Flexible Heat and Power, connecting heat and power networks by harnessing the complexity in distributed thermal flexibility

D5.3 FHP International Conference

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[1] **Disclaimer:**

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1 Introduction

1.1 About this document (structure/objective)

This document describes the dissemination of the FHP project activities in the scope of the events that the FHP consortium organized during the project lifetime. TECNALIA organized a national workshop and the international conference and KEAB/NODA/RISE organized another national workshop. No workshop was organized by HONEYWELL and by Ecovat/VITO.

The information provided contains, for each event, organizational details (promotion material, announcements, dates, venue…), the description of the topics presented and discussed, the list of attendees and profiles and pictures of the event. Company and attendants' names are not disclosed to comply with GDPR.

In a summary section, we provide the lessons learned and the evaluation of the visibility achieved for the set of events, derived from the assessment of the attendance and its feedback during the events.

In the Annex all the presentations of each event are provided for reference.

2 Events

2.1 Workshop in Spain

2.1.1 Organization

Tecnalia organized a national workshop on a specific research item we developed in the FHP project, namely in WP2, which is Building Energy Modelling (BEM) and Model Predictive Control (MPC). The language used for the workshop promotion material and for the presentations was Spanish, to maximize the understanding af the audience, as all presenters and attendants were native Spanish speakers.

The event took place in a building own by Tecnalia, the 204 building, placed in the Bizkaia Technological Park, Zamudio (SPAIN), the 30th of January of 2019.

Figure 1: Brochure of workshop in Spain. Cover

The event was co-organized with other two European Union H2020 funded projects, MOEEBIUS and SABINA represented by Carlos Bandera and Pablo de Agustín respectively, projects which also involve building modelling activities.

The presenters were from Tecnalia (Borja Tellado and Pablo de Agustín), KU Leuven (Javier Arroyo) and Universidad de Navarra (Carlos Fernández). The announcement of the presenters was the following (Spanish):

Pablo de Agustín, licenciado en Física por la UPV, realizó su doctorado en sistemas solares de calefacción y refrigeración, en el Instituto Eduardo Torroja-CSIC. Tiene 10 años de experiencia en energías renovables, su integración en edificios y la reducción de emisiones en los mismos. Actualmente es investigador en la División de Construcción, participando en diversos proyectos europeos como MOEEBIUS o proyectos para clientes privados en Euskadi.

Borja Tellado, licenciado en Física y Master en Ingeniería Computacion y Sistemas Inteligentes por la UPV. Ha desarrollado su actividad en el ambito de los sistemas de supervisión en tiempo real. Actualmente es investigador en la División de Energía en area de Digital Energy participando en diversos proyectos europeos como FHP o proyectos para clientes privados en Euskadi

Carlos Fernandez Bandera. Subdirector del Departamento de Construcción Estructuras e Instalaciones de la Escuela de Arquitectura de la Universidad de Navarra. Investigador principal del proyecto SABINA.

Javier Arroyo está realizando un doctorado en la universidad de Lovaina, Bélgica. Su principal interés es la comparación entre distintos tipos de modelado para el control óptimo de edificios

2.1.2 Topics

The workshop was introduced by Mikel Fernandez which explained that the workshop was divided in two-time sections. On the first section different approaches for building modelling were presented, and in the second the focus was the implementation of different MPCs for building HVAC equipment control based on the models explained before. Ander Romero (MOEEBIUS project coordinator) was the moderator of the workshop, and he conducted the presentation rounds.

BEMs describe the thermal response of buildings, providing an estimation of the energy needed to keep them in comfort conditions. The different techniques used for this purpose were explained, ranging from physical to machine learning modelling, as it is crucial to understand them to know when to apply the different model techniques on different scenarios. Model Predictive Controllers (MPCs), based on BEMs, are a key element in the process of improving the operational performance of HVACs and Building Management Systems (BMSs).

The challenge nowadays is to increase their reliability, affordability and integrability, but this target is being pursued using different implementation strategies. These strategies were be revised to know their advantages and disadvantages, and the suitability of each of them depending on the specific project’s needs.

These topics were selected to be the content of the workshop because of the importance of explaining on which scenarios it is advisable to use one technique or another. The organization was done jointly with SABINA and MOEEBIUS to explain other research approaches and techniques different from those we developed in the frame of the FHP project, to provide different points of views to the attendants, which was indeed highly appreciated.

Pablo de Agustín started the presentation round with the explanation of the white box modelling technique they developed in the MOEEBIUS project using Energy Plus. He explained that the results of this kind of modelling is very accurate, but it is needed to know all physical parameters of the construction elements of the building, so it is advisable for new buildings because in old buildings this kind of data is usually not available.

Borja Tellado presented the black box approach developed in FHP, in which the modelling is done based exclusively of measurements (temperatures, energy and electricity consumptions….). He highlighted that this technique can be applied to any building with good results, but historical data is needed, at least covering each season of one year.

Carlos Fernandez explained how a white box model can be calibrated using measurements when the building is in free oscillation state, i.e. when there is no thermal load demand and indoor temperatures are driven by the external temperature.

Javier Arroyo finished the first presentation round summarising the grey box model approach realized in the FHP project, where the building is represented with a simplified equivalent model composed by resistance and capacitances connected in either parallel or serial configurations, and whose parameters are derived from measurement analysis.

In the second presentation round, Borja explained how MPC can be implemented both in cloud platforms or be embebbed in the HVAC controller.

Carlos Fernandez explained how the utilization of genetic algorithm can improved the time used for calculation of the optimal schedule in MPCs.

To finalize the presentation round, Javier Arroyo presented the results of the application of MPCs in multi-zone buildings, as he researched in the frame of the FHP project using an iterative process in which a cost function is minimized to converge to the optimal solution.

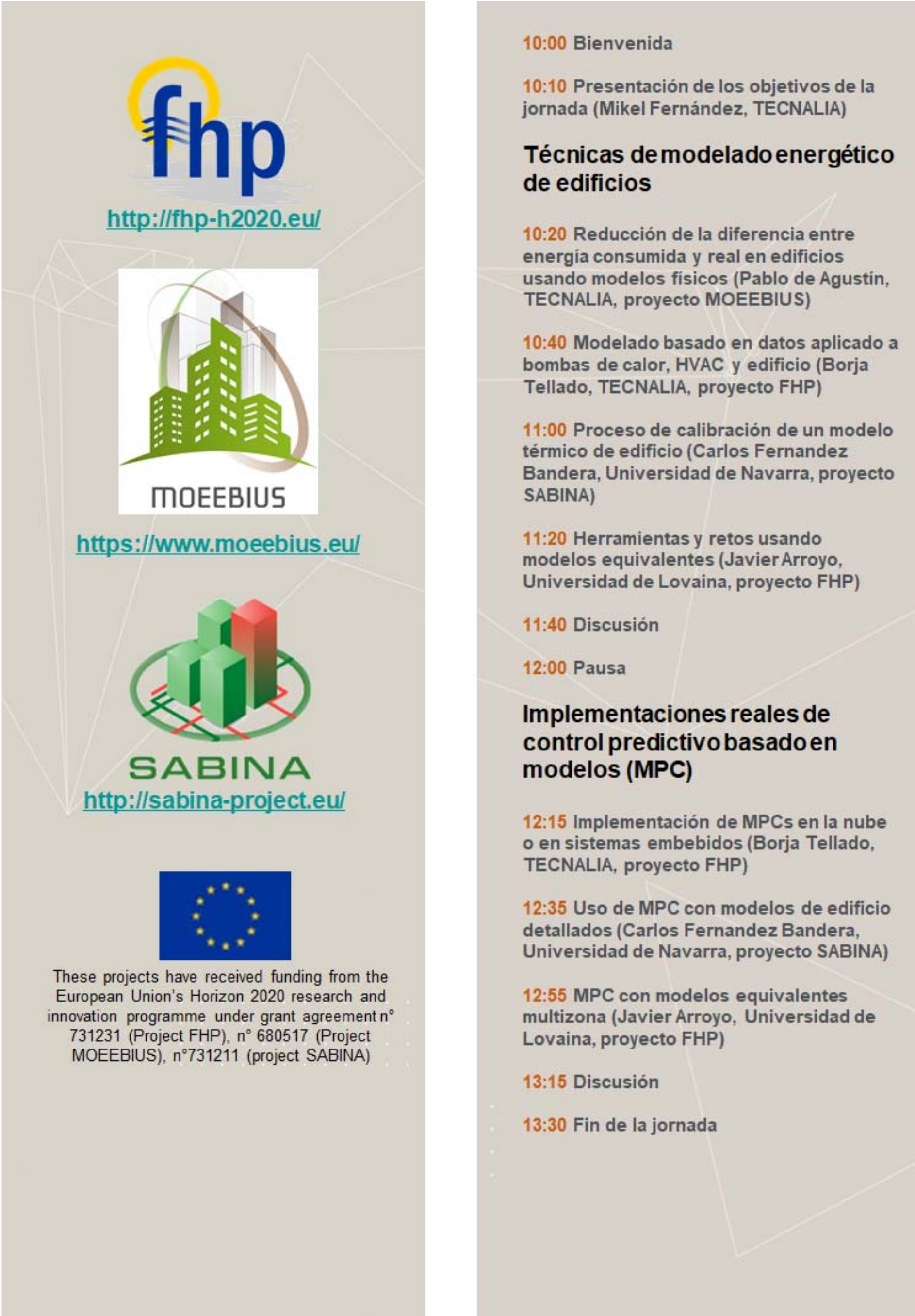


Figure 2: Brochure of workshop in Spain. Agenda

2.1.3 List of attendees

All attendants: ESCOs, architecture firms, construction cluster, HVAC manufacturers, engineering companies, students e.t.c. expressed real interest in presented subject matter. They were very active during all the sessions, making interesting questions and participating in the technical discussions.

Attendee	Attendee profile	Company	Company profile
Attendee #01	Technician	Company #1	ESCO
Attendee #02	Manager	Company #1	ESCO

Attendee #03	CEO	Company #2	ESCO
Attendee #04	Technician	Company #3	Architecture
Attendee #05	Manager	Company #4	HVAC equipment
Attendee #06	Researcher	Company #5	Research institution
Attendee #07	Manager	Company #6	Construction
Attendee #08	Manager	Company #7	ESCO
Attendee #09	Technician	Company #8	Engineering
Attendee #10	CEO	Company #9	Construction
Attendee #11	Technician	Company #10	Engineering
Attendee #12	Student	Company #11	Research institution
Attendee #13	Researcher	Company #11	Research institution
Attendee #14	Researcher	Company #11	Research institution
Attendee #15	Technician	Company #11	Research institution
Attendee #16	Technician	Company #11	Research institution
Attendee #17	Manager	Company #11	Research institution
Attendee #18	Researcher	Company #11	Research institution
Attendee #19	Researcher	Company #11	Research institution
Attendee #20	Researcher	Company #11	Research institution
Attendee #21	Manager	Company #11	Research institution
Attendee #22	Technician	Company #12	Architecture
Attendee #23	Researcher	Company #13	University
Attendee #24	Student	Company #14	University
Attendee #25	Technician	Company #15	ESCO
Attendee #26	Manager	Company #15	ESCO
Attendee #27	Researcher	Company #16	Research institution
Attendee #28	Researcher	Company #17	University

Table 1: Attendees at the workshop in Spain

2.1.4 Pictures

Figure 3: Picture of workshop in Spain 1/3

Figure 4: Picture of workshop in Spain 2/3

Figure 5: Picture of workshop in Spain 3/3

2.2 Workshop in Sweden

2.2.1 Organization

RISE, KEAB and NODA organised the 9th of October of 2019 a national workshop which specific topic was Demand flexible heat pumps, based on the experiences from the FHP project. The workshop also had a guest presentation by the Fossil free Energy Districts FED-project.

The workshop was organized in the Gothia Towers in Gothenburg (Sweden) and the workshop was conducted in the Swedish language as all presenters and attendants were native Swedish speakers.

Figure 6: Brochure of workshop in Sweden. Cover

2.2.2 Topics

This national workshop presented the learnings from the FHP project with focus on the evaluations from the testing in both laboratory and from the pilot site in Karlshamn (Sweden).

The possibility of steering coalitions of heat pumps enables creation of demand flexibility. A big advantage by connecting heat pumps, it is possible to create large energy storage where electricity can be stored as heat utilizing the inertial properties of buildings. Different controlling techniques could be adapted as a strategy, with different possibilities and limitations. Tests and evaluations from both laboratory as well as from the pilot site in Karlshamn were presented.

Marcus Steen (KEAB), the workshop moderator, introduced the project to the audience, presenting the project technological objectives and describing the role of the Swedish partners.

Markus Lindahl (RISE) and Tommy Walfridsson (RISE) presented the results of the testing done by RISE with different heat pump technologies using both direct and indirect control strategies. Indirect control strategies are based on the external temperature sensor override while direct control is based on the delivery of a duty rate setpoint to the heat pump compressor. Both strategies are oriented to run the heat pump in an electricity push mode, so that thermal energy production rate is based on the availability of cheap renewable electricity surplus.

Marcus Steen (KEAB) and Jens Brage (NODA) described the test setup in Karlshamn, both from the point of view of the objectives and the initial objectives and of the results, finding and lessons learnt.

The last presentation, done by Hjalmar Pihl (RISE), was about the FED-market, an interplay between different energy holders.

After the presentation round, an intense debate about the possibilities of driving the demand in heat pump installations in Sweden, depending on the availability of grid energy surplus or the need of different stakeholders to promote consumption, was realized.

Bakgrund

Det EU finansierade forskningsprojektet Flexible Heat and Power (FHP) avslutas under hösten 2019 och har genomförts av sju europeiska forskningsinstitut och företag, varav tre svenska. Inom FHP projektet har man undersökt möjligheten att styra grupper av värmepumpar för att tillhandahålla efterfrågeflexibilitet. Fördelen med värmepumpar är att de omvandlar el till värme och eftersom byggnader, eller andra termiska lager, har en termisk tröghet kan man inom vissa gränser styra när byggnaden ska värmas och ändå behålla en god inomhuskomfort. Genom att styra värmepumpens elförbrukning i tiden har man möjlighet att kunna balansera elsystemets variationer i tillgång och efterfrågan. Att styra eleffekten från en enskild värmepump ger dock en liten tillgänglig flexibilitet, för att få en användbar efterfrågeflexibilitet krävs att flera värmepumpar styrs tillsammans i en grupp.

Workshopen kommer presentera erfarenheter från FHP projektet med fokus på de utvärderingar som gjorts både i labb och i piloten i Karlshamn. Workshopen är en del av FHP projektets aktiviteter för att sprida erfarenheter från projektet. Värd är de svenska projektpartnerna; RISE, Noda och Karlshamn Energi.

För mer information om projektet se: http://fhp-h2020.eu/

Agenda

13.00	Introduktion till Flexible Heat and Power (FHP) samt projektets svenska partners, Marcus Steen, KEAB
	Extern styrning av värmepumpar, Markus Lindahl & Tommy Walfridson, RISE *- Indirekt och direkt styrning – möjligheter och begränsningar*
	Pilot Karlshamn – bakgrund och beskrivning av anläggningar, Marcus Steen KEAB & Jens Brage, NODA *- Utmaningar och möjligheter från den svenska demon och FHP* *- Vad har vi kommit fram till inom projektet* *- Svårigheter på vägen och lärdomar för framtiden*
	FED-marknaden, ett samspel mellan olika energibärare, Hjalmar Pihl, RISE
14.30	Fika
15.00	Efterfrågeflexibilitet ur ett svenskt perspektiv - diskussion
	Summering och avslutning
16.00	Slut

FHP har erhållit finansiering från EU: s forsknings- och innovationsprogram Horizon 2020 enligt bidragsavtal nr 731.231

Figure 7: Brochure of workshop in Sweden. Agenda

2.2.3 List of attendees

Attendants from the energy sector, heat pump installers, engineering companies, researchers and students expressed real interest in the presented subject matters. They were very active during all the sessions, participating in the technical discussions and making interesting questions regarding both modelling as well as what the future could bring in heat pump design.

Attendee	Attendee profile	Company	Company profile
Attendee #01	Researcher	Company #01	Research institution
Attendee #02	Researcher	Company #01	Research institution
Attendee #03	Researcher	Company #01	Research institution
Attendee #04	Researcher	Company #02	Engineering
Attendee #05	Researcher	Company #03	Engineering
Attendee #06	Researcher	Company #04	Construction
Attendee #07	Technician	Company #05	DSO
Attendee #08	Researcher	Company #06	Engineering
Attendee #09	Researcher	Company #07	University
Attendee #10	Student	Company #07	University
Attendee #11	Student	Company #07	University
Attendee #12	Researcher	Company #08	Engineering

Table 2: Attendees at the workshop in Sweden

2.2.4 Pictures

Figure 8: Picture of workshop in Sweden 1/2

Figure 9: Picture of workshop in Sweden 2/2

2.3 International Conference

2.3.1 Organization

The 4th of April 2019 the FHP consortium celebrated the international event as a side event of the international WindEurope Conference & Exhibition 2019. This conference was held in Bilbao (Spain) between the 2nd-4th April 2019. This conference registered the attendance of 8,500 participants, 300 exhibitors, 30 conference sessions and 155 speakers. Our workshop was entitled workshop on FHP wind curtailment mitigation solution, to maximize the attraction of the WindEurope Conference attendees.

Promotional material elaborated was composed by a one-page flyer which TECNALIA distributed at the TECNALIA'S exhibition boot and a roll-up which was also exposed at the boot and during the event.

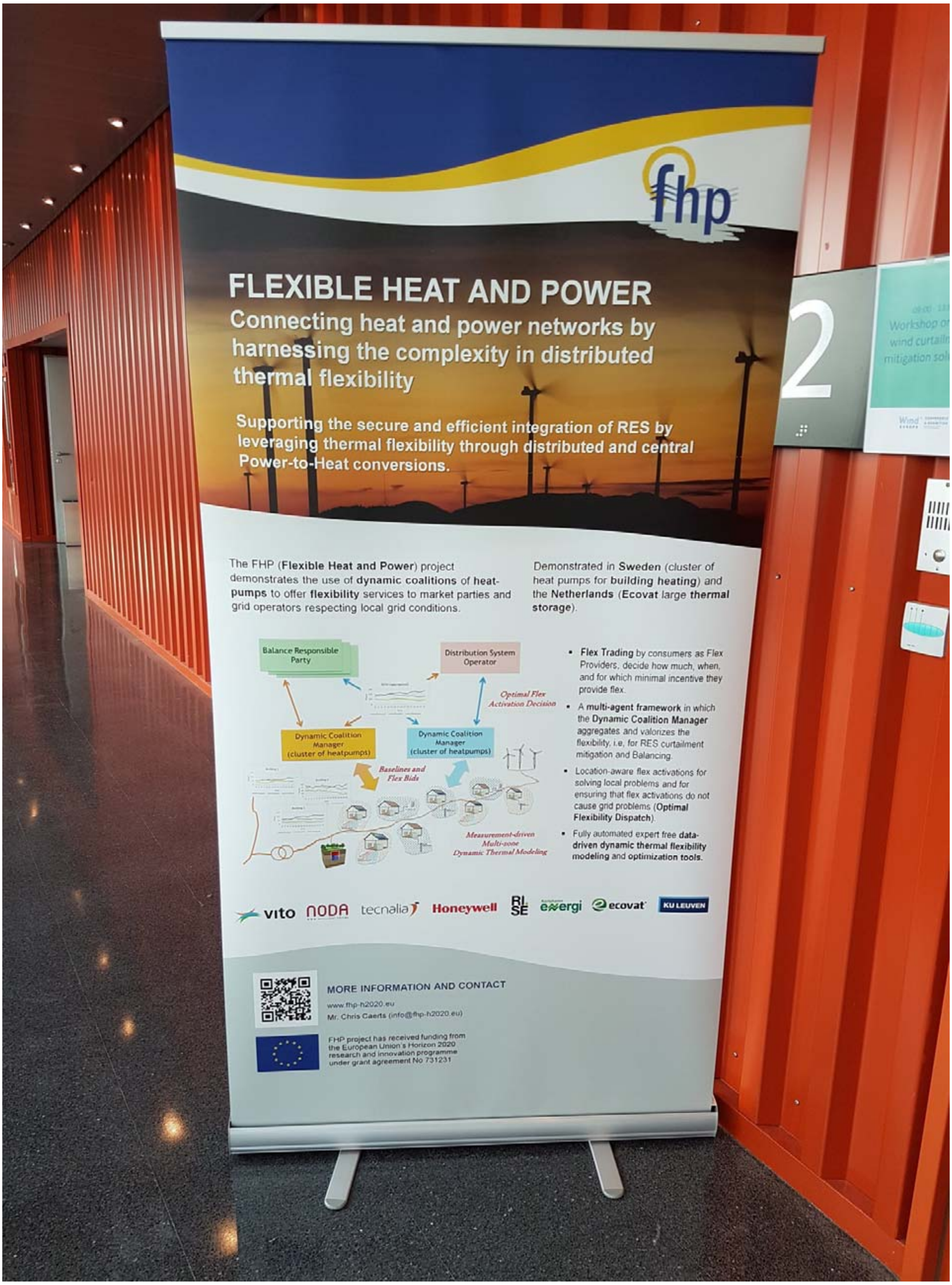


Figure 10: Promotional roll-up

Workshop on FHP wind curtailment mitigation solution

You are welcome to attend this **free workshop**, to learn how to **create the conditions to securely and effectively increase the amount of wind power**.

Thursday 4 April, 9:00-13:00
Level 5, Room 2

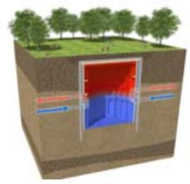
The FHP (**Flexible Heat and Power**) project demonstrates the use of **dynamic coalitions** of **heat-pumps** to offer **flexibility** services to market parties and grid operators respecting local grid conditions.

Demonstrated in **Sweden** (cluster of heat pumps for **building heating**) and the **Netherlands** (**Ecovat** large **thermal storage**).

Supporting the secure and efficient integration of RES by leveraging thermal flexibility through distributed and central Power-to-Heat conversions.

Flexible Heat and Power

- ✓ **Flex Trading** by consumers as Flex Providers, which decide how much, when, and for which minimal incentive they provide flex.
- ✓ A **multi-agent framework** in which the **Dynamic Coalition Manager** aggregates and valorizes the flexibility, i.e, for RES curtailment mitigation and Balancing.
- ✓ Location-aware flex activations for solving local problems and for ensuring that flex activations do not cause grid problems (**Optimal Flexibility Dispatch**).
- ✓ Fully automated expert free **data-driven dynamic thermal flexibility modeling** and **optimization tools.**



Contact point: info@fhp-h2020.eu

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

Figure 11: Flyer of the international conference. Cover

The Challenge

With the increasing share and installed capacity of intermittent renewables, **curtailment** can occur to avoid excess generation.

But curtailment is undesirable both for the **RES owner** who is unable to make optimal use of his investment, and for **society** for environmental reasons. Next to this, the **balancing** with large amounts on intermittent RES is becoming increasingly challenging.

The Opportunity

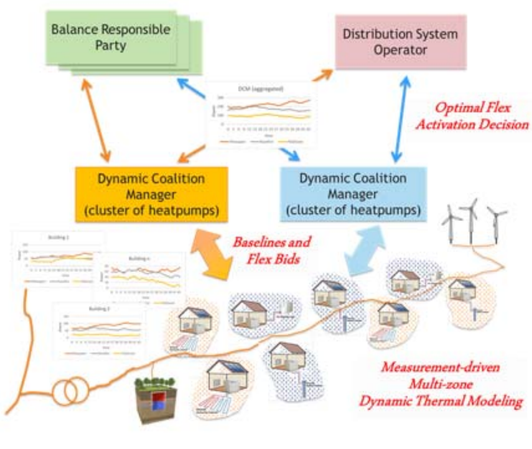
The active control of **flexible consumption**, increasing it **at proper times** such that it absorbs excess RES energy or balances RES forecast errors, and **at proper locations**, where delivery is possible and where the activations themselves do not cause grid problems.

Specifically, **Power-to-Heat** conversion, heat-pumps, and that provide flexibility through the thermal inertia of **buildings**, or through the **storage** and buffering capacity of for instance water vessels.

The Solution

Location aware optimal flex dispatch: flex activation decisions that match the need taking into account local grid conditions. Mitigating **local curtailment** problems related to grid congestions, as well as **system curtailment** problems related to excess generation and imbalance corrections.

Flex Providers forecast their (optimal) **consumption baseline** profile and their **flexibility**, using an **automated data driven** dynamic thermal **model** creation and calibration methodology supporting **multi-zone** modeling, and the minimal **incentive** needed for providing flexibility. They interact with either a **local flex market** or (one of many) **aggregators**, which are called **Dynamic Coalition Managers**.



vito NODA tecnalia Honeywell RISE energi ecovat KU LEUVEN

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

Figure 12: Flyer of the international conference. Back cover

The side event was announced in the WindEurope conference web page, where events were published as soon as their organization was realized. In the case of the FHP event, our event was the second in appearance, several months before the conference date.


WindEurope CONFERENCE & EXHIBITION 2019 2-4 APRIL BILBAO

Delivering a clean economy for all Europeans

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Conference Exhibition Practical Info Social & Side events Sponsorship Media & Press ES

Networking » Workshop on FHP wind curtailment mitigation solution

Workshop on FHP wind curtailment mitigation solution

Workshop on FHP wind curtailment mitigation solution

When: Thursday 4 April, 9:00-13:00

Where: Room 2, level 5

Open to: All registered participants

The FHP (**Flexible Heat and Power**) project demonstrates the use of heat pumps to offer flexibility services while explicitly taking local grid conditions into account. It considers the use of clusters of heat pumps used for building heating, as well as heat pumps feeding large thermal storage buffers (like the Ecovat) and Heating Networks.

As the project explicitly considers the local grid conditions – either solving local problems or ensuring that flex activation will not cause local problems – a bottom-up aggregation approach was developed, founded on specific rather than statistical modelling and forecasting of consumption and flexibility.

A multi-agent framework was developed and piloted, that truly puts the consumer at the centre, empowering them to very dynamically decide if, when and how much flexibility they are willing to offer, as well as to whom. To this purpose, a Dynamic Coalition Manager concept is proposed to aggregate the flexibility offers of a dynamic pool of flexibility providers, and interact on behalf of them with market parties and grid operators. The solution has been piloted in Sweden (cluster of heat pumps) and the Netherlands (Ecovat large thermal storage).

You are welcome to attend this side event, in which we will present the results of our research, which will help to create the conditions to securely and effectively increase the amount of wind power.

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

Find out more

Figure 13: Announcement of the event at the WindEurope web page.

On conference day 2, both Wiet Mazariac (ECOVAT) and Mikel Fernandez (TECNALIA) participated in the conference panel session Coupling power and heating networks.

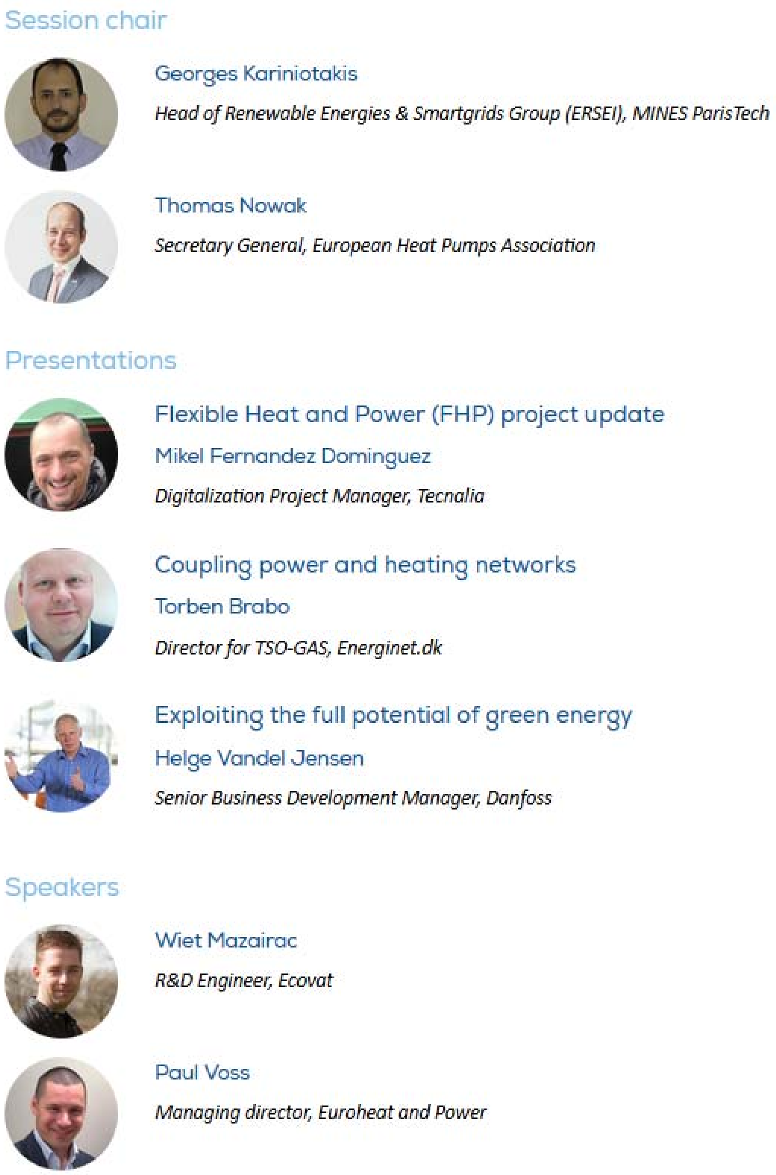

Figure 14: Participants in the panel session

Mikel and Wiet explained the goals of the FHP project, basing their dissertation on the benefits that the flexible operation of heat pumps and ECOVAT storage systems could drive in the mitigation od wind energy curtailment.

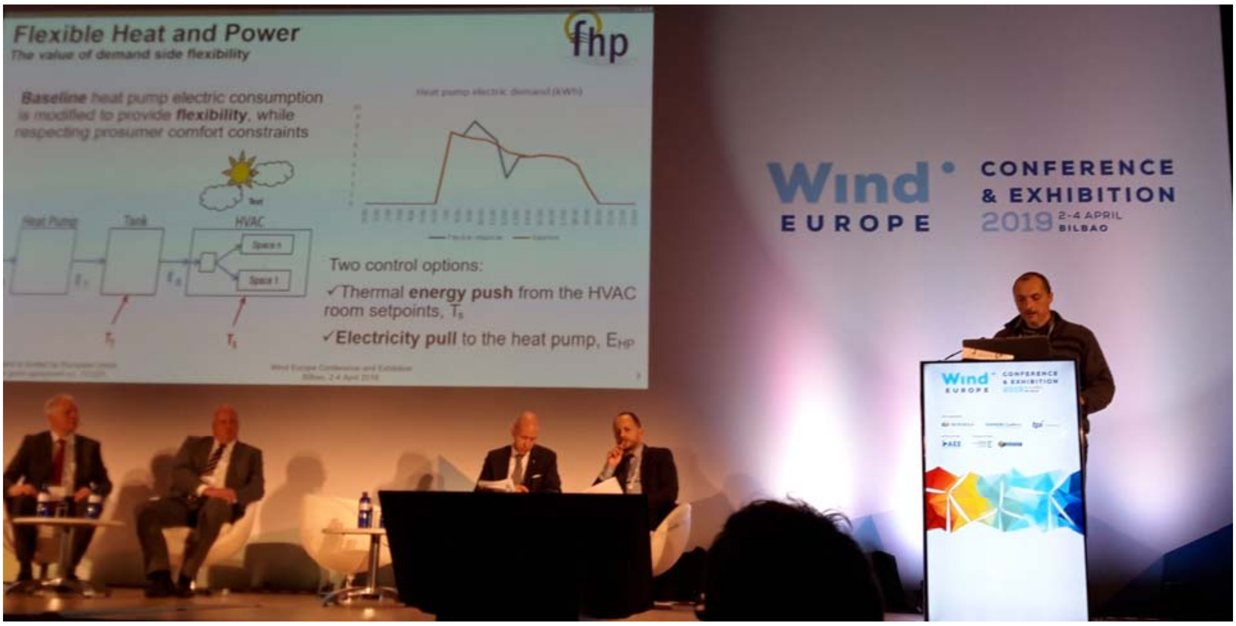

Figure 15: Presentation of the FHP project outcomes by Mikel

During his presentation setup Mikel also promoted the FHP event which was going to be celebrated the following day.

Figure 16: Promotion of the event in the panel session

After the panel presentations, the panellists discussed about how sector coupling, namely heating systems, is increasingly affecting the electric system operation.

Figure 17: Panel discussion with Paul Vass and Wiet Mazariac

The event was also promoted via social networks, trying to maximize visibility to potential attendees.

Figure 18: Event promotion in Twitter

2.3.2 Topics

All project partners presented the achievements and the result of our research in the frame of the FHP Project. Chris Caerts (VITO), who moderated the event as FHP project coordinator, started with the presentation round describing the project root cause, its scientific and technological objectives and the expected impact and presentation of the consortium partners. Enrique Rivero (VITO) presented the assessment of the wind power curtailment scenarios, due to either grid operation constraints or market conditions, and the associated compensation rules in different EU countries. Mikel Fernandez (TECNALIA) explained the roles that manage flexibility to avoid wind curtailment and how they exchange value and how the quantification of that value is made. Davy Geysen (VITO) presented the design of the decentralized agent platform (DCM-Dynamic Coalition Manager) that negotiates flexibility with external flexibility users inspired by the USEF framework. Zdenek Schindler (HONEYWELL) presented the human expert free modelling techniques applied to building response assessment, and application of optimization strategies (MPC-Model Predictive Control) with real-life infrastructure constraints. Wiet Mazairac (ECOVAT) explained the ECOVAT energy storage concept and infrastructure, and how it is coupled to renewable generation and how it is operated based on the FHP system.

After the coffee break Shahab Shariat Torbaghan (VITO), deepened into the algorithms developed for the DSO-Distribution System Operator to evaluate the necessity the flexibility, and operate it, to avoid violation of grid technical constraints due to intermittent renewable generation. Laura Lazaro (TECNALIA) described the context in which the BRP-Balance Responsible requests flexibility and how genetic algorithms are used to decide on the optimal combination of flexibility orders. Markus Lindahl (RISE) presented the study on control alternatives for heat pump operation driven by flexibility provision. Marcus Steen (KEAB) summarised the difficulties encountered, and solutions provided in the pilot set-up. And finally, Martin Borgqvist (NODA) envisaged the future steps for bring up to market the solutions developed within the FHP project.

The brochure distributed to the audience at the beginning of the event contained both the project summary and the agenda.

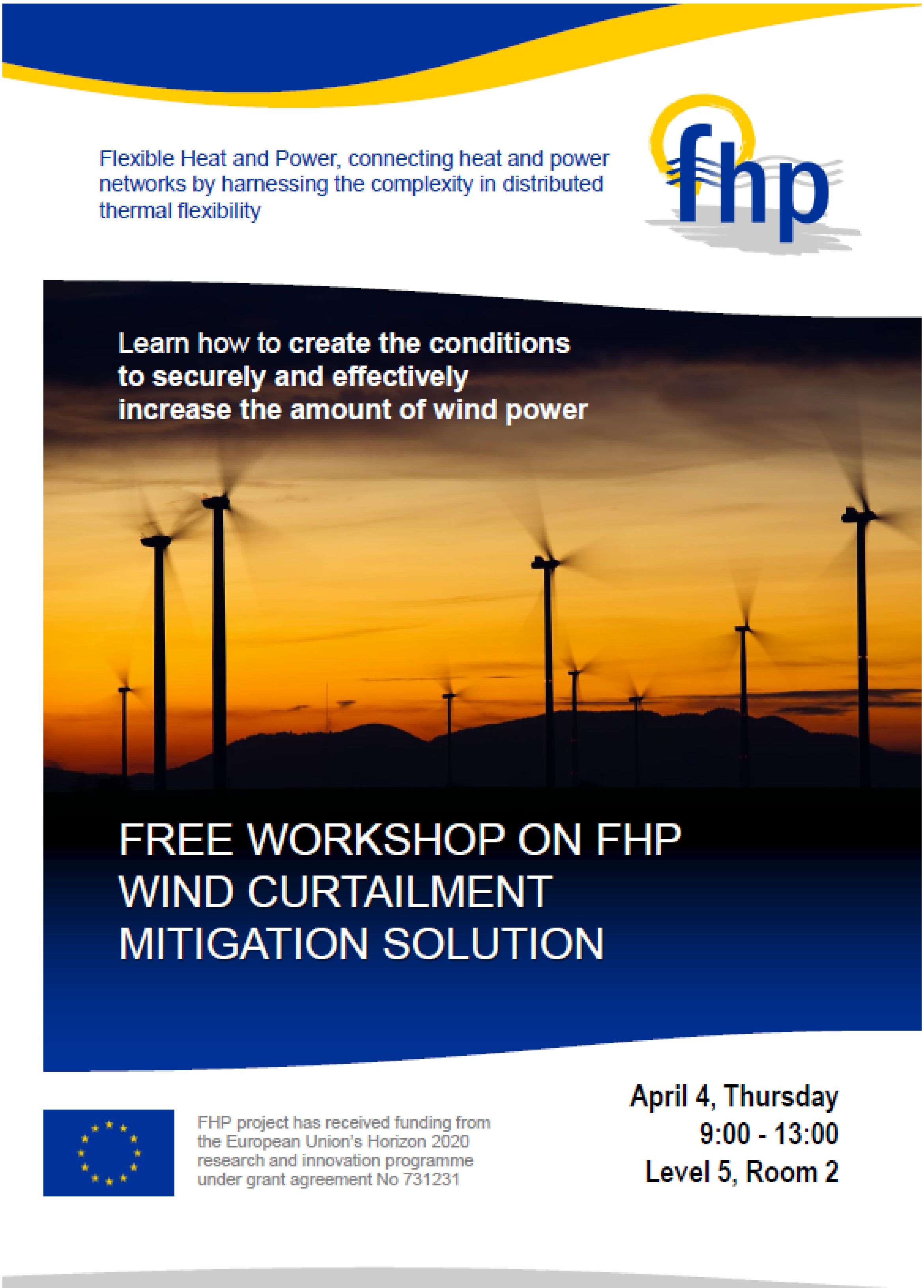

Figure 19: Brochure of the international conference. Page 1

The FHP (Flexible Heat and Power) project demonstrates the use of heat-pumps to offer flexibility services while explicitly taking local grid conditions into account. It considers the use of clusters of heat-pumps used for building heating, as well as heat-pumps feeding large thermal storage buffers (like the Ecovat) connected to Heating Networks.

As the project explicitly considers the local grid conditions – either solving local problems or ensuring that flex activation will not cause local problems – a bottom-up aggregation approach was developed, founded on specific rather than statistical modelling and forecasting of consumption and flexibility.

A multi-agent framework was developed and piloted, that truly puts the consumer at the center, empowering them to very dynamically decide if, when and how much flexibility they are willing to offer, as well as to whom.

To this purpose, a Dynamic Coalition Manager concept is proposed to aggregate the flexibility offers of a dynamic pool of flexibility providers, and interact on behalf of them with market parties and grid operators.

The solution has been piloted in Sweden (cluster of heat pumps) and the Netherlands (Ecovat large thermal storage).

You are welcome to attend this free workshop, in which we will present the results of our research, which will help to create the conditions to securely and effectively increase the amount of wind power.

The Challenge

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But curtailment is undesirable both for the RES owner who is unable to make optimal use of his investment, and for society for environmental reasons. Next to this, the balancing with large amounts on intermittent RES is becoming increasingly challenging.

The Opportunity

The active control of flexible consumption, increasing it at proper times such that it absorbs excess RES energy or balances RES forecast errors, and at proper locations, where delivery is possible and where the activations themselves do not cause grid problems.

Specifically, Power-to-Heat conversion, heat-pumps, and that provide flexibility through the thermal inertia of buildings, or through the storage and buffering capacity of for instance water vessels.

The Solution

Location aware optimal flex dispatch. Flex activation decisions that match the need taking into account local grid conditions. Mitigating local curtailment problems related to grid congestions, as well as system curtailment problems related to excess generation and imbalance corrections.

Flex Providers forecast their (optimal) consumption baseline profile and their flexibility, using an automated data driven dynamic thermal model creation and calibration methodology supporting multi-zone modeling, and the minimal incentive needed for providing flexibility. They interact with either a local flex market or (one of many) aggregators, which are called Dynamic Coalition Managers.

Figure 20: Brochure of the international conference. Page 2

WORKSHOP ON FHP WIND CURTAILMENT MITIGATION SOLUTION

AGENDA

9:00 Welcome coffee.

9:10 FHP project introduction and overview. Chris Caerts (VITO)

Description of the project root cause, its scientific and technological objectives, the expected impact and presentation of the consortium partners

9:20 Wind curtailment scenarios assessment. Enrique Rivero (VITO)

Assessment of the wind power curtailment scenarios, due to either grid operation constraints or market conditions, and the associated compensation rules in different EU countries

9:40 Business Models for flexibility management. Mikel Fernandez (TECNALIA)

Explanation of the roles that manage flexibility to avoid wind curtailment, how they exchange value and quantification of that value

10:00 DCM centric Solution Architecture. Davy Geysen (VITO)

Design of the decentralized agent platform (DCM-Dynamic Coalition Manager) that negotiates flexibility with external flexibility users inspired by the USEF framework

10:20 Building modelling and control strategies. Zdenek Schindler (HONEYWELL)

Human expert free modelling techniques applied to building response assessment, and application of optimization strategies (MPC-Model Predictive Control) with real-life infrastructure constraints

10:40 Ecovat modelling and control. Wiet Mazairac (ECOVAT)

Explanation of the ECOVAT energy storage concept and infrastructure, how it is coupled to renewable generation and how it is operated based on the FHP system

11:00 Coffee break

11:30 DSO Optimal Flexibility Dispatch. Shahab Shariat Torbaghan (VITO)

Algorithms developed for the DSO-Distribution System Operator to evaluate the necessity the flexibility, and operate it, to avoid violation of grid technical constraints due to intermittent renewable generation

11:50 Application of genetic algorithms for BRP flexibility allocation. Laura Lazaro (TECNALIA)

Description of the context in which the BRP-Balance Responsible requests flexibility and how genetic algorithms are used to decide on the optimal combination of flexibility orders

12:10 Grid Flexible Heat Pumps. Markus Lindahl (RISE)

Study on control alternatives for heat pump operation driven by flexibility provision

12:30 Lessons learned from pilot demonstration. Marcus Steen (KEAB)

Difficulties encountered and solutions provided in the pilot set-up

12:45 Steps for further research and exploitation. Martin Borgqvist (NODA)

Future steps for bring up to market the solutions developed within the FHP project

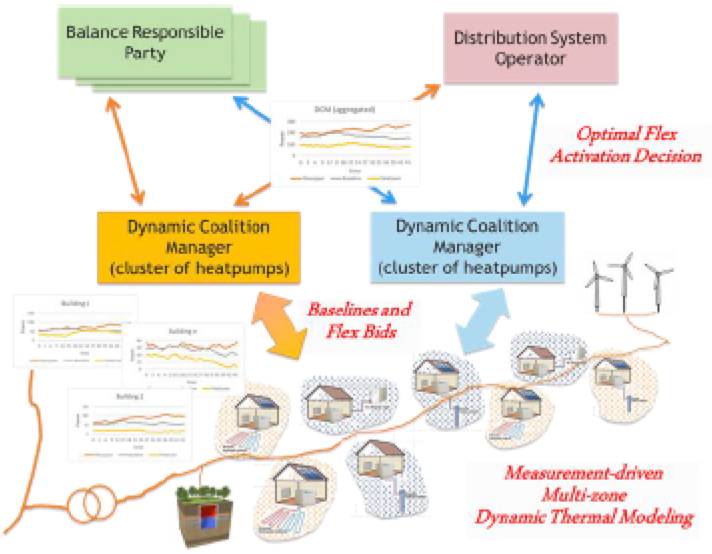
13:00 End of the workshop

Figure 21: Brochure of the international conference. Page 3. Agenda

The FHP (**Flexible Heat and Power**) project demonstrates the use of **dynamic coalitions of heat-pumps** to offer **flexibility** services to market parties and grid operators respecting local grid conditions.

Demonstrated in **Sweden** (cluster of heat pumps for **building heating**) and the **Netherlands** (**Ecovat** large **thermal storage**).

Supporting the secure and efficient integration of RES by leveraging thermal flexibility through distributed and central Power-to-Heat conversions.



- **Flex Trading** by consumers as Flex Providers, decide how much, when, and for which minimal incentive they provide flex.
- A **multi-agent framework** in which the **Dynamic Coalition Manager** aggregates and valorizes the flexibility, i.e, for RES curtailment mitigation and Balancing.
- Location-aware flex activations for solving local problems and for ensuring that flex activations do not cause grid problems (**Optimal Flexibility Dispatch**).
- Fully automated expert free **data-driven dynamic thermal flexibility modeling** and **optimization tools.**

MORE INFORMATION AND CONTACT

www.fhp-h2020.eu
Mr. Chris Caerts (info@fhp-h2020.eu)

vito NODA tecnalia Honeywell RISE Karlshamn energi ecovat KU LEUVEN

Figure 22: Brochure of the international conference. Page 4

2.3.3 List of attendees

Attendee	Attendee profile	Company	Company profile
Attendee #01	Researcher	Company #01	Research institution
Attendee #02	Manager	Company #01	Research institution
Attendee #03	Researcher	Company #01	Research institution
Attendee #04	Researcher	Company #02	Research institution
Attendee #05	Researcher	Company #02	Research institution
Attendee #06	Manager	Company #02	Research institution
Attendee #07	Researcher	Company #02	Research institution
Attendee #08	Technician	Company #03	DSO
Attendee #09	Researcher	Company #04	Research institution
Attendee #10	Technician	Company #05	Engineering
Attendee #11	Technician	Company #06	Storage systems
Attendee #12	Manager	Company #07	Engineering
Attendee #13	Researcher	Company #08	University

Table 3: Attendees at the international conference

2.3.4 Pictures

Figure 23: Picture of the international conference 1/1

Summary

2.3.5 Visibility achieved

In this section we assess the visibility that we have of our project results among the attendees to the events we have organized.

Event	Number of attendees
International conference	13
Spain	28
Sweden	12
Total	53

Table 4: Number of attendees at each event

Most of the attendees have been from the research sector, both from basic research at universities and from applied research at public/private institutions. The technologies for which we have disseminated our results are novel technologies that are current research topics, so it is not a surprise that most of the attendees were participants in other research groups.

The second class of attendees was people working for companies that pursue to apply the FHP technology as a framework that lets them operate the infrastructure of their clients providing new added flexibility-based value services, namely engineering firms and ESCOs. These will be the companies that will be the ones that would take the risk to implement, deploy and operate the FHP infrastructure so we are proud that they had a relevant participation in the workshops.

The last group of company profiles involves both final users (DSO), equipment manufacturers (HVAC, storage systems) and building companies (architecture and construction), which were interested in the update of the state of the art provided by the project.

	Number of attendees
Architecture	2
Construction	3
DSO	2
Engineering	8
ESCO	6
HVAC equipment	1
Research institution	23
Storage systems	1
University	7
Total general	53

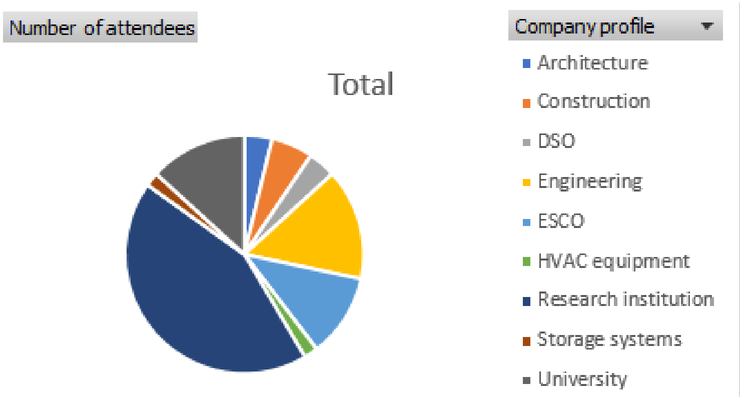


Table 5: Number of attendees per company profile

As more than half of the attendees were from research sector, students and researchers has represented the major part of our audience. The rest of the attendees are split half and half between technicians and decision makers (managers and CEOs), which is a very interesting achievement because this last group of people will be the ones needed to participate in the future exploitation of the FHP assets.

	Number of attendees
CEO	2
Manager	10
Researcher	25
Student	4
Technician	12
Total general	**53**

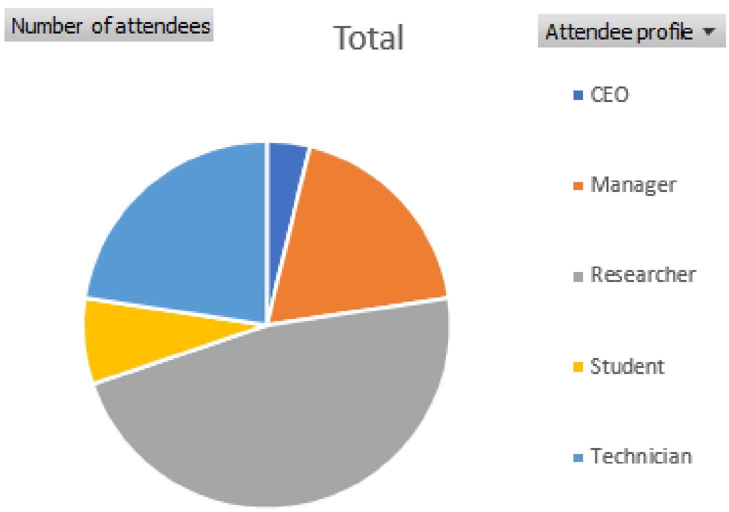


Table 6: Number of attendees per attendee profile

2.3.6 Lessons learnt

Several interesting conclusions and recommendations are derived from the organization of our events:

- ✓ Limiting the scope of the dissemination is convenient. It is better to organize an event in which the topic is clear and concise. People tend to prefer to take part in events in which the deepness of the knowledge presented is high, rather than dissemination events in which activities in all work packages are covered.
- ✓ Nominal invitation to events is preferred. The attendance is highly increased in case the organizer knows which companies, and which persons within those companies, would be willing to participate in the events. The list of customers/providers of the organizating partner is the most important source of attendees to this kind of events, where technology skills are demonstrated to these potential partners.
- ✓ Events with several organizating partners are appreciated. Those events where the results of the research realized in the scope of different projects and research groups are presented, all about the same research topic, are preferred to those events in which it is disclosed just a concrete point of view. For instance, co-organizing workshops with other peer projects, as is advised and promoted through the low TRL Storage Cluster network, may result in more wide participation.
- ✓ Result comparison and guidelines to applicability to real world problems is a must. Benchmarking of results, and if possible, rules of thumb to be used to know when and when not to apply a certain technology is very appreciated.
- ✓ Sometimes announcing an event very in advance is not advisable. It seems that a good opportunity window could be one month in advance. If done before people tend to loose willingness to attend and if later agendas of relevant people tend to be busy. For instance, to maximally promote our international conference, we early on registered

as a side event on the Wind Europe Conference (we were the 2nd side event to register and become public), and we did not attract as many people as expected.

- ✓ Playing the role of second course meal is not good. The International Conference that was organized earlier than planned due to the strategic decision to organize it as a side event to the Wind Europe Conference in April 2019. The decision to co-locate it with the Wind Europe Conference was taken because RES curtailment of wind is an important matter, and the Europe Wind Conference brings together the relevant stakeholders website), but we had a strong competition with many other side events running in parallel and we were allocated to the last conference day, when people is exhausted and tend to be very demanding when selecting if going to an extra sessions worth.
- ✓ There is a certain fatigue of people attending to technology dissemination events. There appears to be an event/workshop fatigue, evidenced by an overload on invitations to other project workshop, and the observation that often in such workshops the audience for a large majority is composed of project partners and invited speakers.

3 Annex 1. Presentations of workshop in Spain

3.1 Annex 1.1. Presentación de los objetivos de la jornada. Mikel Fernandez

TENEMOS
MUCHO
QUE HACER
JUNTOS

Jornada de modelado energético de edificios

Presentación de los objetivos de la jornada

tecnalia Inspiring Business

Contexto

Creciente demanda de edificios energéticamente más eficientes, capaces de planificar su demanda térmica de manera flexible

Electrificación progresiva de sectores tradicionalmente consumidores de combustibles fósiles

- ✓ sistemas de calefacción de edificio con bombas de calor y CHPs
- ✓ Vehículos hibiridos y eléctricos

Descentralización de la producción electrica, que implica la necesidad de nuevas fuentes de flexibilidad para garantizar la calidad de suministro

Introducción de nuevos agentes, (ESEs, agregadores…), que utilizan nuevos modelos de negocio basados en la oferta de nuevos servicios de valor para hacerse con un hueco en el mercado

Retos

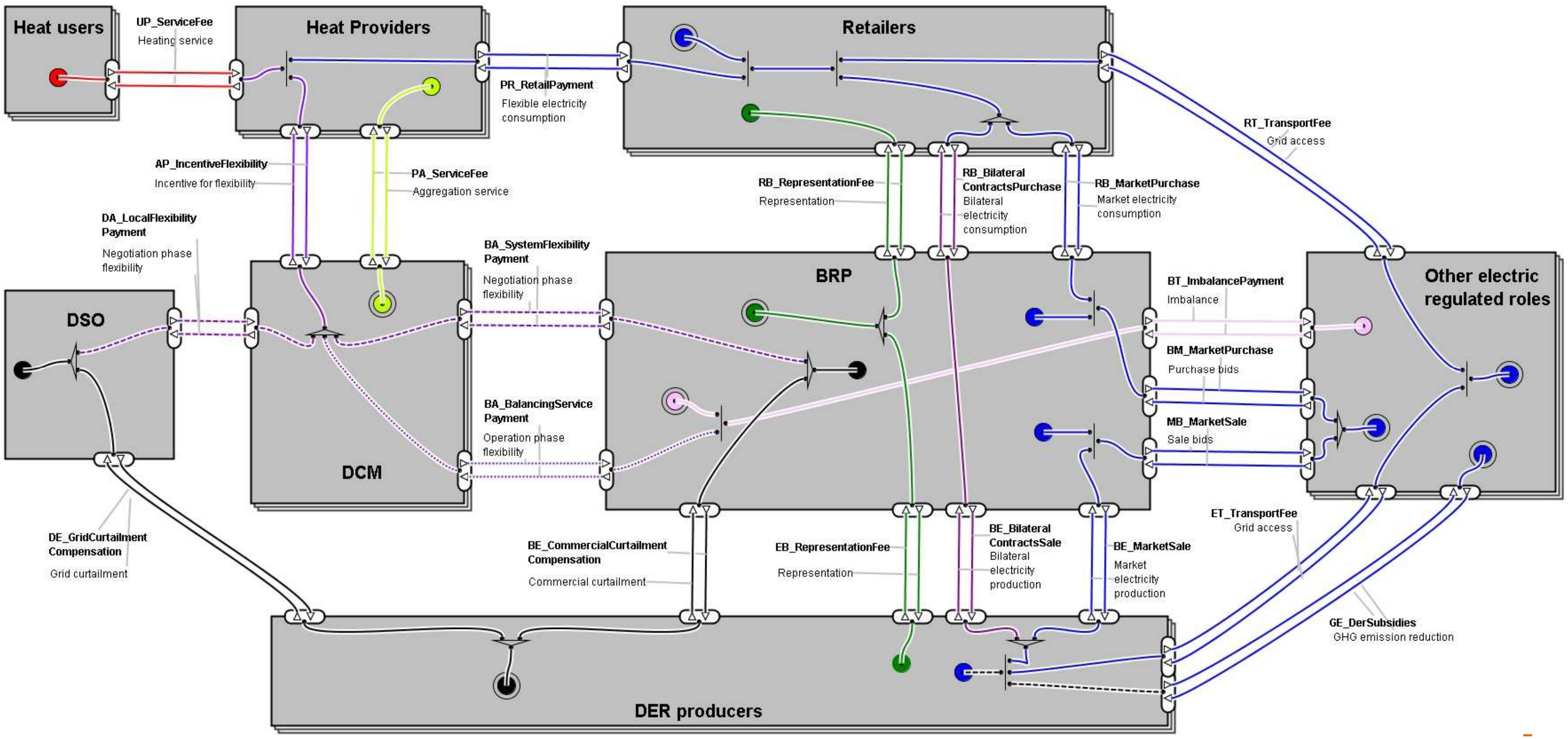
Los sistemas de (co)generación térmica deben poder operarse para minimizer el coste de operación, aprovechando los incentivos por la provision de flexibilidad y garantizando las condiciones de confort de los ocupantes de los edificios.

Necesidad de proporcionar mecanismos para acoplar la operación de redes térmicas y eléctricas de manera eficiente y estandarizada, con objeto de gestionar la demanda eléctrica de los edificios en beneficio de la operación de la red eléctrica, proporcionando un valor añadido tanto a los gestores de edificio como a los agentes del sistema eléctrico.

Las ESEs tienen el reto de asegurar que el comportamiento energético y los ahorros predichos en fase de diseño son realmente alcanzados durante la operación de los equipos y edificios en conjunto, minimizando el desvío entre prevision y realidad o “gap energético”.

Modelos de negocio

Nuevos modelos de negocio, con periodos de retorno atractivos y de una utilidad mayor para todos los agentes implicados (autoconsumidores, gestores de edificios e instalaciones, ESEs, agregadores de demanda, operadores del sistema, agentes del mercado, productores de energía…)

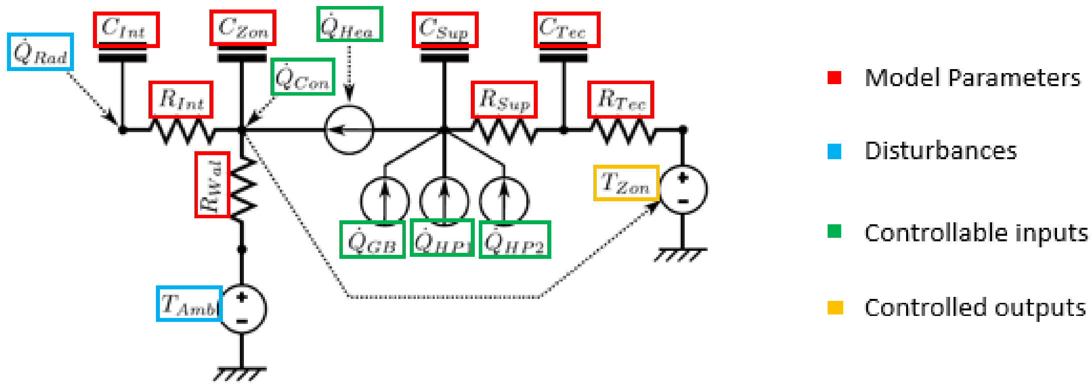


Tecnologías

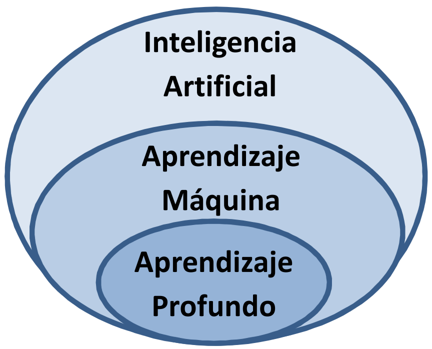
Caja blanca: Modelos físicos basados en ecuaciones de balances energéticos en los que se parametrizan todos aquellos elementos del edificio y de su uso que se consideran relevantes (BIMs)

$$0 = \dot{Q}_{cv} - \dot{W}_{cv} + \sum_i \dot{m}_i \left(h_i + \frac{V_i^2}{2} + g z_i \right) - \sum_e \dot{m}_e \left(h_e + \frac{V_e^2}{2} + g z_e \right)$$

Caja gris: Modelos físicos simplificados cuya estructura está basada en circuitos equivalentes y que son parametrizados en base a datos reales



Caja negra: Modelos basados en técnicas de analítica de datos, que no están basados en un conocimiento explicito de los elementos constructivos del edificio



Programas que imitan el comportamiento humano

Algoritmos que aprenden sin ser que su comportamiento esté programado explícitamente

Algoritmos de aprendizaje máquina en los que sus redes neuronales convolucionales se adaptan y aprenden a partir de big data

Objetivos generales

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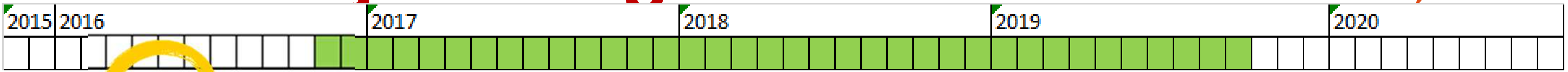
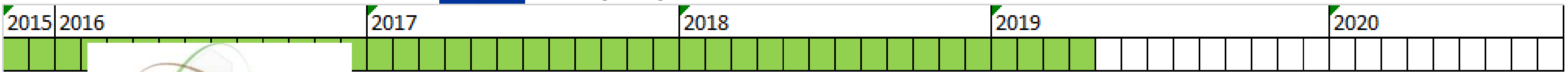


FHP, *Flexible Heat and Power*: Utilizar la **flexibilidad** de **bombas de calor** y **HVACs** para maximizar la generación renovable y para crear las condiciones para incrementar la penetración de **EERR** en la red de distribución

http://fhp-h2020.eu/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 731231

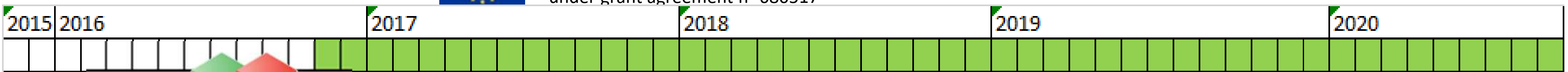


MOEEBIUS, *Modelling Optimization of Energy Efficiency in Buildings for Urban Sustainability,* en el que a partir de un modelado mejorado donde se ha reducido el **performance gap** , se ha construido un marco holístico de **optimización energética** que integra diferentes componentes software/hardware.

MOEEBIUS

https://www.moeebius.eu/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 680517



SABINA, *SmArt BI-directional multi eNergy gAteway*, tiene como propósito desarrollar nuevas **tecnologías** y **modelos financieros** para conectar, **controlar** y administrar activamente la **generación** y **almacenamiento energético** para explotar las sinergias entre la **flexibilidad** eléctrica y la **inercia térmica** de los edificios.

SABINA

http://sabina-project.eu/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211

Objetivos particulares

tecnalia Inspiring Business

http://fhp-h2020.eu/

Desarrollar técnicas de modelado replicables con la minima intervención humana
Proveer de modelos predictivos basados en servitización de modelos en entoros cloud
Gestionar la flexibilidad de los edificios con agregaciones dinámicas, con un software multiagente con interoperabilidad USEF
Proveer capacidad de regulación al DSO para evitar congestions y al BRP para optimizar su portfolio

MOEEBIUS

https://www.moeebius.eu/

Actualización y calibración de modelos: a partir del comportamiento del usuario y la caracterización de las condiciones de uso
Gestión en tiempo real de edificios: monitorización, automatización optimizada y reducción de los picos de demanda
Gestión planificada: mantenimiento predictivo para edificios y distritos
Gestión a futuro: evaluación de escenarios de rehabilitación

SABINA

http://sabina-project.eu/

Desarrollo de nuevos algoritmos de gestión a nivel de edificio y estrategias de agregación a nivel de distrito.
Desarrollo de un método innovador de identificación automática de la inercia térmica de los edificios.
Desarrollo de nuevos algoritmos para identificar automáticamente la topología de la red eléctrica local.
Garantía de calidad de suministro en las redes de distribución.
Desarrollo e implementación de una herramienta de agregación eléctrica y térmica para brindar servicios a los operadores de la red.
Promoción de un novedoso modelo de negocio.
Asegurar el cumplimiento de las normas y estándares actuales del sistema SABINA.

Ecosistema

http://fhp-h2020.eu/

https://www.moeebius.eu/

http://sabina-project.eu/

Demonstraciones

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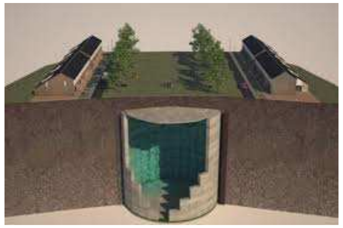

http://fhp-h2020.eu/

Demonstraciones en entornos residenciales y de servicios (Suecia) y en Ecovat (Holanda).



