ENPHASE

Unlocking the potential of the evolving Dutch energy market

Whitepaper for the Netherlands

Contents

1. Executive summary

The Netherlands is one of the most successful countries in the world adopting renewable energy. Dependency on fossil fuels continues to drop, with renewable energy now comprising 50% of the electric energy mix. Of the 8 million Dutch homes, 2.5 million are producing clean, renewable solar energy. This is a remarkable achievement by the Dutch people and society.

Besides the Dutch sense of responsibility for carbon neutrality, one of the key reasons for the adoption of solar is the success of net energy metering (NEM). NEM is an incentive program that provides the same electricity price from the energy provider for re-importing energy that has been previously exported from the home to the grid.

Unfortunately, NEM has a downside. It encourages homeowners to treat the grid like a virtual battery, exporting energy during times of over-generation and consuming at times of high demand. This intermittency of generation and consumption leads to significant imbalances in the grid.

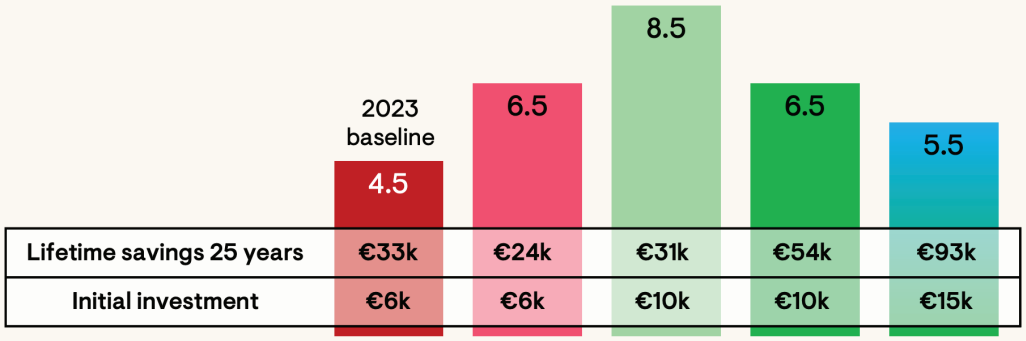
These imbalances are not just a technical problem, but they are creating financial implications. Resolving imbalances increases the cost of energy for retail energy providers and grid operators. The cost of imbalance has increased more than 6x since 2020 to €1.7B in 2022. Until now, this cost has been shared by all homeowners, but increasingly, energy providers are charging export penalties to homeowners with solar, since they are considered to be one of the sources of the imbalance problem.

Additionally, the future of NEM is becoming uncertain based on the imbalance issues it is creating. Export penalties and ambiguity about NEM led many homeowners to shy away from investing in solar systems, thereby causing the Dutch residential solar market to contract by as much as 60% from August 2023 to December 2023.

Yet there are ways to successfully manage the transition of the Dutch solar market into its next stage of maturity. While solar is still a great investment as long as NEM is in place, there are comprehensive solutions of solar, batteries, and energy management software that can help to solve the imbalance problems while maintaining payback periods at 7.5 years, even if NEM was eliminated.

Current solar, regulatory uncertainty

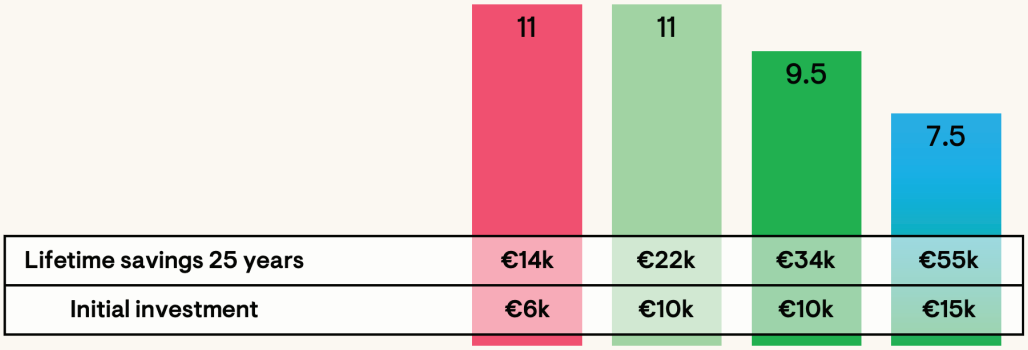
25-year Enphase system, 100% NEM



	2023 baseline	Solar only	Solar + battery	Solar + battery + dynamic tariffs	Solar + battery + dynamic tariffs + imbalance steering
Lifetime savings 25 years	€33k	€24k	€31k	€54k	€93k
Initial investment	€6k	€6k	€10k	€10k	€15k

Future proof, energy independent, savings & earnings

25-year Enphase system, 0% NEM



	Solar only	Solar + battery	Solar + battery + dynamic tariffs	Solar + battery + dynamic tariffs + imbalance steering
Lifetime savings 25 years	€14k	€22k	€34k	€55k
Initial investment	€6k	€10k	€10k	€15k

- 2023 baseline
- Solar only
- Solar + battery
- Solar + battery + dynamic tariffs
- Solar + battery + dynamic tariffs + imbalance steering

- Solar only solution considers export penalty for 100% NEM and no export for 0% NEM
- Solutions including a battery consider battery replacement after 15 years
- Integration of electric vehicle and heat pump will reduce payback by 1 – 2.5 years for battery solutions

Figure 1

2. Problem statement

2.1. Facts and figures

The Dutch grid is under increasing stress, with greater imbalance each year. The peak load in 2022 was 17.5 GW, yet the installed solar power exceeded 19 GW. Installed wind power is already at 8.8 GW and will increase to more than 50 GW in 2050.

Dutch grid (2022)

17.5 GW
Peak load

19.6 GW
Installed solar power

8.8 GW
Installed wind power

108.9 TWh
Consumption

17.1 TWh
Solar energy

21.4 TWh
Wind energy

Figure 2

At the same time, the electrification of households is mature and further accelerating, with 2.5 million homes with solar, approximately 400,000 EV chargers, and 900,000 heat pumps.

Electrification has started (2022)

2.1 M
Households with solar (2.5M in 2023)

384,000
EV Chargers

900,000
Heat-pumps

>90%
Smart meter penetration

Figure 3

Overall, the mix of renewable energy and fossil electric energy is shifting more and more. While renewables only represented 40.2% in 2022, they are expected to reach more than 50% in 2023.

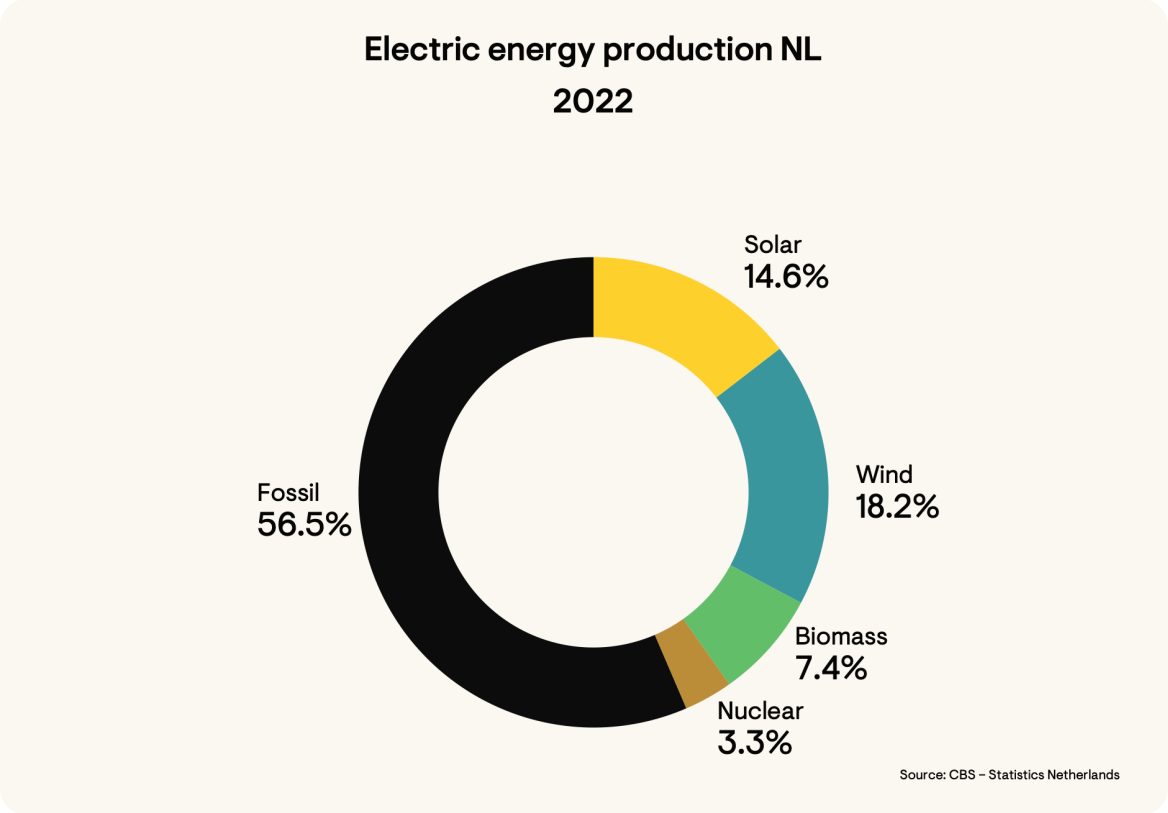


Figure 4

2.2. Problem explanation and definition

2.2.1. Basics of the electricity grid

The grid has no memory and almost no buffer. If someone is consuming energy (taking energy out of the grid), someone else needs to generate the same amount of energy and feed it into the grid at the very same time. This means the grid must always be balanced between supply and demand. Any imbalance can result in severe disruption of the operation of the grid, including grid failure, and is avoided at all times.

