Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)

Annex 42

Heat Pumps in Smart Grids

Overview of demonstration projects

Appendix to the Final report

Operating Agent: The Netherlands

2017

Report no. HPT-AN42-4

Demonstration projects

Smart heat pumps in the field

ABSTRACT
This appendix provides an overview of demonstration projects in each participating country in Annex 42.

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1 AT – Austria

NAME: SCDA Completed

KEY SMART INTERVENTIONS TESTED:

- Dynamic tariffs
- Peak shaving
- Control method: Direct control

DESCRIPTION:

- Large-scale demonstration and implementation of an optimization system approach between buildings, power grids, users and ICT solutions using flexible tariffs.
- The optimization system was tested into new buildings for improving operation and control strategies, optimizing energy usage and reducing CO_2 emissions.

KEY FINDINGS:

- Customers didn't notice any comfort disruption.
- Construction companies faced challenges when implementing the HVAC system, which resulted in the requirement of improvements during the first heating season.
- The lack of documentation for simulating the system's features (such as anti-freeze cycles) prevented a complete simulation of the building and control strategies.
- A complete simulation is complex as it requires modelling the additional features.

NAME: Building as interactive participants in the Smart Grid – SMGS Hit Completed

KEY SMART INTERVENTIONS TESTED:

- Dynamic tariffs
- Control method: Automated response

DESCRIPTION:

- Small scale demonstration of a smart building fully integrated into and optimized by a smart grid built within the subsidy rules of social housing.
- The housing area was evaluated in the real context from the perspective of the power supplier, the building technology, and the residents by using dynamic tariffs.

KEY FINDINGS:

- System was proved technically viable on the long term.
- Balancing the load between grids is complex due to the coincidence of domestic hot water consumption and the peak in demand of electricity.
- Energy consumption decreased while CO_2/primary savings are locally dependant.

2 CH – Switzerland

NAME: WARMup

Completed

KEY SMART INTERVENTIONS TESTED:

- Dynamic Tariffs
- Control method: Automated Response

DESCRIPTION:

- Virtual simulation of a network for optimizing flexibility in thermal storage in order to prove its commercial viability in multi-house buildings, using 5000 brine/water HPs.

KEY FINDINGS:

- Smart meters and dynamic tariffs are essential in the future market as the potential of flexibility can't be attained with the current high/low-tariffs.
- Thermal storages improve load management and flexibility has a profitable value.
- Decentralized energy storage is required to maximise the potential of flexibility as it currently loses value as it is transported long distances.

NAME: Tiko

Commercial

KEY SMART INTERVENTIONS TESTED:

- Dynamic Tariffs
- Peak Shaving
- Load aggregation
- Business Models for leveraging value from DR
- Control method: Automated Response

DESCRIPTION:

- Large scale smart grid implementation for industrial and residential buildings in which all thermal electric appliances can be remotely controlled by the network. The company aims at reducing customer's costs and energy consumption, improving load management and peak shaving and generating energy control based business models.

KEY FINDINGS:

- Market introduction has been successful so far and is expected to grow and achieve a final size of 70,000 households with a supply of 70 MW of control power.
- Customers had a positive engagement and perceived no comfort disruptions.

NAME: Gridbox — Completed

KEY SMART INTERVENTIONS TESTED:

- Peak Shaving
- Control method: Automated Response

DESCRIPTION:

- Development and demonstration of a smart management system for DSOs for a smart grid for all types of buildings with the aims reduce the grid's expansion, optimize regional self-sufficiency and reduce voltage fluctuation.
- The system processes real-time measurements from nodes in the distribution grid.
- The project aims to provide transparency of the low and middle voltage levels.

KEY FINDINGS:

- DSO were successful in finding a balance between smart grid technologies and the conventional expansion of the grid in the short-, middle-, and long-term.

NAME: BKW Home Energy — Completed

KEY SMART INTERVENTIONS TESTED:

- Renewable Integration
- Peak Shaving
- Control method: Automated Response

DESCRIPTION:

- Smart optimization control system that combines decentralized electricity production from PV with HPs and storage batteries to maximize self-sufficiency.

