cVPP Business Model, Mobilization and Replication Roadmap

Interreg

Northern Periphery and Arctic

COPOWER

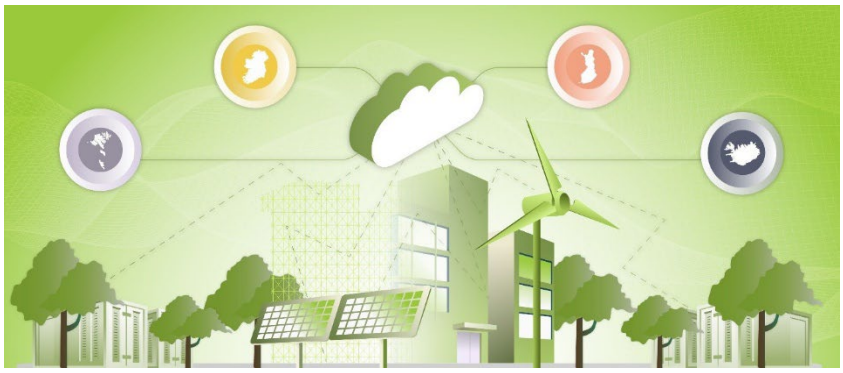


Table of Contents

cVPP Business Model, Mobilization and Replication Roadmap 1
Introduction 5
Joint strategy and action plan followed by all partners. 6
University of Iceland 7
Residential PV and Battery Pilot in Seltjarnarnes 7
Identify Candidates in Iceland 7
Determine scale of local energy generation in Iceland 11
Review promotions/polices in Iceland 15
Identify cVPP to be established in Iceland 16
Assessment of technology solutions in Iceland 18
Implementation of cVPP in Iceland 21
Implementation Timeline 23
Costs of Implementation 25
Transferring the cVPP technical platform 26
Lessons Learnt 27
Donegal County Council, Ireland 30
Virtual Powe Plant in a Local Government setting 30
Identify Candidates in Ireland 30
Determine scale of local energy generation in Ireland 30
Review promotions/polices in Ireland 33
Eligibility (Donegal residents qualify if…) 35
Eligible project types 36
Identify cVPP to be established in Ireland 36
Assessment of technology solutions in Ireland 36
Implementation of cVPP in Ireland 41
Implementation Timeline 42

Costs of Implementation 42
Transferring the cVPP technical platform 42
Lessons Learnt 42
Centria University of Applied Sciences, Finland 43
Biogas plant on an agricultural building 43
Identify Candidates in Finland 43
Determine scale of local energy generation in Finland 47
Review promotions/polices in Finland 52
Identify cVPP to be established in Finland 53
Assessment of technology solutions in Finland 54
Implementation of cVPP in Finland 56
Implementation Timeline 60
Costs of Implementation 61
Transferring the cVPP technical platform 62
Lessons Learnt 63
University of Oulu 65
Smart Energy System Integration in Electrically Heated Residential Buildings 65
Identify Candidates in Northern Ostrobothnia, Finland 66
Determine scale of local energy generation in Oulu (Northern Ostrobothnia) 67
Review promotions/policies 68
Identify cVPP to be established in Oulu 70
Assessment of technology solutions in Oulu 75
Implementation of cVPP in Oulu 77
Implementation Timeline 78
Costs of Implementation 78
Transferring the cVPP technical platform 82
Lessons Learnt 82
Nólsoy, Faroe Islands 85
Ground source heating combining solar generation to independently power system for local museum. 85

Identify candidates that might benefit from and be interested in establishing a Virtual Power Plant in the Faroe Islands 85
Determine scale of local energy generation, demand response and distributed energy resource assets available in each partner region. 86
Review what promotions/policies local/country governments promote 87
Identify cVPP to be established in region 88
Assessment of technology solutions to confirm viability for the cVPP model 89
Implementation of cVPP 90
Implementation Timeline 90
Key costs of Implementation 91
Transferring the cVPP technological platform solution to your region 91
Lessons Learnt 92

Introduction

This report provides a consolidated report from all of the pilot projects on the landscape that each partner faced in their particular regions/countries, the options suitable for generating electricity, the policies and promotions to adopt the use of renewable energy in their regions/countries. It also documents that approach to finalizing the technology they would implement, the steps and timelines for implementing their cVPP, the cost of implementation and any lessons learned.

In addition we outline the joint strategy/action plan that was followed by all partners. All partners followed a similar model to develop their solutions although the actual implementations differed in the energy source for generating power, the software logic used to manage the energy load with some pilots utilizing batteries and others deciding that they were not needed or not cost effective.

Joint strategy and action plan followed by all partners.

All partners met on a bi-weekly basis during Semester 1 and Semester 2 where the joint strategy was agreed and the steps to identify and finalize the pilots to be delivered for each pilot.

The methodology that was followed by the partners was to 'Identify Candidates' by collecting data related to suitable sources of renewable energy that was applicable or available in their region. Then each partner determined the scale of local generation in their particular regions and collected in detail data related to environment conditions in their regions, the forecasted energy production of the various options available to them and charted the decision making which was all documented in deliverable D2.5.1 Test and Monitoring report. Each partner also looked to identify any promotions available in their regions and reviewed any policies which might impact the approach that they wished to follow. Once they identified the particular cVPPP that they planned to establish in their region, they assessed the various technology and software solutions available to them and then each partner proceeded to develop their particular pilot. This was documented in the deliverable D2.3.1 Joint Transitional Methodology .

All partners followed a similar model to develop their solutions although the actual implementations differed in the energy source for generating power, the software logic used to manage the energy load with some pilots utilizing batteries and others deciding that they were not suitable or cost effective for their particular pilots while the consumers of the energy differed from pilot to pilot.

University of Iceland

Residential PV and Battery Pilot in Seltjarnarnes

The University of Iceland pilot proves that even in a fully renewable and highly centralized energy system, small-scale distributed solutions can unlock new value. By integrating PV, battery storage, and intelligent control, the pilot operates as a micro-scale Virtual Power Plant, enabling cooperative energy use, improved resilience, and optimized system performance.

Beyond its technical success, the pilot has acted as a catalyst for market transformation in Iceland. Through its role as a live demonstration platform, it has directly supported the rapid growth of PV and battery deployments across multiple sectors, while also driving regulatory awareness and industry readiness.

The project demonstrates that early-stage pilots are not only technological testbeds, but powerful enablers of systemic change—laying the foundation for scalable Virtual Power Plants and a more flexible, decentralized energy future.

Identify Candidates in Iceland

1. **Identify candidates that might benefit from and be interested in establishing a Virtual Power Plant under the following categories Activity *1.3***
    a. **Normal Energy Producers e.g. wind farm, biogas, solar producers, etc.**

    In the Icelandic context, large-scale energy production is dominated by centralized geothermal and hydropower plants operated by companies such as Reykjavík Energy, HS Orka, and Landsvirkjun. These actors operate utility-scale generation and are therefore not primary candidates for establishing Virtual Power Plants (VPPs).

    Instead, the most relevant candidates within this category are small-scale and distributed energy producers, including rooftop PV owners, farms, and commercial entities with on-site generation. These actors can benefit from aggregation into a VPP, enabling improved self-consumption, increased flexibility, and more efficient utilization of locally generated energy.

b. Public Infrastructure e.g. local electricity companies, municipalities, etc.

Public infrastructure stakeholders, particularly municipalities and publicly owned utilities, represent strong candidates for establishing or participating in Virtual Power Plants (VPPs). In Iceland, municipalities manage a wide range of buildings and services (e.g. schools, offices, and sports facilities) with significant and predictable energy demand.

Although Iceland's electricity supply is already almost entirely renewable (hydropower and geothermal), there is a growing interest in photovoltaic (PV) systems, partly due to their visibility as a clear and tangible demonstration of renewable energy use. One of the key drivers behind this development is the visibility of PV installations, which provide a tangible and publicly recognisable demonstration of renewable energy use and climate action.

By integrating distributed energy resources—such as rooftop PV systems, battery storage, and controllable loads—across multiple public buildings, municipalities can:

- Improve energy efficiency and reduce operational costs
- Increase self-consumption of locally generated energy
- Enhance energy resilience, particularly for critical infrastructure
- Demonstrate leadership in sustainability and climate action

The Icelandic pilot demonstrates a scalable approach that can be extended to public infrastructure, where multiple buildings can be interconnected and managed as a coordinated energy system. This creates opportunities for municipalities and utilities to act as aggregators of distributed energy assets, forming the basis for future VPP implementations.

c. Private Dwellings/Condominiums e.g. households with energy production

Private dwellings, multi-apartment buildings, and rural properties such as farms represent one of the most promising segments for the development

of Virtual Power Plants (VPPs), particularly through the aggregation of distributed energy resources (DERs).

In Iceland, interest in rooftop PV systems combined with battery storage is increasing across both residential and rural settings. While urban households are increasingly adopting such systems for sustainability and energy optimization, farmers and rural users represent one of the most engaged and strategically important groups.

This is driven by several factors:

- Higher electricity costs in rural areas, partly due to transmission and distribution charges
- Increased vulnerability to grid outages, making energy resilience a priority
- Limited access to district heating, especially in remote or “cold areas” without geothermal resources

As a result, PV + battery systems offer farmers:

- Improved energy security
- Reduced operational costs
- Greater independence from the grid

The University of Iceland pilot directly addresses this category by demonstrating a shared energy system across multiple users, where:

- PV generation, battery storage, and grid interaction are jointly managed
- Energy can be dynamically allocated based on availability and demand
- The system optimizes energy use between PV, battery, and grid sources

This reflects a cooperative energy model, which is highly relevant not only for apartment buildings but also for rural communities and farm clusters, forming a natural foundation for residential and community-scale VPPs.

Key benefits for this category include:

- Increased self-consumption of locally generated energy
- Reduced energy costs through optimized energy management
- Improved resilience during grid disturbances or outages
- Opportunities for participation in aggregated energy systems

The pilot further integrates energy monitoring and data-driven control, supporting the future development of AI-based cooperative energy management strategies. This enables both residential and rural users to become active participants in a decentralized and intelligent energy system.

In the Icelandic context, rural users such as farmers may represent one of the most impactful entry points for VPP deployment due to their combined need for energy resilience, cost optimization, and local energy production.

d. Public bodies e.g. municipal or regional councils

Public bodies, including government agencies and publicly owned organisations, represent important candidates for the development and adoption of Virtual Power Plants (VPPs). These entities typically manage large and diverse building portfolios, including offices, service centres, and institutional facilities, which together form a significant and flexible energy demand base.

In Iceland, public bodies are increasingly engaging in sustainability and energy transition initiatives, including the adoption of photovoltaic (PV) systems and energy storage solutions. Their role is particularly important in leading by example, demonstrating the feasibility and benefits of distributed energy systems.

Although Iceland's electricity supply is already almost entirely renewable, there is a growing interest among public bodies in implementing visible renewable energy solutions, such as PV installations.

These systems provide a clear and tangible demonstration of climate action and environmental responsibility, both internally and to the public.

The University of Iceland pilot, together with its associated replication activities, has already contributed to this development. Notably, the associate partner Alor has successfully sold and installed PV and battery systems for public-sector stakeholders, including a system procured by the Ministry of the Environment, Energy and Climate and implemented in a building managed by the Government Property Agency (Ríkiseignir).

Public bodies can benefit from VPP participation through:

- Improved energy efficiency and reduced operational costs across building portfolios
- Enhanced resilience of critical infrastructure
- Better utilization of locally generated renewable energy
- Contribution to national climate and energy targets

Due to their scale, organisational capacity, and policy alignment, public bodies are well-positioned to act as early adopters and coordinators of VPP systems, supporting broader deployment across regions. This demonstrates a clear pathway from pilot-scale research to public-sector implementation.

Determine scale of local energy generation in Iceland

2. **Determine scale of local energy generation, demand response and distributed energy resource assets available in each partner region.**
    a. **Clarify how electricity is predominantly generated in local region (fossil, wind, solar, etc.)**

Electricity generation in Iceland is almost entirely based on renewable energy sources, primarily hydropower (approximately 70%) and geothermal energy (approximately 30%). This results in one of the lowest carbon intensity electricity systems in the world, with minimal reliance on fossil fuels for electricity production.

Generation is largely centralised, with large-scale power plants operated by entities such as Landsvirkjun, Reykjavík Energy, and HS Orka. A significant share of geothermal power plants operate as combined heat and power (CHP) systems, simultaneously producing electricity and supplying hot water for district heating. This integrated approach further increases overall energy efficiency and plays a key role in Iceland's energy system.

Despite this highly renewable and stable system, several important characteristics influence the relevance of distributed energy systems and Virtual Power Plants (VPPs):

- Electricity prices are relatively low, reducing traditional financial incentives for small-scale generation
- The system is highly centralised, with limited penetration of distributed energy resources (DERs)
- Increasing interest in decentralised solutions is emerging, driven by energy resilience, flexibility, and the visibility of renewable technologies (e.g. rooftop PV)
- Rural areas may experience greater vulnerability to outages, increasing the value of local generation and storage

Wind energy, while abundant in Iceland, has historically played a very limited role. In addition to regulatory and societal constraints, technical challenges related to extreme wind conditions—such as strong gusts and high intermittency—have affected reliability, with some early installations experiencing structural issues. Although small pilot wind installations have existed for over a decade, only recently has approval been granted for the development of Iceland's first commercial wind farm.

In this context, the development of distributed PV and battery systems, as demonstrated in the University of Iceland pilot, represents an important step toward decentralized energy management and future VPP integration, complementing Iceland's centralized renewable energy system.

b. Review the market penetration of Distributed Energy Resources (DERs) in local region.

The penetration of Distributed Energy Resources (DERs) in Iceland is currently relatively low but rapidly growing, particularly for photovoltaic (PV) systems and battery energy storage solutions.

Historically, the dominance of low-cost, centrally generated renewable electricity (hydropower and geothermal) has limited the economic incentive for small-scale distributed generation. As a result, rooftop PV systems and battery installations have only recently begun to emerge in the Icelandic energy landscape.

However, this trend is changing. There is a clear and accelerating increase in interest and deployment of PV + battery systems, driven by several factors:

- Increasing focus on sustainability and visible renewable energy solutions
- Government funding mechanisms (e.g. Environmental and Energy Fund)
- Demand for improved energy resilience, particularly in rural areas
- Growing awareness of energy optimization and self-consumption

The University of Iceland pilot, together with its collaboration with the associate partner Alor, has played a role in supporting this emerging market. Following the pilot implementation, a substantial number of PV and battery projects have been initiated and are currently at various stages of development, including feasibility assessment, system design, and implementation.

These projects span multiple sectors including agriculture, industry, commercial buildings, tourism, and public infrastructure. The projects range from small-scale residential systems to larger installations exceeding 100 kW of installed PV capacity, with several projects already completed and many more planned or under development for the period 2025–2027. Many of these initiatives have successfully secured government funding support, further accelerating adoption.

This demonstrates that while DER penetration in Iceland is still in an early growth phase, there is strong momentum toward wider deployment. The pilot contributes to this transition by:

- Providing a real-world demonstration of integrated PV and battery systems
- Supporting stakeholder engagement and knowledge transfer
- Enabling data-driven approaches for future energy system optimization

As DER adoption continues to grow, the aggregation of these distributed assets will create a strong foundation for the development of Virtual Power Plants (VPPs) in the Icelandic context.

c. Local market costs

The economic context for distributed energy resources (DERs) in Iceland differs significantly from many other European regions. Due to the abundance of renewable energy from hydropower and geothermal sources, electricity prices are relatively low, which reduces the direct financial incentive for small-scale energy generation such as rooftop photovoltaic (PV) systems.

At the same time, the cost of installing PV and battery systems in Iceland remains relatively high. This is mainly due to:

- The need to import most equipment
- A relatively small and emerging market
- Installation and labour costs

As a result, the business case for PV and battery systems is often not driven purely by electricity price savings. Instead, value is driven by additional factors, including:

- Energy resilience, particularly in rural areas where outages are more likely
- Reduced dependence on the grid, especially for farms and remote users

- Sustainability goals and environmental visibility, particularly for public bodies and commercial actors
- Access to government funding, which significantly improves project feasibility

Government support schemes, such as grants from the Environmental and Energy Fund, have proven to be a key enabler for deployment. Many of the projects associated with the pilot and its replication activities have relied on such funding to move from feasibility to implementation.

