The potential of energy citizens in the European Union

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Content

Summary

With an increasing share of renewable energy sources (RES) in the European Union (EU), the role of energy consumers as active participants in the energy system is bound to expand, as the developments in an increasing number of EU Member States demonstrate. A growing number of households, public organizations and small enterprises are likely to produce energy, supply demand-side flexibility or store energy in times of oversupply. So far, however, the extent of this prosumer potential in the EU is unknown. Global and EU-wide decarbonisation scenarios typically model increasing RES capacities, but do not go into the details of how this is achieved, and what role prosumers, also referred to as energy citizens, could play in these developments.

This study therefore aims to create more insight into the potential of energy citizens in the EU: how many energy citizens could there be in 2030 and 2050 throughout the EU and what is their potential contribution to renewable energy production and demand side flexibility?

The main result of this project is an Excel workbook that contains the detailed quantitative findings of this study. This report provides the background information to these data, describing the context of the study and the methodology used. The study was commissioned by Greenpeace, Friends of the Earth Europe, European Renewable Energy Federation (EREF) and REScoop.

Project objectives
The main objective of this study is to assess the following, for a number of different categories of energy citizens:
– the potential installed **renewable energy capacity**;
– the potential of **renewable energy generation;**
– the potential capacity for **demand side flexibility** (incl. storage).

Based on these data, the **total number of energy citizens** this represents will be derived.

The study distinguishes between four energy citizen categories: individuals or households producing energy individually, individuals or households producing energy collectively, public entities and small enterprises. The renewable energy sources investigated were solar photovoltaic (PV) and wind energy, demand side flexibility focussed on the potential for electric vehicles, e-boilers and stationary batteries. Data are estimated for today, in 2030 and 2050, at EU and Member State level.

Main conclusions and recommendations
The potential for European households (individually or via energy collectives), public entities and small enterprises to become an energy citizen and to actively contribute to the future energy system is very significant.
We estimate that about 83% of the EU's households could potentially become an energy citizen and contribute to renewable energy production, demand response and/or energy storage, which amounts to about 187 million households. About half of the households, around 113 million, may have the potential to produce energy; even more could provide demand flexibility with their electric vehicles, smart e-boilers or stationary batteries. For (many) other results, we refer to the Excel workbook that was developed during the course of this study.

A calculation methodology and calculation tool was developed to estimate the potential of various energy citizen categories in 2030 and 2050, for the technical options investigated. The calculations are based as much as possible on available data, using a transparent methodology that is based on, in our view, sound reasoning. However, as the research on this topic is still limited, as is the data on the current situation, the findings are subject to many uncertainties. It is therefore recommended to follow up this study with a more in-depth assessment of the calculation methodology and findings of this study, to further enhance the robustness of the results and to determine the key drivers for these developments.

It is also recommended to further develop data gathering about energy citizens and their contribution to the energy system. Other issues that would be interesting to explore further are how this energy citizen potential can be realised, and how a future with a large number of energy citizens compares to a less decentralized development of a sustainable energy future, in terms of, for example, cost, energy security and social and economic effects.

1 Introduction

With an increasing share of renewable energy in the EU, the role of consumers as active participants in the energy system, as energy producers and/or suppliers of demand side flexibility or energy storage, is bound to increase, as the developments in an increasing number of EU Member States demonstrate. Many households, public entities and SMEs have become electricity producers, by installing solar PV on their roofs or by participating in community initiatives for wind turbines. Projects are implemented to use electric vehicles for storage of renewable electricity produced nearby, and various cities and communities are actively pursuing the goal of becoming self-sufficient and reliant on renewable energy only, encouraging their inhabitants to be actively involved in the developments. With a population of more than 500 million, about 216 million households and around 20 million small enterprises (< 50 employees), there is clearly a huge potential of active energy citizens, or prosumers, in the EU[1].

The reduced cost of renewable energy as well as government support creates opportunities for households and other parties to invest in renewable energy sources (RES) and thereby reduce fossil fuel use. Options for citizens to store energy during times of oversupply and adapt their demand to the variable energy generation profile of wind and solar energy are being developed. Unlocking their technical potential for RES generation, flexible demand and storage will reduce cost of the future renewable energy system: reduce grid investments and backup power generation, use their investment capacities, etc. At the same time, it creates public support for the energy transition.

So far, however, there is no overall picture of the extent of the energy citizen potential in the EU. Global and EU-wide decarbonisation scenarios typically model increasing RES capacities, but do not go into the details of how this is achieved, and who will be involved. This study, commissioned by Greenpeace, Friends of the Earth Europe, European Renewable Energy Federation (EREF) and REScoop, therefore aims to create more insight in the potential of energy citizens in the EU: how many energy citizens could there be in 2030 and 2050 throughout the EU and what is their potential contribution to renewable energy production and demand side flexibility?

The potential estimated in this study assumes that policy and regulatory barriers are removed over time, and that the national grids, distribution networks and electricity markets are developed in parallel with the growth of renewable energy production, demand side flexibility and storage options. Clearly, significant policy efforts and investments will be needed to realise this potential.

1 The terms energy citizen and prosumers are often used in parallel, both indicating individuals, households, public or private companies that move from being only energy consumers to also produce energy, or actively take part in the energy system by providing flexible demand or energy storage, in response to the growing share of variable (and partly decentralized) RES production.

It is furthermore important to note that the findings of this study are subject to many uncertainties. The research on this topic is still limited, as is the data on the current situation. However, the calculations are based as much as possible on available data, using a transparent methodology that is based on sound reasoning.

The main result of this project is an Excel workbook that contains the detailed findings (data) of this study. This report aims to describe the context of the study and the methodology used. Some illustrative results are presented in Chapter 4, whereas conclusions and recommendations are provided in the final chapter.

1.1 Project objectives and scope

The main objective of this study is to assess the following, for different categories of energy citizens:
1. The potential installed renewable energy capacity.
2. The potential of renewable energy generation.
3. The potential capacity for demand side flexibility (incl. storage).
4. The total number of prosumers or energy citizens this represents.

The study distinguishes between the following types of energy citizens:
1. Individuals or households producing energy individually.
2. Individuals or households producing energy collectively through organisations such as cooperatives or associations.
3. Public entities (incl. cities and municipal buildings, schools, hospitals, government buildings).
4. Small enterprises (< 50 staff).

The number of households, public entities and small enterprises that could be involved in energy production, demand flexibility and energy storage is estimated for today, in 2030 and 2050, both at the EU level and at Member State level. The Greenpeace Energy [R]evolution scenario was used as a framework for the study. One of the key characteristics of this scenario is that it assumes that the global energy supply is 100% sustainable in 2050.

The study focusses on electricity options, both for energy generation and for demand side flexibility and storage options. It includes the technologies that are currently expected to provide the largest potential contribution to the energy system:
- For renewable energy production, solar photovoltaic (solar PV) and wind power production are included.
- To determine the potential of future flexible demand and storage options, stationary batteries, smart electric boilers and electric vehicles are assessed.

In addition, some insight is provided on the investments and cost benefits of these developments. However, whereas the four questions above are answered quantitatively, this issue is assessed qualitatively only (see Chapter 3).

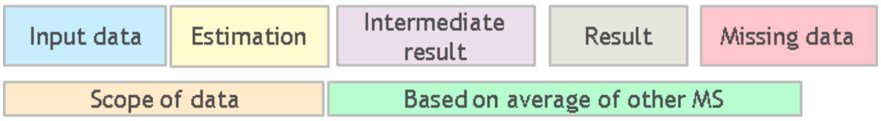
2 Methodology

2.1 Introduction

To derive the quantitative estimates of this study, different calculation methods were developed for each renewable energy source (RES) and flexibility demand option. These methods are visualised as schematics in Paragraph 2.2 to Paragraph 2.10. For RES, wind and solar photovoltaic (PV) were taken into account. For demand side flexibility, stationary batteries, electric boilers and electric vehicles were analysed. The last schematic shows the calculation method that was derived to estimate the total number of energy citizen households that own one or more of these technologies.

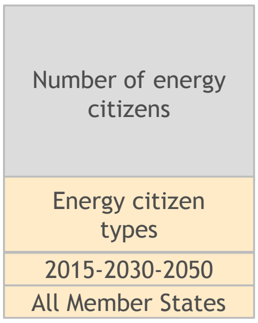
The colouring applied in the schematics in the following paragraphs indicate the type and origin of the data, and use the structure as depicted in the coloured legend below. The numbers in brackets indicate the data source, and refer to the reference list at the end of this report.

Figure 1 Legend of schematics



An example block is shown in Figure 2. The grey upper part indicates a result whereas the orange bottom part indicates the scope of the data. In this case the result is the number of energy citizens which are defined per energy citizen type, for all three years investigated and per Member State.

