ISGAN
international smart grid action network

Benefit-Cost Analyses and Toolkits

Asymmetric benefits of Smart Grids

Discussion Paper

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ISGAN Annex 3

Task 4.5

CLEAN ENERGY MINISTERIAL
Accelerating the Transition to Clean Energy Technologies

iea Energy Technology Network

About ISGAN Discussion Papers

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

Disclaimer

Preface

IEA-ISGAN Annex 3 started Task 4 with the aim to evaluate existing approaches for decision making applied to Smart Grid, and to propose new approaches as needed for quantitative analysis projected to 2050 by comparing a range of scenarios that differ for the level of smart grids deployment on different scales (i.e., local, regional, national and transnational).

Particularly, Subtask 4.5 deals with socioeconomic benefits of smart grids and looks at the relevant regulatory implications. Cost-benefit analysis is crucial in evaluating different regulatory options where the socio-economic perspective is of the outmost relevance. New market functionalities and strengthened interconnections between countries go beyond national borders and need regulators to collaborate making the societal cost-benefit analysis a more complex exercise. The scope of Subtask 4.5 is the identification of social benefits, the definition of suitable metrics for social benefits, and the assessment of the implications on regulation.

Three deliverables have been published with the aim to identify existing gaps and shortcomings in current cost-benefit analysis when applied to Smart Grid projects, to include new metrics for the assessment of benefits that with Smart Grids are not uniformly shared amongst the stakeholders and, finally, to propose new tools that can further improve the CBA with Multi criterial analysis that can fill some of the gaps of CBA and is better suited to non-monetizable and asymmetrical benefits.

- Deliverable 1 - Social costs and benefits of Smart Grid technologies
- Deliverable 2 - Asymmetric benefits of Smart Grids
- Deliverable 3 - Combined MC-CBA methodology for decision making on Smart Grid.

As part of the overall effort taken in subtask 4.5, Deliverable 2 focuses on an analysis of the distribution of costs and benefits primarily in relation to decentralized electricity consumption on the residential level. The aim is to discuss whether social imbalances are induced by shifting the burdens of financing the grid towards lower income classes. Such imbalances may be aggravated by the tendency to go off grid, thereby challenging current cost recovery schemes.

Acknowledgments

The work of the Energieinstitut an der JKU Linz in the IEA-ISGAN Annex 3 is funded by the Austrian Ministry for Transport and Technology under the Grant #848114.

Nomenclature or List of Acronyms

BoS	Balance of service
CBA	Cost-benefit analysis
EPC	Engineering procurement and construction
EU	European Union
EURELECTRIC	Union of the Electricity Industry
EUROSTAT	Statistical office of the European Union
IEA	International Energy Agency
IQR	Interquartile range
IRENA	International Renewable Energy Agency
ISGAN	International Smart Grid Action Network
OECD	Organisation for Economic Co-operation and Developmen
PV	Photovoltaic
PVPS	IEA Photovoltaic Power Systems Programme

Abstract

The following report aims at discussing the allocation of costs and benefits in relation to distributed generation from a socioeconomic point of view. The focus is on assessing whether social imbalances are induced by the introduction of such new smart technologies e.g. in relation to shifting the burdens of financing the grid towards lower income classes. Such imbalances may be aggravated by the tendency to go off grid, thereby challenging current cost recovery schemes.

An assessment of how and by whom decentralized energy technologies are used in the Annex 3 countries, how households respond to public or private participation projects, what that tells us about benefit allocation and who the first-movers are will be part of this deliverable.

As of September 2017, this report is a draft which will be discussed and further elaborated in the IEA-ISGAN Annex 3 working group.

Executive Summary

The world's electricity systems face challenges, including ageing of infrastructures, continued growth in demand, integration of variable renewable energy sources and plug-in electric vehicles, the need to improve the security of supply as well as the need to lower carbon emissions. Smart grid technologies offer a way to meet these challenges and to develop a cleaner and more efficient energy supply. However, national and regional circumstances, such as available sources of supply, grid structure and legislative and regulatory conditions, will give rise to a substantial diversity in the implementation of different smart grid technologies and system solutions.

In order to be able to disseminate experiences and conclusions regarding costs and benefits of these different projects in an efficient and systematic way, a framework for socioeconomic cost-benefit analyses in relation to smart grid solutions needs to be developed. Knowing ex-ante how the socioeconomic effects are distributed can support the design of new policies, the reformation of the regulatory framework as well as the prioritisation of initiatives, and shed light on gaps in research.

This report analyses the distribution of costs and benefits primarily in relation to decentralized electricity consumption on the residential level. The aim is to discuss whether social imbalances are induced by shifting the burdens of financing the grid towards lower income classes. Such imbalances may be aggravated by the tendency to go off grid, thereby challenging current cost recovery schemes.

Socioeconomic analyses are those that aim at identifying differences between groups of people that share similar characteristics like their level of education, employment status, living condition, occupation and income, among other. When assessing smart technologies and regulatory regimes in the context of smart grids, socioeconomic analyses highlight their associated social impact, thereby looking at how related measures affect energy consumption, income and wealth distribution, equity and participation.

The report especially focuses on the question how own, decentralized electricity production changes pricing and tariffing schemes and which socioeconomic factors should be taken into account when designing new cost and benefits models to analyse and assess investments in smart grids related technologies and smart grid regulation.

The main socioeconomic indicators and related impacts

The list of important socioeconomic indicators that have to be taken into consideration while designing and implementing new measures, smart technologies and policies in the energy field, is broad. An overview of the socioeconomic factors that have a significant impact on energy consumption and photovoltaic generation adoption is given in the report. The analysed socioeconomic factors are:

- income;
- dwelling type and property rights;
- household size;
- education;

Income is an important socioeconomic indicator, the literature reviewed highlights that household income is statistically significant and positively associated with residential solar PV share. Conversely, the electricity demand rises only a little with increasing income and suggests that as electricity is a necessity for both low and high-income groups their demand does not differ dramatically.

The surveyed studies about the impact of dwelling type and property rights highlight that energy consumption increases with the degree of detachment of the dwelling. Furthermore, the home ownership is an important pre-requisite for the adoption of PV systems, as the installation of such technology demands property rights, and also space. Another socioeconomic characteristic of households, which has a positive effect on energy consumption and is also an important driver of PV adoption, is household size.

Education is an important socioeconomic indicator as it is related to the lifestyle of the households and might also have an impact on general knowledge and understanding of the current situation on the energy market, and in this sense also influences the decisions and behaviour of households. From this perspective, increasing educational level and better communicating some specifics of the energy market to consumers could contribute significantly to overall welfare and energy efficiency.

The factors mentioned above with related socio-demographic trends in all the European countries on the one hand, and technical innovations and new smart solution on the other hand, inevitably influence energy market. Consequently, these new circumstances in terms of energy production and consumption, communication and signals between consumers and producers and, of course costs, tariffs and policies warrant further investigations.

Distributed generation and Cost recovery

An overview about network tariff schemes and how changing them may affect households is given in the report. With the advent of smart grids and smart technologies, the tariff system will be faced with new factors: the increase of distributed generation, low-capacity storage (e.g. in-home batteries for storing PV-produced electricity), charging of electric vehicles, and the vision of house-to-house electricity trading to balance the overproduction from own generation without the need (of higher levels) of the power grid. Thereby, the connection to the public grid will largely serve as a backup option for a growing share of consumers, rather than being the primary source for their electricity acquisition. Depending on the tariff system in place, their contribution to the financing of the grid may significantly decrease and a significant shift in the allocation of grid cost recovery may happen.

