FOR THE VISUALIZATION OF FLEXIBILITY:

VISOFLEX

A SOLUTION TO ACCOMPANY THE ENERGY TRANSITION

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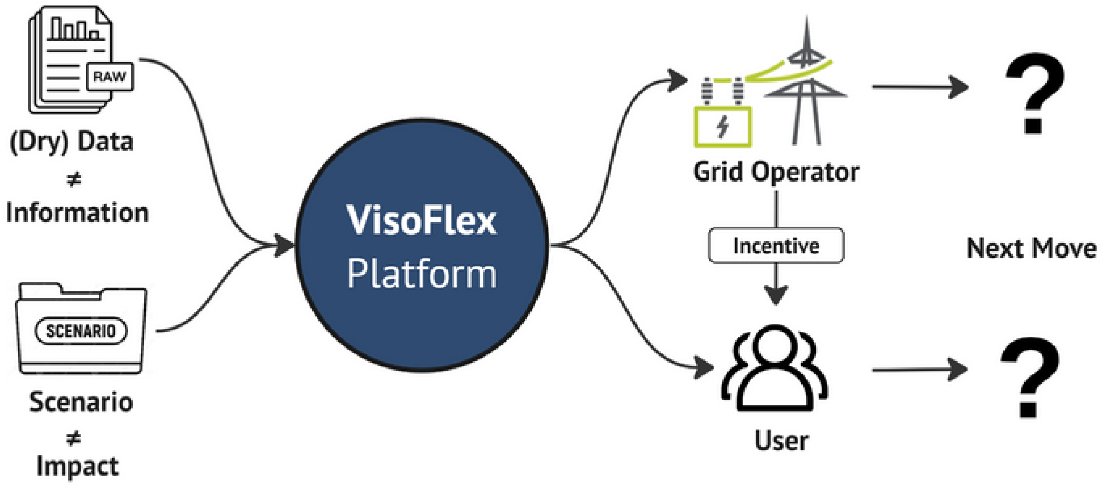
Table of contents

Introduction

As the number of Electric Vehicles rises, there is a growing concern about the readiness of power systems to accommodate charging needs. In a world where raw data doesn't directly mean information and the multitude of envisaged scenarios doesn't correlate with real-world impact, our team has decided to design a platform: VisoFlex.

This platform wouldn't only benefit grid operators by providing them essential information for seamless power integration, but will also serve to engage and incentivize users to adopt better habits in terms of power consumption.



VisoFlex: A **platform** integrating and **visualizing key indicators** for decision making of **stakeholders** with a focus on **electricity felxibility**.

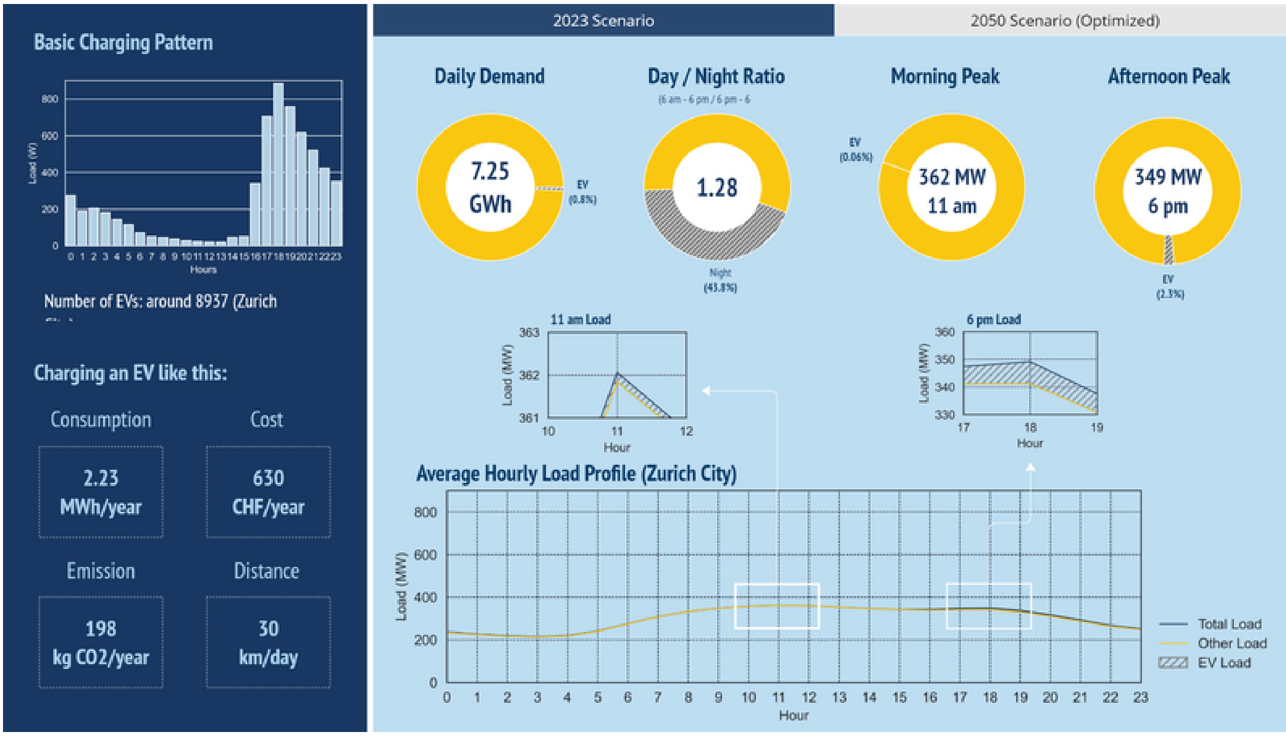
Visoflex stands as a solution that seeks to bridge the gap between the **rising demand for electric mobility** and the **need for a resilient and adaptable energy infrastructure**.

In this report, the team will delve into the key features of the platform, how we developed it, and our vision for a concrete application.

Our Platform

The Visoflex platform serves as a comprehensive information hub for both customers and grid operators. It is designed to integrate diverse types of electricity flexibility data from various sources, such as heat pumps and electric vehicles (EVs). To illustrate the platform's concept, we begin by examining the effects of different EV charging patterns in Zurich on both users and the grid under various scenarios. The platform's design is anchored in identifying the key information that stakeholders find most relevant. From the customer's perspective, the focus is on the direct impact of charging patterns, including aspects like cost and potential driving range. Conversely, grid operators in the city prioritize a broader view, emphasizing the overall demand load. Additionally, the platform considers future scenarios where EV numbers are anticipated to surge and power generation increasingly relies on fluctuating renewable energy sources.

