Flexible **H**eat and **P**ower, connecting heat and power networks by harnessing the complexity in distributed thermal flexibility

D4.1. Pilot definition

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Executive summary

The FHP concept is to use **distributed thermal flexibility**, such as provided by heat pumps in buildings, or large thermal storage solutions, such as the one provided by the Ecovat system, to make most effective use of available renewable energy, and to create the conditions to increase the amount of such renewable energy sources also at distribution system level.

The project has two demonstration sites, one in Uden, the Netherlands and one in Karlshamn, Sweden.

The demonstration site in Uden consist of the ecovat, which is a large subterranean and insulated vessel for thermal energy storage. Heat is exchanged by running hot or cold water through tubes inside the surrounding concrete elements, and the vessel is equipped with sensors to monitor the temperatures of the individual layers.

The site in Karlshamn consist of industrial and residential premises located in the grid of Karlshamn energi.

This report describes the implementation plan for the demonstration sites in the project. It gives a brief overview over the different sites with specifications for installed equipment.

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FHP website: www.fhp-h2020.eu

Authors:

Jens Brage, Martin Borgqvist (NODA)

Marcus Steen (KEAB)

Wiet Mazairac, Verhaagen Joost (ECOVAT)

Fjo De Ridder, Suryanarayana Gowri, d'Hulst Reinhilde, Davy Geysen, Chris Caerts (VITO)

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[1] **Disclaimer:**

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Table of content

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 731231.

List of tables

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

List of figures

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Glossary

Acronym	Full name
AGR	Aggregator
BRP	Balancing Responsible Party
DCM	Dynamic Coalition Manager (extension/specialization of Aggregator)
DM	Day ahead Market
DER	Distributed Energy Resource
DSO	Distribution System Operator
ISP	Imbalance Settlement Period
PBC	Pluggable Business Component
P2H	Power To Heat
PTU	Program Time Unit
RES	Renewable Energy Source
TSO	Transmission System Operator
USEF	Universal Smart Energy Framework (www.usef.energy)

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1 Introduction

This report describes the implementation plan for the demonstration sites in the project. It gives a brief overview over the different sites with specifications for installed equipment.

The plan describes the relevant actions taken during the validation process and defines the timing and runtime of the validation runs in detail. Furthermore, the plan describes the procedure for data management throughout the validation process to ensure a proper evaluation basis during the following tasks within WP4.

1.1 About the FHP Project

The FHP project[2] – *Flexible Heat and Power: connecting Heat and Power networks by harnessing the complexity in distributed thermal flexibility* – was submitted under the call *LCE-01-2016-2017: Next generation innovative technologies enabling smart grids, storage and energy system integration with increasing share of renewables: distribution network*, more specifically under the *Synergies between Energy Networks* area.

The FHP concept is to use **distributed thermal flexibility**, such as provided by heat pumps in buildings, or large thermal storage solutions, such as the one provided by the Ecovat system, to make most effective use of available renewable energy, and to create the conditions to increase the amount of such renewable energy sources also at distribution system level.

We specifically focus on **RES curtailment mitigation**, i.e. minimizing curtailments of temporary excess RES generation that would result in either **market based** (economic reasons) or **grid related** (technical reasons) curtailment. For this, distribution grid connected thermal flexibility will be used, making optimal use of – but not surpassing – the distribution grid capacity. This requires that we:

- **Learn the flexibility**: adopt grey-box building modelling approaches to achieve a high level of replicability without or with minimal human expert intervention.
- **Manage the flexibility:** aggregate distribution grid connected thermal flexibility into **Dynamic Coalitions**[3] of flexibility and interact with grid/system operators for either providing them a **local grid service** (e.g. preventing or solving congestion or voltage problems), or for providing a **system service** (e.g. balancing) making optimal (maximal but secure) use of distribution grid capacity.

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[2] See http://www.fhp-h2020.eu/ and http://cordis.europa.eu/programme/rcn/700614_en.html

[3] Participation of the P2H resources is voluntary, and they have the freedom to decide when, how much, and for what incentive they offer flexibility. So, there is a dynamic pool of flexibility providing resources that each have a dynamic flex offering.

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- **Interface the flexibility:** developing a **multi-agent framework** connecting all stakeholders and systems, needed for the targeted services / use cases, and aligned with the ongoing work in the Smart Grid Task Force and its Experts Groups in the field of **standardization** in general and flexibility management specifically

1.2 About This Document

This document, together with associated schedules, data sheets, and other supplementary data, details the activities of Work Package 4. The document is structured top-down.

Section 2, *Plan, Data Management*, serves to detail the process of data management before the onset of the validation effort to the end of ensuring that the data are well-managed throughout the validation effort, and well-management throughout the entailing life cycle, i.e., scientific and industrial dissemination, and finally, decommission. The data management plan conforms to the commitments of Work Package 7, *Ethics*, and addresses GDPR compliance.

Section 3, *Plan, Evaluation*, serves to describe how to evaluate the technical artifacts developed as part of Work Package 2 and Work Package 3 in a live context (actual weather, actual buildings, actual human behavior and peculiarities). This process can roughly be divided into two parts, verification (have we built it right?) and validation (have we built the right thing?). The idea is to evaluate the solution on three aspects, Stability (verification and validation), Performance (only verification), and Accuracy (only validation) and, moreover, for validation, across four different domains, at the level of the DER (e.g., a residential premise, or the Ecovat), at the level of the DCM, at the level of the DSO, and at the level of the BRP. This, in turn, suggests a number of product-KPIs and other statistics, which are then outlined.

Section 4, *Plan, Execution*, describes how to execute the different test runs to the end of collecting adequate data to perform the desired evaluation. This, in turn, involves spelling out operational procedures, the different combinations of technological artefacts to be evaluated, the different time horizons that they should be evaluated over, and to schedule the different test runs.

Section 5, *Sites and Premises*, describes the sites and premises of the pilot, and the equipment already on site, in particular, heat pumps and other thermal resources and, when applicable, provide context by means of blueprints, technical drawings, and historical data.

Section 6, *Installations and Actions*, serves to make precise what will be measured and controlled, and what activities need to be undertaken to prepare the sites for evaluation. The implementation plan consists of two parts per premise, firstly, a subsection *Installations* outlining what to install and, secondly, a subsection *Actions*

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outlining the corresponding schedule of actions. There are five types of actions, or activities, *Audit*, *Access*, *Configuration*, *Verification*, and *Validation*, which together has served to guarantee the quality of the installations performed.

Finally, there are a number of annexes with contact details and technical data.

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2 Plan, Data Management

The purpose of this data management plan is to describe the process of data management before the validation effort begins, this to ensure that data are well-managed in the present, and prepared for preservation in the future. The actual experiments and subsequent reports constituting the validation effort are described elsewhere, in Section 3 and Section 4.

2.1 Expected Data

The validation effort will collect measurements of temperature and the energy consumption at a highest measurement frequency of one data point every 5 min, and at a lowest frequency of one data point every 15 min. With 80-100 sensors and a life time of about one and a half year, this amounts to 0.5-0.6 GB binary data.

For buildings, temperature measurements will be collected from indoor and outdoor temperature sensors, typically one indoor temperature sensor per apartment and one outdoor temperature sensor per building, and a number of additional temperature sensors mounted on the pipes of the heating system to monitor the activity of auxiliary components such as buffer tanks, electric cartridges and oil burners. For buildings, energy measurements will be collected form energy meters the heat pumps under consideration, and from the billing meters and substations operated by KEAB.

ECOVAT Uden presents a different but comparable range of measurements of temperature and energy consumption.

The collected measurements will be gathered in the NODA platform, where they will be cross-checked and correlated with weather forecasts data on cloudiness, outdoor temperature, wind-direction and wind-speed. In turn, the NODA platform will, among other things, provide an authentication mechanisms, secure communication, and secure backup.

In addition to the collected data, the optimization algorithms will, for every DER and every 5 min, generate and communicate a number of incremental plans. However, this data can be readily recomputed from the measurement data, and will not be collected other than in the reports described in Section 4.

ECOVAT and KEAB will contribute with historical data for their respective domains, presumably at the resolution of one data point every hour, and KEAB will, moreover, contribute with historical data on the two wind farms operated by KEAB. Finally, RISE will contribute with data from the Research House to the end of the development and calibration of algorithms.

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2.2 Data Formats and Dissemination

Data will be communicated in the form of comma-separated values (CSV) encoded data frames, indexed by date and time (ISO 8601), and with uniquely labeled columns populated by floating point numbers (IEEE 754).

While preferably mnemotechnical, the labels (e.g., EV_name1 andEV_name2) cannot be relied upon to carry complete descriptive structure, and will have to be accompanied by metadata on location, equipment type, measurement type (air temperature, water temperature, etc.), and units of measurement. For measurement data, the preferred solution is by cross-reference to this document, or when appropriate, another document located at the project SharePoint. Tabular metadata is preferably communicated as spreadsheets or as comma-separated values with appropriate fields, e.g.,

Table 1, Format of metadata tables

Site	Premise	Database	Equipment	Description	Location	EV_name1	EV_name2
1	1	[anonymized]	CMa12W	°C, air	warehouse	[anonymized]	indoortemp
…							

For the duration of the FHP project, and within the FHP consortium, the data and metadata will be stored and processed in a pseudo-anonymized form that permit the researchers to cross-reference the data and metadata with the buildings or facilities that produced the data.

No data or metadata will be disseminated outside the FHP consortium without the explicit approval of the owner of the building or facilities that produced the data, and no data or metadata will be disseminated in a non-anonymized form unless on the explicit request of the owner of the building or facilities that produced the data and on the subsequent decision by the project manager. When disseminated outside the FHP consortium, and unless otherwise and explicitly decided by the project manager, with the exception of public buildings, i.e., Site 3 and Site 4, and with the exception of Site 5, the data will only be disseminated in anonymized form, that is, the labels will be restricted to mnemotechnical names such as Premise 1.1 for Site 1, Premise 1, free from addresses, building numbers, apartment numbers, or other aspects that can reveal identity, and the associated weather data will be processed in a way to mask location.

2.3 Data Storage and Preservation of Access

The data will be collected through, processed by, and stored on the NODA platform, subject to security best practice, and complete with secure communication, secure processing, and secure backup. For further details, see Work Package 7, *Procedures* *for Incidental Findings*. The metadata and the reports generated by the validation effort will be stored on the project SharePoint hosted by VITO, subject to security best practice, and complete with secure communication, and secure backup. The web services hosted by ECOVAT, HON, TEC and VITO, and responsible for the processing of data, will be held to the same standards, subject to security best practice, and complete with secure communication, and secure processing.

The data stored on the NODA platform will be retained for the duration of the FHP project and, moreover, as long as the owner of the building or facility that generated the data has a vested interest in being able to access the data through the NODA platform. After that, the data will be deleted from the NODA platform.

The metadata and reports stored on the SharePoint hosted by VITO will be retained for the duration of the FHP project. After that, the data will be deleted from the SharePoint.

To preserve access to the data, metadata and reports selected for dissemination in accordance with Section 2.2, the consortium members will, within Task 5.2 and under the leadership of HON, compile a number of packages of the selected data, metadata and reports, complete with a suitable license, and publish the package on the FHP project web site, where it shall remain for the lifetime of the FHP project web site. The web site will be hosted by TEC, who will continue to host the website until 2023-11-01, four years after the completion of the FHP project, after which time, the web site shall be decommissioned and the contents erased.

2.4 Ethics and Privacy

Only the Swedish demonstration involves natural persons. To handle informed consent, to protect privacy, and to handle other ethical issues that may arise, Work Package 7, *Ethics*, describes the *Criteria for Selecting Potential Participants*, the *Procedure for Recruiting Participants*, an *Information Sheet on Flexible Heat and Power* to be handed to the potential participants, a *Consent Form for Flexible Heat and Power* to be handed to the potential participants, and the *Procedures for Incidental Findings*. The two forms have since the publication of *Ethics* been reworked for clarity and translated to Swedish, but the contents remain the same.

In *Procedures for Incidental Findings*, to then end to safeguard the privacy of the residents and protect the business interests of the building owner, the members of the FHP consortium commit to pay data protection due attention, and to use the *European Data Protection Directive and Regulation (EU) 2016/679 of the European Parliament and of the Council*[4] for reference. Actions to safeguard privacy will

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[4] https://publications.europa.eu/en/publication-detail/-/publication/3e485e15-11bd-11e6-ba9a-01aa75ed71a1/language-en

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moreover be taken informed by *Opinion 12/2011 on smart metering*[5], *Opinion 05/2014 on anonymization techniques*[6], and *Privacy and Data Protection by Design*[7].

In particular, the project will adhere to the principle of data minimization and limit the collection of data to what is directly relevant and necessary to accomplish a specified purpose. For example, the project will not collect individual statements when one questionnaire per apartment would suffice. The project will anonymize personal data whenever possible and avoid collecting personal data whenever possible. When applicable, the members of the FHP consortium will utilize differential privacy[8] to aggregate data to the point that it cannot be traced back to any particular natural person. Unless otherwise explicitly decided by the project manager, the data collected will only be kept for as long as necessary, as dictated by the purpose for which it was collected, only shared within the consortium, and only shared on a need to know basis.

The consortium acknowledges the possibility that patterns in the data might reveal privacy sensitive information about the residents' habits. Such incidental findings will be ignored and not used in the research, and best effort will be made to make sure that any incidental findings are not in any other way misused.

2.5 GDPR Compliance

To ensure adherence to GDPR and, in particular, GDPR Article 30, and to facilitate a dialogue between the controllers, the processors, and the FHP consortium, the members of the FHP consortium shall, for the duration of the FHP project, keep the contact details to the respective controllers and processors up to date. For additional contact details, see Section 7, *Annex: Contacts and Email Addresses*.

2.5.1 GDPR Contact Details, ECOVAT

Controller: Joost Verhagen, joost.verhagen@ecovat.eu, +31 657152550.

Processor: Joost Verhagen, joost.verhagen@ecovat.eu, +31 657152550.

2.5.2 GDPR Contact Details, KEAB

Controller: Ingegerd Bengtsson, ingegerd.bengtsson@karlshamnenergi.se, +46 45481847.

Processor: Ingegerd Bengtsson, ingegerd.bengtsson@karlshamnenergi.se, +46 45481847.

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[5] http://ec.europa.eu/justice/policies/privacy/docs/wpdocs/2011/wp183_en.pdf

[6] http://www.cnpd.public.lu/fr/publications/groupe-art29/wp216_en.pdf

[7] https://www.enisa.europa.eu/publications/privacy-and-data-protection-by-design

[8] Differential Privacy by Cynthia Dwork, International Colloquium on Automata, Languages and Programming (ICALP) 2006, p. 1–12. DOI=10.1007/11787006_1

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2.5.3 GDPR Contact Details, NODA

Controller: Tomas.Lof@latourindustries.se
Processor: Tomas.Lof@latourindustries.se

2.5.4 GDPR Contact Details, RISE

Controller: Amanda Gabrielsson, amanda.gabrielsson@ri.se, +46 105165932.
Processor: Amanda Gabrielsson, amanda.gabrielsson@ri.se, +46 105165932.

2.5.5 GDPR Contact Details, TEC

Controller: dpo@tecnalia.com
Processor: dpo@tecnalia.com

2.5.6 GDPR Contact Details, VITO

Controller: Koert Van Espen (koert.vanespen@vito.be)
Processor: Koert Van Espen (koert.vanespen@vito.be)

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3 Plan, Evaluation

The purpose of the evaluation plan is to describe how to evaluate the technical artifacts developed as part of Work Package 2 and Work Package 3 in a live context (actual weather, actual buildings, actual human behavior and peculiarities). This process can roughly be divided into two parts, verification (have we built it right?) and validation (have we built the right thing?). The verification part focuses on the solution as perceived against inside knowledge, while the validation part focuses on the solution as perceived from the outside, without inside knowledge.

While conceptually distinct, the verification efforts and the validation efforts will be interleaved throughout the heating season. Conventionally, the verification efforts are completed before the validation efforts, but the confinement to one heating season, the presence of seasonal variations, i.e., autumn-winter-spring, and the need for comparable weather conditions, take precedence.

3.1 Key Performance Indicators

The solution will be evaluated on three aspects, Stability (verification and validation), Performance (only verification), and Accuracy (only validation) and, moreover, for validation, across four different domains, at the level of the DER (e.g., a residential premise, or the Ecovat), at the level of the DCM, at the level of the DSO, and at the level of the BRP.