Figure 2 Example block in schematics

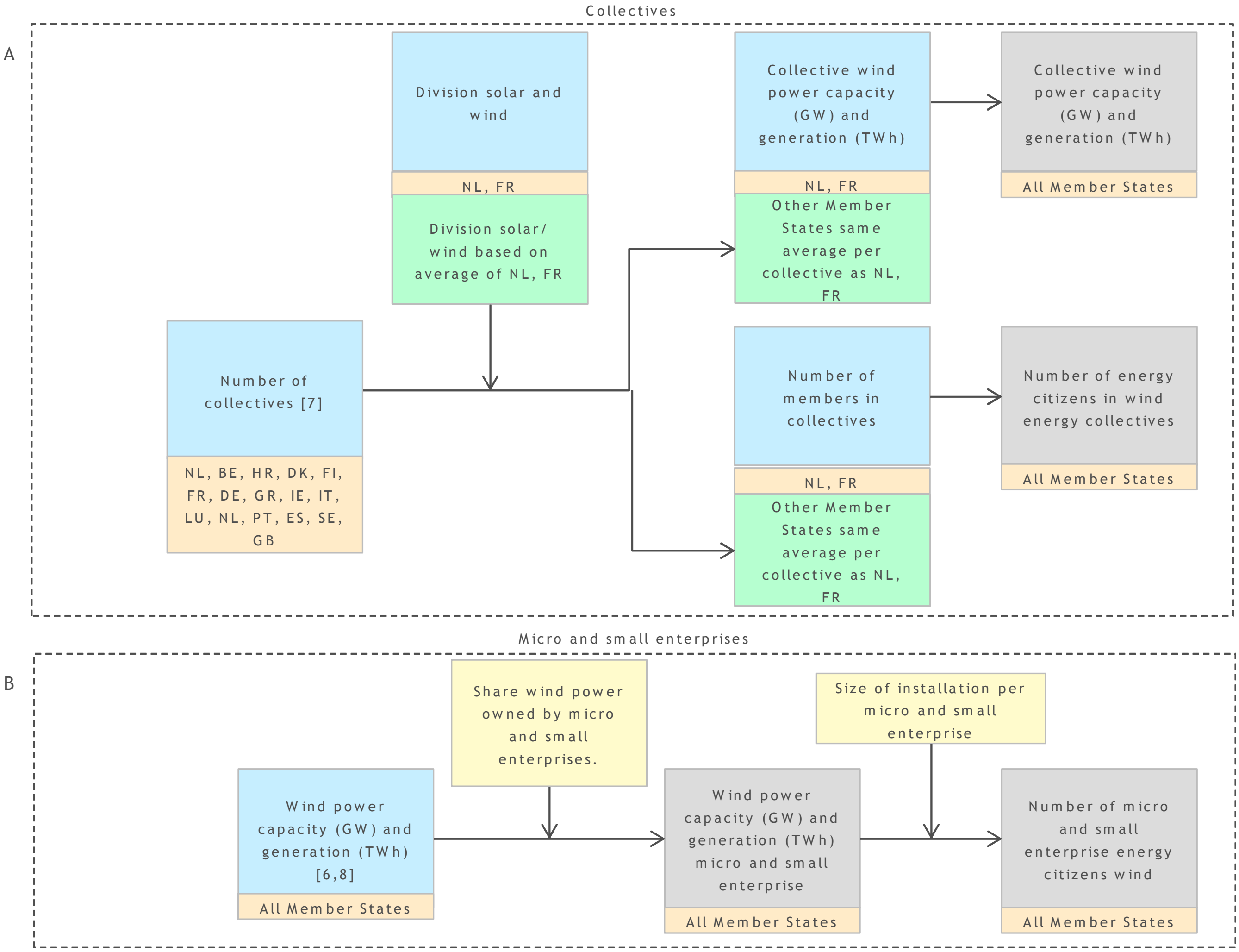


All the calculation methods are elaborated in the Excel workbook where the same colour coding as in Figure 1 is applied.

A comprehensive overview of the variables used for the calculations is included in Annex A of this report. It should be noted that a significant share of these variables is coded yellow, indicating that these are the author's estimates.

2.2 Wind power in 2015

Figure 3 Schematics of the calculation for wind power in 2015



To determine the potential for wind power, the energy citizen groups households collectively (A) and micro and small enterprises (B) are analysed. Public entities and individual households owning wind power are currently very scarce and are therefore ignored in this analysis.

A. The data available on collectives was limited. New Member State data that becomes available can be added to the model and will automatically improve the estimates. In the current calculations the average of the Netherlands and France is used when the specific variable is not available for a certain Member State.

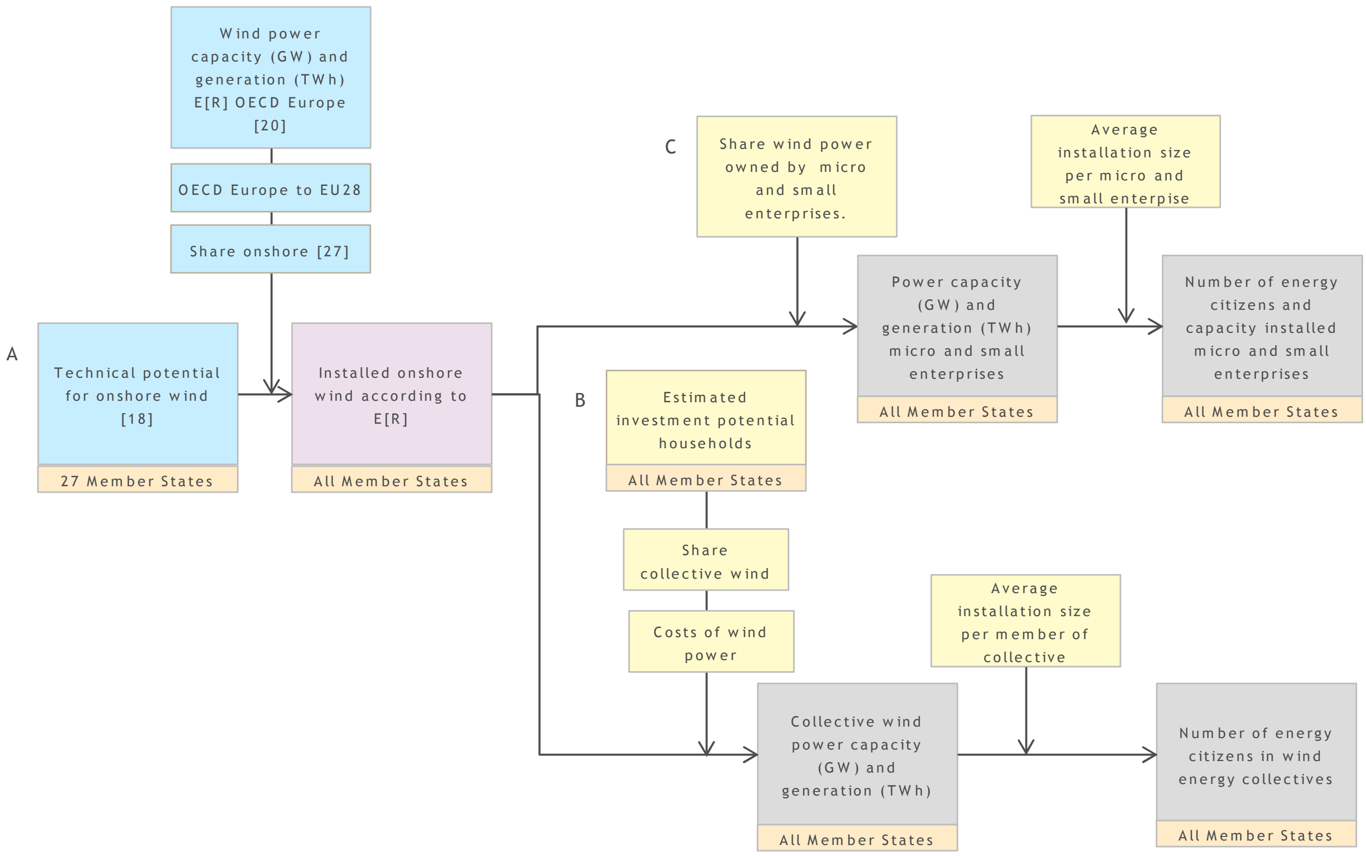
   As a starting point the number of collectives per Member State is split into wind and solar collectives based on the average division of the Netherlands and France.

For both solar and wind, the number of collectives per Member State is multiplied with the following variable (which is based on the average of the Netherlands and France if no data is available for the Member State) to get to the desired end results:
- the average installed capacity per collective is used to calculate the installed capacity per Member State;
- the average electricity generation per collective is used to calculate the electricity generation per Member State;
- the number of members per collective is used to calculate the number of energy citizens per Member State.

B. The currently installed capacity and electricity generation per Member State is used as an input. This is then limited by an estimate of the fraction that is owned by micro and small enterprises (mainly farmers). As a last step this outcome is divided by the average size of installation per micro and small enterprise resulting in the number of energy citizens.