As depicted in the subsequent figure, different scenarios are presented in the top right to further illustrate their corresponding impacts. The interface is intentionally bifurcated: the left section, targeted at customers, initially displays the average daily charging pattern, followed by relevant information such as electricity consumption, cost, emissions, and potential driving distance. The right section, geared towards a city-wide perspective, caters to grid operators. It features the average daily load profile for the entire city, supplemented with key indicators like daily demand, day/night load ratio, and peak loads in the morning and afternoon. These plots effectively demonstrate the impact of current EV charging load profiles on both customers and grid operators.



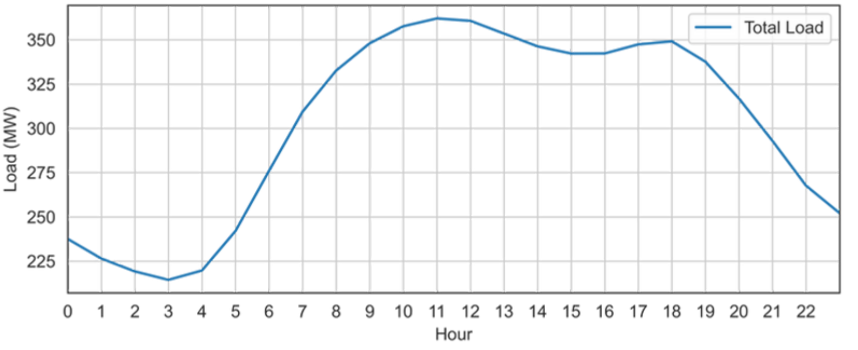
The following sections delve into the acquisition of pertinent and accurate data, detailing the sources and assumptions underlying the different scenarios.

2023 Baseload

Total Electricity Consumption Curve

In visualizing key data, two curves play pivotal roles. The first is the Electric Vehicle (EV) load curve, which we will explore in subsequent sections. The second curve represents the total electricity consumption in the city of Zurich. By subtracting the EV load from the total consumption, we isolate the 'other load' – the electricity usage excluding EVs. This figure is crucial for projecting the city's electricity consumption in a 2050 scenario.

The total electricity consumption data was sourced from open data published by Stadt Zurich [A]. This dataset details Zurich's 2022 electricity usage, recorded at 15-minute intervals. We processed and averaged this metadata to create a daily consumption curve with a one-hour temporal resolution. The resulting curve indicates a daily electricity demand of 7.25 GWh. This data aligns closely with Zurich's daily electricity consumption [B] from EWZ.



[A] https://data.stadt-zuerich.ch/dataset/ewz_bruttolastgang_stadt_zuerich

[B] https://www.ewz.ch/en/about-ewz/newsroom/current-issues/electricity-shortage/city-zurich-energy-consumption.html

EV Load Curve

In 2023, the total EV fleet of Canton Zurich is 31278. Scaling this to the population of only Zurich city, this gives a fleet of 8937 electric cars.[A] The best charging data we could find is from the California Institute of Technology.[B] We aggregated charging data from a period of six months from July to December 2019 to come up with a charging curve. All charging sessions from this period were aggregated to a single day (Figure 1), for a total power approximately equal to the EV charging consumption of the city of Zurich (54.6 MWh/day). This was calculated assuming the number of cars, the average distance driven per day [C], and the average consumption of electric cars [D]. We crossed-checked this calculation with the total consumption of EVs in Switzerland from 2019 and estimated in 2025 from the Energieperspektiven 2050+ [E].

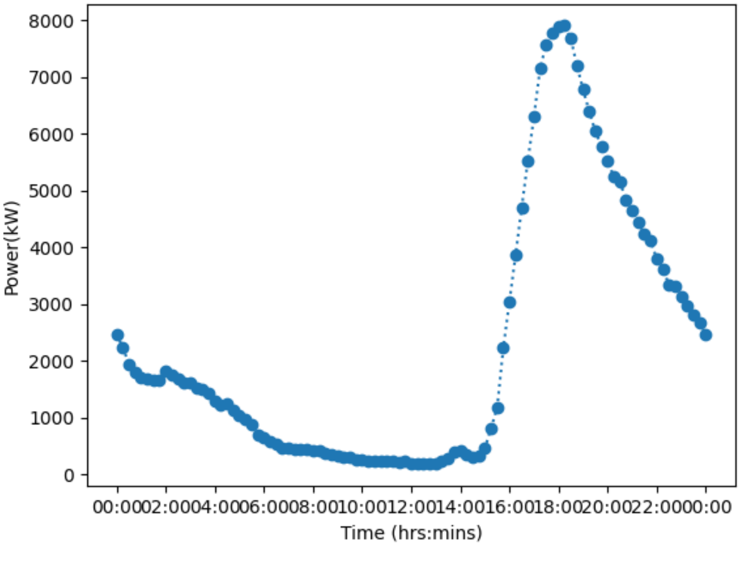


Figure 1

[A] https://www.bfs.admin.ch/bfs/de/home/statistiken/mobilitaet-verkehr/verkehrsinfrastruktur-fahrzeuge/fahrzeuge/strassenfahrzeuge-bestand-motorisierungsgrad.assetdetail.28725609.html

[B] https://ev.caltech.edu/dataset

[C] https://www.bfs.admin.ch/bfs/de/home/statistiken/mobilitaet-verkehr/personenverkehr/verkehrsverhalten.html

[D] https://www.virta.global/blog/ev-charging-101-how-much-electricity-does-an-electric-car-use

[E] Energieperspektiven Schweiz 2050+, Prognos AG, Tabelle 72

2023 Optimized

To provide an optimized total load by shifting the EV load curve for nowadays case, we applied the following strategy:

Identify the peak loads	Determine Distribution percentage	Select Target Times for Redistribution	Redistribute Energy Consumption
determine the period of highest energy consumption for EV's charging	specify what percentage of each peak will be redistributed	target time with low total load consumption	move the specified portion of EV's charging load to the selected off-peak times, thereby spreading the demand

2050 Baseload

Since the percentage of electric cars on the road today is still quite small and therefore, the flexibility potential is quite low, we decided to analyze a potential 2050 scenario. This way, the potential can better be visualized and we can make a stronger argument for the value of flexibility in our future energy system.

