could also increase overall system flexibility by providing flexibility in charging and discharging through DR programs.

Vehicles often remain parked most of the time, sometimes only being driven for about 10% of the time on a given day, and the time needed for a car's battery charge is usually generally considerably shorter than the time the car remains idle. In view of this, it is in principle possible to shift charging periods in time without negatively impacting on user satisfaction, and the energy stored in the vehicles' batteries could even be released back to the grid to cover peak demand. On the other hand, an obvious drawback of this mode of operation is that it generates additional cycling of the batteries, inherently implying more rapid battery wear, so that it remains questionable whether electric car owners would be in favour of such an arrangement, as they would plausibly at least require some form of economic incentive for the associated degradation.

4.2. Overview of country activities

The table Table 3 in Appendix gives an overview of country initiatives, obtained results and relevant insights & remarks in the area of e-mobility.

4.3. Discussion points

E-mobility represents a specific variant of electrical storage, but one that is burdened with an additional degree of hindrance and uncertainty with respect to its potential impact. The first obstacle stems from the fact that, quite simply, electric vehicles represent nowadays only a small part of car sales worldwide (<1%), so that their presence is currently limited; the second difficulty is due to the reason that the majority of car owners are unlikely to want to use their car battery for grid-application purposes. This is reflected in the feedback provided by the country experts, indicating that e-mobility at present generally is still in its infancy. There are however a couple of exceptions:

- Norway has enacted a successful set of policies and incentives for the uptake of e-mobility, resulting in a market share of electric cars of more than 10% for newly registered vehicles. This is admittedly perhaps related to the fact that the Norwegian electrical system is already "completely efficient" in the sense that has been defined within the present work, so that subsidies and incentives can be devoted to e-mobility; on the other hand, other countries can benefit from this experience, if only because a heightened presence of electric cars would improve air quality in urban areas, even if the energy source with which they are charged is not RES-based.

- Another interesting case in point is Germany, since it is a leading manufacturer of automobiles and explicitly aims at promoting its car industry by fostering the growth of a domestic e-mobility market. Although it is again a specific case that cannot be directly emulated by other countries in terms of political and economic motivations, its commitment to developing a domestic e-mobility market and the measures it has taken with respect to the necessary infrastructure development underscore the importance of this technology in the decades to come and provide a blueprint that other nations can follow.

- India features a substantial array of initiatives with ambitious goals aiming at having only EV sales by 2030. National support programmes have been enacted to this end but local initiatives and DSO participation are also crucial to ensure that the targeted transition is achieved in a viable and effective manner. Due to India's urban landscape, which comprises large metropolises with high-density population areas, considerable environmental and social benefits can be garnered by a higher penetration of EVs in city districts.

- It should be kept in mind however that for all countries e-mobility measures are focussed on the transport sector, i.e. the storage functionalities afforded to the grid by electric vehicles will most likely remain limited. Having said this a car that is parked and connected to the grid for re-charging constitutes if not a classical storage unit, at the very least a flexible load (that is, it will only request to be charged but possibly in a flexible manner), so that for example intermittent PV generation could gradually be absorbed throughout the day.

5. Demand Side Management

5.1. Definition of action area

DSM has often been considered as a way of alleviating peak electricity demand so that it is possible for power utilities to defer installing further generation capacity. Additionally, by diminishing the peak load present in a given electric grid, DSM brings about a number of positive side-effects, such as decreasing the frequency of grid blackouts and increasing system reliability. Furthermore, DSM can also play a significant role in allowing TSOs and DSOs to delay having to expand and reinforce the grid, thus avoiding capital-intensive investments in network infrastructure.

Shifting the load also allows one to have an energy buffer at one's disposal that can be used as a "virtual storage unit" to absorb surplus RES generation by temporarily increasing demand or, alternatively, to avoid the need to dispatch units that might feature less favourable CO_2-emission characteristics by temporarily decreasing the load.

Lastly, consumers can also benefit by avoiding peak-load time intervals and shifting at least part of their demand to periods featuring lower prices.

5.2. Overview of country activities

The table Table 4 in Appendix gives an overview of country initiatives, obtained results and relevant insights & remarks in the area of demand side management.

5.3. Discussion points

DSM or DR schemes have been adopted in some form in a number of countries, if only as time-varying rates that encourage end-users to schedule their electricity consumption in the most cost-effective manner. The widespread availability of intelligent metering systems and control actuators furthermore makes possible a host of novel applications. Some highlights from the initiatives listed in Table 4 are featured below:

- The measures adopted in the USA have had a significant impact in terms of relieving the grid of peak load, with reductions of up to 30%, also thanks to substantial support given to AMI. A similar approach has been adopted in the last few years by Sweden, where consumers are free to offer their demand flexibility for multiple purposes on a variety of markets. This could serve as valuable input for countries interested in following any similar scheme.

- The above point is confirmed by the positive results obtained in Ireland within pilot programmes and research projects aiming at reducing peak demand or, more in general, managing demand, proving the applicability of such approaches.

- In general, as far as the grid is concerned the most potential for DSM schemes lies within industrial loads, so that regulators and policymakers should keep this aspect in mind when formulating relevant guidelines and regulations.

6. Automation & Sensor Technologies

6.1. Definition of action area

In future electricity grids advanced measurement and control devices will presumably be increasingly widespread, especially at the distribution grid level, where the electrification of energy consumption is putting a greater strain on the network infrastructure and installed grid capacity already now.

Especially in regions where there is significant potential for overloading, utilities can use existing infrastructure more efficiently and exploit its full capacity by deploying smart metering and automation devices that allow to receive real-time data about the grid's status and operating conditions and act directly upon the latter, thereby forestalling or even altogether avoiding the need for capital-intensive grid upgrades and accordingly improving the attained degree of economic efficiency.

6.2. Overview of country activities

The table Table 5 in Appendix gives an overview of country initiatives, obtained results and relevant insights & remarks in the area of automation & sensor technologies.

6.3. Discussion points

Points of interest include:

- The USA has achieved substantial improvements in all efficiency dimensions thanks to the capabilities afforded by novel automation and sensor devices, which in turn have been funded by a federal funding initiative of unique proportions. This emphasizes the role and importance that public incentives and subsidies can have on the deployment of innovative technologies.

- The experience gained in Sweden confirms in part the above point, since incentives have been approved primarily for facilitating capital-intensive investments and only to a lesser extent for refunding operational expenses, which are inherently more closely linked to automation and sensor technologies. This has not been altogether well received by some parts of the industry, with calls to provide more incentives for smart grid applications. Austria also similarly reports a relative degree of pressure to contain OPEX costs, which is clearly not conducive to innovative operational solutions.