2.3 Wind power in 2030 and 2050

Figure 4 Schematics of the calculation for wind power in 2030 and 2050



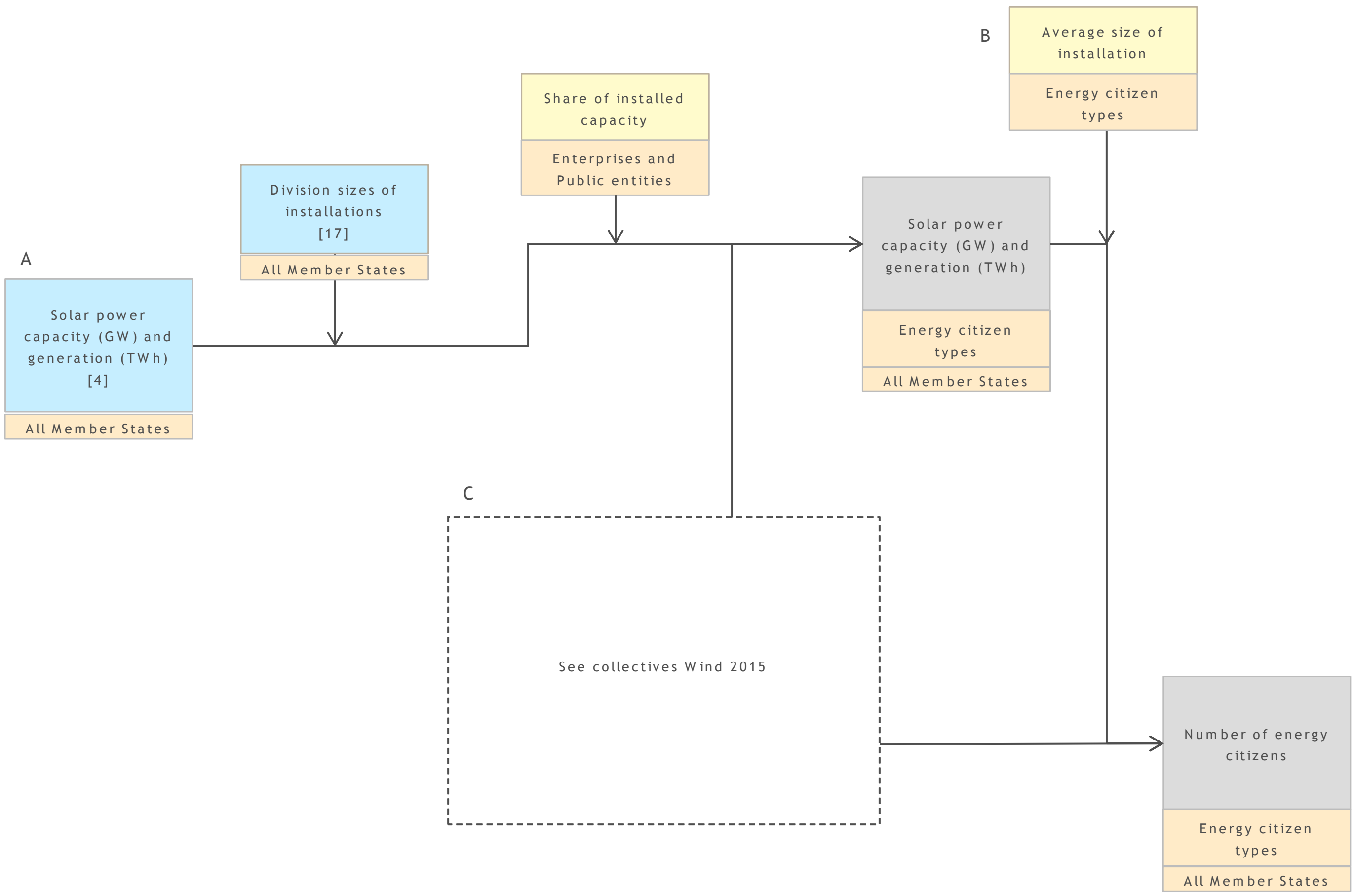
A. The technical potential for onshore wind as published by the European Environmental Agency is taken as a starting point. This potential is then limited by the amount of wind energy needed in the Energy Revolutions 2015 scenario[2] and limited by the share that is currently located onshore.

B. The amount of wind power that will be installed by collectives is determined by the investment potential of households (see Section 2.6) and the cost of wind power. This investment potential is divided among solar on own roof, collective wind and collective solar. The installed capacity can now be divided by the average installation size per member of the collective, to calculate the number of energy citizens.

C. The share of wind power that may be installed by micro and small enterprises is calculated using an estimate of the share of wind owned by this energy citizen group.

2.4 Solar power in 2015

Figure 5 Schematics of the calculation for solar power in 2015



2 Note that the Energy Revolution scenario only provides data for OECD Europe, not for EU28 which is the focus of this study. To arrive at an EU28 figure, the data are corrected using the difference in population of OECD Europe compared to EU28.

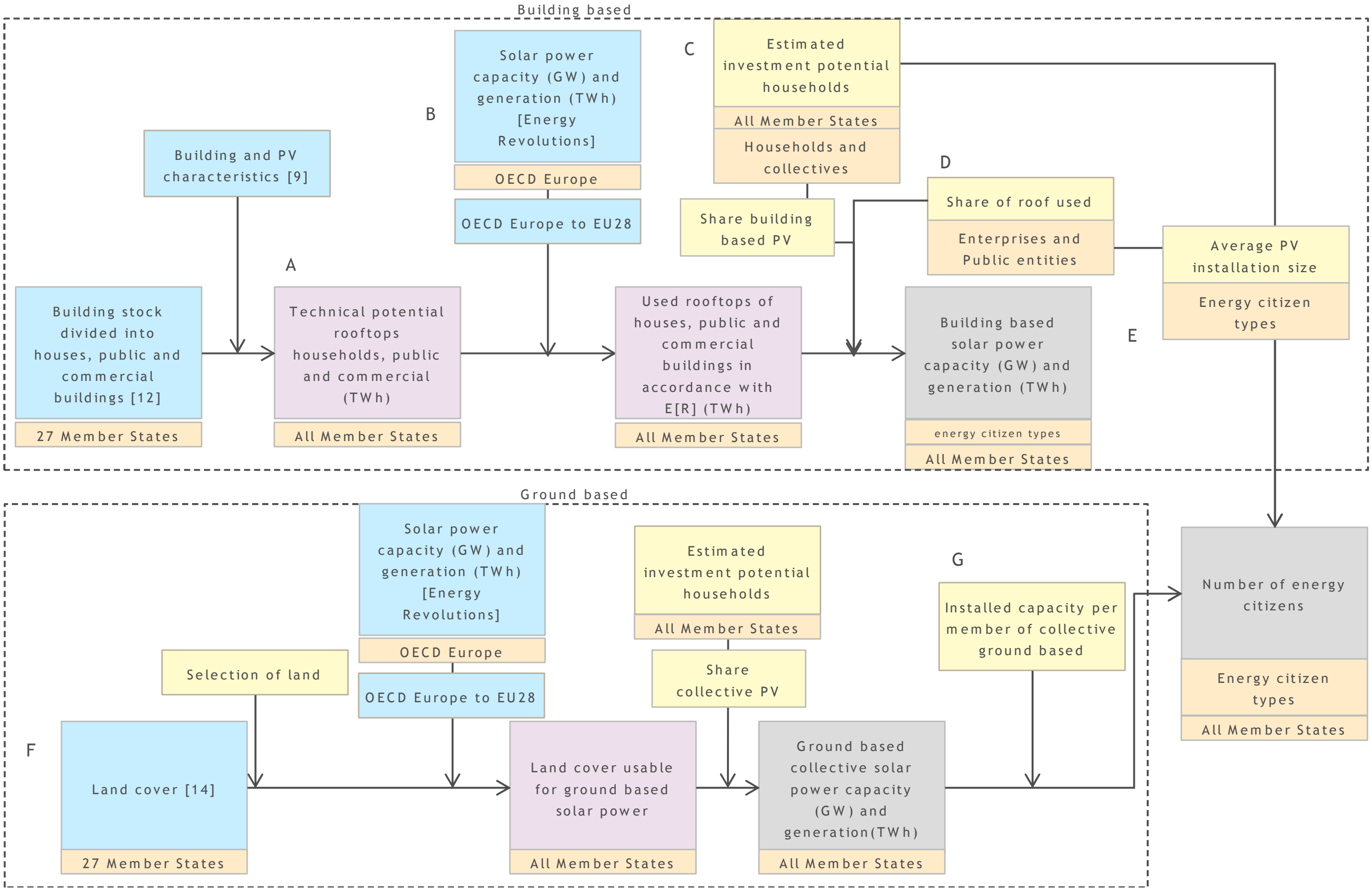
A. The solar PV installed capacity and electricity generation from Eur'Observer is used as a basis, and is divided into different sizes of installations. The smallest size is assigned to the household's category while the larger installations are partly assigned to micro and small enterprises and public entities through an estimate of their share.

B. The number of energy citizens is calculated by dividing the installed capacity by an estimate of the average size of the installations each energy citizen type owns.

C. The data of the collective solar PV is calculated using the methodology for the collectives as described in Section 2.2.

2.5 Solar power in 2030 and 2050

Figure 6 Schematics of the calculation for solar power in 2030 and 2050



For the estimates of solar PV in 2030 and 2050, the calculations make a distinction between building based and ground based solar PV.

A. The technical potential for solar PV on rooftops is calculated using the floor area of the different types of buildings from Eurostat combined with building and solar PV characteristics found in literature.

B. This potential is limited by the total solar PV capacity needed according to the Energy Revolutions scenario (see also Footnote 2). This outcome is divided between ground and building based solar PV using an estimate of the share of each of these.

C. The estimated investment potential (see Section 2.6) is limited by the share that is allocated to solar PV on single family buildings.

D. For the energy citizen categories micro and small enterprises and public entities the share of available roof that they may use to install solar PV is estimated.