In this context, the role of Virtual Power Plants (VPPs) becomes particularly relevant. Rather than relying solely on energy cost savings, VPPs can create additional value through:

- Optimized energy use and load management
- Improved utilization of locally generated energy
- Enhanced system flexibility and resilience

The University of Iceland pilot reflects this shift, demonstrating how PV and battery systems can deliver value beyond simple economic return, supporting a broader transition toward decentralized and intelligent energy systems.

Review promotions/polices in Iceland

3. **Review what promotions/policies local/country governments promote**
    a. **What policies/subsidies are available through government?**

In Iceland, government policies and support mechanisms play an important role in enabling the adoption of distributed energy resources (DERs), particularly in contexts where direct economic incentives are otherwise limited due to low electricity prices.

Several targeted support schemes are relevant to the deployment of photovoltaic (PV) systems, battery storage, and related technologies:

- **Subsidies for renewable energy installations in cold and remote areas:**

Through Orkusjóður (the Energy Fund), operated under the Ministry of the Environment, Energy and Climate, financial support is provided for the installation of renewable energy solutions, including PV and wind systems, particularly in areas without access to geothermal district heating. These "cold areas" rely more heavily on electricity for heating, making local energy generation and storage especially beneficial.

- **Electricity cost equalization for heating:**
  The government subsidizes electricity used for heating in non-geothermal areas, ensuring that households and businesses in these regions are not disadvantaged compared to those connected to district heating systems.
- **Environmental and Energy Fund (Orkusjóður):**
  Orkusjóður also supports investments in renewable energy technologies more broadly, including PV and battery systems. This funding mechanism has been instrumental in enabling several projects linked to the pilot and its replication activities.
- **Support for electrification and energy transition (including EV adoption):**
  Incentives have been introduced to support the transition to electric vehicles (EVs), particularly for companies. This contributes to increasing electricity demand and creates opportunities for integrating EVs into broader energy systems, including VPP frameworks.

These policies collectively support the transition toward more decentralized, flexible, and sustainable energy systems. While Iceland already benefits from a renewable electricity supply, these initiatives encourage local energy production, improved energy efficiency, and enhanced system resilience, all of which are key components of future Virtual Power Plant (VPP) development.

Several of the projects developed in connection with this pilot have successfully received support from Orkusjóður, demonstrating the effectiveness of these policy mechanisms.

Identify cVPP to be established in Iceland

4. **Identify cVPP to be established in region**
   a. **Which potential cVPP was delivered in the region?**

The University of Iceland pilot represents a micro-scale Virtual Power Plant (VPP) implemented in a residential setting in Seltjarnarnes (greater Reykjavík area). The system integrates:

- Photovoltaic (PV) generation (10 × 430 W panels)
- Battery Energy Storage System (BESS) (15 kWh)
- A hybrid inverter with advanced energy management capabilities
- Shared energy usage across three apartments

The system is capable of dynamically managing energy flows between PV generation, battery storage, and the grid. It can operate in both grid-connected and off-grid modes, enabling load prioritization, cost optimization, and backup functionality.

In addition, a complementary experimental setup has been developed, including PV, battery storage, and a diesel generator, to study system dynamics, control strategies, and backup operation scenarios relevant for remote and rural applications.

b. What already exists and what has to be developed?

Existing elements:

- Grid-connected residential infrastructure
- Increasing deployment of PV systems and battery storage
- Government support mechanisms (e.g. Orkusjóður)
- Commercial actors (e.g. the startup Alor) capable of delivering such systems

Developed within the pilot:

- Integrated PV + battery + inverter system with intelligent control
- Shared energy model across multiple users (cooperative approach)
- Real-time monitoring using multiple platforms (Solarman, Shelly, TempestOne)
- Data collection infrastructure for modelling and optimization

To be further developed:

- AI-based cooperative energy management strategies
- Advanced control algorithms for energy sharing and optimization
- Scalable aggregation mechanisms to enable full VPP functionality
- Integration with additional flexible assets (e.g. EVs, demand response)

c. Identify the key partners required to deliver the cVPP

The delivery of a cVPP system in the Icelandic context requires collaboration between several key stakeholders:

- Technology providers and system integrators (e.g. Alor) – responsible for system design, installation, and integration of PV, battery storage, and control systems
- Installers and electricians – responsible for electrical installation, safety compliance, and commissioning
- Utility companies and grid operators – responsible for grid connection, approvals, and operational compliance
- Government bodies and funding agencies (e.g. Orkusjóður) – providing financial support and enabling deployment through policy mechanisms
- End users (residential, commercial, or agricultural stakeholders) – participating in system operation and enabling cooperative energy use

Research institutions, such as the University of Iceland, may support development through testing, data analysis, and innovation, but are not required for the deployment of operational systems.

The pilot developed by the University of Iceland demonstrates the feasibility of such systems and supports knowledge transfer to implementation partners.

Assessment of technology solutions in Iceland

5. Assessment of technology solutions to confirm viability for the cVPP model

a. how to gain access to the grid

Grid access for distributed energy systems in Iceland is well established but requires compliance with local regulations and approval from the relevant utility or grid operator.

In the pilot system:

- The installation is grid-connected via a hybrid inverter, which synchronizes with the grid during normal operation
- The system includes anti-islanding protection, ensuring that no electricity is exported to the grid during outages, thereby protecting maintenance personnel
- Appropriate safety switches and disconnection mechanisms are installed to comply with regulatory requirements

The process of gaining grid access involves coordination with utility companies, approval of system design, and verification of safety and operational compliance.

b. which IT security guidelines should apply

The pilot system uses a combination of cloud-based platforms (e.g. Solarman Smart, Shelly Cloud, TempestOne, and Victron VRM) and local control systems. While the system operates at a small scale, standard IoT and energy system security practices are considered:

- Secure communication via encrypted data transmission (e.g. HTTPS, API-based access)
- Authentication and access control for cloud platforms
- Secure configuration of IoT devices and network components
- Regular firmware updates for inverters, battery management systems (BMS), and sensors

For future scaling toward full VPP implementations, more advanced cybersecurity frameworks (e.g. IEC 62443 or ISO 27001) may be considered.

c. how to enable connection between software interfaces and (often remote) decentralised energy resources in regions

The pilot system integrates multiple hardware and software components through a combination of cloud platforms, local devices, and communication interfaces.

- The hybrid inverter (Solarman platform) provides real-time data on PV generation, battery status, and grid interaction
- Shelly IoT sensors provide detailed monitoring of energy consumption at the apartment level
- The TempestOne weather station provides environmental data relevant for energy production and forecasting

Connectivity between devices and software platforms depends on the available communication infrastructure:

- In locations with existing internet access, systems are connected via local Wi-Fi or wired networks
- In remote or rural locations, connectivity can be established using mobile communication solutions (e.g. 4G/5G routers or modems)

Data is accessed via APIs (e.g. Solarman API) and periodically downloaded to a central repository at the University of Iceland for further processing and analysis.

This architecture enables:

- Integration of multiple data streams
- Centralized data storage and processing
- Development of advanced control and optimization strategies

The approach demonstrates how decentralised energy resources can be connected and coordinated under varying connectivity conditions, forming the basis for scalable Virtual Power Plant (VPP) operation.

This flexibility is particularly important in Iceland, where remote and sparsely populated areas require robust communication solutions.

Implementation of cVPP in Iceland

6. Implementation of cVPP

a. Key administrative challenges (if any)

The main administrative challenge encountered during the implementation of the pilot was related to the regulatory and institutional framework, rather than technical aspects.

In Iceland, the electricity system is highly reliable and relatively low-cost, which has historically reduced the need for distributed energy solutions such as PV and battery systems. As a result, existing regulations, procedures, and utility practices have not been fully adapted to accommodate such systems, particularly in residential and small-scale applications.

This led to challenges such as:

- Limited clarity in procedures for grid connection of hybrid systems
- Lack of established frameworks for shared energy systems across multiple users
- Coordination with utilities and authorities that are still adapting to these emerging technologies

However, this situation is evolving. The increasing interest in distributed energy solutions, combined with projects such as this pilot and related public-sector installations, is actively pushing stakeholders to update and refine regulatory frameworks.

b. Key operational challenges (if any)

From a technical perspective, the core system implementation was straightforward, confirming that the underlying technologies are mature and reliable. However, several operational challenges were encountered during installation and early operation:

- Limited prior experience among installers and electricians, as such systems are still relatively new in the Icelandic market. This required additional time for problem-solving, interpretation of system

requirements, and coordination with equipment providers, which slowed the installation process.
- Firmware compatibility issues, particularly related to the battery management system (BMS), which required updates
- System configuration and tuning, to ensure optimal interaction between PV, battery storage, and grid supply
- Intermittent communication issues, such as occasional loss of connectivity from the weather station

These challenges are typical for emerging technologies in early-stage markets and highlight the importance of knowledge transfer, training, and experience-building among local stakeholders.

c. Key partner challenges (if any)

A key challenge related to partners was the limited prior experience and preparedness for implementing integrated PV and battery systems within the Icelandic context.

As these types of systems are still relatively new in the local market, several stakeholders—including installers, utilities, and other involved parties—were required to address unfamiliar technical, operational, and regulatory aspects during the project. This included:

- Identifying and resolving integration challenges between system components
- Anticipating and mitigating potential operational scenarios (e.g. grid outages, switching between operating modes)
- Interpreting evolving or unclear regulatory requirements
- Coordinating responsibilities across multiple actors with different levels of experience

The involvement of the associate partner Alor played a key role in navigating these challenges, acting as a bridge between technical implementation, practical problem-solving, and stakeholder coordination.

These experiences contribute to building local competence and reducing barriers for future deployments. Following the pilot, and particularly through the continued activities of Alor, there has been a noticeable increase in market activity, which has in turn pushed utilities, regulators, and other stakeholders to adapt and update existing frameworks, facilitating the broader adoption of distributed energy systems.

d. Key service level agreements (if any)

The pilot did not rely on formal service level agreements (SLAs), but rather on close collaboration between project partners and service providers.

- Technical support was provided by installers and system providers
- System performance was monitored through cloud-based platforms
- Issues were addressed through direct communication between stakeholders

For future large-scale deployments, more formal SLAs are expected to be required as the market matures.

Importantly, the pilot—particularly through collaboration with public-sector stakeholders—has contributed to increasing awareness and accelerating the adaptation of regulatory and operational frameworks, helping to prepare the Icelandic energy system for broader deployment of distributed energy solutions and Virtual Power Plants.

Implementation Timeline

7. Implementation Timeline

a. Permission to install requested (if required)

Permissions and approvals were considered prior to installation, including consultation with utility companies, electricians, and the local municipality.

From a municipal planning perspective, the requirements depended on the physical configuration of the installation:

- No formal permission was required when photovoltaic (PV) panels were installed flush with the roof surface
- Planning approval and neighbour consent would be required if the panels were elevated or altered the building's visual profile
- Similar considerations apply to other visible installations, such as small wind turbines

This highlights that while small-scale PV installations can be relatively straightforward to implement, visual impact and local planning regulations may influence system design choices.

These considerations influenced the final system design, favouring a low-profile installation approach.

b. Installation start date

The installation of the pilot system began in 2024, following the design phase, component selection, and coordination with installers, electricians, and relevant stakeholders.

c. Installation end date

The main installation phase was completed in 2025, after which the system entered an operational phase including testing, configuration, and continuous monitoring. Further adjustments and optimization of the system have continued beyond the initial installation.

d. Key challenges encountered

Several key challenges were encountered during the implementation process:

- Regulatory and procedural uncertainties, as existing frameworks were not fully adapted to distributed PV and battery systems
- Limited experience among installers and electricians, requiring additional time for troubleshooting, interpretation of system requirements, and system integration

- Lack of preparedness among stakeholders, leading to an iterative implementation process where solutions had to be developed and refined during execution
- Firmware and configuration issues, particularly related to the battery management system (BMS)
- Intermittent communication issues, such as occasional loss of connectivity from monitoring devices
- Coordination between multiple actors, including utilities, installers, and system providers

Despite these challenges, the implementation was successfully completed, and the experience gained has contributed to improved local expertise, more efficient deployment processes, and increased readiness for future implementations.

Costs of Implementation

8. Key costs of Implementation

The implementation of the pilot system involved several categories of costs, reflecting both hardware and system integration requirements. While exact figures depend on system size and configuration, the main cost components can be summarized as follows:

- **Hardware costs:**
  The primary cost drivers include photovoltaic (PV) panels, battery energy storage systems (BESS), hybrid inverters, and supporting electrical components. Additional equipment such as sensors, communication devices, and monitoring systems also contribute to the overall cost. It should be noted that the PV system, battery, and main installation were not financed through the project and were implemented separately. However, selected components—such as sensors, the weather station, and their installation—were included within the project scope.
- **Installation and integration costs:**
  These include electrical installation, system configuration, and integration of different components. Due to the relatively early stage of such systems in Iceland, **installation required additional time and effort**, as electricians and installers had limited prior experience with integrated PV and battery systems.

This led to longer installation times, as practical solutions and best practices had to be developed during the process.

- **Engineering and design costs:**
  System design, sizing, and planning require technical expertise to ensure optimal performance and compliance with regulations. This includes selecting appropriate components and designing system architecture.
- **Software and data infrastructure:**
  Most monitoring and control systems are based on cloud platforms, often with low or subscription-based costs. Additional effort is required for data collection, storage, and processing, particularly for research and optimization purposes.
- **Operational and maintenance considerations:**
  Ongoing costs include system monitoring, occasional maintenance, firmware updates, and potential replacement of components over time.

Overall, while initial investment costs remain relatively high in the Icelandic context, especially for small-scale systems, government support mechanisms and increasing market maturity are expected to improve cost-effectiveness over time. Furthermore, value is not only derived from direct cost savings, but also from improved energy resilience, flexibility, and system optimization.

Transferring the cVPP technical platform

9. **Transferring the cVPP technological platform solution to your region**
   The University of Iceland pilot has demonstrated strong potential for replication and real-world deployment beyond the initial research scope. Although the pilot itself is relatively small in scale, it has served as an effective demonstration platform for integrated PV and battery energy storage systems in Iceland.

   A key outcome of the pilot has been its role in supporting the activities of the associate partner Alor, who has actively used the installation as a demonstration site for potential customers and stakeholders. This has significantly improved understanding, reduced perceived risk, and increased confidence in such systems.

   As a result, a substantial number of projects have been identified and developed across Iceland, spanning multiple sectors, including:

- Agriculture (e.g. dairy farms, pig farms, and sheep farms)
- Industry (e.g. food processing facilities)
- Commercial buildings and real estate developments
- Tourism sector (e.g. hotels and guesthouses)
- Public sector (e.g. municipalities and government buildings)

Several of these projects have already been implemented, while many others are at various stages of development, including feasibility assessment, design, and planned installation for the period 2025–2027. Many have successfully secured funding through Orkusjóður (Energy Fund), demonstrating strong alignment with national policy mechanisms.

Notably, this replication has already led to commercial and public-sector deployment, including installations delivered by Alor for buildings associated with public-sector stakeholders, such as facilities managed by the Government Property Agency (Ríkiseignir) and procured by the Ministry of the Environment, Energy and Climate.

The pilot has therefore contributed not only as a technical demonstrator, but also as a market enabler, providing:

- A real-world reference system
- A platform for stakeholder engagement and knowledge transfer
- Practical insights for installers, utilities, and regulators
- Increased visibility of distributed energy solutions

This has contributed to a broader shift in the Icelandic market, where:

- Interest in PV and battery systems is rapidly increasing
- New projects are being actively developed across sectors
- Utilities and regulatory actors are beginning to adapt to emerging requirements

Overall, the pilot demonstrates a clear and practical pathway from pilot-scale validation to large-scale replication, supporting the future deployment of distributed energy systems and Virtual Power Plants in Iceland.

Lessons Learnt

10. Lessons Learnt

The implementation of the University of Iceland pilot has provided several important technical, operational, and market-related insights relevant to the development of distributed energy systems and Virtual Power Plants (VPPs).