- Japan appears to have already made considerable headway in terms of deploying advanced metering devices, with regions that feature rates of 50% with respect to their penetration and with plans of having complete coverage by the early 2020s. This will enable widespread adoption of DSM capabilities and contribute to providing flexibility services, although an adequate incentives framework for households is still in the development phase.

- One topic of particular relevance for future developments is represented by machine-to-machine (M2M) operating paradigms. Historically, utilities were reliant on their own communications infrastructure, or were limited in relation to where and how they could connect equipment because they were obliged to employ traditional wired telephone lines or radio communications. Modern cellular networks are practically ubiquitous however and can exploit reliable wireless applications in combination with M2M technologies (cloud platforms, gateways and intelligent embedded modules, expert application development assistance etc.), so that utilities can connect more devices in more places than in the past, and maintain them at a lower cost.

7. Conclusions

The presented work deals with the notion of system efficiency for future electrical energy grids. The concept was formally broken down as CO_2/energy/cost efficiency and brought into relation with 5 action areas - Multi-energy systems, Electric storage, Electric mobility, Demand side management, Automation & sensor technologies – that can be leveraged upon to improve system performance in terms of increased efficiency. Feedback on activities concerning these action areas was requested from the national experts of participating countries and included in the present discussion paper. A brief discussion section on the acquired material has also been featured, although due to the breadth and variety of the considered topics, the diversity of initiatives in the various countries and the regulatory/ economic/industrial/infrastructural differences in the latter it is difficult to draw any generally relevant conclusion.

On the other hand, the presented material does indicate that there is in general a significant amount of on-going activities at an international level and that there is considerable interest in developing and promoting approaches aimed at improving efficiency. Since the energy sector has historically been perceived as a somewhat conservative industry, it is important to have institutional support targeted towards innovation to ensure that novel methods and technologies are adopted in practice. Some highlights from the action areas include:

- Multi-Energy Systems: Several activities and initiatives have been initiated in Europe and incentives have been developed aiming at the support of multi-energy systems and associated technologies. There is already now an increase in the installation of heat pumps, also as a concrete consequence of such policies.
- Electric storage: Battery costs are still somewhat high but are also expected to decrease in the years to come, although an overall assessment of the entire life-cycle of these technologies would also come into play to evaluate their suitability

for wide-scale deployment. One specific incentive for the installation of small batteries could be their joint utilisation with residential PV units. One such programme exists in Germany.

- E-mobility: Norway stands out for its E-mobility programme, which is also facilitated by the specific composition of an electrical energy system that almost entirely consists of hydropower with high storage capacity. Germany also appears to have a prominent role in this area, since it has a strong automotive industry for which it aims to develop a strong domestic e-mobility market. India has enacted a significant set of initiatives at both the national and local level with the explicit aim of achieving only EV sales by 2030.
- DSM: The measures adopted in the USA have had a considerable impact with respect to reducing the peak load, with a decrease of up to 30%, also due to significant support given to novel automation and sensor technologies. Research activities in Ireland are targeted in the same direction and a similar approach has been already implemented recently in Sweden.
- Automation & sensor technologies: the USA has attained significant improvements in terms of system efficiency thanks to the deployment of novel automation and sensor devices, which in turn has been made possible by a federal funding initiative of exceptional proportions. This underscores the value that public incentives and subsidies can have on the adoption of innovative solutions.

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9. Appendix – Tables

9.1. Multi-energy systems

Table 1: Overview of country initiatives, obtained results and insights & remarks.
N/A implies that information was not available at the time of publication, not that the corresponding item is not relevant for the given country

Country	Type of initiative	Results	Insights and remarks
USA	N/A	N/A	N/A
S. Africa	Mining companies use renewable energy heat reclaim and air-conditioning systems for deep level underground mining and also for above ground operations, surface facilities and worker housing. SAPPI and MONDI (pulp & paper industry) account for about 7% of grid electricity. Grid-code prevents non-IPP (Independent Power Producers, with capacity above 100MW) to sell onto the grid.	Generation at load leads to lower losses and CO_2 emissions – introduction of IPPs might lead to closure of larger fossil fuel plants.	Private sector already engaging directly with RES suppliers to take them entirely off grid or limit grid usage with the use of RES systems internally. RES system providers are installing and maintaining systems under contract and companies are switching over at an alarming rate which is a concern for the current dominating operating model of the utility – new business models where the utility keeps providing the technical services and performs direct investment (renewable or otherwise) are considered. Multi-energy systems are already deployed in mining sector and numerous industrial and commercial areas within S. Africa and there is just a definite requirement to manage associated operational best practice. Proper feasibility and payback period studies go hand in hand with decisions made on installing multi-energy and heat recovery systems.
Germany	Regulatory changes with respect to minimum requirements (e.g. Energy	The number of heat pump installations in new buildings has significantly increased due	Power-to-X and, in particular, power-to-gas or power-to-fuel, is a promising way to

	Savings Order, Renewable Energy Heat Act) and funding programmes (e.g. CO_2 building renovation program, market incentive program), Amendments to the Power and Heat Coupling Act and promotion of innovative cogeneration systems.	to the implemented regulatory changes and technology cost decrease.	connect the power generation, gas economy and mobility sectors technologically and economically. While the technology development has achieved significant success in the cost reduction of the plants and components as well as the increased flexibility in the plant operation due to pioneering research projects, the costs for the ongoing operation cannot yet be covered. Additional efforts provide incentives for modern power and heat systems (maintain incentives for investment in low-emission, efficient and flexible CHP installations; promote viable infrastructures like heating networks).
Austria	Multi-energy systems are promoted through national R&D funding. Multi-energy systems are one of the topics which are prominently promoted. Furthermore, there is an increased interest from industry in this topic to use the flexibility from e.g. heat networks to deal with variability of renewable generation. This also includes power-to-heat concepts to offer secondary and tertiary balancing control reserves.	Incentivised R&D projects are key for the market uptake of new technologies and methods. They allow companies to explore and experiment, together with R&D partners. The outcome of such joint projects provides the basis for future decisions, both on the strategic and the technological level. When providing financial incentives to promote a new technology, the promoting schemes have to be set up carefully and reviewed frequently enough to avoid over-incentivising as the cost of new technologies is known to often decrease rapidly.	The scientific basis for the assessment of multi-energy systems has been developed and is available but practical experience, e.g. in large scale demonstration projects, still has to be gained.
Belgium	We have developed a legislation that promotes the development of flexibility in the system, by creating a clear policy framework and compensation rules for transfer of energy. This should also attract additional investments in storage. Under impulse of European Union (EU) legislation, we have developed a national plan for alternative fuel infrastructure, and our gas Transmission System	N/A	Alternative transport fuels have in many countries (e.g. Netherlands) benefited from government or private sector engagement in order to break out of a chicken-and-egg situation. Cost and maturity of some relevant technologies still pose a large barrier.