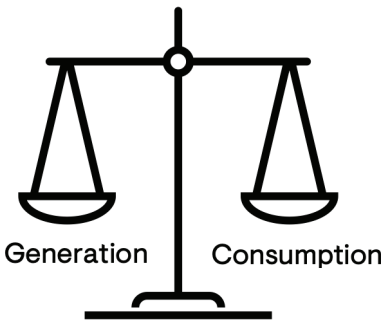


Figure 5

Even though this principle sounds complex, it has been the reality since the introduction of the first power station in the Netherlands in 1886. The grid balance is achieved by generators, usually running on fossil energy, being able to vary their power output quickly enough to follow and mimic the power consumption of the consumers. The power generation was variable, while the power consumption was considered inalterable.

2.2.2. Electricity generation with renewables

More than 100 years after its inception, the power generation in the Netherlands has changed. It is no longer concentrated on a few large, consistent, controllable power plants but decentralized and distributed to include solar and wind energy.

Renewable energy cannot be managed and controlled like fossil power generators. If the sun is shining, solar generation is high, and if the wind is blowing, wind generation is high. This leads to the over-generation of renewable energy, resulting in imbalance of the grid. In example, for nearly 140 hours in June 2023, the power generation of renewables was higher than the entire consumption of the Netherlands at that time.

While some large wind farms can be shut down to limit energy production, residential solar systems always aim to take advantage of the NEM program by generating as much energy as possible and exporting it to the grid to be used later when the sun isn't shining.

This over-generation by wind and solar (see highlighted red areas in Figure 6) is what needs to be managed, and the higher the over-generation is, the more difficult it becomes.

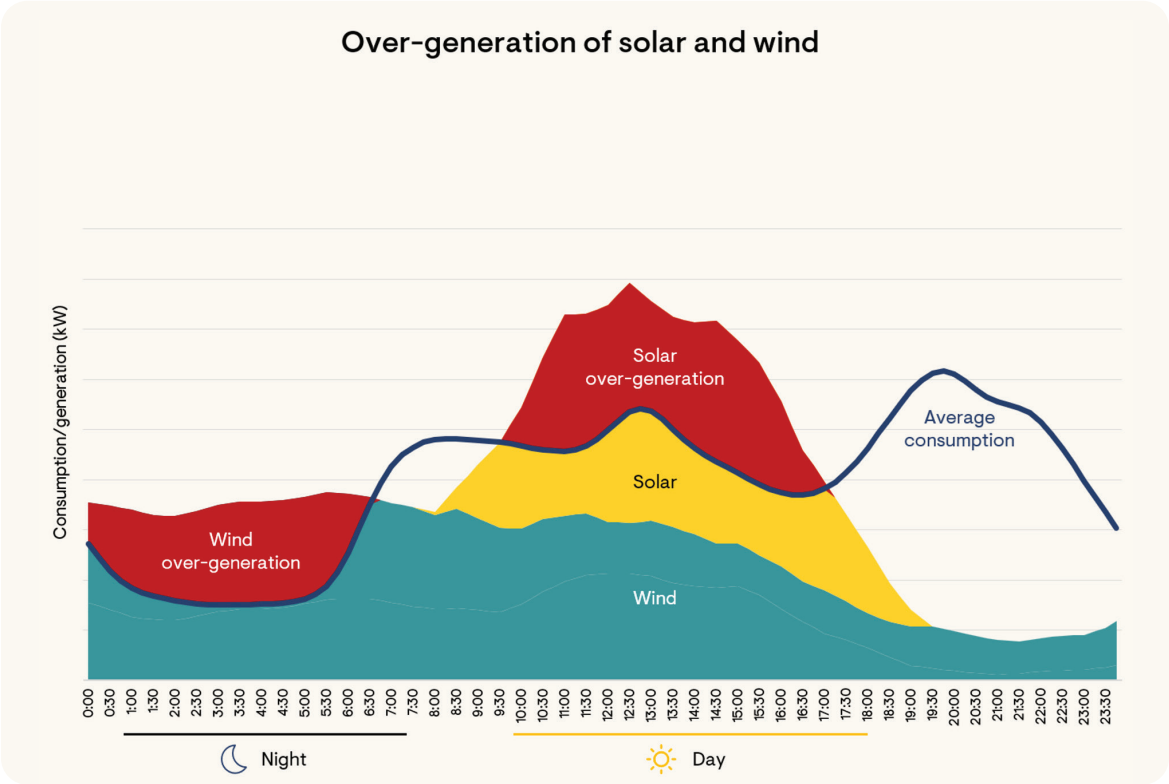


Figure 6

2.2.3. Management of over-generation

The responsibility of managing over-generation lies primarily with two groups:

- **Dutch retail energy providers (more than 50 providers)**
- **TenneT, the Dutch Transmission System Operator**

The energy providers in the Netherlands are responsible for balancing their portfolios. They must ensure at all times that the energy consumed by their customers is equal to the energy they provide to the grid by either generating it themselves or purchasing it on the energy market.

During times of over-generation, this logic is turned upside down. The energy providers must remove excess energy from the grid instead of supplying it. They accomplish this by selling the excess energy in the energy markets or artificially increasing their consumption. Given the rise in over-generation events, it is becoming increasingly difficult for energy providers to balance their portfolios.

If an energy provider cannot balance the portfolio and an actual grid imbalance occurs, the Dutch Transmission System Operator (TSO) is responsible for balancing the grid. This is accomplished by activating previously purchased balancing reserve energy. However, reserve energy is expensive, and the energy provider that caused the imbalance is responsible for the cost.

2.2.4. Cost of imbalance

The cost to balance the grid depends on the volume of balancing power required and the price for this balancing power. The balancing volume required per year has almost tripled from 3.6 TWh in 2015 to over 8.9 TWh in 2022 and the cost of that energy has risen from €160 million to €1,700 million in the same timeframe (see Figure 7).

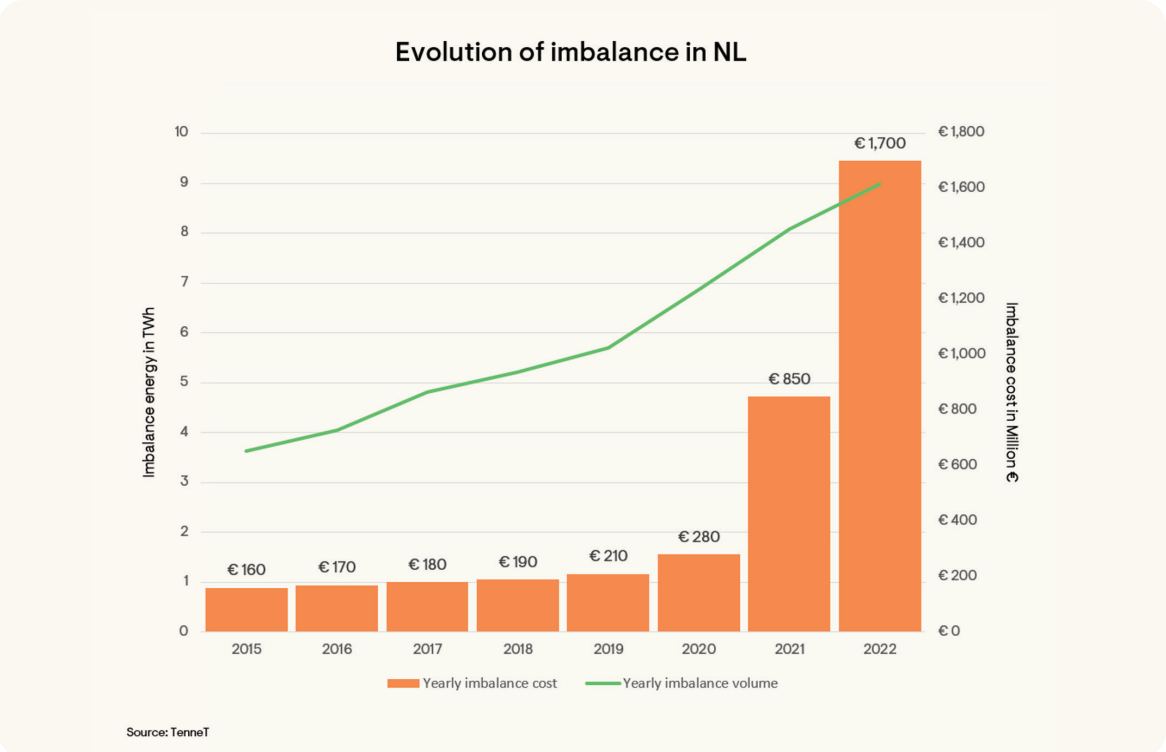
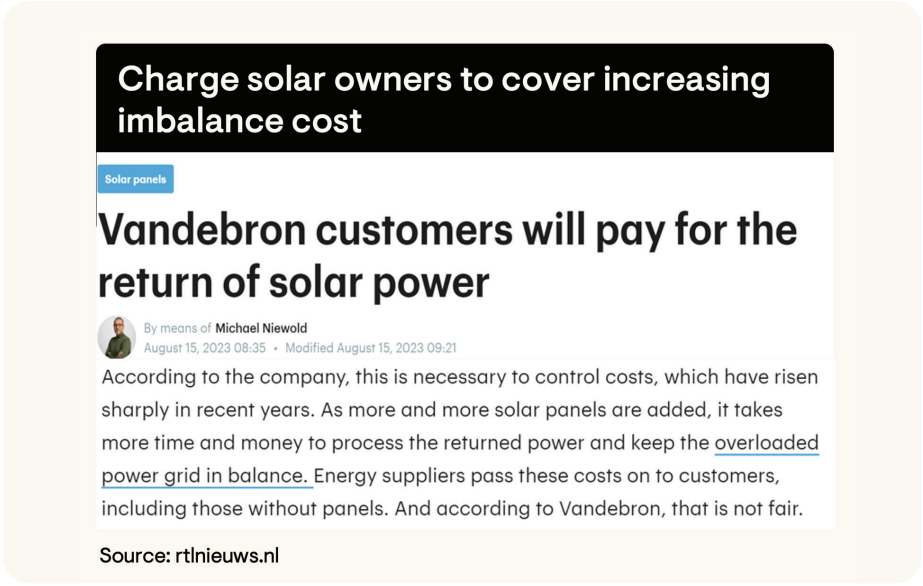