This report focuses in how such changes affect different socioeconomic classes and how new tariff schemes can be designed in order to avoid an adverse cross-class cost allocation.

Network tariffs are defined by regulatory authorities (or a comparable entity) to recover the capital and operational expenditures of providing transmission and distribution of electricity and the investments needed to establish and maintain the required grid capacity. Considering that these innovations (own production, storage) are more likely to happen first among a subgroup of the population owning single-family dwellings (since most of these innovations require property rights for installation), a significant social imbalance induced from shifting the burdens of financing the grid towards lower income classes may hamper the public acceptance of these innovations.

Internationally, different network tariff systems are in force, but usually tariffs include two or three of the following components: 1) a volumetric tariff, reflecting the amount of consumed electricity (kWh), 2) a capacity tariffs, depending on the (measured or non-measured) demand (kW peak load), and 3) a charge to recover fixed costs (e.g. for metering services). Obviously, any new tariff system has implications on a socioeconomic level and especially on the households' budgets.

An Austrian Case Study

To illustrate the arguments presented, the result of the Authors' current research that deals with the distributional impact of different tariffs schemes on households is provided.

In the research project, the effect of introducing different network tariff schemes on households' budget is quantified. The measured load profiles (data for 1 year, 15 min intervals) for 765 Austrian households are combined with socio-demographic data provided by these households in an additional survey. Using this dataset, an ex-post analysis is performed with the aim to assess the effects different network tariff schemes would have had on these households, how their respective contribution to grid cost recovery would have changed and how these results can be interpreted from a socioeconomic point of view.

In the analysis all the socioeconomic factors mentioned above are taken into account. The analysis highlights that tariffs combining measured capacity demand and volumetric components could provide a new balance for the distribution of network costs – as these tariffs are cost reflective, due to the peak load charge, they also signal the consumer to decrease their overall consumption and they do not penalize any group of consumers for a decrease in electricity demand. Therefore, such tariffs could provide a solid response to the increase of prosumers while avoid shifting burdens towards households not yet ready for taking this step.

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1 Introduction

IEA-ISGAN Annex 3 has recently started to work on a new subtask 4.5, which deals with socioeconomic benefits of smart grids and looks at related regulatory implications. The rationale of subtask 4.5 is that the world's electricity systems face challenges, including ageing infrastructures, continued growth in demand, integration of variable renewable energy sources and plug-in electric vehicles, the need to improve the security of supply as well as the need to lower carbon emissions. Smart grid technologies offer a way to meet these challenges and to develop a cleaner and more efficient energy supply. However, national and regional circumstances, such as available sources of supply, grid structure and legislative and regulatory conditions, will give rise to a substantial diversity in the implementation of different smart grid technologies and system solutions.

In order to be able to disseminate experiences and conclusions regarding costs and benefits of these different projects in an efficient and systematic way, a framework for socioeconomic cost-benefit analyses in relation to smart grid solutions needs to be developed. Subtask 4.3 aims at contributing to a common understanding on how to assess costs and benefits of different smart grid solutions, considering local circumstances and socioeconomic costs and benefits as an integrated part of the evaluation.

So far, the smart grids and smart energy technologies domain is dominated by technical and economic research, which was also recently pointed out by ISGAN-Annex 7: *"The structural challenge is that energy research is mainly focusing on technologies for the physical grid with little knowledge on institutional change and the social dimension of energy transition"*.[1] Knowing ex-ante how the socioeconomic effects are distributed can support the design of new policies, the reformation of the regulatory framework as well as the prioritisation of initiatives and shed light on gaps in research.

As part of the overall effort taken in subtask 4.5, deliverable 2 focuses on an analysis of the distribution of costs and benefits primarily in relation to decentralized electricity consumption on the residential level. The aim is to discuss whether social imbalances are induced by shifting the burdens of financing the grid towards lower income classes. Such imbalances may be aggravated by the tendency to go off grid, thereby challenging current cost recovery schemes.

There is no universally accepted definition of the term *socioeconomics*. In this report, socioeconomic analyses are those that aim at identifying differences between groups of people that share similar characteristics like their level of education, employment status, living condition, occupation and income, among other. When assessing smart technologies and regulatory regimes in the context of smart grids, socioeconomic analyses highlight their associated social impact, thereby looking at how related measures affect energy consumption, income and wealth distribution, equity and participation. The central question to be looked at is how the specific situation of an individual or a household influences the adoption of decentralized electricity production plants, what kind of distributional effects related subsidy

[1] ISGAN Annex 7, Policy Conclusions for CEM8: „Why We Do Not Know Much about the Social Dimension of Smart Grids Transitions?", May 2017.

regimes have and whether cross-class subsidization, i.e. implicit wealth transfers, can be detected.

Obviously, these issues are not specific to the analyses of energy markets and energy systems. Social impact analyses have always been an important tool of policy analyses. With the on-going fundamental changes in the energy markets, mainly the advent of digital technologies in the electricity network system, the rapid cost reduction in residential electricity production facilities (most notably in photovoltaics) and overall lifestyle decisions that have led to an increasing interest in self-sufficiency and regionalism, socioeconomic issues have moved to the centre of the discussions.

The challenging task of defining a comprehensive framework to model the cost and benefits of smart grids will need to assess the ‘winners’ and ‘losers’ in the smart grid development in more detail than has been done in the past. To date, consumers have mainly been treated as a homogenous mass. But digital technologies now allow a more detailed, individualized analysis of demands, needs and opportunities on the household level. This will support the on-going shift from the passive electricity demander to an *active participant*.[2]

The European Commission has recently defined what such active participation on the part of households encompasses: they shall have “a better choice of supply, access to reliable energy price comparison tools and the possibility to produce and sell their own electricity”[3]. In order to achieve these aims, transparency needs to be increased and existing regulatory frameworks need to be adapted to better allow consumers’ involvement in the energy system and to give them the opportunity to respond to price signals.[4]

Reassessing the energy system frameworks is also needed to align the change in consumer behaviour with other energy related goals, like increasing energy efficiency and reducing greenhouse gas emissions, ensuring security of supply and reducing import dependence. Smart Grids and related technologies can support these aims and can act as enablers for achieving them.

When presenting the *Winter Package* the European Commission decided to headline their proposals “Clean Energy for All Europeans”. While the importance of this strong commitment of the European Commission to strengthen consumers’ interests in future energy markets signifies a major step in European energy policies, it does not take specific reference to different groups of consumers[5] and their respective access to services, products or technologies with which to become “active and central players”.

But, treating consumers as a homogenous group, European-wide as well as intra-country wide may significantly weaken the success of consumer-centred energy policy.[6] Also, a new cost-

[2] With the presentation of the European Union’s Winter Package, the European Commission has highlighted the important role of the consumer in the current developments on European energy markets. Consumers, as seen from the European Commission’s perspective, shall be “active and central players on the energy markets of the future”.

