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SWEET P+D NEDELA

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Summary

Shifting flexible loads such as electric vehicles and heat pumps in a grid-serving manner is a key lever for reducing distribution-grid expansion costs and a core research question of the SWEET PATHFNDR consortium. Yet most Swiss distribution system operators (DSOs) still rely on static designs such as constant high-low tariffs, which give only an imprecise signal for grid-friendly load shifting. Before the project there was also no agreed standard for transmitting tariff signals to energy management systems (EMS), forcing EMS developers to re-implement a separate interface for every DSO. Dynamic tariffs signal grid bottlenecks far more accurately, but depending on their design they can also trigger "herding" of automated loads and new "rebound peaks" during the lowest-price hours.

NEDELA therefore set out to develop and field-test an interface for transmitting dynamic tariffs to EMS in the grid area of Groupe E, and to test how effective different tariff designs are at reducing grid peak-load and avoiding rebound peaks. It pursued four objectives: identifying a suitable interface standard (Q1), understanding the hurdles of introducing a dynamic tariff and its interfaces (Q2), quantifying the effect of tariff variations on peak grid load and system cost (Q3), and assessing customer acceptance (Q4). Its innovation lies in combining a real-world tariff roll-out with lab experiments, customer surveys and large-scale simulations — moving dynamic distribution-grid tariffs from theory into live operation.

The work combined three strands. In the **field-tests**, Groupe E developed a REST WEB-API for tariff transmission (publishing virtual tariffs from August 2023 and the Vario tariff from January 2024), Empa ran lab experiments on its NEST living-lab building, a pilot study covered four EMS providers across six sites, and the elective Vario tariff was launched. **Surveys** of 50 participating customers were run after the first quarter and at project end. The **simulations** ran in parallel: Siemens assessed bill savings from a model-predictive optimizer for single- and multi-family homes; Empa modeled tariff impacts across EVs, heat pumps, domestic hot water and NEST, and built archetypes for 1.8 million Swiss buildings with a GIS-based simulation tool; and ZHAW simulated how stand-alone tariffs and combinations of dynamic per-kWh prices with capacity charges affect peak load, energy and total system cost.

All four objectives were achieved. The WEB-API has been interfaced by 13 EMS providers and fed directly into a national standard for publishing dynamic grid tariffs, in force since 1 January 2026. The Vario tariff grew steadily to 112 sign-ups by the end of Q1 2026 (for billing in Q2 2026); of the 93 analyzed in Q4 2025, 59 reduced their bill versus the standard double tariff. Field load curves and independent simulations by Empa and ZHAW confirmed that dynamic per-kWh tariffs shift flexible loads into off-peak periods, and the surveys showed adequate acceptance, with more than three quarters of participants adapting their habits by project end. At the same time, savings were limited for many customers, the optimization remained challenging to implement, and at higher shares of automated load dynamic per-kWh tariffs alone can create rebound peaks that need tempering by complementary capacity charges.

NEDELA thus shows that dynamic distribution-grid tariffs are technically feasible, accepted by users and effective at shifting load, but that their net benefit per customer is modest and their grid impact must be managed as flexible loads scale up. The most promising design combines dynamic per-kWh prices with a capacity charge, balancing energy- and grid-cost reductions while avoiding rebound peaks. Building on the new Swiss standard, the next steps are to refine these combined designs and benchmark dynamic tariffs against alternative flexibility mechanisms within PATHFNDR.

Résumé

Le déplacement des charges flexibles telles que les véhicules électriques et les pompes à chaleur d'une manière favorable au réseau constitue un levier essentiel pour réduire les coûts d'expansion du réseau de distribution et une question de recherche centrale de la transition énergétique suisse. Pourtant, la plupart des gestionnaires de réseau de distribution (GRD) suisses s'appuient encore sur des structures statiques telles que des tarifs haut/bas constants, qui ne fournissent qu'un signal imprécis pour un déplacement de charge favorable au réseau. Avant le projet, il n'existait en outre aucune norme reconnue pour transmettre les signaux tarifaires aux systèmes de gestion de l'énergie (EMS), obligeant les développeurs d'EMS à réimplémenter une interface distincte pour chaque GRD. Les tarifs dynamiques signalent les congestions du réseau bien plus précisément, mais, selon leur conception, ils peuvent aussi provoquer un « effet de troupeau » des charges automatisées et de nouveaux « pics de rebond » pendant les heures les moins chères.

NEDELA s'est donc fixé pour objectif de développer et de tester sur le terrain une interface de transmission des tarifs dynamiques aux EMS dans la zone de réseau de Groupe E, et d'évaluer l'efficacité de différentes conceptions tarifaires pour réduire la pointe de charge du réseau et éviter les pics de rebond. Le projet poursuivait quatre objectifs : identifier une norme d'interface appropriée (Q1), comprendre les obstacles à l'introduction d'un tarif dynamique et de ses interfaces (Q2), quantifier l'effet des variations tarifaires sur la pointe de charge du réseau et les coûts du système (Q3) et évaluer l'acceptation des clients (Q4). Son innovation réside dans la combinaison d'un déploiement tarifaire en conditions réelles avec des expériences en laboratoire, des enquêtes auprès des clients et des simulations à grande échelle — faisant passer les tarifs dynamiques de réseau de distribution de la théorie à l'exploitation réelle.

Le travail a combiné trois volets. Lors des tests sur le terrain, Groupe E a développé une API web REST pour la transmission des tarifs (publication de tarifs virtuels dès août 2023 et du tarif Vario dès janvier 2024), l'Empa a mené des expériences en laboratoire dans son bâtiment living-lab NEST, une étude pilote a couvert quatre fournisseurs d'EMS sur six sites, et le tarif optionnel Vario a été lancé. Des enquêtes auprès de 50 clients participants ont été menées après le premier trimestre et à la fin du projet. Les simulations se sont déroulées en parallèle : Siemens a évalué les économies sur la facture générées par un optimiseur à modèle prédictif pour maisons individuelles et immeubles collectifs ; l'Empa a modélisé les effets tarifaires sur les véhicules électriques, les pompes à chaleur, l'eau chaude sanitaire et NEST, et a construit des archétypes pour 1,8 million de bâtiments suisses à l'aide d'un outil de simulation basé sur un SIG ; et la ZHAW a simulé comment des tarifs autonomes ainsi que des combinaisons de prix dynamiques au kWh avec des prix de puissance influent sur la pointe de charge, les coûts de l'énergie et les coûts totaux du système.

Les quatre objectifs ont été atteints. L'API web a été interfacée par 13 fournisseurs d'EMS et a directement alimenté une norme nationale de publication des tarifs de réseau dynamiques, en vigueur depuis le 1er janvier 2026. Le tarif Vario a progressé régulièrement pour atteindre 112 inscriptions à la fin du T1 2026 (pour une facturation au T2 2026) ; sur les 93 cas analysés au T4 2025, 59 ont réduit leur facture par rapport au tarif double standard. Les courbes de charge relevées sur le terrain et les simulations indépendantes de l'Empa et de la ZHAW ont confirmé que les tarifs dynamiques au kWh déplacent les charges flexibles vers les heures creuses, et les enquêtes ont montré une acceptation suffisante, plus des trois quarts des participants ayant adapté leurs habitudes à la fin du projet. Dans le même temps, les économies sont restées limitées pour de nombreux clients, l'optimisation est demeurée difficile à mettre en œuvre, et, à des parts plus élevées de charges automatisées, les tarifs dynamiques au kWh seuls peuvent créer des pics de rebond qu'il faut atténuer par des prix de puissance complémentaires.

NEDELA montre ainsi que les tarifs dynamiques de réseau de distribution sont techniquement réalisables, acceptés par les utilisateurs et efficaces pour déplacer les charges, mais que leur bénéfice net par client est modeste et que leur impact sur le réseau doit être maîtrisé à mesure que les charges flexibles se développent. La conception la plus prometteuse combine des prix dynamiques au kWh avec un prix de puissance, conciliant ainsi la réduction des coûts de l'énergie et de ceux du réseau tout en évitant les pics de rebond. En s'appuyant sur la nouvelle norme suisse, les prochaines étapes consistent à affiner ces conceptions combinées et à comparer les tarifs dynamiques à d'autres mécanismes de flexibilité dans le cadre de PATHFNDR.

Zusammenfassung

Das netzdienliche Verschieben flexibler Lasten wie Elektrofahrzeugen und Wärmepumpen ist ein zentraler Hebel zur Senkung der Verteilnetzausbaukosten und ein zentrales Forschungsthema der Schweizer Energiewende. Dennoch setzen die meisten Schweizer Verteilnetzbetreiber (VNB) weiterhin auf statische Ausgestaltungen wie konstante Hoch-/Niedertarife, die nur ein ungenaues Signal für netzdienliches Lastverschieben geben. Vor dem Projekt gab es zudem keinen anerkannten Standard für die Übermittlung von Tarifsignalen an Energiemanagementsysteme (EMS), sodass EMS-Entwickler für jeden VNB eine separate Schnittstelle neu implementieren mussten. Dynamische Tarife signalisieren Netzengpässe deutlich präziser, können aber je nach Ausgestaltung auch ein „Herdenverhalten" automatisierter Lasten und neue „Rebound-Spitzen" in den günstigsten Stunden auslösen.

NEDELA hatte daher zum Ziel, eine Schnittstelle zur Übermittlung dynamischer Tarife an EMS im Netzgebiet der Groupe E zu entwickeln und im Feld zu erproben sowie zu testen, wie wirksam verschiedene Tarifausgestaltungen die Netzspitzenlast reduzieren und Rebound-Spitzen vermeiden. Es verfolgte vier Ziele: die Identifikation eines geeigneten Schnittstellenstandards (Q1), das Verständnis der Hürden bei der Einführung eines dynamischen Tarifs und seiner Schnittstellen (Q2), die Quantifizierung der Wirkung von Tarifvariationen auf die Netzspitzenlast und die Systemkosten (Q3) sowie die Beurteilung der Kundenakzeptanz (Q4). Seine Innovation liegt in der Kombination eines realen Tarif-Rollouts mit Laborexperimenten, Kundenbefragungen und grossangelegten Simulationen — und darin, dynamische Verteilnetztarife von der Theorie in den Live-Betrieb zu überführen.

Die Arbeit verband drei Stränge. In den Feldtests entwickelte die Groupe E eine REST-Web-API zur Tarifübermittlung (Veröffentlichung virtueller Tarife ab August 2023 und des Vario-Tarifs ab Januar 2024), die Empa führte Laborexperimente in ihrem Living-Lab-Gebäude NEST durch, eine Pilotstudie umfasste vier EMS-Anbieter an sechs Standorten, und der wählbare Vario-Tarif wurde lanciert. Befragungen von 50 teilnehmenden Kundinnen und Kunden wurden nach dem ersten Quartal und zu Projektende durchgeführt. Parallel dazu liefen die Simulationen: Siemens untersuchte die Rechnungseinsparungen durch einen modellprädiktiven Optimierer für Ein- und Mehrfamilienhäuser; die Empa modellierte die Tarifwirkungen über Elektrofahrzeuge, Wärmepumpen, Warmwasser und NEST hinweg und erstellte mit einem GIS-basierten Simulationstool Archetypen für 1,8 Millionen Schweizer Gebäude; und die ZHAW simulierte, wie eigenständige Tarife sowie Kombinationen dynamischer kWh-Preise mit Leistungspreisen die Spitzenlast, die Energiekosten und die Gesamtsystemkosten beeinflussen.

Alle vier Ziele wurden erreicht. Die Web-API wurde von 13 EMS-Anbietern angebunden und floss direkt in einen nationalen Standard zur Veröffentlichung dynamischer Netztarife ein, der seit dem 1. Januar 2026 in Kraft ist. Der Vario-Tarif wuchs stetig auf 112 Anmeldungen bis Ende Q1 2026 (für die Abrechnung in Q2 2026); von den 93 im Q4 2025 analysierten Fällen reduzierten 59 ihre Rechnung gegenüber dem Standard-Doppeltarif. Die im Feld gemessenen Lastkurven und unabhängige Simulationen der Empa und der ZHAW bestätigten, dass dynamische kWh-Tarife flexible Lasten in Schwachlastzeiten verschieben, und die Befragungen zeigten eine ausreichende Akzeptanz, wobei mehr als drei Viertel der Teilnehmenden bis Projektende ihre Gewohnheiten anpassten. Zugleich waren die Einsparungen für viele Kundinnen und Kunden begrenzt, die Optimierung blieb anspruchsvoll in der Umsetzung, und bei höheren Anteilen automatisierter Lasten können dynamische kWh-Tarife allein Rebound-Spitzen erzeugen, die durch ergänzende Leistungspreise gedämpft werden müssen.

NEDELA zeigt somit, dass dynamische Verteilnetztarife technisch machbar, von den Nutzenden akzeptiert und wirksam bei der Lastverschiebung sind, dass ihr Nettonutzen pro Kunde jedoch bescheiden ausfällt und ihre Netzwirkung mit zunehmendem Ausbau flexibler Lasten gesteuert werden muss. Die vielversprechendste Ausgestaltung kombiniert dynamische kWh-Preise mit einem

Leistungspreis und bringt so Reduktionen bei Energie- und Netzkosten in Einklang, während Rebound-Spitzen vermieden werden. Aufbauend auf dem neuen Schweizer Standard bestehen die nächsten Schritte darin, diese kombinierten Ausgestaltungen zu verfeinern und dynamische Tarife innerhalb von PATHFNDR mit alternativen Flexibilitätsmechanismen zu vergleichen (Benchmarking).