MOEEBIUS

3 emplazamientos piloto (Portugal, Serbia, R. Unido), en edificios residenciales y terciarios, y con la participación de *managers* de edificio, ESEs, agregadores de demanda, y consumidores domésticos.

https://www.moeebius.eu/



SABINA

http://sabina-project.eu/

Pruebas del sistema bajo condiciones de laboratorio (España) y en sitios de prueba reales (Dinamarca y Grecia)

Gracias por vuestra atención

tecnalia Inspiring Business

Presentaciones en https://bit.ly/2MGnw2R

Visita nuestro blog:
http://blogs.tecnalia.com/inspiring-blog/

www.tecnalia.com

3.2 Annex 1.2. Reducción de la diferencia entre energía consumida y real en edificios usando modelos físicos. Pablo de Agustin

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Reduciendo la diferencia entre predicción y consumo real

Predicción del comportamiento energético a escala edificio y distrito mediante modelos físicos

Pablo de Agustín, PhD

Building Technologies Division

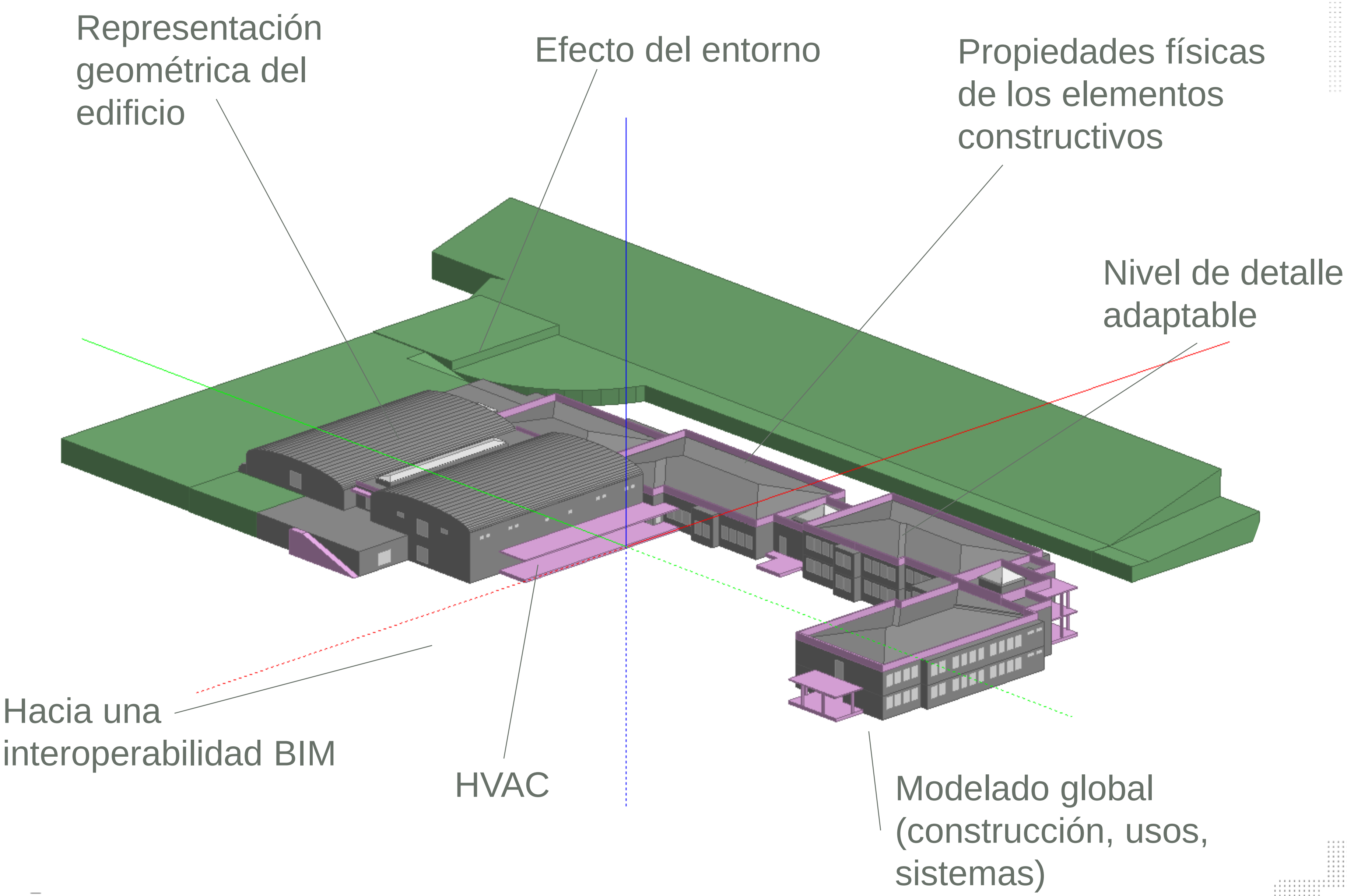
Derio, 30 Enero 2019

MOEEBIUS

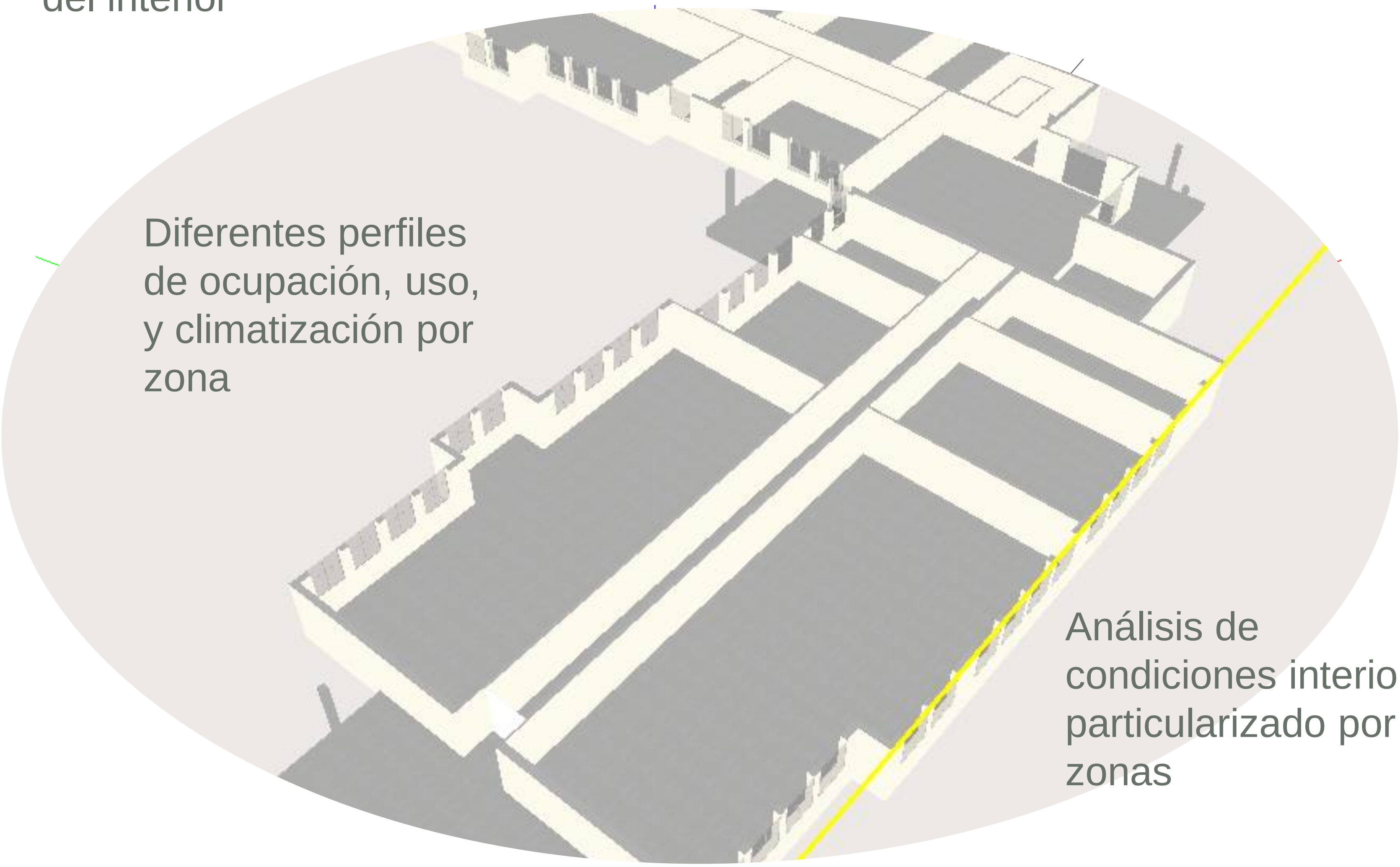
Predicción del comportamiento energético a escala edificio y distrito mediante modelos físicos

Índice

Los desarrollos y ejemplos que se muestran a continuación se han elaborado en el marco de H2020 MOEEBIUS proyecto nº 680517


Representación geométrica del edificio
Efecto del entorno
Propiedades físicas de los elementos constructivos
Nivel de detalle adaptable
Hacia una interoperabilidad BIM
HVAC
Modelado global (construcción, usos, sistemas)

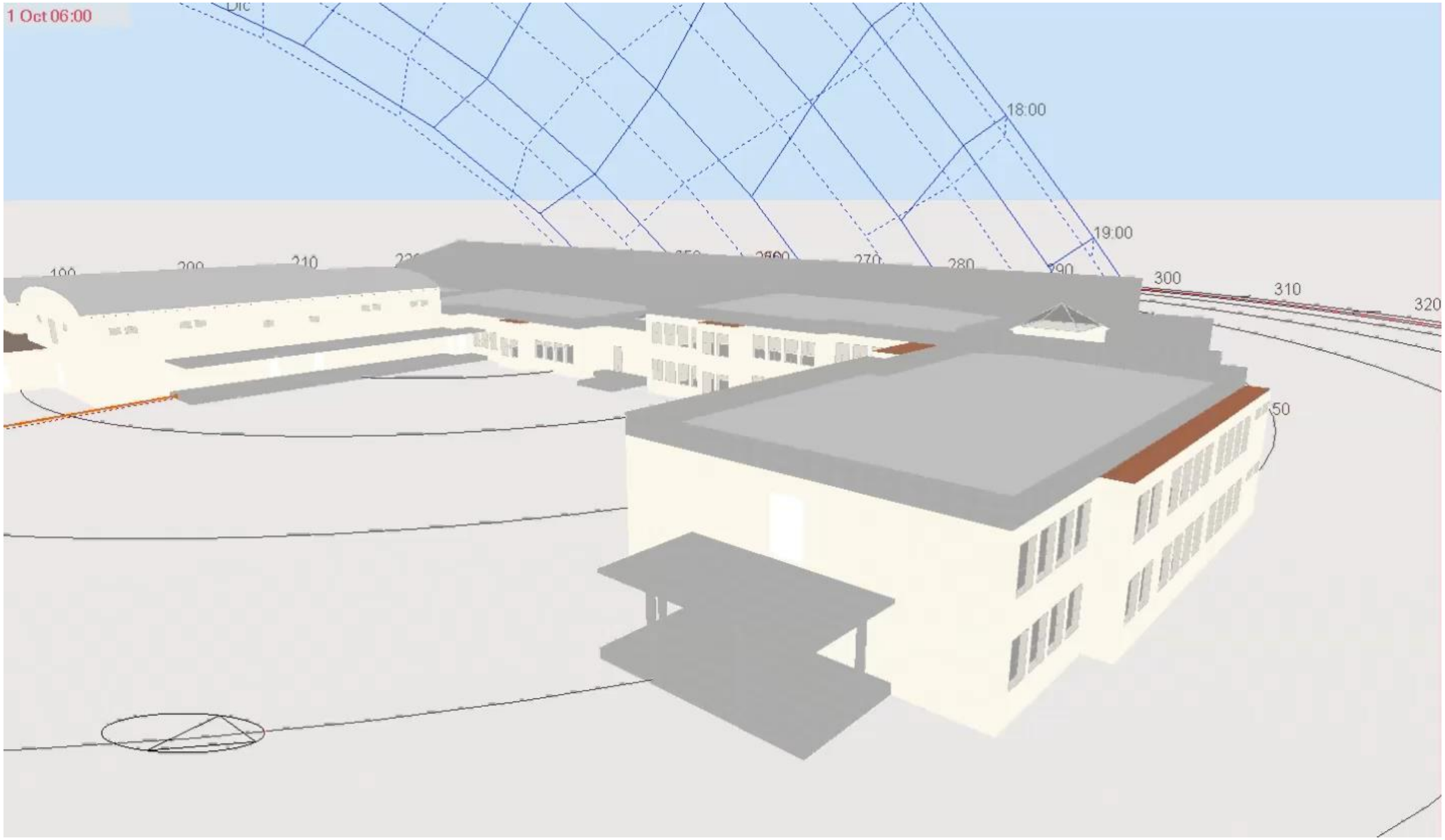
Zonificación del interior



Diferentes perfiles de ocupación, uso, y climatización por zona

Análisis de condiciones interiores particularizado por zonas

Simulación dinámica para condiciones cambiantes



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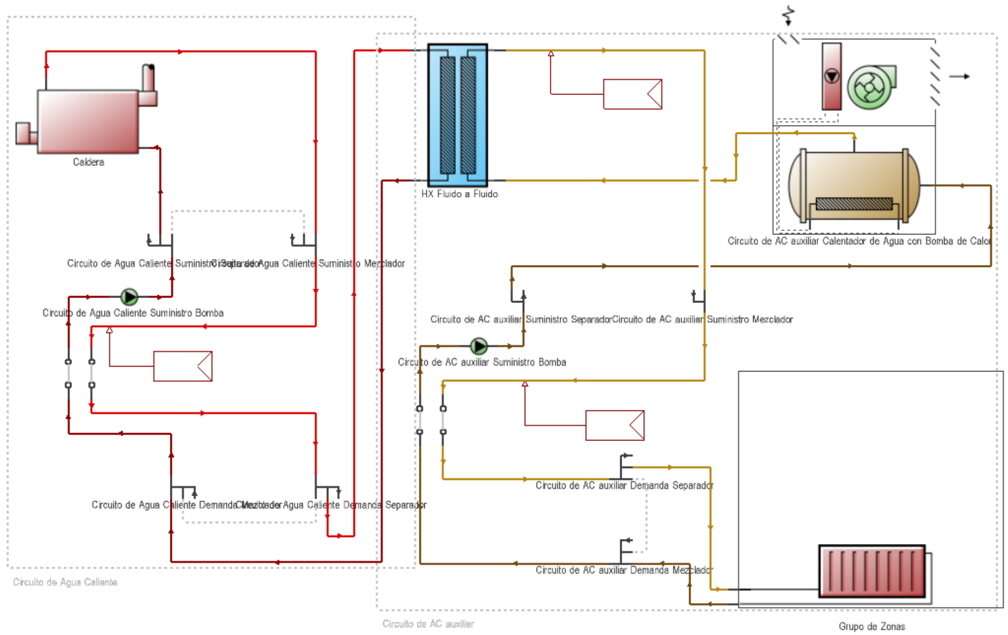
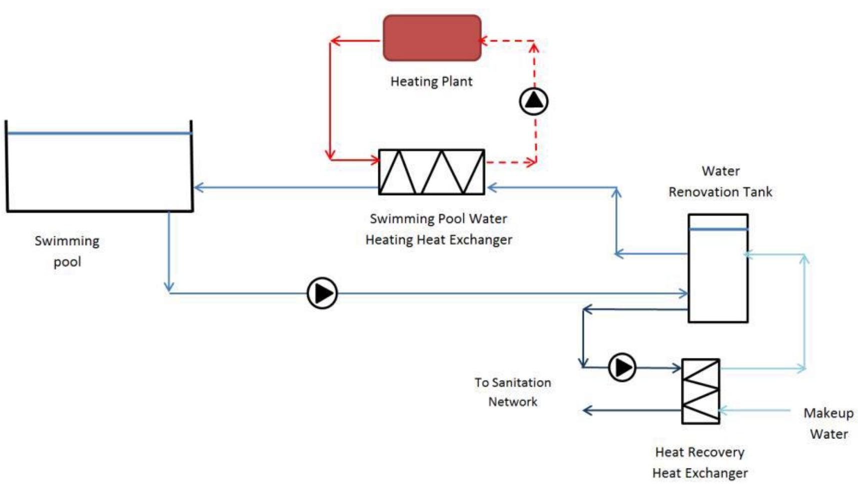
Los sistemas pueden modelizarse al completo, desde las características de los equipos de generación a los sistemas de acumulación, la topología de la distribución y los elementos terminales

La generación y el consumo son simulados de manera acoplada

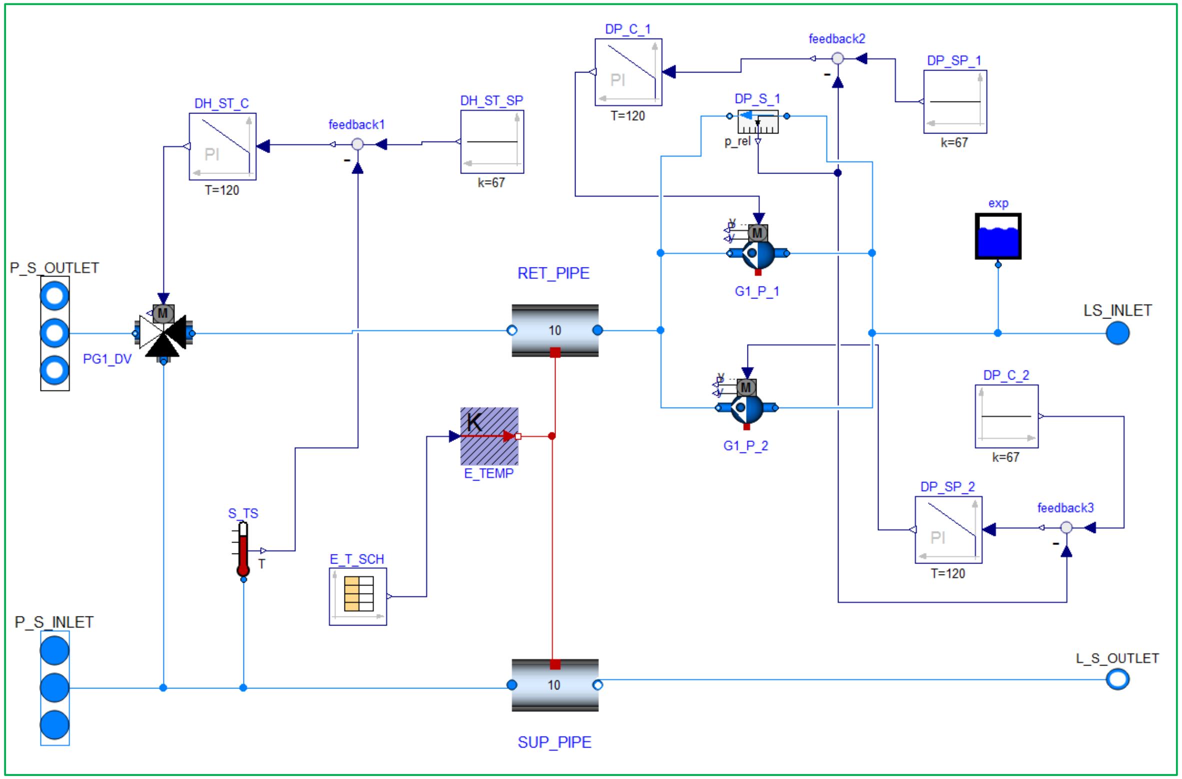




Desarrollamos nuevos modelos en función de la necesidad del proyecto

Las simulaciones a nivel de edificio emplean EnergyPlus como motor de cálculo, mientras que los elementos de distrito son desarrollados en Modelica

Modelica es un lenguaje multi-dominio para el modelado de sistemas complejos



Una estación de bombeo para una red de *District Heating* se modela a partir de subcomponentes mecánicos, térmicos, hidráulicos y de control

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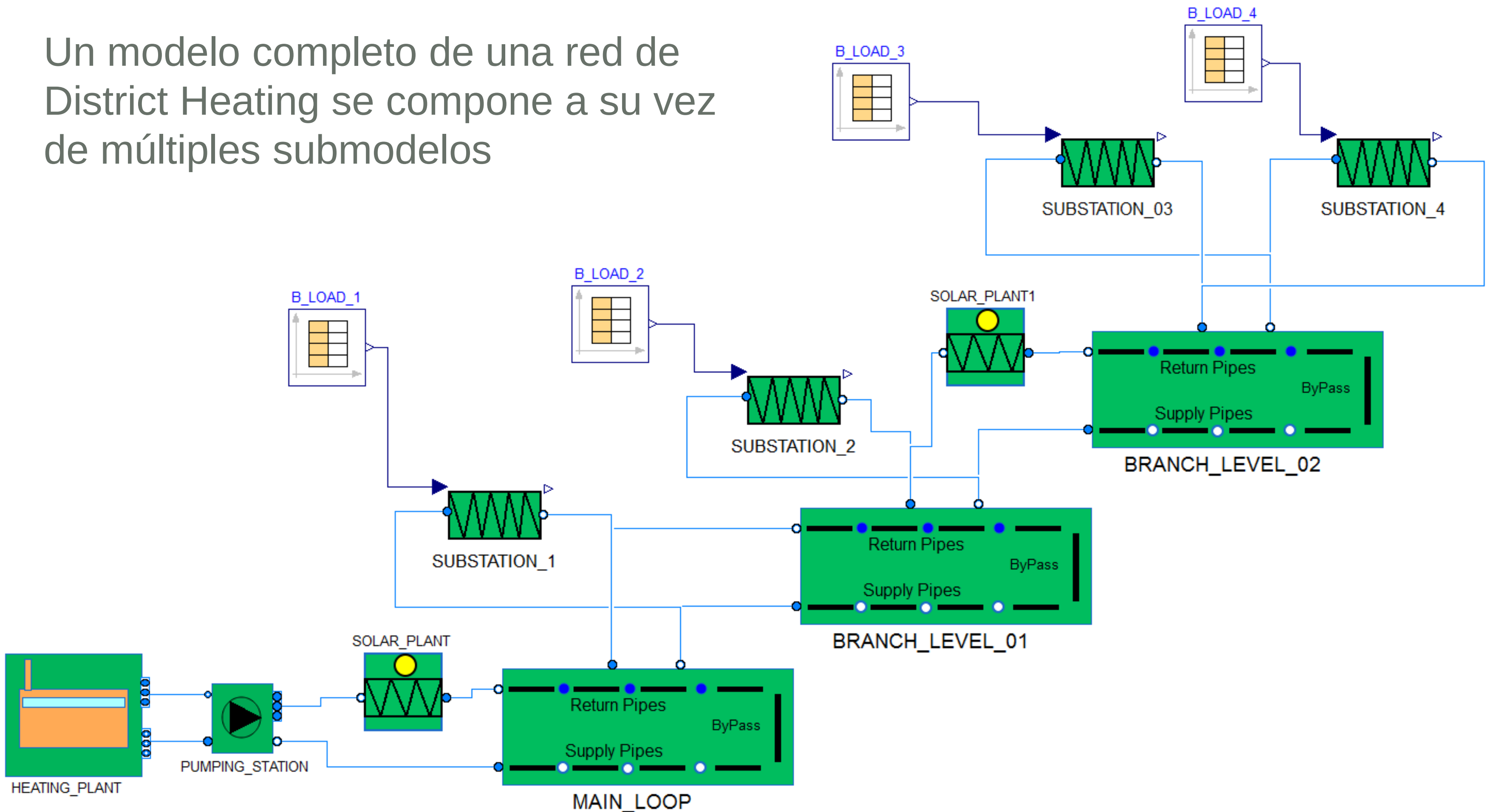
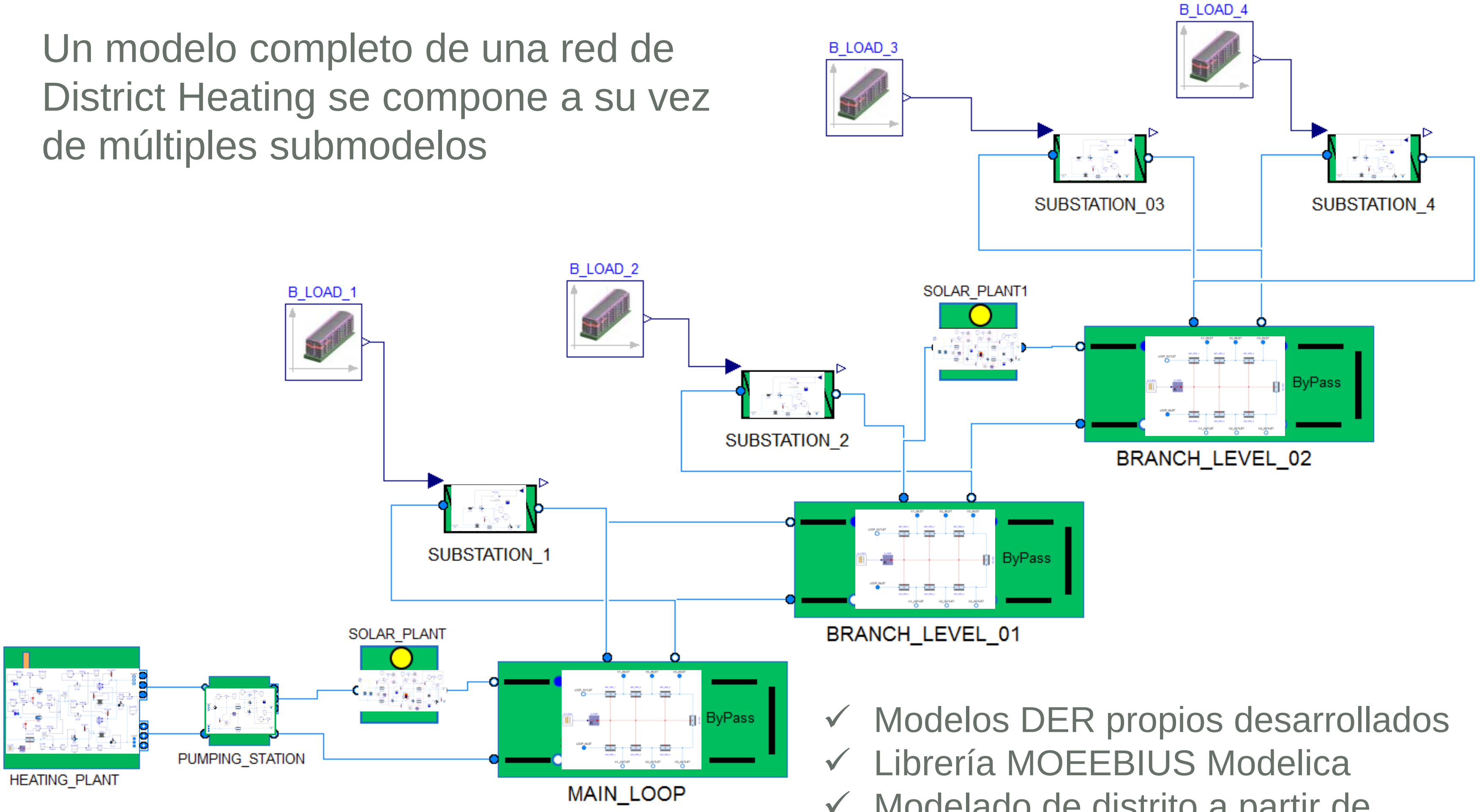
Un modelo completo de una red de District Heating se compone a su vez de múltiples submodelos



Un modelo completo de una red de District Heating se compone a su vez de múltiples submodelos



- ✓ Modelos DER propios desarrollados
- ✓ Librería MOEEBIUS Modelica
- ✓ Modelado de distrito a partir de integración de submodelos
- ✓ Co-simulación entre nivel edificio y distrito

Simulación dinámica y un "simulador dinámico"

MOEEBIUS BEPS (Building and District Energy Performance Simulation tools) es un servidor de simulación propio, aprovechando el motor de cálculo EnergyPlus y yendo más allá del uso standard del mismo.

- ✓ Metodología para estandarización de parámetros
- ✓ Generación de archivos climáticos a partir de la predicción meteorológica
- ✓ Simulación en paralelo de multiples escenarios
- ✓ Modificación automática de modelos, permite:
  - ✓ Actualización
  - ✓ Optimización
  - ✓ Rehabilitación
  - ✓ Calibración

INTERNAL GAINS		
Internal gains	**Schedules**	**Comment**
TZ_001_PLEOPLE	TZ_001_OCC_SCH TZ_001_AC_LEVEL_SCH TZ_001_CLOTHING_SCH TZ_001_AIR_VEL_SCH	Occupancy Metabolic rate Clothing Air velocity
TZ_001_LIGTHS	TZ_001_LIGTHS _SCH	Lighting internal gain
TZ_001_EQUIPMENT	TZ_001_EQUIPMENT _SCH	Equipment internal gain
TZ_I_SENSIBLE_LOAD	TZ_I_SENSIBLE_LOAD_SCH	Generic sensible load
TZ_I_LATENT_LOAD	TZ_I_LATENT_LOAD_SCH	Generic latent load
THERMOSTATS		
Thermostat	**Schedules**	**Comment**
TZ_001_THERMOSTAT	TZ_001_HEATING_SP_SCH TZ_001_COOLING_SP_SCH	Heating setpoint temperature Cooling setpoint temperature
INFILTRATIONS		
Infiltrations	**Schedules**	**Comment**
TZ_001_INFILTRATION	TZ_001_INFILTRATION_SCH	
ZONE NOMINAL VENTILATION FLOW RATES		
EMS program	**Zone nominal ventilation flow rate**	**Comment**
AHU_I_VENT_CALC_PROG	TZ_I_NOM_VENT_FR	Nominal ventilation flow rate

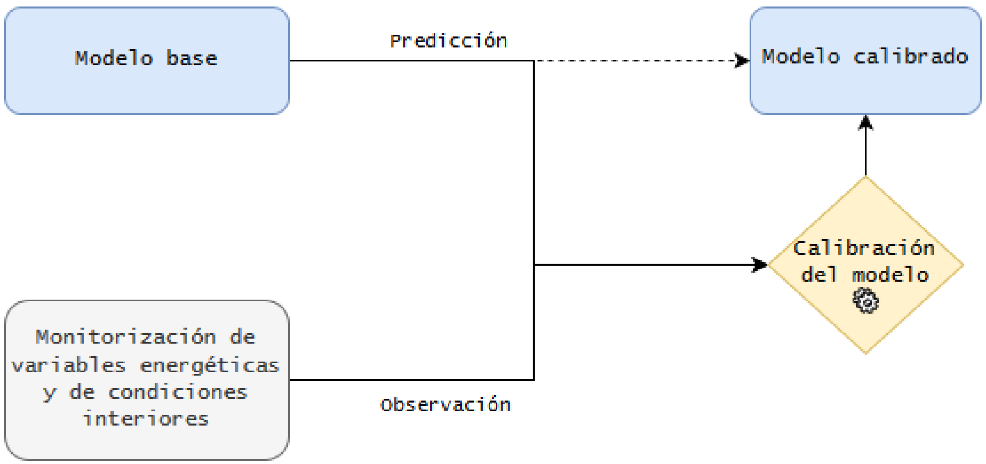
ENVELOPE		
Construction name	**Layer name**	**Comment**
FACADE_01	FACADE_01_INSULATING_LAYER FACADE_01_MASS_LAYER FACADE_01_OUTSIDE_LAYER	Facades of the envelope
G_WALL_01	G_WALL_01_INSULATING_LAYER G_WALL_01_MASS_LAYER	Walls in contact with ground (buried)
ROOF_01	ROOF_01_INSULATING_LAYER ROOF_01_MASS_LAYER ROOF_01_OUTSIDE_LAYER	Roofs of the envelope
INTERIOR_FLOOR_01	INTERIOR_FLOOR_01_INSULATING_LAYER INTERIOR_FLOOR_01_MASS_LAYER	
SLAB_01	SLAB_01_INSULATING_LAYER SLAB_01_MASS_LAYER	
EXTERIOR_FLOOR_01	EXTERIOR_FLOOR_01_INSULATING_LAYER EXTERIOR_FLOOR_01_MASS_LAYER EXTERIOR_FLOOR_01_OUTSIDE_LAYER	
ENVELOPE_PARTITION_01	ENVELOPE_PARTITION_01_INSULATING_LAYER ENVELOPE_PARTITION_01_MASS_LAYER	
ENVELOPE_FLOOR_01	ENVELOPE_FLOOR_01_INSULATING_LAYER ENVELOPE_FLOOR_01_MASS_LAYER	
GLAZING_SOL_01	GLAZING_SOL_01_LAYER	

HEATING AND COOLING GENERATORS		
Generator	**Capacity/efficiency curves**	**Comment**
BOILER_I	BOILER_I_EFF_CURVE	Efficiency curve
CHILLER_I	CHILLER_I_CAP_CURVE CHILLER_I_EFF_T_CURVE CHILLER_I_EFF_PLR_CURVE	Capacity curve Efficiency curve (temperature) Efficiency curve (PRL ratio)
HEATING AND COOLING GENERATOR SETPOINTS		
Generator	**Schedules**	**Comment**
BOILER_I	BOILER_I_SP_TEMP_SCH	Setpoint temperature
CHILLER_I	CHILLER_I_SP_TEMP_SCH	Setpoint temperature
PRODUCTION PLANT SETPOINTS		
Plant	**Schedules**	**Comment**
H_PLANT_I	H_PLANT_I_SP_TEMP_SCH	Setpoint temperature
C_PLANT_I	C_PLANT_I_SP_TEMP_SCH	Setpoint temperature
STORAGE TANK SETPOINTS		
Tank	**Schedules**	**Comment**
TANK_I	TANK_I _SP_TEMP_SCH	Setpoint temperature
AHU AVAILABILITY SCHEDULES		
Components	**Schedules**	**Comment**
AHU_I	AHU_I_LOOP_AVAIL_SCH	AHU availability
AHU_I_SUPPLY_FAN	AHU_I_SUPPLY_FAN_AVAIL_SCH	AHU supply fan availability
AHU_I_EXHAUST_FAN	AHU_I_EXHAUST_FAN_AVAIL_SCH	AHU exhaust fan availability
AHU_I_HEATING_COIL	AHU_I_HEATING_COIL_AVAIL_SCH	Heating coil availability
AHU_I_COOLING_COIL	AHU_I_COOLING_COIL_AVAIL_SCH	Cooling coil availability
AHU_I_HR_HF	AHU_I_HR_HF_AVAIL_SCH	Heat recovery availability

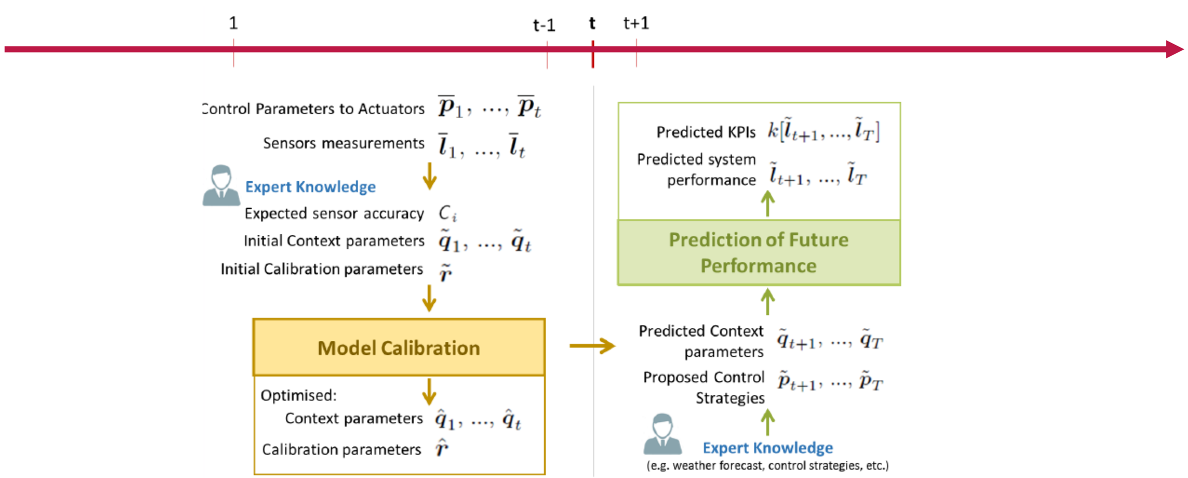
51 Groups – 70 subgroups – Single values, arrays, …

De modo análogo, hemos desarrollado un DEPS para la simulación de distrito

A partir de las comparación entre parámetros energéticos clave predichos y observados, y aplicando métodos bayesianos, el modelo base es calibrado.

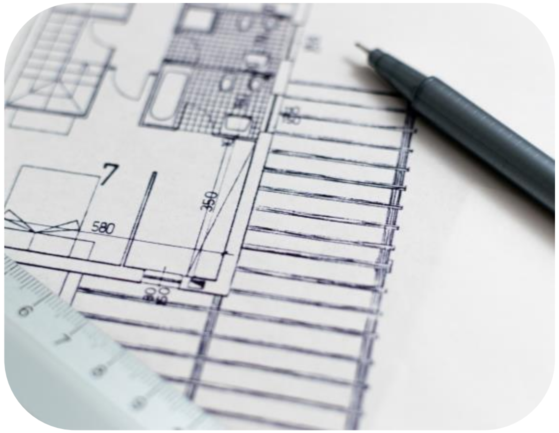


Por otra parte, el modelo es mejorado con archivos climáticos actualizados basados en predicciones y perfiles actualizados de comportamiento de los usuarios.



Modelado polivalente

Un único modelo para tres fases



DISEÑO

OPERACIÓN Y MANTENIMIENTO

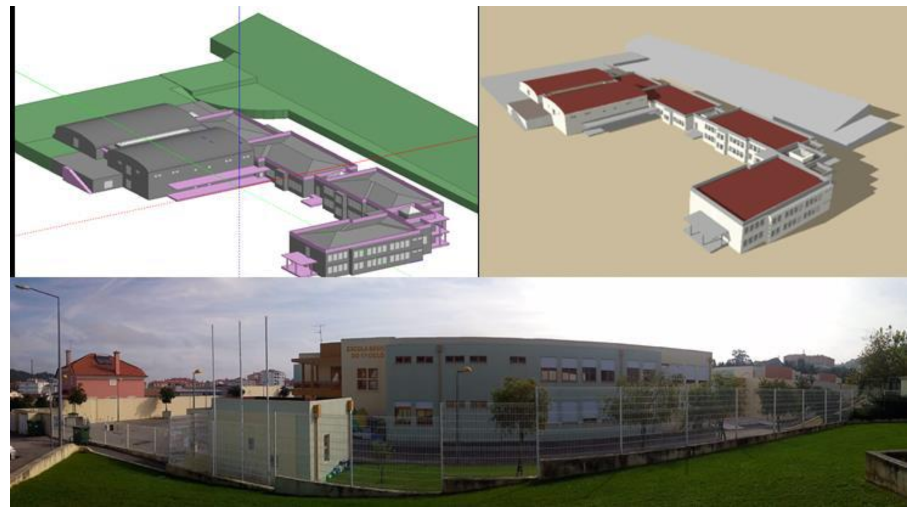
REHABILITACIÓN

Aplicaciones en el proyecto MOEEBIUS

OPERACIÓN Y MANTENIMIENTO

Complejo educacional-deportivo en Mafra (Portugal)

- ✓ Optimización del control de los sistemas HVAC para grandes cargas térmicas (piscina, polideportivo, climatización,…)
- ✓ Monitorización y visualización remota de las condiciones interiors de comfort y variables de consumo
- ✓ Aprendizaje del comportamiento y preferencias de los usuarios
- ✓ Predicciones semanales del consumo energético del edificio



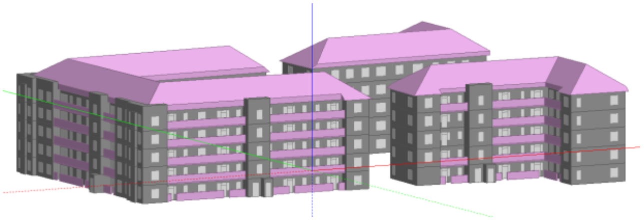
Aplicaciones en el proyecto MOEEBIUS

OPERACIÓN Y MANTENIMIENTO

REHABILITACIÓN

3 bloques de apartamentos en Londres (R.Unido)

- ✓ Análisis del potencial de participación de consumidores domésticos en esquemas de Demand Response
  - ✓ Impacto de la interrupción temporal de la climatización en el comfort interior
  - ✓ Predicciones de consumo semanal para el agregador
- ✓ Evaluación de alternativas de rehabilitación en envolvente
- ✓ Aprendizaje del comportamiento y preferencias de los usuarios
- ✓ Monitorización y visualización remota de las condiciones interiors de comfort y variables de consumo



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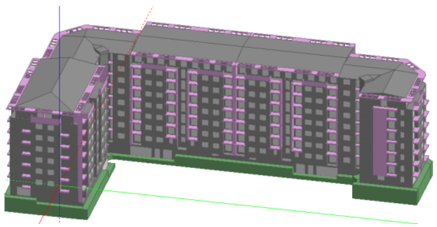
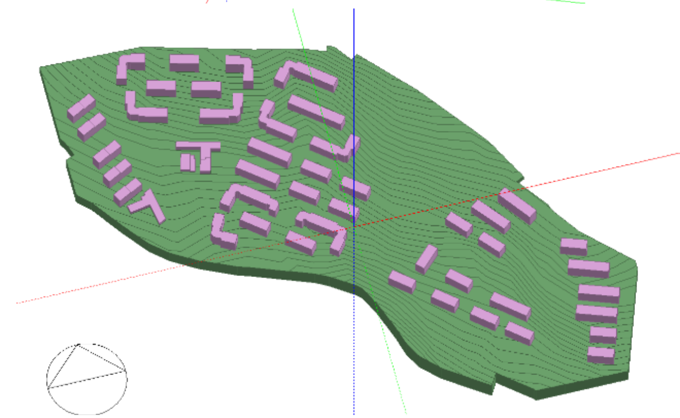
Aplicaciones en el proyecto MOEEBIUS

OPERACIÓN Y MANTENIMIENTO

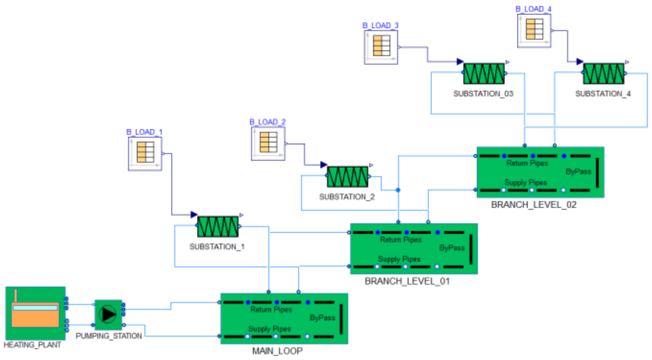
Barrio de 44 edificios residenciales (>4600 apartamentos) y 2 educacionales en Belgrado (Serbia)



- ✓ Monitorización remota del consumo de *District Heating*
  - ✓ Información en tiempo real para el operador de la red
  - ✓ Empoderamiento del consumidor final y mejora de la eficiencia energética a través de la concienciación



- ✓ Modelado y co-simulación edificio distrito
  - ✓ Predicciones de consumo semanal para el operador
  - ✓ Evaluación de estrategias alternativas de operación de la red (*digital twin*) y optimización energética, sin afección al comfort del consumidor final



Proyectos recientes empleando modelado físico

DISEÑO

Diseño y dimensionamiento de una red de distrito de calefacción y ACS en Madrid

- ✓ Ampliación de una planta existente, para cubrir una creciente demanda por agregación de edificios
- ✓ Dimensionamiento de la planta
- ✓ Dimensionamiento de la red de distribución
- ✓ Diseño de las subestaciones a nivel de edificio
- ✓ Definición y evaluación de alternativas de rehabilitación para una red optimizada

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Proyectos recientes empleando modelado físico

OPERACIÓN Y MANTENIMIENTO

Análisis técnico y económico de las redes térmicas en hospitales de Osakidetza

- ✓ Análisis de diferentes módelos técnico-económicos de explotación para las plantas de producción de las redes térmicas, incluyendo la definición de soluciones técnicas para las deficiencias identificadas
- ✓ Definición de los modelos de explotación de las plantas de producción
- ✓ Evaluación del cumplimiento de toda normativa técnica y de seguridad applicable a las plantas de producción
- ✓ Definición de las condiciones de operación más adecuadas e identificación de las estrategias de explotación más ventajosas

Osakidetza
Servicio vasco de salud

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Proyectos recientes empleando modelado físico

REHABILITACIÓN

Rehabilitación energética de los edificios públicos a través de tecnologías adaptables y asequibles

- ✓ Proyecto Europeo A2PBEER, coordinado por Tecnalia, de rehabilitación para Edificios Públicos de Consumo Nulo, con tres demostradores en España, Suecia y Turquía.
- ✓ Soluciones innovadoras de rehabilitación energética:
  - ✓ Superaislamiento de fachada con VIPs
  - ✓ Ventana reversible para optimizer las ganancias solares estacionales
  - ✓ Sistema de iluminación inteligente que optimiza us uso en función de la luz natural
  - ✓ Sistemas de calefacción y refrigeración solar térmicos
  - ✓ Innovador concepto de red térmica y subestaciones

Edificio de la UPV/EHU en el campus de Leioa

A2PBEER
AFFORDABLE AND ADAPTABLE PUBLIC BUILDINGS THROUGH ENERGY EFFICIENT RETROFITTING

ESKERRIK ASKO

GRACIAS

THANK YOU

MERCI

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3.3 Annex 1.3. Modelado basado en datos aplicado a bombas de calor, HVAC y edificio. Borja Tellado

Modelado basado en datos aplicado a bombas de calor

30 de enero 2019

0.- Indice

FHP project is funded by European Union under the grant agreement no. 731231.

A continuación…

- Tipos de modelado según su grado de aproximación al fenómeno a modelar
    - Pros, Contras, ámbitos de aplicación…
- Como sacar ventaja de la hibridación de modelos
    - Generación de datos de entrada, calibración del modelo….
- Tipos de hibridación
    - Hibridación en Serie , Hibridación en Paralelo
- Caso de uso.
    - Vivienda unifamiliar diseñada siguiendo especificaciones tipo “Passive Haus”

FHP project is funded by European Union under the grant agreement no. 731231.

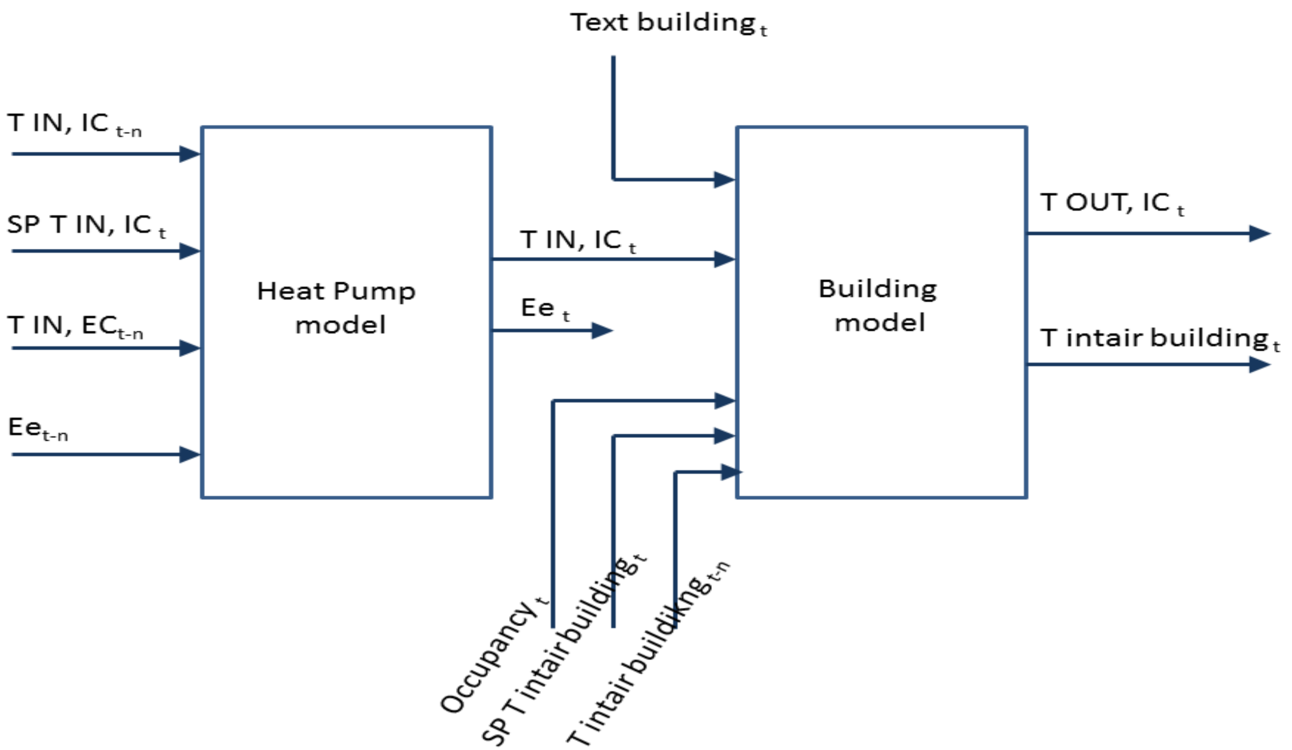
2.- Tipos de Modelado

White Box: se conoce como modelado de caja blanca cuando la arquitectura y todos los datos del sistema son accesibles. Los modelos de caja blanca son modelos de fase de diseño ampliamente reconocidos como inexactos, la mayoría de las veces, debido al uso impredecible del edificio. Los modelos de caja blanca, según la descripción de los detalles físicos del artículo modelado, reducen considerablemente el número de sensores necesarios para producir un resultado. Por otro lado, los enfoques de caja blanca son muy sensibles a las imprecisiones en el modelado. Las inexactitudes pueden deberse a errores o simplificaciones realizadas durante el modelado o debido a desviaciones en los valores dados a los parámetros de modelado.

Gray-Box: se refiere a un sistema mientras tiene algún conocimiento del sistema interno. Generalmente, los enfoques de caja gris, describen el modelo / proceso a modelar mediante expresiones analíticas simplificadas. Después de una fase de calibración, basada en lecturas de sensores, se calculan los coeficientes de las expresiones analíticas. Una vez que se completa la descripción analítica, el modelo resuelve la (s) ecuación (es) para evaluar el modelo. Los modelos de caja gris no caracterizan la composición del elemento a modelar, sino su comportamiento a las excitaciones en sus límites.

Black-Box: el modelo de caja negra se basa en la idea de probar un sistema sin tener ningún conocimiento del funcionamiento interno del sistema o de su arquitectura. Estos tipos de modelado son muy útiles en la configuración de reconocimiento de patrones. A diferencia de las pruebas de caja blanca, las pruebas de caja negra facilitan las comunicaciones de prueba entre los módulos. Los modelos de caja negra tienen una gran dependencia de los datos de entrada disponibles y el poder de manipularlos; en este contexto, el poder de cómputo disponible es una restricción. En los últimos años, la mejora de los marcos tecnológicos (software y hardware) ha facilitado la aplicación de los enfoques de Black-Box.

Hibridación: XXXXX



Modelo Bomba de Calor

- Predecir la temperatura de impulsión y consumo eléctrico de la bomba.
- Optimizar el set point de la temperartua de impulsión.

Modelo del edificio

- *Predecir la evolución de la temperatura interior*
- *Predecir la demanda térmica del edificio*
- La temperara exterior y la ocupación se consideran como variables de de entrada.

FHP project is funded by European Union under the grant agreement no. 731231.

4.- Hibridación de Modelos

Generación de datos de entrenamiento

Calibración del modelo de caja gris: el proceso de calibración alimenta con datos medidos reales el modelo físico simplificado implementado en los conceptos de caja gris.

Teóricamente, la necesidad de calibración disminuye de los sistemas de caja negra a caja blanca, pero no obstante, no hay enfoque
está libre de necesidad de calibración, ya que ninguno es capaz de reproducir la vida real completamente

El modelo de caja gris que se utiliza para producir el conjunto de datos de entrenamiento virtual para el enfoque de extracción de energía se ha calibrado utilizando

- Verificación de la estabilidad del modelo: uno de los requisitos más importantes de cualquier modelo, independientemente del enfoque que siga, que deben converger y estar libres de singularidades en su dominio de aplicación.
- La generación de un conjunto de datos de entrenamiento requiere excitar el modelo de caja gris con entradas que implementan cierta desviación de los que se han utilizado durante el proceso de calibración.

El conjunto de datos de entrenamiento creado incluirá datos obtenidos con horizontes de tiempo de 24 horas y 7 días. Los resultados de la verificación concluyeron que el modelo no tiene singularidades en una amplia gama de energía térmica produce resultados estables independientemente del horizonte temporal utilizado.

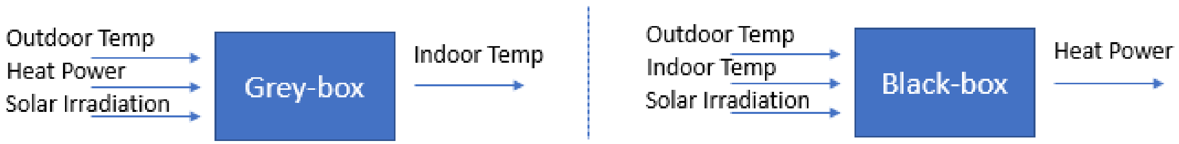


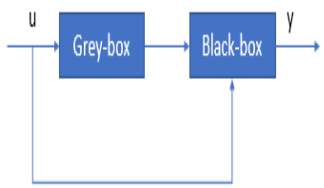
Figure 23: HP Energy push and Energy pull concepts

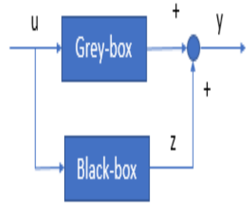
4.- Hibridación de Modelos

Modelos de hibridación de modelos

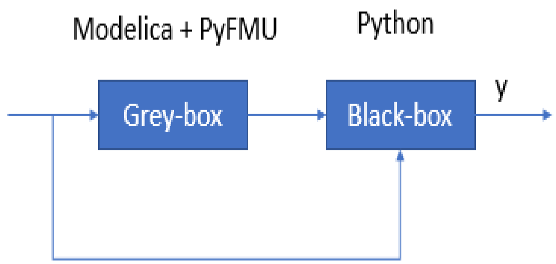
- **Hibridación en Serie**: Las salida del modelo GB o BB alimenta al siguiente modelo para producir una salida. Los parámetros del entrada para cada uno de los modelos no son los mismos.

- **Hibridación en Paralelo**: La salida del modelo GB y BB se componen para producir una salida. Los parámetros de entrada al modelo son comunes.

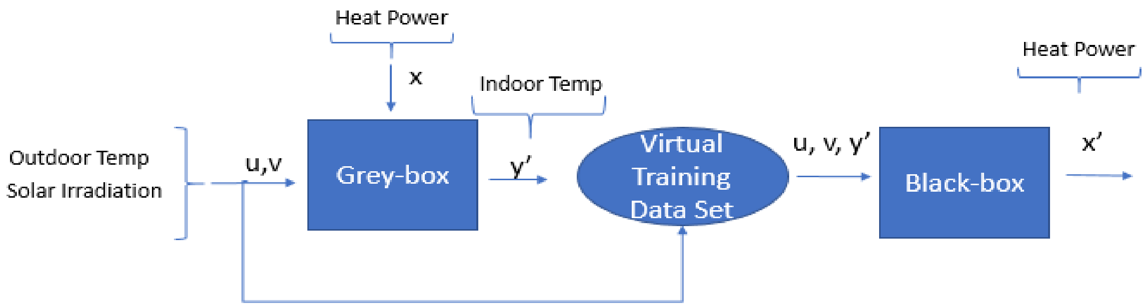




- **Modelo Implementado:** Modelo hibrido en serie implementado en Modélica e integrado en entorno Python junto con una modelo de caja negra.



El modelo de GB es utilizado para crear un set de datos de entrenamiento utilizado por el modelo de caja negra. El modelo de BB da como resultado la energía térmica necesaria para satisfacer ciertas condiciones de confort bajo condiciones externas conocidas



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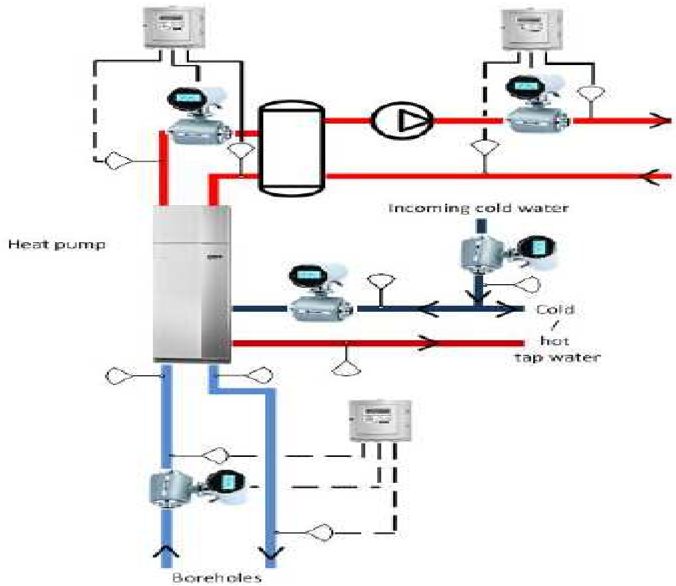
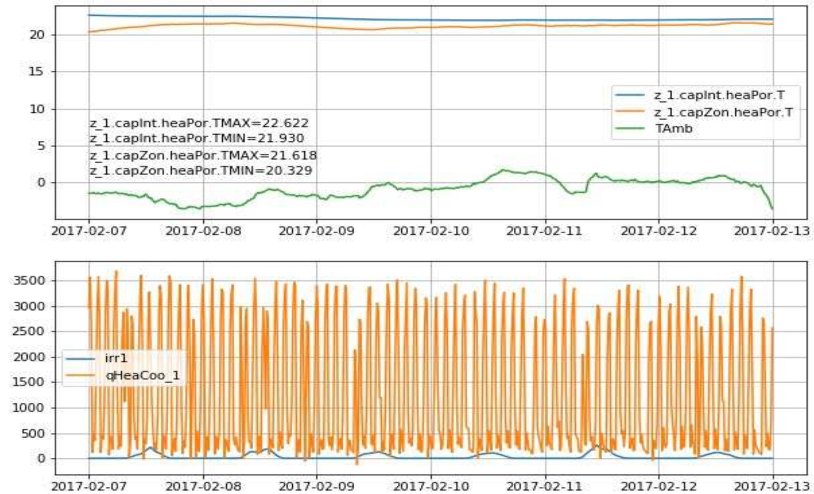
5.- Caso de Uso

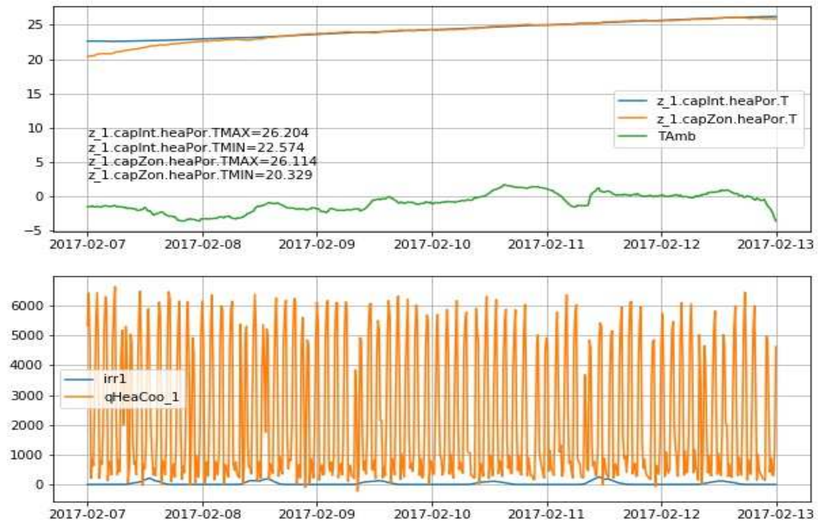
La casa de investigación es una vivienda unifamiliar de energía casi nula disponible para pruebas de productos en la vida real y con un tipo de alojamiento definido o variado. Más de 100 puntos de medición detectan, a nivel de detalle, cómo diferentes instalaciones técnicas, componentes o comportamientos del usuario afectan el rendimiento y la función del sistema de instalación del edificio.



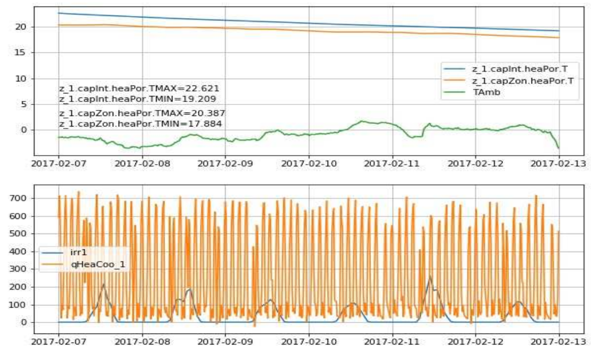
Magnitudes de Entrenamiento				Objetivo	Periodo
Temperatura Ext. (series)	Radiación Solar (series)	Temperatura Int. (series)	Energía Térmica (series)	Incremento de Temperatura Int.	Febrero 2017



Valores obtenidos a partir del modelo calibrado. 7 días

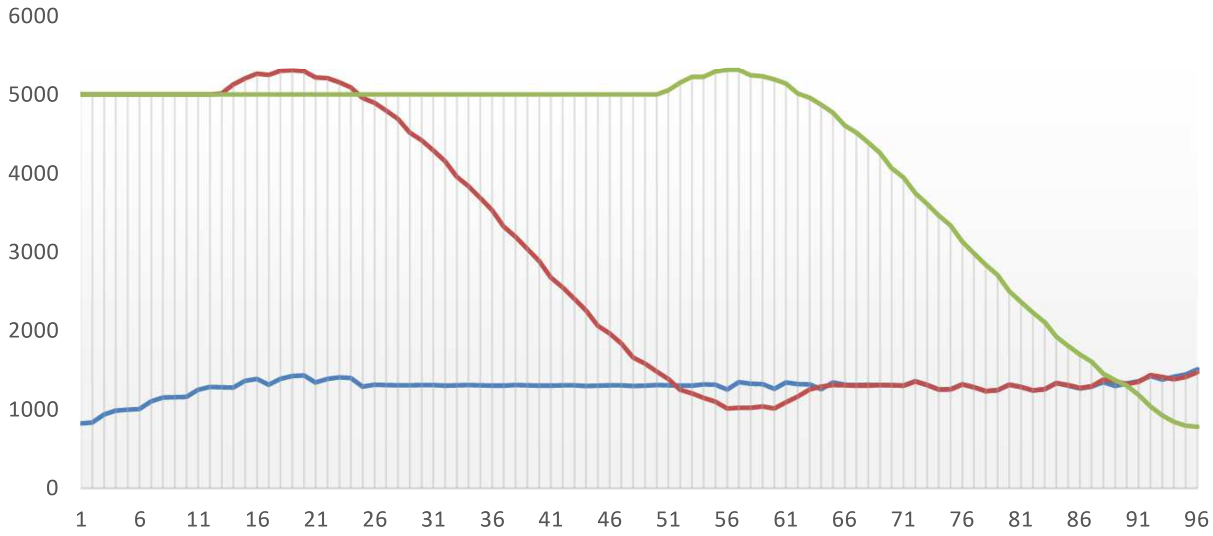


Valores obtenido a partir de aumentar la energía termica con relación al valor de referencia. 7 días

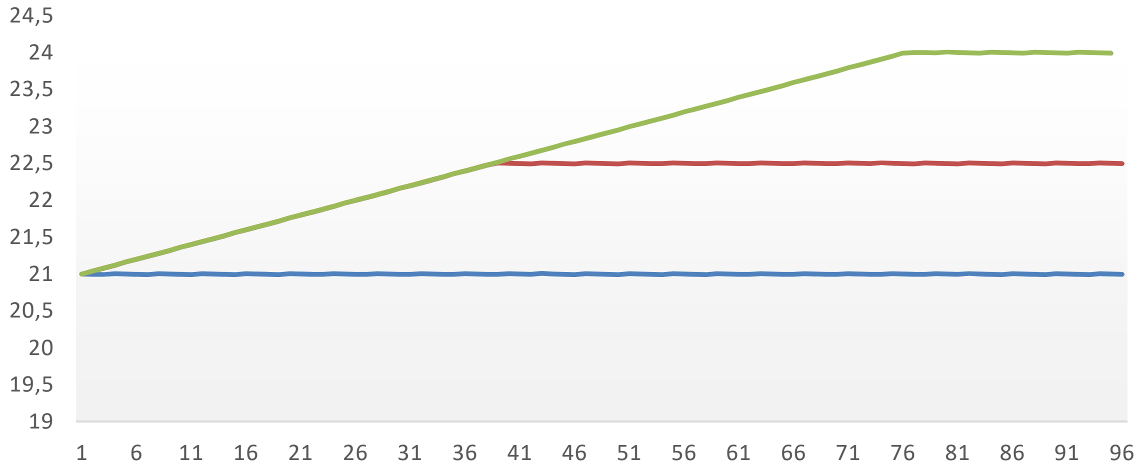


Valores obtenido a partir de disminuir la energía termica con relación al valor de referencia.

pean Union under the grant agreement no. 731231.



Consumo de referencia con temperatura interior a 21ºC (azul), punto de ajuste aumentado a 22,5ºC (amarillo) , 24 (verde) durante 96 períodos



Temperaturas interiores para puntos de consigna 21ºC (azul), punto de consigna 22.5ºC (amarillo) , 24 (verde) por 96 periodos

FHP project is funded by European Union under the grant agreement no. 731231.

5.- Conclusiones

Conclusiones:

- No existe una metodología de modelado mejor “per se”
- La hibridación de modelos resuelve:
  - La falta de datos de entrenamiento
  - Mitiga el impacto de las incertidumbres de modelado
- Las bombas de calor debido a lo acotado del problema son idóneas para el modelado hibrido
- Existen multitud de herramientas de libre distribución que permiten crear modelos avanzados
- Cada vez más se trabaja en la interoperabilidad de las herramientas de modelado de forma que el ámbito de aplicación sea mayor.

FHP project is funded by European Union under the grant agreement no. 731231.

3.4 Annex 1.4. Proceso de calibración de un modelo térmico de edificio. Carlos Fernandez Bandera

Calibración de un modelo térmico de edificio a través de la combinación de modelos tradicionales basado en datos (inversos) y físicos (directos)

Carlos Fernández Bandera

Universidad de Navarra

SABINA

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PROBLEMÁTICA ACTUAL
Variabilidad intrínseca de la fuentes de energía renovable

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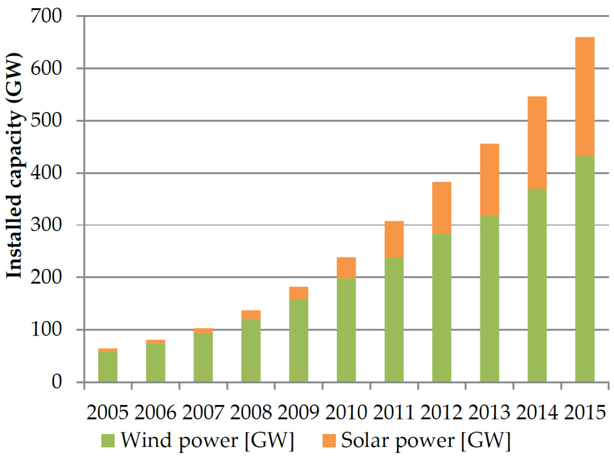
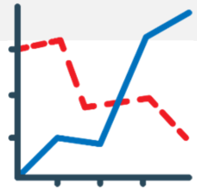


PROBLEMA

INESTABILIDAD DE LA RED ELÉCTRICA

SOLUCIÓN

- CONSUMO DE ENERGÍA FLEXIBLE
- SMART GRIDS



2014=**11%** RES → 2020= **20%** RES → 2030= **32%** RES

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SOLUCIÓN
Edificios energéticamente flexibles

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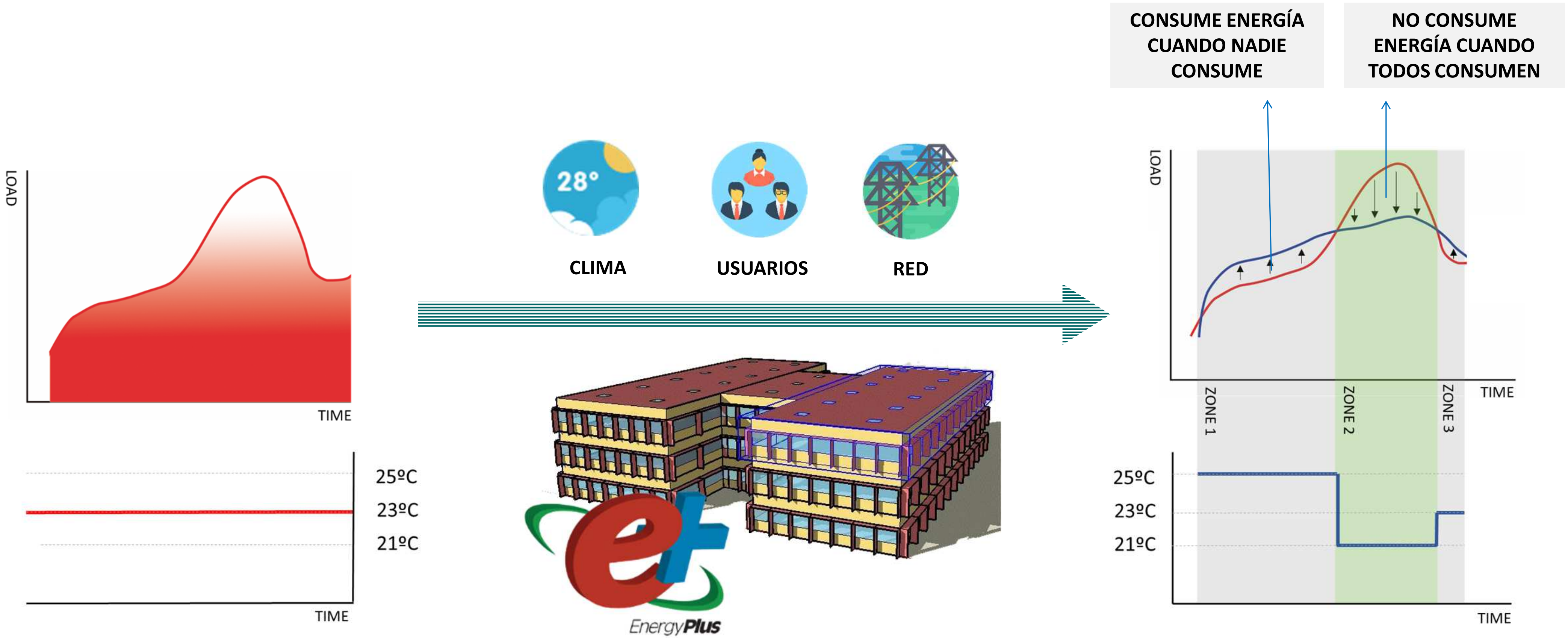

SIN FLEXIBILIDAD

CON FLEXIBILIDAD

Universidad de Navarra

H2020 PROJECT - SABINA
SmArt BI-directional multi eNergy gAteway

SABINA

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SABINA se basa en la fuente de flexibilidad más económica posible:
la inercia térmica existente en los edificios

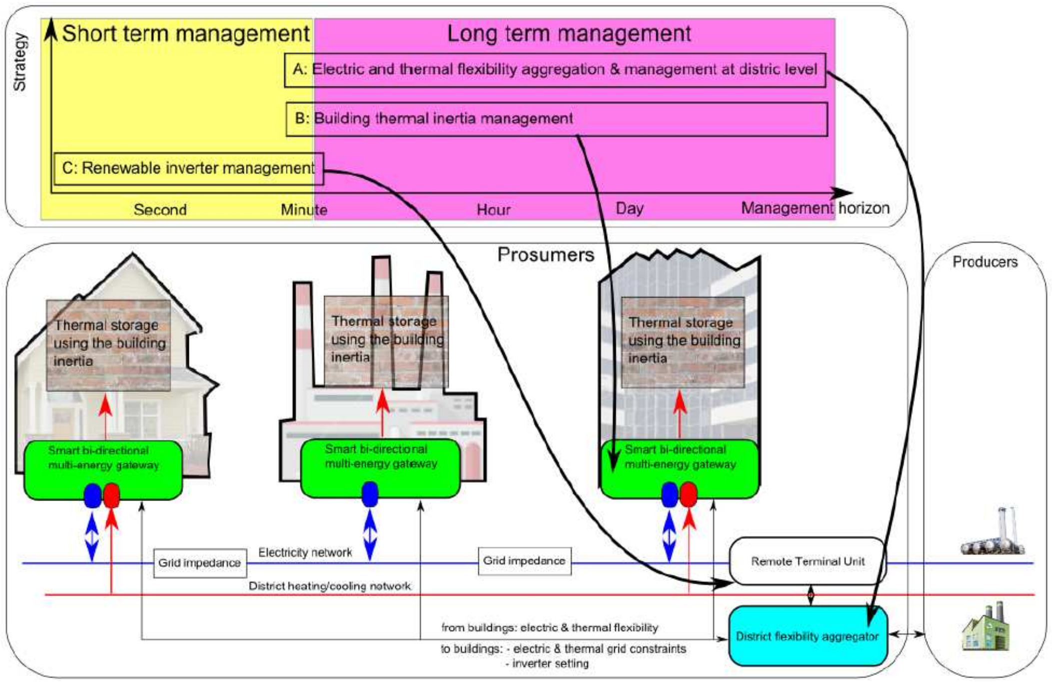
3 esquemas de gestión:

Largo plazo (horizonte diario)

- Conversión exceso de energía eléctrica en calor o frío y almacenamiento usando la **inercia térmica** de los edificios
- Explotación sinergias red eléctrica y térmica a nivel de distrito **compartiendo producción y consumo** de energías renovables para aumentar su penetración.