KEY FINDINGS:

- A reduction of electricity fed in the grid and peak loads is observed as energy flow in households is optimized and utilizes most of the decentral electricity produced on site.

NAME: GridSense — Completed

KEY SMART INTERVENTIONS TESTED:

- Renewable Integration
- Peak Shaving
- Control method: Automated Response

DESCRIPTION:

- Small scale demonstration of a control algorithm that reduces electricity consumption and grid loads in modern single family houses. Each house contained a HP, PV, battery storage and a boiler and were connected to the same transformer.
- The algorithm processes parameters such as grid load, tariffs, power consumption and generation for controlling all households' devices consuming or producing electricity. The algorithm can learn how the user behaves and improves itself continuously.

KEY FINDINGS:

- Profitable algorithm as it reduces peak loads and decreases onsite consumption.

NAME: SoloGrid Ongoing

KEY SMART INTERVENTIONS TESTED:

- Peak Shaving
- Dynamic tariffs
- Control method: Direct Control

DESCRIPTION:

- Follow up of GridSense. Connection of a neighbourhood of modern single family houses with HPs into a smart grid to analyse the usage of smart technologies in a distribution network as well as comparing GridSense with other market solutions.
- Demonstration is tested by carrying a simulation of all possible scenarios using Adaptricity and combining their information with the field test.

KEY FINDINGS:

- Not applicable as project is still ongoing.

NAME: Adaptricity Ongoing

KEY SMART INTERVENTIONS TESTED:

- Peak Shaving
- Control method: Automated Response

DESCRIPTION:

- Software that simulates different grid scenarios, with a focus towards decentralized electricity production and electro mobility, by connecting them to decentralized storage systems and local grid transformers, or with the traditional expansion of the grid.
- The software is based on functional models of different loads, producing and storage systems. In it, smart meter models and individual electricity tariffs can be implemented.

KEY FINDINGS:

- As it allows the integration and evaluation of different smart grid technologies, the software is currently applied in various projects throughout Switzerland.

NAME: Lucerne UASA

Completed

KEY SMART INTERVENTIONS TESTED:

- Peak Shaving
- Dynamic tariffs
- Control method: Automated Response

DESCRIPTION:

- Parameter study that focuses on maximizing flexibility and minimizing losses when connecting HPs and thermal storage to the smart grid.
- The study is based on computational models for three types of single family house buildings to elaborate on the effects of varying control algorithms, types and sizes of storages, as well as types and power of HPs on flexibility and efficiency.

KEY FINDINGS:

- Flexibility is improved by smart predictive control algorithms using the thermal mass of the building as an active storage. Flexibility can be further increased by thermal storages, with cost and cycle numbers reductions of 36% and 74% respectively.

3 DK – Denmark

NAME: READY

Completed

KEY SMART INTERVENTIONS TESTED:

- Dynamic tariffs
- Peak shifting
- Load aggregation
- Control method: Direct Control

DESCRIPTION:

- Large-scale demonstration of a direct control system for heat pumps with thermal storage controlled by spot prices that help balancing the system during operating hours by delivering regulating power to the TSO.
- The modelling system senses and aggregates indoor and outdoor environmental conditions with price forecasts to provide flexibility services while minimizing costs.

KEY FINDINGS:

- Potential savings of 15-20% on electricity prices and regulating power market to TSO.
- Energy consumption can be moved and a forecast energy plan can be followed.
- Disturbances from the behaviour of residents coupled with changes in weather conditions make it difficult to respect and maintain the comfort level in the houses.

NAME: EcoGrid EU 2.0

Ongoing

KEY SMART INTERVENTIONS TESTED:

- Dynamic tariffs
- Load aggregation
- Control method: Direct control

DESCRIPTION:

- Large scale implementation of tools and products for developing a commercially ready market based system for DR controlled by aggregators in private households.
- Demonstration of how customers can help with the operation of the power system and overcome the incoming challenges from renewables, electric vehicles and heat pumps.
- Three types of HPs with small storage capabilities will be tested in private dwellings and holiday houses with their control executed by price and activation signals.