[3] European Commission (2016) “Clean Energy for All Europeans – unlocking Europe’s growth potential. http://bit.ly/2fQbVQk

[4] See https://ec.europa.eu/energy/en/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition for the whole statement.

[5] Except so-called „vulnerable consumers“ for whom specific protecting measures shall be defined.

[6] Additionally, consumers need access to different forms of energy (electricity, gas, heat, fuels) which adds another dimension to the challenges of making consumers more active.

benefit assessment framework should be able to inform policy makers about competing interest and programs and about possible adverse effects of policy measures on specific consumer groups. Knowing ex-ante how the socioeconomic effects (costs as well as benefits) will be distributed can support the design of new policies, the reformation of the regulatory framework as well as the prioritisation of initiatives and shed light on gaps in research.

In the following, we especially focus on the question how own, decentralized electricity production changes pricing and tariffing schemes and which socioeconomic factors should be taken into account when designing new cost and benefits models to analyse and assess investments in smart grids related technologies and smart grid regulation.

In Section 2, we will briefly discuss main socioeconomic indicators, which we consider important to the discussion. Section 3 will give literature overview about network tariff schemes and how changing them may effect households. To illustrate our arguments, we use Section 4 to present the results of research we are currently engaged in and that deals with the distributional impact of different tariffs schemes on households.

2 The socioeconomic perspective

The list of important socioeconomic indicators that have to be taken into consideration while designing and implementing new measures, smart technologies and policies in the energy field, is broad. Following Jones et al. (2015), who provide an overview of the literature on socioeconomic factors that have significant impact on electricity consumption, we focus here on the key factors, including income of the household, property rights and type of the dwelling, household size and education level. These factors provide a first insight of the energy lifestyle of households and can support the analysis of the effects, smart grids and related smart technologies may have on particular groups of consumers as well as their respective reaction to it.

To our knowledge, no study has empirically assessed the impact of socioeconomic factors on the adoption of Smart Grids and smart technologies and the respective policy implications so far.

In the following, we will provide an overview of the socioeconomic factors that have a significant impact on energy consumption and photovoltaics adoption. We suggest there is a strong parallel between these factors and factors that should be taken into consideration when assessing the socioeconomic dimension of smart grids and smart technologies.

2.1 The effect of income on the adoption of photovoltaic systems

Even though costs for photovoltaic systems have rapidly declined in the past several years (IEA; 2014; IRENA, 2017)[7], the upfront investment needed, is still substantial[8]. As mentioned in the introduction, income is an important socioeconomic indicator. Studies dealing with the identification of factors influencing the adoption of photovoltaic systems show a uniform picture, regardless of the country size and method of research. Schaffer and Brun (2015) find that "[…] investments in residential photovoltaics are generally realized by comparatively rich homeowners" in their study of adoption behaviour in Germany. Their findings are confirmed by Dharshing (2017) who explains his results in terms of the "[…] significant capital investment linked to residential PV systems." Briguglio and Formosa (2017) find similar results in their study of photovoltaic installation behaviour in Malta: "Further insights, confirming previous studies, pertain to the limitations that the capital outlay may impose on low income households […]."

Also Kwan (2012) examines how residential solar PV installations in the USA are influenced by income levels and finds that household income is statistically significant and positively associated with residential solar PV share. Further on, Vasseur and Kemp (2015) consider the adoption of PV in the Netherlands and suggest that "[…] comparing the PV adopters with the representative sample of the Dutch population, we see that the adopters are in general higher in income. Of the adopters, 31.6% have an income between €22,500 and €36,000 and 13.2%

[7] IEA (2014) Technology Roadmap: Solar Photovoltaic Energy, 2014 edition. http://bit.ly/1zp91C8; IRENA (2017) BOOSTING SOLAR PV MARKETS: THE ROLE OF QUALITY INFRASTRUCTURE; http://bit.ly/2xfS99o

[8] We do not consider leasing possibilities.

have an income above €36,000. For non-adopters these numbers are different, the majority have an income below €22,500 (47.0%) and only 5.6% have an income above €36,000 […].”

Groote et al. (2016) who analysed the heterogeneity in the adoption of photovoltaic systems in Flanders confirm this finding but argue that “[…] wealthier households are more likely to benefit from the PV subsidies [...] not because of their higher income per se, but rather because they are more likely to adopt PVs as high users and as more frequent house owners and because they live in houses that are better suited for PVs.”.

Figure 1 shows the system cost breakdown for utility-scale photovoltaics.

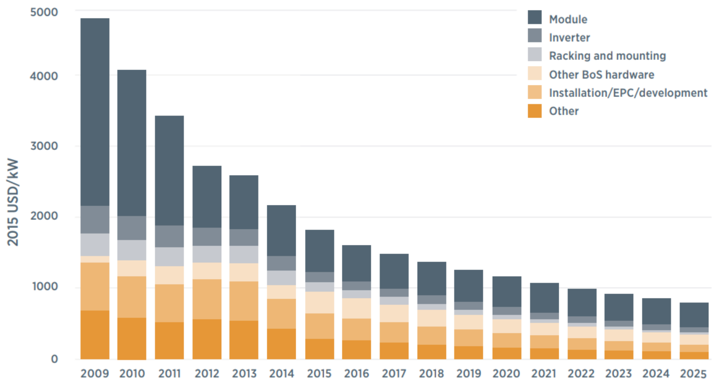

Figure 1. System cost breakdown for utility-scale photovoltaics: Global weighted average (Source: IRENA, 2017)

Numbers are for utility-scale photovoltaic systems; BoS = balance of systems; EPC=engineering, procurement and construction

The effect of income on energy consumption is extensively discussed in the literature. Most of the researches agree that electrical energy consumption increases significantly with income (Jones et al., 2015). At the same time Zhou and Teng (2013) in the survey of 5,980 households in China find that electricity demand rises only a little with increasing income and suggest that as electricity is a necessity for both low and high income groups their demand does not differ dramatically. Similar conclusions can be made based on Austrian data (Figure 3), which represents yearly energy demand of 765 households in 2012 depending on their income – the first quartile is the low income group, the second is low-median income, the third is median income and the fourth is high income. It can be seen from the graph that there are major overlaps between the energy consumption of low and high income groups, although the high income group consumes more energy than the low income one.

2.1.1 The effect of dwelling type and property rights

European statistics show how diverse the tenure status of the population is: even though more than half of the population in each EU Member State lived in owner-occupied dwellings in 2015, the shares range from 51.8% in Germany up to 96.5% in Romania. In addition, in 2015 more than 4 out of every 10 persons (42.0%) in the EU-28 lived in flats, close to one quarter (24.1%) in semi-detached houses and one third (33.3%) in detached houses (for sources and illustration see Figure 8). The proportion of people living in flats was highest in Spain (65.9%), while the highest proportions of people living in semi-detached houses were reported in the Netherlands and the United Kingdom (both 59.9%). The share of people living in detached houses peaked in Croatia (73.4%).

The relationship between dwelling type and energy consumption is widely discussed in the literature and a large number of studies states that "[…] energy consumption increases with the degree of detachment of the dwelling, suggesting that detached houses consume more energy than semi-detached and those consume more than apartments […]", (e.g. Jones et al., 2015). This statement is confirmed by Bedir et al. (2013), Wiesmann et al. (2011), Druckman and Jackson (2008).