	Operator (TSO) has already undertaken an analysis to transform its network to cater for renewable gas and/or power-to-X technologies. There have been some interesting proposals from stakeholders in which the network infrastructure for hydrogen would be built by the government and leased by the companies, but the specific regulatory aspects are to be determined.		
Norway	N/A	N/A	N/A
Italy	N/A	N/A	N/A
Ireland	N/A	N/A	N/A
Sweden	Investigated is heating used for power balance. Research on district heating for example as flexible storage. Alternative possibilities when the heating requirement are fulfilled e.g. electricity production is looked into.	In the last couple of years increased amount of heat pumps in Sweden. More decentralized heat solutions are the future.	As markets that earlier were separated are now getting integrated, barriers are mainly regulatory and operational economic (specifically unsustainable business models) but not so much technological barriers.
Singapore	N/A	N/A	N/A
India	India has aggressive renewable energy generation goals. India plans large targets of 175 gigawatts (GW) of renewable energy generation by 2022, which comprises of 100 GW Solar, 60 GW Wind, 10 GW Biomass, and 5 GW Small Hydro and has plans for 40% of total generation capacity from non-fossil sources by 2030.	As of September 2017, the Government of India (GOI) had over 58 GW of generation from RES installed (Indian Ministry of New and Renewable Energy , 2017), and is working on plans to integrate it with the electric grid with initiatives such as Greening the Grid (The United States Agency for International Development and Government of India, 2017). The GOI and progressive Indian distribution utilities are taking measures, such as demand response (DR), as an effective tool to address electricity reliability during peak demand and accelerate the deployment of	While India's plans for RES generation is a step in the right direction, with the ratification of Paris Agreement, India plans to meet 40% of energy needs from non-fossil based resources by 2030. To meet the 2030 goal, the renewable portfolio must exceed 230 GW where over 100 GW may be from solar energy, against the projected total generation capacity of 670 GW (Ghatikar, Parchure, & Pillai, Integration of Multifarious Electric Vehicle Charging Infrastructure Flexibility: Applications in India, 2017). Additionally, integration of such DERs and RES like rooftop solar, electric vehicles (EV),

		distributed energy resources (DER) to meet the goals of Indian national missions and future energy technologies.	and demand flexibility becomes important to address the challenges of supply variability and cost-effective grid integration.
Japan	Subsidy to support R&D, demonstration Project for hydrogen and fuel cell Deregulation on hydrogen such as High Pressure Gas Safety Act Demonstration project or subsidy for distributed energy resource such as biomass CHP, district heating using CHP and heat pump	R&D projects for Power-to-Gas to produce hydrogen As an example of demonstration project, "Fukushima new energy society initiative" launched in 2016 strongly promotes Power-to-Gas associated with development of renewable energy within Fukushima prefecture area where 10MW class hydrogen production plant will be installed by 2020. Demonstration project for "Power to heat device" (wind power generating heat to be stored) plans to launch within this year The demonstration projects have been carried out to examine the challenges (NEDO, 2016)	Regulatory and institutional reforms should continue improving. Cost and energy loss should be improved. Cost merit should be considered before installation Activities mentioned are still in demonstration phase, thus not yet in “lessons learnt stage”

9.2. Electric storage

Table 2: Overview of country initiatives, obtained results and insights & remarks.
N/A implies that information was not available at the time of publication, not that the corresponding item is not relevant for the given country.

Country	Type of initiative	Results	Insights and remarks
USA	The Office of Electricity Delivery and Energy Reliability of the Department of Energy (DOE OE) provides R&D funding to the U.S. national labs and private sector to advance several technologies, including energy storage.	The R&D programs have advanced the adoption of technologies into the commercial marketplace, e.g., energy storage devices that can be used for multiple applications, including more efficient frequency response, reductions in peak demand, and asset investment deferral.	Government funding is needed to test and demonstrate advanced technologies, where utilities do not have requisite incentives to undertake R&D. The development of effective strategies for the staged, proportional deployment of advanced technology, including how it might efficiently replace traditional assets, needs to be undertaken in concert with decision-makers (regulators, utilities, customers, and technology providers).
S. Africa	Safer (non-exploding) technologies should be promoted by regulations.	R&D pilot projects investigate the potential of (system/large) battery systems and generator support in micro grid environments as an alternative for network investments. A multi-level use of such battery systems (meaning also for other purposes at the same time, e.g. reducing peak loading, ensuring a high degree of network stability and providing balancing services) could make this possible. Industry are and have been using storage without Eskom (South African electricity public utility) and have been doing so for many years already to save on production downtime and provide power in remote or power constrained/underground environments.	Vast amount of RES systems in S. Africa, over 200 MW of RES installed already with storage as we are not allowed to be grid tied at present – NERSA (National Energy Regulator of South Africa) need to promulgate.
Germany	Photovoltaic (PV) battery storage program (investment in battery storage, which is installed in connection with a PV system and connected to the electrical grid).	N/A	In the future, producers of renewable energies as well as storage and flexible loads will have to contribute to system stability.

Austria	Concerning storage, there is a wide range of support schemes available. On a provincial level, investment support is provided in the majority of provinces. Sometimes, this investment support is coupled with some additional (technical) requirements, such as sharing measurement data. Furthermore, Austria is currently writing a Storage Roadmap, to give clear directions on the way forward for (battery) storage. This includes discussions on different technologies, analysis of technical and juridical requirements and recommendations towards policy makers.	Current R&D projects investigate the potential of large scale battery systems to provide system operation support services, on the distribution as well as on the transmission level. Examples are the use of battery storage systems as an alternative for network investments and the provision of balancing services. Battery storage systems are being used ever more to provide balancing services.	Electrical storage is a mature technology, and deployment of electrical storage will follow its expected price decrease. The regulatory framework for the use of electrical storage for network operation support has to be clarified. One key topic is whether or not a network operator is allowed to own and/or operate electrical storage devices.
Belgium	We have developed a legislation that promotes the development of flexibility in the system, by creating a clear policy framework and compensation rules for transfer of energy. This should also attract additional investments in storage.	N/A	The need for back-up capacity through production and/or storage, due to a higher penetration of RES, may not result in a lower energy cost.
Norway	N/A	N/A	N/A
Italy	In Italy, electric storage was subject of some deliberations from our Regulator and it was established that a few pilot project, both for transmission and distribution grids had to be created. Only after a thorough analysis of the outcome of such pilots, see (Terna, 2015), and, in particular, only after a cost benefit analysis (CBA) will it be decided if and in what way to regulate this. Meanwhile, it has emerged that the TSO would not be allowed to directly install storage, whereas for distribution system operators (DSOs) this could be permitted.	Electric storage is an important source of flexibility and, if located in the right points of the network would prevent spillage from energy produced by RES. Concerning CO_2 efficiency, as well as on possible pollution problems deriving from batteries disposal, this remains to be seen: one should carry out a full lifecycle assessment, including the CO_2 produced to create the batteries and for their disposal.	Work is still on-going.
Ireland	EirGrid Group is midway through a multi-year programme, “Delivering a Secure, Sustainable Electricity System” (DS3).	Qualification Trial Process operational since Q1 2017, final results are still pending; the aim of the DS3 Programme is	The DS3 programme entails regular communication between TSOs and Regulatory Authorities, given its ambition

