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What if… there were a nationwide rollout of PV battery systems?

A preliminary assessment

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Several energy-economic analyses have concluded that the expansion of renewables in Germany does not need to wait for the increased deployment of storage capacity, given the affordability of other flexibility options. Widespread storage capacity, it is argued, won't be needed until renewable energy reaches 60 per cent of gross electricity consumption.[2] Judging from the expansion corridor stipulated by the German Renewable Energy Act (EEG), new storage capacity will not be required until after 2035.

In the meantime, however, battery prices have dropped considerably.[3] In particular, Tesla's announcement of its Powerwall and the prospect of storage costs per charge cycle of – under optimistic assumptions – 20 ct/kWh have raised expectations among stakeholders.[4] Combined with electricity generation cost from solar power of 10 ct/kWh, battery power will under those assumptions cost around 30 ct/kWh – which is about the cost of household electricity in Germany. Tesla has put the lower limit for storage costs at 5 ct/kWh, roughly the same rate expected for future solar power.[5] This means that the private generation and storage of electricity could dip as low as 10 ct/kWh. What is more, batteries for cars might one day be available free of charge thanks to consumers' willingness to pay a premium for electric vehicles.

It remains uncertain which of these possible futures – a world with less storage capacity or more – will occur. Below, we consider a scenario in which residential battery storage becomes widespread. In addressing the energy policy questions raised by the scenario, we consider these factors:

- The technical potential of battery storage in Germany, including household batteries and electric vehicles;
- How different charging strategies positively or negatively affect the power system; and
- The repercussions for residual load and conventional power plants.

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[1] We would like to thank Andreas Jahn, Lars Waldmann and Kai-Philipp Kairies for their helpful comments.
[2] FENES et al. (2014): *Stromspeicher in der Energiewende;* Fh-IWES et al. (2014): *Roadmap Speicher*.
[3] IRENA (2015): *Battery storage for renewables. Market status and technology outlook*. As with PV price trends, it is possible to identify learning curves for batteries. See Hoffmann (2014): *Importance and evidence for cost efficient electricity storage*. Forum Solarpraxis, 27.11.2014, Berlin.
[4] IRENA (2015): *Renewables and electricity storage*. WirtschaftsWoche (2015): *Der Stromspeicher-Check: Wie günstig ist Teslas Powerwall wirklich?* The 20 ct/kWh figure relies on Tesla's claim of a 5,000-cycle lifespan for the Powerwall. Since in Germany only about 250 cycles can be realized per year, this requires a battery lifespan of 20 years. It should be noted that Tesla's guarantee ends after 10 years.
[5] Fh-ISE (2015): *Current and future cost of photovoltaics*, study commissioned by Agora Energiewende.

1 Storage Potential

The technical and economic potential for battery storage in Germany given the low acquisition costs assumed in our scenario is generally very large.[6] On the basis of previous studies, we were able to approximate a battery output of just under 200 GW, with 68 GW of that stationary and 125 GW mobile.

Electric vehicles make up the largest share (125 GW), followed by household batteries (40 GW), power storage in the industrial sector (23 GW) and balancing reserves (5 GW).[7]

Table 1: Battery storage potential

Application/ area	Output (GW)	Capacity (GWh)
Household battery units	40	120
Industry, trade, services	23	46
Balancing reserve	5	10
Subtotal stationary storage systems	**68**	**176**
Electric vehicles, including plug-in hybrids	125	250
Total	**193**	**426**

Source: FENES et al. (2014), Weniger et al. (2015)

In sum, the storage potential across all these applications amounts to an output of some 193 GW and a capacity of 426 GWh. Not only is this potential many times higher than Germany's current installed capacity from pumped storage power plants, which have an output of around 7 GW and a capacity of some 40 GWh. This potential is also considerably higher than currently forecast in various scenarios. Two recent scenarios for 2050 expect a battery storage output in the general vicinity of 40 to 70 GW.[8]

