Applying the efficiency first principle to photovoltaic self-consumption

Andreas Jahn
The Regulatory Assistance Project
Anna-Louisa-Karsch-Straße 2
DE-10178 Berlin
Germany
ajahn@raponline.org

Jan Rosenow
The Regulatory Assistance Project
Rue de la Science 23
B-1040 Brussels
Belgium
jrosenow@raponline.org

Keywords

photovoltaics, efficiency first, retrofits, dynamic windows, financial incentives, efficiency standards

Abstract

Self-consumption from photovoltaic (PV) rooftop installations is an important driver for private investment in renewable energy in Germany. Financial incentives for PV provided by the feed-in tariffs are now so low that an investment in rooftop PV only makes sense if the benefits of self-consumption, including the avoided cost of buying electricity from the grid, are fully considered. In addition, ongoing battery support schemes for PV installations continue to increase the amount of renewable electricity consumed by the owner of the installation ("self-consumption"). The incentives provided by this approach encourage fuel-switching to electricity in the heating and transport sectors, too.

This paper argues, however, that the incentives to maximise PV self-consumption discourage electric efficiency improvements, as those would lower the share of self-consumption and thus the financial rewards. Also, the window of opportunity created when renewable energy investments are considered, is not being used for energy efficiency interventions. This is contrary to the Efficiency First principle, which states that, whenever solutions on the demand-side, such as energy efficiency improvements, deliver higher economic net benefits than the generation, transport, and consumption of energy, these measures should be implemented first.

In this paper, we demonstrate how the proper support for PV self-consumption can become an important mechanism to fund energy efficiency improvements for inefficient homes. One need only to look to Europe and abroad for examples of renewable support schemes that prioritise self-consumption *and* incentivise energy efficiency improvements. We show how this experience can offer important lessons for EU member states, such as Germany, that provide strong incentives for self-consumption of on-site renewable generation.

Introduction

The German *Energiewende*, or energy transition, is often described as a transformation to greater decentralisation of, and more efficient, energy production and use. It fosters the participation of local citizens and aims to overcome the market power of the established energy industry. Due in particular to the reduced costs of photovoltaics, electricity generation on one's own roof has increasingly moved to the centre of the decentralisation movement. Some consumers even equate generating their own power with energy self-sufficiency, or independence from the grid and energy suppliers (Agora Energiewende 2017). Yet, as the examples from the islands of Pellworm (North Sea) and Hierro (Canarias)[1] show, it is important to exercise caution. The islands' plans for gaining independence from the system by meeting their needs with self-generated renewable energy were ultimately dropped, as it was much more costly than connecting to the electricity system, despite sufficient local electricity generation. Electricity can be transported inexpensively over long distances; thus the islands' plans to balance generation and consumption locally were more expensive. Even if the levelized cost of elec-

1. https://www.researchgate.net/publication/328370049_El_Hierro_Renewable_Energy_Hybrid_System_A_Tough_Compromise, https://ruhrkultour.de/pellworm-das-ziel-der-autarkie-wurde-verfehlt/