The paragraph suggests the following product-KPIs,

Table 2, Suggested product KPIs

Product KPI	Description
VER_STA	Stability, as measured from the inside.
VER_PER	Performance, as measured from the inside.
VAL_STA_DER	Stability at the level of DER, as measured from the outside.
VAL_STA_DCM	Stability at the level of DCM, as measured from the outside.
VAL_STA_DSO	Stability at the level of DSO, as measured from the outside.
VAL_STA_BRP	Stability at the level of BRP, as measured from the outside.
VAL_ACC_DER	Performance at the level of DER, as measured from the outside.
VAL_ACC_DCM	Performance at the level of DCM, as measured from the outside.
VAL_ACC_DSO	Performance at the level of DSO, as measured from the outside.
VAL_ACC_BRP	Performance at the level of BRP, as measured from the outside.

However, the solution should also be evaluated with respect to the three principal use cases, UC1-3, and, moreover, with respect to different technological combinations, in particular, the three different thermal models and associated

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Shaper solutions developed by HON, TEC, and VITO, and with respect to different time horizons. Finally, depending on future weather conditions and other external factors, it can become necessary to further categorize the statistics.

Taken together, this will result in a large number of statistics. However, from the standpoint of whether to adapt the FHP solution, one will most likely only be interested in the top performing combination of technologies. Therefore, while the intermediate statistics shall be reported in full detail for completeness, it is desirable to restrict the product KPIs to the best of breed solution together with a precise account of the decisions involved.

The rest of the evaluation plan is dedicated to the technical aspects of how to quantify Stability, Performance, and Accuracy. The subsequent statistics shall then be used to evaluate the different test runs as scheduled in Section 4 and associated spreadsheets, i.e., the execution plan.

3.2 Statistics

There exists a large number of different statistics for quantifying averages and statistical dispersion, some of the most common being the *mean* and the *standard deviation*, and the *median* and the *mean absolute difference*. The multitude of forms comes about from the desire to be relevant. Depending on the nature of the distribution under consideration, different forms of measurements contain different amounts of information, and the statistics should be chosen to be informative. However, in practice, the nature of the distribution under consideration cannot be known until the data have been inspected. That said, the processes for working with these quantities are comparable, and it suffices to spell out the intended statistics in terms of means and standard deviations.

Moreover, to facilitate comparison between different signals, i.e., measurements, predictions, and control signals, it will be necessary to interpolate the individual signals against a preferred time resolution which, again, can be done in a large number of ways and, again, is best done with access to the actual data. However, independent of the choice of how to interpolate the signals, the statistics should be normalized with respect to the preferred time resolution in such a way as to make them independent of the choice of time resolution. Furthermore, the statistics should be normalized to facilitate comparison between DERs, DCMs, DSOs, and BRPs of different characteristics, i.e., to be independent of the number of temperature sensors, the number of DERs, and the size of DERs involved.

We demonstrate the process for how to evaluate the predictive accuracy of a model for a DER over a 24-hour time horizon against data over some period of several days interpolated to hourly values.

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Let t denote the date and time of the start of an experiment at the resolution of hours, i.e., t = yyyy-MM-ddTHH, and let dt denote the offset of a number of hours into the future to the date and time to forecast. Let $\mathbf{X}(t)$ denote the vector valued random variable to predict with respect to the time interval $[t, t + 1)$, and let $\hat{\mathbf{X}}(t, dt)$ denote the at time t predicted value of $\mathbf{X}(t + dt)$. Finally, write $\mathbf{X}_{\text{premise}}(t)$ and $\hat{\mathbf{X}}_{\text{premise}}(t, dt)$ for $\mathbf{X}$ restricted to the premise in question and, moreover, note that for an unbiased $\hat{\mathbf{X}}$, $\hat{\mathbf{X}}(t, -1) = \mathbf{X}(t)$.

We shall focus on $\mathbf{X} = \mathbf{W}, \mathbf{T}$, with one coordinate per sensor, where $\mathbf{W}(t)$ denotes the electricity consumption (kWh) during the hour $[t, t + 1)$, and $\mathbf{T}(t)$ denotes the average endogenous temperature (°C) during the hour $[t, t + 1)$. We shall moreover restrict attention to suitably normalized errors $\hat{\mathbf{X}}(t, dt) - \mathbf{X}(t + dt)$ for $t \in$ period and $dt \in \{0, \ldots, 23\}$,

$$\mathrm{err}\,(\hat{\mathbf{X}}_{\text{premise}}, \text{period}, dt) = \mathrm{sqrt}\,(\mathrm{err}^2(\hat{\mathbf{X}}_{\text{premise}}, \text{period}, dt))$$

$$\mathrm{err}^2\,(\hat{\mathbf{X}}_{\text{premise}}, \text{period}, dt) = \mathrm{sum}\,(t \in \text{period}, \mathrm{err}^2(\hat{\mathbf{X}}_{\text{premise}}, t, dt)) \,/\, (\mathrm{len}\,(\text{period}) - 1)$$

$$\mathrm{err}^2\,(\hat{\mathbf{W}}_{\text{premise}}, t, dt) = |(\mathbf{1}' \cdot \hat{\mathbf{W}}_{\text{premise}}(t, dt) - \mathbf{1}' \cdot \mathbf{W}_{\text{premise}}(t + dt)) \,/\, (\mathbf{1}' \cdot \mathbf{W}_{\text{premise}}(t + dt))|^2$$

$$\mathrm{err}^2\,(\hat{\mathbf{T}}_{\text{premise}}, t, dt) = |\hat{\mathbf{T}}_{\text{premise}}(t, dt) - \mathbf{T}_{\text{premise}}(t + dt)|^2 \,/\, \mathrm{len}\,(\mathbf{T}_{\text{premise}}(t + dt))$$

where period is a set of hours and $\mathbf{1}' \cdot \mathbf{W}_{\text{premise}}(t)$ denotes the total electric energy (kWh) of the premise in question. Note that, even though $\mathrm{len}\,(\mathbf{W}_{\text{premise}}(t)) = 1$ for most premises, $\mathrm{len}\,(\mathbf{W}_{\text{Premise 1.2}}(t)) = 2$ for Premise 1.2, an industrial premise with two independently controlled air handling units, whence the need for $\mathbf{1}' \cdot \mathbf{W}_{\text{premise}}(t)$.

In short, $\mathrm{err}^2\,(\hat{\mathbf{W}}_{\text{premise}}, t, dt)$ and $\mathrm{err}^2\,(\hat{\mathbf{T}}_{\text{premise}}, t, dt)$ are normalized sum of squares indexed over $t \in$ period and $dt \in \{0, \ldots, 23\}$, $\mathrm{err}^2\,(\hat{\mathbf{X}}_{\text{premise}}, \text{period}, dt)$ is the normalized sum of squares of the period indexed over $dt \in \{0, \ldots, 23\}$, and $\mathrm{err}\,(\hat{\mathbf{X}}_{\text{premise}}, \text{period}, dt)$ is the corresponding standard deviation for the period indexed over $dt \in \{0, \ldots, 23\}$.

Taken together, $\mathrm{err}^2\,(\hat{\mathbf{W}}_{\text{premise}}, t, dt)$ and $\mathrm{err}^2\,(\hat{\mathbf{T}}_{\text{premise}}, t, dt)$ serve to quantify how the accuracy of the model varies with the time offset dt into the future and can, moreover, be presented as graphs. And computing the averages, we arrive at corresponding scalar measures of accuracy,

$$\mathrm{err}\,(\hat{\mathbf{X}}_{\text{premise}}, \text{period}, \{0, \ldots, 23\}) = \mathrm{sum}\,(dt \in \{0, \ldots, 23\}, \mathrm{err}\,(\hat{\mathbf{X}}_{\text{premise}}, \text{period}, dt)) \,/\, \mathrm{len}\,(\{0, \ldots, 23\}).$$

3.2.1 Stability

Stability will be characterized by computing appropriate statistics for uptime throughout the heating season, with failure to manage measurement signals and control signals in a timely manner shall be considered downtime. This shall, moreover, be done at the level of software component as well as from a system perspective, with the former pertaining to the continuous improvement of the solution and the latter pertaining to the quality of service of the solution.

As for the generation of thermal models in accordance with of Deliverable 2.1, it might be possible to characterize how sensitive a model is in terms of how well it generalizes across different weather conditions. However, the precise choice of statistics will have to wait until data have become available.

3.2.2 Performance

Performance is suitably characterized by statistics on communication and computational delays across the solution. The communication delays can be further divided into those of measurement signals and those of control signals, where the former is expected to dominate but can also be expected to improve in tandem with contemporary IoT technology. The latter is on the other hand expected to reflect internet speed and the relative location of the corresponding software agents. And while it is beyond the FHP project to address internet infrastructure, the corresponding statistics are expected to facilitate an informed discussion on where to locate the software agents; does the statistics favor a centralized solution, or does it permit the software agents to be localized close to the consumer, at the edges of the network?

To facilitate an informed discussion on the architecture, it will also be necessary to characterize the computational delays, in particular, on the number of iterations necessary for the solution to converge with adequate numerical precision, and on the time per iteration, with the latter involving message passing between the DCM and the Safer agents.

3.2.3 Accuracy

The processes for evaluating the accuracy of day-ahead (DA) and intraday (ID) predictions for a DER are comparable, though with the difference that DA restricts attention to predictions with a specific start time of the day while ID follows the previous laid out pattern. Furthermore, the process generalizes to the level of DCM, DSO, and BRP.

Analogously, one can write down statistics that quantify how well an MPC solution can track an electricity consumption profile (DER, or aggregated). In the case of DER, this degenerate to a rough measure of how well the method of indirect control

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by means of temperature offset suffice for controlling the energy consumption, while in the case of aggregated electricity consumption subject to an MPC solution targeting the social optimum, the statistics provide a more relevant measurement of accuracy.

The above-mentioned measure for how well the method of indirect control by means of temperature offset suffice for controlling the energy consumption of a DER fails to take the delay between onset of control and induced response into account. To quantify the delay, instead compute the correlation across different delays and characterize the distribution, preferably by means of a measurement of the average delay and a measurement of the statistical dispersion of the delay.

Unless otherwise stated, we shall perform these computations over a 24-hour time horizon and at the time resolution set by the sample rate of the corresponding measurement equipment, i.e., the pilot in the Netherlands shall be evaluated against a sample rate of once per 15 min, and the pilot in Sweden shall be evaluated against a sample rate of once per 5 min.

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4 Plan, Execution

The purpose of the execution plan is to describe how to execute the different test runs to the end of collecting adequate data to perform the desired evaluation. This, in turn, involves spelling out operational procedures, the different combinations of technological artefacts to be evaluated, the different time horizons that they should be evaluated over, and to schedule the different test runs. Furthermore, it is necessary to design the schedule to accommodate relaxation periods, were a perturbed DER has time to return to its unperturbed thermal state, and to accommodate reference periods, where the relaxed DER can be monitored to provide data for the thermal models and to facilitate evaluation against the backdrop of seasonal variations, i.e., autumn-winter-spring.

To keep the presentation readable, and to facilitate tracking of the execution effort throughout the heating season, the schedules will be managed in a separate spreadsheet located at the project SharePoint.

4.1 Task 4.3, The Netherlands (NL)

The pilot in the Netherlands will be executed with a sample rate of once per 15 min.

4.1.1 Unit Tests

Here, unit tests only refer to the evaluation of the hardware and communication solutions, and the generation and evaluation of thermal models, and not the software unit tests integral to the software development process.

4.1.1.1 Verification and Validation of Installed Equipment

Here, *verification and validation* serve to confirm digital access, other operational capabilities, and desired functionality, i.e., to establish a record of tests conducted over a number of successive days, and to confirm that the recorded behavior falls within the expected as well as desired behavior. In practice, the process consists of a toggling the communication settings every few hours over an extended period, as well as attempting a standardized set of control actions, and recording the responses, and once the record is complete, evaluating the recorded behavior.

As of 2018-10-01, the hardware and communications solutions of Site 5 are deemed fully operational. For further details, see the corresponding parts of Section 6, *Installations and Actions*.

4.1.1.2 Generation and Evaluation of Thermal Models

As part of Deliverable 2.1, HON, TEC and VITO have each developed one data-driven algorithm for constructing a thermal model. To verify that the algorithms are fit for the intended purpose, they shall be used to generate thermal models for Site 5, which shall then be used to gauge the algorithms by means of comparing the by the

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model predicted behavior against the observed behavior, cf., Section 3.2, *Statistics*, and Section 3.2.3, *Accuracy*.

Since the generation and evaluation of thermal models does not involve any active control, the different solutions can be evaluated simultaneously. Instead, the weather can, depending on the solution, constitute a limiting factor in the sense that generation and evaluation requires an extended period of representative outdoor temperatures.

4.1.2 Integration Tests

The integration tests, one per use case, serves to validate that the different parts work together as desired This is done by repeatedly executing Use Case 1-3, day-ahead (DA) and intraday (ID), subject to realistic market interactions and realistic requests for flexibility modelling the presence of intermittent energy sources.

4.1.2.1 Use Case 1

Evaluate the solution VITO DSO and DCM (Forecaster, Planner, Tracker) + VITO Shaper (Ecovat) against the Ecovat over three days, each day structured in the same way, e.g.,

Time	**Action**
12:00	Generate a thermal model
14:00	24:00 h horizon DA
20:00	18:00 h horizon ID
02:00	12:00 h horizon ID
08:00	06:00 h horizon ID

Here, the plan assumes that the day-ahead market opens/closes 14:00.

To be deemed a success, the evaluation should execute automatically, without manual intervention, and as desired over the period of three days,

Start	**End**	**Site**	**Solution**
2018-11-05 14:00		5	VITO + VITO
	2018-11-08 14:00	5	VITO + VITO

While essentially a measure of stability, the results is necessary qualitative in nature, i.e., success or failure.

4.1.2.2 Use Case 2

Evaluate the solution TEC BRP + VITO DSO and DCM (Forecaster, Planner, Tracker) + VITO Shaper (Ecovat) against the Ecovat over two days, each day structured in the same way, e.g.,

Time	**Action**
14:00	24:00 h horizon DA

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20:00	18:00 h horizon ID
02:00	12:00 h horizon ID
08:00	06:00 h horizon ID

Here, the plan assumes that the day-ahead market opens/closes 14:00.

To be deemed a success, the evaluation should execute automatically, without manual intervention, and as desired over the period of three days,

Start	End	Site	Solution
2018-12-03 14:00		5	TEC + VITO + VITO
	2018-12-05 14:00	5	TEC + VITO + VITO

While essentially a measure of stability, the results is necessary qualitative in nature, i.e., success or failure.

4.1.2.3 Use Case 3

Evaluate the solution TEC BRP + VITO DSO and DCM (Forecaster, Planner, Tracker) + VITO Shaper (Ecovat) against the Ecovat over two days divided into 2 × 24 × 4 = 96 PTU cycles of 15 min, e.g.,

Time	Action
14:00	00:15 h horizon PTU
…	
13:45	00:15 h horizon PTU
14:00	00:15 h horizon PTU
14:15	00:15 h horizon PTU
…	
13:34	00:15 h horizon PTU

Here, the plan assumes that the day-ahead market opens/closes 14:00.

To be deemed a success, the evaluation should execute automatically, without manual intervention, and as desired over the period of three days,

Start	End	Site	Solution
2019-02-04 14:00		5	TEC + VITO + VITO
	2019-02-06 14:00	5	TEC + VITO + VITO

While essentially a measure of stability, the results is necessary qualitative in nature, i.e., success or failure.

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4.1.3 Stress and Robustness Tests

The stress tests and the robustness tests focus on diametrically opposite operational conditions, from the extreme to the mundane. And while the stress tests are necessary qualitative in nature, the robustness test are quantitative in nature, and serves to provide the bulk of data for computing the KPIs of Section 3, *Plan, Evaluation*.

4.1.3.1 Stress Tests

The stress tests consist of triggering specific corner cases with respect to timing, both day-ahead and intraday, as well as with respect to requested flexibility. The choice of corner cases shall be informed by domain experts but could, for example, cover the solution initiating market interaction in a way that overlap with critical points in time, such as the opening or closing of the market, and exceptional requests for flexibility.

While individually brief, proper execution of the stress tests may require the presence of domain experts, why it is advisable to set aside at least two weeks for these tests, e.g.,

Table 3, Suggested schedule for stress tests in the NL-site

Start	End	Site	Solution
2019-02-11		5	VITO, TEC
	2019-02-24	5	VITO, TEC

While essentially a measure of stability, the results of each stress test is necessary qualitative in nature, i.e., success or failure.

4.1.3.2 Robustness Tests

The robustness tests involve executing the solution for longer periods subject to continuous MPC and to realistic requests for flexibility modelling the presence of intermittent energy sources. The tests start with periods of one week and continues with periods up to one month towards the end of the heating season, the idea being to provide more rapid feedback early on.

For the Ecovat, the choice of periods is dictated by the desired level of confidence with respect to the energy market interaction, which is more prominent than for the Swedish pilot.