The aim of the DS3 Programme is to meet the challenges of operating the electricity system in a secure manner while achieving the 2020 renewable electricity targets. The DS3 Programme is designed to ensure that we can securely operate the power system with increasing amounts of variable non-synchronous renewable generation over the coming years.

Part of this programme involves the procurement of system services (newly defined ancillary services) to facilitate increased renewable levels (e.g. very fast frequency response). We are working to obtain services from as wide a market of generators and other participants as possible and as such, are looking to facilitate the entry of new providers including storage providers.

Storage providers (other than pumped hydro storage) are in their relative infancy in Ireland. EirGrid have set up a Qualifier Trial Process (QTP) for new technologies to demonstrate their technical capability for delivering such system services.

The initial Qualification Trial Process will be operational from Q1 2017 and will comprise of both "Provenability" and "Measurability" trials. The Provenability Trials will afford technologies (unproven from a Service provision perspective) an opportunity to demonstrate their capabilities to provide a subset of Services, that are representative of a number of Services. The Measurability Trials will be used to establish the necessary measurement approaches so that reliable performance metrics can be established for the provision of services from new or existing Service Providers.

to facilitate increasing levels of renewables on the system which in turn, will reduce CO_2 output and reduce consumer bills.

and the breadth of involvement necessary across all market and system stakeholders. This engagement has taken to form of regular teleconferences supplemented by physical meetings as necessary. Wider engagement with all stakeholders has taken place on a quarterly basis via the DS3 Advisory Council which contains members representing conventional generators, renewable generators and organisations, DSOs, academics as well as NRA (National Regulatory Authority) and TSOs.

	More information can be found at (DS3 programme, 2017)		
Sweden	Digitalization, grid flexibility and energy storage are key priorities for the moment. The Swedish Energy Agency (SEA) supports for example a feasibility study for a new Swedish battery factory. The conversion of the energy system is a lot about energy storage. The need for batteries to the transport sector, system services in the electricity grid, and storage of electricity from renewable electricity generation is likely to be greater than ever before. This can lead to Sweden supplying Europe's automotive and electrical industry with high quality lithium-ion batteries. The Battery Fund Program is a research and development program at SEA focusing on technology areas and battery reuse /recycling/second life. SweGrids, another important centre for smart grids and energy storage, is located at KTH and Uppsala University, also receives substantial funding from the Swedish Energy Agency. Ångström Advanced Battery Center (ÅABC) is the largest battery research group in the Nordic region. The research focuses on all aspects of lithium batteries and fuel cell chemistry: cathode, anode and electrolyte materials. Applications are mainly batteries for electric vehicles, micro batteries and lithium-air batteries.	N/A	One impediment is still to some extent battery capacity. Barriers also include regulatory aspects with both taxes and ownership that are not designed for trading of storage and flexibility capacity. Today markets instead are optimized for supplying energy from fuel to end-user.
Singapore	Singapore has adopted a two-pronged approach to facilitate energy storage: Regulation. Launched a consultation paper to seek industry feedback on how we can better fit energy storage into the current regulatory	By facilitating the deployment of energy storage, such technology can be used to implement functionalities such as optimising energy usage and providing balancing services to support more renewable energy	There are inherent challenges in adopting innovation, e.g. uncertainty on how these can fit into existing regulatory framework. For instance, there is uncertainty on the regulatory framework for energy storage,

	framework and whether the network operator can own and/or operate such technology R&D. Established a $25 million energy storage programme to develop technologies that will enhance the overall stability and resilience of our power system. One of the initiatives include an energy storage testbed jointly conducted with the network operator to better understand the feasibility of deploying grid-level energy storage technologies in Singapore.	in our power system.	such as the licensing requirements and payment mechanism, as well as ownership considerations on whether the network operator is allowed to own and/or operate energy storage. For storage, technology maturity and payback period (which could affect investor sentiments) also pose another challenge for adoption.
India	For cleaner form of energy storage, the Government of India (GOI) and organizations such as the India Energy Storage Alliance (IESA) are promoting Electric Energy Storage and micro-grid technologies and their applications. To address reliability, India has a large deployment of energy storage in form of fossil fuel-based diesel generators (DG).	With increasing intermittency from grid-scale and behind-the-meter RES generation and lower cost of storage technologies, other forms of energy storage such as batteries are forecasted for wider adoption. Due to the high-cost of renewable form of energy storage, DG-based storage is still most popular energy storage strategy in India.	The aggressive push for generation of RES and electric mobility will axiomatically lead to the large-scale adoption of energy storage systems and various technologies that can be used to address intermittency and provide grid reliability services through electricity market mechanisms such as DR programs.
Japan	Subsidy to support R&D for development of innovative battery system and demonstration projects for advanced battery usage such as Virtual Power Plant. Subsidy and guide line for zero energy house/building include PV panel and battery.	A number of demonstration projects have been launched over the past years to install large capacity battery units to increase flexibility of the grid	High cost of battery unit Application for multi-purpose use to improve cost merit Electrical storage for absorption of excess RES production is currently in a demonstration phase, thus not yet in "lessons learnt stage"

9.3. Electric mobility

Table 3: Overview of country initiatives, obtained results and insights & remarks.
N/A implies that information was not available at the time of publication, not that the corresponding item is not relevant for the given country.