In what follows, we assume that a breakthrough in the use of battery storage will be accompanied by a massive expansion of distributed PV systems for self-generation. In particular, we assume a total installed output of 150 GW of photovoltaic (70 GW without storage; the remaining with 40 GW of household storage and 120 GWh of capacity), and 72 GW wind. This leaves out the large potential in the area of electric vehicles, and ignores the possibilities of installing more solar panels on buildings. PV potential estimates for roofs and facades in Germany put total output at around 300 GW.[9]

[6] Under "potential" we refer to bottom-up appraisals in which battery storage is deemed technologically feasible in different areas of application. The main parameter for household batteries, for instance, is the number of single- and two-family houses in Germany. According to the Federal Statistical Office, Germany at the end of 2013 had around 12 million single-family houses and 3 million two-family houses. Since battery installation is unlikely to be hindered by lack of space, the installed capacity will ultimately be limited by economic considerations. These lie beyond the scope of this study.

[7] Output data for electric vehicles, household battery systems and balancing reserve reflect maximum values for 2050 (rounded), see FENES et al. (2014); assumed discharge time is generally two hours, except for household battery systems (three hours). The data for electric vehicles assumes a connected load of 3 kW per vehicle and around 42 million vehicles. For the industry sector, a high amount of self-generated electricity without storage can be expected, as load curves often better match PV feed-in curves. Here storage capacity would only play a role in increasing self-sufficiency. See Europäische Kommission (2015): *Best practices on renewable energy self-consumption*; SWD (2015) 141 final; and VDE (2015): *Batteriespeicher in der Nieder- und Mittelspannungsebene*.

[8] Fh-IWES (2015): *Interaktion EE-Strom, Wärme und Verkehr;* Acatech (2015): *Energie.System.Wende. Flexibilitätskonzepte für die Stromversorgung 2050*, an expert discussion on 12.6.2015. See also Weniger et al. (2015): *Dezentrale Solarstromspeicher für die Energiewende*.

[9] Fh-IWES (2012): *Vorstudie zur Integration großer Anteile PV in die elektrische Energieversorgung*.

2 Charging strategies for battery units

Depending on the regulatory framework, the charging strategy for battery units can positively or negatively affect the electricity system in general. Below we sketch some unfavourable strategies that occur with uncontrolled charging. Then we consider favourable strategies and some approaches for implementing them.

2.1 Unfavourable charging strategies

Battery operation can have a negative effect when many batteries run simultaneously in an uncontrolled way, as Table 2 shows: **household battery units** can cause feed-in peaks with steep gradients when excess PV electricity flows directly into the grid after charging; **electric vehicle batteries** can lead to very high demand peaks when they are charged at the same time – typically in the evenings, after the last use.

Table 2: Unfavourable charging strategies for household and electric vehicle batteries

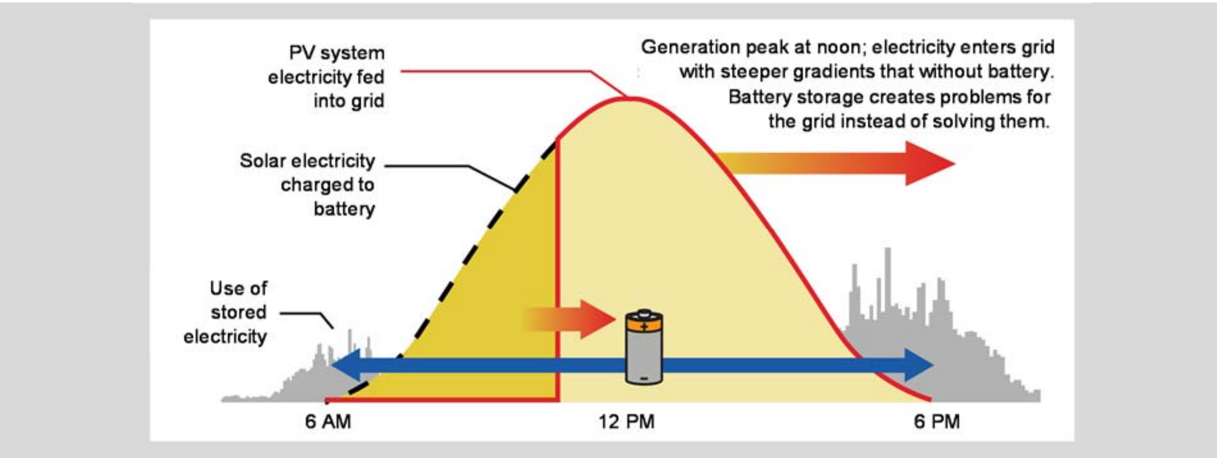
	Single household units	Electric vehicle batteries
Charging strategies	Uncontrolled, optimised for self-consumption: direct grid feed-in after battery charging	Uncontrolled: Direct charging at home after last use
Effect during high levels of simultaneity	Feed-in peaks with steep gradients	Demand peaks with steep gradients