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Abbreviations

EMS	*energy management systems*
EV	*electric vehicles*
HEMS	*home energy management systems*
HP	*heat pumps*
HVAC	*heating, ventilation, and air conditioning*
MFH	*multi-family home*
SFH	*single-family home*
RMPC	*rule-based model predictive controller*

1 Introduction

1.1 Background information and current situation

Despite the need to reduce grid expansion cost by shifting flexible loads such as electric vehicles (EV) and heat pumps (HP) in a grid-serving manner, at the start of the NEDELA project:

- most distribution grid operators (DSOs) in Switzerland still used static tariff designs such as constant high-low tariffs. Compared to dynamic tariff designs, static high-low tariffs provide a much less precise signal for shifting flexible loads in a way that alleviates the grid.
- there was no commonly agreed standard for transmitting such tariff signals to market participants. A common standard would greatly help developers of energy management systems (EMS) to offer the flexibility of their customers without having to re-program a different price interface for each distribution grid operator.

During the NEDELA project, dynamic grid tariffs have only become possible as a standard offering: since the revised electricity law entered into force in 2026, distribution system operators may use dynamic tariffs as a base tariff rather than only as an optional alternative (Art. 18a StromVG). To date, however, all Swiss implementations are still offered as *optional* tariffs alongside the conventional high-low tariff; an overview of the current implementations is maintained by SmartGridready. Most of these use the data interface for transmitting dynamic grid tariffs that was co-developed in parallel to this project and has since become a national standard. Practical experience so far is mixed: some implementations achieve tangible load-shifting — for example the EKZ tariff (EKZ & ETHZ, 2025) and the Groupe E Vario tariff described in this report — while other Swiss field studies have observed comparatively little load-shifting volume (Swisspower & ZHAW, 2025). This early experience confirms that dynamic tariffs *can* move flexible load to off-peak periods. The achievable effect, however, depends strongly on the share of customers with automated, flexible assets, the volume of flexible load actually connected to the EMS, and how the user configures the EMS — for example, whether it is set to maximize own-consumption or to optimize in response to the tariff. Automation is therefore a double-edged sword: it is required to achieve tangible load-shifting, but the resulting synchronization of automatically controlled loads can also create new, even larger peaks during the lowest-price night-time hours (Winzer & Hensler-Ludwig, 2024).

Concretely, NEDELA served as the field-test and tariff-development arm for the grid-tariff strand of the **SWEET PATHFNDR** consortium: it took up tariff design ideas developed within PATHFNDR (work-package 7), tested and further developed them through the field study and simulations described in this report, and fed the resulting insights back into the PATHFNDR synthesis reports. A formal cross-validation of the NEDELA tariffs and their systematic benchmarking against other approaches for contracting flexible loads (such as market-based flexibility procurement) was foreseen but could ultimately not be carried out, as the supplementary funding required for this additional work step was not available.

1.2 Purpose of the project

The purpose of the NEDELA project was to develop and field-test an interface for transmitting dynamic tariffs to EMS in the grid-area of Groupe E, and to test the effectiveness of different tariff designs for reducing grid peak-load through a field-study and simulations.

The project set out to go beyond previously implemented solutions in three innovative respects, each addressing one of the challenges set out in section 1.1. First, rather than relying on the static high-low tariffs that dominate Swiss distribution grids and give only an imprecise load-shifting signal, it aimed to introduce a genuinely *dynamic*, grid-load-following tariff (the Vario tariff), recalculated at quarter-hourly resolution and designed to be revenue-neutral so that only customers whose load profile is more grid-friendly than the reference load profile used for calibration pay less. Second, instead of the bespoke, operator-specific price interfaces that previously forced EMS developers to re-implement a separate

solution for every grid operator, it aimed to transmit the tariff automatically to energy management systems through a single, standardized REST WEB-API developed jointly with EMS providers. Third, the project aimed not merely to demonstrate that load can be shifted, but to address the rebound-peak risk by simulating how dynamic per-kWh signals can be combined with capacity charges to shift load without creating new, even larger peaks during the lowest-price hours.

1.3 Objectives

The detailed objectives of the NEDELA project are:
Q1. Which interface definition is suitable as an industry standard for the transmission of corresponding tariff signals to home energy management systems (HEMS)?
Q2. What are the hurdles and problems in introducing a dynamic grid tariff and in implementing the interfaces?
Q3. What effect do different tariff variations have on the maximum grid load and the system costs (energy + grid)?
Q4. How are the tariffs accepted by end customers?

2 Approach, method, results and discussion

As described in Figure 1, the NEDELA project evaluated the impact of dynamic tariffs through field-tests (section 2.1), surveys regarding tariff acceptance and experience (section 2.2) and simulations (section 2.3.1), which were run in parallel to the field-tests to identify options for tariff improvement in case of higher shares of automated load. The three strands were closely interlinked: the field-tests provided measurement data and practical implementation experience for the simulations, while the simulations identified tariff design improvements beyond what could be tested in the field.

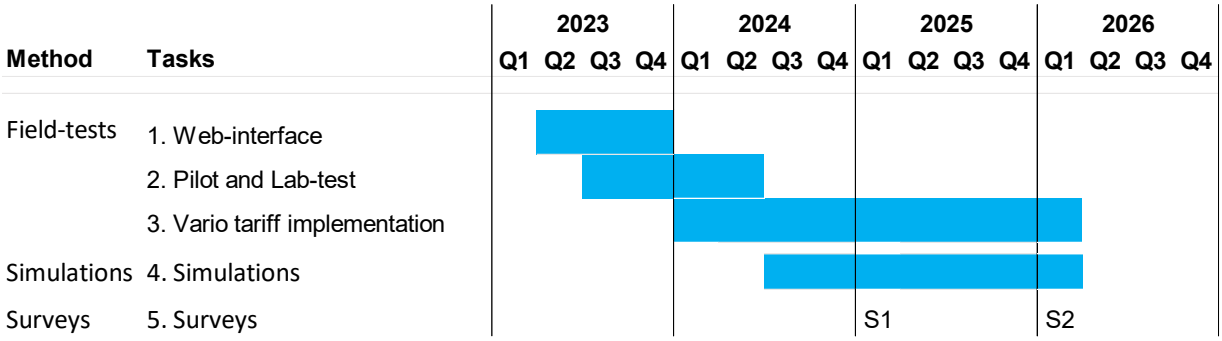


Figure 1: Overview of the NEDELA project.

We describe each of these in a separate section below.

2.1 Field-tests

As part of the field-study, we developed a web-interface (section 2.1.1), ran a pilot-test with Groupe E customers (section 2.1.3) and a lab-test at EMPA's NEST living lab (2.1.2) and rolled out the elective Vario-tariff in the grid-area of Groupe E (0). Results from each of these tasks are described in a separate section below.

2.1.1 Web-Interface (Groupe E)

During workshops with EMS providers, there was a broad agreement that dynamic tariffs should be transmitted to EMS via a REST WEB-API. The details for the publication format of the tariffs were defined after exchanges with various EMS providers and Groupe E implemented a fist version (v1) of such a WEB-API that started publishing virtual tariffs from August 2023 and publishes the newly introduced Vario-Tarif starting from January 2024. In general, it was encouraging to see the wide agreement about the preference for utilizing a Web-API for tariff transmission, and the widespread interest of EMS developers in implementing and testing the API.

By the end of 2025, the WEB-API for transmitting dynamic tariff signals of the Vario tariff has been interfaced by the following energy management system providers:

- **CLEMAP Load Management**
- **Eigenverbrauchsmanager Smart Energy Engineering**
- **evcc** mit oder ohne Portal und Installation von **CaptaWatt**
- **FENECON Energiemanagementsystem**
- **Jenni Energietechnik - Forecast Interface**
- **LOXONE**
- **Optinergy** (nur auf Französisch)
- **SALLY Salt Bank by Salzstrom** (nur auf Französisch oder Englisch)
- **Smart Energy Link**
- **SOLAR MANAGER**
- **SOLECO Optimizer**
- **Studer Innotec - next3**
- **sun2wheel**

Based on previous work from Groupe E and results during the NEDELA project, a similar Web-interface has been developed as part of the **"ESIT" P&D project** by Swisspower. Based on these experiences, Groupe E and Swisspower collaborated with other utilities and stakeholders in a work group of Association of Swiss Electricity Companies (VSE) and defined a Swiss standard for the publication of dynamic grid tariffs entering into force on 1.1.2026 (**https://www.strom.ch/de/shop/dynamische-netznutzungstarife-im-verteilnetz-hdn-ch-2025**).

Groupe E implemented the new tariff publication format according to the new standard in late 2025 on a new API v2-version and decommissioned the v1-version after Q1 2026.

- Details on the v2 version are available on: **LINK**
- Example request on the new v2 API corresponding to the Swiss Standard : **https://api.tariffs.groupe-e.ch/v2/tariffs**

2.1.2 Lab-test in NEST building (Empa):

Empa prepared the tariff evaluation experiment for dynamic tariff designs on the living laboratory, the NEST building at Empa. NEST is the modular research and innovation building of Empa and Eawag. At NEST, new technologies, materials and systems are tested, researched, further developed and validated under real conditions. NEST incorporates an energy "hub" that functions as a multi-carrier microgrid with three thermal networks at different temperature levels, an electrical grid, a gas grid, and on-site storage (batteries and supercapacitors), designed to maximize the use

of locally generated renewable energy (mainly PV) and reduce peak demand through active load management and operational flexibility of the connected units. Each unit acts as an almost independent building that can either inject surplus energy into, or draw energy from, the low-, medium-, or high-temperature grids and the electrical grid, and units on the top platform are required to achieve around a 50% annual energy surplus to help cover the needs of less favorably oriented units, fostering advanced distributed generation and flexibility strategies. The sizing of storage (96 kWh/180 kW batteries and 1 kWh/70 kW supercaps) and the structure of the microgrid enable experiments with island operation and active grid management, including the potential to react to external control signals (such as price or operator signals).

This experiment optimally adjusted the operational set points of the EV, batteries, domestic hot water, and heat pumps in the real-time response to dynamic tariffs by minimizing the end-user cost without sacrificing their comfort. The experimental workflow and the flexibility assets modeled in the context of this work has been illustrated below in Figure 2. The experiment preparation included: 1) modeling of project-relevant flexibility loads, 2) implementing baseline controllers to serve as a benchmark case and,3) Simulating a controller that can consider tariff signals.

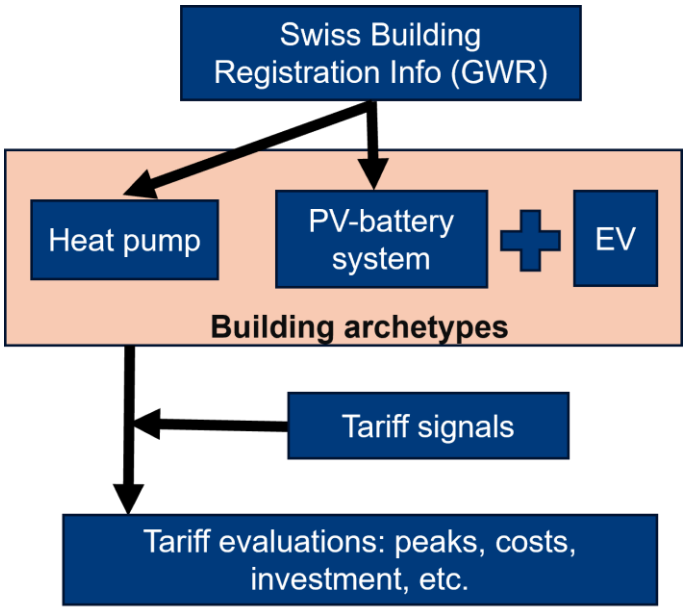


Figure 2: Illustration of the experimental workflow and the flexibility assets modeled.

Three tariff schemes were modeled, (i) a flat tariff with no feed-in option, (ii) a dual tariff with day/night prices and flat feed-in price and, (iii) a fully variable tariff with variable price for electricity consumption along with a variable feed-in price. For each tariff, the same optimization was run, so that the controller schedules imports, exports, and operation of HP, PV, battery and EV to exploit the specific price structure. The goal was to investigate how different tariff designs affect both annual electricity costs and the shape of aggregated demand, including emergence of synchronized load shifts under highly variable prices. Figure 3 below shows the different electricity tariffs and associated feed-in tariffs from Group E for the year 2024 used in the analysis.