Country	Type of initiative	Results	Insights and remarks
USA	N/A	N/A	N/A
S. Africa	Need ideas and solutions to facilitate low cost local production and feasible infrastructure solutions.	N/A	Time required to effectively charge should be shortened. Or drop and replace battery storage to be considered. Lack of proper infrastructure, short travel distance, safety and costs. High price of Electric Vehicles and associated insurance costs still a deterrent at present in South Africa.
Germany	E-mobility is stipulated by an environmental bonus for the purchase of electric vehicles and the support program for charging infrastructure. Moreover, electric vehicles are exempted from taxes for 10 years.	Since 2010, the total number of electric cars has increased tenfold. A mobility vision with one million electric vehicles will be implemented by 2020 with considerable effort also by the economy. More than 7.400 publicly accessible charging stations were installed by end of 2016, thereof 292 capable of fast charging.	The automotive industry in Germany will only remain a leader in electric vehicles if a domestic market for electric vehicles is created. With the environmental bonus for the purchase of electric vehicles and the subsidy program for charging infrastructure, as decided in May 2016, the Federal Government is therefore continuing its efforts to make electric mobility with a battery or hydrogen / fuel cell mass-marketable across all modes of transport. Bottlenecks remain charging infrastructure and range. Publication of “Energy transition in transport” funding initiative.
Austria	Initiatives to promote E-mobility are ongoing. There is financial incentive when buying an EV, for both private customers as well as for companies. An implementation plan for electro-mobility has been published by the involved ministries. This plan puts electric vehicles in the broader perspective of the	The benefit of EV in terms of CO_2 emissions is obvious. (Fast-)charging stations are currently planned at strategic locations throughout Austria.	Technologically mature, with expected price decrease together with price decrease of lithium-based battery storage technology. Development of e-charging infrastructure goes hand in hand with success of EVs. This infrastructure development is expected to be a steady evolution as its business case

	mobility challenge and sets out guidelines towards the implementation and promotion of electric mobility, both in terms of vehicles and in terms of necessary infrastructure. It also puts emphasis on Austria as a technology provider for the E-mobility sector.		depends on the number of charging EVs.
Belgium	N/A	N/A	N/A
Norway	The incentives given to electric vehicles are unique. The incentives include tax reductions on investment, no fees on toll roads and priority when it comes to e.g. parking, driving in bus/taxi lanes.	The adopted policies have stimulated a very high growth in electric vehicles, and the share of electric vehicles in Norway has probably increased much faster than anyone expected.	The key insight is that strong incentives work effectively. Of course, one strong political reason for incentivising electric vehicles to begin with is related to fact that almost 100% of electric power is produced from renewable sources (mainly hydropower), and at the moment there is a surplus that can be used to shift transport from using fossil fuels to electricity. There are two possible showstoppers however: a) politicians decide to remove the incentives because the "initial goals" have been achieved, and b) that the infrastructure regarding charging stations, ability to charge at home, etc. is not developed at the same pace as the growth in number of vehicles.
Italy	For electric mobility, some pilot experiments were carried out some time ago; one outcome was that the decision was taken that DSOs can't be required to provide recharging services, but that the latter should be provided directly by car vendors, depending on their commercial strategy.	E-Mobility resembles storage as far as the grid is concerned, but has many more constraints dictated by users' uncertain drive behaviours, by the limitations on the use of batteries because of the degradation of the devices due to more frequent loading cycles (and extra costs for their more frequent replacement), and by the limits due to the necessity to guarantee a given load at a given time. Costs and reliability for distributed storage management could further limit the interest for e-mobility.	All in all, it would be interested to read a serious and independent CBA assessment rather than the more or less "fideistic" assumptions that one often comes across.
Ireland	N/A	N/A	N/A

Sweden	Focus on emissions as domestic transport by 2030 must be at least 70 percent lower than in 2010. Transport policy aims to ensure a socio-economically efficient and long-term sustainable transport supply for citizens and businesses throughout the country. Efforts for research and innovation in the field of energy should be geared towards contributing to the achievement of established energy and climate targets, long-term energy and climate policy, energy-related environmental policy goals and strengthening Swedish business. So far Sweden has not provided subsidies for buying electrical cars but on charging equipment, for example for residential homes. The transport sector is stimulated by good examples, R&D projects as well as regulated by restrictions. SEA has financed demo projects with electrical buses, autonomous cars, electric roads, coordinating of transport in a sustainable society and PV battery storage charged infrastructure as part of smart homes.	N/A	Relevant impediments are infrastructure planning and user behavior.
Singapore	N/A	N/A	N/A
India	India's National Electricity Mobility Mission Plan (NEMM) 2020 envisages 6-7 Million EVs by 2020 and plans for only EV sales by 2030 (Ghatikar, Pillai, & Ahuja, Electric Transportation: Action Plan for India, 2016). 100 Smart Cities, Smart Grid, and Micro-grid initiatives include lowering carbon footprint by renewable generation, electric vehicles, energy access, Smart Grid modernization,	Local manufacturing (FAME, Make in India) programs and GOI provide an opportunity for EV scaling, and to reduce component, device, and system-level costs for infrastructure and equipment. Bottom-up city-level initiatives have the potential to address specific micro-level needs and drive the improvement in the CO_2 emissions, air-quality and health	India's push for e-mobility has a significant potential to lower CO_2 emissions from the transportation sector, reduce oil-import bill, and improve air- and health-quality. The role of DSOs to deploy the charging infrastructure and leveraging of EVs, as a grid resource is key to accelerate the adoption and address grid reliability issues that will arise from RES generation.

	waste management, and improve air-quality in cities (Dobriansky, Ghatikar, & Ton, 2017). The program FAME (Faster Adoption and Manufacturing of Electric and hybrid vehicles) considers R&D activities on systems integration and platform for electric mobility (Ghatikar, Ahuja, & Pillai, Global Adoption Practices & Distribution Grid Impacts: Preliminary Case Study for Delhi, 2017).	improvements, while enabling the use of EVs, as a grid resource (Ahuja , Ghatikar, Seethapathy, & Pillai, 2017).	
Japan	Subsidy for R&D of next-generation battery technology which is far beyond the limitation of the current Li-ion battery, enabling long-duration electrical vehicles equivalent to ICEs. Pilot city program for preparing EV infrastructure such as quick charger	No actual action taken yet to absorb excess RES production Demonstration projects have been carried out to examine the challenges (E-mobility Malaga Project), (E-Mobility Hawaii Project)	Short duration of battery compared to the duration of internal combustion engines (ICEs) Long charging time High cost of battery Application for heavy duty vehicle Currently still in a demonstration phase, thus not yet in “lessons learnt stage”

9.4. Demand side management

Table 4: Overview of country initiatives, obtained results and insights & remarks.
N/A implies that information was not available at the time of publication, not that the corresponding item is not relevant for the given country.

