EXECUTIVE SUMMARY

The benefits of energy flexibility at home

Leveraging the use of electric vehicles, heat pumps and other forms of demand-side response at the household level

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Executive Summary
The benefits of energy flexibility at home. Leveraging the use of electric vehicles, heat pumps and other forms of demand-side response at the household level. (English translation of the executive summary of the German study *Haushaltsnahe Flexibilitäten nutzen*)

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Responsibility for the content of Chapters 3 to 5, with the exception of Section 5.1.2, lies exclusively with FfE. Agora Energiewende wrote the summary, Chapter 2, Section 5.1.2 and Chapter 6. Only the summary has been translated into English.

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- → Viessmann Climate Solutions SE
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- → Tibber Deutschland GmbH
- → Sonnen GmbH
- → The Mobility House GmbH
- → Bundesverband der Energie- und Wasserwirtschaft e.V.
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- → SWM Infrastruktur GmbH & Co. KG
- → Techem GmbH
- → Easy Smart Grid GmbH

Preface

Dear reader,

Wind and solar power plants will play a central role in the future of our power systems. However, only with sufficient system flexibility can their fluctuating generation reliably meet a growing demand for electricity.

Driven by the electrification of the heating and transport sectors, many millions of heat pumps, home storage systems and electric vehicles will become a part of the German power grid in the coming years. What they all have in common is that they can adapt their electricity requirements at short notice, i.e., provide flexibility. They have significant potential: by the end of this decade, their capacity will far exceed today's annual peak load.

The calculations in this study show that flexible demand-side response at the household level can coordinate supply and demand very efficiently. This flexibility can not only reduce emissions, but also reduce the need for state subsidies and ultimately decrease electricity prices for everyone.

For this to succeed, the appropriate price signals must reach the households in question. This study addresses this issue by examining different tariff models, considering their effects on the overall system, electricity grids, and costs for households. Throughout the study, practical feasibility for both grid operators and customers remains a central consideration.

I wish you an enjoyable read!

Simon Müller
Director Germany, Agora Energiewende

Key findings at a glance

1 **Electric cars, heat pumps and home energy storage systems could make 100 terawatt hours of electricity demand more flexible in 2035, saving the electricity system 4.8 billion euros in that year alone.** This electricity volume corresponds to 10 percent of total electricity consumption. By swiftly adapting and automating their operation, millions of these demand-side flexibilities can contribute to the cost-effective integration of renewable energies. However, without a reform of the electricity tariffs, household demand-side flexibilities could significantly increase the strain on electricity grids.

2 **Dynamic electricity tariffs (incl. dynamic grid feeds) activate household demand-side flexibility while simultaneously reducing the need to expand the electricity grids.** These tariffs combine dynamic electricity prices and dynamicgrid fees. The electricity price component indicates whether electricity is currently in short supply or in abundance. The grid fee component reflects the local grid utilisation. Dynamic grid fees thus mitigate load peaks in the grid, making the current pace of grid expansion feasible.

3 **The digitalisation of the distribution grids enables the introduction of dynamic electricity tariffs (incl. dynamic grid fees).** The growing number of smart meters allows electricity demand to be billed at various times. Moreover, distribution grid operators are currently developing a comprehensive system for measuring grid load. The Bundesnetzagentur (German Federal Network Agency) could therefore promptly facilitate the adoption of dynamic grid fees by establishing the necessary framework conditions for grid operators.

4 **Consumers save on their electricity bills and can play an active role in shaping the energy transition.** By automatically adjusting their consumption, an increasing number of households can influence their own electricity costs. Households with dynamic tariffs can save 600 euros per year in the long term and at the same time contribute to the success of the energy transition. Customers without the option of load shifting also benefit from lower electricity prices overall and improved grid utilisation.

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1 Summary and key findings

1.1 Summary

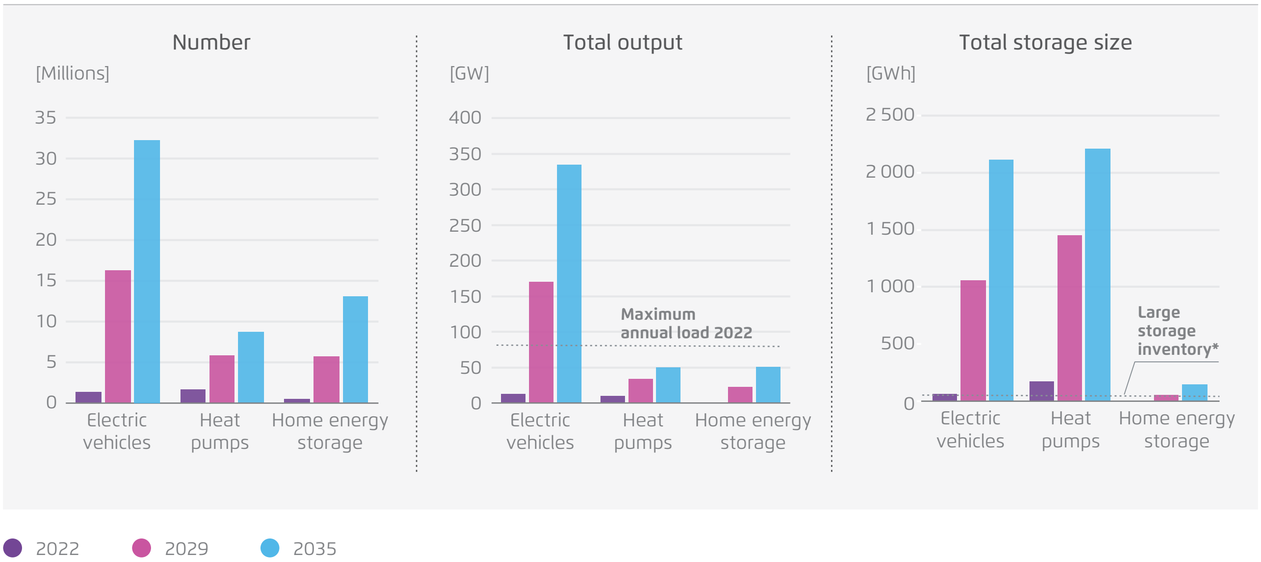
1.1.1 Demand-side response at the household level (electric vehicles, heat pumps and home energy storage systems) offer considerable flexibility potential.