- **Regulatory frameworks lag behind technological readiness:**
  The pilot confirmed that the required technologies for PV, battery storage, and intelligent energy management are mature and viable. However, existing regulatory frameworks, utility procedures, and market structures were not fully prepared to support these systems. This created initial barriers but also highlighted areas where adaptation is needed. Encouragingly, this situation is evolving, with increasing activity in the sector pushing stakeholders to update regulations and practices.
- **Demonstration projects are critical for market adoption:**
  The pilot has shown that having a physical, operational system significantly improves stakeholder understanding and confidence. The use of the pilot as a demonstration site by the associate partner Alor has directly contributed to increased interest, successful funding applications, and multiple follow-up projects.
- **Skills and experience gaps impact implementation:**
  Limited prior experience among electricians, installers, and other stakeholders resulted in longer installation times and an iterative implementation process. This highlights the importance of training, knowledge transfer, and building local competence as the market develops.
- **Stakeholder preparedness and coordination are essential:**
  Many actors involved in the project were required to address unfamiliar challenges, including system integration, operational scenarios, and regulatory interpretation. Early and continuous coordination between stakeholders is essential to ensure smooth implementation.
- **Data and monitoring are key enablers for future optimization:**
  The integration of multiple monitoring systems (energy, weather, and consumption) provides a valuable dataset for developing advanced control strategies, including AI-based cooperative energy management. Data availability will be critical for scaling toward VPP functionality.
- **Value extends beyond direct economic savings:**
  In the Icelandic context, the benefits of PV and battery systems are not driven solely by electricity cost savings. Instead, value is created through improved

energy resilience, flexibility, visibility of renewable energy use, and alignment with sustainability goals.

- **Market momentum can be triggered by early pilots:**
  The pilot, together with subsequent activities led by Alor, has contributed to a noticeable increase in deployment activity. This has accelerated market development and prompted utilities, regulators, and other stakeholders to adapt to new requirements.

Overall, the pilot demonstrates that early-stage projects can play a pivotal role in accelerating both market adoption and institutional readiness for distributed energy systems and Virtual Power Plants.

Donegal County Council, Ireland

Virtual Powe Plant in a Local Government setting

Identify Candidates in Ireland

1. **Identify candidates that might benefit from and be interested in establishing a Virtual Power Plant under the following categories Activity *1.3***
    a. Normal Energy Producers e.g. wind farm, biogas, solar producers, etc.
    b. Public Infrastructure e.g. local electricity companies, municipalities, etc.
        i. Based on the project in Donegal County Council, any local authority would benefit from implementing a VPP
    c. Private Dwellings/Condominiums e.g. households with energy production
    d. Public bodies e.g. municipal or regional councils
        i. Based on the project in Donegal County Council, any public body, Council or regional authority would benefit from implementing a VPP

Determine scale of local energy generation in Ireland

2. **Determine scale of local energy generation, demand response and distributed energy resource assets available in each partner region.**
    a. Clarify how electricity is predominantly generated in local region (fossil, wind, solar, etc.)
        i. Wind Energy
            1. Electricity generation in County Donegal is dominated by onshore wind energy. Donegal has one of the highest concentrations of wind farms in Ireland, due to its Atlantic location and consistently strong wind resource. Donegal has the third-highest installed wind capacity of any county in Ireland
        ii. Fossil Fuels: Not Generated Locally
            1. There are no fossil-fuel power stations (coal, gas, or oil) located in County Donegal. Electricity is not generated from fossil fuels within Donegal, but fossil-generated electricity can form part of what is consumed locally via the national grid.
        iii. Solar Energy: Minor Contribution

1. Solar photovoltaic (PV) generation in County Donegal exists but contributes **a small share** of total electricity production due to its lower solar irradiation compared to Southern counties in Ireland but it is growing rapidly.

iv. Other Renewables (Biomass, Hydro, Offshore Wind)

1. Biomass is used locally for heat (e.g. ATU in Letterkenny), not electricity generation at grid scale. The **Cathaleen's Fall hydroelectric power station in Ballyshannon produces 206 GWh of power annually. Donegal has great potential for offshore wind energy production, but nothing has been implemented yet.**

b. Review the market penetration of Distributed Energy Resources (DERs) in local region.

i. According to ESB Networks' county-level energy statistics **(Updated 15 August 2024)**, Donegal has the following Distributed Energy Resource counts

- Distributed Energy Resources in Donegal
  - Micro-generation units: 81,583
    - Solar PV: 81,175
      - Wind: 408
  - Mini-generation units: 7,041
    - Solar PV: 6,830
    - Wind: 211
      [esbnetworks.ie]
    - These two categories represent the *actual count of DER installations* in the county that are connected to ESB Networks and participating in Ireland's distributed generation framework

Micro-gen includes small-scale systems such as domestic or small business rooftop solar.
Mini-gen includes larger distributed systems, often commercial or community-scale.

c. Local market costs

i. Solar PV

1. Solar PV is by far the most common and most affordable DER technology in Ireland. This is strongly reinforced by national microgeneration data, where "rooftop solar microgenerators" make up the bulk of all microgeneration connections.

2. Typical installation costs (2026 market)
    a. Based on Irish solar cost assessments:
    b. Small system (6 panels / 2.64 kWp):
    €4,000–€7,000 before grants.
    c. Medium system (10 panels / ~4.4 kWp, suitable for a 3-bed house):
    €6,000–€10,000 before grants.
    [goingsolar.ie]
    d. Available grants
    e. SEAI Domestic Solar PV grant (2026): Up to €1,500 (reduced annually).
    [goingsolar.ie]
    f. Export revenue (Clean Export Guarantee – CEG)

    As of March 2026:

    - Export rates range €0.1589–€0.25 per kWh depending on supplier.
    - Best rate currently: Pinergy at €0.25/kWh (incl. VAT).
    [selectra.ie]

    Typical annual earnings from export

    Electric Ireland estimates export earnings for h households at:

    - €50–€300 per year, depending on system size.
    [electricireland.ie]

d. 2) Micro-wind (small domestic turbines)

Micro-wind is *much less common* than solar PV in Ireland due to siting, planning, and cost barriers. National microgeneration guidance confirms micro-wind exists but is not widely deployed compared to solar. [switcher.ie], [citizensin...rmation.ie]

Typical cost range (Irish installer market averages)

Market surveys and installer quotes consistently show:

- Small 1–2 kW micro-wind turbine: €3,000–€6,000 (equipment only).

- 5–10 kW farm-scale micro-wind: €20,000–€40,000+ installed.

Because the government's SEAI grant does NOT cover wind, micro-wind is significantly less cost-competitive than solar. (SEAI grants currently cover only solar PV; wind grants are still "under consideration"). [citizensin...rmation.ie]

Review promotions/polices in Ireland

3. **Review what promotions/policies local/country governments promote**
    a. **What policies/subsidies are available through government?**
        i. **SEAI Individual Energy Upgrade Grants (Solar PV, Heat Pumps, Insulation, etc.)**

These grants apply to all homeowners in Donegal with houses built and occupied before 2011. They cover a range of renewable and energy-efficiency upgrades. [seai.ie]

Solar PV Grant (SEAI Solar Electricity Grant)

- Supports installation of rooftop solar electricity systems.
- Part of SEAI's individual upgrade grants for renewable systems.
  [seai.ie]

Heat Pump Grants

- Air-to-water, air-to-air, and ground-source heat pumps all funded.
- Grant amount (2026): €6,500 for most heat pump types.
- Requires good insulation to reach B2 BER potential.
  [climatejar...nbuster.ie]

Insulation Grants

- Attic, cavity wall, internal and external wall insulation, floor insulation.
- Grant examples (2026 SEAI levels):
    - Attic insulation: €1,500
    - Cavity wall insulation: €1,700

- External wall insulation: €5,500–€8,000 depending on dwelling type
- Internal wall insulation: €2,000–€4,500 depending on dwelling type
  [climatejar...nbuster.ie]

b. Heating Controls Upgrade

- Grants available for upgrading to modern heating controls.
  [moneymatte...onegal.com]

c. Solar Thermal (Hot Water)

- Grants available under SEAI individual upgrade system.
  [moneymatte...onegal.com]

d. BER Assessment Grant

- SEAI provides grant support for a BER rating assessment after works.
  [moneymatte...onegal.com]

---

e. SEAI National Home Energy Upgrade Scheme (One-Stop Shop)

This scheme provides large grants for deep retrofits (to achieve a B2 rating or better). It is open to all Donegal homeowners with homes built before 2011. [citizensin...rmation.ie]

What it covers:

- Solar PV
- Heat pumps
- Insulation (attic, cavity, internal, external)
- Windows & doors (in some cases)
- Ventilation upgrades
- Whole-home energy redesign

Grants are deducted up-front so homeowners only pay the net cost.
[citizensin...rmation.ie]

f. Fully Funded Energy Upgrades (Free for eligible low-income households)

Formerly the *Warmer Homes Scheme*, these upgrades are 100% free if eligibility criteria are met.
Supported upgrades include:

- Attic and wall insulation
- Heat pump installation
- Heating controls
- Solar thermal
- Solar PV
  [donegalhardware.ie]

Eligibility (Donegal residents qualify if…)

- Home built before 2006
- Owner-occupied
- Receiving eligible welfare payments (Fuel Allowance, Working Family Payment, Disability Allowance, One-Parent Family etc.)
  [moneymatte...onegal.com]

g. SEAI Home Energy Upgrade Loan (low-interest green loans)

A Government-backed low-interest loan available only when availing of SEAI energy-upgrade grants.
Helps cover remaining costs not covered by grant funding.
[seai.ie]

h. Vacant Home Energy Upgrade Support (Donegal eligible)

Homeowners restoring a vacant or derelict property may receive additional energy-upgrade supports.
[seai.ie]

i. Local Authority Climate Action Plans (Mandatory)

Local authorities must prepare Local Authority Climate Action Plans (LACAPs) that include policies and measures to promote renewable energy within their administrative areas.

- Supported by €35 million in 2026 Government funding to accelerate local climate action. [gov.ie]

- Funding includes:
  - €30 million START Scheme (EU Just Transition Fund) for climate-action infrastructure, including *renewable energy solutions*. [gov.ie]
  - €4.9 million national increase supporting all local authorities' climate action roles (including renewable deployment). [gov.ie]

Eligible project types

Under START and local climate plans, councils may support:

- Renewable-energy installations (solar, wind, district heating).
- Energy efficiency upgrades in public/community buildings.
- Community sustainability projects.
- Projects in Decarbonising Zones (DZs). [gov.ie]

Identify cVPP to be established in Ireland

4. **Identify cVPP to be established in region**
   a. Which potential cVPP was delivered in the region?
      i. This was implemented for the Barracks in Lifford, County Donegal for Donegal County Council
   b. What already exists and what has to be developed?
      i. Some installations had solar panels installed but nothing else. Meters were installed to measure load demand from the mains and software developed to incorporate Carbon emissions, solar intensity, solar production, cost, potential battery storage inputs and ASHP consumption patterns.
   c. Identify the key partners required to deliver the cVPP
      i. Donegal County Council and Reverve

Assessment of technology solutions in Ireland

5. **Assessment of technology solutions to confirm viability for the cVPP model**
    a. how to gain access to the grid
        i. Load demand is measured by meters being installed at the sites main electric panel. Agreement already exists for excess electricity being generated by Solar already being fed back to the grid.
    b. which IT security guidelines should apply
        - **Mandatory/Strongly Recommended**
            - ISO/IEC 27001 & 27019 — Information security management & energy sector controls
            - NIST Cybersecurity Framework (NIST CSF) — Identify, Protect, Detect, Respond, Recover
            - NIST SP 800-82 — Securing Industrial Control Systems (ICS)
            - IEC 62443 Series — Cybersecurity for industrial automation & control systems (very relevant for DERs, SCADA, inverters)
            - EU NIS2 Directive (enforced in 2025) — Applies to energy and digital infrastructure
            - Cybersecurity standards for smart meters (DLMS/COSEM security suite, GBCS if using UK smart meter tech)

        These frameworks ensure the VPP meets the same standards as conventional utility infrastructure.

        1. **Secure DER & IoT Device Management**
            - DERs (solar inverters, batteries, EV chargers, heat pumps) are often the weakest links.
            - Key guidelines:
                - Zero-trust authentication between all DER assets and the VPP platform
                - Mandatory device identity certificates (X.509)
                - Firmware signing & secure OTA updates
                - Disable default credentials / enforce complex password policies
                - Network segmentation: DERs on a separate VLAN or IoT network
                - Device hardening (remove unused ports, restrict admin interfaces, disable Telnet/HTTP)

This prevents compromised solar inverters or batteries from becoming an entry point

2. **Secure Communications & Data Exchange**

VPPs rely heavily on real-time data from smart meters, DER controllers, and market interfaces.

c. Requirements:

- End-to-end encryption (TLS 1.3 minimum)
- MQTT/AMQP communications with strong authentication (no anonymous access)
- Certificate pinning for DER-to-cloud communication
- Replay-attack protection (timestamps, nonce tokens)

For community VPPs, protecting consumption data is also a GDPR requirement.

Cloud & Platform Security Controls

Most VPPs operate in the cloud (Azure, AWS, or private cloud).

Required cloud protection:

- Identity & Access Management (IAM) with MFA and least privilege
- API security using OAuth2 / OpenID Connect / signed JWT tokens
- Audit logging across all services
- VPP control platform must run on hardened VMs or container infrastructure
- Encrypted storage for all customer and asset data
- Backup & disaster recovery plans tested regularly

If the VPP coordinates energy trading (e.g., flexibility markets), secure API handling is essential.

SCADA/Control System Security

If the VPP interacts with grid assets or local energy management systems:

- Use IEC 104, Modbus-TCP, or OPC-UA with security layers enabled
- Strict network segmentation between IT and OT networks
- Firewalls with deep packet inspection for ICS protocols
- Unidirectional gateways (data diodes) for sensitive control systems
- Continuous monitoring for anomalies in energy flow commands

5. Cyber Threat Monitoring & Incident Response

A VPP should have utility-grade cybersecurity operations.

Key Measures

- SOC monitoring / SIEM (Azure Sentinel, Splunk etc.)
- Anomaly detection on DER behaviours (unexpected power export/import, command spamming)
- Defined incident response plan including:
  - isolation of compromised DERs
  - shutting down external API connections
  - alerting grid operators

6. Physical Security Measures

Even though VPPs are digital, physical security matters:

- Secure physical access to community battery systems
- Lock and tamper-proof local controllers (e.g., edge gateways)
- CCTV/alarms for shared infrastructure
- Prevent access to network ports, USB interfaces, and Wi-Fi routers

---

7. Privacy & GDPR Compliance (Community Projects)

Because VPPs process household energy data, compliance must include:

- Data minimization
- Consent for data usage (especially for flexibility services)
- Clear data retention policies
- Anonymisation/pseudonymisation for analytics
- Annual Data Protection Impact Assessment (DPIA)

8. Third Party Vendor Security

Most VPPs use services from inverter vendors, IoT gateways, aggregators, and energy suppliers.

Requirements

- Vendor must comply with ISO 27001 or IEC 62443-4-1
- Review vendor firmware update policy
- Require SBOM (Software Bill of Materials) for critical components
- Ensure vendors offer vulnerability disclosure programs

9. Community & User Security Practices

At community scale, individual homes participate, so:

- Homeowners must secure Wi-Fi networks (WPA3, strong passwords)
- Provide cybersecurity training for community coordinators
- Enforce secure installation procedures for DER installers
- Publish a simple “Cybersecurity Guide for Participants”

i.

d. how to enable connection between software interfaces and (often remote) decentralised energy resources in regions
    i. **Select the communication standard**

Use IEEE 2030.5 or IEC 61850 for most DERs; use IEC 60870-5-104 for utility-grade infrastructure.

ii. Implement the appropriate networking model

Use secure Internet-based connectivity for small DERs; SCADA-like direct l links for larger plants.

iii. Use standardized DER data models

Adopt IEC 61850 DER-OM to expose a unified data structure.

iv. Secure all communication channels

Apply TLS, certificates, IAM policies, device authentication, and monitoring.

v. Use a DERMS/VPP platform

Integrate real-time plant data with forecasting and control systems.

vi. Follow interconnection & VPP standards

Comply with DOE/IEEE roadmaps for consistency across regions.

Implementation of cVPP in Ireland

6. **Implementation of cVPP**
    i. Key administrative challenges (if any)
        1. No
    ii. Key operational challenges
        1. When the electrical meters were installed, one of them caused problems with the electrical panel which only became apparent later. Access to panels and relevant staff.
    iii. Key partner challenges (if any)
        1. No
    iv. Key service level agreements (if any)
        1. No other than keeping the facilities team informed at all times whenever there was work going on at the site.

Implementation Timeline

7. **Implementation Timeline**
    i. Permission to install requested (if required)
        1. Yes, via the facilities management team
    ii. Installation start date
        1. April 2025
    iii. Installation end date
        1. ongoing
    iv. Key challenges encountered
        1. Access to APIs and working with them

Costs of Implementation

8. **Key costs of Implementation**
    i. External expertise, software and meter installation
        1. Software is not necessary to be owned. It is cheaper to adopt Software as a Service to ensure that ongoing support and maintenance is not an issue.
        2. In retrospect, multiple sensors and implementation should be the main cost.
        3. External expertise is necessary.