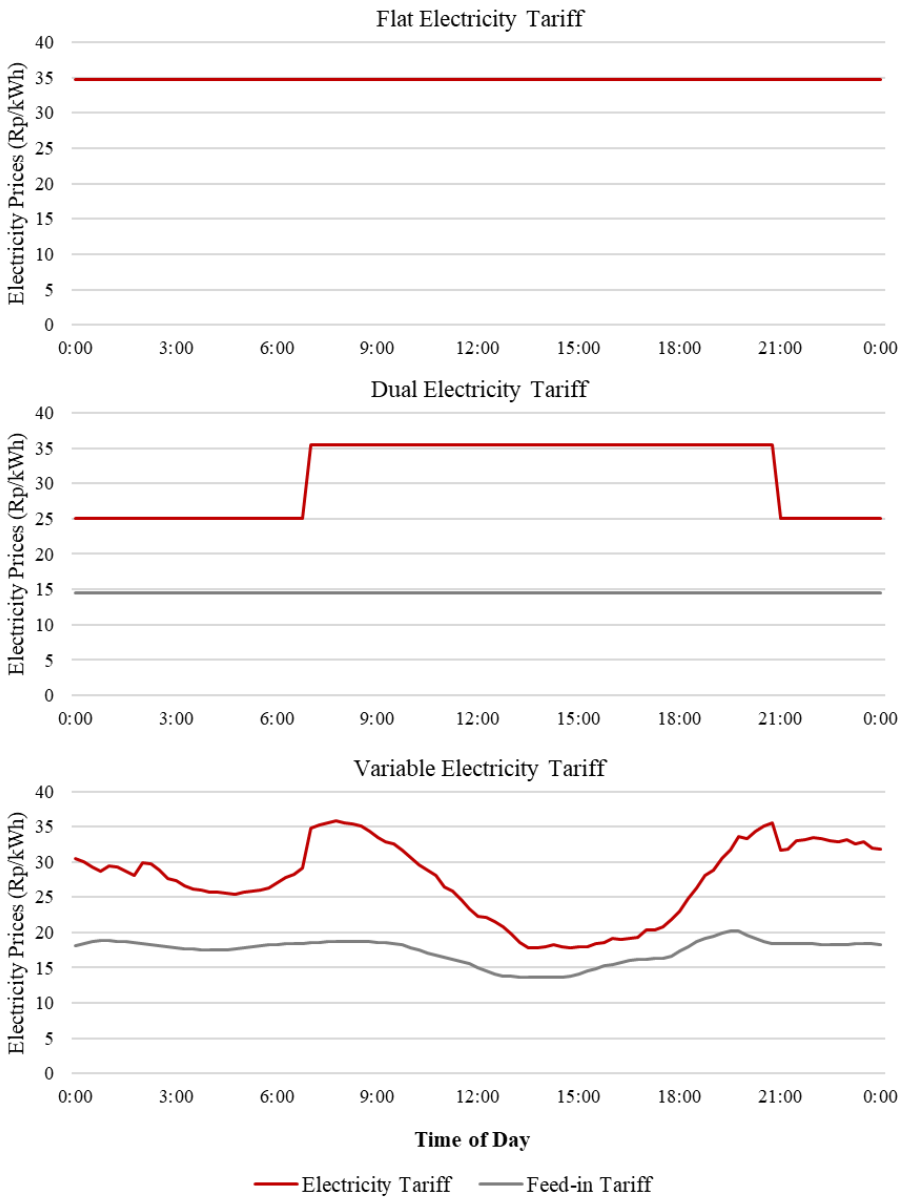


Figure 3: Different electricity tariffs and associated feed-in tariffs from Group E for the year 2024 used in the analysis.

2.1.3 Pilot-study (Groupe E)

The pilot projects were conducted in 2023 and 2024 with 4 EMS-providers, on 6 sites (2 EMS had one site, 2 EMS, had two sites). While real billing was done based on the standard site tariff of Groupe E, simulated electricity cost calculations using the Vario Tariff (dynamic pricing) and the Standard Double Tariff (fixed-time-of-use pricing) of Groupe E allowed the evaluation of potential savings. All the 4 EMS-providers confirmed that the technical implementation of the Vario-Tarif from the API was straightforward and easy. One EMS also reported that the optimization with the dynamic Vario tariff was quite straightforward, because the system already implemented a financial optimization in earlier projects. 3 of the 4 EMS-providers confirmed that the optimization algorithm was a challenge to implement, because they performed only one-dimensional self-consumption optimization so far and had to adapt their algorithms for the new financial dimension. Benefits of

switching from a rule-based self-consumption optimization to a controller which includes dynamic tariffs in the optimization have been quantified by Siemens in section 2.3.1. From the 6 sites, two were abandoned because the technical implementation on site proved too complicated, 3 sites did some optimization but with limited flexibility available and would have paid more with the Vario tariff compared to the standard double tariff. Only one site (Figures 4 and 5) managed to optimize significant flexibilities and thus improve electricity costs. As illustrated in Figure 4, based on the load-shifting patterns of this customer, our preliminary conclusion is, that the Vario tariff provides very good incentives to move customer peak-load to off-peak periods. While in absence of the Vario tariff, the customer peak-load often occurred during hours with high grid load (Figure 4, top), the introduction of the Vario tariff was able to move customer peak-load to off-peak hours (Figure 4, bottom).

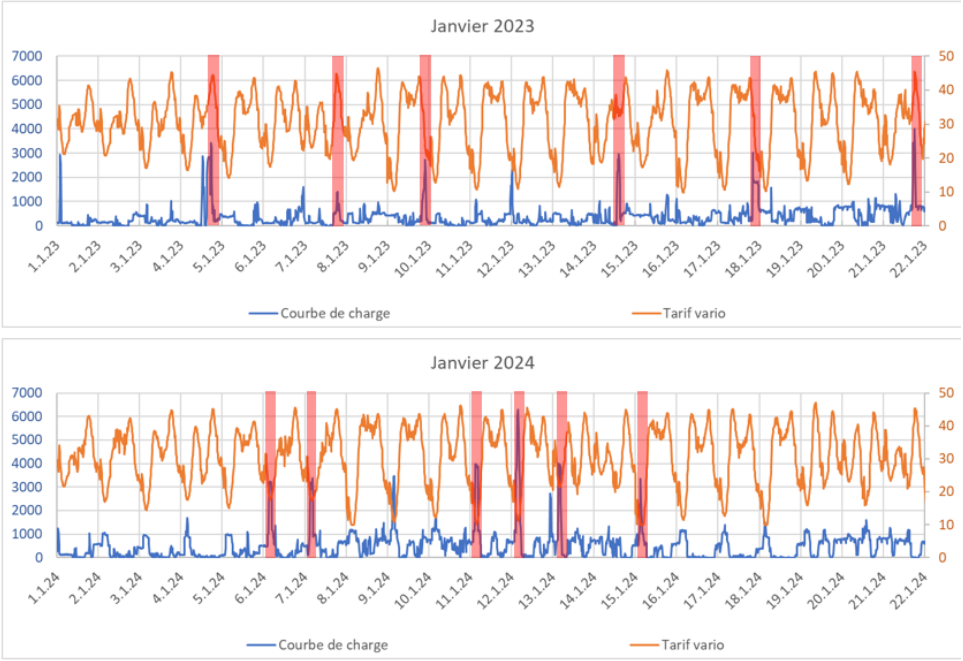


Figure 4: Load curve of a sample customer without vario tariff (top) and with vario tariff (bottom).

Figure 5 shows this single-family house's monthly bill (with PV, heat pump, battery and EV) simulated under the double tariff (orange) and the Vario tariff (blue); the 617 CHF saving is the cumulative difference over the 18-month trial. Before the green line, while the customer still optimized for the double tariff, the two bills almost coincide — confirming the comparison is well-calibrated.

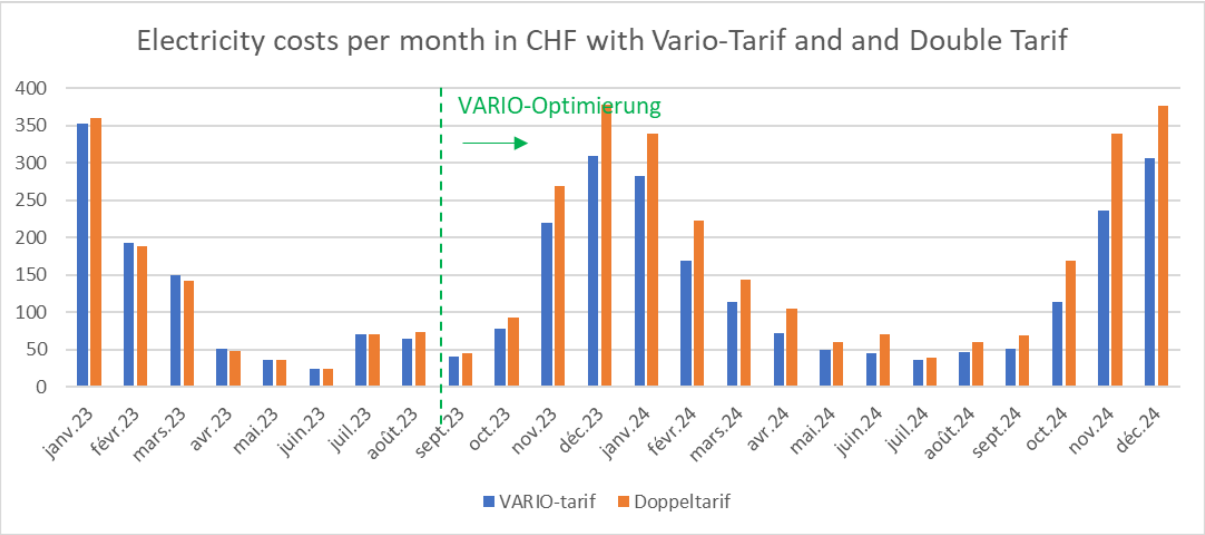


Figure 5: Monthly electricity bill of a sample customer with standard double tariff (orange) and with vario tariff (blue).

2.1.4 Vario Tariff (Groupe E)

Groupe E developed the formula that allows to calculate the dynamic Vario tariff. The Vario tariff together with the other tariffs available are published on Group E's website. The tariffs are sent to ElCom as required by the regulator. Groupe E further implemented the tariff in its billing system.

The formula for the vario tariff, which is running for the tariff 2024 is as follows:

(1)
$$Price_i = (NL_i - NL_{24h} + F) \cdot \frac{\sum_{i=15min}^{24h} NL_i \cdot DT_i}{\sum_{i=15min}^{24h} NL_i \cdot (NL_i - NL_{24h} + F)}$$

Where:

- $Price_i$= vario tariff during quarter hour i
- NL_i= Gridload during quarter hour i
- NL_{24h}= average Gridload during the day
- F= Variability factor, for 2024 this equals to +35
- DT_i= Double tariff during the quarter hour i

The Vario tariff is proportional to the difference between the grid load NL_i during hour i and the average gridload during the day NL_{24h} plus an offset F, and includes a daily scaling factor to ensure that a customer whose load follows the grid load profile NL_i pays the same in case of the vario tariff and the double tariff. This ensures that only customers whose load profile is more beneficial than the grid load profile pay less under the vario tariff than under the double tariff.

The formula that defines how the regulated tariff is calculated must be published by end auf August for the following year cannot change until the next year. The formula was slightly improved for the Vario tariff 2025 and 2026. In 2026 the following formulas:

(2) $$GRID_Vario_{i,j} = (GL_{i,j} - GL_{avg_j} + F_j) \times \frac{\sum_{i=15min}^{24h} GL_{i,j} \cdot CHF_DT_i}{\sum_{i=15min}^{24h} GL_{i,j} \cdot (GL_{i,j} - GL_{avg_j} + F_j)} + FIX$$

(3) $$F_j = min(F_{j_high}; F_{j_low})$$

(4) $$F_{j_high} = F_{max} - (F_{max} - F_{min}) \cdot \frac{max(GL_{max_j} - (YGL_{max} - MGLO_{high}); 0)}{MGLO_{high}}$$

(5) $$F_{j_low} = F_{max} - (F_{max} - F_{min}) \cdot \frac{max((YGL_{min} + MGLO_{low}) - GL_{min_j}; 0)}{MGLO_{low}}$$

Where:

- $GRID_Vario_{i,j}$= Grid component of vario tariff price during quarter-hour i on day j
- $GL_{i,j}$= Grid load during quarter-hour i on day j
- GL_{avg_j}= Average grid load on day j
- GL_{max_j} and GL_{min_j}= Forecast maximum and minimum grid load on day j
- F_j= Variability factor for day j
- CHF_DT_i= Double tariff during quarter-hour i
- YGL_{max} and YGL_{min}= Maximum and minimum measured grid load two years before the tariff year
- $MGLO_{high}$ and $MGLO_{low}$= YGL shift for increased variability
- FIX= Fixed component added for integrated tariffs

With the following constants:

Variable	Value 2024	Value 2025	Value 2026	Unit	Description
F_{min}	35	35	35	MW	Minimum offset for grid-load variation that increases tariff variability (= high variability)
F_{max}	35	55	75	MW	Maximum offset for grid-load variation that increases tariff variability (= low variability)
YGL_{min}	30	−30	−100	MW	Minimum measured grid load two years prior to the tariff year
YGL_{max}	550	550	550	MW	Maximum measured grid load two years prior to the tariff year
$MGLO_{low}$	0	280	250	MW	Minimum grid-load offset for increasing variability
$MGLO_{high}$	0	200	150	MW	Maximum grid-load negative offset for increasing variability

More details on the tariff calculation are published in (Cuony, 2025).

The Vario tariff was introduced as planned in January 2024 and the number of customers signed up increased slowly but steadily, from 10 customers billed in Q4 2024, to 93 in Q4 2025, and 112 sign-ups by the end of Q1 2026 (billed from Q2 2026). The roll-out is therefore in line with expectations and allows for a qualitative analysis of customer satisfaction and behavior.

In Q4 2025 93 customers were billed with the Vario-Tariff. Figure 6 below shows the absolute and relative gain of these customers with respect to the standard double tariff.

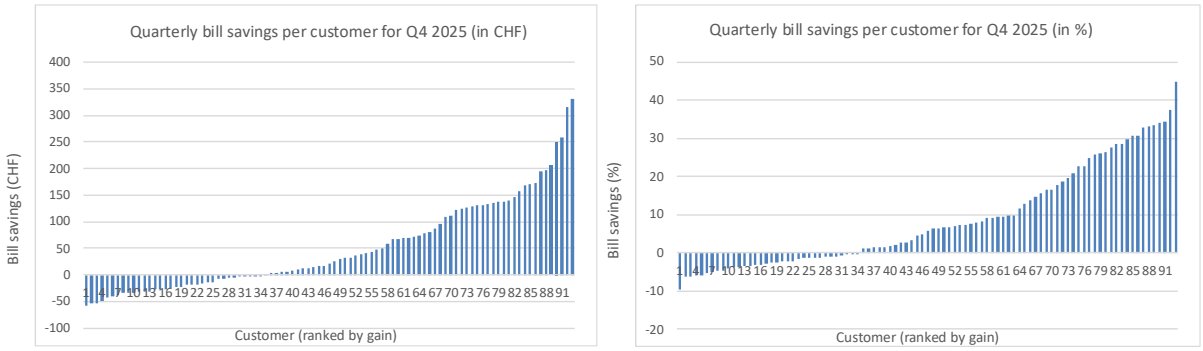


Figure 6: Bill savings with vario tariff, compared to the standard double tariff in CHF (left) and percent (right). The values are presented in ascending order for both plots.

