REPORT

Electricity tariffs for price security *and* flexibility

Designing a dynamic tariff with price hedging

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On behalf of LichtBlick SE

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Designing a dynamic tariff with price hedging

In this brief study, we propose a new electricity tariff that incentivizes load-side flexibility and energy savings while protecting against nasty surprises on the electricity bill: The dynamic tariff with price protection. The tariff specifies an annual volume, an hourly consumption profile and a price over the contract term of one or more years. This protects households from energy crises and other price rises. However, if actual consumption deviates from the agreed volume, the hourly excess or shortfall is billed at the current spot price. In this way, households can benefit financially from smart charging of their electric car or other load shifting.

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Neon Neue Energieökonomik is an energy industry consultancy based in Berlin. As a boutique, we have specialized in sophisticated quantitative and economic-theoretical analyses of the electricity market since 2014. With consulting projects, studies and training courses, we support decision-makers with the current challenges and future issues of the energy transition. Our clients include governments, regulatory authorities, grid operators, energy suppliers and electricity traders from Germany and Europe.

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Contents

Summary

Making electricity consumption more flexible is crucial to the success of the energy transition. This involves both load shifting and saving energy in times of scarce energy. To ensure that electric vehicles, heat pumps and home storage systems prefer to draw electricity when there is a lot of wind and solar power available and the grids are underutilized, scientists often recommend the introduction of dynamic end customer tariffs based on the hourly spot price on the electricity exchanges.

However, such tariffs, which have been widely used in many European countries for a long time, have a serious disadvantage, as the energy crisis showed: rising electricity prices on the stock exchange have a direct impact on electricity bills. This not only had serious social consequences during the 2021/22 energy crisis, but also generated political pressure that often led to problematic interventions on the energy markets - for example in Spain.

Against this background, it is clear that electricity tariffs should not only be evaluated in terms of their incentive effect, but also in terms of their insurance effect in the event of electricity price crises. However, traditional electricity tariffs offer either economically sensible incentives (dynamic tariffs) *or* an implicit insurance function (fixed-price tariffs).

In this brief study, we propose a tariff model that provides both incentives and security: The dynamic tariff with price hedging. The tariff specifies an annual volume (kWh), an hourly consumption profile and a price (cents per kWh) over the contract term of one or more years. If households consume as much electricity as agreed, they pay exactly the contractually agreed price - regardless of price movements on the spot market. In other words, they are fully insured against price peaks for these quantities.

However, if actual consumption deviates from the agreed volume, the hourly excess or shortfall is billed or reimbursed at spot prices. This means that the incentive for savings and load shifting is always determined by the spot price, regardless of the previously hedged profile. This allows households to use their flexibility and energy-saving potential to reduce their electricity bills. Instead of suffering from price peaks, they could even benefit financially from them.

No major political reforms are necessary to enable the dynamic tariff with price protection. However, politicians should refrain from intervening in prices so that households have an interest in taking out individual insurance at all. It would also make sense to introduce a fair switching fee based on market prices for the early termination of contracts in order to reconcile consumer protection with a long contract term.

1 Introduction

Load-side flexibility. Activating load-side decentralized flexibility is essential for the success of the energy transition. In particular, the inherent load shifting potential of electric vehicles, heat pumps and home storage systems should be leveraged so that these devices prefer to draw electricity when there is an abundant supply of wind and solar power and the transmission and distribution grids are underutilized.

Dynamic electricity tariffs. Energy economists often recommend that this should be achieved through dynamic retail tariffs that pass on the hourly spot price and time-variable grid charges. While these tariffs have long been commonplace in many European countries and were introduced as standard in Spain in 2014, for example, the vast majority of German households have traditional fixed-price tariffs, where the electricity price is fixed for one to two years, partly due to the lack of intelligent metering systems (smart meters). Billing for fixed-price contracts is usually based on standard load profiles. In such tariffs, it is not possible to benefit financially from cheap wind and solar power and there is no incentive to make consumption more flexible.

Energy crisis. During the 2021/22 energy crisis, however, a serious disadvantage of dynamic electricity tariffs became apparent when wholesale prices increased tenfold in just a few months and this had an immediate impact on electricity bills. This not only resulted in depressing social consequences and energy poverty, but also immense political pressure, which led to far-reaching, often problematic interventions on the energy markets. For this reason, a return to fixed price tariffs is being actively considered, for example as part of the EU electricity market reform. A similar problem arose in Texas at the beginning of 2021, when a cold spell and a dark doldrum not only led to astronomical electricity bills, but also ultimately to the insolvency of the most prominent provider of dynamic electricity tariffs.

Objectives of tariff design. Against this background, it becomes clear that tariffs should not only be assessed in terms of their incentive effect, but also in terms of their insurance character in the event of electricity price crises. Electricity tariffs should therefore satisfy at least three objectives: they should provide incentives for load shifting (flexibility) and incentives to save electricity during periods of darkness and energy crises (situational energy saving), but at the same time also protect against exploding electricity bills (insurance function). Traditional electricity tariffs offer either sensible incentives (dynamic tariffs) *or* an insurance function (fixed-price tariffs).

Proposal. In this brief study, we propose a new retail tariff that combines both aspects: A dynamic tariff with price hedging. This tariff transfers the principle of hedging, which large industrial consumers use to protect themselves against price risks, to the retail segment. The contract specifies a certain consumption volume and profile at a fixed price over a period of one or more years. If this volume of electricity is purchased, the exact agreed price is charged. Hourly surpluses or shortfalls, on the other hand, are billed at the current spot price.

Full incentives. If, for example, the electricity price on the exchange briefly rises tenfold during a dark doldrum, this does not lead to an increase in the electricity bill if consumption is at the level of the hedge - however, every kWh saved is compensated with the tenfold increase in the electricity price. Situational electricity saving and load shifting therefore become lucrative. The same applies to load shifting through intelligent control of electric cars, heat pumps or home storage systems: the daily fluctuations in electricity prices make load shifting in line with the system financially attractive.

This study. In this short study, we present the proposal and discuss the relevant design options such as the choice of consumption profile and the combination of long-term contracts with consumer protection. Finally, we identify a number of regulatory hurdles and necessary reforms.

2 Background

In this section, we recapitulate the essential role of load-side flexibility in an electrified energy system based on wind and solar power, discuss the differences between price signals and intervention rights, and provide an overview of the basic types of electricity tariffs today and their role in the energy crisis. In the final part of this section, we look at the objectives of tariff design.

2.1 The essential role of load-side flexibility

Energy transition. The decarbonization of the energy system means, on the one hand, the conversion of electricity generation to primarily wind and solar and, on the other hand, the extensive electrification of the previously fossil fuel-consuming sectors of space heating (primarily through heat pumps), transport (primarily through battery electric vehicles) and industry. Extensive electrification of these sectors naturally means a massive increase in annual electricity consumption. If consumers are not exposed to appropriate incentives, this also means a massive increase in peak load, because people then heat their homes and charge their vehicles when it is convenient or just happens to be convenient. The consequences would be high costs for the provision of electricity through large-scale storage and hydrogen as well as a massive need to expand the transmission and distribution grids.

Flexibility. However, many of the new consumption devices have an inherent flexibility: heat pumps due to the thermal inertia of buildings or water heat storage, electric vehicles due to batteries. In principle, it is often technically possible to shift the load by a few hours or (in the case of cars) days without incurring significant costs or sacrificing comfort. However, this requires financial incentives, which are currently lacking across the board. Decentralized flexibility, i.e. appliances that are connected to the low voltage and operated by private households or small businesses, plays a prominent role here due to their sheer mass.

