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Capacity-based grid tariffs

TARIFF 2.0

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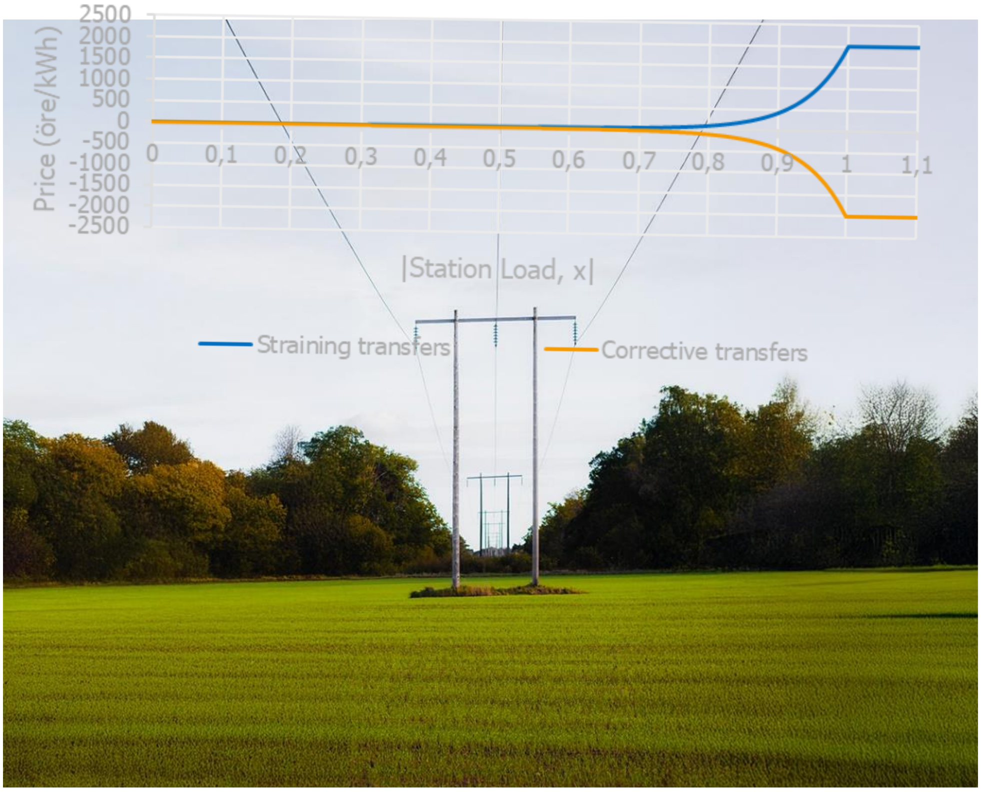

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Preface

Sweden's electricity mix is nearly fossil-free, yet significant challenges remain. Flexible resources will be critical, not only from a systemic perspective but also from a locally, where residents have greater potential to actively contribute to the rapid energy transition.

Electricity grid tariffs impact everyone. Unlike electricity trading, current grid tariffs offer limited incentives for flexibility. There is significant potential to redesign them to encourage more dynamic and efficient energy use.

This project explores a new conceptual approach to electricity grid tariffs. Its goal is to develop a tariff system that reflects actual grid station behaviour and provides meaningful incentives beyond the traditional flat-rate models. A failure to innovate could limit the ability of subscribers to respond to spot prices, impeding renewable integration. Our proposed solution complements spot price signals and addresses local challenges.

We are also exploring the development of a new voltage control system and foresee the need for an AI-based engine capable of managing short-term variable costs and congestion at the grid level. Additionally, we emphasize the need for automation and user customization.

Project manager for Tariff 2.0 and technical project manager at Energicentrum
Magnus Jennerholm, Visby, 2025-05-19

Summary

This report presents the Justice Tariff model for a capacity-based electricity grid tariff developed through the Tariff 2.0 project, building on insights from Tariff 1.0. The project is a collaboration between Energicentrum Gotland, Gotlands Elnät, Plexigrid and Ngenic, and is being tested on Gotland.

The model aims to increase grid flexibility, reduce costs, and facilitate the renewable transition. A long-term trial began in March 2025 to verify and further develop the model under real-world conditions.

The Justice Tariff consists of three components:

- **Energy Fee (per kWh):** Reflects local Station Load and short-term grid stress. It disincentivizes straining energy transfers and rewards corrective ones.
- **Justice Fee (per kW):** Equalized across the DSO grid, ensuring fair cost distribution based on connection size, adjusted for Energy Fee outcomes.
- **Customer-Specific Fee:** Fixed charge for metering, billing and related services.

Due to current Swedish law prohibiting localization signals, the tariff model is not yet legally compliant. Nonetheless, it aligns with the intentions of both Swedish law and Energy Market Inspectorate (Ei) regulations. Legislative changes under discussion may eventually support its implementation.

The tariff encourages optimal use of existing connections and discourages oversizing. It formally acknowledges shared connections, incentivizing aggregation (e.g., in apartment buildings) and thereby improving grid utilization.

AI-driven pricing signals, tailored to each station's forecasted load, are delivered to test-pilots via a custom interface. Early results suggest socio-economic benefits, such as decreased expansion needs and better integration of variable renewables.

Future development priorities include voltage control and enhancing AI capabilities for broader grid optimization.

Content

1. Introduction

Energy Transition and Grid Challenges

To meet future energy needs, electricity grids have historically been over-dimensioned to handle the most extreme load peaks. However, with the continuing trend of electrification, the need for balancing through flexibility is rapidly increasing. Without flexibility, it becomes increasingly difficult to maintain operational margins. Flexibility is essential to reduce transmission losses, prevent blackouts, and lower the overall cost of the energy system.

Focusing solely on physical grid development is neither cost-effective nor sustainable. Therefore, it is critical to use grid tariffs more strategically to reduce the need for unnecessary development. Only after maximizing the potential of tariffs should additional solutions such as flexibility markets and conditional agreements be used (Blomqvist, et al., 2024; SWECO, 2024; Ei, 2025).

Challenges with the current system

A significant challenge has been the growing need for grid reinforcement, particularly due to the expansion of solar photovoltaics in weaker grid areas and the broader electrification process. These developments are being hampered by poorly structured economic incentives, for example:

- **Unconditional tax exemptions** on exported household solar energy (per kWh): These provide guaranteed compensation, even when generation exceeds demand, contributing to negative spot prices.
- **Energy tax per kWh**: This acts as a barrier during times of high energy availability and low demand, thereby contributing to negative spot prices.
- **Non-capacity-based grid tariffs:** As spot price-related flexibility increases, the risk of localized grid overloads also rises. The absence of capacity-based incentives can make flexibility counterproductive. Flexibility is therefore not always welcomed with open arms, despite the critical need for it – where the lack of flexibility also contributes to negative spot prices.

Capacity-based tariffs correct these imbalances by discouraging straining energy transfers and encouraging corrective ones. This mirrors the polluter-pays-principle (PPP) and emphasizes that incentives should align system-wide, avoiding adverse interactions between different regulatory goals. Nature-based solutions (NbS) serve as a parallel, where solutions must contribute holistically without undermining other objectives.

Need for new solutions

Despite the upcoming challenges, grid capacity is often underutilized – "we are running with half-full trains", as a Vattenfall manager observed (Takács, 2023). This underuse of such an expensive resource is both economically and environmentally wasteful.

Sweco (2023) estimates that SEK 900 billion in grid investments will be needed in Sweden by 2045, half of which will be for local grids. While this estimate already assumes a certain level of flexibility, there is likely additional potential to reduce investment needs by using smarter, more targeted incentives that influence all grid subscribers.

The Energy Market Inspectorate (Ei) notes that many existing grid tariffs are based on conditions from 10-20 years ago (Ei, 2022a). While new regulations are being developed, all grid companies in Sweden are required to implement power tariffs by 2027.

These tariffs are a step forward, particularly due to their requirement to lower Energy Fees. Traditionally, Energy Fees were inflated well beyond the short-term marginal cost-basis allowed under new regulations, impairing energy use and renewable integration – similar in effect to the Swedish energy tax.