Looking at the impact of dwelling type and property rights in the context of PV, we find that home ownership is considered an important pre-requisite, as the installation of such technology demands property rights, and also space. For instance, Sommerfeld et al. (2017), in their analysis of socioeconomic variables influencing PV uptake in Australia, find that home ownership is a significant explanatory variable positively correlated with the adoption of PV. This result is confirmed by Groote (2016), who also concludes "[…] household ownership status turns out to have a strong positive impact on PV adoption. Hence, PV adoption is more likely on the roofs of owned than on the roofs of rented houses. This is consistent with previous work, which has established that house renting forms a barrier to the adoption of new technologies within the house, as it is often difficult to allocate the benefits and the cost between tenants and landlords (Jaffe and Stavins, 1994; Sutherland, 1996) […]".

2.1.2 The effect of household size

Another socioeconomic characteristic of households, which has a positive effect on energy consumption and is also an important driver of PV adoption, is household size.

Looking at data on household composition statistic in Europe (Eurostat, 2017), the average household size in the EU-28 is 2.3 persons. The largest average household size was recorded in Croatia (2.8 persons), while the smallest were observed in Sweden (1.9 persons), Germany and Denmark (both 2.0 persons). The most common type of household is composed of a single person (33.1%), two persons corresponded to 31.7%, three persons (15.9%), four persons (13.4%), while households with five persons or more accounted for 5.8%. While the share of single households grows, the share of larger households (three, four and five persons) faces a strong reduction.

According to OECD projections, the share of single person households will continue to grow while the share of larger households is expected to further decrease in the future. For instance, a 22% and a 15% decrease in number of households with kids (3 or more person households) is expected in Germany and Austria, respectively (see Figure 2).

This trend should be accounted for in future energy policies, as in the existing literature including Mills and Schleich (2009), Groote et al., (2016), Sommerfeld et al., (2017), it is suggested that households with 3-4 persons are much more likely to adopt PV compared to single households. This is explained by the fact the larger households also consume more electricity (Kavousian et al., 2013, Zhou and Teng, 2013, Gram-Hassen et al., 2004) and so they invest more in PV as they can spread the fixed costs of adoption over more members, which makes such an investment more attractive for larger households.

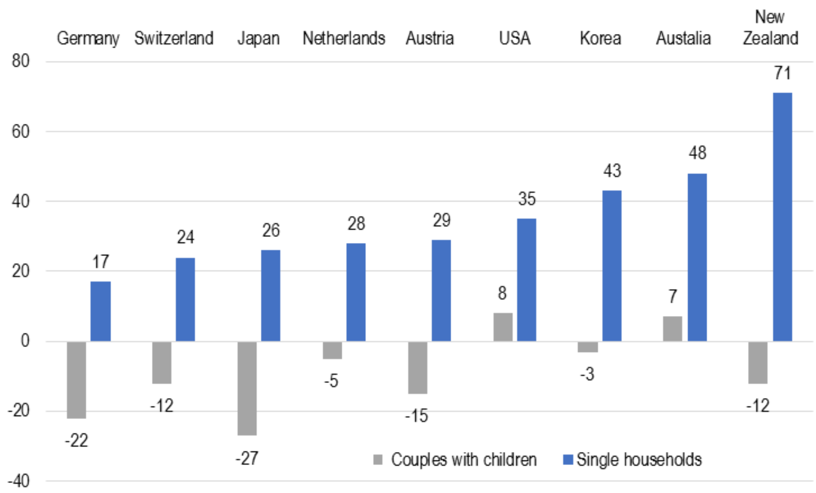

Figure 2. Projected % increase in number of couples with children and single households in selected OECD countries, from early-mid-2000s to 2025-2030 (Source: OECD "the future of families to 2030 projections, policy challenges and policy options. A Synthesis Report". 2017)

Kavousian et al., (2013) also finds that although larger households have a higher absolute energy consumption, their per capita consumption is lower. Based on the data from a currently running Austrian project, we find similar effect: looking at Figure 3, representing annual energy consumption for 765 households in Austria, we find that consumption per person decreases with increasing size of the households. For instance average consumption per year per person for single person households is ~2,000 kWh while for 4 persons household only ~1,000 kWh.

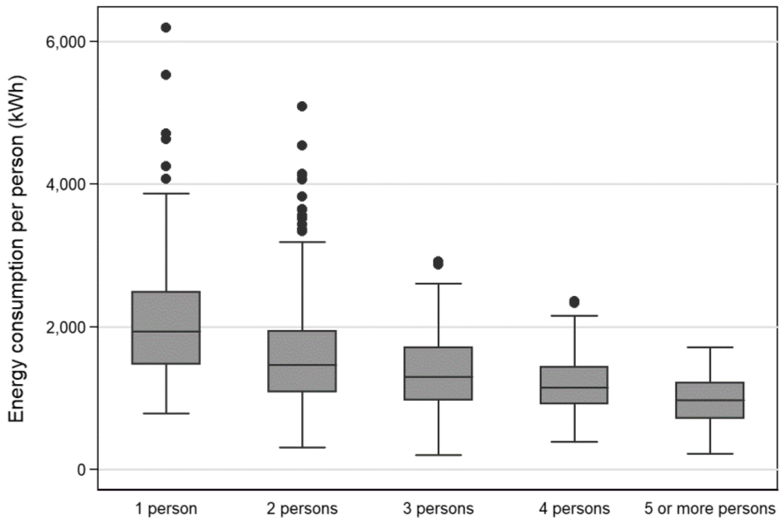

Figure 3. Yearly energy consumption per person based on households' size (Source: Own illustration)

Considering the trends mentioned above, a decrease in the number of larger households in Europe together with their lower per capita energy consumption per capita than smaller households and lower involvement of single households in adoption of PV should be taken into consideration in regulatory implications concerning smart energy technologies, and Smart Grids in particular.

2.1.3 Education

Different effects of the education level on energy consumption and PV adoption have been reported. While Caird et al. (2008) indicate that education is a critical feature in PV adoption decisions, Sommerfeld (2017) finds that the postal areas with the highest uptake of solar PV had the lowest level of university/tertiary education in his analysis of influence of demographic variables on uptake of domestic solar PV technology in Australia. Considering energy consumption, the results are also mixed: Gram-Hanssen (2004) finds a significant decrease in the level of electricity consumption with increased level of education in Denmark, while Bedir (2013) finds no significant effect of education on electricity use in Dutch dwellings respectively.

Such mixed results can partially be explained by different levels and methods of research, but also could be country specific, which means a deeper target analysis for each European country in terms of educational impact on the adoption and benefits of smart technologies is required.

We consider education an important socioeconomic indicator as it is related to the lifestyle of the households and might also have an impact on general knowledge and understanding of the current situation on the energy market, and in this sense also influence the decisions and behaviour of households. For instance, Hall et al. (2016) report the results of an Australian study, in which they found that "[…] there is currently only a basic understanding of peak electricity demand and its impact on electricity prices. This understanding may need to grow to increase the shifting of electricity demand from peak to non-peak periods". From this perspective, increasing educational level and better communicating some specifics of the energy market to consumers could contribute significantly to overall welfare and energy efficiency.