Large volume. While the cumulative connected and charging capacity of heat pumps, electric cars and home storage systems in the low-voltage grid is currently around 20 GW and therefore around a quarter of the installed capacity of flexible power plants, the ratio will be reversed by 2030. The capacity of decentralized flexibility will reach over 200 GW if the BMWK long-term scenarios and plausible assumptions on installed electromobility connected load are taken as a basis. Decentralized flexibility will then account for around 280% of flexible power plant capacity, and even 620% by 2045. The cumulative output of decentralized flexibility not only exceeds the available power plant output many times over, it also exceeds the installed output of large-scale flexibility options such as electrolysers, large batteries and power-to-heat plants in district heating grids (Figure 1).

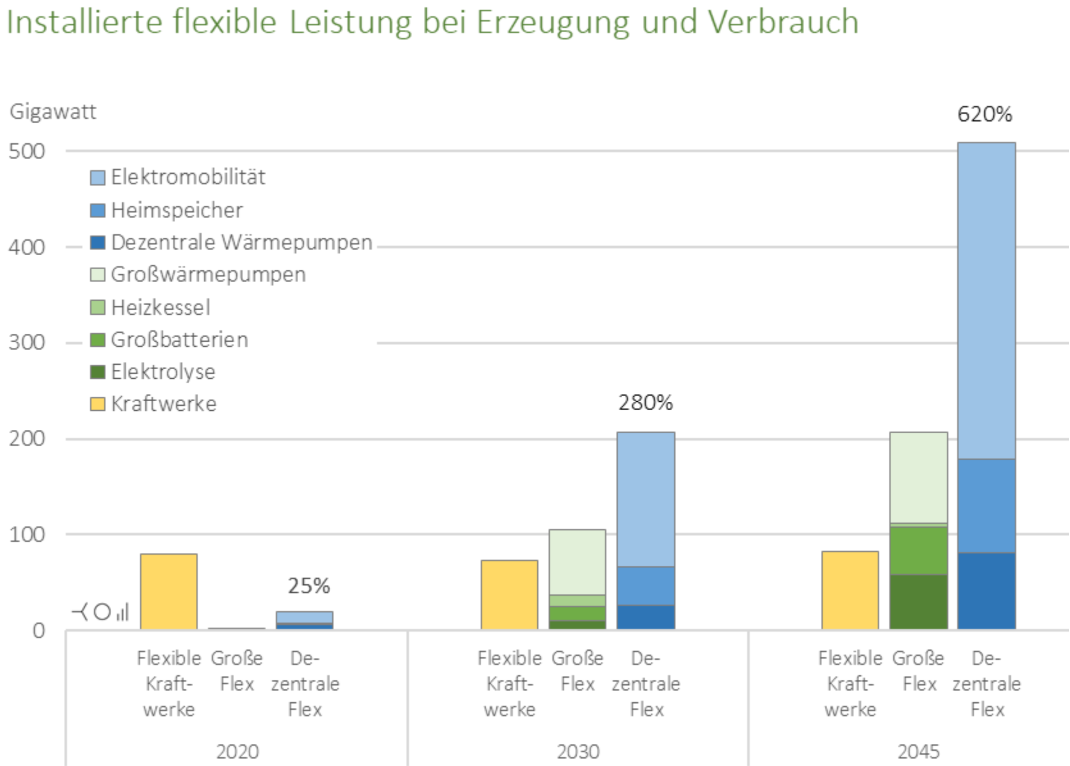

Figure 1. Installed capacity of various potentially flexible technologies today and in the future. Decentralized flexibility refers to low-voltage connections. Own illustration based on the BMWK long-term scenario "T45 electricity" (2022); the electromobility connection capacity was calculated as 11 kW for 75% of the number of electric cars (17 million in 2030 and 40 million in 2045); the capacity of large batteries and home storage systems is based on the corresponding data in the Electricity Grid Development Plan 2037 / 2045 (2023) and was calculated for 2030 by linear interpolation between the data for 2020 and 2037.

Signals for end customers. A key challenge of the energy transition is therefore to encourage heat pumps, electric cars and home storage systems to preferably draw electricity when the wind is blowing or the sun is shining and the grids have sufficient free capacity. This requires price signals for end customers. They need to know whether electricity is scarce or in abundance, whether grids are free or at their limit. Of course, the goal cannot be manual switching by humans, but rather the optimization of devices by aggregators and algorithms provided by energy suppliers, device manufacturers and/or service providers. However, aggregators and algorithms also need signals in order to optimize.

Dynamic prices. In a market economy, this is precisely the task of prices: To express costs and scarcities. Load shifting or load shedding will not be sensible, possible or desirable in every situation. Prices express the current value of flexibility. Consumers can then decide whether, when, under what conditions and to what extent they provide flexibility. Price signals for electricity generation already exist today in the form of prices on the wholesale markets. Price signals for grid usage do not yet exist, but the Federal Network Agency has already announced the introduction of static, time-variable grid fees for the coming year as part of §14a of the Energy Industry Act. These must then be made visible for small consumers. The scientific community generally recommends that this should be done through dynamic end customer tariffs ("real-time pricing"), which pass on the hourly spot price and time-variable grid charges. Such tariffs require an intelligent measuring device (smart meter) that can measure and transmit the hourly electricity consumption. Billing will then no longer be based on standard load profiles, but on actual quarter-hourly consumption according to meter reading.

Feedback. It is sometimes argued that dynamic tariffs cannot influence the exchange market result at all and would therefore be ineffective because the prices for customers are only fixed after the day-ahead auction has been determined. Of course, this is not the case because distributors anticipate the price reaction and translate it into bid curves for procurement on the spot market - just as is usual in business with bulk buyers.

2.2 Price incentives vs. intervention rights

Rights of intervention. Instead of dynamic prices, it would also be conceivable in principle to leave the control of flexible consumption units to the grid operator, i.e. to establish a direct right of access. In return, the grid operator could offer customers a reduced but constant grid fee. However, this approach entails two problems.

Situational energy saving. On the one hand, although the model is suitable for load shifting (to a limited extent), it is not suitable for situational energy saving. This means that households cannot fully benefit financially from extremely high prices during periods of scarcity (cold dark doldrums) and would therefore inefficiently save little energy - which is both "money left on the street" for them and suboptimal for the system as a whole.

Voluntariness. Secondly, such a model only works well even for load shifting if the willingness to provide flexibility is constant over time. However, if households want to allow load control at some times but not at others - e.g. because the car needs to be charged for a vacation - this is either not possible at all if load control is delegated to the grid operator, or at least not in such a way that an optimal balance is struck between the costs and benefits of prioritizing electricity consumption. A right of intervention by the grid operator is generally not voluntary, at least in the case of demand. Price signals, on the other hand, enable both efficient balancing decisions and incentives to save electricity depending on the situation.

2.3 Flexible *or* secure: electricity tariffs today

Two basic types. Most of the retail tariffs currently on the (European) market can be classified along a spectrum of fixed energy charges on the one hand and dynamic tariffs that vary at short notice on the other. There are mixed forms between these extremes.

Fixed-price tariffs. Most electricity tariffs concluded in Germany are classic fixed-price contracts, i.e. they have a contractually fixed energy charge that does not change over a longer contract period of typically one to two years. As these tariffs only require annual consumption to be measured, they are also suitable for customers without smart metering systems who are billed according to standard load profiles. Fixed-price tariffs offer no incentives for flexibilization of electricity demand, neither for load shifting nor for situational electricity savings in times of scarcity.