The robustness test should focus on Use Case 3 and the intraday market, for which the FHP project provide three solutions (HON, TEC, VITO). Since the scenario involves MPC, there is only possible to evaluate one solution per collection of DERs and period. And to facilitate the evaluation of more complex market scenarios, it is suggested that the periods are kept moderate in length, e.g.,

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Table 4, Suggested schedule for robustness tests in the NL-site

Start	End	Site	Solution
2019-03-18		5	VITO + TEC
	2019-03-24	5	VITO + TEC
2019-03-25		5	VITO + TEC
	2019-03-31	5	VITO + TEC
2019-04-01		5	VITO + TEC
	2019-04-07	5	VITO + TEC
2019-04-08		5	VITO + TEC
	2019-04-14	5	VITO + TEC
2019-04-15		5	VITO + TEC
	2019-04-21	5	VITO + TEC
2019-04-22		5	VITO + TEC
	2019-04-28	5	VITO + TEC

The robustness tests should generate data suitable for ascertaining stability and precision as well as accuracy, cf., Section 3.2, *Statistics*.

4.2 Task 4.4, Sweden (SE)

The pilot in Sweden will be executed with a sample rate of once per 5 min.

4.2.1 Unit Tests

Here, unit tests only refer to the evaluation of the hardware and communication solutions, and the generation and evaluation of thermal models, and not the software unit tests integral to the software development process.

4.2.1.1 Verification and Validation of Installed Equipment

Here, *verification and validation* serve to confirm digital access, other operational capabilities, and desired functionality, i.e., to establish a record of tests conducted over a number of successive days, and to confirm that the recorded behavior falls within the expected as well as desired behavior. In practice, the process consists of a toggling the communication settings every few hours over an extended period, as well as attempting a standardized set of control actions, and recording the responses, and once the record is complete, evaluating the recorded behavior.

As of 2018-10-01, the hardware and communications solutions of Site 1 and Site 2, with the exception of the most recent contribution of Premise 2.1, are deemed fully operational. As of 2018-10-30, the latter is undergoing standardized verification and validation tests in accordance with the NODA Smart Heat Building product. The process extends over a two-week period and will be completed in advance of 2018-11-15. For further details, see the corresponding parts of Section 6, *Installations and Actions*.

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research and innovation programme under grant agreement No 731231.

4.2.1.2 *Generation and Evaluation of Thermal Models*

As part of Deliverable 2.1, HON, TEC and VITO have each developed one data-driven algorithm for constructing a thermal model. To verify that the algorithms are fit for the intended purpose, they shall be used to generate thermal models for Site 5, which shall then be used to gauge the algorithms by means of comparing the by the model predicted behavior against the observed behavior, cf., Section 3.2, *Statistics*, and Section 3.2.3, *Accuracy*.

Since the generation and evaluation of thermal models does not involve any active control, the different solutions can be evaluated simultaneously. Instead, the weather can, depending on the solution, constitute a limiting factor in the sense that generation and evaluation requires an extended period of representative outdoor temperatures.

As of 2018-10-30, the outdoor temperatures in Karlshamn, Sweden, have been sufficiently low for about two weeks, and with the exception of Premise 2.1, which is still under active control, the different premises have remained unperturbed for about the same period. Consequently, the situation is deemed suitable for the generation and evaluation of thermal models. However, note that the solutions should be executed per premise, e.g.,

Table 5, Suggested schedule for thermal models' generation and evaluation based on the SE-site

Start	End	Premise	Solution
2018-11-19		1.1-3, 2.1-3	HON, TEC, VITO
	2018-11-25	1.1-3, 2.1-3	HON, TEC, VITO

The data gathered should suffice for an initial assessment of stability, performance, and accuracy (at the level of DER), cf., Section 3.2, *Statistics*.

4.2.2 Integration Tests

The integration tests, one per use case, serves to validate that the different parts work together as desired.

4.2.2.1 *Use Case 1*

Evaluate the solution VITO DSO and DCM (Forecaster, Planner, Tracker) + HON | TEC | VITO Shaper (MPC) against Site 1 + Site 2 over three days, each day structured in the same way, e.g.,

Time	Action
12:00	Generate a thermal model
14:00	24:00 h horizon DA
20:00	18:00 h horizon ID
02:00	12:00 h horizon ID
08:00	06:00 h horizon ID

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Here, the plan assumes that the day-ahead market opens/closes 14:00.

To be deemed a success, the evaluation should execute automatically, without manual intervention, and as desired over the period of three days,

Start	End	Site	Solution
2018-11-12 14:00		1, 2	VITO + HON
	2018-11-15 14:00	1, 2	VITO + HON
2018-11-19 14:00		1, 2	VITO + TEC
	2018-11-22 14:00	1, 2	VITO + TEC
2018-11-26 14:00		1, 2	VITO + VITO
	2018-11-29 14:00	1, 2	VITO + VITO

While essentially a measure of stability, the results is necessary qualitative in nature, i.e., success or failure.

4.2.2.2 Use Case 2

Evaluate the solution TEC BRP + VITO DSO and DCM (Forecaster, Planner, Tracker) + HON | TEC | VITO Shaper (MPC) against Site 1 + Site 2 over two days, each day structured in the same way, e.g.,

Time	Action
14:00	24:00 h horizon DA
20:00	18:00 h horizon ID
02:00	12:00 h horizon ID
08:00	06:00 h horizon ID

Here, the plan assumes that the day-ahead market opens/closes 14:00.

To be deemed a success, the evaluation should execute automatically, without manual intervention, and as desired over the period of three days,

Start	End	Site	Solution
2018-12-03 14:00		1, 2	TEC + VITO + HON
	2018-12-05 14:00	1, 2	TEC + VITO + HON
2018-12-10 14:00		1, 2	TEC + VITO + TEC
	2018-12-12 14:00	1, 2	TEC + VITO + TEC
2018-12-17 14:00		1, 2	TEC + VITO + VITO
	2018-12-19 14:00	1, 2	TEC + VITO + VITO

While essentially a measure of stability, the results is necessary qualitative in nature, i.e., success or failure.

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4.2.2.3 *Use Case 3*

Evaluate the solution TEC BRP + VITO DSO and DCM (Forecaster, Planner, Tracker) + HON | TEC | VITO Shaper (MPC) against Site 1 + Site 2 over two days divided into 2 × 24 × 4 = 96 PTU cycles of 15 min, e.g.,

Time	Action
14:00	00:15 h horizon PTU
…	
13:45	00:15 h horizon PTU
14:00	00:15 h horizon PTU
14:15	00:15 h horizon PTU
…	
13:34	00:15 h horizon PTU

Here, the plan assumes that the day-ahead market opens/closes 14:00.

To be deemed a success, the evaluation should execute automatically, without manual intervention, and as desired over the period of three days,

Start	End	Site	Solution
2019-02-04 14:00		1, 2	TEC + VITO + HON
	2019-02-06 14:00	1, 2	TEC + VITO + HON
2019-02-11 14:00		1, 2	TEC + VITO + TEC
	2019-02-13 14:00	1, 2	TEC + VITO + TEC
2019-02-18 14:00		1, 2	TEC + VITO + VITO
	2019-02-20 14:00	1, 2	TEC + VITO + VITO

While essentially a measure of stability, the results is necessary qualitative in nature, i.e., success or failure.

4.2.3 Stress and Robustness Tests

The stress tests and the robustness tests focus on diametrically opposite operational conditions, from the extreme to the mundane. And while the stress tests are necessary qualitative in nature, the robustness test are quantitative in nature, and serves to provide the bulk of data for computing the KPIs of Section 3, *Plan, Evaluation*.

4.2.3.1 *Stress Tests*

The stress tests consist of triggering specific corner cases with respect to timing, both day-ahead and intraday, as well as with respect to requested flexibility. The choice of corner cases shall be informed by domain experts but could, for example, cover the solution initiating market interaction in a way that overlap with critical

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points in time, such as the opening or closing of the market, and exceptional requests for flexibility.

While individually brief, proper execution of the stress tests may require the presence of domain experts, why it is advisable to set aside at least two weeks for these tests, e.g.,

Table 6, Suggested schedule for stress tests in the SE-site

Start	End	Site	Solution
2019-02-25		1, 2	HON, TEC, VITO
	2019-03-10	1, 2	HON, TEC, VITO

While essentially a measure of stability, the results of each stress test is necessary qualitative in nature, i.e., success or failure.

4.2.3.2 Robustness Tests

The robustness tests involve executing the solution for longer periods subject to continuous MPC and to realistic requests for flexibility modelling the presence of intermittent energy sources. The tests start with periods of one week and continues with periods up to one month towards the end of the heating season, the idea being to provide more rapid feedback early on.

For the Swedish pilot, the focus is less on realistic market interaction (which will have to be simulated) and more on quality of service throughout the heating season, which suggests a rapid increase towards longer periods.

The robustness test should focus on Use Case 3 and the intraday market, for which the FHP project provide three solutions (HON, TEC, VITO). Since the scenario involves MPC, there is only possible to evaluate one solution per collection of DERs and period, and it is suggested three solutions are rotated through Site 1 and Site 2 over three longer periods towards the end of the heating season, e.g.,

Table 7, Suggested schedule for robustness tests in the SE-site

Start	End	Site	Solution
2019-03-18		1, 2	TEC + VITO + HON
	2019-03-24	1, 2	TEC + VITO + TEC
2019-03-25		1, 2	TEC + VITO + VITO
	2019-03-31	1, 2	TEC + VITO + HON
2019-04-01		1, 2	TEC + VITO + TEC
	2019-04-07	1, 2	TEC + VITO + VITO
2019-04-08		1, 2	TEC + VITO + HON

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	2019-04-14	1, 2	TEC + VITO + TEC
2019-04-15		1, 2	TEC + VITO + VITO
	2019-04-21	1, 2	TEC + VITO + HON
2019-04-22		1, 2	TEC + VITO + TEC
	2019-04-28	1, 2	TEC + VITO + VITO

The robustness tests should generate data suitable for ascertaining stability and precision as well as accuracy, cf., Section 3.2, *Statistics*.

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5 Sites and Premises

The purpose of this section is to provide a description of the sites and premises, and the equipment already on site, in particular, heat pumps and other thermal resources and, when applicable, provide context by means of blueprints, technical drawings, and historical data. The content of this section reflects what have become known through surveys and through the subsequent audits of Section 6. However, this section focuses on what can be controlled and measured while the audits of Section 6 are tailored towards how to implement the desired capabilities. The figure below provides and overview of the electricity consumption of the industrial and residential premises.

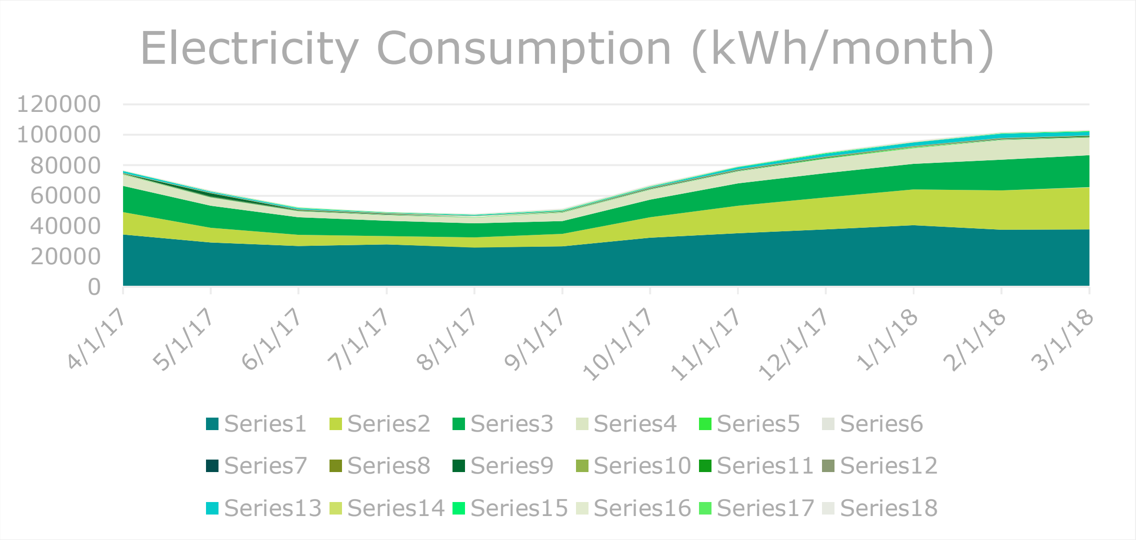

Figure 1 Electricity consumption of Site 1 + Site 2. Series 1-3 correspond to the industrial premises in order. Series 4 correspond to the base load of Premise 1.2 [anonymized].

The industrial premises of Site 1 and the residential premises of Site 2 have been anonymized to protect the business interests and privacy of the companies and natural persons involved, who have so kindly agreed to participate in this research project. The industrial premises will be referred to as Premise 1.1-3 and the residential premises will be referred to as Premise 2.1-3, with a corresponding self-explanatory naming convention for the associated substations.

5.1 Site 1: Industrial Premises

The three industrial premises are located along the same road [anonymized], and connected to the same electricity substation, Substation 1.1 [anonymized] (800 kVA). The site presents the combined opportunity of a common electrical grid that can be probed for details with buildings subject to a wide range of natural temperature variations, where induced temperature variations are unlikely to result in material damage or complaints. To be precise, there are still temperature constraints that should be respected at all times, such as the temperatures in offices and the temperatures in frost-protected areas, but taken together, these constraints are still less severe than those for residential buildings or for the storage of food stuff. The figure below provides provide an overview of the electricity consumption of Site 1.

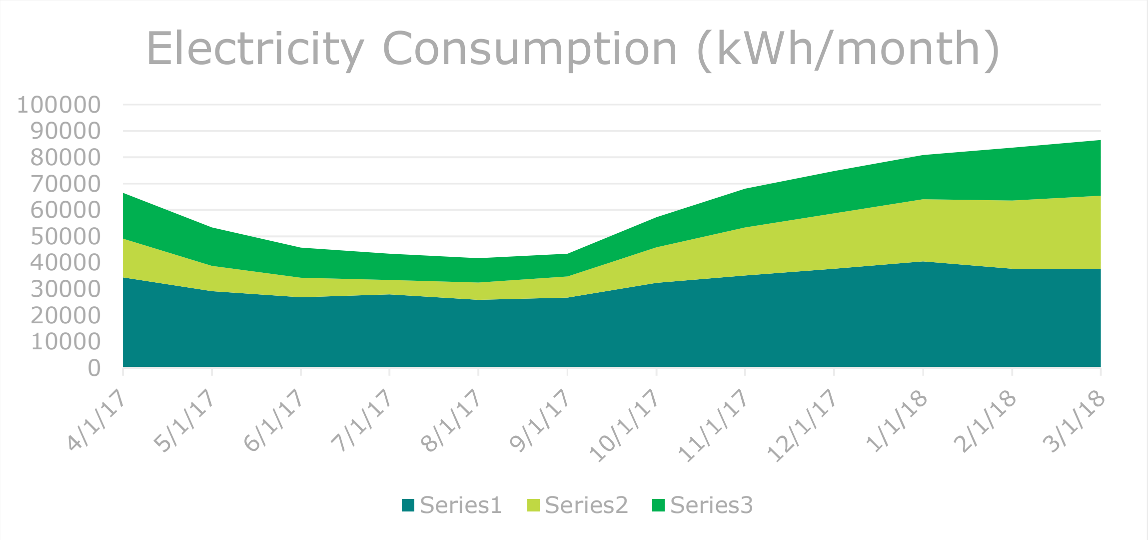

Figure 2 Energy consumption of Site 1. Series 1-3 correspond to the industrial premises in order.

5.1.1 Premise 1.1 [anonymized]

Premise 1.1 is a logistics company with three main buildings, a combined office and hangar (top-left/north-west), two refrigerated containers just outside the hangar (top-left/north-west), a frost-protected warehouse (top-right/north-east), and a combined garage and workshop (bottom-left/south-west). The load on the electrical grid is dictated by the power consumption of the heat pumps together with the power consumption of compressors, the power consumption for welding, and load for the charging of electrical fork lifters. The figure below provides an overview of the electricity consumption of Premise 1.1.