KEY FINDINGS:

- Not applicable as project is still ongoing.

NAME: Control-Your-Heat-Pump Completed

KEY SMART INTERVENTIONS TESTED:

- Demand Response
- Standardised IT infrastructure
- Control method: Automated Response

DESCRIPTION:

- Large scale demonstration for the development of a standardized open source IT infrastructure that manages HPs and their data in private dwellings for supporting business models and forming the basis for a future Smart Grid market.

KEY FINDINGS:

- HP electricity consumption can be shifted for 2 hours on average, even in cold weather, while maintaining a comfort temperature of +/- 1.5° C around the set point.
- Heating consumption decreased by 8% and the average SCOP was 290%.
- Customers were interested in the project and gave a positive feedback.

NAME: HeatUp Completed

KEY SMART INTERVENTIONS TESTED:

- Dynamic tariffs
- Commercially ready HP product integrating standardised IT infrastructure (see Control-Your-Heat-Pump above)
- Control method: Automated Response

DESCRIPTION:

- Developing and demonstrating a cost-effective, efficient and flexible heat pump for older private dwellings with a need for a high flow temperature.
- The heat pump's requirements were ease of installation, a modular structure and direct online controllability as well as smart-grid readiness through the integration of a standardised communication protocol.

KEY FINDINGS:

- A new type of inverter-based air/water HP without storage that retrofits existing heating systems and can be monitored and controlled online was successfully adapted for DR.
- Integrating the external control management system from the *Control-Your-Heat-Pump* project with the existing software in the heat pump was found to be challenging.
- The flexibility market needs further development in order to maximize the advantages from

NAME: HPCOM Ongoing

KEY SMART INTERVENTIONS TESTED:

- Standardise ICT infrastructure for DR
- Control method: Automated Response

DESCRIPTION:

- Spin-off project from Control-Your-Heat-Pump that aims at a small-scale research for developing and implementing a standardized communication infrastructure system between HPs, system operators, utility companies, HP manufacturers, etc.
- This industry cooperation – including their partners Insero, Neogrid Technologies, Eurisco, Danish Technological Institute and Intelligent Energistyring - is aimed so that HPs can be used both for providing regulating and balancing power, but also as a flexible resource in the distribution network.

KEY FINDINGS:

- Not applicable as project is still ongoing.

NAME: Demonstration of new business model for selling heat from heat pumps & leveraging value from demand response Completed

KEY SMART INTERVENTIONS TESTED:

- Business Models
- Demand Response (non-specified)
- Business models for lever-aging value from DR
- Control method: Automated Response

DESCRIPTION:

- Development of business models for HPs that transfer the risks from customers to Heating Suppliers and allow aggregators, TSOs and DSOs to balance network DR.
- Heating Suppliers are responsible for investment, installation and operation of HPs. Customers are subject to an initial one-off payment, a yearly fixed price per kWh of heat and a fixed price for service and maintenance. The Heating Supplier refunds the cost for electricity used for heating at a fixed price to the customers.

KEY FINDINGS:

- The target group had a preference towards a reliable heating solution at a fair price with relevant and transparent information from the Heating Supplier.
- The target group had small understanding and interest in heating technologies.

NAME: DREAM Phase 1 Completed

KEY SMART INTERVENTIONS TESTED:

- Dynamic tariffs
- Control method: Automated Response

DESCRIPTION:

- Feasibility study for developing a commercially viable solution using variable tariffs for the implementation of a smart grid ready equipment to dwellings with low energy consumption in areas outside district heating or the gas grid.

KEY FINDINGS:

- Before a full deployment of a Smart Grid based on open standards, further R&D is required on an interoperable communication protocol based on existing technologies.
- The majority of private homes will not invest in Smart Grid Ready equipment without some type of incentive, which could be financial, legal or ideological.
- Flexibility brings minor savings that can be offset by the added costs. When working on a number of HPs in a specific area, flexibility potential can be achieved.
- Customers perceive HPs and Smart Grid technologies as obscure and complex which reduce their implementation, since they are used to DIY mechanical technologies.