The new regulation also requires a time-dependent power fee, although geographic differentiation is still prohibited by law. Instead, the fee will apply during high-load periods across the DSO grid. While this aims to reduce peak demand, it may lead to inefficient grid use outside of the actual high-load zones. If power tariffs succeed in increasing overall grid efficiency, high-load instances may become more common – thus, the lack of location-based signals could eventually limit further improvement.

2. Project Description

The Tariff 2.0 project builds on the groundwork laid in Tariff 1.0. Both initiatives are part of Energicentrum Gotland's ongoing effort within the hub for storage and flexibility to promote a more resource-efficient society. They are co-funded by the European Regional Development Fund, through the Swedish Agency for Economic and Regional Growth, and with 1:1 funds through Region Gotland, financed by the state.

Energicentrum Gotland is the project owner and Gotlands Elnät AB is project partner.

Tariff 1.0 ran from September 2023 to January 2025 and primarily focused on designing a foundational tariff model and control infrastructure. This included grid analysis, communication systems, a pilot customer interface, and an early development of the key energy price signals based on local grid conditions. A precondition for the project was the early rollout of smart meters (initiated due to a statutory requirement) in the selected test area.

Tariff 2.0 continues and extends this work over a 15-month period starting in February 2025 and concluding in April 2026. The focus is on validating and refining the Justice Tariff model through a long-term field test, involving real users and operational conditions. This includes dynamic pricing, shared connection incentives, and the integration of AI-based forecasting tools.

The test area consists of about 1,700 subscribers located downstream from the Kräklingbo distribution station on Östergarnslandet, Gotland. Ten pilot users are actively involved, distributed across five grid stations, and represent a mix of small and medium-sized enterprises, such as farms, a grocery store, a smokehouse, and a wastewater treatment plant.

Advanced metering and automated control systems are used to enable both autonomous and manual subscriber responses to grid conditions. Technologies include smart heat control, defrost cycle control, electric vehicle charging management, and battery storage optimization. While some systems are controlled manually, others operate automatically via integrations with software from Ngenic and Home Assistant.

Although voltage control was not included in the scope of Tariff 1.0, it has become a priority area for development under Tariff 2.0. Additionally, the project now aims to optimize the interface between local station signals and overarching grid needs through enhanced AI tools. These tools are central to providing dynamic price signals based on real-time grid stress and forecasted loads.

In summary, Tariff 1.0 developed the initial tools and concepts, while Tariff 2.0 operationalizes and tests them in a comprehensive real-world setting, with the Justice Tariff being the most refined and policy-aligned outcome of the effort.

3. Regulatory Challenges and Proposals

Swedish law prohibits geographic price differentiation (i.e., localization signals). Although, the law does support the development of wider boundary experimental tariffs such as the Justice Tariff. These are only allowed on a limited number of subscribers where the aim is to develop more efficient tariffs.

However, the regulatory constraint against localization signals is increasingly seen as a bottleneck for efficient grid utilization and renewable integration.

3.1 Regulatory Barriers to Location-Based Pricing

A key regulatory reform recommended by the project is to allow the use of localization signals at all grid levels. The Energy Market Inspectorate (Ei) has already proposed this change in previous work (Tvingsjö, et al., 2020) and is revisiting the topic in a study due for completion in 2026 (Ei, 2025).

Allowing localization signals would enable grid operators to send geographically differentiated price signals. These would incentivize subscribers to respond to both local and system-wide grid constraints. Importantly, the project asserts that this can be implemented in a way that does not penalize subscribers in weaker grid areas. The cost will nevertheless be more prone to increase in these areas – for those who fail to act flexibly, while the opposite is true for those who do act flexibly with the project's Justice Tariff.

3.2 New Distribution of Costs

This section outlines how the Justice Tariff model reinterprets the allocation of electricity grid costs, compared to the guidelines issued by the Energy market Inspectorate (Ei). The revised distribution is structured to reflect cost causality more accurately and promote efficient grid usage.

Overview of Regulatory Cost Categories

Table 1 below presents an overview of the current legislation (Ei, 2024), with four cost categories, tariff components and distribution methods.

Table 1. Overview of Ei's regulations on how a grid company's costs should be distributed.

	Cost category	Distribution method
1	Residual costs – Primarily capital costs for the existing infrastructure.	Should be distributed via fixed fees based on subscribed power or equivalent.
2	Short-term variable costs – Mainly energy losses and grid usage fees paid to other operators.	Should be recovered through an Energy Fee. Can be time-differentiated.
3	Customer-specific costs – Costs for metering, billing, and customer-specific grid costs to other grids.	Should be charged as fixed, cost-reflective and individualized fees.
4	Forward-looking costs – Anticipated costs for grid expansion and increased overload risk. Includes power fees to other grids.	Should be allocated through a time-dependent power fee.

Justice Tariff Allocation Principles

The Justice Tariff retains the same overarching cost categories but modifies the allocation mechanism.

Table 2. Overview of the Justice Tariff's allocation of the grid company's costs.

	Cost category	Distribution method
2.1 4.2	Controllable short-term variable costs. Reactive forward-looking costs.	Distributed with a location- and time differentiated **Energy Fee**. It provides dynamic incentives for corrective behaviour.
1 2.2 4.1	Residual costs. Non-controllable short-term variable and invariable costs. Proactive forward-looking costs.	Covered by the **Justice Fee**, which is modified by the Energy Fee and thereby creating an even distribution per kW of subscribed connection power across the grid.
3	Customer-specific costs.	Remain unchanged and are recovered via a **Customer-Specific Fee**.

Justice Tariff Refinements

- Excluding invariable non-controllable core losses in transformers from the Energy Fee, since these do not vary with usage and should be considered residual costs.
- Excluding variable non-controllable non-ideal energy losses which should be considered residual costs, since these occur as a result from a non-optimized grid.
- Recognizing that variable controllable short-term marginal costs are only part of the picture; future risks like overloads also justify location-aware pricing.

A tabular comparison of the Ei guidelines versus the Justice Tariff allocation helps clarify the changes:

Table 3. Overview of differences between Ei guidelines and the Justice Tariff.

Cost category	Ei Allocation	Justice Tariff Allocation
Residual	Fixed Fee (per kW)	Justice Fee (per kW)
Short-term Variable	Energy Fee (per kWh, can be time-differentiated)	Split: Controllable via Energy Fee (per kWh, time + location); Non-controllable via Justice Fee
Forward-looking	Power Fee (per kW, time-differentiated)	Split: Reactive via Energy Fee; Proactive via Justice Fee
Customer-Specific	Customer-Specific Fee (fixed)	Customer-Specific Fee (unchanged)

This distribution ensures that dynamic behaviour is encouraged through the Energy Fee, while fairness and cost stability are maintained via the Justice Fee.

3.3 Grid Benefit Compensation, Not Exclusively for Producers

In Sweden, grid benefit compensations are traditionally used to compensate producers for measured cost reductions specifically as a result of electricity generation. It is a way to acknowledge the local value their generation adds to grid stability. However, the Justice Tariff expands this concept.

The project proposes that both consumers as well as producers, should be eligible for grid benefit compensations when their energy transfers actively support local grid balance. For example, when grid strain is caused by over-generation of solar energy, consumption (i.e. utilization) is required to reach towards a more balanced local grid.

The cost and compensation per kWh for both consumption and generation is always equal in size but differ in the sign (+/-), forming a positive Energy Fee interpreted as a cost, and a negative Energy Fee interpreted as a financial compensation. In this way, the model creates symmetrical incentives: straining transfers are charged, while corrective transfers are compensated at the same price level, based on station-specific load forecasts.

This principle reflects a more holistic view of system value, where both imports and exports can contribute to grid efficiency depending on context. It also improves fairness by extending the benefits of flexibility beyond a narrow definition of "production".

4. The Developed Tariff Model

The Justice Tariff is structured around three interrelated components:

1. **Energy Fee (per kWh)** – A dynamic, station-specific price signal that reflects local grid load and directionality of power flow. It discourages transfers that add strain and rewards those who can help relieve it.
2. **Justice Fee (per kW)** – A capacity-based cost allocated proportionally across all subscribers, adjusted for station-level differences in Energy Fee collection. It ensures a fair distribution of infrastructure and long-term costs.
3. **Customer-Specific Fee** – A fixed cost per customer to cover for metering, billing, and administrative services. This fee is independent of usage patterns or connection size.