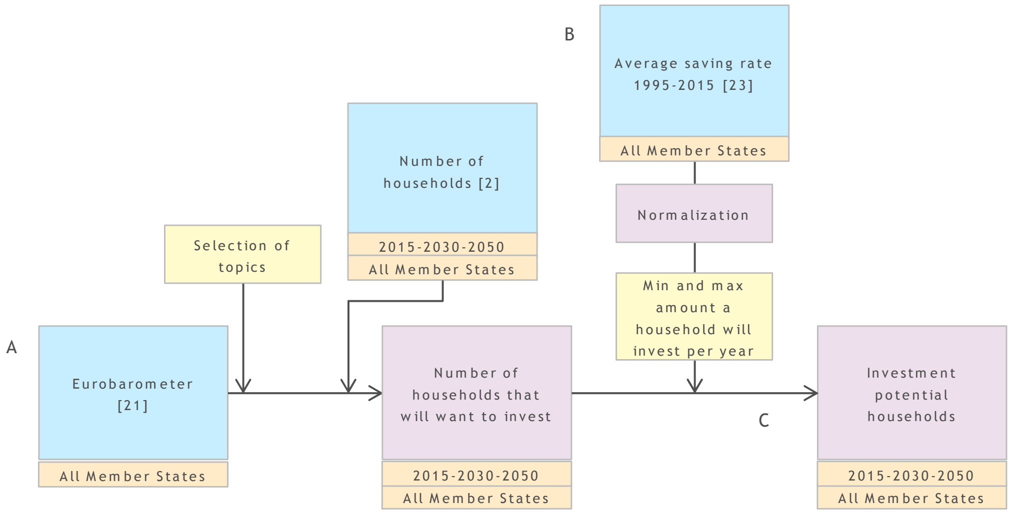
E. Both C and D are first combined into the total installed capacity and electricity generation. They are then used to calculate the number of energy citizens using an estimate of the average solar PV installation size per energy citizen type.

F. For ground based application of solar PV the land cover from Eurostat is used as an input[3]. This surface per Member State is limited by the selection of land. Once again this surface is limited by the amount needed for the Energy Revolutions scenario. The share of investment potential of households allocated for collective solar PV is split between building and ground based. Using the price of solar PV the installed capacity and electricity generation is calculated.

G. By dividing the output of F by the estimate of the installed capacity per member of collective, the number of energy citizens that collectively invest in ground based solar PV is calculated.

2.6 Investment potential households in renewable energy

Figure 7 Schematics of the calculation of the investment potential of households in renewable energy



3 The data source for land cover is the LUCAS survey which defines 9 types of land cover of which 'bare land' was used for this study. The definition of bare land is 'Areas with no dominant vegetation cover on at least 90% of the area or areas covered by lichens.''. This also includes bare agricultural land but only a very small fraction of the bare land is being used for PV in our calculations.

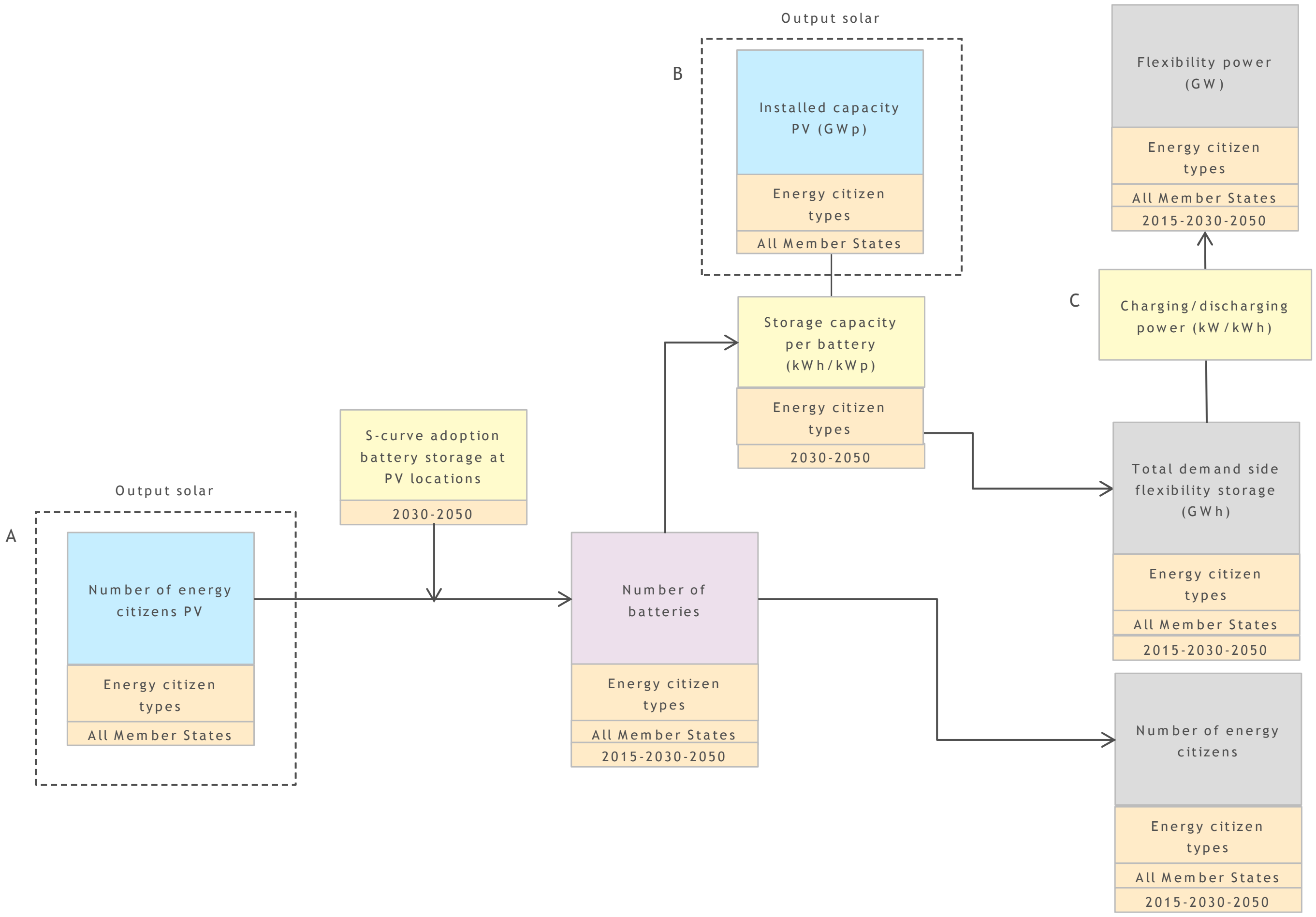
A. The Eurobarometer contains statistics on which topics concern citizens the most. By selecting the relevant topics, the share of households that will want to invest in renewable energy is estimated.

B. The total amount this group can invest is limited by multiplying their normalized average savings rate between 1995 and 2015 with an estimated minimal and maximum amount each household will invest yearly.

C. By multiplying the number of households that will want to invest by the amount calculated in B, the investment potential per country is calculated.

2.7 Stationary batteries

Figure 8 Schematics of the calculation for stationary batteries



A. In this calculation the number of installed stationary batteries is expressed as a share of solar PV installations calculated in Paragraph 2.5. This share is expressed using an S-curve adoption rate with two values for 2030 and 2050. Since the current number of stationary batteries is negligible, no value is calculated for 2015.

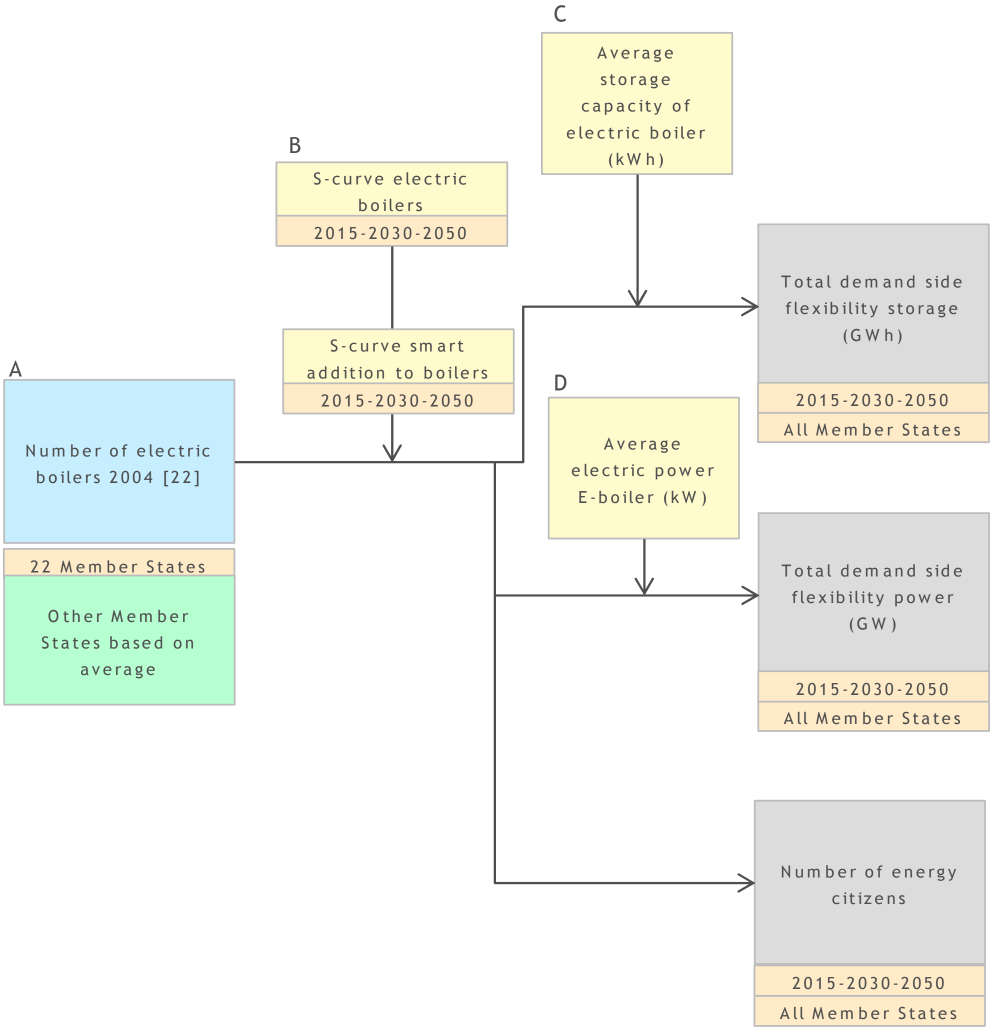
B. The total demand side flexibility storage of these stationary batteries is calculated by multiplying the number of batteries by the storage amount needed per kWp of solar PV installed.