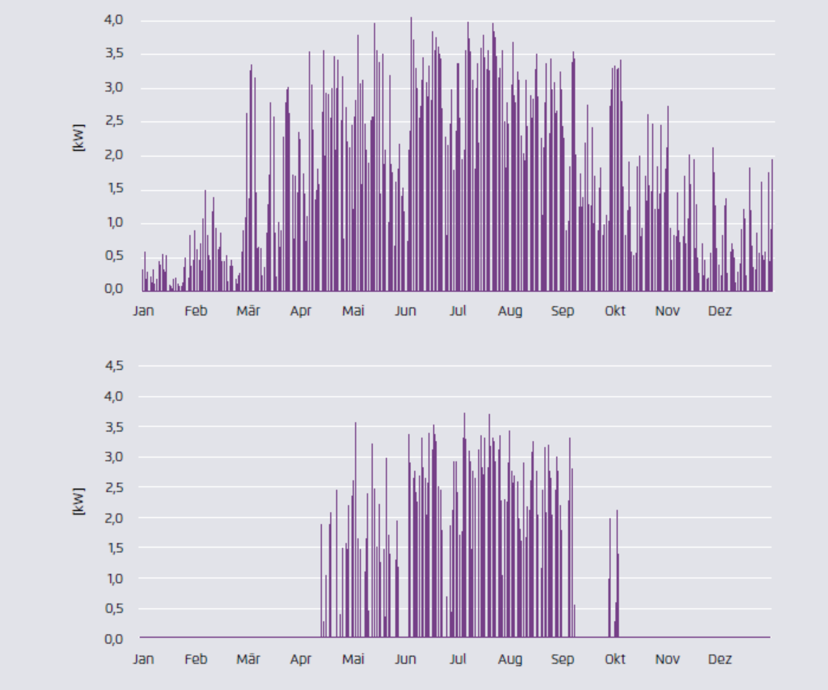

Figure 1. Feed-in of total generation from PV vs. feed-in after self-consumption. Source: Prognos, 2016

tricity is lower than wholesale market prices, balancing demand and supply to ensure a reliable power system is critical and is normally paid for by a very large number of customers. Similar plans for creating self-sufficient energy regions have often turned out to be unfeasible, despite avoided pipelines and fuel imports.

Parallels can be drawn to self-consumption of renewable energy generated in or on buildings, which is becoming an important driver for installing PV, as the levelized cost of electricity for generating solar energy is well below the cost of purchasing electricity from the grid. In other words, self-generated PV electricity is already cheaper in most cases than electricity drawn from the grid, even without subsidies.

Self-consumption has been encouraged in Germany, for example, since 2009 by the Renewable Energy Act (*Erneuerbare-Energien-Gesetz (EEG))* through additional financial incentives such as feed-in tariffs (for unused self-generated power or for selling all self-generated power) and financial support schemes for batteries (to maximise self- supply). These increasing incentives to promote self-consumption have the unwanted side-effect that they discourage electric efficiency improvements – the lower the share of self-consumption, the lower the financial rewards (Quaschning 2018). Also, the time frame when a building owner is considering renewable energy investments is currently not leveraged to integrate both supply-side and demand-side resources (ibid).

Support of Self-Consumption in Germany

The goal of building local commitments to energy system transformation is closely linked to self-consumption. Politicians have advanced this concept and hope that it will create new impetus to the energy system transformation, be it in the form of acceptance, through increasing participation by customers who generate and consume their own energy, or by mobilising private investment. Accordingly, with the German Renewable Energy Act of 2009, the legislator explicitly endorsed the consumption of self-generated photovoltaic energy through additional financial incentives and continues to do so. At present, the remuneration for rooftop solar power is designed in such a way that it only covers costs or becomes profitable if at least a portion of the power is used by the owner. With the latest amendment to the EEG in 2017, the focus was extended beyond homeowners to also include a subsidy to encourage self-consumption by tenants.

Today, consumers pay for networks and renewable support via non-varying volumetric fees and levies. Since PV self-consuming customers can avoid a significant part of this bill with very little or no effect to total network costs or levies, customers without PV have to bear these shifted costs. However, as a consequence of the explained restrictions on self-consumption, the success of self-consumption and the cost increase for non-self-consuming customers remain low. (Prognos, 2016).

Today's feed-in tariffs only differentiate between the generation technology and the size of the plant, but not the use of the resource. The tariffs don't consider that a plant that is designed and operated for its own consumption feeds into the grid differently than a plant that is designed and operated for feed-in only. Solar radiation fluctuates in central Europe, being high in the summer and low in the winter. Demand for electricity and electric heating applications is generally higher in the winter and lower in the summer. This means that all of a PV owner's generation can be used for electricity and heat applications in the winter. Surpluses, which are remunerated under the German subsidy regime in the same way as feeding in all of the electricity generated, occur particularly in the summer, when there is no heat demand (Figure 1).

Germany's power systems, like most European systems, are winter peaking systems and, reflecting those peaks, prices in the winter are generally higher than they are in the summer. The decarbonisation of the heat and transport sector by electrification, as part of the energy transition, and the associated increase in renewable energy resources, such as wind and solar, will drive this connection even further.

It is important to recognise that, often, self-consumption is suboptimal as a local solution. From an economic point of view, it is generally cheaper to balance supply and demand on a larger scale. But, even in a decentralised power system, the so-called peer-to-peer approach[2] is used to organise balancing between individual consumers. For example, a consumer should use the midday photovoltaic supply from a neighbouring household directly, in order to avoid additional storage behind the meter. In some countries, there are extensive debates about the benefits of this method of promoting self-consumption, e.g., around net energy metering in the U.S. (Muro and Saha 2016) and the value of solar (RMI 2013), that have seldom been the subject of analysis or discussion in Germany.