Together, these components are designed to align individual incentives with grid needs, encourage flexible behaviour, and ensure that cost distribution remains both fair and reflective of actual system use.

Key Design Principles

- **Hybrid Energy/Power Fee Structure:** The Energy Fee integrates elements of both energy and power pricing. It reflects not just volume but also timing, location, and system stress. This enhances responsiveness to local grid needs.
- **Station-Level Cost Balancing:** The Justice Fee acts as a stabilizer. It ensures that all subscribers pay the same average cost per kW of capacity, regardless of whether their station has a high or low Energy Fee collection.
- **Simplicity for Users:** Despite its sophistication, the tariff is designed to be user-friendly. Automation tools simplify interaction for subscribers, making participation accessible without requiring constant attention.
- **Regulatory Alignment:** The model maintains compatibility with Ei's overarching cost categories and policy objectives, while introducing location-aware refinements that anticipate future legislative support.

This tariff structure encourages smarter grid usage, supports distributed energy resources, and provides a scalable pathway towards a flexible, cost-reflective and fair energy system.

In the following sections, the Justice Tariff components are explained in greater detail.

4.1 Energy Fee

The definition of an energy fee is that it is a cost on energy (SEK cents/kWh). The Justice Tariff's Energy Fee is unique for every grid station and time instant, where it is based on the forecasted transformer load. A future goal is to also include voltage control and station-specific overhead grid pricing in the Energy Fee.

4.1.1 Consistency with Regulatory Guidelines

Ei (2024) guidelines states that the **energy fee** shall charge for marginal costs of transmitting electricity in the grid. The cost shall reflect short-term variable costs. The energy fee may be time-differentiated. If necessary, additional variable marginal costs for transmissions may be included.

- The Justice Tariff's *Energy Fee* meets the requirements of the energy fee guidelines. However, only controllable ideal energy losses remain as a basis, where non-controllable variable (non-ideal-) and invariable (core-) energy losses are moved to the Justice Fee.

Ei (2024) guidelines states that the **power fee** shall allocate forward looking costs on cost-reflective and objective grounds – linked to a certain straining behaviour. The fee shall be time-differentiated, and based on *total* grid load (i.e., localization signals are prohibited). The signal shall give subscribers a chance to reduce their load in order to avoid excessive grid investment needs.

- The Justice Tariff's *Energy Fee* meets the requirements of a power fee as it is time-dependent and load-based. However, it does not meet current regulations as it is geographically dependent. Moreover, it is not cost covering for all forward-looking costs. Only a functional risk-cost remain of the forward-looking costs – called *reactive* forward-looking costs, while the remainder of forward-looking costs – called *proactive* forward-looking costs – are moved to the Justice Fee.

4.1.2 Unique Station-Specific Price-Curves

It may be more or less sensitive for one station transformer compared to another, to run at various load levels. It may entail different relative levels of energy losses and over-load-risks. Therefore, every unique station should have their own unique price curve adapted to local situations, as cost-reflectivity varies with local grid properties, for example voltage level and transformer type.

4.1.3 Optimized Electricity Market

These fine-tuned energy prices will pave the way for a well-trimmed energy market. When loads are normally low – grid prices will also be low. If grid prices are high, it is a signal to start moving the centre of attention from the spot price to maintaining a stable electric grid.

In this way, cost-reflectivity stimulates an increased flexibility for demand in times when cheap solar- and wind energy is overflowing the electricity market. In turn, this entails a possibility to turn up spot prices, improving profitability margins for variable energy producers. This will benefit the energy transition and energy security, with an increased potential to rely on flowing energy sources.

If these flowing energy sources are the best for humans and the environment, they should also be the relatively cheapest in the long-run, if or when polluter-pays-principles are applied.

4.1.4 Mirrored and Functional Price Signals

The Justice Tariff's Energy Fee creates mirrored price signals: A subscriber's net energy transfers over the measuring time period in the station's dominant power flow direction (straining energy) incur a positive cost, while energy flows in the corrective (non-dominant) direction yields an equal but negative cost, i.e. a reward or compensation.

This structure is functionally effective: it always creates an incentive to move toward station-level energy balance, with no cost applied when the net load is zero.

However, this symmetry introduces a deliberate departure from strict cost-reflectivity.

Example 1: Net-zero at subscribers' level

The station net load is zero over a measuring time period, measured on all subscriber-meters in a station, i.e. there are exactly equal amounts of exports and imports measured on these meters. However, the station as a whole must still import power to cover transformer core losses and intra-station energy losses. Therefore, imports will be straining, meaning there will be a grid energy cost for imports.

However, the net station-Energy Fee income for the DSO will be zero since charges for imports exactly equals compensations for exports. The same situation will also arise if no energy was transferred. If they did not transfer energy, there was only core energy losses in the transformer to cover for – while if there were transfers, there will be more costs for increased energy losses. In the extreme, where gross transfers are maxed to the level of connection power capacities, intra-station energy losses would have been much larger compared to if no energy was transferred. The latter means that the subscriber gross utilization level is maxed.

Example 2: Net-zero at station level
Assume instead an over-production within the station that exactly equals that of all intra-station energy losses occurring, including core-losses. On the subscribers' meters, the net-dominant power flow direction would be exports. But since the Station Load is zero, the grid-energy price will be zero for both imports and exports. Nonetheless, there will be costs for the DSO to cover for energy losses, with relatively higher costs the higher the gross utilization level is.

Example 3: Higher station- and subscriber gross utilization level
Getting the Station Load to higher levels is due to one of imports or exports being dominant. If for example imports is drawing the Station Load to imbalance while there are no exports at all (i.e. net-power flow equals gross power flow), then energy losses will be correctly priced via the Energy Fee. When instead both imports and exports are flowing at the same time (i.e. subscriber gross utilization level increases, where the net power flow is less than the gross power flow), then energy losses will again increase beyond cost-reflectivity.

These three examples shed light on an important question, following a design-based subsidy for energy utilization:

> Energy efficiency improvements are one means to reach a more sustainable society, but this Energy Fee design promotes increased use of energy.
> – Is it a counter-productive design?

Discussion:

- A defence for the design is that it promotes optimally sized power capacities, which in turn will free up space for others who can better utilize a limited grid capacity space. This can be both an energy efficiency improvement and a resource efficiency improvement, where grid reinforcements require both energy and resources.
- The Energy Fee can theoretically be updated at a later stage to better take into account losses due to gross power flows. But keeping this subsidy for gross flows is also a subsidy for an increased self-sufficiency, which is also an incentive for minimized system-wide energy losses.
- In the process of removing obstacles (misplaced energy prices) for an optimized energy market, it gets even more important to add prices directly on the source of problems

(to obey the polluter-pays-principle) and to promote solutions that are neutrally or positively aligned with all sustainability targets (i.e. promote nature based solutions).

Conclusions:
The Energy Fee design's deviation from cost-reflectivity is deliberate to promote functionality and to improve gross utilization levels. In this way, it promotes self-sufficiency, where stations with the largest gross power flows get away with relatively more subsidised energy costs.

Costs for energy losses is only a relatively small part of all grid costs. It might therefore also be reasonable to set Energy Fee prices to zero for as long as there are no risks for it, where all short-term variable costs, except reactive future-looking costs – are transferred to the Justice Fee. However, drawing the line where higher gross flows are promoted over net flows, could also be a communicative advantage that promotes energy self-sufficiency.

When a station is close to perfectly balanced, the net power flow is close to zero. Mainly gross power flows (i.e. exports roughly equal imports) can reach higher during these conditions. Since the current Justice Tariff's Energy Fee design promotes functionality and efficient utilization, it dismisses any actual energy costs that do arise during these circumstances. These costs are instead transferred and charged via the Justice Fee.

4.1.5 Motives for the Energy Fee Basis

Firstly, the Energy Fee – as described in last section – is only based on net power flows, i.e. which are flows that impact station balance. All flows beyond net power flows, are gross power flows – which are exempted from Energy Fee costs. This is the result when the energy price is set based on Station Load, i.e. station transformer balance.