Source: Data drawn from Sterner et al. (2015), Weniger et al. (2015), Zimmer et al. (2015) and VDE (2015)

Below we consider the case of household batteries more closely, though the issues are similar for electric vehicle batteries.

The optimisation of self-consumption for self-generated electricity has been one of the main motivators of investors in the household battery sector. Household PV battery systems can directly store excess electricity and use it later if the sunlight is insufficient to cover electricity needs. (See the dark yellow section in Figure 1.) If the batteries are full, the electricity is fed into the grid.

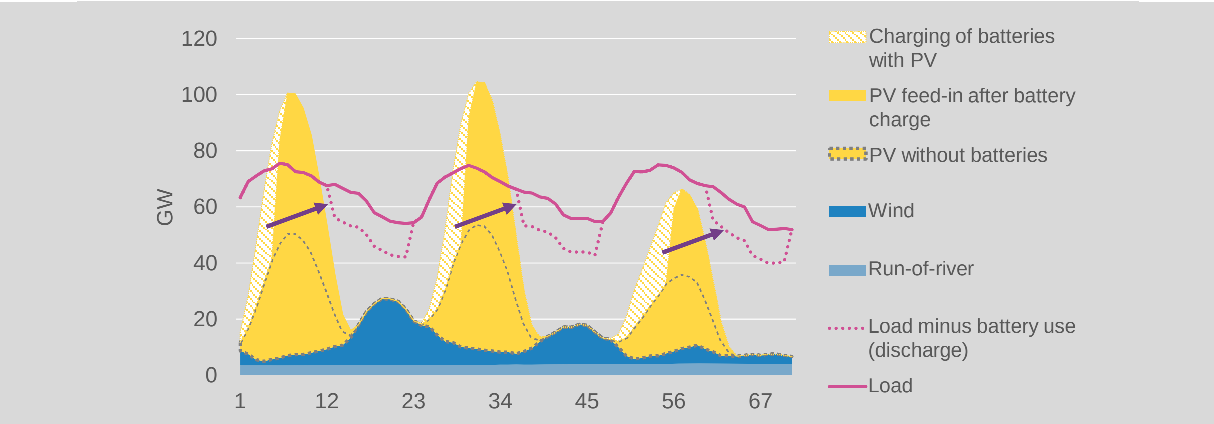
Figure 1: Uncontrolled operation of household batteries optimised for self-consumption leads to steep feed-in gradients



Source: own translation, adapted from Sterner et al. (2015)

The effect on the electricity system as a whole results from the sum of many individual household systems (Figure 2). In our scenario, these individual systems generate a total of 80 GW PV with 40 GW of battery output. In Figure 2, the lower part of PV feed-in, following the familiar bell curve, represents PV systems **without** battery units. PV systems **with** battery systems do not feed into the grid while the batteries are being charged (represented by the hatched area). As soon as the batteries are full, the direct grid feed-in begins. In this period, the PV feed-in output level rises steeply. Later in the day the battery drains again (represented in simplified form by a dotted line with a drop in grid demand).