As wind and solar energy continue to expand, the need for flexibility is growing significantly. Flexibility has long been recognised as a key requirement of an efficient and secure electricity system. Traditionally, this involved adapting to fluctuations in electricity consumption, especially between winter and summer or day and night. However, in an electricity system based increasingly on wind power and photovoltaics, it becomes necessary to balance out large fluctuations in generation as well. Today, renewable energies already account for a large proportion of electricity generation (55% in the first half of 2023). Germany aims to achieve a largely climate-neutral electricity supply by 2025, with wind and solar energy as the predominant energy sources. This will significantly increase the need for demand-side flexibility.

Demand-side response at the household level[1] (electric vehicles, heat pumps and home energy storage systems) offers very high flexibility potential.
In the scenario *Klimaneutrales Stromsystem 2035* (Climate-neutral electricity system 2035), the electrification of transport and district heating introduces a considerable increase in electricity demand that is far more flexible than current electricity consumption. The expected total capacity (435 gigawatts [GW]) of household demand-side flexibility is more than five times greater than the peak load of 2022. The total storage capacity (4.5 Terrawatt hours [TWh]) is around 110 times greater than the current stock of

1 Hereinafter referred to as "household demand-side flexibility".

Development of household demand-side flexible consumption facilities → Figure A



Agora Energiewende (2023) based on the study *Klimaneutrales Stromsystem 2035*.
* Pump storage and large batteries.

large storage facilities (Figure A). The total capacity also exceeds the capacity of climate-neutral gas-fired power plants in 2035 (61 GW) and the trading capacity with neighbours in the European electricity grid expected for 2035 (38 GW). This means that there is a significant opportunity for households to consume more electricity in periods where it is abundant and cheap.

A modernised tariff structure is the key to unlocking the potential of household demand-side flexibility. Today, nearly all customers are limited to fixed electricity tariffs, which incentivise maximising the use of self-generated solar power from rooftops. However, there is no incentive for load shifting to benefit the overall system, thus failing to fully exploit the potential of household demand-side flexibility. From 2025 onwards, customers will have more options: suppliers will then also have to offer "dynamic tariffs". Under these tariffs, the electricity price will respond to the current conditions in the electricity system, for example every quarter-hour; higher prices during hours of scarcity and cheaper rates during times of abundance. Such dynamic tariffs can activate household demand-side flexibility.

Household demand-side flexibility can strain the local electricity grid, particularly when too many consumers simultaneously and independently ramp up their electricity consumption. The introduction of electric vehicles and heat pumps further compound this strain by raising both overall consumption levels and power peaks within the low-voltage grid. Moreover, dynamic tariffs can further exacerbate this situation, as these new loads may all substantially increase their consumption during periods of low prices. As a result, the load on the grid and the subsequent need to expand low-voltage grids can increase significantly.

A reform of grid fees will allow household demand-side flexibilities to respond to low prices in a grid-friendly manner. The share of grid fees in household electricity prices is substantial: from 2012 to 2021, it averaged around 25 percent.[2] Similar to electricity tariffs, grid fees can be dynamically structured. However, unlike in many other European countries, German consumers are limited to fixed grid fees. In these other countries, grid fee levels reflect the grid load: a "full" grid translates into high fees, while grid usage is particularly cheap if there is still plenty of "space" in the grid.

Dynamic electricity tariffs[3] combine dynamic procurement electricity prices and dynamic grid fees. They enable the optimised use of household demand-side flexibility. These tariffs reflect both the availability of electricity and the usage of the (local) grid. They can thus balance supply and demand on the electricity exchange without inducing load peaks in the grid. This study models possible implementations of dynamic electricity tariffs, focusing on grid load and the associated grid expansion requirements.

1.1.2 This study examines the effects of four different electricity tariff structures on household demand-side flexibility

The modelling framework assumes that each participating household minimises its electricity costs. Accordingly, it considers: 1) the degree of flexibility afforded, 2) the load on the electricity grid and 3) the broader economic ramifications on the entire system.

1. The households' optimised behaviour is calculated based on the respective price scenario (see below). These calculations yield quarter-hourly and household-specific load curves, along with the additional flexibility quantified.
2. These results form the basis for a load flow simulation of the German low-voltage grids. The grid expansion requirements for the four scenarios are quantified with the help of type grids.

2 BDEW electricity price analysis July 2023
3 The definition of "dynamic electricity tariffs" used here differs from the definition currently set out in Section 3 EnWG. In this study, dynamic electricity tariffs include not only dynamic procurement electricity prices, but also dynamic grid fees.

Composition of the dynamic electricity tariffs per scenario → Table 1

Scenario	Procurement price	Grid fees	Scenario
lowFlex	consistent	consistent	–
Flex	dynamic*	consistent	–
Flex-ToU	dynamic*	time-variable	static
Flex-dynToU	dynamic*	time-variable	dynamic

FfE (2023). * Dynamic procurement price = direct pass-through of the exchange electricity price. For this purpose, dispatch-prices from the study *Klimaneutrales Stromsystem 2035* are used and serve as representatives of short-term electricity exchange prices.

3. The resulting grid costs are compared with the costs of alternative flexibility provision on the generation side. To achieve this, we use the outcomes of the electricity market modelling from the *Klimaneutrales Stromsystem 2035* (Climate-neutral electricity system 2035) study. This study extends its analysis beyond the target year of 2035 to include 2029, as by then at least 50 percent of the mandatory installations for smart meters must be completed, and dynamic grid control must be implemented according to Section 14a of the *Energiewirtschaftsgesetz* (EnWG), or the German Energy Industry Act.

This study focuses on the analysis of different tariff models with an emphasis on dynamic electricity tariffs. An efficient system to unlock household demand-side flexibility must, firstly, reach a significant portion of low-voltage customers and, secondly, minimise the potential for market manipulation. Given that local flexibility markets face inherent structural challenges regarding market manipulation such as "increase-decrease gaming", they were not examined in this study.