Transferring the cVPP technical platform

9. **Transferring the cVPP technological platform solution to your region**
    i. Several meetings have been held with the energy management team internal to Donegal County Council to discuss the potential of a VPP for the broader Council unit based on outputs from the current system on data gathered over the previous year.

Lessons Learnt

Centria University of Applied Sciences, Finland

Biogas plant on an agricultural building

Identify Candidates in Finland

1. **Identify candidates that might benefit from and be interested in establishing a Virtual Power Plant under the following categories Activity 1.3**

    a. ***Normal Energy Producers e.g. wind farm, biogas, solar producers, etc..***

Operators of wind farms and solar farms are in particular benefiting financially if a virtual powerplant is connected to their infrastructure. Also larger biogas plants are suitable for this.

By adding VPP's & battery energy storage systems (BESS) directly to the DER infrastructure, such as the wind farm, or large scale PV systems, the flexibility of the system can generate additional income.

This leads to a shorter payback period, compared to traditional investments into wind farms alone. The main reason for this is the additional income generated when a VPP participates in the reserve market of electricity.

Operators of wind farms, solar PV systems or other DER's do not need to create their own VPP system. During the project duration, new business models have evolved in Europe and worldwide, where software or engineering companies now offer a VPP as a service model.

    a. ***Public Infrastructure e.g. local electricity companies, municipalities, etc..***

Public infrastructure is also suitable for participating in VPP's. Especially local energy companies that have assets that can produce or consume electricity are a key target group for VPP's. Also operators of district heating networks can participate in VPP's, as long of the heat is produced at least party by electrical methods, such as electric boilers.

Municipalities that own PV panels on buildings are also a suitable target group for VPP's, as long as the PV systems are connected to a BESS installed to the same premises.

The participation of municipalities in VPP systems should be done via the manufacturer of the BESS, as this service is included in some manufacturers business.

b. *Private Dwellings/Condominiums e.g. households with energy production*

Private end customers can also participate in VPP's, if they own a PV system that is connected to a BESS. The manufacturer of that BESS must then be a company that offers the VPP service. The investment into a BESS can be significantly more profitable if the BESS is allowed to participate as part of a larger VPP. The management of the VPP and the remotely controlled BESS is done via the manufacturers own system. Thus the end customer do not need an technical skills or engineering knowledge to participate.

c. *Public bodies e.g. municipal or regional councils*

Public bodies are not a key target group for participating in VPP's. However a municipal council can make a decision whether public infrastructure, such a libraries, schools, museums etc. can be utilized for the participation in VPP systems. The public energy infrastructure, such as PV panels on buildings, can generate more income to the municipality if a VPP is integrated.

Overview of VPP service providers						
Focus on large scale projects						
Name of the VPP provider	**Type of VPP**	**Website**	**Country of company operations**	**Suitable for private end customers?**	**Suitable for SME's and public bodies?**	**Suitable for larger DER infrastructure?**
Capalo Ai	Central VPP that manages local assets	https://capaloai.com/capalo	Finland Sweden Estonia Latvia	No	No	Yes

		-zeus-vpp/	Lithuania Poland Spain Portugal Romania Bulgaria Greece			
VIBECO (part of Siemens)	Central VPP that manages local assets	https://vibeco.fi/en/services/virtual-power-plant/	Europe	No	No	Yes
Next Kraftwerke GmbH	Central VPP that manages local assets	https://www.next-kraftwerke.com/	Germany Belgium Netherlands Poland France Austria	No	Yes, but limited to bigger assets	Yes
ABB OPTIMAX	Central VPP that manages local assets	https://new.abb.com/process-automation/energy-industries/digital/solutions/abb-ability-energy-management-and-optimization-optimax/optimax-for-virtual-power-plants	Europe	No	No	Yes

Flexitricity	Central VPP that manages local assets	https://www.flexitricity.com/	UK	No	No	Yes
Fortum Spring	Central VPP that manages local assets	https://www.fortum.com/services/power-trading-and-energy-supply/fortum-spring	Europe	No	No	Yes
Focus on private and/or commercial customers						
Name of the VPP provider	**Type of VPP**	**Website**	**Country of company operations**	**Suitable for private end customers?**	**Suitable for SME's and public bodies?**	**Suitable for larger DER infrastructure?**
Sonnen GmbH	BESS manufacturer with own VPP system	https://sonnengroup.com/	Germany Austria Italy UK Belgium Denmark Spain Sweden Switzerland	Yes	Yes	No
Enpal GmbH	BESS manufacturer with own VPP system	https://www.enpal.com/	Germany	Yes	Yes	No
Octopus Energy	Energy supplier, selling and installing BESS and solar PV	https://octopus.energy/energy-explore/	UK Germany Spain France Italy	Yes	Yes	No

Cactos Oy	BESS manufacturer, with their own VPP	https://cactos.com/	Finland Sweden Netherlands	Yes	Yes	Yes
Enetron Oy	BESS manufacturer, with their own VPP	https://www.enetron.fi/	Finland Sweden	No	Yes	Yes
Heliostorage Oy	BESS manufacturer, with intelligent functions	https://heliostorage.com/products/battery/	Finland and Nordics	Yes	Yes	No
CheckWatt Oy	Offers a VPP service for a wide range of batteries from other manufacturers. An own control box will be installed to the battery, for remote controlling.	https://checkwatt.com/en/	Finland Sweden Denmark	Yes	Yes	No

Determine scale of local energy generation in Finland

a. **Clarify how electricity is predominantly generated in local region (fosil, wind, solar, etc..)**

In Finland, the share of CO2 free electricity production already reached 96% in 2025.

Although nuclear power, which accounts for ~40% of Finlands electricity production is not renewable, the energy mix of Finland is now almost CO2 neutral.

The following graph illustrates the mix of Finlands electricity generation for 2025.

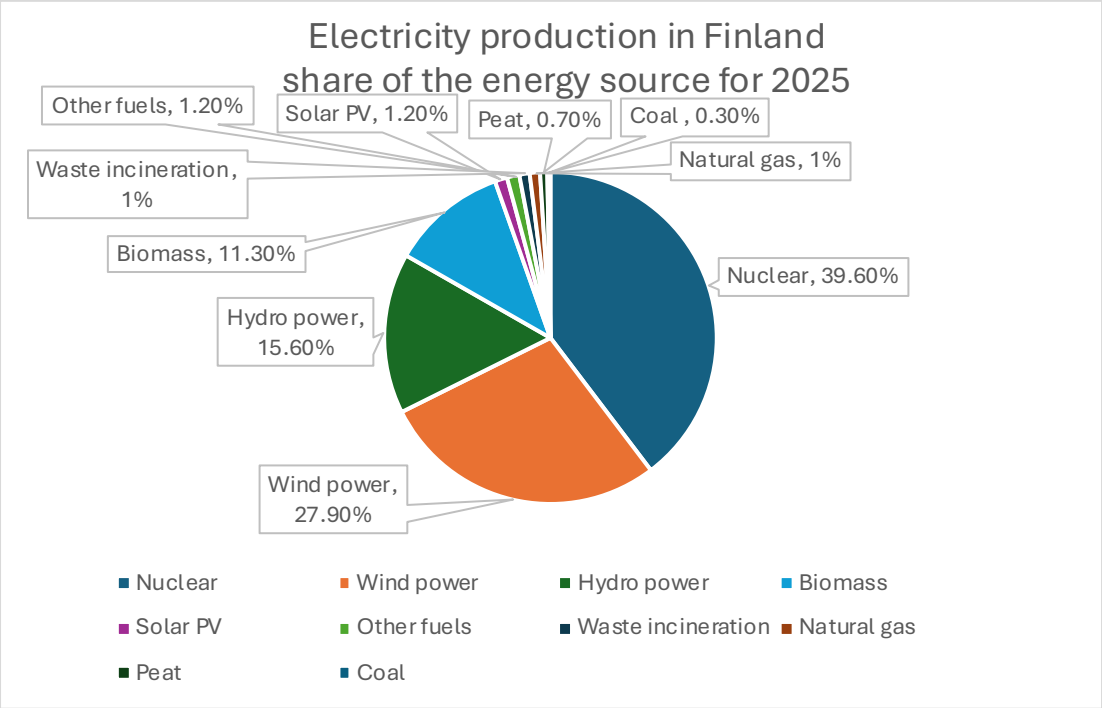


Figure 1: Finlands electricity generation share in 2025. Source: FinnishEnergy. (Electricity generation - Finnish Energy)

Due to rapid growth of wind power production in western and northern Finland, the grid capacity limits are becoming a clear bottleneck. Many new wind parks and large scale PV parks, that are under development at the moment, will therefore include a BESS to the site, to manage the grid capacity limit in a more flexible way.

b. Review the market penetration of Distributed Energy Resources (DERs) in local region.

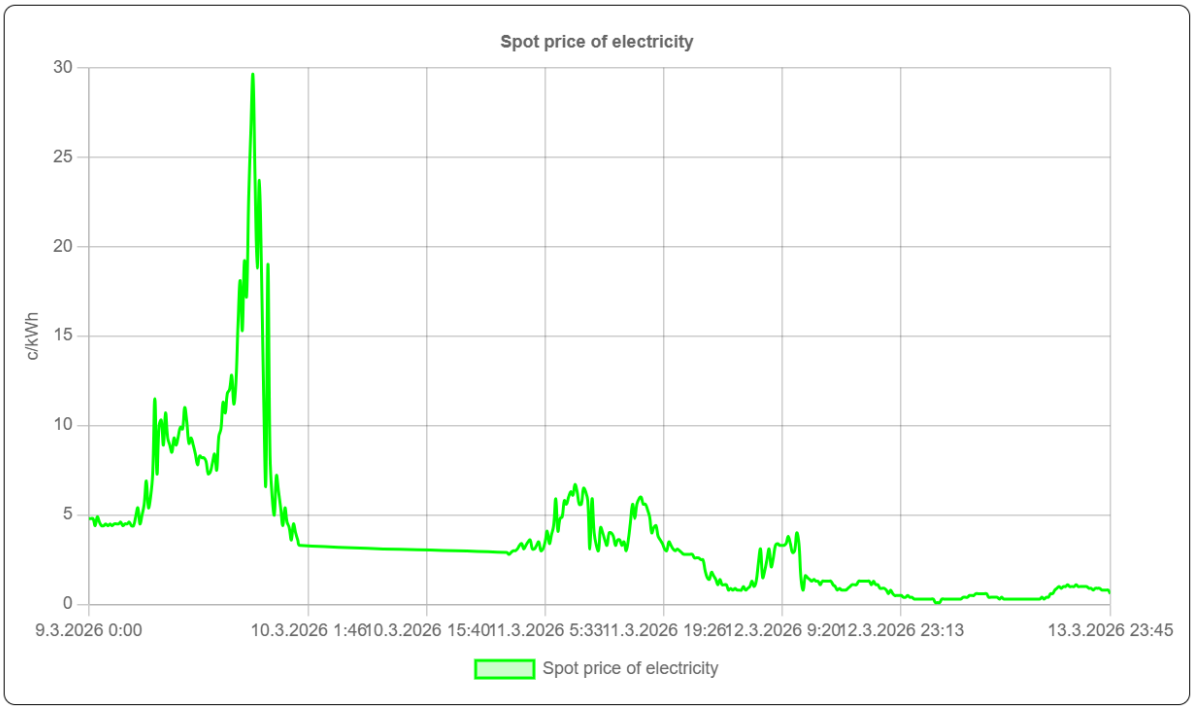
Finlands total electricity production was 79TWh in 2025.

56% of that was generated by renewable energy sources. (Wind 27,9%, Hydro power 15,6%, Biomass 11,3%, Solar PV 1,2%).

The high share of renewable electricity production has lead to large price fluctuations in the spot price of electricity. During days with high wind speeds, the large production volume of wind power lead to very low prices of electricity. And vice versa, during days with no wind, the low production volumes of wind power lead to a shortage of electricity in the Finnish energy system, which has a high influence on the spot market prices.

The following graph illustrates the electricity spot price in Finland for a 5 day period. In the beginning of the period, low wind speeds in Finland lead to a situation of high spot

prices, due to a shortage of energy in the system. During the last 2 days of the 5 day period, the wind speed in Finland increased, which resulted in high production volumes of electricity from wind turbines. This had a direct impact on the spot price, as the prices reached 0 c/kWh at some point.



The correlation between outdoor temperature and spot prices

Another factor, other than the wind speed, is the outdoor temperature in Finland.

During the winter, when electricity based heating systems are operating, a large increase in electricity demand during cold days can be observed. This is due to a high proportion of Finnish houses that are heated by either heat pumps, or with direct electricity.

During cold spells, such as the 1st week in February 2026 in the graph below, the increase in electricity demand lead to very high spot prices of electricity of up to 77c/kWh.

The large price fluctuations in February 2026 were due to a large variation of available wind power, as well as the outdoor temperature.

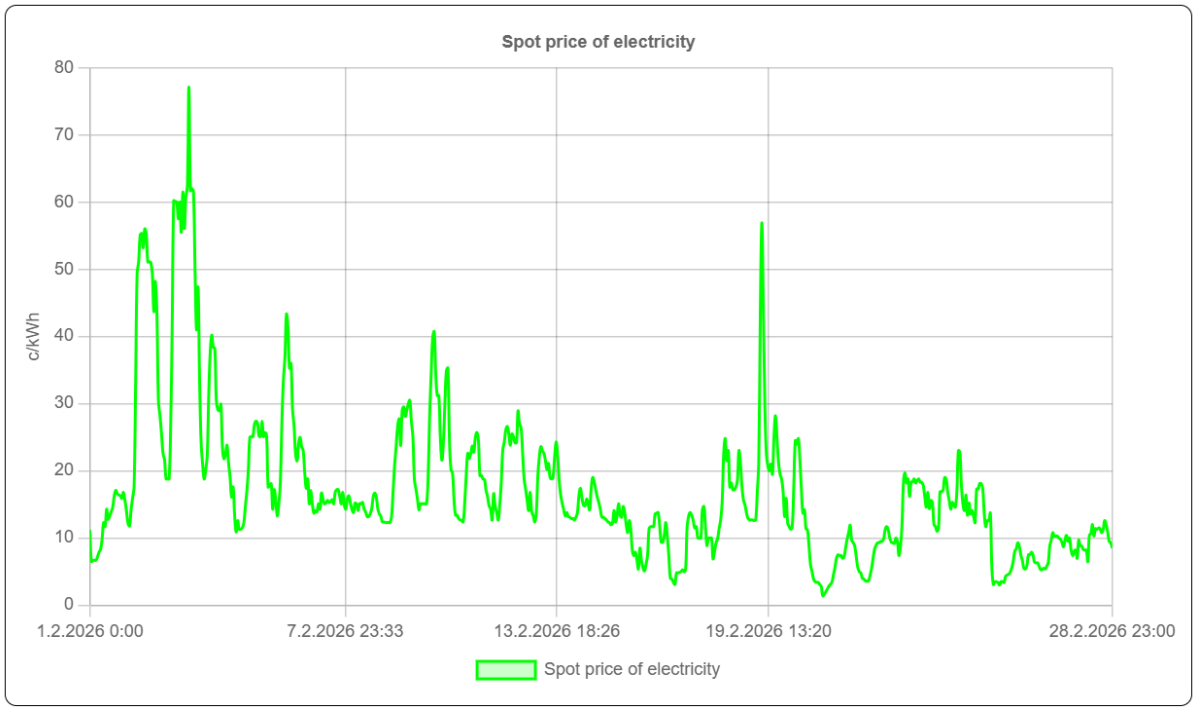


Figure 2: Electricity spot prices in Finland during february 2026.