From the 93 customers, 59 customers reduced their electricity bill (gain see Figure 6 above), whereas 34 paid higher electricity bills compared to what they would have paid with the standard double tariff. The bill savings in Figure 6 are the difference between each customer's bill under the double tariff and under the Vario tariff, computed on the same measured Q4 2025 consumption; In the summer quarters the relative bill savings for these customers are similar, whereas the absolute bill savings are lower, because most of them are PV-producers and have significantly lower electricity costs in the summer quarters.

One of the main challenges of the introduction of such optional dynamic grid tariffs is to quantify the effect on the grid load of such a tariff and the cost of this approach to remunerate flexibility. To attempt quantification, we wanted to analyze the load curves for the quarters Q1, Q2, Q3 and Q4 2025 of the Vario customers and compared them with the load curve from the same quarter the year before. As Groupe E started the roll-out of smart meters in 2023 there were however no load curves available for the year before for a large part of the Vario customers. For the analysis of the effect of Vario in Q4 2025, there were load curves available for Q4 2024 and Q4 2025 for 54 out of the 93 customers that had signed up to the vario tariff until then. For these customers we calculated average daily load curves by taking the average power consumed from the grid for each hour in the day over the entire quarter. Figure 7 below shows three representative examples (probably single-family houses with PV). Customer x1 shows a typical consumption profile with a consumption peak in the morning and in the evening without any optimization in 2024 and clear reduction of these peaks in the 2025 profile with a new peak in the night and in the afternoon, typically, when the Vario-tariff is the lowest. Customer x2 shows a similar behavior but has already a peak in the evening due to a tariff optimization with the double tariff that passed form high to low tariff at 21 o'clock in 2025. For this customer, the evening peak is shifted to the middle of the night with the Vario tariff in 2025 and the morning and evening peak disappear and a new peak in the afternoon appears. Customer x3 shows no significant changes between the two years.

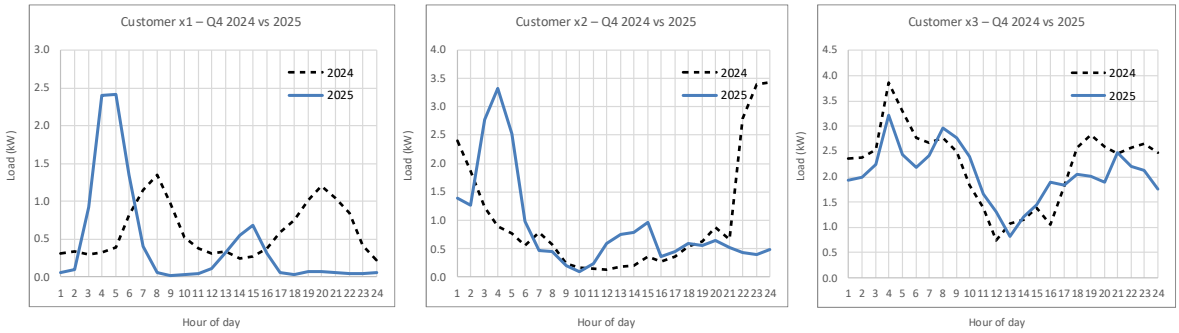


Figure 7: Three examples of average daily load curves from customers with the Vario-Tariff.

It is probable that the customers that pay more with the Vario-Tariff will change back to the standard tariff. To analyze the probable enduring impact in on the load curve we summed the daily average load profiles of the 32 customers in the Vario-Tariff where we had load curves for Q4 2024 and Q4 2025 and who had a financial gain in the Vario-Tariff compared to the standard double tariff.

As Groupe E still was in an early phase of the smart meter roll-out in 2024, the number of customers with smart meter data in the earlier quarters is lower. Figure 8 and Figure 9 show the impact of the tariff on the aggregated load curve for Q1, Q2 and Q3 of 2024 vs.2025 and approximate power and energy displacement effects are indicated with arrows in green and red. The comparison between the tariff impact in summer (Q2, Q3) and winter quarters seems to indicate, a reduced load-shifting during summer months. Two reasons could explain this. On the one hand, increasing temperatures during summer could reduce the volume of flexible thermal loads from heat-pumps and boilers. On the other hand, increasing PV production during summer could attract much of the remaining flexibility to maximize own consumption, leaving less free flexibility for additional tariff optimization.

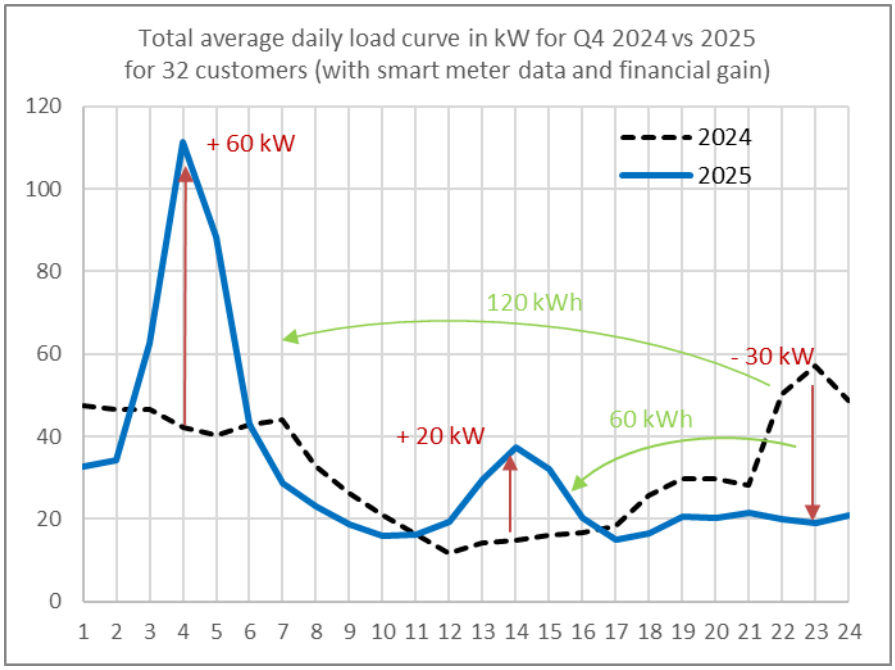


Figure 8: Sum of average daily load profiles of the 32 customers who reduced their bill with the Vario tariff compared to the standard double tariff in Q4. The load curve of 2024 is adjusted to the energy consumption of 2025 for better comparison of load shifting.

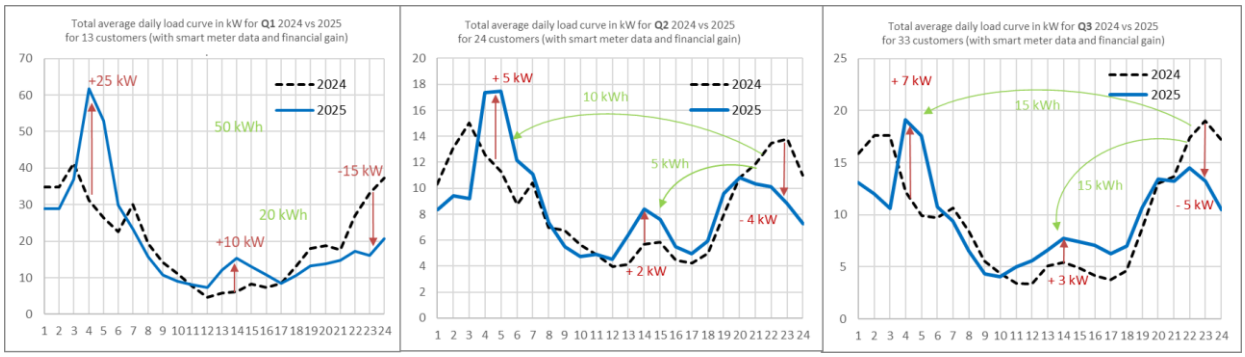


Figure 9: Sum of average daily load profiles for customers who reduced their bill with the Vario tariff compared to the standard double tariff in Q1-3.

2.2 Surveys (Groupe E)

Description of the approach:

In collaboration with Groupe E, an energy management system (EMS) provider contacted 200 customers equipped with their EMS in the Groupe E grid area to invite them to test the Vario tariff for the year 2025. Participation was limited to 50 customers. As a thank-you, participants received an 80 CHF Migros gift card and were guaranteed protection against any additional costs during the pilot year. Groupe E analyzed each customer's energy bill and reimbursed the difference if the Vario tariff turned out to be more expensive than the standard dual tariff. Participants agreed to complete two surveys: one after the first quarter and another at the end of the project.

Questions asked in the first quarter:

1. What motivated you to choose this tariff?
2. Have you changed your consumption habits since the start of the project?
3. Do you let your energy management system run automatically, or do you make manual changes? If so, when?
4. Are you satisfied with the optimization, or did you have higher expectations?
5. Have you noticed any changes in the energy management system? If so, how did these changes manifest themselves?
6. How do you actually use the tariff and what lessons have you learned from it?
7. How satisfied are you with the vario tariff? Why?
8. Do you have any suggestions to help us improve our vario tariff? Would you like to add anything else about your experience with the vario tariff?

Questions asked in the final survey:

1. Have you changed your consumption habits since the start of the project?
2. Do you let your energy management system run automatically, or do you make manual changes? If so, when?

3. Are you satisfied with the optimization, or did you have higher expectations?
4. Have you noticed any changes in the energy management system? If so, how did this change manifest itself?
5. How often do you check the tariff? Rarely – several times a month – several times a week – several times a day
6. How satisfied are you with the vario rate? Why?
7. Do you have any suggestions to help us improve our variable rate? Would you like to add anything about your experience with the variable rate?

Conducting two surveys, one after the first quarter and one at the end of the project, revealed an increasing change in consumption patterns and an increase in customer satisfaction with the tariff.

Main results:

- **Motivations for choosing the Vario tariff:** The main reasons mentioned were cost savings and consumption optimization. Curiosity, interest in innovation, and contributing to the energy transition were also cited.
- **Changes in consumption behavior:** As shown in Figure 10, a majority of participants reported having adapted their consumption habits already during the first quarter, and this number increased to three quarters of all responding participants by the end of the project.

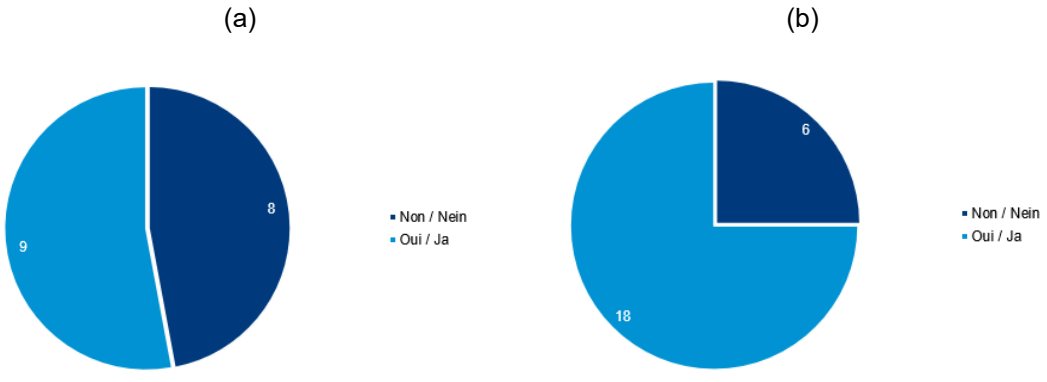


Figure 10: Change in consumption habits (a) during first quarter and (b) at the end of the project.

- **Automation vs. manual actions:** Approximately one-third rely fully on automatic EMS operation, one-third act manually, and the remaining third use a combination of both.
- **Satisfaction:** As shown in Figure 11, most customers expressed high satisfaction with the optimization and with the Vario tariff overall, and satisfaction increased between the first quarter until the end of the project. The high satisfaction with automated optimization observed here is consistent with the central role that automation plays for realizing customer benefits in the simulations (sections 2.3.1 and 2.3.2).

(a) (b)

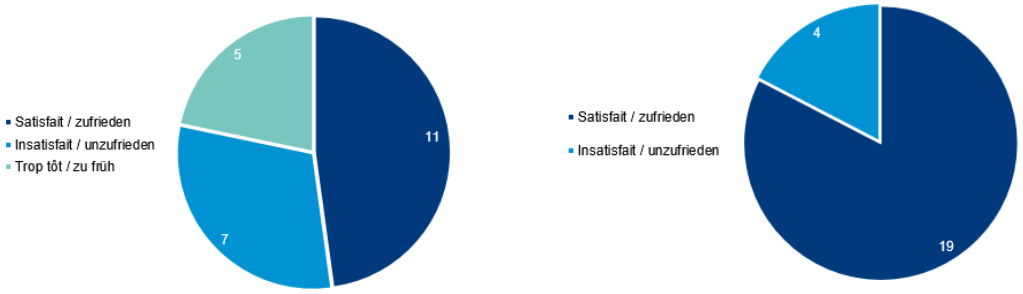


Figure 11: Customer satisfaction with vario tariff (a) during first quarter and (b) at the end of the project.