Corto plazo (horizonte de segundos a minutos)

- **Control eficiente** de los inversores de producción renovable para gestionar el impacto local de la generación distribuida



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CALIBRACIÓN DE MODELOS ENERGÉTICOS
¿Por qué necesitamos un modelo calibrado?

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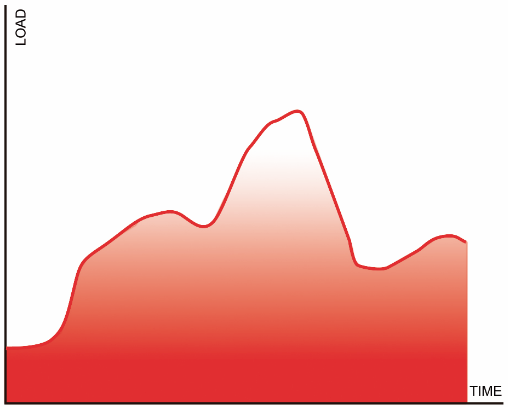
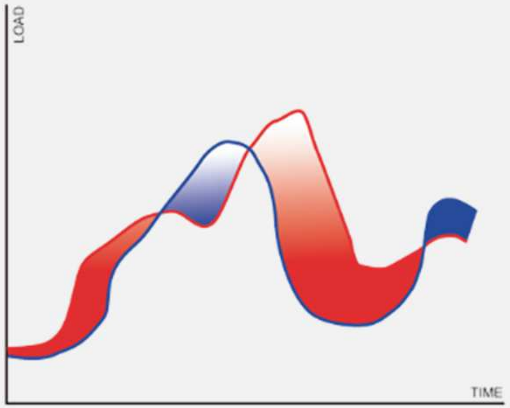
Edificio real

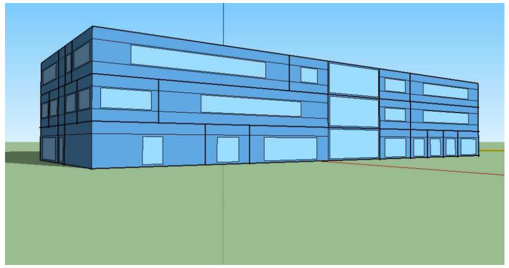


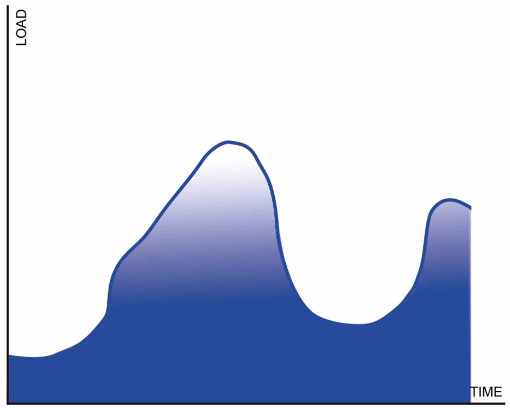
Curva de demanda edificio real

Desajuste de la curva de demanda



Modelo de simulación energética del edificio (BES)





Curva de demanda modelo del edificio

CALIBRACIÓN DE MODELOS ENERGÉTICOS

Concepto – Modelo *law-data-driven*

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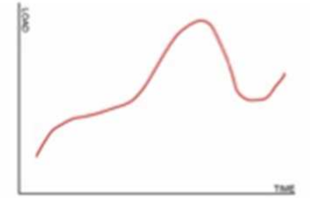
EDIFICIO REAL

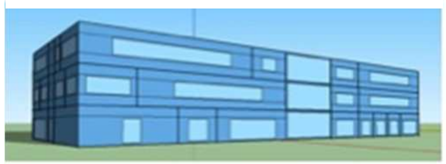


DATOS REALES MEDIDOS

MACHINE LEARNING

MODELO **LAW-DATA-DRIVEN** CALIBRADO

LAW-DRIVEN MODEL (modelo basado en leyes)



FACHADA VENTANAS CUBIERTA

GEOMETRÍA Y PARÁMETROS

CALIBRACIÓN DE MODELOS ENERGÉTICOS

Metodología

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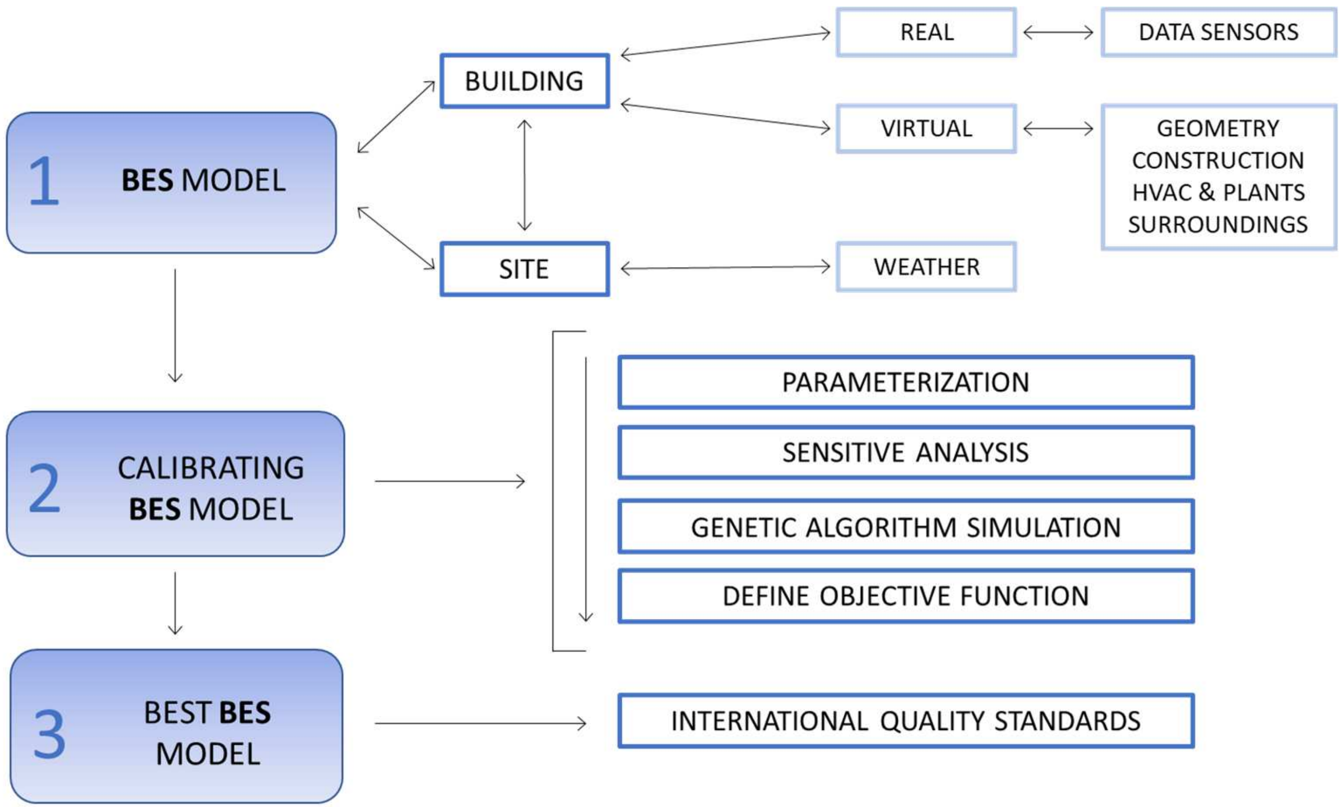

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CALIBRACIÓN DE MODELOS ENERGÉTICOS
Metodología – Modelo energético del edificio (BES)

SABINA

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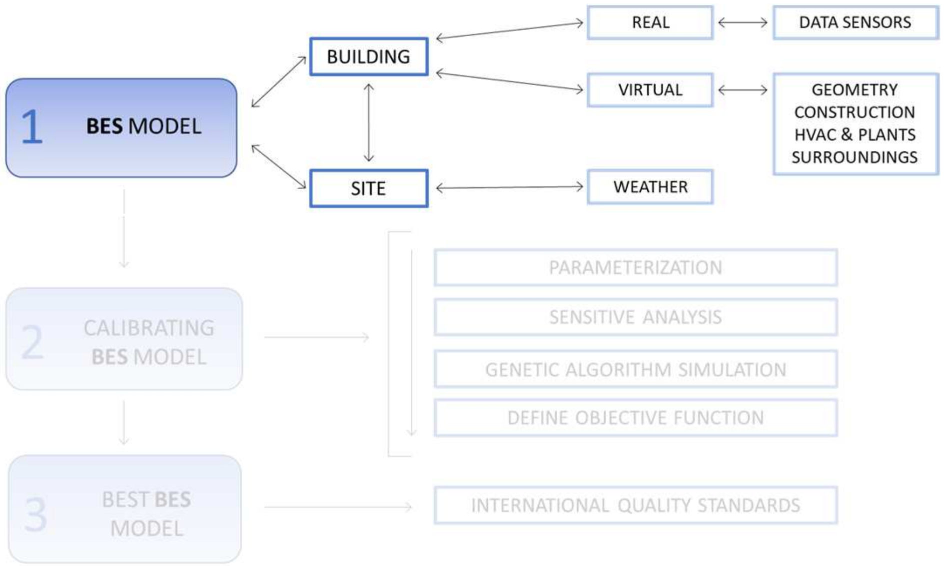
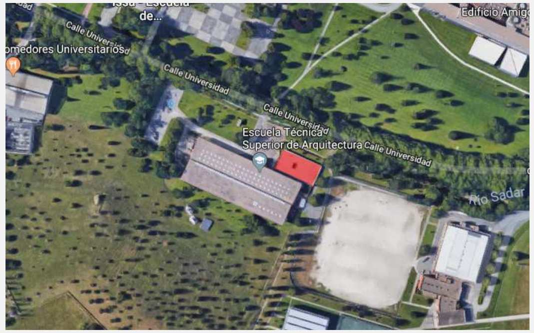
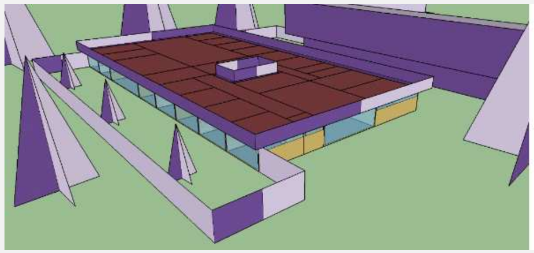


CASO ESTUDIO
Edificio administrativo y Posgrado
Escuela de Arquitectura.
Universidad de Navarra

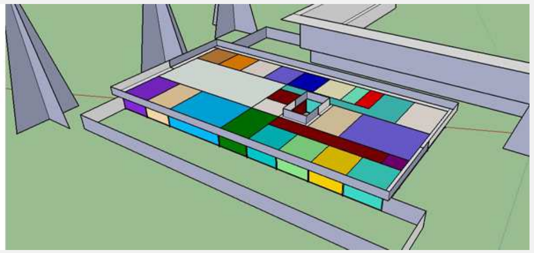


Ubicación

Edificio real



Modelo de simulación energética



Zonas térmicas del modelo

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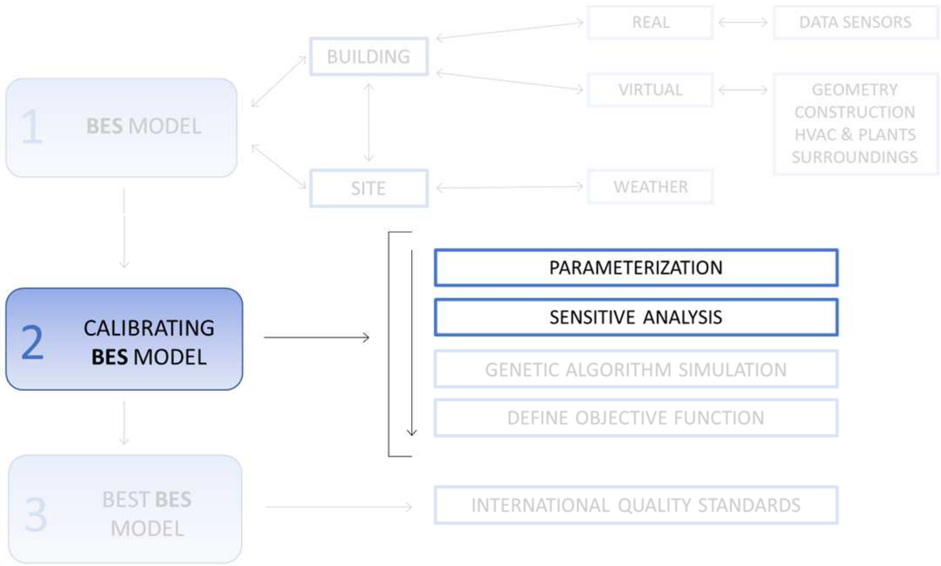
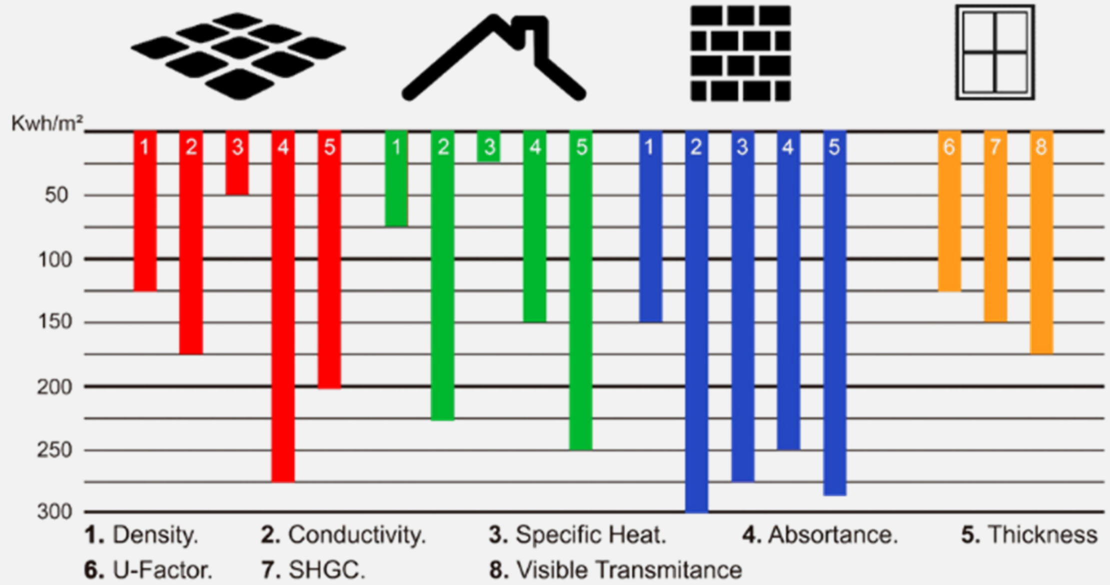
CALIBRACIÓN DE MODELOS ENERGÉTICOS

Metodología – Parametrización y análisis de sensibilidad

SABINA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.





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CALIBRACIÓN DE MODELOS ENERGÉTICOS
Metodología – Algoritmo genético y funciones objetivo

SABINA

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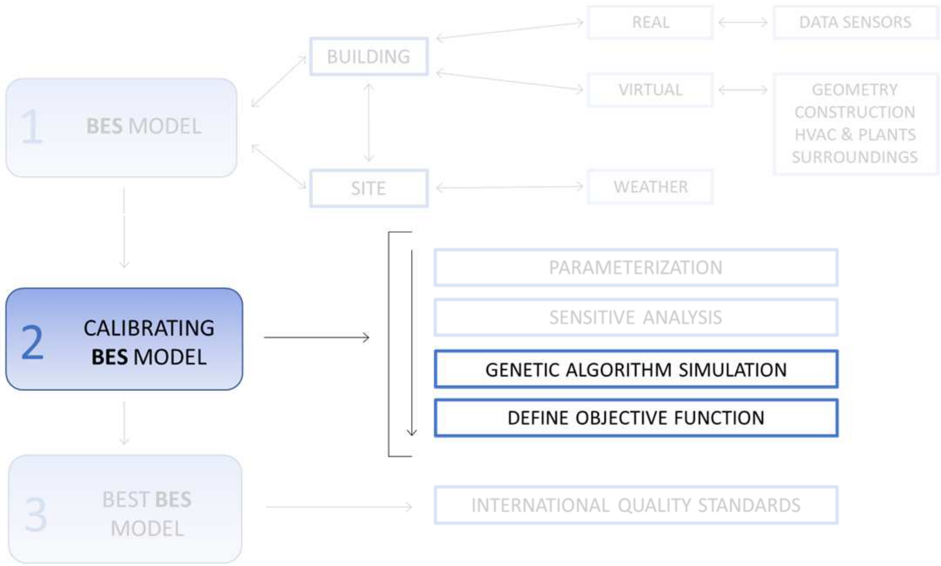
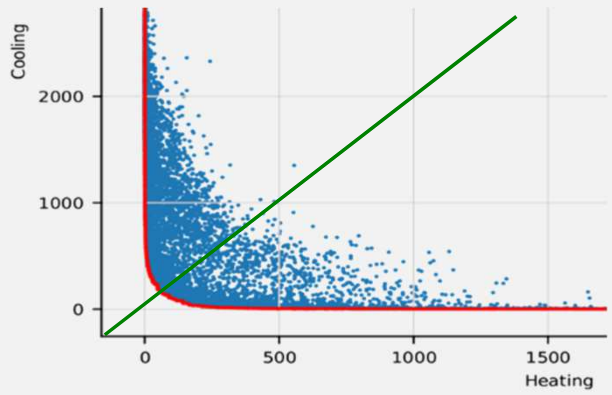
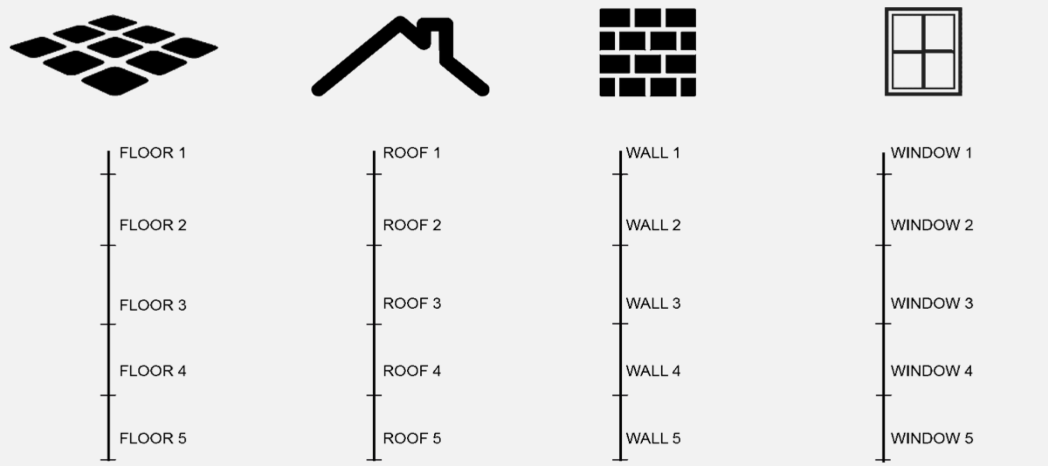


ALGORITMO GENÉTICO NSGA II



The best model



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CALIBRACIÓN DE MODELOS ENERGÉTICOS

Metodología – Selección mejor modelo y evaluación

SABINA

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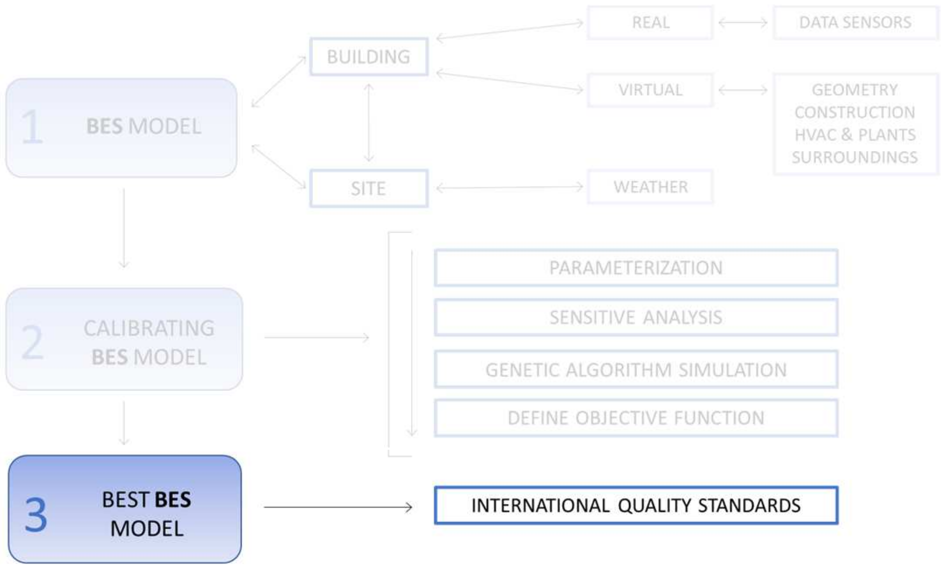
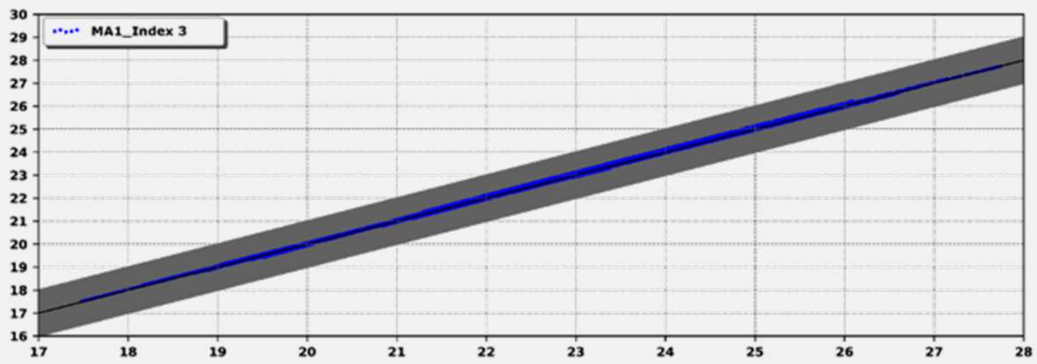
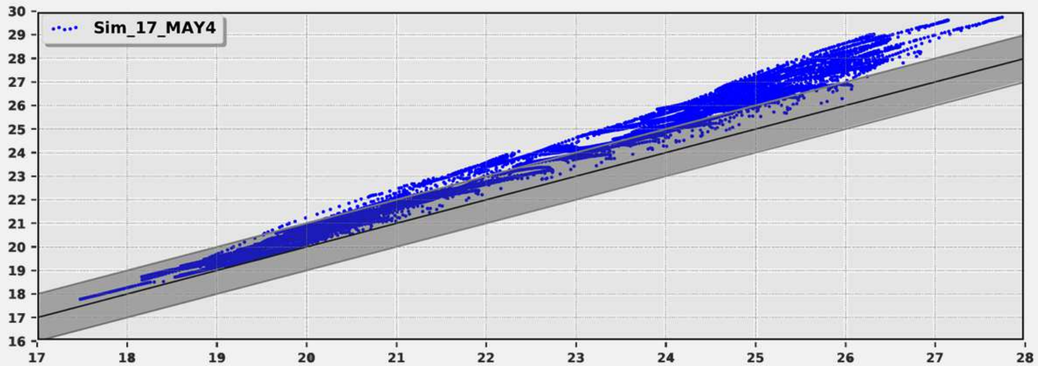


Index	Monthly calibration			Hourly calibration		
	ASHRAE	IPMVP	FEMP	ASHRAE	IPMVP	FEMP
NMBE [%]	± 5	± 20	± 5	± 10	± 5	± 10
CV (RMSE) [%]	15	---	15	30	20	30
R2		> 75%			> 75%	

Modelo calibrado – Mejor modelo



Modelo no calibrado



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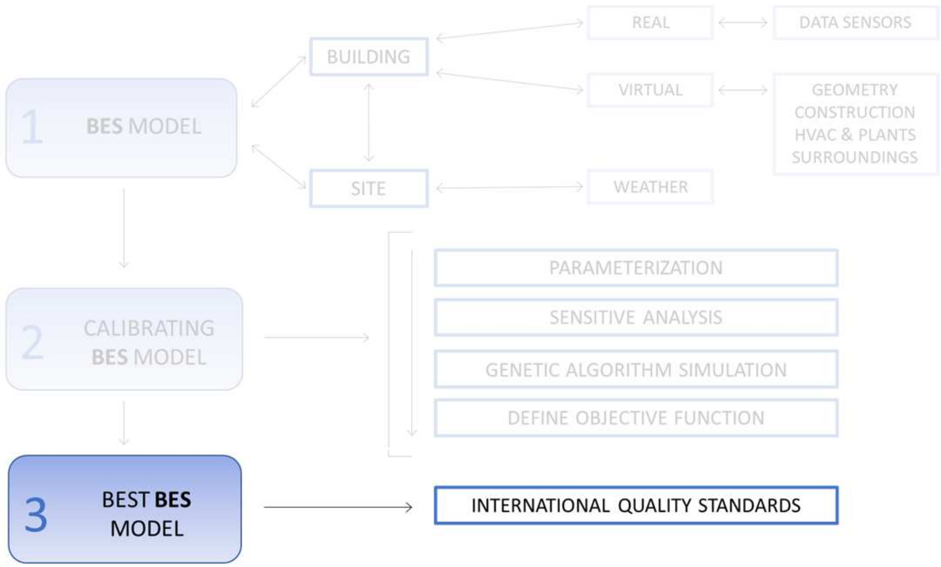
CALIBRACIÓN DE MODELOS ENERGÉTICOS

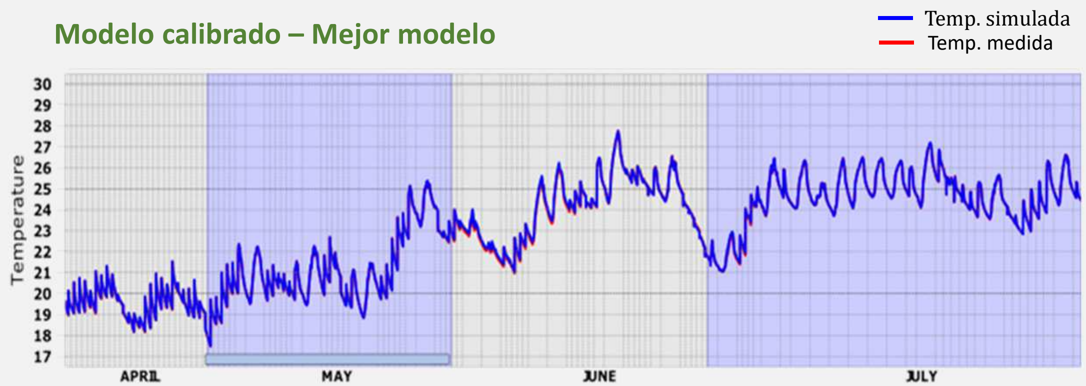
Metodología – Selección mejor modelo y evaluación

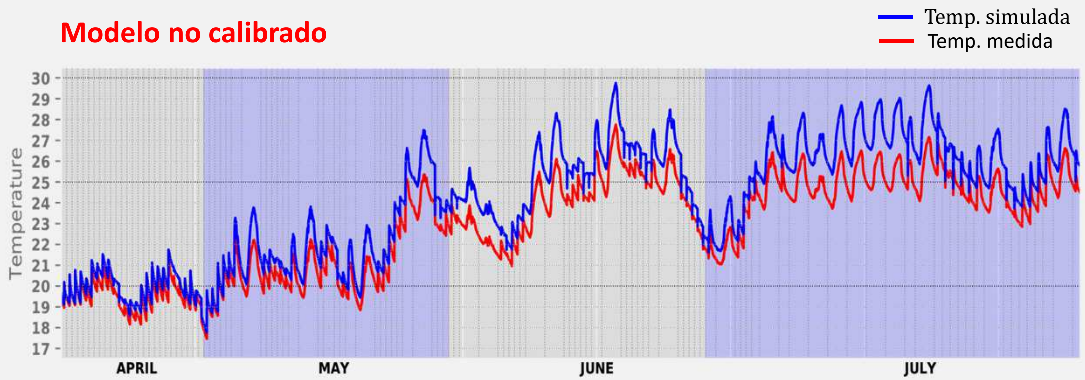
SABINA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.



Index	Monthly calibration			Hourly calibration		
	ASHRAE	IPMVP	FEMP	ASHRAE	IPMVP	FEMP
NMBE [%]	± 5	± 20	± 5	± 10	± 5	± 10
CV (RMSE) [%]	15	---	15	30	20	30
R2		> 75%			> 75%	





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CONCLUSIONES
Puntos clave y próximos pasos

SABINA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.

- Esta metodología genera **modelos calibrados** que predicen el **comportamiento térmico** de un edificio de una manera precisa

- Estos modelos calibrados permiten identificar su inercia térmica y, por tanto, su **capacidad de almacenamiento térmico gratuito.**

- El almacenamiento gratuito de los edificios puede ser utilizado para proporcionar **flexibilidad a la red** e **incrementar el uso de energías renovables**

- Metodología de calibración probada en un modelo sintético. Dentro del **proyecto SABINA**, esta metodología se aplicará en **diferentes escenarios**:

MODELO SINTÉTICO → **TEST EN LABORATORIO** → **TEST REALES: GRECIA Y DINAMARCA**



Universidad de Navarra

Muchas gracias

SABINA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.

Carlos Fernández Bandera
cfbandera@unav.es

3.5 Annex 1.5. Herramientas y retos usando modelos equivalentes. Javier Arroyo

Retos y Herramientas para el Modelado Térmico de Edificios

Javier Arroyo – javier.arroyo@kuleuven.be

TECNALIA - Parque Científico y Tecnológico de Bizkaia

30 enero 2019

Supervisora
Prof. dr. ir. Lieve Helsen
KU Leuven, EnergyVille

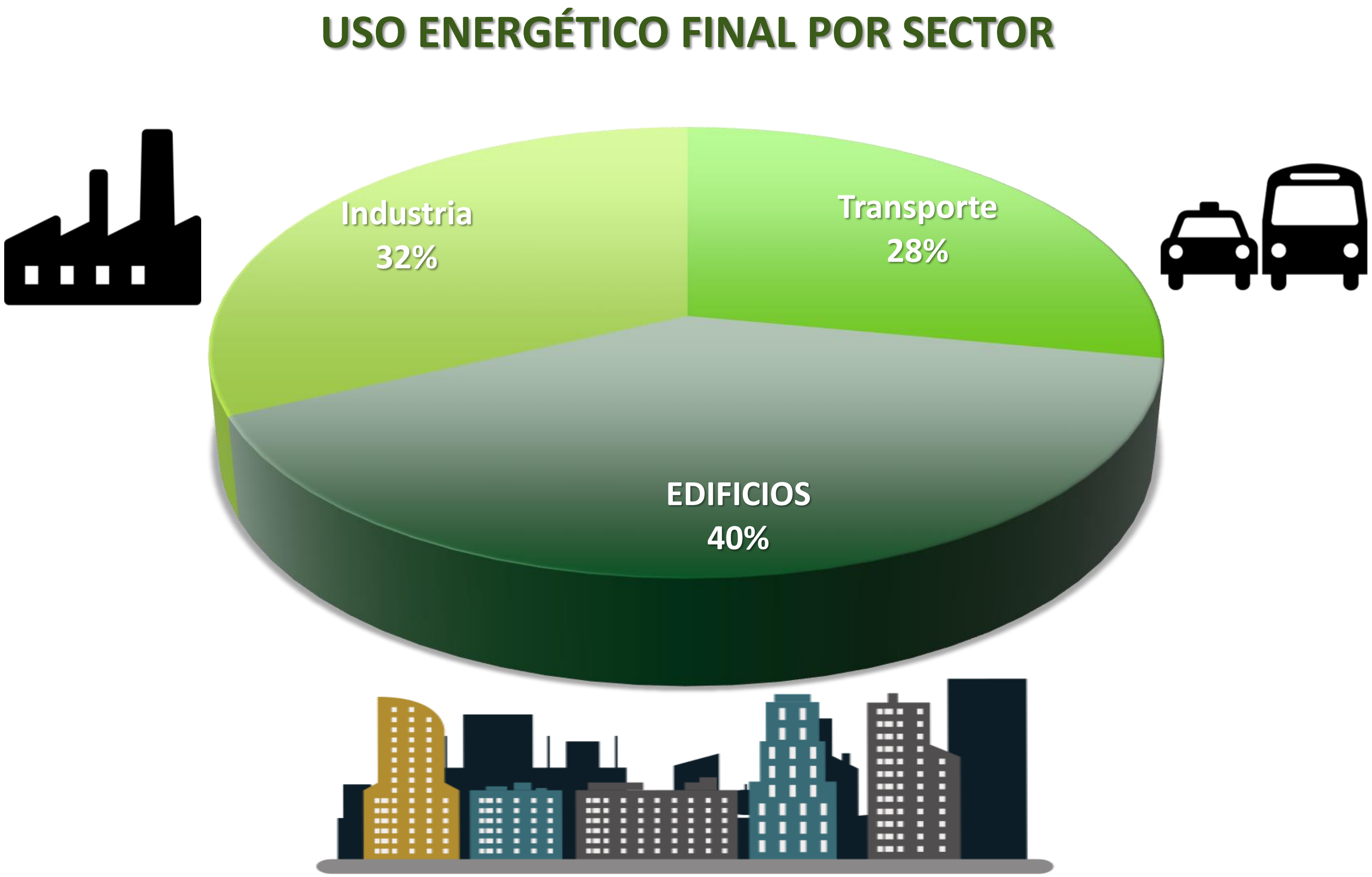
Co-Supervisor
Dr. Alfred Spiessens
VITO, EnergyVille

NUESTRA ESPECIALIDAD

Optimizamos el rendimiento de los sistemas térmicos a través de la integración de control y diseño óptimo

- **Enfoque:**
  - Sistemas térmicos en sistemas multidisciplinarios a gran escala
  - Integración óptima de diseño y control
- **Objetivos:**
  - Mejorar el confort y la calidad de servicio en edificios
  - Mejorar la eficiencia energética reducir el coste energético
  - Integrar energías renovables
  - Desbloquear el uso de la flexibilidad energética
  - Uso sostenible de recursos

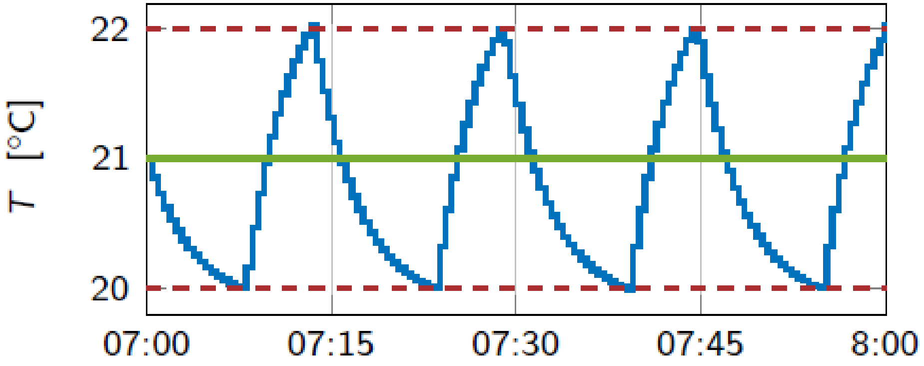
¿POR QUÉ OPTIMIZAR?



Ref: "Atam, E., & Helsen, L. (2016). Control-Oriented Thermal Modeling of Multizone Buildings: Methods and Issues: Intelligent Control of a Building System. IEEE Control Systems, 36(3), 86-111"

¿POR QUÉ OPTIMIZAR?

Sistema actual para el control de edificios



Ref: Ján Drgona

¿POR QUÉ OPTIMIZAR?

Sistema **FUTURO** para el control de edificios

Ref: http://www.billfrymire.com/gallery/weblarge/Teton-mountains-Wyoming-driver.jpg

CONTENIDO

Modelado:

- **Retos y herramientas para el modelado energético de edificios**
  - Introducción
  - Retos en el modelado
  - Tipos de modelos
  - Herramientas para el modelado

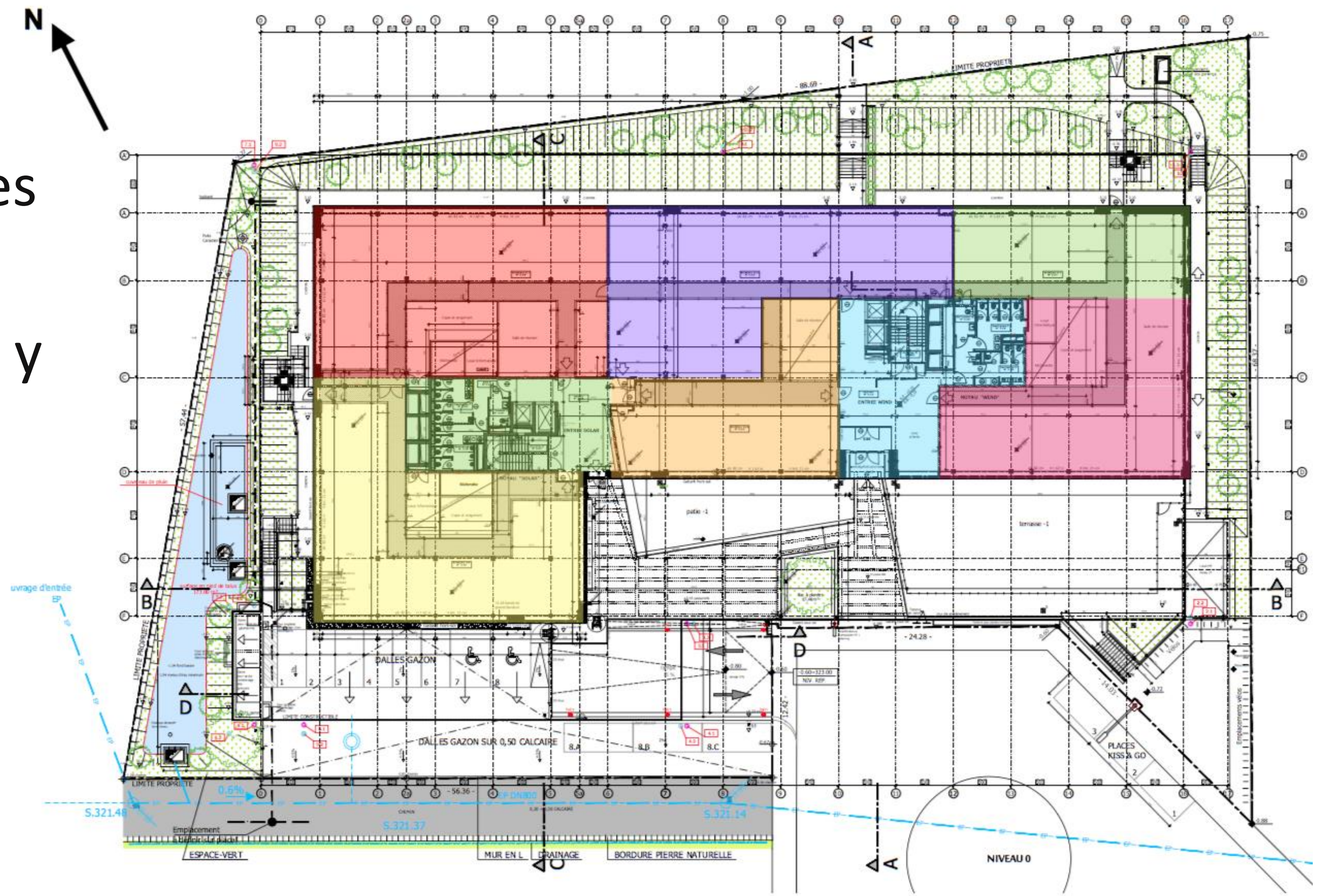
Optimización:

- **Retos y herramientas para el control óptimo de edificios**
  - Enfoques para el control óptimo
  - Aplicaciones
  - Retos en el control óptimo
  - Herramientas para el control óptimo

RETOS EN EL MODELADO DE EDIFICIOS

Complejidad y sistemas multidisciplinarios

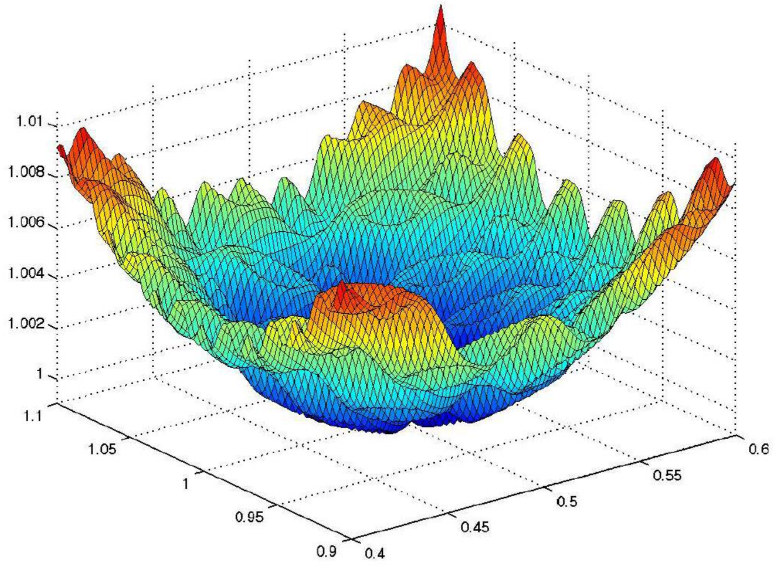
- No lineal
- Distintas constantes de tiempo
- Variables discretas y continuas
- Variables sujetas a incertidumbre



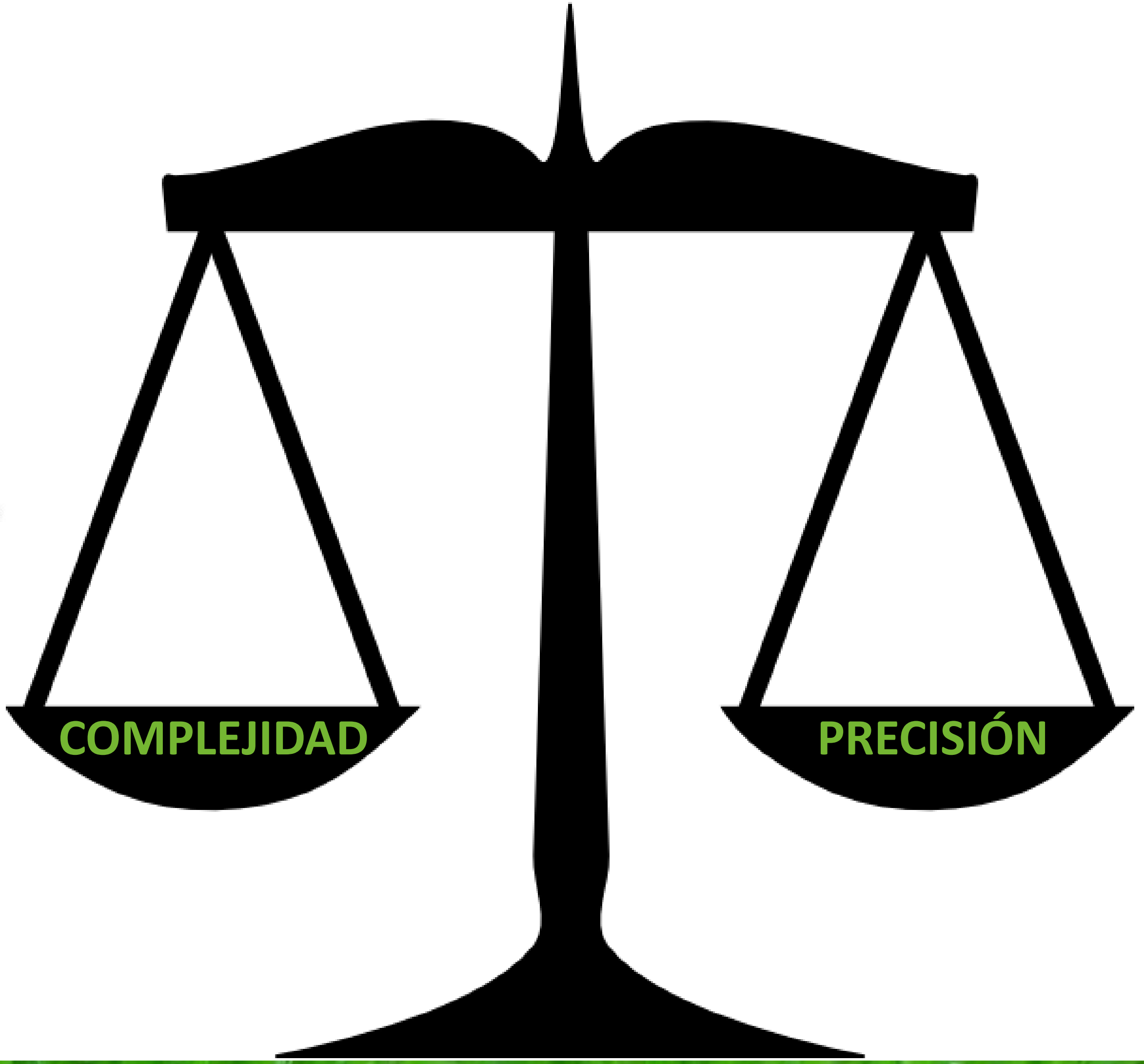
Ref: Hybrid GEOTABS project

RETOS EN EL MODELADO DE EDIFICIOS

Balance entre complejidad y precisión



Ref: Ján Drgona



RETOS EN EL MODELADO DE EDIFICIOS

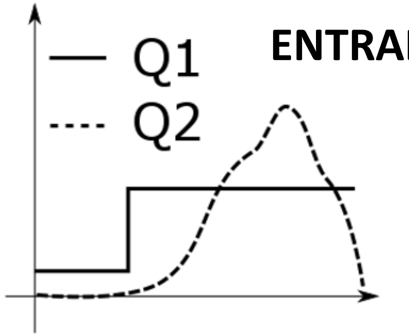
Acceso a los datos

Ref: “https://lucidconnects.com/library/videos-and-webinars?page=3”

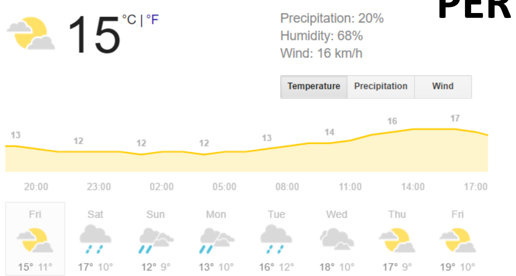
TIPOS DE MODELOS

Entradas/Salidas

ENTRADAS

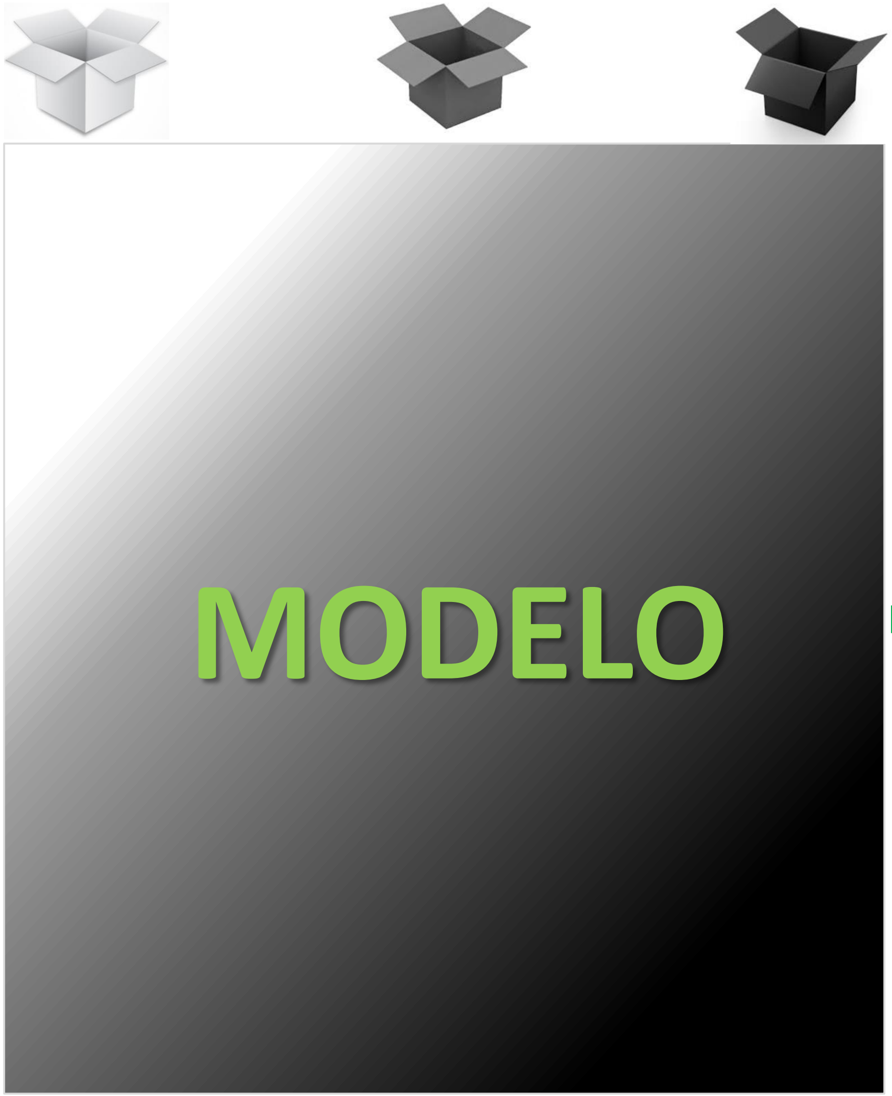


ENTRADAS CONTROLABLES

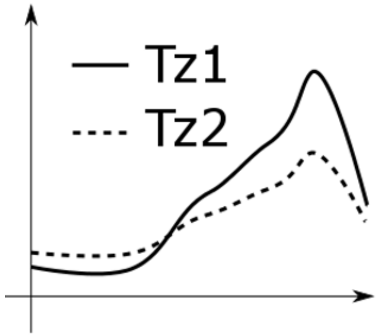


PERTURBACIONES

ESTADO INICIAL



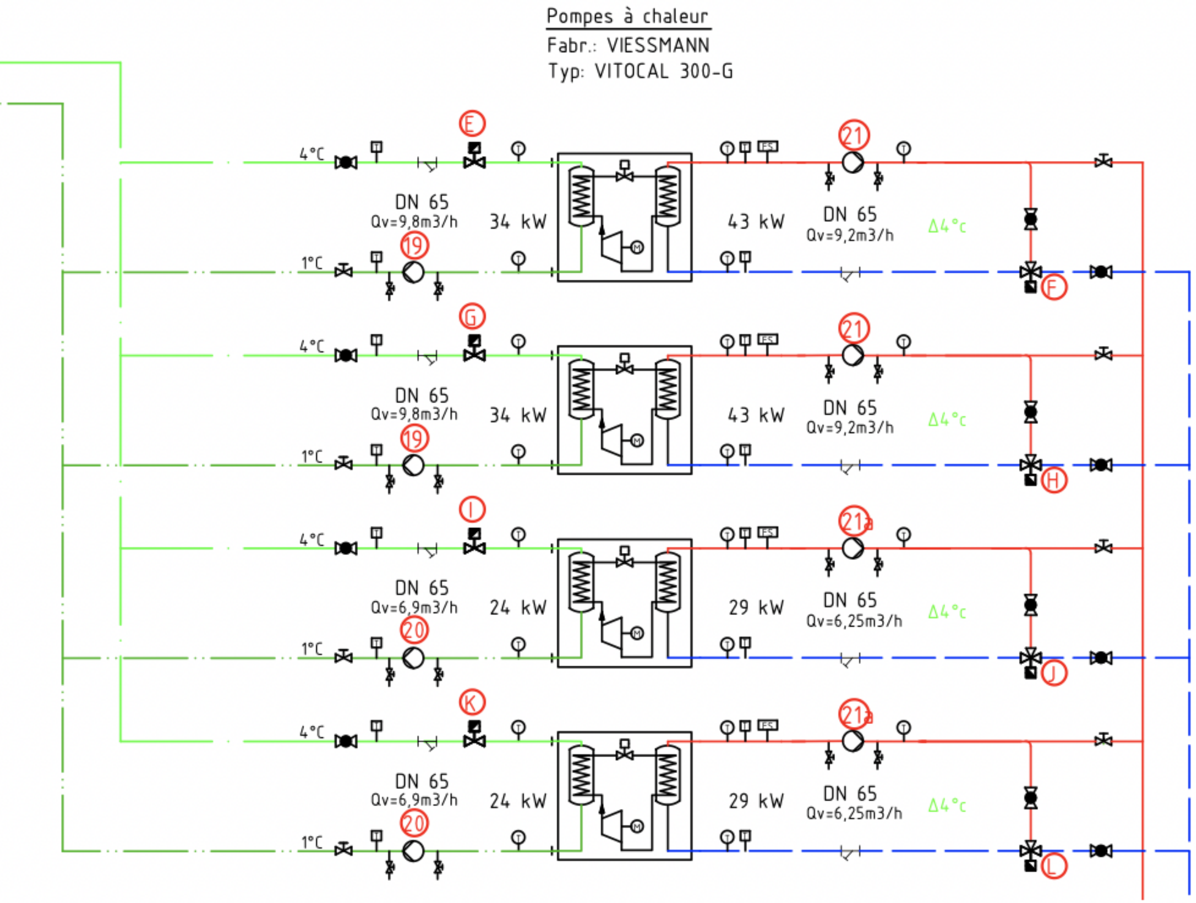
SALIDAS

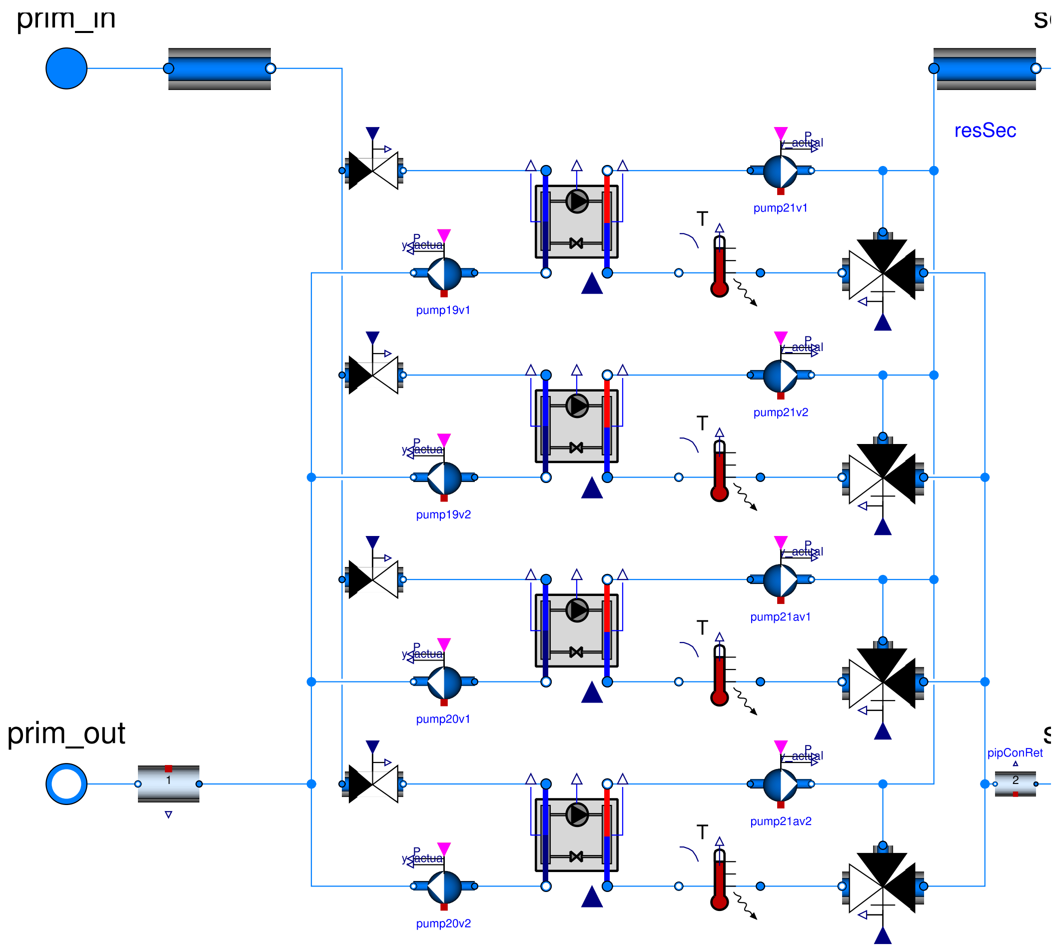


TEMPERATURA EN CADA ZONA TÉRMICA

TIPOS DE MODELOS

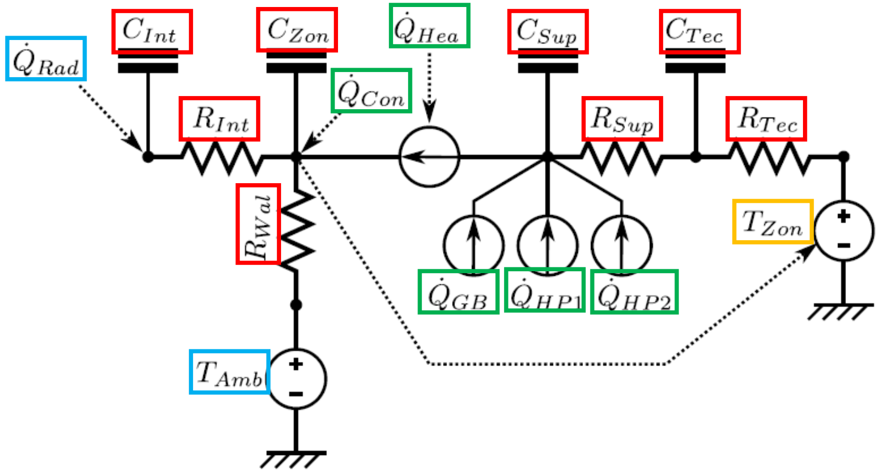
Modelos físicos o directos





TIPOS DE MODELOS

Modelos semi-físicos



Ref: "Practical implementation and evaluation of model predictive control for an office building in Brussels", Roel De Coninck, Lieve Helsen"

- Parámetros
- Perturbaciones
- Entradas controlables
- Salidas controladas

$$\text{minimise} \quad \int_{t_0}^{t_f} e(t)^T Q e(t)\,\mathrm{d}t, \quad (1a)$$

$$\text{with respect to} \quad x(t), w(t), u(t), p,$$

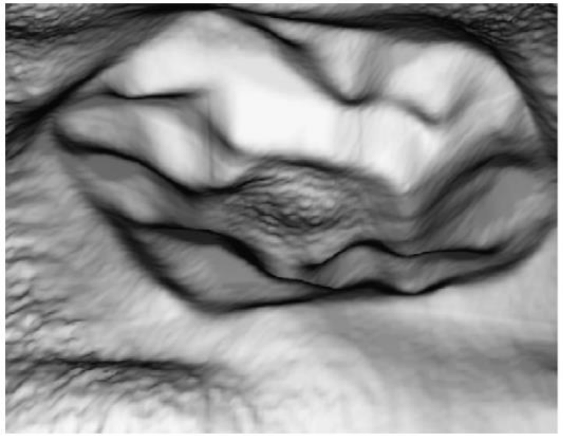
$$\text{subject to} \quad F(t, \dot{x}(t), x(t), w(t), u(t), p) = 0, \quad (1b)$$

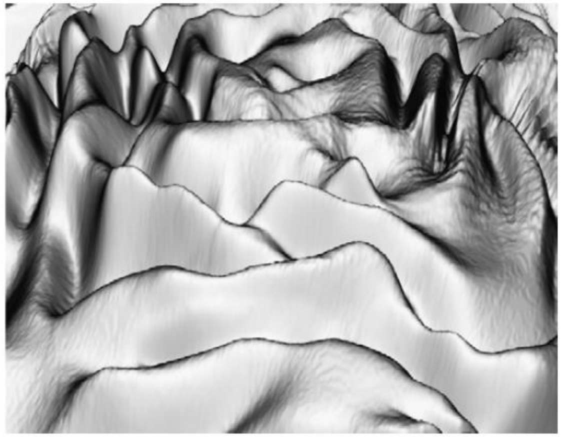
$$x(t_0) = x_0, \quad (1c)$$

$$\forall t \in [t_0, t_f].$$

$$RMSE_j = \sqrt{\frac{\sum_{i=1}^{m} (y_j(t_i) - M_j(t_i))^2}{m}}$$

Ref: "Gutschker O Parameter identification with the software package LORD. Building and Environment (2006), doi:10.1016/j.buildenv.2006.10.010"

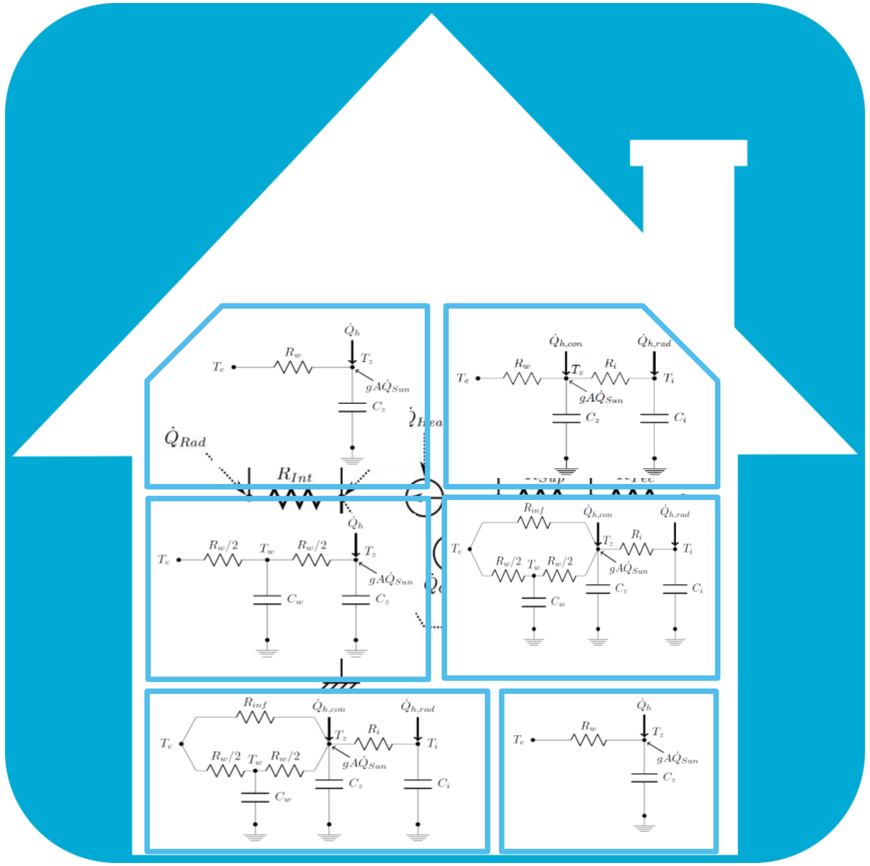


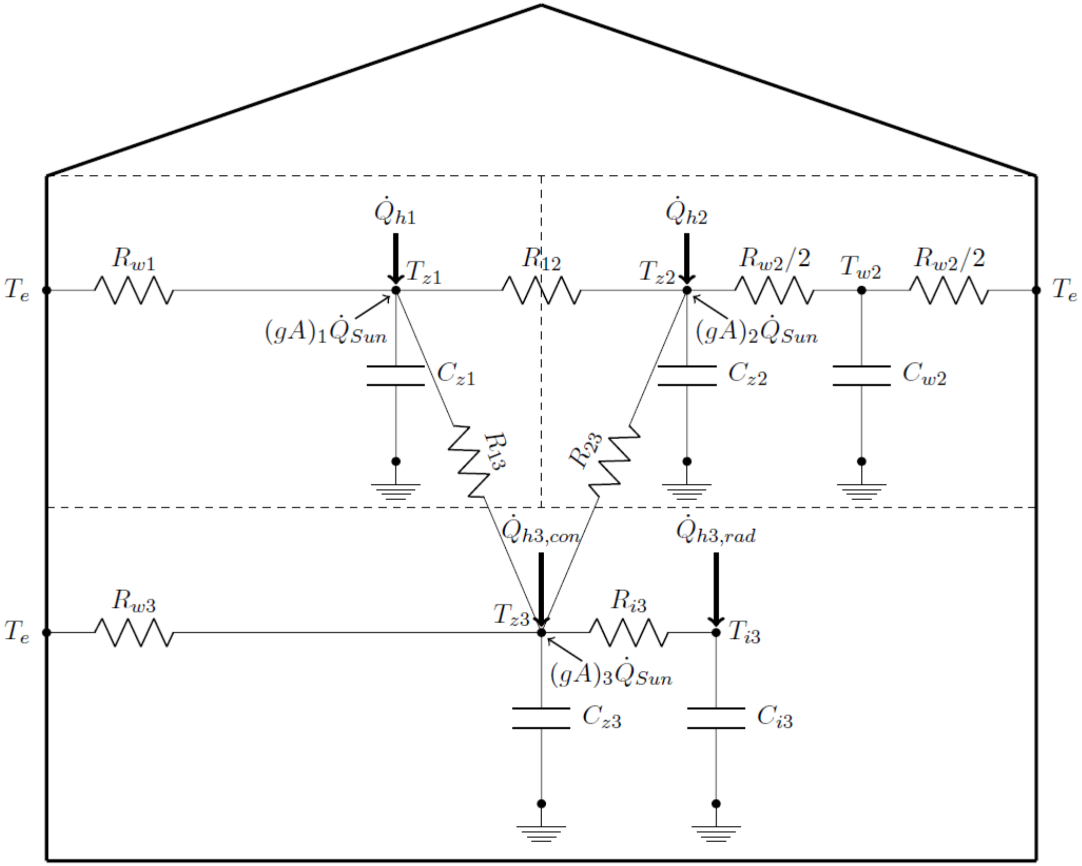


TIPOS DE MODELOS

Modelos semi-físicos multizona

- Arquitectura descentralizada
- Arquitectura centralizada





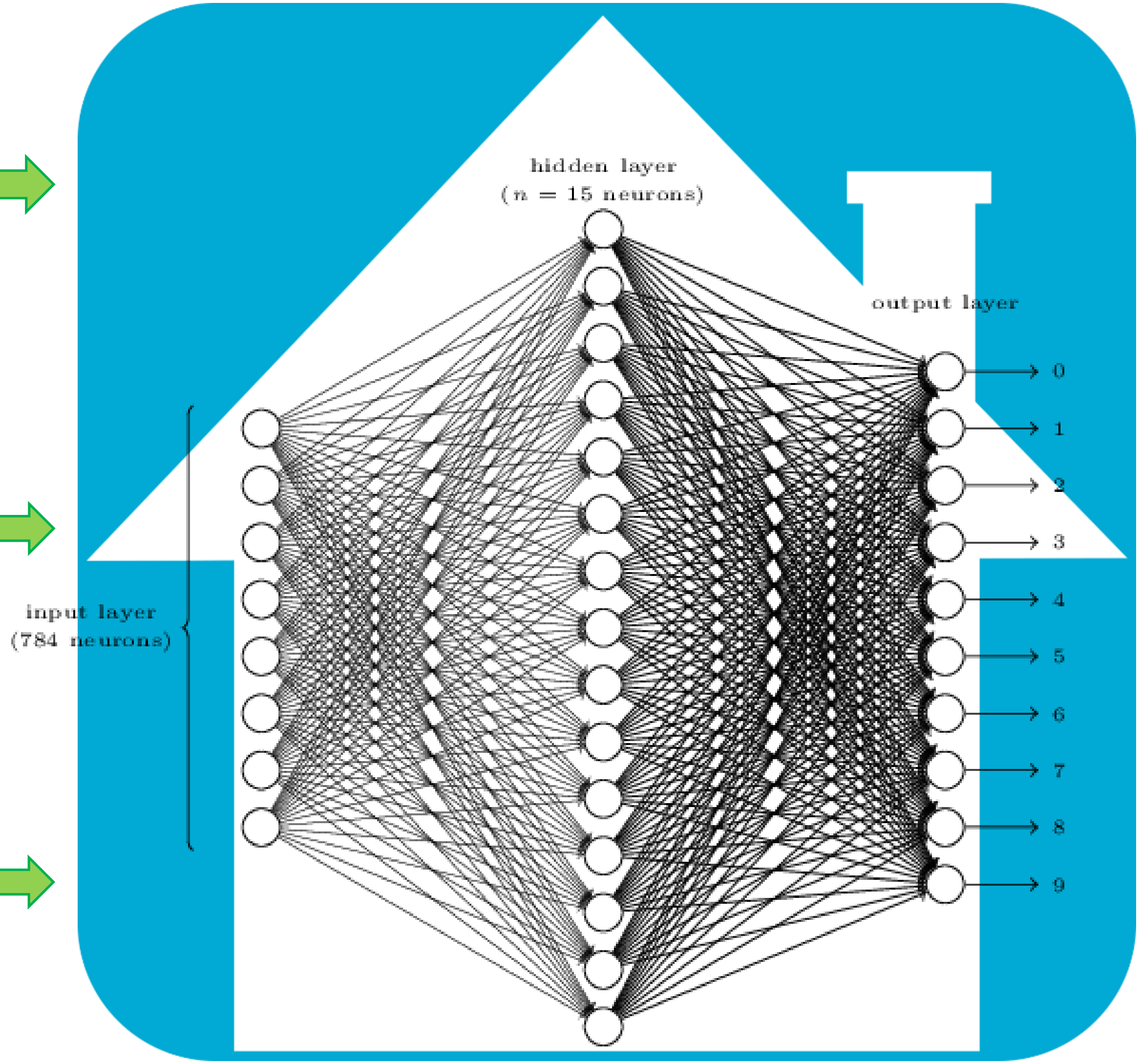
TIPOS DE MODELOS

Modelos puramente matemáticos o inversos

ENTRADAS CONTROLABLES

PERTURBACIONES

ESTADO INICIAL

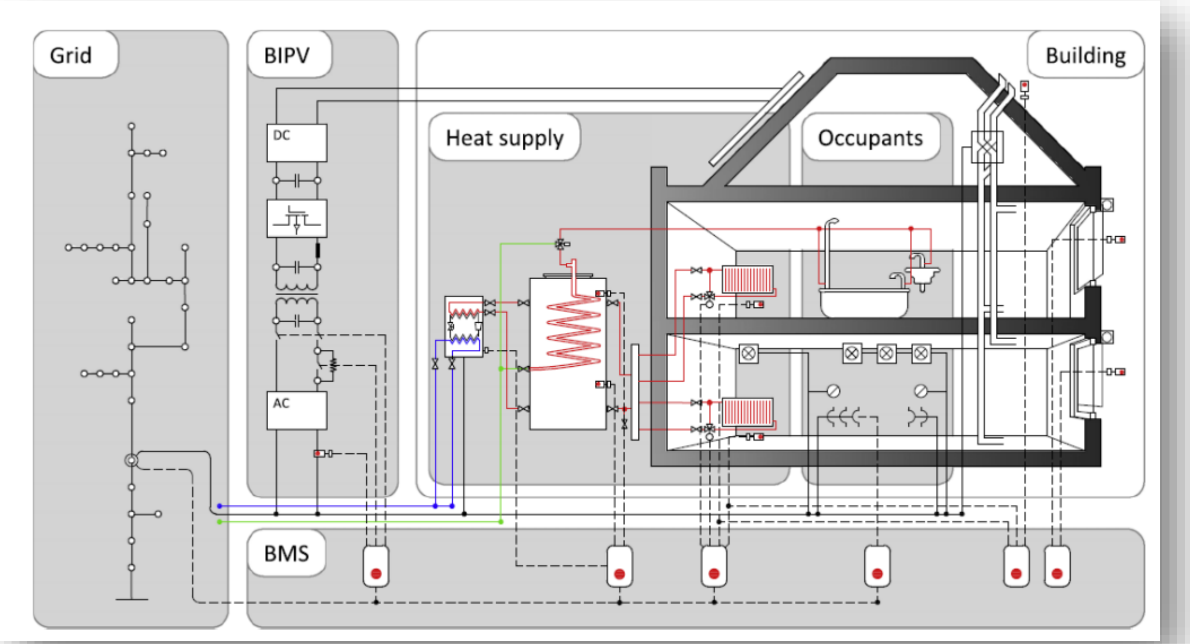


TEMPERATURA EN CADA ZONA TÉRMICA

Ref: "https://machinelearnings.co/text-classification-using-neural-networks-f5cd7b8765c6"