Option character. In economic terms, fixed-price tariffs are options: Customers have the option, but not the obligation, to purchase any amount of electricity for the price agreed in advance. The purchase is only limited by the capacity of the house connection. From the customer's perspective, fixed-price tariffs offer a high degree of predictability of the electricity price, but from the supplier's perspective, they are quite complex to calculate due to the volume risk, because the option obligation must also be hedged and serviced. For this reason, such tariffs include significant risk premiums and are on average more expensive than dynamic tariffs.

Dynamic tariffs. In contrast to fixed-price tariffs, dynamic electricity tariffs pass on hourly spot prices from the electricity exchange to end customers, usually day-ahead prices. These tariffs are also known as "spot tariffs" or "(hourly) real-time pricing" and require quarter-hourly metering using an intelligent metering system. As they are not a financial option from the energy supplier's point of view, there are no risk premiums. Dynamic tariffs provide incentives to make demand more flexible: the high-resolution scarcity signal offers incentives for load shifting and situational electricity saving.

Price risks. However, dynamic electricity tariffs expose private households to a greater cost risk, as prices on the electricity exchange fluctuate greatly. In addition, high prices correlate with high consumption: When it is cold, both consumption and the price rise, which further increases the fluctuation range of the electricity bill amount (and the risk of very high electricity bills).

Mixed forms. A number of mixed forms of tariffs combine elements of fixed-price tariffs with elements of dynamic tariffs. These are particularly noteworthy:

- Pre-defined price levels at certain times of day (static time-variable or "time-of-use" tariffs)
- Higher prices in times of critical system and grid load ("critical peak pricing")
- Fixed prices with automatic adjustment to price trends, e.g. every month
- A fixed price for a certain quantity of electricity, with excess and shortfall quantities billed at current market prices ("fixed price / fixed volume")

In terms of their incentive effect on flexibility and their insurance character against electricity price fluctuations, such tariffs are located between the aforementioned extreme points of fixed and dynamic electricity tariffs. Figure 2 shows the prevalence of time-variable electricity tariffs in Europe in 2016. Since then, the prevalence of dynamic electricity tariffs has increased again.

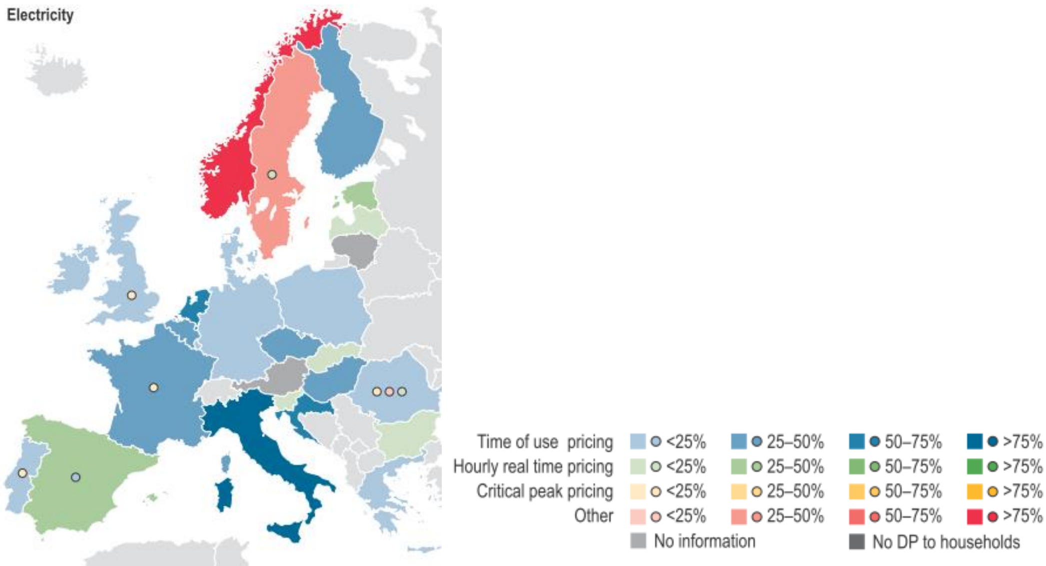

Figure 2. Dominant time-variable household electricity tariffs in Europe. Source: ACER (2016). More recent figures are not available. In Germany, time-of-use refers to tariffs for night storage heaters.

2.4 Electricity tariffs in the energy crisis

Energy crisis. During the 2021/22 energy crisis, many people became painfully aware of the lack of insurance character of dynamic tariffs for the first time when wholesale prices rose more than tenfold in just a few months. Figure 3 shows a comparison of the effective electricity costs for an exemplary dynamic tariff and the average actual electricity tariffs of household customers in Germany, the majority of which are fixed-price tariffs. In countries where dynamic tariffs are more widespread, such as Spain, the rising wholesale prices for electricity had a much faster impact on household expenditure than in Germany. This explains, at least in part, the faster and more far-reaching political interventions in electricity markets in these countries. An inherent safeguard against electricity price crises therefore also acts as a preventive measure to reduce the pressure for ad hoc political interventions. (However, dynamic tariffs have been significantly lower than fixed tariffs since the beginning of 2023).

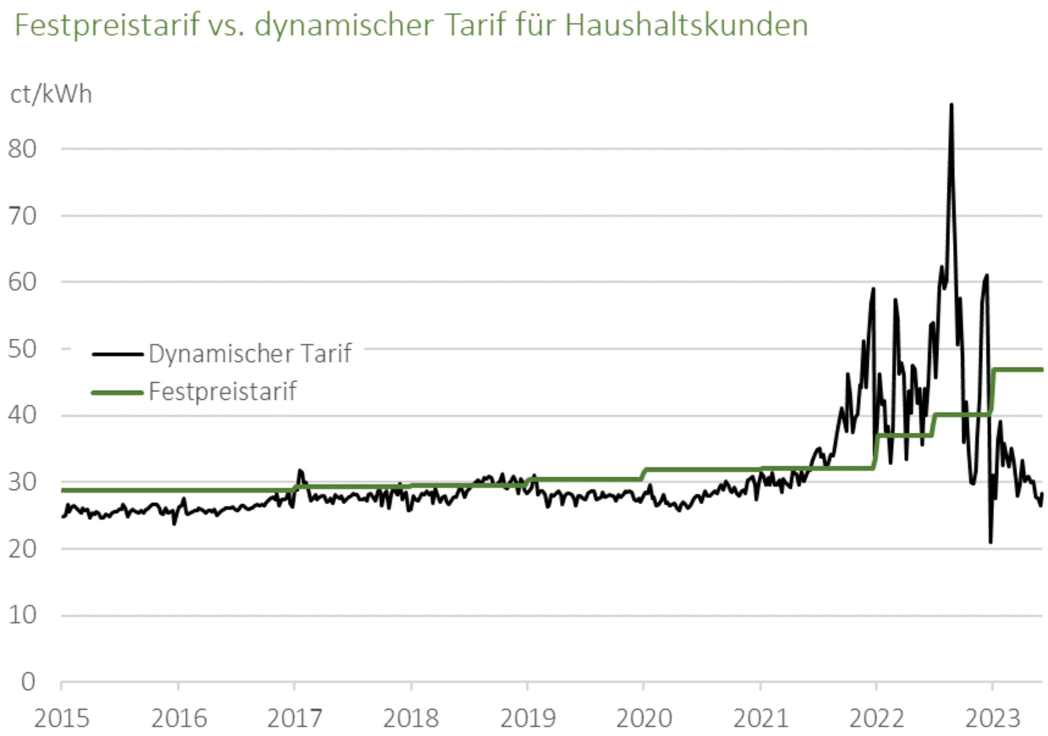

Figure 3. Fixed price tariff vs. dynamic tariff for household customers in Germany with a consumption of 3500 kWh/year. The fixed-price tariff corresponds to the average of the available tariffs for electricity in the respective period according to BDEW (2023). The costs of the dynamic tariff include an annual base price of €60 as well as the same taxes, levies and surcharges as the fixed-price tariff and were calculated as weekly average spot prices assuming a constant consumption profile.