The four tariff models vary in their consideration of either the current wholesale price or grid utilisation (Table 1).

These four main scenarios are supplemented with sensitivities to evaluate, for example, the interaction of tariff models with grid congestion management according to Section 14a EnWG.

1.1.3 Dynamic electricity tariffs have four key advantages for the electricity system, grid operators and customers.

Dynamic electricity tariffs offer several advantages. The four main advantages can be summarised as follows. Dynamic electricity tariffs:

→ **effectively activate household demand-side flexibility.** In 2035, over 100 TWh of load can be shifted to align with households' needs. This accounts for over ten percent of the total annual electricity consumption - and around half of household electricity consumption - and exceeds previous expectations regarding available demand-side flexibility potential.

→ **contribute to fuel savings in flexible generation plants.** In 2035, 20 TWh of electricity generation in climate-neutral gas-fired power plants can be avoided, resulting in cost savings of 5.4 billion euros. As the additional grid expansion costs for household-demand-side flexibilities amount to just 0.6 billion euros per year, total savings reach 4.8 billion euros.

→ **reduce the load on the low-voltage grid, consequently reducing the need for expansion.** The additional costs for grid expansion due to flexibility can be almost halved from 10.5 billion euros to 5.8 billion euros. By 2035, the total costs for grid expansion in the low-voltage grid, required to integrate 33 million electric vehicles, 9 million heat pumps and 53 gigawatts of home storage, will amount to 12.8 billion euros.

→ **enable all customers to benefit from lower electricity bills.** By decreasing the reliance on expensive hydrogen power plants, overall electricity generation costs are reduced. Flexible customers experience an average electricity price (procurement cost share) decrease of approximately five cents per kWh, while even non-flexible customers save one cent per kWh. More efficient grid utilisation also contributed to lower grid costs per kWh.

1.1.4 The *Bundesnetzagentur* (German Federal Network Agency) and grid operators are the key players in providing customers with access to dynamic electricity tariffs.

The Bundesnetzagentur is responsible for implementing dynamic grid fees. With the latest amendment to the EnWG, the responsibility for introducing dynamic grid fees lies with the *Bundesnetzagentur*. Existing regulatory processes serve as a solid foundation for advancing the introduction of dynamic grid fees.

Distribution system operators are key players in identifying and implementing the main steps of the process. Introducing a dynamic grid fee system is a complex task. Nonetheless, the contribution designing an efficient climate-neutral electricity system makes it worthwhile.

1.2 Study findings and options for action

1.2.1 Dynamic tariffs can activate household demand-side flexibility to a considerable extent.

The potential of household demand-side flexibility can be fully activated through price incentives. In the "Flex" and "Flex-dynToU" scenarios, over 100 TWh of load will be shifted in line with households' needs in 2035. This corresponds to more than ten percent of total annual electricity consumption – and around half of household electricity consumption – and exceeds previous expectations regarding the available load-side flexibility potential.

The shift in consumption is most significant for electric vehicles. The building-specific analysis shows that there is an individual economic advantage for households with electric vehicles, heat pumps or battery home storage systems. As a result, these households adjust their consumption behaviour – often automatically – in response to pricing to a significant degree. Electric vehicles play a prominent role in this change, contributing to more than half of household demand-side flexibility through variable charging times and bidirectional charging (Figure B).

1.2.2 Dynamic tariffs can provide flexibility far more cheaply than flexible generation plants.

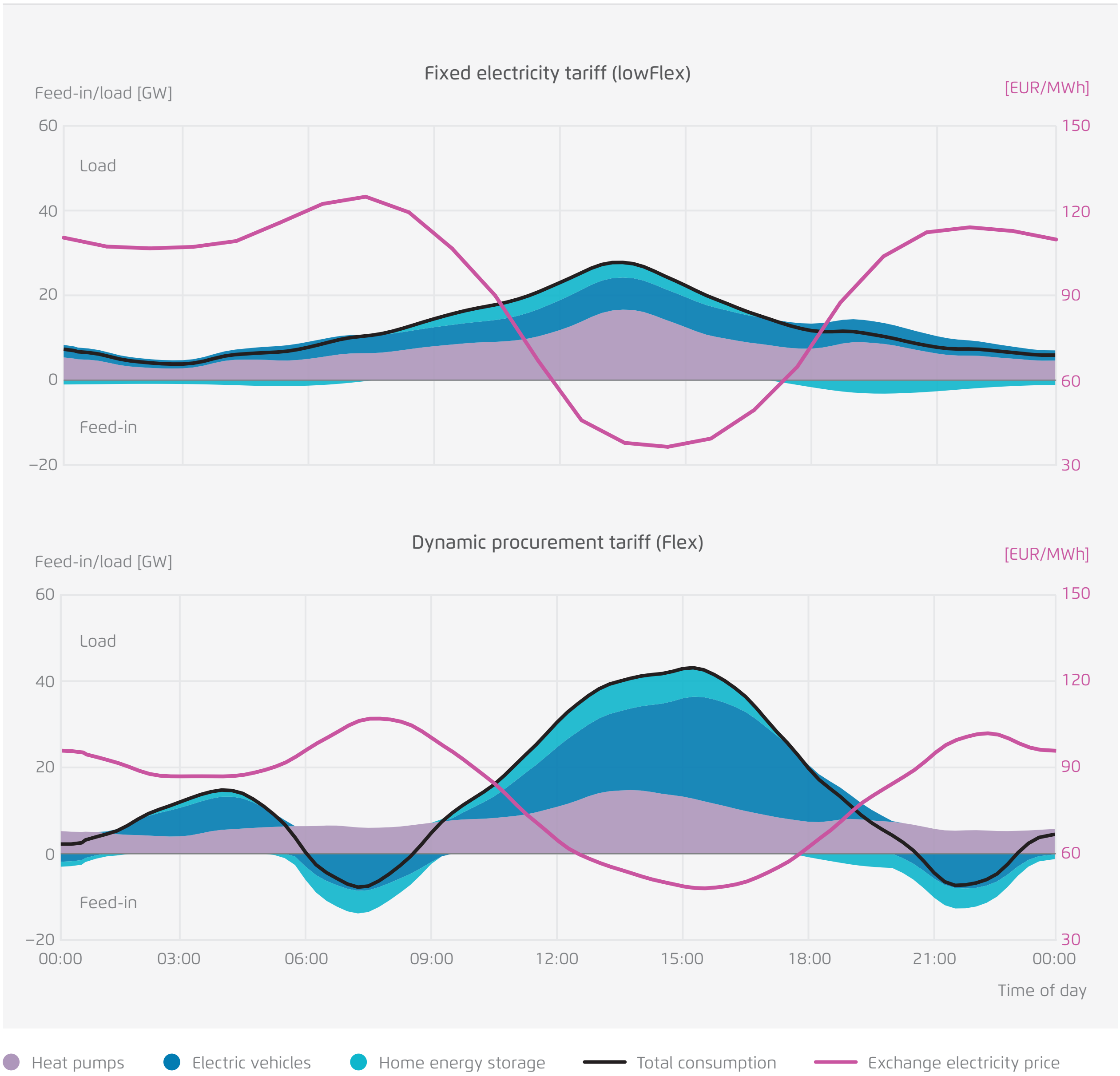
The use of demand-side flexibility is nine times cheaper than generation-side alternatives. If the flexibility of electric vehicles, heat pumps and home energy storage systems is used intelligently, the need for flexibility on the generation side from sources such as gas-fired power plants and large batteries can be considerably reduced. This results in significant annual savings in fuel costs for natural gas and climate-neutral hydrogen. For instance, in 2035, the annual savings – primarily due to approximately 20 TWh less electricity generation from hydrogen-powered gas-fired power plants – will amount to around 5.4 billion euros (Figure C). These savings are complemented by significantly lower additional costs for grid expansion and operation when utilising demand-side flexibility; 4.8 billion euros can be saved in 2035 alone.