C. This storage capacity is multiplied by the charging/discharging power to get to the flexibility power (GW).

N.B. In this calculation the number of installed stationary batteries is directly linked to the number of energy citizens with a solar PV installation.
The motivation for this is that the batteries are most beneficial for those citizens that generate their own energy, since the batteries then enable them to store any excess electricity for later consumption or sale. If the battery is only used to speculate on the electricity prices, the value added will be lower.

2.8 Smart electric boilers

Figure 9 Schematics of the calculation for electric boilers



A. Data on the number of electric boilers in 2004 for 22 Member States is used as a primary input. The number of electric boilers in the other Member States is estimated using the average share of households with an electric boiler in these 22 Member States.

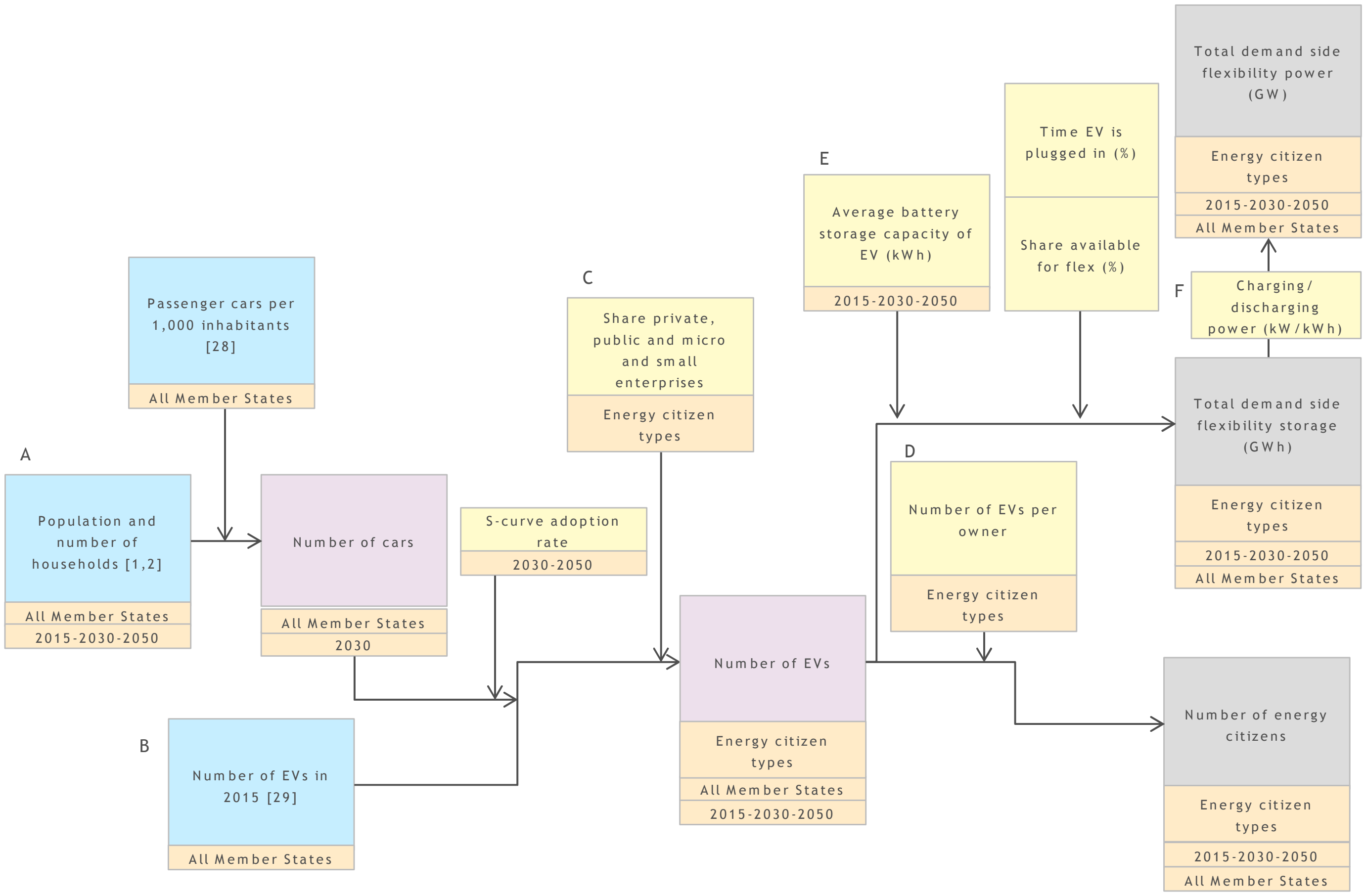
B. The number of electric boilers in 2004 is expected to grow over time, to estimate this growth rate an S-curve adoption rate is applied. Current boilers are not ‘smart’, though, i.e. they are not yet equipped to provide demand flexibility. An S-curve adoption rate is therefore also used to determine the share of these boilers that will be enhanced with smart abilities so it can be used for flex demand. The output with both these S-curves applied, is the number of energy citizens.

C. To calculate the total demand side flexibility storage (GWh), the amount of smart electric boilers is multiplied by their average storage capacity.

D. To calculate the total demand side flexibility power (GW), the number of smart electric boilers is multiplied by the average electric power of the electric boilers.

2.9 Electric vehicles

Figure 10 Schematics of the calculation for electric vehicles



A. The number of cars in total and per household is calculated using the Eurostat statistics for the population, number of households and number of passenger cars per 1,000 inhabitants. In the model it is assumed that the current number of cars will stay the same. By applying an estimated adoption rate, the number of electric vehicles (EVs) is estimated for 2030 and 2050.

B. For 2015 the current number of EVs is known, this number per Member State is further processed the same for all three time frames.

C. The total number of EVs is split into the different energy citizen types using an estimate based on literature.

D. By dividing the number of EVs by an estimate for the number of cars per type of energy citizen, the number of energy citizens per type is calculated. For households this is estimated using the statistics from A and an estimate for the percentage of households that have one car or more.

E. To calculate the total demand side flexibility storage the number of EVs is multiplied by the average battery capacity, the percentage of time the EV is plugged in and the share of the battery capacity available for flex. It is assumed that all EVs (or their charging installations) are equipped with smart charging capabilities[4].

F. This is again multiplied by the charging and discharging power to calculate the flexible power potential.

2.10 Deduplication energy citizen households

To arrive at the total number of energy citizen households, the number of households that were calculated in the previous section (i.e. the number that produce energy, or own specific demand flexibility options) need to be deduplicated since the same household can have multiple technologies applied. Three different totals are calculated:

– the potential number that have demand response capacity;
– the potential number of energy citizens that produce energy;
– the number of energy citizens that have both.

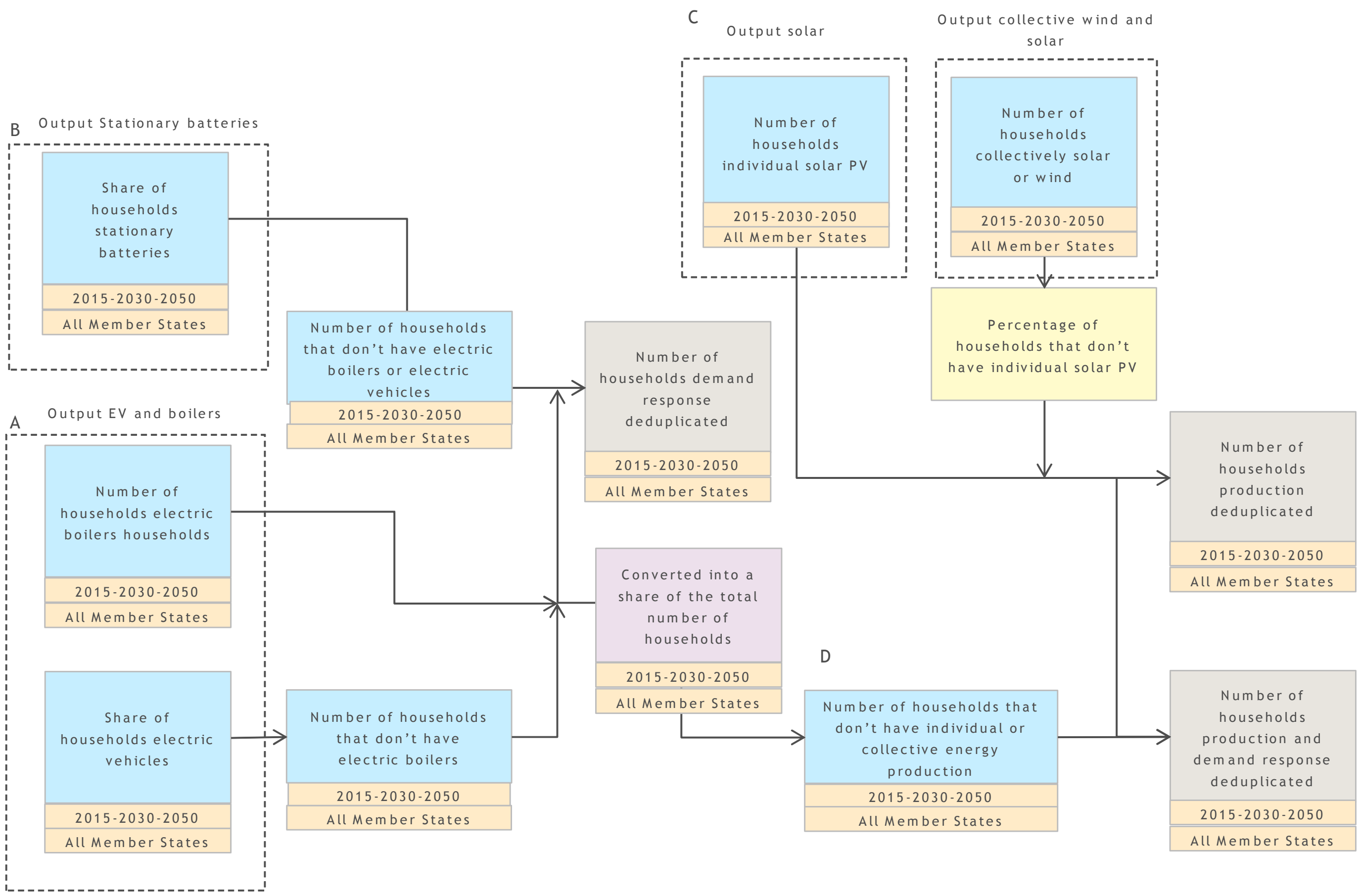
The number of energy citizen households that have demand response capability is calculated as followed:

A. As a basis the number of households that have an electric boiler is used. Added to this the share of households with an electric vehicle multiplied with the number of households that don't have an electric boiler.

B. As a last step the share of households that have a stationary battery is multiplied with the number of households that don't have an electric boiler or an electric vehicle. This results in the total number of households that can offer demand response.

[4] This seems to be a reasonable assumption as EVs are still at the beginning of market uptake, their technical development is still very much ongoing and smart charging is an issue that has a lot of attention.

Figure 11 Schematics of the deduplication of energy citizen households



The number of energy citizen households that produce electricity is calculated as followed:

C. As a basis the number of households that have individual solar PV installed is used. Added to this is the number of households that are participating in collective solar PV or wind energy, multiplied with the percentage of households that don't have individual solar PV. This results in the total number of households that produce electricity.

The total number of energy citizen households that produce electricity and/or provide demand response is calculated as followed:

D. The result from step A is converted to a share of the total number of households and multiplied by the number of households that don't have solar or wind energy production. This is added to the result from C to get to the total number.

3 Investments and cost impacts

The focus of this study was on estimating the potential of energy citizens, looking at indicators such as renewable energy production capacity, energy storage capacity and total number of energy citizens in the EU and its Member States. The economic impacts of these developments – to society as a whole, to the energy citizens themselves or to other stakeholders – were not assessed, even though they are without doubt one of the key drivers or barriers to these developments.

Since this assessment would require detailed and complex modelling, it was decided not to include it in the scope of this study. Nevertheless, to provide some insight into the economical aspects of energy citizen developments, the following contains a brief outline of the key mechanisms that may be expected.

The large-scale emergence of energy citizens is part of a much larger and profound transition of the energy system. Energy companies will invest in large scale on- and off-shore wind parks, industry will implement a range of demand side flexibility options such as power to heat and power to products. Power to gas and power to liquid plants might emerge and energy infrastructure needs to be adapted to the new situation. And, last but not least, government authorities (EU and national) will need to modify energy market regulations and adapt their legal, regulatory and probably also fiscal framework. All these developments will impact future electricity price and price fluctuations.

Determining the cost and benefits of energy citizens within these complex and still uncertain developments would require a thorough assessment of potential developments in the system, including a detailed modelling exercise of a number of feasible scenarios.

For example, demand side flexibility of energy citizens can have a clear economic value, most notably:
- It can reduce peak loads on grids.
- It reduces the need for backup capacity in times of low RES production.
- Flexibility allows the energy citizen to benefit from periods of low electricity price in times of high solar and wind generation.

However, the extent of this benefit depends significantly on what other flexibility and storage measures are implemented by the other actors in the system, on the local grid character, on interconnection capacity developments, etc.

As another example, the cost savings that can be achieved through a wind energy cooperation will depend on, inter alia, the electricity price that is received for the wind energy generated. Since the amount of wind generated electricity will increase significantly over the coming years, the risk increases that the price will be low in times of high wind speeds – unless there are sufficient options in place to reduce these price fluctuations, such as demand side flexibility, storage and interconnections.

Clearly, developing the potential of energy citizens requires investments and generates significant societal, environmental and economic benefits. However, it will also save the need for other investments in RES, demand side flexibility and storage, which would also create benefits. To assess the net cost, the economic benefits and cost of the developments analyzed in this study should therefore be compared against other scenarios for a 100% renewable energy system, or to a well-defined reference scenario.

4 Results

As explained in the introductory chapter, the main result of this project is a comprehensive Excel spreadsheet which contains all quantitative results of this project. From these data, quite a number of different cross sections can be made, since the data differentiate between a number of categories of energy citizens, assess different technologies and indicators, for different years and EU Member States.

In the following, a number of graphs are shown that illustrate the range of data produced and show some key results. These results are produced using the methodology described in Chapter 2, with the assumptions listed in the Annex to this report.

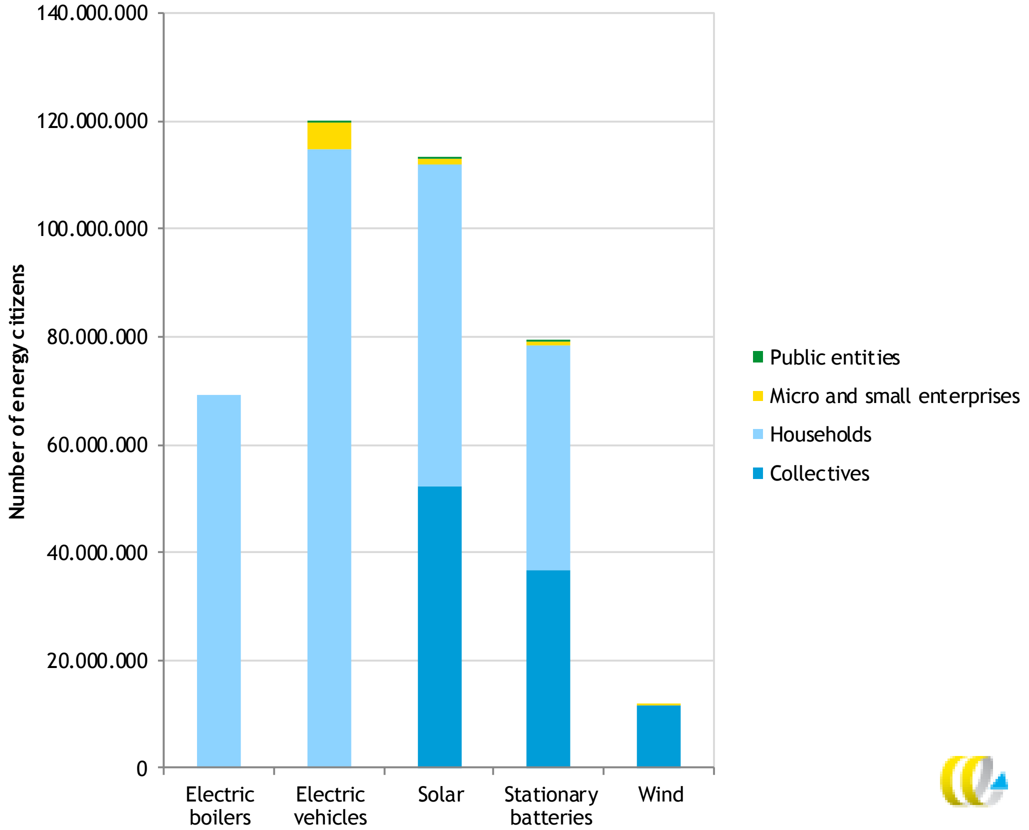
Figure 12 shows the potential number of EU energy citizens for the various technologies assessed, in 2050. With the assumptions used, we estimate that about 115 million EU households will have an electric vehicle in 2050, 70 million may have a smart electric boiler, 60 million may have solar PV on their roof and 42 million may have stationary batteries on their premises. Another 64 million households could participate in renewable energy production through an energy collective.

Some of these households will have more than one of these technologies, so using the deduplication methodology described in the previous chapter we arrive at an estimated total of 187 million EU households that may contribute to renewable energy production, demand response and/or energy storage in 2050. This is about 83% of the total number of EU households.

About half of all EU households, around 113 million, may produce energy, either individually or through a collective. About 161 million can potentially provide flexible demand services with an EV, (smart) electric boiler or stationary batteries. A large share of the households that could have demand flexibility could also be an energy producer.

We furthermore estimate the potential number of small enterprises that can actively participate in the energy system in 2050 to be 5 to 6 million, the potential number of public entities about 400 thousand.

Figure 12 **Number of energy citizens for the various technologies assessed, potential to 2050 for the EU28**



The following graphs show some more results, on:

- The potential electricity production by energy citizens in 2050, per category (Figure 13) and per Member State (Figure 14);
- The potential development of energy storage by energy citizens over time (Figure 15).