On the one hand, promotion of photovoltaic self-consumption is granted through a combined battery subsidy and time-independent remuneration claims for surplus quantities. Other, indirect promotion of self-consumption occurs generally because the current system grants these consumers an advantage by saving a significant proportion of non-varying network fees. If the network costs for other consumers rise as a result, this is certainly a type of subsidy.

On the other hand, only a limited number of customers generating their own power benefit from this support. Photovoltaic self-consumption in Germany today is limited to certain scenarios. The most relevant restriction is the personal identity of the producer and consumer. If the legal entity of a manufacturing company or household is a tenant, they would have to own the PV-installation on the leased building in order to take advantage of the benefits of self-consumption. As a result, a limited number of customers benefit from this support, but there is no aggregated effect for the system. This restriction also means that today's less targeted (and potentially inefficient) support scheme does not foster the required uptake of renewable energy resources and the power system transformation.

Self-consumption and the electrification of heat and transport

For consumers today, a kilowatt-hour of electricity is more expensive than a kilowatt-hour of non-electric heating fuels (natural gas, heating oil, and the like). In order to make the use of emissions-free electricity from solar PV more attractive for heating, policymakers are considering lowering the electricity tax or imposing higher taxes on fossil fuels in the electricity sector.

An increasing amount of self-generated and self-consumed renewable electricity means that the electricity generated by consumers can also be used for heating, hot water, charging a car battery, and similar uses. From the consumer's point of view, this use of electricity is understandable and attractive. Why should one not use his or her own energy to decarbonise other end-uses such as heating and transport, particularly when there are financial rewards on offer? Therefore, consumers are demanding the same support and promotion for this form of self-consumption (Couture and Ridge, 2018). We do not look into the extent to which investments can be generated more effectively and at lower cost through "self-sufficiency incentives" in this paper. Rather, it is simply important to recognise that there is considerable potential to promoting a "do-it-yourself" approach, which should be addressed systemically from the outset in order to decarbonise the electricity and heating sectors cost-effectively.

The Heat Challenge

A significant challenge in the energy transition is decarbonising the heating sector. Around three times as much energy is consumed for heating than for electric end-uses. Unfortunately, the solution is not as simple as replacing the fossil energy used here with clean electricity. This would mean massive investment into power generation and grid infrastructure, which is hardly feasible due to limited public acceptance of new power system infrastructure, the associated costs, and, most importantly, the amount of land that would be needed to do so. This applies to both the heat sector and to the individual consumer. The electric power consumption of a single-family home would at least double if the oil heater were replaced with a heat pump. At latest when one takes into account an electric vehicle, the rooftop surface required to generate adequate power is no longer sufficient. On a 100-square-meter rooftop, a 10 kWp photovoltaic installation can generate about 10,000 kilowatt-hours annually, while the annual demand for power, heat, and transport combined would be easily double that amount. As explained above, if the consumer optimises the system for self-consumption, any feed-in of excess power supply can only be expected in the summer (Figure 1). With the increasing electrification of heat, the winter peak will increase even further and the average value of the remaining feed-in tariffs from oversupply will decrease accordingly.

Another challenge in the building heating sector is that the building infrastructure and its heating systems are extremely diverse, as are the interests of the owners. Due to the long investment cycles for buildings, it is therefore important to establish timely incentives (Rosenow and Jahn 2016) that take into account the individual heating requirements (ifeu at al. 2018) and go beyond only incentivising self-consumption.

The German housing stock comprises around 41 million apartments and is divided roughly equally into two categories: multi-family houses, and single-family and two-family houses. In the case of the latter (Figure 2), there is a greater share of buildings with higher energy consumption, i.e., buildings for which energy efficiency improvements will be sought in the next 10 to 20 years. Due to the legal requirements relating to the personal identity of the owner and consumer, the incentives for a PV self-production system are now available, especially for the building category needing energy efficiency investments.

