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An analysis of smart meter deployment in Sweden with applicability to the case of India

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Abstract

The energy landscape as we know it today is undergoing a radical revolution. New strategies for grid management, *smart grids*, are vital to facilitate this development in the power sector. Advanced Metering Infrastructure (AMI), devices often denoted as Smart Meters, is the most mature and widespread of these technologies today.

In a first stage, this thesis studies smart meters in Sweden reflecting on the first wave roll-out and while on the verge of a second wave technology deployment. The initial drivers behind smart meters are studied as well as the consequences that the deployment has had on different stakeholders. Furthermore,the thesis analyses the barriers and incentives perceived by the main energy stakeholders involved in the ecosystem today (regulator, end-consumers, distribution companies) and how these impact smart grid applications of smart meters in Sweden now and in the near future.

In a second stage, the transferability of the lessons learned from Sweden to the current smart meter case of India is assessed. A comparison from the perspective of the main stakeholders identifies similarities and differences driven by local smart meter boundary conditions in the two countries. The study has revealed several issues that arise from the aim of a knowledge transfer between Sweden and India, ranging from a retrospective view of the current situation in Sweden to identification of barriers of different kinds that are present.

From this, the thesis concludes that the main developments in the two countries are to that extent driven by their local parameters that the relevance of a knowledge transfer becomes questionable.

Acknowledgements

The past five months have been incredibly intense. Tremendous experiences have been intertwined with difficult periods, and reflecting on this I would like to express my gratitude to the people who have guided me to end up with this result today. This thesis would not have been realized without the contribution of the following people.

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Chapter 1

Introduction

1.1 Background

1.1.1 Smart Grids

The energy landscape as we know it today is undergoing a radical revolution. Sustainable growth paths drive an energy transition, aiming for a collective response to the energy trilemma. That is, future energy provision must be based on three core values: security, social equity and environmental sustainability. In the light of the context of a growing and changing global energy demand, following this pathway will require a far-reaching transformation of energy services and infrastructure (World Energy Council and Oliver Wyman, 2016). The energy transition encompasses many evolutions in all parts of the energy supply chain. This certainly holds for the electricity sector, where new technologies that are introduced question the grid system as it is designed today. New strategies for grid management, *Smart Grids*, are vital to facilitate this continued growth to sustainability.

Numerous definitions and as many applications of the term *Smart Grid* exist today. According to the International Energy Agency (2011), smart grids are defined as *"electricity networks that use digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet varying electricity demand of end-users"*. During the past decade, the technology behind smart grids has become a widely discussed topic, driven by the different appearances of the energy transition specifically in the power sector. Firstly, the recent development of smart grids is pulled by the rapid growth of renewable energy as part of the global energy production. In order to reach the global *Sustainable Energy for All* objective, the share of renewable energy in the global energy mix would need to double by 2030 (International Renewable Energy Agency, 2013). However, the decentralized and intermittent power production that comes from renewable energy sources puts stresses on prevailing grid structures. Whereas in past energy provision electricity demand was the independent variable and electricity generation was the dependent variable in the equation, the ongoing developments completely turn this around where demand grows into a more responsible role to adapt to variable generation from renewable energy. Besides, new downstream energy demand, storage and generation facilities require a flexible and adaptive grid for optimal applicability that optimally allows a decentralized electricity system. Finally, the potential of smart grids is facilitated by the recent evolution of different communication standards and technologies, now providing a toolbox that enables new smart and digital solutions. As a result of the aforementioned, future smart grids will be characterized by the so-called *Disruptive 3Ds: Decarbonization, Decentralization and Digitalization.*

1.1.2 Smart Meters

It is clear that the concept of smart grids is very broad and encompasses several facets and parallel developments. Advanced Metering Infrastructure (AMI), often denoted as Smart Meters is the most mature and widespread of these technologies today (IRENA, 2013). Smart Meters are measuring devices that can be used to measure either electricity, water or gas consumption for different types of users – industrial, residential or commercial. In the following study, the term will refer to advanced electricity measuring devices. These are distinguished from ordinary electricity meters by three key characteristics (IRENA, 2013):

- Two-way communication between the consumer and the data collecting system
- Higher time resolution
- Communicate data at higher frequency

However, numerous types of smart meters are on the market, all of which incorporate different functionalities. Ultimately, smart meters could be an enabler of smart grids that could for instance reduce peaks and allow for demand response through pricing signals (EPRS, 2015). In practice however, advanced metering is concluded not to be crucial for to support the penetration of renewables (IRENA, 2013). Nevertheless, globally economic and social incentives are identified that can potentially pave the way for large-scale deployment of smart meters.

1.1.3 Smart Meters in Sweden and India

In 2002, the Swedish government mandated monthly electricity metering for all household consumers. Albeit indirectly, this mandate has resulted in a first wave of smart meters being installed by power distribution companies, making Sweden the first country in Europe where smart metering technology was 100 % penetrated now almost a decade ago (AT Kearney, 2010). On the one hand, this makes Sweden one of the most mature cases for smart meter experience that are available. Now more than 15 years after the first mandate, the benefits, shortfalls and overall implications are brought to the light, thereby revealing an illustration of the potential of smart meters but also providing lessons that can be learned in the future by later adopters. On the other hand, referring once more to the stretch that exists in the concepts of *smart* meters, it can be questioned which level of smartness has been reached with the current technology installed and how successful the roll-out has been in facilitating a better and smarter electricity ecosystem. The barriers that were encountered by Sweden in this process can provide critical lessons learned for other regions that are yet to initiate this development.

India is currently still in a premature stage of smart meter and smart grid technology. However, driven by a significant growth in both energy demand, goals of electrification and renewable energy generation targets in the short-term to mid-term future, grid technology will necessarily require far- reaching upgrades towards smart grid technology. Smart meter pilot projects have been initiated, mainly driven by the aim to reduce Aggregate Technical and Commercial (AT&C) losses that arise from poor grid management and excessive shares of energy theft and other means of non-payment of power used by end-consumers. By 2019, the Indian government has set a target of 35 million smart meters installed (PowerLine, 2018). However, several challenges for a large-scale smart meter deployment still arise today in the Indian context, among which the limited knowledge and awareness of decision makers.

This thesis will study the Swedish experience with smart meters resulting from the first wave while on the verge of a second wave technology deployment. It intends to do so in a holistic manner, shedding light on the different boundary conditions that reflect in successful or unsuccessful deployment and application of smart meters. In a second stage, the transferability and applicability of the knowledge and lessons learned from Sweden to the current case of India will be assessed. This requires an analysis to the comparison of the Swedish and Indian context. Finally, it will be concluded whether the Swedish experience can bring value to India and if so and which aspects should be focused on in India.

1.2 Problem Statement

In *Smart Grids and Renewables* by the International Renewable Energy Agency (2013), it is stated that the development of smart grids is largely dependent on system-specific requirements, however that some general overlap between cases exists. Following this, the problem to be addressed in this thesis is whether the mature case of smart meters in Sweden can provide any value to the current situation for India. In order for any conclusions to be valid, it is of critical importance to assess the relevance of the Swedish experience to the Indian case. It can be expected that the two countries are different on numerous aspects like socio-economic situation, energy system and issues to be resolved by the smart meters. However, within specific niches of knowledge and experience, the former's lessons learned can be valuable for the latter to avoid similar pitfalls.

The research will be logically divided in two subsequent objectives:

Firstly, the focus will be on Sweden first wave of smart meters, from 2002 to 2009 and the consequences observed up to today. The aim of this section is twofold. On the one hand, it fits within the aforementioned bigger picture of a potential knowledge transfer to India. On the other hand however, this part on itself fulfills a knowledge gap of a comprehensive reflection within the Swedish borders that appears to exist today. With the governmental mandate being enforced by 2009, the larger share of the installed meters was put into place the years 2006 to 2009. With a lifetime of 10 to 15 years, this implies an upcoming wave of replacements in the near future. This allows to incorporate the previous experiences and resolve the issues that have been present up to now by introducing new policy and technologies. In order to maximally benefit from this opportunity, it is key for Sweden to better understand the implications of the first wave meters as well as the lessons learned by identifying the barriers to be overcome from the perspective of different stakeholders. Although knowledge on different aspects of this is available, they are fragmented and no single piece of holistic literature on this exists. This lack of harmonization between the different decisive parties is a potentially serious concern that can largely influence the future of smart grids in Sweden. For this reason, it is vital to provide a study about the key experiences from different perspectives to decision makers, which is what this section is aiming for.

Secondly, the assessment of the relevance of some of the conclusions of the first part to the case of India will be made. Key to this is to understand the comparability between the two smart meter ecosystems that exist within the greater context of presumably largely different regions. That is, although naturally numerous differences between Sweden and India exist, this does not necessarily hold for the niches of smart grids and smart meters. However, it is clear that also these are to a large extent correlated with local boundary conditions. Thus, the aim of this section should be interpreted as the identification of different bridges that exist over which knowledge from Sweden can be transferred to India, so as to filter to only retain those experiences that are potentially relevant.

The above comes down to a segmentation in the following research questions:

1. What are the barriers and incentives for smart grid usage of smart meters from the perspective of the two main Swedish actors?
   (a) Distribution Companies
   (b) Consumers
2. What is the influence of the regulatory situation for the results of the above question?
3. What are the main differences and similarities between Sweden and India for each of the above perspectives that influence successful experience sharing?

1.3 Previous Work

The context and feasibility of smart meter deployment has been studied thoroughly several times within a specified boundary on different levels. That is, a regional scope is defined and an analysis is done for the situation within the scope. Generally, one can make a division in three types of reports to be found, presented here according to increased regional focus and direct local applicability.

Firstly, there are projections, analyses and potential pathways forward by leading international and independent institutions. Examples of this are International Energy Agency (2011) or International Renewable Energy Agency (2013). These are high quality documents that point out final goals, guidelines and potential pitfalls for implementation of smart grids and smart meters. However, these institutions tend to give general overviews with aims for the long-term. Although relevant for policy makers to identify general trends, challenges and opportunities, they generally do not aim to take into account local parameters and therefore they lack direct applicability.

Secondly, there exist specific guidelines published by large political bodies or related research institutes, that a priori elaborate on more specific goals of and methodologies for implementation. For the European case, these are documents that supplement and support policies and directives, e.g. European Commission (2014), Giordano et al. (2012) and also ERGEG and CEER (2011) and (European Parliamentary Research Service (EPRS), 2015). These are more specific and applied than the first category of sources and besides they can be an important source of data for comparison among countries. They give frameworks and methodologies for unified results and benchmarks of the current status of events within the scope chosen, for most literature studied this was the European Union. These however do not assess specific country situations in much detail nor give sound evaluations of the implication of the smart meter decision.

Thirdly, one can find literature that studies country specific cases of smart meter deployment, a priori and to some extend also a posteriori. This includes Cost-Benefit Analyses, Case Studies, general context studies and evaluations. Valid sources for the particular case of Sweden are Campillo and Vassileva (2016), Swedish Competition Authority (1996), Söderbom (2012), Andrésen (2009) and Álvarez (2014). Regarding the gap that exists in this literature where the first research question intends to contribute, it is striking that most research describes the status of smart metering projects during roll-out and very little attention is paid to an evaluation of the measures taken in the past. This is very well illustrated by the lack of recent studies about the first wave of smart meter roll-out in Sweden. It appears that after deployment, interest in evaluating the measures already taken has diminished rapidly. This is potentially hindering decisive measures taken today for the future development of the technology. For instance, the European Union published a directive for a cost-benefit analysis of smart meter deployment prior to the implementation phase, but no such directive or CBAs exist to assess the situation after implementation. There remains a clear gap in the literature of analysis and evaluation on the success of the projects in different countries, as well as the lessons that can be learned from this.

The second part of the study aims to use Sweden as a starting point to facilitate a knowledge transfer that contributes to the current challenges for the case of India. Little research exists in the transfer of smart meter knowledge across country boarders. Especially connections between the more mature Western countries and the emerging Asian countries is barely existent. Finding relevant and recent information on the latter is therefore cumbersome. Some literature on the technology and knowledge transfer of smart meters globally is found in Hashmi et al. (2011), Verhaegh and de Boer (2016), Zhou and Brown (2016) and Ma et al. (2015). These provide information, frameworks or analyses on cross- border transfer of smart metering knowledge. It includes first efforts to shed light on from how policies within countries' systems can influence smart meter deployment from a meta-country perspective while taking into account local influences. The conclusions are however still fragmented and not in directly applicable to the Sweden- India case, that is still merely influenced by local conditions. A major limitation of existing literature is that oftentimes comparisons that are made appear as a subsequent elaboration of the regions discussed. Little contribution is made in actually interconnecting or bridging the gap between them.

Ma et al. (2015) confirms this research gap of transferability for the wider subject of smart grid solutions. It states:

"This paper argues that, the global drivers and challenges provide a possible platform for the international transition of the smart grid solution, such cross-national technological and managerial transfer. [...] Despite the recognition of the importance of the smart grid globalization, there has been little research to provide the smart grid solution in the dynamic market. Plenty of researches have done the comparative studies of the smart grid development with the national or cross-national aspects. Majority of the research focuses on the technological aspects, and little has stated the correlation across countries or the management aspects."

Other information that is related to cross-border smart meter knowledge transfer, but that is deemed less relevant for the scope of the study, is found in U.S. International Trade Commission (2014), Simoes et al. (2014), Carvalho (2015) and A. Sharma et al. (2017).

1.4 Contribution

Overall, the study aims to complement the existing listed literature in two manners.

Firstly, the results aim for direct applicability in each of the two ongoing discussions at critical turning points in both Sweden and India. In the former, it will fill the existing gap of a posteriori evaluations of the specific decisions taken as well as the influence of certain boundary condition that are in or out of the power of decision makers but nevertheless critical in understanding the full picture. This will materialize through an impact analysis of the smart meter deployment for the perspective of the energy stakeholders involved. Besides, the key enablers and barriers identified by the three key actors in the field will be discussed, being regulation, distribution companies and consumers. By combining these complementing perspectives, the ecosystem of Swedish smart grid deployment will be revealed. This will result in suggestions to enhance future smart grid usage of smart meters installed in Sweden. For logical order of reasoning and convenience of the reader, the assessment of the applicability of lessons learned and the key differences and similarities in this regard between Sweden and India will follow the same structure and perspectives. Key for the analysis is the starting point from Sweden. Suggestions and expectations made for the case of India will depend on the experience of Sweden rather than domestic predictions by Indian experts. For India, this analysis can serve as a starting point for expectations to take into account in the upcoming large-scale deployment.

Secondly, the study hopes to contribute by providing application of a first systematic approach of smart meter knowledge transfer between countries. This choice for a knowledge transfer is in contrast to general analyses about smart meter installation that are available that would make conclusions based on predictions and expectations for the future starting from the domestic baseline at present. The limitations of these kinds of analyses that scope solely within well-defined boundaries – for instance India in this particular case - is that those are necessarily based on uncertainties. That is, since smart meters have not yet been deployed in India, one can only make educated guesses about outcomes. Instead, this study intends to benefit from the experience of a more mature case of smart meters to gain a deeper understanding that is founded on a real case. Based on this is phrased what is to be expected for the region that is possible going down the same road with some delay. In the ideal case of perfectly aligned boundary conditions between the two, this would be maximally relevant. In practice, some serious distinctions between the cases are to be made that prevent knowledge to be transferable, the reason for which this comparative study is required. The latter is of course critical to the success of making a knowledge transfer. In that regard, the study contributes to the existing literature by providing an application of a framework that has not yet been introduced in the field of smart meter and smart grid development research, as was mentioned in the previous section already. Regardless of the success of the transfer, this framework and methodology can showcase further studies of smart meter knowledge transfer between other regions.

1.5 Thesis Outline

The figure below gives an overview of the outline of the thesis. After the general introduction and methodology, the overall situation of smart meters in Sweden and India will be given as a background to the topic. Following this, the experiences of the Swedish smart meter roll-out will be discussed. In the next section, an assessment of the two smart meter ecosystems will be made, which is thereafter discussed and from which are finally drawn conclusions.

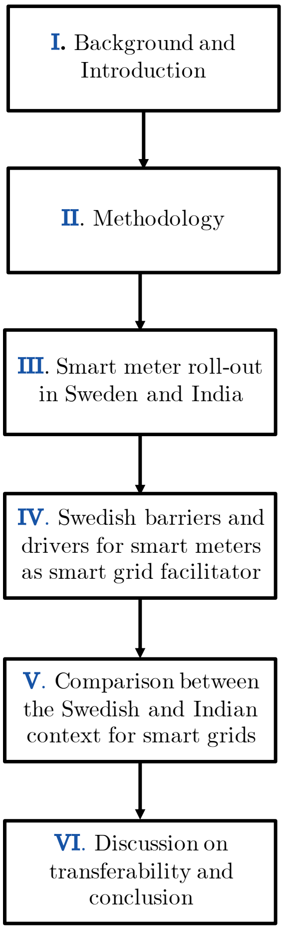

Figure 1.1: *Outline of the thesis*

Chapter 2

Methodology

2.1 General Methodology

From the proposed research questions, it can be understood that a significant part of the study is qualitative. For some key conclusions however, this is necessarily in triangulation with quantitative methods. Relatively small data sets are used in order to complement and validate qualitative results. Following the *Portal of Research Methods and Methodologies*, taken from Håkansson (2013), further strategies were developed. The approach taken will be a combination of *Descriptive* and *Applied Research*, based on *inductive reasoning.*

The overall research purpose is to build up the smart meter ecosystem from the perspective of three main actors for smart grid applications of smart meters:

(i) **Regulatory body**: Since electricity distribution is regarded as a natural monopoly, there is no free market competition and the sole market monopolist is guided and supervised by the regulator. Mandates from government through legislation and regulation are at the basis of smart meter deployment. Besides, they are still a decisive party in the future development through the enforcement of meter requirements. For this reason, they are a key actor in the smart meter ecosystem.

(ii) **Residential consumers**: Smart meters are installed with different types of electricity consumers that vary in function and size. Any advanced application of smart meters through electricity or flexibility programs requires participation of the downstream electricity consumers. Residential consumers are numerous smaller electricity consumers that together form a significant potential target group. Among other consumers as industrial loads, the research focuses on residential consumers, in this setting they are an important second actor.

(iii) **Distribution Companies**: the responsibility of the actual deployment, as well as the data collection and processing are given to electricity distribution companies. Within the boundaries prepared by regulation, they have great freedom to make choices that largely impact the type, the usage and the spillover services of smart meters. Naturally, they form a crucial third actor in the ecosystem.

2.2 Literature Study

As a first step, the research starts with a literature study on smart grids and smart meters, specifically in the case of Sweden and India.

For the former, it is important to understand the drivers and critical measures that have been taken on the past roll-out of smart meters. The starting point is chosen in order to maximally serve as a background to the research questions. Since Sweden is regarded in the study as the country to share experiences, it is important to sufficiently study the evolution from the past up to today. Therefore, the study is done in a logical structure of (1) drivers of implementation; (2) roll-out; and (3) evaluation after first wave. Several types of documents are used, ranging from international benchmarks and academic literature to radio interviews with experts. By comparing the results, the market and socio-economic context are analyzed that have led to the smart meter deployment that is present today as well as its implications on the several stakeholders involved.

On the side of India, the necessary literature is studied as well. However, in this case the analysis is also guided by the primary experience collected during the India Smart Grid Week 2018. Analogous to the situation above though with different consequence, this part of the literature study focused on the current situations and the problems and needs that India knows in its smart meter development.

Combining the two parts, the reader is familiarized with the situation in both regions of focus in the study.

2.3 Data Collection

The first research question of the thesis aims to study the key incentives and barriers for advanced application of smart meters from the perspective of regulation, consumers and distribution companies, in Sweden. This is primarily based on interview with several experts of different sides of the energy field. The interviews conducted are with the following experts:

- **Technical Analyst** for **Swedish Energy Markets Inspectorate (EI)**
  Being the designated regulatory body in Sweden, EI has the responsibility and authority to supervise the electricity, natural gas and district heating markets in Sweden. They monitor developments on the markets and provide guidance to the actors. The respondent has knowledge and experience with the first wave of smart meter roll-out, including the period 2007 – 2009 when a lot of meters were to be replace due to new regulation.

- **Analyst** for **Swedish Energy Markets Inspectorate (EI)**
  The role of EI has been elaborated in the introduction of Tor Ny. The respondent was one of the members of the project within EI that had the governmental task to study the functional requirements for the second wave of smart meters. She contributed to the functional requirement list that was the result of this.

- **Energy expert** for **InnoEnergy Sweden**
  InnoEnergy is a European company dedicated to promoting innovation, entrepreneurship and education in the sustainable energy field by bringing together academics, businesses and research institutes. The respondent works at InnoEnergy contributing to analyses and reports about key topics in the energy field. He has a focus on Innovation, Decentralized Energy and Battery Storage. Furthermore, he holds a postdoc in the field of Smart grid and Intelligent Systems Applications in Power Systems at the Royal Institute of Technology, KTH.

- **CEO** for **Greenely**
  Greenely is a mobile application that automatically connects, analyses and visualizes household electricity usage without hardware requirements .By combining data analysis and behavioral science, it helps consumers reduce their electricity costs for free. The respondent is graduated as an engineer from KTH, Stockholm. He is co-founder of Greenely and is the currently CEO of the company.

- **Smart Grid and Smart Metering expert** for **E.ON**
  E.ON is an international, privately owned energy supplier based in Essen, Germany, and has around 43,000 employees. In Sweden, they have a significant market share in electricity generation and retail. Eon Distribution is one of the three big network operators, and is responsible for parts of the electricity distribution in regional medium and low voltage levels. The respondent has been Project Manager for E.ON's first wave smart meter roll-out from 2003 to 2010, and currently holds the position of smart grid and smart metering expert and process manager of "Meter to Cash" within E.ON.