Figure 13 Estimated potential for electricity production by the various energy citizen categories, in 2050 for the EU28 (TWh)

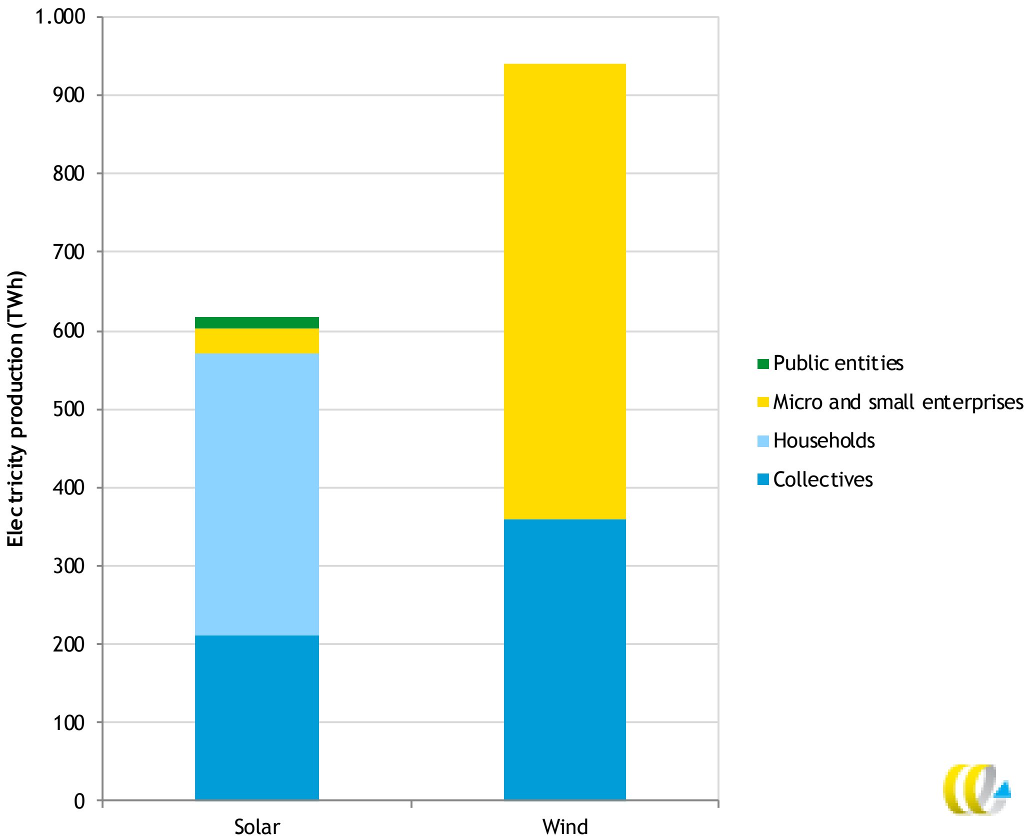


Figure 14 Electricity production by energy citizens, potential to 2050 per Member State (TWh)

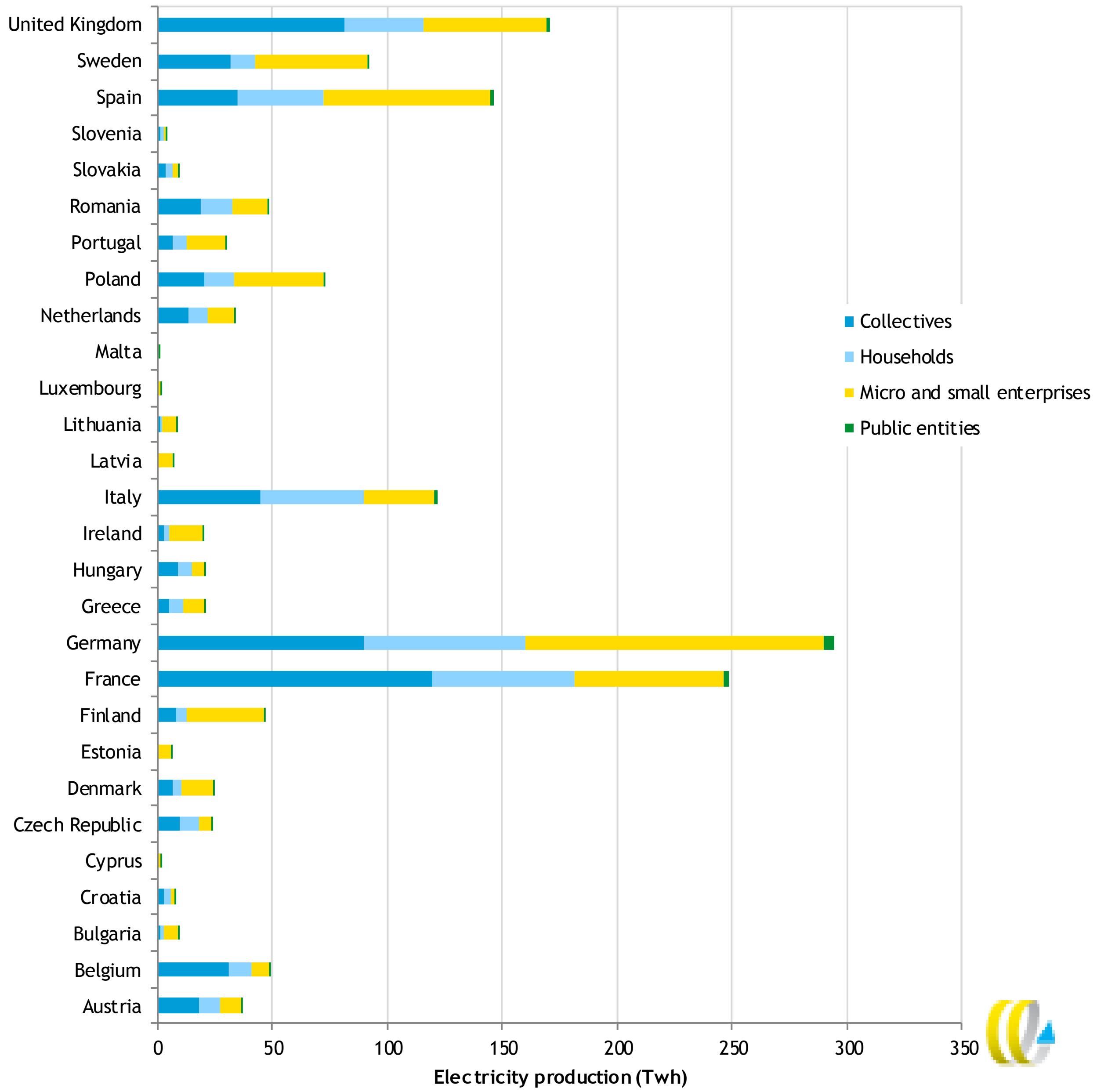
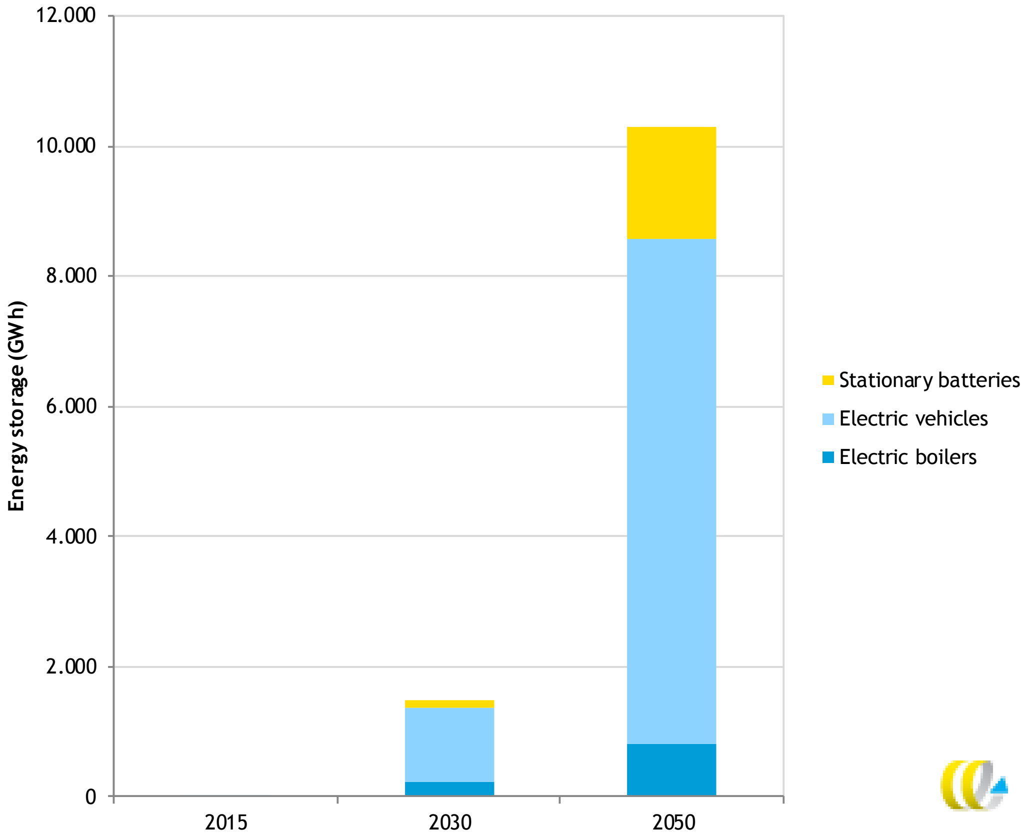


Figure 15 Potential energy storage by energy citizens, estimates for 2015, 2030 and 2050 (GWh)



5 Conclusions and recommendations

The potential for European households, energy collectives, public entities and small enterprises to actively contribute to the future energy system is clearly very significant. We estimate that about 83% of the EU's households could potentially become an active participant, which amounts to about 187 million households. These energy citizens could produce renewable electricity, adapt electricity demand to renewable energy production or store energy at times of oversupply.