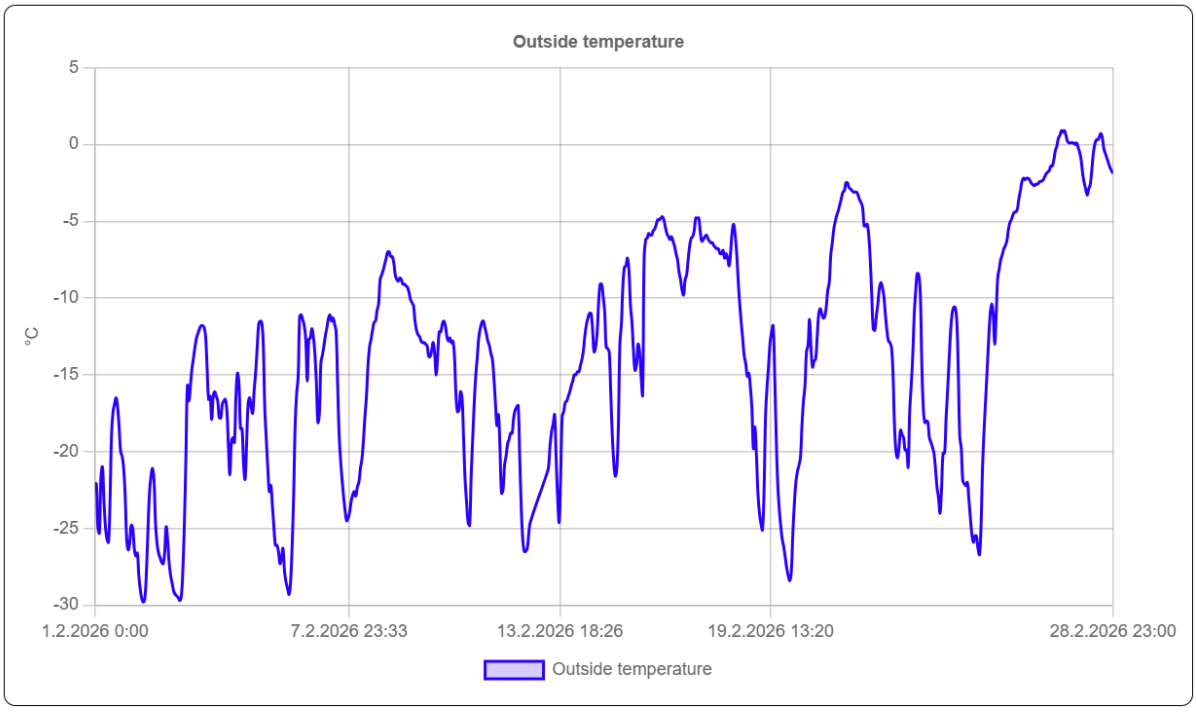


Figure 3: Outdoor air temperature in Toholampi, Finland in february 2026.

a. Local market costs

The prices of electricity in Finland have remained among the lowest in Europe during the last years. The following graph illustrates the comparison of wholesale prices in Europe for 2025.

This price index does not show end customer prices. The end customers need to pay a sales margin, taxes and transmission fees on top of the wholesale price. In Finland these additional cost are depending on the local grid operator, but are roughly 10-11 EUR/MWh for end customers.

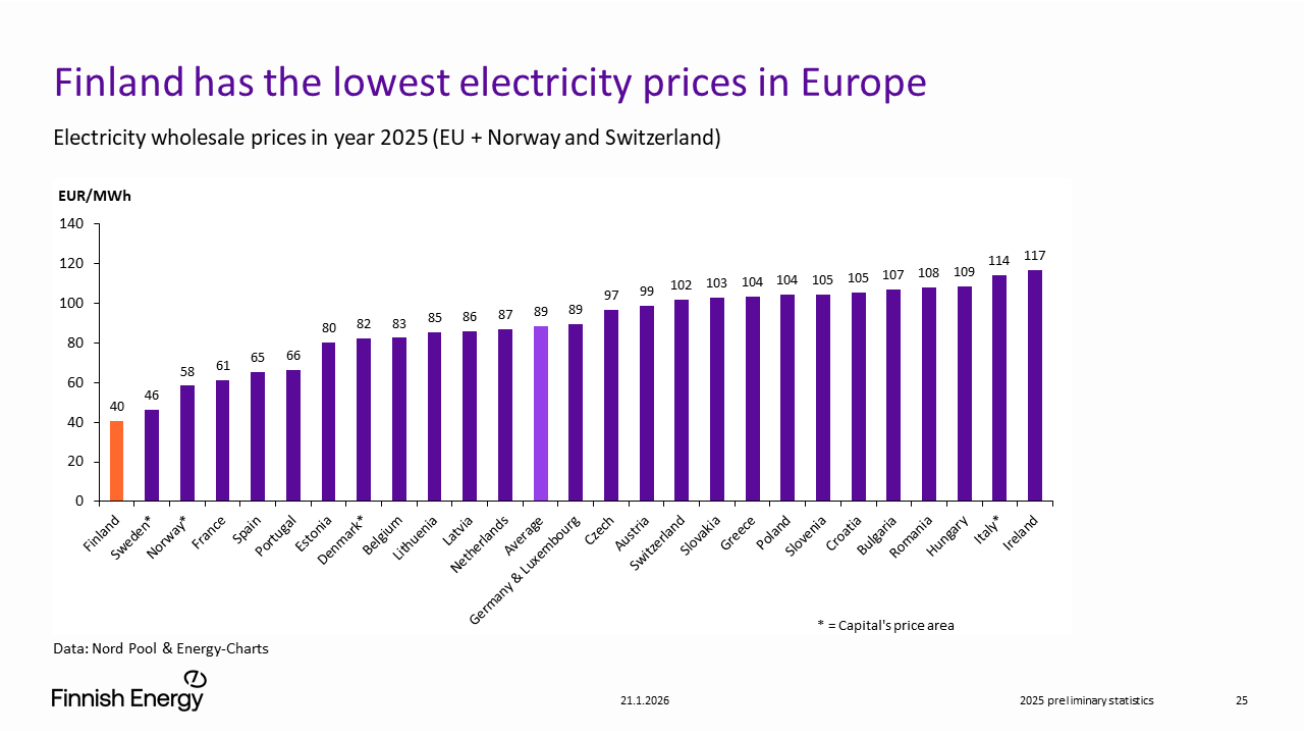


Figure 4: Comparison of European electricity prices in 2025. Source: Finnish Energy.

When looking at end customers costs of electricity in Finland, the price development over the last years has stabilized again. During the energy crisis of 2022-2023, the price of electricity increased sharply, but has since decrease to a level that is close to the pre-crisis costs.

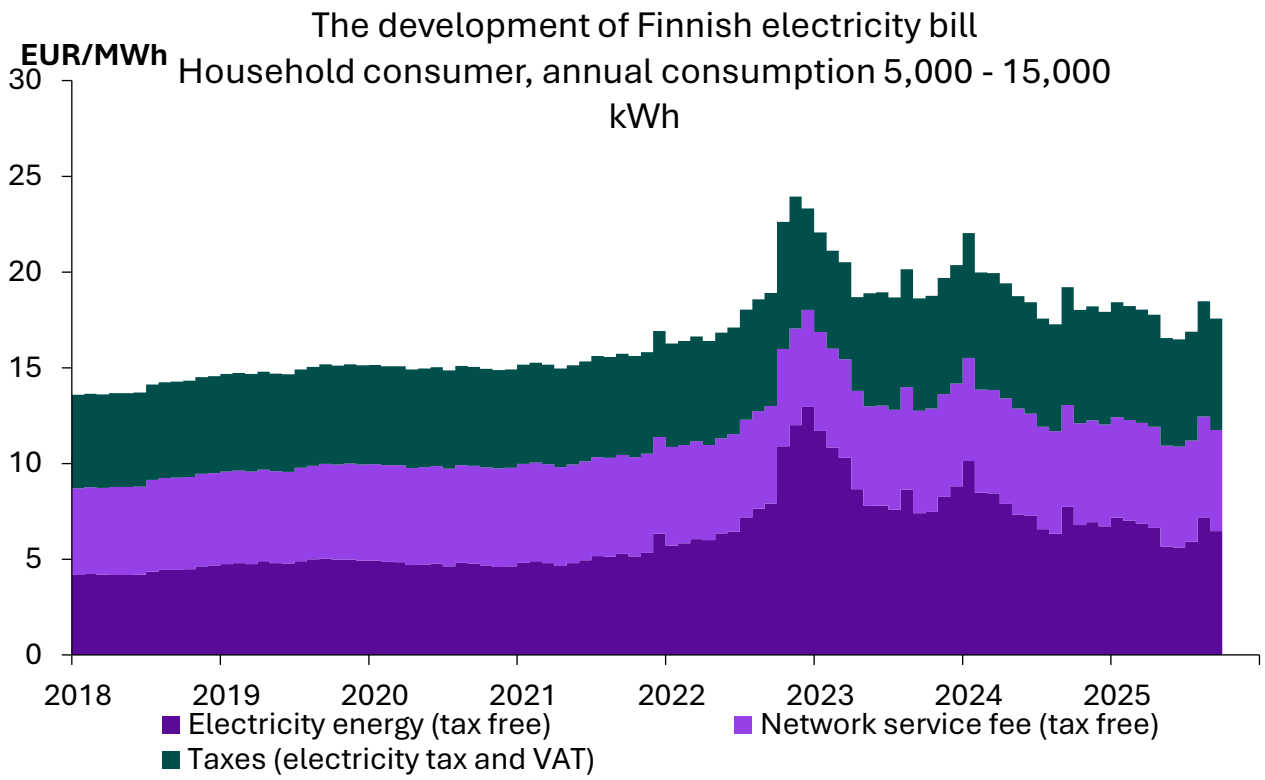


Figure 5: Finnish electricity end user price development over the years. Source: Finnish Energy

Review promotions/polices in Finland

a. What policies/subsidies are available through government?

In Finland, the general public energy policy focuses on open market developments, and a technology neutral policy. This means there are very few public support schemes or subsidies available on the energy market.

The low prices of electricity are a key focus of the government, and these are achieved by long term planning of sufficient energy production projects, to keep the supply and demand in balance. The actual implementation is done by actors on the market.

For private end users, this means there is no financial support for solar PV, no support for BESS, no support for EV's.

Some tax reduction options are the only financial support

Identify cVPP to be established in Finland

b. Which potential cVPP was delivered in the region?

Overall, as a general conclusion the type of VPP to be implemented depends on the requirements of the customer and energy sources, but not on the region. There is no difference whether the VPP will be implemented in e.g. Finland, Iceland or in Ireland. Of course there are differences in local energy policies, support schemes and laws, but this does not affect the type of VPP required for the site specific requirements.

The pilot VPP that Centria implemented, was developed for a community of a biogas plant and a farm. The VPP was custom made for the pilot, as Centria developed large parts of the software within the project. A commercial VPP solution, limited in scope, was purchased in addition, in order to implement the pilot within the planned project timeframe. The commercial VPP solution has been operational since September 2025, and Centria's own VPP software is only being commissioned now in the beginning of march 2026. The commercial VPP solution is not open-source, but Centria's own software solution will be made open-source after the commissioning phase is completed.

<u>Requirements of Centria's specific VPP:</u>

The pilot required an electrical energy storage to fully utilize the potential, and a commercial BESS was chosen as the right technology.

The biogas plant's own control system was not amended, as this was too risky for a research project. In commercial VPP's it absolutely makes sense to include the biogas plant control system into the VPP control, as biogas plants have the capability to operate in a somewhat flexible way. The CHP engine of the biogas plant can be controlled remotely, to enable a flexible operation of the electrical output of the plant.

c. What already exists and what has to be developed?

In the case of Centria's pilot, which is using a biogas plant as a base for the development of the virtual powerplant system, the following technology was purchased "off the shelf":

- The battery energy storage system
- The automation system that controls the battery on-site
- The energy meters and sensors
- All cables, fuses, electric cabinet, display, etc.
- The data communication equipment
- The servers where data is stored in the cloud

And the following technology was custom developed for the pilot, due to no readily available product being available on the market:

- A software to predict the future electricity consumption of the farm, and the future electricity production of the biogas plant.
- The optimization of the battery energy storage. When to charge, when to discharge, when to "hold", so not to do anything.
- The buying and selling of electricity on the spot market.
- The user interface where all process measurements are shown.

d. Identify the key partners required to deliver the cVPP

For Centria's pilot, the following key partners were required for the VPP implementation:

- The owner of the biogas plant,
- The manufacturer of the biogas plant, to get remote access to some process measurements, such as the power production values.
- A local electrician to install our pilot equipment, such as the BESS, energy meters, and our automation system.
- The manufacturer of the BESS
- The supplier of the VPP software system

Assessment of technology solutions in Finland

e. how to gain access to the grid

Access to the grid is always the key priority to be identified first. The grid power limitations need to be checked with the local grid operator, the DSO. The limitations in power are then the guideline for the VPP development.

If a grid connection to an existing site already exists, the VPP can be planned for that limit set by the DSO.

With help of a BESS, the same grid power connection can be utilized more effectively, thus a VPP can always be realized, regardless of the grid power limitations.

As an example: The grid power capacity of 3x 50A for a single family house is the limit set by the DSO. This limit will now be utilized by the VPP more effectively, but using the BESS to stay under the 3x 50A limit on the grid side. Behind the meter, inside the buildings internal electric distribution, the power may even exceed the 3x 50A limit, with help of the BESS's optimization.

f. which IT security guidelines should apply

As VPP's are part of the grid infrastructure, IT security must be taken seriously.

The operator of the VPP software system is responsible for following and maintaining the IT security.

Important tasks are:

- Regular security updates to the software system.
- Prevention of unauthorized access by using a VPN connection between the server and the client.
- Using hardware that is certified, such as VDE certification or similar. As the absolute minimum, devices must follow the EU norms, and have the CE marking.
- Using hardware from trusted European suppliers, and not the cheapest offers from China.

From the customer point of view, these issues should be checked before an agreement with a VPP provider is made.

g. how to enable connection between software interfaces and (often remote) decentralised energy resources in regions

Data communication between the server and the client is always implemented via an internet connection. As many DER's are located in remote regions, the actual internet

connection on-site should be checked in advance. If, for example, no cable connection is available to the site, a wireless 4G or 5G connection would be the alternative.

Such 4G or 5G connections vary greatly in network connection quality. If several network operators offer such service, it is recommended to test the internet connection on-site, or at least use the internet provider's online map coverage tool, to select the most suitable network operator for the site.

Implementation of cVPP in Finland

h. Key administrative challenges (if any)

The biggest challenges from the administrative perspective are the community investment decisions. If a VPP is planned by an energy community, the following decisions needs to be made before any contracts are made:

- Is every member of the energy community investing the same amount?
- If there are differences between the investments between the members, how will the revenue be distributed?
- If the energy community has different electrical consumers, how will the available energy be distributed between the members?
- If a BESS is included in the VPP of the energy community, how will the energy stored in the BESS be shared inside the community?

i. Key operational challenges (if any)

If an energy community is implementing the VPP, the following operational issues need to be defined before any contracts are made:

- Is there any regular maintenance fee?
- Is there any planned system regular overhaul, and how much will this cost?
- Who is responsible for the maintenance?
- How long security update of the VPP software is included in the original offer?

j. Key partner challenges (if any)

The scope of supply needs to be defined in detail, before any contracts are signed.

The following potential issues need to be defined:

- Which party is responsible for which part of the VPP?
- Where are the interfaces of software?
- Where are the interfaces of the hardware?
- Who will act as the system operator?

k. Key service level agreements (if any)

Agreements between the different parties need to be defined before contracts are signed.

Important definitions that need to be clarified are for example the following:

1. Service Scope & Definitions

Clarifies what the VPP provider is responsible for delivering.

Such as the following tasks:

- Description of VPP platform functionalities (aggregation, optimization, dispatch, asset monitoring, forecasting, market participation)
- Type of assets included (e.g., batteries, EV chargers, heat pumps, industrial loads, PV)
- Markets supported (frequency regulation, intraday, day-ahead, reserve markets, imbalance markets)
- Operating model (fully automated dispatch, semi-automated, customer approval)

2. Availability & Uptime Guarantees

Defines how reliable the VPP platform must be.

- Platform uptime (e.g., 99.5% monthly uptime)
- Communication uptime with connected assets
- Maximum allowable outage duration
- Scheduled maintenance windows and notification rules
- Penalties or service credits for downtime

3. Performance & Dispatch Guarantees

Critical in VPP operations where failure to deliver can cause market penalties.

- Dispatch accuracy (% of command signals correctly executed)
- Latency requirements (e.g., response under 2 seconds)
- Forecast accuracy targets (load, generation, flexibility)
- Balancing/market performance KPIs
- Requirements for reducing imbalance costs or meeting reserve obligations

4. Cybersecurity & Data Protection

Essential due to grid-interface risk.

- Encryption requirements (data-in-transit, data-at-rest)
- Asset authentication procedures
- Compliance with standards (e.g., ISO 27001, NIS2, GDPR)
- Data ownership clauses
- Incident detection & response times
- Backup & disaster recovery SLAs

5. Connectivity & Integration Requirements

Ensures that assets can connect reliably.

- Supported protocols (Modbus, MQTT, OCPP, EEBUS, proprietary APIs)
- Onboarding time per asset
- Validation & commissioning processes
- Minimum communication frequency
- Edge device requirements (if used)

6. Customer Support & Response Times

Defines how quickly issues are handled.