Figure 2.1 shows how the combination of interviewees is made in order to be maximally representative for the study of Swedish smart meter deployment, according to the aforementioned three dimensions of regulation, consumers and distribution companies. The focus of expertise of any of the experts is clear and this perspective has somehow been the main focus of the interview, guided by the specific questions asked. Generally, questions are aiming to identify different types of barriers and incentives that exist from the three different perspectives taken.

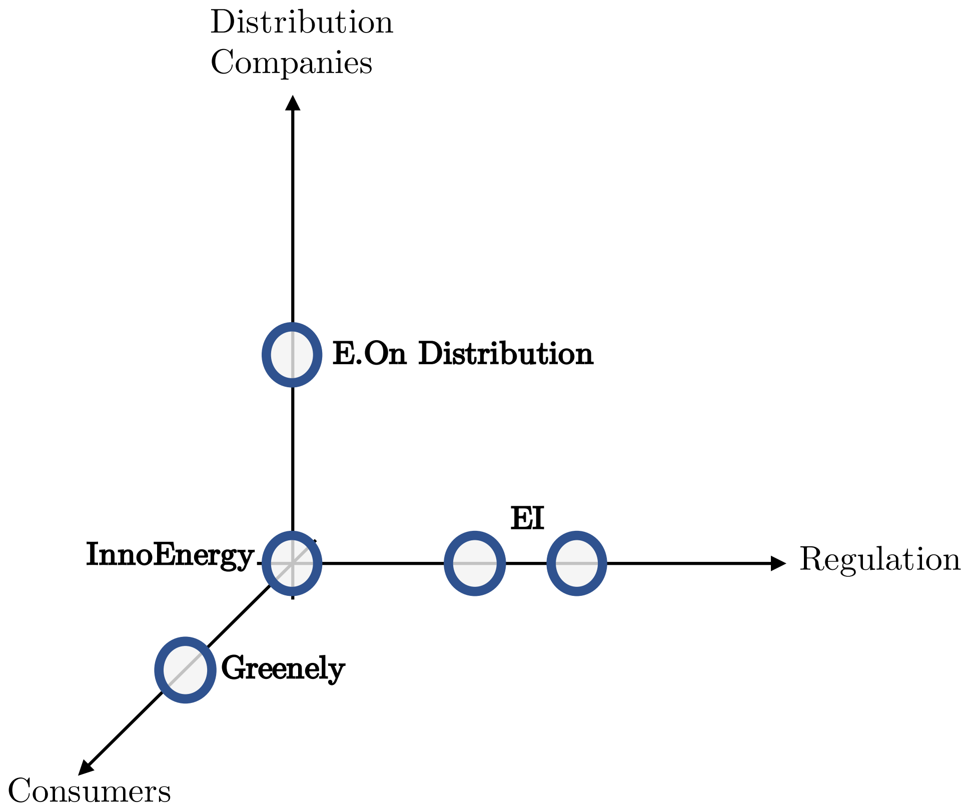

Figure 2.1: *Thesis Dimensions*

The interviews are conducted in a *semi-structured* manner. This means that the six topics of interest are touched through guidance by particular questions by the interviewer. However, sufficient freedom is left to the respondents to contribute from their experiences with some particular input, which is explicitly encouraged at the beginning of the interviews. Sometimes, respondents are not sufficiently acquainted with any of the three dimensions in case that these were not their core activity. In that case, their input on these particular topic is discarded. Taking this limit into account, the interviews do however aim at a maximum overlap within the topics to provide as many inputs as possible for each individual topic.

Besides, the primary research to the Swedish experience is complemented by attending one day of the *Nordic Clean Energy Week 2018* in Malmö (Sweden), participating in interactive sessions and speaker sessions, in order to complement the information from the interviews. The sessions followed are:

- *"Exploring the limits of solar power in a future sustainable city"* by **City of Malmö** and **Klimatkommunera**
- *"Driving change towards clean and climate friendly transports"* by **E.ON**
- *"Intelligent Market Design – Boosting Global Smart Grid Deployment"* by **ISGAN** and **Swedish Smart Grid**

Finally, all of the above is complemented and compared with secondary research from literature of different kinds. Most of the literature studied is of academic origin or is a work published by a relevant company or international institute.

For the second research question the differences in boundary conditions for each of the dimensions of regulation, consumers and distribution companies between Sweden and India are to by studied. Data for this is largely collected through secondary research. In order to build strong comparisons between the two contexts, a significant part of the data collected for this section is of a quantitative nature, taken from official sources or academic literature. This is complemented with qualitative data from several secondary sources. Finally, also on the side of India an interview is done with the following person:

- **Project Manager** for **Fortum Sweden**
  Employing around 8000 people, Fortum is one of the three leading energy utilities in Sweden and is also active in Finland. They provide electricity to around 2,5 million of the consumers in the Nordic region. The respondent is active for Fortum's innovation accelerator. They are currently working on the project Solar-to-go, that focuses on smart metering for mini-grids in India.

2.4 Data Analysis

For the first research question the answers of respondents are collected per topic. The selection of these is done according to research questions mentioned above, resulting in the following key points in the results section:

(i) Consumers
   - Current consumer interest
   - Barriers and incentives for consumers
   - How to enhance consumer interest in the future

(ii) Distribution Companies
   - Current interest of distribution companies
   - Internal incentives and barriers for distribution companies
   - Regulatory Incentives and barriers for distribution companies

On each of these six topics, the experiences of the several respondents is assessed, taking into account their background and expertise. That implies that all the different inputs are maximally incorporated, but that somewhat more weight is given to the opinion of experts in topics that were directly in their field. The strength and credibility of some of the inputs is analyzed or put into the context of the specific respondent. In this, it is particularly important to find the true answers from the

Smart meter involved party	Indicators for Transferability
Regulation	• Actors of the regulated market • Regulatory structure and responsibility • Jurisdictive power of regulation • Tariff determination
Consumers	• Residential DR capability • Electricity cost in residential expenditures • Economic DR incentive
Distribution companies	• Network responsibility • Smart grid incentive: long-term • Smart grid incentive: short-term • Technological and Financial smart grid capabilities

Table 2.1: *Indicators for comparison between Sweden and India*

different perspectives from which it is perceived by the different respondents. From this, conclusions of two types are made. Firstly, direct implications based on the answers collected are given. The topics on which the respondents agree are naturally those that lead to the stronger. On other topics, respondents give answers of a different nature or do not agree with each other. In this case, the topic merely limits itself to the discussion of the visions given. Secondly, an evaluation of the different inputs collected is performed on a more holistic way, that is analyzing the different experiences from a broader and systems approach. In this part, a reflection is given not only through the eyes of the respondents but also by assessing the specific responses from a meta perspective, taking into account the background of each. These are discussed as a second section.

For the second research question the data analysis methodology used is straightforward and intuitive although systematic. For each of the dimensions, a set of key indicators specifically relevant for the particular dimension is defined. By subsequently analyzing each of the indicators, a systematic comparison of the selected boundary conditions is made. On the one hand, this allows for a far better understanding of the Swedish experiences, barriers and incentives that were concluded in the first chapter. On the other hand, the aim is to study to whether and if so to which extent the conclusions from the Swedish case can be expected in the Indian situation, presuming that this boundary conditions are sufficiently comparable. Table 2.1 shows the sets of indicators chosen. Based on an independent analysis of each, a final evaluation of transferability and expectation for India is concluded for each of the three dimensions. For each of the sections, the results are discussed in the order given according to the indicators and comprehensively given at the end of each section.

Chapter 3

Literature Study: smart meters in Sweden and India

3.1 Smart meters: the case of Sweden

3.1.1 Drivers for implementation

Price increase after electricity market deregulation

Smart meters were introduced in the market as an indirect result of a mandate by the Swedish government in 2003. This decision was not driven by smart grid incentives but merely by other projected social and economic benefits that were identified. In 1996, Sweden deregulated the electricity market. Transmission and network access were still regarded as natural monopolies due to the large fixed capital cost and therefore these were kept as regulated monopolies through concessions. Competition was only introduced in electricity generation and trading. The initial aim of this decision was to make the market more efficient i.e. a greater freedom of choice for consumers resulting in decreasing costs and prices for final electricity supply (Swedish Competition Authority, 1996).

However, although the number of distribution companies soared after the deregulation making the market competitive, the largest share of consumers was still served by the three dominating utilities: Vattenfall, Eon and Fortum. Besides, there was a requirement that changing supplier was only possible if hourly metering was installed. This created a major barrier for the many residential consumers that would need to install an expensive new meter in order to be able to change supplier (Mannikof and Nilsson, 2009). The deregulation was therefore not effective in bending the price curves, and by 2003, residential electricity prices would already have gone up with another 40 % compared to 1996 (Swedish Energy Agency, 2015). Sweden's electricity consumption is very high compared to other European countries. Apart from an energy intensive industry, for the residential and commercial side this is mainly due to the long and cold winters combined with the large penetration of electrical heating and heat pumps (Van Geenhuizen et al., 2010). This implies that electricity consumption already had a significant share in Swedish households' spendings. Additional legislative measures were therefore needed to change the situation that prevailed after the deregulation to resolve the flaws in the system and enhance competition.

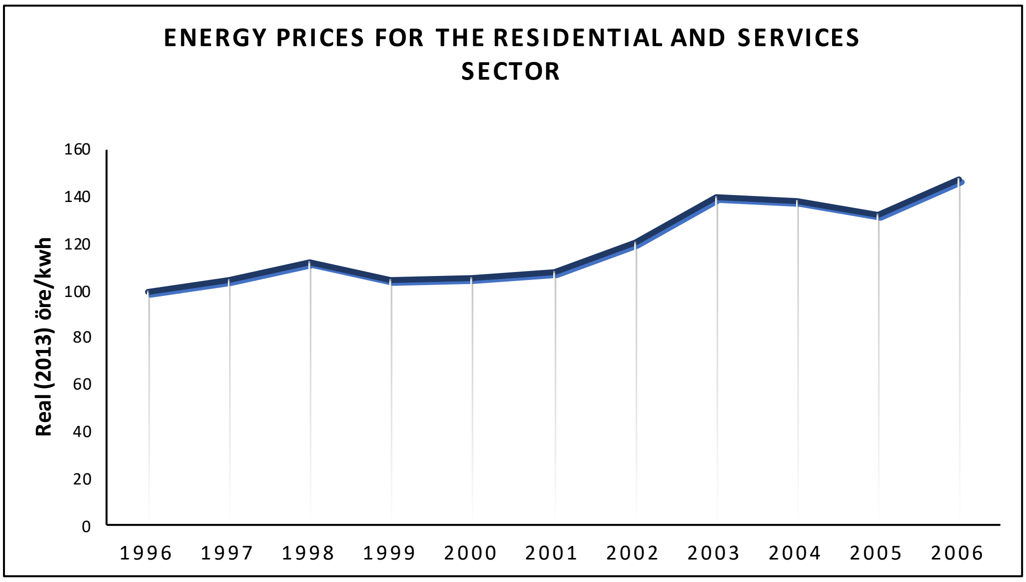

Figure 3.1: *Energy Prices for the residential and services sector*

Consumer dissatisfaction

The electricity billing system that was generally in place in Sweden before 2003 used the consumption data of the previous year to estimate monthly consumption for the current year. The latter is then used to generate the monthly invoices for electricity consumption. At the end of the year, a settlement was made by comparing the estimated and actual consumption, resulting in an additional invoice or remuneration (Morch et al., 2007). The billing system generated a lot of criticism from the residential electricity consumers, mostly about (1) inaccurate invoices; (2) Data errors during switching; (3) Long settlement periods resulting in large invoice at once (World Energy Council, 2013) ; Zhou and Brown, 2016). Different consumer organizations were therefore pressuring demanding for an improved billing system (Morch et al., 2007). The widespread dissatisfaction among consumers about energy utilities at that time is illustrated by the results of a public survey conducted in 2003, the year of the mandate. It turned out that the three major players (Eon, Vattenfall and Fortum) were the most unpopular public services of all, even outperforming the police and the national tax office (World Energy Council, 2013). It was clear that additional measures from the Swedish government were necessary to assure improved utility services in the future.

Monthly metering Directive

Driven by the aforementioned market failures and consumer dissatisfaction, political support for smart metering in Sweden was growing. On top of that, at the end of 2002, the Swedish Energy Authority presented a study that predicted 600 million SEK of annual benefits for the Swedish economy by more frequent readings. This gains would come mainly from reduction in energy consumption and reduction in the costs of the utilities (Van Geenhuizen et al., 2010). For this reason, in 2002 proposition 2002/03:85 was filed by the Swedish Government, passed in 2003:

"In order to facilitate supplier changes and give electricity customers a more direct connection between consumption and billing, the government has passed a decision to introduce monthly metering of electricity usage among all electricity customers by 1 July 2009. Within the given timeframe, the network companies are free to decide the pace of implementation. The cost of the reform is estimated at around SEK 10 billion (€1.1 billion) and will be paid for by the end consumers." (Persson and Pagrotsky, 2003)

Some of the direct key objectives of the proposal were (Widegren, 2013 ; World Energy Council, 2013):

- More accurate monthly electricity bills instead of estimated invoices
- Improve data handling between DSOs and electricity retailers during consumer switch
- Enhance competition in the electricity market
- Encourage behavioral changes resulting in increased energy efficiency due to greater awareness of consumption

In order to reach these goals, the Swedish government only mandated monthly meter readings. There was no obligation for the utilities to implement smart meters. Utilities decided themselves to automate meter readings since it was economically beneficial over manual monthly meter readings. In conclusion, one can see that the foundations of the smart meter implementation were other than smart grid strategies, it was merely driven by social issues that occurred in the prevailing system and identified economic opportunities in the proposal.

3.1.2 Deployment of the smart meters

"Smart" meters?

The Swedish Government did not directly mandate smart meter implementation in any way. Following the legislation, by July 1, 2009 all of the 5,2 million connected consumers must have monthly meter reading. The responsibility for implementation was given for a 100% to the grid operators over a time frame of 6 years (Söderbom, 2012). The cost for the installation of the metering and communication technology would initially be totally covered by the grid operators. Generally, the latter would not perform the installation themselves and instead many contracted specialized companies to do the actual installation on the field. This was a very large investment for the DSO (Persson, 2013). Eventually, it was allowed for the DSOs to recover their expenses for the implementation by an additional network. In this way, the final cost of the smart meter deployment would be paid by the end consumers. This was deemed fair since the latter would benefit by accurate invoices (Vaasa ett, 2010).

This set-up implied that each DSO independently decided to automate meter reading instead of manual monthly measurements. Studies and cost-benefit analyses were performed and showed that the financial benefits of this for utilities should be generally significant for utilities compared to the old system (Andrésen, 2009). The weak nature of the policy also gave the DSOs the freedom to choose the most convenient and beneficial implementation means for their specific business model. With over 200 distribution companies present at that time, numerous different technologies and smart metering systems with varying levels of functionality were installed (Andrésen, 2009). For an illustration of a business case comparing manual and automated monthly reading for one of the biggest utilities Vattenfall is referred to Söderbom (2012). The a priori results were –both financially and non- financially - clearly in favor of automated meter reading.

Another implication of the lacking policy for minimum smart metering requirements was that investment decisions were solely based on the utilities' strives for maximum profit while complying with the legislation (Vaasa ett, 2010). Therefore, initially only meters with very basic capabilities were installed supplier (Van Geenhuizen et al., 2010); AMR technologies that could only communicate in one way from the consumer to the energy. The usefulness of two-way communication was valued not worth the cost of more expensive meters – advanced pricing and feedback programs was naturally not possible with the installed technology. Measurements were delayed and no real-time information could be given to consumers. This illustrates the fact that the possibility to use smart meters to facilitate today's smart grid strategy was completely overlooked by the Swedish government (World Energy Council, 2013).

Market drives advanced metering

While the first smart meters had very basic functionalities that hardly went beyond basic ARM capabilities. Although retailers had interest in additional functionalities that allowed pricing and feedback programs, the investment decision was solely taken by the network operators who did not benefit from these features. However, due to the large-scale deployment, the meter manufacturing sales and marketing activities exploded. During the first years of after the legislation, the technologies available improved rapidly, including more functionalities, while the price of the devices decreased (Persson, 2013). By the deadline for actual implementation, the majority of the meters installed had the possibility for two-way communication

(Andrésen, 2009). Most newly installed meters also have two-way communication as well as more advanced capabilities (Van Geenhuizen et al., 2010). One can conclude that even with a lack of restrictive policy requirements, the smart meter market independently evolved to better technologies. Hereby it was driven by both the meter supply side as well as the demand side by economic benefits that grid operators identified in more advanced, smart meters.

However, by 2014 only roughly 20% of the installed meters was capable of measuring with hourly precision (NordReg, 2014). The remaining 80% only had the ability to measure with monthly precision. Although this complies with the legislation of 2003, this is a large barrier for an effective working of energy efficiency and demand response programs that are part of the general smart grid strategy. For this reason, Sweden is considering a second wave roll- out in the near future although the situation is moving slowly. The installed meters from the first wave in Sweden have a lifetime of around 10 years so replacement should happen around 2020. The Swedish Energy Markets Inspectorate is currently working on a proposal list with functional requirements for new metering infrastructure (Ryberg, 2017).

3.1.3 Evaluation of smart meter deployment

This section will make an analysis of the implications of the smart meter deployment for all the stakeholders involved, generally structured according to the power supply chain, with an additional section for external societal benefits. Since Sweden is at present among the most mature developed countries in the smart meter implementation process, it is useful to study the impact for this specific case. It can serve as an illustration and point out pitfalls and lessons learned.

Table 3.1 gives a summary of the main conclusions. For the table sections that are denoted as "not identified", no relevant direct information could be found in the literature that was used. The discussion that follows will elaborate on each of the identified impacts for each stakeholder. Generally, smart meters have to potential to bring value in all parts of the supply chain (Capgemini, 2008). One can notice that there is no clear answer to whether the overall evaluation of the smart meter deployment in the specific case of Sweden is positive. This is due to the many actors involved, non-financial benefits and externalities and potential (future) spillover effects. Although several financial and non-financial results can be identified, the conclusion on the success of the decision is therefore not unilateral.

Generation

The power production side is least impacted by the deployment of smart metering on the downstream side of the power supply. They are not involved in any investment regarding smart meters. Demand response programs are a vital aspect in supply and demand balancing and a key enabler of modern, renewable electricity generation (International Energy Agency, 2011). Advanced smart meters do facilitate this

	Generation	Grid operators	Retailers	Consumers	Externalities
Net Financial Result	Not Identified	Positive	Positive	Negative	Not Identified
Non-Financial result	Positive	Positive	Positive	Positive	Positive
Most significant gain	Improved long-term planning	Lower operational costs	Lower customer service cost	Improved billing process	Increased energy eficiency
Most significant loss	Not identified	High initial CAPEX	Not identified	Increased network tarrif	Risk of data integrity

Table 3.1: *Summary table of smart meter deployment on all stakeholders in Sweden*

and would thereby largely impact the generation side. As mentioned earlier, the majority of the currently installed meters in Sweden however do not yet include the frequent measuring features. The major vertically integrated utilities in Sweden could potentially benefit from an increased data availability. This allows them to identify energy consumption trends and anticipate future investment.

Grid operator

Costs: Over 200 distribution companies existed around the time of the mandate, varying from very big to very small. The monthly measuring obligation implied a serious investment that was especially was a barrier for smaller DSOs. The total cost of implementation is uncertain and is estimated €1-1,5 billion, all of which comes down to €190-290 per installed meter (5,2 million meters installed) (Swedish Ministry of Enterprise, Energy and Communications, 2010). While assessing these values one needs to keep in mind that both the costs and the benefits will be highly unevenly distributed among the stakeholders, as was predicted in the cost-benefit analysis prior to implementation (International Confederation of Energy Regulators, 2012). The smart meter installation and running costs are largely influenced by the choice of communication solution and the functionality of the meters (Persson, 2013). A survey by Andrésen (2009) to 15 Swedish Utilities indeed confirms a large variation in the final costs of implementation for each.

As stated in the mandate however, the final costs of the smart meter deployment in Sweden would be borne by the end consumers. Cost recovery of relevant and cost-efficient investments by the DSO is organized in Sweden through network-tariffs. The sum that a DSO is allowed to charge was ex ante regulated after 2012 – the Swedish Energy Markets Inspectorate decided the allowed network-tariff for the next four years, based on cost data that the DSO provided (International Confederation of Energy Regulators, 2012). This will be discussed in more detail in later parts of the report.

Direct Financial Benefits: Globally there are considerable indicators that smart meter technology can potentially make a positive business case. A study by King (2012) of 30 large- scale smart meter projects, of which most at utility level, showed that the net present value over the meters' lifetime of the benefits was around two times that of the costs. Indeed, also in Sweden many DSOs concluded that smart meters led to financial benefits (Widegren, 2013). They mainly benefit from increased back-office efficiency resulting in lower own costs and cost of customer service (Vaasa ett, 2010).

As an illustration on the potential impact, Vattenfall publically revealed their estimations on the impact of the smart meter deployment, which they conclude to be financially positive. Being one of the major utilities, with a market share of about 17% of smart meters installed in Sweden, they estimate up to €12 savings per installed smart meter each year. Most of this comes from decreased non-technical network losses (electricity theft, broken meters, poor data quality...) and would also involve additional measures to improve the process. Savings on metering expenses would account for the second biggest benefit, though significantly smaller than the first. Savings on the latter are mainly caused by (1) direct decrease of reading cost; (2) savings on move in/ move out or supplier change reading; (3) reduced costs for customer service. For more details on the case of Vattenfall is referred to (Söderbom, 2012).

Indirect Benefits: Apart from the aforementioned impacts for grid operators that have a direct and visible impact on their cost structure, smart meters also have to potential to introduce some indirect advantages for the companies work. The by far most important aspects are related or consequences of an increased data availability. Firstly, as is the case for the generator companies, grid operators also indirectly benefit from smart meter data for long-term infrastructural investments under uncertainty (Widegren, 2013). Secondly, increased information flows enhance the ability to perform detailed grid calculations. These can help to reduce losses, improve monitoring and control possibilities and help to locate system defaults, mainly on the low voltage side. In this way, both internal technical processes and several types of communication to the customer are faster and of higher quality (Persson, 2013).