A calculation tool was developed to estimate the potential of various energy citizen categories in 2030 and 2050 (households, public entities etc.), looking at a number of different technical options. This resulted in a range of data on the potentials, in terms of number of energy citizens, renewable energy capacity or production, etc. The main results can be found in the Excel file that accompanies this report.

The data and knowledge on the role of energy citizens, both now and in the future, is still very limited. Consequently, the results in this study depend on a large number of assumptions, estimates and methodological choices, and the uncertainties are significant. However, the calculations were based on existing data as far as possible, and the methodology developed is as much as possible based on well-founded reasoning. The resulting data can therefore be seen as a first assessment of the potential of energy citizens in the EU.

The main objective of this study was to produce estimates for the potential number of energy citizens and their contribution to the energy system.
It is recommended to follow up this study with a further assessment of the data, and of the calculation methodology. A sensitivity analysis of the various assumptions and variables may be useful to further test the robustness of the methodology used, and to determine and analyse the key drivers for these developments. It is also recommended to further develop data gathering about energy citizens, and increase research on these potential future developments.

Other issues that could be explored further are how this potential for European households, energy collectives, public entities and small enterprises to actively contribute to the future energy system can be realised, and how a future with a large number of energy citizens compares with a more centralized development of a sustainable energy future.

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Annex A Assumptions

Table 1 Solar PV

E[R] OECD Europe E[R]-scenario [20]		**2030**	**2050**	
Installed capacity (GW)		305	555	Capacity and generation in Energy Revolution scenario.
Electricity generation (TWh/y)		337	647	
Average size of installation (kWp)	**2015**	**2030**	**2050**	
Households	4	5	6	Average size of installation for different energy citizens groups. For households very typical, size increases due to efficiency improvements up to 2050. For SME, public entities provisional estimates.
SME	25	30	35	
Public entitites	25	30	35	
Per member of collective	1,3	2	2,5	
	2015 [9]	**2030 [9]**	**2050**	Conversion efficiency improves over time due to technology learning. Note: rough estimate for 2050.
Average efficiency of PV modules installed	15,80%	19,70%	23,60%	
Performance ratio [9]	80%			Factor representing conversion losses (inverter) and other system losses.
Number of floors per building type				
Single family dwellings [9]	2			These figures are needed to calculate roof surface area for PV.
Multi-family average of low- and high-rise [9]	5,75			
Commercial buildings	4			
Public buildings	4			
Solar suitable area [9]	40%			Factor to correct for obstacles on roof (windows, heat exchangers, chimneys, etc.).
		2030	**2050**	
Investment costs 1 kWp (2015 Euro)		€ 800	€ 500	Indicative costs, needed to calculate energy citizen capacity based on savings rate.
Share of commercial grade PV installations (10-250kWp) on roofs of micro and small enterprises	40%			Provisional figure that is needed to attribute some solar PV capacity to micro and small enterprises and public entities. We have tried to find some literature backing up these shares but that is very difficult. The share is assumed to be the same in all years.
Share of commercial grade PV installations (10-250kWp) on roofs of public entities	20%			
	Building based	Ground based		
Share of installed capacity (2030 and 2050)	80%	20%		Estimate.

Table 2 Wind

E[R] OECD Europe E[R]-scenario [20]		**2030**	**2050**	
Installed capacity (GW)		325	510	Capacity and generation in Energy Revolution scenario.
Electricity generation (TWh/y)		819	1.426	
Share onshore in Europe [27]	92%			We have to assume a share of wind onshore/offshore to translate the Greenpeace figures.
		2030	**2050**	
Investment costs 1 kW (2015 Euro)		€ 900	€ 700	Indicative costs, e.g. needed to calculate energy citizen capacity based on investment potential
Share of wind power owned by micro and small enterprises (mainly farmers)	30%			Provisional figure that is needed to attribute some wind generation to small enterprises (mainly farmers). We have tried to find some literature backing up these shares but that is very difficult. The share is assumed to be the same in all years.
	2015	**2030**	**2050**	
Average installed capacity at farmer (MW)	0,5	1	1,5	Provisional figures to assess the number of energy citizens (farmers and collectives)
Capacity per member of collective (kW)	8,3	10	13	

Table 3 Electric boilers

	2015	**2030**	**2050**	
E-boilers added in comparison to 2004	3%	7%	15%	Estimates of growth of E-boiler thanks to electrification and excess renewable electricity. The implied S-curve of technology adoption results in total electric boiler capacity being growing from 30% in 2004 to a level of 45% in 2050.
	2015	**2030**	**2050**	As of yet, all boilers are 'dumb', at best they switch on during off-peak hours. Due to smart grid technology, they can be steered to be price responsive and complement renewable electricity grid infeed. We assume 100% of boilers to be 'smart' by 2050, with an implied S-curve/exponential growth in the number of smart appliances in the next 35 years.
Adoption rate smart addition to E-boilers	0%	30%	100%	
Energy capacity average E-boiler (kWh)	11,5			Indicative (conservative) assessment, corresponds to what can be easily stored in an average E-boiler of say 200 litres.
Electric power E-boiler (kW) @230 V	2,0			An average electric capacity of 2 kW per boiler is in line with current technology.

Table 4 Stationary batteries

		2030	2050	
Adoption battery storage at PV locations		20%	70%	For this study we assume that grid connected batteries are only placed at energy citizens that employ solar PV because the incentive is the strongest for them e.g. to prevent the waste of energy due to e.g. solar PV curtailment. We assume the solar PV capacities to be growing so fast that the grid cannot keep up, increasing being a bottleneck after 2030 in many locations. Also we expected storage technology to improve over time, meaning we assume an exponential growth rate that approaches 70% market adoption in 2050.
		2030	2050	
Storage capacity per PV capacity (kWh/kWp)		3	4	The figure reflects the assumption that the storage size reflects the approximate daily peak production that cannot be directly used in summertime.
Charging/discharging power (kW/kWh)	0,30			Charging/discharging capacity reflects charging and discharging to the level of entire storage drained/charged in 3 hours time, which is reasonable.

Table 5 Electric vehicles

		2030	2050		These are provisional estimates of the share of EVs in the EU vehicle fleet for individual transportation. These figures are very ambitious, current sales figures must increase profoundly to meet 20% in 2030. To move from fossil fuels to carbon transport, we will have to use high share of electric personal transport, however.
EV share in fleet		20%	80%		
	Households	Micro and small enterprises	Public [30]	Other enterprises	The share of households and other energy citizen groups have been derived from the current status quo of vehicle ownership (Dutch data), assumed to be applicable to future years as well.
Share of fleet per energy citizen type	89%	5%	1%	5%	
Number of cars per owner		2	50		Provisional estimate.
	2015	2030	2050		
Average battery capacity EV (kWh)	45	60	100		Provisional estimate of battery capacity. We assume a technology development that works in two areas - price reduction and footprint reduction. Both of these developments allow manufacturers to increase the storage capacity and range of the average EV.
Charging/discharging power (kW/kWh)	0,10				We assume that average peak charging and discharging of the capacity is done in 10 hours. We obviously chose a lower figure than fast charging, because of grid constraints.

Share of time plugged in	50%	Provisional figure.
Share of capacity available for flex	80%	Provisional figure, we don't want every kWh storage to be allotted to the market (people want a minimum transport distance to be able to e.g. go to a hospital at all times).
Share of households without a car [32]	28,5%	Average of NL is used for EU28 due to missing data.

Table 6 Investment potential

	Min	**Max**		Provisional figure for the investment potential per MS. We assume that investment depends on the average savings rate of EU countries. The savings rate is normalised and used to calculate an investment potential from households for solar PV/wind in the different member states, where the lower end of the investment amount specified is allotted to the EU countries with the lowest households savings rate, and the higher figure to the EU country with the highest savings rate, with the other MS falling in between.
Maximum investment per household per year (Euro)	100	500		
		2030	**2050**	We assume that as the energy transition is further shaped and the effects of climate change are being felt more and more, that the awareness of the population growths and consequently also the amount that consumers will want to invest can grow, with the indicated figures.
Growth in share of citizens that will want to invest in either solar PV on own roof, or in collective		50%	100%	
Share of investment potential for solar on roofs of single family buildings (upper limit)	50%			We assume that the investment potential of households is first allocated to install solar PV on own roofs since this is financially more attractive in multiple MS compared to collective energy (due to subsidies, energy tax and VAT).
	Wind collective	**Solar collective**		The remaining investment potential is split among wind collectives and solar collectives. We assume there is no preference between the two.
Division of remaining investment	50%	50%		

Table 7 General

EU28 population compared to OECD Europe [1, 33, 34, 35]	-10%	This factor indicates the difference between the OECD Europe and EU28 population. It is used to translate the Energy Revolutions OECD Europe outcomes to EU28.
Share of collective energy citizen households that have also invested in their own PV	20%	We expect that most collective solar PV and wind is owned by households that didn't have the possibility to install solar PV on their own roof.