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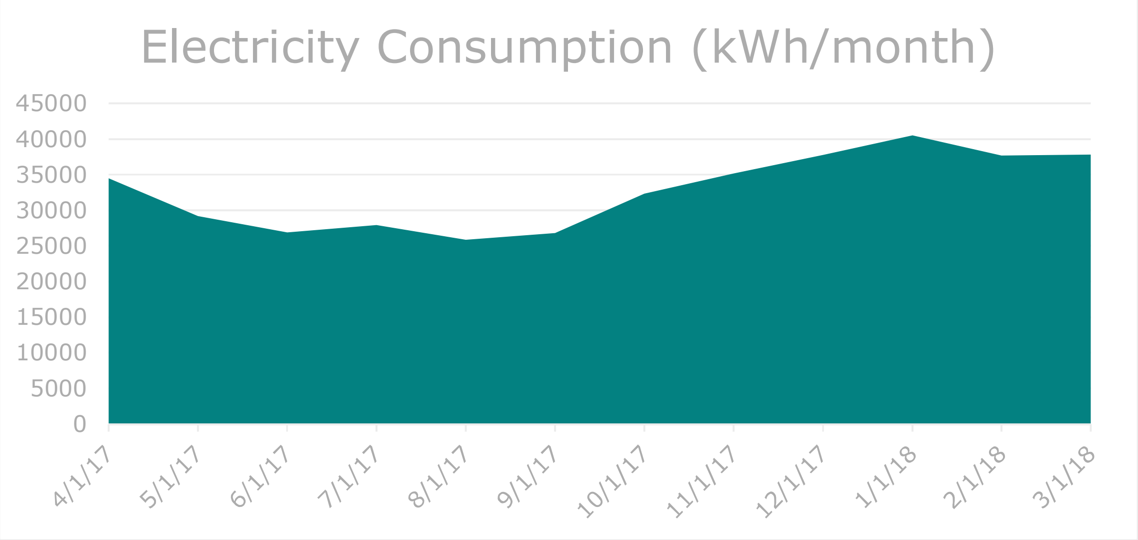

Figure 3 Electricity consumption of Premise 1.1.

The situation is outlined in the table below.

Location	**Installation**	**Power (kW)**	**Heat**
Garage/Workshop	2 × AAHP	2 × 1-3	15 %
Garage/Workshop	1 × Oil Burner	1 × 200	30 %
Hangar/Office	1 × GSHP	1 × 3-10	40 %
Warehouse	2 × AAHP	2 × 1-3	15 %

The oil burner is from the 70's and is difficult to monitor and control directly. However, it can be monitored by a suitably placed 1-wire sensor [datasheet_thermokon_VFG54_LON.pdf]. There is a risk that the oil burner will compensate for down regulation of the heat pumps, which is undesirable from an economic as well as an environmental perspective and should be avoided. Moreover, as the ASHPs are wall mounted and thus also difficult to monitor and control, it is suggested that the pilot here focuses on the GSHP.

The heat pump (GSHP) is configured to maintain a supply temperature as determined by a heating curve, which in turn is determined by the outdoor temperature. The water flow can be assumed constant.

Heating Curve	
-20 °C	60 °C
-10 °C	60 °C
-5 °C	49 °C
0 °C	58 °C
5 °C	49 °C
10 °C	35 °C
20 °C	27 °C

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5.1.2 Premise 1.2 [anonymized]

Premise 1.2 is a logistics company that rents out half of its hangar to another company that sells industrial robots, and which uses the hangar for control assembly of the same robots before delivery. The two parts are separated by a thick plastic curtain, with the part used for robots (west) significant warmer than the part used by the logistics company (east). Adjacent to the east hangar is a vacant office. The figure below provides an overview of the electricity consumption of Premise 1.2.

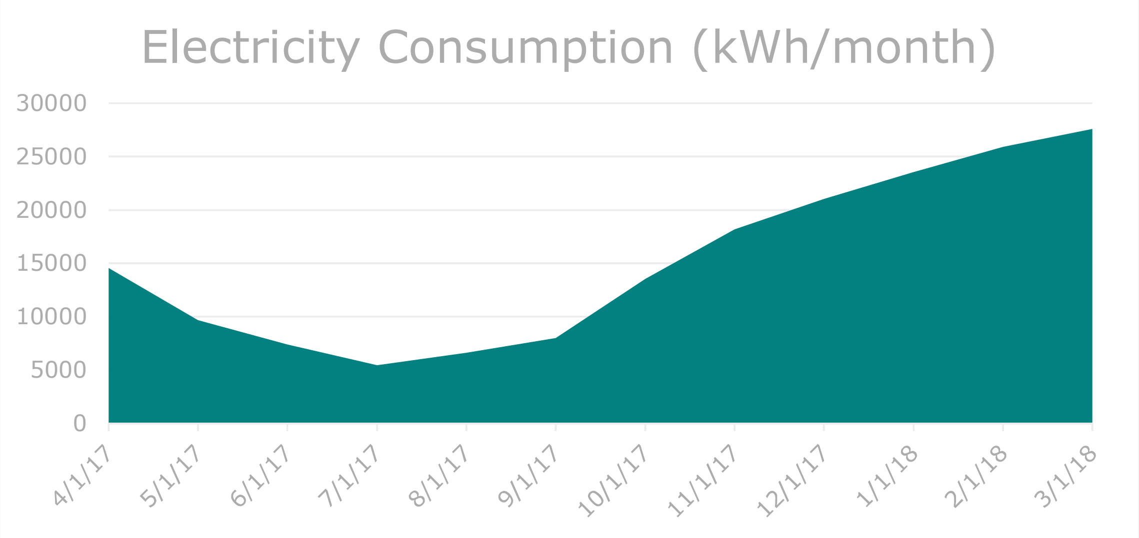

Figure 4 Electricity consumption of Premise 1.2.

The premise is heated by two industrial air handling unit, one for each part, each which in turn contains two Mitsubishi ASHP. The situation is outlined in the table below.

Table 8, Installations in premise 1.2

Location	Installation	Power (kW)	Heat
Hangar (east)	2 × ASHP	2 × 2-10	50 % (2 × 10-30 kW)
Hangar (west)	2 × ASHP	2 × 2-10	50 % (2 × 10-30 kW)

For each air handling unit, the indoor temperature determines the temperature set point, which in turn regulates the air inlet in cascade. Each air handling unit is controlled by a Modbus DUC. The individual heat pumps are controlled by a 0-10 V signal, where 0-4 V means OFF and the compressor permits 7 steps above 4 V.

The heat pumps (ASHG, A/A) are regulated on measured indoor temperature. The controlling logic is implemented by means of a PID with unknown coefficients but

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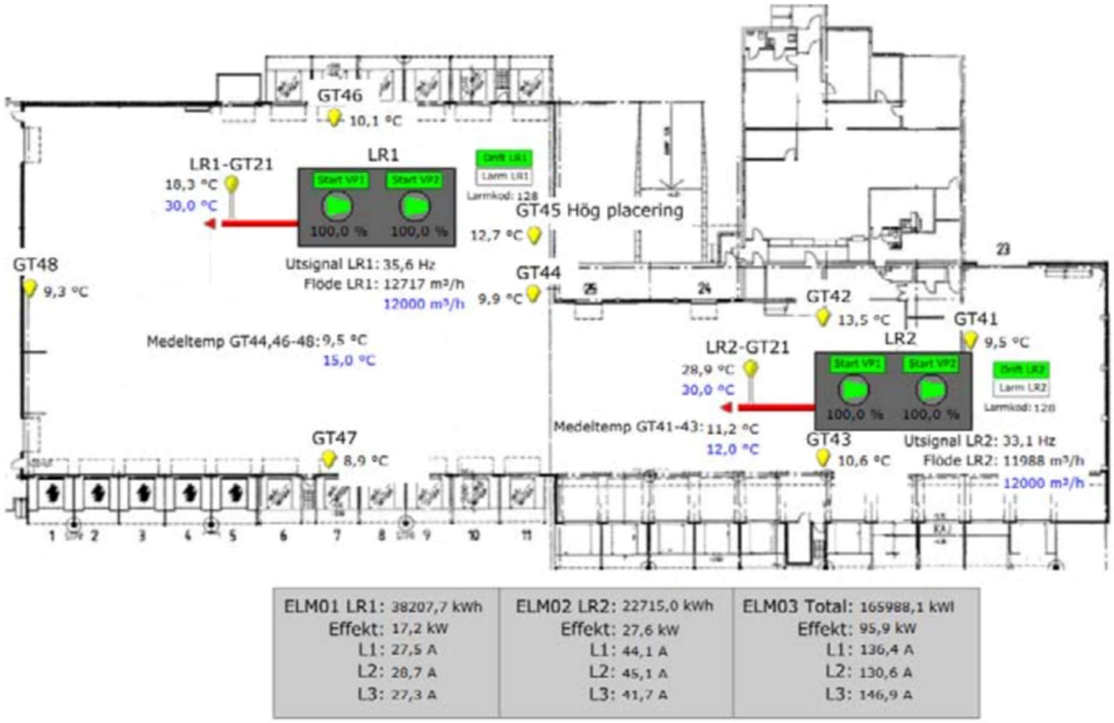
with known setpoints. The airflow can be assumed constant during the day and turned off at night and weekends.

By replacing the measured value with a synthetic value, it is possible to increase as well as reduce the heat pump's power consumption. Furthermore, the two air handling units can be controlled independently, and the premise is suited to a multi-zone approach.



ELM01 LR1: 38207,7 kWh
Effekt: 17,2 kW
L1: 27,5 A
L2: 28,7 A
L3: 27,3 A

ELM02 LR2: 22715,0 kWh
Effekt: 27,6 kW
L1: 44,1 A
L2: 45,1 A
L3: 41,7 A

ELM03 Total: 165988,1 kWl
Effekt: 95,9 kW
L1: 136,4 A
L2: 130,6 A
L3: 146,9 A

Figure 5 Layout of the premise, with cross references to the operational card.

Table 9, System settings in premise 1.2

Settings (west)		
Component	**Description**	**Value**
LR1	Service	7000 m3/h
LR1	Full Operation	7500 m3/h
GT44, 46-48	Room Temperature	15 °C
GT21	Min Inlet Temperature	10 °C
GT21	Max Inlet Temperature	21 °C
GT44, 46-48	Room Start/Stop	15 °C
GT44, 46-48	Room Hysteresis	2 °C

Settings (east)		
Component	**Description**	**Value**
LR2	Service	9000 m3/h

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LR2	Full Operation	12000 m3/h
GT41-43	Room Temperature	12 °C
LR2-GT21	Min Inlet Temperature	10 °C
LR2-GT21	Max Inlet Temperature	15 °C
GT41-43	Room Start/Stop	12 °C
GT41-43	Room Hysteresis	2 °C

Time Channel		
Component	**Description**	**Value**
LR1	Service, Weekdays	05:30-07:30
LR1	Service, Weekdays	22:00-24:00
LR1	Full Operation, Weekdays	05:30-07:30
LR1	Full Operation, Weekdays	22:00-24:00
LR2	Service, Weekdays	05:30-07:30
LR2	Service, Weekdays	22:00-24:00
LR2	Full Operation, Weekdays	05:30-07:30
LR2	Full Operation, Weekdays	22:00-24:00

5.1.3 Premise 1.3 [anonymized]

Premise 1.2 is an engineering company that produce check valves. The building consists of two parts, an office (west) and a poorly insulated workshop (east). The premise is heated by a number electric radiator and ASHPs divided between the office (west) and the poorly insulated workshop (east), respectively. The figure below provides an overview of the electricity consumption of Premise 1.3.

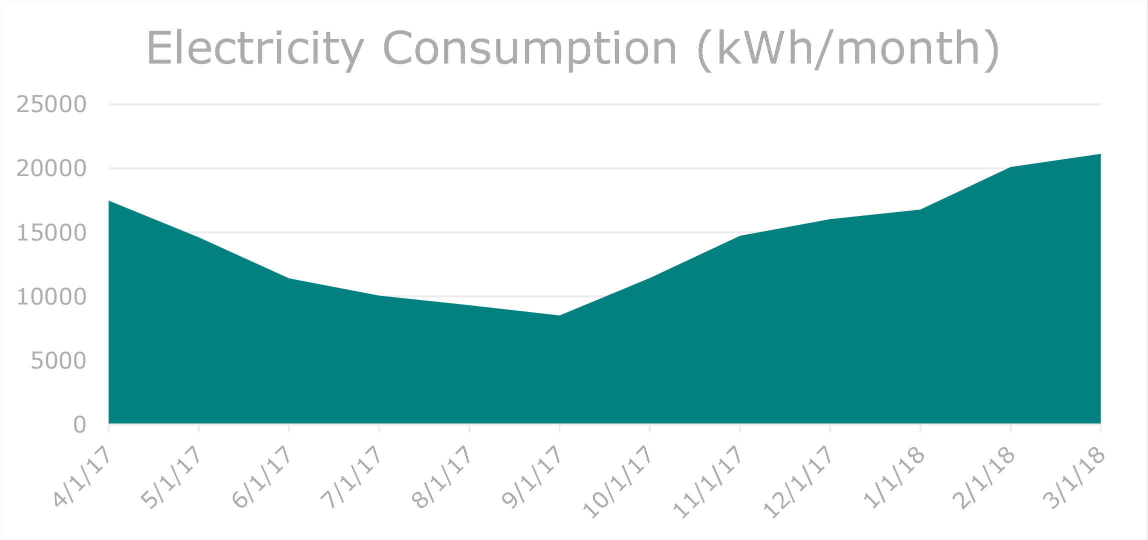

Figure 6 Electricity consumption of Premise 1.3.

The situation is outlined in the table below.

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Table 10, Installations in premise 1.3

Location	Installation	Power (kW)	Heat
Office (west)	1 × AC	Unknown	n/a
Office (west)	n × Electric Radiator	Unknown	20 %
Workshop (east)	5 × AAHP	5 × 1-3	80 %
Workshop (east)	1 × Air Handling Unit	Unknown	n/a

There is, moreover, an electric water heater for DHW which connects to the office as well as to the air handling unit. The latter plausibly for defrosting. Moreover, as the ASHPs are wall mounted and thus also difficult to monitor and control, it is suggested that the pilot here focuses on the generation of thermal models.

The wall mounted heat pumps (ASHG, A2A) are regulated on measured indoor temperature. The controlling logic is implemented by means of a PID with unknown coefficients and unknown setpoints. The airflow can be assumed constant during the day and turned off at night and weekends.

5.2 Site 2: Residential Premises

The three residential premises are located in central Karlshamn under different substations, and the buildings are representative for the central parts of the city of Karlshamn, which mostly consists of small shops and residential housing, with the exception that they rely on heat pumps rather than district heating. That said, the power consumption of Karlshamn is typical for a smaller city, and historical meter data can be made available per apartment as well as for the substations at a resolution of 15 minutes and can be used to establish a baseline. The figure below provides and overview of the electricity consumption of the three premises.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 731231.

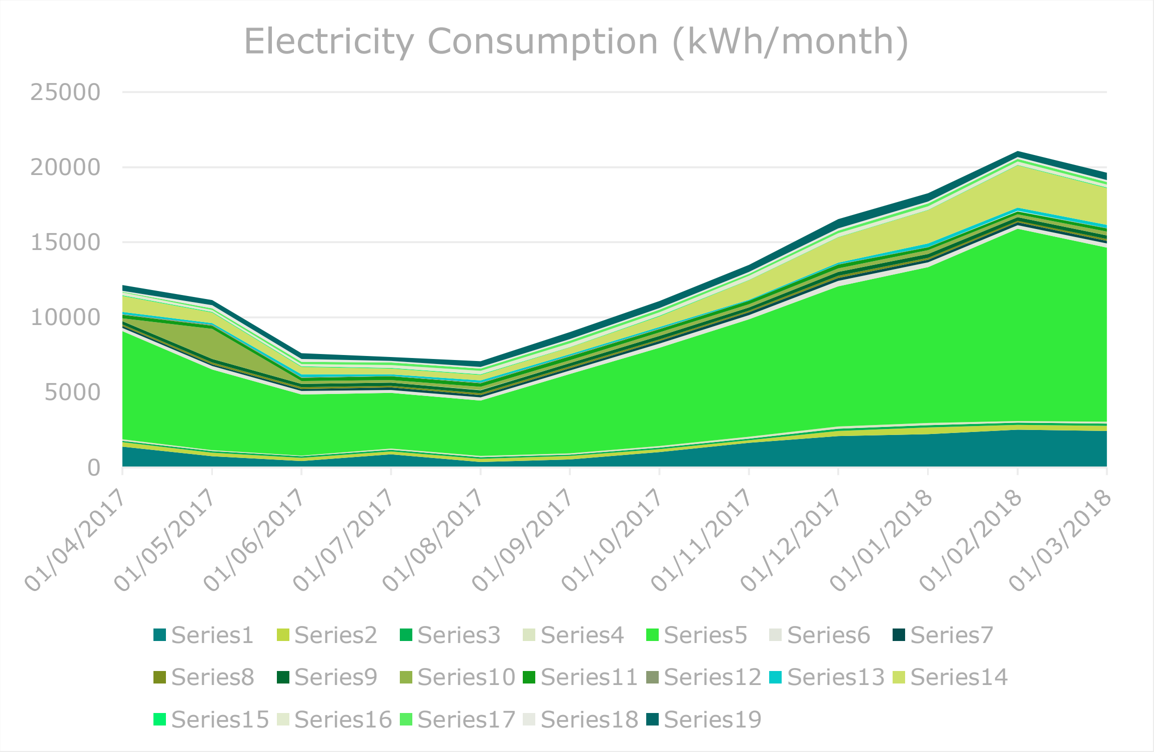

Figure 7 Electricity consumption of Site 2. Series 1 corresponds to the base load of Premise 2.1. Series 5 corresponds to the base load of Premise 2.2. Series 14 correspond to the base load of Premise 2.3.