Vattenfall identified the most noticeable benefits of this type as (1) increased Quality and Customer Satisfaction (2) Reduction of environmental impact and (3) Safety (Söderbom, 2012) However, because of the qualitative nature of this indicators in the analysis, it can be questioned to which extent these goals were actually reached.

Retailers

The evaluation of monthly metering for retailers is financially positive. They are not required to make additional investments for the metering infrastructure, they do however get access to the data that these meters produce. This implies a major simplification of the billing and customer switching processes. As a direct consequence of this, the number of customer complaints dropped. Eon even declared a drop of 60% in customer invoice complaints, 8 months after the roll-out. In this regard, retailers save a significant amount on expenses for call centers for customer service (Vaasa ett, 2010)

Consumers

Being the target group of the initial governmental mandate, there were several proposed benefits for end-users in the form of improved processes and customer service. Referring back to the drivers of implementation, consumers now indeed have more accurate electricity bills and avoid large invoices and the end of the settlement period as they did before. Supplier switching is facilitated and the Swedish people made use of this option very frequently: around 10% of residential consumers change supplier per year (World Energy Council, 2013).

The smart meter deployment did increase the awareness of energy consumption in Sweden (International Confederation of Energy Regulators, 2012). One of the reasons for this is a direct result of the monthly billing. Electricity bills are now based on actual consumption during the past month, which implies that invoices in (cold) winters can be very high while summer invoices are lower. This has been serious financial burden for low income families (Vaasa ett, 2010). In consequence, residential users are now more aware of their consumption and the energy market.

Apart from this increased operational convenience however, overall one concludes that the impact on the consumer side regarding demand side management is still limited and uncertain. A case study performed in Västerås by Campillo and Vassileva (2016) showed that information is not detailed enough for customers to react accordingly. Feedback of consumption data is given, but on the one hand does the monthly frequency not incentivize flexibility and on the other hand information is too aggregated to adapt behaviour. Moreover, a survey by Christakopoulos and Makrygiannis, (2012) to 150 Swedish residential electricity users suggests that only 21% of respondents was actually interested in more accurate consumption information, while only 44% knew the answer to whether the meter installed in their home was a smart meter. Therefore, one can conclude that several opportunities on the demand side are still left untaken in the current system. The final cost of smart meters, around €200 in total, is to be borne by these consumers and it is concluded that Sweden will pay quite a lot for not so much functionality (Vaasa ett, 2010).

Since the initial aim of the Swedish government was not driven by any advanced smart grid strategy, it should be no surprise that there are still lessons to be learnt. Furthermore, Sweden's early adopter position explains why the cost for the smart meters is relatively high compared late majority of countries giving green light. The analysis of the consumer impact shows that the initially projected benefits are reached, but that additional measures can increase the effect.

Externalities

According to the study from EPRS (2015), smart meter deployment in Sweden has introduced an overall energy saving of 1-3% by higher consumer awareness. This is considerably less than the 5 % savings that were suggested in earlier studies from Darby and Strömbäck (Bergendorff, 2009). According to Vaasa ett (2010) the environmental impact is rather limited, although the truth of this kind of statement remains very hard to validate. One of the biggest limitations currently is the human impact and behavioral barriers. Generally, people are concerned about their privacy which leads them to not fully participate and miss some of the benefits like energy saving (Campillo and Vassileva, 2016). Furthermore, consumers still are too unfamiliar with the potential benefits from demand response

3.2 Smart meters: the case of India

3.2.1 Electricity market situation

India is the third largest energy producer globally, with energy production still growing rapidly. 65% of its currently installed capacity is based on thermal generation. 15% is produced by hydropower, and total other renewables (excluding hydropower) have a 18% share in the installed capacity (Buckley and Shah, 2017). Energy demand is increasing at 5% annually. With this growth expected to continue, demand will almost double in the upcoming decade. Driven by high electrification, electricity consumption in India is projected to triple by 2030. It will require a quadrupling of the Indian Power Grid's size by 2040 to keep up with these trends. (International Energy Agency, 2015). India has pledged to meet this increasing demand by mainly focusing on renewable energy and has a target of 175 GW renewable power installed by 2022. Although future electricity provision is projected to remain largely coal-based, the growth of renewable power is significant. It is therefore deemed vital for India's evolution to develop new grid technologies (International Renewable Energy Agency, 2017). This implies both an expansion and innovative design of the transmission and distribution system, requiring an investment program for India specifically of around 200 billion USD to 2030 (Buckley and Shah, 2017).

Through an ambitious plan of policy and reforms, India aims to reach *24x7 Power for All* by 2022. In the energy supply chain –Fuel, Generation, Transmission, Distribution, Consumption- the distribution companies are identified as the weakest link. That is, the financial situation of the latter is highly problematic, causing barriers to reach the targets. Figure 3.2 from (Saath and Vikas, 2015) based on audited accounts shows the yearly losses by distribution companies in crore (10 Million) Rs.

Accumulated debt of distribution companies of only the past 6 years accounts 3,6 Trillion Rs., which is equivalent to around 290 Billion USD. One of the major sources of this is the operational inefficiency. The difference between average revenue and costs for distribution companies is negative, leading to increased losses on every unit sold, as can be seen in Figure 3.3, taken from (Buckley and Shah, 2017). Until recently, distribution companies were trapped in these debts since interest rates can amount up to 15%. The Government of India (GoI) has therefore intervened by taking over shares of the debt and in parallel launching drastic reform plans. By doing this, it aims to lead the distribution companies to a sustainable financial situation so they can contribute to the long-term goals.

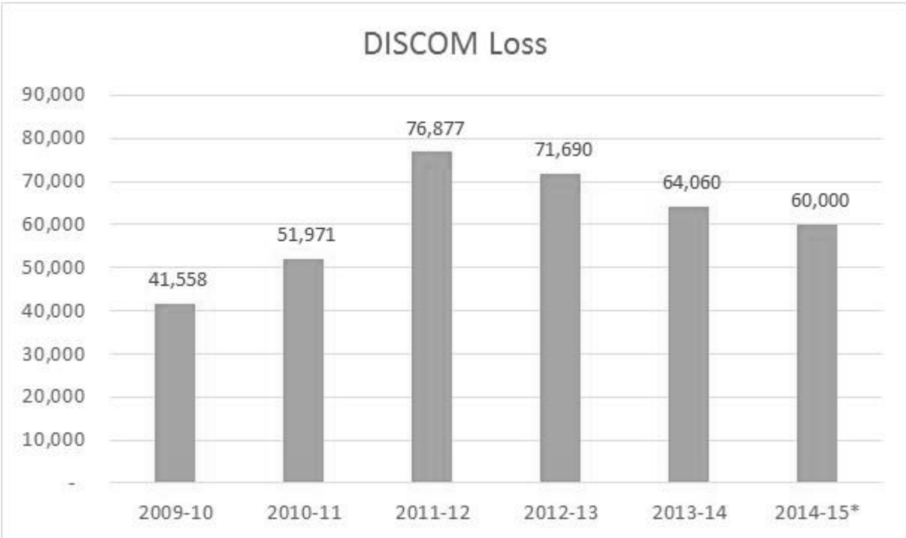

Figure 3.2: *Financial losses of distribution companies in India*

Source: Saath and Vikas, 2015

In 2015, the scheme *Ujjwal Discom Assurance Yojana* (UDAY) was initiated. The program had several targets that directly impact the profitability of distribution companies (Buckley and Shah, 2017):

1. *"To remove the gap between average cost of supply and average revenue realisation, thereby creating a positive incentive for distribution companies to sell electricity and creating positive retained earnings to fund investment in distribution networks.*

2. *To improve operational efficiency by reducing aggregate technical and commercial (AT&C) losses, that is, losses due to electricity theft, thereby lowering the cost of doing business for the distribution companies.*

3. *To formally bring onto state government balance sheets previously undisclosed, off- balance sheet distribution company debts, improving transparency and accountability.*

4. *To lower the cost of servicing these companies' debts".*

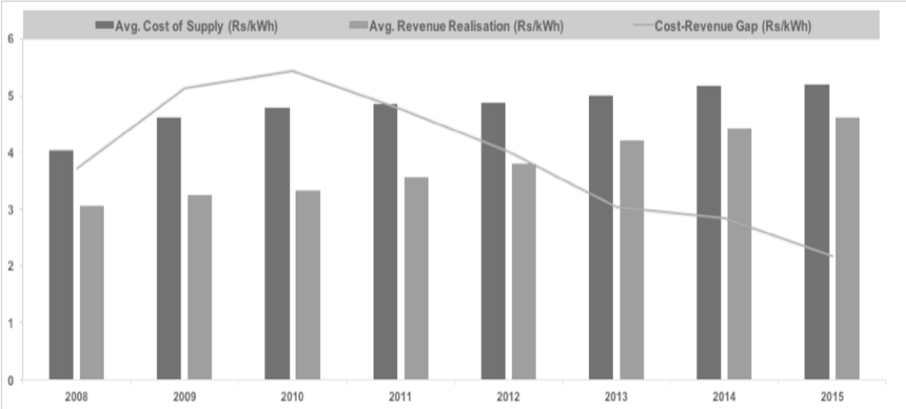

Figure 3.3: *Cost-revenue gap of distribution companies in India*

Source: Buckley and Shah, 2017

3.2.2 Opportunities for smart metering

One of the main drivers of the financial issues of distribution companies in India is the tremendous rates of Aggregate Technical and Commercial Losses. On the one hand, this indicator aggregates all technical losses caused by energy conversion and transport. These are inherently connected to physical system design and network specifications and are the results of physical properties. To some extent technical losses are therefore unavoidable although optimization is oftentimes possible. Non-technical commercial losses however arise from operational deficiencies. Commonly occurring types of commercial losses are:

- energy theft
- meter tampering
- non-payment
- inadequate revenue collection
- inefficient billing

In India, energy theft is a major contributor for non-technical losses, being the source of 16,2 Billion USD of financial loss per year, the highest number in the world (Kulkarni, 2017). In 2015 total AT&C losses were 21% on average, compared to 10% for most developed countries (Upadhyay, 2017). It is therefore clear that, in order to assure sustainable financial situations while addressing the key issues in energy provision for the future, measures to lower the AT&C loss are crucial.

Automated Meter Reading (AMR) and Advanced Metering Infrastructure (AMI) are identified as potential contributions in resolving some of the issues that drive today's AT& C loss (PowerLine, 2018). By the installation of reading devices many of the aforementioned issues can naturally be mitigated. Tamper proof automated consumption measurement largely increases the barriers for energy theft, meter tampering etc. Finally, smart meter deployment creates the potential to introduce additional benefits for all stakeholders involved – industry, government, consumers. For the utilities, apart from AT&C, on the cost side it will cause a reduction in operational expenses from meter reading. Furthermore, power factor measurements can result in faster feedback and VAR compensation and therefore improved power quality of supply. The increased data availability will also lead to a better system understanding which is monetized by several indirect operational benefits regarding asset management and optimal utilization e.g. reduced infrastructure overloading or lower default timespans (Hemendra, 2017). Finally, smart meters are a key-enabler of further smart grid strategies as demand response and energy efficiency programs (Sahoo and Vikram, 2017). McKinsey Global Institute (2018) estimates a total potential impact of smart meter deployment in India of roughly 15-20 billion USD by 2025.

It is clear that the business case for smart meter deployment in India is – as in many other countries- merely dependent on the operational business case. However, although many of the suggested benefits are widely known, smart meter deployment in India is still at a very nascent stage (Fernandes, 2016). The ministry of Power has now initiated 14 smart grid pilots deployed by state-owned Indian distribution companies, the majority of which being implemented today. Table 3.2 from A. M. Barua and P. K. Goswami, (2017) gives an overview of the projects that are ongoing.

On the short-term, India has the aim to move beyond these first pilot and demonstration projects that have been deployed recently and to move into a phase of large scale deployment. In spite of the initial stage of the smart meter technology today, India has the highly ambitious vision to install up to 130 million smart meters by 2021 (PowerLine, 2018). In August of 2017, a 500 million USD tendering was launched by Energy Efficiency Services Ltd. to install 5 million smart meters in Haryana and Uttar Pradesh. However, pilot roll-out are still generally only performed by few utilities with available financing and highly dependent on government support (Fernandes, 2016).

3.2.3 Challenges for smart meter deployment

Although first roll-outs are ongoing, smart meter deployment is still merely performed in isolated and fragmented manners (De et al., 2018). That is, several challenges and barriers for full penetration of smart meters in India are yet to be overcome (India Smart Grid Forum and Bloomberg New Energy Finance, 2017; A. M. Barua and P. K. Goswami, 2017; Kappagantu and Daniel, 2018):

(i) **Financial situation:** As stated earlier, in general distribution companies in India have tremendous debts. Although smart meters might be financially beneficial in the long-term, the upfront investment costs are very high. Many utilities have a limited access to capital and high interest rates on borrowed

States	Major Utilities	Date of Award	Sanctioned Cost (Crores)	No. of Consumers
Assam	APDCL SGIA- Phoenix	Mar'15	29.94	15,083
Tripura	TSECL SGIA- WIPRO	Sep'15	24.08	42,676
West Bengal	WBSEDCL, SGIA- Chemtrols	Jun'15	7.03	5,275
Haryana	UHBVNL SGIA- NEDO, Japan	Apr'14	20.07	11,000
Himachal Pradesh	HPSEBL SGIA- Alstom	Feb'15	19.45	1,251
Punjab	PSPCL SGIA- Kalkitech	Mar'15	10.11	2,734
Puducherry	PED SGIA- Dongfang	May'16	46.11	34,000
Karnataka	CESCL SGIA - Enzen	Mar'14	32.59	21,824
Gujarat	UGVCL	July'15	48.78	39,422
Telangana	TSPDCL SGIA - ECIL	Oct'15	41.82	11,904

Table 3.2: *Overview of smart meter pilot projects in India*

Source: A. M. Barua and P. K. Goswami, (2017)

money. Of all challenges, this creates a one of the highest barriers for them to take action for large-scale deployment.

(ii) **Customer engagement:** In order to maximally benefit from deployment of smart meters, there is need for an awareness of the consumers about their energy consumption and about how it is delivered to the homes. Therefore, education plans are needed .

(iii) **Expertise of workforce:** Both on and off the field, smart meters as well as smart grids in general face a lack of educated experts. People working in the system of conventional meter reading must receive appropriate training to fully understand the system of smart metering. That is, installing and operating AMI technology requires a knowledge of three distinct domains: meter technology, telecommunication and digital. Distribution companies naturally have their expertise in the first, but still have uncomplete knowledge in the latter two.

(iv) **Lack of Universal Standards:** As was also the case in Sweden's smart meter deployment, India has made no central standard for smart meters yet. This implies that distribution companies in projects individually decide on technical specifications and features, oftentimes driven by the proposal of the lowest bidder. Not only can this lead to inefficient or unproven technology deployed, the absence of universal standards also can lead to increased costs and increased time-to-market, as illustrated by earlier cases in Europe e.g. Sweden.

(v) **Limited Knowledge and awareness of decision makers:** Regulators and distribution companies are still not fully understanding the entire concept of AMI. Distribution companies are still not incentivized enough to invest in AMI because of the uncertainty in the outcome that is still perceived. Also, mainly caused by the limited domestic smart meter penetration and even few mature cases available globally, information on success cases about AMI deployment is limited. For this reason, decision makers still have unclear pictures of the consequences of the new technology and need to gain better insight to enable decisive action.

Chapter 4

Barriers and incentives for smart meter as smart grid facilitator: the Swedish experience

4.1 Smart Meters as smart grid facilitator

The deployment of smart meters is oftentimes framed within the larger ecosystem of smart grids. Moreover, the numerous smart grid applications are generally given as one of the main drivers to initiate installation of smart meters in the first place. This for instance became clear during the India Smart Grid Week, where Praveer Sinha, CEO of Tata Power Dehli Distribution Limited, clearly stated the importance of the current pilot projects of smart metering in India as a vital step in India's smart grid journey. Another example from the conference is an interview with Massimiliano Claps, Vice-President of global public sector at SAP. He announced that SAP is *working with various utilities to implement smart metering and enhance their capabilities to undertake intelligent demand management"* (PowerLine, 2018). It is indeed generally agreed among energy experts that smart metering deployment is a key facilitator for different smart grid applications. However, in practice it turns out that – as can also be illustrated by the case of the first wave roll-out in Sweden – many other factors are driving this except for these smart grid strategies.

Smart grids are comprised of several aspects and technologies. This report follows the division in smart grid technologies that is suggested by (International Renewable Energy Agency, 2013). On the downstream side i.e. the distribution network, some of these applications are directly linked and would not work without the presence of AMI installed. That is, these are founded on high frequency data availability on the one hand and bidirectional communication and steering possibilities on the other. This section will focus on the smart grid spillovers that can originate from AMI deployment, that can be seen in Figure 4.1. It is important to note that the possibilities for these spillovers are largely facilitated or hindered depending on the specific choice of AMI technology and specifications. Besides, the success of these spillovers is certainly influenced by other socio-economic parameters and the local boundary conditions of the energy system. In what follows, the experiences of Sweden on the impact of AMI deployment on the six smart grid applications of Figure 4.1 will be analyzed. In a second step, it will be assessed to which extent this allows conclusions to be made about the expectations and lessons learned for the ongoing and future Indian smart meter roll-out.

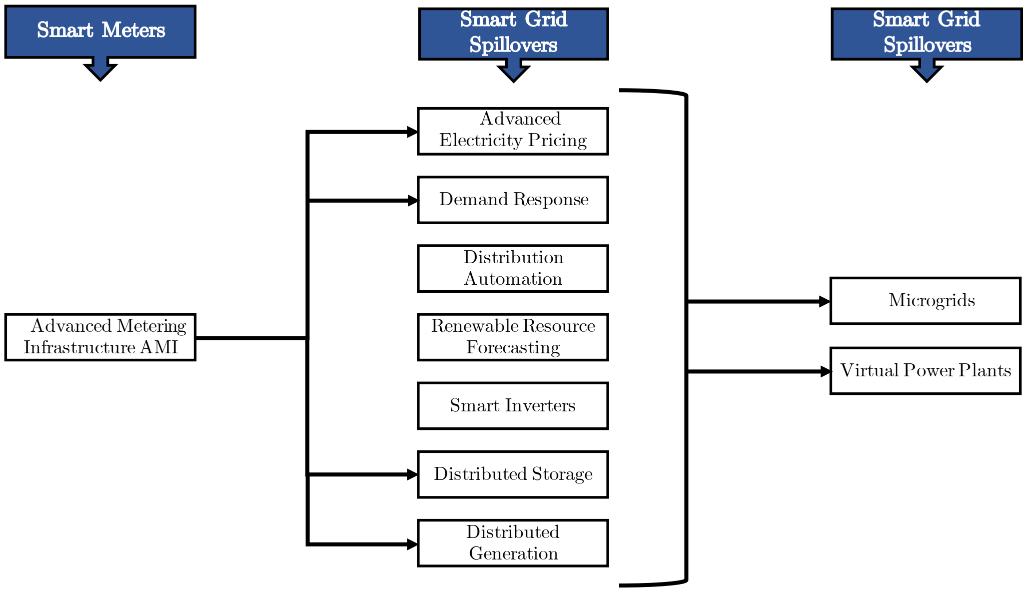

Figure 4.1: *Smart grid applications of smart meters*

4.1.1 Advanced dynamic pricing

Pricing of electricity for end-consumers involves two main parts. Firstly, one is required to pay for the electricity – the current through the wires. This is referred to as *content* and is generally the responsibility of the electricity supplier. Secondly, one there is a fee to the electricity network operators – for the cost of the wires. This is called the *carriage* part of the electricity price. Finally, it is possible that the governments sets taxes to electricity consumption, as is the case in Sweden. The shares of each of these three parts is dependent on the local tariff and taxing system, the type of supplier and network operator contract and the user-specific consumption. For convenience, for a regular household in Sweden these parts can roughly be approximated as more or less equal as can be seen in for instance (Swedish Energy Markets Inspectorate, 2017), although variations due to the above parameters occur.

The content part of a household's electricity bill is currently normally charged through fixed contracts between consumers and a supplier with prices that are adapted every X period, depending on the contract type. However, for the case of Sweden these adaptations are in the order of magnitude of months or years (Campillo and Vassileva, 2016). This is in contrast to the electricity wholesale market where the supplier is required to buy the electricity it provides to its consumers. Prices in the latter are settled each hour depending on the (expected) supply and demand during this time. Dynamic Pricing of the content part of billing implies that end consumer prices are varying according to this wholesale electricity prices. In this way, end-consumers are charged more or less depending on the availability of electricity during the time of usage, so called time-of-use contracts (NordReg, 2015). The introduction of this type of tariff can only happen if electricity consumption is measured with sufficient time-accuracy. Therefore, AMI (or at least AMR) must be installed.

The carriage charge for electricity distribution has generally two parts: one for the connection, which is based on the size of the fuse and called the capacity charge; one for the transmission of energy, based on the total consumption (Svenska Kraftnät, 2011). Note that each of these two parts are integral and do not require time-differentiated measurements. ADP for network tariff could imply the addition of a consumption-based price component. This is reasonable, since the cost of the network owner is dependent on the capacity of the distribution network, which is based on the maximum power to be transported rather than on the energy to be transported. Several options for power based pricing are found in (Rautiainen et al., 2015). However, ADP for network tariff does also require time-differentiated measurement i.e. advanced metering.

4.1.2 Demand response

According to (International Energy Agency, 2011), demand response is the *"the mechanism by which end-users (at the industrial, service or residential sector level) alter consumption in response to price or other signals"*. Basically, demand response (DR) allows to better match electricity production and consumption in the case of variable power production, by adapting the loads to the available power. For instance, generally residential power peaks occur in the morning or at night, while most solar power would be available at noon. DR is the action that adapts the load to better match the power that is available. One can see that this is very closely related to ADP – which is a method to incentivize DR.