The factors mentioned above, including income, dwelling size and property right, size of the household and education, with related sociodemographic trends in all the European countries on the one hand, and technical innovations and new smart solution on the other hand, inevitably influence energy market. Consequently, these new circumstances in terms of energy production and consumption, communication and signals between consumers and producers and, of course costs, tariffs and policies warrant further investigations.

3 Distributed generation and Cost recovery

With the advent of smart grids and smart technologies, the tariff system will be faced with new factors: the increase of distributed generation, low-capacity storage (e.g. in-home batteries for storing PV-produced electricity), charging of electric vehicles, and the vision of house-to-house electricity trading to balance the overproduction from own generation without the need (of higher levels) of the power grid. (Jenkins and Pérez-Arriaga, 2017; Schreiber et al., 2015)

Especially, the promotion of renewable energy production on the household level contributes to increasing multi-directional operation modes of electricity grids. Thereby, the connection to the public grid will largely serve as a backup option for a growing share of consumers, rather than being the primary source for their electricity acquisition (see i.e. McLaren et al., 2015). Consequently, for these consumers *(prosumers)* the volumes of electricity consumed from the grid will be subordinate. Depending on the tariff system in place, their contribution to the financing of the grid may significantly decrease and a significant shift in the allocation of grid cost recovery may happen. With regards to the aim of this short report, we are interested in how such changes affect different socioeconomic classes and how new tariff schemes can be designed in order to avoid an adverse cross-class cost allocation.

Network tariffs

Residential electricity prices are made up of a number of components, including network tariffs, taxes and surcharges e.g. renewables surcharge, usage surcharge, etc., and an energy charge.

Network tariffs are defined by regulatory authorities (or a comparable entity) to recover the capital and operational expenditures of providing transmission and distribution of electricity and the investments needed to establish and maintain the required grid capacity. Internationally, different network tariff systems are in force, but usually tariffs include two or three of the following components: 1) a volumetric tariff, reflecting the amount of consumed electricity (kWh), 2) a capacity tariffs, depending on the (measured or non-measured) demand (kW peak load), and 3) a charge to recover fixed costs (e.g. for metering services).

The costs of electricity networks are mainly determined by their capacity i.e. the maximum amount of energy that the grid is dimensioned to stand at any given point in time, but volumetric tariffs, which do not directly reflect the nature of these costs, are still widely applied. For instance, Eurelectric (2016) shows that many EU countries including Austria, Cyprus, France, Germany, Great Britain, Greece, Hungary, Luxembourg, and Romania make use of a tariff, in which the volumetric charge has a share of 75-100% (see Table 1). They also highlight that such tariff structures are not able to provide fair network cost recovery anymore due to the increase in the numbers of prosumers and the ongoing transformation of households' consumption patterns.

As mentioned above, a growing share of consumers who make use of own electricity production technologies will use the public grid as a back-up option only, but will still require connection to the grid. The costs this group of consumers induce for grid operation may not be fully reflected through volumetric tariffs but may have to be cross-subsidized by other consumers, who do not have access to such technologies and are still exclusively supplied via the grid. (Schill et al., 2017; Picciariello et al., 2015; Cossent et al., 2009).

Table 1. Tariff scenarios; classification of the 28 EU countries with respect to the shares of revenues collected from the volumetric tariff component and the capacity related tariff component

		0%	0-25%	25-50%	50-75%	75-100%	100%
Households	Energy Charge (%)	NL	ES, SE	NO	IE, IT, PL, PT, SK, SI	AT, CY, CZ, FR, DE, GB, GR, HU, LU, RO	
	Fixed + Capacity Component (%)		AT, CY, CZ, FR, DE, GB, GR, HU, LU, RO	IE, IT, PL, PT, SK, SI	NO	ES, SE	NL

Source: Eurelectric (2016) Network Tariffs, A Eurelectric position paper.

Considering that these innovations (own production, storage) are more likely to happen first among a subgroup of the population owning single-family dwellings (since most of these innovations require property rights for installation), a significant social imbalance induced from shifting the burdens of financing the grid towards lower income classes may hamper the public acceptance of these innovations. Moreover Severance (2011) even allows for possible "death spiral scenario" in the energy market, where higher network tariffs will be charged by poorer customers, which in the end threatens to collapse the whole electricity supply system. More recent studies, i.e. Muaafa et al. (2017), call such worries “overdone”, but still acknowledge, that a careful revision of tariffs might be due in order to avoid free-riding behaviour on the part of PV owners.

Several options have been proposed to deal with this issue, among them minimum bills, increased fixed charges and demand charges (see i.e. McLaren, 2015). Demand charges have long been used in commercial and industrial network tariffs (Hledik, 2014), but they are a novel development in the residential electricity market made. The installation of smart meter makes it possible to implement such new tariff schemes in an economic way (Rubin, 2015).

In the past, capacity tariffs (if put in place) reflected contracted capacity, not actually measured loads. With smart meters (meters with maximum (kW) demand reading capability), actual capacity demand becomes measurable. This development has triggered discussions about including capacity charges (also called demand charges) in residential network tariffs. Reconsidering volumetric network tariffs for households and introducing capacity oriented schemes can indeed be one way of addressing the issues outlined above and re-establishing cost transparency.

However, the impacts of these new tariff structures on the households’ electricity bills are unknown while possibly significant. This will inevitably lead to a reallocation of burdens in the grid costs’ recovery (Eid et al., 2014; Pérez-Arriaga et al., 2013). At the same time, increasing the share of renewables is constantly being promoted and supported on the governmental level also through significant and appealing subsidies, which increases the likelihood of the further growth in the number of solar cells, electro vehicles, and in-home storage capacities in the nearest future. A new balance thus has to be reached through adjustment of currently applied grid tariffs’ structures to new circumstances.

Capacity charges have been a highly discussed issue in related literature in the past several years, where they are either promoted or disapproved. For example, Rubin (2015) argues that residential demand charges may better reflect actual customer demand but also discusses associated problems like the need to educate costumers and adapted existing billing procedures. He also points that there is no perfect rate design but the overall goal has to be a fair treatment of all customers. Others argue that there is a strong correlation between kWh consumption and maximum kW demand (Blank and Gegax (2014) and current volumetric charges therefore already reflect capacity demand.

Obviously, any new tariff system has implications on a socioeconomic level and especially on the households' budgets. As discussed above the socioeconomic position of a household is defined by various factors that either support or discourage the adoption of smart technologies. In an analysis of changes in the residential sector in Queensland, Australia, Simshauser (2016) finds that "[…] non-solar households are paying more than they should, while solar households are paying too little. This is because demand in peak and critical peak periods drives the costs of the networks, and solar PV units in Southeast Queensland reduce peak load only marginally. He goes on to conclude that "[…] the extent of implicit wealth transfers was found to be material." His findings are support by Strielkowski et al. (2017) who focused on the situation in the United Kingdom: "[...] the increase in the solar PV panels energy generation lead to the redistribution of wealth and costs among existing customers. […] UK solar PV households bear a lower share of the per kWh costs of the distribution system which in turn leads to the increase of per unit charges as well as to the changes in the distribution of their payment between different types of households." They conclude their analysis by suggesting that "[…] to install the most cost reflective apportionment of charges between fixed, per kW peak and per kWh use of system charges […]." Grösche and Schröder (2013) make an additional argument by pointing out that electricity "[…] has characteristics of a necessity good, it cannot easily be substituted, and related expenditures make up a substantial fraction of low-income households' budgets".