Net power flows are charged in relation to the following cost-base:

- Reactive forward-looking costs
- Controllable energy losses

Costs that are not charged by the Energy Fee, that are transferred to the Justice Fee:

- Losses beyond net-, and net-zero flows
- Un-controllable core energy losses
- Non-ideal energy losses
- Proactive forward-looking costs

Motives to exempt the first of the four categories above has been described in the previous section. The reasons to move also the three other cost categories to the Justice Fee is shortly described below.

Core Energy Losses

In grid stations, transformers are installed to adjust voltage levels through their windings. When a transformer is connected to the grid, alternating current and voltage induce eddy currents and cause energy losses in its iron core. These losses, known as core losses, occur even when the net energy flow through the transformer is zero. They are constant and independent of the load.

Properties of Core Energy Losses:

- Non-variable
- Non-dependent on utilization
- Non-controllable for subscribers

Conclusions:
The Energy Fee is a behaviour-based charge. To charge for core losses in the Energy Fee would therefore not be cost-reflective. It should instead be counted as an operational cost linked to the built grid, to be charged for via the Justice Fee.

Non-ideal energy losses

Energy losses occur in ordinary electricity lines even if they are optimized for the task. Energy losses still occurring in an optimized setting are called ideal, while all energy losses beyond this are called non-ideal.

Background:
The Station Load forecast is a stand-alone feature, where the exact reasons behind has no further meaning for the prices. Thus, energy prices in a station with above normal non-ideal energy losses still has a way to maintain stability – even with lowered energy costs related to a certain Station Load. The result is reduced energy prices for optimally functioning stations. It helps to maintain incentives at a high level for those who can utilize energy when spot prices are low. When imbalance problems exist, the Energy Fee's exponential relation to Station Load is a built-in economic incentive alarm to avoid station overloading (providing there is enough automatic flexibility that can react).

Properties of Non-ideal Energy Losses:

- Higher-than-normal losses
- Varies with transfer volume
- Non-uniform over the DSO-grid
- Its existence is non-controllable for subscribers

The occurrence of non-ideal energy losses is not something that subscribers can influence. The difference if non-ideal energy losses were to be included would be a somewhat higher grid energy price. Many other things could also be included as an approach to relate general patterns of Station Load-related costs to the Energy Fee price. To promote grid utilization however, the Justice Tariff uses a trimmed Energy Fee where such add-on costs are moved to the Justice Fee.

Conclusion:
Keeping costs for non-ideal energy losses in the Energy Fee would increase energy costs marginally and thereby reduce grid utilization marginally. Removing it makes the Energy maximally trimmed to promote high grid utilization. In this way, non-ideal energy losses are instead treated as operational costs linked to the non-optimality of the built grid, to be charged for via the Justice Fee.

Proactive Forward-Looking Costs

Forward-looking costs can be defined as costs relating to future physical grid requirements, which in a way can be linked to a certain behaviour, but perhaps more so to a general need highlighted by the society.

Background:
Ei (2022a) states that forward-looking costs should be charged for via a power fee. The fee should be time-differentiated and based on overall grid-load. The most common way to do this is to pin-point instances in time where the overall grid has more load-based problems and then use measured maximum power during these instances as a basis for the power fee.

Firstly, to reduce power is probably only important in some parts of the grid. And perhaps the power did only need to be fine-tuned to avoid over-loads. A general threat on usage – where maximum power is to be the basis for a power fee – is therefore not cost-reflective. It is merely a method with little relevance for distributing costs for a planned grid development.

To seriously avoid overloads and needs for strengthened grids, it should be clearly shown with higher energy prices when and where there are problems. If somewhere in the grid, the grid's dimensions are weak in relation to the needs – will it then be the fault of those who are connected to these weaker grids? In a way, - Yes. In another way, - No. Historical costs for different subscribers differs a lot. The Justice Tariff's philosophy is to have every subscriber in the grid on the same economical level in relation to connection capacity – once they are connected. The tariff should therefore be complemented with a cost-reflective connection fee, which reflect costs based on a somewhat generalized reality, and perhaps also on the will of the society to develop grids in different areas.

It is also acknowledged – in the same way as Ei (2022a) does, that it will not be possible to use the energy fee to cover for costs beyond short-term variable costs. Such increased energy costs would reduce energy transfers in advance, before the costs had been covered for.

Proactive Forward-Looking costs as a Basis for the Energy Fee:

- Is questionable if it is cost-reflective
- Will reduce incentives to transfer energy
- Will reduce cost-coverage
- Will lower grid utilization beyond real needs
- Will lead to a generally reduced dependence on electric energy

Conclusions:
The Justice Tariff's Energy Fee uses reactive forward-looking costs as a basis to clearly show with high energy prices where and when real imbalance-problems exist. The heightened energy prices for these situations will be clearly communicated – at least to those who have flexibility capacity. This enables utilization at high levels in all places and at all times. Where and when reduced power flows actually are required, there is a way to maintain high utilization with a margin below allowed maximum levels.

Reactive future-looking costs is merely a functional cost-relation with Station Load used to stage a necessary behavioural response. Other future-looking costs are called *proactive*, which are required to cover for all planned grid development costs that are not covered for by the Energy Fee. This cost category is instead charged via the Justice Tariff's Justice Fee.

4.1.6 Customer Interface

Next-day price signals are published approximately three hours after spot prices are released, meaning that subscribers have access to information for the next 24 hours around 4 p.m. the day ahead. Each grid station receives unique energy price signals, which in Sweden theoretically could be generated every quarter of an hour. In the project, a 30-minute interval is chosen to match power quality and energy measurements taken every 10 and 15 minutes, respectively.

The Station Load, which is the basis for pricing, is a technical detail that is not normally displayed to subscribers. For those who want to control their loads manually, the price signals are displayed in an app, where they are combined with the spot price to provide a simple price for utilization and one for generation. However, automated control is most effective, as it reduces the need for manual adjustments. When the settings are properly adjusted, subscribers control their electricity usage to minimize costs, which at the same time benefits the stability of the electricity grid and the environment.

4.1.7 Artificial Intelligence (AI) to Predict Station Load

A subscriber's price signals are based on the time-differentiated Station Load in the local grid station to which the subscriber is connected. The Station Load shows how much and in what power flow direction the transformer in the grid station is loaded. To predict these Station Loads, measurement data from grid stations and their transformers is used to train an AI engine. The AI engine is an advanced algorithm based on *artificial intelligence*, with the ability to learn and improve its forecasts.

The AI engine is trained with data on weather, changes in electricity use over time, spot prices and the price signals that have been generated previously. The grid Energy Fee is often insignificant during normal load in comparison with spot prices and the energy tax. Only during high load will grid Energy Fee price signals affect straining and corrective energy transfers, which in turn changes the load – and recursively the grid Energy Fee prices. Therefore, with each calculation, the prices are adjusted based on changes in forecasted Station Load, which leads to new forecasted power flows. This is an iterative process that continues until the price changes between cycles become so small that the forecast is deemed stable. The result is the final Energy Fee prices, uniquely adapted for every specific time instances and station, for the next day.

4.1.8 Energy Fee Prices based on Station Load

The future Energy Fee will also include energy quality control to balance voltage and a station-specific load adjustments to align with overhead grid-system requirements.

Currently, the single basis for the Energy Fee is transformer Station Load, which is determined by Formula 1 below. The Station Load gives a negative value when the transformer is exporting energy (flow up in the grid network structure), while it is a positive value when it imports energy (flow down in the grid network structure).

Formula 1. Station Load (x) is a unitless capacity-based measure of balance in the station transformer.

$$Station\ Load, x = \frac{imports_{station} - exports_{station}}{capacity_{station} \cdot t}$$

In its original form, the Station Load is a value between -1 at the net capacity ceiling for exports, and +1 at the net capacity ceiling for imports in the local grid station. The value is then compared with the subscriber's electricity utilization (import, $E > 0$) and generation (export, $E < 0$) to determine whether the subscriber's transmission is in the dominant and straining direction (E and x have the same sign) or in the corrective direction (E and x have different signs). When knowledge of which directions are straining and corrective is assumed, it is more practical to refer to the Station Load in absolute terms ($|x|$), which varies between 0 and 1.