1.2.3 Dynamic grid fees are a very efficient means of reducing load in the low-voltage grid.

Tariffs based solely on dynamic procurement electricity prices increase load peaks during low-price periods, leading to additional expansion needs in the distribution grid. Even without dynamic tariffs, the additional electricity demand stemming from electric vehicles and heat pumps will necessitate an investment of seven billion euros in household demand-side low-voltage grids by 2035 (Figure D). If new consumers react exclusively to exchange electricity prices, their electricity consumption

Total load profile of flexible consumption facilities in 2035 averaged over one day

→ Figure B



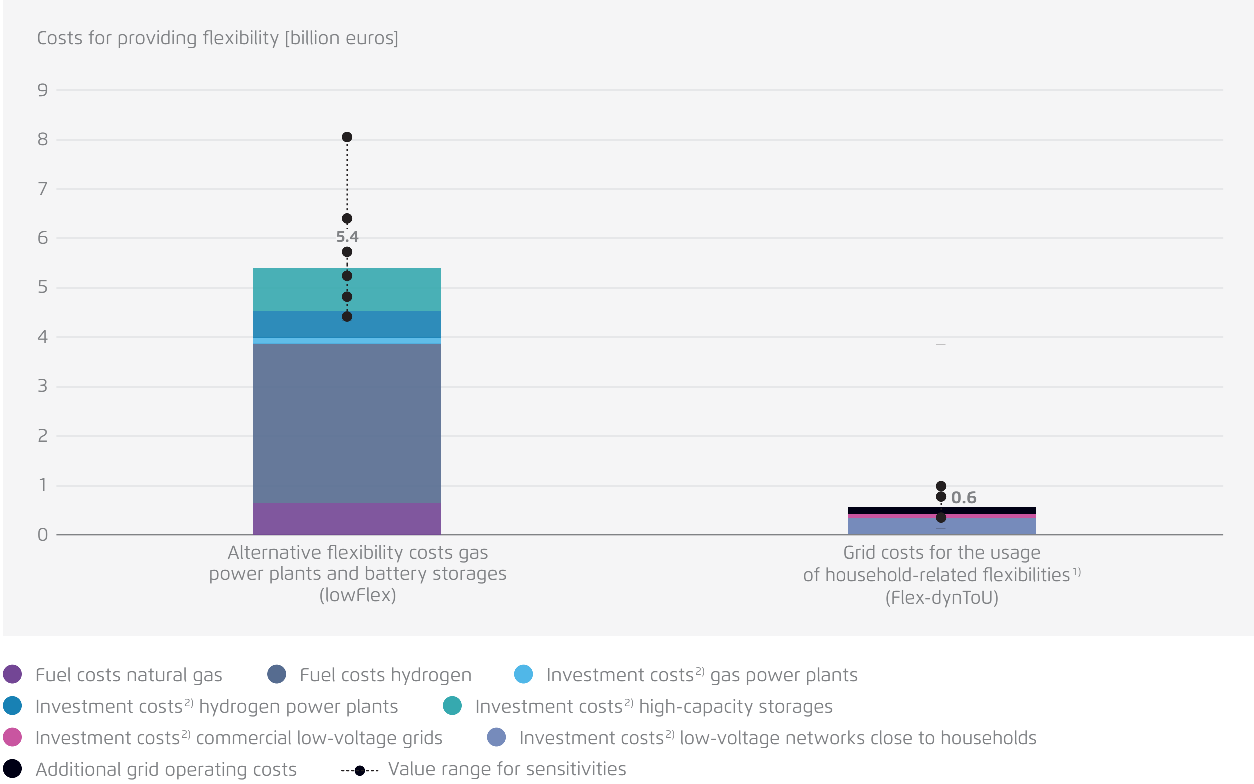
FfE (2023)

become more synchronised, placing additional strain on the low-voltage grid. Consequently, the investment requirement increases by 10.5 billion euros to a total of 17.5 billion euros by 2035 ("Flex" scenario). Activating flexibility under this scenario therefore requires a major upgrade of the grids and entails significantly higher grid expansion costs.