Figure 2: Uncontrolled operation of millions of house battery systems optimised for self-consumption leads to steep feed-in gradients in the power system as a whole



Source: Authors' assessment of Agorameter data for 21 – 23 May, 2014, scaled to 72 GW wind and 150 GW PV (70 GW PV without battery storage; 80 GW PV with 40 GW of battery output and 120 GWh of storage capacity)

Effects on residual load

The grid feed-in described above would affect the residual load to be covered by dispatchable power plants or industry sector demand response. Given the wind and PV assumptions in Figure 2, the residual load gradients on the days in question could reach up to -40 GW an hour. These hourly gradients amount to more than half of demand – considerably higher than those supposed in recent scenarios for renewables.[10]

All in all, the operation of total installed household battery capacity in an uncontrolled way – that is to say, capacity from battery units optimised for self-consumption with direct charging and subsequent grid feed-in – would pose significant additional flexibility challenges for the electricity system. We should note, however, that this assessment reflects the upper limit of the projected effects. In real life, these effects would be mitigated by a stochastic distribution of various unit configurations.[11]

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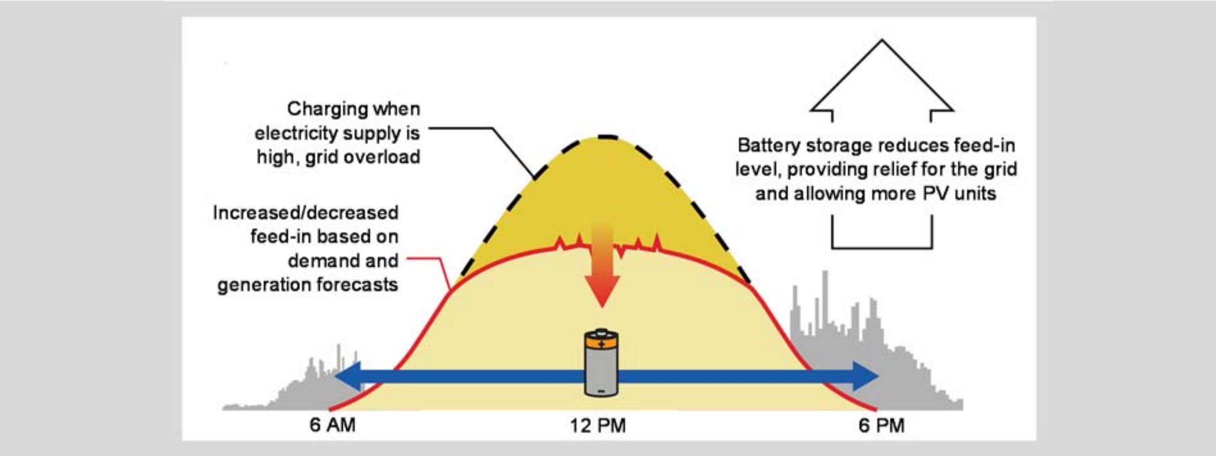
[10] See the maximum gradients of +22 and -19 GW/h for 120 GW PV in the 80 per cent scenario of BET (2013): *Möglichkeiten zum Ausgleich fluktuierender Einspeisungen aus erneuerbaren Energien*, a study commissioned by the Bundesverband Erneuerbare Energie. Also see the maximum gradient of -26.5 GW/h in Schill (2013): *Residual Load, Renewable Surplus Generation and Storage Requirements in Germany*, DIW Discussion Paper 1316.

[11] Weniger et al. (2015): *Einfluss verschiedener Betriebsstrategien auf die Netzeinspeisung räumlich verteilter PV-Speichersysteme*. The possible effect on residual load is the object of ongoing research. For instance, the project "PV Nutzen" is currently analysing a scenario with 120 GW PV (80 GW from small-

2.2 Favourable charging strategies

Favourable charging strategies for household battery units not only optimise self-consumption but also benefit the grid or the power system in general.[12] A charging strategy is **beneficial for the grid** when it contributes actively to a smooth and stable network operation. This could mean providing balancing energy, voltage control or system restoration. Above all, a battery charging strategy that benefits the grid needs to prevent steep feed-in peaks. Forecasts are a means to achieve this end: in lowering uncertainty about sunlight and demand, they allow the PV system to better meter out charging. Figure 3 illustrates forecast-based charging. At first, excess PV electricity is fed into the grid; later it is used to charge the battery unit (dark yellow area), thereby diminishing noon feed-in peaks.