4 DE – Germany

NAME: EnVisaGe Ongoing

KEY SMART INTERVENTIONS TESTED:

- Peak Shaving
- Renewables Integration
- Load Aggregation

DESCRIPTION:

- EnVisaGe uses flexible systems such as heat pumps and batteries to reduce peak loads and provide flexibility to the grid via an intelligent control system in a Virtual Power Plant.
- Furthermore, EnVisaGe increases self-consumption of own PV electricity production.

KEY FINDINGS:

- Key challenges lay in the large diversity of the different solutions built in the plus energy neighbourhood and in the delay of the construction of the individual buildings.
- Communication with the building owners was also a challenge.
- A follow-up project, EnVisaGe-Plus will carry on with the testing and analysis of the intelligent control system which will should be fully installed by the end of this project.

NAME: Flexible Power-to-Heat Ongoing

KEY SMART INTERVENTIONS TESTED:

- Peak Shifting
- Flexible Tariffs
- Renewable Integration

DESCRIPTION:

- The projects aim is to allow as much flexibility and potential for load shifting by any supplier while avoiding local overloads in the distribution network.
- Implementation takes place in the form of grid quotas representing the load limit of the respective network section, within which potential suppliers can shift power consumption.
- In addition, it was investigated to what extent network expansion, as well as the shutdown of generation facilities (feed-in management) can be avoided by way of regional load activation

KEY FINDINGS:

- The approaches in the field test are able to use the flexibility of customers in a grid friendly way.
- Integrating the developed mechanism of the grid quotas to prevent grid bottle necks into the regulatory framework and the rollout of smart meters as an enabler are key challenges.
- Customer response was very positive, they are expecting appropriate tariffs now.

5 FR – France

NAME: PREMIO — Completed

KEY SMART INTERVENTIONS TESTED:

- Dynamic Tariffs
- Peak Shaving
- Load aggregation
- Control method: Direct Control & Automated Response

DESCRIPTION:

- Small scale demonstration of a virtual power plant integrating varied distributed resources and air/water HPs connected to the low voltage grid in residential areas.
- A control unit that aggregates and optimizes the use of resources for offering both day-ahead and intraday load curtailment services to an upstream operator was developed.

KEY FINDINGS:

- Installation of heating storage is complex in existing dwellings.
- Positive customer response as none overrode the heating control function.

NAME: Smart Electric Lyon — Ongoing

KEY SMART INTERVENTIONS TESTED:

- Peak Shaving
- Dynamic tariffs
- Control method: Direct Control

DESCRIPTION:

- Large scale development of a range of interactive services and equipment (including air/water HPs) for customers, businesses and communities in urban areas.
- Services centred around the smart metering system 'Linky' which sends a high peak price during 18h and 20h, 20 days per winter (from November to March).

KEY FINDINGS:

- Not applicable as project is still ongoing.

NAME: EDONICE Completed

KEY SMART INTERVENTIONS TESTED:

- Peak Shaving
- Control method: Direct Control

DESCRIPTION:

- Demonstration of the modifications of residential customer's load management when the temperature set point of air/air HPs is remotely controlled during long period in combination with providing incentives.

KEY FINDINGS:

- Information not available.

6 KR – South Korea

NAME: Jeju Smart Grid Test-Bed — Completed

KEY SMART INTERVENTIONS TESTED:

- Dynamic Tariffs
- Renewable Integration
- Business models for leverage value from DR
- Control method: Direct Control

DESCRIPTION:

- Large scale development of a smart grid infrastructure that includes smart metering, real time trading, and renewables with the aim to assess technologies, business models, policies and regulations.
- The project focused on rural areas and consisted of 5 smart sub projects that targeted the power grid, customers, transportation, renewables and the electricity service.

KEY FINDINGS:

- Limited potential of flexibility when the market has achieved high penetration ratio of energy supply by central companies under the separated energy-grid circumstance.
- Importance of the development of unified and high-level architecture to the demonstration projects.