Efficiency First as a Solution

EFFICIENCY FIRST AND RENEWABLE ENERGY

In order to completely decarbonise energy production, we need more investment in renewables, not less. But just as the energy system cannot be decarbonised through energy effi-

2. New York Times (2017) Solar Experiment Lets Neighbors Trade Energy Among Themselves. Retrieved from: https://www.nytimes.com/2017/03/13/business/energy-environment/brooklyn-solar-grid-energy-trading.html

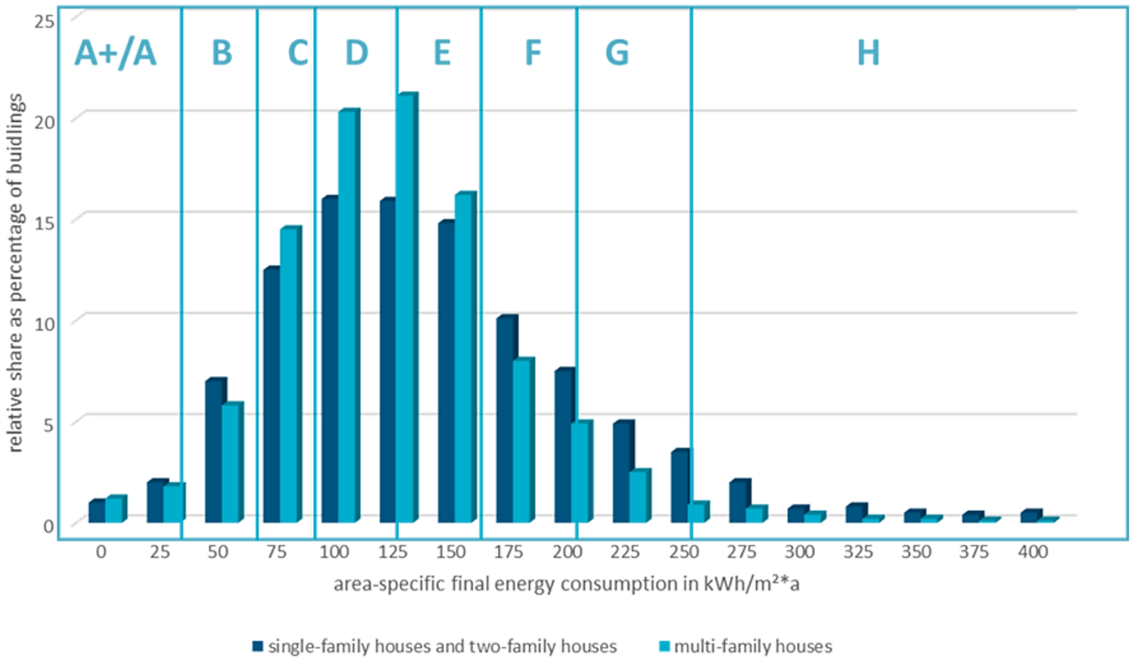

Figure 2. Relative frequency of various energy performance classes in Germany, differentiated by single-family and two-family houses, or multi-family houses. Source: Steuwer, 2018.

ciency alone, a system with 100 percent renewables cannot be achieved without extensive energy efficiency. This is one reason why the International Energy Agency (IEA 2016) has described energy efficiency as a "first fuel."

A study by Lechtenböhmer et al. (2017) shows that the emission reductions necessary to meet the climate goals – especially reductions resulting from the electrification of heating and transport – are neither easily achieved through technology, nor economically efficient without substantial energy efficiency gains. For a successful energy transition, we therefore need to accelerate the deployment of renewable energy, while drawing on more energy efficiency and demand response to optimise and reduce demand. Trying to decarbonise wasteful energy consumption by simply subsidising more and more energy production is an exercise in futility.

The question is rather: How can we achieve a world with 100 percent renewable energy and systematically tap into the existing energy efficiency potential? This has been neglected in many EU countries. Renewable energy was promoted and grid expansion was approved. However, groups advocating for reduced energy consumption have been less successful than those lobbying for more renewable generation and larger grids. This is partly a result of the disparate nature of the energy efficiency industry's many different technological solutions.

The International Renewable Energy Agency (IRENA 2017) recently published a study systematically assessing the synergistic effects of energy efficiency and renewable energy. The conclusion is that, in tandem with efficiency, higher penetrations of renewable energy can be achieved, leading to significantly lower energy system costs and faster decarbonisation of the energy system. This is the ideal scenario for the Efficiency First principle (Jahn and Gottstein 2015; BMWi 2016): If the long-term savings are more favourable than generating and transporting electricity, then the savings should be acquired, even in the case of local renewable generation. Wasting renewable energy due to inefficient end consumption is at cross-purposes with the energy transition and consumer interests. This takes us to the role of self-consumption.