It is important to distinguish demand response, hereafter referred to as DR, from energy efficiency. That is, DR has a focus on *shifting* the load in time, by for instance consuming energy when prices are lower, while in the case of energy efficiency consumption is *reduced*. Note that this definition does at first sight not match with the thermodynamic efficiency. It assumes that people reduce their energy consumption while maintaining utility, which is therefore called energy efficiency. AMI might introduce this through feedback mechanisms to consumers (European Parliamentary Research Service (EPRS), 2015). Thus, although both principles can result from AMI deployment, the meter requirements as well as the consequences are different.

DR has several appearances that vary regarding active steering capabilities. AMI is particularly facilitating voluntary load control that leaves the decision of DR to the consumers, whereas load steering or automatic load control through for example frequency-sensing of loads would require more advanced technologies to be installed.

4.1.3 Distributed storage and generation

Distributed energy resources have a great potential in the future electricity system. While distributed generation (DG) as rooftop photovoltaic installations are already growing to maturity, storage today is still mainly performed on larger scale (*bulk storage*) rather than on household level (*distributed storage DS*). It is certainly the case that large scale storage can be a major contributor to the development of a smart grid by providing a buffer for uncertainty and reduce the operational impact of fluctuations (Beaudin et al., 2015). This study narrows down to the distribution low voltage network and will focus on distributed storage, which will in the end fulfill the same duty. High battery prices lead the latter to remain unprofitable on residential level yet and thus are hindering its widespread penetration(Uddin et al., 2017). However, prices of these low power/energy storage are decreasing rapidly and examples as Tesla's Powerwall indicate that residential applications might scale up in the short-term. It is generally accepted that also Electric Vehicles can become established means of distributed storage as well, that through dynamic charging can perform the duty of a battery.

DS can have a plethora of functionalities in a smart distribution grid that go far beyond a function of storage of private generation for later private consumption but that serve the working of the entire distribution grid (International Renewable Energy Agency, 2013). Examples are:

- Frequency control: Peak shaving by providing extra load or generation during periods of excess of the other
- Local grid voltage and power quality control
- Buffering variability of undispatchable generation so as to smooth out
- Back-up power source in short cases of interruption
- ...

From the above reasoning it can be concluded that the benefits of DS can be significant. Installing DS naturally implies an investment of a private consumer. Besides, every singly usage as one of the above will cause a degradation of the material per loading cycle – for instance current lithium-ion batteries can take 300-10000 cycles depending on the quality before they have to be replaced (Beaudin et al., 2015). Thus, smart grid control will be provided as a service that requires a fair compensation. Due to the dynamics and the time-dependency of the value of these interventions, it needs little explanation that time-differentiated measurement is required. Moreover, to reach optimal working also active control or clear incentives will have to be provided, resulting in an absolute necessity for AMI. For distributed generation compensation for produced energy today is generally given independent of the time-of-production, by reducing the cumulative energy consumed for every unit that is given to the grid. This principle is called *net metering*. For this reason, strictly speaking distributed generation can also work without installation of AMI or even AMR technology. They are taken within the scope of discussion following the new role that AMI can play in facilitating solar PV through time-dependent compensation schemes and even integrated production-storage systems in the further future. For illustration of the interlinkage between AMI and distributed solar pv, in the case of Flanders (Belgium) where a first wave roll-out is yet to start in 2019. One of the three first target groups is indeed owners of rooftop pv with the aim of proceeding to dynamic tariffing soon (De Vlaamse Overheid, 2018).

4.1.4 Microgrids and virtual power plants

Microgrids are relatively small electric grids that can operate fully autonomously. On the one hand, microgrids can normally operate as a normal subsection of a larger grid, but in certain circumstances be able to fully disconnect and nevertheless provide power to its loads. On the other hand, they can be implemented in remote regions out of the reach of large grids to provide electrification.

Virtual Power Plants (VPP) are collections of energy generators, loads and potentially storage facilities that are individually not sufficiently large to participate on the wholesale electricity market, due to the principle of minimum power bids. The operators of VPPs, called *Aggregators*, aggregate several small actors to make them significant on the electricity market. At the same time, it allows for the smoothing of power by means of flexibility provided by each of the actors.

As is illustrated in Figure 4.1, microgrids and VPPs are concepts that rely on several other smart grid applications in order for them to work. The extent of smartness to which this is the case can vary significantly. For instance, the easiest form of a microgrid would be a remote village that is powered by its own diesel generators, which is only based on Distributed Generation and Automation through some voltage and power quality control techniques. On the other side of the spectrum, in January 2017 the European Union launched the six Interflex projects that investigate stand-alone working including distributed generation, energy storage, electric vehicles, demand response and distribution automation. Founded on these building blocks that require AMI to operate as was elaborated in the previous subsections, these advanced types of microgrids are indirectly though absolutely dependent on AMI. An analogous reasoning can be made for VPPs, that indirectly rely on smart metering as well.

4.2 Barriers and drivers in Sweden

This chapter will study the experience of Sweden with smart meters following a multi-stakeholder approach. It will be divided according to the three most important actors in the discussion, being the regulator, the distribution companies and the consumers. It will be mainly based on the interviews that were performed, for which is referred to the methodology part or the appendices. As a first step, the most important contributions from each of them will be given sequentially, complemented with a reflection on the situation the specific actor. In a second step, the total smart meter ecosystem will be discussed, identifying the key barriers and opportunities for Swedish smart grid usage of smart meters in a holistic way, from which some suggestions will be made.

4.2.1 Relevant regulatory developments

Regulation in Sweden, the Energy Markets Inspectorate (EI) in particular, has had a leading role in the entire process of smart meters in Sweden so far. That is, they have been at the basis of all of the most important steps that have been taken, as well as the ones to be taken in the very near future. A short overview of the influence of EI is given below.

- **2003:** Proposition 2002/03:85 was passed in the government that mandates monthly metering to be obliged for all residential consumers by 2009. Although the first usage of the term smart grid dates several years after the bill was passed, this mandate has been the trigger for the first-wave of smart meters in Sweden. For more information about this is referred to the previous chapter.
- **2012:** Distribution revenue regulation is changed from ex-post to ex-ante with a time horizon of four years. The main drivers for this were the aim to avoid complexity and unpredictability of an retrospective system, in which only impermissible charges were penalized after investigation of EI (P. Finnström, 2013). The relevance for smart meter deployment is twofold: firstly, distribution companies were allowed by EI to include the smart meters as a part of the asset base. This provided the capability for the costs of the deployment to be reimbursed and finally to be borne by the consumer. Secondly, it provided a first step towards the more incentive based revenue scheme in the next regulatory period. The tariff framework for the period 2016 to 2019 was concluded as is given in Figure 4.2, taken from (Wallnerström et al., 2016).

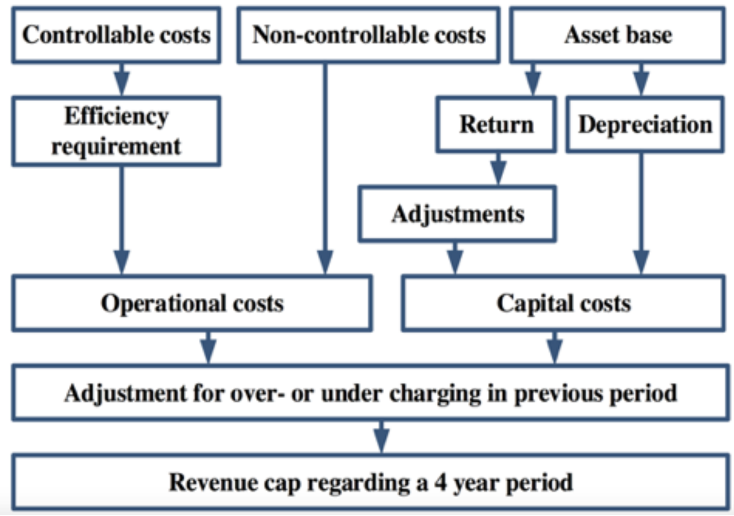

Figure 4.2: *Overview of the Swedish revenue cap framework after 2016*

Source: Wallnerström et al., 2016

- **2016:** The tariff regulation was adapted to provide quality incentives to the distribution companies, that reward peak shaving and reduced system losses. Figure 4.2 includes a section for so-called Adjustments. Here, two potentially very important incentives that can contribute to enhanced demand flexibility were included in the new regulation. They are implemented in the revenue cap calculation by introducing an increase or decrease to the cap that was oringally reached based on the other factors. The maximum impact of these measures is also capped at 5% of the revenue cap. The two incentives are:

  (i) **Reduced internal losses:** The total cap adaptation Kn is dependent on the difference in percentual loss Nf; the total energy E transported in the network; the average electricity price P during the regulatory period, as
  $$K_n = 0,5 * (Nf_{norm} - Nf) * E * P$$
  The correction factor 0,5 is to be interpreted in a way that half of the financial benefits created by efficiency improvements of the distribution companies are given to them, while the other half is given to the consumers through a non-raise of the cap. Nevertheless, distribution companies are now both internally and externally benefitting from reduced losses. The incentive of this to initiate demand response is to be put in context since it is only one of several ways how to reduce internal losses.

  (ii) **Peak shaving:** The total cap adaptation Kb is dependent on the average load factor Lf; the saving of DSO from grid fees per MWh B; the total energy E transported, as:
  $$K_b = Lf * B * E$$

- **2018**: EI has suggested a final list of requirements to the Swedish government, at request of the latter. The list is the result of two studies carried out by EI, and it is to a large extent based on the guidelines of the European Union about the functional meter requirements. The list will be enforced by the Swedish government in the summer of 2018 and the functionalities will be mandatory for all residential electricity meters from 2025. Table 4.1 shows the list of requirements, from (Swedish Energy Markets Inspectorate, 2018).

Suggested Metering Functionality	Purpose
The meter should for every phase be able to measure voltage, current, active and reactive power for withdrawal and input of electricity. The meter should also be able to measure and register the total energy for withdrawal and input of electricity.	Promotes efficient network operation. Facilitates integration of micro production in the network.
The meter should be equipped with a customer interface, supported by an open standard, for the customer to be able to take part of the measured values (see functionality no. 1) in near real time. It should not be possible to send information to the meter through the interface. The interface needs to be activated by the DSO, on request by the customer, to provide information. The DSO should control the identity of the user and must deactivate the interface when the customer moves out.	Creates conditions for a developed energy services market. Promotes demand side flexibility and energy efficiency. Increases customer empowerment.
The DSO should be able to read the measured values (see functionality no. 1) remotely (with remote control).	Promotes efficient collection of meter data.
The meter should be able to measure the energy for every hour and be able to convert to measure the energy for every fifteen minutes.	Increases the customers possibility to be active (participate) in the market.
The meter should be able to register data about the beginning and end of a power outage in one or more phases, that is three minutes long or more.	Facilitates for the DSOs to pay compensation to the customer for interruptions longer than 12 hours and to report data to Ei. Empowers the customer.
The DSO should be able to update software and change settings of the meter with remote control.	Provides that new functionalities can be introduced in a cost-efficient way. Expensive field visits can be avoided.
The DSOs should be able to turn on and off the power through the meter with remote control. This requirement only applies for meters that are not transformer connected.	Facilitates for the DSOs to turn off the power if the customer moves out. Expensive field visits can be avoided.

Table 4.1: *Suggested functional requirements in EI R2017:08*

4.2.2 Results from the interviews

This section will describe the experience of Swedish smart meter deployment and its consequences for residential smart grid applications, from the perspective of different Swedish energy experts. Reflecting a decade after the first wave roll-out and at the verge of the enforcement of the new legislation, the responses of the interviews give insight in the Swedish goals for the further development of smart grid applications and as a result of this the role that Sweden can play in this field globally.

The results are presented according to six selected topics from which relevant experience was to be deducted from sufficient respondents during the interview. They will be structured in the following manner:

(i) Consumers
- Current consumer interest
- Barriers and incentives for consumers
- How to enhance consumer interest in the future

(ii) Distribution Companies
- Current interest of distribution companies
- Internal incentives and barriers for distribution companies
- Regulatory Incentives and barriers for distribution companies

The results will be limited to describing overall conclusions that can be drawn from the interviews, guided by some interesting citations. For the relevant answers of all of the respondents following the same structure as the above is referred to the appendices. It can be noticed that for some subjects there was a large similarity and coherence in the respondents' input, which leads to the stronger of the conclusions. For other subjects, the spread or interpretation of the topic was distinct, presumably driven by the different background from which the respondents were speaking about the issues touched. Finally, there are topics on which (at least some) the respondents did not agree. The following section will shed light on the different views that were put forward, and afterwards a discussion of the most important lessons learned from a more holistic point of view.

Current consumer interest

All of the respondents except for one perceived the interest of consumers in participation in demand response applications as very low. Two out of them referred to the fact that the main driver for this is a lack of awareness. To the contrary, the respondent from Greenely was convinced that consumers can be interested. One interesting comment that he gave was:

“I would say that peoples’ awareness has increased. ***A lot of people do not even care when they start, they just try it.*** *And* ***when they start seeing the data****, they think "wow" and so* ***they gain interest from getting feedback*** *[...] The people you hear that say that consumers are not interested in flexibility or demand response are the same that would say that consumers are not interested in looking at their own data. Greenely is the only company in the Nordics that is doing things in this way, so I would say we have more knowledge about that than any other stakeholder.”*

From the above citation can be concluded that he also suggested that consumer interest is a priori low. From his experience, consumers gain interest from using a feedback application like his that informs them about their electricity consumption. On the one hand, of all respondents the one of Greenely can be expected to have the well-founded opinion that is based on a closer connection to the specific topic of interest – the consumer – which he also used as an argument for the trustworthiness of his believes. On the other hand, it is plausible that, since he is a stakeholder that is more directly involved and would directly benefit from the above to be true, his opinion loses objectivity.

Finally, one should take into account that the respondent with a positive answer and the others with a negative were not basing their conclusions on an identical statistical population. That is, the respondent from Greenely spoke about his experience on the users of his application (15 000 in June 2018), while the others werr speaking about the several million Swedish residential consumers. Therefore, it is certainly possible that all of their statements hold, but that general consumer interest in Sweden is still very low. Finally, in (Fortum, 2017) is stated that the biggest barrier for smart home solutions is the behavior of consumers. Also given the bold part of the citation, it seems like the most likely conclusion that consumer interest is low.

Barriers and incentives for consumers

As mentioned in the previous subsection, even a decade after the finalization of the first wave roll-out, awareness was seen by some of the respondents as a potential barrier for consumer participation in Sweden. Besides, two of respondents mentioned that there exists a group of consumers that are environmentally concerned, while only one of them thought that this might lead to active participation. All of the respondents believed that the potential financial benefits are the main incentive for residential consumers to participate in demand response programs. At the same time, they identified the fact that the current electricity prices in Sweden are too low to incentivize participation of the consumer sufficiently as the main barrier from a consumer perspective.

Two of the respondents suggested that a second barrier that induces low participation is the lack of proper services that interact with consumers. The respondent from InnoEnergy states that there are certainly positive business models present today for residential consumers in Sweden to participate in the market, merely but not solely in the regions where some form of dynamic pricing is present. He said:

*“**Even if they [consumers] are to some extent aware of the existence of hourly prices** - the fact that there is a costly hour and a cheaper hour- **then still they are not aware of the existence of these innovative business models**. People do not see the bigger picture, you need more people pushing the business models that can come from these smart meters.”*

In conclusion, the challenges to overcome in Sweden on the consumer side, according the interview results, are twofold. Firstly, in order to promote further consumer participation, it is needed to further increase awareness of consumers. Secondly, the financial incentive must be larger to really create an incentive. Market dynamics can potentially play a significant part in this.

How to enhance consumer interest in the future

Logically, this subsection is directly linked with the previous one. That is, following a systematic methodology, one can reach a goal by maximally removing the barriers that prevent this. Resolving the above concern of consumer awareness, all of the respondents shared a common thought that it is key to provide better information to the consumers. However they did have somehow varying visions on how this should be done. According to one respondent, the new regulation that is depicted in Figure 4.2 will facilitate this. Another stated that the information provided on utilities' webpage can lead to consumers wanting more information. Two of the respondents believed that it is up to the market to reach out to the consumers to inform and convince them of the benefits that can be achieved by participation. A last respondent believed that this can be reached by market principles of the prevailing energy retail companies, through engagement and branding.

It is interesting that, although the barrier of financial incentives is acknowledged by all of the respondents, only one of them mentioned potential measures for this. In general, he noted that a specific niche of people, those with high electricity consumption, those with PV installations or electric vehicles might be easier to engage. On the regulatory side, he suggested that adaptions to the electricity taxation system could increase the incentives for consumers to participate.

Three of the respondents show the potential of the current trend toward specific consumer applications as residential solar PV, batteries or electric vehicles that can indirectly stimulate the interest of consumers that will own these applications. One of them phrased:

“There is a trend that are a lot of people getting solar panels on their roofs, that you could combine with a battery, and there is a trend getting electric cars, so the possibility that you will need energy, produce your own energy and to store energy, so it is a two-way possibility. When more and more people do this, there will be also more possibility for people to save money by using electricity in a smart way”

It is observed that the three respondents believed that these new applications will provide a greater toolbox for consumers and potentially further incentivize them to participate. It can be expected that for future prosumers (consumers that also produce) of electricity, the threshold is likely to be lower. At the same time, one of the respondents questioned the impact as well as the need for such developments, indicating that households form such a small parts of Sweden's energy consumption that it remains merely a symbolic value to engage them more. The latter is very important since it puts questions marks to the entire value of residential consumer participation.

Current interest of distribution companies

The opinion of the interest of distribution companies to engage in increased consumer participation is somewhat spread among the respondents. Both the respondents from EI gave the most positive answer. One of them believed that distribution companies are interested, illustrated by the presence of them in numerous talks and conferences about smart grids that are organized. The other thought that some companies are interested while other are not, illustrated by the fact that some of them are installing power-based tariffs. The difference between companies might be caused partially by a difference in size -some of the smaller municipal distribution companies could not have sufficient manpower to do these projects- but also by a different intrinsic interest and mindset, the respondent said.

The other three respondents rather radically stated their feeling of the disinterest of distribution companies. One of them says:

"For me that is one of the biggest barrier, that the grid companies see this in another way. [...] So certainly -and that is the dilemma of IRENA actually- there are all these smart solutions (demand response, batteries, local systems and flexibility) that are good for societies but not for grid companies."

It can be seen from the type of answers that the arguments behind the opinions given differ between the positive and the negative answers. That is, all the three that believed that distribution companies have no interest speak about a lack of incentives for them, which will be described in more detail in the next subsection. In contrast, the respondents from the regulator spoke from personal observations. The argument about presence in conferences is assessed as not sufficiently compelling. According to (NordReg, 2015), in 2015 there were five distribution grids with power based charging: Falbygden, Malung, Partille, Sala-Heby and Sollentuna. From (Pöyry, 2017), that states that 50% of distribution companies in Sweden is currently not using any data management system to work with hourly meterings, which is a key requirement for dynamic tariffs, it is assessed that the second respondents statement on dynamic prices, albeit true for some specific distribution companies, can never hold for a majority of them. Finally, in (Hansson and Carlsson, 2015), the disinterest of a significant share of Swedish distribution companies in smart grid applications is concluded.

As a result, it is concluded that the interest of distribution companies is low, mainly driven by on the one hand the argumentation given by the respondents, and on the other hand giving a higher value to the opinion of the distribution companies themselves, that stated low interest because of a lack of incentives.

Internal incentives and barriers for distribution companies

On this subject, the perspective of the different respondents became clear, leading to different suggestions and insights in several potential internal incentives and barriers. Note that the term *internal* is used for those incentives and barriers that are directly linked to operational issues are to be compared with those of the *regulatory* or *external* type in the next subsection.

One of the respondents said that distribution companies have an incentive to participate, since operations as peak shaving reduce the peak capacity for which grid infrastructure needs to be built. In that sense it is a financial incentive for distribution companies. While the statement is in nature correct, it is questionable if distribution companies are truly incentivized by this potential internal benefit, or whether this is hindered by the regulatory framework, which will be discussed in the next subsection. The respondent from Eon stated that the main incentive for distribution companies is the optimization of grid management when bottlenecks occur. At the same time, he thought that this incentive is not present in Sweden, which is a barrier for distribution companies to take action.

The existence of several barriers was suggested by some of the respondents. As mentioned above, for smaller distribution companies it can be harder to initiate these kinds of projects, because no sufficient manpower is present to do this. Besides, another brought to the attention that power systems are much more conservative. This is because power is regarded as a critical good for societies and reliability must be assured. He gave the following example:

"Two years ago, I had a conversation with the Head of R& D of a big utility in Sweden. He asked me to look through his office window. On that street only, there were five new buildings under construction. He told me: "In six months, I need to give connection to hundred apartments in each of these five buildings, which we are obliged to by law as a distribution company. If we cannot do this, then I am fired. And the safest way for me that I know I can rely upon is putting a cable in the ground. Now you are showing me some beautiful slides, but I do not see what is behind these slides. Can I risk my job and the image of the companies because of something that might or might not be working?"

Regulatory Incentives and barriers for distribution companies

Firstly, the respondent from InnoEnergy and from Eon both agreed with the fact that the regulatory system in Sweden today is generally made to promote investments. This statement is confirmed in (Ellevio AB, 2016). Here, Ellevio, one of the big three distribution companies in Sweden, states that the regulation is rewarding investments, and that Ellevio believes that this is the right approach. While for some reasons these are justifiable, the interviewees thought that this investment rewarding system is a large barrier for companies to seek solutions as demand response. From the previous subsection, the financial incentives were mentioned but assessed as questionable. This can indeed be true if more investments are actually promoted by the regulatory system. In that case, distribution companies are seeking to invest in larger capacity rather than promoting solutions as demand response, since from the latter they do not necessarily benefit. The respondent from InnoEnergy said:

"The regulations are in a way that distribution companies are paid for investments in grid infrastructure, and they are allowed to get it reimbursed by the customer. There is a revenue cap, so they can reach to this cap. This of course needs to be justified, but they are all able to justify, because they use arguments like urbanization. Partially this is true, so they claim they need to invest in more infrastructure to provide electricity to all these new people".