Figure 7

That imbalance cost must be borne by the energy providers, who then charge all their customers. So far, it has been shared by all customers evenly, but given the magnitude of the increasing cost, customers with solar are expected to carry the entire cost. This cost is estimated at about €105 per home per year.

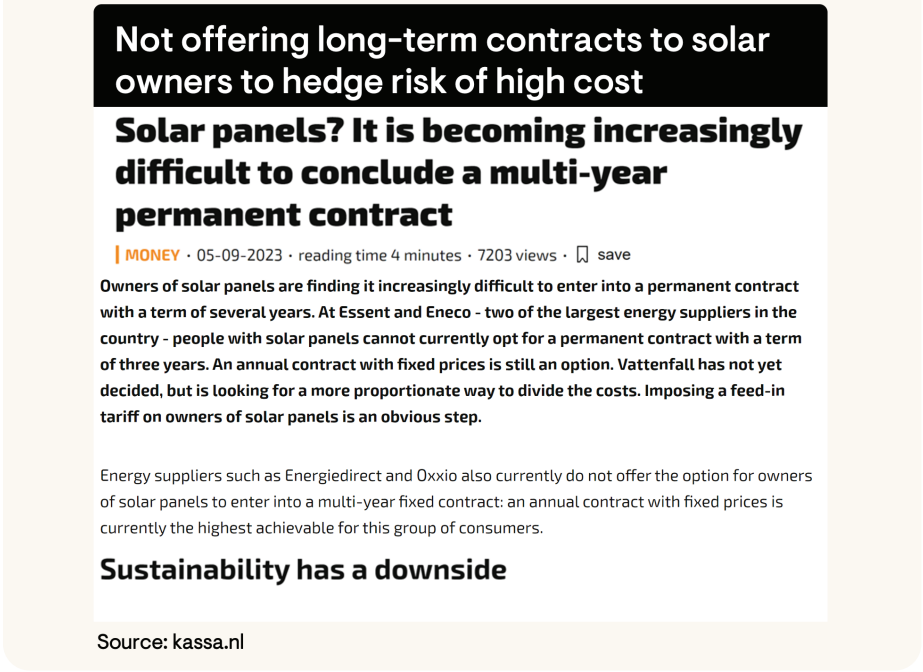
2.3. Reaction of energy providers

The first energy provider that openly addressed the issue by introducing export penalties for solar customers was Vandebron. They introduced variable penalties for their solar customers depending on the yearly kWh exported to the grid. It is likely that other energy providers may also begin charging an export penalty. With many energy providers, it is also getting increasingly difficult to sign a multi-year fixed energy contract with similar terms as non-solar customers.



Source: rtlnieuws.nl

Figure 8

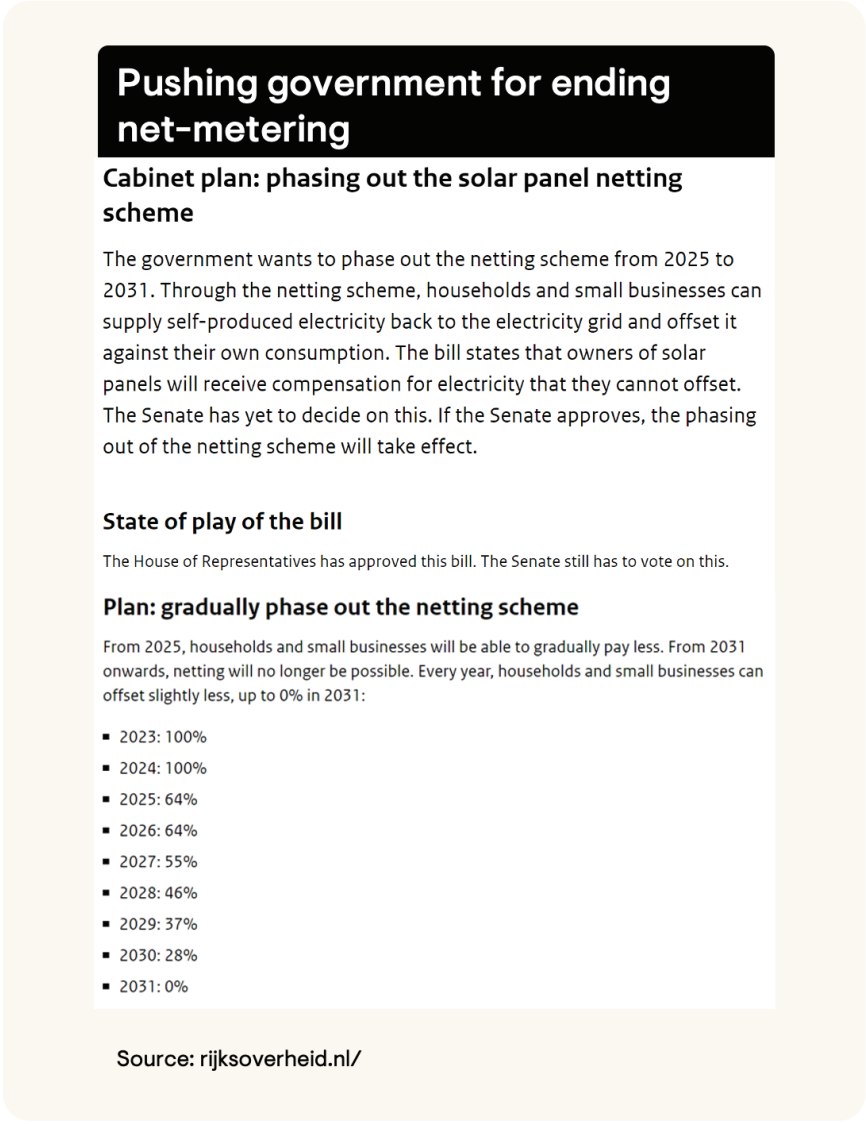


Source: kassa.nl

Figure 9

Either way, energy providers are preparing for very high imbalance costs, which are expected to increase heavily in the upcoming summer and years.

At the same time, numerous groups have become more vocal about the NEM program. There are stakeholders and interest groups lobbying to end NEM as already proposed in the Dutch parliament, as well as other groups speaking out to keep it. Given the 2023 elections, the future of net-metering is more unclear than ever before.



Pushing government for ending net-metering

Cabinet plan: phasing out the solar panel netting scheme

The government wants to phase out the netting scheme from 2025 to 2031. Through the netting scheme, households and small businesses can supply self-produced electricity back to the electricity grid and offset it against their own consumption. The bill states that owners of solar panels will receive compensation for electricity that they cannot offset. The Senate has yet to decide on this. If the Senate approves, the phasing out of the netting scheme will take effect.

State of play of the bill

The House of Representatives has approved this bill. The Senate still has to vote on this.

Plan: gradually phase out the netting scheme

From 2025, households and small businesses will be able to gradually pay less. From 2031 onwards, netting will no longer be possible. Every year, households and small businesses can offset slightly less, up to 0% in 2031:

- 2023: 100%
- 2024: 100%
- 2025: 64%
- 2026: 64%
- 2027: 55%
- 2028: 46%
- 2029: 37%
- 2030: 28%
- 2031: 0%

Source: rijksoverheid.nl/

Figure 10

Not in question is that net metering is a root cause of the over-generation issue since it's allowing the re-import of previously exported energy for free. With NEM, the grid acts like a virtual battery for homeowners. However, as mentioned in chapter 2.2.1, the grid does not have the ability to ebb and flow like a battery. Both generation and consumption must be balanced at all times.

This leads to another decremental effect for energy providers. They are forced to take over-generated, low-priced energy in the summer and provide high-demand, high-priced energy back to the homeowner in the winter.