2050 Electricity Production

In this scenario, we decided to look at the estimated production as well, because the main challenge in 2050 will be the non-dispatchability of renewable energy production. For this, we used data from Energieperspektiven 2050+ from Prognos AG and the scenario "Netto null (ZERO)" [A].

For simplicity, the assumption was made that all electricity sources except solar and storage hydro remain constant throughout the day. This was assumed based on the curves in the report for winter and summer estimated production in 2050 (see Figures 2 and 3).

Abbildung 23: Stündliche Stromerzeugung (Winterhalbjahr)

Stündliche Stromerzeugung und Stromverbrauch der Schweiz für eine ausgewählte Winterwoche im Szenario ZERO Basis, Strategievariante «ausgeglichene Jahresbilanz 2050», in GWh/h

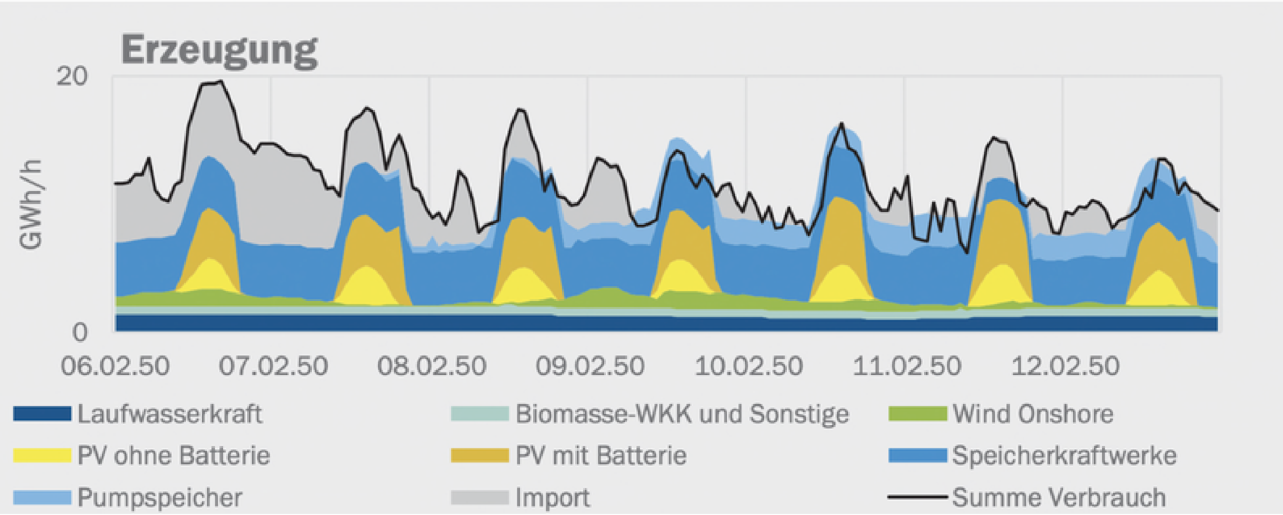


Figure 2 [B]

Abbildung 24: Stündliche Stromerzeugung (Sommerhalbjahr)

Stündliche Stromerzeugung und Stromverbrauch der Schweiz für eine ausgewählte Sommerwoche im Szenario ZERO Basis, Strategievariante «ausgeglichene Jahresbilanz 2050», in GWh/h

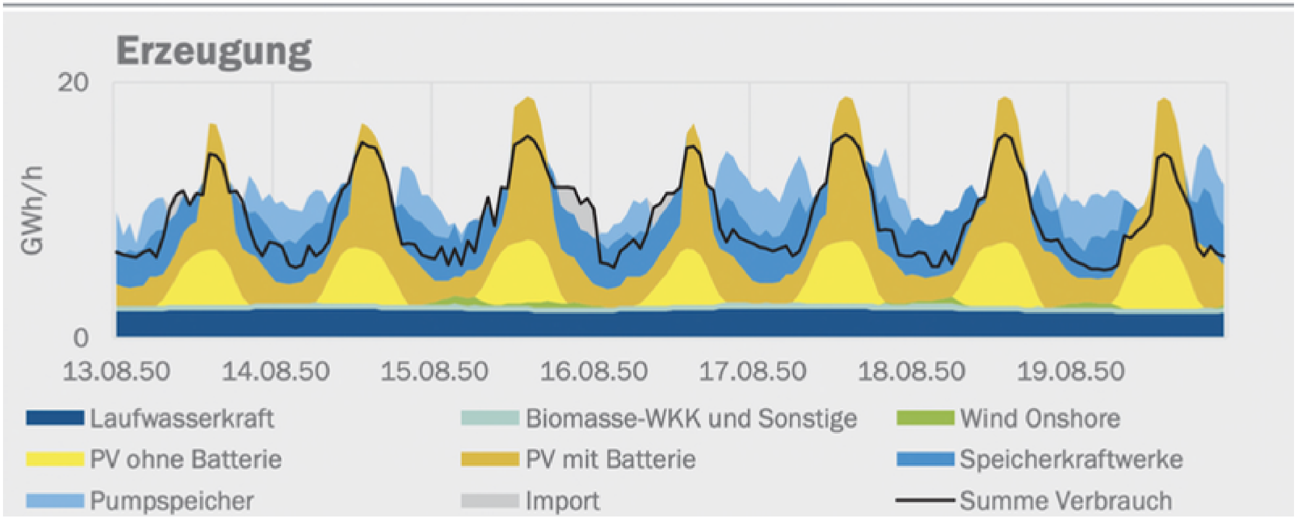


Figure 3 [C]

We adjusted the energy production to be on an average day (September 20), scaled to the city of Zurich based on the ratio between Zurich and Switzerland's energy consumption. The solar production follows the solar intensity, and the storage hydro is reduced proportionally to the solar production up to a value of 50%.