Incentive to save. At the same time, the crisis itself has of course also underlined the effectiveness of prices as an incentive to save energy with unprecedented clarity. Across Europe, industry, commerce and private households have drastically reduced their electricity and gas consumption, certainly not only, but also as a reaction to the high prices (Ruhnau et al. 2023). High prices were therefore not only a problem, but also part of the solution: without high prices, the gas shortage would have been even more dramatic.

Dark doldrums. It is possible that the geopolitically induced European energy crisis will not be repeated in this form in 2021/22. However, other types of electricity price crises or periods of very high spot prices are highly likely in the future: Winter cold spells with low solar and wind generation ("cold dark doldrums"). With extensive electrification of heat generation, high demand and low renewable generation come together here, and such weather periods will occur again and again. Texas experienced just such a dark doldrum in February 2021, which was also accompanied by a widespread loss of conventional generation capacity due to very low temperatures. As a result, wholesale prices rose for several days in a row to a peak price of USD 9,000 per megawatt hour, around thirty times the normal value. In such periods of electricity shortages, it is important to make every possible effort to save energy. We call this "situational energy saving".

Price risks. At the same time, the Texas crisis also demonstrates the explosive power of dynamic tariffs. Such tariffs, which the provider Griddy in particular had popularized in Texas, lead to exorbitant electricity bills, which were prominently discussed in the press and on social media. Griddy, which had advised its customers to cancel and switch to a competitor shortly before the cold snap, lost its stock exchange listing shortly afterwards and ultimately had to file for bankruptcy.

Cold dark doldrums in Texas (February 2021)

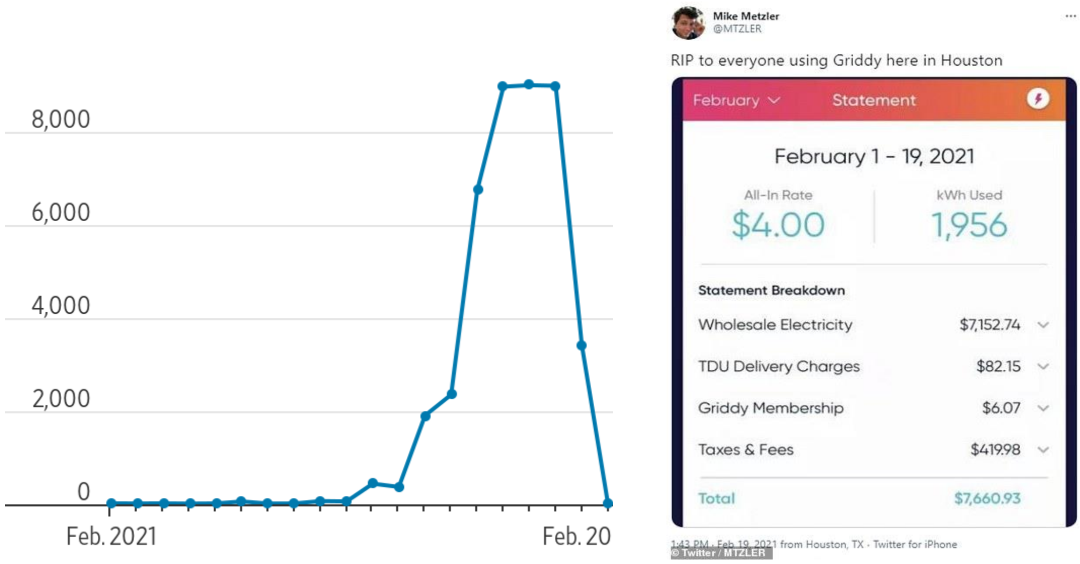

Figure 4. Wholesale prices in Texas in February 2021 (left), tweet with Griddy bill (right).

Back to the future? Against this backdrop, it is understandable, but also worrying, that the European Commission is proposing in its proposal to reform the EU electricity market design to return to fixed-price tariffs across the board, which are still common in Germany but are a thing of the past in many other countries. This would mean a departure from the idea of a responsive load side, both for load shifting and for saving electricity in times of crisis. This would make an electrified energy system based on wind and solar significantly more expensive and resource-intensive and increase the need for grids, peak-load power plants and large-scale storage facilities.

2.5 Three objectives of the tariff structure

With a view to the energy transition, three goals can be formulated for the design of electricity tariffs.

Load shifting (flex incentives). Electricity tariffs should be designed in such a way that they offer incentives to shift electricity consumption to periods when electricity is available in abundance and to reduce it during periods when electricity is scarce. In other words, they should provide incentives to preferentially consume cheap wind and solar power instead of electricity from power plants with high generation costs. The scarcity of electricity is reflected on the electricity market by short-term electricity prices. Tariffs should therefore provide incentives to shift consumption to particularly favorable time windows. Load shifting usually takes place within a day or over a few days and is particularly likely in the areas of electromobility and electrical heat generation. Optimization is likely to be automated as a rule. However, manual load shifting would also be possible ("washing at midday instead of in the evening"), but would probably account for a much smaller proportion of the load shifting that takes place in terms of volume.

Situational energy saving (dark doldrums). In longer periods of scarcity lasting a few days or a few weeks, it also makes sense to save energy. This involves not only postponing electricity consumption, but reducing it without making up for it. In an electrified energy system based on wind and solar power, this is likely to be the case above all during so-called cold doldrums, i.e. cold spells in winter with low wind power generation. Of course, this means forgoing consumption, but this can make economic and individual financial sense because the marginal costs of electricity generation can be exorbitantly high during such periods. Ultimately, incentives for load shifting and situational energy saving are two examples of the more general goal of ensuring that prices reflect the actual marginal costs of providing electricity.

Cost security (stable electricity bill). In particular, the rise in electricity costs during the energy crisis has shown that an important function of electricity tariffs should also be to minimize electricity cost risks for consumers. Without an implicit insurance function, electricity costs can quickly take on high proportions during price crises, especially if the heat supply is also operated electrically. Practical experience from the crisis as well as welfare theory considerations on the risk aversion of private households suggest that they have a preference for stable energy bills.

Evaluation of current electricity tariffs. With regard to the aforementioned targets, none of today's standard tariffs achieve the three targets simultaneously (Table 1). While the most widespread fixed-price tariff in Germany today offers a high degree of cost security over the term of the contract, it offers no incentives for load shifting or situational electricity saving. Dynamic electricity tariffs based on the spot market price, on the other hand, offer incentives for load shifting and situational electricity saving, but they involve a high cost risk. At first glance, this appears to be a trade-off: either efficient incentives *or* hedging electricity costs. In the following, however, we show that the objectives are not a dilemma, but can largely be achieved simultaneously by separating the insurance function from the price function.