2.4. Response of Dutch market

The unknowns surrounding net metering programs, penalties, and energy rate plans clouded buyers' perception of solar. Their apprehension was further fueled by incomplete or inaccurate media coverage. Homeowners could no longer see solar being a sound financial investment and abruptly stopped buying solar for their homes. As a result, demand dropped nearly 60% from August to December 2023.

The Dutch solar industry was unprepared for the sudden changes in the market and could not take corrective action quickly enough. The perception was created that there was no value in a solar-only system, and solar installers didn't have a compelling alternative solution. Enphase has responded by releasing a comprehensive solution of solar, battery and energy management software, for the Netherlands. This solution, as outlined below, clearly demonstrates the financial benefit of an Enphase Energy System in the new Dutch energy market.

3. Comprehensive solutions

The key to solving the complex issues of grid imbalance is moving from solar only systems to energy management solutions. This is when a homeowner can generate, store, and use energy at exactly the right time based on their energy needs. It's made possible by a comprehensive suite of hardware and software that work together. Hardware consists of microinverters, batteries, EV chargers, and heat pump integration. The energy management software controls the hardware and interaction with the energy grid.

There are five key use cases:

1. **Solar only**
2. **Solar + battery**
3. **Solar + battery + dynamic tariffs**
4. **Solar + battery + dynamic tariffs + imbalance steering**
5. **Solargraf design and proposal software**

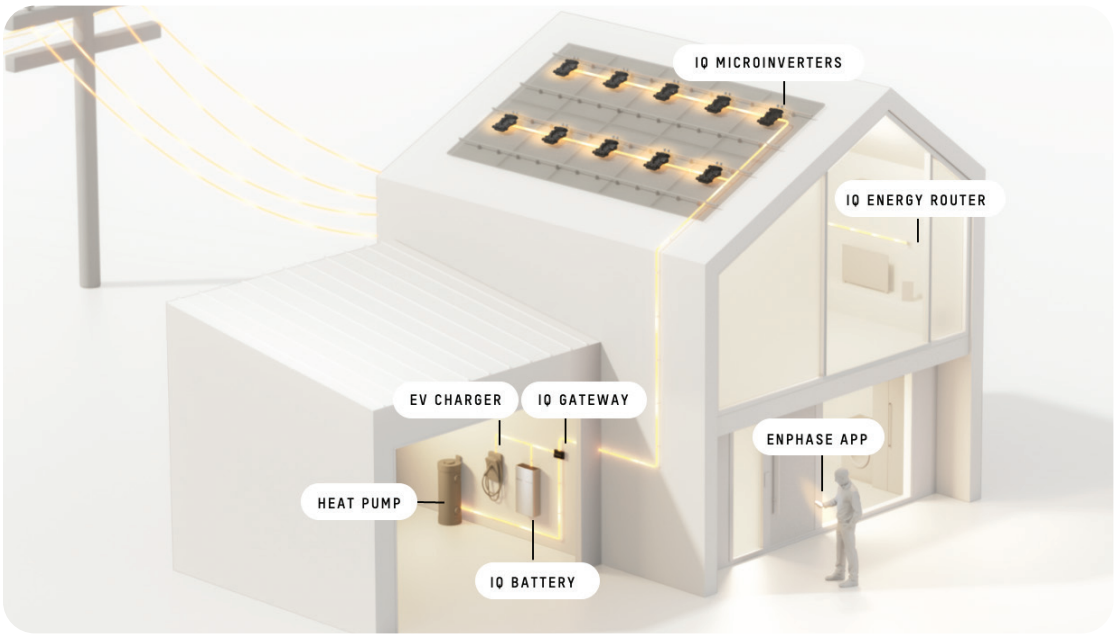


Figure 11

3.1. Solar only

Even though the latest developments in the Dutch market make the existing solution of a solar only system less attractive, it still represents a good investment for homeowners. The benefits a solar system generates outweigh the penalties being charged by energy providers. Even if NEM would be removed, the proposition still remains financially attractive.

Since the investment for such a system is relatively low, the payback period will increase from 4.5 years to 6.5 years. Considering a 25-year warranty period for Enphase Microinverters, the system will still provide more than double its investment in savings over the lifetime.

If regulations or penalties would change over the coming years, a solar only system can easily be upgraded with a battery given Enphase's modular architecture.

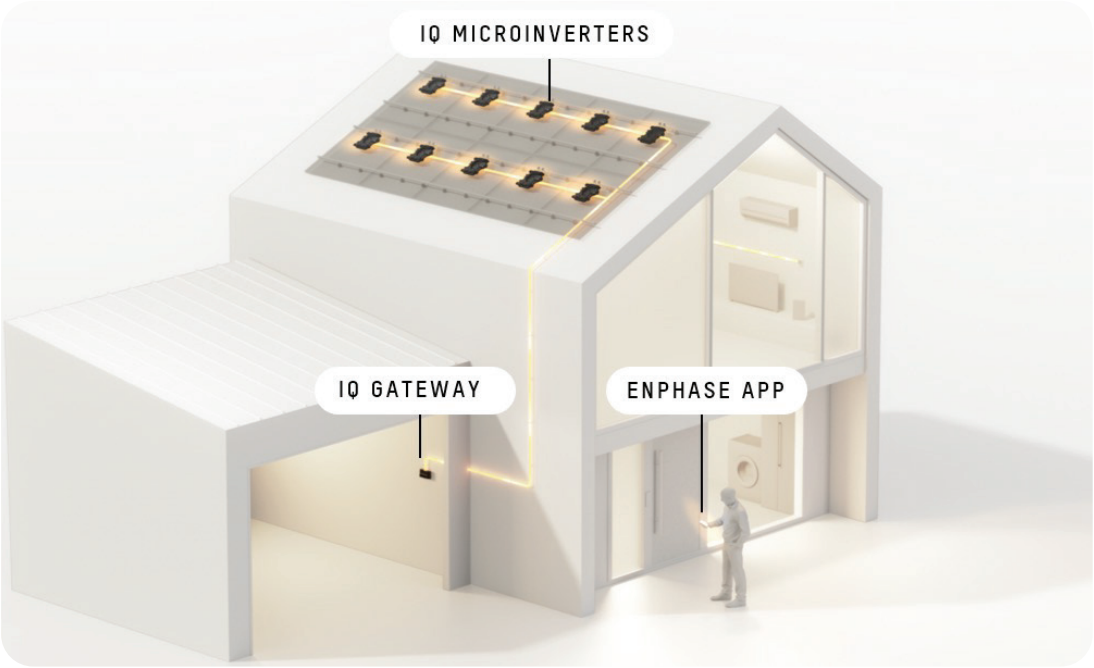


Figure 12

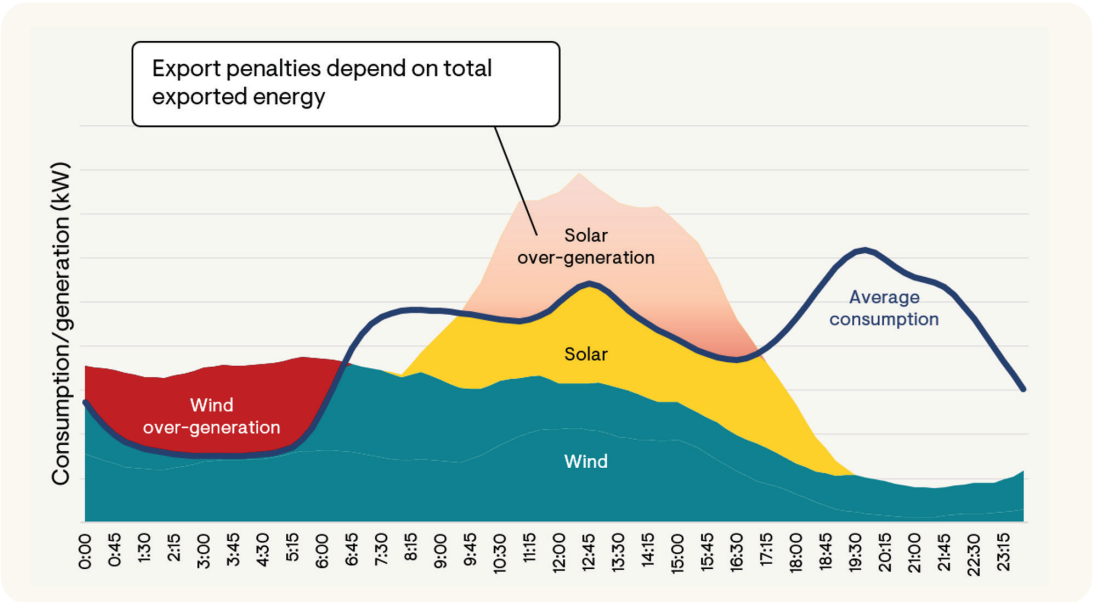


Figure 13

3.2. Solar + battery

To address the root cause of the over-generation of solar energy, the excess energy needs to be stored locally. This can be easily achieved by installing a battery in the home (see Figure 14).