Country	Type of initiative	Results	Insights and remarks
USA	Support for Advanced Metering Infrastructure (AMI) was one of the measures included in the American Recovery and Reinvestment Act (ARRA) of 2009 that made available $4 billion to the Office of Electricity Delivery and Energy Reliability (OE) to provide funding for the deployment of smart grid technologies. The OE provides technical assistance to state-level decision-makers for the implementation of cost/energy efficiency practices and advanced technologies.	AMI enabled the use of time-varying rates and where they were deployed we saw peak demand reductions of up to 30% or more. Technical assistance has helped regulators understand a) approaches for instituting practices to enable energy efficiency and b) how to effectively deploy advanced technologies leading to improved efficiency (in energy efficiency and operations).	Regulators are particularly interested in understanding and assessing technology options, as technology (including information, communications and control technologies and distributed energy resources) is advancing rapidly. Technical assistance can be crafted to address this immediate need. Government funding is needed to test and demonstrate advanced technologies, where utilities do not have requisite incentives to undertake R&D.
S. Africa	Industry, mining, pulp & paper and commercial have been self-driving energy efficiency measures for many years and with advent of green economy globally local industry etc. have followed suit using RES across all sectors - partly due to load shedding and lack of grid supply during capacity constraint times but also largely due to self-sufficiency and cost reduction to ensure market competitiveness. Non staggered ripple control (switch off or on) for high consumption devices, e.g. solar geysers might introduce detrimental effects on low voltage network infrastructure. Staggered on and off should be available for all large scale demand management, especially on residential systems.	DSM programme promulgated by NERSA is deployed, resulting in more efficient processes and lower electricity demand and more competition on the balancing markets. Higher Peak tariffs for industrial and primary sector (mining) customers are reasons for savings gained with effective peak clipping and load shifting solutions.	Reliable control/measurement solutions are few and far between – many solutions have high maintenance implications and depend upon control methodologies that may not be up to date with the system state. If particular investment into DSM solutions improves production and/or cost it will be applied. More open knowledge sharing on technologies that work and don't work could enhance cost assessments of pre-feasibility studies.
Germany	Procurement and use of switchable loads have been further developed recently in comparison to prior regulation. In particular, procurement has been strengthened more	DSM in Germany is already implemented and operational, but it is used for switchable loads only. Furthermore, DSM loads are mainly used for re-dispatch, which means	At the moment, usually tariffs for industrial loads (that would offer more potential for an extensive and comprehensive variant of a DSM scheme) are formulated in such a way

	competitively and the possibilities of use have been expanded and optimized.	that there are severe constraints for e.g. industrial customers. Moreover, they are usually disconnected and are to be used in periods of high renewable infeed.	as to financially reward constant loads. If the latter exceed their maximum admissible demand value, the customer is charged with an extra fee. This is counteracting the flexibility concept of DSM.
Austria	DSM has been in the focus of (incentivised) R&D projects during the past decade, and has received increasing industrial interest during the past years. For industrial players, demand side flexibility is mainly used to benefit from short term energy markets and to offer system balancing services. Recent R&D projects, supported by national support schemes include the dual use of demand side flexibility: for energy and balancing markets and for grid operation support.	DSM is increasingly deployed by industrial customers, resulting in lower costs for electricity and more competition on the balancing markets. DSM to support distribution grid operation is a topic of ongoing research.	Technologically mature, however it is not always easy for industry to adopt the technology as it might interfere or interact with their implemented production processes. No regulatory measures are required for DSM.
Belgium	N/A	N/A	As a general remark, the impact on the level of comfort for the user should be evaluated. In general, to have a large breakthrough it should be cheaper and improve (or at least not deteriorate) the level of comfort of the user (either perceived or real) through e.g. automation.
Norway	N/A	N/A	N/A
Italy	N/A	N/A	DSM could increase efficiency, but, as for the previous categories, limitations on the real flexibility of the customers could result in a strong limitation of the potentials. It would appear plausible that flexibility should be sought more in the industrial sector rather than through the aggregation of households.
Ireland	EirGrid are involved in a number of projects, among them Power Off & Save and RealValue, looking to utilise demand side participation in the facilitation of renewable integration and delivery of increased	Power Off & Save allows consumers to directly save money on their bills by reducing their energy usage when requested. Though this is currently in its trial phase, such consumer action can be of benefit in the	Regular communication between TSOs and Regulatory Authorities has been key to the successful progression of the initiatives listed above.

consumer welfare.

Power Off & Save is a pilot programme that will reward customers who agree to reduce their energy use when electricity demand is high. The Power Off and Save programme involves 1500 residential customers over an 18 month-period and is run in partnership with Electric Ireland (electricity supplier). Those who sign up will be asked to switch off appliances for about 30 minutes on ten occasions. Customers will be rewarded with up to 100 Euro off their bill. They will be notified by SMS text message on these occasions. Results so far have shown excellent engagement from residential customers and has improved our understanding of how best to actively engage these consumers in the future. More information can be found at (Power off & save Project, 2017).

RealValue aims to demonstrate how local small-scale energy storage, optimised across the EU energy system with advanced information technology, could bring benefits to all market participants. RealValue applied for funding under the Horizon 2020 funding programme under LCE-8 Call, Low Carbon Energy: Local/ small scale storage and received a grant of 12 million Euro.

The RealValue project commenced in June 2015 and will end in June 2018. It involves three physical deployments of Smart Electric Thermal Storage (SETS) appliances in 1250 homes in Germany, Latvia and Ireland, each representing unique market conditions, representative of the diversity of EU energy markets. More information can be found at (Realvalue Project, 2017).

future for enabling the TSO to meet energy demands in the most cost efficient way whilst ensuring system security.

Sweden	Customers' possibility to choose time variable retail price contracts facilitated by smart meters is the base for DSM in Sweden. Rollout of smart meters was made already 2009. Availability of such contracts give consumers a choice to react upon price signals to minimize their costs of electricity. Another possibility is aggregated explicit demand response, offered directly to short term markets or to network operators. However, this type of solutions is not very common mainly because there is an abundance of flexible hydro and large scale industry active in DR which leads to low prices for flexibility. The regulatory and policy goal is also to ensure that all types of flexibility is valued equally within the same market segment (day-ahead, intraday, balancing and ancillary service). All types of consumers have the opportunity to implicitly value their flexibility and are free to sign up for a retail contract based on time variable prices with an hourly reading interval without any extra cost to the consumer for metering equipment etc. Measures on how to remove barriers for demand response have been investigated by the Swedish regulator, The Swedish Energy Markets Inspectorate, as part of a governmental assignment. A report with proposed measures on how to increase demand side flexibility in Sweden was presented to the Government by the end of 2016. Also, The Forum for Swedish Smart Grid, appointed by the government, has proposed measures on how to increase the flexibility in Sweden.	N/A	Relevant issues to be addressed are how/if to formulate adequate regulations and incentives.
Singapore	In order to realise the potential benefits of	The benefits of DSM are potentially two-fold	A key challenge would be in promoting