HERRAMIENTAS PARA EL MODELADO

- **Integrated District Energy Assessment Simulations (IDEAS)**
  - **Libre:**
    - https://github.com/open-ideas/IDEAS
  - **Orientado a objetos**
  - **Fruto de colaboración internacional (IBPSA Project 1)**
  - **Validación: TwinHouse, BESTEST, PhDs**

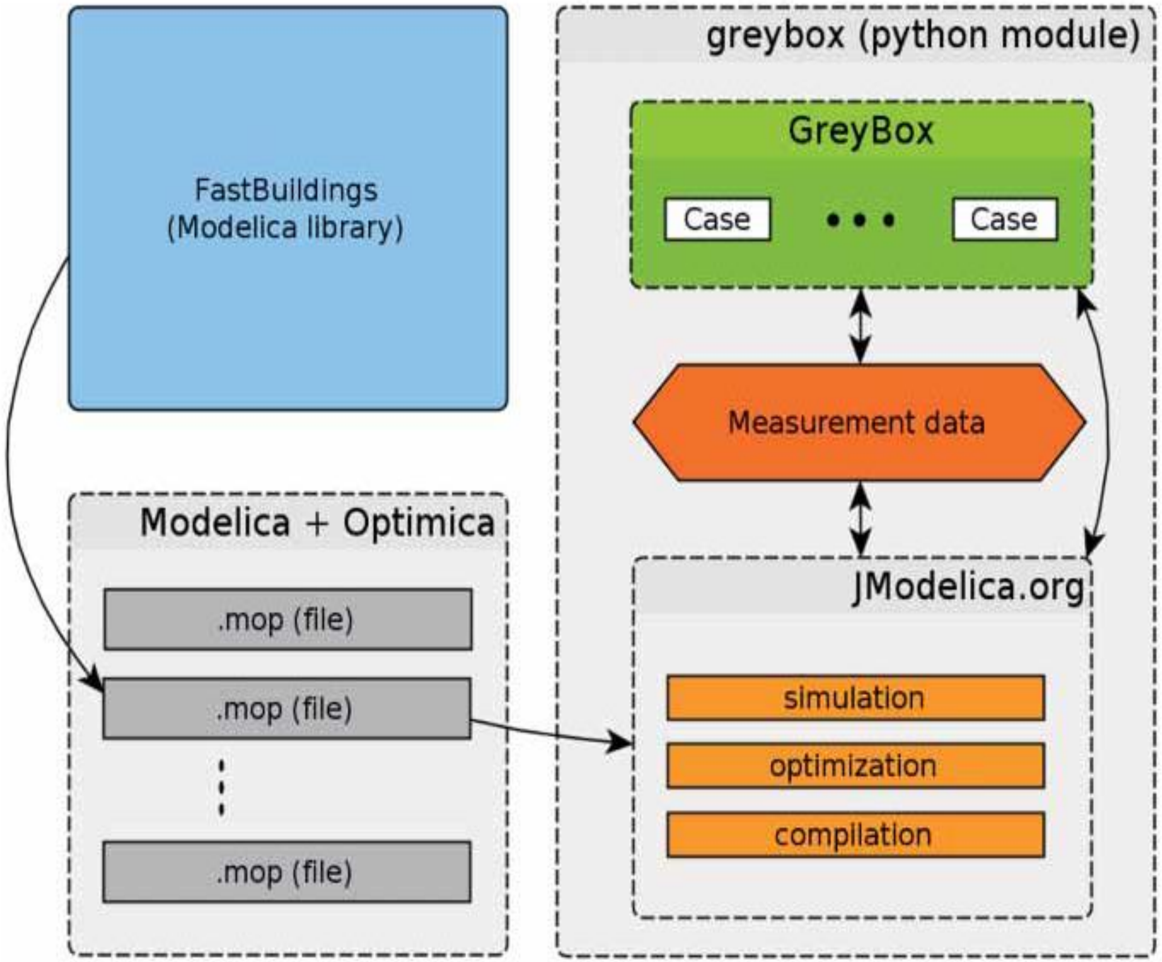


Ref: "F. Jorissen, G. Reynders, R. Baetens, D. Picard, D. Saelens & L. Helsen. Implementation and verification of the IDEAS building energy simulation library, Journal of Building Performance Simulation, 2018"

HERRAMIENTAS PARA EL MODELADO

The Grey-Box Toolbox

- **Optimización de parámetros en modelos de modélica utilizando datos.**
- **Interfaz en Python para proveer de una amigable estimación, validación y comparación de diferentes modelos.**



HERRAMIENTAS PARA EL MODELADO

Resumen

- Simscape
- ME for MPC
- OpenBuild
- BRCM
- BLDG
- BASBenchmarks
- MoCaVa
- SI Toolbox

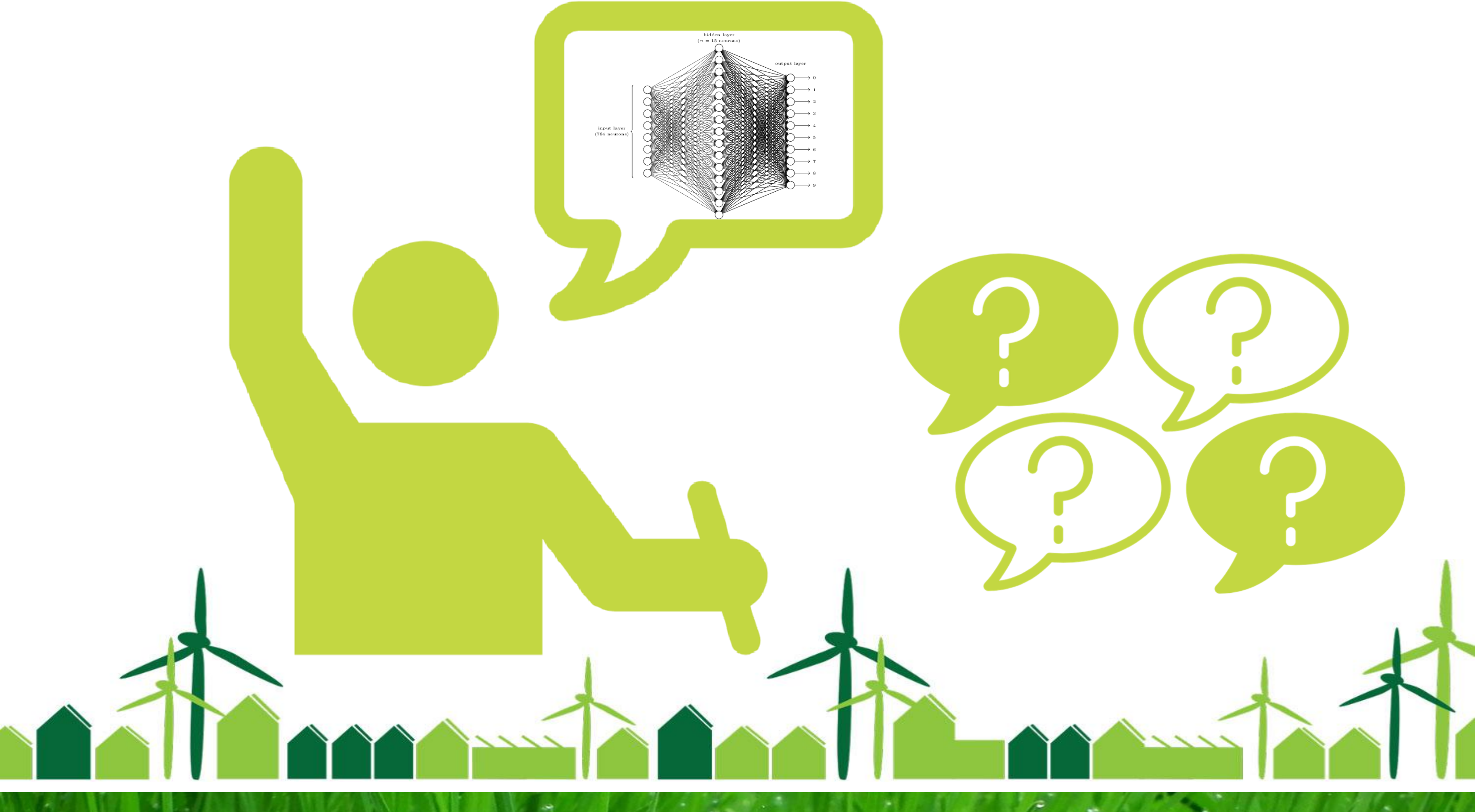
- Scikitlearn
- SciPy

- IDEAS
- LIDEAS
- IBPSA Project 1

- CTSM-R

- MPCpy
- Grey-Box Toolbox

- LORD


hidden layer
(n = 15 neurons)
output layer
input layer
(784 neurons)
0
1
2
3
4
5
6
7
8
9

3.6 Annex 1.6. Implementación de MPCs en la nube o en sistemas embebidos. Borja Tellado

Implementación MPC en la nube o Sistemas Embebidos

30 de enero 2019

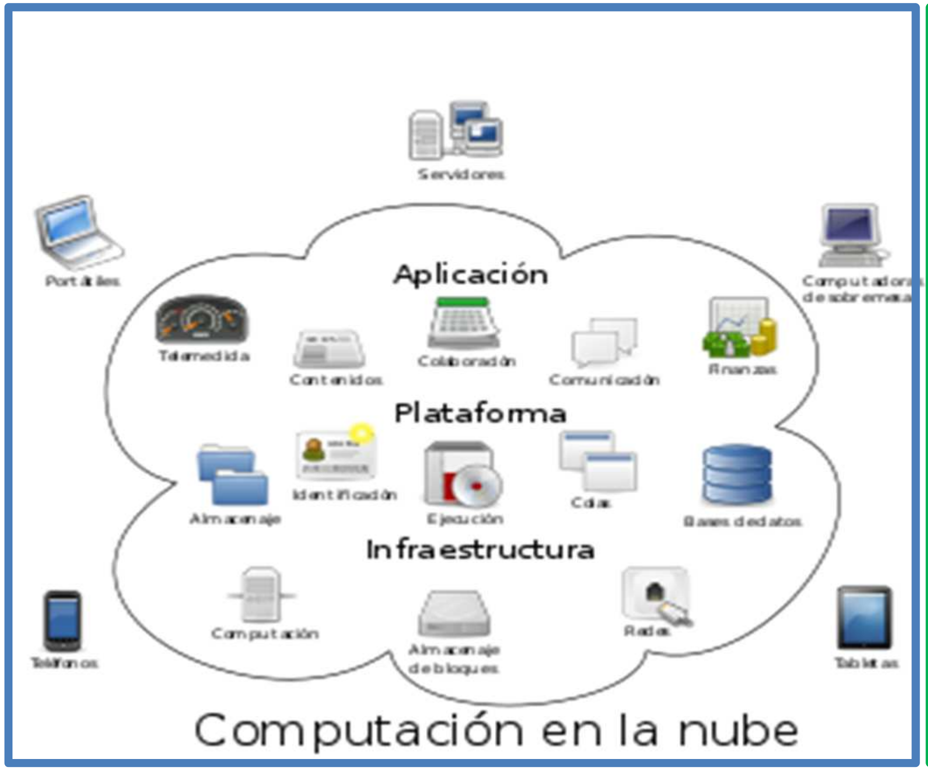
tecnalia Inspiring Business

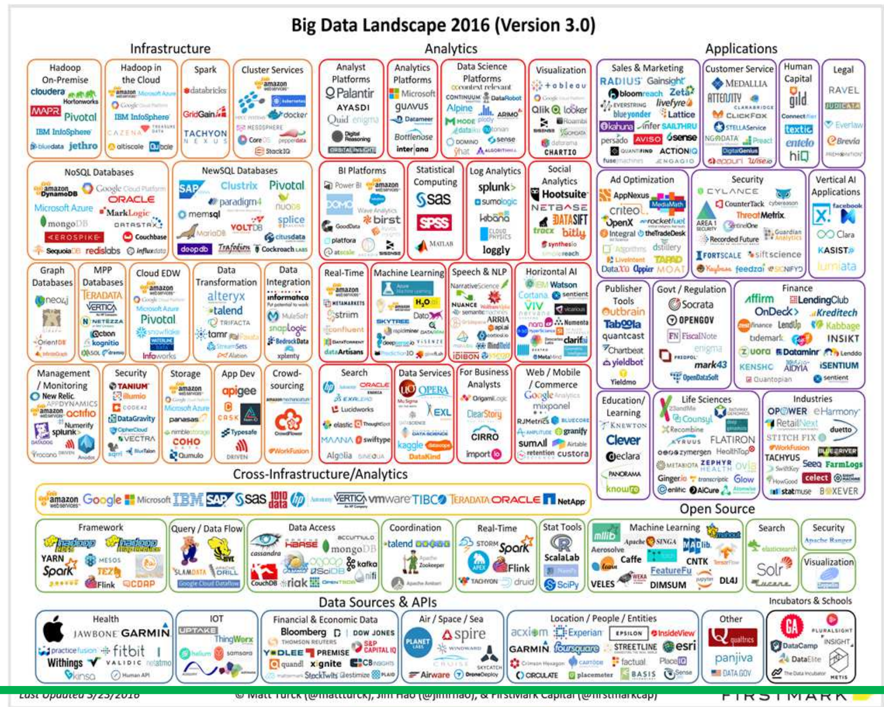
0.- Indice

FHP project is funded by European Union under the grant agreement no. 731231.
FHP project is funded by European Union under the grant agreement no. 731231.

El paradigma de la computación cloud: Se parte de un concepto muy sencillo pero se termina con un entorno de una complejidad considerable….

- Pros: Flexibilidad, escalabilidad
- Contras: Mantenimiento en Producción

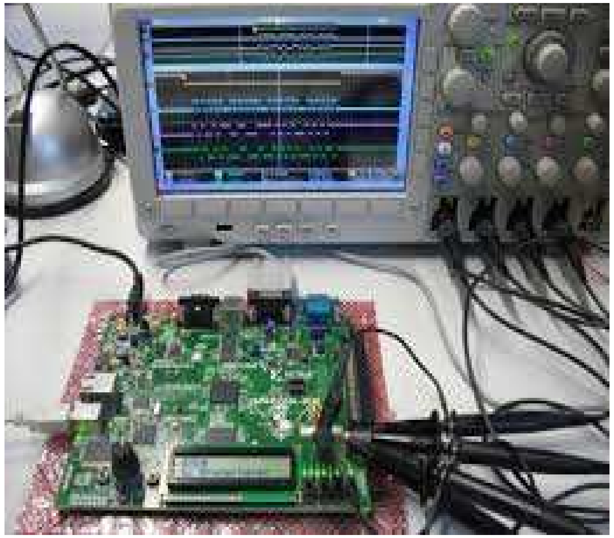


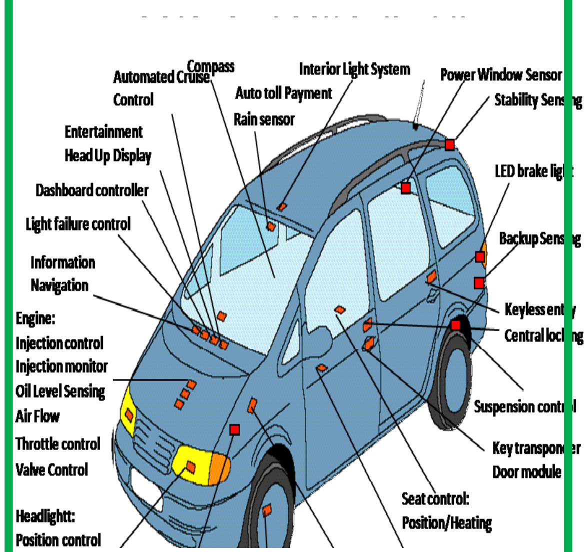


FHP project is funded by European Union under the grant agreement no. 731231.

El paradigma de la computación embebida: Se parte de un entorno de gran complejidad para terminar ofreciendo una funcionalidad muy concreta….

- Pros: Simplicidad en operación
- Contras: Dificultades en flexibilidad y escalabilidad





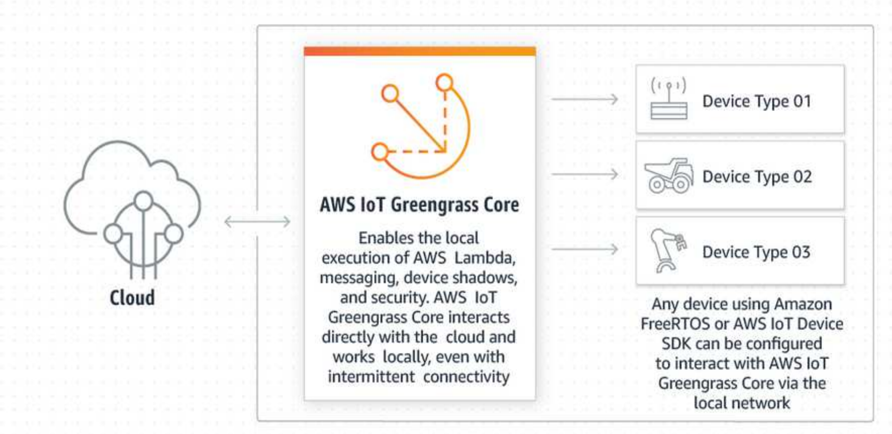
FHP project is funded by European Union under the grant agreement no. 731231.

Los principales ámbitos de aplicación de desarrollos CLOUD son:

- Despliegue de redes de sensores inalámbricos (Smart Cities,…)
- Integración de sistemas domésticos incluyendo ocio y confort
- Salud, un paciente puede llevar una colección de sensores que monitorean además de la proliferación de Smart Weareables
- Seguridad, sistemas de monitorización remota y alarma videovigilancia móvil, etc. Estos sistemas están diseñados para grandes eventos públicos tales como eventos deportivos, demostraciones y similares que son de corta duración y donde grandes
- Localización, como puede ser la de coches de alquiler y los autos que se sospecha que son robados también pueden beneficiarse de un bajo costo integrado

¿Que es el Edge Computing?

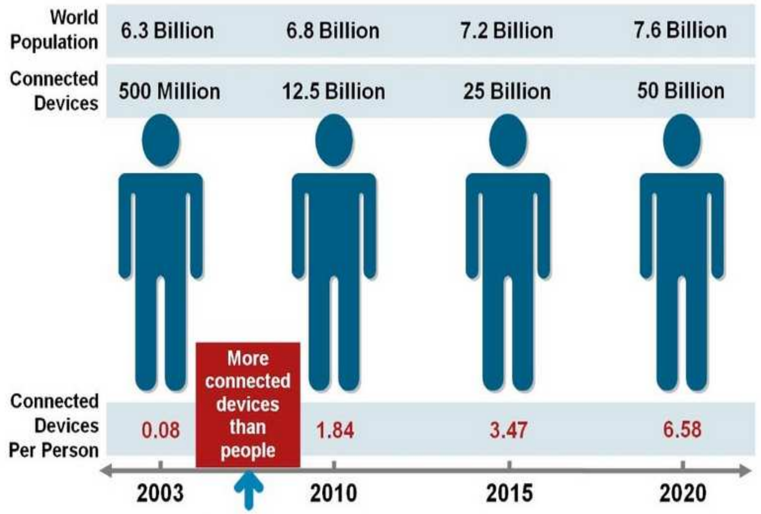
Transferir capacidades de computación de la nube a nodos periféricos…. **IoT**



FHP project is funded by European Union under the grant agreement no. 731231.

¿Es necesario Edge Computing?

- 50.000 millones de dispositivos IoT en 2020 (Cisco- Ericsson en 2010 2011)
- 30.000 millones de dispositivos IoT en 2021 (Cisco- Ericsson en 2015)



Source: Cisco IBSG, April 2011

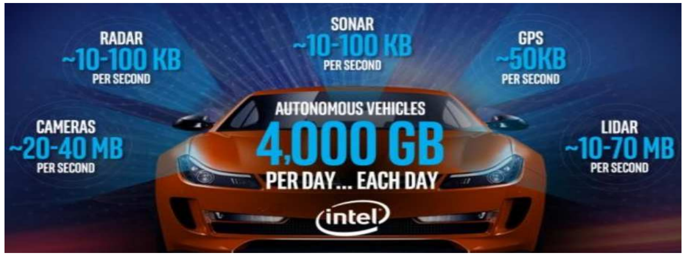
No tener que transmitir todos esos datos a la nube supondrá un ahorro importante.

¿Se crea un nuevo concepto?

- Fog Computing. La nube lo cubre todo

¿Un ejemplo concreto de Edge Computing..?

- El coche autónomo… no puede esperar a comunicar con la nube..



FHP project is funded by European Union under the grant agreement no. 731231.

Objetivo de Edge Computing:

- Minimizar la latencia de comunicación con la red
- Acercar las capacidades de computación Cloud.

Los proveedores de servicios Cloud proveen ya de “variantes” Edge.

- Amazon: AWS Green Grass (aun no incorpora inteligencia)
- Microsoft Azure IoT Edge.

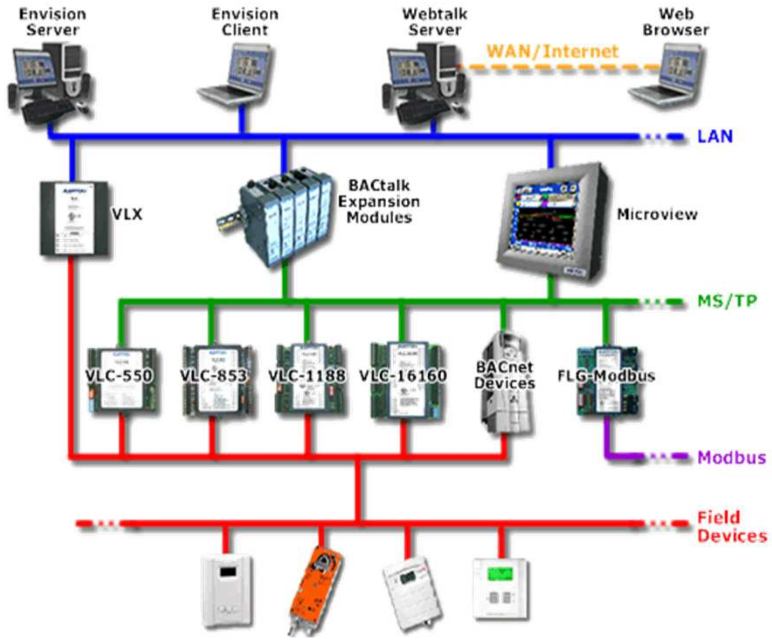
La inteligencia artificioal On Edge software y dispositivos pequeños utilizados por personas de la vida cotidiana, con una máquina integrada y un aprendizaje profundo diseñados para simplificar las tareas diarias del usuario. Alexa y Google Home son las iniciativas más populares en ese ámbito

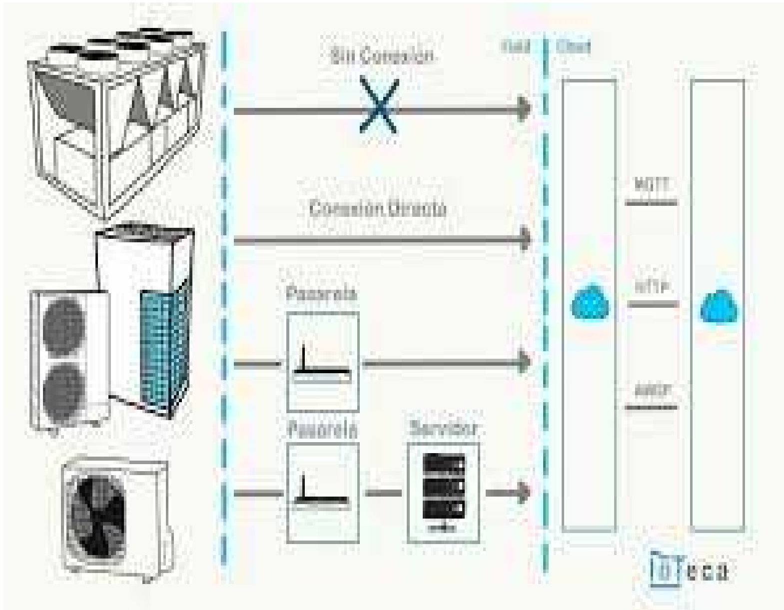
https://www.embedded.com/electronics-blogs/say-what-/4460873/Bringing-machine-learning-to-the-edge--A-Q-A-with-Neurala-s-Anatoli-Gorshechnikov-

FHP project is funded by European Union under the grant agreement no. 731231.

Conceptos de arquitectura

- On Premise: El control reside en servidores locales solo la visualización accesible desde el exterior
- On Cloud: Toda la lógica de control, almacenamiento y visualización residen en servidores externos.

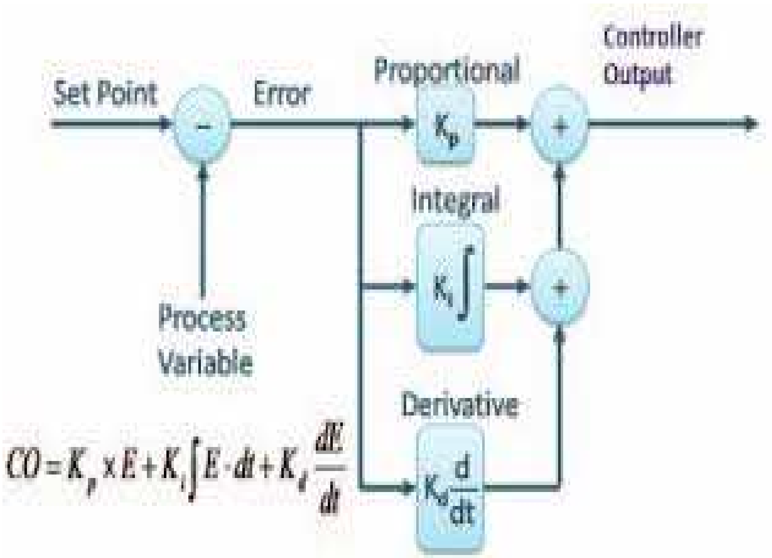


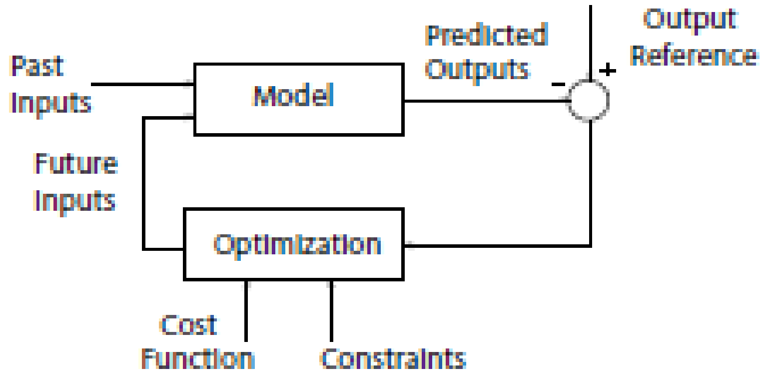


FHP project is funded by European Union under the grant agreement no. 731231.

Modelos de Controlador

- PID: Basado en el valor del error no tiene capacidad de predecir el futuro
- MPC: Contiene el modelo del sistema a controlar tiene capacidad de optimización y
- predecir el futuro

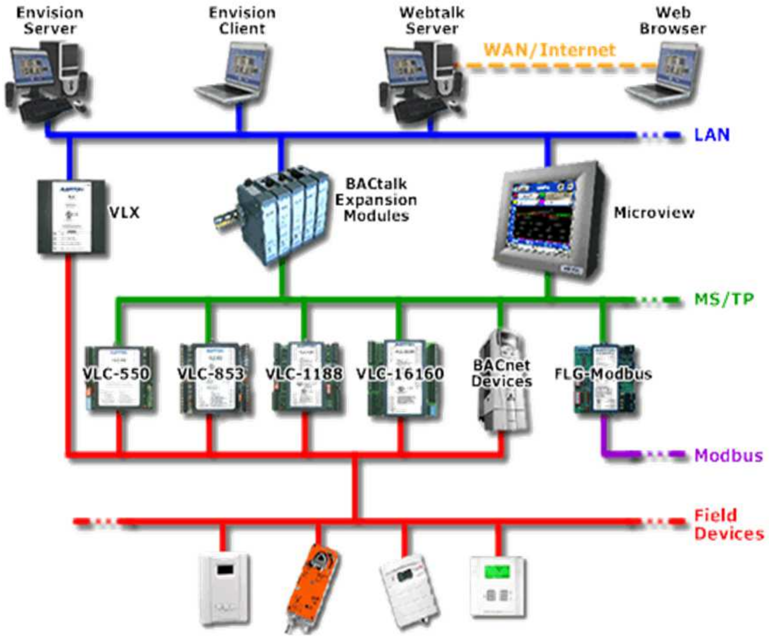


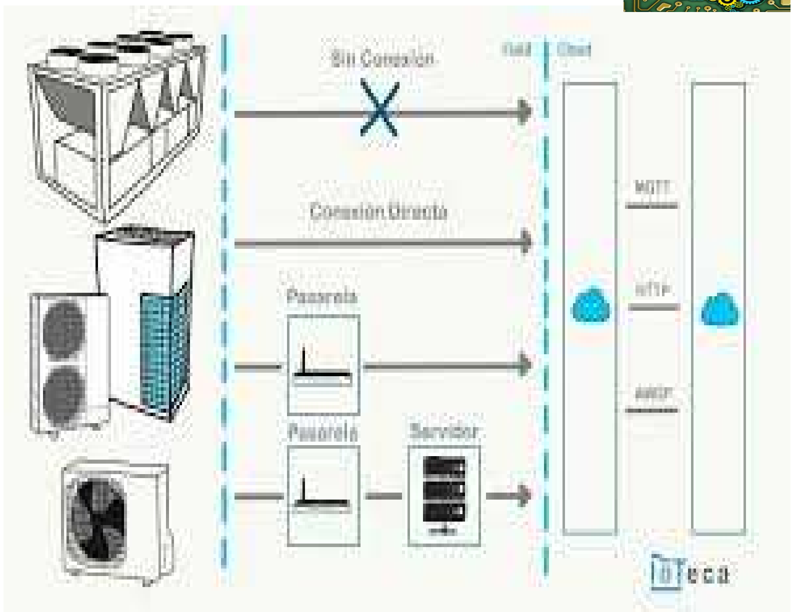


<u>¿Cuál es el adecuado? ¿Dónde debe ser ubicado? ¿En la nube? ¿Local?</u>

FHP project is funded by European Union under the grant agreement no. 731231.

¿Cuál es el adecuado? ¿Dónde debe ser ubicado? ¿En la nube? ¿Local?

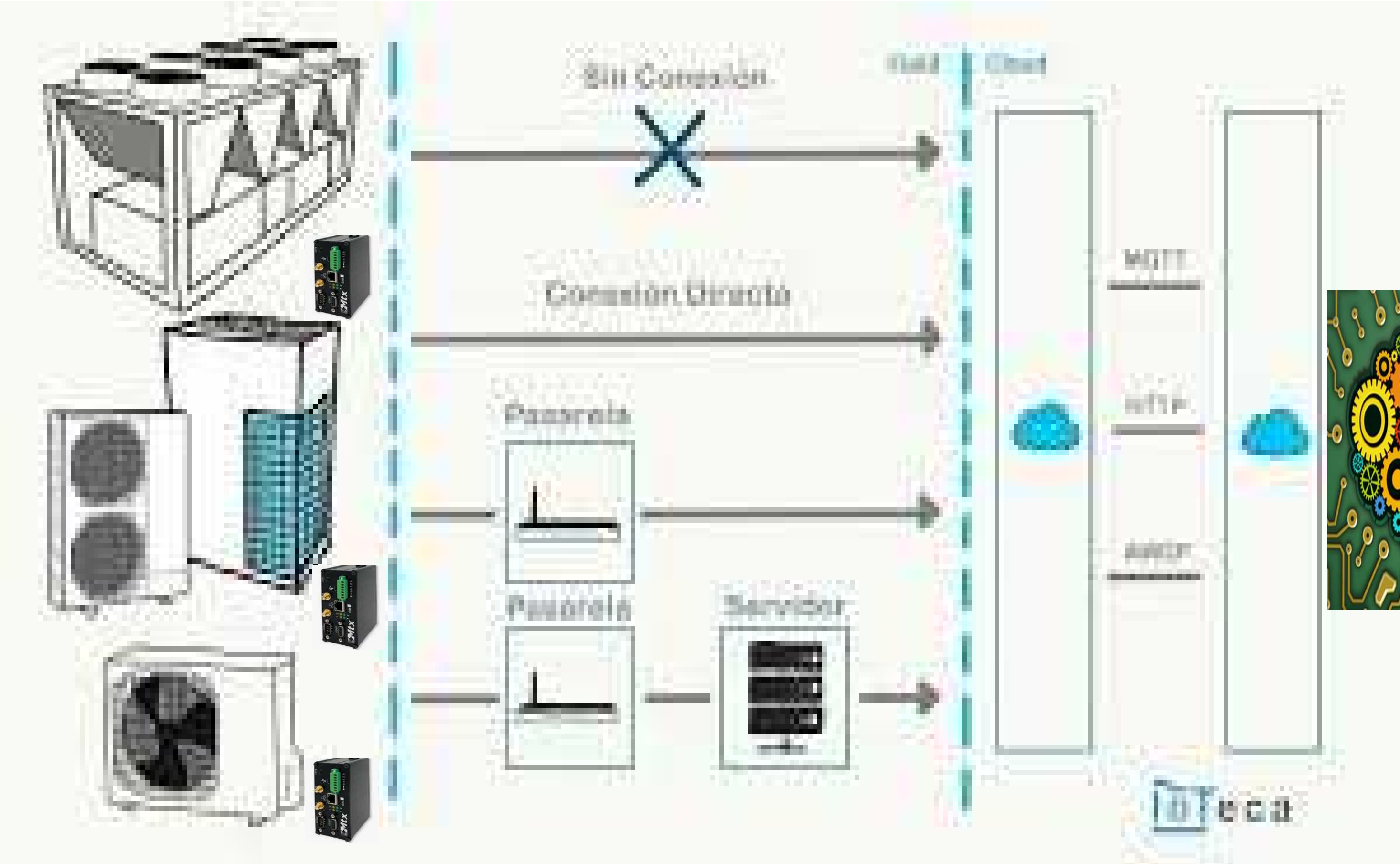


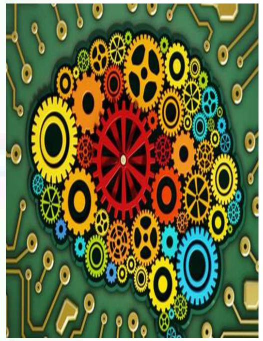


Siemens: Mind Sphere
Honeywell: OBS
Johnson C: Metasys

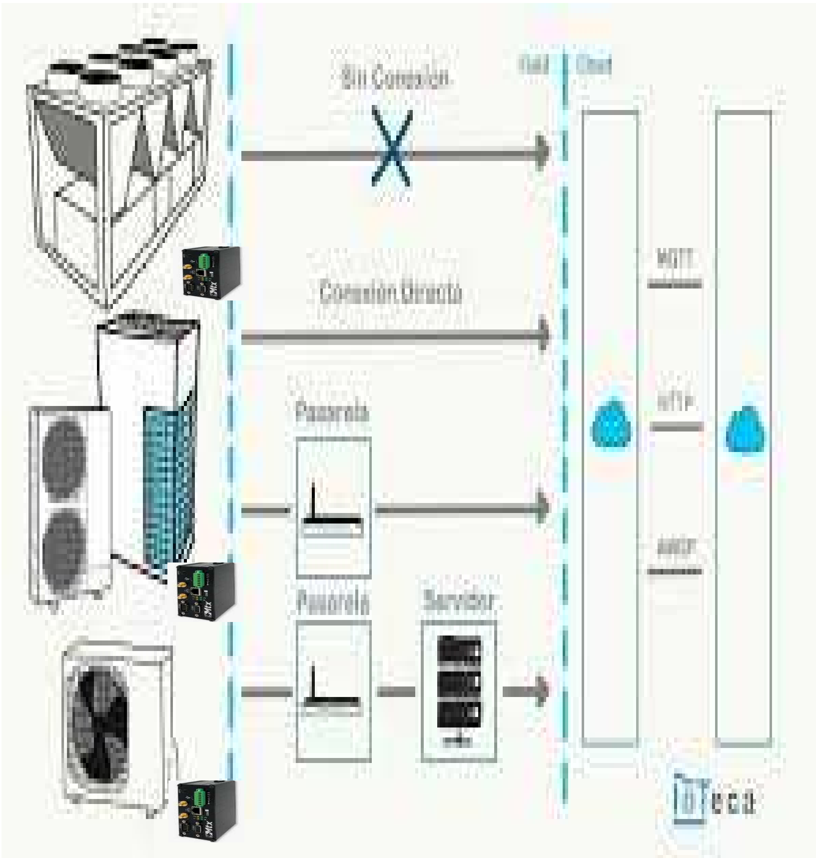
FHP project is funded by European Union under the grant agreement no. 731231.

¿Cuál es el adecuado? ¿Dónde debe ser ubicado? ¿En la nube? ¿Local?





FHP project is funded by European Union under the grant agreement no. 731231.



MPC Local & Optimización Cloud

- Cálculo de analíticas del equipo (Perfil de uso…)
- Optimización de parámetros de funcionamiento
- Simplificación de la instalación y configuración
- Reducir el tráfico en la nube
- Facilitar la elaboración de analíticas complejas
- Optimización de los algoritmos de detección de avería o desviación de punto de operación
- Facilitar la operativa entre fabricantes, integradores responsables finales de la instalación

FHP project is funded by European Union under the grant agreement no. 731231.

Conclusiones:

- Los fabricantes de BMS se han fijado en la nube como plataforma global
- La nube “populariza” los algoritmos de IA.
- La complejidad del los equipos sus capacidades de funcionamiento requieren de modelos optimizados de funcionamiento para sacarle todo el partido
- La optimización del todo es excesivamente compleja. Dividir para vencer.
- La descentralización de las analíticas reduce el conste de los servicios Cloud
- On-Premise vs On-Cloud ? No hay norma según el caso..

FHP project is funded by European Union under the grant agreement no. 731231.

3.7 Annex 1.7. Uso de MPC con modelos de edificio detallados. Carlos Fernandez Bandera

Superación del obstáculo del tiempo computacional requerido para le ejecución de MPCs basados en modelos físicos de edificio detallados.

Carlos Fernández Bandera

Universidad de Navarra

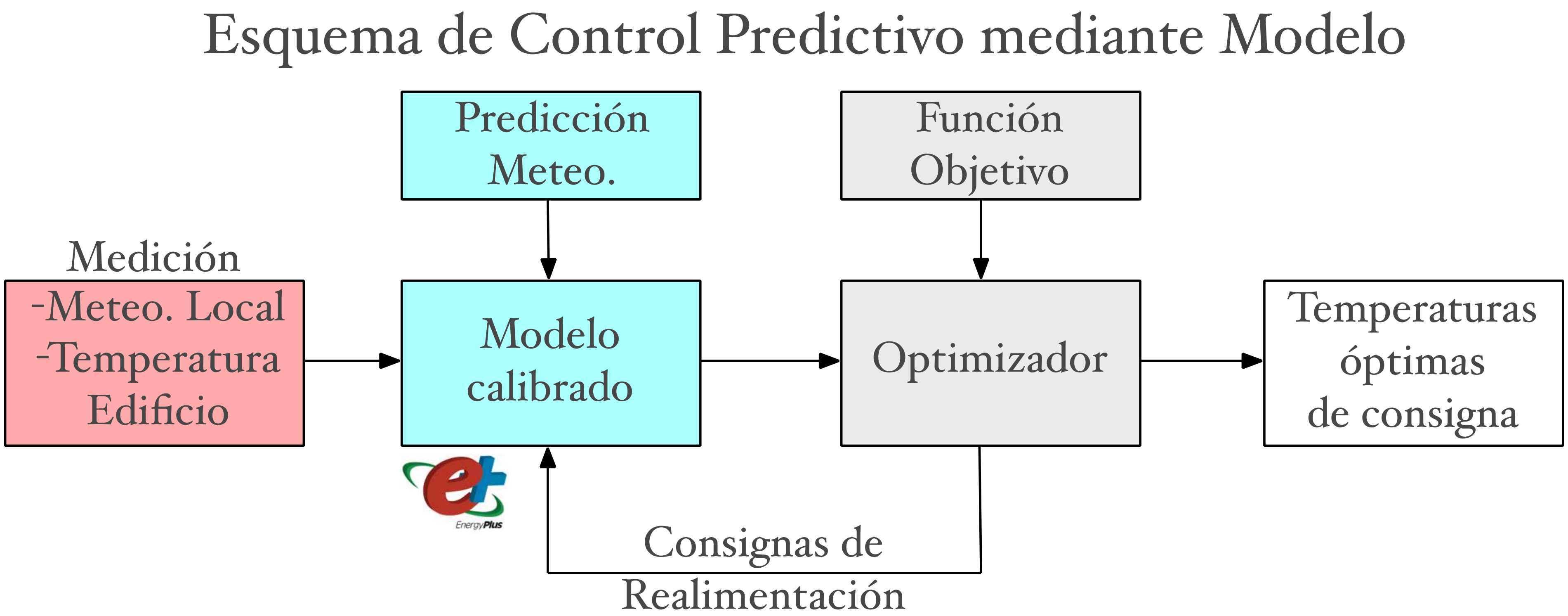
SABINA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.

SABINA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.

Esquema general



SOLUCIÓN – Reducción espacio de búsqueda
2. Curva de libre oscilación

SABINA
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.

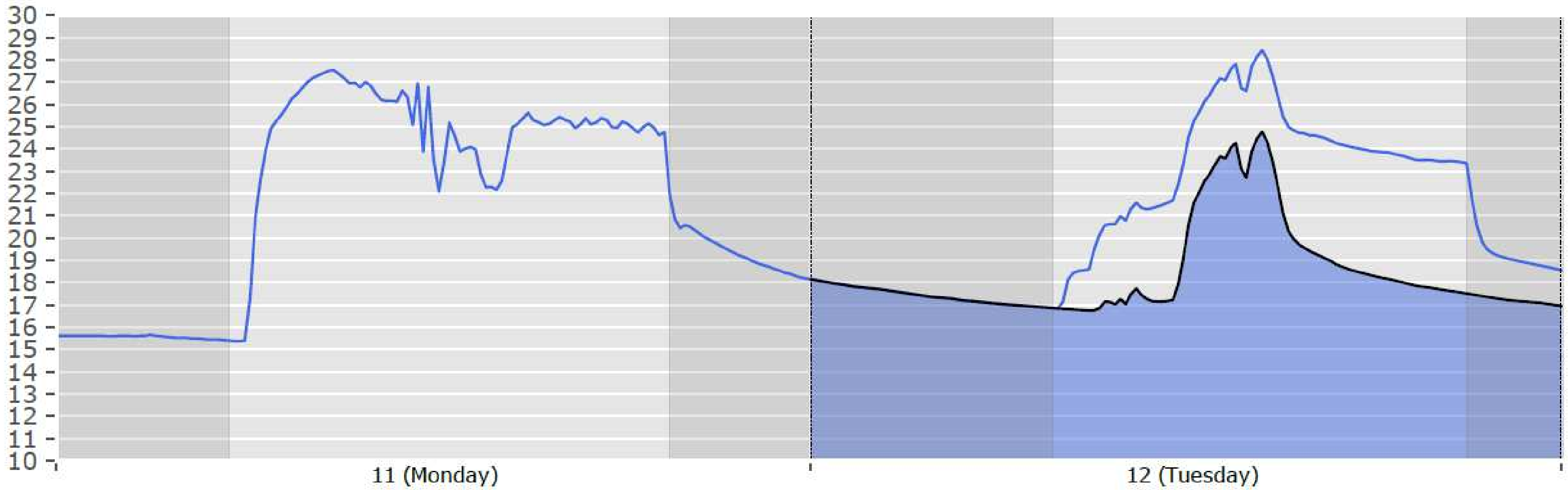


Figure 2. Measured temperature (blue line) and free oscillation temperature (black line) of thermal zone 14 (see Figure 4). Office building, School of Architecture (University of Navarra), December 11-12, 2017.

Universidad de Navarra

SOLUCIÓN – Reducción espacio de búsqueda
2. Curva de libre oscilación

SABINA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.

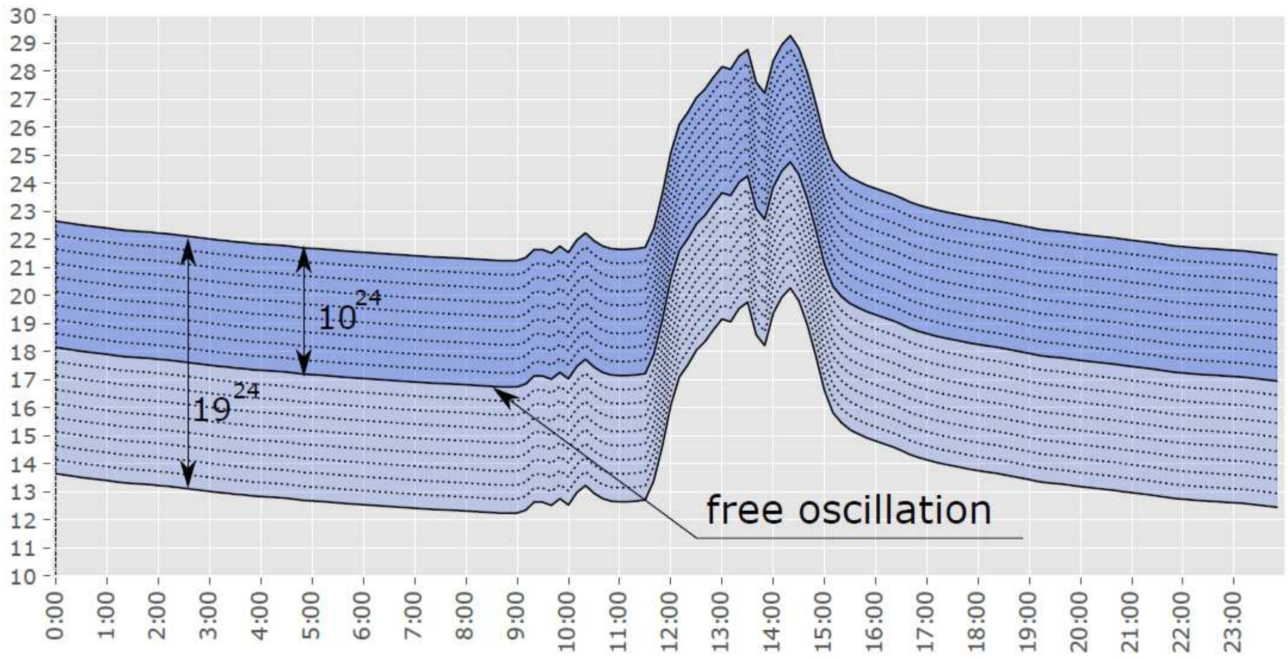
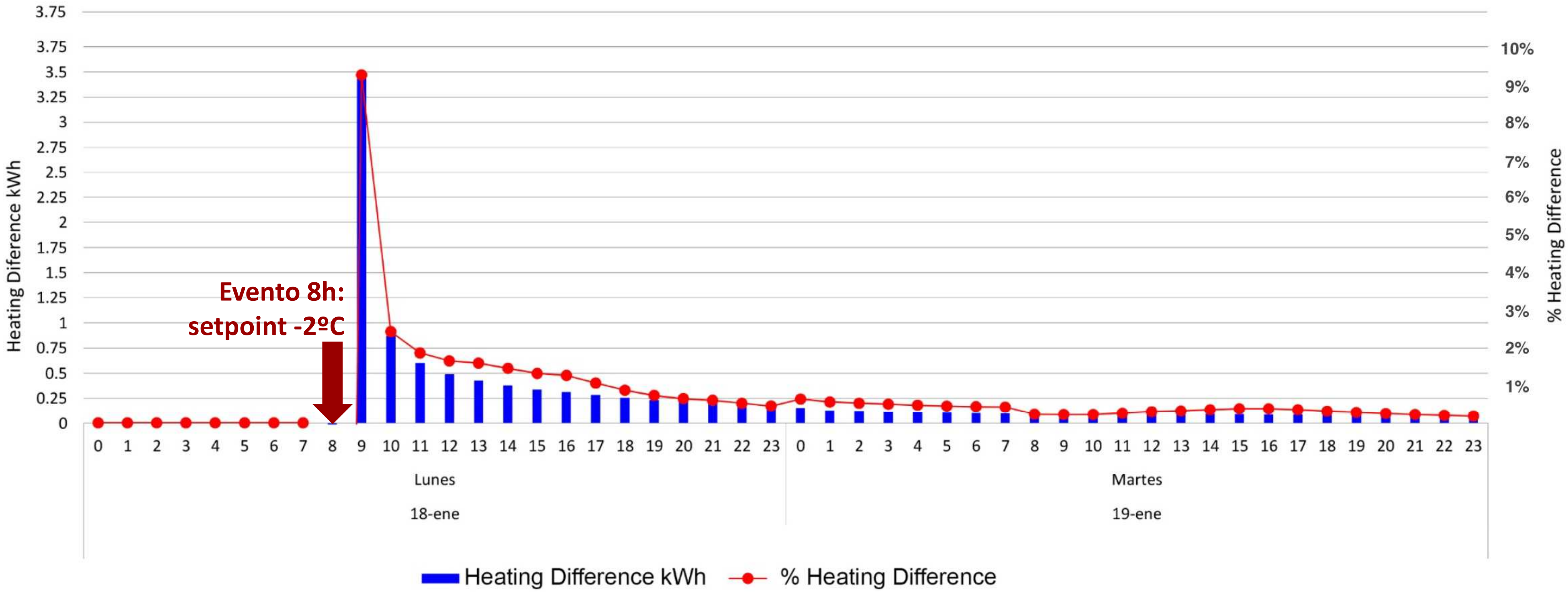


Figure 6. Search space reduction that supposes the consideration of the free oscillation curve in winter season.

Universidad de Navarra

SOLUCIÓN – Reducción espacio de búsqueda
3. Proceso en dos etapas

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.



Universidad de Navarra

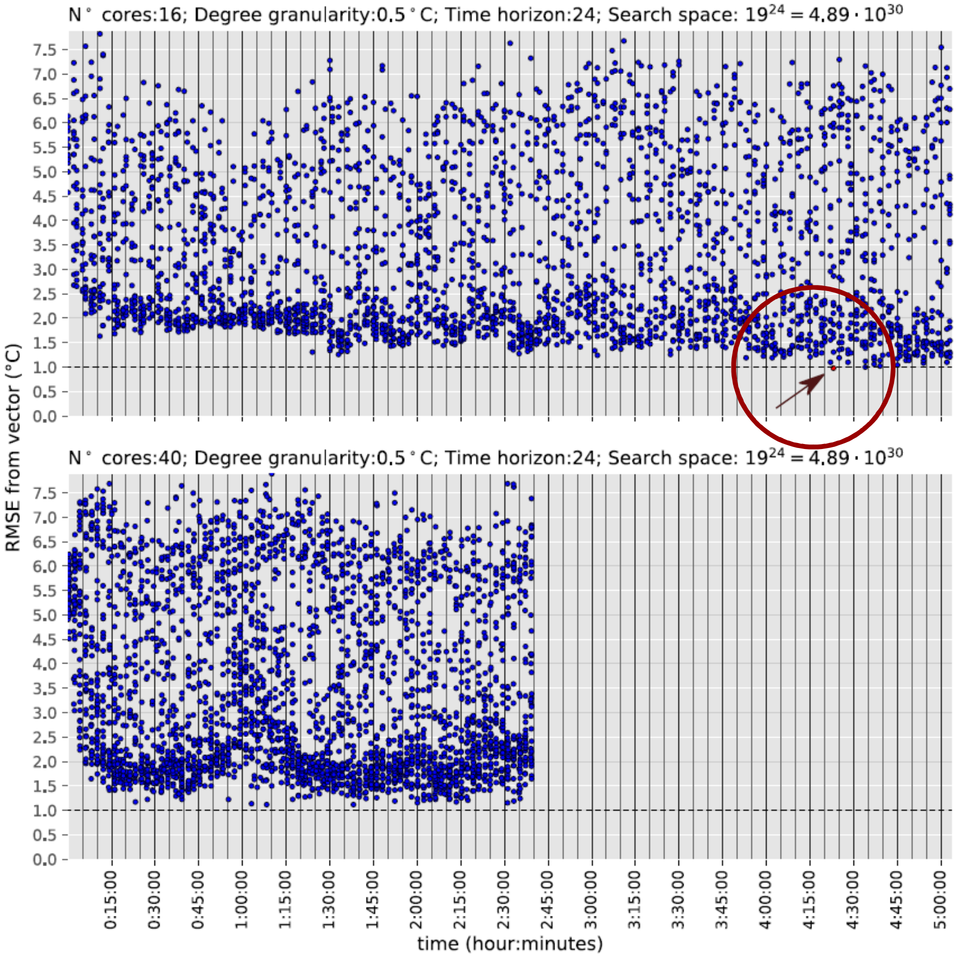
SOLUCIÓN – Reducción espacio de búsqueda

2. Curva de libre oscilación

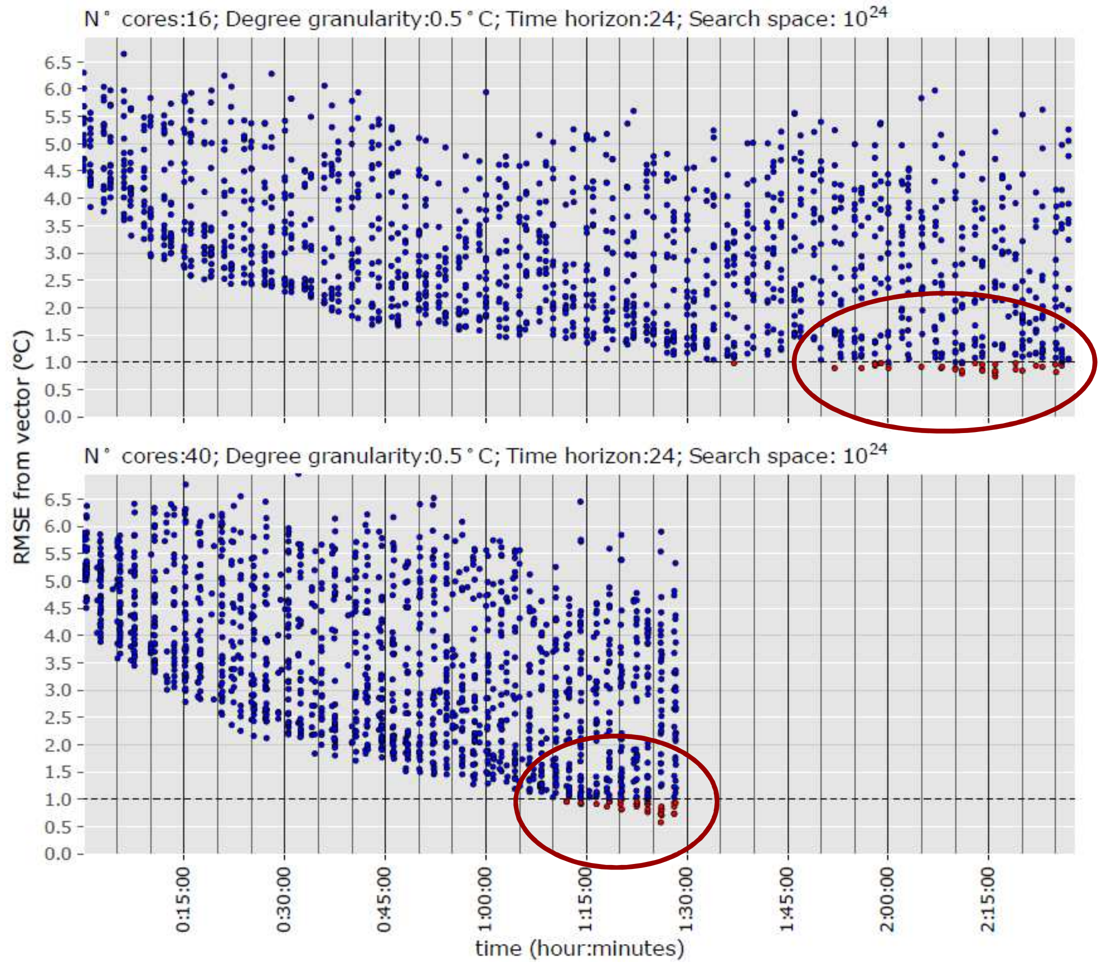
SABINA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.

Espacio de búsqueda inicial: 19^{24}

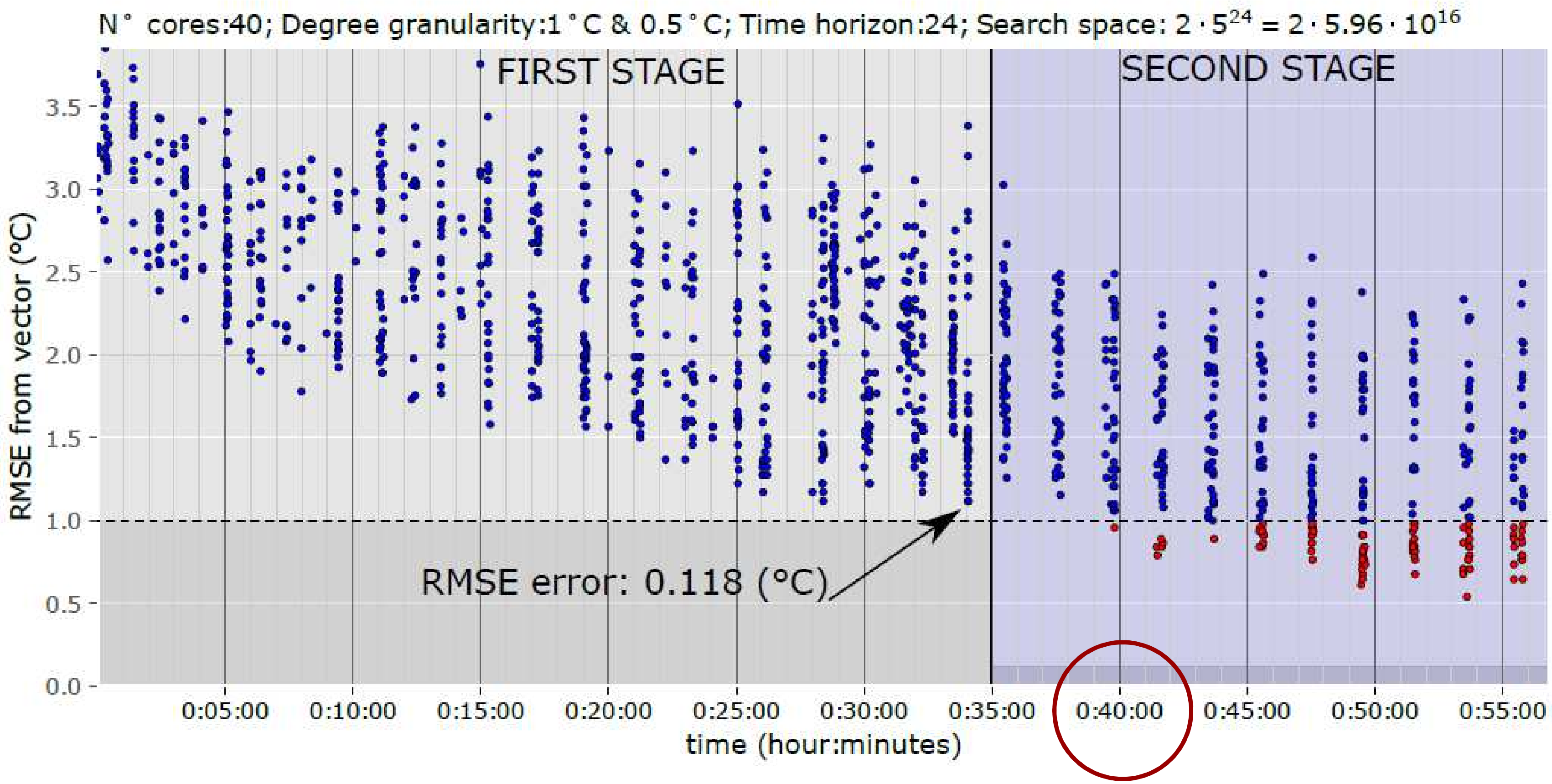


Espacio de búsqueda con curva libre oscilación: 10^{24}



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.

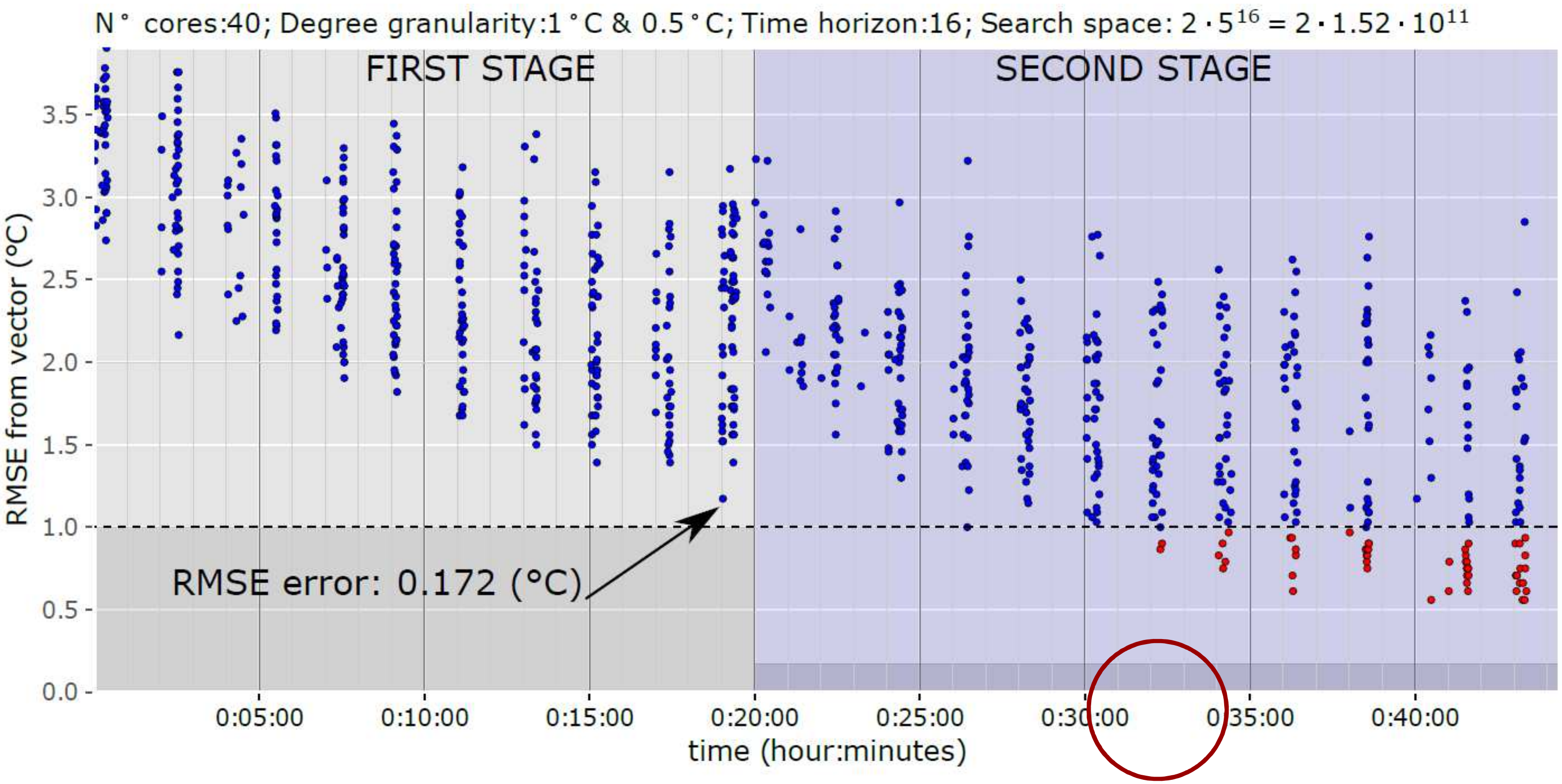
Time horizon: 24 h



SOLUCIÓN – Reducción espacio de búsqueda
3. Proceso en dos etapas

SABINA
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.