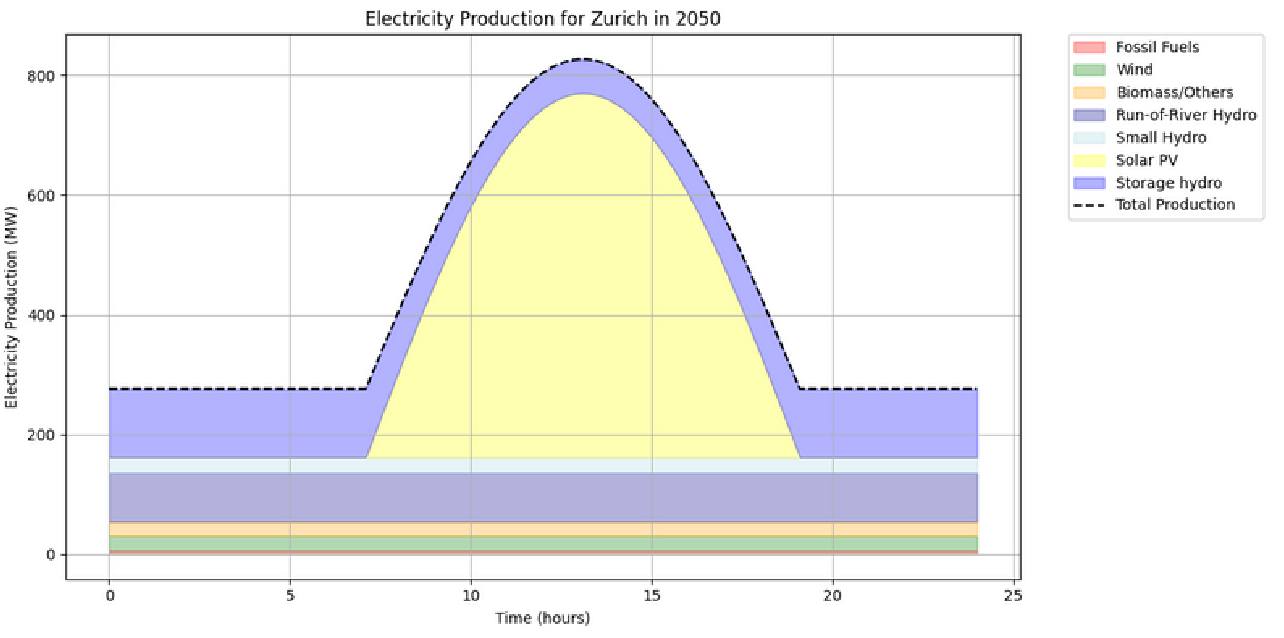


Figure 4

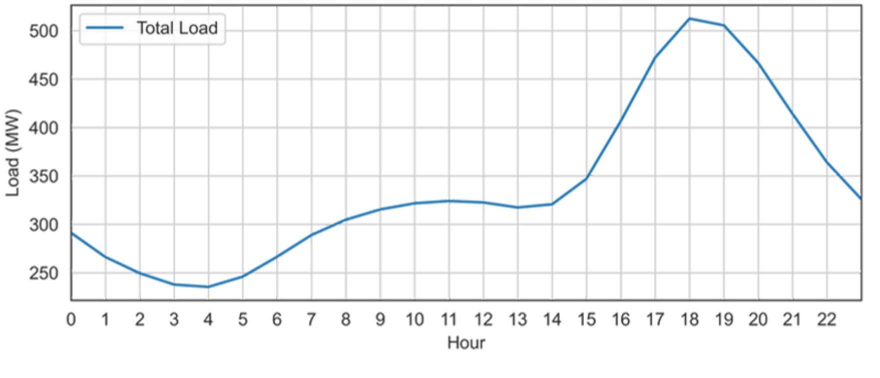
[A] https://www.uvek-gis.admin.ch/BFE/storymaps/AP_Energieperspektiven/index3.html?lang=de&selectedSzenario=ZB&selectedVariant=AJB&selectedNuclear=50

[B] Energieperspektiven 2050+, Kurzbericht, Abbildung 23, Prognos AG

[C] Energieperspektiven 2050+, Kurzbericht, Abbildung 24, Prognos AG

2050 Electricity Consumption

The projected total electricity consumption for Zurich in 2050 is derived from two key components. Firstly, the 2050 EV (Electric Vehicle) load curve will be detailed in the following section. Secondly, a modified version of the 2023 'other load' curve. The 'other load' curve, calculated by subtracting the 2023 EV load from the total electricity load of that year, is adjusted downwards by a factor of 0.873. This scaling reflects anticipated reductions in electricity usage from residential buildings and other sectors, owing to technological advancements. [A] The final projection for the 2050 total electricity consumption is obtained by combining the 2050 EV load curve with this adjusted 'other load' curve, as illustrated in the figure below.



[A] Energieperspektiven Schweiz 2050+ Kurzbericht, Abbildung 10, Prognos AG,

2050 EV Load Curve

According to Swiss data, the EV charging energy consumption should be multiplied by a factor of approximately 33.6 by the year 2050. We estimated this by calculating the total electricity consumption by EVs in Zurich today with the projected consumption in 2050 for all of Switzerland, scaling to Zurich. [A] The increased amount of EVs would lead to a slightly more distributed load due to the increased number of customers. To model this, for every charging session used to generate the 2023 curve, we added 33 more similar charging sessions, differing only by their starting time. The starting times were normally distributed around the original starting time, to simulate an increased number of customers with inherently similar needs. The curve now has a smoother and wider peak. The curve now has a smoother and wider peak. (Figure 5)

The 2050 estimated daily power consumption is 1.8 GWh (13.1TWh for a year for all of Switzerland, [A]).

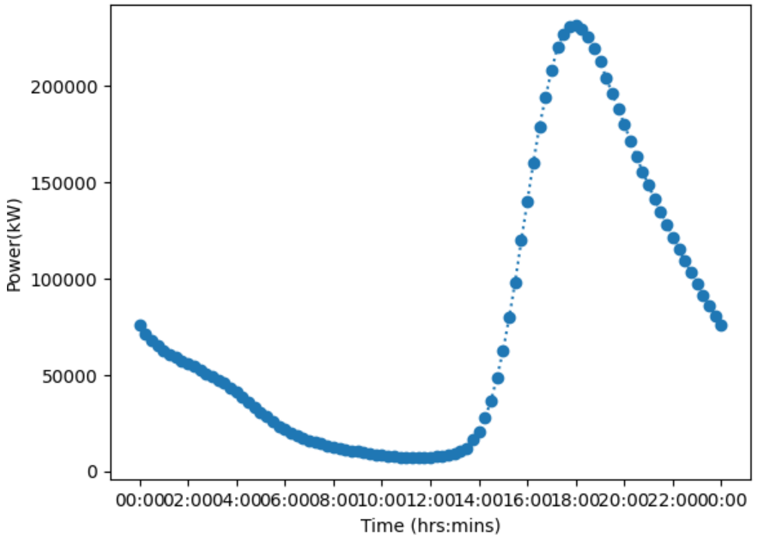


Figure 5

[A] Energieperspektiven 2050+, Technischer Bericht, Tabelle 72, Prognos AG

2050 Optimized

For the 2050 scenario, the goal was no longer to reduce peak load but to redistribute the EV load such that electricity demand better follows the supply (minimize necessary imports).