Dynamic tariffs including dynamic grid fees halve the grid expansion costs incurred by activating flexibility. If the flexibility incentives from dynamic electricity prices are expanded to include dynamic grid fees ("Flex-dynToU" scenario), low-voltage grids can be relieved significantly. The additional costs related to flexibility for grid expansion can be almost halved from 10.5 billion euros to 5.8 billion euros. Conversely, limiting flexibility incentives

Annuity cost comparison of the options to provide flexibility in 2035

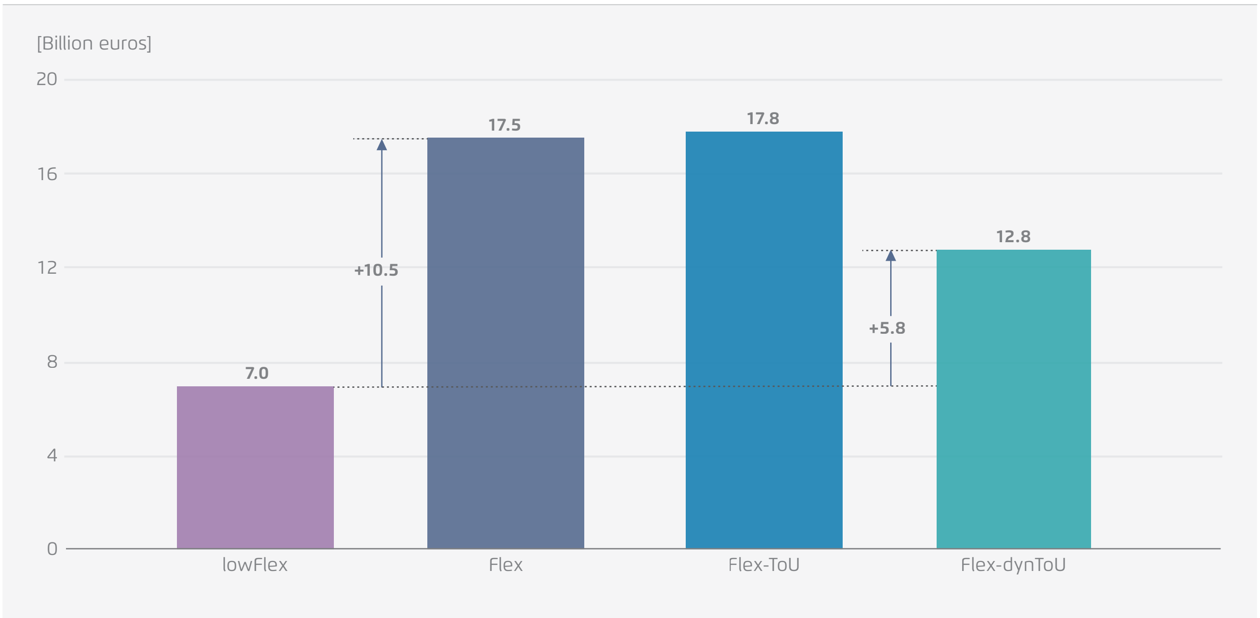
→ Figure C



Agora Energiewende (2023). Note: Annuity investment costs, real values. [1] Heat pumps, electric vehicles and home energy storage systems in domestic and commercial low-voltage grids. [2] Consideration of annuities.

Grid expansion costs in the low-voltage grid by 2035*

→ Figure D



Agora Energiewende (2023). Note: * Accumulated up to 2035, real values.

to simple time-variable grid fees with static time windows ("Flex-ToU" scenario) makes no contribution to reducing grid expansion costs. Such tariffs are therefore not suitable for increasing flexibility in a grid-friendly manner over the long term.

To achieve significant grid relief, only a ten percent reduction in market flexibility potential is necessary. Dynamic grid fees inhibit the use of flexibility during periods of (very) high grid utilisation. These selective adjustments to relieve the grid only slightly change the use of flexibility: 90 percent of the flexibility remains available to the electricity market.

1.2.4 All customers benefit from the activation of household demand-side flexibility.

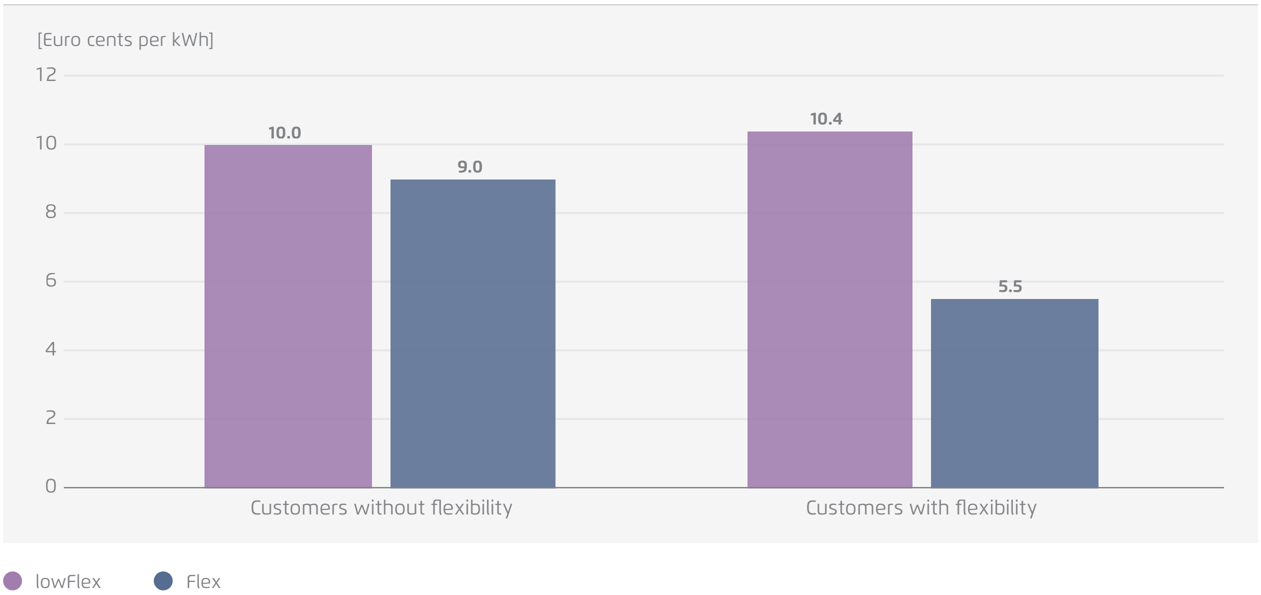
Activating household demand-side flexibility by passing on dynamic procurement electricity prices has a positive effect on electricity costs for all customers. Over the past ten years, the procurement price has on average accounted for around a quarter of the household electricity price.[4] As outlined above, the use of decentralised flexibility is cheaper than the provision of flexibility by gas-fired power plants. This effect is reflected in lower electricity costs for *all* customers. In the scenario with dynamic procurement electricity prices ("Flex"), they are one cent – or ten percent – lower for customers who do not use flexibility than in the scenario without flexibility incentives ("lowFlex"). As customers with flexible consumption systems can also make better use of low-price windows, they benefit twice as much (see Figure E); their average procurement price falls by 4.9 cents – by almost half. Even with dynamic grid fees and thus slightly adjusted use of flexibility, the savings of around half of the procurement costs persist.