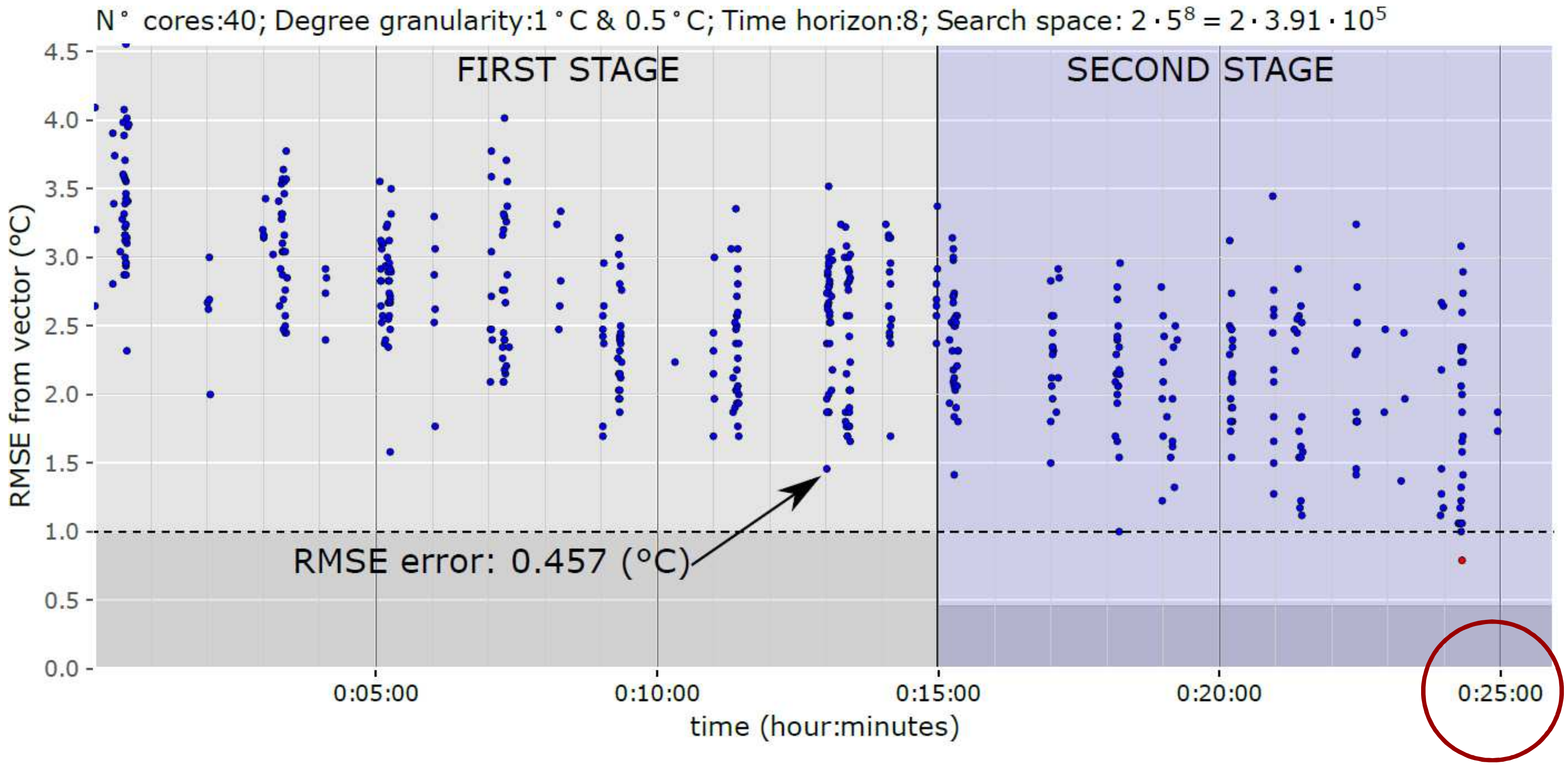
Time horizon: 16 h



SOLUCIÓN – Reducción espacio de búsqueda
3. Proceso en dos etapas

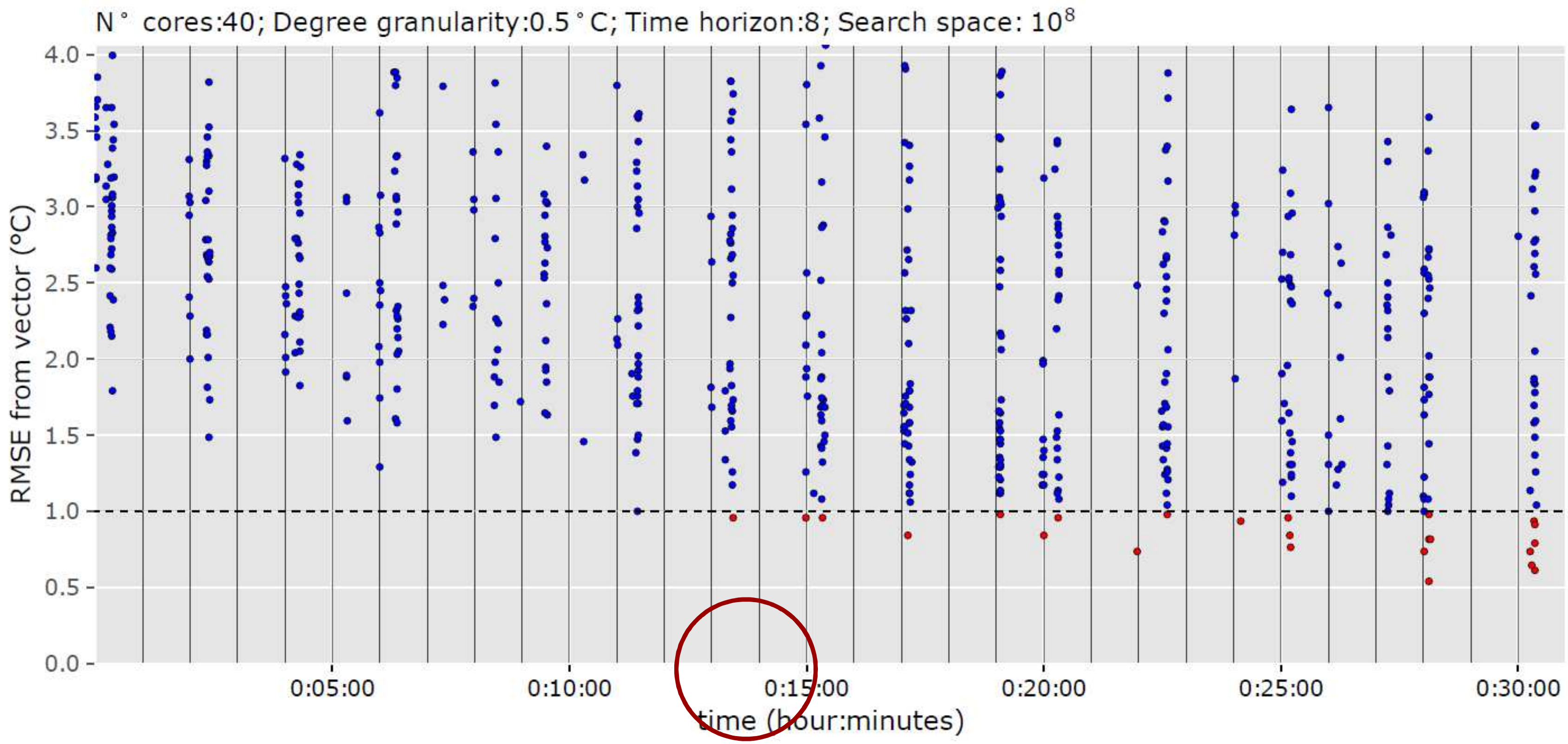
SABINA
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.

Time horizon: 8 h



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.

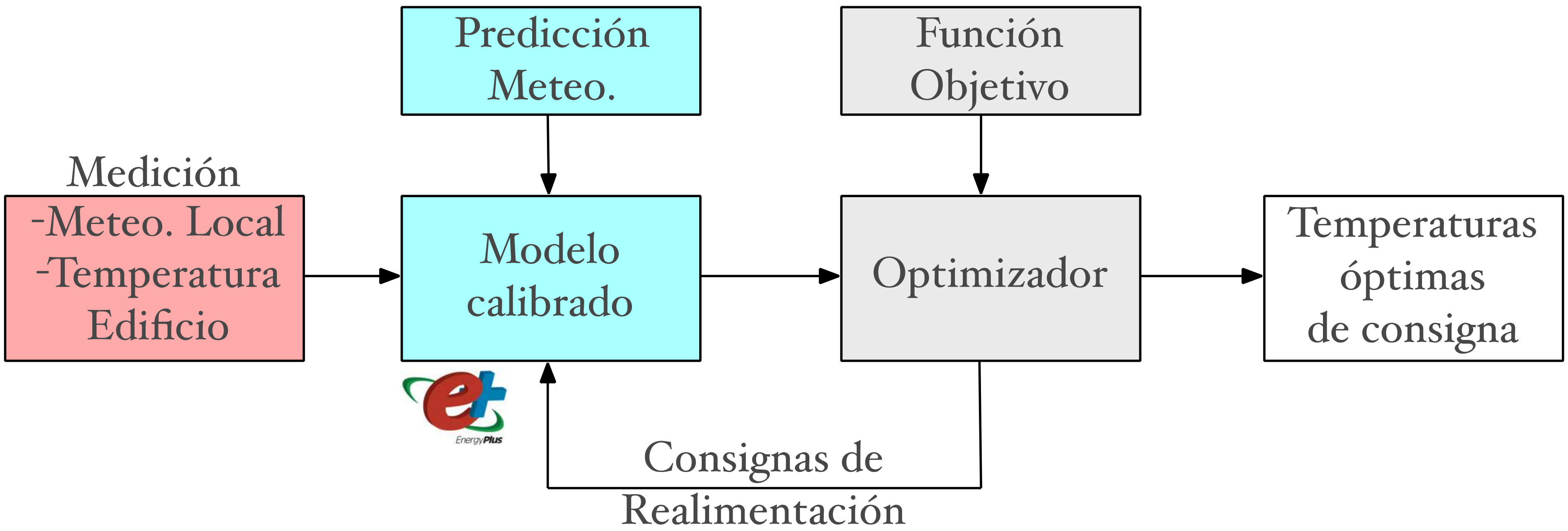
Time horizon: 8 h en una etapa



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.

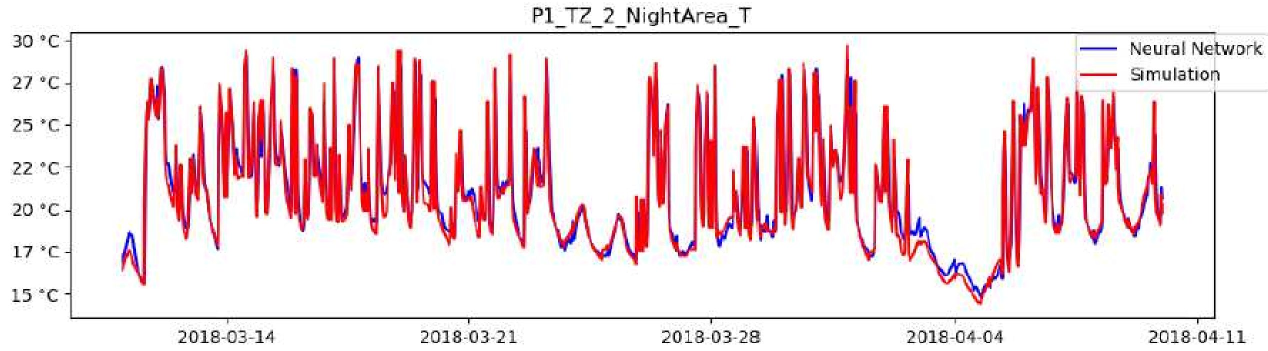
Esquema general

Esquema de Control Predictivo mediante Modelo

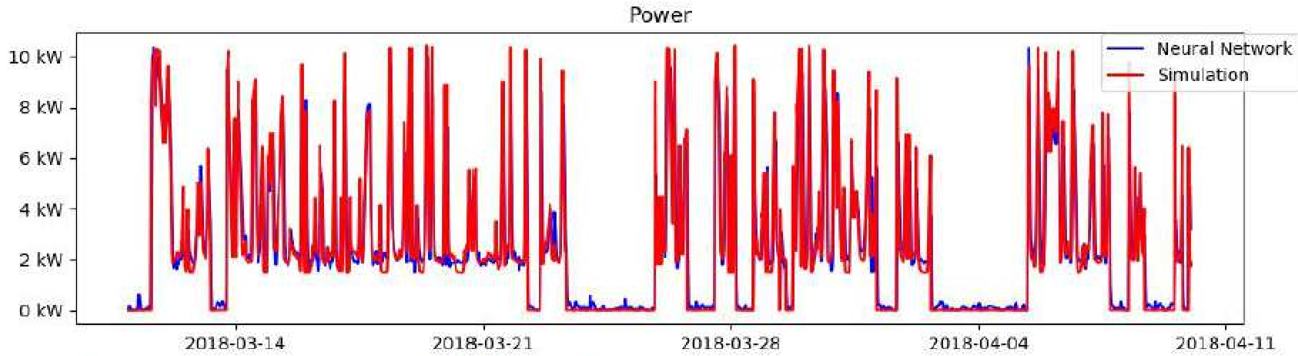


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.

Neural Network tiempo de optimización con horizontes de predicción de 24 h y granularidad de 10 min → 380 s



Temperature in a zone (~0.45°C error)



Total electric power (~300W or 3% error)

Neural Network

EnergyPlus model

Universidad de Navarra

Muchas gracias

SABINA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°731211, project SABINA.

Carlos Fernández Bandera
cfbandera@unav.es

3.8 Annex 1.8. MPC con modelos equivalentes multizona. Javier Arroyo

Retos y Herramientas para el Control Óptimo en Edificios

Javier Arroyo – javier.arroyo@kuleuven.be

TECNALIA - Parque Científico y Tecnológico de Bizkaia

30 enero 2019

Supervisora
Prof. dr. ir. Lieve Helsen
KU Leuven, EnergyVille

Co-Supervisor
Dr. Alfred Spiessens
VITO, EnergyVille

CONTENIDO

Modelado:

- **Retos y herramientas para el modelado energético de edificios**
  - Introducción
  - Retos en el modelado
  - Tipos de modelos
  - Herramientas para el modelado

Optimización:

- **Retos y herramientas para el control óptimo de edificios**
  - Enfoques para el control óptimo
  - Aplicaciones
  - Retos en el control óptimo
  - Herramientas para el control óptimo

LOS DOS GRANDES ENFOQUES PARA EL CONTROL ÓPTIMO

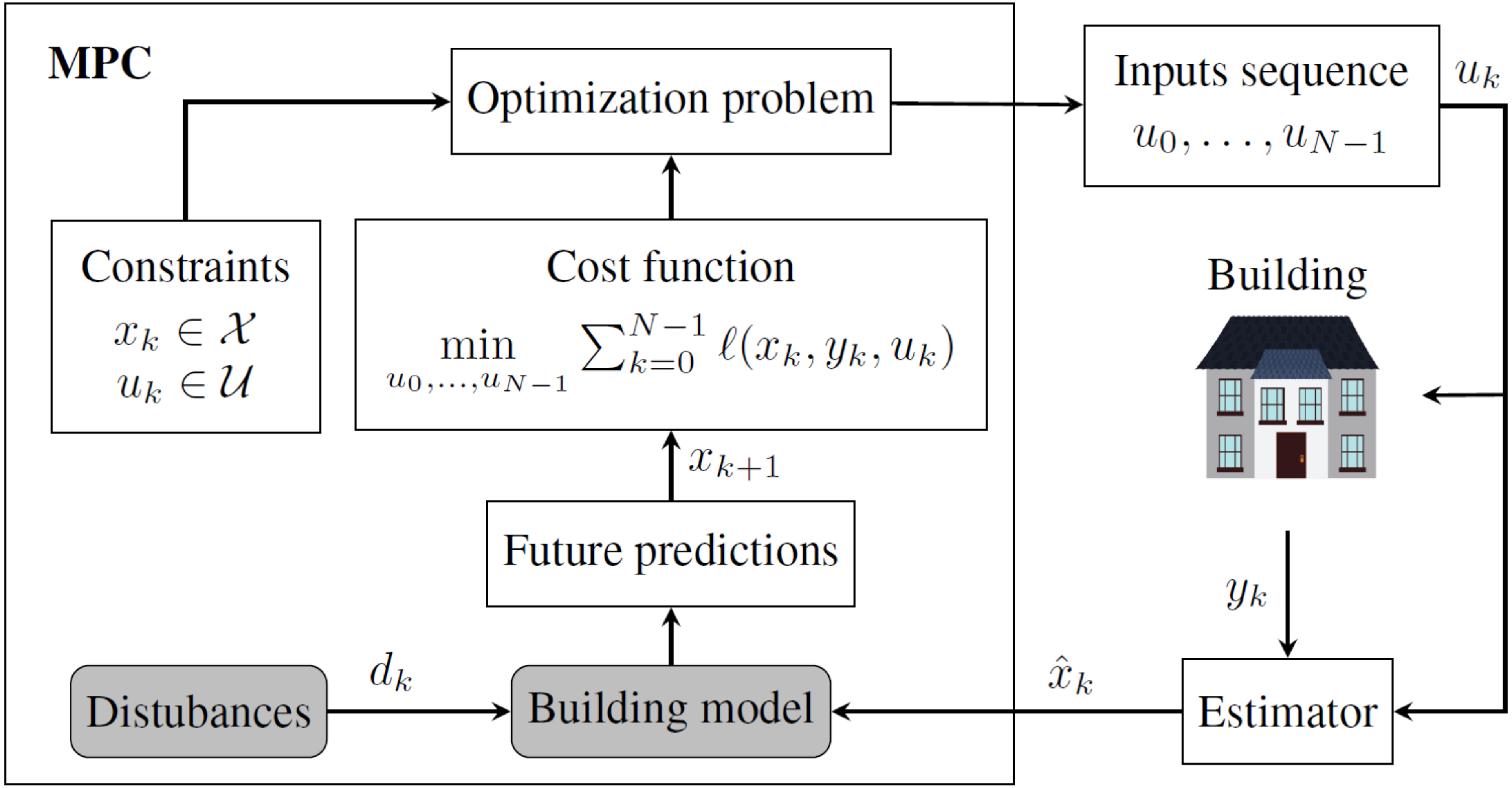
Property	Model Predictive Control	Reinforcement Learning
Model	required ✗	not required ✓
Convexity	required (usually) ✗	not required ✓
Adaptivity	immature (usually based on robustness) ✗	mature (inherent) ✓
Online Complexity	high (except explicit and neural MPC) ✗	low ✓
Offline Complexity	low (except explicit and neural MPC) ✓	high ✗
Stability Theory	mature (e.g. based on terminal cost) ✓	immature ✗
Feasibility Theory	mature (e.g. based on terminal constraints) ✓	immature ✗
Robustness Theory	mature (e.g. based on tubes or ISS) ✓	immature ✗
Constraint Handling	mature (inherent) ✓	immature (except input constraints) ✗

Table 1. Properties of Model Predictive Control and Reinforcement Learning

Ref: Daniel Gores. Relations between Model Predictive Control and Reinforcement Learning. 2017

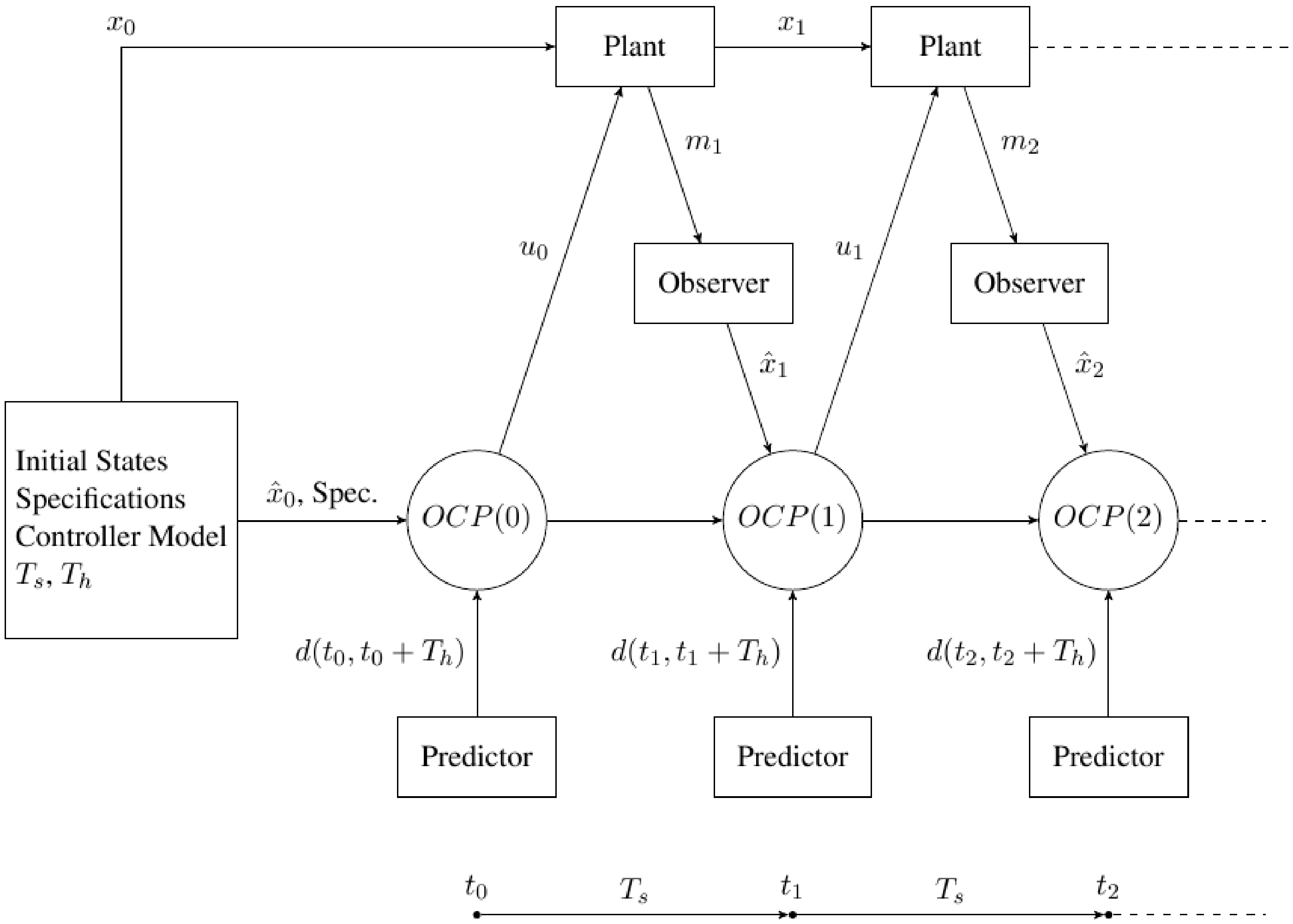
.

CONTROLADOR PREDICTIVO CON MODELOS



Ref: E. P. Ollé, Design and experimental implementation of a data interface for the optimal control of thermal systems, Master Thesis, KU Leuven.

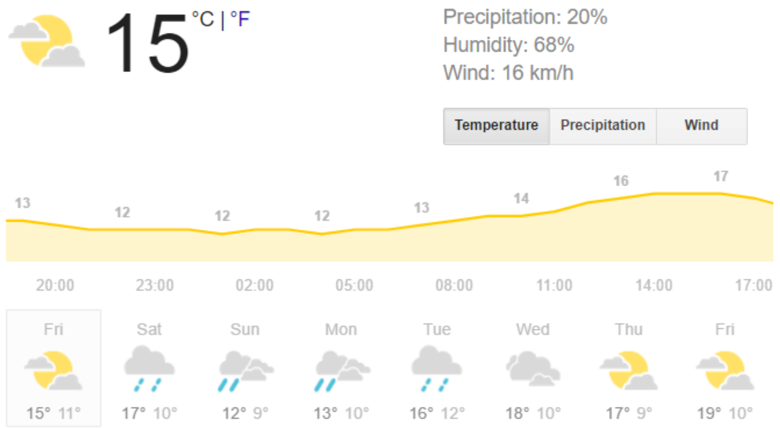
CONTROLADOR PREDICTIVO CON MODELOS

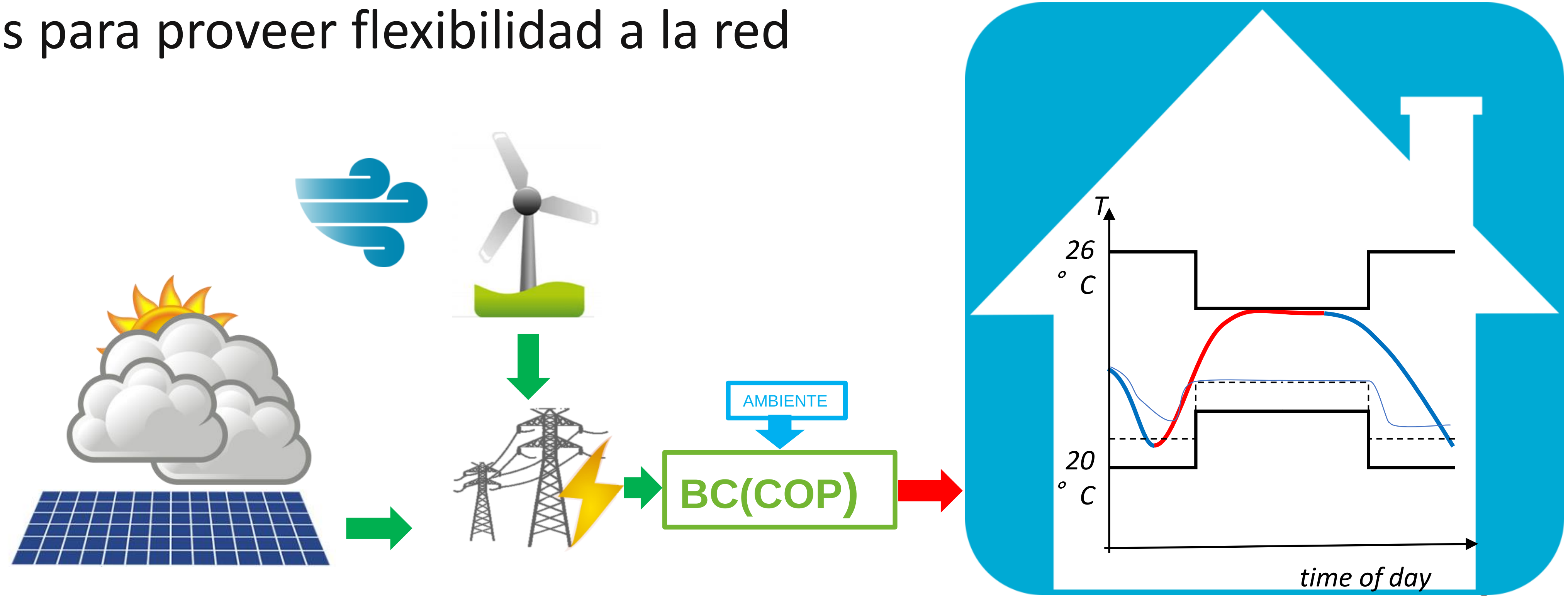


Ref: J. Arroyo, A Python-Based Toolbox for Model Predictive Control Applied to Buildings, 5th International High Performance Buildings Conference at Purdue, July 9-12, 2018

APLICACIONES

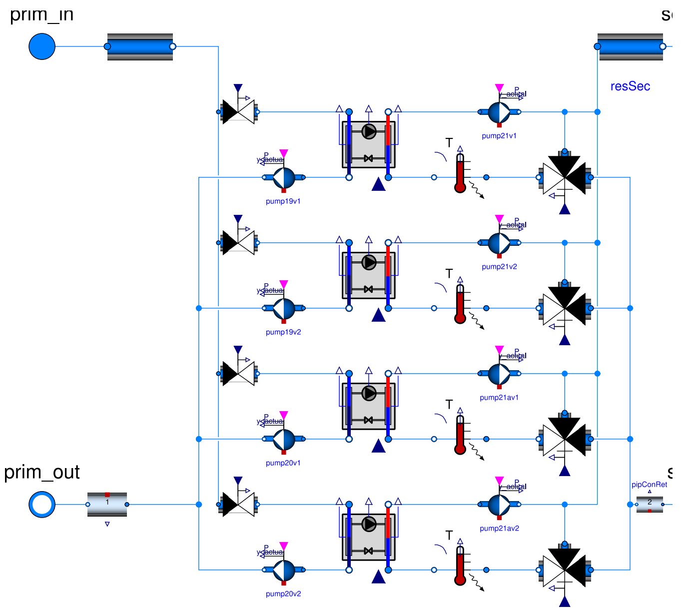
- Mejora de la eficiencia energética y calidad de servicio
- Capaz de explotar la inercia térmica de los edificios para proveer flexibilidad a la red





APLICACIONES

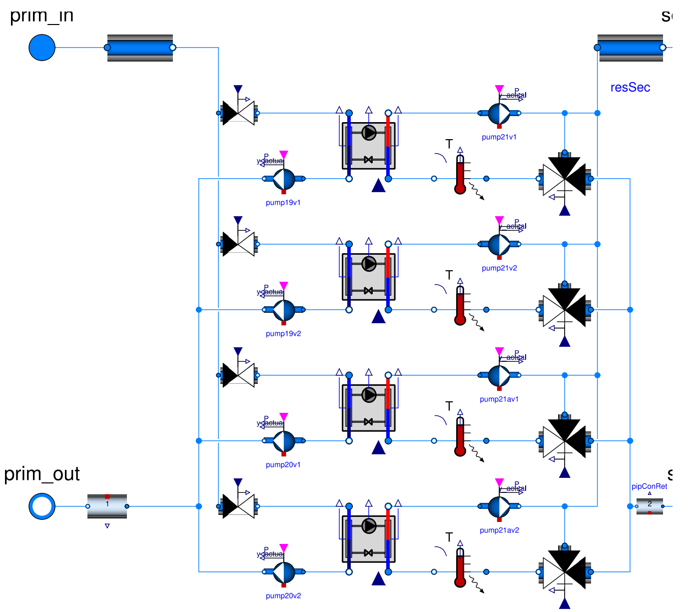
Infrax



Ref: http://www.boydens.be/en/references/office/infrax_in_dilbeek-467.html

APLICACIONES

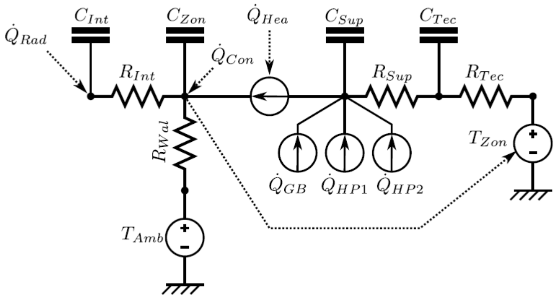
SolarWind



Ref: https://www.construction21.org/case-studies/lu/solarwind.html

APLICACIONES

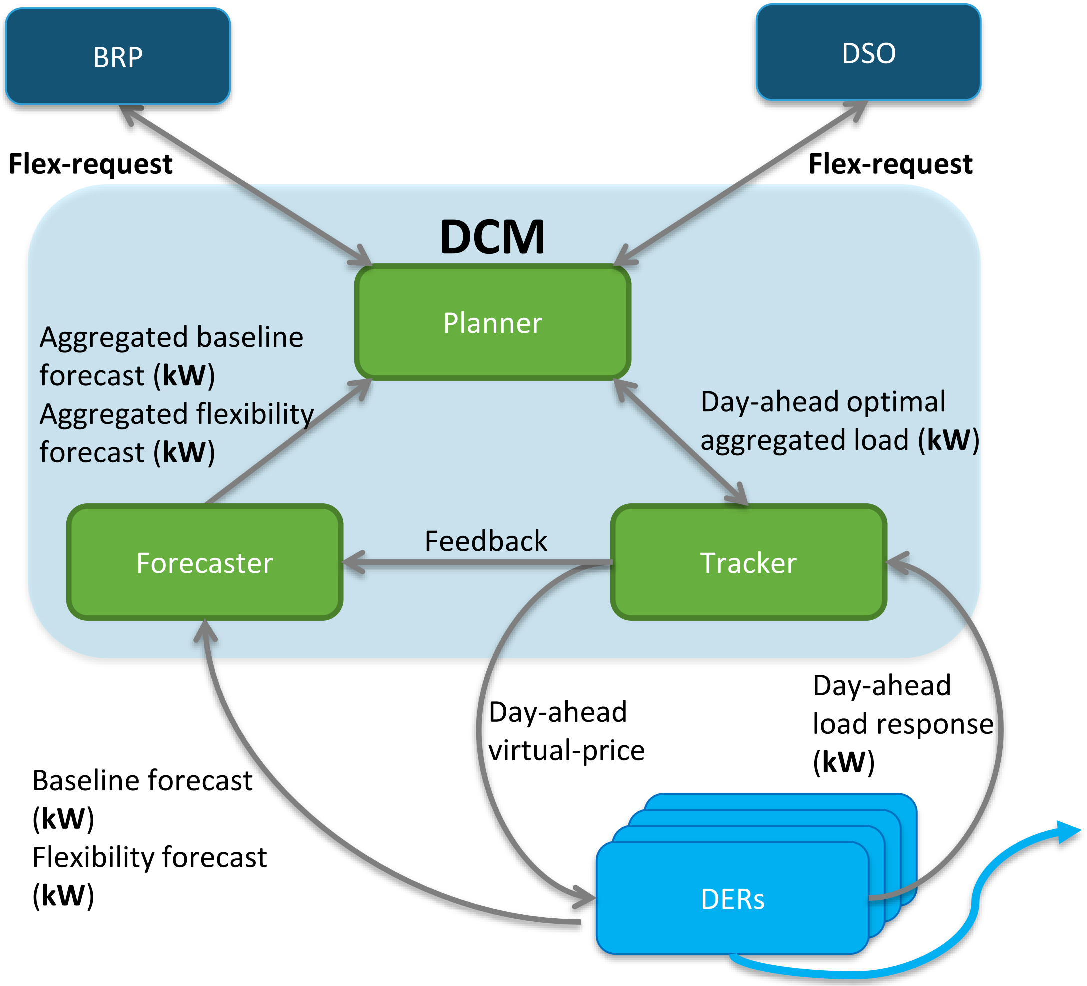
3E

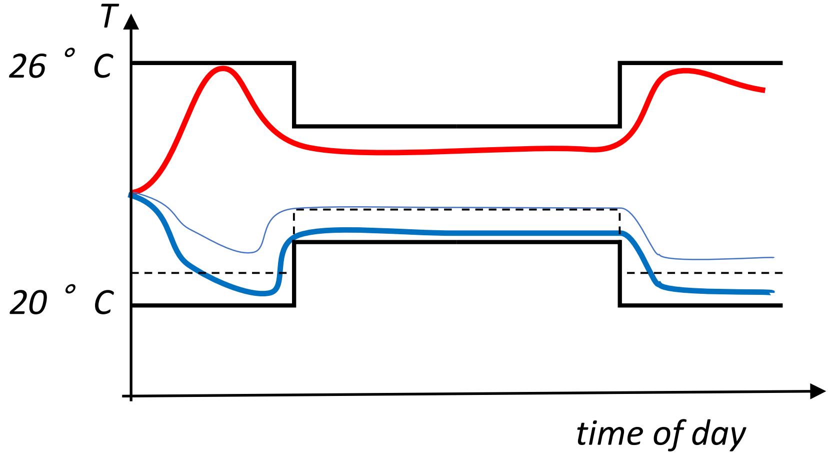


Ref: R. De Coninck and L. Helsen, "Practical implementation and evaluation of model predictive control for an office building in brussels", Energy and Buildings, 2015, Submitted on 17/03/2015.

APLICACIONES

Dynamic Coalition Manager: plataforma para explotar la flexibilidad





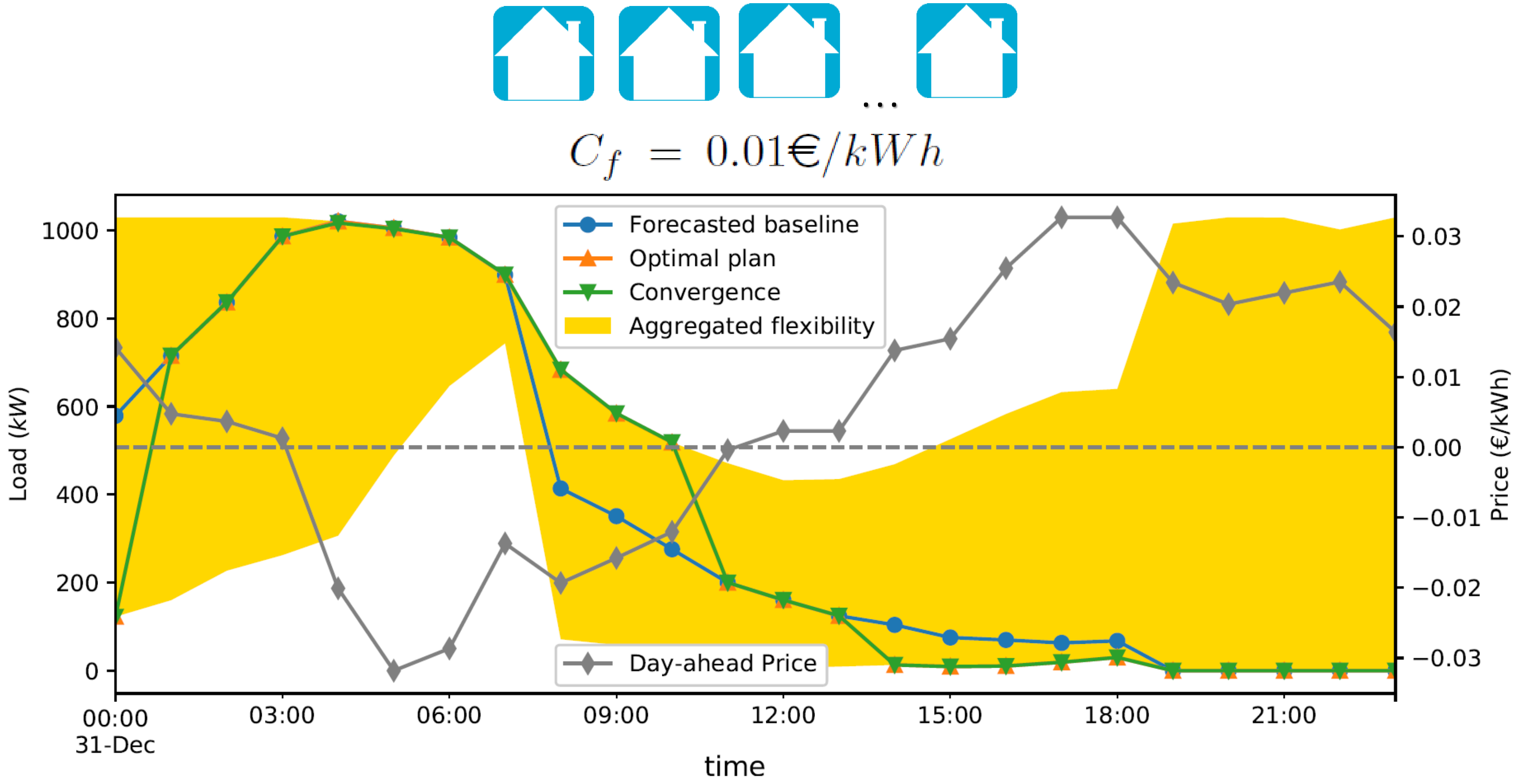
$$\min_{x,P^l} \sum_{k=1}^{N} \left(\lambda_k^l P_k^l + w\, \Delta T_k^l + \frac{\rho}{2} \left(P_k^l - R_k^l \right)^2 \right) \Delta t$$

$$s.t. \quad g(x,P,d) = 0$$
$$x(t=0) = x_0$$
$$\underline{T}_{set} - \underline{\Delta T} \leq T \leq \overline{T}_{set} + \overline{\Delta T}$$
$$R^l = P^{l-1} - \frac{P_{total}^{l-1} - P^*}{N_b}$$

Ref: J. Arroyo, Flexibility quantification in the context of flexible heat and power for buildings. Proceedings of the REHVA Annual Meeting Conference Low Carbon Technologies in HVAC 23 April 2018, Brussels, Belgium

APLICACIONES

- Dynamic Coalition Manager: plataforma para explotar la flexibilidad



Ref: J. Arroyo, Flexibility quantification in the context of flexible heat and power for buildings. Proceedings of the REHVA Annual Meeting Conference Low Carbon Technologies in HVAC 23 April 2018, Brussels, Belgium

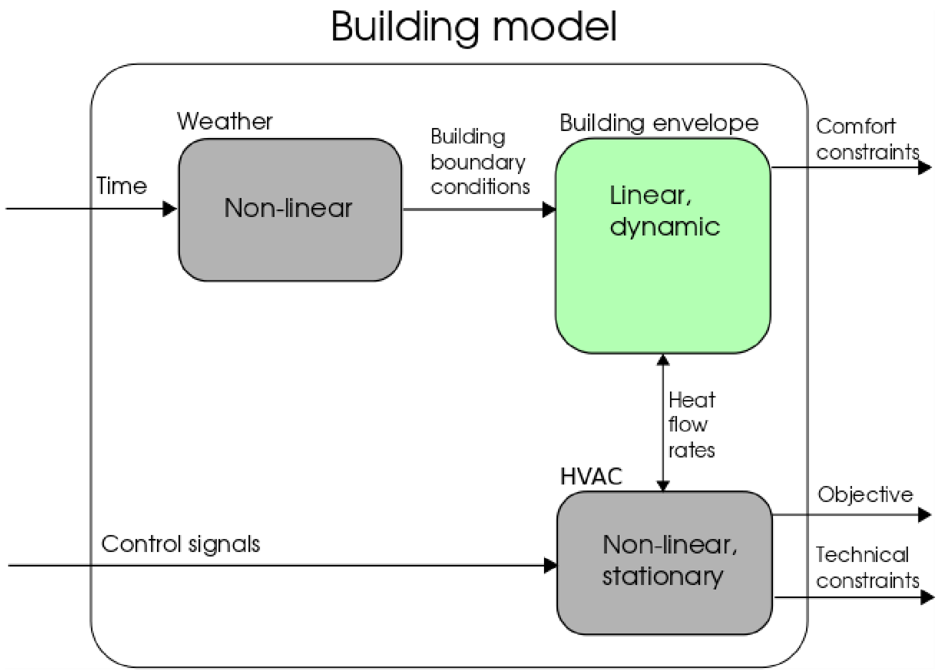
RETOS

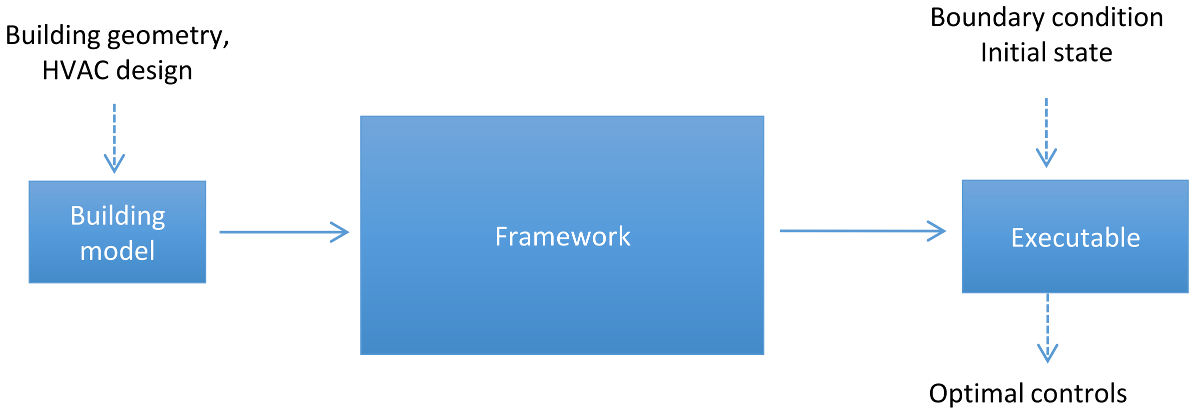
- Convencer a los propietarios
- Todos los retos del modelado:
  - Complejidad y sistema multidisciplinario
  - Balance entre complejidad y precisión
  - Acceso a los datos
- Acceso a los actuadores

HERRAMIENTAS

TACO Toolchain for Automated Control and Optimization

- Conversión de Modelica a MPC no lineal
- Uso de la librería IDEAS
- Concepto demonstrado:
  - 92 variables de control
  - 100 veces más rápido que el período de control
  - >50% ahorro energético

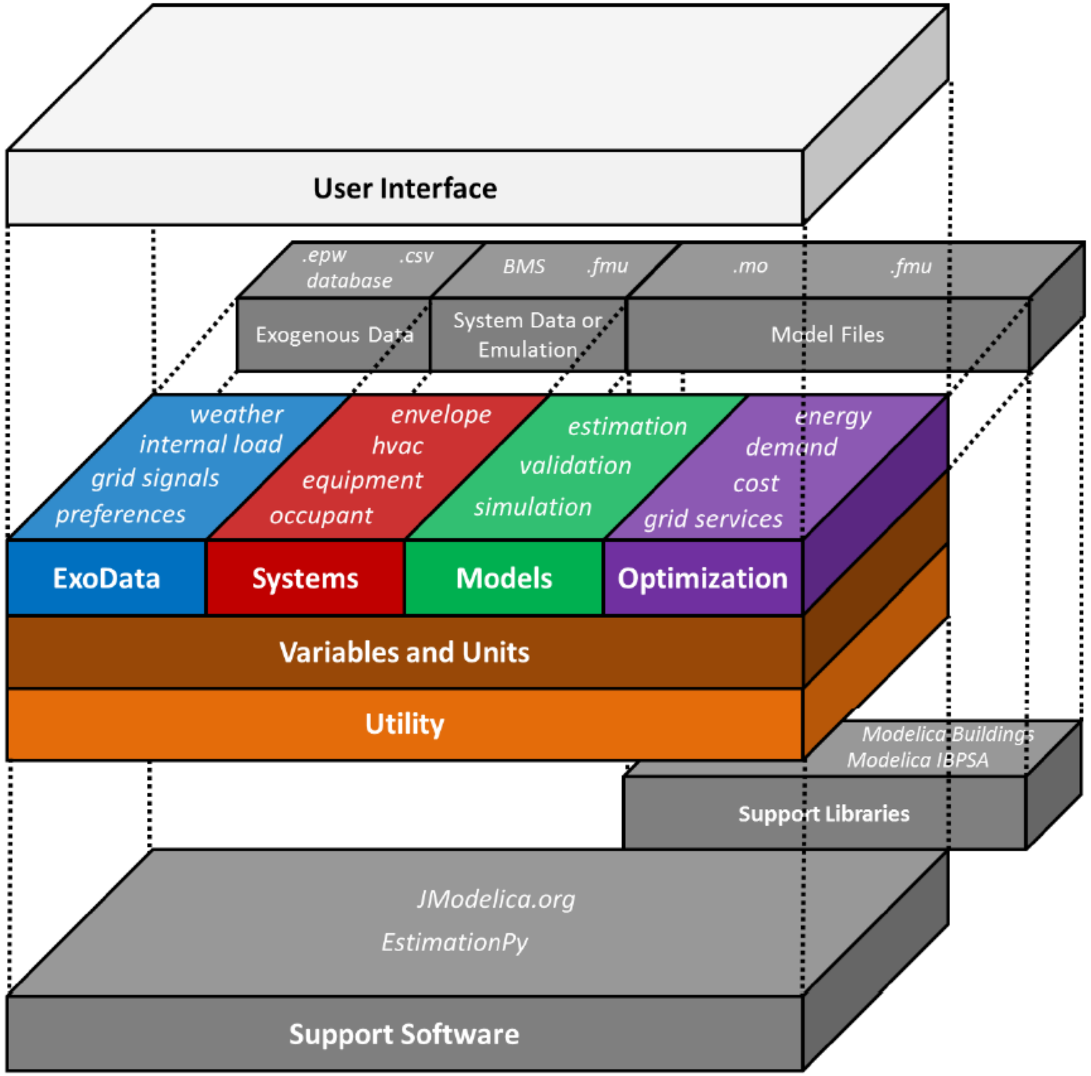




Ref: . F. Jorissen, W. Boydens, L. Helsen TACO, an automated toolchain for model predictive control of building systems: implementation and verification, Journal of Building Performance Simulation, 2018, doi: 10.1080/19401493.2018.1498537

HERRAMIENTAS

MPCpy



MPCPy

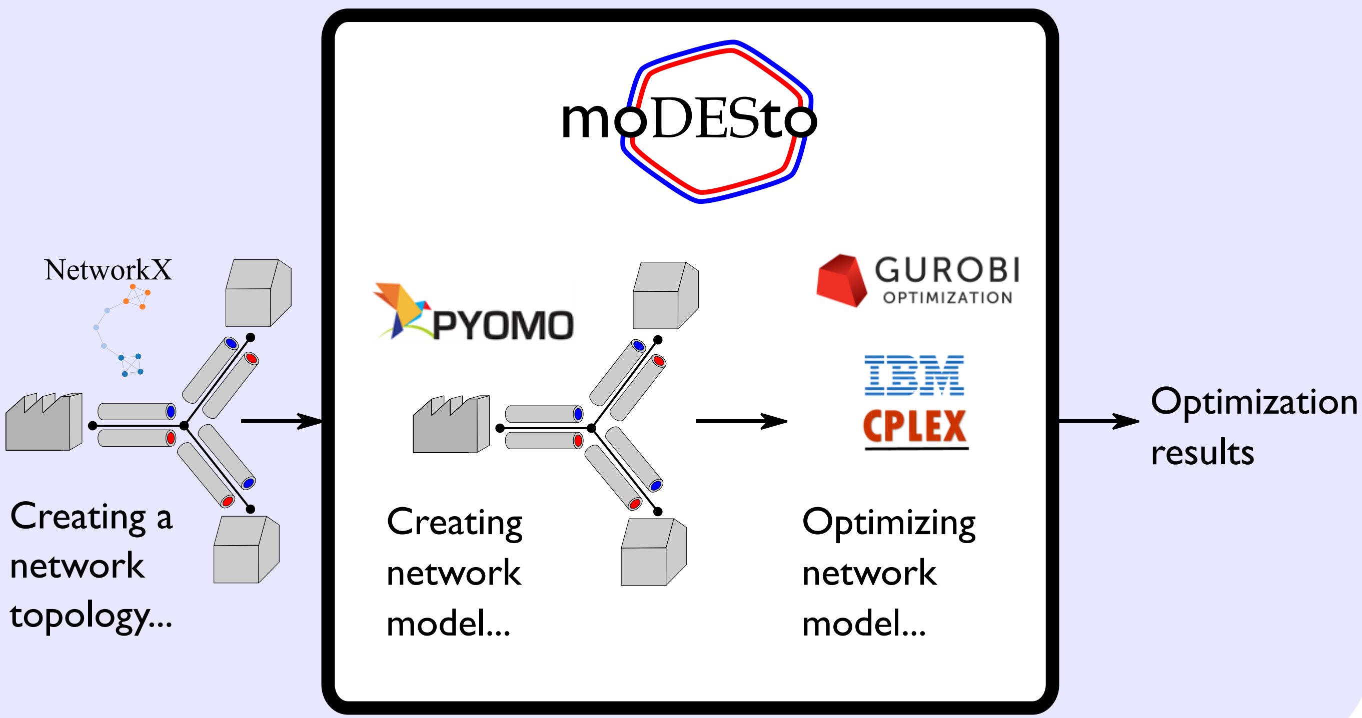
Ref: https://github.com/lbl-srg/MPCPy

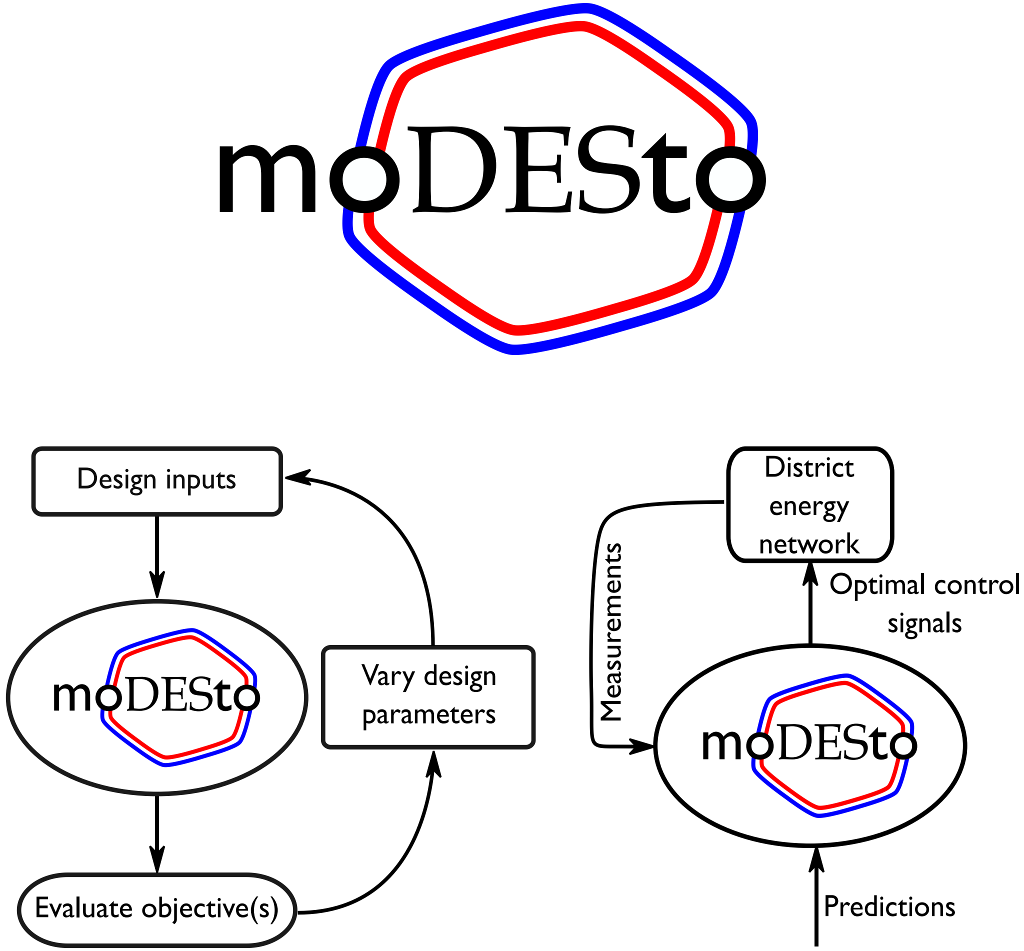
Ref: Blum, D. H. and Wetter, M. "MPCPy: An Open-Source Software Platform for Model Predictive Control in Buildings." Proceedings of the 15th Conference of International Building Performance Simulation, Aug 7 – 9, 2017. San Francisco, CA.

HERRAMIENTAS

moDESto

Arquitectura

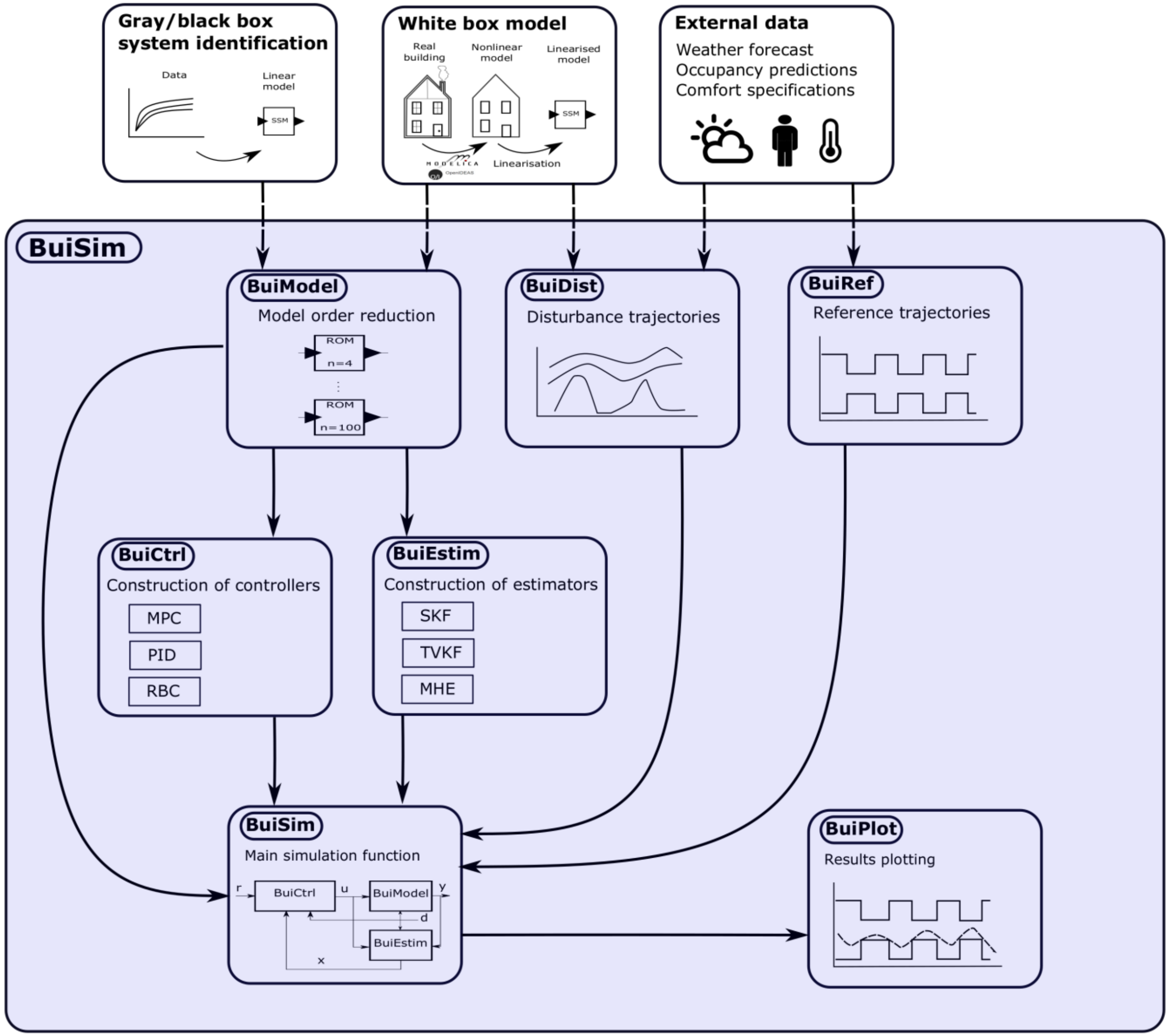




HERRAMIENTAS

BUISIM Matlab toolbox

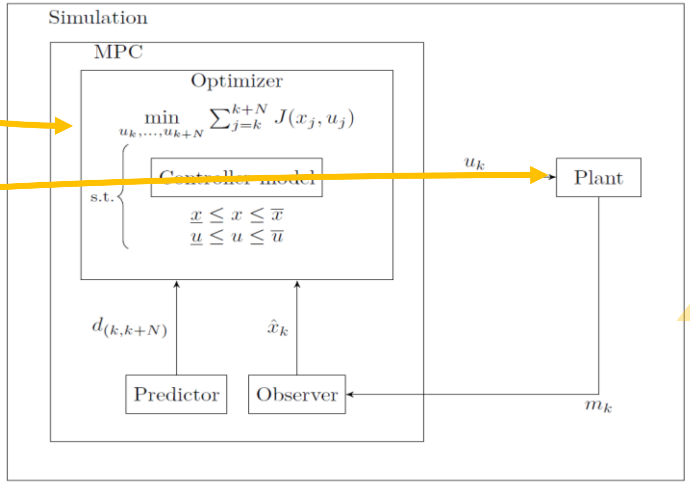
- Para un rápido desarrollo y simulación de MPCs para edificios



HERRAMIENTAS

FastSim Python Toolbox

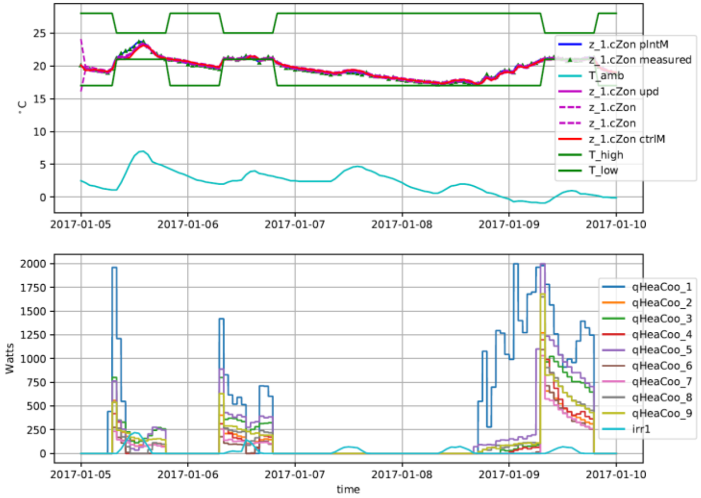
Prepara tu controlador



Prepara tu emulador

Corre una co-simulación

EVALÚA



Ref: J.Arroyo, B. v.d. Heijde, A. Spiessens and L. Helsen, "A Python-Based Toolbox for Model Predictive Control Applied to Buildings", 5th International High Performance Buildings Conference at Purdue, July 9-12, 2018.

HERRAMIENTAS

- **BOPTEST:**
  - **Para una JUSTA y CLARA evaluación de controladores avanzados de edificios**

HERRAMIENTAS

BOPTEST:

TIPO	TAMAÑO	DISTRIBUCIÓN POR AGUA	DISTRIBUCIÓN POR AIRE
RESIDENCIAL	ZONA ÚNICA		
	MULTI ZONA		
COMERCIAL	ZONA ÚNICA		
	MULTI ZONA		
	MULTI ZONA COMPLEJO		

KU LEUVEN THERMAL SYSTEMS SIMULATION


BRP
DSO
Flex-request
Flex-request
DCM
Planner
Aggregated baseline forecast (kW)
Aggregated flexibility forecast (kW)
Day-ahead optimal aggregated load (kW)
Forecaster
Feedback
Tracker
Day-ahead virtual-price
Day-ahead load response (kW)
Baseline forecast (kW)
Flexibility forecast (kW)
DERs

4 Annex 2. Presentations of workshop in Sweden

4.1 Annex 2.1. Introduktion till Flexible Heat and Power (FHP) samt projektets svenska partners. Marcus Steen

Workshop

Värmepumpar för efterfrågeflexibilitet

Erfarenheter från EU-projektet Flexible Heat and Power

Göteborg – 9 oktober 2019, kl.13.00-16.00

FHP project is funded by European Union under the grant agreement no. 731231.

Agenda

13.00 **Introduktion till Flexible Heat and Power (FHP) samt projektets svenska partners,** *Marcus Steen, KEAB*
Extern styrning av värmepumpar, *Markus Lindahl & Tommy Walfridson, RISE*
- Indirekt och direkt styrning – möjligheter och begränsningar
Pilot Karlshamn – bakgrund och beskrivning av anläggningar, *Marcus Steen KEAB & Jens Brage, NODA*
- Utmaningar och möjligheter från den svenska demon och FHP
- Vad har vi kommit fram till inom projektet
- Svårigheter på vägen och lärdomar för framtiden
FED-marknaden, ett samspel mellan olika energibärare, *Hjalmar Pihl, RISE*

14.30 **Fika**

15.00 **Efterfrågeflexibilitet ur ett svenskt perspektiv - diskussion**
Summering och avslutning

16.00 **Slut**

FHP project is funded by European Union
under the grant agreement no. 731231.

Marcus Steen

VÄLKOMMEN

VI ÄR STARKA PÅ HEMMAPLAN

Karlshamn energi

AFFÄRSIDÉ

”Karlshamn Energi skapar enkla, prisvärda och kundnära lösningar med stark fokus på hållbarhet, lokala samarbeten och med ständig fokus på utveckling och service.”

AFFÄRSOMRÅDEN

VÄRME

ELNÄT

BREDBAND

TJÄNSTER

ELHANDEL

ELPRODUKTION

VATTEN

ÄGARE

KARLSHAMN KOMMUN

STADSVAPNET I KARLSHAMN AB

KARLSHAMN ENERGI AB

- KARLSHAMN ENERGI ELFÖRSÄLJNING AB
- KARLSHAMN ENERGI VATTEN AB

325

Karlshamn Energi AB
i siffror

	2018
Omsättning, Mkr	325
Anställda	90

KONTAKT

Marcus Steen

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0454 - 204 808

NODA – Företagsinfo

- HK i Karlshamn, Sverige. Kontor i Malmö och London. Partners i Belgien, Tyskland och Polen
- Nätoperatörer, fastighetsägare och automationsföretag som kunder i Sverige, Polen, Benelux, UK och Tyskland
- Fokus på innovation inom artificiell intelligens och datavetenskap för applikationer inom energisystem
- Grundat år 2005

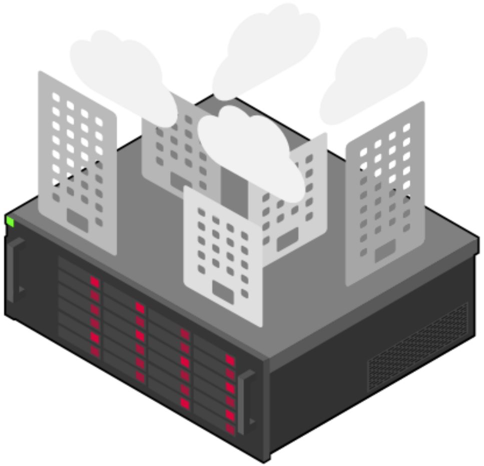
Skapa hållbara energisystem

Innovation med mål att skapa långsiktig affärsnytta

- Möjliggöra affärer
- Minska miljöpåverkan
- Säkerställa quality of service

Områden för innovation

- Kontroll
  - Smart Heat Grid, Smart Heat Building, Hybrid system
- Analys
  - Förebyggande underhåll, automatiserade kundrapporter, support system för beslutsfattning
- Plattform
  - Moln, Säkerhet, Tillgänglighet, API, OEM strategi



NODA INTELLIGENT SYSTEMS

FHP project is funded by European Union
under the grant agreement no. 731231.

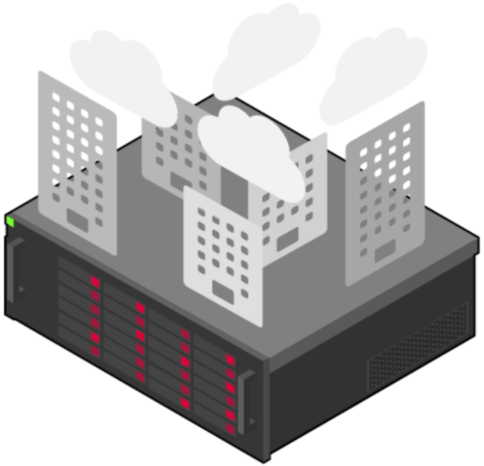
Kontaktuppgifter

Jens Brage

Head of Research and Innovation Unit

Jens är Head of Research and Innovation på NODA.Han har en doktorsexamen i matematik från Stockholms universitet och en gedigen bakgrund inom datavetenskap och har flera års arbetslivserfarenhet inom mjukvaruutveckling.

jens.brage@noda.se



NODA INTELLIGENT SYSTEMS

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RISE

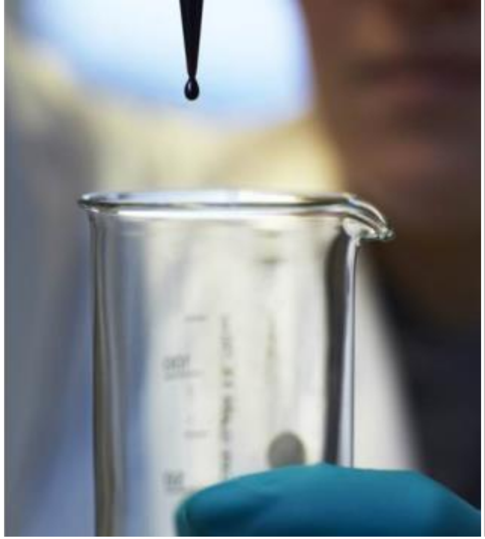
För ett hållbart och konkurrenskraftigt Sverige

Markus Lindahl

2019-09-11

RISE Research Institutes of Sweden

Division Samhällsbyggnad
Energi och cirkulär ekonomi



Hela Sveriges forsknings- och innovationspartner

Ägarens uppdrag till RISE

”Industriforskningsinstituten ska vara internationellt konkurrenskraftiga och verka för hållbar tillväxt i Sverige genom att stärka näringslivets konkurrenskraft och förnyelse.”