Conclusion:

The two surveys conducted - after the first quarter and at the end of the year - highlight a clear interest in the Vario tariff and a willingness to optimize energy consumption. A majority of participants modified their habits, demonstrating strong engagement. Areas for improvement remain, particularly regarding expectations for higher savings and more transparent billing. Overall, the Vario tariff is perceived as a promising solution, even if certain practical and structural adjustments will be necessary to fully meet user expectations.

2.3 Simulations

As described in Figure 1, the simulations in this section were run in parallel to the field-tests. Siemens (section 2.3.1) quantified the customer benefits of switching from a conventional controller without optimization to an optimizing controller that includes PV self-consumption optimization and exploiting dynamic tariffs in the optimization. Recall that the inclusion of tariff levels in the optimization is what EMS providers identified as the main implementation challenge in the pilot-study (section 2.1.3). Empa (section 2.3.2) broadened this perspective from single buildings to building portfolios and smart communities, evaluating the Vario tariff and alternative tariff designs across technologies and analyzing the aggregated demand effects when many automated buildings respond to the same price signal. Tariff simulations by Siemens (section 2.3.1) and EMPA (section 2.3.2) both assumed a daily rolling planning horizon, which can directly be used in the field. However, this approach cannot capture the impact of direct load control of all loads by the system operator or tariff design variations such as monthly or yearly capacity charges per-kWp maximum withdrawal. During the project, ZHAW therefore worked on two complementary simulations (section 2.3.3), which broaden the assessment further by testing additional tariff design variations that were not possible with the other two simulation approaches.

2.3.1 Simulation of bill-impacts (Siemens)

Siemens investigated how attractive the load-dependent tariff of Groupe E would be for end-customers. This was first done for a preliminary tariff in July 2023, and then again for the final tariff in September 2023, after its publication. To this end, the savings that an optimizer can achieve compared to a well-tuned conventional state-of-the-art controller **(=Reference Controller)** were assessed. This was done by means of whole-year simulations. A **Rule-based Model Predictive Controller (RMPC)** with a receding horizon of 24h and 15min stepsize was used for the optimization. The optimizer was designed as an add-on to the reference controller, leaving all exception handling with the reference controller. The

necessary forecasts for PV production, electrical baseload, and heat consumption for room heating and domestic hot water were generated by data-driven forecasters (i.e., without a-priori knowledge), as it must also be done in a real product. The optimization algorithm used was thus very close to a real product. The reference controller and the RMPC optimizer thus control the same equipment under the same comfort constraints. The key difference is that the reference controller controls the plant in a conventional way, without any information on grid tariff and PV production, and without any form of self-consumption optimization, whereas the RMPC optimizer additionally uses the tariff, the measurement and prediction of the PV production, and the above forecasts over the next 24 hours to schedule heat pump operation and storage management at least cost. The need to add the price dimension to control algorithms that previously only optimized self-consumption is also what the EMS providers in the pilot-study described as the main implementation challenge (see section 2.1.3).

The heating, ventilation, and air conditioning (HVAC) cost savings were assessed for a single-family home (SFH) and a large multi-family home (MFH). Since 2023, the RMPC optimizer could be further improved. The savings are now around 9% to 13% for the MFH and around 25% for the SFH. This shows that it can be attractive for end customers to shift their heat pump operation according to a grid-friendly tariff.

2.3.1.1 Single-family home

Firstly, we demonstrated the savings of the optimizer on a single-family home with 140m2 floor space, for the two scenarios with and without PV. The relevant HVAC dimensionings were as follows: Heat pump with 1.5 kWel, minimal modulation rate 30%, DHW storage 500 L, and Room heating storage 400 L. We show the results both as bar plots (Figure 12) and as a table (Table 1).

Let's first discuss the methodology. The trivial part is to determine the absolute savings (in CHF). The tricky part is to determine the relative savings, which allows to compare the "success" of the optimizer between different buildings. The energy bill is not a suitable reference value for calculating the relative savings. This follows from the imaginary case with large PV where the bill is already negative (= SFH owner gets money from energy supplier) without optimization. Also, the baseload should not be included in the reference value because it cannot be influenced from the HVAC controls. Instead, we use the HVAC cost with the reference controller as a reference value. And the HVAC cost is computed as the sum of cost for electricity consumption from the grid, and opportunity cost for self-consumed PV power.

We discuss this based on Figure 12 below. In the bar plot below, the two right bars depict the scenario with PV. The green positive bars denote the value of the PV valued at the feed-in tariff. This is thus the money that the SFH owner would get if the PV production was entirely fed into the grid. Next, let's look at the baseload cost. The baseload cost is composed of the cost for electricity from the grid (dark blue) and the cost for self-consumed PV energy (light blue). The latter is an opportunity cost – it is money that the house owner does not get because he/she doesn't feed in the related energy into the grid. Similarly, the HVAC cost includes cost for electricity from the grid (red), and opportunity cost for self-consumed PV energy (orange). Obviously, the absolute savings [CHF] in the energy bill thanks to the RMPC are identical to the reduction of the HVAC cost.

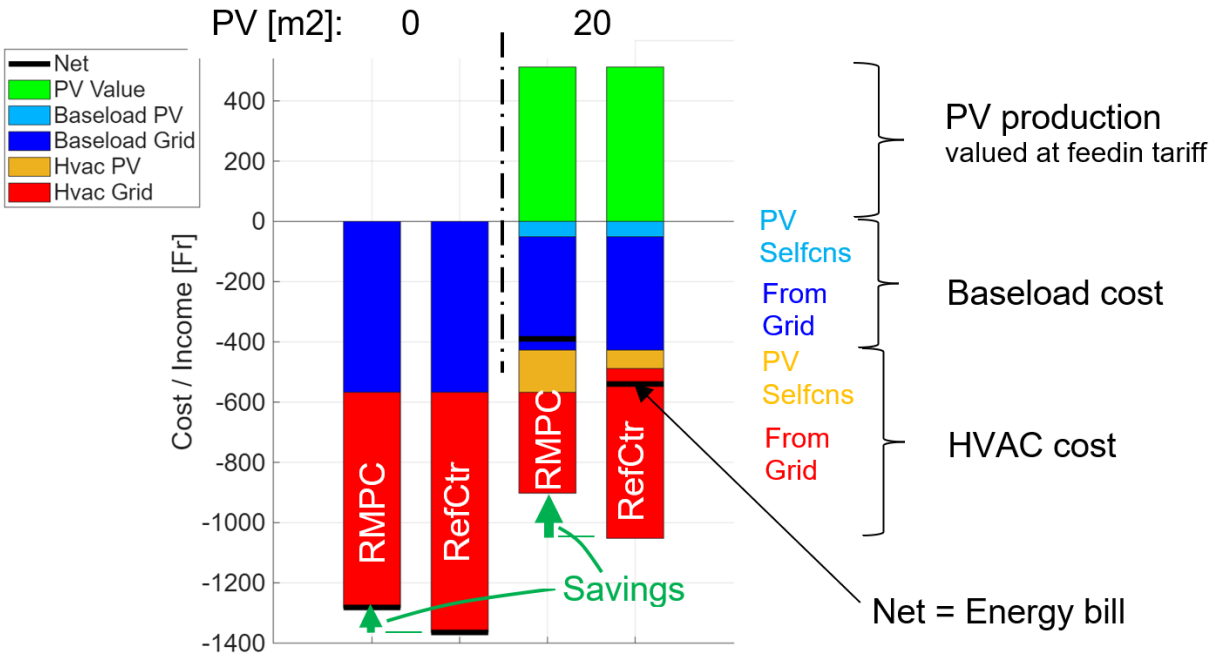


Figure 12: Customer cost with dynamic tariff for single-family home without PV (=left half) and with 20 m2 PV (=right half). The costs with RMPC optimizer are compared to the case without optimizer, i.e. only the reference controller (RefCtr).

Table 1: Numeric results for the same single-family home with dynamic tariff. RMPC savings = reduction of HVAC cost and energy bill by the RMPC optimizer, compared to the case with a reference controller that doesn't optimize the dispatch (=RefCtr). The relative savings are calculated using the HVAC cost as a reference value.

PV Size	**RMPC Savings**		**RMPC** Cost H	Cost H+Bld	**RefCtr** Cost H	Cost H+Bld	**PV** Value	**Baseload** Cost
	Abs [Fr]	Rel [%]						
No	83	10.4%	715	1282	798	1365	0	567
20 m^2	150	24.0%	475	902	625	1052	512	427

The simulation results show the following noteworthy facts:

- With PV, the RMPC optimizer can reduce cost compared to the reference controller by an impressive 10% to 24% of HVAC cost (6% to 14% of total household cost), and more than double the PV self-consumption for HVAC.

- Without PV, the savings generated by switching from a reference controller to an RMPC optimizer amount to 10% of HVAC cost (6% of total household cost).

- Using the RMPC optimizer can be financially attractive if the commissioning process is very simple (near plug&play).

2.3.1.2 Multifamily home (MFH)

Secondly, we demonstrated the savings of the RMPC optimizer on a huge MFH complex of 19'000 m net floor space that is located in Vienna. We simplified the building's shape and HVAC equipment structure while preserving its overall dimensions and characteristics, as well as measured consumption data. Below, we present the simulation results for 3 different PV sizings (no PV, 300 m2 PV, and 600 m2 PV). Note that, unlike in Figure 12, only the HVAC cost and the PV feed-in are depicted below; the baseload is omitted. The absolute cost levels are therefore not directly comparable to those in Figure 12. The RMPC optimizer reduces the yearly HVAC cost by between 7'700 and 9'600 CHF, or between 9 and 13%.

Below, the simulation results are given for 3 different PV sizings both as bar plots and as a table.

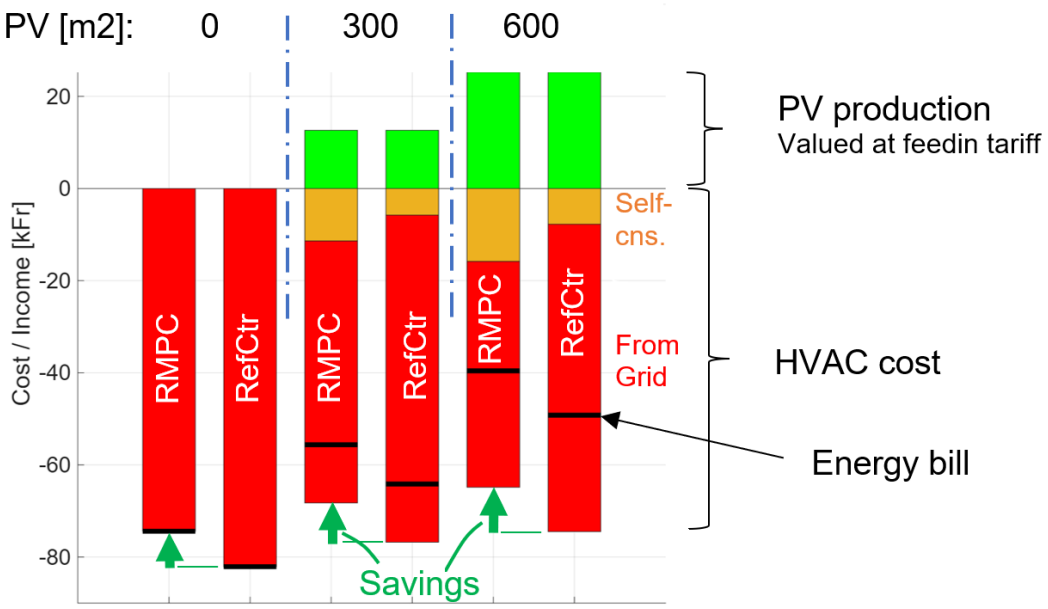


Figure 13: Customer cost with dynamic tariff for multi-family home without PV (=left), with 300 m2 PV (=middle) and with 600 m2 PV (=right). The cost with RMPC optimizer are compared to the case without optimizer, i.e. only the reference controller (RefCtr).

Table 2: Numeric results for the same multi-family home with dynamic tariff. RMPC savings = reduction of HVAC cost and energy bill for the HVAC (excluding the baseload) by the RMPC optimizer, compared to the case with a reference controller that doesn't optimize the dispatch (=RefCtr). The relative savings are calculated both using the HVAC cost as a reference value, both using the HVAC cost and using the energy bill as a reference value.

PV size	Savings RMPC			Cost RMPC	Cost RefCtr	Value PV
	Abs [kFr]	Rel [%] related to HVAC cost	Rel [%] related to energy bill	[kFr]	[kFr]	[kFr]
No	7.70	9.4%	9.4%	74.40	82.10	0.00
300 m^2	8.53	11.1%	13.3%	68.26	76.79	12.64
600 m^2	9.63	12.9%	19.6%	64.86	74.49	25.28

The simulation results show the following noteworthy facts:

- The RMPC optimizer can save roughly 8'000 to 10'000 CHF per year. This corresponds to between 9% and 13% of the HVAC cost, and between 9% and 20% of the energy bill (excluding baseload costs).

- The degree of self-consumption is doubled from 46% to 90% in the case of 300m2 PV.

This suggests that using the RMPC optimizer for large MFH buildings could be an excellent business case, as the typical cost of an RMPC controller, including work for engineering and commissioning is well below the annual cost savings of roughly 8'000 to 10'000 CHF that could be achieved by an RMPC.