The strategy for redistributing electric vehicle (EV) charging loads operates in the following manner:

1. **Period Analysis**: Each time period is reviewed to assess energy demand and production.
2. **Identify Overload Periods:** Time slots where energy demand surpasses production are identified

as key periods for load adjustment.

3. Determine Load Redistribution: In these high-demand periods, the EV load is earmarked for redistribution to balance the load.

4. Locate Redistribution Windows: Time periods where energy production exceeds demand are pinpointed as suitable for accommodating additional load.

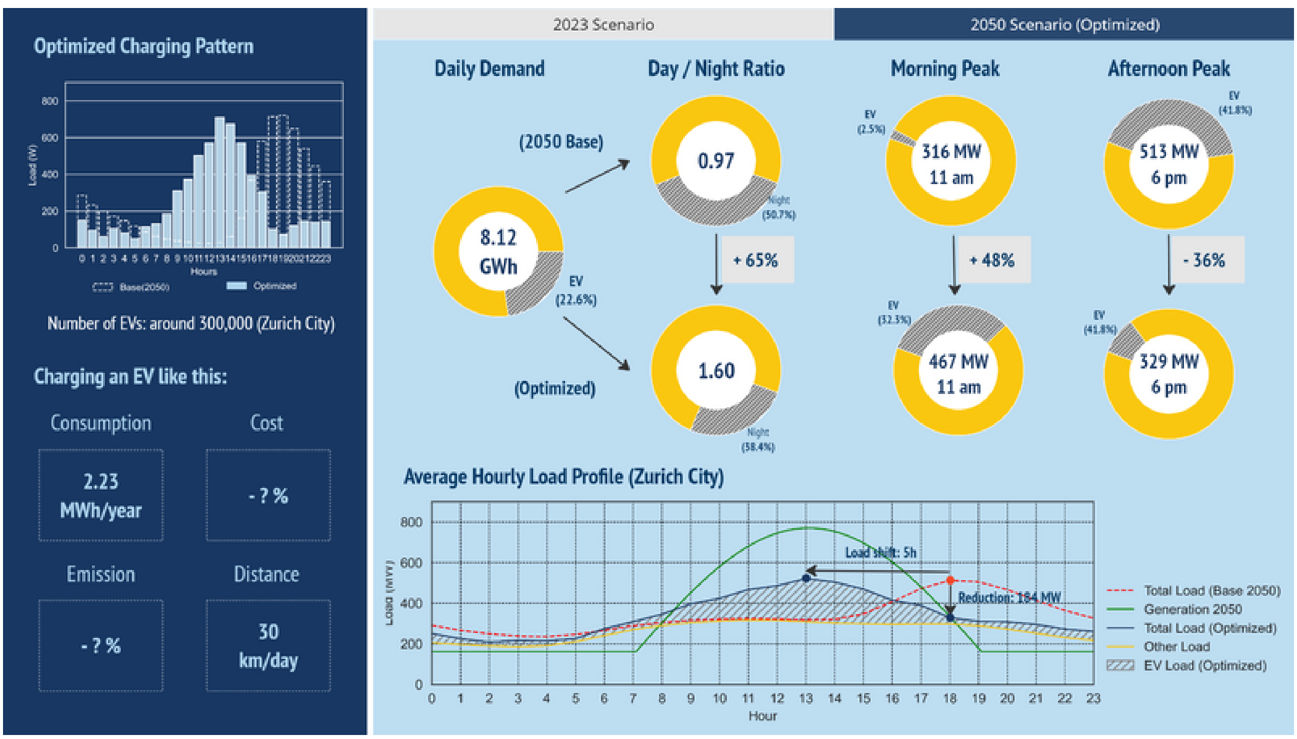
5. Even Distribution of Excess Load: The excess EV load from high-demand periods is evenly spread across these identified lower-demand periods.

6. Update Load Profiles: Following redistribution, the load profiles for both high-demand and selected low-demand periods are adjusted to reflect the redistributed EV load.

7. Overall Load Adjustment: Finally, the total energy load for each time period is recalculated to include the newly distributed EV charging loads.

By implementing this strategy, we shift electric vehicle (EV) charging from periods of high energy demand to times when there is excess production capacity. This helps maintain a balanced energy network, as illustrated in the subsequent figure. The data reveals that:

1. In 2050, with the anticipated increase in EV usage, electricity demand for EV charging is expected to account for 22.6% of the total demand. This could lead to a significant mismatch if we continue to follow our current base charging profile.
2. The EV charging load profile significantly influences the demand curve. Consequently, it offers a degree of flexibility that can be harnessed if optimized effectively. By adjusting the charging profile to coincide with peak solar electricity production at noon, we can achieve better alignment between the demand and generation curves. This optimization could result in a 5-hour load shift and a reduction of 184 MW in load at 6 pm.



Flexibility Assumption

To justify our ability to move the EV charging times throughout the day in the optimized scenarios, we came up with a simple model to estimate how often EVs need to charge.

For that, we used data derived from a study titled "Electric Vehicles: How much range is required for a day's driving," [A] originally conducted in the United States. We adjusted the data to better align with the Swiss context. We adapted the distances driven to match the average distance that Swiss people drive per day. [B] The results from the study adapted to the Swiss context can be seen in Figure 6.