5.2.1 Premise 2.1 [anonymized]

The premise consists of one major building of three apartments amounting to 316 m^2. The premise is connected to the Substation 2 (800 kVA). The figure below provides an overview of the electricity consumption of Premise 2.1.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

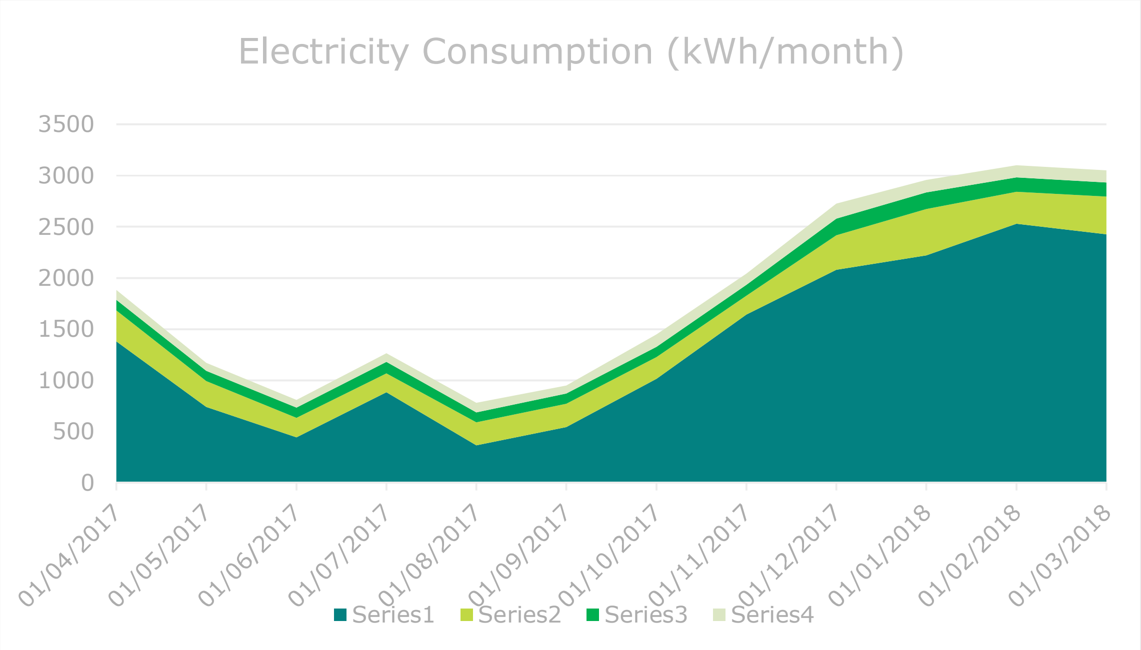

Figure 8 Electricity consumption of Premise 2.1. Series 1 corresponds to the base load, i.e., heating, laundry and stair lightning, while the other series correspond to the electricity consumption of the apartments.

The major building is heated by hot water radiators supplied by one NIBE F1155-12 (3-12 kW) GSHP [datasheet_nibe_F1155.pdf] located in the cellar of the major building. The situation is outlined in the table below.

Table 11, Installation in premise 2.1

Location	Installation	Power (kW)	Heat
Major building	1 × GSHP	1 × 3-12	100 %

The heat pump (GSHP) is configured to maintain a supply temperature as determined by a heating curve, which in turn is determined by the outdoor temperature. The water flow can be assumed constant.

Table 12, Heating curve in premise 2.1

Heating Curve	
-20 °C	40 °C
-10 °C	35 °C
0 °C	32 °C
10 °C	26 °C
20 °C	15 °C
30 °C	15 °C

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

5.2.2 Premise 2.2 [anonymized]

The premise consists of one major building of seven apartments and one minor building of one apartment, the eight apartments amounting to 688 m^2. The two building are heated by hot water radiators supplied with heat by the heating system, which is located in the minor building and connected to the major building through a culvert. The heat is then supplied through two branches, one for the norther part of the major building and one for the southern part of the major building. In addition to the heating system, the minor building also houses a laundry facility. The premise is connected to Substation 2 (800 kVA). The figure below provides an overview of the electricity consumption of Premise 2.2.

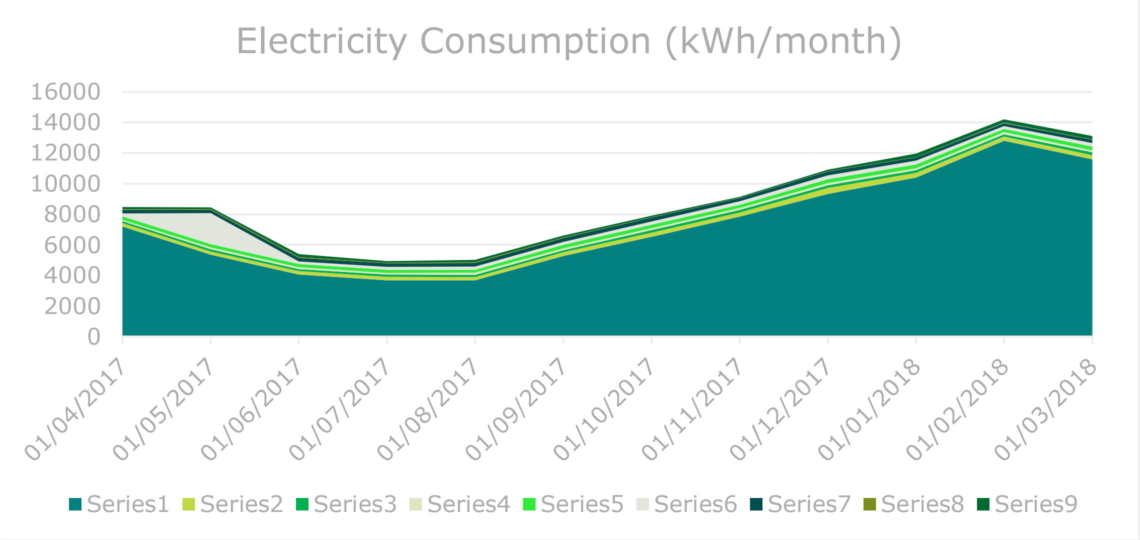

Figure 9 Electricity consumption of Premise 2.2. Series 1 corresponds to the base load, i.e., heating, laundry and stair lightning, while the other series correspond to the electricity consumption of the apartments.

The heating system consists of one Mitsubishi (3-10 kW) AWHP, two water heaters, one stand-alone electric cartridge, and one oil burner. The building owners prefer to use the heat pump [datasheet_mitsubishi_PEA-RP250GAQ.pdf, datasheet_mitsubishi_PUHZ-ZRP200_swedish.pdf, datasheet_alfalaval_ACH-70X-70H.pdf]. However, it is uncertain to what extent the other components are used. The situation is outlined in the table below.

Table 13, Installations premise 2.2

Location	Installation	Power (kW)	Heat
Minor building	1 × AWHP	1 × 3-10	60 %
Minor building	1 × CETE Therma	1 × 1-9	
Minor building	1 × NIBE water heater	1 × 1-3	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

Minor building	1 × electric cartridge	1 × 15	
Minor building	1 × oil burner	1 × 37-50	
Minor building	1 × heat exchanger		

The heat pump (ASHP, A2W) is configured to maintain a constant supply temperature in the primary heating circuit. The amount of heating needed to maintain the constant supply temperature is determined by a three-way vault that controls how much (p) of the heated water from the primary circuit to mix with returning and cooler water from the secondary circuit (1- p), and then to return to the secondary circuit. The other part (1 -p) of heated water from the primary circuit is mixed with the other part (p) of returning cooler water from the secondary circuit and feed back to the heat pump for reheating. The valve is regulated to maintain a desired supply temperature for the secondary circuit, which in turn is determined by the outdoor temperature by means of a heating curve. The two flows can be assumed constant.

Table 14, Heating curve in premise 2.2

Heating Curve	
-20 °C	65 °C
-10 °C	55 °C
0 °C	45 °C
10 °C	35 °C
20 °C	25 °C
30 °C	15 °C

Note that the apartments are for rent and that the heating is included in the rent. Anecdotal evidence suggests that while some tenants tend to lower the set point temperature of their radiators when not using the apartment in question, other tenants have a more wasteful attitude and regulate their apartment temperature by opening and closing windows.

5.2.3 Premise 2.3 [anonymized]

The premise consists of one major building of three apartments and one minor building of two apartments of equal size, the five apartments amounting to 250 m^2. The premise is connected to the Substation 2.1 (800 kVA). The figure below provides an overview of the electricity consumption of Premise 2.3.

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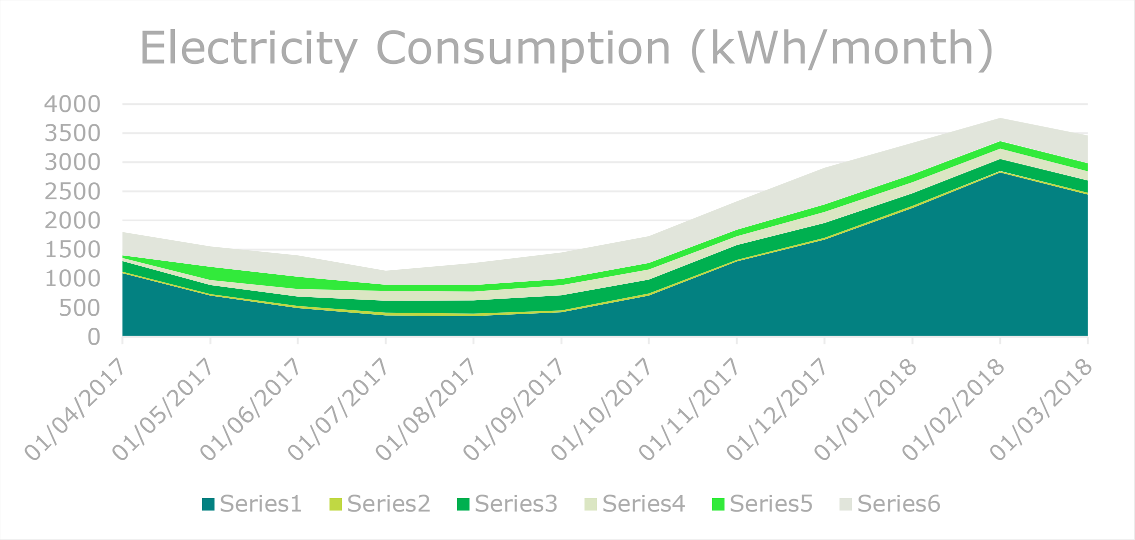

Figure 10 Electricity consumption of Premise 2.3. Series 1 corresponds to the base load, i.e., heating, laundry and stair lightning, while the other series correspond to the electricity consumption of the apartments.

The major building is heated by hot water radiators supplied by one NIBE F1155-12 (3-12 kW) GSHP [datasheet_nibe_F1155.pdf] located in the cellar of the major building while the minor building is heated by a hydronic floor supplied by the same heat pump through a culvert. The situation is outlined in the table below.

Table 15, Installation in premise 2.3

Location	Installation	Power (kW)	Heat
Major building	1 × GSHP	1 × 3-12	100 %

The heat pump (GSHP) is configured to maintain a supply temperature as determined by a heating curve, which in turn is determined by the outdoor temperature. The water flow can be assumed constant.

Table 16, Heating curve in premise 2.3

Heating Curve	
-20 °C	40 °C
-10 °C	35 °C
0 °C	32 °C
10 °C	26 °C
20 °C	15 °C
30 °C	15 °C

Note that the apartments are for rent and that the heating is included in the rent.

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5.3 Site 3 Supermarket

5.3.1 Premise

The supermarket is a modern facility located in the outskirts of Karlshamn, with photovoltaics on the roof. The refrigeration system consists entirely of compressors with about half of the compressors acting directly on refrigerators and temperature-controlled areas through the refrigerant, while the other half acting through a fluid-based coolant system. The heat generated by the compressor units is recycled to the heating system, which is otherwise supported by district heating. RISE have performed an initial analysis of the refrigeration system, though further studies are needed to judge the relative contributions of recycled heat contra district heating.

Note that while the photovoltaics have the capacity to cover the average electricity demand, they seldom do due to the weather. The figure below provides an overview of the electricity consumption of the supermarket.

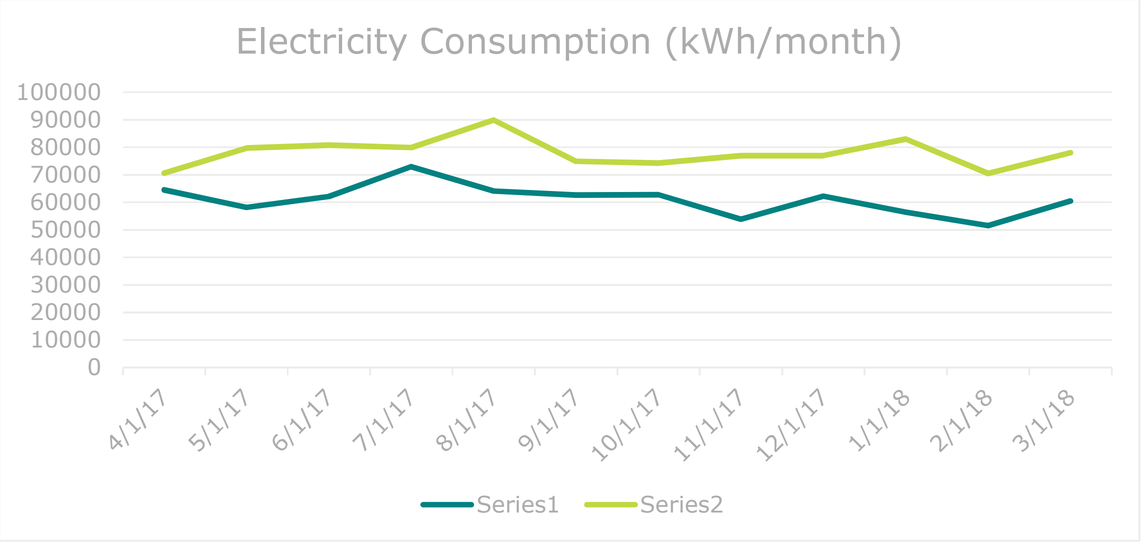

Figure 11 Electricity consumption of Site 3. The supermarket is billed on maximal load (kW) per hour rather than on total consumption (kWh/month). Series 1 depicts to the minimal load per month. Series 2 depicts to the maximal load per month.

The facility is located under its own electricity substation, T50 Scandic, and is otherwise supplied by the photovoltaic panels on its roof. The photovoltaic panels cover about 10 % of the facility’s yearly electricity consumption, though the production can be assumed to be unevenly distributed thought the year with the greater part concentrated to the summer. The facility has the right to sell excess electricity to the grid, though it rarely happens. The situation is outlined in Table 17.

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Table 17, Installations supermarket

Location	Installation	Power (kW)	Heat
Roof	1 × photovoltaics	1 × 0-173	∝ 177 MWh/year
Building	1 × electric subs.	100 (average)	∝ 1767 MWh/year
Building	1 × refrigeration sys.		
Building	1 × DH subs.		383 MWh/year

5.4 Site 4: RISE Research House

5.4.1 Premise

RISE commands a research house [datasheet_rise_RH.pdf] which provides an ideal situation for data collection and presents the opportunity to perform tests unconstrained by commercial concerns and concerns for the comfort of residents. It contains over 100 measuring points for monitoring different installations at a high level of detail and can simulate different loads, currently in the form of a family with programmable behavior. Furthermore, the house offers great flexibility regarding the choice of heat distribution systems, and is equipped with radiators, underfloor heating, and air heating. It can be heated by a source heat pump, a ground heat pump, or district heating, and is prepared for biofuel. It is moreover equipped with photovoltaic panels on the roof.

The research house is currently being upgraded to one NIBE F1155-12 (3-12 kW) GSHP [datasheet_nibe_F1255.pdf]. The situation is outlined in the table below.

Table 18, Installation in the Research House

Location	Installation	Power (kW)	Heat
Building	1 × GSHP	1 × 3-12	100 %

Note that, when controlling inhabited buildings, NODA will impose additional constraints on the amount of control that can be exercised by whatever algorithm is responsible for the control, this to the end of restricting exploratory behaviors to well within acceptable behavior. This to the end to safeguard the comfort of the residents. The research house offers a way around this.