2.3.2 Simulation of tariff impacts (EMPA)

Empa developed the tariff evaluation models and optimization problems for various techniques, i.e., electric vehicles, heat pumps, domestic hot water, and a living laboratory NEST as a specific building archetype at Empa, which allows us to evaluate the impact of different tariff designs. The tariff evaluation models for techniques are based on the measurement data and their statistic knowledge, as the transportation behaviors of EVs, the heat pumps and boilers behaviors under various weather patterns. Empa simulated the hourly time-series load curves using different techniques for the feed-in and withdrawal tariff designs described in Figure 3. Each of these tariff designs was either run without an additional peak tariff (=without peak case), or in combination with a tariff per daily, measured peak consumption (=with peak case). The evaluation results between Groupe – E Vario tariff and the classic double tariff (as a benchmark) demonstrated that the dynamic tariff is successful in peak shifting under different scenarios.

Building archetypes for 1.8 million buildings in Switzerland were developed at Empa to support tariff evaluation, using the GWR (Switzerland's official Building and Housing Register) public dataset. These archetypes incorporate various household energy control devices, including EVs, PV-battery systems, HPs, domestic hot water systems, and plug-in loads. The thermal model of each individual building is parameterized based on its construction type, year of construction, and year of retrofit. We consider the size of the PV panels to be related to the rooftop area, which is assumed to be equal to the ground area. The plug-in load trajectories were developed based on a group of real measurements with randomness. To improve the granularity of the simulation results, all buildings were connected to the nearest ambient temperature measurement stations (700 stations in total). Additionally, as illustrated in Figure 14, a tariff simulation software with a user-friendly graphical user interface (GUI) was developed to accommodate a range of input parameters, such as PV-battery deployment plans, end-user tariff choices (energy tariffs, peak tariffs, and PV feed-in tariffs), and the number of EVs in the household. In this software, we can easily select one house to simulate its energy bills, with outputs including energy consumption and the operating trajectories of all the above-mentioned devices under various tariffs. We consider this software to have great potential for effectively analyzing the impacts and benefits of tariffs at the levels of individual

households, municipalities, and even larger scales. In addition, it also has educational value and could be used by utilities or municipalities to inform the public and promote newly developed tariffs and green energy technologies. This approach allowed analyzing how different tariff designs impact households with varying energy consumption patterns.

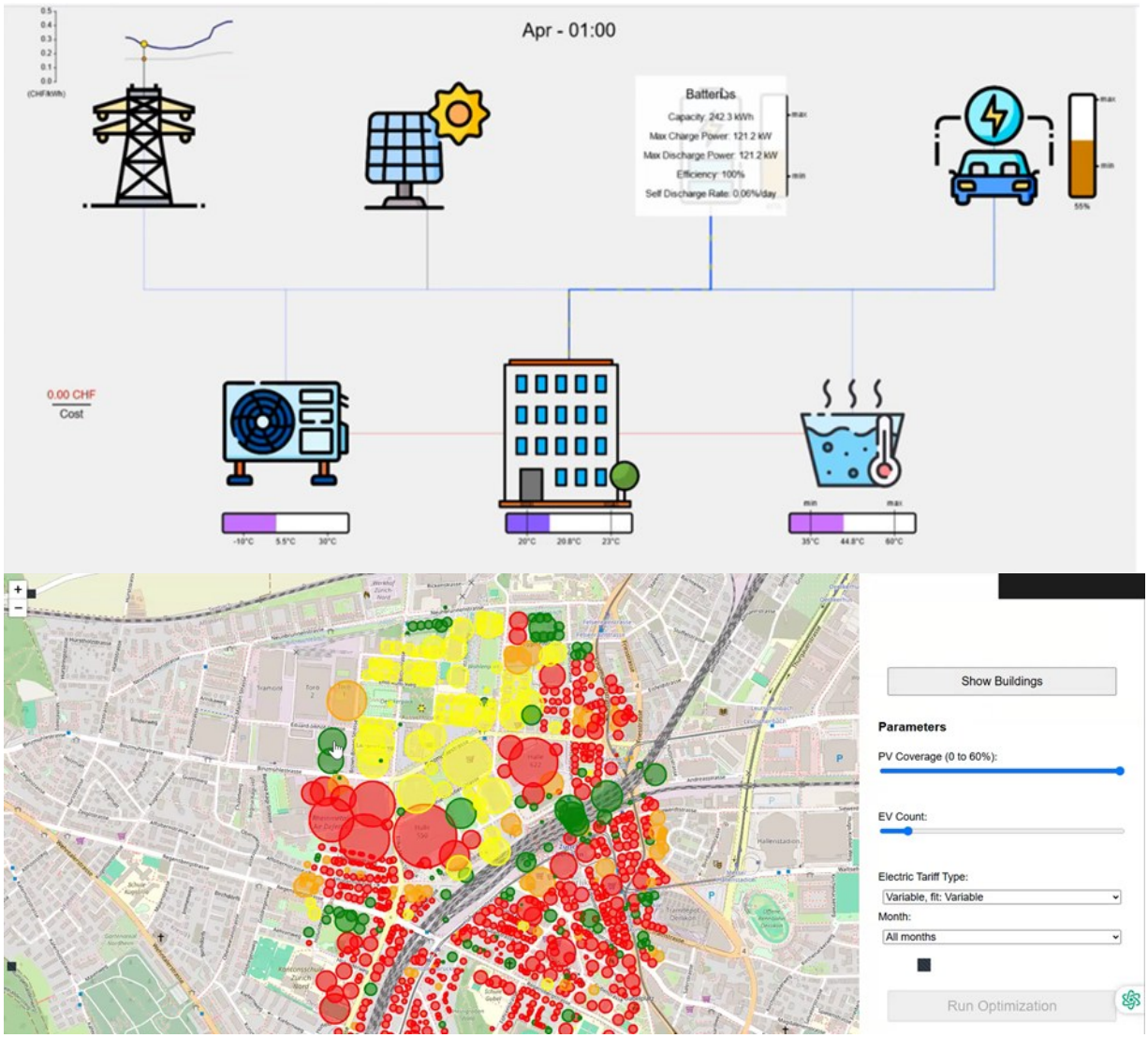


Figure 14: Graphical user interface of the GIS-based grid tariff simulation software.

The tariff simulation tool focused on residential buildings and developed a model to optimize the control of distributed energy resources, including batteries, EV charging stations, and rooftop PV systems. It grouped buildings into archetypes based on characteristics such as size, thermal mass, and insulation quality, and then evaluated how different optimization strategies performed across these diverse conditions. It also assessed the economic incentives for households to invest in rooftop PV and EVs by quantifying how smart controllers can influence electricity costs under different assumptions. In addition, the tool analyzed the role of external drivers, such as outdoor temperature variation and user comfort preferences, to understand their effects on energy consumption patterns. Finally, it examined how alternative electricity pricing schemes and feed-in tariffs (i.e., the remuneration paid for electricity fed into

the grid, varied here together with the pricing scheme, cf. Figure 3) shape the behavior of smart communities, providing insights into how policy measures can encourage more sustainable energy use. Figure 15 and Figure 16 illustrate the average electricity costs for three different tariff structures (flat, dual, and variable; see Figure 3), without and with a peak tariff, respectively. In all scenarios, PV feed-in is remunerated at the feed-in tariff associated with the respective tariff scheme (see Figure 3). The results are categorized into four scenarios based on available energy resources: buildings without PV or EV, buildings with only EV, buildings with only PV, and buildings with both EV and PV. In these charts, the gray difference represents the cost reduction achieved through optimization compared to a non-optimized baseline. Two key observations can be made comparing the different scenarios: (i) Buildings equipped with PV systems experience significantly lower electricity costs compared to those without PV. This effect is particularly pronounced under the dual and variable tariffs, which allow customers to generate more revenue from electricity feed-in than the flat tariff, because each tariff scheme has its own associated feed-in remuneration (see Figure 3). (ii) The presence of EVs has a minor impact on cost reduction, which is only observed in buildings utilizing smart controllers. The extent of cost savings due to optimization (i.e. smart control that schedules EV charging, heat pump, and domestic hot water operation in response to the tariff) increases with greater tariff variability and when a peak tariff is applied.

From the grid operator's perspective, understanding how different electricity tariffs shape building electricity demand is crucial. Figure 17 presents the aggregated electricity demand of 100 buildings, composed of 25 buildings per scenario. The results highlight that electricity tariffs significantly influence demand patterns, as seen in the distinct demand curves for each tariff. The Flat tariff offers no control over the demand, the dual tariff offers very little control over the demand, and the variable tariff offers the most control over the demand. However, as the number of smart buildings increases, demand profiles become more sensitive to tariff structures. This is due to the synchronization effect within smart communities: when electricity prices drop at a specific time, all smart buildings respond simultaneously by increasing their consumption, potentially leading to demand spikes. This effect is particularly visible for the representative day of December. Note that the simulated buildings include PV-battery systems; the export peaks visible in the morning and evening result from tariff-driven discharge of these home batteries, not from vehicle-to-grid (V2G) feed-in, which was not considered in the simulations.

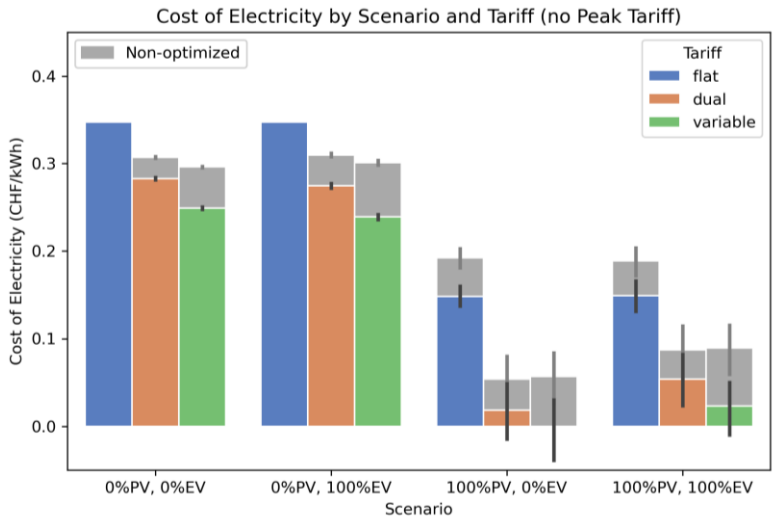


Figure 15: Average cost of electricity for different tariffs and scenarios without peak tariff application.

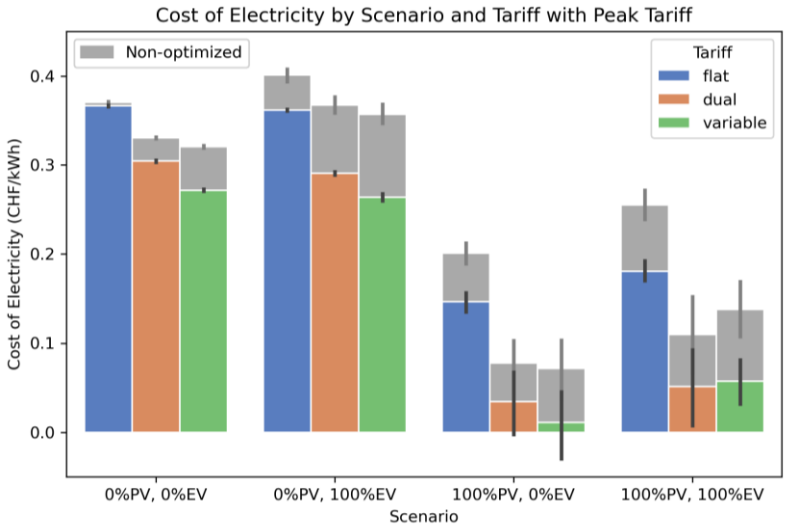


Figure 16: Average cost of electricity for different tariffs and scenarios with a peak tariff applied.



Figure 17: Aggregated electricity demand of 100 buildings under different tariff structures for a representative day of each month.

Figure 18 compares electricity import profiles under a variable tariff for three representative months (February, June, and October), contrasting operation with a peak-tariff constraint (left) versus without a peak tariff (right) across the time of day. With a peak tariff, the import trajectory is noticeably smoother and tends to avoid sharp excursions, staying closer to the central band indicated by the dashed reference lines. Without a peak tariff, the profiles exhibit more pronounced spikes and troughs, most clearly in February and October, indicating larger short-duration imports (and in some periods net export) compared with the peak-tariff case. The results demonstrate that the peak tariff effectively reduces peak loads and overall demand variability.