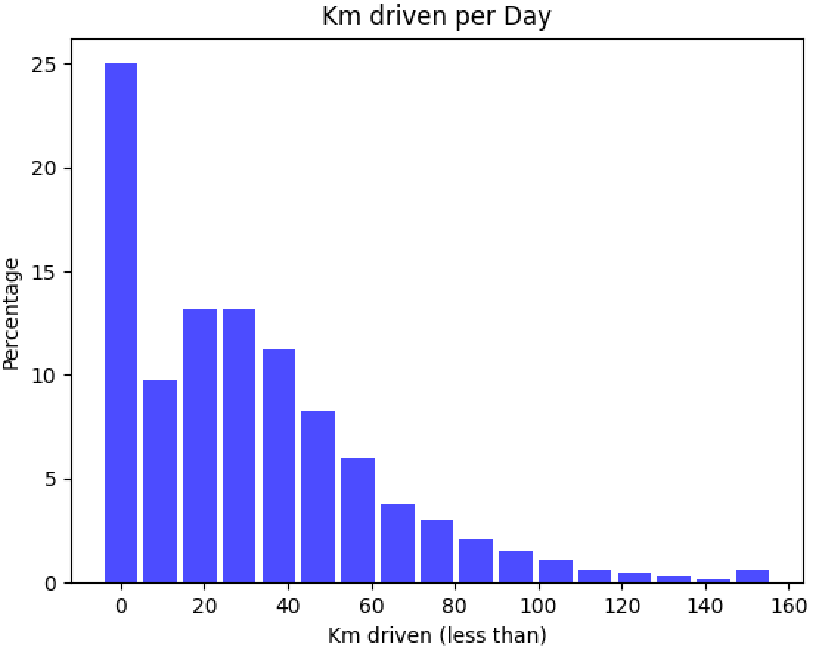


Figure 6

To go from the distance of driving data to the time in which an EV needs to be fully charged once, the following assumptions were made:

- average energy consumption for EVs is estimated at 0.2 kWh/km [C]
- average speed is 38.1 km/h [D]
- the average battery electric vehicle (BEV) range is approximately 290 km [E]
- a safety factor of 2 (accounting for all the uncertainties and discharge effects)
- a psychological factor assumes a minimum range of 50 km (meaning that we assume the car has to be charged once the range reaches 50 km).
- average charging time for EVs is 8 hours

The flexibility potential is defined in the model as the non-driving and non-charging time within one interval, where an interval is the time between two necessary charging sessions to charge the car enough for the day's driving. Given that people in Zurich drive relatively short distances per day on average and considering the high range of EVs, it becomes clear that cars only need to be charged once every few days. The main assumption we made is that during these parked intervals, the car can be charged, and the charging time can be shifted within the overall interval, as long as it fulfills the requirement of an 8-hour full charge within that interval.

The model does not currently account for the constraint that a fully charged EV cannot be charged further until it is partially discharged from driving.

The flexibility potential varies based on driving distances, with different levels of flexibility corresponding to the energy consumption patterns. For instance, 9% of cars require charging every 10 days, resulting in a flexibility potential of 230 hours (240h - charging time - driving time).

Figure 7 illustrates the flexibility potential for different energy consumption levels, with 1.6 MWh providing a flexibility of 230 hours and approximately 30 MWh offering a flexibility of 24 hours. All energy values and flexibility considerations are specific to the city of Zurich. Future iterations may delve into factors such as EVs parked at locations with charging stations to further refine the model.