Text Box 1. Excerpt of the 2016 Snapshot of Global Photovoltaic Markets (IEA-PVPS), p. 9

In Belgium, the region of Flanders imposed a grid connection tax in 2015 aimed at compensating for the losses in grid revenue linked to the existing net-metering scheme. This same question has been raised by policymakers and grid operators in several countries but led to few concrete policies. In the USA, several debates took place with regard to the compensation of net-metering policies, with the consequence of establishing either caps to net-metering or adding small additional fees in some states. Other countries such as Italy (but not implemented) and Spain (with its famous sun tax) have either set up or discussed additional taxes on solar PV systems. In Germany, the decision has been taken to force prosumers to pay a significant percentage of the levy paid by electricity consumers to finance renewables incentives, even on the self-consumed part of the PV electricity. Such payment has been refused in France for prosumers, which shows the variety of positions with regard to PV taxation.

4 An Austrian Case Study

To illustrate the literature overview we presented so far, we use this section to provide an example taken from an on-going research. In this project, we quantify the effect of introducing different network tariff schemes on households' budget. We combine measured load profiles (data for 1 year, 15 min intervals) for 765 Austrian households with socio-demographic data provided by these households in an additional survey. Using this dataset, we perform an ex-post analysis to assess the effects different network tariff schemes would have had on these households, how their respective contribution to grid cost recovery would have changed and how these results can be interpreted from a socioeconomic point of view.

When designing network tariffs, the first step is to determine the overall quantity of the costs that need be recovered via the tariffs. In a second step, a distribution key needs to be defined by putting weights on the respective tariff components. In accordance with this, we treat the 765 households in our sample as if it they were all part of one tariff zone and calculate the total of their current network charges. The respective sum of charges is used to construct tariff scenarios representing different weights of the two components a) energy volume in kWh and b) capacity demand in kW peak load. Thereby, while the following four alternate tariff schemes described in the following all lead to the same overall sum of charges, the way the costs are distributed among households changes subject to their actual electricity demand pattern. Currently, network tariffs in Austria are made up of a volumetric charge that accounts for about 80% of the overall tariff and a fixed charge. Our four alternative tariff schemes are:

- **Scenario P100/V0**[9] represents a scheme charging for capacity demand only, and we assume that smart meter data is available. In this example, peak load is not defined as the one maximum load out of the 35,040 metered load values during one year but is defined as the average of the 12 monthly peak loads during the respective year.
- **Scenario P75/V25** puts 75% of the weight on the measured capacity demand of households and 25% on the consumed volume.
- **Scenario P50/V50** balances the capacity demand component and the volumetric component, and capacity charges address the measured peak.
- **Scenario P25/V75** is a modification of scenario P75/V25 but reverses the weights between measured peak load and volume.

Investigating the data on the 765 households, we find that the change in network charges, depending on the scenarios applied, varies significantly. For some households a decrease of 50% is achieved, while others face a (theoretical) increase of 250%. An average, the changes are more moderate but still substantially varying from -3% to +20%, depending on tariff scenario used. Further on, we find that nearly 40% of the households in our sample have a similar energy consumption pattern – namely they consume relatively moderate volumes of energy and at the same time frequently produce peaks loads, not taken into account in the current network tariff, while the rest of the sample is rather heterogenic in terms of their pattern of energy consumption.

9 Where P means peak and V means volume.

Figure 4 shows the difference bewteen currently applied tariff and alternative tariff scenarios.

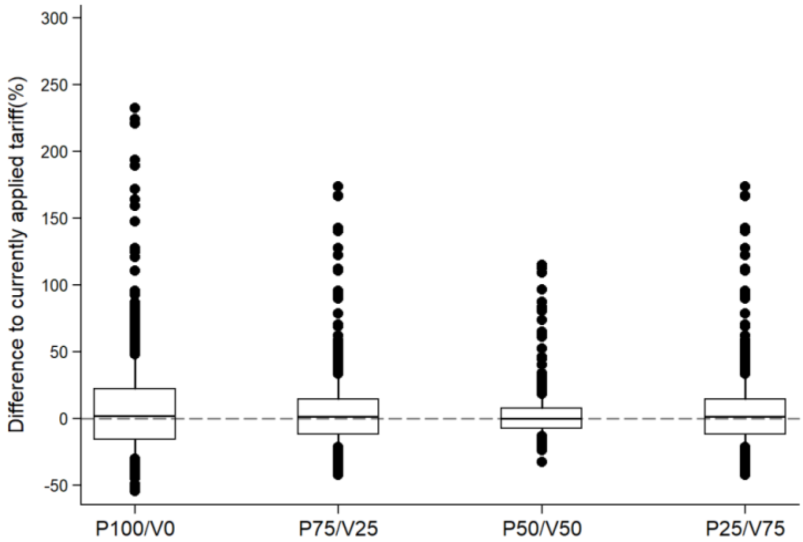

Figure 4. Difference bewteen currently applied tariff and alternative tariff scenarios (Source: Own illustration)

The available sociodemographic characteristics of the households in our sample include information about the number of people per household, the type (apartment, single-family house, semi-detached house) and size (in square meters) of their dwelling and the technologies used for warm water and heat preparation (electricity, gas, district heating, heat pumps, biomass, oil). We also obtained more detailed characteristics for 406 households including information on the endowment with large electricity consuming appliances (such as swimming pool, fish tank, water bed, sauna, home cinema), number of children under 14 years old present in the household, as well as income and education level.

As already mentioned above, household characteristics like size, composition and location are important factors that should be taken into account while constructing network tariffs. Considering further in detail the available socioeconomic characteristic of the households in our sample we find that such characteristics as higher number of residents in a household, bigger living space (in square meters), location in rural environment and owning a single family house, are associated with lower network costs under scenarios with a charge for measured capacity demand compared to the currently applied network tariff.

From a political perspective, it is important to notice that most of the parameters that significantly contribute to lower network charges under the respective alternative scenario (i.e. households living in single family houses, having larger living spaces) are frequently associated with higher income levels. Since the sum of collected revenues from all households together is required to remain unchanged under any new tariff scheme, a reduction of the financial contribution of higher income households would automatically mean an increase of burden for lower income households compared to the situation under the reference scenario.

This effect can be explained by the fact that higher income households (ceteris paribus) consume higher volumes of electricity and thereby benefit from tariffs putting only subordinate weight on the number of consumed units. To check whether this assumption holds we look at yearly energy consumption of households for different income quartiles. As we can see on

Figure 5, the median value for 1st and 4th (low and high income groups of the sample) is quite different, although there is a strong overlap of interquartile range (IQR) for these two income groups on the sample; for instance the IQR for 1st quartile is from ~2,000 to 4,000 kWh while for the 4th quartile from ~2,000 to 6,000 kWh per year. Further on, if we consider the difference in yearly energy consumption for different types of households (Figure 5), we can see that couples with children and 3-generations households have the highest median consumption, while single households have the lowest median (around 2,000 kWh). Yet there are also some single households in our sample whose yearly energy consumption goes up to 4,000 kWh or in extreme cases even up to 6,000 kWh.