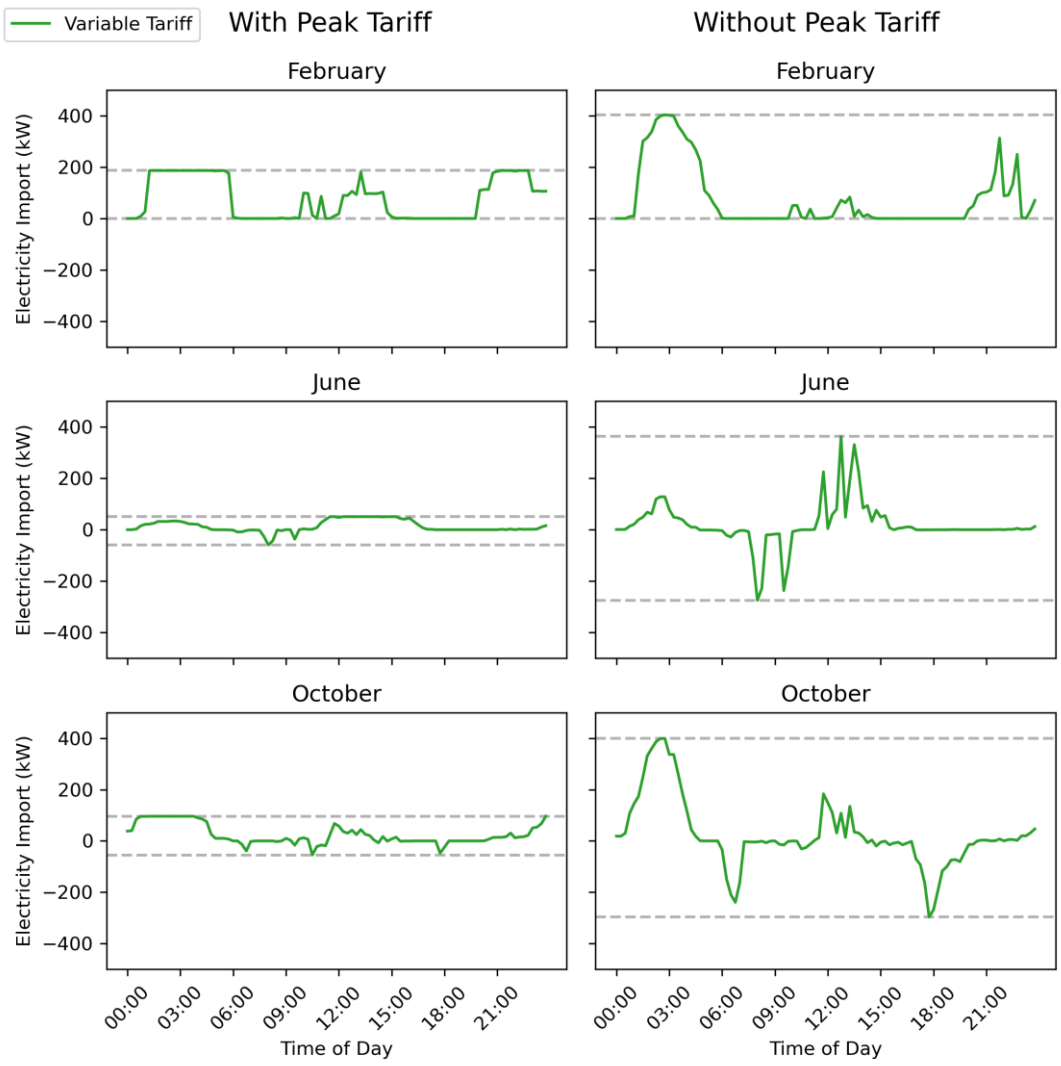
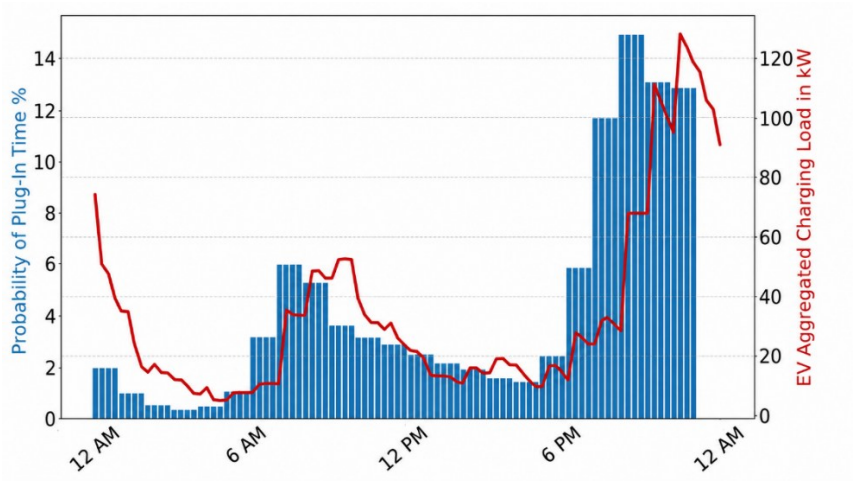


Figure 18: Aggregated demand of a smart community of 25 buildings with PV and EV under a variable tariff, with and without peak tariff, for a representative day in three different months. The buildings include PV-battery systems; the export peaks in the early morning and evening result from tariff-driven battery discharge (no V2G is assumed).

EMPA also simulated the effect of different tariffs on EV-charging load curves. Figure 19 shows the probability of plug-in time and the aggregated charging load without any tariff incentive (Figure 19a). This un-influenced charging behavior shows a load peak of 120 kW in the evening which is problematic for distribution grids as the current grid peaks is already taking place in the evening. Assumptions underlying the simulation are listed in (Figure 19b).

(a)



(b)

	Parameters
Simulation Periods	2022-01-01T00:15:00.000+01:00 2022-01-07T23:45:00.000+01:00
Initial SOC	[0.3, 0.6] (randomly distributed)
Charging power (kW)	[8, 12] (randomly distributed, but fixed for individual EVs)
Constraints on SOC	[0.05, 1.00]
Battery capacity (kWh)	50 (fixed)
Daily energy consumption (kWh)	[0, 0.5*50] (randomly distributed by Poisson Distribution with the mean value of 8.5kWh)
Plug-in time	Randomly generated by the distribution as shown in the plot below
Plug-in duration in hours	[7, 10] (randomly distributed with the mean value of 9)
Number of EVs per simulation	100 (scenarios)
Time interval	15 minutes

Figure 19: (a) Simulated plug-in probability (blue) and aggregate charging load (red) in absence of tariff incentives as well as (b) assumptions underlying the simulation.

The simulated aggregated EV charging load (red) if all the EVs respond to the tariff incentive (green), are shown in Figure 20. For a double tariff (Figure 20a) all the cars wait until the tariff change and start charging at the beginning of the low-tariff period. Such a tariff allows to displace the charging peak away from the grid peak, but results in an even higher peak load at the beginning of the low tariff period due to the high simultaneity of consumption. Similarly, the charging peak is also very high with the dynamic tariff because all the cars are charging at the time with the lowest tariff during the night (Figure 20bb). The peak in the early morning during the lowest grid load hours caused by a dynamic tariff is less problematic for distribution grids than the peak in the late evening produced by the double tariff. Even if the assumption that all the EVs respond to the tariff incentives is not very realistic, this can be a worrying prospect for DSOs. EMPA therefore simulated various complements to the dynamic tariff that allow to displace le EV load to the hours with the lowest grid load while also limiting the magnitude of the new peak. Figure 19c shows the charging load curve produced by the dynamic tariff complemented with a power component of 15 cts/kW that is billed each day during the low tariff hours of the dynamic tariff. The results show that with such a tariff design it is possible to reduce the peak load by a factor of almost 4 by broadening the load profile around the hours with the lowest grid load and thus lowest prices.

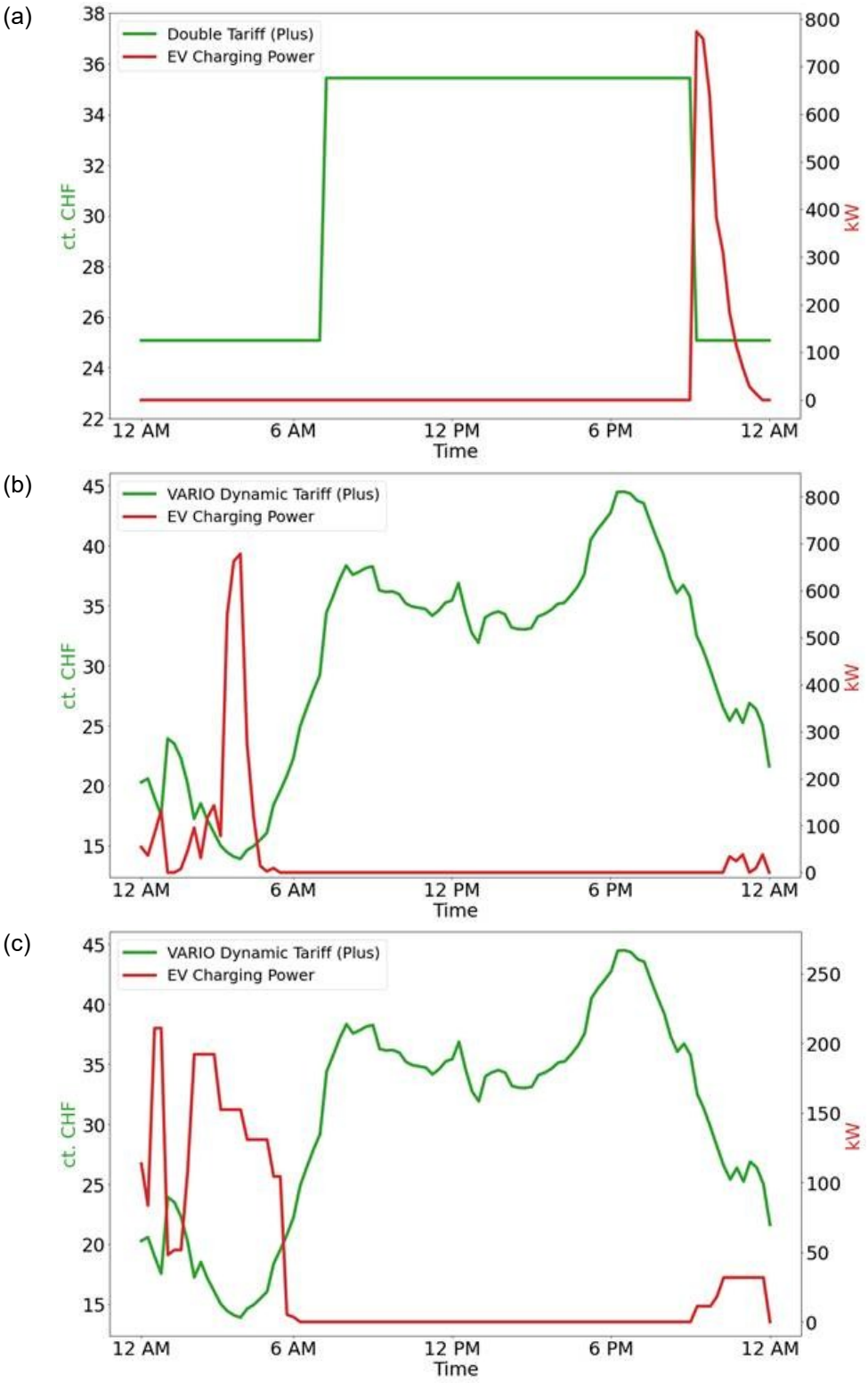


Figure 20: Tariff (green) and simulated load from 100 EVs (red) in case of (a) Double Tariff, (b) Vario Tariff and (c) Vario Tariff with an additional capacity charge per kWp of maximum daily withdrawal.

In summary, we evaluated the Groupe E Vario tariff across different technologies, such as electric vehicles, heat pumps, domestic hot water systems at different scales, and living laboratory, in comparison with the other per-kWh withdrawal and feed-in tariffs described in Figure 3, both for the case with and without an additional capacity charge per kWp of maximum daily withdrawal. Throughout this report, kWp denotes the customer's maximum daily withdrawal, not installed PV capacity. We note that the Vario tariff has the capability to incentivize flexible demand-side electricity consumers abovementioned to operate during periods of relatively low electricity prices without sacrificing their performance

2.3.3 Simulation of tariff design variations (ZHAW)

As explained in the introduction to section 0, ZHAW worked on two complementary simulations, which are summarized in separate sections below.

2.3.3.1 Impact of different stand-alone tariff designs

The first paper (Winzer & Hensler-Ludwig, 2024) compared the impact of separately applying different grid tariff designs on grid-peak load, energy cost and total system cost. ZHAW simulated the impact of tariffs on households which are equipped with different combinations of flexible loads (electric vehicles, heat-pumps, batteries) and PV. Simulation results suggest, that while dynamic per-kWh tariffs proportional to the grid-load forecast can help to reduce system peak-load in case of a low share of flexible loads which react automatically to tariff signals (see the gridload and gridload_spot scenarios in Figure 21, a), the over-coordination and herding behavior of automatically controlled loads may lead to rebound peaks that exceed the original peak-load in case of higher share of flexible loads which react automatically to tariff signals (Figure 21, b). A simple capacity price on customers' individual peak-load, applied on its own without any dynamic per-kWh component, achieves a much smaller impact but seems to avoid over-coordination because it creates an incentive to spread loads across time (see the capacity scenario in Figure 21, a and b).

Results have been presented on several occasions (e.g., at the PATHFNDR Site-Visit in Zurich, in May 2024). A systematic comparison to other flexibility incentives, such as market-based flexibility procurement, was foreseen as an additional work step but could not be carried out within this project, as the required supplementary funding was not available (see section 1.1).

(a)

(b)



Figure 21: Change in peak-load compared to the status quo (SQ) scenario which assumes a flat per-kWh tariff if all residential electric vehicles, heat-pumps, and batteries connected in 2020 (a) or in 2050 (b) are automatically controlled in response to capacity tariffs (capacity), time-of-use tariffs (TOU), hourly and daily critical-peak prices (CPP_h and CPPd), tariffs proportional to grid load (gridload), grid load and spot (gridload_spot) and proportional to spot prices only (spot) as well as direct load control (DLC, i.e., not a tariff but a benchmark scenario in which the grid operator controls the flexible loads directly with the objective to minimize the peak load of the grid). Blue bars show the change in load during the hour of the day at which the load reaches its peak in the SQ scenario. Red bars show the change in load during the hour at which the load reaches its peak in the respective tariff scenario. Source: Winzer and Hensler-Ludwig (2024).

2.3.3.2 Impact of combining dynamic per-kWh prices with different types of capacity charges

In the second, forthcoming, paper (Winzer & Darudi, 2026), ZHAW explored to what extent the rebound peaks that are caused by dynamic per-kWh tariffs, can be mitigated by different types of per-kWp capacity charges. Preliminary results shown in Figure 22 below were obtained from simulations using only a subset of the 300 households (each equipped with the same combinations of electric vehicles, heat pumps, batteries, and PV, as in the first paper (Winzer & Hensler-Ludwig, 2024)) that will be simulated in the forthcoming paper (Winzer & Darudi, 2026), and may thus be revised in the course of the publication process.