Table 1. Evaluation of the two classic electricity tariffs based on the three objectives

	Incentive for load shifting	Incentive for situational electricity saving	Insurance against price crises
Fixed price tariff	✗	✗	✓
Dynamic tariff	✓	✓	✗

3 Dynamic tariff with price protection

In this section, we present our proposal for a new tariff. The dynamic tariff with price hedging offers households with smart meters the opportunity to benefit from load flexibility while at the same time having a hedged monthly electricity bill. The special feature of the tariff is that the incentives from electricity prices are received by households completely undistorted (i.e. in full and in depth) and for the entire consumption volume, but the monthly electricity bill is balanced thanks to the tariff's hedging function. The hedging function is designed in such a way that it does not cause any distortion of incentives. As a result, households can even benefit from high electricity prices. The tariff therefore dispels the widespread notion that variable tariffs cannot go hand in hand with electricity cost security.

3.1 Basic concept of the tariff

The tariff. The dynamic tariff with price hedging (hedged spot tariff) has a long term of one or more years. Where legally permissible, longer terms of two to five years also appear reasonable. The tariff specifies an annual volume (kWh), an hourly consumption profile (e.g. standard load profile) and a price (cents per kWh) for the predefined consumption profile. If the actual consumption in an hour deviates from the quantity agreed in advance for the hour, the hourly excess or shortfall is billed or reimbursed at spot prices. Such tariffs are not new in the scientific literature. The American energy economist Severin Borenstein already analyzed and recommended such tariffs in 2007 (Borenstein, 2007); Winzer et al. (2023) developed this tariff further.

Analogy to mobile phone tariffs. Similar to today's mobile phone tariffs with a certain agreed data volume, electricity tariffs would also ask for a volume at the time of conclusion (or, for example, the size of the household on the basis of which the electricity provider calculates the volume). In contrast to the data volume for mobile phone tariffs, however, for dynamic tariffs with price protection it would be relevant *when* the consumption takes place: Here, the volume would be allocated to the individual hours of the contract period according to a formula, resulting in an exact amount of electricity hedged for each hour of the contract term. This distribution over the individual hours of the year is also known as the consumption profile. In this tariff, customers therefore buy a certain amount of electricity in advance, which precisely divides a typical household consumption profile into individual hours of the contract term. In the event of hourly deviations in actual consumption from the predefined consumption profile, the spot price always applies: the hourly spot price is paid for excess consumption and the hourly spot price is reimbursed for reduced consumption.

Insurance effect. If households consume exactly as much as the predefined consumption profile specifies, they pay exactly the contractually agreed price - regardless of price movements on the spot market. In other words, they are fully insured against price peaks for these quantities. For example, if annual consumption is 3,000 kWh and the price is 20 ct/kWh, households pay €600 per year, regardless of how the spot market price moves.

Incentives for load shifting. If household consumption deviates from the agreed profile, households pay the hourly spot price for the additional quantities and are reimbursed the hourly spot price for reduced quantities. The fact that lower volumes are also reimbursed at the spot price means that the incentive for savings and load shifting is always determined by the spot price, regardless of the previously hedged profile. Anyone who avoids the expensive evening hours when charging electric cars will be reimbursed the full spot price for the corresponding hours (e.g. 30 ct/kWh) for the reduced consumption compared to the predefined profile. By contrast, only the significantly lower price for these hours (e.g. 5 ct/kWh) is due for charging the car on a windy night. This is shown as an example in Figure 5 as an example.

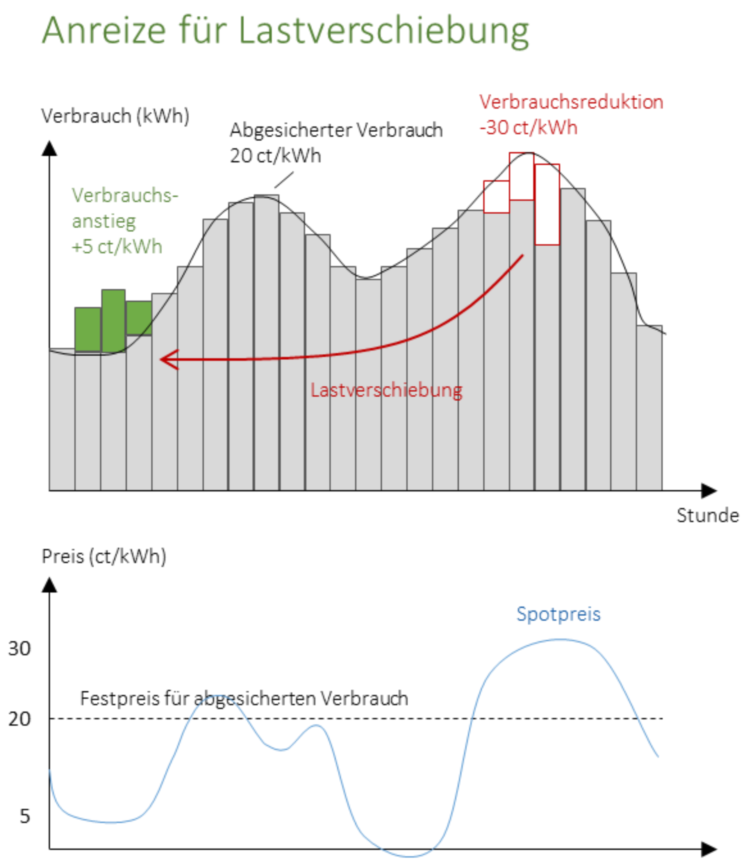

Figure 5. Households benefit from load shifts in the dynamic tariff with price hedging by taking advantage of daily fluctuations in the electricity price, for example to optimize the charging times of electric cars.

Incentives for situational energy savings. If a winter doldrums or a scenario like the one in Texas occurs in 2021 and spot prices peak at 1000 ct/kWh, even small savings compared to the predefined profile would be extremely attractive (Figure 6). This allows them to benefit financially from high electricity prices: They have purchased energy in advance (also) for these phases, which they can now implicitly resell through reduced consumption (or receive refunds in the amount of the spot price on reduced consumption). Specifically, one can imagine that in such a situation, customers receive a push message on their cell phone with the information: "You have purchased 10 kilowatt hours for today at a price of 20 ct/kWh. However, every kilowatt hour you save today will be reimbursed at 1000 ct/kWh. Here are three tips for effectively saving electricity..." If a person saves even just 1 kWh of their electricity consumption in such a situation, the financial compensation is enough to pay their electricity bill in full for five days. Instead of suffering from price peaks, households could benefit from them.

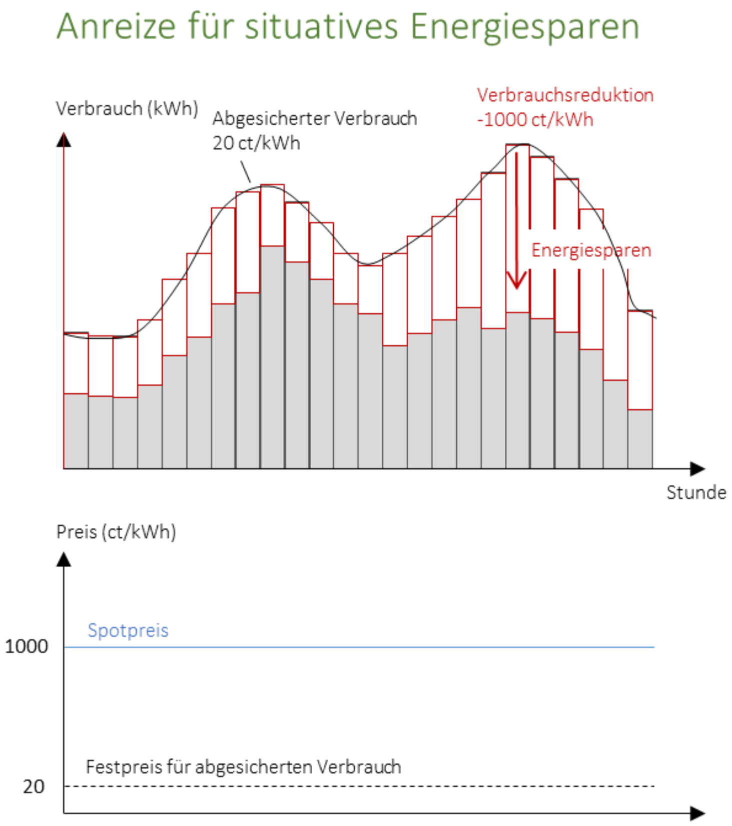

Figure 6. Households benefit in the dynamic tariff with price hedging from situational energy savings in times of very high electricity prices, e.g. during a dark doldrums.