Figure 1 below shows so-called loss equivalents per kilowatt-hour of straining transmission. The term "loss equivalents" is used to represent both the magnitude of the ideal energy losses (category 2.1) at low Station Loads, and the magnitude of the reactive forward-looking cost- (category 4.2) *loss equivalents* at high Station Loads, in terms of the absolute of Station Load values.

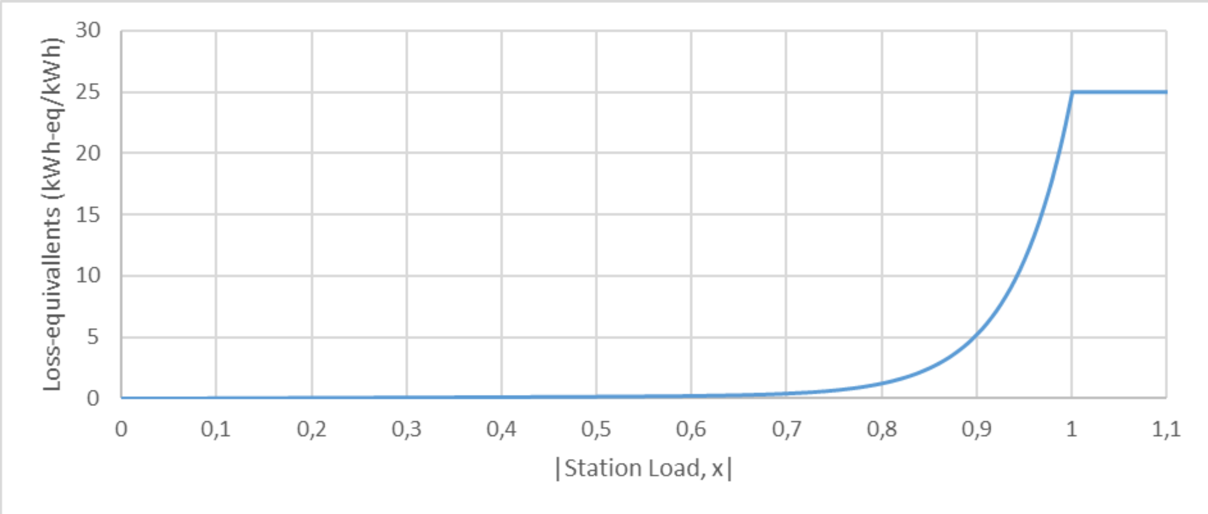

Figure 1. The curve in the diagram represents ideal energy losses (category 2.1) at low Station Loads and reactive forward-looking costs (category 4.2) expressed as loss equivalents at high Station Loads. With the maximum price setting, subscriber responsibility ends beyond Station Load |x|=1.

To obtain the price signal for straining transfers, the curve also needs to be multiplied by the DSO's loss price (öre/kWh).

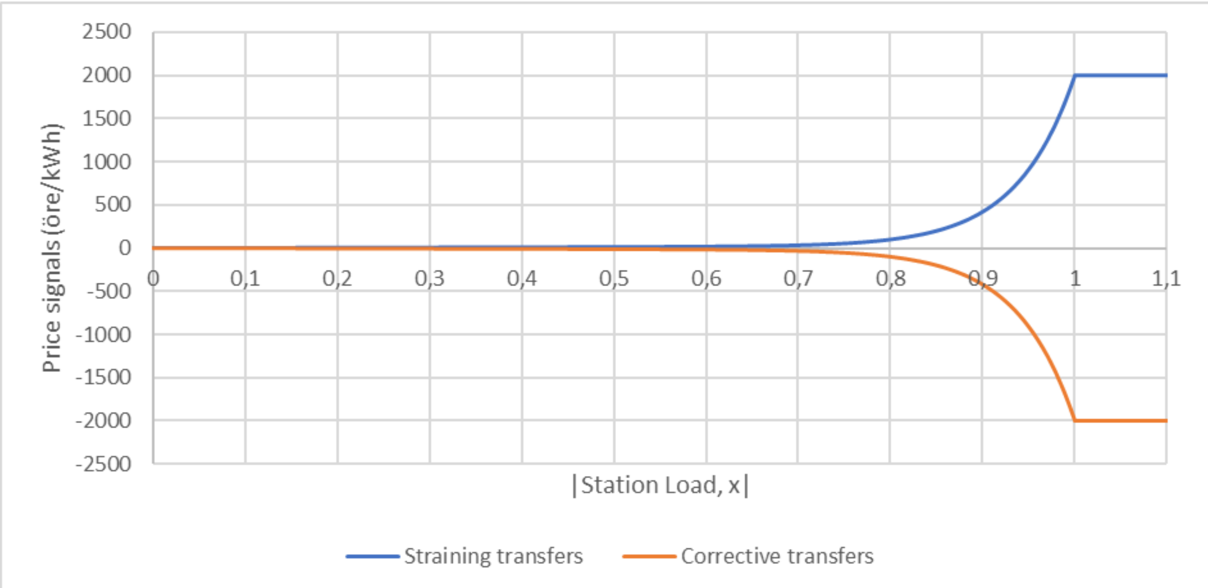

Figure 2. The diagram shows the prices for straining and corrective transfers, and how they are mirrored over the x-axis (over y = 0). Where a subscriber's responsibility ends at |x|=1, the price is set to be 20 SEK/kWh for straining transfers, while corrective transfers are rewarded with the same amount.

4.1.9 Maximum Energy Cost

The capacity limit of a transformer is a formal limit that should not be transgressed. At this limit value, the Station Load is 1, and the energy price reaches its respective maximum for straining transfers, and minimum for corrective transfers. In reality, the Station Load can actually go beyond this limit during shorter periods. However, neither the energy cost nor the mirrored compensation should transgress a set maximum and minimum price. If Station Load would surpass the capacity limit without price limits, energy prices might raise to very high prices. Such occasions should normally not occur. But if they do, the DSO should instead bear responsibility, and not the subscribers.

The maximum Energy Fee price should fulfil needs to be seen as reasonable and fair in relation to the heightened risk for blackouts it entails to go to this level of strain. For example, if the capacity of a station is 100 kW, and the forecast is a Station Load at 1 during one instance, $t = 0{,}5\ hours$, it means that the station energy price may maximally collect a net value of 1000 SEK during one instant, ($100\ kW \cdot 0{,}5\ h\ \cdot 20\ SEK/kWh$). As high prices may lead to protests, the DSO should be careful to communicate what the economic risks are, preferably together with template examples to visualize grid costs related to various flexibility capacities.

If an excessively high risk-energy price during high loads was required, complementary solutions should be considered. One is to help subscribers to be more flexible. Other solutions are flexibility trading, conditional contracts and grid network reinforcements.

4.1.10 Future Energy Fee Optimizations

The Gotland Tariff project has an ambition to also find a solution to control voltage. But until yet, there is no such solution to be presented. This section will therefore only include a description of a potential solution to the optimization of whole DSO grids.

DSO grid Optimization

The project does not include more than a small grid area with approximately 1700 subscribers, which means that a larger grid analysis cannot be done in the project to optimize the grid based on a holistic picture. But, if no obstacles later prove to be in the way of the method below, the project sees a preliminary possible way forward to optimize whole DSO grids.

The method includes two main steps which are reiterated until results have been stabilized:

- **Step 1**: The (already existing) locally focused AI engine analyses power flows in each node in the electricity grid for the next day, resulting in a “heat-map” for every instance during the next day – based on Station Loads for the entire DSO grid.
- **Step 2**: A new AI is trained to produce new energy price signals. These are made to reduce congestion on the overhead grid (above station-level), convey overhead energy losses, and tariff costs to other grids. These prices are then simply added to the local grid energy prices.

Reiteration of Step 1: The overhead energy price signals will yet again be taken into consideration for the local AI engine, where the cost is no more different to it than a change in the spot price. This results in a new Station Load heat map for the whole DSO grid.

Reiteration of Step 2: The overhead AI engine reiterates new overhead energy price signals.

Finalized energy prices: Iterations stop when differences are small enough between consecutive iterations. Thereby, the Energy Fee prices for production (exports) and utilization (imports) are realised.