Secondly, as was already discussed in an earlier section, after the new ex ante regulation for distribution companies was put in place, there have now been introduced quality incentives for distribution companies that impact the final result of their revenue cap. By the nature of the incentives, reduced grid losses and peak shaving, these have the potential to be directly applicable as incentives distribution companies for demand response. The respondents agreed that the current incentive scheme is not effective. According to one, the impact on the money saved is small and compared to all the other factors in the calculation, the incentives are marginal.

Finally, a last barrier was mentioned that arises from the role of the distribution company in the electricity market system. That is, grid companies are not allowed to become a market participant, since they are only responsible for the network services that work as a regulated monopoly. This takes away many potential financial incentives that are present for other commercial players as retailers in the electricity market, for who beneficial business cases do exist.

When talking about the responsibility of new regulation in the future, respondents gave different perspectives. Two of them commented that more regulatory incentives can be introduced on top of the ones that exist today. The respondent from Greenely, speaking from his own experience, felt that there is currently no sufficient regulatory framework for market services regarding data systems. It is striking that the respondent from Eon, who earlier agreed that regulation is not incentivizing enough, stated that further promoting demand response programs is not up to the regulation, but up to new market services, showcasing some conservatism:

"This is up to the market forces for energy services to develop that. I do not think that is a regulatory issue. It is more to have a critical mass of controllable products. Then you could better create this service market. So it is more for the market to make these new services and business models appear. I would say that regulation is already doing their piece, with the unification of functional requirements that will now be happening in Sweden, so providing a basis for new services."

Direct conclusion on the interviews

The results above show that for some topics, the different statements do not show sufficient coherence to allow strong conclusions to be taken. However, some are agreed by several different experts in the field, giving them significant likelihood to hold. Table 4.2 shows the most important direct conclusions of the interviews taken. For the relevant citations is referred to the appendices.

Smart meter involved party	Direct conclusion from interviews
Consumers	• Current interest in demand response is very low • The lack of (1) awareness and (2) financial incentives due to low a electricity price (variation) provide the biggest barriers for participation • Penetration of new applications as electric vehicles or solar PV are expected to potentially raise interest, although uncertain
Distribution Companies	• Current interest in demand response is very low • The investment focus of the current regulatory revenue cap framework provides provides the biggest barrier for participation • Current regulatory measures for reduced network losses and peak-shaving to incentivize distribution companies are not effective

Table 4.2: *Direct conclusions from the interviews with Swedish experts*

Discussion of Swedish smart meter ecosystem based on interviews

This part will briefly discuss the Swedish smart meter ecosystem, reflecting on the interviews and past developments.

Firstly, of the three prevailing stakeholders who are involved in the Swedish ecosystem (1) consumers, (2) distribution companies and (3) regulator, the regulator (EI) currently has the pivoting role in the smart meter development in Sweden. This has been shown during the first wave roll-out and remains the case on the verge of the second wave. The revenue limitations from the new regulation have been extensively brought to court by several distribution companies. In spite of this, from the penetration that followed proposition 2002/03:85 and from the experience of the interviews, it has become clear that compliance of utilities with the measures taken regarding smart meter is generally good, suggesting the power for the regulator to take new measures if this is deemed appropriate. However, within these boundaries that are created and guarded by the regulator, Swedish utilities are very conservative still and show little intention to take action beyond regulatory requirements. For this reason, it is suggested that the regulator still has a very important responsibility in direction future smart meter deployment.

Secondly, it appears that none of the three stakeholders is currently sufficiently interested to on the short-term engage in more advanced residential application of smart meters. Both the distribution companies and consumers are merely driven by financial incentives, albeit within the regulated boundaries for the former. Currently these incentives are not sufficient and therefore the interest in participation is low. On the regulatory side, from the new list of requirements from EI as well as from the interviews, it is perceived that the focus is still mainly on the operational side. As an illustration of this, when openly asked about the benefits of the first or the second wave, answers from the respondents from Eon or EI remain merely on operational opportunities that arise from smart meter deployment. Besides, during one of the interviews a respondent from EI who was directly involved with new smart meter regulation even questioned the necessity of advanced applications as demand response from Swedish smart meters on a residential level.

Thirdly, among some of the different stakeholders the expectation exists that a fourth stakeholder, being businesses that arise from the data availability and smart meters installed, can have the potential to increase the residential participation. In order to achieve this, barriers are yet to be overcome that are in the power of the incumbent parties. On the regulatory side, currently two developments are ongoing: the work towards a supplier-centric model can better facilitate data access for third parties; also, the new metering requirements that will be enforced in the summer of 2018 will ensure a common standard for minimum functionality and measurement frequency. However, both of these will take several years to complete, possible until 2025 for both according to one interviewee. On the short term and until the arrival of the hub system, distribution companies will remain responsible for data delivery to third parties. Referring once more to the 50% of data management systems that today are adapted to hourly measurement, it needs to be ensured that old data systems are updated and that full participation to this and quality is guaranteed so to maximally allow third party usage.

In conclusion, one could say that residential demand response can be an opportunity from a system perspective, but that is not regarded as an urgent need in the current Swedish electricity market. Under the planned developments today, the main role of smart meters on the short-term will therefore largely remain in the operational usage.

Chapter 5

Boundary conditions of smart meters as smart grid facilitator in Sweden and India

5.1 Smart grid status in Sweden and India

5.1.1 Overview

The previous section has discussed the influence of smart meter deployment in Sweden on the development of residential smart grid spillovers from smart meters. This section intends to analyze to which extent the experiences of Sweden can be relevant for the upcoming roll-out in India. For the previous conclusions to hold, the report will first study the current situation of the different smart grid applications in Sweden vis-ä-vis India. This is necessary to get insight in the a priori relevance of any lessons learned from Sweden. It is reasonable to state that Sweden has only relevant experience to share for smart grid applications where its own development is in a further stage than that of India. For this, the earlier division in smart grid application is kept, naturally only focusing on those that are enabled or whose results are impacted AMI installed. After, the boundary conditions of the lessons that are learned from the Swedish experience are compared to the ones in India to assess the relevance of each for Indian smart grid strategies.

Table 5.1 below gives a comparison of the different grid applications in Sweden and India. It shows the current status and ongoing development in each of the domains. The right column indicates the relative experience of the two countries, which is a key indicator for the direction of knowledge transfer that would be the most logical.

Smart Grid Technology	Sweden		India		Relative Experience
	Present	Soon to arrive	Present	Soon to arrive	
Smart Meters (SM)	1st wave AMI: • 100% penetration, • Monthly precision legislated • 50% used with hourly precision 2nd wave: • List of functional requirements	2nd wave AMI roll-out finished not before 2025: • 15 minute precision capability legislated • Advanced features • No active demand response capability	• 14 pilots projects, around 200 000 households (0,1% penetration) • Several large-scale projects confirmed	Governmental target: 35 million by 2019 (15% penetration)	 *Sweden benefits from first-mover experience, while India is scaling-up rapidly. By 2019, the latter will have as many meters installed as the former, with more advanced technology, however penetration in India remains very low on the short-term.*
Dynamic Network Pricing (DNP)	-Monthly tariff change most dynamic option - Very few local grids try ToU tariff (3 in total at end of 2015)	Still to be discussed for residential consumers	Time-independent, per unit price increases with increasing consumption	Peak pricing pilots planned intertwined with AMI roll-out (e.g. TPDDL)	 *Dynamic pricing in India is non-existent due to primitive metering. Sweden economically benefits from monthly price dynamics, but has no further smart grid spillover benefits that require higher frequencies.*
Demand Response (DR)	No established programs, few pilot projects ongoing (e.g. Stockholm royal Seaport; Smart Grid Gotland)	- Research phase: feasibility studies about willingness to participate, regulatory barriers... - No large-scale program expected	No established programs, few pilot projects ongoing (e.g. Tata Power Dehli and Mumbai)	Uncertain	 *Both Sweden and India have underdeveloped DR programs, mainly due to the lack of proper SM and DNP. While Sweden has no direct drive forward on the short term, India appears to be more eager and outcomes of pilot projects are to be followed-up.*
Distributed Generation	Small Scale PV 74 MW (<0,1% of total capacity)	Continued governmental support, steady growth expected but no governmental target.	Small Scale PV 1,3 GW (<0,5% of total capacity)	Target 40 GW of small scale solar by 2022	 *Penetration of small scale power generation on distribution grid is very low, with future growth based on governmental incentives. Absolute capacity as well as penetration numbers are significantly larger in India. The rapid growth of the past years is expected to continue on the short-term, merely based on market mechanisms only.*
Microgrids	Nascent stage: research and demonstration projects (e.g. Simris)		• Many microgrid projects ongoing (e.g. OMC Power) • Policy released in 5 states	Target of 500 MW rural by 2021	 *Driven by larger shares of rural regions, micrograds are in a further stage of development in India, while Sweden is lagging behind.*

1. (Pöyry, 2017)
2.(Høynes and Berntzen, 2016)
3. (NordReg, 2015)
4. (Bijli Bachao, 2015)
5. (NordReg, 2016)
6. (Ranjan, 2017)
7. (Belline, 2017)
8. (Pothecary, 2016)(Bloomberg New Energy Finance, 2017)
9. (Shah, 2017)

Table 5.1: *The status status of the most important smart grid applications in Sweden and India*

5.1.2 Discussion of table results

Sweden to India: From the current status, Sweden has a more mature case than India for the dimensions *Smart Meter Deployment*, *Dynamic Network Pricing* and *Demand Response*. For the first of these is referred to other parts of the report. The other two dimensions are the most direct spillovers of smart meters in which Sweden has some experience. It is interesting to see that Sweden is a slow mover in each of the two domains. Identification of the reasons for this and realizing potential barriers and pitfalls could be of utmost importance for India so as to avoid these. Since the scope of the report is mainly to facilitate knowledge sharing in a one-directional way, the latter two dimensions of DNP and DR will be key focal points. Naturally and as expected, these are also the ones that have relevant Swedish experiences to share, as can be seen in the previous section.

India to Sweden: Although not in the main scope of the report, it is interesting to mention the farther stage of *Distributed Generation* and *Microgrids* for India compared to Sweden. This is likely to be caused by the intrinsic need of both countries for the two applications i.e. the strong central grid of Sweden compared to the large share of remote locations without grid connection in India. Besides, although usage these technologies can be radically adapted and improved by smart meters, applications without smart meters are technically possible, which is logically the case in India. Finally, one should also keep in mind the large variety that can exist regarding the implementation of microgrids, as was mentioned earlier in this report. Nevertheless, it is expected that there is certainly relevant knowledge to be transferred from India to Sweden regarding these dimensions.

5.2 Regulation

The previous section revealed that the responsibility and measures taken by the regulator have been of large importance for the Swedish smart meter roll-out. In the first wave, the entire smart meter deployment was in the first place initiated by a governmental mandate that required smart metering by 2009 for residential consumers. In the second wave, the list of requirements for new generation meters that is to be enforced this summer will again have a leading role in deciding the direction of smart meters and smart grids in Sweden. This subsection will study the key similarities and differences between Sweden and India regarding electricity policy, specifically focusing on the smart meter roll-out in both countries and the potential application of smart grid programs. A prerequisite for any regulatory measure from the Swedish experience to have relevance in the context of India is however a study that examines to which extent the two environments of energy policy allow this without a loss of their strength. As an illustration, in order for conclusions to be relevant, it is for instance required that the responsibility of the regulator and the bodies regulated in the two countries is similar. If not, policies that are binding and effective in Sweden might not be applicable or even be possible in the setting of India. The study will follow a systematic methodology that assesses similarity in the specific smart meter condition. Therefore, it will focus on the following indicators.

- Actors of the regulated market
- Regulatory structure and responsibility
- Jurisdictive power of regulation
- Tariff determination

5.2.1 Actors of the regulated market

Electricity markets can be segmented in two types: a regulated and a deregulated form. In a regulated electricity market, large utilities own all parts of the power value chain, so called vertically integrated utilities. That is, they possess generation plants, as well as the physical transport over transmission and distributed lines. Consumers of electricity have contracts with these utilities. Since this is an oligopolistic market functioning, there needs to be a regulating party that ensures quality of supply and reasonable tariffs. In Sweden, this oligopolistic model was abandoned in 1996 to introduce a more efficient market resulting in lower end-consumer prices of electricity (Swedish Competition Authority, 1996). In India, the Electricity Act of 2003 proposed similar unbundling of the nationalized vertically integrated utilities (State Electricity Boards) into separate functional entities. As a consequence, independent regulatory bodies were created in both countries to supervise the new market functioning. In conclusion, one can say that both of them did move from a purely regulated into a more deregulated market form, where the power value chain is functionally separated, which is still the case today.

However, there is a significant difference between the current market structure and the parts of the energy value chain that are regulated, as can be noticed in Figure 5.1 below, which for completeness also depicts a fully regulated market. This critical difference implies that the regulators in Sweden and India do not have the same jurisdictive power. The transmission of electricity is in both cases perceived as a natural monopoly. An efficient working of this is supervised by the regulatory instance through licensing and standards. However, in the deregulation process, in India the distribution sector has been kept responsible for both the network operations as the supply of energy, so called *carriage* (the grid) and content (the electricity that flows through). Nonetheless, to promote private participation, it is not regarded as a monopoly and instead multiple licensees are allowed – possibly resulting in parallel networking. This is in large contrast to the situation of Sweden. In the latter, the network part of power distribution (carriage) is regulated as a natural monopoly largely comparable to the transmission system. The actual supply of energy (content) is a fully deregulated competitive market.

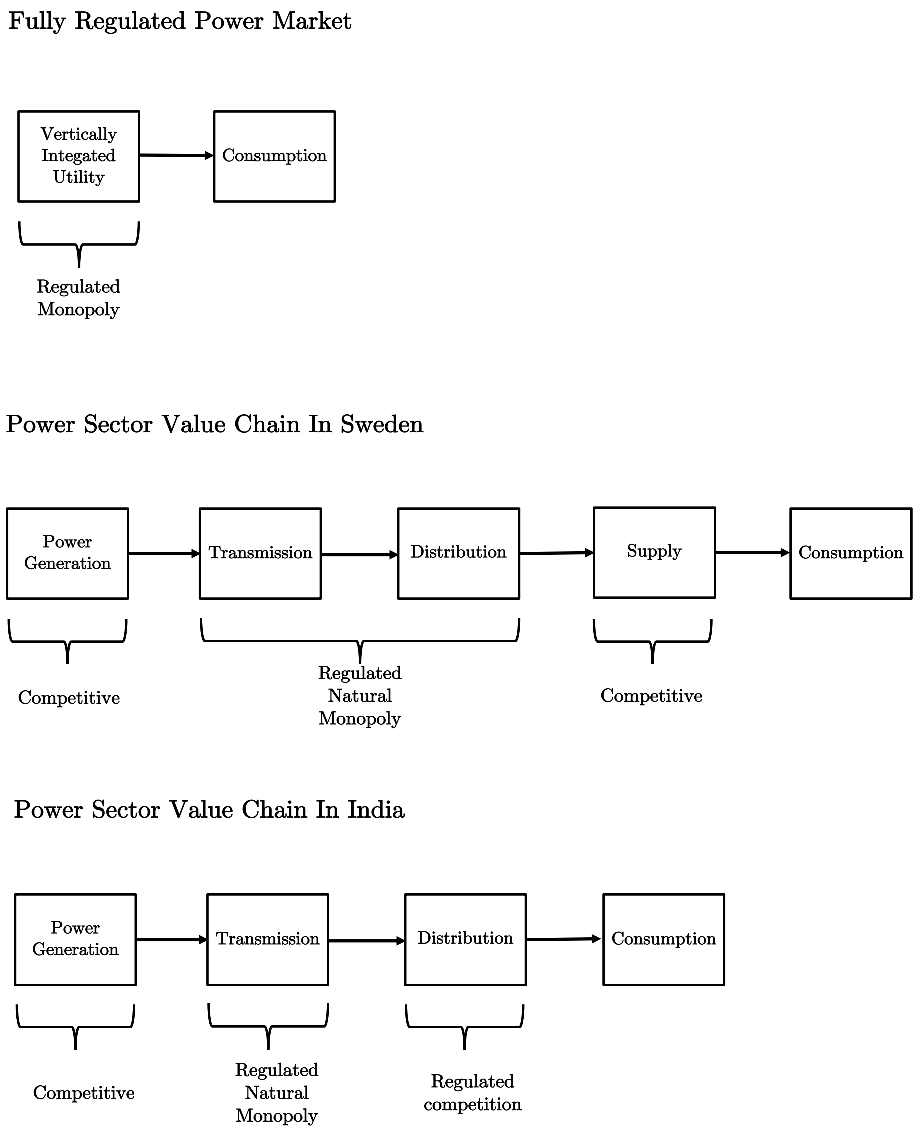

Figure 5.1: *Structure and regulation of the electricity market in Sweden and India*

5.2.2 Regulatory structure and responsibility

Regulation of the electricity market is in Sweden performed by a centralized body, *the Swedish Energy Markets Inspectorate* (EI). It is organized as a fully independent institute that supervises the market of electricity, district heating and natural for all consumers and participants in the Swedish territory (International Energy Agency, 2013). Together with the similar other Scandinavian countries, Sweden is cooperating and harmonizing policies through NordReg. The latter has the mission to *"promote legal and institutional framework and conditions necessary for developing the Nordic and European electricity markets"* (NordReg, 2018). Nonetheless, all the supervisory power is centralized in one institute, EI.

In India, a centralized regulator exists, the *Central Electricity Regulatory Commis-*

sion (CERC). However, by the Electricity Act of 2003, each state is also mandated to have an independent *State Electricity Regulatory Commission* (SERC) or a Joint Electricity Regulatory Commission shared between some states. Currently a total of 27 state or joint state commissions exist (CERC, 2018). Finally, also a Forum of Regulators (FOR) exists to harmonize the regulatory approaches though without binding power.

Taking into account the difference in number of power consumers in Sweden versus India – 5,2 million versus 200 million – it is reasonable that the latter can only manage the situation by partially segmenting further on state level. This is even more the case since there is a large variation in practices required between states, caused by distinct parameters like geographic characteristics, population density and income levels (International Energy Agency, 2015). Legislation on state level in India is based on central acts policies, and SERCs are by law required to follow these, which provides general guidelines and milestones. The actual implementation on the other hand is the responsibility of the states and it is therefore questionable and debated to which extent these central policies are binding (Kumar and Chatterjee, 2012). The complexity of the regulatory system in India compared to the case of Sweden is well illustrated by Figure 5.2 from The World Bank, taken from (Austin Daniel, 2009).

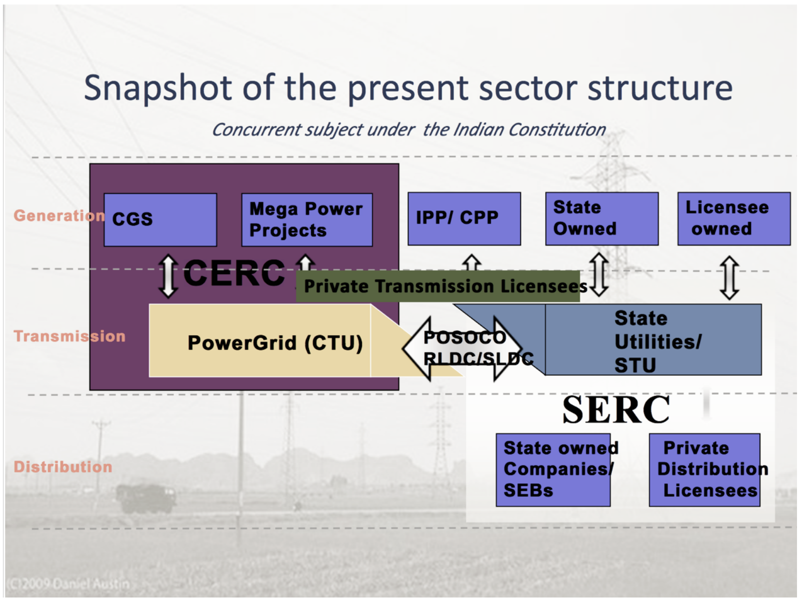

Figure 5.2: *Regulatory structure in India*

Source: Austin Daniel, 2009

Since the power distribution level activities are naturally focused on a more local level i.e. within state, the SERCs have full responsibility over the distribution matters in India. In Sweden, the EI is responsible for distribution. A similar role of the regulator in the energy system is a sine qua non for the transfer of lessons learned and effective policy regarding smart meters from Sweden to India. Generally, it can be concluded that is indeed the case that these are highly comparable, as can be

Regulatory Responsibility	SERC in India	EI in Sweden
Distribution Tariff Setting	Yes	Yes
Distribution Licensing	Yes	Yes
Enforcing Performance Standards for licensees	Yes	Yes
Supervise and levy of fees for non-compliance	Yes	Yes

Table 5.2: *Comparison of regulatory responsibilities in Sweden and India*

seen in Table 5.2, based on (Kumar and Chatterjee, 2012) and (Swedish Energy Markets Inspectorate, 2016).

5.2.3 Jurisdictive power of regulation

In order to understand the impact of legislation in Sweden vis-à-vis India, it is key to investigate the power of the regulator. That is, if policies or regulatory frameworks are put in place, there is need for a strong supervision and there must be serious consequences for non-compliance. If not, the effect of the specific legislation might not be reached, which can naturally be a high barrier for fruitful transfer.