3.2 The tariff as a hedging transaction

Three components. Conceptually, the contract can be broken down into three components: a contracted quantity, a fixed profile and differential quantity billing. Firstly, the contract is concluded for a fixed annual quantity. This is the opposite of traditional fixed-price contracts, which represent an option to purchase as much energy as you like. Only this switch to a fixed quantity enables the tariff to offer efficient situational energy-saving incentives, i.e. to incentivize reduced consumption in times of high prices and to make increased consumption in times of surplus electricity adequately affordable. Secondly, the tariff is based on a profile that is independent of the customer's own electricity consumption. It is important that the profile, or at least the calculation formula for the profile, is already defined in advance and is not influenced by the actual electricity consumption. In the following section, we discuss various possible designs of the profiles. The third important component of the contract is the settlement of the differential quantities on the basis of spot prices. This leads to efficient incentives.

Like bulk consumers. The tariff presented transfers the concept of hedging, which is common in industrial supply contracts and companies' own wholesale procurement, to the retail market. In other words, it enables private households to do what industry can already do. The principle of such tariffs could be summarized as "Hedge the bill, don't fix the price", i.e. hedge the electricity bill instead of fixing the price. In this sense, the dynamic tariff with price hedging can also be interpreted as a financial forward contract - a different view of the same tariff: households are exposed to spot prices, but receive financial compensation when prices rise, so that they are financially prepared for the high spot prices.

Undistorted incentives. Even if households are insured against the effect of price peaks on their electricity bill with this tariff and have a high degree of cost certainty, they still benefit from saving electricity when it is necessary from a system perspective. In economic terms, the full, undistorted incentives from spot prices take effect "at the limit" (i.e. for a marginal increase or decrease in consumption), while the previously hedged profile acts like an insurance policy that "pays out" precisely when prices are high. The key point here is that this implicit insurance pays out regardless of whether and how much was actually consumed, but is only based on the pre-defined profile and the pre-defined quantity. While the insurance effect leads to an overall high level of cost certainty for electricity bills, dynamic pricing means that customers can fully benefit from making their electricity consumption more flexible. Unlike the market interventions currently proposed by the EU in the event of a crisis, which provide for a price subsidy for 80% of the previous year's consumption, the incentives in the tariff proposed here are fully effective, i.e. for any reduction or increase in consumption in full.

Cheaper electricity purchase. The tariff makes it possible to leverage the added value of flexibility offered by heat pumps and electric cars. It leads to a reduction in the cost of purchasing electricity for such flexible consumption systems, as it is primarily the low-price hours that can be exploited. This means that anyone who systematically charges their car at night or during sunny midday hours will systematically benefit from lower electricity prices. This is the efficiency effect of the tariff, which increases economic welfare and benefits private households.

New risk sharing. The tariff redistributes the risks between energy suppliers and private households: distributors assume the price risk for the contractually agreed profile and volume, which they then hedge on forward markets. Private households, on the other hand, assume the risk of deviations in their own consumption from the previously hedged profile. This gives them the opportunity to benefit from price differences between different hours by cleverly timing their consumption - but of course they also bear the risk that high electricity consumption in particularly expensive hours will be at their expense. However, this makes the tariff cheaper for distributors and they can pass on this added value in the form of lower prices, especially if competition arises between different providers of this tariff model. However, such a change in risk allocation is not a zero-sum game, as it also creates new incentives and enables load flexibility, i.e. reacting to prices, and thus the aforementioned efficiency gain. The "cake" is therefore not only redistributed, but also becomes larger compared to fixed-price tariffs.

System benefits. In addition to the direct benefits for private households through load shifting, the tariff also leads to positive effects for the system as a whole, which can be classified economically as positive pecuniary externalities, i.e. externalities mediated by the market. They are therefore also desirable from an economic point of view. This is because load shifting and situational energy saving mitigate the problems that cause high prices. If many households have a flexible tariff and react to prices, prices rise less sharply during periods of scarcity and the need to maintain reserve power plants can be avoided or reduced. This lowers overall system costs and helps to mitigate price peaks, which also benefits private households *without* flexible loads.

3.3 Choice of profile and hedging quantity

Quantity & profile. Both the hedged quantity and the shape of the profile, i.e. how the hedged quantity is distributed over the individual hours of the contract term, are relevant for the insurance effect.

Independence from actual consumption. The hedged profile can either be predefined ex-ante (e.g. a standard household load profile or, in the simplest case, a base profile that is always the same) or dynamically adjusted to external factors, such as the weather, using a formula. However, it is important that the profile is not influenced by actual individual consumption, as this would undermine the incentives for load shifting and situational energy saving.

Differentiation of the profiles. The secured profiles could, for example, be differentiated according to whether it is a single-family house or an apartment, whether there is a heat pump in the household (or whether the connection is only used to supply a heat pump) and whether an electric car is used. Individual consumption profiles based on data from the previous year would also be possible, provided this is available. A radically simple variant would also be conceivable: a base profile, i.e. simply a "line consumption", possibly with monthly or seasonally differentiated hedging quantities to take account of typically higher consumption in winter.

Hedging on average, not every hour. Regardless of how the profile is defined, the actual consumption of individual households will deviate considerably from the predefined profile in almost every hour. Real load profiles are much more stochastic, as each individual switching on of appliances such as vacuum cleaners leads to strong fluctuations in the load profile. However, it is also not necessary for the profile and consumption to correspond one-to-one. Although every deviation between the two profiles has a direct impact on the electricity bill, it is not the hourly bill amount that is decisive for private households, but the monthly or annual bill amount, and this averages out randomly distributed deviations over the many hours of the year. Large fluctuations in electricity prices, for example as a result of an energy crisis, are therefore well absorbed in the vast majority of cases by a dynamic tariff with price hedging. This is also confirmed by quantitative analyses in Winzer et al. (2023) based on empirical smart meter data.

Hedged quantity. In addition to the profile, customers must also specify the quantity to be hedged when concluding the contract. This can be calculated automatically using structural factors such as household size and building type or based on the previous year's consumption. Estimates of consumption when the contract is concluded are also common in the fixed-price tariffs widely used in Germany. However, the consequences of incorrect estimates vary greatly: in the fixed-price tariff, an overestimation of consumption leads to a refund of the excessively high advance payments and an underestimation leads to an additional payment - in total, however, this remains a zero-sum game for private households. With the dynamic tariff with price hedging, on the other hand, an incorrect estimate of consumption results in the hedging being too low or too high and therefore has a material impact on the electricity bill.

Overinsurance possible. If private households are primarily interested in avoiding the risk of surprisingly *high* electricity bills, they can take advantage of this by deliberately hedging a larger amount than their consumption estimate, i.e. overestimating their consumption. This limits the risk of incurring a particularly high electricity bill in the event of excess consumption. Moderate, plannable additional costs in the event of favorable spot prices ("falling market") can thus limit the upside risk in the event of high spot prices and surprisingly high consumption volumes, in line with the motto "better to hedge too much in advance to be on the safe side". The electricity bill is then hedged upwards, but becomes more volatile downwards (i.e. "how low the electricity bill will be").