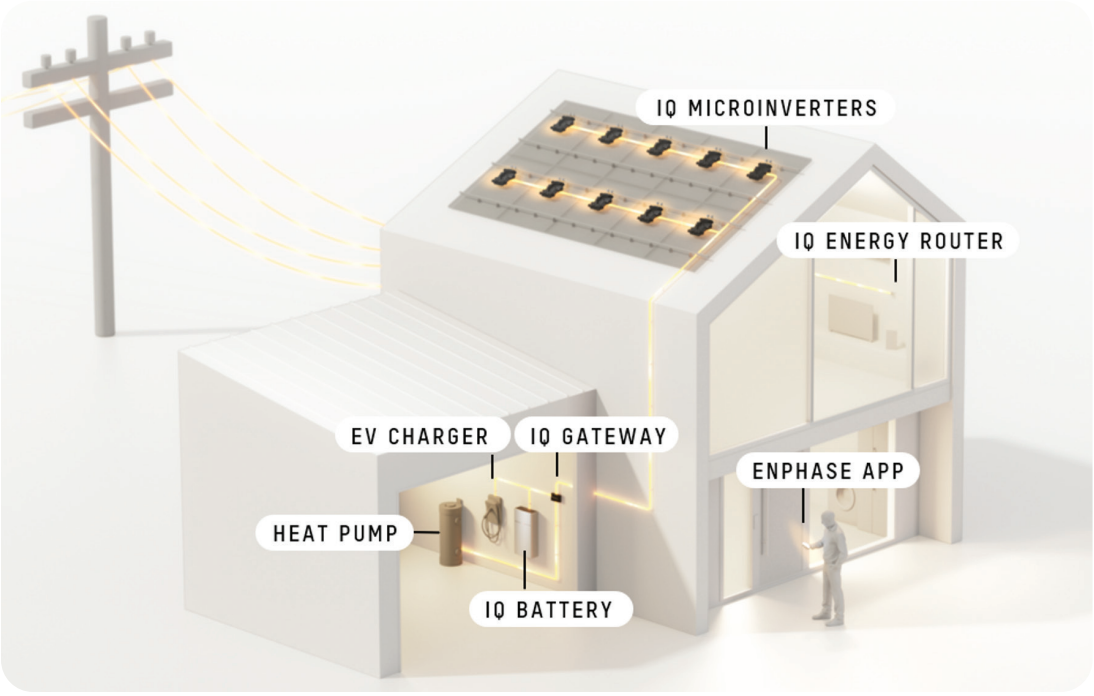


Figure 14

When generation exceeds consumption, the battery automatically charges itself instead of exporting the power to the grid. Later that day, when the consumption exceeds generation, the battery will discharge and supply power to the house. That way, self-consumption, meaning the amount of energy that is self-consumed without relying on the grid, can be increased from about 30-45% without a battery to nearly 60-70% with a battery.

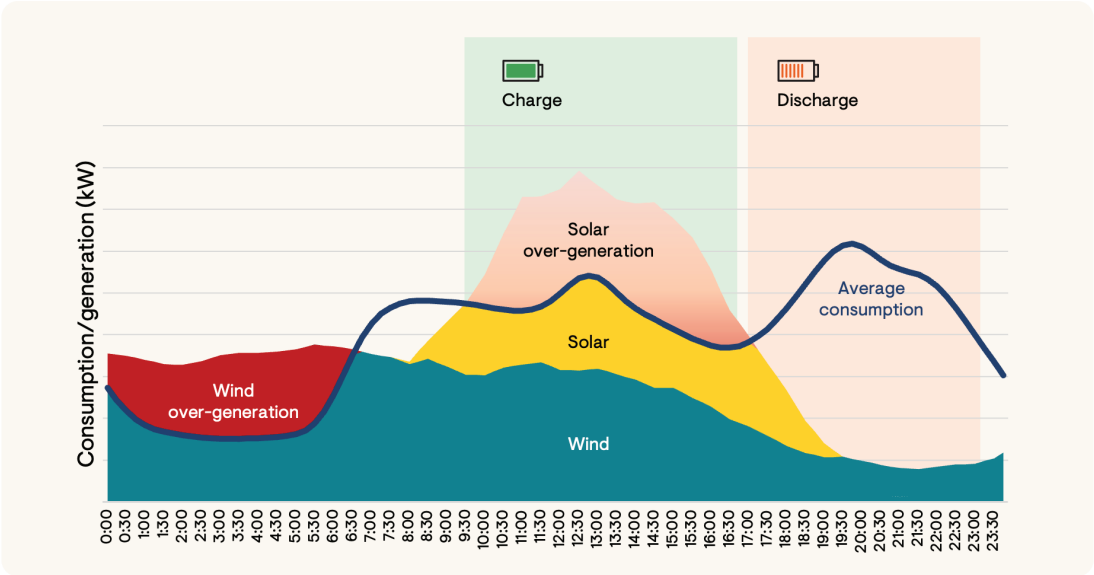


Figure 15

Self-consumption achieves the goal of limiting export by charging the battery and thereby avoiding most export penalties. It also achieves the goal of prioritizing the use of green energy.

In addition to the battery, other home appliances can be used to prevent exporting solar energy. The most common option is an electric vehicle that can charge and store energy during over-generation. Heat pumps can also help by using the excess energy to heat a water tank, acting as a thermal storage device. Energy management software can control all of these devices and boost self-consumption up to 85%.

While 100% net metering is still available, the financial benefit for consumers in this solution is limited to reducing export penalties charged by energy suppliers. The payback period is longer since the investment into the battery is needed, but this protects the homeowner from further increases in export penalties. The payback period in this case will increase from 4.5 years to 8.5 years.

3.3. Solar + battery + dynamic tariff

3.3.1. What is a dynamic tariff?

A dynamic tariff is an energy rate plan in which prices are variable. It also reflects the amount the homeowner has pay to buy energy and what the homeowner will get paid for selling energy to the grid. Some homeowners may already have experience with a simple variable rate plan where rates vary from day to night. This is commonly referred to as time-of-use. The main difference between time-of-use and dynamic tariffs is the frequency of rate changes. Unlike a time-of-use plan with just a few different rates in a day, a dynamic tariff plan is based on the hourly changing market price of electricity. Also known as the day-ahead spot price.

Electricity gets traded on central marketplaces in Europe. One of the most relevant marketplaces for the Netherlands is the EPEX day-ahead spot market. In this marketplace, energy gets traded for each hour of the next day based on supply and demand. Each day there is a new auction for the following day to determine the new hourly spot prices. This results in different hourly spot prices every day, and they are only known about 11 hours before the start of a new day.

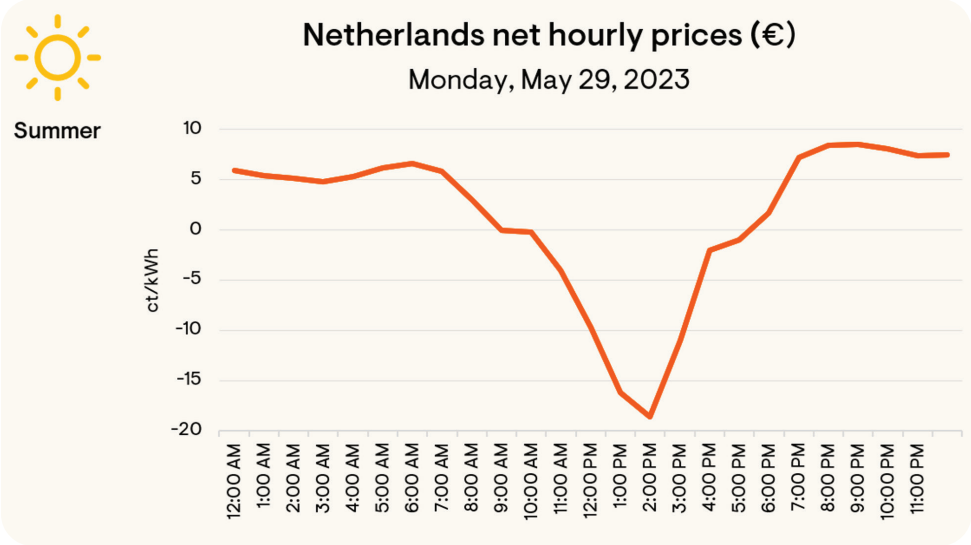


Figure 16

Source: epexspot.com

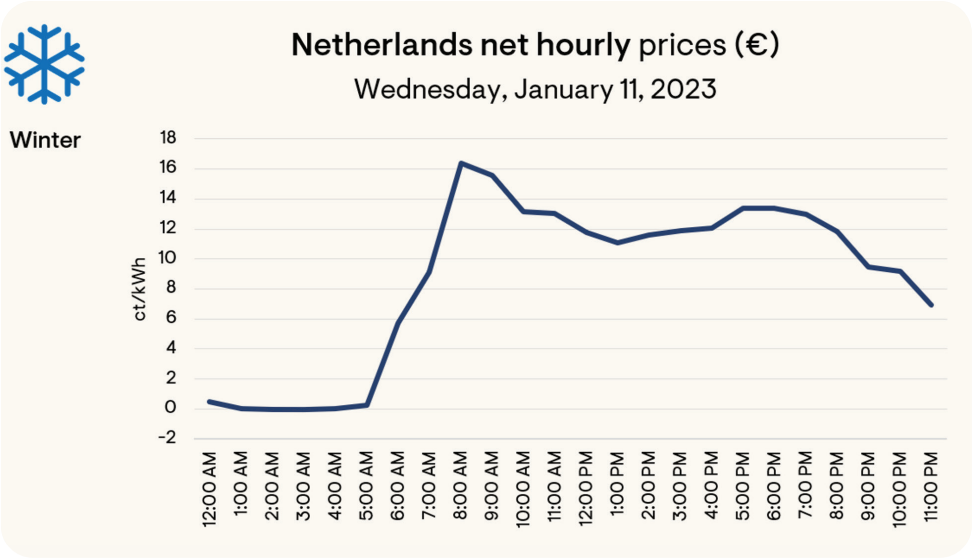


Figure 17

Source: epexspot.com

Since the prices are determined by energy supply and demand, they accurately reflect the state of renewable energy. During sunny summer days, prices are low in the early afternoon since demand is low and generation is high (see Figure 16). The prices are also low on stormy winter nights because of the high wind energy generation (see Figure 17). Prices increase when demand is high and renewable power generation is low, like on days with cloudy weather.