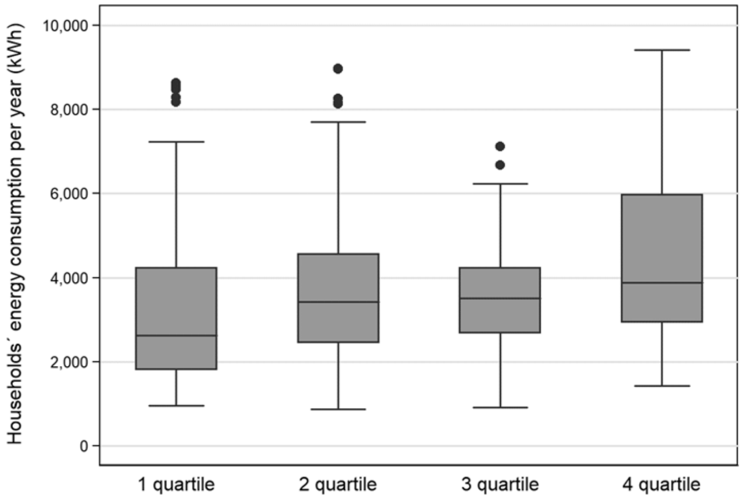

Figure 5. Energy consumption (kWh/a) based on households income levels shown in quartiles (n=406) (Source: Own illustration)

As for the size of the household based on the number of its permanent residents, we can see from Figure 6 that yearly energy consumption is growing with the number of persons in the households: for instance, single person household demonstrating the lowest median of around 2,000 kWh, 2 persons households with the median of 3,000 kWh and 5 persons with the median of approximately 5,000 kWh per year.

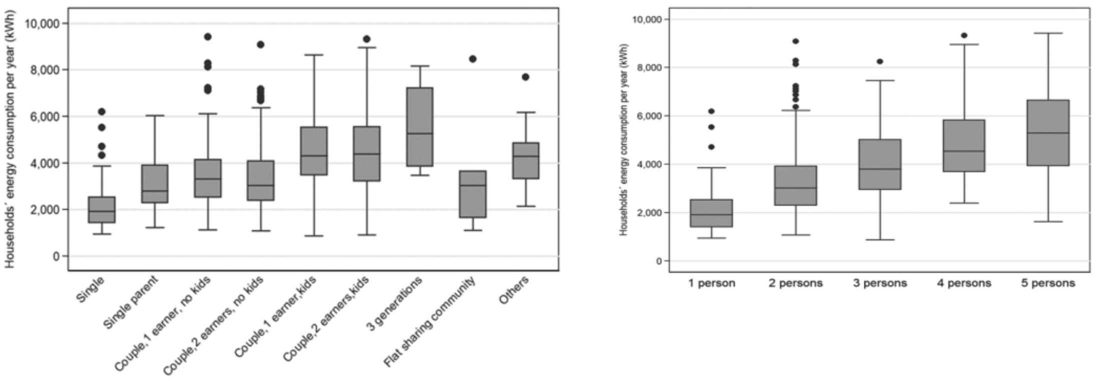

Figure 6. Energy consumption (in kWh/a) for different types (left) and sizes (right) of households (Source: Own illustration)

In our analysis we take in account all the socioeconomic factors mentioned above and we come to the conclusions that tariffs combining measured capacity demand and volumetric components could provide a new balance for the distribution of network costs – as these tariffs are cost reflective, due to the peak load charge, they also signal the consumer to decrease their overall consumption and they do not penalize any group of consumers for a decrease in electricity demand. Therefore, such tariffs could provide a solid response to the increase of prosumers, while avoid shifting burdens towards households not yet ready for taking this step.

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Appendix

4.1 Background information[10]

The world's electricity systems face several challenges, including ageing infrastructures, continued growth in demand, integration of variable renewable energy sources and plug-in electric vehicles, the need to improve the security of supply and the need to lower carbon emissions. Smart grid technologies offer a rational way to meet these challenges and to develop a cleaner and more efficient energy supply. However, national and regional circumstances, such as available sources of supply, grid structure and legislative and regulatory conditions, will give rise to a substantial diversity in the implementation of different smart grid technologies and system solutions. Moreover, national and regional smart grid solutions are not limited to project investments but also includes e.g. strengthened transmission grid over international borders and opportunities for new market functionalities which will influence customers and society in a broader sense.

To be able to more efficiently disseminate experiences and conclusions regarding costs and benefits of these different projects in a more systematic way an elaborated framework for socioeconomic cost benefit analyses (CBA) in relation to smart grid solutions needs to be developed. The substantial experiences gained from demonstration and implementation projects worldwide among ISGAN members and collaborating partners have the potential to be an important base for such a framework.

In a regulated environment faced by many network operators cost-benefit analysis is an important tool in evaluating different regulatory options. However, there is no existing common framework for the assessment of the balance between the benefits that can be achieved with the use of these technologies and the financial commitments needed. The regulation provides incentives for such a change and sets the framework. Especially, the socioeconomic aspects are important from a regulatory perspective. The costs are often straight forward, the challenge is instead to capture the benefits and define the system boundaries in the analysis. Moreover new market functionalities and strengthened interconnections between countries go beyond national borders and call for regulators to collaborate and develop a common view on the economic framework for network investments.

The project[11] will be divided into two separate phases with specific deliverables and milestones. In its first phase the aim is to contribute to a common understanding on how to fully assess costs and benefits of different smart grid solutions with local circumstances and socioeconomic costs and benefits as an integrated part of the evaluation. The assessment will primarily be made on system level and include an initial discussion on the influence of different regulatory models on market actors' incentives for smart grid investments with an overall positive socioeconomic impact. In this phase the evaluated framework/model are primarily regarded as tools to facilitate a systematic approach and a qualified discussion on how to evaluate dynamic influences created by different smart grid solutions (such as environmental

[10] In the following the work plan for IEA-ISGAN Annex 3 is reproduced.

[11] In the following, the project refers to all activities done within subtask 4.5: Socioeconomic Benefits of Smart Grid and regulatory Implications in IEA-ISGAN Annex 3.

benefits, job creation etc.) Due to the complexity of the matter the project is not expected to deliver comprehensive and complete metrics for direct application in smart grid CBA.

In a second phase we envisage to further analyse existing tools/models for socioeconomic CBA and their applicability to different smart grid solutions. Based on these analyses, recommendations which can be applied in a policy context or directly by regulatory authorities will be developed.

First phase of the work program

Subtask 4.5 will conduct the first phase of its work based on in-kind contributions, primarily from Sweden (Deliverable 1), Austria (Deliverable 2) and Italy (Deliverable 3), each exploring different aspects of the subject.