If dynamic grid fees are introduced, customers also benefit from reduced grid fees. The analysis shows that the distribution grid operates more efficiently

4 BDEW electricity price analysis July 2023

Average procurement prices for customers with and without flexibility in the year 2035

→ Figure E



Agora Energiewende (2023). Note: Real values.

with the implementation of dynamic grid fees and therefore does not need to be expanded as much. These reduced grid costs translate into lower average grid fees for all customers. Flexible customers further reduce their average grid fee by increasing their purchase of electricity during periods when grid fees are lower. In 2035, they pay eleven percent lower grid fees per kilowatt hour compared to households that do not use flexibility (Figure F).[5]

Flexible customers achieve overall savings of almost 600 euros per year.[6] Under the simplified assumption that average grid fees for household customers remain consistent in 2035 compared to 2022, this would result in savings of around 75 euros in grid fees and around 415 euros in the procurement share of electricity costs, plus value added tax (VAT), in exchange for providing flexibility. Despite their comparatively lower relative grid fees, flexible customers pay higher grid fees in absolute terms due to their significantly higher electricity consumption. Consequently, they make a greater overall contribution to financing the grids than customers without electric vehicles, heat pumps or home energy storage systems. This development is therefore in line with the polluter-pays principle.

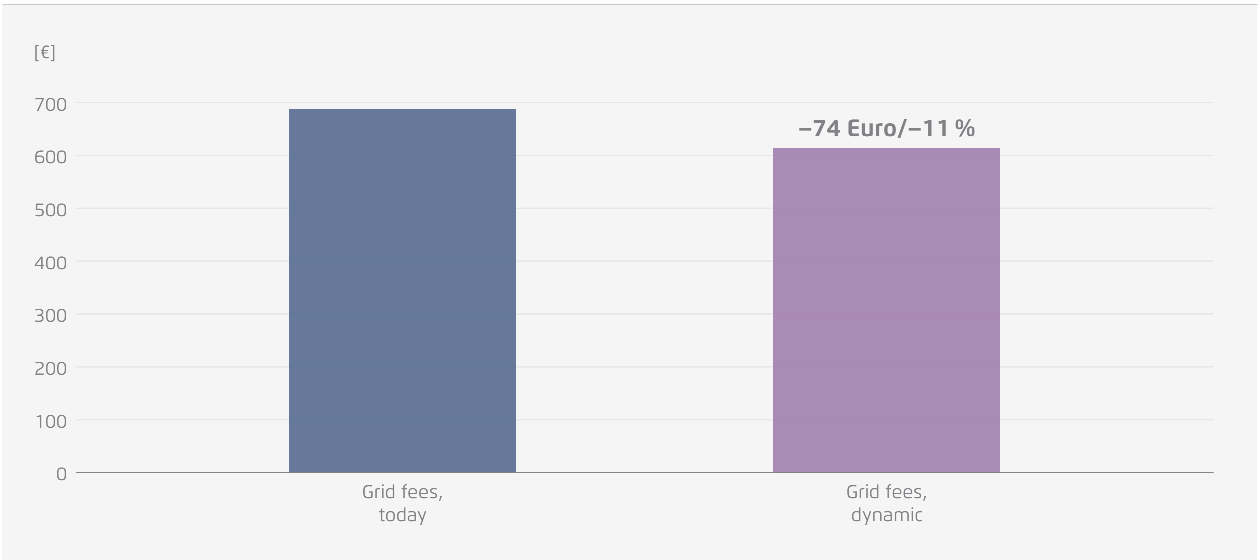
Anyone who wants to participate should have a smart meter and a home energy management (HEM) system. Smart meters enable the measurement and billing of fluctuating prices on a granular level. Customers do not have to worry about day-to-day financial optimisation themselves. As is already the case today for electricity procurement, service providers (likely aggregators) will assume this responsibility for customers. The use of HEM systems will also increase in this context. This is the digital link between the aggregator, customer systems and smart meter, acting as the conduit to the grid operator. The HEM system ensures that the customer's preferences

5 40 percent of today's flexible customers benefit from higher grid fee reductions due to their grid operator's consent to temporary disconnection in accordance with Section 14a EnWG (the grid fee discount for the household is 25 percent in the case study used). The discount serves to compensate for the damage caused by these disconnections and is therefore not directly comparable with dynamic grid fees, which prevent consumers from suffering losses in usage. The overall package of possible savings in conjunction with the dynamic exchange electricity price is also very attractive for this group.

6 According to the case study used including VAT, see Figure E.

Impact of dynamic grid fees on customers with flexibility

→ Figure F



Agora Energiewende (2023). Notes: Based on a consumption of 3 500 kWh per year for household electricity and 5 000 kWh per year for heat pumps. Grid fees today: average grid fees for household customers in 2022 according to BDEW electricity price analysis July 2022; dynamic grid fees: average grid fee according to this study based on the 2022 grid fees, net price.

are considered when optimising flexibility and that load shifts are executed through appropriate control signals for the customer.