Over-hedging only problematic in the event of negative prices. However, there is a certain risk associated with overhedging in connection with negative prices on the electricity markets. This is because if a household has hedged more electricity for an hour than it actually consumes in that hour and electricity prices for that hour become strongly negative, then it has to pay for this under-consumption. So if prices become negative, the strategy of "playing it safe by buying too much" no longer works. Negative prices should not actually occur in an electricity system with a lot of renewable energy, because renewables have marginal costs of zero, so they should already be curtailed at a price of zero. Negative prices only occur if politicians continue to support renewables with distorting support systems. However, the problems of distortions based on support systems are currently the subject of much political debate, so it is to be hoped that in future European states will design support systems in such a way that they also expose renewable energies to price signals and no longer distort bids. There should then be fewer and fewer negative prices and the resulting problems for secure end customer tariffs should disappear.

3.4 Heating requirement and temperature-dependent profiles

Temperature risk. Household electricity consumption is temperature-dependent, especially when heating is provided electrically, e.g. by heat pumps. However, at high temperatures there is also an increasing need for cooling. During periods of particularly high electricity consumption, electricity prices are usually also particularly high. With a fixed profile, there is a risk that increased demand will be accompanied by high spot prices, resulting in price risks.

Temperature-dependent profiles. In order to take account of additional consumption, e.g. due to particularly cold winters, the tariff could be designed in such a way that the hedged quantity automatically increases depending on the temperature. If necessary, this could also be offered as an option, especially for the supply of heat pumps. Such a temperature-dependent profile could, for example, be designed in such a way that a certain amount of kWh per hour would be additionally secured for each degree Celsius (°C) below zero.

price incentives. In terms of its incentive effect, such a temperature dependency of the hedged quantity is unproblematic. This is because temperature is an exogenous variable over which consumers have no direct influence. Thus, a weather or temperature dependency of the hedged quantity would simply influence the payment of the insurance component of the tariff (i.e. stabilize the electricity bill), but without disrupting the effect of electricity prices as incentives for situational energy saving. Customers could therefore consume a lot of electricity during cold periods with full coverage, but would still be rewarded for savings with the spot price.

Established practice. At first glance, the temperature dependency of the hedged quantity poses challenges for electricity providers. After all, they would not be able to hedge themselves with fixed quantities, as they would have to provide more electricity in phases of particularly high electricity consumption and then usually also particularly high electricity prices. They would have to hedge this for their part via weather derivatives, for example. However, this task is not new for electricity distributors: the fixed-price contracts that are common today also present distributors with the same challenge - here too, increased consumption is accompanied by higher electricity prices.

3.5 What spot price?

Short-term markets. One aim of the tariff is to allow short-term price signals to take effect. However, there is not just one single short-term price signal on the electricity market, but several: The largest short-term market is the day-ahead auction ("previous day market"), but then trading continues continuously in the intraday market until a few minutes before delivery. There is also the balancing energy price, which is used to settle deviations from schedules and is only calculated retrospectively.

Day-ahead price. The day-ahead market is the lead market of the German short-term electricity market with the largest volumes. It therefore seems sensible to base the dynamic tariff on this price for the settlement of surplus and shortfall volumes. Another advantage of the day-ahead market is that it is a centralized auction and not continuous trading like the intraday market and can therefore absorb large volumes without triggering strong price reactions. The time at midday on the previous day also gives customers sufficient time to plan load flexibility and therefore offers at least short-term price certainty from the publication of prices.

Forecast of customer reaction. At the time of the day-ahead market, it is not yet clear how strongly customers will actually react to the spot price. Therefore, distributors offering such tariffs would have to forecast how consumption will turn out depending on the spot price and bid into the day-ahead spot market with a corresponding bidding function. With a sufficiently large customer base with a corresponding tariff, the behavior can easily be estimated statistically.

3.6 Interaction with time-variable grid charges

Time-variable grid charges. Alongside energy procurement, grid fees are the second major factor on the electricity bill. Small consumers normally pay a basic price and an energy charge that is multiplied by the annual electricity consumption. As part of the development of §14a EnWG, the Federal Network Agency has now announced that distribution system operators will have to offer a static, time-variable grid fee for flexible consumption facilities from 2024. Such "time-of-use" grid charges are already used in most European countries and are a useful instrument for incentivizing grid-friendly behavior.

Interaction. Time-variable grid charges can be usefully combined with dynamic tariffs. On the one hand, such grid charges may make optimizing consumption patterns more financially attractive if, for example, shifting electricity consumption to night-time hours not only saves energy costs but also grid charges. Load shifting is then given "more lift", so to speak (Figure 7). On the other hand, there is hope that dynamic tariffs, which pass on the spot price, will leverage the effectiveness of time-variable grid charges: if people or algorithms already react to the electricity price, they will also react to differences in grid charges.

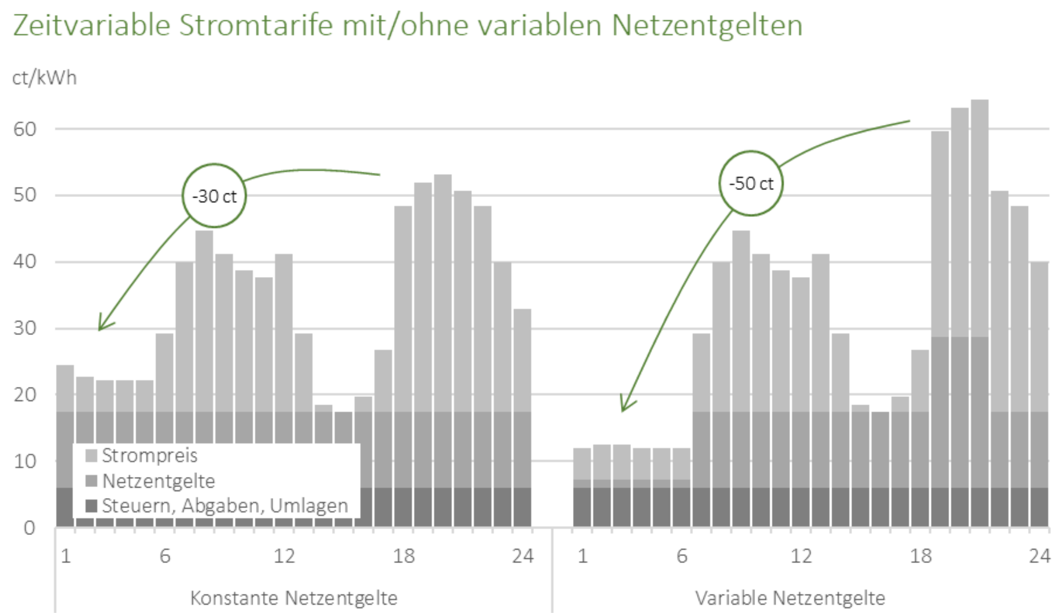

Figure 7. Dynamic tariffs with constant (left) and time-variable (right) grid charges (illustration). The grid fee structure is based on the proposals of the Federal Network Agency (2023) with three tariff levels and a maximum spread.

4 Contract term and right of termination

Consumer protection vs. consumer protection. The longer the contract term of a secured tariff, the longer consumers remain protected from price increases on the wholesale market. However, long contract terms also hinder innovation and competition and are in conflict with consumer protection regulation, which prohibits long contract terms. This means that one consumer protection issue (protection against electricity price increases) clashes with another (protection against long contract terms). This dilemma affects all long-term contracts, the dynamic tariff with price hedging proposed here as well as fixed-price or other contracts.