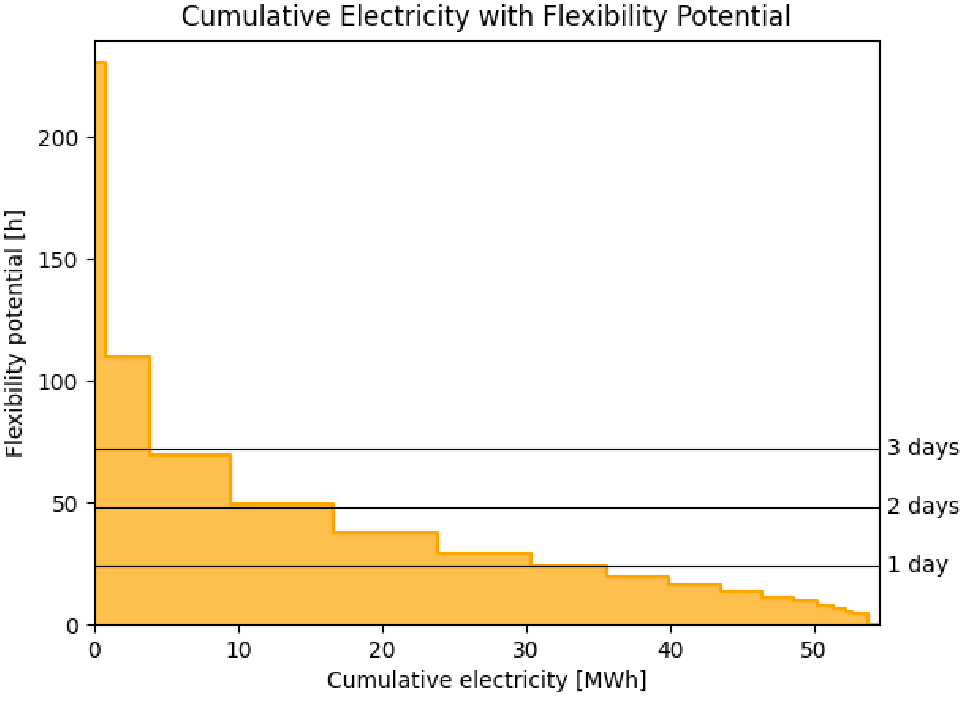


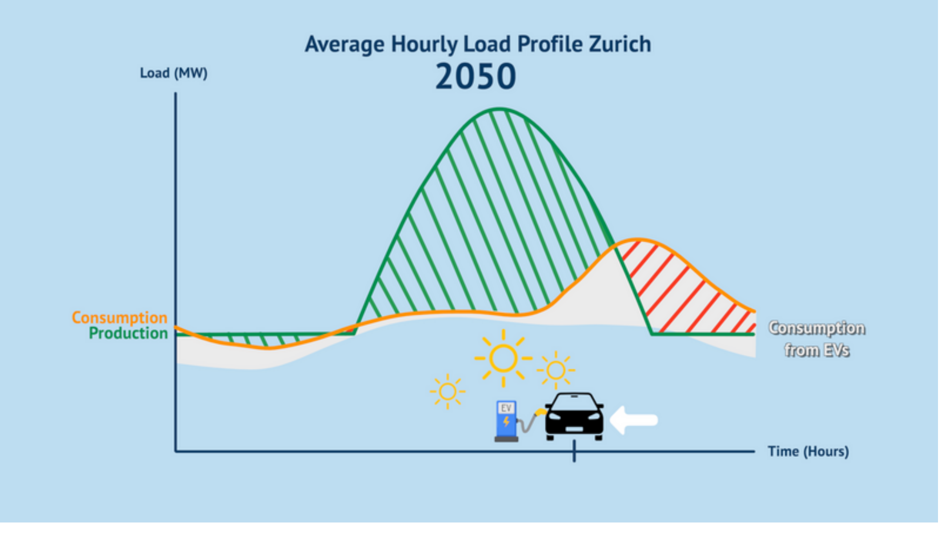
Figure 7

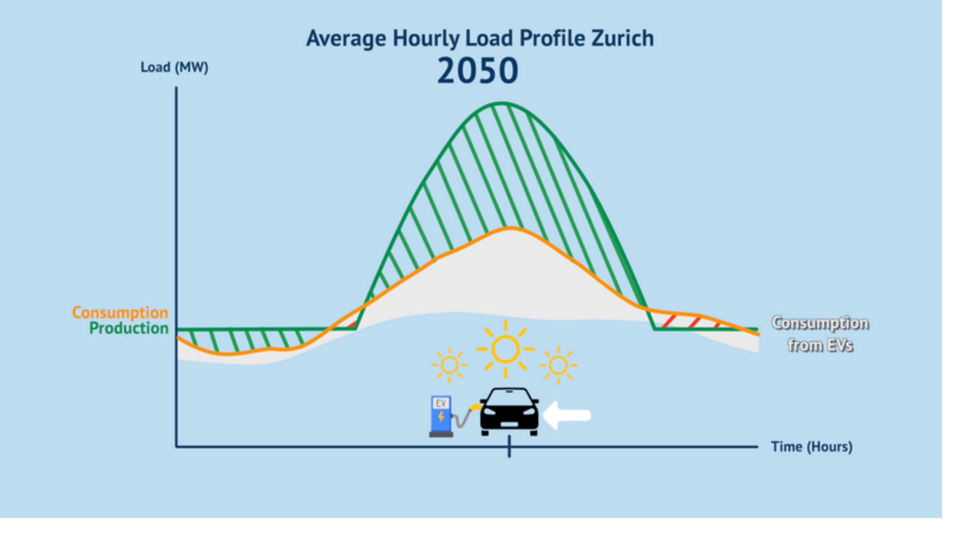
[A] https://www.sciencedirect.com/science/article/pii/S0968090X1100012X
[B] https://www.bfs.admin.ch/bfs/de/home/statistiken/mobilitaet-verkehr/personenverkehr/verkehrsverhalten.html
[C] https://www.virta.global/blog/ev-charging-101-how-much-electricity-does-an-electric-car-use

[D] https://www.bfs.admin.ch/bfs/de/home/statistiken/mobilitaet-verkehr/personenverkehr/verkehrsverhalten/tageszeit-unterwegszeit.html#1491748850
[E] https://shellrecharge.com/en-gb/solutions/knowledge-centre/news-and-updates/the-electric-range-of-an-ev

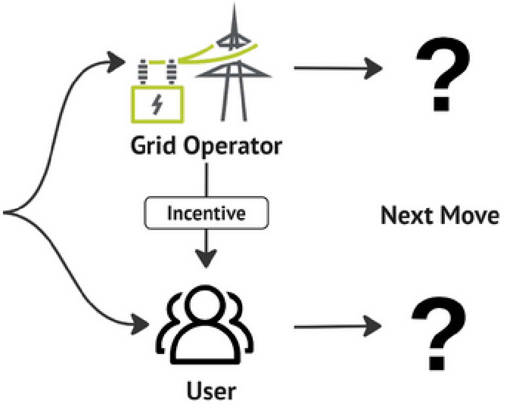
Video

To address one of our stakeholders (the consumer) we created a 1-minute animation explaining visually what a large difference charging EVs can make in terms of the stability of the future electricity grid. This video was kept untechnical and was simply meant to motivate people to charge their EVs when electricity production from PVs is abundant, by visualizing the change from people's current charging behavior to a more optimized charging behavior. The necessary imports (consumption - production) were highlighted in red and the excess electricity (production - consumption) in green.





Next Steps

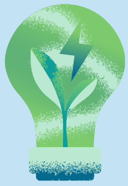
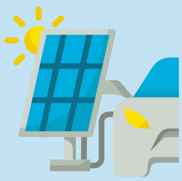
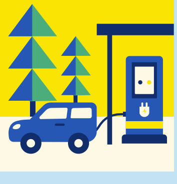


Our vision for VisoFlex is ambitious and forward-thinking, focusing on:

User Education	Renewable Energy Integration	Smart Charging	Grid Optimization

There is an interconnection in the benefits provided to our different stakeholders:

User-Centric Features:

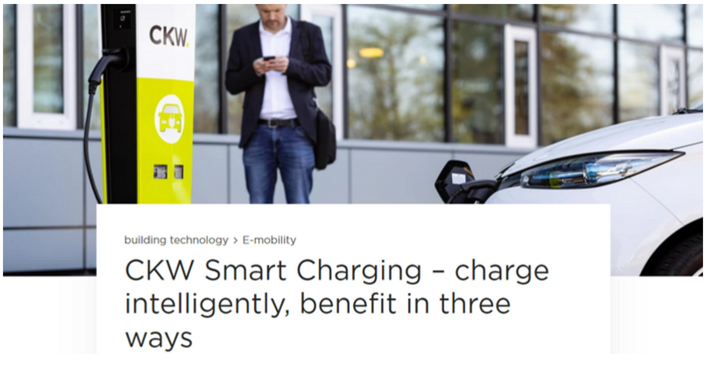
User Awareness and Education		• VisoFlex educates users about optimizing EV charging patterns to benefit the energy system • Features such as notifications suggesting optimal charging times for cost savings
Shift to Renewable Energy		• Long-term goal of aligning demand with renewable energy supply, utilizing PV for EV charging • Possibility of energy suppliers providing incentives for users who avoid peak charging times
Smart Charging Infrastructure		• Integration of VisoFlex with smart chargers, enabling dynamic charging based on grid conditions • Features like calculating travel distance and allowing users to manually schedule charging
Charging locations		• Distribution of charging points at strategic locations like **ski resorts**, **hiking trails**, **restaurants**, **parking lots** and **big supermarkets** to align with user habits and maximize renewable energy utilization

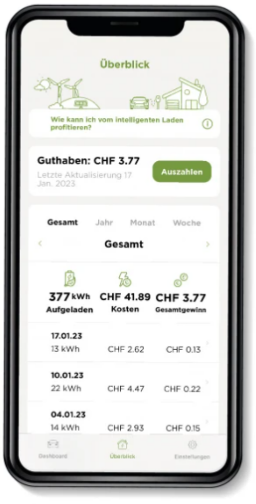
Grid Operator Benefits:

Grid Operator	**Data Visualization and Scenario Construction:**	• VisoFlex provides grid operators with clear visualizations of consumption patterns, aiding in scenario construction and better energy purchasing decision • The visualization would facilitate the real-time operation of the transmission grid, the monitoring and control the flow of electricity, ensuring that the system remains secure and reliable.
	Client Incentivization	• VisoFlex allows grid operators to participate in incentivizing users to charge during off-peak hours, contributing to grid stability
Cantons, Municipalities (Energy suppliers)	**Urban planning, infrastructure**	• Visualization of future scenarios will allow them to better calculate and plan new infrastructure, installation of smart chargers

First Next Steps of VisoFlex

For the first steps of VisoFlex, we mainly focus on the EV owner benefits. The platform could be integrated into a mobile application with features such as notifications on when is the best time to charge. Municipalities and Cantons (Energy Suppliers) will be responsible for the incentivization of the customers and the encouragement to use the platform, even install smart chargers following the model of CKW Smart Charging application.





https://www.ckw.ch/gebaeudetechnik/e-mobilitaet/smartcharging?gad_source=1&gclid=Cj0KCQiA35urBhDCARIsAOU7QwmlL8HhOyDYd11MU8gW736B6CUbYgH3TywBGHn5kngd-ojKz0wFSBEaAvQUEALw_wcB

https://www.aldautomotive.ch/en/useful-information/mobility-blog/articles/an-overview-of-the-tax-advantages-of-e-mobility#:~:text=Tessin%20%2F%20Ticino-,Tax%20bonus%20available.,for%20a%20bidirectional%20charging%20station.

There are already some incentives for EV owners. For example in the canton of Zurich, a Tax bonus is available, no traffic tax needs to be paid for vehicles with an all-electric drive. Other cantons offer subventions to EV owners. Within these programs, further subsidies or price-incentives could be offered to the user if they make use of the platform and charge at appropriate times.

Further Next Steps of VisoFlex

In the future, the successful implementation of VisoFlex could revolutionize how grid operators and Transmission System Operators (TSOs) manage demand forecasting. With access to advanced projections from our tool, they would gain a forward-looking perspective on energy demands. This foresight would enable them to develop more informed strategies. For instance, to address potential disparities between energy generation and consumption, grid operators and TSOs could encourage customers to align their Electric Vehicle (EV) charging habits with the supply curve. Promoting the use of smart chargers would facilitate this alignment, allowing for more controlled charging processes. Consequently, TSOs may reduce their reliance on acquiring additional reserve capacity for ancillary services, such as upward regulation to correct system imbalances. This approach not only enhances efficiency but also supports a more sustainable energy ecosystem.

Market access: TSOs. Being one of the TSO responsibilities to plan for future development and accommodate changes in electricity generation, demand, and new technologies, the grid operator could incentivize the distribution of smart chargers.

Limitations: Customers' reaction to smart charging and incentivization

Although the advantages of smart charging are evident, a significant challenge lies in enrolling and retaining EV owners in smart charging programs. To date, savings on electricity costs alone have not sufficiently motivated behavioral change. However, in the 2050 scenario, with the expected rise in EV usage, the grid will experience increased pressure from these vehicles. Consequently, incentives for charging EVs at optimal times are likely to become increasingly appealing, which leads to more use of smart chargers. There is still ongoing research to understand customer responses to these programs and their willingness to participate.

Additional information can be found in this article: Do incentives make a difference? Understanding smart charging program adoption for electric vehicles

[A] https://www.sciencedirect.com/science/article/pii/S0968090X23001122

Alignment with policies

One should keep in mind the surging policies: in the future Carbon Taxes and switching to EV may become mandatory for everyone. In order to meet our Net Zero goals, VisoFlex helps us adapt to these changes by incorporating all kinds of data into information therefore facilating decisons.

Case Study

Implementation Costs and Revenue Generation:

1. Costs:

- User Interface (UI) Development
- Backend Development
- Implementing the logic for data processing, real-time updates, and calculations for EV charging estimations and CO_2 emissions.
- Database Development
- SMS Integration (approx. 8000 users - city of Zurich)
- Data Updates:
  - Implementing a mechanism for daily data updates, including consumption, EV curve estimations, and CO_2 emissions.
- Security Features
- Scalability
- Regulatory Compliance:
  - Ensuring compliance with any relevant regulations or standards, which may add complexity to the development process.
- Testing and Quality Assurance
- Maintenance and Support (bug fixes and potential improvements)

Considering the above, we approximate the development cost to a range of 100k to 200K CHF.

Removing the notification feature would reduce the cost by 10-30%.

2. Revenue Streams or Potential cost saving:

- Revenue opportunities: such as subscription models for advanced features, partnerships with energy suppliers, or government incentives for grid optimization.
- Electricity Cost Savings
- User Adoption Rate:
  - The success of the platform depends on how many users adopt the recommended charging times. The more users who follow the suggestions, the higher the potential overall cost savings.
- Scale of Adoption:
  - The total number of EV owners using the platform will impact the overall savings. A higher adoption rate and a larger user base will lead to more significant potential savings.
- Peak Demand Reduction

- Positive Environmental Impact

Conclusion

Our vision for VisoFlex aligns with the evolving landscape of renewable energy, smart grid technologies, and user-centric solutions. Adapting and implementing these ideas in collaboration with key stakeholders can contribute to a more sustainable and efficient energy future in Switzerland!

About us

I'm Emma, a mechanical engineering student with a background in robotics, but currently interested in and focused on energy technologies and systems. I decided to participate in the challenge to further deepen my knowledge and understanding of problems and possible solutions in the energy transition.

I'm Maria, a Master's student in Electrical Engineering with a specialization in Energy and Power Electronics. From a very young age I knew I would pursue a career in energy. Participating in this challenge allowed me to have a more concrete understanding, and to learn that there is still a lot to do in accompanying the energy transition!

I'm Charlotte, a Master's student in Mechanical Engineering with an emphasis on energy systems. My current academic pursuit is centered around the reliability of demand-side flexibility in buildings. Therefore, I am excited to participate in the Energy Now Challenge tackling the visualization of flexibility.

I'm Alexandre, a Master's student in Energy Science & Technology with a Bachelor in Microengineering. My area of interest is energy, in particular in its electrical form, so joining this project was a clear opportunity for me to deepen my understanding of the challenges we face to realize the energetic transition.

I'm Zhi, a Master's student in Integrated Building Systems. My interest in energy begins at the building scale and progressively expands to a broader perspective. This motivates me to engage in challenges and propose solutions that encompass various viewpoints.