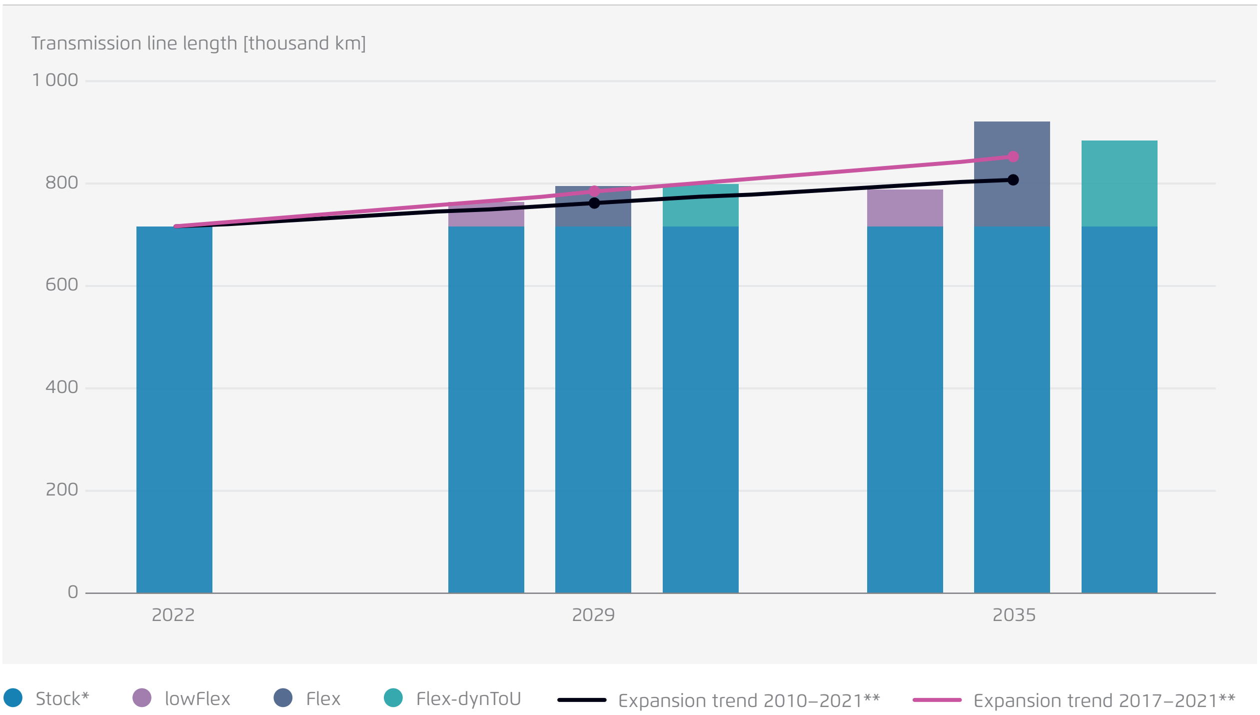
1.2.5 The combination of dynamic grid fees with emergency intervention options gives grid operators time to expand the grid.

The introduction of dynamic grid fees limits the necessary grid expansion to a scale already implemented in the past. The projected expansion rate of low-voltage grids is comparable to the investments of the recent past.[7] By 2029, the line lengths must be extended by one eighth, and by 2035, by a total of one quarter compared to today (Figure G). In addition, almost one in four local grid transformers will have to be replaced by 2035. The expansion requirement for local grid transformers, which serve as the interface to medium voltage, is even lower with dynamic grid fees ("Flex-dynToU" scenario) than without the use of flexibility ("lowFlex" scenario). This means that dynamic grid fees control the additional load due to the use of flexibility in the low voltage so well that the overload does not affect the medium voltage.

Grid expansion is still necessary particularly in rural and suburban regions. In all the scenarios considered, 80 to 90 percent of the total grid expansion requirements arise in rural and suburban regions. The presence of longer lines, combined with the population distribution, means these areas are prone to quicker overloading. However, the future will see a shift towards urban grids as well. With a high density of flexibly charging electric vehicles, local grid transformers will reach their limits. Dynamic grid fees will effectively relieve the burden on these transformers,

7 The pace of expansion has already increased recently, driven in particular by the expansion of photovoltaics.

Pipeline expansion requirements compared with the historical expansion trend → Figure G



Agora Energiewende (2023). Note: * Domestic low-voltage grids. ** Assumption: 56 percent of recorded historical expansion measures are in low-voltage grids close to households. This corresponds to the current share of household-related networks in the total length of low-voltage lines.

reducing the frequency of necessary expansions. This, in turn, can reduce the need for complex and expensive construction sites in urban areas.

The growth in photovoltaic systems is no longer the sole driver of grid expansion in the low-voltage grid. With the use of flexibility, the consumption-related grid load from heat pumps and electromobility is increasing. In future, local surplus generation from photovoltaics will be well integrated by increasingly more home energy storage systems. Irrespective of the use of flexibility, heat pumps will drive grid expansion instead. With increasing flexibility, electric vehicles are the most frequent cause of the need to expand the grid because they can generally use their high supply power more flexibly than, say, heat pumps. Despite larger amounts of energy fed back from bidirectional vehicles and home energy storage systems, the load case usually determines the need for grid expansion.

The emergency instrument of power reduction in accordance with Section 14a EnWG is an effective tool for bridging delays in grid expansion. Rapid expansion is necessary in particularly heavily loaded grids. Otherwise, expansion delays would require very long and frequent power reductions in accordance with Section 14a EnWG. To avoid this, these grids must be expanded as a priority. In less heavily loaded grids, the instrument of power reduction as a bridging mechanism can effectively relieve the grid with only minor losses for customers. For example, in the event of staff shortages or supply bottlenecks, resources can be strategically deployed.

1.2.6 The introduction of dynamic grid fees will be facilitated by recent measures for measurement and control in the low-voltage grid.