Need for hedging. The future electricity consumption of private individuals is subject to comparatively little uncertainty: Unless the household goes out of business, electricity consumption will continue in the future. The possibility of business closure or fluctuations in production does not exist here, unlike in trade and industry. From a risk perspective, it is therefore plausible that private households want very long-term price hedging against electricity price risks.

Avoidance of lock-in. However, consumer protection legislation prohibits very long-term contracts in order to prevent long-term commitment to unsuitable or ill-considered contracts. This also applies to electricity supply contracts, which in Germany may have an initial contract term of a maximum of two years. In addition, the German Civil Code requires a notice period of just one month for renewals beyond the initial contract term, for mobile phone contracts as well as for electricity and gas. In order to promote innovation and keep the market dynamic, such short notice periods are to be welcomed.

Conflicting objectives. However, the goal of long-term electricity price hedging conflicts with consumer protection legislation, as the former requires long contract terms and the latter short notice periods. This conflict of objectives could be resolved by abolishing retail competition and introducing a single, regulated, state-owned provider - which would, however, entail a number of other fundamental problems. Figure 8 visualizes this conflict of objectives.

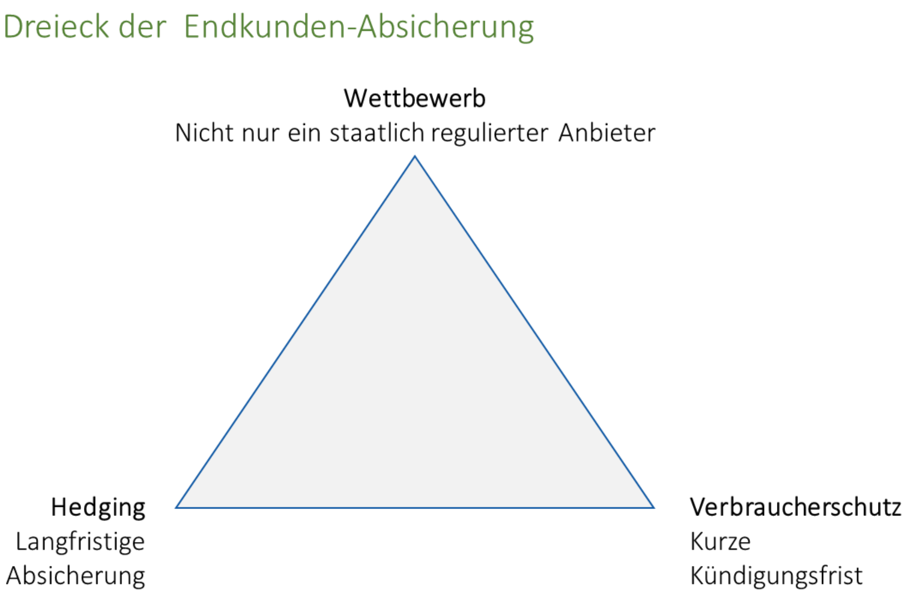

Figure 8. Conflicting objectives with regard to contract duration and consumer protection. Own illustration.

Exchange fee. One possible way out of this conflict of objectives could be fair, regulated switching fees. After all, anyone who hedges electricity prices in the long term but decides to switch to another supplier after a short time should be able to do so, but should have to pay (or receive) compensation that compensates for the price development on the relevant forward markets. If the price level is unchanged, there should be no switching fee. If prices have fallen since the contract was concluded, a fee is payable to the old supplier. Conversely, if prices have risen since the contract was concluded, it is even conceivable that the supplier will pay out to the customer in the event of early termination. This aspect of contract design also already exists in business with large customers: In the event of early termination of contracts, residual electricity volumes are valued and paid out "mark-to-market", i.e. based on the price development since the contract was concluded.

5 Regulatory hurdles and reforms

Need for action. In principle, dynamic electricity tariffs with price hedging can be introduced on a voluntary basis by electricity distributors without state regulation. Nevertheless, it makes sense to adapt existing and planned regulations in various areas.

No price fixing. In the electricity market reform proposed by the EU Commission at the beginning of 2023, some regulations go in exactly the opposite direction: instead of relying on flexible prices and private-sector hedging, the EU electricity market reform calls for a return to fixed-price tariffs. Energy suppliers are to be forced to offer fixed-price contracts. This is particularly relevant for countries where these do not yet or no longer exist.

Price intervention. In addition, the EU Commission's proposal provides for state intervention rights in retail prices for electricity in phases of particularly high retail electricity prices. The focus is therefore on price fixing and intervention instead of variable prices and prevention. To the extent that these price interventions are credible, they reduce the incentive for private provision: why should consumers choose a tariff with an insurance function if the state intervenes anyway? Such intervention penalizes individual provision and thus makes it less attractive.

No artificial markets. Instead of primarily incentivizing load flexibility via the variable spot price, the reform also relies on secondary additional instruments with which flexibility is to be financed by the general public and tendered separately, for example new support systems for flexibility. In our view, it would be more advisable to rely on a single, well-functioning electricity market and to base tariff structures on this instead of inventing new additional instruments.

Basic supply. It is conceivable that dynamic tariffs with price hedging could become the standard tariff in a future competitive basic supply for flexible systems such as heat pumps and electric cars. This would increase the number of devices that have incentives for price-optimized charging or heating. However, a regulation for the short notice periods in the basic supply would have to be found.

Linking to subsidies. Subsidy premiums for e-car charging stations or heat pumps could also be linked to the use of dynamic tariffs with price hedging. The general public has an interest in as many consumers as possible using such tariffs, as fewer backup power plants would then have to be kept in reserve, as a stronger demand response could be expected in hours of scarcity. In addition, the likelihood of political demands for ex-post intervention in the electricity market during price crises could be reduced if the usual electricity tariffs had a hedging function from the outset.

Permission for longer contract periods. In order to be able to offer longer-term protection against electricity costs, it would be desirable if electricity tariffs could be concluded for longer than is currently the case. Although a contract term of just one or two years would also provide effective protection against dark doldrums and other short-term price spikes, it would only offer limited protection against an energy crisis such as that of 2021/22. Maximum contract terms of 2 to 5 years and the option of entering into longer commitments after the minimum contract term would appear to be worth considering. However, such long contract terms should always be accompanied by the possibility of switching at short notice, albeit with the payment (or receipt) of switching fees.

Regulated exchange fees. It is conceivable that, on the one hand, state regulation could enable switching fees or payments (in order to, as described in section 3.5 to make short notice periods possible in the first place in the case of long price insurance), but on the other hand regulate their level in such a way that they must reflect fair forward price developments.

PPAs and mandatory hedging. The EU electricity market reform 2023 focuses on PPAs and long-term contracts. It also contains regulations to oblige distributors to engage in long-term hedging. This is intended to stabilize electricity costs and provide RE investors with buyers. However, distributors are only able to conclude long-term PPAs on the purchasing side if they are also allowed to conclude longer-term contracts with end customers on the sales side. The introduction of longer-term electricity contracts would therefore also facilitate the conclusion of PPAs by distributors and promote the expansion of RE.

Need for political action. The aforementioned political proposals would make a dynamic tariff with price hedging more attractive and sensible. However, the introduction of such a tariff model is also possible without reform. With this brief study, we hope to make a contribution to promoting decentralized flexibility and thus the energy transition, while at the same time providing private households and small businesses with certainty about their electricity costs.

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