EFFICIENCY FIRST AND SELF-CONSUMPTION

Since self-consumption obviously stimulates investment while taking into account the individual interests of the owner and the circumstances of the building, this motivation should also be leveraged in other sectors. Accordingly, a fundamental privilege, or support, for self-consumption should target the *efficient use of self-generated electricity*.[3]

For example, the level of privileges can be linked to the efficiency class of the building or the implementation of remedial measures (in Germany, an *individueller Sanierunsfahrplan*, or individual refurbishment schedule). Consequently, self-consumption for a well-insulated building with an efficient heating system would be rewarded at a higher rate than an inefficient building. Since this subsidised self-consumption applies to lower volumes of electricity, the privilege also puts less strain on other consumers compared to maximised self-consumption in an inefficient building. From an economic perspective, a cost-neutral approach can be applied that maximises the added value, since the decarbonisation result per euro invested can be increased. Looking beyond our borders reveals that this approach is not entirely new.

3. In principle, it is, of course, up to the consumer to decide for what purpose and in what quantities they consume electricity. A state acting in the public interest should, however, only discuss improving individual targets in combination with achieving overall societal targets, i.e. climate targets.

INTERNATIONAL EXPERIENCE

There are already international practices with linking end-use efficiency improvements to customer-sited renewables production and consumption:

United Kingdom

In April 2012, the British government introduced an energy efficiency requirement for households (Rosenow et al. 2016) that want to install solar modules on their buildings and claim the full feed-in tariff. This minimum legal requirement stipulates that the building must have energy efficiency class D or better (DECC 2012; DECC 2015).

In Kirklees County, West Yorkshire, a similar requirement was introduced at the local level (Schofield et al. 2010) before 2012: Under the RE-Charge system, the installation of renewable energy technologies, such as photovoltaic systems and air source heat pumps, was only encouraged if basic energy efficiency measures had already been carried out in the building. Analysis of UK feed-in tariffs and efficiency requirements has shown that households that have installed a photovoltaic system are more likely to have invested in energy efficiency measures than households without PV. For example, 86 percent of all households with photovoltaic systems have also invested in wall insulation and roof insulation measures (DECC 2015).

Flanders

In Flanders (Belgium), a comparable approach was already adopted in 2010 (government of Flanders 2019): In order to obtain a so-called Green Certificate for the generation of electricity using photovoltaic systems, the roof or attic floor must achieve a minimum thermal resistance of 3 m^2 Kelvin per watt.

California

In California, consumers must undergo an energy audit before they can claim their own consumption privilege (State of California 2018). Here, for example, the efficiency potentials to be fulfilled are determined and even the financing for their implementation. Only after implementation of the efficiency measures can a grid-connected rooftop photovoltaic system be used accordingly.

Netherlands

Successful renovation is beginning to establish itself in the Netherlands through the so-called energy *sprong*. The costs have already been considerably reduced by economical, industrial prefabrication and installation of the insulation elements. The remaining electricity and heat consumption of the building is covered to the greatest extent possible by photovoltaics on the building's rooftop. This option provides consumers with the security provided by housing costs that, by law, will not be subject to fluctuations from heating costs. However, the basis for this "net zero energy" refurbishment is the annual balancing of the household's own electricity generation with electricity consumption (Transition Zero, 2017).

Conclusions

In order to systematically comply with consumer demand for self-consumption, policymakers must evaluate the energy and heating sectors together and address them in a coordinated fashion. This implies that self-consumption represents a higher overall value for efficient use cases and should therefore be rewarded at a greater rate than less efficient cases.

The current decision for the EU Renewable Energy Directive stipulates that self-consumption for renewable energy plants with a capacity of up to 30 kilowatts will no longer be burdened with levies and taxes. Even if this is fully implemented in Germany, there is also an additional privilege, for example through the remuneration rules for surplus electricity fed into the system and subsidies for photovoltaic battery storage systems. Therefore, consideration should be given to linking these privileges to efficiency standards or to the efficiency class of the respective building. Moreover, in order to address the improvement of the building efficiency class. Applicants could be required to prepare and implement the recommended measures outlined in the individual refurbishment schedule (BMWi 2017). There are also other options relating to network charges, such as time-differentiated network fees or independent feed-in tariffs (Kolokathis et al., 2017), that can be linked to the efficiency level of the building.