In Sweden, it was concluded in an earlier section that the regulator is working independently and is not significantly influenced by regulatory hold-up nor regulatory capture. Furthermore, the regulatory instances in the EU are required to follow the tasks that are stated in Directive 2009/72/EC and Directive 2009/73/EC by the European Parliament and Council. Also, the Swedish Energy Markets Inspectorate is involved in the Council of European Energy Regulators in which is agreed on certain procedures. All of this leads to conclude that the working of the Swedish regulator is properly supervised by higher instances. Regarding smart meters, high compliance by the distribution companies with the mandate is indicated by the 100% penetration of smart meters by 2009, just as was demanded (AT Kearney, 2010)

In India, by the Electricity Act of 2003, it was required for each state to have an independent regulatory commission - the SERC. This was mandated so as to abandon the highly nationalized situation of before where the entire electricity market was controlled by the government, accompanied with the unbundling of the vertically integrated State Electricity Boards (Kumar and Chatterjee, 2012). As described above, the current supervisory responsibility of SERCs over the electricity market is highly similar to the situation in Sweden, as well as the provisions for fees if licensees do not follow the standards. Hence, in theory the two situations of Sweden and India are highly comparable. To some extent this is effectively the case, however there are still traces of situation of two decades ago in India. Regulatory Commissions are still struggling with a true enforcement of their orders, without a sound power of execution. This is mainly caused by the governmental involvement that is still present (Kumar and Chatterjee, 2012). That is to say, despite the aim for increased private interaction, especially the distribution sector is yet dominated by state-owned distribution companies. Figure 5.3 below compares the ownership structure of the distribution companies in Sweden and India, which reveals one of the key drivers behind this issue. The data for which is taken from (Agrawal et al., 2017) and (IVA Royal Swedish Academy of Engineering Sciences, 2017). From Figure 5.3, it can be seen that government influence is still very large in Indian power distribution.

Thus, in Sweden there is a clear split between the regulatory power of EI and the distribution companies that have to comply with these rules. In India, on the one hand the line between the government and the distribution companies is way thinner. On the other hand, the Indian government still has large influence on the regulatory measures as tariff setting. This creates a governmental impact at both the regulating and the regulated parties, which is naturally counterproductive. (The Energy and Resources Institute, 2015) states that *"Autonomy of the State Electricity Regulatory Commission has remained elusive in reality. Scopes to revamp the current regulatory structure may be explored with the aim to keep the State government at arm's length from the tariff-setting exercise."*

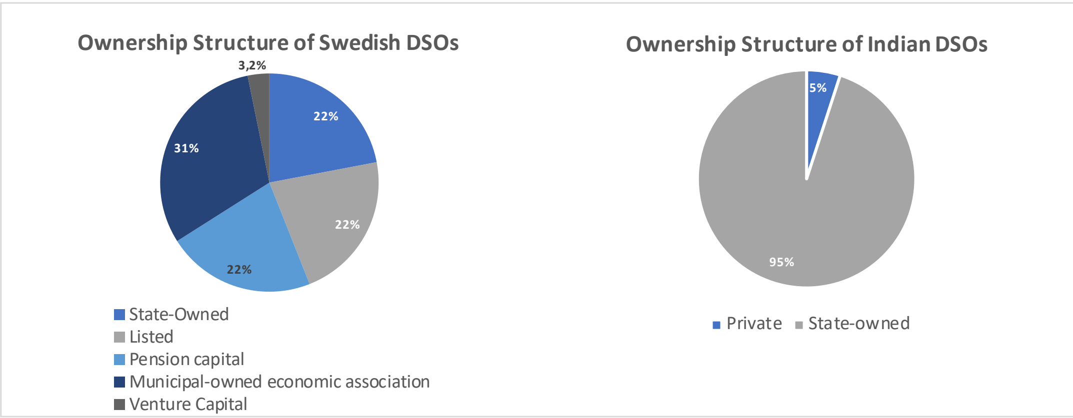

Figure 5.3: *Ownership structure of distribution companies in Sweden and India*

5.2.4 Tariff determination

One of the most important responsibilities of both EI in Sweden and SERC in India regarding the distribution sector is the tariff-setting. In the monopolistic segments of the electricity system – or at least quasi monopolistic in case of multiple distribution licenses in India – market abuse of distribution companies needs to be supervised. In other words, to prevent unreasonable high tariffs that consumers would be forced to pay due to a lack of competition, the regulator has a certain framework to determine which tariffs can be charged. Generally, tariff determination systems can be divided in two categories: *revenue* or *price cap regulation* and *rate of return regulation*. In the former model either one of the two parameters are fixed, whereas the distribution companies try to optimize profit by lowering its costs. In the latter, distribution companies are allowed to charge a price that is based on their costs plus a certain profit margin. For further elaboration is referred to specialized literature. For this section however, it is important to discuss the basis of tariff determination. That is, the Swedish experience has shown that the network tariff has been a critical parameter in the business case of smart meters for distribution companies in Sweden. As was mandated in the original governmental statement in Sweden, the final cost of implementation was to be borne by the end-consumer. Following this approach, it was critical for the return of the distribution companies that inclusion of this in the network tariff was allowed.

Starting from 2012, network charges to electricity consumers in Sweden are determined by EI ex ante for periods of four years, using a multi-year revenue cap. In order to incentivize efficient network usage, an increase or decrease of the allowed cap can be achieved through the level of performance on certain indicators as network losses or peak shaving ability. For more information is referred to the previous section or to (G. Wigenborg et al., 2016).

In India, tariffs on the distribution level are regulated using principles of *Annual Revenue Requirement*. It is interesting to mention once more the combined role of content and carriage for Indian distribution companies, implying that costs to be recovered can be attributed to both this network and supply business. For illustration, 60-70% of expenditures are from power purchase costs (Kumar and Chatterjee, 2012), a segment that is naturally not present for Swedish DSOs. In this regard, tariffs might be a priori less comparable already. Rationalization of the network tariff has been largely discussed topic in India since the Electricity Act of 2003. However, at present this is still not the case. There is still a lack of cost-reflective tariff setting – industrial and commercial consumers are yet cross-subsidizing poor agricultural and domestic consumers. In other words, residential and agricultural consumers are charged artificially while the main cost is borne by the industrial and the commercial users. Once more referring to the strong connection between state governments and distribution companies, the former are providing monetary support to the latter to lower tariffs for the vulnerable consumers, leading to a not cost-reflective tariff. The main barrier that is identified however is the existence and extensive usage of **regulatory assets** by regulators in India. Through the Annual Revenue Requirement framework, allowed charges are calculated ex ante. Oftentimes there is a revenue cap, which would then be recovered in the next regulatory period – in the case of India the next year – by increased allowances by the regulator. The critical point of this issue is that the SERC is resistant in increasing this allowed customer rates (The Energy and Resources Institute, 2015). There are two main reasons for this. Firstly, there are socio-economic reasons - they fear that a sudden price increase would damage end consumers. Secondly, there are political reasons. As mentioned before, governments are highly influencing the regulation and tariff setting, partly driven by the strive for votes and reelection.

As a result of this, tariffs have in many cases not been revised for the last several years, while the annual revenue requirement has increased. This has a consequence that distribution companies are receiving less money than they are allowed to have and are short of revenues and therefore not at the end of the booking year. To formally assess this issue, revenue gaps are acknowledged by SERC in the form of Regulatory Assets for many sequential years. In short, these are revenues that are not yet allowed to be recovered in the next regulatory period. The National Tariff

Policy states that:

"The practice of regulatory assets (which is generally created to defer tariff hike) should be used as an exception and when resorted to, the carrying cost should be allowed. It should be amortized in a maximum of three years." (Kumar and Chatterjee, 2012)

However, what should be an exception has now become the ordinary way of handling, all of this driven by the social situation and the resistance to tariff increase due to social consequences. As a result, the formal books of distribution companies are clear, however debts are rising and there is no sufficient return on any new investments made.

5.2.5 Summary of the regulation in Sweden and India

This section has strived to map the extent to which lessons learned regarding regulatory measures that have affected smart meter deployment in Sweden are transferable to the Indian context. It is concluded that there are some similarities in the general way of regulating, but that the differences between the two ecosystems are large to that extent that these form significant barriers so efficiently transfer legislative lessons learned between Sweden and India.

It is clear that the composition of the regulated actors in the electricity market significantly differs between in Sweden and India. For the case of smart meter policies however this does not necessarily imply that a knowledge transfer is entirely hindered. That is, regulation that affected smart meter deployment was largely focused on the carriage side of the distribution segment. Although the environment of regulation is generally different, narrowing down reveals that this specific part of the value chain supervised in a similar manner by a regulator in both cases. The differences caused by the multiple licensees in India compared to monopolistic character in Sweden are observed but not identified as a barrier for transferability. The difference between the simple nature of the centralized regulation and the complex structure in India can be a limit to decisive policy transfer, as licensing and standards of distribution activities fall under the mandate of the SERCs. An unambiguous implementation of specific smart meter measures would therefore need to be introduced in each of the 28 SERCs, potentially initiated by a centralized policy. As a result of this, it is likely that some legislations will be more relevant to some states and less to others leading to diverging use cases. In that case, a somehow distinct transfer should be made taking into account the different states, which is out of the scope of this study. This is worsened by the fact that some local SERCs are not independent enough and still influenced or overpowered by governments, which is more thoroughly discussed in the next subsections.

It is understood that – assuming that the implementation of certain legislations in India based on the lessons learned in Sweden – the proper execution of policies is a vital condition in order for this to have any relevance whatsoever. From the above conclusion it can be highly questionable whether the state regulatory commissions

Similar — Not Similar	Differences and similarities	Observation regarding smart meter transfer
Actors of the regulated market	• *Different electricity market structure:* o *Sweden: Separation of network and supply service* o *India: Combined network and supply service* • *Smart meters are network responsibility* • *Network part is regulated similarly*	The general electricity market structure largely differs between the two countries, as a consequence this also holds for the regulated system. Nonetheless, the network services of the distribution companies are in both cases regulated in similar ways.
Regulatory structure and responsibility	• *Different amount of regulators* o *Sweden: uniqe regulator* o *India: National regulator and state regulator* • *Regulatory variation on state level driven by local conditions* • *Within state, unique state regulator for network services* • *Responsibilities of regulation are similar*	The complex regulatory system in India can imply a barrier for efficient knowledge transfer from the relatively simple regulatory system in Sweden. The relevance of policies will likely vary for each state.
Jurisdictive power of regulation	• *Different degree of independence of regulator:* • *Sweden: high degree of independence* • *India: Strong regulatory capture* • *Different independence of distribution companies* • *Sweden: mixed ownership* • *India:Governmental dominance in distribution sector*	The regulator in Sweden is independent and not subject to extensive regulatory capture or hold-up. In India, governmental and political interference is highly disturbing the enforcement power of the regulator. As a result of this, it is questionable if measures that were successfully mandated in the Swedish system can be enforced in India.
Tariff determination	• *Similar tariff determination framework* • *Largely different consequence of execution:* • *Sweden: normal compliance* • *India: fiscal structure of regulatory assets to match regulation with artificially set tariffs.* • *Different incentive and reward for investment*	The different revenue and tariff allowances system in Sweden and India can pose a serious barrier for knowledge transfer that is likely to be very hard to overcome.

Table 5.3: *Summary of regulatory context of smart meters in Sweden and India*

will be able to enforce any smart meter penetration policy or standard against the power of state-owned distribution companies. This is in contrast to the strong and independent position of the EI in Sweden. It is believed that this tremendous difference can potentially cause high barriers for the transferability of successful policies to support smart meter development from Sweden to India.

In conclusion of the above reasoning, Sweden has a revenue cap tariff determination which allowed distribution companies to introduce some costs related to smart meter deployment in the tariff calculation framework present. In India however, charges are not cost-representative. At present, rates are completely blocked by the social situation that prevents tariff increases and artificially keeps them down for vulnerable users. This implies that a similar legislation of cost recovery from smart meter deployment for distribution companies – a vital aspect of the business case in Sweden – can be expected to have no potential in the current Indian environment.

Therefore, it can be stated that the situation of tariff- determination is different between Sweden and India to this extent that is creates very high barriers for this specific policy to be transferred.

5.3 Residential Consumers

The Swedish experience concluded that the lack customer participation has appeared to be an existing barrier to demand response resulting from smart meters in Sweden. This is a critical issue that needs to be identified prior to making technological decisions on smart meters. As a result, some features that increase the cost of smart meters might be not worth to be installed if the expected actual usage on the field is not significant. This section will briefly analyze and discuss the expected consumer interest in demand response participation. It will do this with the help of the following quantitative indicators:

- Residential DR capability
- Relevance of residential electricity cost
- Residential DR incentive

The aim of this section is twofold. Firstly, it provides further quantitative insight in the lack of consumer participation in Sweden. Secondly and most importantly, by using the situation of as a reference, the result for the above indicators for India can be compared to the values for Sweden. In this way, an expected conclusion for the interest in demand response in India can be made.

5.3.1 Residential DR capability

The first requirement for participation in demand response is the capability to do so. In other words, consumers need to be able to shift load without extensive behavioral changes. In a first step, it is therefore reasonable to focus on appliances with a certain inertia and time delay, mainly thermal applications as water or space heating, air conditioning or refrigeration... where energy can be somehow stored thermally (hereafter denoted with *Demand Response Appliances* DRA). This would imply that the load shift is barely noticeable in consumers' daily life. On the other hand, applications that require direct power to work e.g. lighting, television, household appliances, have a significant higher impact on people's behavior and are therefore less appropriate for demand response (hereafter denoted with *Non-Demand Response Appliances* NDRA). Figure 5.4 compares the penetration of DRA and NDRA applications in Sweden and India, and is based on data from (Chunekar et al., 2016) and (Lapillonne et al., 2015).

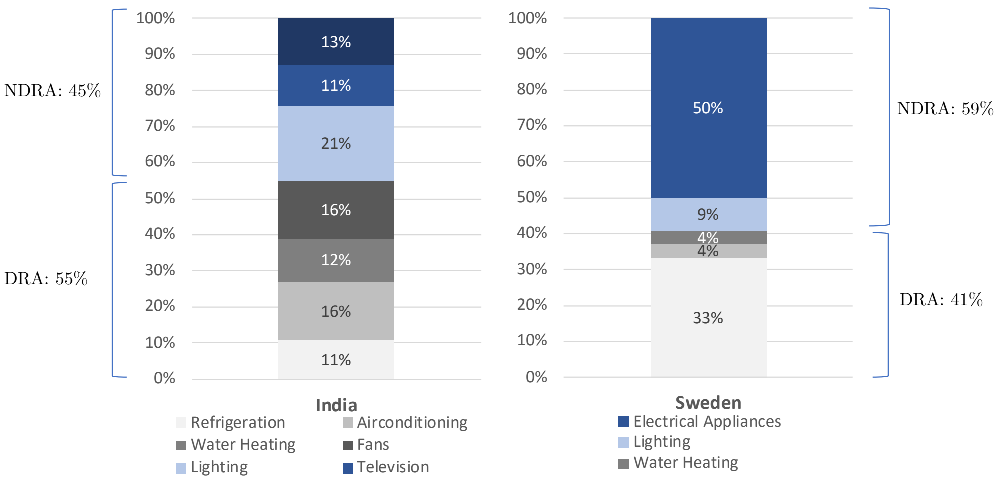

Figure 5.4: *DRA and NDRA appliances in Sweden and India*

Figure 5.4 shows that the penetration of DRA in both countries is largely sufficient to ensure participation possibilities. It should be noted that actual demand response capabilities are depending on time-based load variations. However, the numbers are in both countries sufficiently large to conclude that sufficient DRA are present. From this, it can be concluded that the lack of participation in demand response in Sweden is not caused by consumers' capability and that this can expected to be also the case in India.

5.3.2 Relevance of residential electricity cost

Table 5.4 provides a summary of energy consumption and cost in Sweden and India. To take into account the variability among different states in India without overloading the results with data from all the states, a selection is made of seven states with the highest residential energy consumption numbers in India (Chunekar et al., 2016) and for which proper data was available.

	Maharashtra	Uttar Pradesh	Tamil Nadu	Delhi	Gujarat	West Bengal	Punjab	Sweden
Avg. REC [kWh/month]	200	256,5	223,9	217,4	247,8	230,4	204,3	583,3
Avg. REC cost [INR – SEK/month]	1432,1	1557,2	960,1	1096,8	1158,2	1239,4	1237,4	967,8
Avg. income per capita [INR – SEK]	10769,6	3364,4	10697,2	20070,8	9166,7	6575,3	6575,3	27958,5
Electricity cost as share of income [%]	13,3	46,2	9,0	5,5	12,6	18,8	14,9	3,5

1. REC: Residential Electricity Consumption - (Central Electricity Authority, 2015); Sweden (Pöyry, 2017)
2. Estimated cost by state extrapolated from (Chunekar et al., 2016); Sweden: (Pöyry, 2017)
3. India: (Government of India (NITI Aayog), 2015) – Sweden: (Eurostat, 2014)

Table 5.4: *Importance of electricity cost in Sweden and selected Indian states*

The table shows that variation in electricity consumption among the Indian states discussed is modest, although significantly lower than for Sweden, as one would expect. The same holds for the variation in energy cost since residential electricity price variation among states is low as well.

Two important results can be observed when comparing electricity costs with income. Firstly, the importance of electricity costs for Indian households is a multiple of the same value for Sweden, where the importance is only 3,5%. Secondly, the variation among Indian states is large, from 5,5% in Dehli to 46,2% in Uttar Pradesh. In general, this leads to the conclusion that significance of electricity costs can be expected to be far higher in India than in Sweden, although variation occurs. This will have an impact on the interest of consumers to participate in demand response programs so as to reduce their energy bills. Based on this result, the latter can be expected to be higher in India.

5.3.3 Residential DR incentive

Finally, it is relevant to estimate the potential economic incentive for end-consumers to engage in demand response programs. In other words, *what is the amount that customers in Sweden and India can save by shifting their consumption by the retail price different between peak and off-peak electricity usage.*

The Clean Energy Package states *"a 'dynamic electricity price contract' as an electricity supply contract between a supplier and a final customer that reflects the price at the spot market or at the day ahead market at intervals at least equal to the market settlement frequency"* (Eurelectric, 2017). Following this, the report will assume that dynamic retail prices are well-reflected by day ahead wholesale prices, although an electricity retailer premium will in practice exist.

As will be explained later in this subsection, wholesale price variation is only a large minority of electricity transactions in India still, where the importance of the wholesale market is small and most electricity is bought by distribution companies through long term power purchase agreements (PPA). This highly limits the direct applicability of the results below. Nonetheless, it is relevant to compare the results for wholesale prices given since it this number is an indicator for the balance and working of the entire electricity system, which lies at the basis of many of the potential benefits from consumer participation. Besides, consumers are currently charged subsidized retail prices and pay volumetric tariffs based on total consumption. The value of this illustration is therefore what the incentive of consumers could be if the proper technology and regulation would be in place to allow participation. For the other barriers that still exist is referred to the other sections.

Table 5.5 shows the average hourly day ahead wholesale electricity price in Sweden (Nordpool) and India (IEX), for February 2018.

Demand response will reduce the consumption in peak-price hours and consume the same amount of energy when prices are lower. Since wholesale prices show a peak during the morning and during the evening, this shift can be interpreted as earlier

Hour-of-day - avg. 02/2018	00 - 01	01 - 02	02 - 03	03 - 04	04 - 05	05 - 06	06 - 07	07 - 08	08 - 09	09 - 10	10 - 11	11 - 12
Indian DAP [INR/kWh]	2,25	2,16	2,12	2,10	2,14	2,36	3,14	4,29	4,70	4,57	4,13	3,74
Swedish DAP [SEK/kWh]	0,35	0,34	0,34	0,34	0,35	0,36	0,40	0,48	0,49	0,48	0,47	0,43
Hour-of-day - avg. 02/2018	12 - 13	13 - 14	14 - 15	15 - 16	16 - 17	17 - 18	18 - 19	19 - 20	20 - 21	21 - 22	22 - 23	23 - 00
Indian DAP [INR/kWh]	3,27	2,66	2,70	2,84	3,35	3,75	3,88	4,11	4,00	3,31	2,64	2,36
Swedish DAP [SEK/kWh]	0,40	0,40	0,40	0,40	0,42	0,49	0,52	0,45	0,40	0,38	0,37	0,35

Table 5.5: *Average daily wholesale price variation in February 2018 in Sweden and India*

consumption in the morning or delayed consumption in the evening. The results below show the potential savings from two illustrative cases of demand response that show maximum economic saving capability in Sweden and India. In both situations, they are observed assuming a uniform load shift from the four highest price slots to the four lowest.

- Average peak price
  - 4,42 INR in India
  - 0,50 SEK in Sweden
- Average low price
  - 2,13 INR in India
  - 0,34 SEK in Sweden
- Savings per shifted kWh
  - 2,3 INR in India
  - 0,16 SEK in Sweden

The above results show that relative price differences between peak and lowest wholesale prices during one day are significantly larger in India than in Sweden. This results in higher relative savings from demand response participation in the former. However, due to the low prices and consumption in both countries, the results of this illustrative case show monthly savings of varying between 42,26-54,2 INR (0.6 -0,8 USD2018) in India and 8,15 SEK (0,9 USD2018) from a 10% load shift compared to the current energy expenditures. Taking into account that this is an extreme price difference case where a shift from the absolutely highest to lowers prices was assumed, this is a very low amount. Due to the lower electricity cost in India, the percent impact of this would be however three times higher than in Sweden. Taking into account the notes on the illustration made, it is very important to understand the meaning as well as the limits of this illustration in the current context for India. The above reasoning uses wholesale prices as basis for comparison of the electricity supply and demand balances for Sweden and India. Percent savings are based on the current electricity prices, which are kept low. Deviations would be noticed if people's energy expenditures would be based on these varying prices too, which would inflate the impact of a load shift.

During the interview, the respondent from Fortum stated about incentive of consumers:

"Demand response and consumer side management works, but the question is if you need to control some loads, e.g. air conditioning is a big load in India, if you want to control those loads, you need to ask the question who is benefitting? For the end-consumer it is only beneficial if they get paid a certain amount of money. And current electricity prices are not incentivizing enough."