	DSM, Singapore has put in place a variety of measures to empower participation by electricity consumers to optimise their energy use, which includes: DR programme: DR enables consumers to reduce their electricity demand voluntarily, in exchange for a share in the system-wide benefits, in terms of reduction in wholesale energy prices as a result of their actions. Interruptible Load (IL) programme: IL enables consumers to be paid to be on standby in response to system contingency events. Project OptiWatt: a pilot programme launched in 2016 to demonstrate the viability of DSM initiatives to consumers. This includes testing relevant technologies and business models, as well as understanding consumer behaviour.	at the individual and system level. First, consumers can reduce their electricity bills by adjusting the timing and amount of electricity use. Second, the energy system can benefit from the shifting of energy consumption from peak to non-peak hours.	consumer awareness and engagement to facilitate greater adoption of DSM.
India	DSOs have initiated DR programs for Internet and standards-based automated DR, Smart Metring, AMI. The Indian utilities have conducted field demonstrations of demand flexibility using automated demand response (AutoDR) to leverage flexibility from customer loads. The implementation of utility demonstrations has shown the value of DR. For example, a demonstration was conducted by a distribution utility, Tata Power Delhi Distribution Limited (TPDDL), to automate DR for commercial and industrial (C&I) customers.	Indian state energy regulatory agencies are considering DR programs and market design to improve peak demand costs, system-level efficiency, and price arbitrage for the utilities. Previous DR-related demonstration and studies have: (1) identified and characterized each category customer's load duration curve and aggregated demand (Yin, Ghatikar, Deshmukh, & Khan, 2015); (2) characterized AutoDR system, including smart meters and advanced metering infrastructure (AMI), data analytics, and standards (Ghatikar, Yin, Deshmukh, & Das, 2015); and (3) estimated the DR potential in the state of Delhi (Deshmukh, Ghatikar, Yin , Das, & Saha, 2015).	India's DR and energy efficiency potential is huge. While aggressive steps are taken to address energy efficiency, India has recently taking measures to support market redesign and dynamic electricity rate tariffs that provide DSOs and customers the value from offering and participating in the DR programs. Use of advanced automated DR technologies and standardized communication platforms improve cost-effectiveness of the programs and grid interoperability prerogatives. Within the context of improving electric reliability, arbitrage for price volatility, and improving better integration of renewable resources, DR programs and communication and control technologies provide a significant value and have the potential now.
Japan	Energy Plan 2014 states that DSM will be	Incentive-type DR is introduced in the	Regulatory framework should be

effectively utilised with dynamic pricing for stabilisation of the balance between supply and demand of electricity Setting the guidelines for public calls for electricity adjustment include DR in October 2016. Public calls starts from April 2017.	capacity auction market Dynamic pricing is partly introduced on an opt-in basis but not widely accepted with very little impact as DR	continuously improved Lack of powerful incentive for individual household to participate in DSM Currently in demonstration phase, thus not yet in “lessons learnt stage”

9.5. Automation & sensor technologies

Table 5: Overview of country initiatives, obtained results and insights & remarks.
N/A implies that information was not available at the time of publication, not that the corresponding item is not relevant for the given country.

Country	Type of initiative	Results	Insights and remarks
USA	The American Recovery and Reinvestment Act (ARRA) of 2009 provided $4 billion to the Office of Electricity Delivery and Energy Reliability (OE) within the U.S. Department of Energy (DOE) to provide funding for the deployment of smart grid technologies, including fault location, isolation and restoration technology, AMI, voltage optimization systems, equipment health monitoring devices, and synchrophasor technology. The 5-year effort (2010 – 2015) applied federal government grants and cooperative agreements to the private sector (e.g., utilities and technology developers) and required minimally 50/50 cost-share. This level of funding is unique, but moved the ball considerably with respect to implementing efficiency measures. DOE OE also provides R&D funding to the U.S. national labs and private sector to advance several technologies, including energy storage, microgrids, power electronics, and advanced distribution management systems.	With respect to ARRA there were significant improvements in both energy and cost efficiencies, as well as carbon reduction gains. For example: i) AMI enabled more effective metering and emergency restoration efforts, so that we saw a significant reduction in truck rolls (operational efficiency and carbon reduction gains) and a reduction in restoration times; ii) the application of conservation voltage reduction through voltage optimization techniques also resulted in significant reductions in peak demand (oftentimes close to a 1% reduction in energy requirements with a 1% voltage drop) and customer savings; iii) automated feeder switching also reduced the duration of outages with corresponding avoided costs by customers; iv) synchrophasor technology applied at the transmission system level provided numerous benefits, including improved operations (e.g., online generator model validation, improvements in forensics, identifying malfunctioning equipment) and power flow. In general, technical assistance has helped regulators understand a) approaches for instituting practices to enable energy efficiency and b) how to effectively deploy advanced technologies leading to improved efficiency (in energy efficiency and operations).	Regulators are particularly interested in understanding and assessing technology options, as technology (including information, communications and control technologies and distributed energy resources) is advancing rapidly. Technical assistance can be crafted to address this immediate need. Government funding is needed to test and demonstrate advanced technologies, where utilities do not have requisite incentives to undertake R&D.

S. Africa	Machine-to-machine (M2M) SIM (Subscriber Identity Module) Cards to be handled separately from normal SIM cards with longer (14 digit) numbers. Influx of optic fibre installations in residential units might affect infrastructure of choice for future installations as most technologies rely on mobile networks with a small footprint of LoRa in South Africa.	Unnecessary consumption could be inhibited by customer controllable schedules.	Collaboration with French power utilities through a FEXTE (Fonds d'expertise technique et d'échanges d'expériences) Agreement provided lessons on several aspects of Smart Metering such as the approach of a utility design (Linky) rolled out to the Open Market. Several South African challenges such as illegal connections, cable theft and meter bypasses however requires split metering technologies when applied to South Africa. Remote connectivity – long distance reliable communication infrastructure non-existent in rural areas. Deployment of sensors and automation systems takes months, especially in remote locations, and the deployment teams with the correct skills and tools are in short supply. Control bandwidth and power on wireless (Ultra High Frequency Whitespace) and wired technologies (power line communications or PLC). Cost of providing remote sensor infrastructure needs to be carefully conducted on a cost-benefit study for each specific case. Within the mining sector the roll-out of automation and remote sensing is mature and controls for efficiency automation programmes are in place. Large scale sensory and automation throughout all sectors of industry are also following the trend.
Germany	Within the electricity market several adaptations and innovations are either planned or envisioned, among them a number of changes that would rely on	N/A	In the future, producers of renewable energies as well as storage and flexible loads will have to contribute to system stability, and advanced measurement and control