It is important to note that the energy system transformation will not be achieved solely through the promotion of self-consumption. Even so, without systematically factoring self-consumption into the energy transition, there is risk of lock-in effects, making the overall transition more expensive and more difficult. The energy refurbishment rate in Germany must increase to two to three percent per year in order to meet climate change and energy transition targets (Rein 2016). However, the energy efficiency incentives required to do so are inadequate, especially for existing buildings (Rosenow and Jahn 2016) and the current renovation rate remains at around one percent per year (dena 2018). The incentive to consume self-generated electricity inefficiently results in higher support costs. Therefore, the promotion of solar self-consumption should be in some way dependent on a target level of overall building efficiency. One way to do this is to link this privilege, at a minimum, to a sustainable insulation standard (Flanders). As the example of the Netherlands shows, it is even possible to refinance complete energy refurbishment of buildings by means of a long-term improvement scheme such as annual net energy metering.

Further on, as long as today's German system of promoting battery storage, a single feed-in-tariff for roof top PV, and non-time-varying network charges is linked with the intention of optimising private self-consumption, it will be an expensive and inefficient approach that needs to be reconsidered. If the promotion measures mentioned above cannot be adjusted due to other policy requirements, such as public acceptance, connecting energy efficiency and PV self-consumption addresses several issues while making best use of available funding. Viewing the challenges, goals, and options around self-consumption and building efficiency as one comprehensive issue opens up new possibilities that should be urgently discussed.

References

Agora Energiewende (2017): Energiewende und Dezentralität. Zu den Grundlagen einer politisierten Debatte. Retrieved from: https://www.agora-energiewende.de/fileadmin2/Projekte/2016/Dezentralitaet/Agora_Dezentralitaet_WEB.pdf.

Bundesministerium für Wirtschaft und Energie (BMWi 2017): Mein Sanierungsfahrplan. Retrieved from: www.bmwi.de/Redaktion/DE/Downloads/S-T/sanierungsfahrplan-muster.pdf.

Bundesministerium für Wirtschaft und Energie (BMWi 2016): Green Paper on Energy Efficiency. Retrieved from: https://www.bmwi.de/Redaktion/EN/Publikationen/green-paper-on-energy-efficiency.pdf.

Couture, T., Ridge, G. (2018): Re-engaging FIT system owners and accelerating the Energy Transition, E3Analytics. Retrieved from: www.e3analytics.eu/wp-content/uploads/2018/04/Analytical-Brief_March-29-2018.pdf.

Cowart, R., (2014): Unlocking the Promise of the Energy Union: "Efficiency First" is Key. Retrieved from; https://www.raponline.org/wp-content/uploads/2016/05/rap-cowart-efficiencyfirst-2014-dec-04.pdf.

DECC (2015): Annex B: Electricity use in households with solar PV.

dena (2018): dena-Gebäudereport kompakt 2018. Retrieved from: https://shop.dena.de/de/sortiment/detail/produkt/broschuere-dena-gebaeudereport-kompakt-2018/.

Government of Flanders (2010): Legal framework for photovoltaics (Wetgevend kader ivm zonnepanelen), Retrieved from: https://www.energiesparen.be/sites/default/files/atoms/files/dakisolatie.pdf.

IEA (2016): Energy Efficiency Market Report 2016. Retrieved from: https://www.iea.org/eemr16/files/medium-term-energy-efficiency-2016_WEB.PDF.

ifeu, Fraunhofer IEE and Consentec (2018): Wert der Effizienz im Gebäudesektor in Zeiten der Sektorenkopplung. Study commissioned by Agora Energiewende. Retrieved from: https://www.agora-energiewende.de/fileadmin2/Projekte/2017/Heat_System_Benefit/143_Heat_System_benefits_WEB.pdf.

IRENA (2017): Synergies between renewable energy and energy efficiency. Retrieved from: https://www.irena.org/publications/2017/Aug/Synergies-between-renewable-energy-and-energy-efficiency.