The AI doing the DSO-grid optimizations can be trained to activate only those who can resolve important problems and who can help to lower other energy related costs. A reason being that it is generally more useful for the energy system if subscribers are free and available – i.e., not constrained to solve grid problems. This is done by using functional overhead grid price signals to eliminate risks of overloads, and cost-reflective price signals for controllable energy costs.

In normal cases, the spot price as a control signal will still be dominant for influencing behaviour, except when it is urgent for the local and/or whole DSO grid. Smaller cost optimizations for the electricity grid will – or should –be trimmed to be cost-reflective. In this way, subscribers' ability or "freedom" to follow spot prices will be secured.

4.2 Customer-Specific Fee

The Customer Specific-Fee (category 3) for metering, billing and reporting is not directly related to the actual kW-connection size, which is one reason for why it is fairer to include this fee aside from other fees. This cost category should also be cost-reflective and equal for similar subscribers Ei (Ei, 2022b).

Background:
With the Justice Tariff's Justice Fee, it is highly incentivised to have an as small as possible power connection to the grid. An important context is also (as described in section *4.3.6* Power for Billing below) that a way has been introduced for shared connections to benefit from aggregation behind a larger master connection meter. The method assumes that a subscriber's individual billing power size will be their unit connection size (kW), which equates to their connection size's share of all aggregated connections in relation to their shared master connection size.

Conclusion:
When subscribers are utilizing the option to share connections behind a master connection, while keeping separate DSO subscriber accounts – it will be the most cost-reflective to have a Customer-Specific Fee separated from other tariff components. This will also align with Ei regulations (Ei, 2022b).

The Justice Tariff does not have a new method proposal for how to distribute customer-specific costs.

4.3 Justice Fee

The Justice Tariff's Justice Fee is a cost-covering fee that covers for remaining costs, complementing the Customer-Specific Fee and Energy Fee.

4.3.1 Conceptual Description

- Determine a cost per kW connection size (i.e., power connection for billing) that is the same for every subscriber in the DSO grid. To do this, a monthly cost-basis – excluding only customer-specific costs, and a summed subscriber connection size within the DSO grid needs to be determined.

- This full kW-specific cost is then migrated to the station level. Every DSO station's cost will be based on the summed station subscriber connection size in relation to the connection size sum for the whole DSO grid.
- Next step is to withdraw from this station-wise cost basis, the summed station Energy Fee-costs – disregarding grid benefit compensations which is handled as a DSO-wide cost. The result is the Station Justice Fee.
- Finally, the Station Justice Fee is again distributed with respect to each subscriber's connection size in relation to the station sum of connection sizes.

The final result is the individual subscriber's Justice Fee.

Consequences:

- Subscribers in more heavily loaded and relatively weaker grid stations – with a higher-than-normal Energy Fee, will be compensated with a lower Justice Fee.
- Within these stations, some will have higher than normal Energy Fee cost, while others have relatively lower costs. In relation to the per-kW average cost for all DSO subscribers, these will respectively have higher or lower per-kW grid costs.
- The above point means respectively, that straining and corrective behaviour is discouraged and encouraged via the Energy Fee, while the Justice Fee is lower for all subscribers in more stressed stations. In turn, this is a natural way to compensate when there is a need for behavioural changes and thus, for economic incentives via the Energy Fee.
- The cost for Grid Benefit Compensations will increase the size of the equal-for-all per-kW cost (made up by the station Justice Fee and the station Energy Fee costs together), while the reward goes directly to subscribers who earned it.

4.3.2 Grid Benefit Compensation Tax Adjustment

The grid benefit compensation is tax-exempted, which means that – without necessary precautions – the Justice Fee will include a cost that should not be VAT taxed. Grid benefit compensations should therefore be withdrawn from the tax basis when VAT is calculated.

4.3.3 Tariff Component Analysis

The Justice Fee is a twist of a combined power- and fixed fee. The functional part of the power fee is placed in the Energy Fee, while the remaining cost-covering part of the power fee is included in the Justice Fee.

However, there is a turn-around difference between a power fee and the Justice Fee:

- With the weight of all future-looking costs, a power fee intends to increase the cost for subscribers who is believed to stress the DSO grid.
- Since the Station Justice Fee withdraws Station Energy Fee costs when the kW-price is determined, it is in fact reducing the Justice Fee more – the more stressed a stations is. Instead, the subscribers' Energy Fee includes all the incentives needed to act for balance.

The key differences above come from an ambition with the Justice Tariff, to use economic incentives as efficiently as possible to avoid further stress. It does so by pinpointing exactly when and where stronger price signals are required and then compensate for it to those it concerns – i.e., for the relatively lower grid dimensions that led to circumstances which required extra flexible efforts.

While the heightened Energy Fee will entail an increased compensation via grid benefit compensations – if they invest in flexibility resources. The lowered Justice Fee will also help to finance the required flexibility capabilities.

4.3.4 An Imagined Power Fee without Localization Signals

A power fee according to regulations (Ei, 2022b) is constrained by the inability to use incentives that differentiates geographically where problems exist. Such a power fee will in the optimal scenario use highly time-differentiated energy price signals that communicates what power flow is problematic, and how much of a problem it is. But if all future-looking costs were to be distributed via an energy fee in this way, it would lead to extremely high energy prices and radically lowered utilization levels. In turn, it would lead to a radically lowered cost-coverage for grid costs.

A solution could be a cost-splitting method similar to the one used by the Justice Tariff, with an additional functional future-looking "power fee-" cost in the energy fee weighted by the severity of overall grid stress in every time instance. For cost-coverage of future looking costs, this part of the power fee should instead be covered by a fixed fee. However, this may still result in a tariff that was not clearly aligned with regulations – e.g. since it increases energy transfer costs in many places where it is not necessary, which is clearly not improving grid utilization.

The downsides of this arrangement:

- It is not only those who can potentially contribute to solve grid stress who will have to reduce grid utilization when a functional power-energy hybrid fee sends heightened economic incentives for behavioural changes.
- If the hybrid fee was to use mirrored incentives – with in magnitude equal costs and grid benefit compensations – the resulting corrective behaviour changes may in most cases not be what actually was needed, resulting in higher than necessary costs for the grid.
- All subscribers will have equal economic incentives to invest into flexibility capacities, regardless of what the needs would be.
- Inefficient demands, higher costs and a reduced grid utilization means a lowered attractiveness for the electricity system.

All of these downsides are solved with the localization signals and cost-redistributions used with the Justice Tariff. It is also a more forgiving tariff design that potentially will yield higher acceptance when it is necessary to adjust behaviour.

Nevertheless – with the Justice Tariff – a subscriber's own all-included (except Customer-Specific costs) kW-connection price will be different depending on its behaviour. It will be larger than the average for those who transfer more straining energy in stressed stations. On the other hand, subscribers adding less strain, and/or even add relief to the same stressed stations with corrective energy transfers, will have a lower than average "all"-included kW-price.

4.3.5 Justice Tariff Applicability with Regulations

According to Ei (2024), the fixed fee shall allocate all costs that are not customer-specific, forward-looking or short-term variable costs. This category of costs is called residual costs. The power fee on the other hand, should be an instrument to influence subscriber behaviour, when necessary, in order to avoid the need for expensive investments in the electricity grid, if possible. According to Ei, the power fee should allocate forward-looking costs, which means that the allocation should be made on cost-reflective and objective grounds.

As already specified, the Ei power fee is in the Justice Tariff split with one functional part placed in the Energy Fee, and one cost-covering – but "reversed" – part in the Justice Fee. The project believes that the Justice Fee distribution method may shed light on a new philosophical way of thinking about cost-reflectivity and fairness. The method makes way for more stringent Energy Fee price-signals, where necessary, since it compensates for it with the Justice Fee. This increases investment flexibility for the DSO, who can do upgrades where it finds it to be most suitable and urgent. A consequence for subscribers where station capacity is strengthened through grid development, is that subscriber flexibility for maintaining grid stability is reduced, i.e. the magnitude of their Energy Fee reduces while their Justice Fee increases. When this happens, there is an increased potential to use the same subscriber flexibility for improving the electricity trade market for variable energy.