NAME: Jukdong Zero Energy House — Completed

KEY SMART INTERVENTIONS TESTED:

- Energy independence
- Renewable Integration
- Control method: No control

DESCRIPTION:

- Small scale development of a renewable energy system that includes PV, solar thermal and a geothermal HP for a backup heating in urban houses that only use electricity as their energy source.
- Grid-connected photovoltaic power generation responds first to electricity demand in the house. When surplus power is generated, it is transmitted backward to the grid.

KEY FINDINGS:

- Existence of potential market for energy independence of residential sector in Korea.
- Need for the combination of renewable electricity and heat to achieve energy independency in

NAME: Jincheon eco-friendly energy town Ongoing

KEY SMART INTERVENTIONS TESTED:

- Renewable Integration
- Control method: Automated Response

DESCRIPTION:

- Demonstration of an energy society model to be applied to urban areas that aims to provide an independent energy supply solution that meets local characteristics.
- Electricity is generated generates via solar and fuel cells while solar thermal, thermal storage, and HPs are used to provide heating, cooling and hot water.

KEY FINDINGS:

- Importance of the policy support to promote renewable energy community.
- Energy management system demonstration for public facilities of a small community.

7 NL – The Netherlands

NAME: Couperus smart grid — Completed

KEY SMART INTERVENTIONS TESTED:

- Dynamic tariff
- Peak Shaving
- Renewable Integration
- Control method: Direct Control

DESCRIPTION:

- Demonstration of commercial services and products proving the potential for flexibility and the behaviour of customers for balancing the grid in new multifamily buildings.
- Development and demonstration of Powermatcher technology, an auctioneer model where instant biddings from all customers and producers of energy that are connected meet at an equilibrium price.
- Demonstration of DR with HP and local wind turbine.

KEY FINDINGS:

- Potential for reducing the imbalance generated from a connected wind turbine *and* peak shave the total load of the grid was proved.
- HP power was 21% flexible, despite the HPs control was to heat up the water tank only in night tariff, which conflicted with the need for flexibility (larger during the day).

NAME: Energy frontiers Heerhugowaard — Completed

KEY SMART INTERVENTIONS TESTED:

- System & Renewable Integration
- Dynamic tariffs
- Peak Shaving
- Control method: Direct Control

DESCRIPTION:

- Development of a smart grid in one urban area where roles, responsibilities, risks and value are developed to form a market for grid flexibility by testing ventilation air/water HPs, PV, fuel cells and electric boilers without the use of storage.
- Powermatcher technology and energy trading was used at variable time intervals, with the end use having the ability to turn on/off the smart control mechanism.

KEY FINDINGS:

- Approximately 2/3 of the ordered flexibility was delivered, with 92 kWh per day per household was traded on average.
- Very positive customer engagement and response as they were strongly involved in the trial.

8 UK – United Kingdom

NAME: Greater Manchester Smart Energy (NEDO) Ongoing

KEY SMART INTERVENTIONS TESTED:

- Peak shaving
- Load aggregation
- Business models for leveraging value from DR

DESCRIPTION:

- Project fully funded by NEDO, a Japanese Government Agency promoting the development & introduction of new energy technologies.
- Large scale field trial of air-to-water heat pumps and hybrid systems (total of 550 units), testing the suitability of these products to provide demand response capacity in a stable and reliable manner.

KEY FINDINGS:

- The project successfully demonstrated the ability to use the pool for demand response interventions
- Customer engagement has been a key challenge so far, in particular in the recruitment phase of the project.
- Ensuring an adequate level of connectivity to the HP is also difficult, the change of broadband supplier is sufficient to disconnect a system, requiring a service visit.

NAME: Low Carbon London Completed

KEY SMART INTERVENTIONS TESTED:

- Dynamic tariffs
- Business models for leveraging value from DR
- Control method: Automated Response

DESCRIPTION:

- Small scale demonstration of the impact of new technologies such as EVs and HPs on the grid and the best solutions for adjusting its operation and infrastructure as well as researching business and technology solutions for contracting DR loads.
- The trial focused on offices and industrial in urban areas and only monitored (not controlled) HPs based on ToU tariffs.