Jahn, A., Gottstein, M. (2015): Wege zu einem effizienten Energiesystem in Deutschland, Regulatory Assistance Project. Retrieved from: www.raponline.org/knowledge-center/wege-zu-einem-effizienten-energiesystem-in-deutschland/.

Kolokathis, C., Hogan, M., Jahn, A. (2018): Cleaner Smarter, Cheaper: Network tariff design for a smart future, Regulatory Assistance Project. Retrieved from, www.raponline.org/knowledge-center/cleaner-smarter-cheaper-network-tariff-design-for-a-smart-future/.

Lechtenboehmer, S., Schneider, C., & Samadi, S. (2017): Energy efficiency quo vadis? – The role of energy efficiency in a 100% renewable future. In: Proceedings of the eceee Summer Study 2017, pp. 171–182Muro, M., Saha, D. (2016): Rooftop Solar: Net metering is a net benefit, Brookings Institution. Retrieved from: www.brookings.edu/research/rooftop-solar-net-metering-is-a-net-benefit/.

Prognos (2016): Eigenversorgung aus Solaranlagen. Das Potenzial für Photovoltaik-Speicher-Systeme in Ein- und Zweifamilienhäusern (Analyse im Auftrag von Agora Energiewende). Retrieved from: www.agora-energiewende.de/fileadmin/Projekte/2016/Dezentralitaet/Agora_Eigenversorgung_PV_web-02.pdf.

Quaschning, V., et al. (2018): Vergesst den Eigenverbrauch und macht die Dächer voll! HTW Berlin. Retrieved from: https://pvspeicher.htw-berlin.de/wp-content/uploads/BERGNER_2018_stadtwerk_5_6_2018.pdf.

Rein, S. (2016): Datenbasis zum Gebäudebestand, BBSR-Analysen Kompakt, 09/2016.

Rocky Mountain Institut (RMI) 2013: A Review of Solar PV Benefits & Cost Studies, 2nd edition. Energy Innovation Lab. Retrieved from https://rmi.org/wp-content/uploads/2017/05/RMI_Document_Repository_Public-Reprts_eLab-DER-Benefit-Cost-Deck_2nd_Edition131015.pdf.

Rosenow, J., et al., (2016): Efficiency First: From Principle to Practice with Real World Examples from Across Europe. Retrieved from: www.raponline.org/knowledge-center/efficiency-first-from-principle-to-practice-with-real-world-examples-from-across-europe/.

Rosenow, J., Jahn, A. (2016): Grunderwerbsteuer als Anreiz für energetische Sanierungen, Regulatory Assistance Project. Retrieved from: https://www.raponline.org/wp-content/uploads/2016/07/rap-jahn-grunderwerbsteuer-anreiz-energetische-sanierungen-2016-juli.pdf.

Schofield, A., Rosenow, J., Barker, J. (2010): Getting Warmer? Homes, energy efficiency and microgeneration in the UK. Retrieved from: https://www.researchgate.net/profile/Jan_Rosenow/publication/271498145_Getting_Warmer_Homes_energy_efficiency_and_microgeneration_in_the_UK/links/54c8ecd40cf289f0ced12105/Getting-Warmer-Homes-energy-efficiency-and-microgeneration-in-the-UK.pdf.

State of California (2018): California Energy Commission and California Public Utilities Commission, Think Efficiency First. Retrieved from: https://www.gosolarcalifornia.ca.gov/csi/index.php.

Steuwer, S., Jahn. A., Rosenow, J. (2018): Energetische Mindeststandards für eine sozial gerechte Wärmewende. Retrieved from: http://bpie.eu/wp-content/uploads/2018/09/20180918-Diskussionpapier-Minimumstandards-BPIE-RAP-1.pdf.

Transition Zero (2017): Recommendations for decision makers of necessary or desirable changes to the regulatory framework. Retrieved from http://transition-zero.eu/wp-content/uploads/2017/09/D3.3-Recommendations-for-Decision-Makers_July2017.pdf.

United Kingdom Department of Energy and Climate Change (DECC 2012): Feed-in Tariffs – Frequently Asked Questions. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/48488/5902-feedin-tariffs--frequently-asked-questions.pdf.

United Kingdom Department of Energy and Climate Change (DECC 2015): Annex B: Electricity use in households with solar PV. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/437097/Annex_B_Electricity_use_in_households_with_solar_PV_panels.pdf.