- Support channels (24/7 hotline, email, portal)
- Response times and resolution times by priority level
- Incident reporting format & frequency

7. Market Participation & Compliance

Covers obligations for participating in energy markets.

- Compliance with market rules (TSO/DSO requirements)
- Aggregation rules and registration responsibilities
- Metering requirements and validation
- Responsibility for imbalance costs
- Reporting and auditing processes

8. Revenue & Settlement Terms

How money is earned, calculated, and paid out.

- Revenue-sharing model (percentage split, fixed fee, hybrid)
- Minimum performance guarantees (if any)
- Settlement frequency (monthly, quarterly)
- Transparency of revenue calculation
- Handling of penalties (market non-delivery, availability failures)

9. Asset Owner Obligations

Clarifies what the customer must do.

- Ensuring asset availability
- Maintaining minimum state of charge (for batteries)
- Providing accurate technical data
- Allowing remote control when required
- Reporting maintenance outages

10. KPIs & Reporting

Defines what is measured and how it's reported.

- Asset availability
- Dispatch success rate
- Forecast accuracy
- Market revenue performance
- Carbon reduction or grid-support metrics

- Monthly/quarterly performance reports

11. Penalties, Service Credits & Liability

Addresses consequences of underperformance.

- Financial penalties for SLA breaches
- Service credit structure
- Caps on liability
- Exclusions (force majeure, communication issues outside provider control)

12. Termination Conditions

When and how the contract can end.

- Breach of SLA over consecutive months
- Customer or supplier change of ownership
- Asset portfolio reduction
- Notice periods
- Post-termination data retention & transfer

Implementation Timeline

The implementation timeline greatly depends on the type of project and scope.

The pilot implementation for our Centria VPP has taken a lot longer than anticipated. In total over 1 ½ years.5 This is due to the custom made project that we decided to implement. Furthermore we chose to follow the strictest procurement rules, which involved the writing, publishing and selection of public tenders for several of our purchases. This alone took over 6 months.

l. Permission to install requested

As the very first step in our Centria pilot, we had to get an agreement with the owner of the biogas plant about the implementation of the pilot.

m. Installation start date

The pilot implementation phase took over 1 year. This is due to the software development, which we partly developed ourselves. The actual installation time on site has been significantly shorter, with approximately 6 months.

n. Key challenges encountered

Several challenges were encountered during the pilot implementation.

- Procurement rules inside Centria: The rules for procurement inside Centria require at least 3 offers from 3 different suppliers for minor procurements. For bigger procurements, a public tender is mandatory. The offers must always be fixed price.
  This proved challenging, as many suppliers for the required installation work did not respond to requests for fixed price offers. This is apparently due to the complex requirements that we had, and the difficulty of assessing the required work amount for a custom made project.
- Another challenge was the low budget for the pilot implementation. The procurement of hardware and software for the VPP had to be severely scaled down in ambitions, as the VPP software system alone can cost up to 50 000€. We therefore decided to develop parts of the VPP system ourselves, with help of IT students and our own IT experts working in the project.
- Delays due to procurement rules. The pilot implementation was started late, due to a lack of offers for the outsourced work from external companies. No company showed interest in giving us an offer for the VPP software. We then scaled down the scope, and divided the pilot into smaller parts, to receive offers for those specific parts from different suppliers.
- Commissioning challenges. We faced challenges in the system start, as the VPP was partly developed by ourselves, and partly by an external company. The interfaces between these 2 systems did not work in the beginning. The data communication, and control system operation was the main issue.

Costs of Implementation

The main costs for the VPP implementation of Centria's pilot were the following:

- Procurement of the **BESS**. We had a budget of 7530€ for this.

- Procurement of the **automation** & communication **system** that controls the BESS. This included several energy meters, the PLC unit, a display, data communication gateways, power supply, fuses and cables. ~2000€ was paid for this.
- Procurement of the **inverter** that is required to charge and discharge the BESS. The inverter cost was 2570€.
- **Electrical installation** of the BESS, inverter and the control system. This was a major expense that added up to 4450€. We only got one offer for this work.
- **Assembly work** of the automation system. This did cost 3700€.
- Procurement of the **VPP software**. The VPP software scope was scaled down significantly, due to the limited budget. We had 8000€ available for this.
- Server fees.

Transferring the cVPP technical platform

The transferability of the VPP solution to other regions is fairly easy. The main requirements that need to be localized in the VPP software are the following:

- Local energy production data. This should be obtained from energy meters installed on site.
- Local energy consumption data. This should be obtained from energy meters installed on site.
- Country specific electricity spot prices. The electric spot prices need to be updated in the software, in order for the VPP to work.
- Local weather forecast. This is required if the system includes PV or wind power production.
- Size of the BESS. The actual size of the BESS should be known by the VPP software, as the right charging and discharging strategy can be made with such information available.
- Charging and discharging power of the BESS inverter. This information is not mandatory, but helps for the right control strategy of the VPP.

Site specific requirements may add complexity, but this is by default not the case.

Lessons Learnt

The **general lessons learnt** during the CoPower project duration are the following:

- Commercial VPP's have really entered the market during the last 3 years. Now the technology is proven, and used in commercial applications, totally without public subsidies. This is very good news.
- The rollout of community owned VPP's is very slow. Energy communities are not a key target for VPP's due to the complex revenue model involved when several owners share the energy infrastructure. This is unlikely to change in the near future.
- The implementation of energy storages, such as BESS, has become a key factor for successful VPP operation. Without energy storage, a VPP is more difficult to operate profitably.
- The decreased costs of BESS have made investments into VPP's with BESS more profitable. This development is very positive for the energy transition, as the flexibility obtained from BESS has a very positive impact on grid stability.

The **lessons learnt from our own Centria pilot** are the following:

- The development of our own VPP has been much more complex and complicated than originally anticipated. The devil is in the details, as always.

- **Complex revenue models**. A real commercial VPP must "play" on several revenue markets to optimise the asset and the income generated. These markets are for example the followings:
    - Day Ahead (DA)
    - Intraday (ID)
    - Fast Frequency Response (FFR)
    - aFRR (automatic frequency restoration) reserve capacity market
    - FCR-D (Frequency Containment Reserve – Disturbance)
    - FCR-N (Frequency Containment Reserve – Normal)
    - M-FFR (Moderate Fast Frequency Response)
    - mFRR (manual Frequency Restoration Reserve

  Participating on those markets requires special knowledge, licensed hardware, and operating licenses. Withing this project, this was absolutely not possible.

- The required **hardware** to implement a real VPP **is not cheap**. The limited project budget lead to compromises on the software procurement, as the hardware procurement consumed a big part of the available budget.

- The **software development** of a VPP **is** also **no trivial task**. There are many data interface points between 3rd party API's, the actual VPP scrips, the cloud server database, the sensors installed on-site, the automation system and the BESS. This leads to a high level of complexity that is hard to keep track of. If something stops working, the consequences to the VPP functionality are immediate.

- **Involving students is a great idea**. We did involve several students in this project, mostly from IT studies. This proved to be positive for both us, the experts working in the project, and also for the students, because the topics were really interesting and advanced.

University of Oulu

Smart Energy System Integration in Electrically Heated Residential Buildings

Direct electric heating is a common heating method in Finnish detached houses due to its simplicity and reliability. Its popularity has also been driven by the low investment costs compared to alternatives such as district heating and its associated connection fees, as well as by electricity prices that were previously considered affordable and expected to remain competitive in the future.

However, traditional direct electric heating systems often operate passively and do not take into account factors such as fluctuations in electricity prices, outdoor temperature, or the actual occupancy rate of the building. Smart control solutions provide an opportunity to improve the energy efficiency and controllability of heating by utilizing sensors, automation, and real-time data.

In recent years, the development of smart technologies has created new opportunities for modernizing older heating systems. Control modules and sensors offered by various manufacturers enable remote control and automated optimization of heating, ventilation, and other electrical appliances. These solutions can improve energy efficiency, reduce electricity costs, and enhance living comfort.



Identify Candidates in Northern Ostrobothnia, Finland

In Northern Finland, maintaining power system balance is particularly challenging due to long transmission lines, widely dispersed consumption points, and limited local electricity generation. Power system stability requires a continuous balance between electricity generation and consumption under all operating conditions while accounting for transmission losses and maintaining voltage and frequency within acceptable limits. This challenge is further intensified by the increasing share of renewable energy sources, as weather-dependent generation introduces greater uncertainty into, for example, day-ahead market forecasts.

Supply and demand in the electricity market are determined by the electricity generated by producers and consumed by end users. Electricity network companies act as market facilitators, as power grids physically connect electricity generation and consumption. Transmission system operators (TSOs) transmit electricity from power plants to distribution system operators (DSOs) and directly to large-scale consumers. Distribution system operators then distribute electricity to their own customers.

As decentralized electricity generation becomes more common, production is increasingly shifting to low-voltage networks, enabling individual small-scale consumers to also produce electricity for the market. This structural shift highlights why conventional energy producers, together with aggregated small-scale actors, are considered key candidates for Virtual Power Plant (VPP) models aimed at mitigating market uncertainties and supporting grid stability.

Private Dwellings/Condominiums e.g. households with energy production

The Northern Ostrobothnia region has established itself as a cornerstone of Finland's green transition, characterized by a high share of renewable energy generation and a rapidly developing ecosystem of distributed energy assets.

A household-scale, community-based Virtual Power Plant (cVPP) focused on optimizing electricity consumption and enhancing local grid stability represents a particularly suitable model for the climate-challenged regions of Northern Finland. By aggregating electrically heated homes, smart EV charging, and residential automation:

- Individual households benefit from economic savings and improved comfort.
- Communities gain collective bargaining power and enhanced energy resilience.
- The local electricity grid operates more reliably, particularly under conditions of high renewable energy penetration.

This approach transforms households from passive consumers into active participants in stabilizing the energy system.

Determine scale of local energy generation in Oulu (Northern Ostrobothnia)

Electricity generation in the Oulu region is predominantly low-carbon, with fossil fuels accounting for less than 6% of total production. As one of Finland's leading wind power regions, North Ostrobothnia relies heavily on wind power, bioenergy, and hydropower. The rapid expansion of wind power has significantly increased electricity price volatility, resulting in near-zero or even negative prices during periods of peak production and sharp price spikes during cold and calm weather conditions. Furthermore, the region is evolving into a hub for the hydrogen economy, which is expected to increase flexible electricity demand in the future.

Review of the Market Penetration of Distributed Energy Resources (DERs) in the Local Region

The Oulu region features a highly digitalized and rapidly expanding Distributed Energy Resource (DER) ecosystem. Solar photovoltaic (PV) capacity and energy storage systems are increasing at both grid and household levels.

Because compensation for exporting electricity to the grid remains relatively low, maximizing solar self-consumption is economically advantageous. By utilizing smart control systems to automatically optimize electricity consumption based on weather conditions and market prices, households can reduce their energy costs by an estimated 20–30%.

The Community-Based Virtual Power Plant (cVPP) Model

Households are transitioning from passive consumers to active "prosumers" who produce, store, and manage energy. In a community-based Virtual Power Plant (cVPP) model, individual households collectively function as a "virtual battery."

By aggregating a large number of controllable loads, such as electric heating systems and electric vehicle (EV) charging, Virtual Power Plants can shift electricity consumption away from peak demand periods. This aggregated flexibility enables small-scale energy resources to participate in electricity markets, enhance grid resilience, and reduce overall emissions and energy costs.

Local market costs

Electricity market prices in the Oulu region are characterized by high volatility, largely driven by fluctuations in wind power generation.

- Low-price periods: During times of high wind power production, electricity prices may decrease significantly or even become negative.
- High-price periods: During periods of low wind generation combined with cold weather conditions, electricity prices can increase rapidly.

Cost Optimization and Savings

- Solar self-consumption: Utilizing locally generated solar energy for self-consumption is economically highly advantageous. Although compensation for exporting excess electricity to the grid remains relatively low, optimizing local consumption can reduce household energy costs by an estimated 20–30%.
- Smart control systems: Automated household-level smart control systems optimize energy consumption based on real-time market prices, thereby improving economic efficiency and strengthening consumers' flexibility and market responsiveness.

The Role of Community-Based Virtual Power Plants (cVPPs) in Cost Management

The role of households is shifting from passive consumers to active "prosumers" capable of producing, storing, and managing energy.

In a community-based Virtual Power Plant (cVPP) model, households collectively function as a "virtual battery." By aggregating a large number of controllable loads, such as electric heating systems and electric vehicle (EV) charging, communities can participate in electricity markets, including flexibility markets. This aggregated flexibility supports the regional energy system, reduces emissions, and lowers electricity costs for both individual households and the community as a whole.

Review promotions/policies

The Oulu region is well positioned for the adoption of decentralized energy solutions due to its strong technical expertise, advanced digital infrastructure, and proactive local utility companies.

By combining aggregator-based services, financial incentives, and regional support programs, barriers to participation can be reduced while enabling residents to contribute to a more flexible, resilient, and carbon-neutral energy system.

Financial incentives (2025–2026)

Individual Homeowner Integration into Fingrid's Reserve Markets

For detached house owners, participation primarily involves optimizing privately owned flexible energy assets, including solar PV systems, battery storage, EV chargers, and heat pumps. To enable participation, these systems must be compatible with smart grid communication protocols.

Since individual households do not meet the minimum capacity requirements for direct participation in Fingrid reserve markets, they must enter into agreements

with commercial aggregators. In the Oulu region, utility companies such as Oulun Energia aggregate residential flexibility into market-capable portfolios.

Once integrated through a Home Energy Management System (HEMS), the aggregator can remotely optimize flexible loads, such as adjusting heating systems or controlling battery charging cycles, to support grid balancing while generating financial benefits for the homeowner.

Household Tax Deduction — The Most Common Form of Support for Renovation Labor Costs

The household tax deduction is one of the most important forms of financial support available to consumers for work carried out in their homes, such as heating system installations and other labor and installation services. In 2025, the general conditions for the household tax deduction are as follows:

- Deduction percentage for labor costs: 35%
- Maximum annual deduction: €1,600 per person (typically €3,200 in total for a couple
- Deductible (self-liability threshold): €150 per person per year
- An increased deduction may apply under certain conditions if the project involves phasing out oil heating
- The replacement of oil heating with renewable energy systems, such as heat pumps or district heating, may qualify for enhanced support the maximum tax deduction is €3,500 per person per year.

Energy Advice and Other Free Services

Motiva and many municipalities offer free energy advisory services, guidelines, and calculation tools to support the planning of cost-effective renovation projects. Although these services do not provide direct financial support, they can:

- Assist in preparing funding applications
- Support informed decision-making
- Improve overall project planning and cost efficiency

Identify cVPP to be established in Oulu

The pilot building is a 160-square-meter detached house with a two-story layout, where the heating systems differ partially between floors. The first floor utilizes hydronic (water-based) underfloor heating, while the upper floor is equipped with electric radiators as well as electric underfloor heating in selected rooms.

Additionally, the property is equipped with an air-source heat pump, which serves as an energy-efficient heating solution when it provides the most cost-effective option for the overall system.

The simultaneous operation of multiple heating systems requires precise control optimization to ensure efficient interaction between the different heating methods and to avoid overlapping energy consumption. For this reason, the plan is to integrate all heating systems under a single control.

A central component of the heating system is a 1,200-liter water storage tank, which is used for domestic hot water production and thermal energy storage. The tank enables heat to be generated during periods of low electricity demand, with the stored thermal energy subsequently utilized according to heating requirements.

In addition to the main building, the property includes a separate 35-square-meter sauna building, which is used as a remote workspace on weekdays. Heating in this building is provided by electric underfloor heating and electric radiators. Due to its use for remote work, the heating demand varies depending on the time of day and occupancy, making it particularly well suited for smart control solutions.

The property is also equipped with an 8.9 kWp solar photovoltaic (PV) system. The generated solar power is integrated into the building's overall energy consumption, with the primary objective of maximizing self-consumption.

Implemented Smart Control Solution

The objective of the pilot property is to enable centralized control of all key heating and ventilation systems through a single, unified control system. The aim is to create an integrated setup in which different heating methods, energy generation, and consumption monitoring complement each other and operate according to a shared control logic.

The control of the water storage tank is one of the most critical components of the system. The 1,200-liter tank is equipped with two 6 kW heating elements (electric resistors) and one 7.5 kW heating element. The tank enables thermal energy storage and is primarily heated during periods of low electricity demand or when local solar PV generation is available.