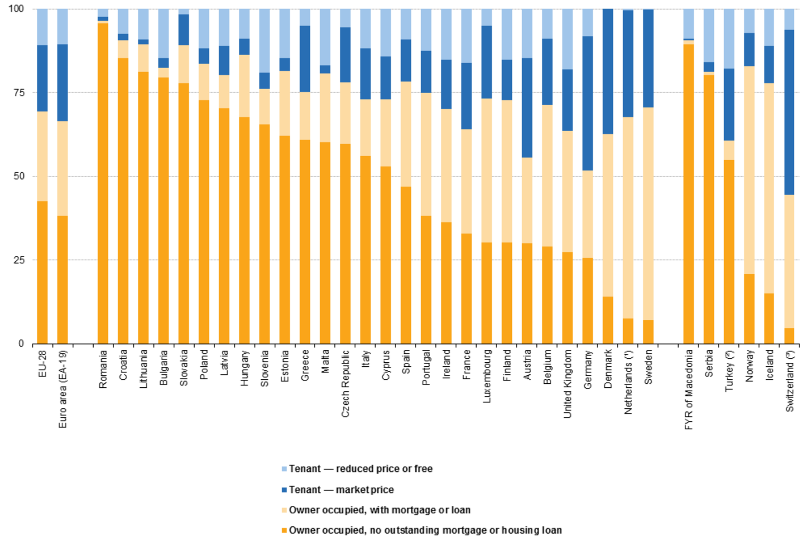
Deliverable 1 will give an overview of the state of the art concerning identification of social benefits and metrics for their evaluation with focus on different smart grid applications. The project will leverage existing knowledge and experience gained in different participating countries (e.g. in the U.S. through the DOE-EPRI methodology and computational tool, in the EU through its approach based on Key Performances Indicators, in other countries, etc.), as well as in current international efforts underway and through cooperation among major smart grids stakeholders globally. Examples of broader smart grid solutions and their socioeconomic effects to be included in the analytical work are:

1. Influence of customer behaviour since the deployment of smart grids is expected to facilitate e.g. demand-side flexibility and increased self-generation through local PV installations;
2. whole energy system aspects in relation to integration of large scale renewable energy that is located on a relatively greater distance from the load than is the case today, including strategies for dispatch and curtailment and opportunities for new market functions with strengthened transmission grid over international borders;
3. smart grid solutions for EV charging and vehicle to grid and vehicle to home applications. Based on this overview a discussion paper will be presented identifying relevant use cases and related social benefits to be included in the proposed framework. The discussion paper will also include an assessment of pros and cons with alternative methods for the evaluation of these socioeconomic benefits.

Deliverable 2 will focus on asymmetric distribution of costs and benefits primarily in relation to distributed generation. The focus is on discussing whether social imbalances are induced by shifting the burdens of financing the grid towards lower income classes. Such imbalances may be aggravated by the tendency to go off grid, thereby challenging current cost recovery schemes. An assessment of how and by whom decentralized energy technologies are used in the Annex 3 countries, how households respond to public or private participation projects, what that tells us about benefit allocation and who the first-movers are will be part of this deliverable.

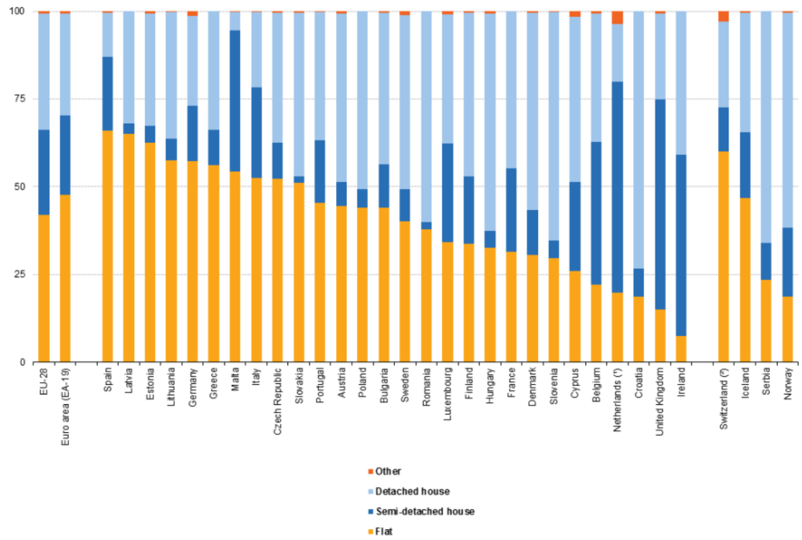
Deliverable 3 will focus on how to include CBA in wider Multi Criteria Analysis as CBA is only one part of decision-making, which is inherently a multi criteria process. MCA issues related to the assessment of not monetary benefits or benefits without a consolidated market is an interested approach in evaluating overall benefits in relation to smart grid.

4.2 Annex



(¹) Provisional data.
(²) 2013.
(³) 2014.
Source: Eurostat (online data code: ilc_lvho02)

Figure 7. Distribution of population by tenure status, 2015 (% of population)



(¹) Provisional data.
(²) 2014.
Source: Eurostat (online data code: ilc_lvho01)

Figure 8. Distribution of population by tenure status, 2015 (% of population)

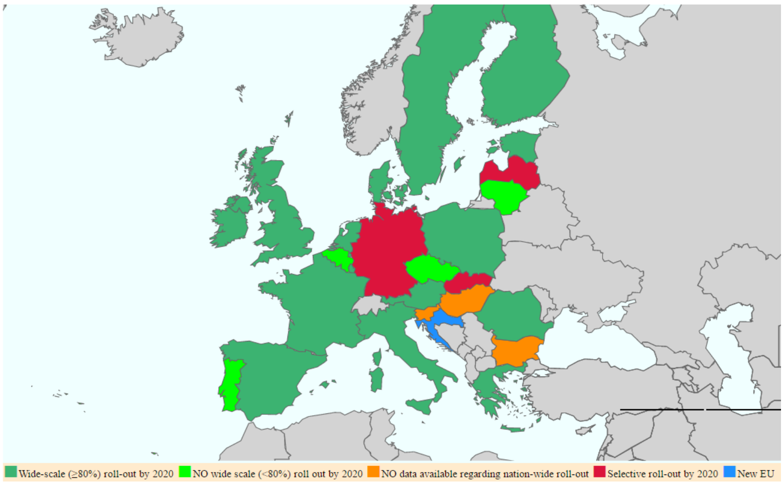


Figure 9. Smart Meter Roll-Out in the EU till 2020

Source: [*http://ses.jrc.ec.europa.eu/smart-metering-deployment-european-union*](http://ses.jrc.ec.europa.eu/smart-metering-deployment-european-union)

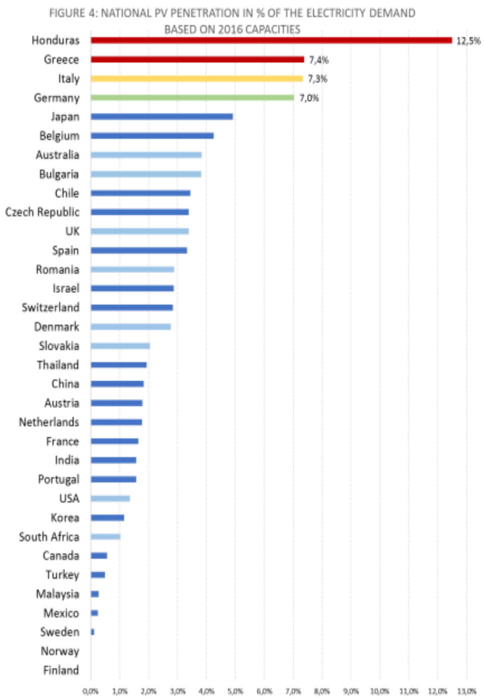


Figure 10. Source IEA, Snapshot report 2017