5.3.4 Conclusion on residential DR participation

The analysis above was based on consumption awareness, DR capability and DR incentive. From the Swedish reference case, one can conclude that in theory, consumers have sufficient means to shift loads due to a high percentage of DRA. The main barrier for DR in Sweden from consumers' perspective is that electricity retail prices are far too low to raise consumption awareness. Besides, the incentive – in the form of money saved from participating – is non-existent due to the low variation of prices between peak and off-peak periods.

In India, a sufficiently large penetration of DRA is present to facilitate residential DR, as it is the case in Sweden. Moreover, the share of electricity costs in the household budget is in many cases several times larger in India than in Sweden, although a large variation among different states is observed. For instance, in the state of Uttar Pradesh, consumer awareness and a priori interest in DR is likely to be slightly higher, since it holds such a large share in consumers budget. Although relative price differences between peak and off-peak periods are larger for the case of India than in Sweden, the financial gains for consumers in return for load shift would relatively small in India as well. Therefore, it is expected that willingness for consumers to participate would also be small.

As mentioned before, India currently has some barriers on regulatory and electricity market structure that prevent a residential demand response as it is presented in this analysis. However, taking into account the aims of India to move towards a system as it is presented here, where wholesale prices become the norm, the results show that even in that case providing sufficient incentives to residential consumers will be challenging. Similar to the experts in the interviews on the Swedish experience, the respondent from Fortum refers to the trend of a new consumer group for which the interest might be higher than average.

"I think an interesting case could be when there is a sufficient critical mass of electric vehicles, because, when it comes to EV's, an average car is driven only for 5-7% of the time, the rest of the time it is parked, so it can serve as a battery to operate in vehicle-to-grid mode or peak-shaving. This is something where there can be value, but there is a very long way for EV's to penetrate in India still."

However, unlike in Sweden, the penetration of this group will be very slow. Referring to the comparison in the beginning of this chapter, one can notice that larger pene-

Similar ← → Not Similar	Differences and similarities	Observation regarding smart meter transfer
Residential DR capability	• *Different energy consumption mix due to:* o *Different basic needs (heating vs. Cooling)* o *Large penetration of applicances in Sweden, not present in India* • *Aggregation shows similar split of DRA and NDRA*	The most appropriate applicances for DR are those with thermal inertia where load shift is barely noticed in the consumers' daily life. In both Sweden and India, roughly half of consumption would be avaialable and therefore this is not a limiting factor in either of them.
Relevance of residential electricity cost	• *Difference in share of electricity cost in household expenses* • *Sweden: small 3,5%* • *India: significant (5,5-46%)* • *Large variation between different states in India*	The importance of electricity costs are far larger in India than in Sweden. Moreover, current costs are subsidized and could be even higher in the future. From this, the situation between Sweden and India is largely distinct, and it coulc be expected that consumers in India would be more interested.
Residential DR incentive	• *Different importance of wholesale market prices in the eletrcitiy market* • *Similar daily price variation* • *Relative price difference higher in India* • *Residential consumption low in India* • *Similar low incentive for residential consumers based on wholesale price variation*	Assuming accessibility to wholesale price variation, the incentive to participate in a DR response program in a reasonable manner is small for both consumers in Sweden and India. Regarding this part, the results are comparable for both countries.

Table 5.6: *Summary table of residential DR interest in Sweden and India*

tration of small-scale solar PV in India. Many of the Swedish experts referred to this consumer group as a major opportunity for future DR, which could be indicative for possibilities in India.

5.4 Distribution companies

The Swedish experience concluded that, in general the interest of distribution companies in a full and advanced application of smart meters for smart grid and flexibility purposes is low in Sweden. These results can be problematic in the case where distribution companies should be at the wheel of further investments. It is naturally of utmost importance to assess how this situation is likely to reflect in the case of Indian distribution companies. This section will therefore study to which extent a comparison is relevant in the first place and in that case whether parameters indicate expected similar conclusions for India as for Sweden. It will be structured in the following way:

- Network responsibility
- Smart grid incentive: long term

- Smart grid incentive: short term
- Capability: technological and financial

5.4.1 Network responsibility

In both Sweden and India the responsibility for actual roll-out of smart meters is given to the distribution companies, although influence of regulation and requirements is stronger in Sweden. In the end, the main responsibility comprised of meter installation, communication technology provision and data handling is similar for both cases. The section about transferability of regulations already touched upon a very important structural difference between distribution companies – the unity of carriage and content in India versus the separation in Sweden. For a more detailed elaboration is referred to this section. This difference does have a large impact not only on smart meter installation in the first place but also on the incentive for distribution companies to invest in further smart grid applications.

5.4.2 Smart grid incentive: long term

From an energy system perspective, the need for downstream flexibility is largely dependent on the dispatchability of the local energy mix. Different types of power generation fuels are inherently connected to plants with a certain degree of flexibility. Hydro power plants generally show the highest flexibility of all, although the application potential of this can be complex and bounded by several external dispatchability constraints (Farahmand et al., 2017). Electrically speaking however, they remain very capable of dynamic behavior responding to an unbalance with supply and demand. Classic thermal plants that run on coal or biomass have the lowest ramp rates, the same holds for nuclear power plants, that can technically be shut down rapidly in emergency situations but at tremendous economic costs. Naturally, renewable energy from for instance wind and solar sources is by definition not dispatchable. Natural gas plants are positioned somewhere in between in this spectrum. Following this, Figure 5.5 below compares the grid flexibility of Sweden and India, based on data from (Swedish Energy Agency, 2016) and (India Brand Equity Foundation, 2018).

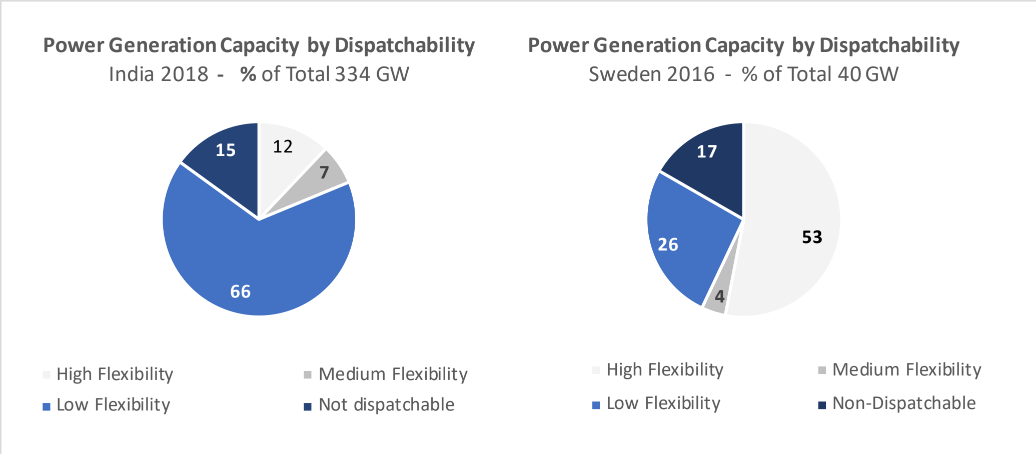

Figure 5.5: *Flexibility of generation in Sweden and India*

The difference in the flexibility of the generation sources between Sweden and India is very large. 81% of the power plants in India show no or low potential for dispatchable generation, and according to the IEA New Policies Scenario this number will only decrease a few percentage points by 2040 (International Energy Agency, 2015). This low number is driven by on the one hand the low number of peak plants due to insufficient incentives and on the other hand a low flexibility potential for incumbent generators. Natural gas is scarce as a resource and hydro flexibility is severely bounded by its role as water supply (Tongia, 2015). This is in contrast to Sweden, where only 43% of generation currently has low dynamic potential. System operators are responsible for ensuring a sound working of the grid and reliable power supply. With increasing shares of unpredictable and non-dispatchable generation, there is a need of sufficient responsive capabilities to ensure this, both on a national and on a regional level. With the limited flexibility in the Indian system, it is absolutely critical for the Indian network operators to take measures that maintain the balance between supply and demand, especially when taking into account the massive investments in variable renewable energy that are planned. This indicates that the implicit need for smart grid and demand response technologies has – at least on the long term – more importance for Indian than for Swedish network companies.

Moreover, besides the variability, the need for smart grid using demand side participation is enforced by a capacity issue – the capability to provide enough power to supply all the loads that demand it. Normal Western-European countries have capacity margins of around 15-20% (Tongia, 2015), and for the case of Sweden there is currently sufficient generation adequacy, with rather low margins relatively speaking. However, taking into account the ancillary services market and the good interconnection of the Nordic electricity market, the capacity situation is currently not at all comparable to the Indian one. Finally, simulation studies by Svenska kraftnät in 2015 showed that overall Sweden is not expected to experience shortages by 2025 (Statnett et al., 2016). In conclusion, the generation adequacy is not the main issue for transmission and distribution system operators that are at the wheel of a large penetration of demand response applications in Sweden. In India, contrary to a margin of supply versus demand in Sweden, it is sometimes the case that supply cannot provide demand i.e. that shortages occur. Official numbers give shortfall of the Indian grid as 5% although it is questionable whether this could be higher in reality (Tongia, 2015). India's grid is weak and unstable. Peak plants are scarce as was explained before and finally there is a lack of ancillary services. India's last black out was in 2012, affecting 20 states and over 700 million people. As a consequence, distribution companies have currently no alternative but to perform load shedding to keep prevent the grid frequency from decreasing leading to a system collapse. Naturally, **load shedding must be a measure of last resort that is to be avoided at all time, taking into account the socio-economic consequences. This is a major opportunity for the penetration of demand response programs**.

As a result, from an analysis of the electricity system from generation dispatchability and generation adequacy, one can conclude that there is a significant difference between the system's need for downstream flexibility between Sweden and India. As was also shown by the interviews with experts in the previous section, this analysis shows that the Swedish system has overall – without undermining some of the beneficial consequences it can have - no urgent need of rapid large-scale penetration of demand response penetration facilitated by smart meters, since sufficient alternative flexibility potential is present. The Indian system however is currently having severe issues and theoretically demand response can certainly bring a sound alternative for load shedding in the system.

5.4.3 Smart grid incentive: short term

The previous subsection has shown the comparison of long-term potential and perspectives of smart grid participation for distribution companies. In what follows, the short-term drivers for this will be assessed. This is an important part of the analysis since it is likely that investment decisions are largely based on the latter short-term rather than on long-term prospects. In Sweden, the *internal incentives* of distribution companies to initiate demand response programs are threefold, following a study by (Eklund, 2014):

- **Reduced internal losses:** since Joule losses $[W]$ from power transfer scale as $R.I^2$, with R line resistance $[\Omega]$ and I load current $[A]$, there is a non-linear behavior between load and loss. This implies that transmission of equal amounts of energy by constant power induces less losses than from variable power, in other words that peak shaving reduces overall transmission losses.
- **Reduced expenses:** Distribution companies pay a fee to the transmission operator based on the maximum power they require from the upstream grid. Reducing the peak power transported over the distribution network will therefore result in lower fees and initiate savings.
- **Defer capacity investments:** To ensure provision of supply, distribution companies are required to upgrade capacity restricted lines if demand is growing. However, one needs to take into account that the physical structure of

power transmission is designed based on the peak capacity, while large shares of the time this is not reached. By promoting peak shaving, distribution companies can better use the line potential while deferring the need for upgrades.

For the case of India, it needs to be assessed what the current drivers for distribution companies are, and if any of the experiences from Sweden can be applicable. Firstly, the internal incentives that were identified for Sweden do also hold for India and are thus directly applicable to for decision makers. Taking into account the financial situation of the India distribution companies and the expected tremendous grid expansions that are needed, the relative importance of these is likely to be stronger in India as well. Since the success of these internal parameters in driving smart grid deployment by distribution companies in Sweden is marginal, it is uncertain whether these will have sufficient impact in India.

Moreover, In Sweden distribution companies are also given *external incentives*. Since the enforcement of the new ex ante regulation, rewards are given by the regulatory instances to distribution companies for improved quality of supply, through an adaptation of the revenue cap in a positive or negative direction (G. Wigenborg et al., 2016). Rewards are given for reduced internal losses and for peak shaving, as was discussed in the previous chapter.

The aforementioned points briefly summarize the different financial drivers for Swedish distribution companies to invest in demand response. From the Swedish experience in the earlier section, it is clear that these in general fail to be sufficient in the Swedish context. This is reasonable, since several of the points made can be reached in other manners that are closer to their comfort zone and distribution companies do not see demand response as the low hanging fruit, as was concluded in the previous chapter.

The potential for these external measures -or even optimized measures that would have a higher effectiveness than in Sweden- to be taken in India is assessed as low. The main barrier that is present in India for the State Electricity Regulatory Commission (SERC) to put these or similar incentives in place is the current tariff determination structure. Driven by the artificially low prices that are maintained due to social and political reasons, distribution companies are prevented from receiving fair compensation. As long as the system of the regulatory assets instead of billing revenues is there, incentive schemes are on the one hand a priori irrelevant and on the other hand not in the interest of the SERC for whom it would mean an increase of the revenue cap after all. This is exactly what SERCs are currently refusing to do so as to keep end-consumer prices low. Since the external incentives for smart grid participation by distribution companies are to be enforced by the regulatory power, for a detailed elaboration of the Swedish and Indian regulatory context is referred to the section of this report that studies the dimension of regulation. This is a good illustration of the way in which the three perspectives are intertwined.

Peak supply through load-shedding:

From the comparison of system flexibility between Sweden and India, it was shown that in order to meet the peak demand, India distribution operators have currently no short-term alternative but to perform massive load shedding. This is seen as an option of last resort, but is an option that today is regarded as a normal way of balancing the grid in India (Tongia, 2015). This naturally suggests a tremendous potential for demand response applications in India, which is to the core a kind of load shedding supported by market mechanisms. However, the incentives for grid companies to seek alternatives for load shedding are inexistent or insufficient, while the socio-economic impact of load shedding and as a result the cost of this practice to the Indian society is high. Only recently, Minister of Power Raj Kumar Singh announced very heavy penalties for gratuitous load-shedding companies, which can potentially bring some surplus incentive for demand response initiatives for Indian distribution companies (Singh, 2017).

Incentive from retailer responsibility of Indian distribution companies:

As was already touched upon, a critical difference in the Indian is the unity of carriage and content for distribution companies. This implies that comparing the incentives for both Sweden and India requires adding the energy retailer's perspective to the Swedish side of the equation as well. At first sight it appears that this will highly disturb the similarities. That is, Swedish retailers do have significant financial benefits from demand response. Electricity is bought on the day-ahead market based on calculated expected consumption for the next day. This is subject to stochastic uncertainties that retailers are aiming to hedge for in order to avoid high unbalance fees. Demand response can be a vital tool for these hedging techniques and therefore, in contrast to distribution companies, electricity retailers can have major benefits from demand response activities. For a further elaboration on this is referred to (Ghazvini et al., 2017).

However, comparison of this retailer function for Sweden and India is difficult and hence the above argument is not valid in the context of India. The reason for this can be noticed in the Figure 5.6, which depicts the electricity market structure in both countries. All physical electricity transactions in Sweden are performed through the Nordpool wholesale day-ahead or intraday market. Retailers buy electricity via the bidding mechanism based on expected consumption in their portfolio and are penalized for inaccuracies. Although long-term and short term contracts and transactions are already used to hedge for uncertainties, demand response programs provide an alternative that can increase the profit of the electricity retailers (Ghazvini et al., 2017). An analogous reasoning can be followed for the case of Indian distribution companies that perform the task of a retailer in Sweden in relation with the IEX power exchange, with similar conclusions. However, as can be seen in Figure 5.6, there are many other physical transaction possibilities in the Indian electricity market. Currently 97% of the electricity sold in India apart from real time balancing is arranged through party-to-party agreements. Of thi, s 93% are Power Purchase

Agreements (PPAs) that have a duration of seven years or more while 4% are Over The Counter (OTC) contracts with duration of three months to five years (Indian Energy Exchange, 2017) .

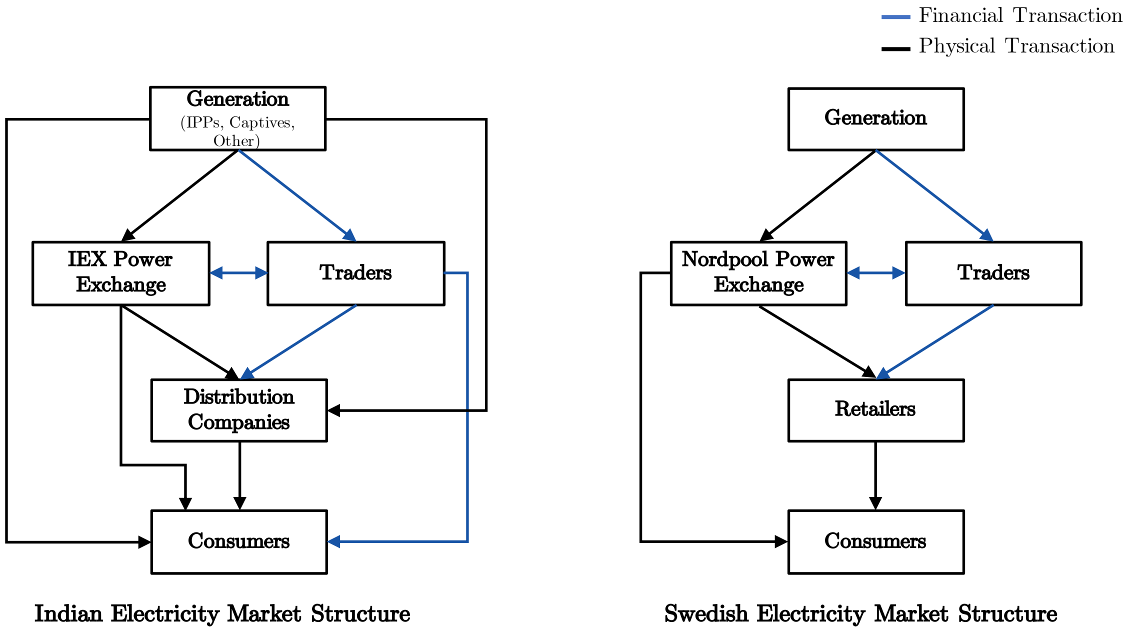

Figure 5.6: *Electricity market structure in Sweden and India*

Although the initiation of IEX was only recently and it therefore has a large growing potential, the former implies that currently virtually all energy exchanges by distribution companies are happening through fixed contracts. This is a major barrier for the above opportunity to hold – the fact that distribution companies in India have power purchase prices that are not present in Sweden does not create any increased incentive for them to support demand response activities.

5.4.4 Demand response capabilities: technological and financial

As was discussed in earlier chapters, it can be concluded that the main barrier for demand response in Sweden was the incentive rather than the capabilities. It was stated that behavioral barriers are the dominating factor for distribution companies. The latter is very well illustrated by the fact that although 90% of the installed meters now do have hourly measurement capability, only 50% of distribution companies is using this data in any way (Pöyry, 2017). For the IT technology is in a more advanced stage than current technology used in smart meters and smart grids, technological barriers are low, as became also clear during the expert interviews. From the perspective of financial capabilities for Swedish distribution companies to invest, the fragmented structure is not beneficial. It was seen that many smaller ones had difficulties with making the high upfront investments needed for the first wave of smart meter deployment. With the upcoming large investments that are expected, it is a possibility that the number of consolidations will increase in the near future (Ellevio AB, 2016). However, through the regulatory system, a fair compensation to the companies has now been allowed resulting in the end-consumer paying the final bill. It is likely that similar measures will be taken allowing the next generation meters. As a result, nor technological nor financial aspects of further demand response from distribution companies' side are not the main hurdles present today in Sweden.

In India, technological capabilities in a capital unlimited environment are largely sufficient to provide the demand response applications. The issue that is present instead is that installed technology and financial capabilities are strongly connected. This is exactly as can be expected from looking at the full picture. Distribution companies are having tremendous losses, that are mainly connected to the downstream side of tariff setting with cross-subsidizing of residential and agricultural consumers and to the very high AT&C losses in the network. Partly resolving the latter issue by reducing energy theft with the installation of smart meters is already challenging taking into account the large investment costs that this requires. According to the interview with the respondent from Fortum, the bigger issue is that in India the trend is to settle on lower technology just because the cost of this is lower. Meter cost are the dominating decisive factor for distribution companies when installing smart meters, with tendering prices dropping below 20 USD in the next 1-2 years, he said. This has of course a negative effect on the quality as well as the capabilities of the metering infrastructure. He continued:

"The operational side of smart meter deployment has certainly the main focus in India, since the operational side is the major hassle for distribution companies today. [...] Smart grid spillovers are absolutely not the main interest of India. However it brings in a lot of funding and networks and people who talk about it, which is always nice to have. The question always is, what is the main problem? The current problem in India is that people are not paying, and that is a problem that has nothing to do with the development of smart grids."

As an illustration of the aforementioned, during a discussion at the India Smart Grid Week 2018 with Head of Consumer Engineering & Network Planning of Tata Power Company Limited – one of the big utilities in India- he revealed that the company's focus in the upcoming local projects was merely on AMR rather than AMI metering, merely driven by a cost-efficient solution for the operational issues discussed earlier than the focus on demand response or other smart grid applications. Since AMR does not even provide two-way communication, this is very indicative of the status that smart grid spillovers and demand response have on the priority list of Indian distribution companies, but that instead the financial viability and margins to invest are a large hurdle.

5.4.5 Summary of distribution companies' situation in Sweden and India

Table 5.6 gives the summary of the comparison for smart grid incentives and capabilities between distribution companies in Sweden and India. Overall one can see that there are significant differences and barriers to be overcome. For a further discussion of this is referred to the next section.

Similar — Not Similar	Differences and similarities	Observation regarding smart meter transfer

Network Responsibility	• *Different market responsibility: see regulation section*
	• *Similar smart meter deployment responsibility:*
	  o *Meter installation*
	  o *Technology provision*
	  o *Data Handling*
		Regarding smart meter deployment, the distributoin companies have similar responsibilities in both countries.