Figure 22: Tariff scenarios sorted by impact on energy cost (top), grid cost (middle) and total cost (bottom).

As we can see in Figure 22, in our simulations the lowest energy cost was achieved by scenarios with **dynamic per-kWh prices** based on spot-prices and grid-load (blue bars) which achieved **up to 20% energy cost reductions** compared to the reference scenario with a constant per-kWh price and no capacity charges. Unfortunately, this was achieved at the expense of large increases in grid cost (blue bars reaching up to 200% reference grid cost in the second row are not fully visible, because the maximum y-axis value was set to 150% reference cost).

Lowest grid cost, was achieved by **proportional or constant per-kWp capacity charges** (purple and green bars) without dynamic per-kWh prices, which achieved **up to 12% grid cost reductions** compared to the reference scenario. Unfortunately, these tariffs hardly achieved any energy cost reductions.

Lowest total cost, which we assumed to be composed of 50% grid cost and 50% energy cost, was achieved by **combinations of proportional or flat per-kWp charges and dynamic per-kWh charges**. In our simulations, these scenarios achieved **up to 10% total cost reductions** by striking a balance between up to 6% energy cost reductions and up to 5 % grid cost reductions.

As described in Figure 23, a more detailed look at the impact of different tariff designs on the simulated loads during the week, when grid-load originally reached its maximum, shows that compared to the reference case of flat-per-kWh tariffs (Figure 23 a), the simulated loads (red-curve) an introduction of dynamic per-kWh charges (Figure 23 b) resulted in **load shifting** towards the night-time hours (see right charts in Figure 23 a and b, which shows the average values for each hour of the day). However, this leads to new peaks, in particular during those hours, with the lowest per-kWh tariff signals (see middle charts of Figure 23 a and b, where values were sorted from hours with largest to hours with smallest historical grid-load). The introduction of flat per-kWp charges on top of the dynamic energy charges (Figure 23 c) also resulted in load-shifting towards night-time hours, but with significant **peak reduction** during night-time hours and a second peak during noon hours.

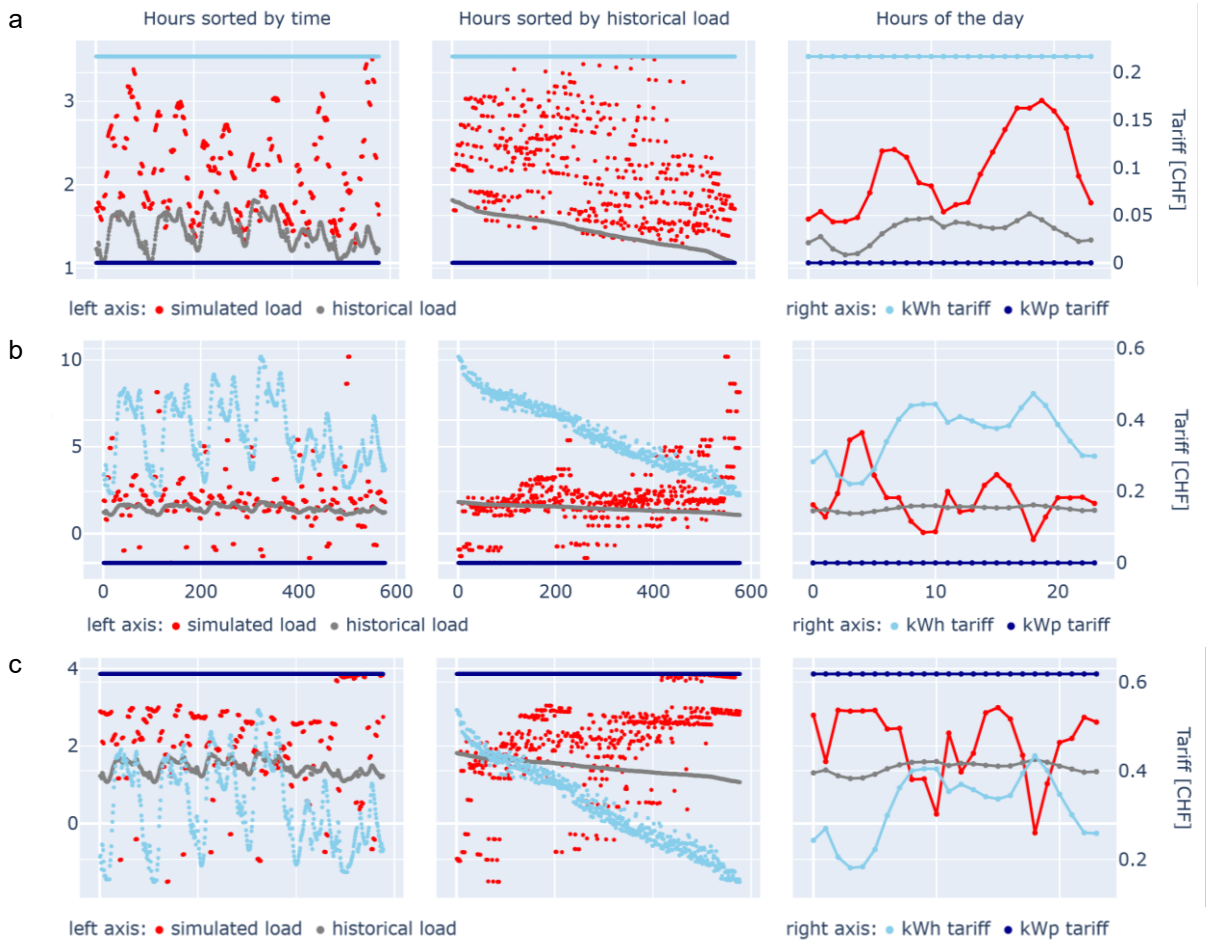


Figure 23: Load profiles for (a) flat-per-kWh only, (b) dynamic per-kWh only and (c) flat per-kWp combined with dynamic per-kWh charges.

3 Conclusion and outlook

The NEDELA project successfully demonstrated the implementation of dynamic tariffs in a real-life setting and achieved all of the four objectives that were specified at the beginning of the project (see section 1.3).

Regarding Q1, the definition of an **industry standard** for transmitting tariff signals (see section 2.1.1), initial workshops of Groupe E with EMS manufacturers concluded that dynamic tariffs should be transmitted to energy management systems via a standardized REST web-API. In the course of the NEDELA project, a first version of the Web-Interface was developed by Groupe E. Subsequent collaborations between Groupe E and Swisspower with other utilities and stakeholders in a work group of Association of Swiss Electricity Companies (VSE) resulted in the definition of a Swiss standard for the publication of dynamic grid tariffs entering into force on 1.1.2026.

Regarding Q2, the pilot-study by Groupe E (see section 2.1.3) identified and addressed a number of **implementation hurdles** which were partly also echoed in Lab-tests by EMPA (section 2.1.2). All of the 4 EMS-providers that were involved in the pre-tests confirmed that the dynamic electricity prices required adjustments to their optimization algorithms, which were sometimes challenging to implement. Even after the algorithms had been adjusted, many of the households did not have enough to reduce their electricity bill compared to the high-low tariff that was used as a benchmark. As described in section 0, in the long run, Groupe E therefore only expects those customers to remain in the Vario tariff, which were able to reduce their bill.

Regarding Q3, the **tariff impact** on grid load and system cost, an evaluation of the field-study results for the subset of 32 customers that are likely to remain in the Vario tariff indicates, that the tariff successfully shifted flexible loads to off-peak periods in all four quarters that were analyzed (see section 0). Independent simulations by EMPA (section 2.3.2) and ZHAW (section 2.3.3) both confirmed the effectiveness of load-shifting incentives from dynamic per-kWh charges and suggest that, if the volume of flexible loads increases, dynamic per-kWh charges may need to be accompanied by capacity prices, to reduce the herding behavior during hours with low per-kWh prices. As a result of this, Siemens realigned its energy cost optimization strategy to incorporate the new short-window peak power tariff structure into its Rule-based Model Predictive Control (RMPC) algorithm. The integration was successfully completed as a proof of concept, demonstrating that the RMPC methodology could be adapted to dynamic peak-based pricing. This was a key achievement, as it was initially uncertain whether the existing RMPC framework could accommodate such a pricing model.

Regarding Q4, the two **tariff acceptance** surveys that were conducted (see section 2.2) revealed that about half of the customers participating in the field-study were satisfied with the tariff and had changed their consumption habits already during the first quarter of the field-study, and these numbers increased to more than 75% at the end of the field-study.

Overall, the project results support the merits of dynamic grid tariffs, while clarifying the conditions for their success. The field-study demonstrated that a dynamic, grid-load-following tariff can be implemented in practice, transmitted to energy management systems through a standardized interface, and accepted by customers, and that it shifts flexible loads to off-peak periods. At the same time, the savings potential remains limited for most customers: only those with a sufficient volume of automated flexible loads (such as electric vehicles, heat pumps, or batteries controlled by an EMS) were able to reduce their bills, and the adjustment of EMS optimization algorithms to dynamic prices proved technically challenging. The

NEDELA approach of combining a revenue-neutral dynamic per-kWh tariff with a standardized transmission interface has nevertheless proven to be a workable blueprint, whose interface has since been adopted as a national standard.

Looking ahead, while the general effectiveness of dynamic tariffs in shifting flexible loads has been proven, the optimal design of capacity charges remains an open topic, which will be addressed by the planned forthcoming publication (Winzer & Darudi, 2026). Further important research topics include the optimal calibration of dynamic tariffs, in order to align customer savings with grid-operator savings while also providing efficient investment incentives; the design of injection tariffs, with and without own-consumption benefits or a minimum off-take price; and the interactions between PV curtailment schemes and their impact on the investment in and dispatch of PV-battery systems as well as on system cost. For the NEDELA approach in particular, the next steps are to observe the long-term retention of customers in the Vario tariff after the end of the pilot-phase cost protection, to benchmark the tariff against alternative mechanisms for contracting flexibility (which could not be carried out within this project), and to transfer the lessons of the field-study to the broader roll-out of dynamic base tariffs that is now possible under Art. 18a StromVG.

4 Outputs and outreach

Publications (peer-reviewed or others)

Description:
Winzer, Christian, and Patrick Hensler-Ludwig. 2024. “Design and Impact of Grid Tariffs.” Energies 17 (6): 1364. https://doi.org/10.3390/en17061364.
Winzer, Christian, and Hongliang Zhang. 2024. “Cost Focus versus Comfort Focus: Evidence from a Discrete Choice Experiment with Swiss Residential Electricity Customers.” The Energy Journal 45 (2): 209–35. https://doi.org/10.5547/01956574.45.2.cwin.
Cuony, Peter, Federica Bellizio, Cédric Chanez, Philipp Heer, and Christian Winzer. 2023. “Dynamische Tarife für ein effizientes Stromsystem | VSE,” July 19, 2023. https://www.strom.ch/de/nachrichten/dynamische-tarife-fuer-ein-effizientes-stromsystem.
Winzer, Christian, and Patrick Dümmler. 2023. “Versorgungslücken im Strommarkt schliessen.” Die Volkswirtschaft, June. https://dievolkswirtschaft.ch/de/2023/06/versorgungsluecken-im-strommarkt-schliessen/.
Elsenbast, Wolfgang, and Christian Winzer. 2024. “Dynamische Netztarife und ihre Alternativen.” ENERGIEWIRTSCHAFTLICHE TAGESFRAGEN 74 (January): 39–43
Winzer, C., & Darudi, A. (2026). *Avoiding Rebound Peaks: Which Capacity Charges Best Complement Dynamic Electricity Tariffs in Distribution Grids* (Forthcoming)

Public oral and visual presentations (scientific or broad audience)

Description:
Cuony and Winzer: “Dynamische Tarife bei Groupe E und NEDELA Projekt”, VSE Tarif Workshop, Aarau, 2023
Christian Winzer: „Network Tariffs for Decentral Load Control”, PATHFNDR Research Seminar, Zurich, April 2024
Christian Winzer: “PATHFNDR ausgewählte Ergebnisse zur Integration von Erneuerbaren», BFE Seminar, October 2025
Christian Winzer: “Dynamische Tarife - Akzeptanz, Effizienz und Empfehlungen», Vertriebsleitertagung, Zurich, November 2025

Spin-offs

Description: name of spin-off company, founder, year of incorporation, town, brief description of the business idea
Kuafu AG, Bellizio, 2025, Zurich: Energy management plattform.
Add as needed

5 References

Cuony, P. (2025). *Tarif dynamique dans la pratique*. https://www.bulletin.ch/sites/default/files/2025-04/2025_3_Cuony_Tarif_dynamique_dans_la_pratique.pdf

EKZ, & ETHZ. (2025). *OrtsNetz*. https://www.aramis.admin.ch/Default?DocumentID=73403&Load=true

Swisspower, & ZHAW. (2025). *ESIT – Entlastung im Stromnetz durch innovative Netztarife—Texte*. https://www.aramis.admin.ch/Texte/?ProjectID=53922

Winzer, C., & Darudi, A. (2026). *Avoiding Rebound Peaks: Which Capacity Charges Best Complement Dynamic Electricity Tariffs in Distribution Grids* (SSRN Scholarly Paper Nr. 6156107). Social Science Research Network. https://papers.ssrn.com/abstract=6156107

Winzer, C., & Hensler-Ludwig, P. (2024). Design and Impact of Grid Tariffs. *Energies*, *17*(6), Artikel 6. https://doi.org/10.3390/en17061364