Due to the over-generation of renewable energy, prices can even become negative. This effect can be observed more and more each year. It reflects the need of the market to get rid of over-generated energy. If prices are negative, consumers get paid to consume energy to help balance the grid and mitigate the over-generation issue.

3.3.2. Solar + battery + dynamic tariff

Energy management technology can unlock the financial benefits by leveraging dynamic tariffs. Instead of optimizing the home for the highest possible self-consumption, like in the previous solution, the system will take advantage of all available energy sources with the goal of maximizing financial savings for the homeowner. An artificial intelligence-based algorithm will ensure that the least expensive source of power will be used for the house, but also energy will be stored during low-price period and exported back to the grid during high-price periods to generate additional earnings.

For example, the system charges the battery during the night using grid energy to take advantage of low rates due to the over-generation of wind energy. Then supply the stored energy to the house prior to the sun rising. It will charge the battery from solar over-generation during the day and discharge it to the grid during times of high demand in the evening, generating a profit (see Figure 19). It will optimize the household at each hour of the day and by doing so, generating significant savings for the consumer while minimizing their reliance on the grid.

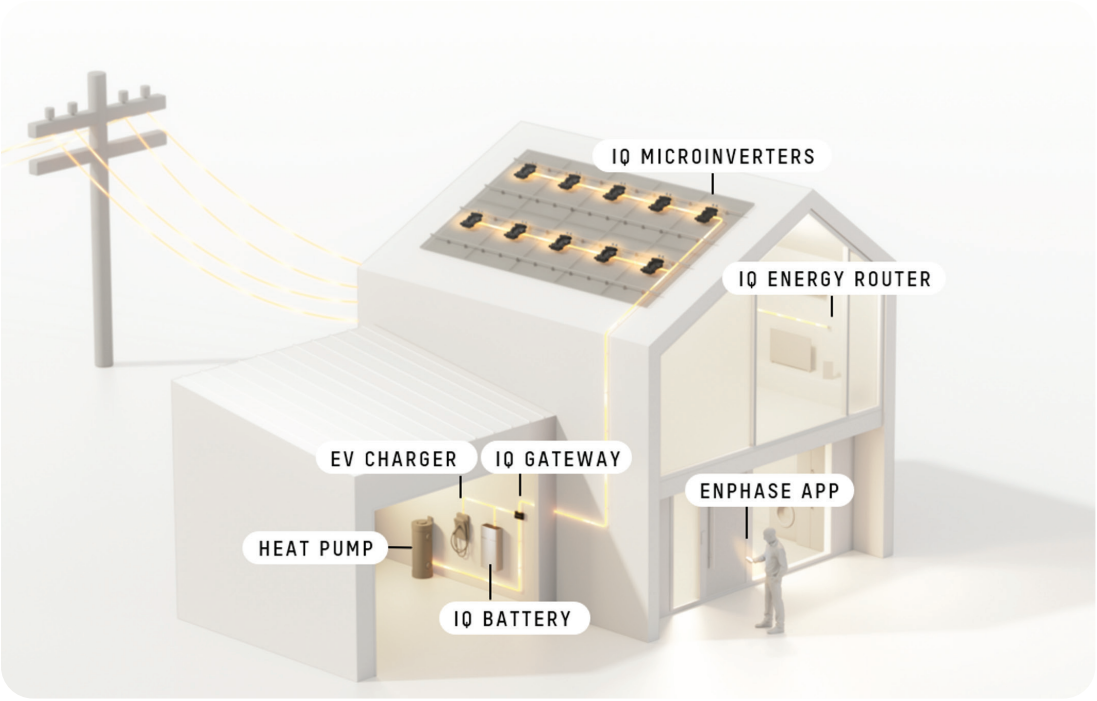


Figure 18

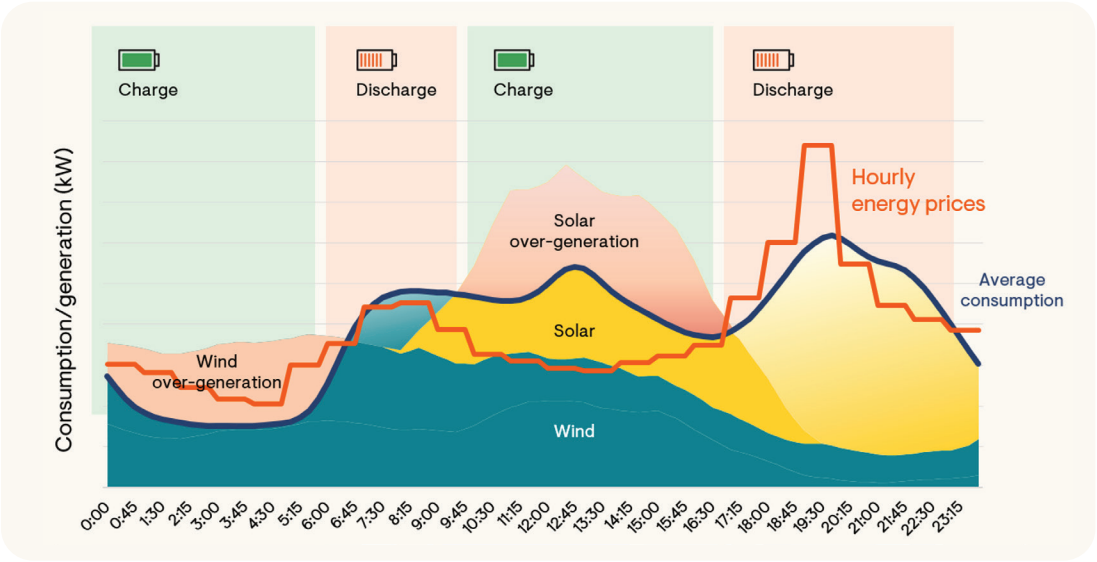


Figure 19

Another significant advantage of switching to a dynamic tariff with energy management software is the additional savings that can be earned with an electric vehicle or heat pump. The system can control those devices just like a battery. The vehicle will charge at a low rate at night or on sunny summer days to avoid high energy prices.

This solution, Solar + battery + dynamic tariff, will significantly improve the payback of the entire system and generate more savings and earnings for the homeowner. The payback period with this solution can improve from 8.5 years back down to about 6.5 years, similar to a solar only solution.

This solution will be available in May 2024.

3.4. Solar + battery + dynamic tariff + imbalance steering

Further improvement to the financial payback period can be achieved by participating in the imbalance market. Enphase Energy Systems will support this use case in the future.

3.4.1. What is the imbalance market?

The imbalance market is hosted by the transmission system operator TenneT. In this market, TenneT gives all energy providers a forecast of the imbalance financial penalty. This enables energy providers to take action to balance their portfolios proactively before any penalty is applied. In this market, prices change every minute with settlement periods every 15 minutes. Participating in the imbalance market takes the form of a Virtual Power Plant (VPP) and requires much faster response times than the day-ahead market for dynamic tariffs, which varies every hour.

The value of this short-term balancing energy is significantly higher than in slower markets like the day-ahead market. Participating in the imbalance market, meaning providing pro-active balancing

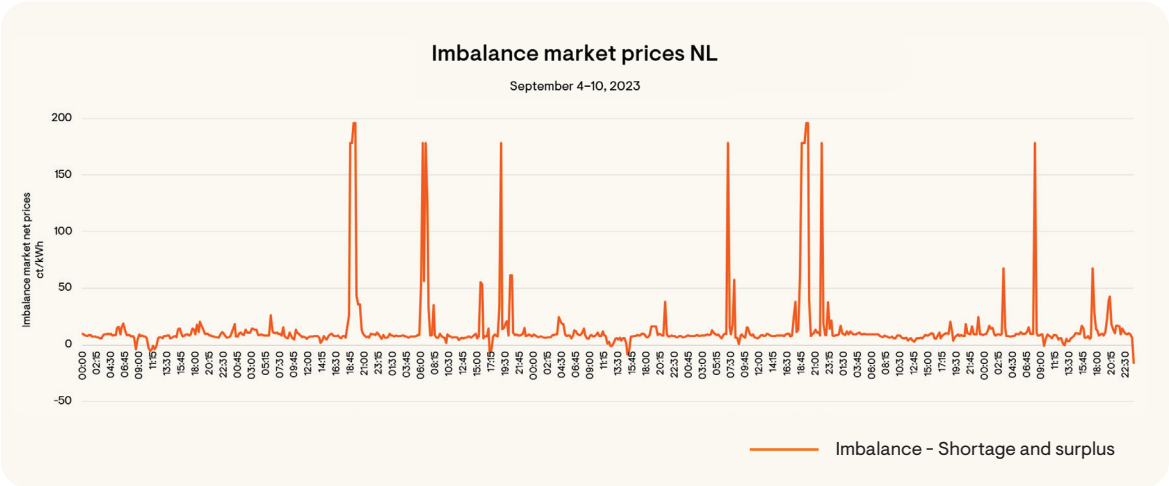


Figure 20

Source: TenneT

energy, can be compensated with several €/kWh. (see Figure 20).