Figure 3: Forecast-based charging diminishes feed-in peaks



Source: own translation, adapted from Sterner et al. (2015)

A charging strategy is **beneficial for the power system in general** when it contributes flexibility, adapts to variable generation of renewables and minimises residual load. As a result of these attributes, such a method can also orient battery operation to electricity market prices.

scale units) and PV battery storage. See Cramer (2015): *Auswirkungen von PV-Speichern auf Netze und Stromerzeugung*, presentation on 2.6.2015.

[12] Somewhat varying interpretations exist about what constitutes "the grid" and the "power system" in this context. For the most part, we follow Sterner et al. (2015). See also VDE (2015), whose authors propose greater differentiations between network levels.

Types of forecasts and ICT requirements

A strategy that benefits the grid while optimising self-consumption can be accomplished with two types of forecast-based charging (Table 3):

The **persistence forecast** uses local data for projecting demand and sunlight levels without the need for communication infrastructure. Although such forecasts are simple, they provide enough information to reduce high feed-in levels.

An **ICT-based** forecast, by contrast, requires a communication infrastructure to be in place. By factoring in external demand and weather reports in battery operation, it benefits both the grid and the power system as a whole. An ICT-based forecast delivers self-consumption levels second only to direct battery charging, which while optimising self-consumption benefits neither the grid nor the power system.[13]

Table 3: Types of forecasts

Type	Persistence forecast	ICT-based forecast
Communication infrastructure	no	yes
Demand and weather forecasts	local data	external data
Optimised for self-consumption	x	x
Beneficial for the grid	x	x
Beneficial for the system		x
Possibilities for performing system services	limited	extensive

Source: Sterner et al. (2015), Weniger et al. (2015), PV Nutzen (2015)

This gives consumers a choice. PV battery system users, given their strong desire for self-reliance,[14] could see persistence forecasts with autonomous monitoring and no external control as a favourable standard approach. By contrast, ICT-based forecasts will be more attractive for users of battery pools; district battery storage; and battery storage in industry, trade and services. It is also conceivable that energy providers might offer an hourly electricity rate that requires certain ICT capabilities from the battery units. In general, the two forecast approaches could exist side by side or, if needed, implemented in complementary stages. Once the needed ICT infrastructure is in place, system services such as a primary balancing energy can be provided.[15]

Decisive for future development are the expected price drops in ICT and the likelihood that smart meters will be required for PV battery units larger than 7 KW, with extension to small units possible. But the marginal costs of installing additional smart meters are low. As soon as a smart meter infrastructure is available for a given street, other households in the street can purchase a smart meter at an affordable price. This means that the real obstacle to ICT control of household battery units is less cost than the wish for independence. But even persistence forecasts alone – the preferred strategy for independent-minded consumers –can benefit the grid.

[13] See Kairies et al. (2015): *Aktuelle Ergebnisse der Begleitforschung zum KfW-Förderprogramm für PV-Speicher*, presentation on 2.7.2015; Sterner et al. (2015)
[14] See Hirschl (2015): *Nutzen der Eigenversorgung durch Solarstromspeicher. Ökonomische, ökologische und soziale Wirkungen*. This study found that some 80 per cent of the 532 individuals surveyed wanted more independence from utility companies.
[15] See FENES et al. (2014); VDE (2015). ICT also allows battery charging to switch dynamically from market-based operation to grid-optimized operation and back.