Utdrag ur Forskningsproposition 2016/17:50 (Kunskap i samverkan)

RI. SE

Fakta om RISE-koncernen

- Finns över hela Sverige – och lite till.
- 2 700 medarbetare, varav 30 % disputerade forskare.
- Omsatte 2018 3 miljarder SEK.
- Driver över 100 test- och demonstrationsmiljöer, öppna för företag och lärosäten

KONTAKTUPPGIFTER

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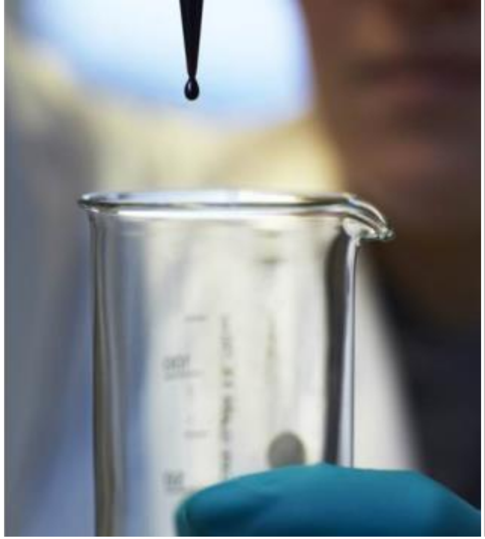
RISE Research Institutes of Sweden

Division Samhällsbyggnad
Energi och cirkulär ekonomi



Flexible Heat and Power

Introduktion

- Projektet har beviljats under LCE-01-2016 “*Next generation innovative technologies enabling smart grids, storage and energy system integration with increasing share of renewables: distribution network*”, subtopic “*Synergies between Energy Networks*”
- 1/Nov/2016 – 31/Oct/2019

Flexible Heat and Power
Problemställning/utmaning

Ökad andel installerad kapacitet av intermittenta förnyelsebara källor

- Vid vissa tillfällen: för mycket produktion
  - Mer än behovet (överskott jämfört med lasten)
  - Mer än vad nätet klarar av
  - ***Stänga ned produktion?***

- Intermittens: Utmaning för prognoser och balans
  - Matchning av tillgång och efterfrågan
  - ***Balanskraft?***

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Flexible Heat and Power
Möjlighet

- Hävstångseffekt av flexibilitet tillhandahållen genom omvandling av elektrisk energi till värme
  - Termisk lagring och termisk tröghet
  - Värmepumpar
- Tillhandahålls (nästan) ‘gratis’ …
- Förbättrar affärsmöjligheterna för VP … bidrar till minskade utsläpp som leder till minskad uppvärmning/växthuseffekt
- Utspridd och (i framtiden, potentiellt) tillgänglig överallt … löser problem effektivt genom att ta nätets villkor i beräkning
  - VP värmer upp byggnader
  - VP laddar stora termiska lagringstankar (➔ DHN)

Flexible Heat and Power

Möjlighet – VP trender och potential

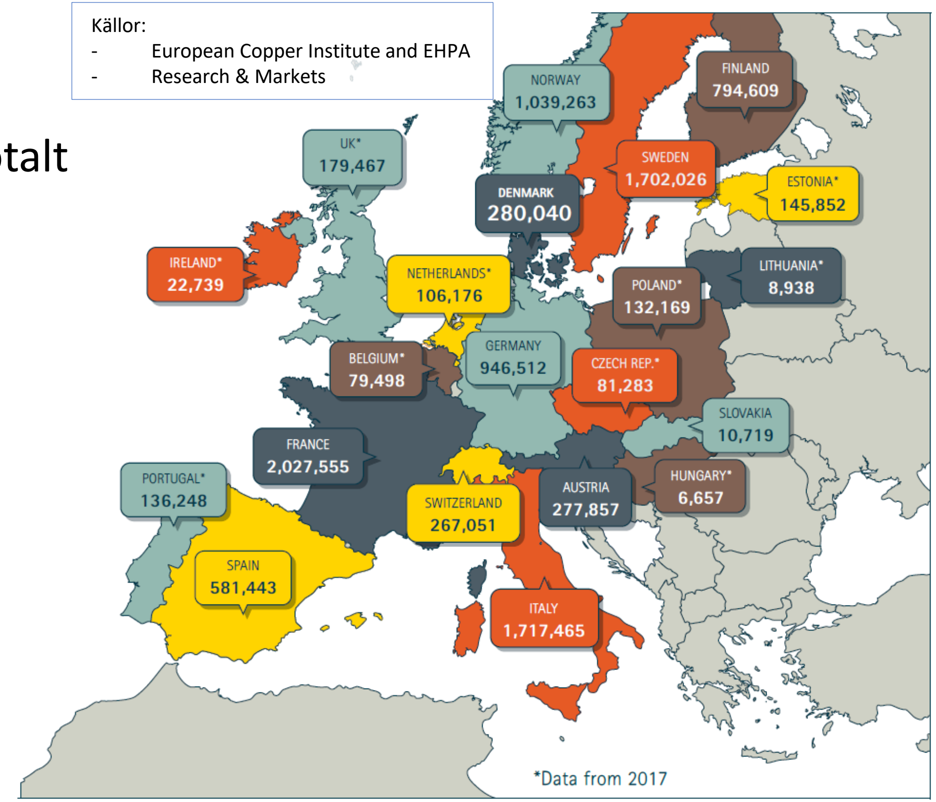
<u>EU nyckeltal</u>:

- 1.1 miljoner värmepumpar såldes 2017
- 10.56 miljoner värmepumpar installerade totalt
- Växande marknad för 4e året i rad
- Tvåsiffrig tillväxt för 3e året i rad
- Dubblering av installerad kapacitet till 2024 verkar realistisk

<u>Installerad kapacitet:</u>

- Genererar 181.1 TWh användbar värme
- 115.8 TWh varav förnybara energikällor
- Besparar 29.7 miljoner ton CO_2 utsläpp
- Flex-potential mellan 1 och 3.2 TWh/år

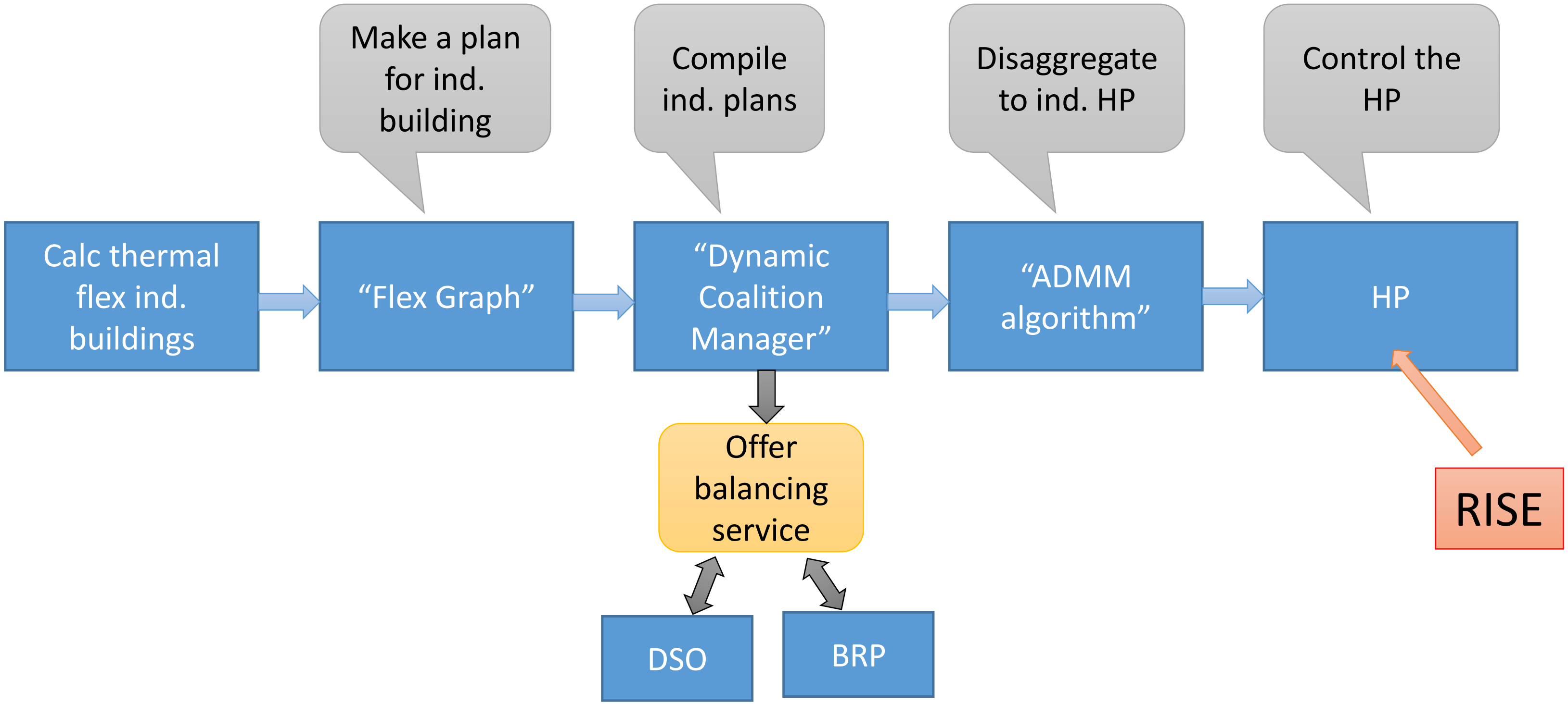
Källor:
- European Copper Institute and EHPA
- Research & Markets



Flexible Heat and Power
Projektmål

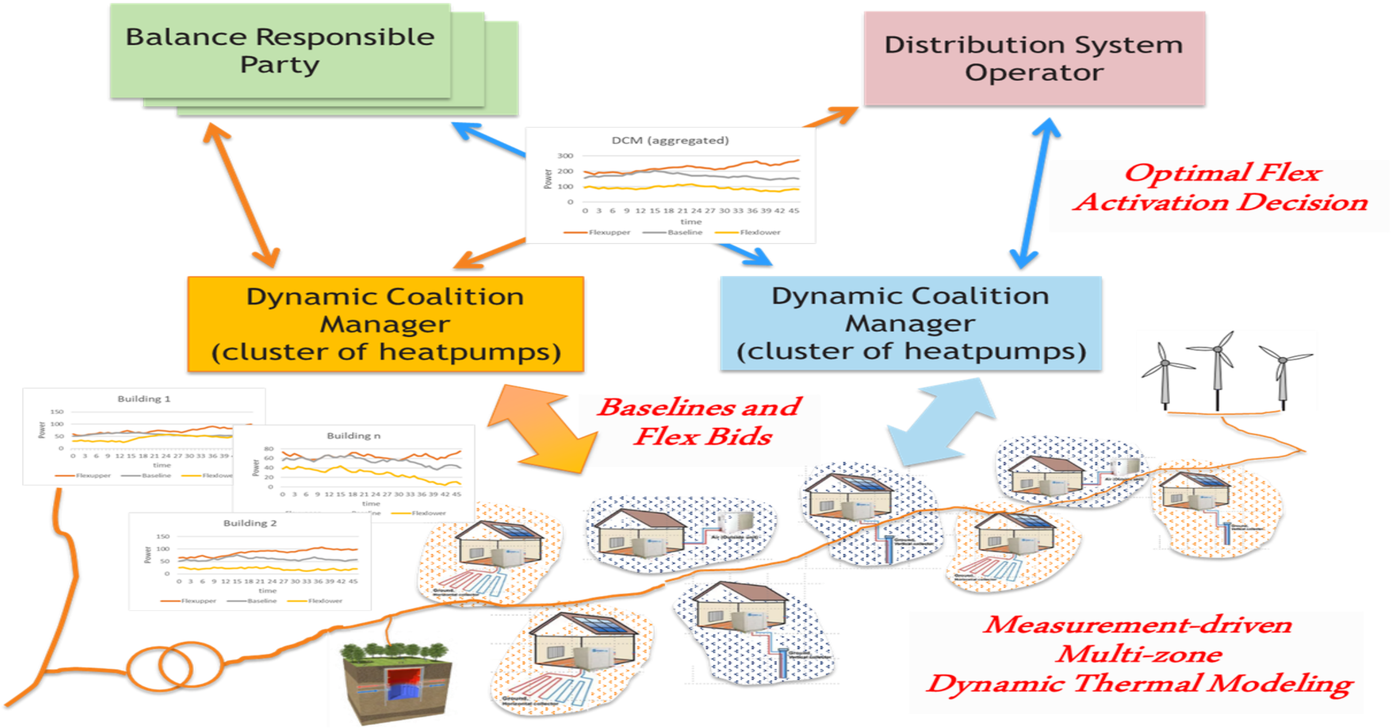
- Öka andelen flexibilitet genom att maximera incitamentet för leverantörer av termisk flexibilitet
- **Flex Trading** & **Dynamic Coalition Manager**
  - Tillgängliggör efterfrågeflexibilitet som kan möjliggöra handel för leverantörer av flexibilitet(byggnader) och DCM skapar förutsättningar för dem att maximera värdet av deras flexibilitet
- **Platsmedveten flexaktivering** … löser lokala problem och problem på systemnivå på ett säkert sätt för elnätet
  - Aggregering nedifrån & upp av prognoser och flexibilitetsinformation tillhandahållen av leverantörerna av flexibilitet själva, följt av strategier för optimal flexibilitet
- **Nätflexibla värmepumpar** … gör så att VP bättre anpassas för att bidra med tjänster inom flexibilitet

Flexible Heat and Power
Koncept



Flexible Heat and Power

Multi-agent arkitektur



4.2 Annex 2.2. Extern styrning av värmepumpar. Markus Lindahl & Tommy Walfridson

Workshop

Värmepumpar för efterfrågeflexibilitet

Markus Lindahl, RISE Research Institutes of Sweden

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Introduktion värmepumpar

Värme

- ✓ Rumsvärme (fokus i FHP-projektet)
- ✓ Varmvatten (VV)
- ✓ Industriell värme
- ✓ Fjärrvärme

Kompressorteknik

- ✓ On/Off
- ✓ Frekvensstyrd kompressor

- ✓ $COP = \frac{Avgiven\ värme\ från\ värmepumpen}{Värmepumpens\ förbrukade\ el}$

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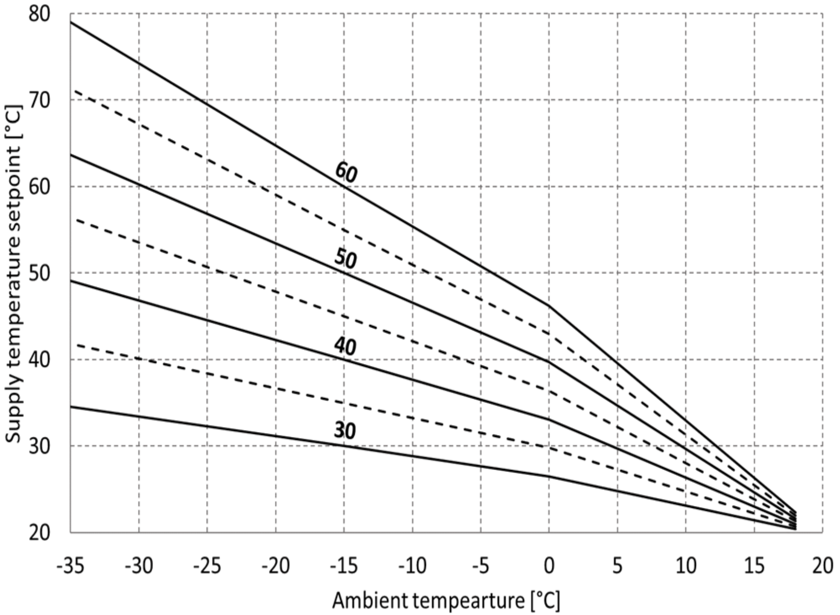
Värmepumpens kontrollsystem

- ✓ Mängden producerad värme beror på:
  - ✓ Utomhustemperatur
  - ✓ Temperatur i fastigheten

- ✓ Värmekurvan bestämmer vilken framledningstemperatur värmepumpen ska hålla

Exampel värmekurva



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Standard för Smart grid ready

- ✓ Smart grid ready (SG ready) är en standard för smart kontroll
  - ✓ Utvecklad av German Bundesverband Wärmepumpe e.V.
- ✓ Varje driftläge aktiveras med hjälp av två elektriska ingångar i värmepumpen, dvs om de är öppna (0) eller stängda (1)

Fyra olika driftlägen:

1. Blockerad (1:0)
2. Normaldrift (0:0)
3. Lågpris (0:1)
4. Överkapacitet i nätet (1:1)

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Styrning av värmepumpens effekt

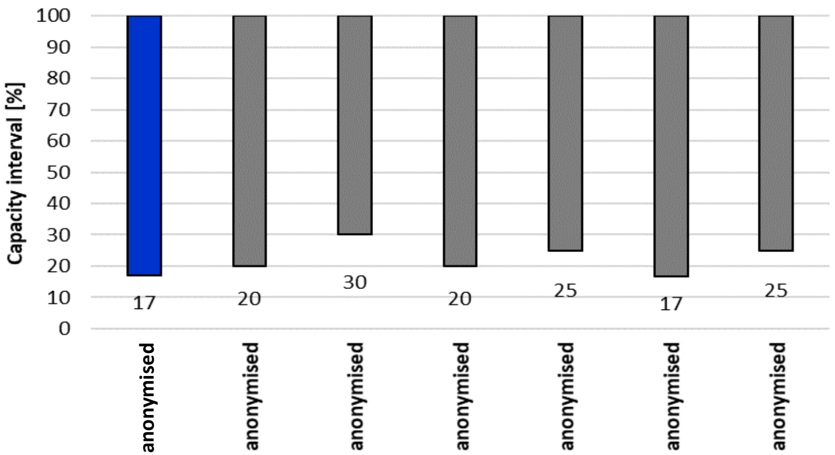
Värmeproduktion och elförbrukning kan styras på tre sätt:

- ✓Starta/stoppa kompressorn
- ✓Ändra kompressorns varvtal
- ✓Starta/stoppa elpatronen

Enkät (Fyra Svenska värmepumps-tillverkare)

- ✓Bosch (IVT)
- ✓Enertech (CTC)
- ✓Nibe
- ✓Stiebel Eltron (Thermia)

Kompressorns kapacitetsområde



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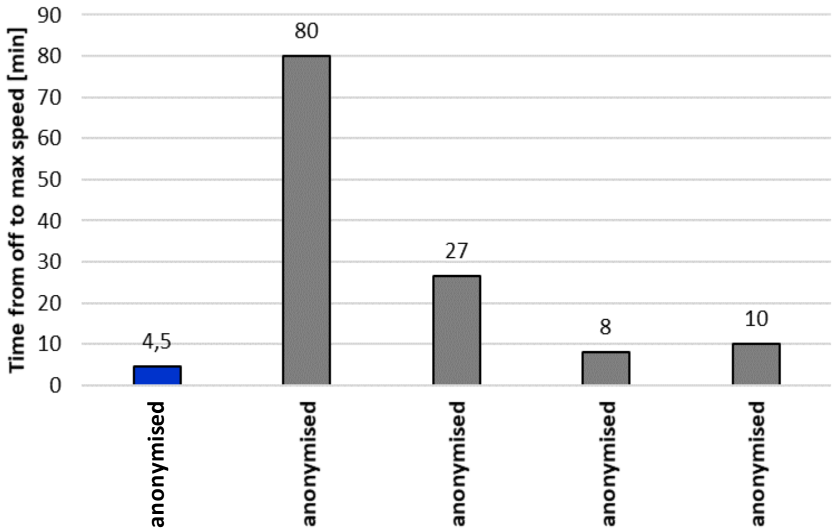
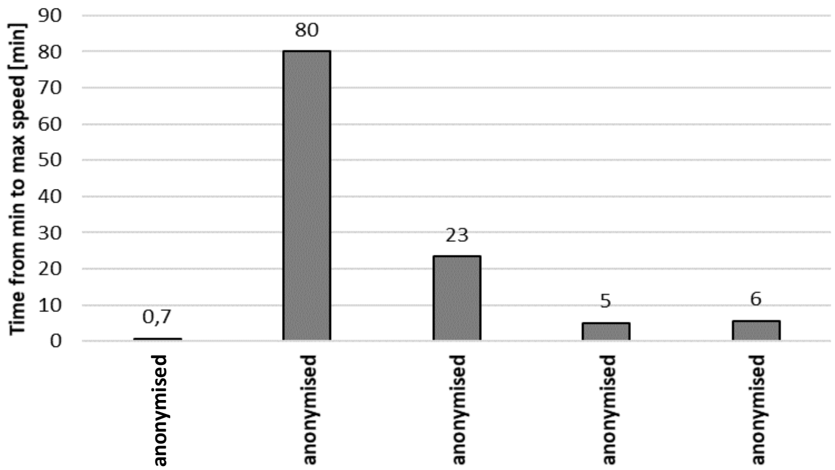
Varvtalstyrda kompressorer

Tid från avstängd till max varvtal



Tid från lägsta till högsta varvtal



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Labbtest

- ✓ Bergvärmepump
- ✓ För villa
  - ✓ 12 kW värmeeffekt (max)
  - ✓ Elpatron
- ✓ Varvtalsstyrd kompressor

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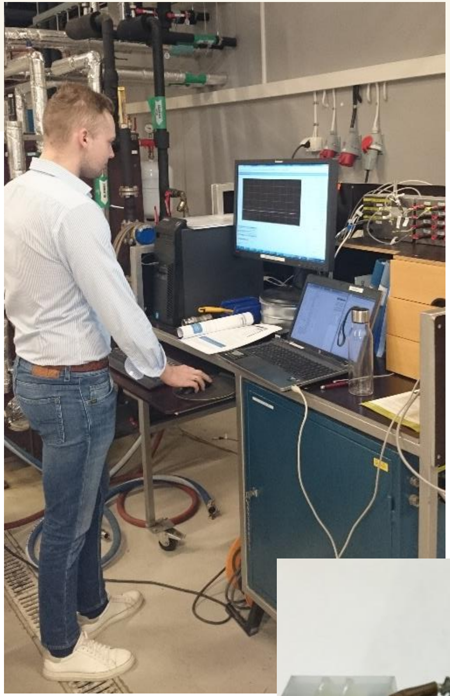
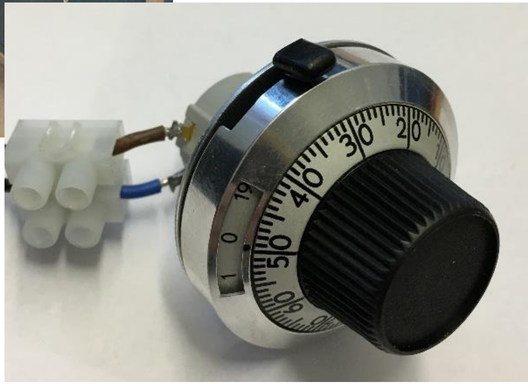
Styrning av värmepumpen

- ✓ Direktstyrning av kompressorns varvtal
  - ✓ Värmepumpens kompressor styrs via ett styrprogram i extern dator.
  - ✓ Utfördes manuellt eller automatiskt
- ✓ Indirekt styrning
  - ✓ Överrider utegivarens temperatur
  - ✓ Utegivaren ersattes med en precisionspotentiometer
  - ✓ Utfördes manuellt av testingenjör





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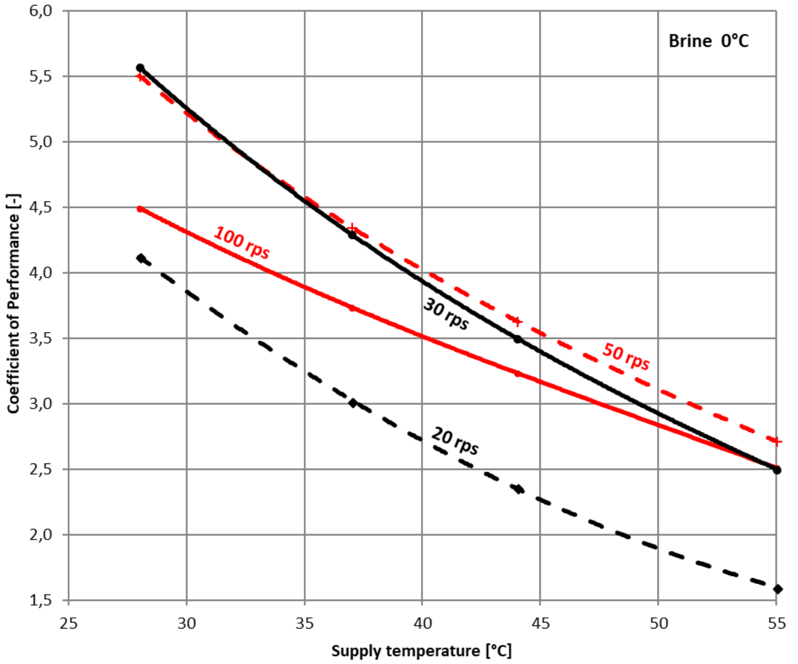
Värmepumpens prestanda

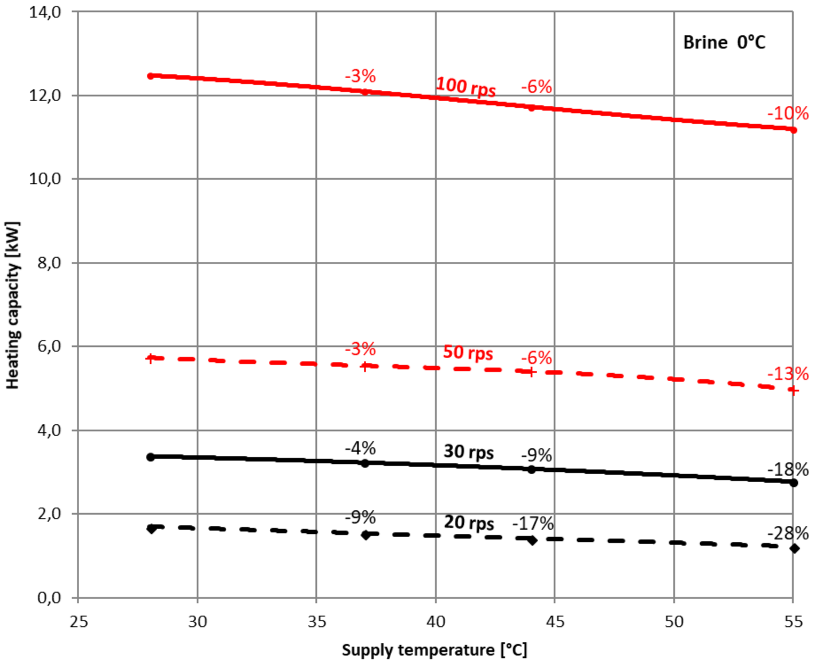
COP

- sfa framledningstemperatur



Värmeeffekt

- sfa framledningstemperatur



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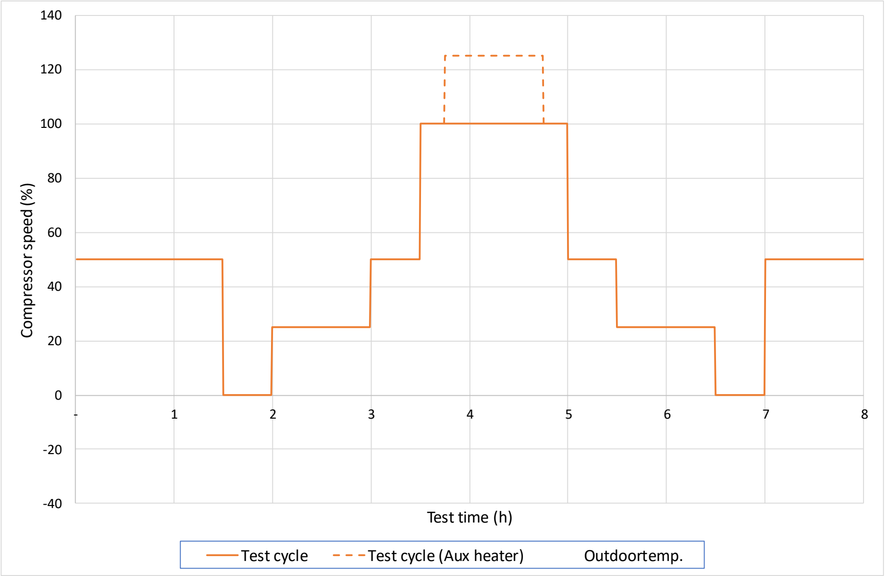
Testcykel för labbtester
- Utvärdering av en nätflexibel värmepump

Syfte:

- ✓ Strukturerad utvärdering av extern styrning i labb
- ✓ Hur väl kan vi följa testcykeln
- ✓ Påverkan på COP
  - ✓ Jämfört med stabile förhållanden
- ✓ Test att styra ett antal funktioner
  - ✓ Starta och stoppa värmepumpen
  - ✓ Öka värmeproduktionen i steg
  - ✓ Arbeta på maximal värmekapacitet
  - ✓ Minska värmeproduktionen I steg
  - ✓ Starta och stoppa tillsatsvärmen
  - ✓ Justera tillsatsvärmen till önskad nivå



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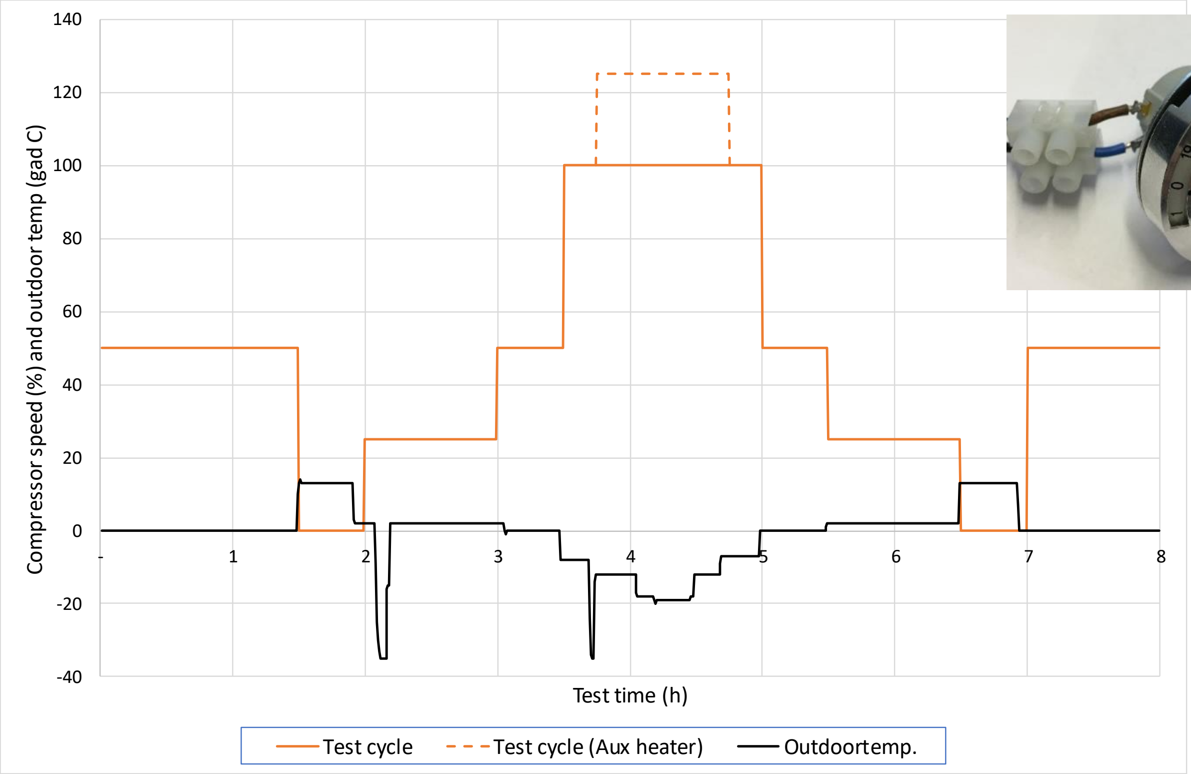
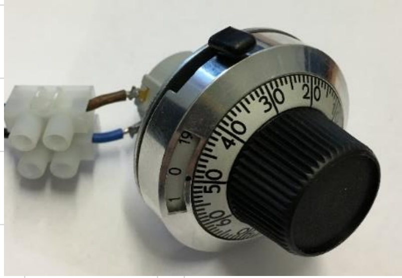
Indirekt kontroll





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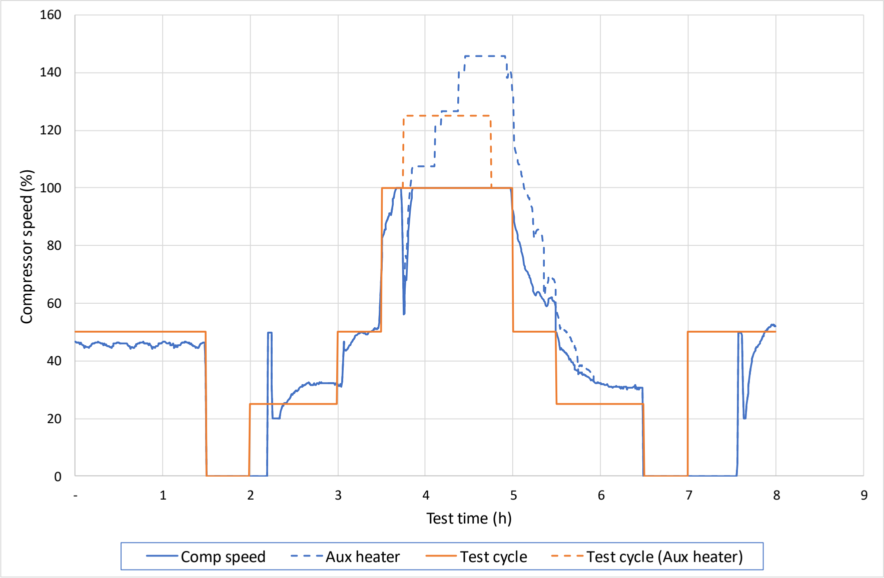
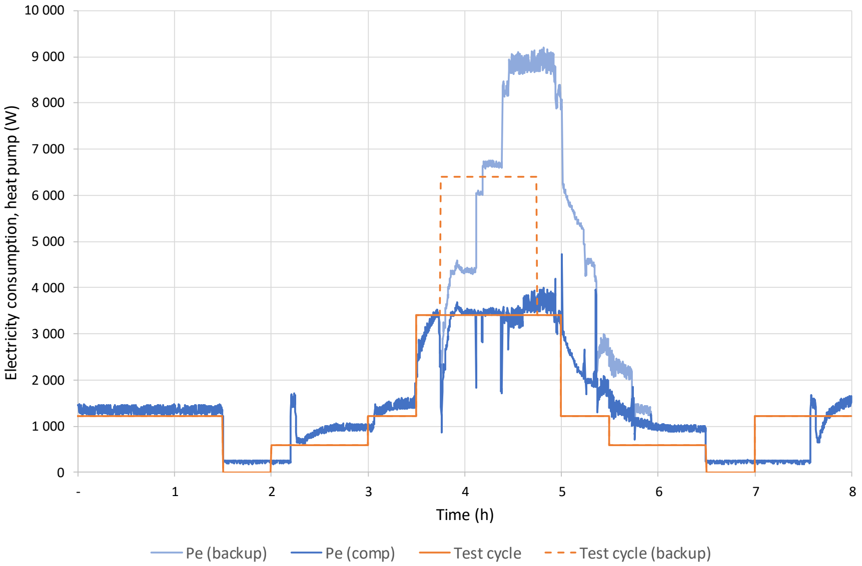
Indirekt kontroll

Kompressorhastighet



Elförbrukning



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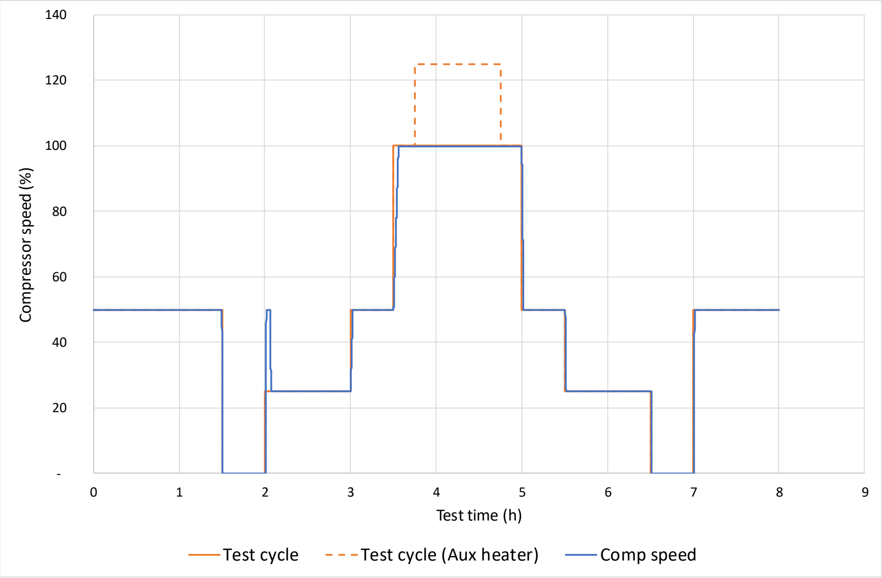
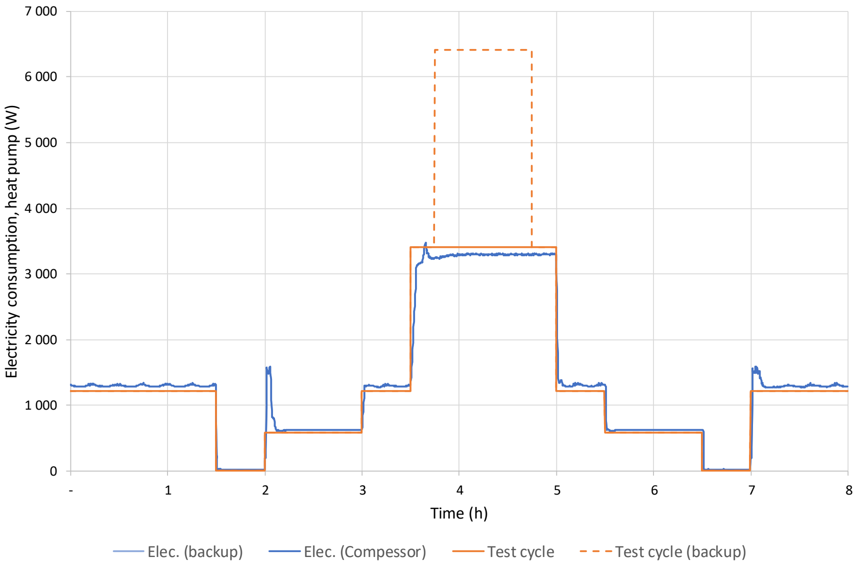
Direkt kontroll

Kompressorhastighet



Elförbrukning



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Utvärdering av resultaten

KPI	Beskrivning
KPI_1:	Avvikelsen i medel från testcykeln
KPI_2:	Andel av tiden inom ±3% av testcykeln
KPI_3:	Andel av tiden inom ±10% av testcykeln
KPI_4:	Påverkan på COP

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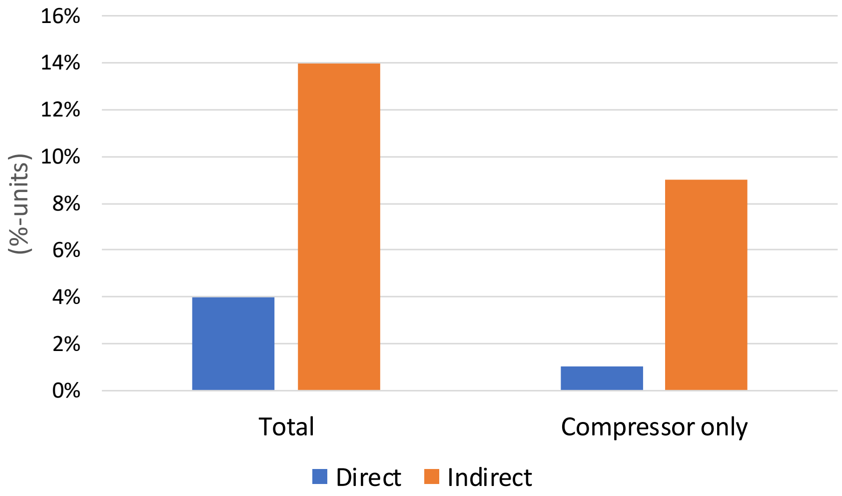
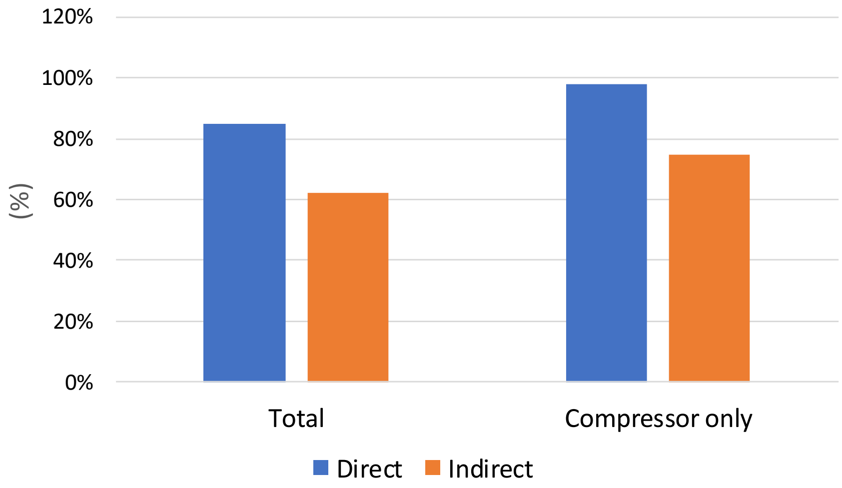
Resultat
- Hur väl följer värmepumpen testcykeln

Avvikelse i medel
från testcykeln



Andel av tiden inom
±10% av testcykeln



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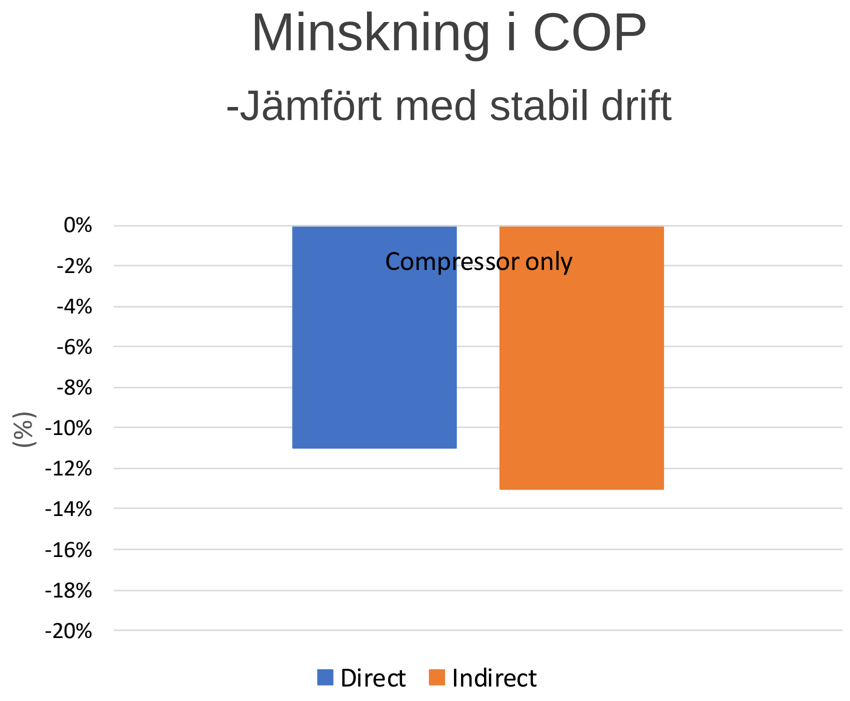
Resultat
- Påverkan på värmepumpens effektivitet (COP)

- ✓ COP minskar 10-15% med testcykeln
  - ✓ Jämfört med stabil drift
    - ✓ 50% kompressorhastighet
  - ✓ Kompressordrift enbart
    - ✓ (Backup värme exkluderat)
- ✓ Andra tester: Påverkan på COP beror på testprofilen



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Direkt styrning
- 24h profiler

- Nya testprofiler med direkt styrning av kompressorn

- Syfte:
  – Utvärdera om VP kan följa en föreslagen profil, och hur väl.
  – Utvärdera hur COP påverkas av att man följer en profil i stället för att köra på konstant effekt

- Profilerna baserat på möjliga användningsområden:
  – Peak shaving
  – Profiler använda i Karlshamnspiloten (Framtagna av Vito)
  – Kostnadsminimering
    - Exempel Aarhus, 26 nov 2018

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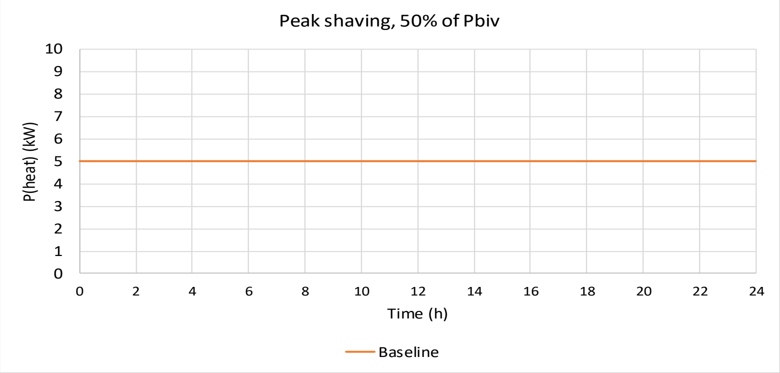
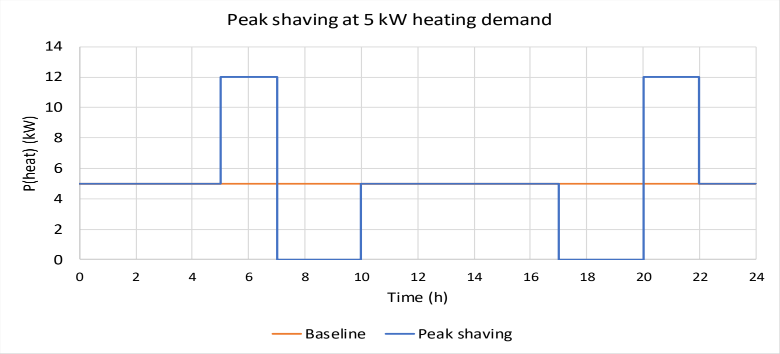
Peak shaving

- 5 kW värmebehov konstant över dygnet
- Utomhustemperatur: +3°C
- Husets värmebehov enl. provningsstandarden för VP: EN14825





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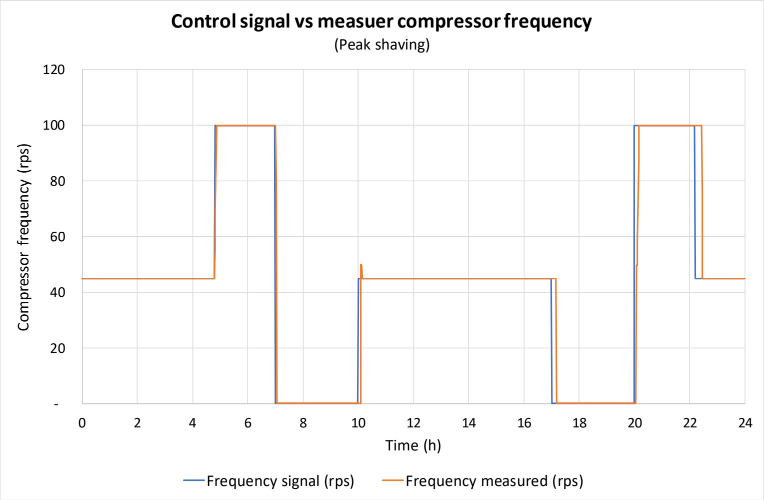
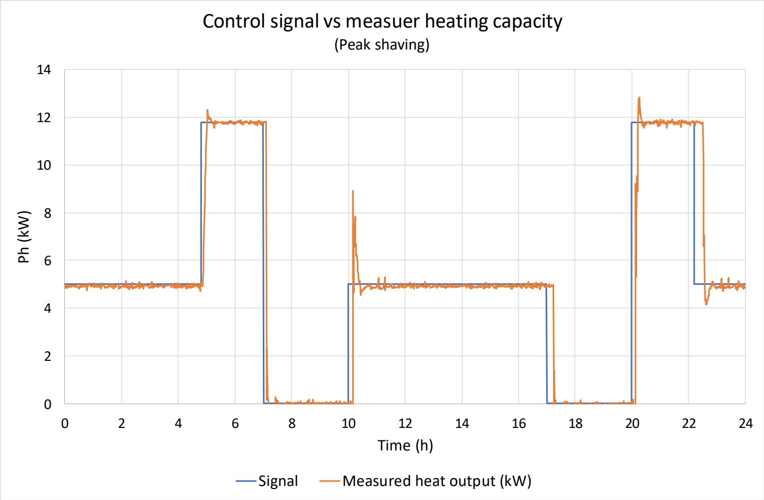
Peak shaving, resultat





KPI	Komp. frekvens	Värmeeffekt, Ph
KPI 1: Medel avvikelse från testcykel	1,9 rps	460 W
KPI 2: Andel av tiden då avvikelsen är inom 3%	96%	92%
KPI 3: Andel av tiden då avvikelsen är inom 10%	97%	94%
KPI 4: Minskning i COP pga flex	-8%	

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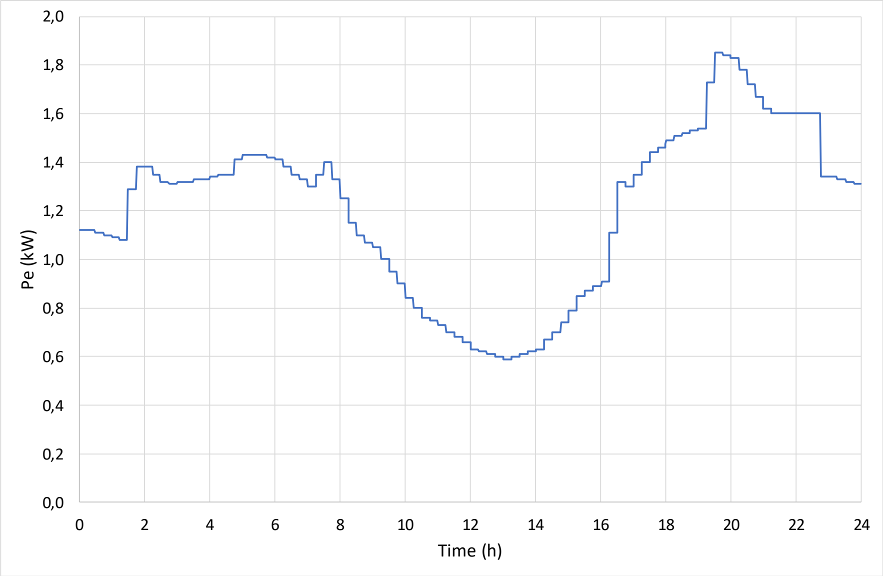
Signal till flerfamiljshus,
- Profil från Karlshamns piloten

- Framtagen signal med önskad elförbrukning
  - Syfte kostnadsminimering
- Framtagen för piloten i Karlshamn
  - Flerfamiljshus
  - VP testad i labb har lägre värmekapacitet=> Originalprofilens elförbrukning har minskats.
  - 24 h har valts ut ur en längre frekvens
- Framledningstemperatur uppskattad baserad på verklig utomhustemperatur
  - 20 feb 2019
  - Utomhustemp mellan +1 och +8°C



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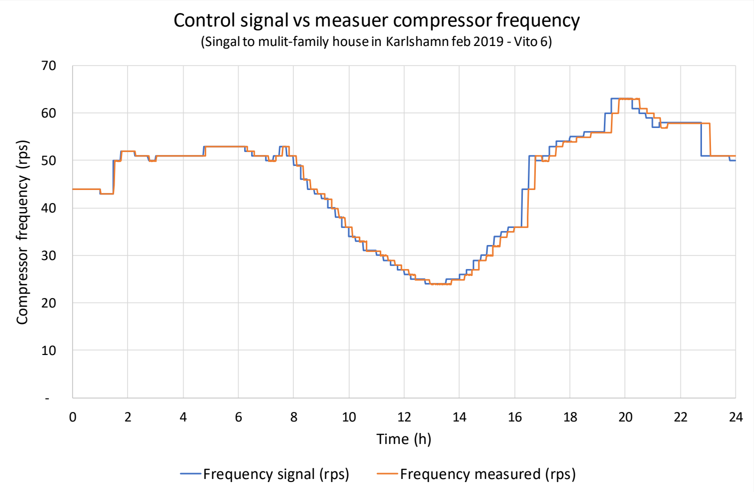
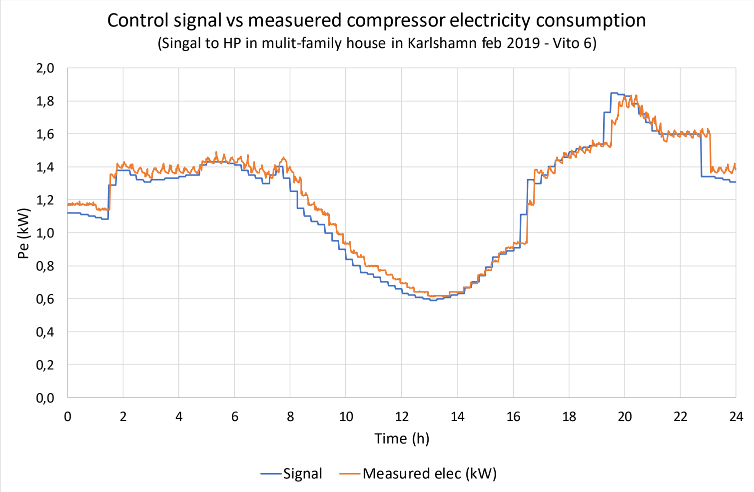
Resultat, signal till flerfamiljshus





KPI	Frekvens	Pe tot	Pe komp
KPI 1: Medel avvikelse från testcykel	0,8	80 W	49 W
KPI 2: Andel av tiden då avvikelsen är inom 3%	95%	30%	67%
KPI 3: Andel av tiden då avvikelsen är inom 10%	100%	98%	97%
KPI 4: Minskning i COP pga flex	0%		

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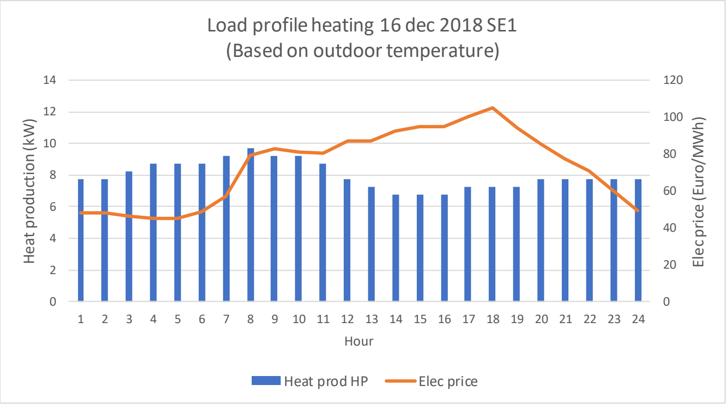
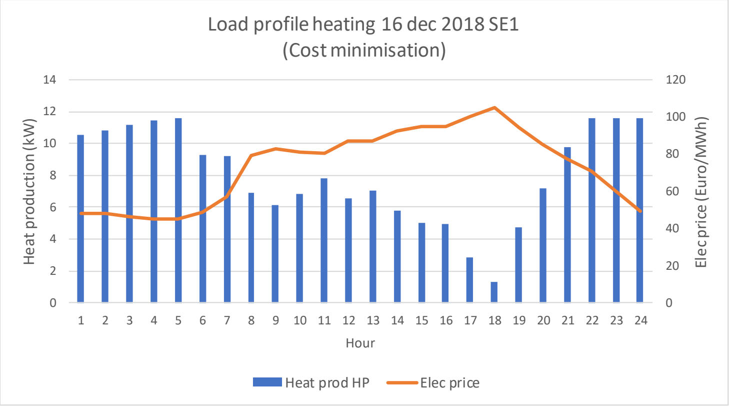
Kostnadsminimering,
- Aahus 26 nov 2018

- Dag med:
  - Stora variationer i elpris
  - Viss variation utomhustemp. -4 - +2°C
- Data från
  - Elpris: Nordpool, timvärden
  - Temperatur: DMI, timvärden
- Kostnadsminimering under 24 h
  - Förhållandevis enkel modell
  - Minimering av uppvärmningskostnaden: Excels problemlösare
  - Syfte att få fram en möjlig profil, inte optimal kostnadsminimering.
  - COP beror av:
    - Utomhustemp
    - Framledningstemperaturen: COP minskas med 2,5% per grad som framledningen höjs när VP levererar mer värme
- Besparing uppvärmningskostnad: 6%





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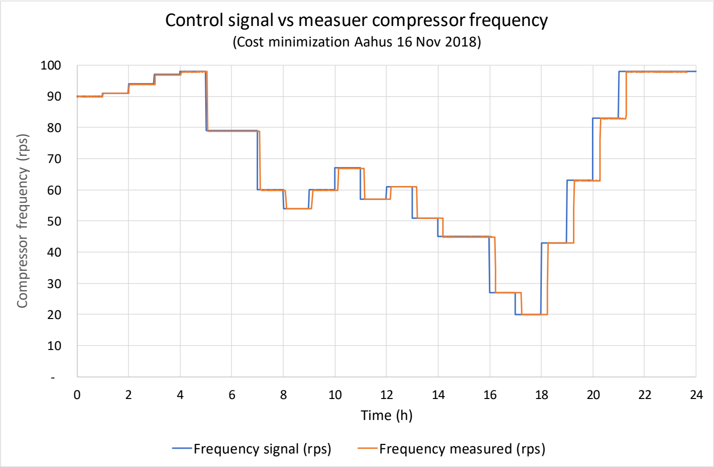
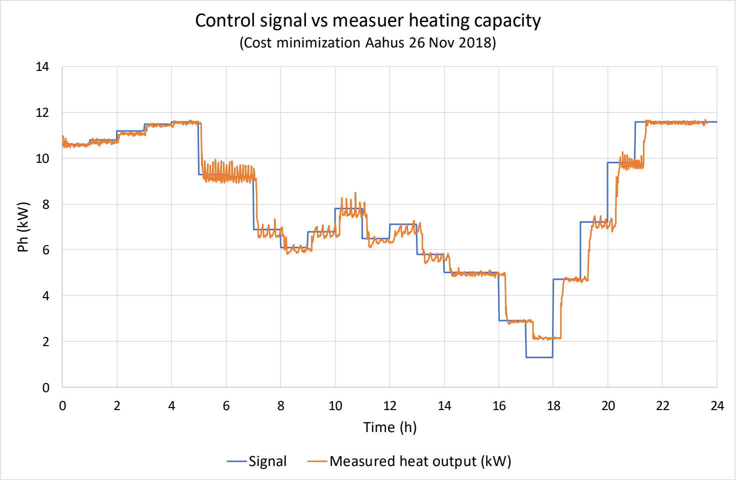
Kostnadsminimering Aahus, resultat





KPI	Frekvens	Ph
KPI 1: Medel avvikelse från testcykel	1,7	380 W
KPI 2: Andel av tiden då avvikelsen är inom 3%	88%	76%
KPI 3: Andel av tiden då avvikelsen är inom 10%	94%	91%
KPI 4: Minskning i COP pga flex	-4%	

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under the grant agreement no. 731231.

Design av nätflexibla värmepumpar

- ✓ Överdimensionerade VP-system ger högre flexibilitet
  - ✓ Högre investeringskostnader
  - ✓ Risk för lägre systemeffektivitet
- ✓ Labbtester indikerar att COP kommer sjunka
  - ✓ Elförbrukningen kommer öka om VP används för efterfrågeflexibilitet
  - ✓ Kompensation för att tillhandahålla flexibilitet krävs
- ✓ Tillgänglig flexibilitet beror på värmebehovet och därmed utomhustemperaturen
- ✓ Stora skillnader i hur snabbt kompressorfrekvensen kan ändras mellan olika VP modeller
  - ✓ Svensk kartläggning: 40 s – 80 min från min till max frekvens
  - ✓ Troligen tekniskt möjligt med snabba ändringar

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Rekommendationer för extern kontroll

Äldre värmepumpar eller enklare värmepumpar som säljs idag:

- ✓ Indirekt kontroll genom att manipulera utomhustemperaturgivaren
- ✓ Fungerar på mer eller mindre alla värmepumpar

Premium värmepumpar som säljs idag och framtidens värmepumpar

- ✓ Indirekt kontroll: Ändra temperaturinställningarna genom att justera t.ex. värmekurvan
- ✓ Använd web-API, många premium värmepumpar som säljs idag är uppkopplade
  - ✓ Värmepumpsägaren kan ändra värmepumpsinställningar på distans via en webben eller en app.

Framtida värmepumpar

- ✓ Direkt kontroll
- ✓ Snabbare kontroll, bättre noggrannhet
- ✓ Kräver standardisering

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Tack!

Markus Lindahl, RISE

markus.lindahl@ri.se,

FHP project is funded by European Union under the grant agreement no. 731231.

4.3 Annex 2.3. Pilot Karlshamn – bakgrund och beskrivning av anläggningar. Marcus Steen & Jens Brage

Workshop

Värmepumpar för efterfrågeflexibilitet

Erfarenheter från EU-projektet Flexible Heat and Power

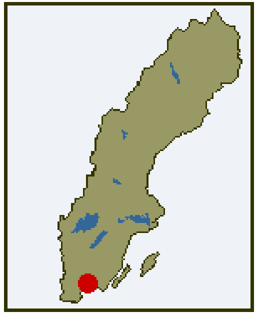
Göteborg – 9 oktober 2019, kl.13.00-16.00

FHP project is funded by European Union under the grant agreement no. 731231.

Introduktion

Karlshamn kommun och Karlshamn Energi AB

- ✓ ***Karlshamn kommun***
  - ✓ ***Karlshamn tätort***
- ✓ ***Karlshamn Energi AB***
  - ✓ ***Olika nyttigheter***
  - ✓ ***DSO – lokalt elnätsbolag***
  - ✓ ***Lokal förnyelsebar produktion***
  - ✓ ***Fjärrvärme***
  - ✓ ***Vatten och avlopp***
  - ✓ ***Bredband***



Bostadshus

pilot set-up

Bostadshus i stadens centrum

- ✓ ***Flerfamiljshus***
  - ✓***Byggnad 1***
    - ✓ ***3 lägenheter, totalt boyta 316 m2.***
    - ✓ ***Jordvärmepump – Nibe F1155-12 3-12kW***

Bostadshus
pilot set-up

Bostadshus i stadens centrum

- ✓ *Flerfamiljshus*
  - ✓ *Byggnad 2*
    - ✓ *8 lägenheter, total boyta 688 m2.*
    - ✓ *Luft-VattenVP – Mitsubishi 3-10kW*
    - ✓ *Elpatron 15 kW backup*
    - ✓ *Oljepanna 37-50 kW backup*

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under the grant agreement no. 731231.

Bostadshus
pilot set-up

Bostadshus i stadens centrum

- ✓ *Flerfamiljshus*
  - ✓ *Byggnad 3*
    - ✓ *5 lägenheter, total boyta 250 m2.*
    - ✓ *Jordvärmepump – Nibe F1155-12 3-12kW*

Industrifastigheter
pilot set-up

Industri

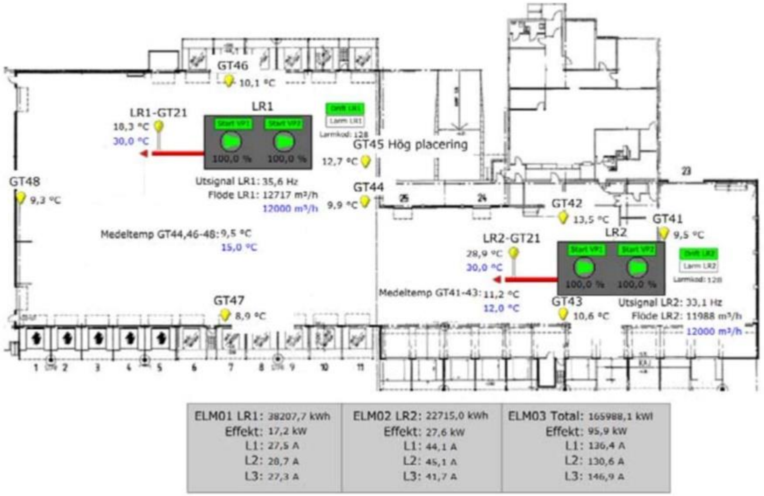
- ✓ Fastighet 1
  - ✓ Logistikföretag – 3 större byggnader
  - ✓ Jordvärmepump – 3-10 kW
  - ✓ Luft-luftVP - 4 mindre, 1-3 kW vardera
  - ✓ Oljepanna – 200 kW, mestadels för tappvatten

Industrifastigheter

pilot set-up

Industri

- ✓ ***Fastighet 2***
  - ✓ ***Logistikföretag, delvis tillverkningsindustri***
  - ✓ ***Luft-LuftVP - 4 Mitsubishi 2-10kW vardera***



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Industrifastigheter
pilot set-up

Industri

- ✓ ***Fastighet 1***
  - ✓ ***Luft-luftVP – flertalet små VP 1-3 kW***

Lösningar för pilotprojekt KHN

tekniska installationer

- ✓ *One-wire sensorer(enklare temperatursensorer)*
- ✓ *Temperaturgivare*
- ✓ *NODA IEC*
- ✓ *Energimätare*
- ✓ *Kommunikation - Wifi / GPRS*

Lösningar för pilotprojekt KHN
tekniska installationer

- ✓ ***Nätstation installation***
  - ✓ ***Nätövervakning för de industriella fastigheterna***

Summering

Resultat och erfarenheter

Svårigheter i pilotprojektet

- ✓ ***Begränsad tillgång av fastigheter***
- ✓ ***Frivilliga fastigheter tenderar att ha någon form av problem från start***
  - ✓ ***Ofta behov för energieffektivisering***
- ✓ ***Väldigt komplexa och varierande energisystem***
  - ✓ ***Fastigheterna ser långt ifrån likadana ut***
- ✓ ***Vissa tekniska installationer är för kostsamma***
  - ✓ ***Flödesgivare, värmemängdsmätare osv.***
- ✓ ***Mänskligt beteende skapar ’brus’, gör analysen svår***
- ✓ ***Modellering kontra verkligheten***

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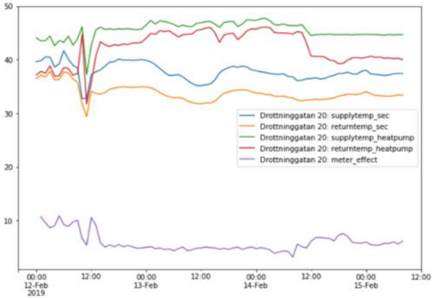
under the grant agreement no. 731231.