For example, on September 5, 2023, at about 18:45 pm, participation in the imbalance market would have paid the homeowner almost 2€/kWh. Given the setup of the imbalance market, it requires a direct connection between the energy management system and the partnering energy provider. The energy provider needs to understand exactly what energy reserves are available in the home and then use that energy to trade it as balancing energy to generate profits. This will not be done on a per home basis, but with multiple homes aggregated into a VPP.

3.4.2. Solar + battery + dynamic tariff + imbalance steering

Building on the overall optimization and savings with a dynamic tariff but augmenting it with participation in the imbalance market has a significant upside to the savings and profits generated by an energy management system. Without any additional hardware, the system will actively help to balance the grid during critical imbalance events.

To activate this option, the homeowner must sign up for an imbalance energy contract with a partnering energy provider. The Enphase App will link the Enphase Energy System directly to the selected energy provider. As soon as the energy provider detects a price peak in the imbalance market, it will signal the Enphase Energy System to charge or discharge the battery (see Figure 22)

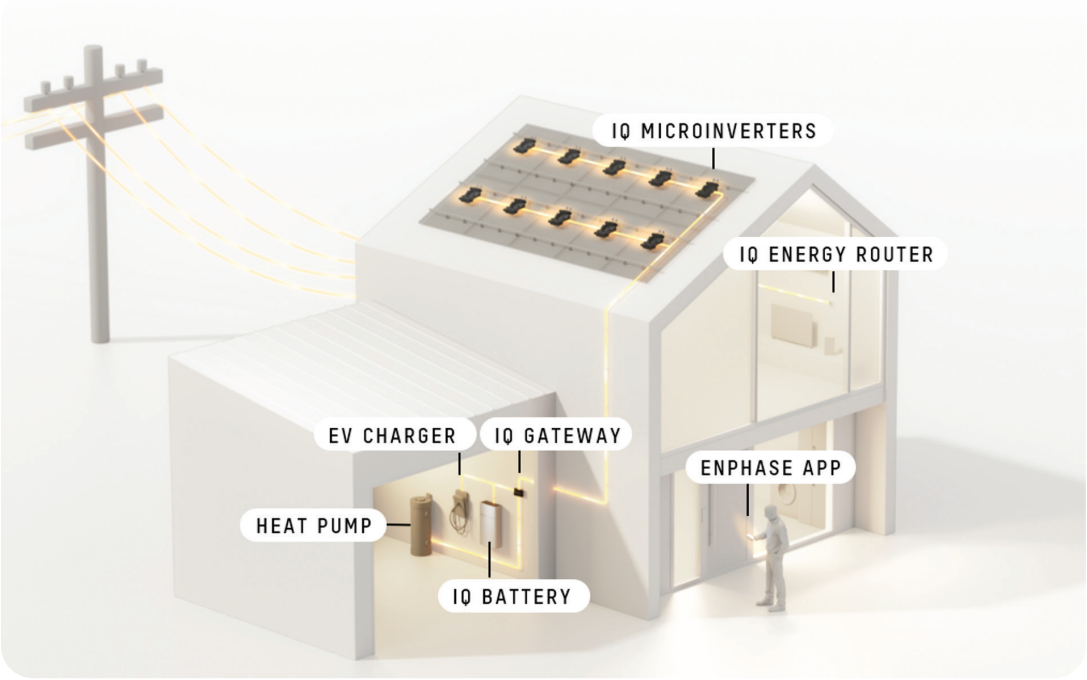


Figure 21

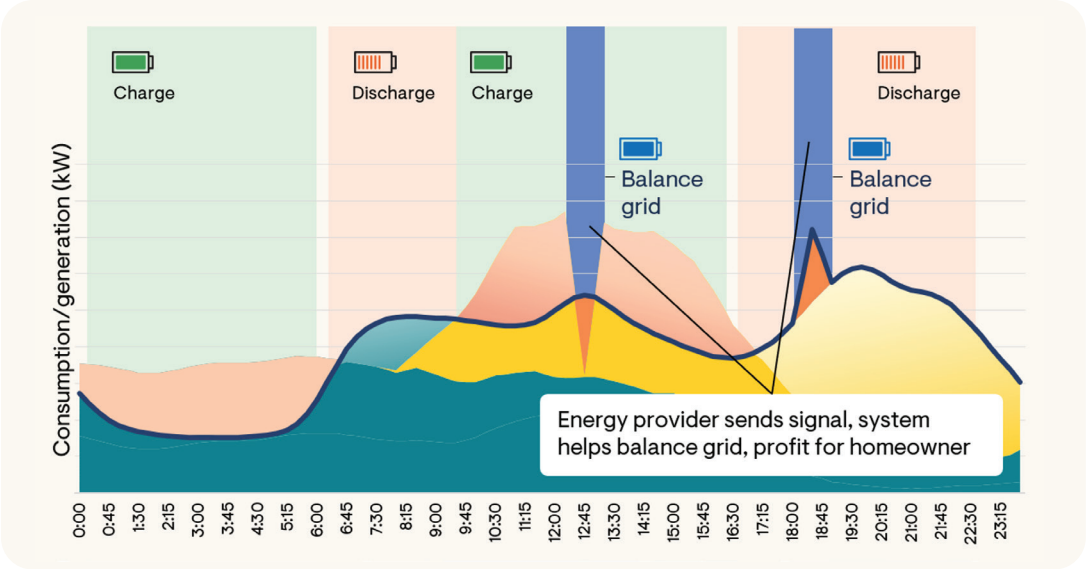


Figure 22

Like dynamic tariffs, EVs and heat pumps can provide a significant financial upside to this solution. Profits in the imbalance market are gained by either providing or absorbing energy. An EV can increase the energy consumption of a household for participation in the imbalance market. Adding imbalance market participation can further improve the payback period from 6.5 years to 5.5 years.

This solution will be available in December 2024.

3.5. Solargraf design and proposal software

Designing a system for integration with energy markets is very complex. To help installers design systems quickly and easily, Enphase offers Solargraf, a design and proposal software solution that automates the design of systems by modeling energy generation and consumption using the same logic found in the energy management software. Solargraf will also help identify the optimal energy rate plan and summarize everything in an easy-to-understand proposal for homeowners.

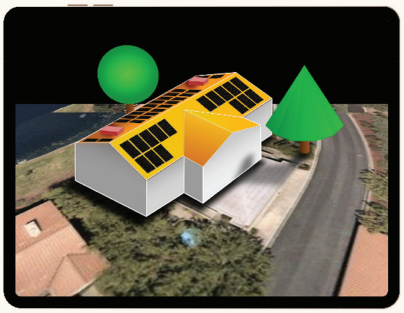
Design your roof

Rooftop 3D modelling for convincing visualization

AI-based auto-detection of obstructions, trees, azimuth, walls

Intelligent & optimized panel placement

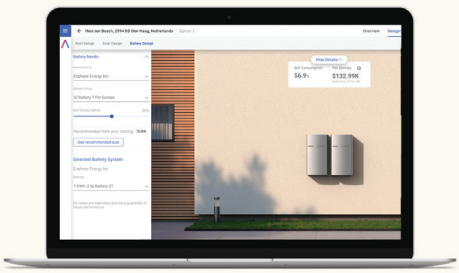
Accurate shade analysis – with only one click



Add your battery

Individual battery sizing recommendations based on household consumption and production

Compare battery sizes and get a transparent view of their impact, e.g., on self-consumption



Select electricity tariff and participate in imbalance market

Preview savings and payback from selecting the best-fit electricity contract

Opt-in to participate in imbalance market via virtual powerplant (VPP) to make money

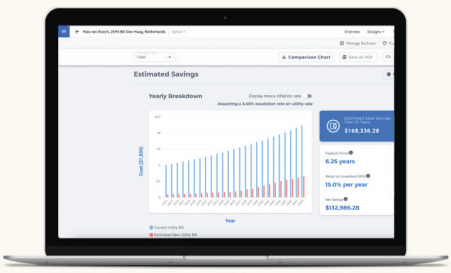


Figure 23

Solargraf will be released in the Netherlands in May 2024.