Smart Grid Incentive: Long Term	• *Different situation regarding system variability:*
	  o *Sweden: large system flexibility*
	  o *India: low system flexibility*
	• *Different situation regarding system capacity:*
	  o *Susweden: sufficient generation adequacy*
	  o *India: peak supply through load shedding*
		The long term incentives for the energy system and its operators are largely distinct between the two countries. While the Swedish system has sufficient flexibility and adequacy without DR, the India system has an urgent need of measures to assure reliable power delivery. With the prospects of variable generation for the future, India needs to seeks solutions and DR can play a role in this.

Smart Grid Incentive: Short Term	• *Internal incentives: similar for Sweden and India, but importance higher for India through regulation system: see section regulation* • *External Incentives: possibilities for India severly limited due to regulatory system* • *India: announced penalties for load shedding incentive for alternatives* • *Different electricity market structure causes large barrier between Sweden and India*	Incentives for distribution companies to participate in DR programs are largely distinct in nature, mainly caused by the differences in regulatory situation and electricity market. In Sweden, external incentives are likely to be the most effective, while internal incentives are more important in Sweden. Although for different reasons, the DR incentives for distribution companies are currently low in both countries

Technological and Financial Smart Grid Capabilities	• *Similar technological capabilites for smart meters*
	• *Large difference in financial capabilities:*
	  o *Sweden: cost covered by consumers*
	  o *India: cost for distribution companies*
	• *As a result, different technologies installed with different DR potential*
		Driven by the tremendous difference in financial situation, the capabilities of the smart meters installed are distinct in Sweden and India, resulting in a different DR capability. In India, the need for low-cost solutions to solve operational issues as energy theft are outweighing DR incentives, due to the limited capital available.

Table 5.7: *Summary table of distribution company comparison for Sweden and India*

Chapter 6

Discussion: The potential of smart meter experience sharing in Sweden and India

The study about smart meters in Sweden and India has aimed to investigate the applicability of the Swedish experiences to the case of India today and in the near future. Firstly, this was done by thoroughly analyzing the situation of the smart meter roll-out in Sweden. Starting from the governmental proposition 2002/03:85, a sound understanding was reached of the implications of the Swedish pioneering role in smart meters today and what the prospects are for the future. Secondly, structured following a multi-stakeholder approach, the most important boundary conditions for smart meter deployment and its implications were assessed comparing Sweden and India. As a result of this, the following conclusions are reached.

6.1 Consumer interest and segmentation

Within the perspective of smart meters, residential consumers in Sweden and India do have to some extent comparable limitations, mainly driven by a lack of interest and incentives. While in Sweden this is mainly caused by low prices and in India by low consumption, the end result is similar. For the case of Sweden, it was showed that generally the awareness about electricity consumption as well as the financial incentives for consumers to participate are hindering current progress on the consumer side, since the demand for these applications from their side is barely existent. In India, results show that the importance of electricity for consumers is larger but nevertheless still small for large regions. The lack of consumer participation is a major barrier for spillover applications of smart meters installed. That is, any advanced features that could be potentially introduced in a new generation of smart meters lose every effectivity if the end-user is not interested to participate. From Swedish experience and as suggested by some experts in the interviews, it is therefore reflected that it is necessary to assess which applications will be used by certain consumers and which will not. This is an exercise that will have to be made on a state level in India due to the large variation of boundary conditions locally and that can possibly even require further segmentation of consumer types in order to avoid installation of technology that will remain unused. In India, one has to take into account that one of the main drivers to install new metering infrastructure is to reduce AT&C losses, of which a large part is caused by electricity theft. It is highly unlikely that consumers who are now committing electricity theft will be willing to participate in demand response programs after they have a smart meter installed. Rather, it would be expected that manners will be sought to tamper the meter once again. For this reason, the best possible trade of between an effective and cost-efficient solution for India could be to design different meters within the spectrum between AMR and AMI, depending on the expected consumer behavior. In Sweden, it is expected that further penetration of small scale solar installations and electric vehicles will lead to a consumer group with far higher potential. While the latter is a long-term development in India, the large penetration of small scale solar might lead to a viable consumer focus group in India.

6.2 Incentive versus capability of distribution companies

Regarding the interest of distribution companies in advanced application of smart meters, for both Sweden and India this appears to be low. However, the core drivers of the lack of interest are genuinely distinct for the two cases. That is, for Sweden, the main barriers for distribution companies are the lack of incentives. Financially, with the regulatory revenue cap system in Sweden as described, investments in new infrastructure are strongly promoted. This has as a result that the largest internal incentive for distribution companies of deferred investments from lower peak capacity is mitigated by the regulation. Regarding quality incentives, the Swedish grid is working properly, both on system and on distribution level, with not sufficient grid management issues that require solutions of residential participation with installed smart meters. To externally provide these incentives, the regulator has tried to include them in the revenue cap but without significant results. Consequently, distribution companies are not interested because the current situation is not pushing them in any way (nor internal nor external incentives) to overcome the barrier of adapting incumbent structures and natural conservative behavior. The situation is completely different for distribution companies in India. The Indian power grid is in a severe need of measures that prevent it from failing. The two main issues that are relevant to the context of smart meters are variability of the power generation on the one hand and the peak generation capacity on the other. Currently, the grid is kept afloat by massive load shedding by the distribution companies. Residential participation with smart meters installed has therefore a direct potential in the Indian distribution context. However, in India the main issue is not the incentive – although this is not there either – but the capability of deployment. With this is not only meant the tremendous debts of distribution companies. It also includes the current electricity market structure that prevents a roll-out as in Sweden.

6.3 Impact of socio-economic situation on smart meter decisions

Firstly, the financial boundary conditions for a smart meter roll-out are radically different between the two countries. For the case of Sweden, the situation is rather straightforward. It is critical to see that in a wealthy and developed country as Sweden with strong purchasing power, the implication of decisions regarding smart meters is relatively speaking far less important. The total cost of first wave roll-out is estimated at around 1,1 Billion €. All of this was to be paid by the consumers, which reimbursed the distribution companies for their investment. In Sweden this option of letting the consumers pay was almost trivial. When reflecting on the first wave, it is questionable whether consumers have benefitted sufficiently from this so that it was worth the cost. While this might be true, since electricity prices are low and the purchasing power is generally high, the implications of this are relatively small. The financial situation also has an impact in the decision processes today. It is recognized that there are opportunities to reach a more efficient electricity system from consumer participation from (new types of) smart meters installed. However, the situation as it is today is regarded as a good-enough solution. That is, although residential demand response has the potential of inducing deferred investments of distribution companies in grid infrastructure, the incentive for this is relatively low since the current investments can be easily reimbursed by the consumers to the tariff framework as well. Although electricity prices are rising, they still form a negligible part of the budget of many households. In that sense, the socio-economic situation highly simplifies the entire smart meter decision process and relaxes some of its needs to move forward.

In contrast, the socio-economic situation of a large part of residential electricity consumers is a large financial barrier for the entire smart meter deployment. Residential consumers are still cross-subsidized today by electricity tariffs charged for them that are artificially kept low. Distribution tariffs have in many cases not been updated in several years, driven by on the one hand the fear of damaging the socio-economic situation and on the other hand political reasons that influence the regulator. This is highly relevant for the smart meter ecosystem, since unlike the situation in Sweden, smart meter deployment cannot be covered simply by introducing the price in the distribution tariff. Taking into account the debts of Indian distribution companies that have accumulated throughout the past years, the large AT&C losses in the network and the artificially low distribution prices charged, the situation for Indian distribution companies is largely different from the one of Sweden. The former have as a main focus to reduce the losses and reduce energy theft to stabilize their financial situation. Smart meter deployment is therefore mainly focusing on this operational aspect, while costs of deployment must be severely restricted. Therefore, if distribution companies in India install smart meters, it is to face the aforementioned issues at the lowest cost possible. Meter tenders will soon result in prices below 20 USD per meter, which has of course consequences for the advancement of the technologies included. In conclusion, advanced applications of smart meters in India are hindered by the financial situation for distribution companies that are forced go for low-cost solutions, which is largely different from the situation in Sweden. As a consequence of this local socio-economic situation, financial limits lead to lower grade technologies with less capability installed in India and priorities of stakeholders in the ecosystem are apart.

6.4 Electricity market structure

The study has revealed several anomalies of the Indian system compared to the present standards in Sweden. These make the electricity market structures inherently different in some of its core foundations, which reflects to applications as smart meters deployed and therefore poses a barrier for the transfer of solutions. All of these are recognized as deficiencies and malfunctions of the Indian system and efforts are done to bring adaptations. The impact of these can be radical and disruptive and so this takes time. Overcoming these barriers will certainly lead to a comparability between Sweden and India that is far higher than it is today. However, it is expected that this will only be the case in the mid-term future.

Firstly, the state governments still have a dominant position in the electricity market in India. The large majority of distribution companies are still owned by the state, a remainder of the former vertically integrated energy utilities that were entirely state-owned. At the same time, the governments do have a large impact on the regulatory measure taken, leading to a regulatory hold-up situation. By its influence in both stakeholders, governments have a lot of power in deciding on critical developments in the electricity market. Tariffs that distribution companies charge to consumers are influenced by the government and artificially kept low for socio-economic and political reasons – to gain elective popularity by low tariffs.

Secondly, the basic electricity retail market structure is different. While Sweden has a fully competitive electricity retail market, in India this is the responsibility of the distribution companies that are for 95% of the cases state-owned. This implies that no commercial party is currently responsible for the delivery of electricity to the final consumers, as is the case in Sweden. Naturally, this leads to a direct wedge from other market dynamics that influences the entire smart meter process in all its facets. Measures are currently being analyzed and will hopefully be taken in the near future to deregulate the electricity retail market, but there is still a long way ahead before this will be finally put in place.

Thirdly, also the basic electricity wholesale market is different. Apart from the different buyers of electricity that is caused by the retail market, also the actual wholesale market is totally different. Physical electricity transactions are in Sweden made through the Nordpool energy exchange. Through the day-ahead market system, prices are variable for every hour based on the clearing point from (expected) supply and demand. That implies that retailers on the market have direct influence from variation in supply and demand which can boil down to their own off-takers - the residential consumers. However, in India, the wholesale market is currently only responsible for 3% of energy transactions. Most electricity retail is performed through long-term power purchase agreements with length of several years. Therefore, the financial incentive that can lead to interest in demand response to hedge for variation that is present in Sweden, is not there in India.

Chapter 7

Conclusion

As a final reflection on the potential residential consumer participation from smart meters deployed, one could state that the interest in Sweden is low because the ecosystem is currently working sufficiently. In India, the interest is low because the current ecosystem has several malfunctions that prevent effective solutions to arise from smart meters. The study has revealed several issues that arise from the aim of a knowledge transfer between Sweden and India, ranging from a retrospective view of the current situation in India to identification of barriers of different kinds that are present. From this, the study concludes that the main developments in the two countries are to that extent driven by their local boundary conditions that the relevance of a knowledge transfer becomes questionable. The main opportunity for Sweden is by taking a step back and sharing their experiences on the core barriers that exist today – the experience with the current electricity market structure and its regulatory frameworks. In parallel, it is important for Sweden to reflect on its own situation and the goals it has for the future. If and only if the two aforementioned issues are resolved, further steps towards smart meter collaboration gain applicability.

Chapter 8

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Appendix A

Results from the interviews

A.1 Consumers

A.1.1 Current consumer interest

- EI-2: No, indeed, I do not think that all the consumers will use the smartness. [Q: when asked if the incentive for consumers is enough today]

- EI-1: The responsible instances are sending forms to people to ask about their interest to participate in these kinds of applications. To be honest, I wonder to which extent the ordinary Swedes will be actually interested in this. For instance, the people you meet on the street, if explained what we do, find it interesting to hear, but they do not know anything about this. People are not aware of their electricity consumption.

- InnoEnergy: One of the big impacts which is in Sweden is that as a result of smart meters there is connection with hourly prices. But I think that awareness is not enough.

- Eon: No not really, there is only a very small amount of customers who is interested in this still.

- Greenely: Yes I would say that peoples' awareness has increased. A lot of people do not even care when they start, they just try it. And when they start seeing the data, they think "wow" and so they gain interest from getting feedback! [...]The people you hear that say that consumers are not interested in flexibility or demand response are they same that would say that consumers are not interested in looking at their own data. Greenely is the only company in the Nordics that is doing things in this way, so I would say we have more knowledge about that than any other stakeholders. [...] Sure, I definitely think that consumers are [answering the question if in conclusion he thinks that consumers can be interested in demand response programs.]

A.1.2 Barriers and incentives for consumers

- EI-2: If you want to change the behavior of the customer, some people will be driven by saving money, some will be driven by the environmental purposes and some other people will be attracted by the technical side and even pay more because they think it is fun. Now, the part of the customers that need the possibility to save money to do it, because it is not so much money to save today, because electricity prices are low, so I think as a customer you do not have so much money to save from being flexible. So today I guess it is mostly the interested people that want to be flexible.

- EI-1: I believe that this is a similar situation that you notice with all types of new technologies. In the end, it has a lot to do with the interest of the customer. For this reason, I believe we really need to get the customer interested. Otherwise, there are so many other alternatives that people can do, and as long as electricity is not very, very expensive, I doubt if people will be willing to do anything with this. This will of course vary depending on the place where people live or the type of customer you are. There are large differences between houses and apartments. For example, many owners of large houses, villas, have electric heating. In this case for example the demand response potential will be higher. What is key here is that one needs to find the right customer for the right product.

- InnoEnergy: For now, the classical reasoning is that the electricity price is not enough, so why should I bother as a consumer. I think to some extent that is why it is not fully successful, because people are not sufficiently aware. And even if they are to some extent aware of the existence of hourly prices, the fact that there is a costly hour and a cheaper hour, then still they are not aware of the existence of these innovative business models. People do not see the bigger picture, you need more people pushing the business models that can come from these smart meters.

- Eon: The electricity prices in Sweden are fairly low still, so I think that that is one reason for the low interest as well.

- Greenely:
  - There are several types of consumers that we identify, one of them is more interested in the financial side and wants to cut back electricity costs, another group cares a lot about the environment. [Answer to question who would be most interested in demand response:] Mainly those consumers that have financial incentives
  - It is hard because there has not been a solution that is fine to use and through which you gain value, it is about where you present that information. Now, utilities send out an sms or an email saying "say your behavior during this time", of course that is hard because they do not have any platform to push out that kind of information.

- The electricity cost gives some barriers yes, but I think there is still a potentia. So I would say a bit.

A.1.3 Barriers and incentives for consumers

- EI-2: Yes, one important goal is to improve the market. [...] if you have the electricity market work, with consumption and production that balances to a certain price. In that way, you can respond to that price by adapting production or consumption. In order for that to work, the customers need more information. By suggesting the same functionalities for all meters, that will both give new opportunities for the customers to find better solutions.
- EI-1: Consumption is displayed on webpages of utility companies. These things might help for customer awareness. It could be expected that having this kind of information leads people wanting more information. In that case you can get people interested in these services.
- InnoEnergy: The rate at which people are changing their contract from fixed to hourly is very low. The reason is that people do not see the value. Why is this? There are not enough start-ups that are making these innovative business models and reaching out to customers showing them why they should do it
- Eon: I think the role there will more for the energy sales and retailers, that will use that. It is now already used to promote interest for energy among the customers. This is done very much through marketing activities through tv adds, the homepage... You see a lot of promotions for energy usage and getting the customers to be more aware of consumption. It is not so much due to the functional requirements, more due to the competition between the companies, as a branding. Electricity as such is a very boring product, so it is very much about how you perceive the company as such and about branding.
- Greenely:
  - First you need to make them more aware. For example what we are doing is the perfect example on how to get people envolved. Good services can actually engage people.
  - If electricity prices would be going up, this would of course incentivize people as well
  - We also see that a lot of people that use our application have solar on their roof or drive an electrical vehicle, and then all of a sudden it becomes much more interesting.
  - On the regulatory side, you can maybe adapt taxes

A.1.4 Expectations for future consumer interest

- EI-2: There is a trend that are a lot of people getting solar panels on their roofs, that you could combine with a battery, and there is a trend getting electric cars, so the possibility that you will need energy, produce your own energy and to store energy, so it is a two way possibility. When more and more people do this they will be also more possibility for people to save money by using electricity in a smart way. Because, if you buy an electric car and you want to charge it, you might not be able to heat your house and charge your car without doing adjustments. Then if you have some control equipment that for instance controls the heating system people can benefit, because otherwise you might need for example a bigger fuse, and when you use smart grid techniques you would not need it. In the future there is certainly a possibility for these kinds of solutions

- EI-1: It can be especially interesting for people who drive electric vehicles. On the one hand, you can try to optimize the charging time so people charge in a cheaper way. Once the new meters are put into place, there will have to be found means or regulation to let people know about this possibility.
- Eon: In the future, with PV that are becoming cheaper and more interesting and you also get investment support now, so of course that will increase the customers' interesting. But still, the households, the villas, it is a very small portion of the consumers in Sweden. The households are more important as a symbolic value, to increase the interest of the customers.

A.2 Distribution Companies

A.2.1 Current interest of distribution companies

- EI-1: From my experiences, distribution companies are interested in smart grids. There are numerous conferences and talks about smart meters and smart grids, which is a good illustration about the interest of these utilities in the topic.
- Greenely:
  - I think some distribution companies are interested in this because they see some possibilities, but not all of them.
  - Some companies have tried with power tariff - that you pay a higher price to use the network at specific times. To be able to have this kind of tariff, you need hourly metering from the consumers. I believe that more and more distribution companies are introducing these kinds of tariffs, to be able to maybe, in some way, change the consumption pattern of consumers.
  - I think it is a bit dependent on the size. For the small ones it will probably be more difficult to do projects, because there are even not so many people working in the company. Maybe in a big company you can have one person doing something, while in a small company one person

can perform the same task only 10% of their time. So from that I think that it is probably easier for a company that is a bit bigger. But besides that it is also a lot about the person working there. Some people or companies are very innovative and like to try new things.

- InnoEnergy: So that is the reason why grid companies are not interested in making smart meters more advanced. For me that is one of the biggest barrier, that the grid companies see this in another way. [...] So certainly, in these smart solution -and that is the dilemma of IRENA actually- there are all these smart solutions (demand response, batteries, local systems, flexibility...) this is good for societies but not for grid companies.

- Eon [When asked to describe the interest of distribution companies of demand response and flexibility] I think that is not of that great use today. [...] But at this point there is no real incentive to go for demand response programs or dynamic tariffs as being a distribution company, not for the moment at least.

- Greenely: Distribution companies have no interest in doing it. I cannot see any benefit or incentives for distribution companies to do it right now. The only thing we see it that we create so much errors for them that they might need to hire extra employees. I cannot see anything that distribution companies have to gain today. Maybe when you have some flexibility and demand response there might be some incentive for them to get involved more with these applications. Today, I see very little benefit, and I assume that for demand response you need to aggregate quite a large consumption in a small area to make it beneficial for them to participate.

A.2.2 Internal incentives and barriers for distribution companies

- EI-2:
  - If you can lower the highest peaks, that can lower the cost for the network. For example if you can reduce the highest peaks, you can avoid building new capacity, or you can lower the fee to be paid to the grid.
  - I think it is a bit dependent on the size. For the small ones it will probably be more difficult to do projects, because there are even not so many people working in the company. Maybe in a big company you can have one person doing something, while in a small company one person can perform the same task only 10% of their time.
- Innoenergy
  - Two years ago, I have a conversation with the Head of R&D of a big utility in Sweden. And I presented the same issue to him. He asked me to look through his office window. On that street only, there were five new buildings under construction. He said me: "In six months time, I

need to give connection to these 100 apartments in each of the 5 buildings, which we are obliged to give them by law as a distribution company. If we cannot do this, then I am fired. And the most safe way for me that I know I can rely upon is putting a cable in the ground. Now you are showing me some beautiful slides, but I do not see what is behind these slides. Can I risk my job and the image of the companies because of something that might or might not be working"

  - Power systems are much more conservative than many other industries.[...].In power systems, we cannot afford something that has a chance to fail. This is because the power system is considered as a critical infrastructure on which society relies

- Greenely
  - The only thing we see it that we create so much errors for them that they might need to hire extra employees. I cannot see anything that distribution companies have to gain today
  - One thing that happens sometimes, when we are receiving data, the export of data suddenly stops, so sometimes the user that regularly get data do not get data for five days, and then all of a sudden it starts again. So there are a lot of different types of old systems that the utility uses, which is a huge barrier

- Eon: Maybe in Sweden it will become more used in the future, when you maybe have more bottlenecks in the grid and so on. We do not have that in Sweden for the moment, but if you see that for example the number of electric vehicles increases, then you may need some means to control the loads at consumers' premises. So this would be mainly for reasons of congestion management.

A.2.3 Regulatory incentives and barriers for distribution companies

- EI-2: There is a quality incentive today for efficient utilization of the grid, but that incentive has received some criticism for not being so efficient. Even if some companies shaved the peaks, when you transfer that to a certain amount of money the impact was small. The revenue cap is reached by a certain method, and the change of the incentive compared to the different parameters of the revenue cap is small.

- InnoEnergy
  - Grid companies are not allowed to own and operate storage and become a market participant. So for them there is not enough incentive for this compared to building new infrastructure

  - The regulations are in a way that distribution companies are paid for investments in grid infrastructure, and they are allowed to get it reimbursed by the customer. There is a revenue cap, so they can reach to this cap. This of course needs to be justified, but they are all able to justify, because they use arguments like urbanization: "lots of people are moving into the big cities like Stockholm". Partially this is true, there are some areas (as Solna, ..) where everywhere new apartment buildings are popping up, so they claim they need to invest in more infrastructure to provide electricity to all these new people

- Greenely
  - I think that it could be [When asked about the potential of regulatory incentives to promote demandresponse]. However for now I do not think that it has much impact. The distribution companies must learn how to use these regulatory incentives maybe, but I cannot see that today yet, that someone is starting to utilize these incentives. So for the moment these have not been so effective for now.
  - It is indeed the case that the regulatory model today in Sweden is promoting investments very much.