Summering

Resultat och erfarenheter

Resultat och erfarenheter från pilotprojektet

- ✓ ***Gott samarbete med fastighetsägare***
  - ✓ ***Gemensamt intresse för en lyckad pilot***
  - ✓ ***Var redo på att lösa problem***
- ✓ ***Placering av sensorer måste planeras noggrant***
- ✓ ***Styrning mot temperaturkurva fungerar i stort, tidsupplösningen ställer andra krav***



4.4 Annex 2.4. FED-marknaden, ett samspel mellan olika energibärare. Hjalmar Pihl

FED – Fossil-free Energy Districts

Workshop -Värmepumpar för efterfrågeflexibilitet

8 oktober 2019

Hjalmar Pihl

FED I EUROPA

- FED finansieras av EU-programmet Urban Innovative Actions
- Påbörjades 2016
- FEDs budget är cirka 50 miljoner kronor

EUROPEAN UNION

UIA URBAN INNOVATIVE ACTIONS

#fedgbg

Göteborgs Stad

Göteborg Energi

Johanneberg Science Park

RI. SE

SAMVERKAN MELLAN NIO PARTNERS

AKADEMISKA HUS

BUSINESS REGION GÖTEBORG

CHALMERSFASTIGHETER

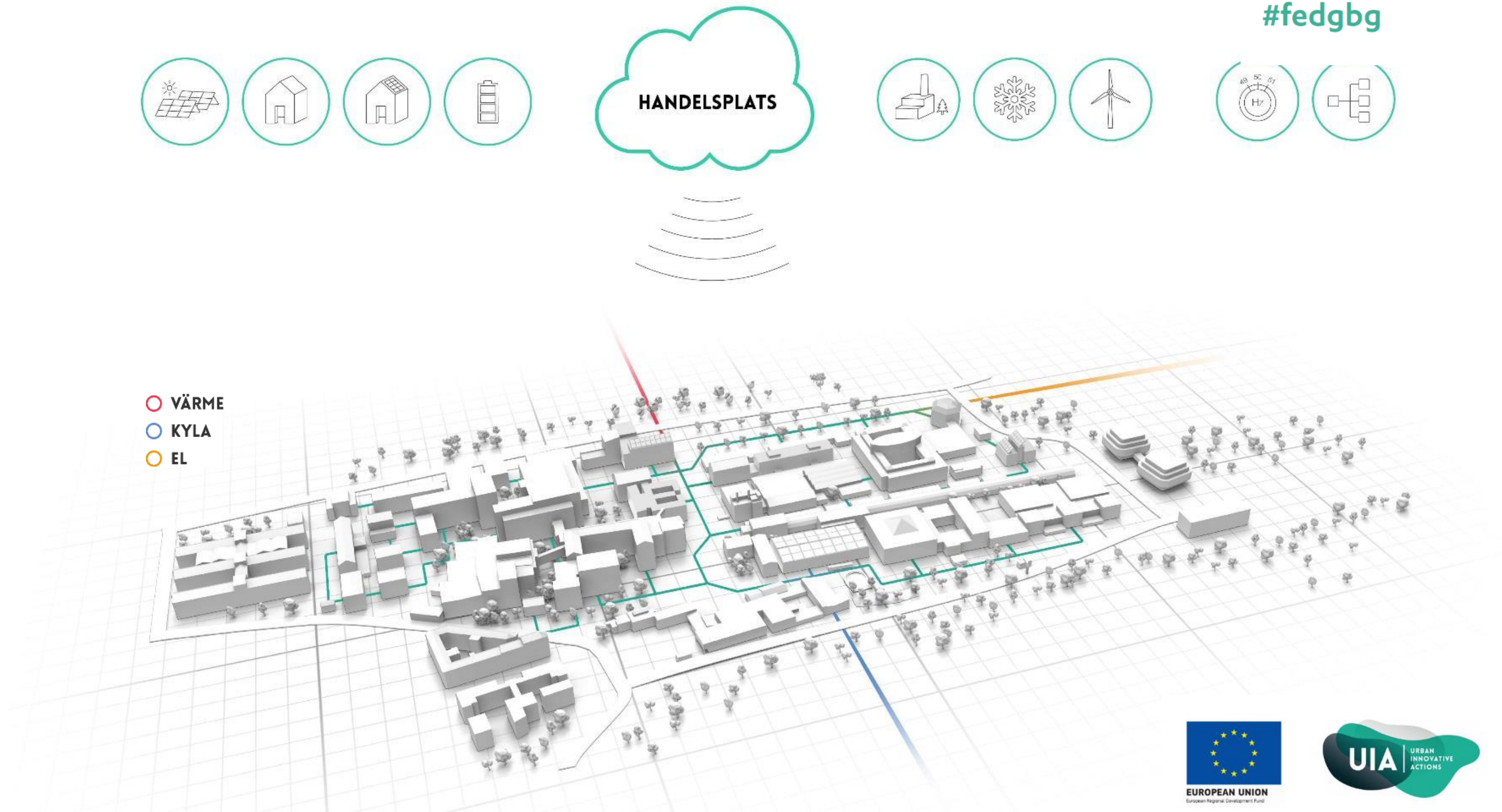
ERICSSON

CHALMERS

EUROPEAN UNION

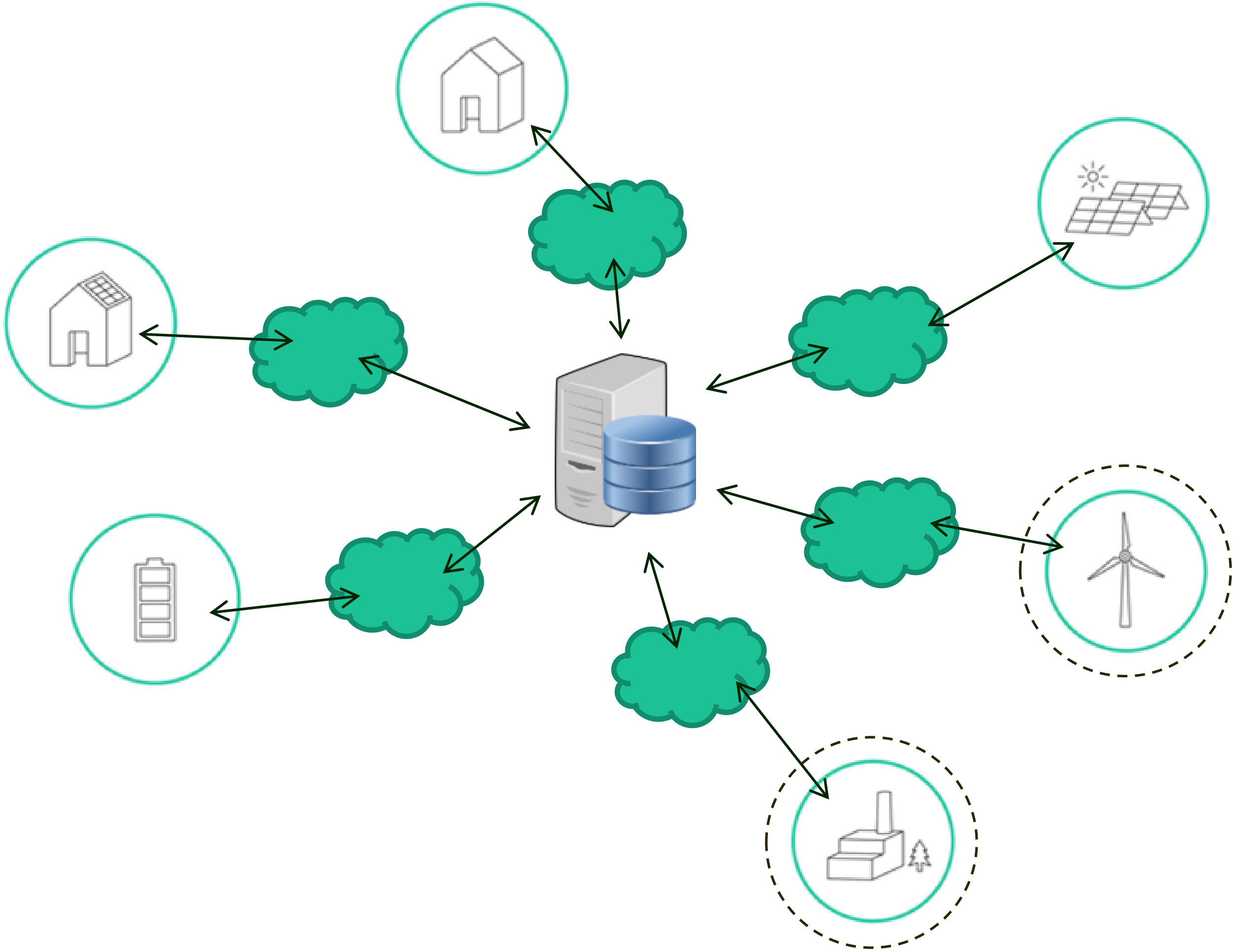
European Regional Development Fund

UIA URBAN INNOVATIVE ACTIONS



EUROPEAN UNION

UIA URBAN INNOVATIVE ACTIONS



Agenter lägger bud

Timvisa bud för energi (kWh), med betalningsvilja (öre/kWh)

Varje bud specificerar:

- Energibärare
- Timme
- In- eller utmatningspunkt

Möjlighet att knyta ihop bud med budberoenden

- Komplement
- Substitut
- Summeringar

Marknadslösaren avgör vilka bud som ’clearar’

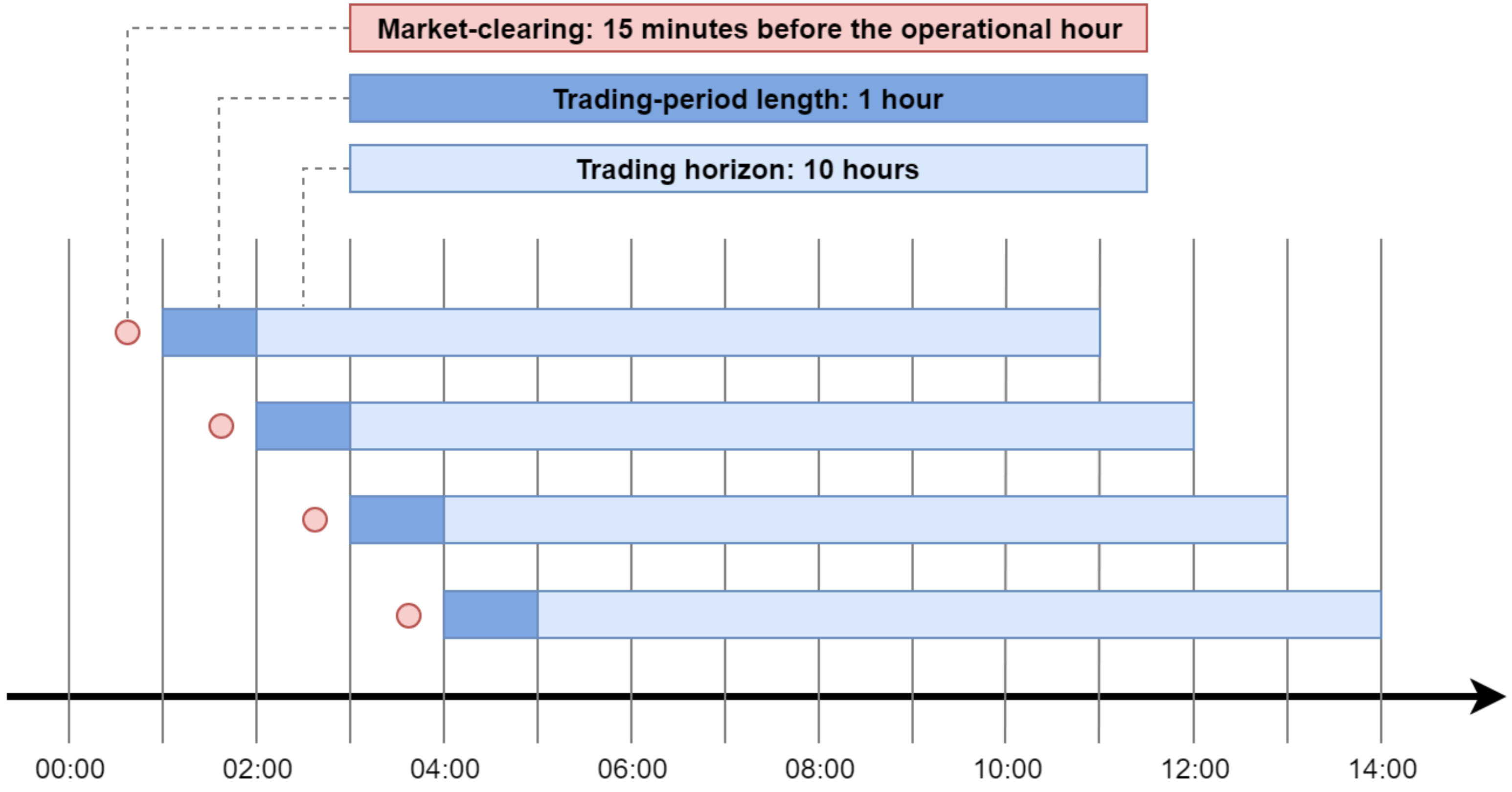
Implementerad som ett optimeringsproblem

- Maximerar konsument- och producentöverskott

Ett marknadspris fås som skuggpriset på villkoret för utbud=efterfrågan

Underliggande nätmodell för att hantera flaskhalsar

- Priserna anpassas därefter


Market-clearing: 15 minutes before the operational hour
Trading-period length: 1 hour
Trading horizon: 10 hours
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00

TACK!

EUROPEAN UNION
European Regional Development Fund
UIA URBAN INNOVATIVE ACTIONS

4.5 Annex 2.5. Diskussion. Tommy Walfridson

Diskussion

Workshop
Värmepumpar för efterfrågeflexibilitet

Tommy Walfridson - RISE Research Institutes of Sweden

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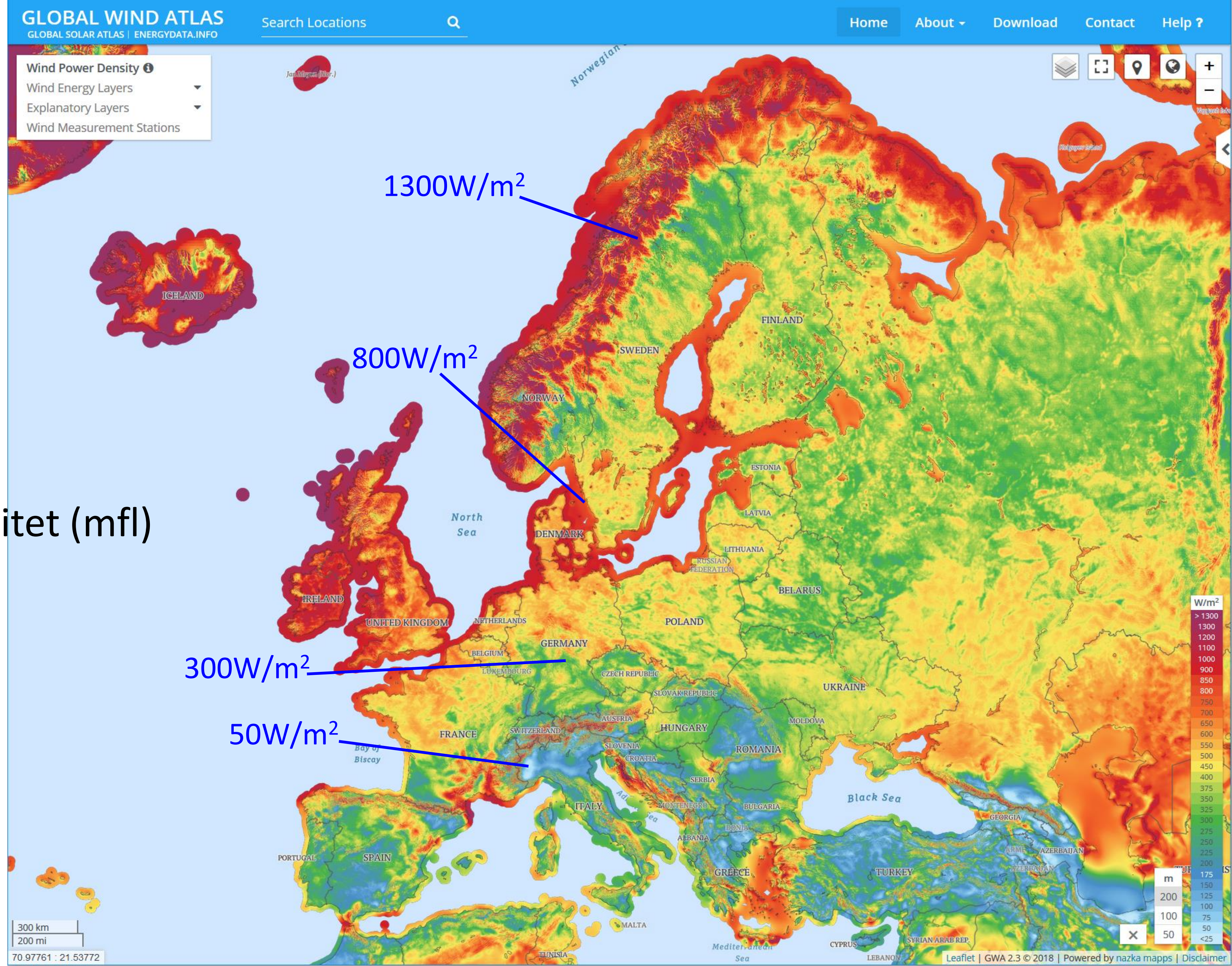
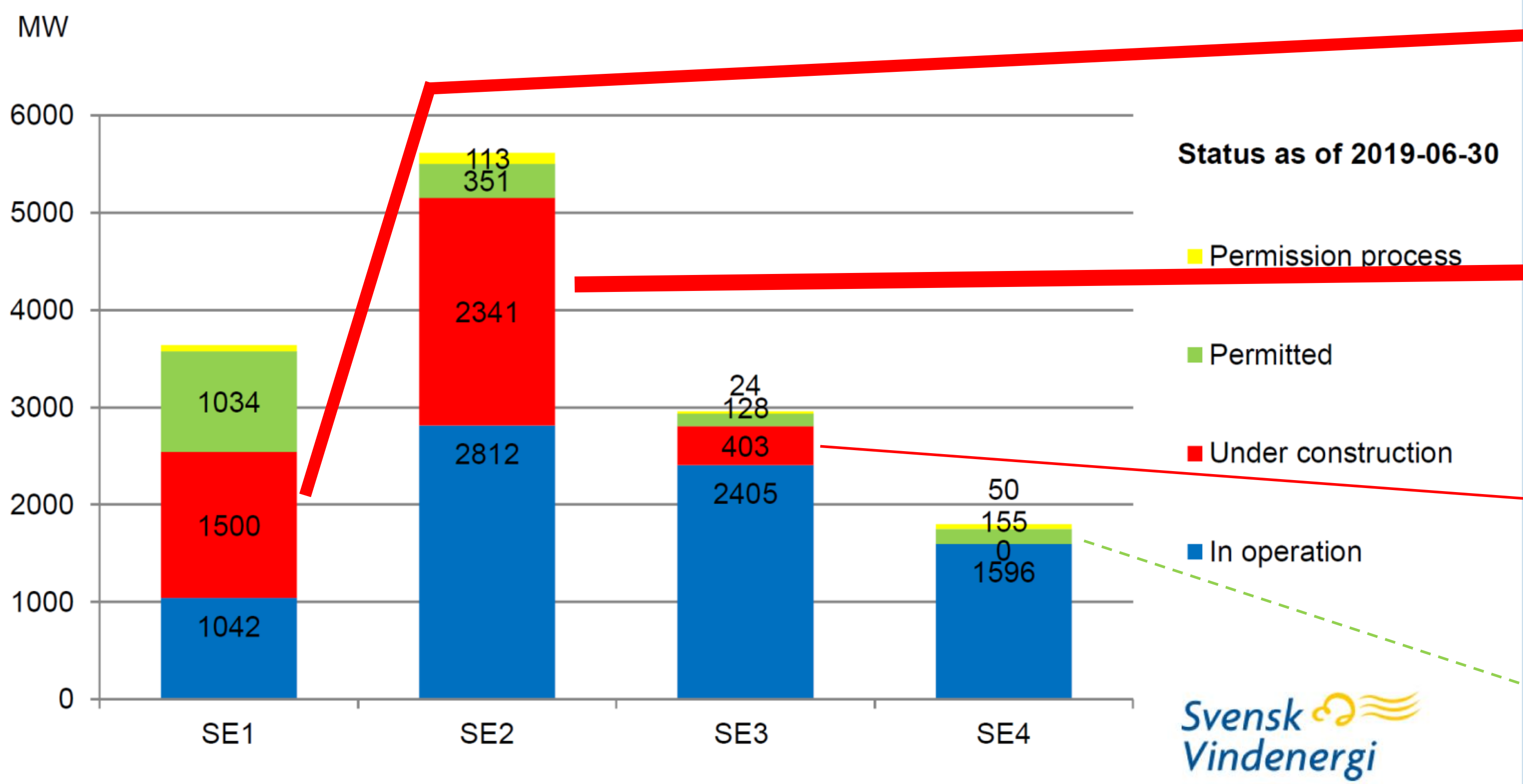


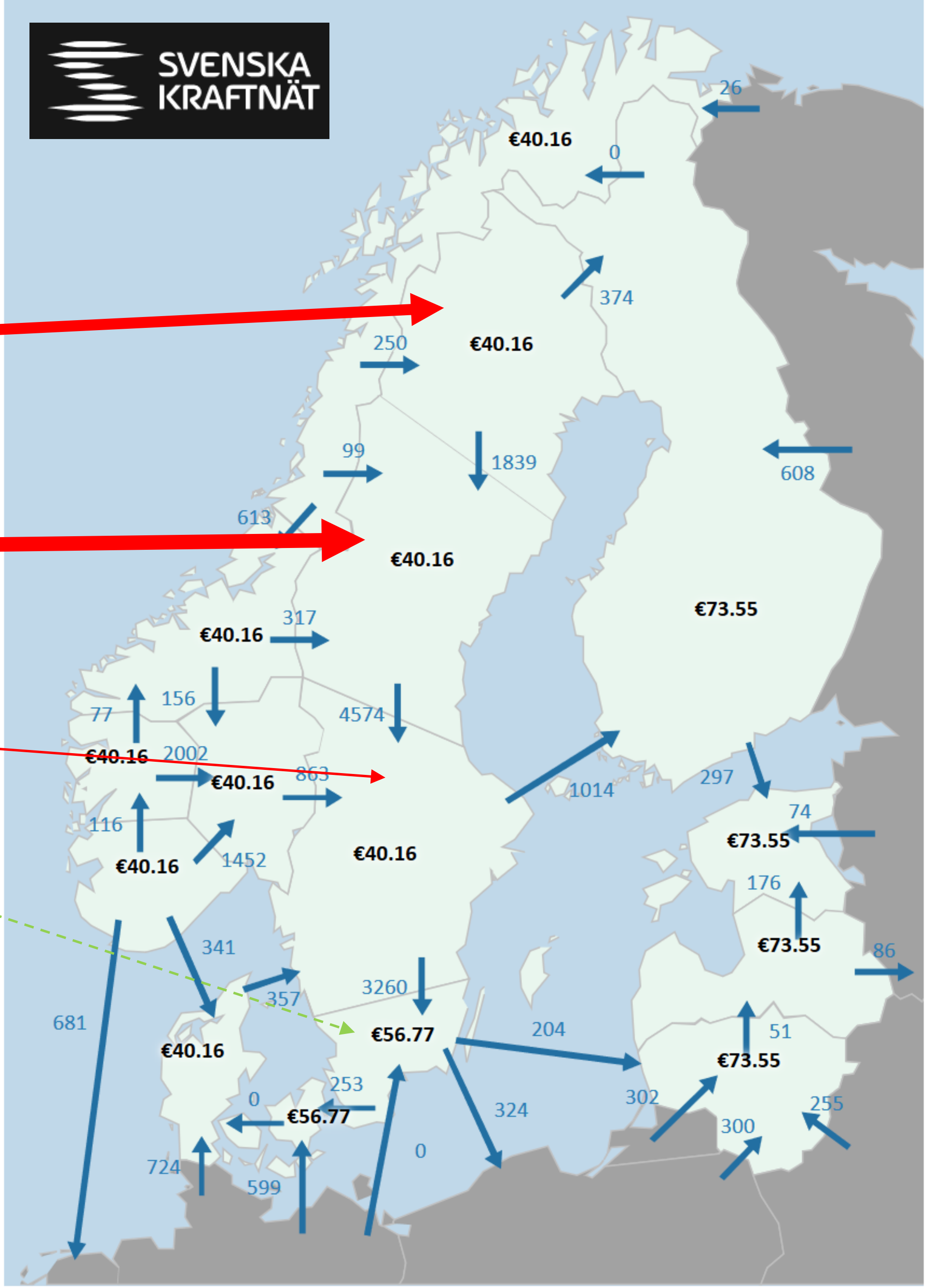
Global Wind Atlas
Danmarks Tekniske Universitet (mfl)

1300/50 = 26

FHP project is funded by European Union under the grant agreement no. 731231.

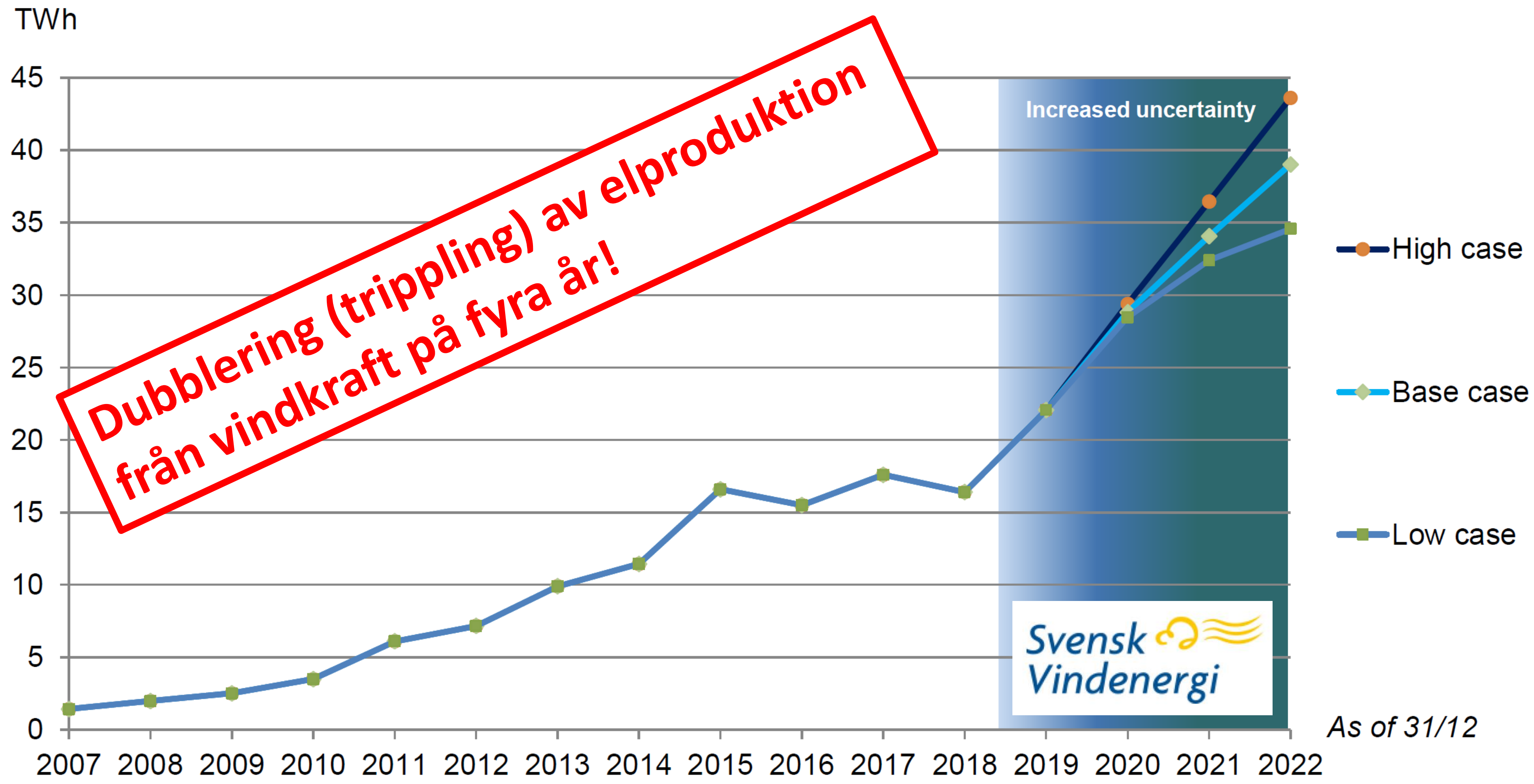
Installerad effekt i olika områden i Sverige, inkl under produktion mm





FHP project is funded by European Union
under the grant agreement no. 731231.

Produktion från vindkraft i Sverige, inkl prognos till 2022



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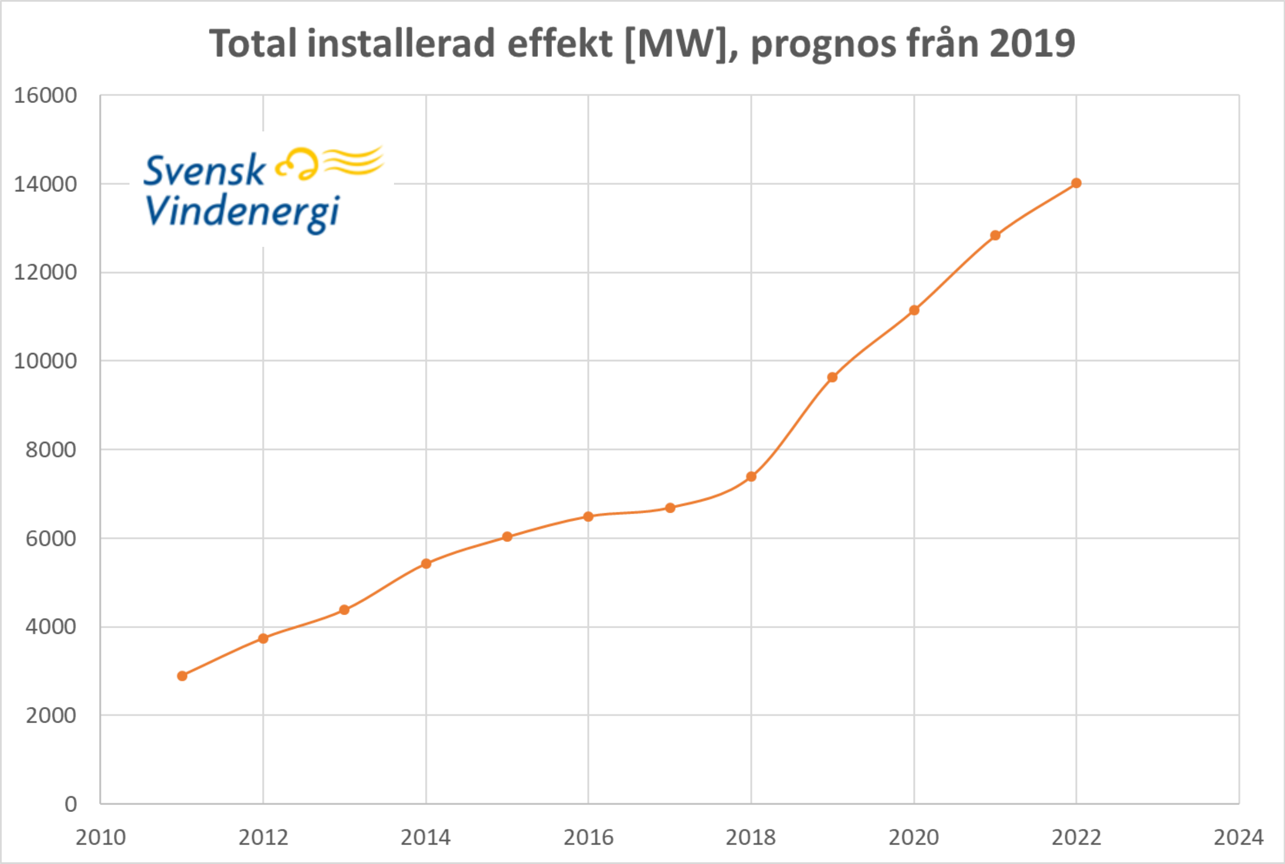
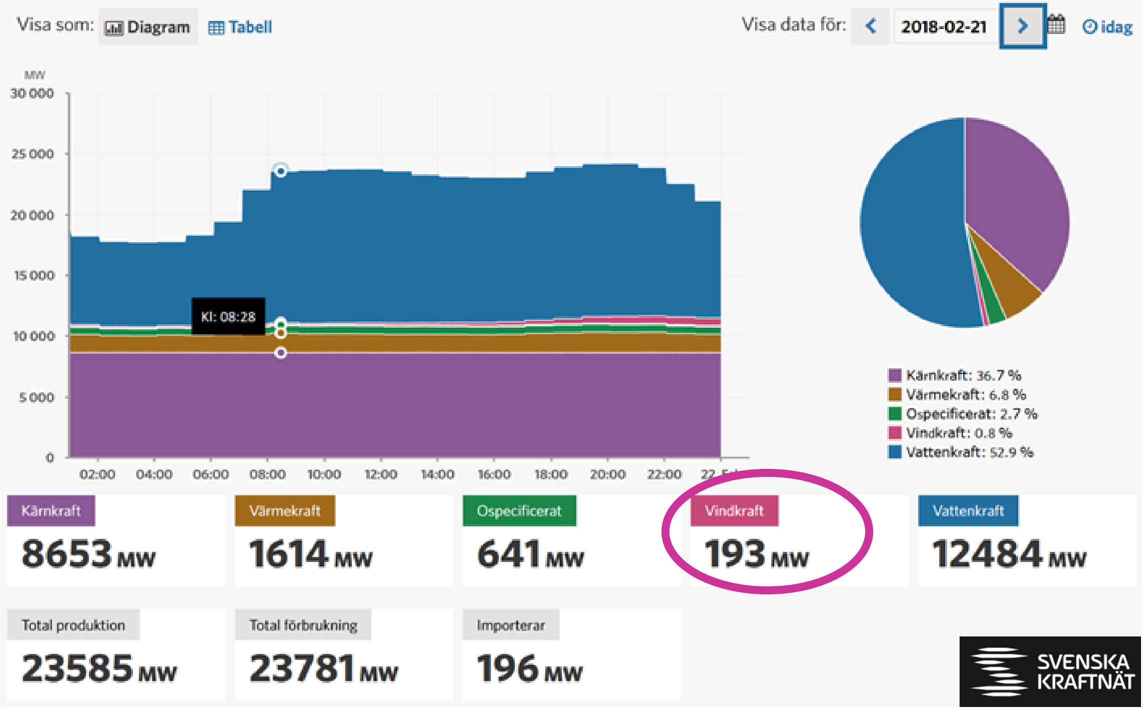
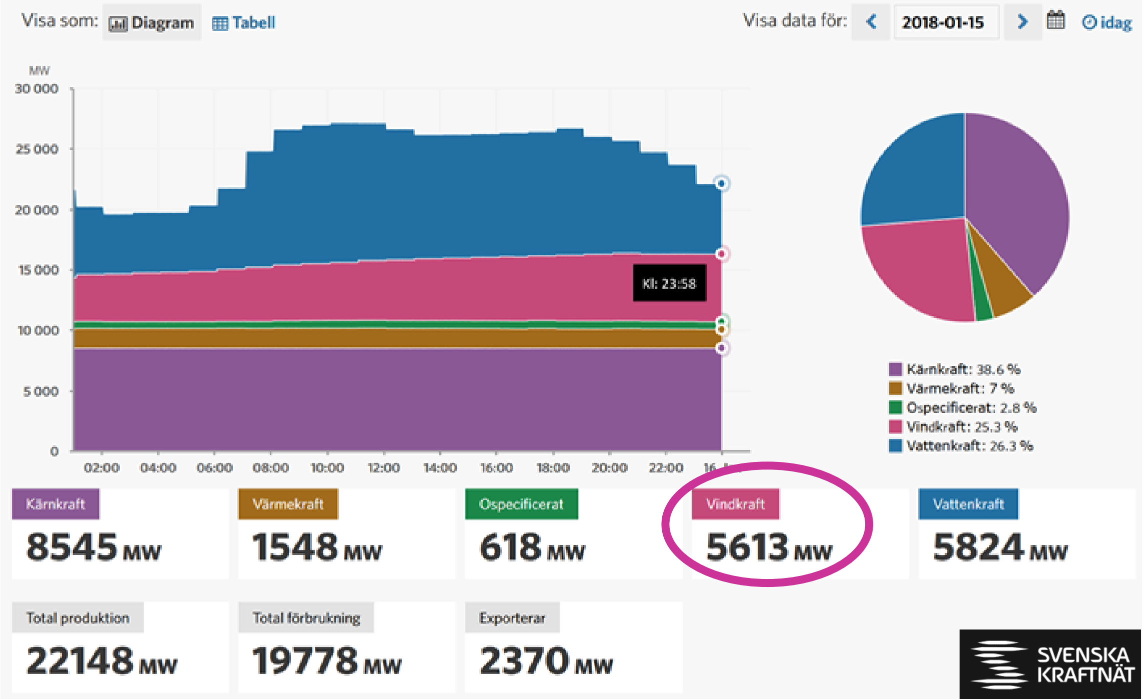






<u>Spann på produktion en vinterdag år 2022:</u>
ca 2-50% av Sveriges effektbehov.

FHP project is funded by European Union
under the grant agreement no. 731231.

Foto: Blondinrickard Fröberg
(vindkraftverk pålagt ovanpå
annars originalfoto)

Foto: Khamtran (Wikipedia Common)

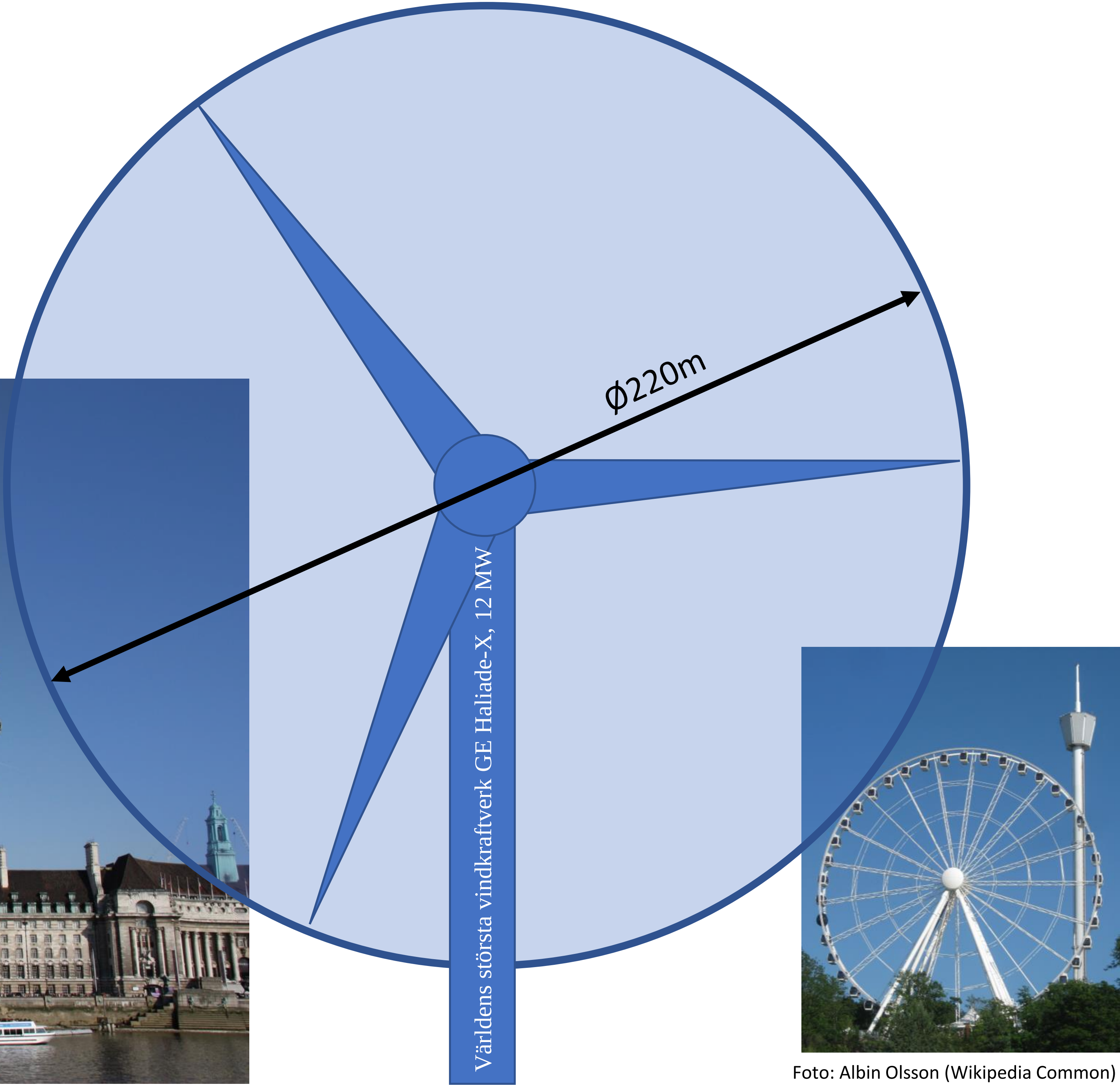
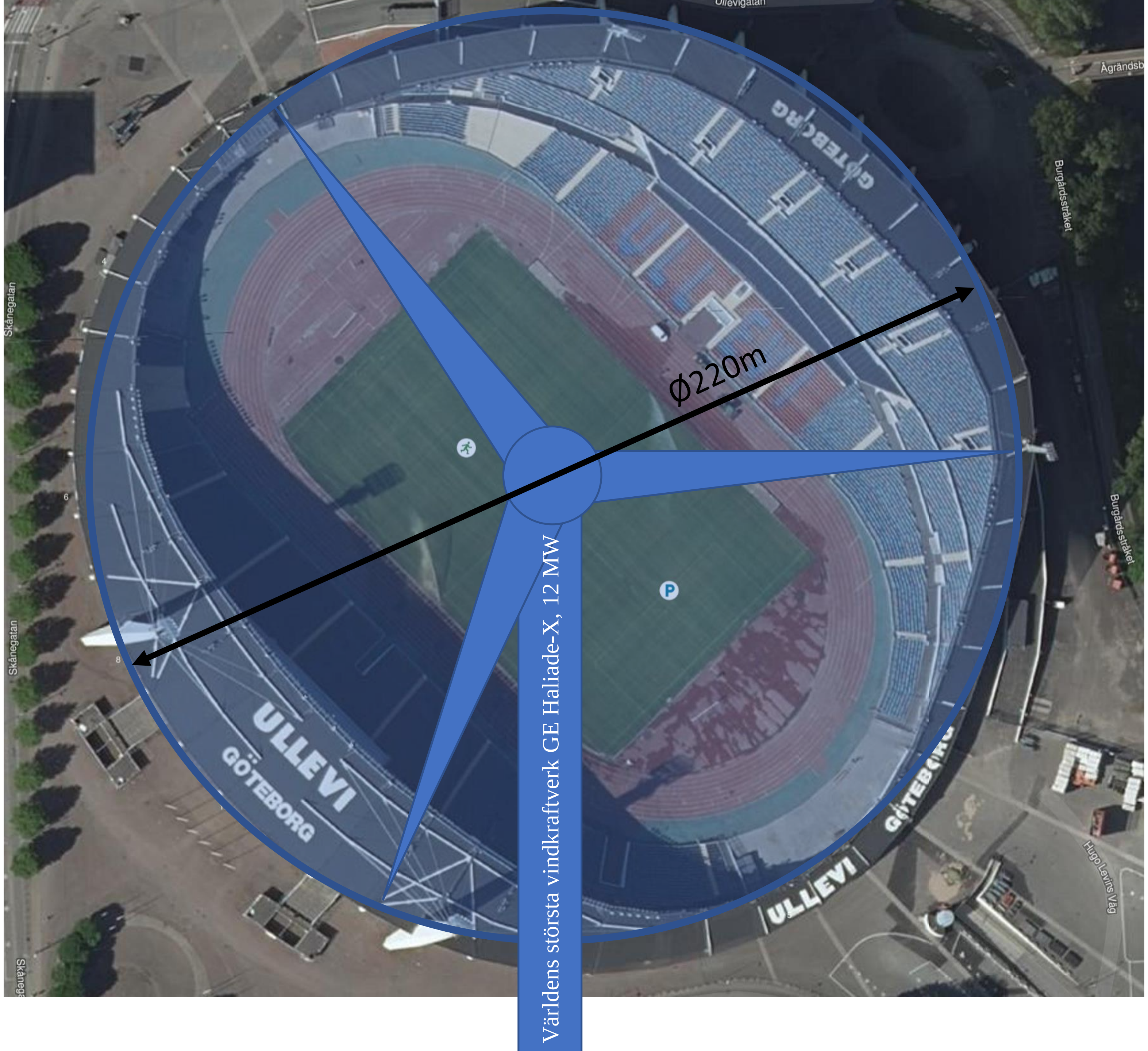


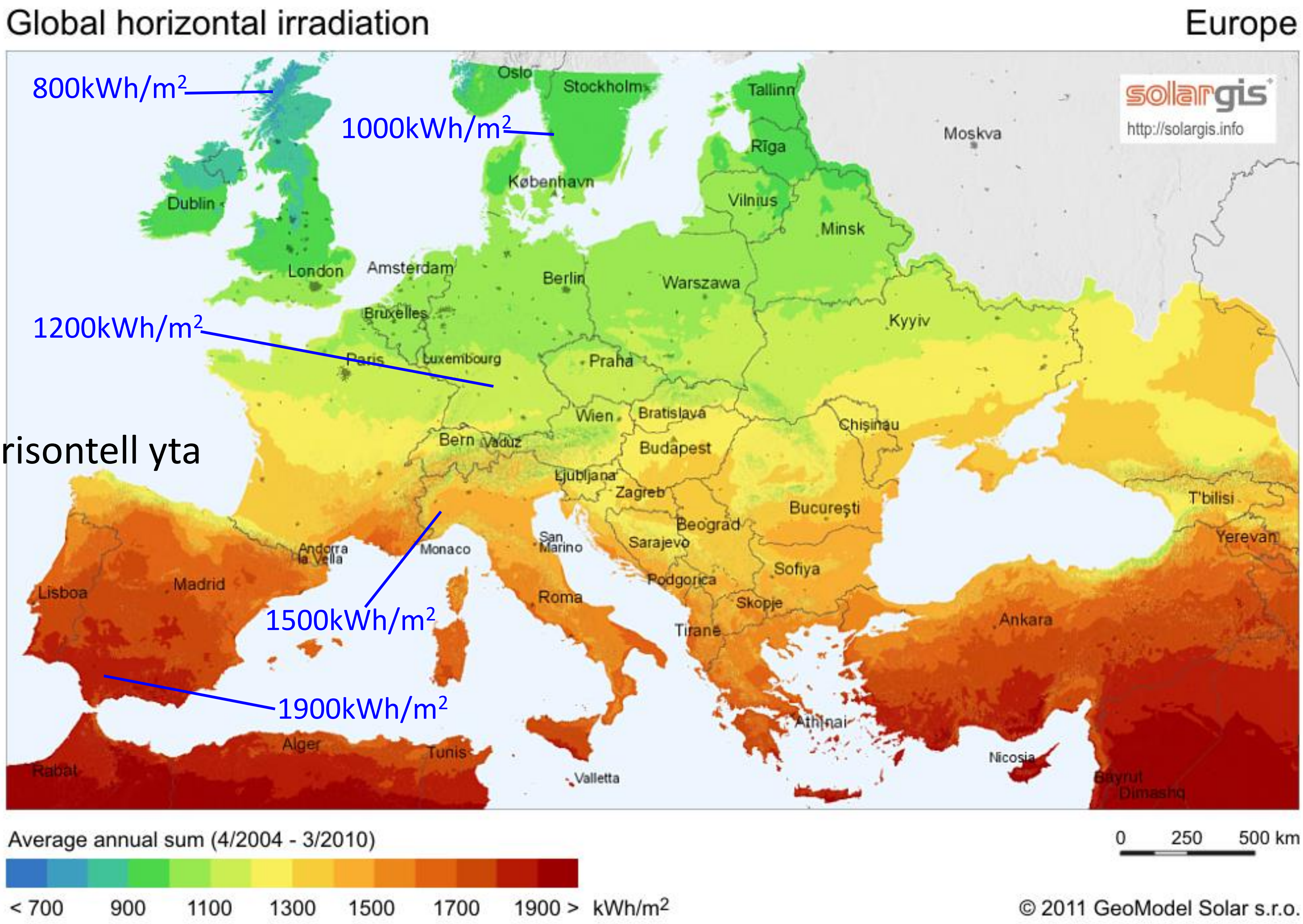
Foto: Albin Olsson (Wikipedia Common)



ϕ220m
Världens största vindkraftverk GE Haliade-X, 12 MW
ULLEVI
GÖTEBORG
ULLEVI
GÖTEBORG
Skånegatan
Burgårdsstråket
Hugo Levins Väg

Solinstrålning mot horisontell yta
Solargis

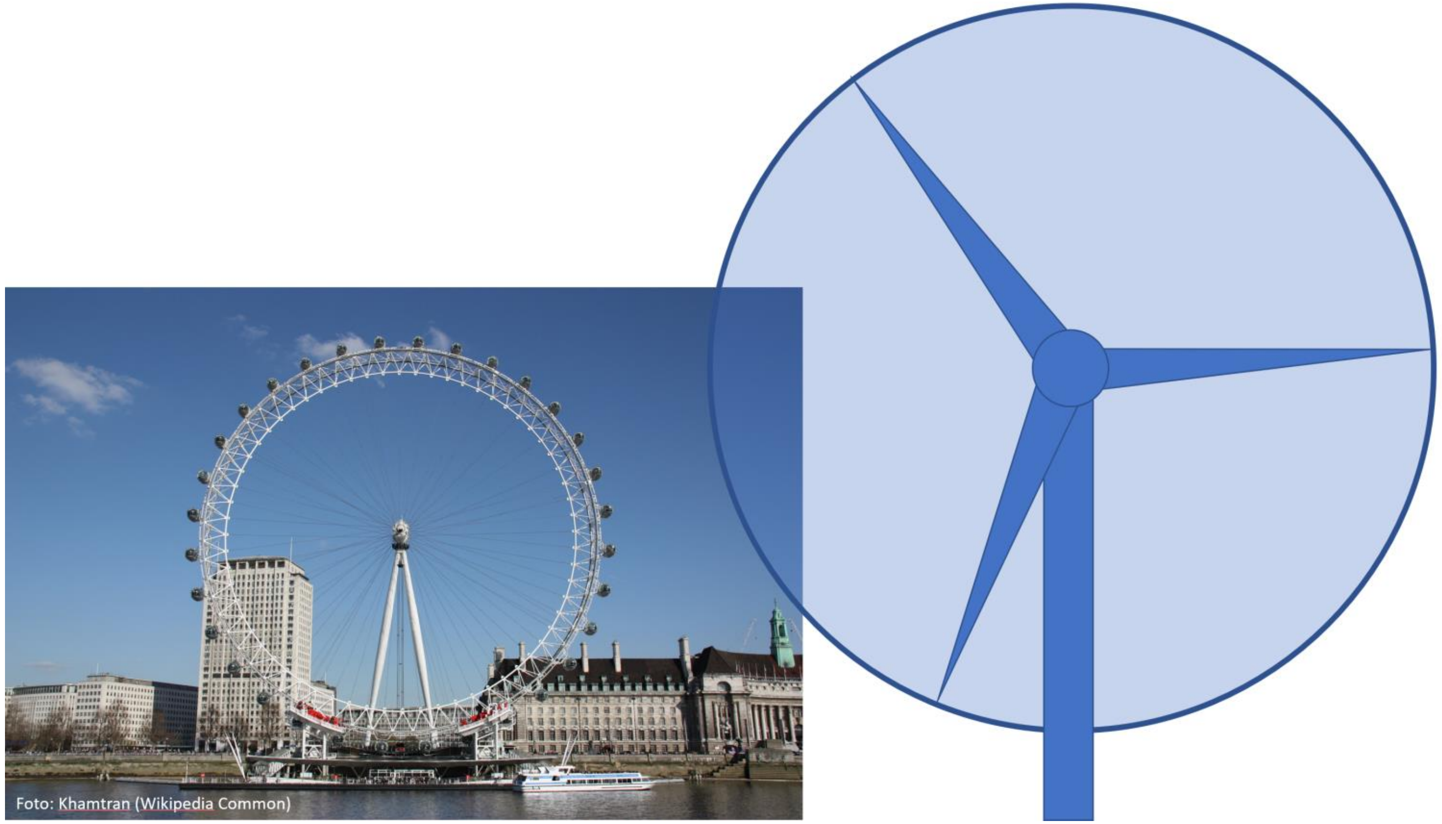
1900/800 = 2,4



FHP project is funded by Europ
under the grant agreement no.

Diskussionspunkter

- Tillverkare - vad tycker de om att deras styrning tas över?
  - Prisstyrning räcker?
  - Branschen öppna för lösningar (?)
  - Ansvarsfrågan!
- Hur noga behöver vi styra varje enskild värmepump?
  - Hur ofta?
  - Hur väl?
- Vilka incitament krävs hos privatpersoner/fastighetsägare?
  - Hur kommer vi dit?
  - Politiska beslut?
- Extern analyser för varje enskild byggnad – realistiskt?
  - Komplexa modeller jmf enkla & robusta?



London Eye jämfört med världens största vindkraftverk GE Haliade-X, 12 MW

FHP project is funded by European Union u
nder the grant agreement no. 731231.

Tack!

Markus Lindahl, Tommy Walfridson RISE

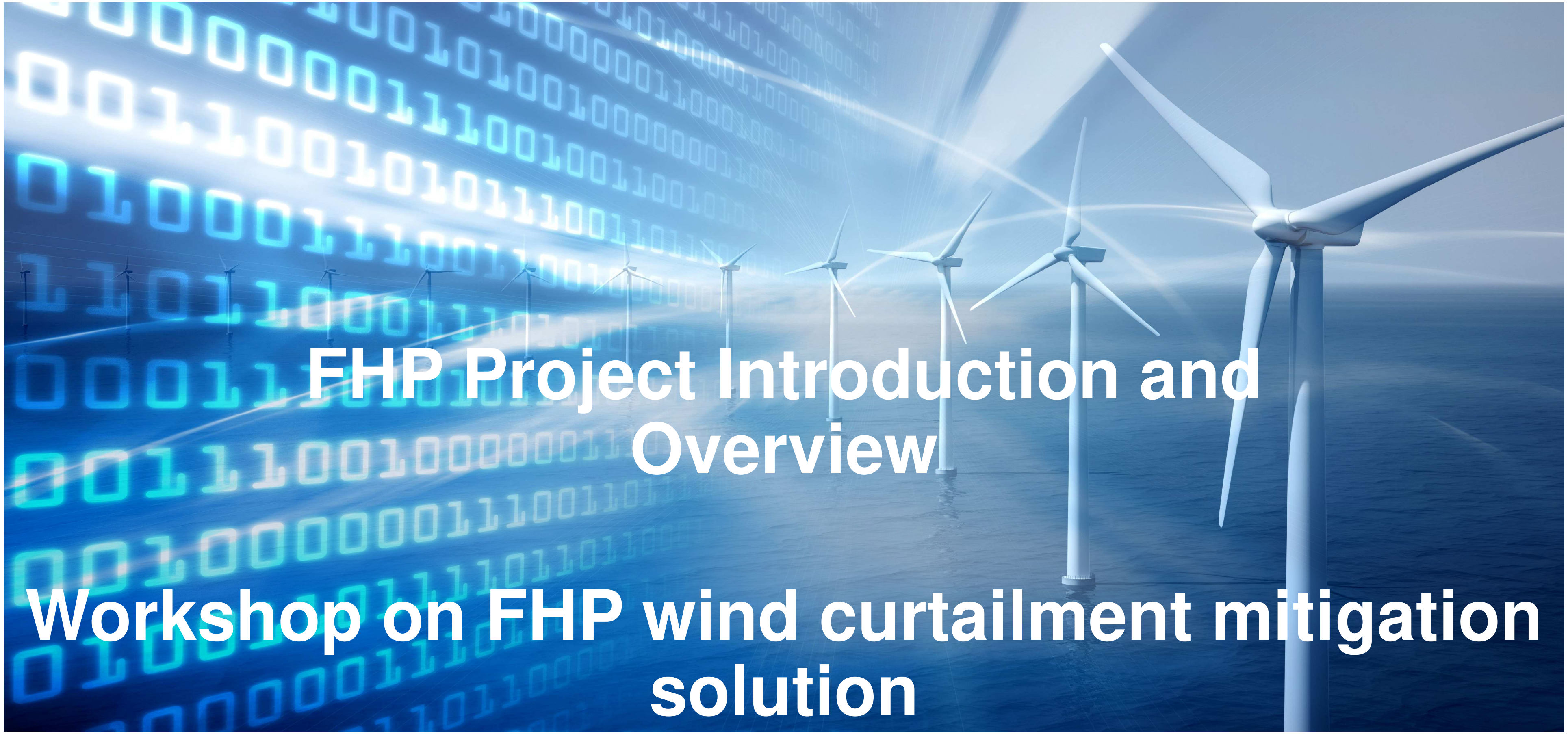
markus.lindahl@ri.se,

tommy.walfridson@ri.se

FHP project is funded by European Union under the grant agreement no. 731231.

5 Annex 3. Presentations of international conference

5.1 Annex 3.1. FHP project introduction and overview. Chris Caerts



FHP Project Introduction and Overview

Workshop on FHP wind curtailment mitigation solution

Chris Caerts - VITO

FHP project is funded by European Union under the grant agreement no. 731231.

Flexible Heat and Power

- Project granted under LCE-01-2016 "*Next generation innovative technologies enabling smart grids, storage and energy system integration with increasing share of renewables: distribution network*", subtopic "*Synergies between Energy Networks*"
- 1/Nov/2016 – 31/Oct/2019

Flexible Heat and Power

The problem/challenge

Increasing share/installed capacity
of intermittent renewables

- At some times: too much generation
  - More than needed (excess compared to load)
  - More than the grid can accommodate
  - ***Curtail ?***
- Intermittency: forecasting and balancing challenge
  - Demand-Supply matching
  - ***Balancing power plants ?***

Flexible Heat and Power

The opportunity

- Leverage flexibility provided by Power-to-Heat conversions
  - Thermal storage and thermal inertia
  - Heat Pumps
- Comes (almost) ‘for free’ …
- Improves Business Case for HP … accelerating decarbonization of heating
- Distributed and (in future, potentially) available everywhere … solve problems effectively taking grid conditions into account
  - HP heating buildings
  - HP charging large seasonal thermal storage vessels (➔ DHN)

Flexible Heat and Power

The opportunity – HP trends and potential

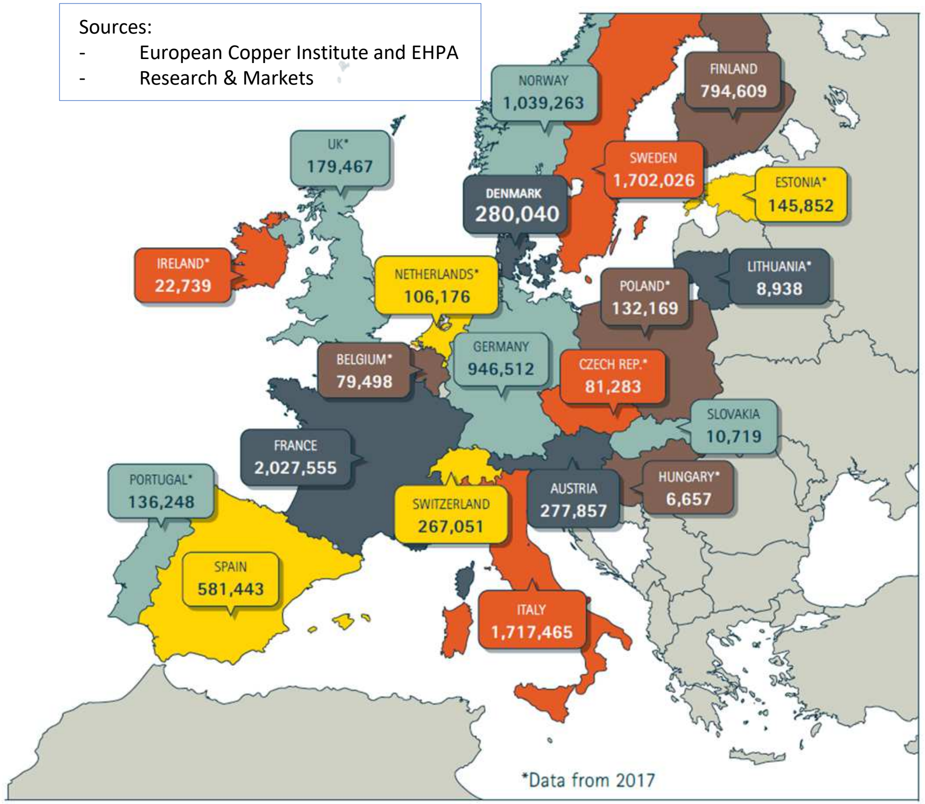
<u>EU Key Data</u>:

- 1.1 million heat pumps sold in 2017
- 10.56 million heat pumps total installed base
- growing market … 4th year in a row
- double-digit growth 3rd year in a row
- doubling installed base by 2024 is realistic

<u>Installed base:</u>

- generates 181.1 TWh of useful heat
- 115.8 TWh of which coming from renewable sources
- Saves 29.7 Mt of CO2 emissions
- Flex potential between 1 and 3.2 TWh/yr

Sources:
- European Copper Institute and EHPA
- Research & Markets



Flexible Heat and Power

Project goals

- Increase amount of addressable flexibility by maximally incentifying Flex Providers
  - **Flex Trading** & **Dynamic Coalition Manager** concepts
  - … empowering Flex Providers (buildings) and creating conditions for them to maximally (beyond traditional DR) valorize their flexibility
- **Location-aware flex activations** … solving local problems and solving system level problems in a grid secure manner
  - Bottom-up aggregation of forecasts and flexibility information provided by Flex Providers themselves, followed by Optimal Flexibility Dispatch
- **Grid Flexible Heatpump** control concept … making HP better fit for providing high-value flexibility services

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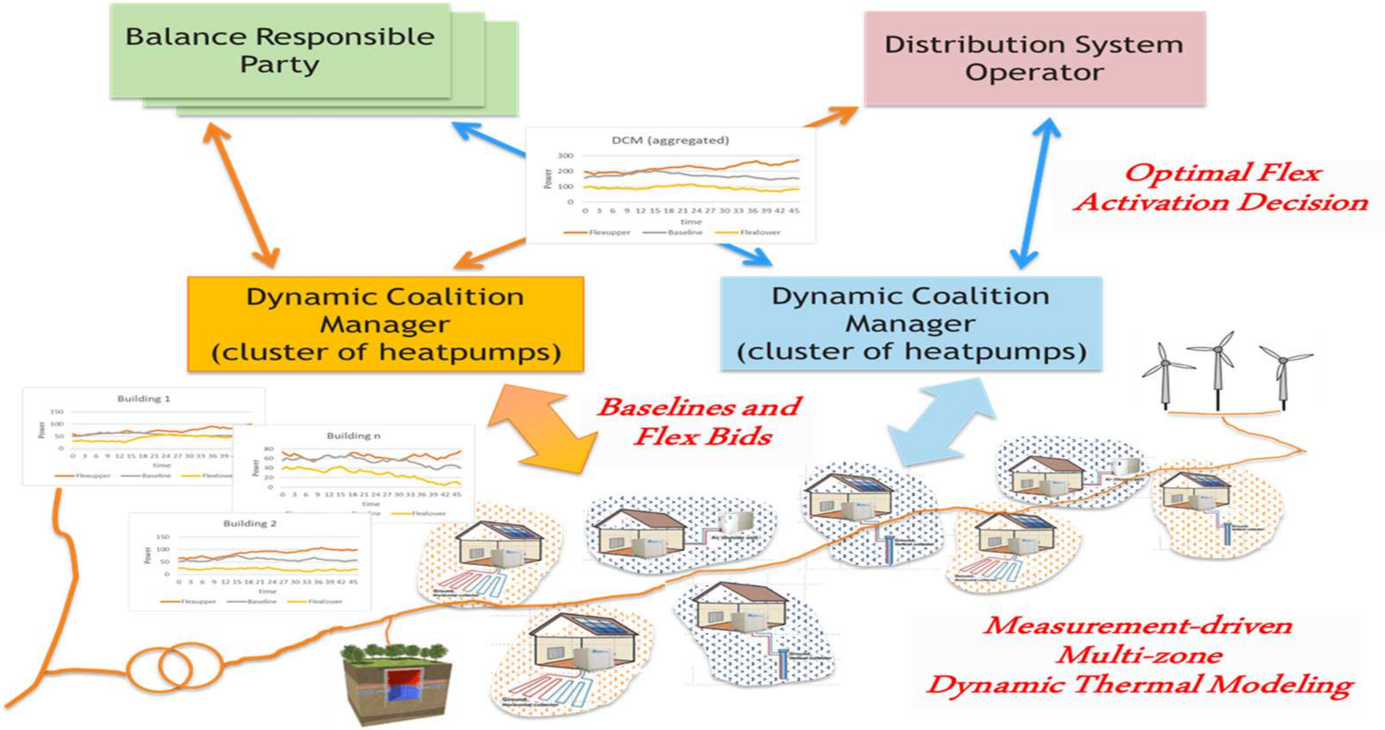
under the grant agreement no. 731231.

Flexible Heat and Power
Multi-agent architecture



FHP project is funded by European Union under the grant agreement no. 731231.

FHP project is funded by European Union under the grant agreement no. 731231.

5.2 Annex 3.2. Wind curtailment scenarios assessment. Enrique Rivero

Wind curtailment scenarios assessment

Workshop on FHP wind curtailment mitigation solutions

Enrique Rivero - VITO

FHP project is funded by European Union under the grant agreement no. 731231.

A more volatile power system

Volatility

Predictability

→

More frequent situations that could lead to operational issues, e.g., network congestion, system stability, minimum operating reserve, voltage control.

→

System operator actions

- Ever-increasing capacity of wind and solar PV
- Growing share in the overall power supply
- Wind and solar PV are largely weather dependent

Electricity demand is showing more volatility, e.g., low visibility on where and when electric cars will charge

A more volatile power system

Efforts to integrate RES, specially variable generation – wind and solar PV, may create situations, where, depending on the power system and market characteristics,

- RES infeed is cut short

Providing alternatives to **vRES curtailment** is important because …

- … they could (significantly) prevent the slow down of renewable capacity expansion
- … they may reduce the impact on the capacity factor of generation technologies
- … in case of curtailment, compensation may not always be provided

- Under which circumstances curtailment of vRES could be expected?
- How much energy has been wasted?
- Is vRES curtailment a lost opportunity?

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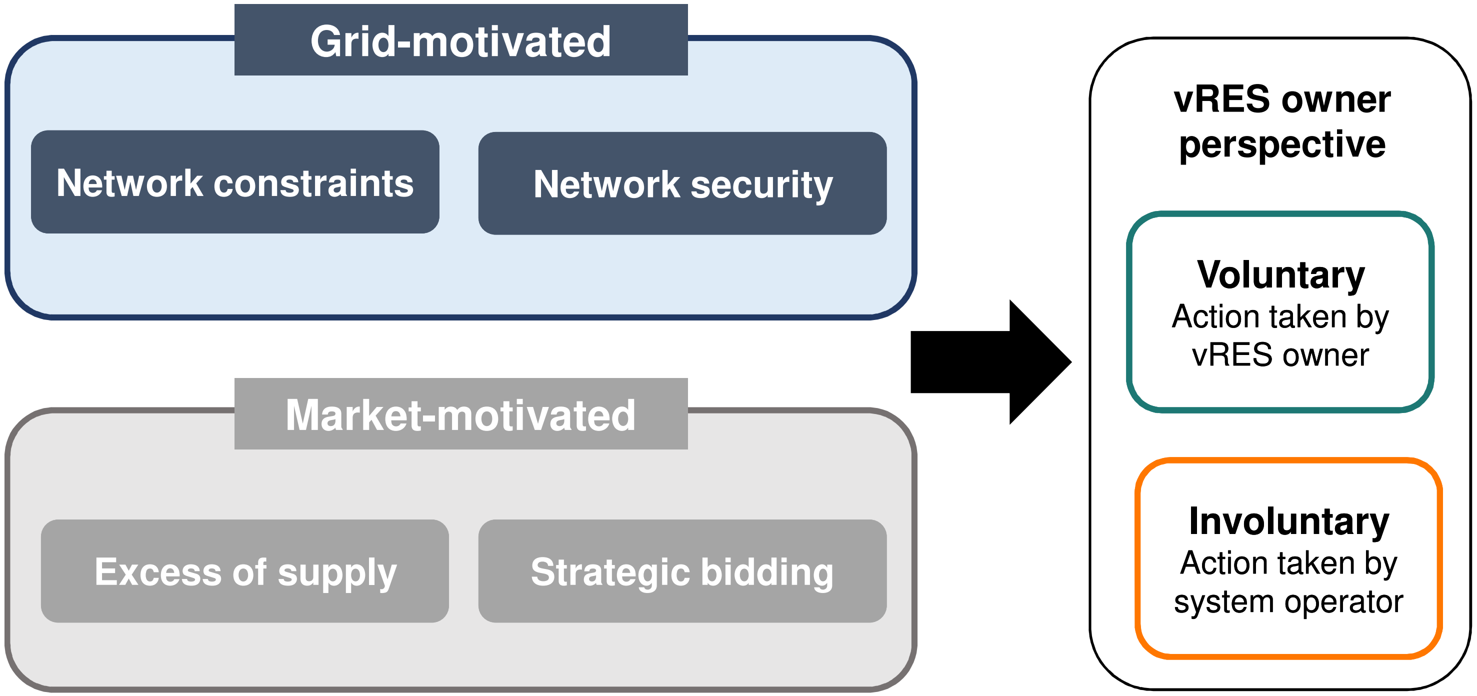
under the grant agreement no. 731231.