With the Justice Tariff, subscribers are incentivised both to be more flexible, and if possible, reduce their connection size to get a lowered Justice Fee. To the extent that connection sizes are adjusted downwards, it will make room for new grid connections without requiring physical grid development. Beyond the Energy Fee's incentive for behaviour changes, the Justice Fee is distributing grid costs according to fixed and fair rules, with a kW-connection basis, meaning that the Justice Fee will not influence behaviour in a way that reduces grid utilization. The project therefore concludes that the Justice Fee should be well within the ambitions sought for with the Ei regulations.

4.3.6 Power for Billing

With the transition from a more energy-based tariff that had higher costs per unit of energy – to a power-based tariff with implicitly lower costs per unit of energy, means a relatively higher cost-increase for subscribers who only utilize a smaller amount of energy in relation to their power connection capacity. Apartment subscribers is such a group who traditionally also have been favoured with a comparably lower fixed fee. The Justice Tariff actually sympathize with the traditional way of distributing costs.

For example, apartment buildings who both have individual grid connection meters and a master grid connection meter in the building, tend in the project area to aggregate about three times the amount of summed individual power connection capacity in relation to that of the apartment-buildings master power connection. This large aggregation means that apartment subscribers cannot utilize too much of their individual connection, or their utilization has to be controlled by a signal to avoid that the main fuse breaks. The traditionally used control measure is to limit their allowed maximum annual energy utilization and hope for aggregation to be enough misaligned to avoid breaking the master fuse.

With the Justice Tariff, there will still be lowered grid costs for apartment subscribers. But now, instead of a template cost-reduction, it is based on the actual measured capacity limitation for each shared connection. However, a complementary method will be necessary to control loads and avoid breaking the master fuse. It could for example be the ordinary traditional maximum energy limit, or a new complementary smart signal specifically adapted to each shared connection.

Determine Power for Billing:
For shared connection subscribers, the following formula yields the shared unit connection size, P_{unit}.

$$P_{unit} = P_{connection} \cdot \frac{P_{master}}{SUM_{shared}(P_{connection})}$$

Where $P_{connection}$ is the individual physical or digital fuse size; P_{master} is the limiting shared master connection size, restricting total capacity for the group of subscribers below it; and where $SUM_{shared}(P_{connection})$ is the sum of $P_{connection}$ for all subscribers who are sharing one master connection.

If P_{unit} has been determined, use the following formula:

$$P_{billing} = MIN(P_{connection}; P_{unit})$$

Otherwise, use the following formula:

$$P_{billing} = P_{connection}$$

Example:
A physical connection size for an apartment subscriber is 11.07 kW (16 A). The subscriber and its neighbours in the same apartment building has a summed total connection at 279.52 kW (404 A). They all share a 110.7 kW (160 A) master connection.

$$\begin{aligned} P_{unit} &= 11.07\ kW \cdot \frac{110.7\ kW}{279.52\ kW} \\ &= 4.38\ kW \end{aligned}$$

Since the unit connection size is lower than the physical (or digital) connection size, power connection size for billing is therefore not 11.07 kW, but 4.38 kW for all apartments with a 16 amperes fuse and 230 V three phase connections.

The lowered size reflects the share of the total capacity and constitutes the dimensioning power connection size to determine the Justice Fee. The example results is a 60 % cost-reduction for the Justice Fee, which is cost-reflective considering the lowered capacity.

Without a limiting master connection, i.e. it is either a single connection or an aggregated connection size exactly or lower than the master connection size – then the billed power connection size is also the same as the physical/digital power connection size.

4.3.7 Future Development for Improved Grid Utilization and Fairness

With digitalization comes new opportunities, and needs for new regulations.

The list below contains possible future development topics for further improvements:

- More frequent use of aggregation of shared connections behind master connections
  One case example may be churches on Gotland who often need large amounts of power during shorter periods. To lower their cost, they can potentially aggregate with energy communities, energy production, energy storages and energy utilization. Two limitations are the need for a high enough flexibility to avoid breaking the master connection fuse, and the need to localize shared activities within a reasonable distance from the master connection.

- Control and temporally adjustment of connection sizes with digital fuses
  Adjust connection sizes more exactly to needs.

Allow to rent and/or temporally step up or –down connection sizes, with the possible gain that it alleviates capacity in the grid for flexible actors with temporal needs to use, to increase grid utilization. May only require a cost-reflective service cost.

- A fairer cost-allocation regulation for new connections, considering if capacity already exist or if it needs to be developed

  A key philosophy for the Justice Tariff is the idea to make every kW cost the same in the whole DSO grid – once they are "in". To get in, there may have to be a connection fee. This philosophy changes the preconditions from a traditional point of view. Now, it needs to be clarified who, when, where and how big the price tag needs to be.

The wanted changes is a fairer and more optimized grid utilization, that allow for more flexibility to meet different needs, to make room for new types of connections without a necessary requirement to physically strengthen the grid first.

5. Comparison with the Projects Previous Tariffs

Until now – with the Justice Tariff – the Gotland tariff project (Tariff 1.0 and Tariff 2.0) has emphasized the role of the subscribers' so-called "footprint" on the grid. A straining behaviour – linked to straining transfers during high load instances for the local grid – was linked to a need for balancing power from further away, i.e. a larger grid had to be involved. Naturally, larger grid requirements should also mean a requirement to take larger shares e.g. of both the capital costs (category 1) and grid-development costs (category 4).

For this footprint-centered distribution concept to be fair, grid conditions should be close to similar for all subscribers. For example, similar station aggregation and utilization levels, as well as similar structural and technical properties of the local grids to which all subscribers are connected to. But in reality, it may differ. With the footprint concept, the same type of subscriber in different parts of the grid would potentially have to face very different grid costs. To some extent, the same will be the result even with the Justice Tariff, since the Energy Fee will increase with a straining behaviour in grid stations where higher strain is more common. However, with the Justice Tariff – where higher strain is more common the Justice Fee will be lowered. In contrast, all of the tariff project's previous footprint-based tariffs would instead increase both the energy and power fee.

The project therefore argues that the Justice Tariff is fairer, and also a simpler method in comparison with previous tariffs.

6. Sensitivity Analysis

This chapter explores the philosophical viewpoints on the Justice Tariff design, with regards to its fairness and functionality. Through the Tariff project's history, this philosophical type of reasoning has given rise to a number of tariff designs, where the Justice Tariff is of course the latest.

6.1 Faults in AI Forecasts

Faults will always occur, where larger faults may be due to scarcity of data for the learning process, or energy transfer changes that the AI possibly cannot foresee. Charging of electric cars could potentially be a problematic event in this respect. The project does not yet have sufficient data to analyse the extent and where this is a problem. If this is a problem, complementary solutions to the tariff may be needed such as a real-time flexibility control system.

6.2 Faults in Measurements

Faulty metering values will lead to an incorrect Energy Fee (i.e. both costs and grid benefit compensations) for the station subscribers, which in turn means that the Justice Fee is also faulty. Taken together however, if assuming grid benefit compensations are zero in both cases – the station Energy Fee *costs* and station Justice Fee is fully correct. If grid benefit compensations are non-zero, there will be a cost change reproducing beyond the station level since costs for grid benefit compensations are added to the over-arching DSO grid level. However, faults of this sort can probably be easily handled within a general economic buffer capacity.

Thus, metering faults will for the meaningful part not reproduce itself beyond station level.

6.3 Varying Power Connection Sizes

If the summed power connection size changes, it will reproduce as a cost change per kW to all subscribers in the grid. The reason is because the total over-arching grid cost is divided on the total connection size (*direct* or *shared master* connections). These changes are probably very small, and can be either accepted, or the DSO can utilize a kW-size buffer, if needed even to the level where cost changes are postponed to changes on a year-on-year basis. The use of a buffer makes it easier to be flexible with regards to timing – to allow connections when it is most suitable from other points of views.

6.4 Justice Tariff Fairness

Grid connections go either via direct- or shared master connections, where either way the Justice Tariff uses the size of these connections as the most important parameter for determining the size of the Justice Tariff for those behind every connection. Moreover, the core idea of the Justice Tariff is to have equal costs per kW connection size – aside from customer specific costs. Thus, customer specific costs are withdrawn from the over-arching cost-basis level, while all other costs are the basis for a size-equal kW connection cost.