KEY FINDINGS:

- Negative customer response due to low trial participation.
- No customer insight of ToU tariffs.

NAME: Customer Led Network Revolution — Completed

KEY SMART INTERVENTIONS TESTED:

- Peak Shaving & Shifting
- Dynamic tariffs
- Renewable Integration
- Control method: Direct Control & Automated Response

DESCRIPTION:

- Demonstration of new technologies (HPs, EVs, PVs), smart metering and control systems for managing the grid's congestion and expansion as well as testing consumer behaviour with changing or shifting loads in varied building types in both urban and rural areas.
- Demand side flexibility provided by HPs will be tested through different methods of control/influence, and with different levels of thermal storage.

KEY FINDINGS:

- ToU tariffs with HP have not encouraged flexibility but encouraged shifting of domestic chores and cooking especially where combined with an In-Home Display.
- Shift in peak demand is possible through direct controlled HP despite the occurrence of problematic payback spikes.
- Upfront cost still a challenge to customers. Engaging customers may be easier if the value created from the controlled smart-ready HPs was clearer.
- Users find interaction with HPs difficult. Configuration and operation issues, such as noise and interruptions to hot water supply contributed to negative feedback.

NAME: Seamless Demand Response — Completed

KEY SMART INTERVENTIONS TESTED:

- Dynamic Tariffs
- Demand Response (unspecified)
- Control method: Direct control

DESCRIPTION:

- Small scale HP control optimisation system demonstration for DSR and ToU tariffs in social housings.

KEY FINDINGS:

- Positive effect of Economy 10 tariffs as energy consumption reduced by 10%.
- Technical and control issues emerged, leading to drop outs.
- DR with fabric heat storage needs to take into account householder's limits on thermal flexibility.
- Customers can have a big impact on demand shifts – behavioural changes are needed to minimize this. Demand shifting may also be increased by improving thermal inertia of homes, zoning, or re-siting of the HPs.

NAME: Freedom Ongoing

KEY SMART INTERVENTIONS TESTED:

- Dynamic Tariffs
- Peak Shaving
- Control method: Direct Control

DESCRIPTION:

- Demonstration of a hybrid HP control optimisation system and its impact on network services and the technical and commercial barriers to implementation.

KEY FINDINGS:

- Not applicable as project is still ongoing.

9 US – United States of America

NAME: Commercial HVAC Advanced Demand Response — Ongoing

KEY SMART INTERVENTIONS TESTED:

- Peak Shaving

DESCRIPTION:

- Small scale demonstration of the DR potential of variable HVAC and HPs. Variable refrigerant flow (VRF) and variable roof-top units (RTU) reduce the cooling/heating capacity of HVAC and HP during DR events with limited need for additional hardware.
- The project is a pilot of systems in four regions: California, Mid-South, Deep-South and Hawaii. Each region will test several commercial building sites through actual (or simulated) utility DR events, through Open ADR communications.

KEY FINDINGS:

- Not available, as project will only be collecting data from Summer 2017.

NAME: Next-Generation Residential Heat Pumps — Ongoing

KEY SMART INTERVENTIONS TESTED:

- Peak Shaving

DESCRIPTION:

- Development and large scale demonstration of the use of the variable capacity of air-to-air HPs for advanced DR as well as improving energy efficiency in the residential sector.

KEY FINDINGS:

- Generally positive customer response so far.
- Complexity in assessing the capability and usefulness of a system type for demand response is high, as a lot of factors need to be considered, such as home design, system design and user

NAME: Controllable Heat Pump Water Heaters — Ongoing

KEY SMART INTERVENTIONS TESTED:

- Peak Shaving

DESCRIPTION:

- Small scale demonstration in single family residential buildings of the load control capabilities of HP water heaters using water as thermal storage combined with a standardized communication system based on the CTA-2045 standard.

KEY FINDINGS:

- So far, no comfort disruptions to customers, as load control remains undetected due to the water storage system.
- Project is still collecting data.

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