Ongoing regulatory adjustments form a suitable basis for distribution grid operators to introduce dynamic grid fees. As a result of the amendment to Section 14a EnWG, distribution grid operators must be able to dynamically manage grid congestion from 2029. This presupposes that a load forecast is available, for example at the level of the local grid transformers.

Necessary process components including progress made so far and additional development requirements → Figure H

Creating the capacity utilisation forecast	Grid fee calculation and billing	Control of household consumption systems at the customer's premises
Capacity utilisation forecast to establish dynamic taxes in accordance with Section 14a EnWG to be implemented by 2029 at the latest	**Grid fee billing** already automated and suitable for mass data today → adaptation to new requirements feasible	Optimisation of consumption and **control of appliances**: already technically possible today via home energy systems (HEMs)
Schedules of flex-free consumers are already available to the grid operator today	*Smart Meters* are required to determine the **consumption of flexible customers** → accelerated rollout in accordance with GNDEW already started	Scheduling compliance: **fulfilment of the schedule** of controllable consumption devices can already be ensured by HEMs today
Dispatching the schedules of flexible consumers requires considerable process extension	**Grid fee rate** must be **derived** from the capacity utilisation forecast and **published** via existing services (e. g. web services) and integrated into processes	Standardisation required so that **all new devices can be controlled** by HEMs

Agora Energiewende (2023).

This will create the basis for determining dynamic grid fees. In addition, the rollout schedule adopted in the *Gesetz zur Digitalisierung der Energiewende* (GNDEW), or Act on the Digitisation of the Energy Transition, will accelerate the up-take of the necessary smart meters. Figure H provides an overview of additional process requirements and an assessment of the degree of further development required.

The preparation for introducing dynamic grid fees could involve an interim measure through time-variable grid fees with static time windows. The increasing ramp-up of flexible consumption systems should be utilised in the best possible way. In the long term, time-variable grid fees with static time windows are not sufficient to effectively reduce grid congestion. Nonetheless, during a transitional phase, they can help to increase the attractiveness of flexibility marketing and to gradually develop and implement the necessary process adjustments. However, the ultimate objective is clear: only dynamic grid fees will be an effective measure to meet the challenges in the distribution grid of the future. Therefore, a comprehensive transition to such a system should be completed by 2030 at the latest.

1.2.7 Recommendations

Recommendations for action and implementation. The advantages outlined above show that dynamic grid fees benefit the overall system and therefore also electricity customers. The implementation is the **responsibility of the *Bundesnetzagentur* and distribution system operators.**

a. **The *Bundesnetzagentur* is responsible for implementing dynamic grid fees.** With the latest amendment to the EnWG, the introduction of dynamic grid fees is the responsibility of the *Bundesnetzagentur*. The following aspects appear particularly relevant:

   - **Security of supply and polluter-pays principle:** The goal set out in the internal electricity market regulation of prioritising flexibilisation in connection with security of supply is also a guiding principle for the regulatory authority. Simultaneously, a price system with dynamic grid fees should also aim for a cost distribution that is largely rooted in the polluter-pays principle.
   - **Advancing the price incentive for grid efficiency.** The *Bundesnetzagentur* has long recognised the significant role flexible consumption systems play in grid operations. An important step towards dynamic grid fees is the amendment to Section 14a EnWG planned by the *Bundesnetzagentur*. It will make dynamic grid control mandatory from the start of 2029. This will be based, for example, on the capacity utilisation forecast of the local grid transformer. The determination on Section 14a EnWG of 27 November 2023 shows that the *Bundesnetzagentur* attaches great importance to the more grid-friendly integration of controllable consumption systems. In a consistent further development, however, the price incentive through dynamic grid fees should prevent any grid bottlenecks ex ante, rather than serving as compensation for any consumption restrictions, as currently observed.
   - **Linking dynamic electricity tariffs to dynamic grid fees.** Dynamic electricity tariffs should be offered in a package with dynamic grid fees. Otherwise, there is a risk that the activation of flexibility will greatly increase grid costs due to a unilateral market-based signal. This initiative ultimately establishes a price incentive system accessible to all customers equipped with a smart meter. Smart meters are becoming even more attractive because customers benefit from the grid fee discount in addition to the lower procurement costs. The introduction of the dynamic grid fee has the advantage that multiple measurements are no longer necessary, as this tariff can be applied to the entire electricity consumption. Currently, when installing appliances such as heat pumps, additional meters are often installed to benefit from the grid fee discount in accordance with Section 14a EnWG.
   - **Universal introduction in 2030.** The introduction of dynamic grid fees in conjunction with dynamic tariffs should be completed by 2030 at the latest. As a first intermediate step,

time-variable grid fees with static time windows can be used, which can then be refined and made dynamic. This will make it possible to integrate as many consumer installations as possible directly into the new system. In addition, the negative effect of any design errors is reduced, and they can be corrected more easily. The learning effect of all those involved thus leads to a more resilient implementation across the board.

- **Ensuring a balanced relationship between the price signals for procurement and grid efficiency.** The design of the dynamic grid fees used in the study shows that the goal of minimising grid expansion while activating flexibility can be achieved with a balanced interplay of price signals for procurement and the grid.
- **Utilisation forecasts of the local grid transformer serve as a suitable calibration tool.** The load forecast of the local grid transformer – assumed in this analysis – is suitable for calibration (although further investigation is needed to determine its applicability to other forms of design). Generating such a forecast is already required for dynamic grid control in accordance with Section 14a EnWG and allows a sufficiently accurate congestion forecast for the low-voltage grid.

b. **The distribution system operators are key players in the identification and implementation of important process steps.** They generate capacity utilisation forecasts, derive prices and link these to the corresponding customers. They also process timetable notifications and calculate significantly smaller time windows compared to previous practices. It is helpful that most market and billing processes have already been automated for mass data. Further process enhancements are on the horizon as part of the ongoing digitalisation efforts within distribution grids. While the task at hand remains complex, the contribution towards designing an efficient climate-neutral electricity system is undeniably worthwhile.

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Agora Energiewende develops scientifically sound, politically feasible ways to ensure the success of the energy transition – in Germany, Europe and the rest of the world. The organisation works independently of economic and partisan interests. Its only commitment is to climate action.

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