	advanced grid technologies: i) reduction of entry barriers for providers of DSM; ii) more efficient network planning; iii) extension of monitoring of security of supply; iv) Smart Energy Showcases - Digital Agenda for the Energy Transition (SINTEG); v) Law for the Digitization of the Energy Transition.		technologies can contribute to this goal. They can also be put to use for the further development of regulations covering net tariffs, e.g. to i) ensure the fair distribution of network costs to grid users and guarantee transparency regarding cost allocation; ii) take into account the increasingly complex supplier-side/ demand-side structures; iii) when developing the grid charge system further, facilitate the use of flexibility that meets the needs of the system.
Austria	Apart from the incentivized R&D projects for industries and network operators there are no specific incentives towards automation and sensor technologies. Of course, smart meters can be seen as a sensor in distribution grids. The national goal is to have 70% of all meters replaced by a smart meter by 2017.	N/A	Apart from the Smart Metering, no additional regulatory measures are required nor foreseen. Implementation of automation and sensor technologies is a question of network planning and operation of the respective network operators. One important aspect here is the difference between operational expenditures (OPEX) and capital expenditures (CAPEX). With more automation and sensor technologies, expenses for IT, data management, data processing etc. will increase, increasing OPEX expenses, which are currently under pressure throughout Europe. Expenses for IT, data management, data processing etc. are therefore harder to explain.
Belgium	N/A	N/A	N/A
Norway	N/A	N/A	N/A
Italy	N/A	N/A	Automation can also contribute to flexibility, provided that the cost to implement it is less than the losses

			generated by RES spillage, etc. A serious CBA would be needed, whereas often the information of economically interested manufacturers tends to prevail.
Ireland	One of our innovation focus areas is to explore utilising the existing transmission infrastructure rather than building new lines. In Waterford we have trialled Smart Wire's Powerline Guardian device to control power flows with real-time sensing capabilities. From this we are moving to deploy distributed series reactance (DSR) type technology for a full deployment by 2018. This will allow us to better utilise the capacity of existing lines which long term will help reduce the need for future new infrastructure.	The Smart Wires project enables the increased utilisation of existing assets, reducing cost of new infrastructure and delivering associated consumer welfare.	Regular communication between TSOs and Regulatory Authorities has been key to the successful progression of the undertaken activities.
Sweden	There is a national energy research policy and a national road map for smart grids (developed by the Swedish Smart Grid Forum). The Swedish Smart Grid Forum is a national forum appointed by the Swedish Ministry of the Environment and Energy. The mission is to implement the action plan, set up by the former council, to further develop a store of knowledge on the website and to support Swedish export within smart grids. There is also an overarching governmental energy policy specified for which the energy R&D works as an implementation tool. Sweden has a common overall strategy for the whole energy system and within this strategy there are sub-strategies for different areas. The main framework for research, innovation and demonstration in the smart	Example of large pilot/demo-projects during the last five years: Royal Seaport Stockholm, Smart Grid Gotland, and Smart Grid Hyllie. The 3 flagship demo/pilot projects which are finalizing right now have been around for 5+ years and have been an important part of the smart grid community during the rapid transition which has taken place in recent years. SEA provides also some support for business development and market introduction, mainly based on loans. Communication about project results widely in the sector and to the public at large could also be seen to aid market introduction.	The Swedish incentive-based regulation model has been criticized, primarily by the industry, for not providing enough incentives to invest in Smart Grid applications. This is due to two main reasons; investments in capital intensive plants are premiered over smart grid applications linked to higher operating costs. The second reason being that incentives for effective utilization of the network premiering smart grids are low in comparison to other incentives. Also other general barriers are mentioned such as not allowing differentiated pricing in smart grid demonstration projects, as the law stipulates that all customers have to be treated equally. Relevant issues to be addressed are business models, incentives and to some

	grids spectrum is covered in the SEAs SamspEL programme. This programme has a vision for 2050 and projects funded through the programme are selected so that they can yield results contributing to certain societal effects by 2030. These effects should be leading towards the vision 2050. In the last five years SEA has provided approximately 50MEUR of funding for smart grids. Funding for individual projects ranges between 0,05MEUR to ~2.5MEUR. Since 2012, the Swedish Energy Market Inspectorate have regulated the revenues for each network company, by providing a revenue cap during a four-year period. The regulation is technology neutral and does not give any specific incentives for new technology. However, complementary incentives for effective utilization of the electricity network and security of supply (few disruptions in delivery) are included in the regulation.		extent regulation. In general the combined effect of digitalization and rapid transition makes it difficult to predict the future, so that the project portfolio needs to reflect a variety of approaches and enhance innovation both in products, organisation and society.
Singapore	N/A	N/A	N/A
India	The Indian DSOs have initiatives for Smart Metring, AMI, OMS, Aggregate Technical & Commercial losses. 100 Smart Cities initiative for renewable integration, Smart Grid integration and automation, etc. provide large-scale deployment opportunities and value proposition to such technologies.	India's Smart Metering, AMI, OMS, automated DR, etc., programs have shown a significant potential for control, communications, and sensor-based technologies to solve the current problem and leapfrog the grid modernization efforts.	With increasing pressure for energy access, 24x7 power, and electric mobility adoption, the role of control and sensor communications and technologies will play a key role in attaining those goals. India must consider plans and understanding of grid- and customer-benefits of deployments of such technologies and fast track them for adoption. Such deployments must be based on open standards and grid interoperability prerogatives.

Japan	Energy Plan 2014 states that smart meter will be installed at all of electricity consumers by the early 2020s enabling DSM to contribute to stabilising the balance between supply and demand of electricity Energy Plan 2014 also states that transmission technology for information provided by smart meters in individual consumers will be standardised in order to build up smart communities Implement the guidelines for cybersecurity in power grid operation and smart-metering established in 2016 by JESC (Japan Electrotechnical Standards and Codes Committee)	The current penetration rates of smart meters are 30-50% (depending upon the regional grid areas) Major utilities plan to complete the installation of smart meters at all of their customers by 2023-24	Connective technology between smart-meter and other devices such as energy management systems (EMS) is important Handling and sharing of private information of each individual consumer must be done with care Continuous improvement and updates needed for cyber-security Currently in a demonstration phase, thus not yet in “lessons learnt stage”