Control is implemented using a Shelly Pro 3 smart relay, which allows the heating system to be switched on or off automatically based on predefined conditions. Temperature sensors installed in the tank provide real-time data, enabling the system to monitor water temperature and optimize heating according to demand.



Figure 2. Shelly Pro 3 smart relay installed

The control of the hydronic underfloor heating is based on room-specific thermostats and a centralized control unit that uses electric actuators (valves) to regulate individual underfloor heating circuits. The traditional thermostats, which lacked smart functionality, have been replaced with a Shelly Plus Uni smart controller, enabling the integration of the underfloor heating system into the smart control platform.

This setup allows the underfloor heating to be controlled automatically based on factors such as outdoor temperature, electricity prices, and the operation of other heating systems.

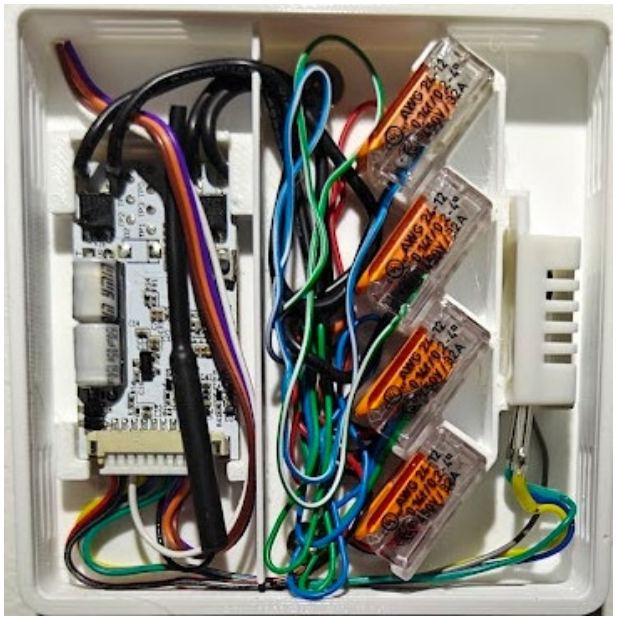


Figure 3: Shelly Plus Uni controller module installed

The electric radiators on the upper floor feature integrated mechanical thermostats, which offer limited control accuracy and scheduling capabilities. To enable smart control, a Shelly 1PM has been installed in connection with the radiators, allowing them to be controlled automatically.

Room temperatures are monitored using separate wireless temperature sensors (Shelly BLU H&T), enabling room-specific heating optimization.

Furthermore, the traditional electric underfloor heating thermostats in both the sauna building and selected rooms of the main building have been replaced with smart thermostats, allowing the underfloor heating systems to be integrated into the same unified control system.



Figure 4: Shelly 1PM Gen3 smart relay installed

The property is also equipped with an air-source heat pump, which operates alongside the other systems as one of the building's heating methods. However, optimizing the interaction between the air-source heat pump and the other heating systems is not straightforward, as the performance and suitability of each system vary depending on the situation. For this reason, the air-source heat pump has also been integrated into the same unified control system as the other heating systems, enabling the system to compare different alternatives and select the most appropriate heating method for each specific scenario.

In addition, door and motion sensors have been installed in various rooms across the property, allowing the system to detect occupancy levels. These sensors enable heating and lighting control based on real-time usage. In particular, in the sauna building used for remote work, motion sensors are used to automatically reduce heating if no occupancy is detected within a predefined period. If necessary, similar functionality can be extended to other areas of the property as well.



Figure 5: Door and motion sensors installed near the exterior door

Regarding ventilation, smart control is used to automate the previously manually adjustable system. Ventilation can be controlled based on schedules, motion sensors, carbon dioxide (CO_2) level measurements, and other relevant inputs. This enables

ventilation to be increased during periods of active occupancy and reduced accordingly at other times, thereby minimizing unnecessary energy consumption and heat loss.
Energy consumption monitoring is an essential component of the smart control solution. With the help of electricity metering devices installed on-site, it is possible to monitor the energy usage of different devices and systems. The collected measurement data can be used to evaluate how effectively the implemented automations perform in practice and what impact they have on overall energy consumption. Consumption monitoring also enables further development and fine-tuning of the system.
Energy consumption monitoring is further supported by Shelly Wall Display devices. These allow the user to locally monitor real-time electricity consumption, room temperatures, and heating-related settings.



Figure 6: Shelly Wall Display units installed

What already exists and what has to be developed

Existing elements

- Manually adjustable heating system (passive control)
- Air-source heat pump
- 1,200-liter water tank and heating elements
- Hydronic underfloor heating (living room)

- Electric radiators and electric underfloor heating cables
- Mechanical ventilation system
- Smart electricity meter

Developed within the pilot

- Integrated intelligent heating control system
- PV panels and inverter system
- Real-time monitoring and automated smart thermostat control (Home Assistant, Shelly components)
- Microcomputer-based control infrastructure
- Wireless air quality monitors and room-specific temperature sensors

Key partners required to deliver the cVPP

- Solar panel supplier and authorized installer
- Local grid operator / distribution system operator (DSO)
- Selected electricity supplier (electricity sales and purchase agreements)
- Authorized electrician for heating system modifications and integrations

Assessment of technology solutions in Oulu

How to gain access to the grid

In the pilot property, the legacy electricity meter has been replaced with a next-generation smart meter. This meter records household energy consumption at 15-minute intervals and securely transmits the data to the distribution network operator (DNO) via IoT-based communication channels.

Key advantages include:

- Accurate billing: Electricity bills are based on actual consumption data rather than estimates.
- Real-time monitoring: Household energy usage can be tracked in real time through the energy provider's mobile application.
- Load management and flexibility: The meter supports more efficient utilization of renewable energy, enables shifting consumption to lower-price hours, and

facilitates modern microgeneration by allowing surplus electricity to be fed back into the local grid.

Which IT security guidelines should apply

Cybersecurity can be strengthened through several measures, including encrypted communication channels, strong user authentication, and automated software updates that address known vulnerabilities.

In the pilot property, the control system is implemented using the Home Assistant platform, which enables local data processing. This architecture offers both advantages and challenges:

Advantages:

- Since data is processed locally within the home network, exposure to external cyber threats is reduced.
- The system continues to operate during internet outages, improving overall reliability and resilience.

Challenges:

- The system is more technically complex and requires greater user responsibility for maintenance, including security updates.
- Deployment and ongoing management require more technical expertise compared to commercial cloud-based solutions.
- Remote access capabilities are more limited unless additional secure configurations are implemented.

Many modern smart home products support the Matter smart home standard. Backed by the Connectivity Standards Alliance—an organization formed by major technology companies—Matter is an open, interoperable standard designed to enable secure and seamless communication between different IoT devices across ecosystems.

How to enable connection between software interfaces and (often remote) decentralised energy resources in regions

The operation of the system is based on the Internet of Things (IoT), in which the home's various devices, sensors, and control units are interconnected via a network. These devices collect and transmit data, enabling the system to make automatic adjustments without continuous user intervention.

Many modern smart home products support the Matter smart home standard. Backed by the Connectivity Standards Alliance—an organization established by major technology companies—Matter is an open standard designed to enable secure and seamless communication between disparate IoT devices across ecosystems.

The Shelly devices have proven to be highly reliable when integrated with the Home Assistant platform.

Implementation of cVPP in Oulu

The installation and commissioning of a smart control system consist of both electrical and software-related phases. The electrical installations include, for example, wiring relays, sensors, and other control modules that are integrated into the building's electrical system. With regard to electrical work, it is important to note that fixed electrical installations require professional electrical qualifications, as they are legally required to be carried out by certified professionals. From a safety perspective, it is essential that all components connected to the electrical network are installed correctly, since faulty connections may cause equipment damage or, in the worst case, create a fire hazard.

Once the electrical installations have been completed, the process proceeds to the software commissioning stage. At this stage, the control unit is connected to the home network, and the selected automation platform, such as Home Assistant, is installed. The required sensors, relays, and other components are then added to the system and configured to operate together. During commissioning, necessary integrations are also defined, such as data sources for electricity prices or weather services, and the desired automations for heating and ventilation control are created.

An essential part of commissioning is system testing. During this phase, it is verified that sensors provide accurate measurements, relays operate devices as intended, and automations function correctly. Testing should also ensure that the system responds safely in fault situations. For example, heating and ventilation systems should continue operating with default settings even if the smart control system becomes unavailable.

After the installation of solar panels, an authorized installer submits an inspection report to the local electricity distribution network operator. Once approval has been granted, the system can be commissioned. A separate electricity sales agreement for surplus electricity is then established with the user's electricity provider.

Cybersecurity should also be considered during the commissioning phase. This includes updating software, using strong passwords, and securing the home network. Once all functions have been tested and settings adjusted, the system is ready for use. The system

can later be further optimized based on user experience, changes in living habits, energy consumption data, or heating requirements.

Implementation Timeline

The design phase and selection of components began in summer 2024. The photovoltaic (PV) panels were installed and the installation was completed in February 2025. A smart heating control solution was subsequently installed and commissioned in September 2025.

The installation of electrical cabling, system components, and PV panels was completed within one day. Following installation, the system entered an operational phase that included testing, configuration, and continuous monitoring.

Further adjustments and optimisation have continued beyond the initial installation phase in order to improve overall system performance and efficiency.

Costs of Implementation

Total price of the solar PV system: €6,740 (incl. VAT 25.5%)

- Equipment and materials: €4,500 (incl. VAT)
- Labour and installation: €2,240 (incl. VAT)

Smart home products

- The electrical installation cost amounted to €600, including all required cabling and VAT.

- Component costs:

Item	Purpose	Quantity	Unit Price (€)	Total (€)
Shelly 1PM Gen3	Radiator control	4	21,96	87,84
Shelly BLU H&T	Temperature & humidity sensor	6	22,46	134,76
Ebeco EB-THERM 500	Floor thermostat (WiFi ready)	4	118	472
Ebeco EB-500 WiFi module	Thermostat WiFi module	4	70	280
Shelly Plus Uni	Hydronic thermostat controller	6	18,7	112,2
DHT22 (AM2302)	Temperature & humidity sensor	6	7,9	47,4
Shelly Pro 3EM	Energy meter (sauna)	1	150,47	150,47
Shelly Pro 3EM	Energy meter (water heater)	2	150,47	300,94
Shelly PM Mini Gen3	Energy monitoring (heat pump)	1	16,19	16,19

Shelly PM Mini Gen4	Energy monitoring (floor thermostats)	4	16,19	64,76
Shelly Wall Display + H&T	Control panel	2	156,88	313,76
				1980,32
			Incl. VAT	**2485,30**

Solar PV System Performance and Self-Consumption Optimization

System Overview

An 8.9 kWp photovoltaic (PV) system was installed in February 2025. The primary design objective was to maximise on-site self-consumption of generated electricity rather than exporting surplus energy to the grid at relatively low compensation rates.

In typical Finnish residential PV systems, a significant share of production is exported to the grid due to mismatches between generation and load profiles. In this implementation, this mismatch is mitigated through automated load control, which dynamically adapts household electricity consumption to available solar generation.

The system detects real-time surplus generation and redirects energy to controllable loads, such as:

- Domestic hot water heating
- Space heating and cooling (during summer periods)

During the pilot period (2023–2025), a significant decoupling was observed between total energy consumption and dependence on the external electricity grid.

Performance Metric	2023 (Baseline)	2025 (Pilot Outcome)	Change
Grid Electricity Consumption	22,693 kWh	21,210 kWh	–6.5%
Solar Self-Consumption Rate	0%	60%	+60%
Total Energy Consumption	22,693 kWh	25,293 kWh	+11.5%
Annual Operating Costs	€2,487 (est.)	€2,293	–7.8%

Operational Performance

Energy Balance

During operation, the following trends were observed:

- Increased total electricity consumption due to additional flexible loads (e.g., cooling)
- Reduced dependence on grid electricity
- Improved alignment between electricity production and consumption profiles

Despite a moderate increase in total consumption, grid imports decreased, demonstrating effective utilization of locally generated electricity.

Seasonal Performance

The system exhibited strong seasonal characteristics:

- During summer months, grid dependence decreased significantly, with a large share of demand covered by PV production
- Peak generation periods were effectively utilized through load shifting
- Export to the grid during high-production hours was minimized compared to conventional systems

Cost and Savings Mechanisms

The reduction in electricity costs (approximately 8%) can be attributed to three main mechanisms:

Self-consumption optimisation

On-site generation offsets retail electricity purchases, which include:

- Energy price (spot-based)
- Transmission fees
- Taxes

This makes self-consumed electricity significantly more valuable than electricity exported to the grid.

Load shifting

Flexible loads are activated during periods of high solar production, improving utilisation efficiency without requiring user intervention.

Reduced grid imports

Lower reliance on grid electricity directly reduces total energy expenditure.

Payback Analysis

The estimated simple payback period for the system is:

- 13.3 years (constant electricity price assumption)
- 11.4 years, assuming 2.5% inflation

The sensitivity of the payback period to electricity price development highlights the importance of long-term price assumptions in investment evaluation.

System Operation and Automation

The system operates with a high degree of automation, utilising:

- Real-time production monitoring
- Automated load control
- Rule-based energy flow optimisation

This minimises the need for manual intervention while ensuring continuous optimisation.

Key operational benefits include:

- Dynamic utilisation of solar generation
- Reduced exposure to high electricity prices
- Improved indoor comfort, particularly during summer cooling periods

Future Optimisation Potential

Further improvements could be achieved through:

- Predictive control based on weather forecasts and electricity price signals
- Pre-heating and pre-cooling strategies utilising building thermal mass
- Enhanced load forecasting and scheduling
- Increasing the self-consumption ratio beyond current levels

Conclusion

As a result, the system achieved a self-consumption ratio of approximately 60%, which is considered high for residential-scale installations without battery storage.

The results demonstrate that combining residential PV generation with intelligent control of flexible loads significantly improves system performance.

Transferring the cVPP technical platform

The pilot site serves as an excellent example of the transition from a traditional, passive heating setup to an intelligently controlled system. The site's versatile electric heating configuration includes the following components:

- hydronic underfloor heating with a domestic hot water storage tank
- electric radiators and underfloor heating cables
- an air-to-air heat pump
- mechanical ventilation

This setup is complemented by an 8.9 kWp solar PV system installed on-site. All equipment has been integrated into a unified smart home system that is centrally managed. The integration was achieved using exclusively commercial off-the-shelf components and open-source software.

The solar power system operates at peak efficiency on sunny summer days, during which surplus electricity is effectively utilised via the air-to-air heat pump to cool indoor spaces.

Consequently, the pilot site demonstrates in practice how heating and electricity consumption can be proactively optimised based on both indoor and outdoor conditions (temperature and indoor air quality), as well as fluctuations in electricity spot prices. The developed solution is easily scalable and adaptable to virtually any electrically heated building.

Lessons Learnt

Only a few years ago, the availability of affordable smart home devices was quite limited, and their setup required a relatively high level of technical expertise from the user. Common interoperability standards were largely lacking. Today, the situation has changed significantly: a wide range of manufacturers is available, and product offerings are broad and continuously expanding. Smart features can now be added to homes with an investment of just a few dozen euros, and systems can be gradually expanded according to individual needs.

Smart devices are typically introduced by installing the manufacturer's application on a mobile device. As devices from different manufacturers are added, the number of required applications tends to increase rapidly. For more advanced systems, such as heat pumps or photovoltaic (PV) systems, the manufacturer's application is often essential.

If proactive operation of smart devices is desired—based on factors such as outdoor weather conditions or electricity spot price fluctuations—a higher level of user expertise is required. Relevant data sources must be identified and understood, and their utilisation must be properly managed. In Finland, weather forecast data is provided free of charge by the Finnish Meteorological Institute, and electricity companies publish hourly spot prices for the following day, with a transition toward 15-minute pricing intervals currently underway.

Although devices from different manufacturers may operate within the same ecosystem, overall system design and management still require careful planning and attention to compatibility.

In addition, a decision must be made between operating the smart home system within a closed local network or through cloud-based services. When cloud solutions are used, attention must be paid to cybersecurity, as well as to the type of data collected by applications and how it is processed and utilised.

Electricity generated by solar PV systems should primarily be used for on-site consumption, for example by increasing cooling demand during the summer season. This approach is supported by several factors:

- In Finland, the heating season occurs mainly between autumn and spring, when solar generation is low or negligible.
- From spring to autumn, solar generation reaches its peak, while heating demand is low and electricity spot prices are typically lower.
- Revenue from exporting electricity to the grid is generally relatively low due to low spot prices, whereas purchased electricity includes transmission fees and taxes, making self-consumption more economically attractive.