3 Effects of high levels of PV and PV battery storage on wind power and network expansion

The effects of a world with very high shares of PV and PV storage on wind power and network expansion have received scant attention. The only known analysis to consider this question is the PV Battery Breakthrough scenario in the optimisation study of Consentec for Agora Energiewende (2013).[16] This study presents the costs of a base scenario – scenario B of Germany's Power Grid Development Plan (GDP) 2013 – and juxtaposes them with a scenario in which Germany has achieved 150 GW of PV output and 40 GW of household battery output (with 120 GWh of storage capacity) (Table 4). The goal was to calculate how much cheaper PV battery systems must become so that such a system costs as much as the base scenario.

For 2033, GDP 2013 projects an installed output of around 65 GW PV, 66 GW wind onshore and 25 GW wind offshore.[17] By contrast, the PV Battery Breakthrough scenario projects around 20 GW less energy from wind farms (especially offshore). Nevertheless, because it forecasts more PV – 150 GW – its total volume of RE electricity generation is similar.

The main concentrations of PV feed-in are located in the west and southwest parts of Germany due to the expansion of PV units near the sites of consumption. This, combined with the reduced level of wind farm expansion, changes the load flow in the transmission network. For instance, several network expansion projects in the German 2013 Federal Requirement Plan are no longer necessary in this scenario. Instead, the – at times – very large feed-ins from PV units require additional expansion in regions with high levels of PV generation. The study identifies cost differences between network expansions (Table 4) but draws no conclusions about which transmission lines will be eliminated or added in such a world. For this, a detailed network analysis would be necessary.

Table 4: Base scenario and PV Battery Breakthrough scenario, 2033

Scenario for 2033	Base (GDP 2013, B 2033)	PV Battery Breakthrough
Grid expansion*	delayed	fast
Installed output (GW)		
PV	65	150
Household battery units	~0	40
Wind onshore	66	65
Wind offshore	25	7
Total wind	91	72
Generated electricity (TWh)		
PV	67	147
Wind Onshore	190	185
Wind Offshore	103	29
Cost differences relative to base scenario (million €/year)		
RE expansion PV		n.a.
Battery expansion		n.a.
RE expansion wind		-7.500
Distribution network expansion (HV)		64
Distribution network expansion (MV)		-15
Distribution network expansion (LV)		20
Transmission network expansion		-35
Residual generation costs		-1.600

* See note 16
Source: Consentec (2013); values rounded

[16] Consentec (2013): *Kostenoptimaler Ausbau der Erneuerbaren Energien in Deutschland*, study with data supplement; commissioned by Agora Energiewende.
[17] By comparison, the approved scenario framework for GDP 2015/2025 in scenario B1 2035 has somewhat less PV (around 60 GW), more wind onshore (89 GW) and less wind offshore (19 GW). See BNetzA (2014): *Genehmigung in dem Verwaltungsverfahren wegen der Genehmigung des Szenariorahmens für die Netzentwicklungsplanung und Offshore Netzentwicklungsplanung gem. § 12a Abs. 3 EnWG.*

Relative to the base scenario, PV Battery Breakthrough leads to higher costs for the expansion of PV, battery units and distribution network (high and low voltage) and to cost savings for the expansion of wind, transmission network and distribution network (medium voltage). In addition, the PV Battery Breakthrough sinks residual generation costs because feed-in during the day, when demand is high, reduces the amount of electricity produced by power plants with higher marginal costs and because the multitude of batteries reduces curtailment by around 27 TWh and, with it, the need for conventional generation. The main cost blocks are not the network costs but the costs for offshore wind farms and residual power plants relative to costs for PV battery systems.

The model generally assumes market-oriented battery operation. Charging is compulsory, however, when feed-in burdens the distribution networks more than that in the "generation near consumption" scenario.[18]

The study finds that, by 2033, costs for PV battery systems must drop by 80 per cent from 2013 levels if the PV Battery Breakthrough scenario is to cost as much – economically speaking – as the scenarios with higher shares of wind power.

[18] Hence, the scope of distribution network expansion is the same in both scenarios. See Consentec (2013).