4. Financial analysis

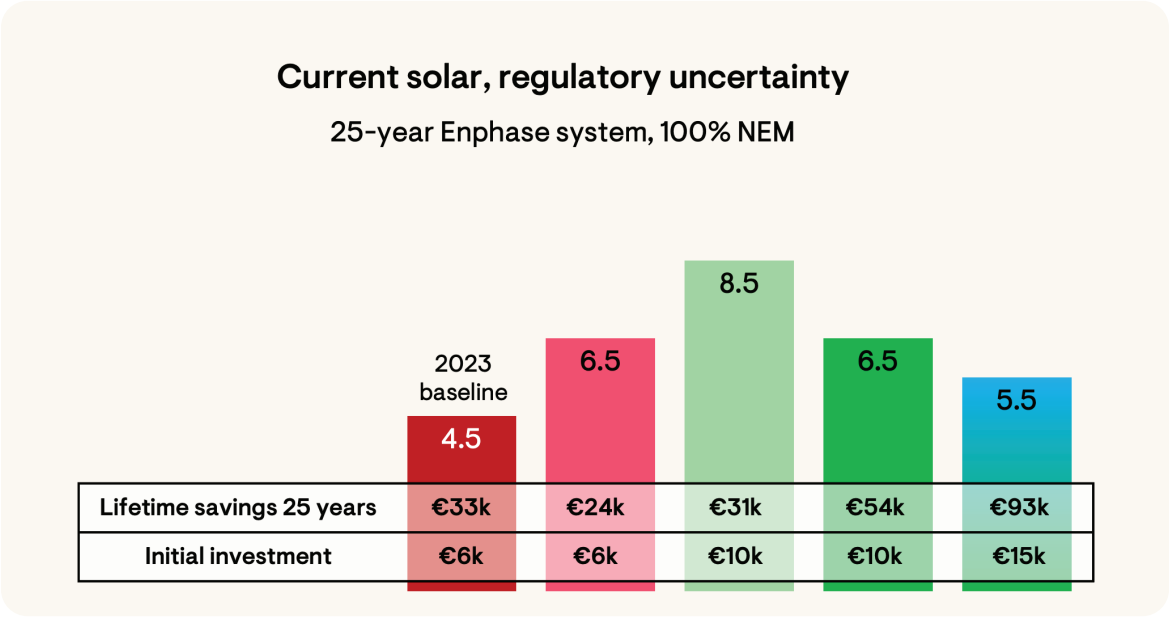
This white paper uses a 25 -year financial model to understand the impact of the solutions described in the previous section. Payback periods, lifetime savings and estimated investment cost are available for each use case.

One key element of this financial model was the AI-based optimization engine of the energy management software that attempts to maximize savings in a dynamic tariff environment or by participating in the imbalance market.

4.1. Payback periods and lifetime savings

Since there is still ambiguity with a NEM revenue model, this whitepaper will further elaborate in two models: the current NEM model and a pessimistic scenario in which NEM will be eliminated completely. This provides best- and worst-case scenarios with actual savings somewhere between these two reference models. The payback period is based on a 25-year warranty period, which includes a replacement of the battery after 15 years.

With 100% NEM present (see Figure 24), the payback period of a solar-only system will increase from 4.5 years to at least 6.5 years considering the introduced penalties from energy-providers. In both situations the lifetime savings are very attractive (€33,000 and €24,000 respectively) with an initial investment of €6,000. However, it is not guaranteed that the export penalties will always be the same. They can change if the imbalance cost continues to increase.



- 2023 baseline
- Solar only
- Solar + battery
- Solar + battery + dynamic tariffs
- Solar + battery + dynamic tariffs + imbalance steering

- Solar only solution considers export penalty for 100% NEM and no export for 0% NEM
- Solutions including a battery consider battery replacement after 15 years
- Integration of electric vehicle and heat pump will reduce payback by 1 – 2.5 years for battery solutions

Figure 24

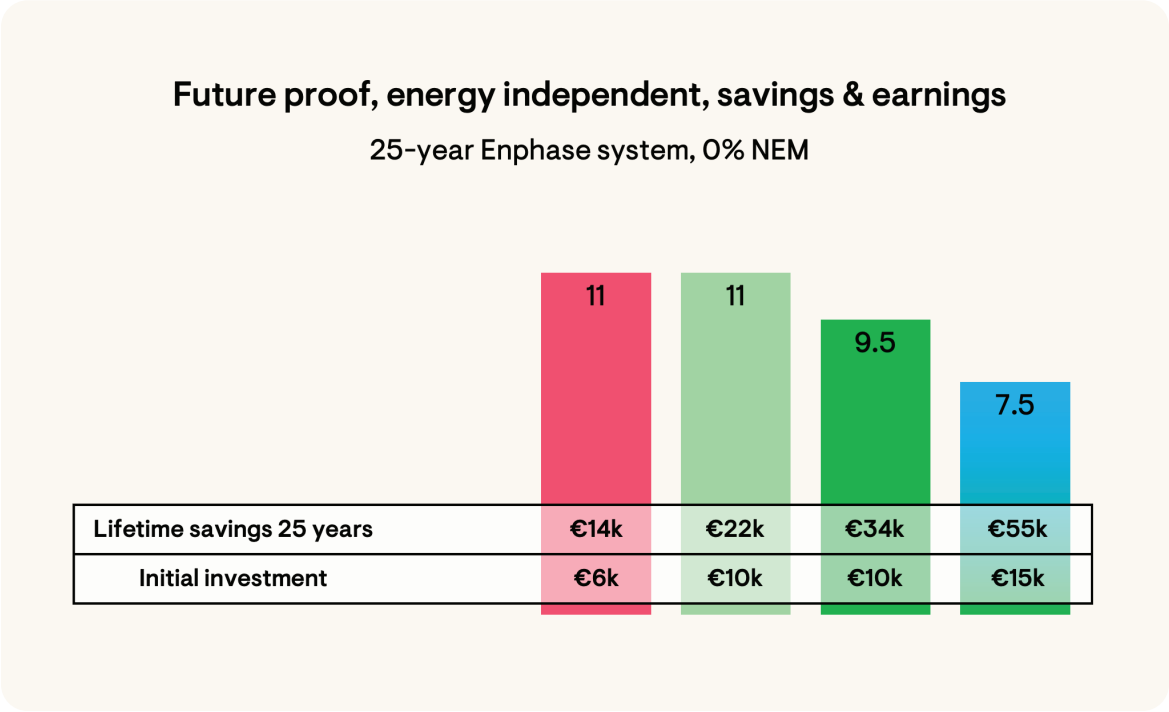
The energy management with self-consumption solution increases the length of the payback to 8.5 years. The lifetime savings are higher than a solar only solution, but the additional investment for a battery will take some time to pay for itself. However, it is protection against any future increases in export penalties.

When energy management is combined with dynamic tariffs, though, the payback is 6.5 years and similar to the solar only solution. The major difference is that no penalties will be applied by an energy provider when the solar customer is using a dynamic tariff. The lifetime savings are very attractive in this case, €54,000 for a €10,000 initial investment.

Finally, energy management with imbalance steering provides the best payback period of 5.5 years, even though the investment into a larger battery would be the highest. The significant lifetime savings of €93,000 in this solution will return the investment very quickly.

Adding an EV charger and a heat pump will also have a positive effect on the payback period of all solutions including a battery. They will further decrease the payback period by an additional 1 – 2.5 years.

In the event NEM is eliminated some time in the future (see Figure 25), the payback periods will increase.



- 2023 baseline
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Figure 25

The most significant effect can be observed for the solar only solution. The payback rises to 11 years but will return double the initial investment over lifetime.

The solar + battery solution will also have an increased payback period of 11 years with a slightly better lifetime saving as solar only.

Solar + battery + dynamic tariffs will bring the payback period even lower at 9.5 years and has a very attractive lifetime saving of €34,000 with an initial investment of €10,000.

The best solution is still represented by solar + battery + dynamic tariff + imbalance steering. This solution offers a 7.5-year payback period and €55,000 lifetime savings with an initial investment of €15,000.

Most notable, all solutions including a battery and therefore energy management software are future proof solutions. They create value without the need for NEM legislation or other subsidies, but by enabling the homeowner to take control of their energy. Either by becoming self-sufficient or actively participating in energy markets and generating earnings on top of savings.

The more steerable assets are added to those systems, the more value they provide. Integrating an electric vehicle or a heat pump into the system will decrease the payback periods by 1 – 2.5 years, since those devices can generate significant savings and earnings given their steerability and high energy consumption.

5. Conclusion

Given the success of the ongoing energy transition in the Netherlands from fossil fuel to renewable energy, the electrical system has reached a point where it requires a paradigm shift. It can no longer encourage unrestrained export of renewable energy to the grid. It must put greater emphasis on systems consisting of solar, batteries, and energy management.

It also requires the consumer to transition from participating passively in the energy system to taking a more active role and becoming a true prosumer. This means not only self-consuming their energy but also participating in the energy markets to help support the operation of the grid. By doing so, the energy transition will maintain momentum, and it will be democratized by enabling everyone to participate in the savings and earnings that are being generated.

While uncertainty and ambiguity are easy to understand, it is important to look at the facts and the technologies that are available to manage this transition. Solar is and will be a good investment despite penalty charges and the potential elimination of NEM. Even with penalty charges, the payback periods are only 6.5 years for traditional savings-oriented solar systems. Homeowners who would like to be future proof can invest in solar + battery + dynamic tariff system. This active role in energy management will generate additional earnings and decrease their payback periods to 7.5 years even with NEM being eliminated.

The Dutch solar market can continue its phenomenal growth, independent of NEM,
by adopting solar, battery, and energy management and thereby remain the driving force of the energy transition.

This is a win for homeowners, installers, energy providers, and grid operators.

Revision history

REVISION	DATE	DESCRIPTION
DSH-00105-1.0	January 2024	Initial release

ENPHASE.