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5.5 Site 5: ECOVAT Uden

5.5.1 Premise

The ecovat is a large subterranean and insulated vessel for thermal energy storage. Heat is exchanged by running hot or cold water through tubes inside the surrounding concrete elements, and the vessel is equipped with sensors to monitor the temperatures of the individual layers. The facility is located at President Kennedylaan 28 in Uden, the Netherlands.

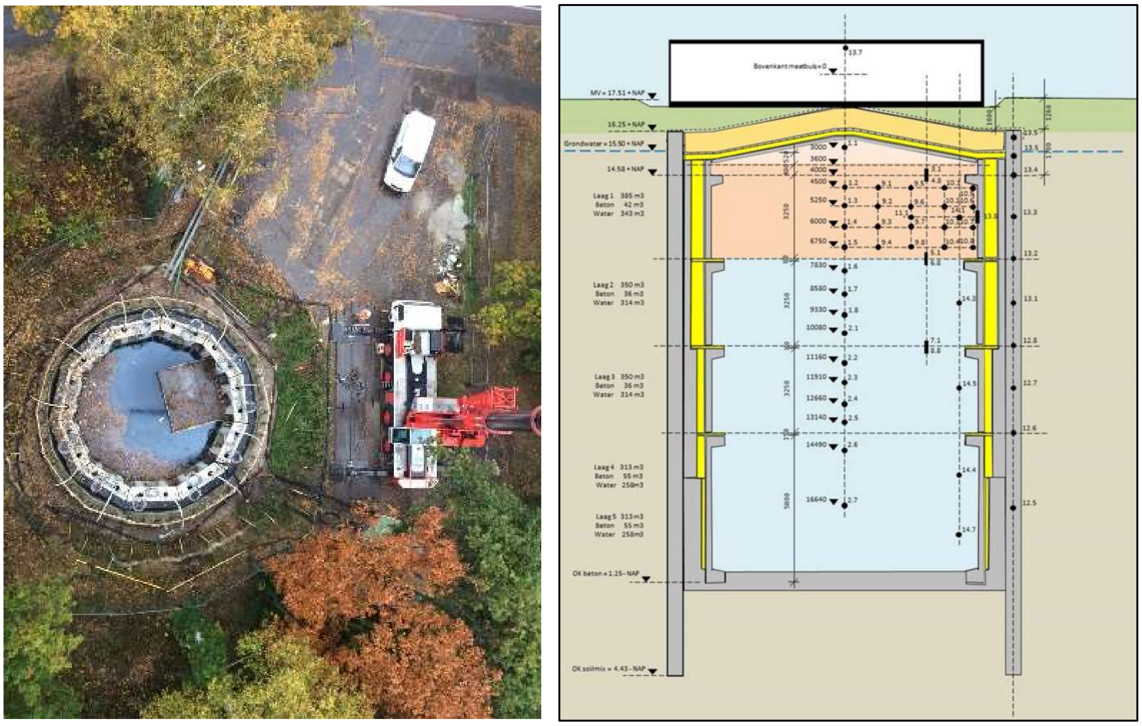

Figure 12, The Ecovat facility

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

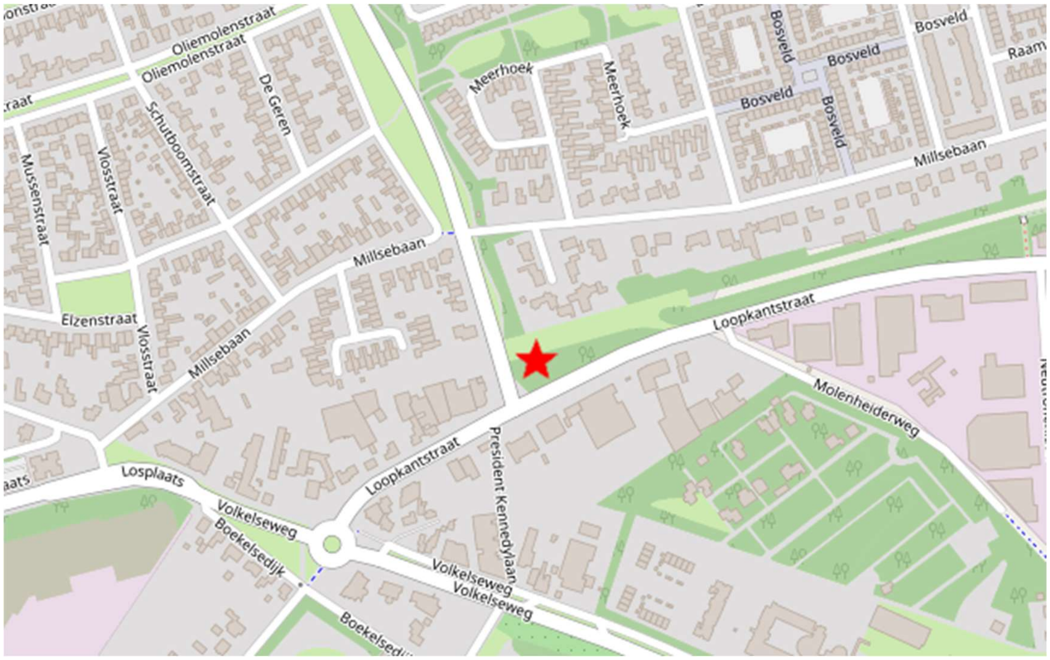

Figure 13 The ecovat is located at President Kennedylaan 28 in Uden, the Netherlands.

The ecovat can roughly be divided into a number software and hardware components, marked in green and red in the figure below.

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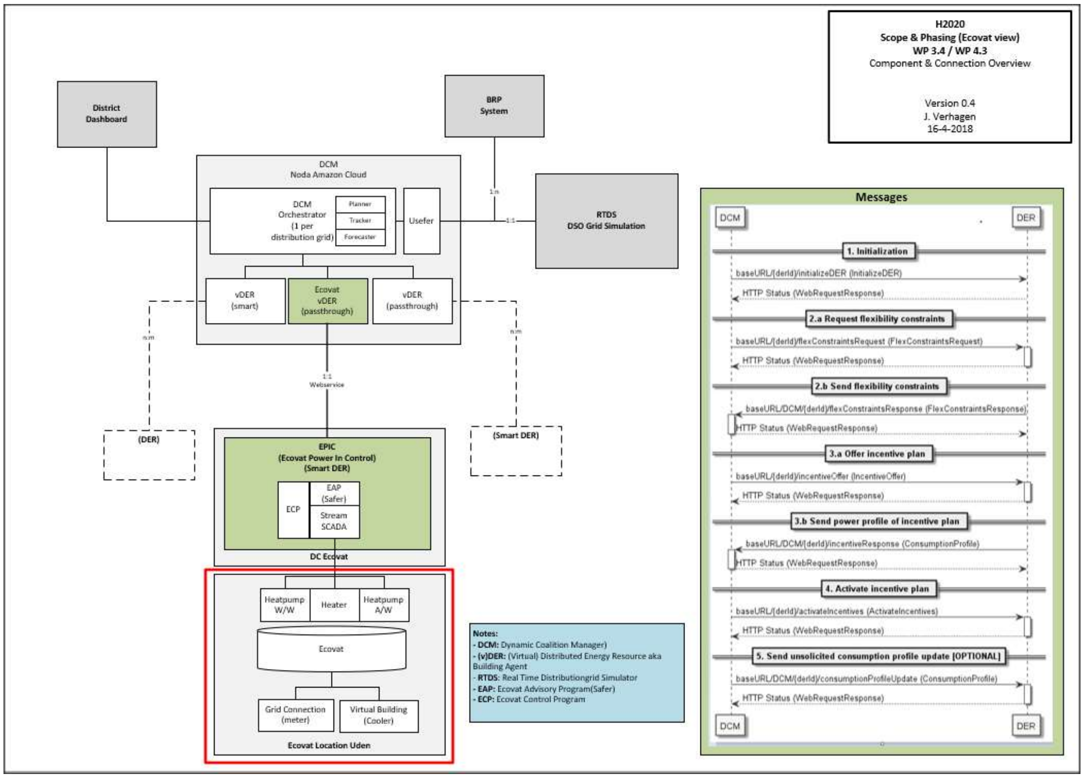

Figure 14 The software and hardware components are marked in green and red, respectively.

5.5.2 ECOVAT Power in Control

The ECOVAT Power in Control (EPIC) system consisting of the ECOVAT Control Program (ECP), the ECOVAT Advice Program (EAP), and the Stream SCADA system.

5.5.2.1 ECOVAT Control Program

The ECOVAT Control Program (ECP) receives commands from the Stream SCADA system and responds with control signals targeting the hardware. ECP prevents the hardware from operating beyond its envelope.

5.5.2.2 ECOVAT Advice Program

The ECOVAT Advice Program (EAP) serves to compute optimal control actions with respect to the state of the Ecovat and exogenous variables such as weather forecasts and energy prices.

5.5.2.3 Stream

The Stream SCADA system is a high-level monitoring and control system connected with the ECP and the EAP.

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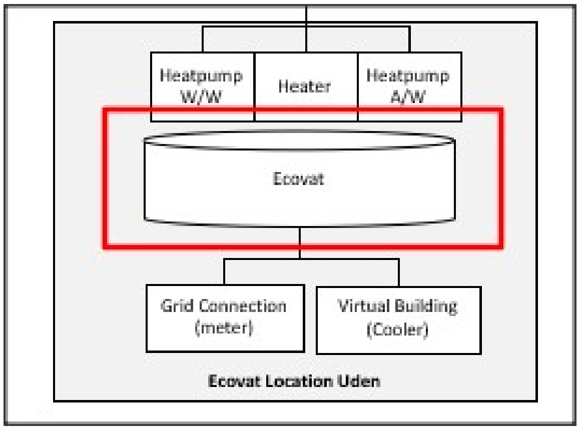
5.5.3 The Ecovat Vessel



Measurement	Quantity	Unit
Diameter of water column	11	m
Outside diameter	13	m
Height of water column	15.5	m
Number of thermal layers	5	
Number of elements per layer	11	
Maximum temperature	90	°C

Figure 15, Data Ecovat vessel

5.5.4 Heat Pumps: A/W and W/W

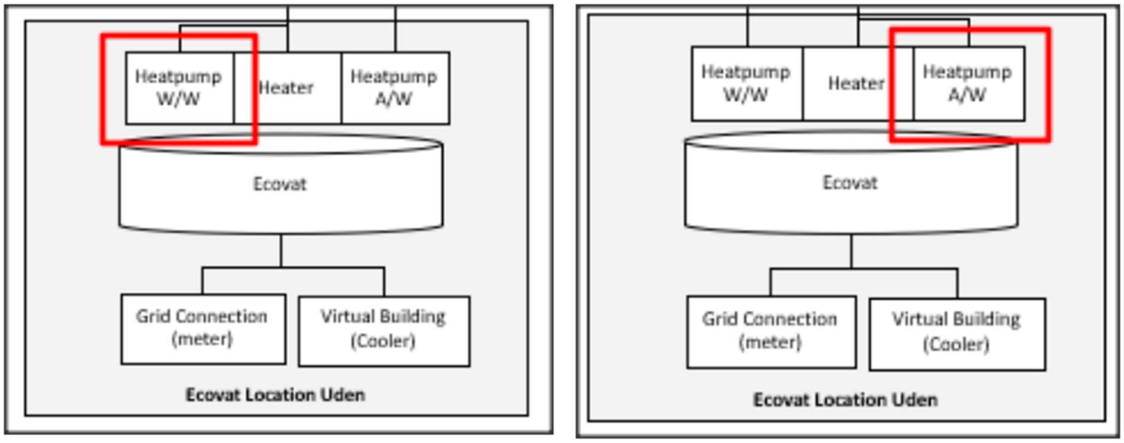


Figure 16, Ecovat heat pumps

The ecovat is equipped with two heat pumps, one NIBE F1155-12 (2-13 kW) GSHP [datasheet_nibe_F1155.pdf] and one NIBE F2120 (3-12 kW) ASHP [datasheet_nibe_F2120.pdf].

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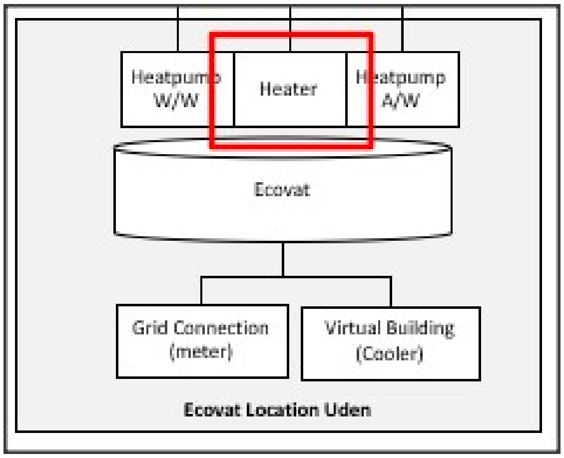
5.5.5 Heater



Measurement, 6 x E-Tech W 28 tri	Quantity	Unit
Capacity (total)	13	L
Max operating temperature	85	°C
Max service pressure heating (primary)	3	bar
Weight (empty)	45	kg
Output power max (80/60°C)	28.8	kW
Output power min (80/60°C)	14.4	kW
Connection, heating	[03/Apr]	[Ø inches]
Voltage	3 × 400 (+N)	V
Protection IP	43	
Electrical power	14.4 / 28.8	kW
Number of heating elements	6	bar
Electrical Resistance	2 × 2.4	mg/kWh
Capacity expansion tank(s)	10	L

Figure 17, Data Ecovat heater

5.5.6 Grid Connection

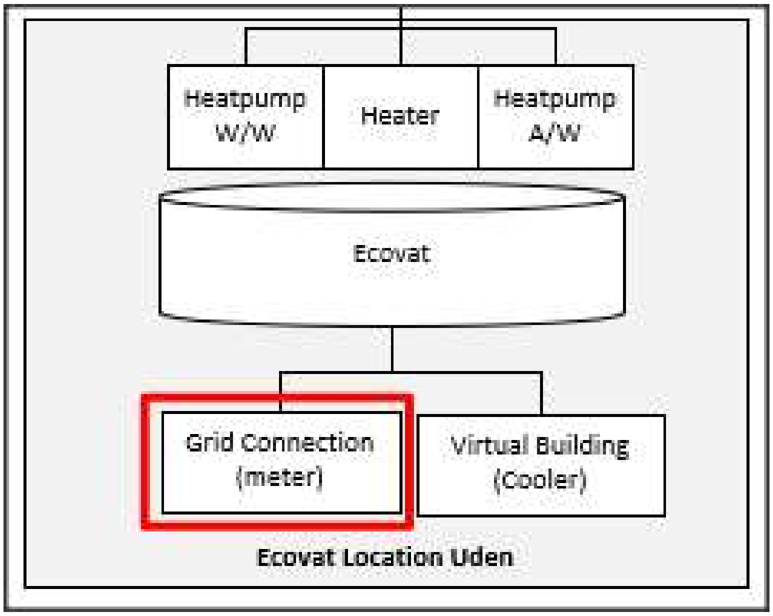
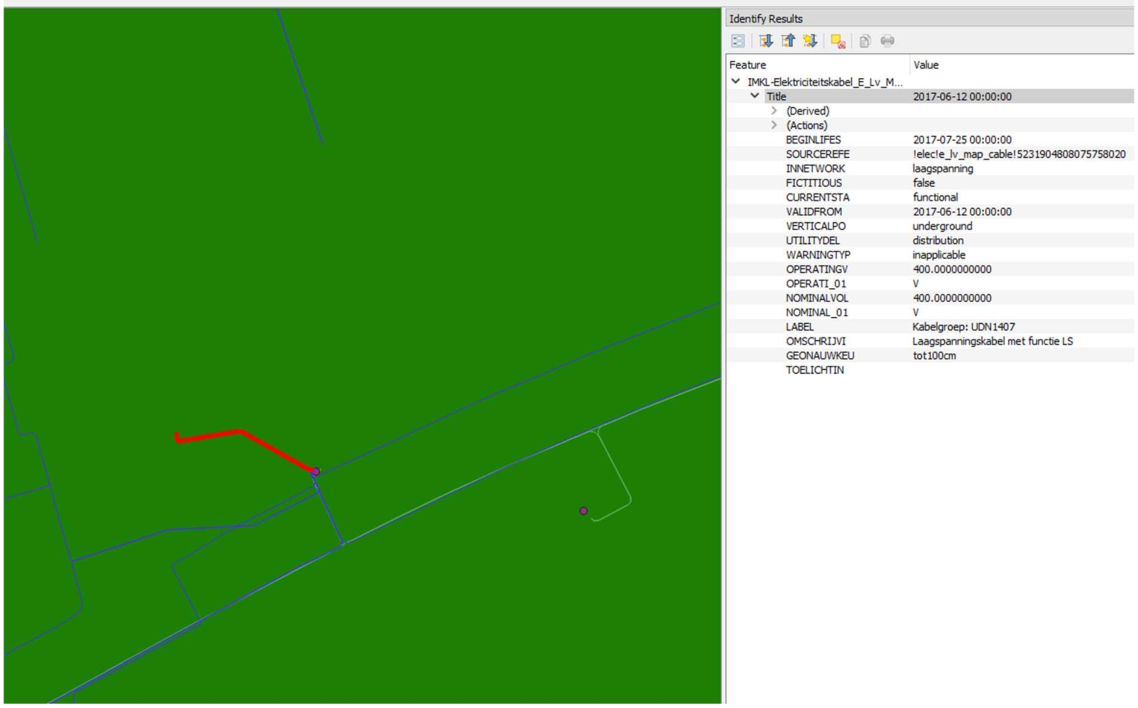


Figure 18, Ecovat grid connection overview

The ecovat is connected to the grid through 3 × 250 A feeders through a medium to low voltage substation.