4 Effects of a high level of PV and PV battery storage on levies and surcharges

The amount of levies and surcharges depends on the total volume of non-privileged electricity consumption. This is the volume that must bear the distributed costs of expanding renewable energy, CHP plants and energy infrastructure. As private households generate more of their own electricity via small, private solar panels – for which they, in most cases, pay neither EEG nor CHP surcharges, not to mention grid fees – the total volume of non-privileged electricity consumption decreases.[19] Owners of PV installations with battery systems have more options for increasing their self-consumption than those without storage capacity. Typically, for basic PV installations, the share of self-consumption in total electricity generated on-site can be up to 30 per cent; when storage capacity is added, the figure can be as high as 70 per cent. Together, the spread of distributed solar power and solar storage increases the likelihood that the remaining consumers – those who draw their electricity from the power grid – will bear a disproportionate share of the costs from EEG and CHP surcharges and grid fees.[20] As a result of the extra burden, these consumers will have additional incentive to install their own PV systems.

So far, this problem has been little cause for concern. Since 2009 the share of private PV installation exempted from the EEG surcharge has remained under 20 per cent of Germany's total annual PV output.[21] But if the private ownership of solar power and storage catches on, the number of exempted installations stands to increase dramatically. In the PV Battery Breakthrough scenario we present above, 80 GW of the 150 GW of PV output for 2033 is projected to come from private roof-mounted solar panels with battery systems. Should current laws remain in effect, the EEG surcharge in the PV Battery Breakthrough scenario will be about 1 ct/kWh higher than in the base scenario.[22] A similar outcome is likely with grid fees, whose costs will be passed on to electricity consumed from the public grid.

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[19] The threshold for "small" private units is 10 kWp of output and 10 MWh of self-consumption per calendar year. See EEG 2014, art. 61, para. 2, no. 4).

[20] Weniger et al. (2015); IEA-RETD (2014): *Residential prosumers – drivers and policy options*.

[21] Fh-ISE (2015): *Photovoltaics report*. 10 August 2015

[22] See Öko-Institut (2015): *EEG-Rechner*. The calculator was designed for Agora Energiewende, version 3.0.5. Assuming 80 GW PV with battery storage, 78 TWh electricity generation, and a self-consumption share of 70 per cent, it projects 55 TWh of self-consumption. The calculator's reference scenario for 2033 sees an EEG surcharge of 4.5 ct/kWh (real prices; base 2015).

5 Necessary energy policy changes

Energy policies must be created in a way that a potential Germany-wide rollout of PV battery systems would avoid imprudent investments, negative effects on the power system or the unfair distribution of costs. To achieve such policies, central changes need to be made:

- **Adjusting the regulatory framework to promote favourable charging strategies:** If a massive increase in storage systems is to avoid the feed-in and demand peaks described above, the proper incentives must be in place. One possible adjustment lever is the **feed-in limit** for PV installations. The current EEG stipulates that small-scale residential PV battery systems in conjunction with PV installations with a peak output of 30 kWp must limit feed-in to 70 per cent of installed capacity.[23] This limit could be lowered to, say, 50 per cent of nominal capacity in the short term or 40 per cent in the medium term. Under the condition of a feed-in limit using forecasts is the most efficient way for users to charge their batteries, allowing them to minimize curtailment losses and maximize self-consumption.[24] Moreover, the **technical connection guidelines** must be expanded for distributed self-regulation.[25] Also, the **directive on the KfW development bank subsidy** should be developed towards minimum standards for charging strategies that are beneficial for the power system in general, in order to keep up the innovation pressure on equipment manufacturers.[26]
- **Creating a regulatory framework for managing distribution network bottlenecks:** To prevent distribution network bottlenecks arising from the nationwide expansion of PV systems, regulations must be found for situations in which high volumes of electricity are fed into or out of regional networks (in response to electricity market prices, say). One possible approach would be the creation of a "traffic light" system[27] in which distribution network

[23] See art. 9, para. 2 of EEG 2014. This regulation plays little role in practice, since very few hours per year reach the 70 per cent limit. The limit under the KfW development bank subsidy is 60 per cent – a more effective restriction. Currently about half of the owners of small PV battery units take advantage of the KfW development bank subsidy. See Sterner et al. (2015): *Der positive Beitrag dezentraler Batteriespeicher für eine stabile Stromversorgung*.