Energy Power Nexus

Since connection sizes are usually the same over time, the second most important for the grid cost is behaviour in relation to other station subscribers. If the station Energy Fee cost goes up, the station Justice Fee cost goes down. But a lower Energy Fee does not directly mean lower grid costs.

If for example a station has only environmentally aware subscribers who keep their utilization of electric energy low – then the station Energy Fee may be lower than otherwise. Regardless of if it is in all well-meaning, these subscribers will still be charged for the remainder beyond small station energy costs in this case, so that the station Energy Fee costs and the station Justice Fee together yields the same cost per kW connection size as everywhere else in the grid. This is seen as fair even though station costs for short-term variable costs (mainly energy losses) may be comparably lower than in other stations. Stations with low Energy Fees for whatever reason, will therefore be obliged to contribute to other stations' relatively higher short-term variable costs. How is this fair? This is a philosophical dilemma, where the project envision that every station ideally should be dimensioned equally in relation to its needs. Anytime when the Energy Fee is low, the capacity is relatively high for the actual needs. This over-capacity is one basis for helping other stations with under-capacity in relation to its needs.

Another factor to consider here, is the functional way of approximating Energy Fee costs. Behind the costs in the Energy Fee curve is for one thing the idea of cost reflectivity in relation to e.g. energy losses and costs to other grids. But when the grid is more efficiently utilized, costs will relate more to the idea to maintain a balanced over-arching control over the entire electric grid. This sought balance is achieved primarily in functional way with the Energy Fee price-signals through the use of AI-engines. While the end-result may be rather cost-reflective, it is difficult to link specific Energy Fee prices directly to a specific short-term variable cost.

Finally, for the environmentally aware subscribers – and from an electric grid's point of view – it is better to keep the connection size as low as possible. Because everywhere connection sizes are lowered, it will make capacity available for new connections. In the end, if a lowered connection size is a feasible thing to do for the subscriber, it also means a more efficient utilization of the existing grid and a lowered requirement to upgrade the grid to accommodate needs for new and upgraded connections.

Efficient Use of Power Connections

It may seem to be that costs between different subscribers differ the most when shared *unit connection* subscribers are compared with subscribers with a *direct connection*, i.e. who are either multiple or single behind their *master connection*. This cost-difference viewpoint is only valid if it is not recognized that shared unit connections are exploiting the same limiting master connection. With a shared organization comes a need to keep utilization low, randomly scattered to different times, and/or coordinated in a way to avoid over-loading of the master connection. Thus, the aggregation pattern becomes important. The traditional way to handle it is to keep the annually summed utilization by each shared connection low enough in order to avoid risks of breaking the fuse of the master connection.

By keeping the shared master connection sizes as the dimensioning for the Justice Tariff, it becomes economical - where possible, to use shared connections. The use of shared connections can be done either formally - where new unit connections are created under a master connection, or informally – in effect where a usage simply increases behind a single direct connection. Although, a more heavily used connection may require handling the aggregation pattern in one way or another via the control of flexibility.

Provided that a way to handle the aggregation-pattern is used, the end-result of the power connection-based economic incentive is a drive towards more efficient use of power connections.

7. Conclusions

The developed Justice Tariff carefully balances positive and negative incentives, with its capacity-based Energy Fee paving the way toward a more balanced grid, and its Justice Fee paving the way for a higher utilization level.

For the Energy Fee, the goal is to avoid blackouts, wear and tear, and to distribute short-term variable costs. It does so by seeking a balance between generation and utilization, though with stronger incentives for balance only applied during periods of very high load. For the Justice Fee, the goal is to achieve a fair cost distribution while also making way for a time- and space-optimization of grid capacity utilization. The high cost for the built grid and for future grid development is distributed via the connection-power based Justice Fee. The fairness is secured as the Justice Fee compensates for higher Energy Fee costs, so that the Justice Tariff as a whole – excluding the Customer-Specific Fee – means an equal monthly cost per kW of connection-power in the whole DSO grid. The time-optimization is a future potential to increase efficient grid utilization seasonally where and when a dynamic approach to handle power-connections digitally is used. A localization-specific optimization can also be explored, perhaps driven by cost-differentiated new connections- and temporal rental fees.

In this way, the project's electricity grid tariff complements flexibility incentives driven by the electricity trade market. The result is a more efficient energy system that supports decentralized, variable energy production and utilization, fostering an energy system that is more decentralized and economically, socially, and environmentally sustainable.

Possibilities with Dynamic Grid Tariffs

The project shows that it is entirely possible to use dynamic capacity-based electricity grid tariffs from a technical point of view. The result is also expected to contribute to efficient grid utilization. A contributing reason for this is that the project's grid tariff does not affect subscribers unnecessarily, while there are strong incentives to act for flexibility when it is really needed.

Differences from Traditional Models

The designed grid tariff differs from how traditional grid tariffs are designed. The project's tariff is based on artificial intelligence learning what the Station Load for the coming day will look like. Based on this, time- and localization-specific price signals are calculated, which provides incentives to solve real challenges in a cost-reflective manner.

Social Benefits and Fairness

From a social context, it is shown that all subscribers are welcomed and economically incentivized to participate in maintaining balance in the grid. Expanded opportunities are also given to be part of the energy transition, with a movement for increased decentralized energy production and control, leading to improved energy security. The project expects an increased grid utilization, leading to a lowered monthly power connection cost. This power connection cost is also inevitably fair, as described above. Even though the Justice Tariff model may seem to be complex, it is no more difficult for a subscriber than following the spot price. The project advocates automation as the only possible way to balance the electricity grid. With these conditions in place, complexity may instead be reduced as subscribers need to be less involved in managing their energy needs.

Need for Regulatory Adjustments

Based on the results, the project sees reason to review the regulations so that localization signals will be allowed in local and regional grids. However, the project believes that the Justice Tariff distributes costs in a way that conforms to Ei's intentions.

Expected Effects of the Model

- Continued opportunity for subscribers to participate in the spot price market.
- Existing and future flexibility can also be used to balance the electricity grid.
- Reduced need for electricity grid expansion, which strengthens electrification.
- Increased demand for green renewable energy.
- Lower economic and resource costs through efficiency improvements.

Possible Challenges

A certain level of digitalization and metering is required to make it possible to use the designed electricity grid tariff. One challenge is that it takes a certain amount of time to initiate new grid areas. The project naturally hopes that the entire electricity grid uses cost-reflective and time- and localization-specific price signals, even if this transition will take time.

Since the price signals vary dynamically, higher demands are placed on subscribers. Trying to control flexibility manually may be possible for some, but for the broad mass, automated flexibility is required. This additional requirement for automation and technical conditions will create gaps between different consumer groups, which means a need for extra efforts from society.

The increased digitalization can mean increased vulnerability. When using a smart grid tariff in critical situations, it is therefore necessary to have a plan B in case something goes wrong. For example, an AI can design forecasts that extend even further into the future. If this also fails, a traditional grid tariff can be used. A third solution is to use the fact that only a relatively short power line separates the transformer from the subscriber. In cases where the usual price signal fails, the transformer balance would then be transmitted directly to avoid excessive imbalances and risks of damage.

It is more likely that the complexity and dynamic of the energy system will instead increase in the future. Could quarter metering be reduced to 5 minutes or even less? It would also be possible to give each customer completely unique price signals. However, the project does not see a need for this. The spatial distribution that the project uses should be well balanced to provide the right control signals. However, longer forecasts can allow the control of flexibility to be optimized in a better way.

Recommendations and Next Steps

The current version of the Justice Tariff does not solve all problems. For example, no solution is presented to handle voltage stability. Voltage instability is today the biggest threat to grid stability. Furthermore, to cope with an uncertain future, it is likely that the aim should be a generally improved ability to control the energy system offline, within ever smaller parts of the grid. To do this, voltage control is key. It is therefore also a first priority for the project to find a solution for this.

The project already combines the spot price with its price signals. The next step is to also include voltage control signals, and to combine the Energy Fee with flexibility trading price signals.

The first part of the project was completed by the end of January 2025. The second part of the project, Tariff 2.0, continues until the end of April 2026. In this project, the tariff will be rigorously tested on the test pilot companies that have been equipped, and with the system that has been calibrated.

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