Feature	Value
IMKL-Elektriciteitskabel_E_Lv_M...	
Title	2017-06-12 00:00:00
(Derived)	
(Actions)	
BEGINLIFES	2017-07-25 00:00:00
SOURCEREFE	!elec!e_lv_map_cable!5231904808075758020
INNETWORK	laagspanning
FICTITIOUS	false
CURRENTSTA	functional
VALIDFROM	2017-06-12 00:00:00
VERTICALPO	underground
UTILITYDEL	distribution
WARNINGTYP	inapplicable
OPERATINGV	400.0000000000
OPERATI_01	V
NOMINALVOL	400.0000000000
NOMINAL_01	V
LABEL	Kabelgroep: UDN1407
OMSCHRIJVI	Laagspanningskabel met functie LS
GEONAUWKEU	tot100cm
TOELICHTIN	

Figure 19 Ecovat grid connection map view.

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5.5.7 Virtual Building

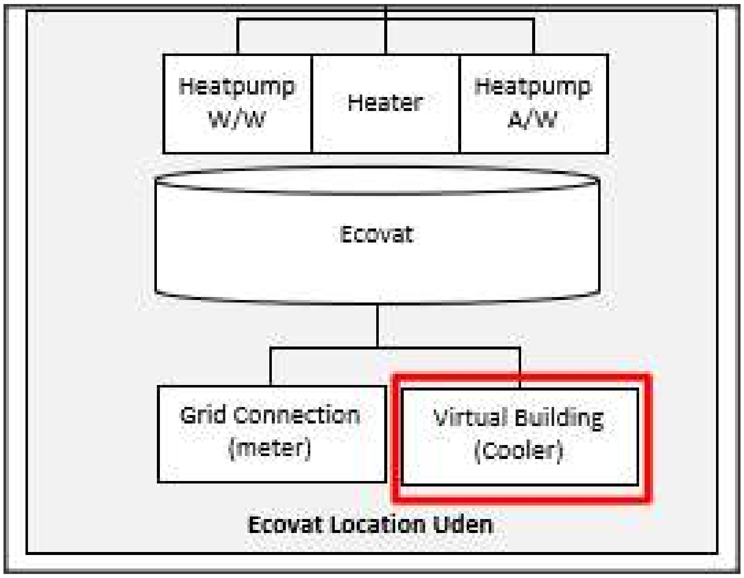

Figure 20, Ecovat virtual building

The heat demand is simulated by means of a Horizontal Thermofin Drycooler `[datasheet_thermofin_TDH_V.pdf]` with 2 × 910 mm fans.

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6 Installations and Actions

The purpose of this section is to make precise what will be measured and controlled, and what activities need to be undertaken to prepare the sites for evaluation. For Site 1, Site 2, Site 3 and Site 5, this involves integration with the NODA platform. For Site 5, a large amount of necessary work falls outside the FHP project plan but will never the less be included when relevant for the FHP project.

The implementation plan consists of two parts per premise, firstly, a subsection *Installations* outlining what to install and, secondly, a subsection *Actions* outlining the corresponding schedule of actions. The former has to be read together with the section *Annex: Data Sheets and Capabilities*, which provides cross references and explanations, while the latter is self-contained.

There are five types of actions, or activities: *Audit*, *Access*, *Configuration*, *Verification*, and *Validation*, with *Access* encompassing the installation work. The activities provide a breakdown of what needs to be done, when it needs to be done, and by whom to realize the desired capabilities, which in turn results in a focus on hardware, communications solutions, and its integration with the NODA platform. For Site 1, Site 2, and Site 3, i.e., the sites in Karlshamn, Sweden, a large number of the involved activities reduce to standard procedures for the two commercial products NODA Smart Heat Building and NODA Smart Heat Grid, and to standard procedures for KEAB, the DSO of Karlshamn. Site 4 and Site 5 are managed by RISE and ECOVAT, respectively, though the processes follow the same pattern.

Audit covers the process of taking inventory and judging what is needed to connect to the premise. As such, it overlaps with the process of taking inventory for the purpose of the pilot design. To a large extent, a process analogous to an audit needs to be completed in order to fill out Section 2. However, while Section 2 focuses on what to measure and control, the audits of Section 3 focuses on gathering the necessary information for deciding on how to implement those capabilities. Moreover, and as a rule, the collection of the two data sets demand somewhat different technical expertise.

Access covers the on-site installation of measurement and communication equipment, or low-level integration with a corresponding digital building management system. What to install and where to install it is based on the preceding audit, e.g., the number of temperature sensors, the need for repeaters, etc.

Configuration covers digital access to the premise. Once the measurement and communication solution have been installed and electronic access have been established, the NODA platform needs to be configured with a corresponding database, with accounts for the individuals that should have access to the data, and

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with appropriate reports tailored to the premise. Altogether digital access, e.g., Site 4 and Site 5, is handled by the Technical Unit.

Verification serves to confirm digital access and other operational capabilities, i.e., to establish a record of operational tests conducted over a number of successive days, and to confirm that the recorded behavior falls within the expected behavior. In practice, the verification process consists of a toggling the communication settings every few hours over about a week and recording the responses, and once the record is complete, evaluating the recorded behavior.

Validation serves to confirm the desired functionality, i.e., to establish a record of functional tests conducted over a number of successive days, and to confirm that the recorded behavior measures up to the desired behavior. In practice, the validation process consists of a repeating a pattern of standardized but realistic control signals over one week and recording the responses, and once the record is complete, evaluating the recorded behavior.

6.1 Site 1: Industrial Premises

6.1.1 Premise 1.1 [anonymized]

6.1.1.1 Installations

Table 19, NODA installations premise 1.1

Date	Location	Installation
2017-07	Garage/Workshop	1 × CMa12W
2017-07	Hangar/Office	3 × CMa12W
2017-07	Refrigerators	2 × CMa12W
2017-07	Warehouse	1 × CMa12W
2018-07	Garage/Workshop	2 × VFG54 LON
2017-07	Hangar/Office	1 × CMi-Box
2018-07	Hangar/Office	3 × VFG54 LON
2018-07	Hangar/Office	1 × RUT900
2018-07	Hangar/Office	1 × NODA Integrated Energy Controller
2018-07	Hangar/Office	1 × NODA Energy Meter

The solution permits resolution down one measurement and control loop per 5 min.

6.1.1.2 Actions

Table 20, NODA actions premise 1.1

Date	Participant	Action
2017-07	NODA	CMa12W & CMi-Box, Audit
2017-07	NODA	CMa12W & CMi-Box, Access
2017-07	NODA	CMa12W & CMi-Box, Configuration
2018-07	NODA	NODA Smart Heat Building, Audit

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2018-07	NODA	NODA Smart Heat Building, Access
2018-07	NODA	NODA Smart Heat Building, Configuration
2018-08	NODA	NODA Smart Heat Building, Verification
2018-08	NODA	NODA Smart Heat Building, Validation
2018-06	NODA	NODA Energy Meter, Audit
2018-08	NODA	NODA Energy Meter, Access
2018-08	NODA	NODA Energy Meter, Configuration
2018-08	NODA	NODA Energy Meter, Verification
2018-08	NODA	NODA Energy Meter, Validation

The actions labeled NODA Smart Heat Building constitute an upgrade from CMa12W & CMi-Box to the full solution with VFG45 LON, RUT900 and the NODA Integrated Energy Controller. The NODA Energy Meter constitute a non-standard extension of NODA Smart Heat Building.

The VFG54 LONs in the Garage/Workshop are intended to monitor the oil burner.

6.1.2 Premise 1.2 [anonymized]

The 2018-06 Audit revealed the necessity to use Modbus to connect to the system to override the temperature sensors controlling the heat pumps and, moreover, the possibility to use Modbus to access the internal electricity meters. However, in the end, is was more cost effective to install separate electricity meters.

6.1.2.1 Installations

Table 21, , NODA installations premise 1.2

Date	**Location**	**Installation**
2017-07	Hangar (east)	2 × CMa12W
2017-07	Hangar (west)	2 × CMa12W
2017-07	Office	1 × CMa12W
2017-07	Hangar (east)	1 × CMi-Box
2018-08	Hangar (east)	2 × CMa12W (intake and supply temperatures)
2018-08	Hangar (east)	1 × RUT900
2018-08	Hangar (east)	1 × NODA Integrated Energy Controller
2018-08	Hangar (east)	1 × NODA Energy Meter
2018-08	Hangar (west)	2 × CMa12W (intake and supply temperatures)
2018-08	Hangar (west)	1 × RUT900
2018-08	Hangar (west)	1 × NODA Integrated Energy Controller
2018-08	Hangar (west)	1 × NODA Energy Meter

The solution permits resolution down one measurement and control loop per 5 min.

The purpose of the double setup of CMa12W, RUT900, NODA Integrated Energy Controller and NODA Energy Meter is to be able to control the two air handling units independently. Moreover, the 2018-08 addition of CMa12W serves the purpose to measure the air temperature of the intake and supply air flow; VFG54 LON only applies to pipes of sufficiently small diameter.

6.1.2.2 Actions

Table 22, NODA actions premise 1.2

Date	Participant	Action
2017-07	NODA	CMa12W & CMi-Box, Audit
2017-07	NODA	CMa12W & CMi-Box, Access
2017-07	NODA	CMa12W & CMi-Box, Configuration
2018-06	NODA	NODA Smart Heat Building, Audit
2018-08	NODA	NODA Smart Heat Building, Access
2018-08	NODA	NODA Smart Heat Building, Configuration
2018-08	NODA	NODA Smart Heat Building, Verification
2018-08	NODA	NODA Smart Heat Building, Validation
2018-06	NODA	NODA Energy Meter, Audit
2018-08	NODA	NODA Energy Meter, Access
2018-08	NODA	NODA Energy Meter, Configuration
2018-08	NODA	NODA Energy Meter, Verification
2018-08	NODA	NODA Energy Meter, Validation

The actions labeled NODA Smart Heat Building constitute an upgrade from CMa12W & CMi-Box to the full solution with VFG45 LON, RUT900 and the NODA Integrated Energy Controller. The NODA Energy Meter constitute a non-standard extension of NODA Smart Heat Building.

6.1.3 Premise 1.3 [anonymized]

6.1.3.1 Installations

Table 23, , NODA installations premise 1.3

Date	Location	Installation
2017-07	Office (west)	1 × CMa12W
2017-07	Workshop (east)	2 × CMa12W
2017-07	Workshop (east)	1 × CMi-Box

The solution permits resolution down one measurement and control loop per 5 min.

6.1.3.2 Actions

Table 24, NODA actions premise 1.3

Date	Participant	Action
2017-07	NODA	CMa12W & CMi-Box, Audit

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2017-07	NODA	CMa12W & CMi-Box, Access
2017-07	NODA	CMa12W & CMi-Box, Configuration

The premise will only be passively studied, and not controlled.

6.1.4 Substation 1.1 [anonymized]

6.1.4.1 Installations

Table 25, KEAB installations substation 1.1

Date	Location	Installation
2018-10	Substation	4 × AXL F PM EF 1F Measurement modules
2018-10	Substation	1 × SD Flash 2GB IEC 61850 License for controller
2018-10	Substation	1 × AXC F 1050 controller
2018-10	Substation	9 × CTSCM40 150/1A Current transformer

6.1.4.2 Actions

Table 26, KEAB/NODA actions substation 1.1

Date	Participant	Action
2017-10	KEAB	Audit
2018-10	KEAB	Access
2018-10	KEAB, NODA	Configuration
2018-10	KEAB, NODA	Verification
2018-10	KEAB, NODA	Validation

6.2 Site 2: Residential Premises

6.2.1 Premise 2.1 [anonymized]

6.2.1.1 Installations

Table 27, NODA installations premise 2.1

Date	Location	Installation
2018-10	Apartment 1-3	3 × CMa12W
2018-10	Major building	1 × CMi-Box
2018-10	Major building	5 × VFG54 LON
2018-10	Major building	1 × RUT900
2018-10	Major building	1 × NODA Integrated Energy Controller
2018-10	Major building	1 × NODA Energy Meter

The solution permits resolution down one measurement and control loop per 5 min.

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6.2.1.2 Actions

Table 28, NODA actions premise 2.1

Date	Participant	Action
2018-10	NODA	NODA Smart Heat Building, Audit
2018-10	NODA	NODA Smart Heat Building, Access
2018-10	NODA	NODA Smart Heat Building, Configuration
2018-10	NODA	NODA Smart Heat Building, Verification
2018-10	NODA	NODA Smart Heat Building, Validation
2018-10	NODA	NODA Energy Meter, Audit
2018-10	NODA	NODA Energy Meter, Access
2018-10	NODA	NODA Energy Meter, Configuration
2018-10	NODA	NODA Energy Meter, Verification
2018-10	NODA	NODA Energy Meter, Validation

6.2.2 Premise 2.2 [anonymized]

The 2018-06 Audit suggested the approach of measuring the combined energy consumption of the heat pump and the electric cartridge. The approach has the advantage of being truthful to the controllable energy consumption, however, in the end, it turned out that situation was better suited to only measure the electricity consumption of the heat pump. Moreover, initial studies suggested that the building consumes electricity in excess. The problem was traced back to the electric cartridge which, for unknown reasons, had been configured with no integration time. This has since then been acted upon by the building owners, and the electric cartridge should since then be used much more sparingly.

6.2.2.1 Installations

Table 29, NODA installations premise 2.2

Date	Location	Installation
2018-03	Apartment 1-8	8 × CMa12W
2018-03	Major building	1 × CMi-Box
2018-03	Minor building	7 × VFG54 LON
2018-03	Minor building	1 × RUT900
2018-03	Minor building	1 × NODA Integrated Energy Controller
2018-06	Minor building	1 × NODA Energy Meter

The solution permits resolution down one measurement and control loop per 5 min.

6.2.2.2 Actions

Table 30, NODA actions premise 2.2

Date	Participant	Action
2018-02	NODA	NODA Smart Heat Building, Audit

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2018-02	NODA	NODA Smart Heat Building, Access
2018-03	NODA	NODA Smart Heat Building, Configuration
2018-03	NODA	NODA Smart Heat Building, Verification
2018-03	NODA	NODA Smart Heat Building, Validation
2018-07	NODA	NODA Energy Meter, Audit
2018-07	NODA	NODA Energy Meter, Access
2018-07	NODA	NODA Energy Meter, Configuration
2018-08	NODA	NODA Energy Meter, Verification
2018-08	NODA	NODA Energy Meter, Validation

6.2.3 Premise 2.3 [anonymized]

6.2.3.1 Installations

Table 31, NODA installations premise 2.3

Date	Location	Installation
2018-07	Apartment 1-5	5 × CMa12W
2018-07	Major building	1 × CMi-Box
2018-07	Major building	5 × VFG54 LON
2018-07	Major building	1 × RUT900
2018-07	Major building	1 × NODA Integrated Energy Controller
2018-07	Major building	1 × NODA Energy Meter

The solution permits resolution down one measurement and control loop per 5 min.

6.2.3.2 Actions

Table 32, NODA actions premise 2.3

Date	Participant	Action
2018-07	NODA	NODA Smart Heat Building, Audit
2018-07	NODA	NODA Smart Heat Building, Access
2018-07	NODA	NODA Smart Heat Building, Configuration
2018-08	NODA	NODA Smart Heat Building, Verification
2018-08	NODA	NODA Smart Heat Building, Validation
2018-07	NODA	NODA Energy Meter, Audit
2018-07	NODA	NODA Energy Meter, Access
2018-07	NODA	NODA Energy Meter, Configuration
2018-08	NODA	NODA Energy Meter, Verification
2018-08	NODA	NODA Energy Meter, Validation

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 731231.