During the previous summer, cooling capacity at the pilot site was increased, enabling a comfortable indoor temperature to be maintained even during hot periods. As a result, electricity consumption during the summer months of 2025 increased by approximately 20–25% compared to the previous year. However, no increase in electricity costs was observed, as the system was primarily operated when surplus solar electricity was available.

Even when the potential revenue loss from exporting excess electricity to the grid is considered, using surplus solar energy for cooling can be regarded as a more beneficial solution due to the improvement in indoor comfort. If an air-source heat pump is not available, investment in standalone cooling units may be considered a viable alternative. In recent years, prolonged heatwaves combined with low wind conditions have been

observed in the Oulu region, contributing to increased electricity consumption and higher prices.

Depending on the building's orientation, solar panels should ideally be installed on multiple sides of the building. In the pilot site, all panels are installed on a single roof plane, which results in reduced production during morning hours when the panels are in shade.

Data reliability and backup considerations

In one detached house case, a lightning strike near the building damaged all circuit boards of a ground-source heat pump, resulting in the loss of more than six months of collected data. This illustrates the importance of data redundancy. A practical solution is the use of automated cloud backups, provided that cybersecurity requirements are properly addressed.

.

Nólsoy, Faroe Islands

Ground source heating combining solar generation to independently power system for local museum.

Identify candidates that might benefit from and be interested in establishing a Virtual Power Plant in the Faroe Islands

Given the Faroe Islands' limited area of 1399 km^2 and the small population of around 55,000 people, the electricity grid system itself can be seen as a microgrid. Historically the electricity has been produced, transmitted, distributed and sold by the monopoly company SEV which is owned jointly by all municipalities on the islands. In recent years, wind energy development has been put out to tender and now some larger privately owned companies have become electricity producers together with SEV. Only in the very last few years it has become relevant for private households and other building owners to be able to produce electricity energy from solar into the grid.

Currently, there is a monopoly on the sale of electricity, and parties other than the monopoly have restrictions on the transfer of electricity across cadastral boundaries. This is a limitation for creating Virtual Power Plants (VPP). The new wind power producers have shown interest in selling their own fluctuating production to flexible users and installing systems such as hydrogen production that can function as an energy storage and thus build a VPP-like system, but this has not been allowed yet.

However, VPP technology is highly relevant within single buildings. The energy transition from oil to electricity is encouraged by the authorities and an increasing number of buildings have replaced their oil-based heating system by various heat pump solutions that run on electricity. Also, an increasing number of electrical cars have replaced conventional combustion engine vehicles. Electricity from wind energy is dominant in the winter, and therefore most of the oil used in electricity production is used in the summer period. To minimize the use of oil in the summer, the electricity company SEV, together with the ministry, has drawn up a plan to significantly increase production from solar energy. To promote the deployment of solar PV systems, all building owners can obtain favourable terms for installing solar energy. It is obvious to configure own electricity production and own electricity consumption for heat pumps and electric cars as a VPP with or without batteries to optimize the economic benefit.

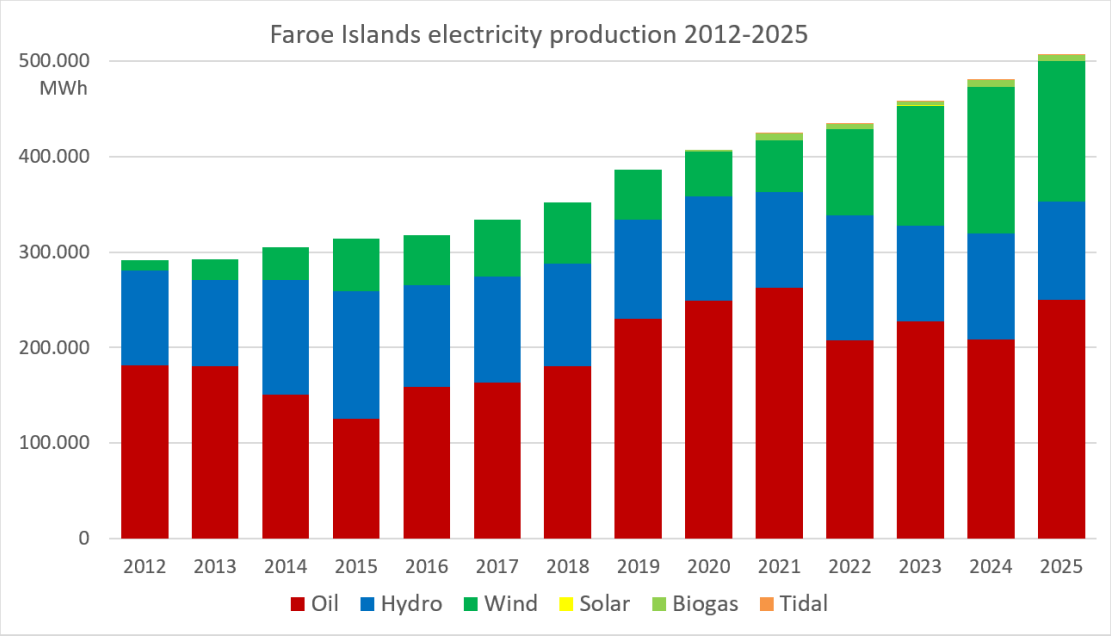
Candidates reviewed included:

a. Normal Energy Producers e.g. wind farm, biogas, solar producers, etc..
b. Public Infrastructure e.g. local electricity companies, municipalities, etc..
c. Private Dwellings/Condominiums e.g. households with energy production
d. Public bodies e.g. municipal or regional councils

Determine scale of local energy generation, demand response and distributed energy resource assets available in each partner region.

o. Clarify how electricity is predominantly generated in local region (fosil, wind, solar, etc..)
p. Review the market penetration of Distributed Energy Resources (DERs) in local region.
q. Local market costs

The electricity production mix in the Faroe Islands is given in the figure below.



Historically the production has been from hydro and oil. During the past two decades wind energy has been introduced. It is expected that in a few years time wind will become the most important electricity producer in the Faroe Islands. There is less wind during summer and therefor solar energy installation is encuraged. Within the last two years the number of solar installations has reached around 50 installations with the majority between 3 and 30 kWp each. Two larger systems have been installed one

around 300 kWp and one around 1 MWp. The investment cost of a solar system is around 10,000 DKK/kWp. The production can be expected to be 700 kWh/kWp/year.

Currently, the only relevant distributed energy resources (DER) in the Faroe Islands are solar panels on buildings and flexible utilization of electric heat energy in the building, as well as chargers for electric cars connected to the electrical installation in the building. Such a system may be expanded with batteries to achieve better economy.

Review what promotions/policies local/country governments promote

What policies/subsidies are available through government?

In recent years, several subsidy initiatives have been introduced to promote the energy transition from oil to electricity, which in the future will be produced from renewable energy sources. A few years ago, 'green meters' were introduced to allow use of electricity for heat pumps and electrical vehicle to be priced with a reduction of 0,50 DKK/kWh which corresponds to a reduction of around 25%. At the same time, a system of VAT-refund was introduced for heat pumps and electrical vehicles investments.

To encourage the installation of solar energy on buildings the price of electricity from solar panels into the grid was fixed a few years ago at 0,90 DKK/kWh. In early 2026 the price of electricity from solar panels was increased to 1.45 DKK/kWh for systems connected within the meter and to 2.00 DKK/kWh if the system is connected outside the meter. If connected inside the meter solar production is firstly used inside the building and the electricity bought from the grid is reduced whereas if the system is connected outside the meter all production is feed into the grid. The new relative high price that can be achieved for own produced solar power fed directly to the grid reduces the interest of developing VPP.

Until now all electricity in the Faroe Islands has been sold at a fixed price that has been decided for one year at the time. From next year, in 2027, it is expected that prices will be flexible and reflect the amount of renewable energy in the system with much lower prices when wind energy is predominant in the system. The reason is that wind energy production is much cheaper than power produced by oil. Flexible prices are expected to reduce excess (surplus) wind energy by shifting the use of electricity to windy periods

with lower prices. It is not known how the change in the electricity pricing regime will affect the viability and interest in developing VPP systems.

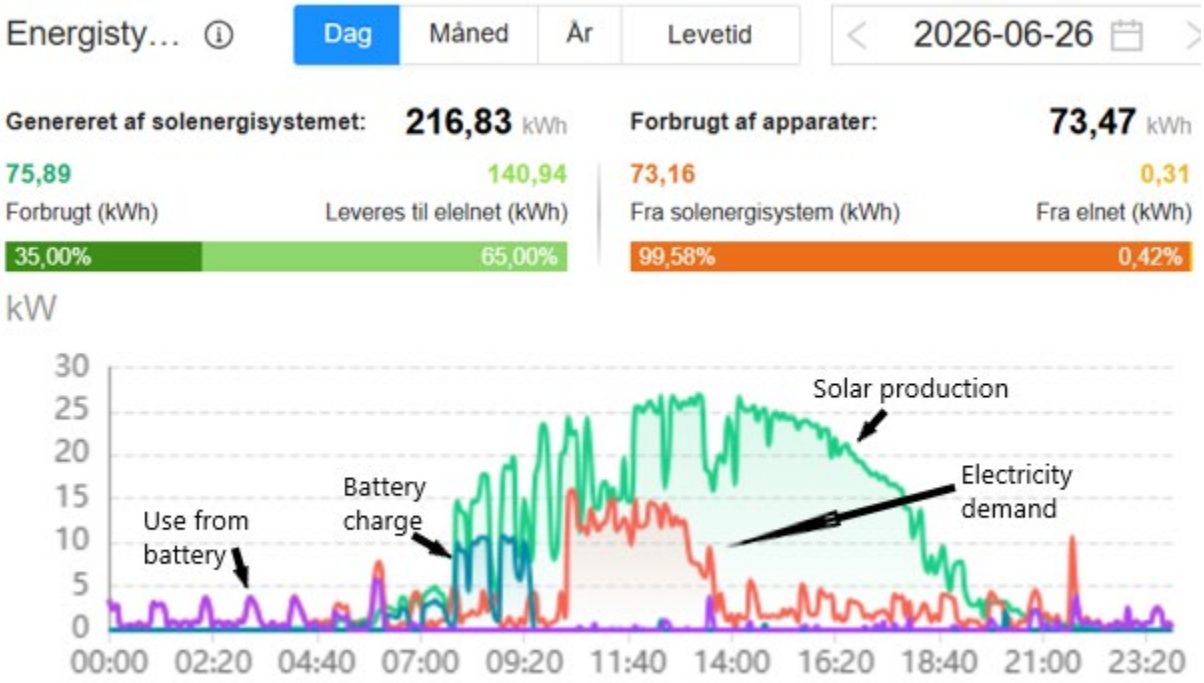
Identify cVPP to be established in region

a. Which potential cVPP was delivered in the region?
b. What already exists and what has to be developed?
c. Identify the key partners required to deliver the cVPP

The cVPP focused on in the Faroe Islands CoPower pilot was a system with own generation from solar panels to cover as much as possible of own demand for electricity for general use and to supply power to new installations of heat pumps and electrical vehicles. Such systems will have increasing interest in the near future as an increased number of heat pumps are installed all over the islands and the number of electrical cars is growing.

It was decided to develop a VPP as part of a privately owned heating system that was planned to heat a few buildings in the centre of Nólsoy. The heating system was planned to be based on a ground source heat pump and to include solar panels for own production of electricity for the heat pump. There were also plans of installing a battery for the system.

As the installation of solar panels were delayed and not installed during the project period another similar solar installation was investigated. This is a system installed at the Red Cross facility building in Tórshavn. A heat pump was installed in June 2025 and an electrical car charger in December 2025. A solar system was installed in October 2025, with 34kWp solar panels, 25kW inverter and a battery of 25kWh. An example of a one-day operation of the system is given in the picture below.



Key partners are owners of buildings, equipment suppliers, builders to mount the equipment, electricians for connections which most often are also the supplier of equipment, financial suppliers, grid company and for larger systems (>11kWp) the authority need to give licence.

Assessment of technology solutions to confirm viability for the cVPP model

a. how to gain access to the grid
b. which IT security guidelines should apply
c. how to enable connection between software interfaces and (often remote) decentralised energy resources in regions

The utility company SEV together with the authorities have prepared and drawn up rules for connection of solar panels systems to the grid. The rules for connection are easy and have favourable condition and reflect the national desire to increase power generation from solar energy to minimize the use of oil during summer.

Internet is widely distributed with very good coverage and fibre optic cables are currently laid out to all corners of the country. At the same time G5 technology is being rolled out. The control and monitoring of connected system such as VPPs is therefore relatively easy to obtain.

Implementation of cVPP

a. Key administrative challenges (if any)
b. Key operational challenges (if any)
c. Key partner challenges (if any)
d. Key service level agreements (if any)

Solar production is highest during the summer, whereas the energy use for heating by heat pump is highest during the winter. The mismatch between power generation and energy consumption is a challenge and result in a lower benefit of a VPP that is based on solar energy to supply energy for a heat pump. A battery will increase the benefit of the system, but batteries are most efficient as energy storage for hours and are less suitable as seasonal storages.

The present system that is installed in Nólsoy is installed and owned by the building owner. The energy is delivered to the museum at an agreed price that reflect the official price of the district heating system in Tórshavn.

The administration and maintenance of the heat pump system is not a challenge, as the the owner has expertise in installing and servicing such systems.

Implementation Timeline

a. Permission to install requested (if required)
b. Installation start date
c. Installation end date
d. Key challenges encountered

At the start of the project, the plan was to use official buildings on Nólsoy in the Faroe Islands, such as the local municipal school and kindergarten, as well as a new building attached to the local church, as locations for the installation of new energy systems that include a cVPP. It turned out that the school and kindergarten were not on the municipal priority list and the church building was postponed. It was therefor decided to develop a VPP as part of a privately owned heating system that was planned to heat a few buildings in the centre of Nólsoy. The heating system was planned to be based on a ground source heat pump and to include solar panels for own production of electricity for the heat pump. There were also plans of installing a battery for the system.

The first building to receive heat from the system was a newly built museum, called ‘Ovasavnið’. The building process started in April 2023, but the museum was not

opened until April 2025. The heat pump was installed, but initially ran on alternative input, primarily with the built-in electric heater. The ground source hole for heat pump input was drilled at the end of October 2025. Data collection Sensors were installed and the first data from the heating system was obtained in the beginning of 2026. Solar system has not been installed yet. The temperature and humidity in the museum (Ovasavnið) were logged over a period as part of CoPower activites.

Key costs of Implementation

The price of solar panel systems in the Faroe Islands reflects the world market as there are several local suppliers that offer such systems with competitive prices. A 11kW system including panels, inverter and mounting materials will be around 75,000 DKK (10,000€). The installation costs will depend on the design and the kind of roof on the building. Heat pumps are also offered by several companies within a fierce competition environment. A heat pump system based on air/water system will be around 100.000 DKK whereas a ground source heat pump system has around 50.000 DKK higher price.

The data acquisition equipment used in this project has been rather cheap as it is built on low-cost arduino-like microcontrollers and sensors. However, a huge number of hours have been used on the programming of the different tasks.

Transferring the cVPP technological platform solution to your region

There is great interest in the energy transition from oil to (renewable) electricity in the Faroe Islands. An increasing number of heat pumps have been installed in recent years, and interest in producing one's own electricity via solar panels is also increasing. There is therefore great interest in systems, such as VPPs, that can optimize the interaction between own production and own consumption of electricity.

The owner of the system, that has been installed in Nólsoy, is active in the market for plumbing including installations of various heat pump systems. The learning from the installation in Nólsoy is therefore available within this area of work. The results of solar panels production and comparison with consumption in a heat pump has also been extensively discussed with advisers at the Faroese Environment Agency as well as with participants in information meetings.

It has been officially announced that flexible electricity prices will be introduced in the near future, likely from 2027. This could result in a fundamental change in business cases for VPP systems.

Lessons Learnt

Development of new systems often takes much longer time than expected.

Heat pump systems are efficient and competitive as a replacement for oil-based heating. Ground source heat pumps are the most efficient heating system. The investment costs are high, but in the long run they are cheap compared to other heating options.

Solar panels are effective even at the Faroe Islands' high latitude of 62°N.

Batteries seems to be too expensive to currently be a viable part of a VPP system. With the new very high price scheme for direct solar power to the grid, the business case for installing batteries has become less.

Frequent and major changes in rules, conditions and prices for the production and use of electricity make it difficult to make long-term planning and decide which investments are best and most economically profitable for a house owner or a company.