[24] Weniger et al. (2015); Sterner et al. (2015); PV Nutzen (2015): *Handlungsempfehlungen.* Workshop on 2.6.2015. For instance, twice as many household PV battery systems can be integrated into the network when feed-in drops to 40 per cent of installed nominal output than when it drops to only 80 per cent of installed nominal output. See also Weniger et al. (2014): *Bedeutung von prognosebasierten Betriebsstrategien für die Netzintegration von PV-Speichersystemen*; and Fh-ISE (2013): *Speicherstudie 2013.*

[25] FNN/VDE (2014): *Anschluss und Betrieb von Speichern am Niederspannungsnetz*. These laws already regulate, among other things, blind power control during discharge, effective power restriction and effective power reduction in the event of overfrequency in the distribution network. But the legislation must be expanded to include automatic discharging during unterfrequency, automatic charging during overfrequency, voltage stability, and the provision of internal storage capacity needed for voltage stability. See Sterner et al. (2015).

[26] Kairies et al. (2015): *Wissenschaftliches Mess- und Evaluierungsprogramm Solarstromspeicher. Jahresbericht 2015;* Sterner et al. (2015)

[27] BDEW (2015): *Smart Grids Ampelkonzept. Ausgestaltung der gelben Phase.*

operators facing imminent network bottlenecks ("yellow lights") can utilize regional flexibility to prevent threats to system stability ("red lights").[28]

- **Calculating a Grid Development Plan with 150 GW of PV: The next scenario framework and Grid Development Plan** must soon determine the network needs that would result if it comes to a nationwide rollout of PV battery systems. A possible result of these calculations could be that the north-to-south power lines envisioned in Germany's 2015 Grid Development Plan will still be necessary but that the powerlines planned for 2025–2035 can be omitted. This would allow politicians to wait and see how the expansion of PV battery systems plays out before thinking beyond the network needs of the 2016 Federal Requirement Plan.
- **Reforming levies and surcharges:** The more electricity that is produced by private individuals, the higher the volume of levies and surcharges that other electricity consumers must pay. Moreover, levies and surcharges on power grid electricity see to it that PV battery systems do not provide flexibility to the electricity market. To ensure the long-term financing of the overhead costs of Germany's transition to renewable energies, comprehensive reform of the levy and surcharge system and proper incentives for PV battery use in the electricity market are urgently needed, at least in the medium term.

[28] For a discussion of yet unanswered questions related to this proposal, see RAP (2014): *Offene Fragen zur Netzampel/ zu regionalen Flexibilitätsmärkten*.

6 Summary

Regardless of how likely the scenario seems, a world with a high percentage of PV and PV battery systems need not pose major problems for the power system. A future in which Germany has an installed capacity of 150 or even 200 GW PV – scenarios that until recently many considered fanciful – is now technologically and economically possible. Whether such a world comes to pass, however, depends on how the costs of PV battery systems shape up, as well as on consumer preferences, regulatory conditions and the business strategies of the energy industry. A breakthrough in electrical vehicle use – a possibility not examined in this paper – could also hasten such a scenario.

To prepare for this eventuality, politicians and the energy industry must create an appropriate framework. The energy industry must put less emphasis on selling electricity than on building partnerships with *prosumers*. They must become energy providers that help their customers – with the optimisation of energy consumption behind the meter; with energy management; with the installation, monitoring, maintenance of PV battery systems; and with selling their unused electricity to third parties.[29]

Politicians, for their part, must pass legislation that ensures that the electricity system functions well whether a PV battery rollout occurs or whether it doesn't. If they undertake the legal changes described in this paper, a distributed PV battery rollout will not only be compatible with the existing system – it will pave the way for a new stage in the evolution of the energy industry.

[29] See Rocky Mountain Institute (2015): *The economics of load defection: How grid-connected solar-plus-battery systems will compete with traditional electric service, why it matters, and possible paths forward.*