6.3 Site 3: Supermarket

6.3.1 Premise

6.3.1.1 Installations

Table 33, NODA installations premise supermarket

Date	Location	Installation
2018-07	freezers	4-8 × CMa20w
2018-07	Major building	1 × CMi-Box
2018-07	Major building	1 × RUT900
2018-07	Major building	1 × Integrated Energy Controller

The solution permits resolution down one measurement and control loop per 5 min.

6.3.1.2 Actions

Table 34, NODA actions premise supermarket

Date	Participant	Action
2018-07	NODA	NODA Smart Heat Building, Audit
2018-07	NODA	NODA Smart Heat Building, Access
2018-07	NODA	NODA Smart Heat Building, Configuration
2018-08	NODA	NODA Smart Heat Building, Verification
2018-08	NODA	NODA Smart Heat Building, Validation

Although the above installation is concerned with the temperature of a number of freezers rather than the indoor climate of a number of buildings, the process is the same as for NODA Smart Heat Building. The only difference is the choice of temperature sensors [`datasheet_elvaco_CMa20w.pdf`]. The wireless communication solution is guaranteed to work down to -20 °C, though is expected to work down to -30 °C subject to the conditions of the freezers. In case of failure, the plan is to switch to the threaded counterpart CMa20 [`datasheet_elvaco_CMa20.pdf`] and an in-house communications solution.

6.4 Site 5: ECOVAT Uden

The figures below provide an overview of the planned actions from the perspective of ECOVAT. The upper lane of the first figure contains the tasks managed by ECOVAT while the lower lane of the first figure contains tasks managed by the FHP consortium. The other figures provide corresponding close-ups of the blue, red and green regions. The FHP consortium is only concerned with the two latter regions, that is, the red region pertaining to the calibration of the ECOVAT Advice Program (EAP), the implementation of the Dynamic Coalition Manager (DCM), and the

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development of the corresponding interfaces, and the green region aligned with verification and validation.

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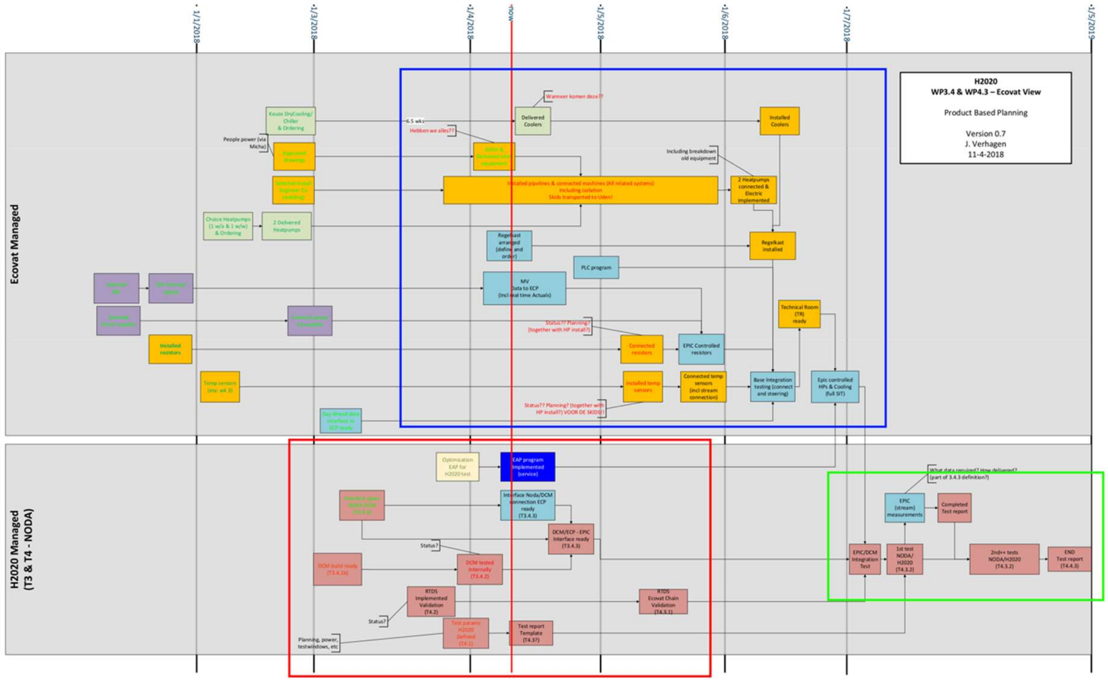

Figure 21, Overview of planned Ecovat actions (I)

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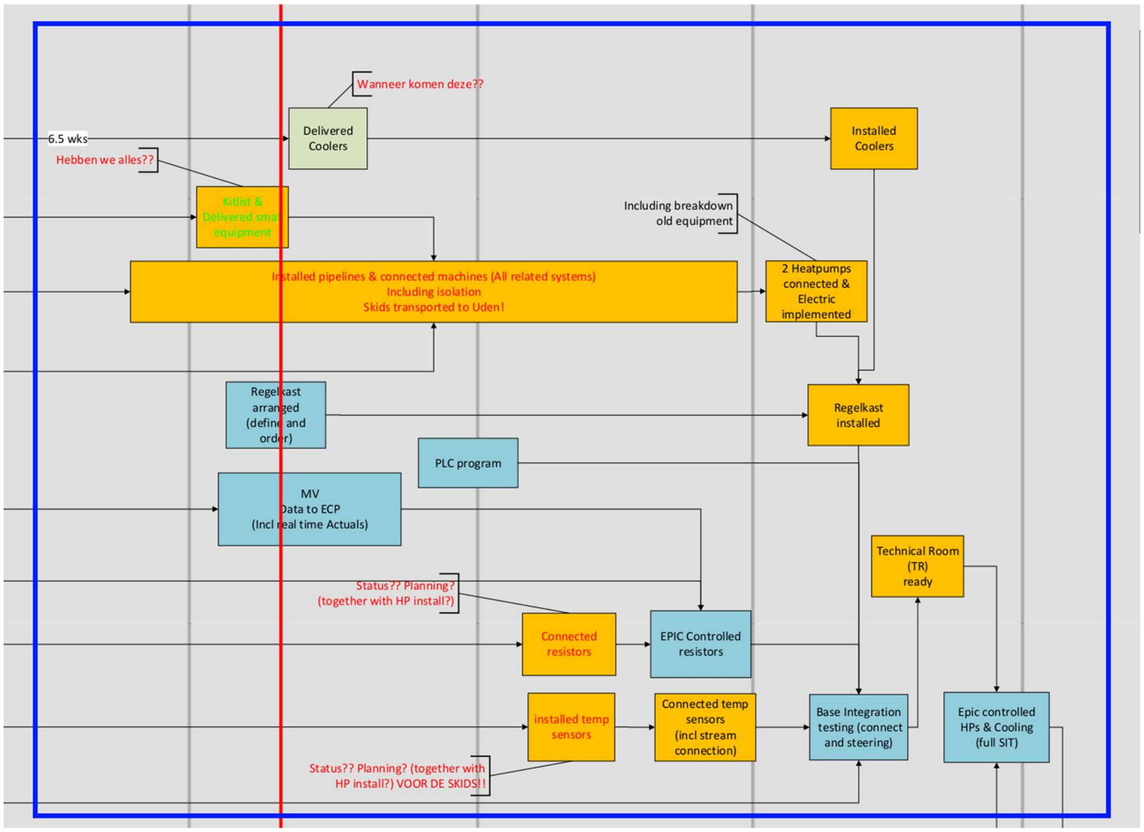

Figure 22, Overview of planned Ecovat actions (II)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731231.

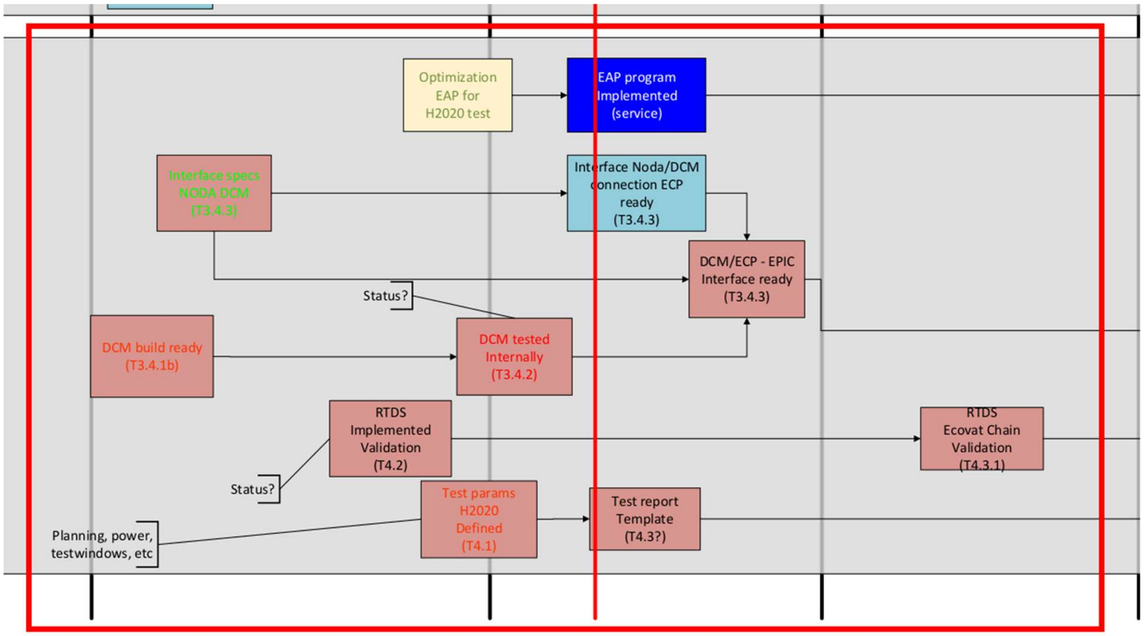

Figure 24, , Overview of planned Ecovat actions (III)

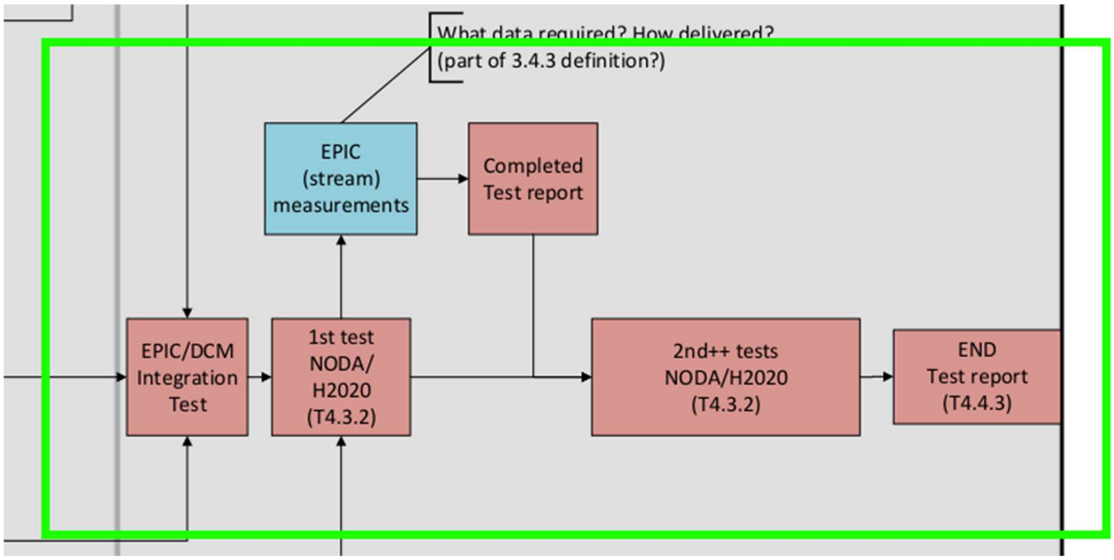

Figure 23, Overview of planned Ecovat actions (IV)

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7 Annex: Contacts and Email Addresses

7.1 Contacts

Table 35, Contact persons

System	Contact
Site representative, Site 1	Steen, Marcus
Site representative, Site 2	Steen, Marcus
Site representative, Site 3	Gustafsson, Ola
Site representative, Site 4	Lindahl, Markus
Site representative, Site 5	Mazairac, Wiet
Hardware, Site 1-3 buildings	Brage, Jens
Hardware, Site 1-3 grid	Steen, Marcus
Hardware, Site 4	Lindahl, Markus
Hardware, Site 5	Mazairac, Wiet
Hardware, heat pumps	Walfridson, Tommy
Hardware, refrigeration systems	Gustafsson, Ola
Software architecture	Ectors, Dominic
Software integration, ECOVAT	Verhagen, Joost
Software integration, NODA	Andersson, Christian
Software algorithms, ECOVAT	Suryanarayana, Gowri
Software algorithms, HON	Schindler, Zdenek
Software algorithms, TEC	Fernandez, Mikel
Software algorithms VITO & KU Leuven	Arroyo, Javier; Jung, Georg; Suryanarayana, Gowri

7.2 Email Addresses

Table 36, E-mail addresses

Contact	Email Address
Andersson, Christian	christian.andersson@noda.se
Arroyo, Javier	javier.arroyo@kuleuven.be
Brage, Jens	jens.brage@noda.se
De Ridder, Fjo	fjo.feridder@vito.be
Ectors, Dominic	dominic.ectors@vito.be
Fernandez, Mikel	mikel.fernandez@tecnalia.com
Gustafsson, Ola	ola.gustafsson@ri.se
Jung, Georg	georg.jung@vito.be
Lindahl, Markus	markus.lindahl@ri.se
Mazairac, Wiet	wiet.mazairac@ecovat.eu
Schindler, Zdenek	zdenek.schindler@honeywell.com
Steen, Marcus	marcus.steen@karlshamnenergi.se
Suryanarayana, Gowri	gowri.suryanarayana@vito.be
Verhagen, Joost	joost.verhagen@ecovat.eu
Walfridson, Tommy	tommy.walfridson@ri.se

8 Data Sheets and Capabilities

This section cross-references the installations with corresponding data sheets as well as brief descriptions of their capabilities.

8.1 Installations

The referred documents are located on the project area on Sharepoint, in the folder *Data Sheets*.

Table 37, References to data sheets

Installation	Data Sheet
CMa12W	datasheet_elvaco_CMa12W.pdf
CMi-Box	datasheet_elvaco_CMi-Box.pdf
RUT900	datasheet_teltonika_RUT900.pdf
NODA Integrated Energy Controller	n/a
NODA Energy Meter	n/a
VFG54 LON	datasheet_thermokon_VFG54_LON.pdf
Techinova Substation metering	datasheet_techinova_T55.pdf

The NODA Integrated Energy Controller is part of the Noda Smart Heat Building product, and the NODA Energy Meter is an inhouse energy meter.

8.2 Capabilities

Table 38, Capabilities of measurement and control equipment

Installation	Capability
CMa12W	Measures air temperature (°C)
CMi-Box	3G com. solution for CMa12W
RUT900	3G com. solution for NODA IEC
NODA Integrated Energy Controller (NODA IEC)	Coordinates measurement and control signals
NODA Energy Meter	Measures electricity consumption (kWh)
VFG54 LON	Measures water temperature (°C)
Techinova Substation metering	Measures electricity consumption (kWh)

The above measurement and control equipment is in principle capable of reliable operation at the resolution of minutes, though in practice, the operation is bounded by the data caps of the 3G solutions. The default resolution of NODA Smart Heat Building is 10 min. However, for Site 1-4, the corresponding equipment will be operated at a resolution of 5 min.

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8.2.1 NODA Integrated Energy Controller

The NODA Integrated Energy Controller connects to the installed RUT900, to any installed sensors (VFG54 LON), and to the already present outdoor temperature sensor, and coordinates measurement and control signals to the NODA platform. In particular, it provides the ability to override the outdoor temperature signal by an offset, and thus indirectly the ability to control the setpoint of the heating system.

Figure 25 The NODA Integrated Energy Controller.

8.2.2 NODA Energy Meter

The NODA Energy Meter is an in-house solution built from standard components and tailored towards using the NODA Integrated Energy Controller for communication. The construction of the NODA Energy Meter has a lead time of at least two weeks due to the need for ordering components based on the information collected during the corresponding audit process.

By law, electrical installations should to be handled by individuals with the adequate certificates and education. Consequently, installation of the NODA Energy Meter requires certified personnel.

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9 References

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http://www.cnpd.public.lu/fr/publications/groupe-art29/wp216_en.pdf

https://www.enisa.europa.eu/publications/privacy-and-data-protection-by-design

Differential Privacy by Cynthia Dwork, International Colloquium on Automata, Languages and Programming (ICALP) 2006, p. 1–12. DOI=10.1007/11787006_1

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 731231.