Outline

- **Scenario assessment of vRES curtailment**
- **Mitigating vRES curtailment - An opportunity**

Scenario assessment of vRES curtailment



Sources: (Klinge and Schröder, 2012), (Fernandez et al., 2017)

Scenario assessment of vRES curtailment Grid-motivated: Network constraints

	Network constraints	Examples

Voluntary
Action taken by vRES owner
	• To get a faster or cheaper connection
	• Originates from a development mismatch
	  • vRES plant vs grid
	• Owner receives a connection capacity lower than max. technical infeed of the plant
	  • Fixed or variable
		• Gflex in Belgium
		• Offshore wind installations in the UK
		  • Capacity of the interconnector is lower than the total installed capacity of the site

Involuntary Action taken by system operator	• To optimize network investments • Also originates from a development mismatch • Insufficient capacity to evacuate vRES infeed • System operator limits vRES infeed in real time for a limited period	• Congestion in Germany (Northwestern)

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under the grant agreement no. 731231.

Scenario assessment of vRES curtailment Grid-motivated: Network security

	Network security	Examples
Voluntary Action taken by vRES owner	• To support the system and maximize profit • Originates from the need of extra flexibility to maintain system reliability • Owner participates as a provider of flexibility services to the system operator • E.g., downward reserve	• Wind participating in tertiary (downward) reserve in Spain
Involuntary Action taken by system operator	• To maintain a system reliability level • Originates from the need to maintain synchronous generation online • System operator imposes a minimum share of conventional generation necessary for system stability • Used as a precautionary measure, e.g., against the “duck” curve or merit order effect	• Dispatch-down of wind in Ireland

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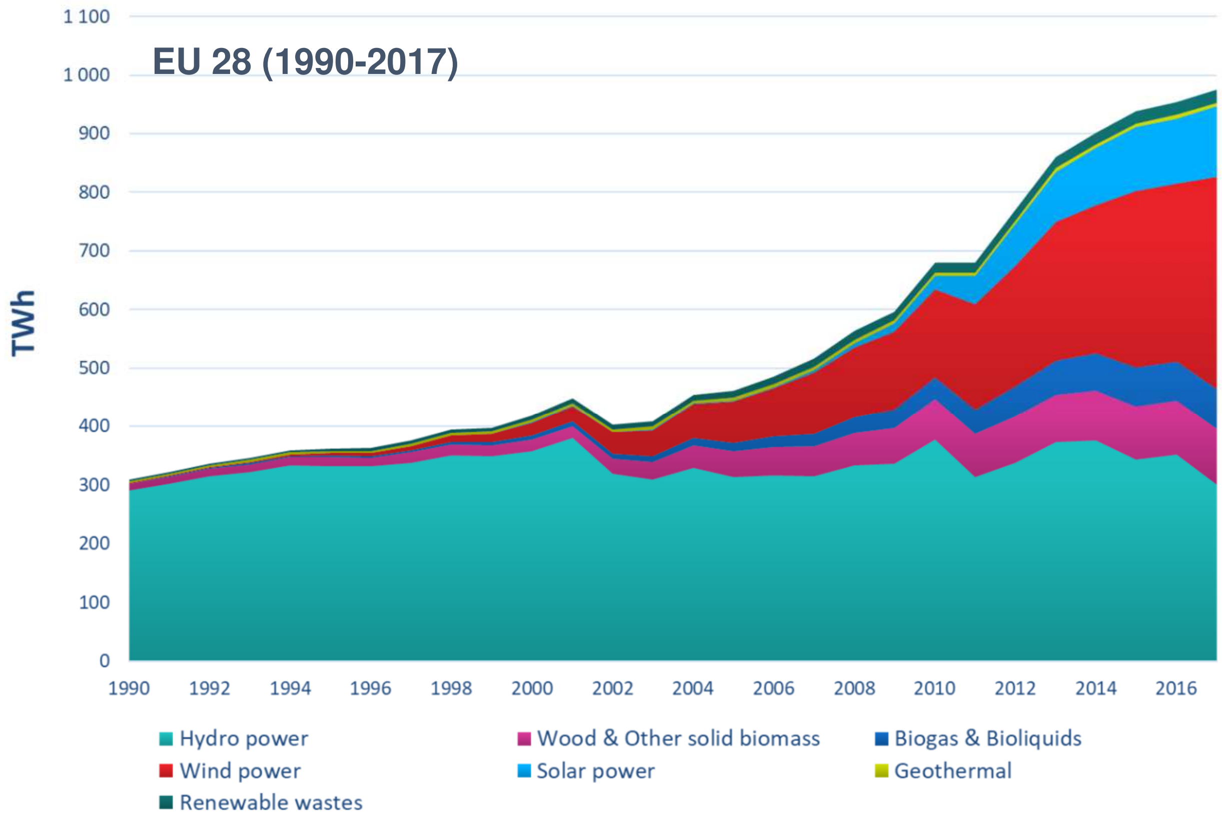
Scenario assessment of vRES curtailment Market-motivated: Demand-Supply

	Excess of supply in respect to demand	Examples
Voluntary Action taken by vRES owner	• To reduce financial losses • Originates from low market prices • Which may be at the limit of system stability • Owner limits infeed according to applicable RES support schemes	• Voluntary curtailment at zero prices in Denmark
Involuntary Action taken by system operator	• To balance supply and demand • Originates from a security concern or a market failure • System operator enforces generation limitations to vRES	• Passive contribution to “last resort” downward tertiary reserve energy provision in Spain

Scenario assessment of vRES curtailment
Market-motivated: Strategic bidding

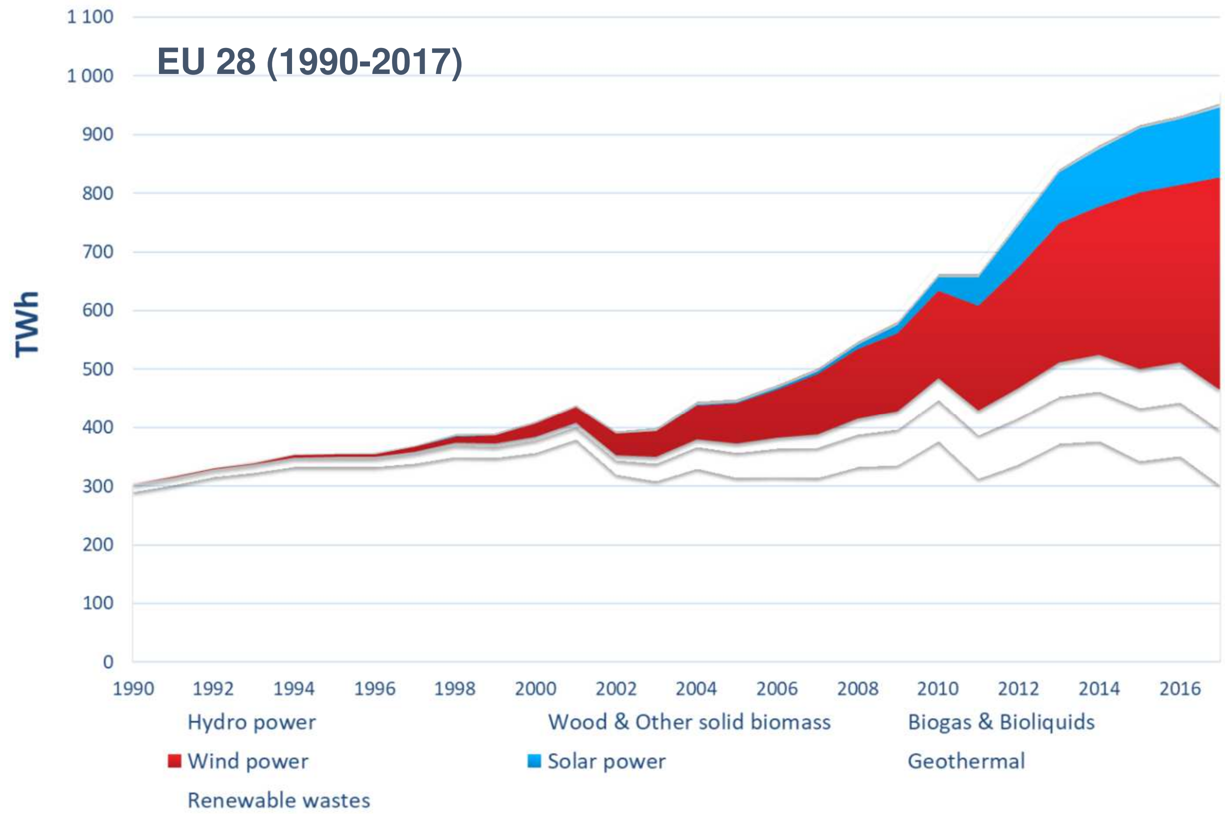
	Strategic bidding
Voluntary Action taken by vRES owner	• To increase short-term profits • Originates from an imperfect market structure • Owner withholds generation capacity to increase the marginal clearing price, i.e., owner manipulates prices by exercising market power

RES landscape in Europe



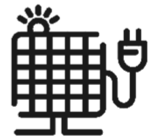
Sources: Eurostat

RES landscape in Europe



2017

Solar Power
12%



Wind Power
36%

Around 50% of all electricity generated from renewable sources comes from wind and solar power

vRES curtailment landscape in Europe
Grid-motivated

Curtailed energy (GWh) | % vRES (GWh)

Wind and solar PV

Country	2016	2017	∆% (2017 – 2016)
Germany	3743 (2,3%)	5518 (2,9%)	47% ↑
Ireland	227 (2,9%)	386 (4%)	70% ↑
Spain	113 (< 1%)	76 (< 1%)	-
Italy	361 (1%)	463 (1,2 %)	28% ↑

No considerable amounts of curtailed energy from vRES were observed in DK, PT, BE, CZ, NL, SE.

Sources: BNetzA, REE, EirGrid, (CEER, 2018)

"Curtailments and compensation measures in case of congestions in the network are also becoming increasingly important in many CEER Member countries."

CEER

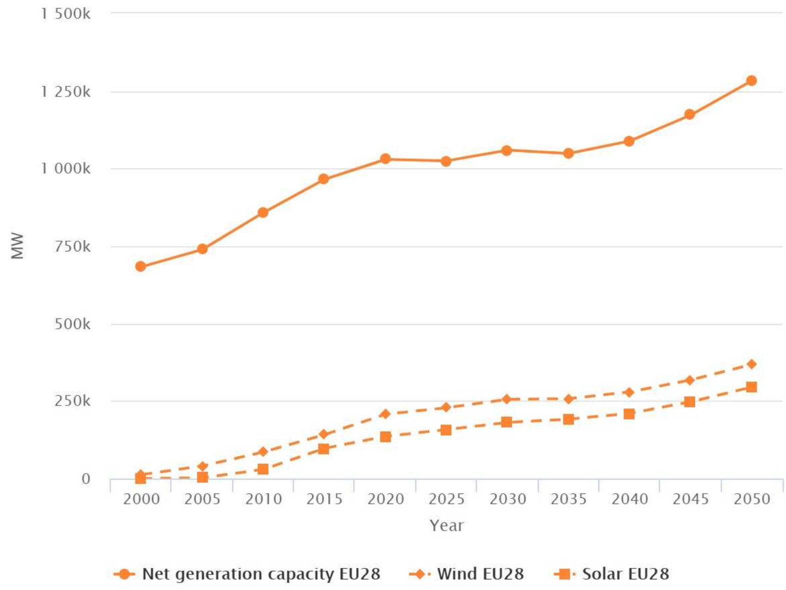
Between 2016 and 2017, at least 17 TWh from RES have been wasted

Sources: (CEER, 2017)

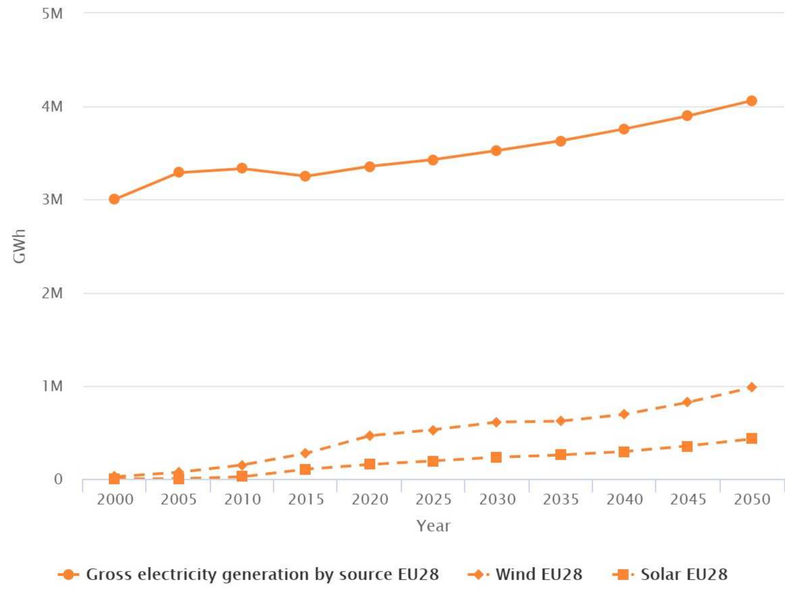
FHP project is funded by European Union
under the grant agreement no. 731231.

Mitigating vRES curtailment: An opportunity

Net generation capacity, wind, solar



Gross electricity generation by source, wind, solar



Source: EC DG Energy

Mitigating vRES curtailment: An opportunity

- In 2017, at least **850 M€** were used to compensate for vRES curtailment (grid-motivated)

Country	2016 (M€)	2017 (M€)	Δ% (2017 – 2016)
Germany	373	610	64% ↑
Ireland	N/A	N/A	N/A
Italy	7	17	142% ↑
Lithuania	95	113	19% ↑

- For some member states, curtailment costs may continue to rise

Source: EC – data for wind and solar PV (MW)

Mitigating vRES curtailment: An opportunity

- Alternatives to curtailment could be offered to vRES owners or system operators
  - The vRES owner may be interested in …
    - … balancing his/her portfolio while maintaining his eligibility to additional support
  - The system operator may be interested in …
    - … reducing the costs of grid curtailment while maintaining grid reliability levels

- These needs could be supplied by …
  - … storing the energy that otherwise would be curtailed (with the aim to differ its use)
  - … consuming this energy on-demand (i.e., applying DR)

The Takeaway

- vRES (wind and PV) is driving the decarbonization and energy independence of European power systems
- vRES impose challenges to stakeholders of the power system
- Energy from vRES may be curtailed in cases where …
  - … not enough network capacity is economically viable or available to evacuate the infeed
  - … a minimum quantity of online resources is required to meet system needs
  - … market prices are lower than the financial support these units receive outside the market
  - … it is more lucrative to limit the infeed
- Efforts to integrate vRES may also lead to increments in curtailment volumes and costs
  - Network expansion is costly and usually takes several years
- The power system needs flexibility options to manage grid capacity and system reliability in the short-term

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5.3 Annex 3.3. Business Models for flexibility management. Mikel Fernandez

Business models for flexibility management

Mikel Fernandez - Tecnalia

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Business models for flexibility management

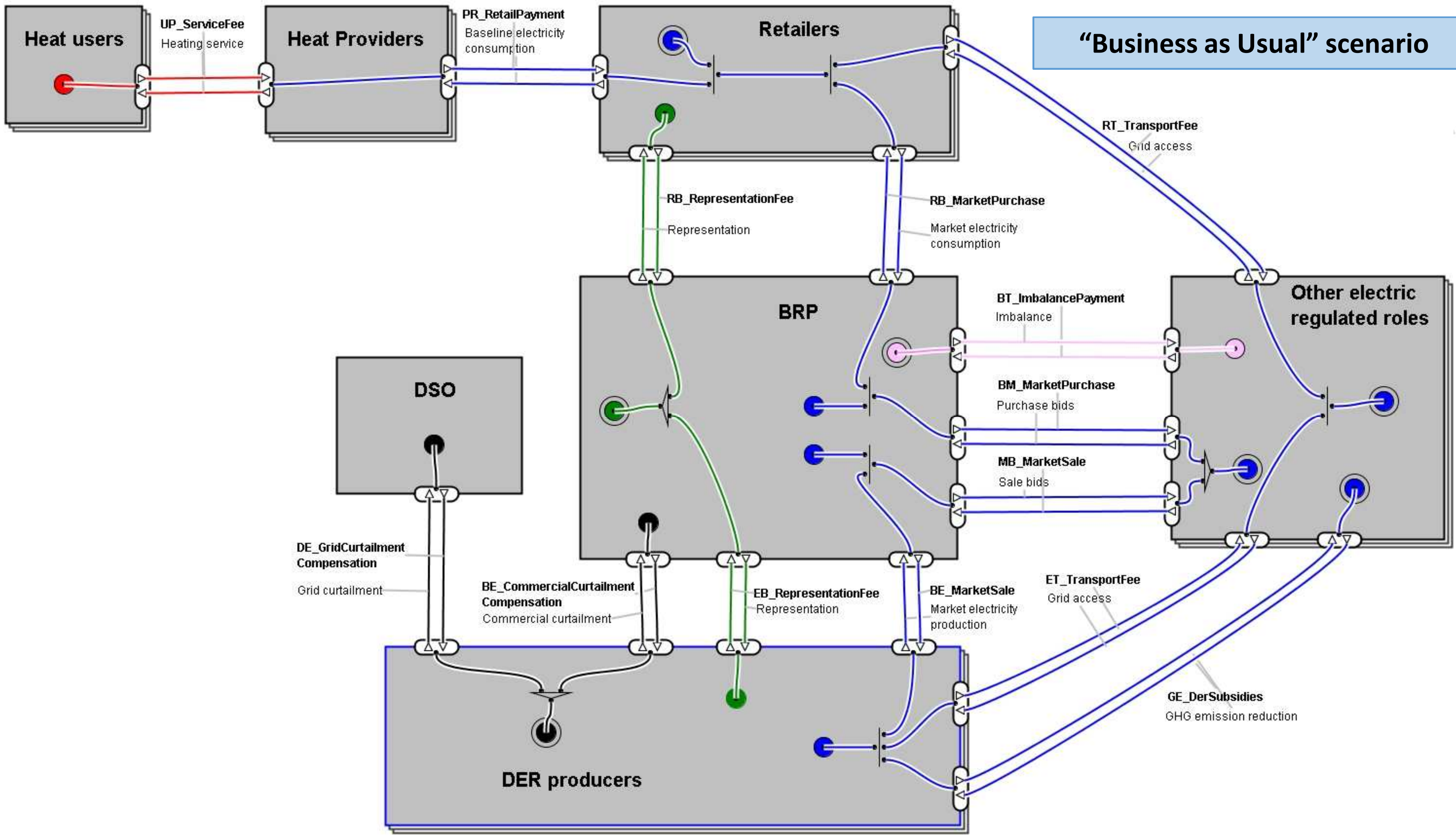
Business use cases

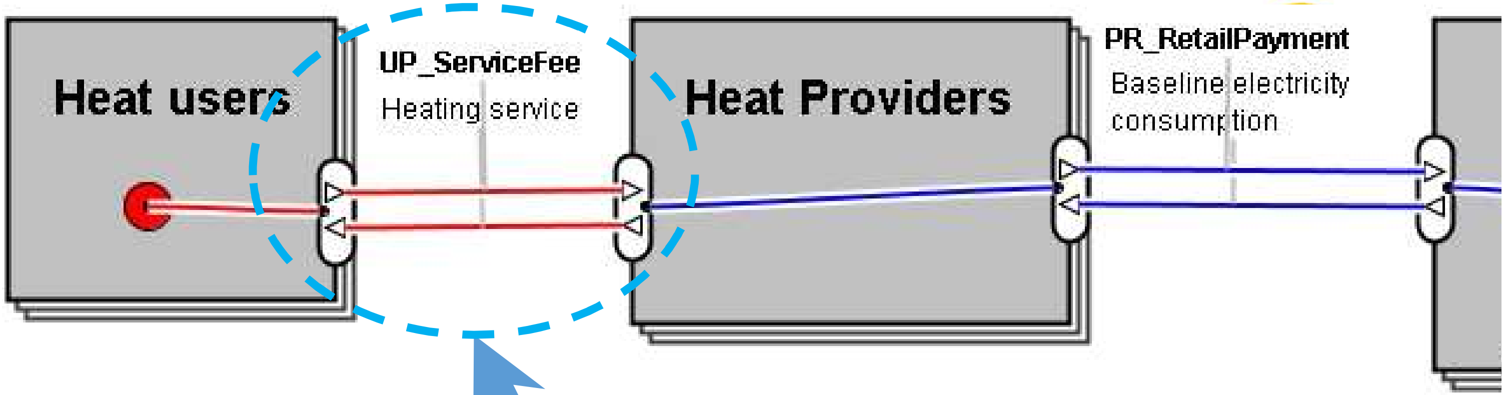
- ***Scenarios***: Three use cases modeled on the FHP scenario, compared to the "Business as Usual" BAS scenario
  - ***localRESCurtailmentMitigation*** : Activates local distribution grid connected P2H flexibility to solve local distribution grid problems that may be caused by excess of local distribution grid connected RES (grid related curtailment).
  - ***systemRESCurtailmentMitigation***: Activates distribution grid connected P2H flexibility to avoid market based curtailment of RES. RES may be located anywhere, but in order to prevent its curtailment, distribution grid connected P2H resources are used in consultation with the local DSO.
  - ***balancingServices***: Changes flexible P2H consumption schedules based on intra-ISP imbalance price forecasts coming from the TSO, acting on the imbalance position of the BRP on either surplus or shortfall situations.

Business use case definition methodology

- ✓ Definition of roles
- ✓ Definition of value exchanged between roles
- ✓ Design of associated monetary exchanges
- ✓ Formulation of the spending and the revenues of each role, to calculate its associated cash flow
- ✓ Comparison of the cash flow of each role in the BAS and FHP scenarios
- ✓ Utilization of the e3 value methodology (https://www.e3value.com/)

“Business as Usual” scenario





The Heat User contracts a Heat Provider, which operates the HVAC (primary energy source of HVAC is based on heat pumps) to provide a heating service.

- ✓ Agreement on acceptable comfort range (indoor temperature). BAS operation is based on a fix temperature setpoint
- ✓ Possibility of override by the Heat User.
- ✓ Fee based on surface, type, comfort range…

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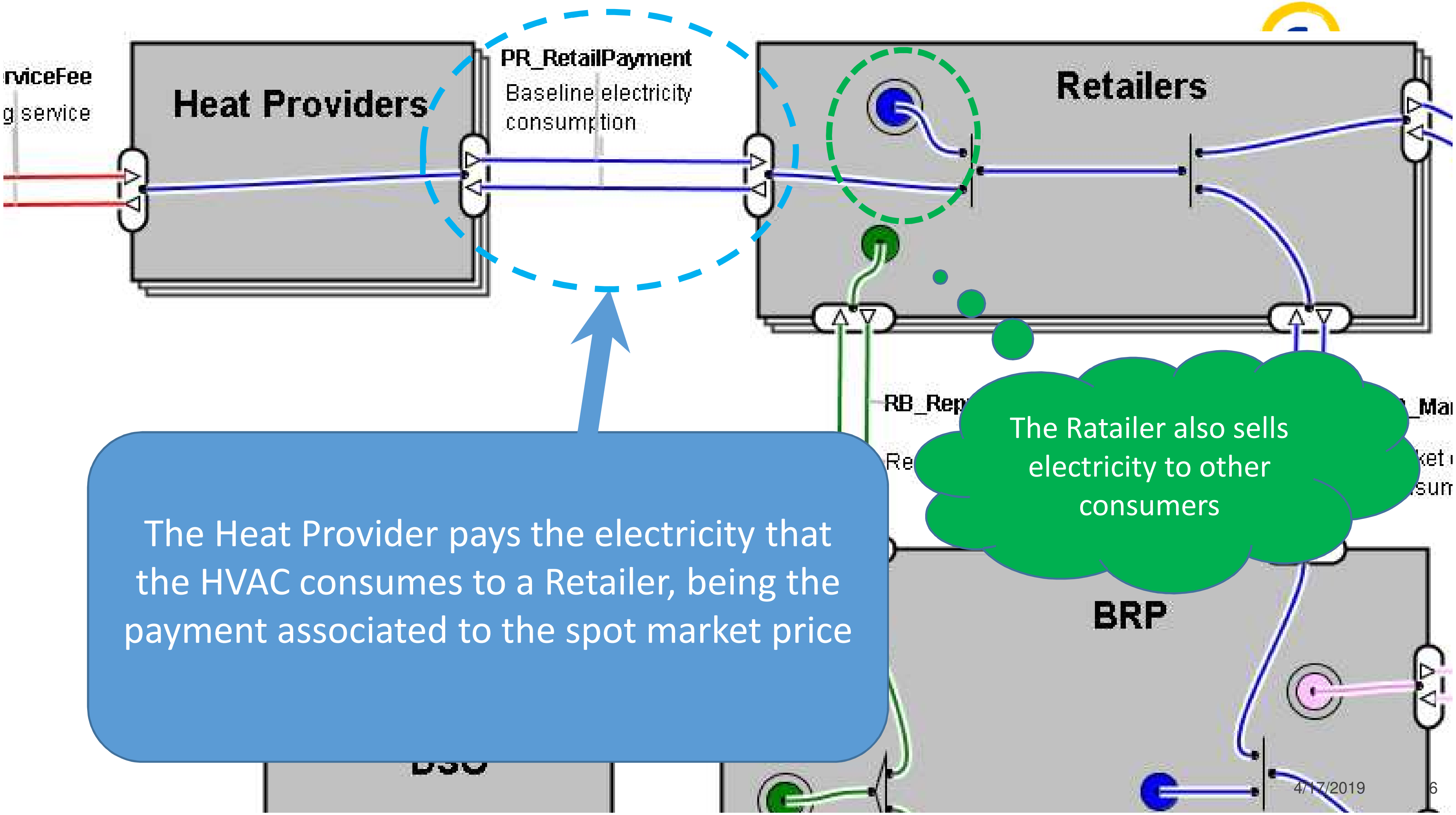
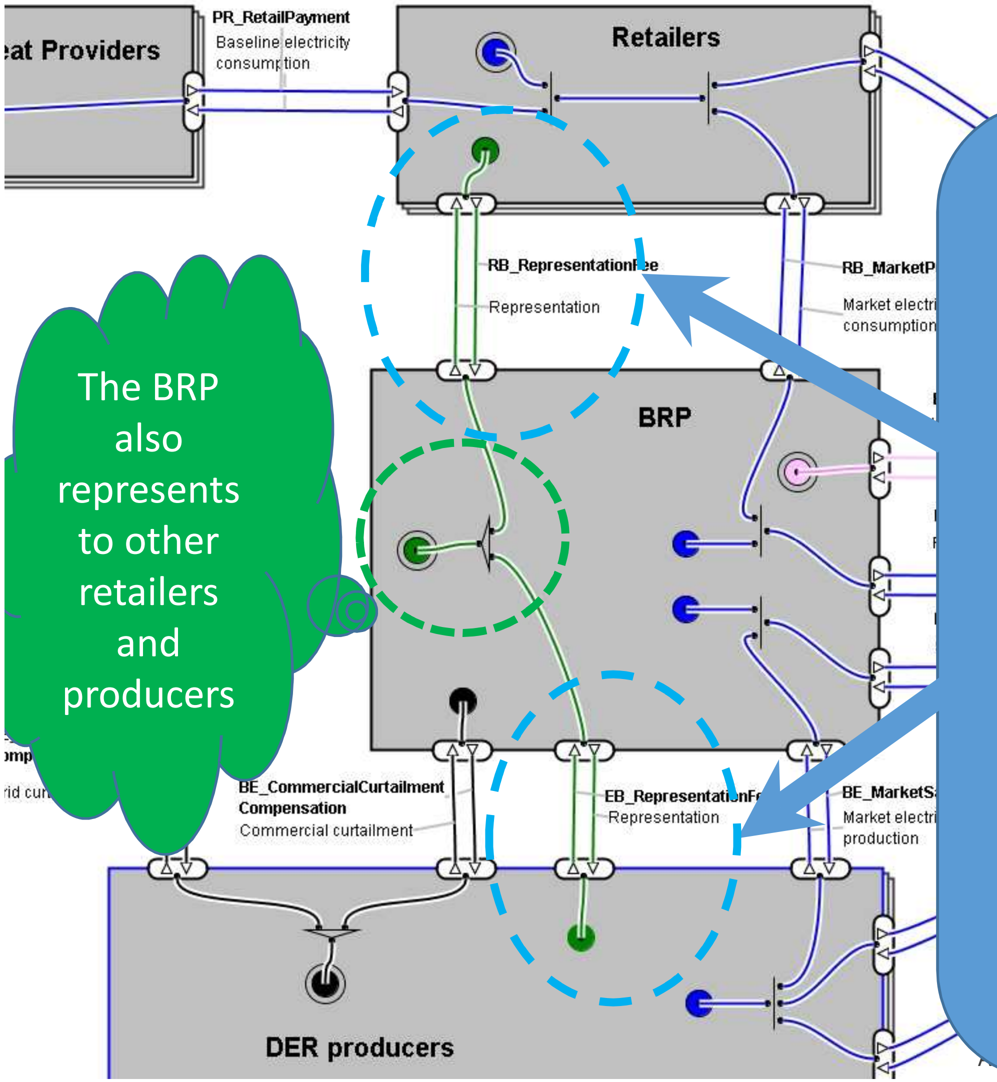
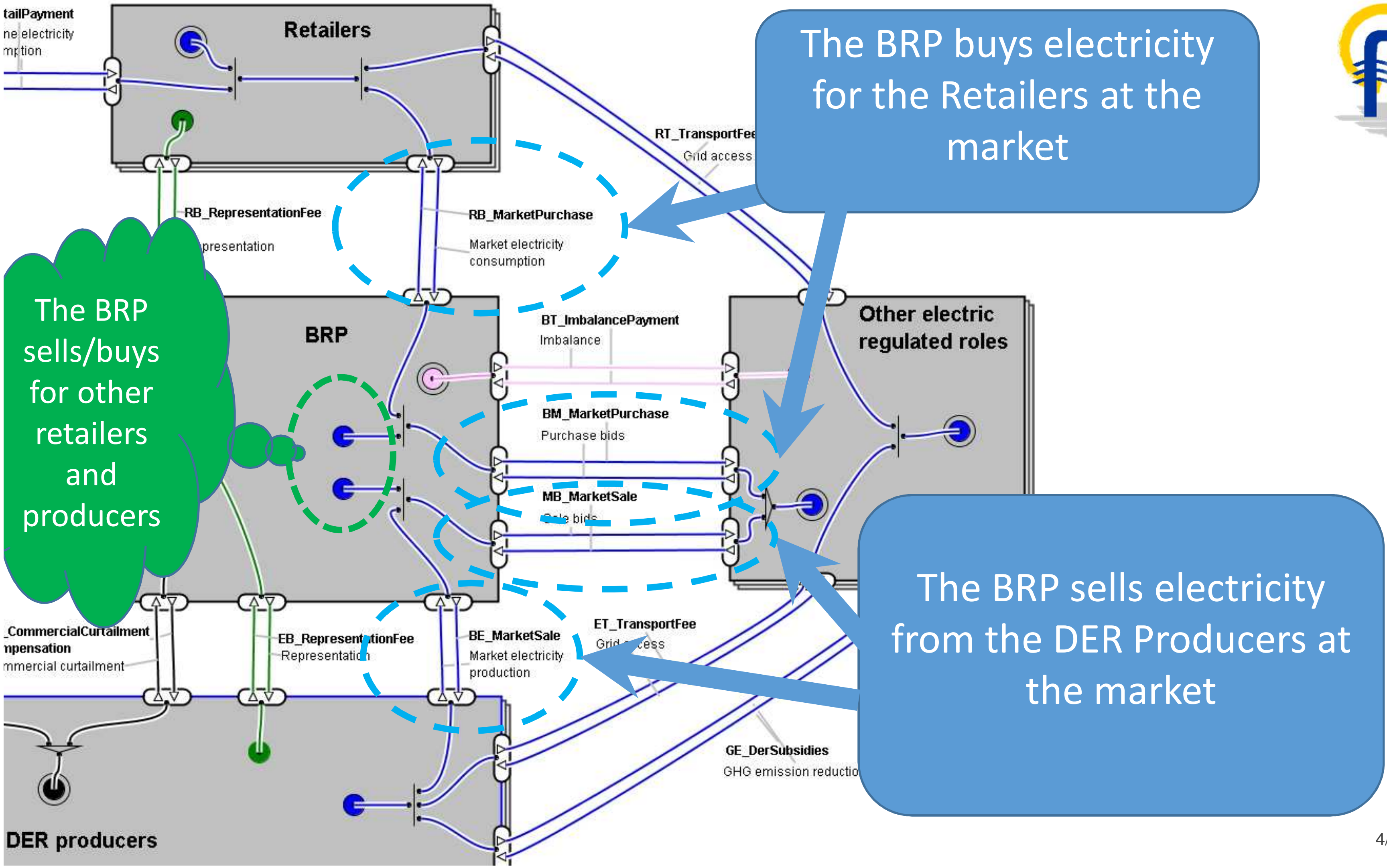

rviceFee
g service
Heat Providers
PR_RetailPayment
Baseline electricity
consumption
Retailers
RB_Rep
Re
BRP
The Ratailer also sells electricity to other consumers
The Heat Provider pays the electricity that the HVAC consumes to a Retailer, being the payment associated to the spot market price

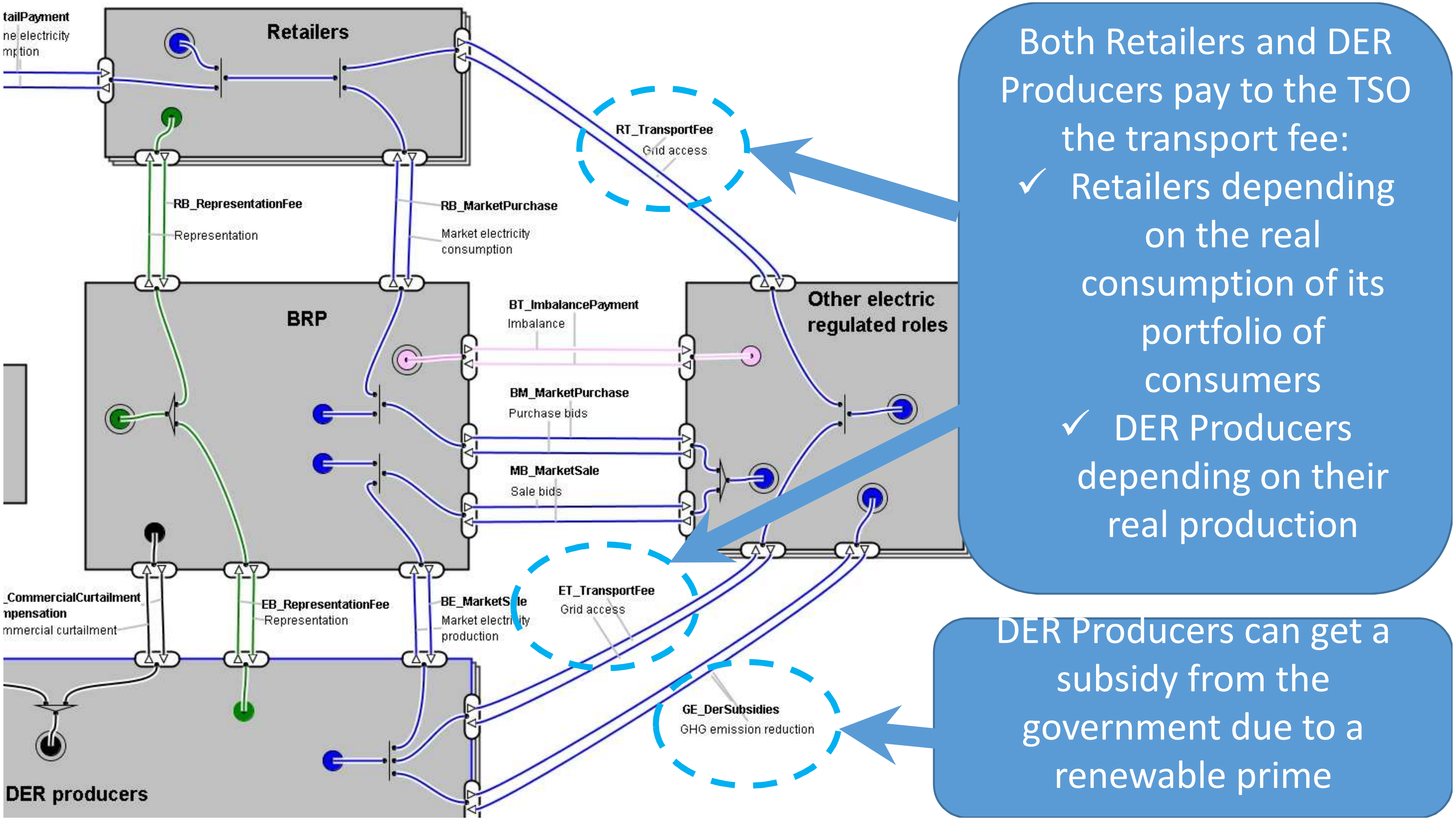


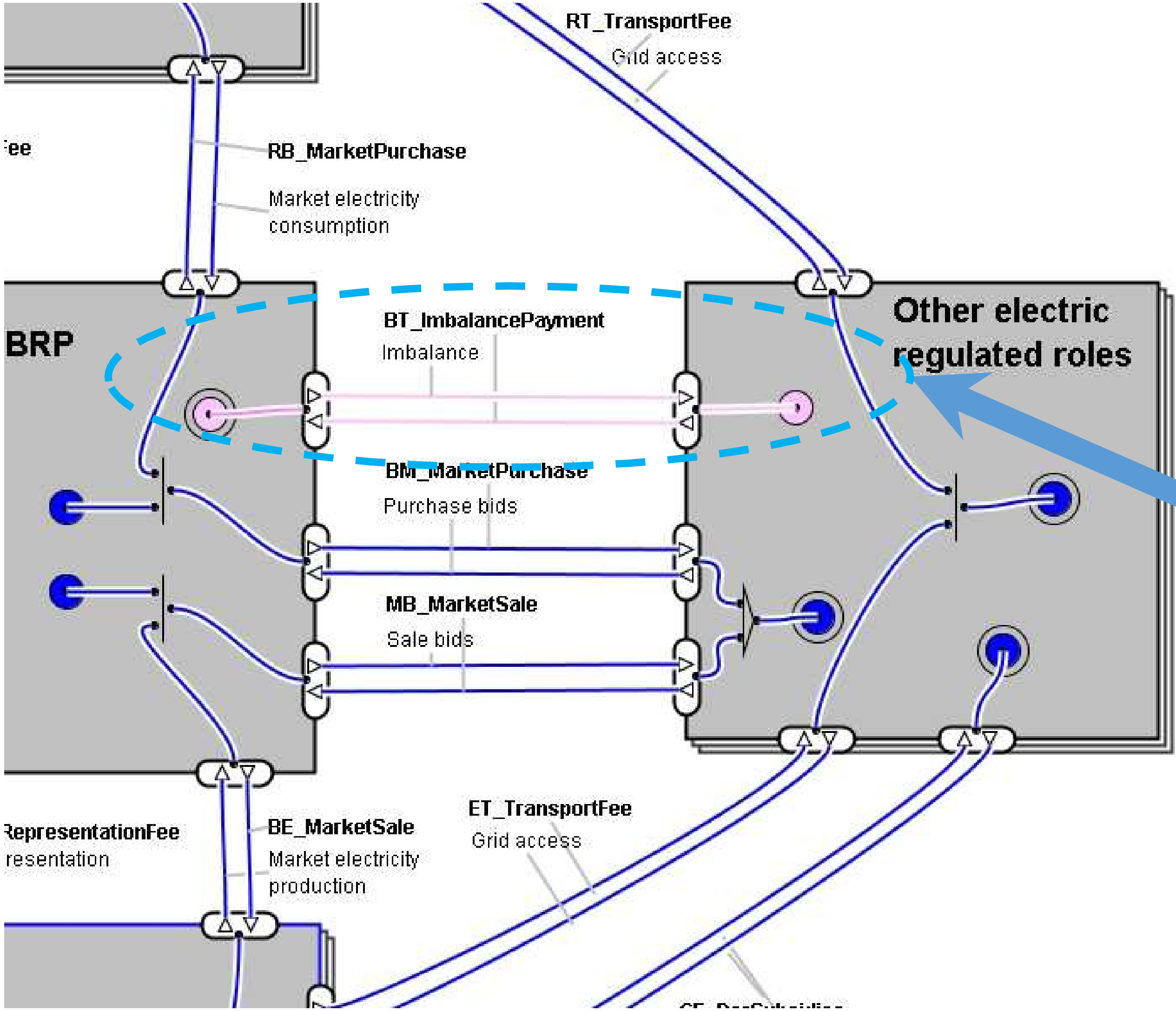
The BRP also represents to other retailers and producers

The BRP represents Retailers and DER producers at the marketplace. It assumes the risk of their imbalances and the responsibility of electricity purchase/sale

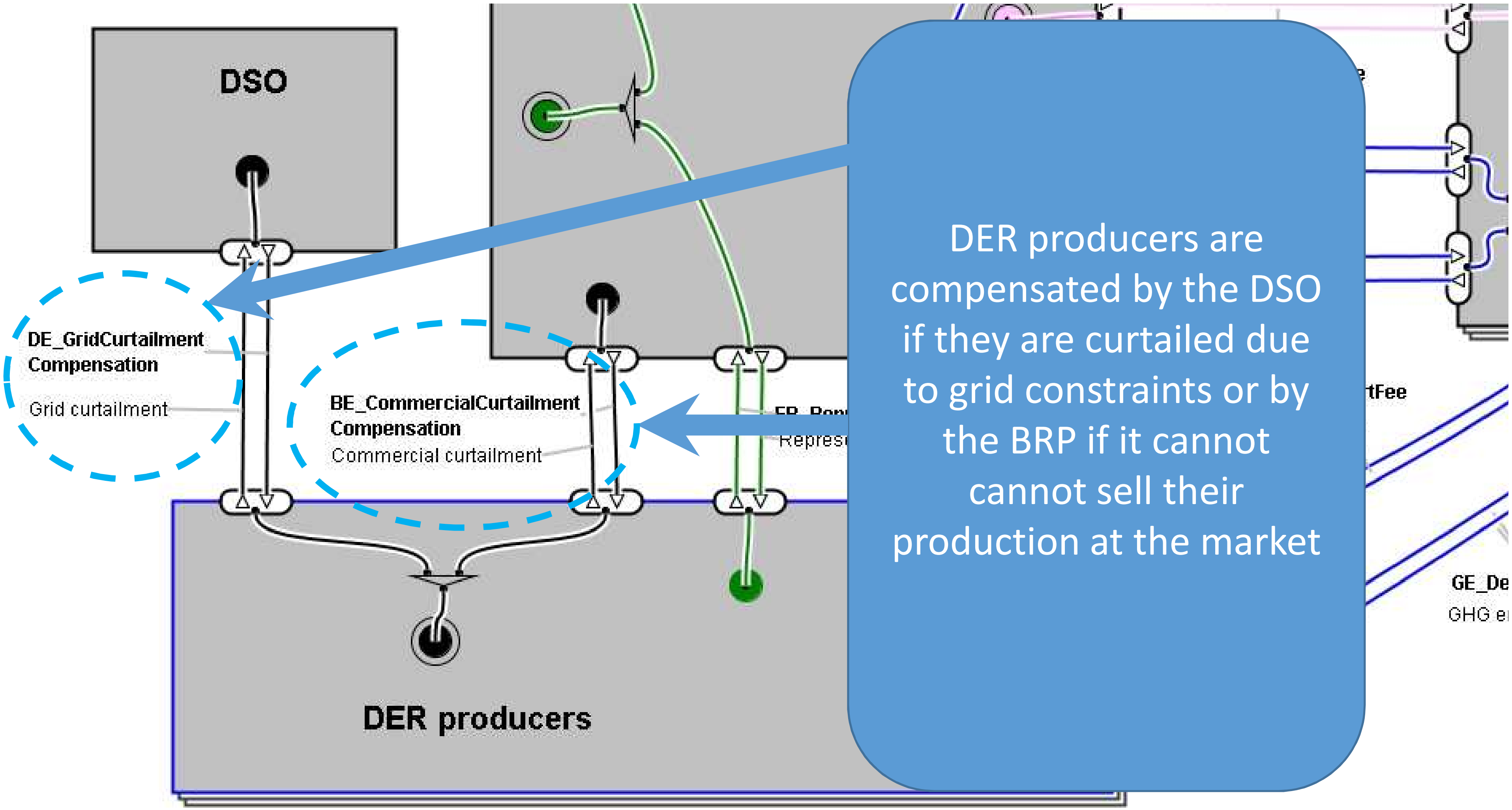


tailPayment
ne electricity
mption
Retailers
RT_TransportFee
Grid access
RB_RepresentationFee
presentation
RB_MarketPurchase
Market electricity
consumption
BRP
BT_ImbalancePayment
Imbalance
Other electric
regulated roles
BM_MarketPurchase
Purchase bids
MB_MarketSale
_CommercialCurtailment
mpensation
mmercial curtailment
EB_RepresentationFee
Representation
BE_MarketSale
Market electricity
production
ET_TransportFee
GE_DerSubsidies
GHG emission reductio
DER producers
The BRP sells/buys for other retailers and producers
The BRP buys electricity for the Retailers at the market
The BRP sells electricity from the DER Producers at the market


Retailers
RB_RepresentationFee
Representation
RB_MarketPurchase
Market electricity consumption
RT_TransportFee
Grid access
BRP
BT_ImbalancePayment
Imbalance
BM_MarketPurchase
Purchase bids
MB_MarketSale
Sale bids
Other electric regulated roles
EB_RepresentationFee
Representation
ET_TransportFee
Grid access
GE_DerSubsidies
GHG emission reduction
DER producers
Both Retailers and DER Producers pay to the TSO the transport fee:
✓ Retailers depending on the real consumption of its portfolio of consumers
✓ DER Producers depending on their real production
DER Producers can get a subsidy from the government due to a renewable prime



The BRP pays to the TSO depending on the amount of its imbalance, and if it is on the same direction of the TSO's imbalance



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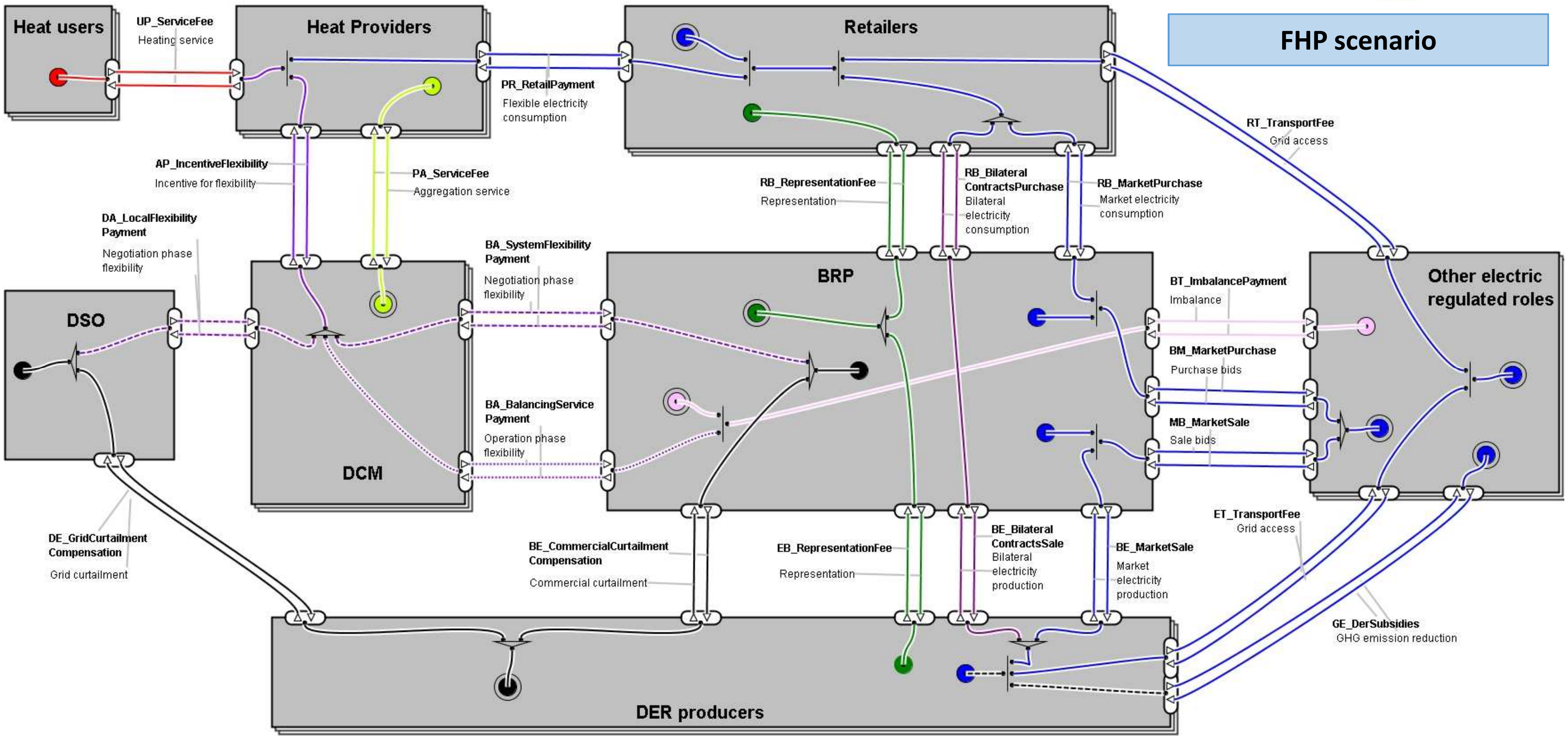
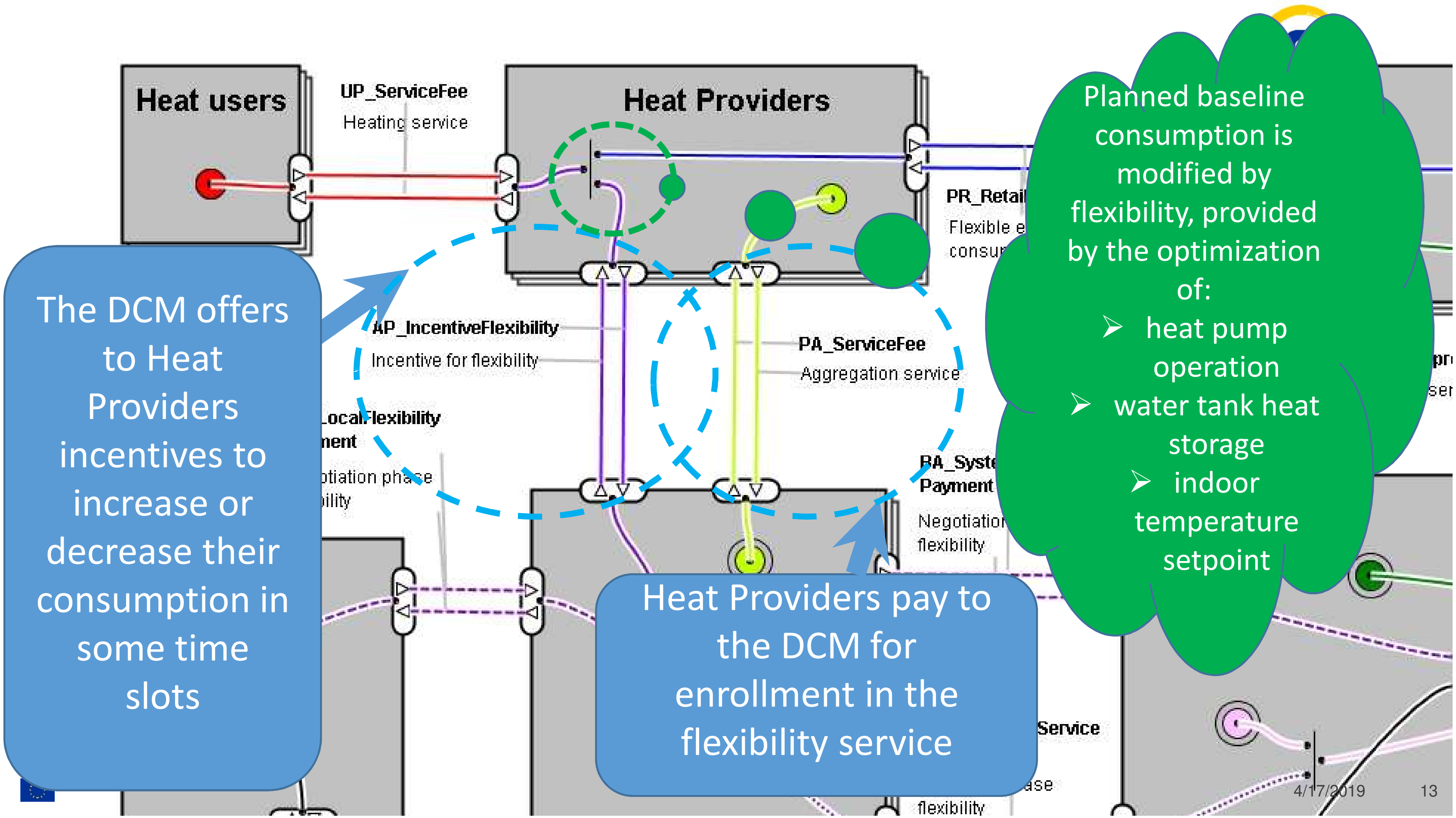
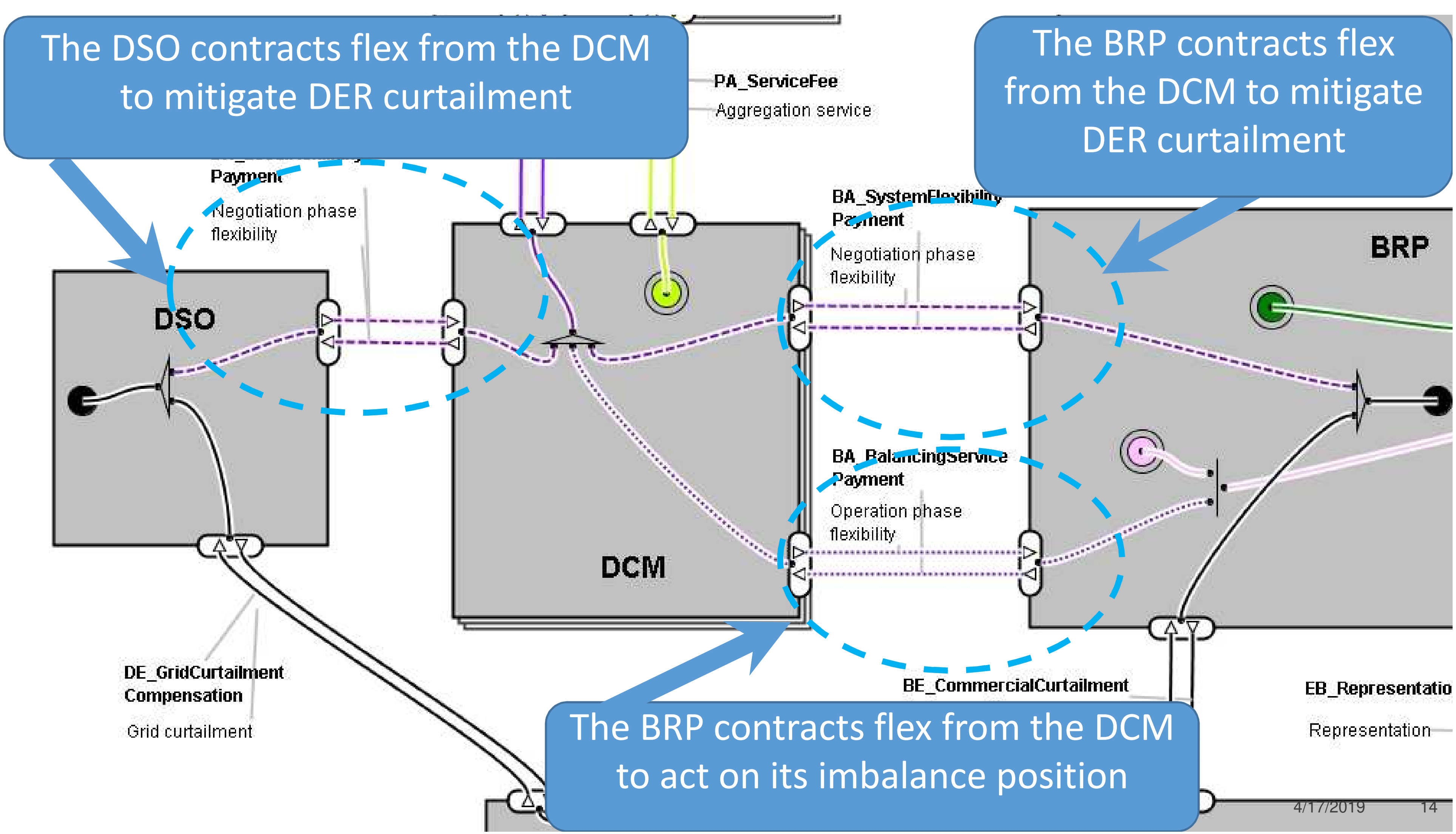
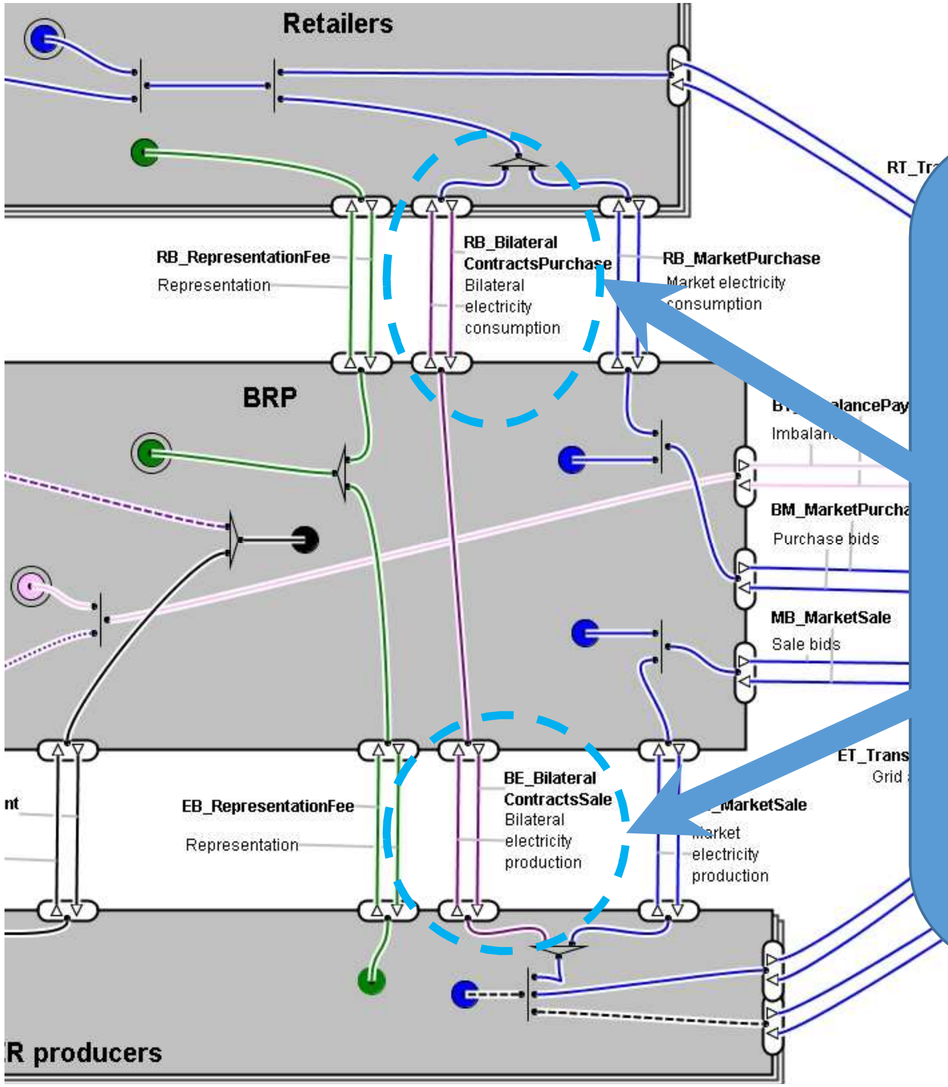


FHP scenario
Heat users
UP_ServiceFee
Heating service
Heat Providers
Retailers
PR_RetailPayment
Flexible electricity consumption
RT_TransportFee
Grid access
AP_IncentiveFlexibility
Incentive for flexibility
PA_ServiceFee
Aggregation service
RB_RepresentationFee
Representation
RB_Bilateral ContractsPurchase
Bilateral electricity consumption
RB_MarketPurchase
Market electricity consumption
DA_LocalFlexibility Payment
Negotiation phase flexibility
BA_SystemFlexibility Payment
Negotiation phase flexibility
BRP
BT_ImbalancePayment
Imbalance
Other electric regulated roles
DSO
BM_MarketPurchase
Purchase bids
BA_BalancingService Payment
Operation phase flexibility
MB_MarketSale
Sale bids
DCM
ET_TransportFee
Grid access
DE_GridCurtailment Compensation
Grid curtailment
BE_CommercialCurtailment Compensation
Commercial curtailment
EB_RepresentationFee
Representation
BE_Bilateral ContractsSale
Bilateral electricity production
BE_MarketSale
Market electricity production
GE_DerSubsidies
GHG emission reduction
DER producers



Heat users
UP_ServiceFee
Heating service
Heat Providers
PR_Retail
AP_IncentiveFlexibility
Incentive for flexibility
PA_ServiceFee
Aggregation service
Planned baseline consumption is modified by flexibility, provided by the optimization of:
heat pump operation
water tank heat storage
indoor temperature setpoint
The DCM offers to Heat Providers incentives to increase or decrease their consumption in some time slots
Heat Providers pay to the DCM for enrollment in the flexibility service
Service
flexibility


The DSO contracts flex from the DCM to mitigate DER curtailment
PA_ServiceFee
Aggregation service
The BRP contracts flex from the DCM to mitigate DER curtailment
Payment
Negotiation phase flexibility
BA_SystemFlexibility Payment
Negotiation phase flexibility
BRP
DSO
BA_BalancingService Payment
Operation phase flexibility
DCM
DE_GridCurtailment Compensation
Grid curtailment
BE_CommercialCurtailment
EB_Representatio
Representation
The BRP contracts flex from the DCM to act on its imbalance position



Consumption increase is allocated to bilateral contracts between the Retailers and the DER producers. Consumption decrease is compensated at the intra-day markets

Business models for flexibility management

Findings

- ✓ ***DCM service fee:*** Baseline operation scheduling tools (Model Predictive Control - MPC) provide an added value to Heat Providers, compared to BAS thermostatic operation, which justifies its engagement.
- ✓ ***DCM incentives***: Absolute incentives, which settlement is not based on baseline estimation, are the entry point to trigger Heat Providers' flexibility provision.
- ✓ ***Flexibility optimization:*** Strategy depends on timing.
  - ✓ ***Short term flexibility***: Based on the operational limits of the heat pump, until indoor temperature gets to the comfort limit.
  - ✓ ***Day ahead (or intraday) flexibility***: Provided by an indoor temperature optimization for the whole simulation period

Business models for flexibility management

Example of cash flow analysis for the a role: Heat User

Types: Single family building (SFB), Multiple family building (MFB), office and commercial

Name	Units	Type1	Type2	Type3	Type4
		SFB	MFB	Office	Commercial
Index		1	2	3	4
UP_Type		Residential	Residential	Commercial	Commercial
Number		2.500.000	3.000.000	50.000	50.000
HP Share		50	50	50	50
FHP Share		100	100	100	100
MaxPower	kW	6,34	2,91	63,53	19,69
MaxPowerFactor	%	1.500	1.500	1.500	1.500
UP_Surface	m2	122	68	2000	620
UP_HighestAverageTemperature	ºC	22	22	23	23
UP_LowestAverageTemperature	ºC	18	18	18	18
UP_ComfortPenaltyPrice	€/ºC	2	2	2	2
AnnualThermalConsumption	kwht/m2	60,7	49,9	37,1	37,1
AverageElectricityPrice	c€/kWhe	40	40	40	40
AverageCopValue		2	2	2	2
TotalAnnualElectricConsumption	kWhe	3702,7	1696,6	37100	11501
UP_YearlySurfaceServiceFee	€/m2	12,14	9,98	7,42	7,42
UP_YearlyServiceFee	€	1.481	679	14.840	4.600
UP_OveridePrice	€	41	19	407	126
BAS_UP_ServiceFee	€	1.481	679	14.840	4.600
FHP_UP_ServiceFee	€	1.481	679	14.840	4.600
BAS_CF_HeatUser	€	-1.481	-679	-14.840	-4.600
FHP_CF_HeatUser	€	-1.481	-679	-14.840	-4.600
CF_HeatUser	€	0	0	0	0

$$CF_{HU} = -Heating\ service$$

$$Service\ fee_y = \sum_{h=1}^{8760} Hourly\ service\ fee + (Override\ price * \ Energy\ overriden_y)$$

Energy Overridden: energy surplus that the Heat Provider has to face in case of override, *0*, we assume the user has no complaints

UP_OverridePrice: price to which the Heat Provider would bill this energy, *(10*daily service fee).*

UP_YearlyServiceFee: money which the Heat User has to pay for the heating service.

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5.4 Annex 3.4. DCM centric Solution Architecture. Davy Geysen

DCM centric Solution Architecture

Workshop on FHP wind curtailment mitigation solution

Davy Geysen – VITO N.V. / EnergyVille

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Overview

- ***Dynamic Coalition Manager: what and why?***
- ***DCM multi-agent platform***
- ***DCM building blocks & services***
- ***DCM activity flow***
- ***Summary***

Dynamic Coalition Manager (DCM)

What?

- ✔ ***Central actor/agent in the FHP flex trading concept***
- ✔ ***Collecting and aggregation of prosumption forecasts and flexibility***
- ✔ ***Specialization of (local) aggregator or local community manager***

Dynamic Coalition Manager (DCM)

Why?

- ✔ ***Empowering flexibility providers***
  - ✔ ***Prosumers, buildings, Ecovat,…***
  - ✔ ***Flex providers decide***

- ✔ ***Better forecasts***
  - ✔ ***More flexibility***
  - ✔ ***Less uncertainty***

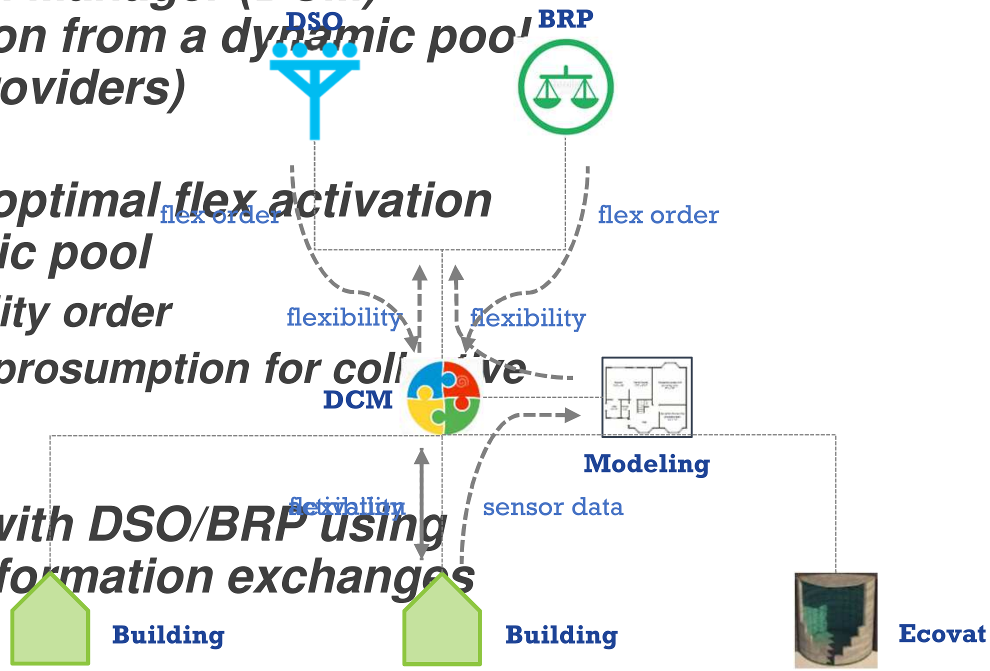
- ✔ ***Bottom up aggregations***
  - ✔ ***Location aware***

Overview

- ✔ ***Dynamic Coalition Manager: what and why?***
- ✔ ***DCM multi-agent platform***
- ✔ ***DCM building blocks & services***
- ✔ ***DCM activity flow***
- ✔ ***Summary***

DCM
Multi-agent platform

- ✔ ***Dynamic Coalition Manager (DCM) collects information from a dynamic pool of Flex Owners/Providers)***
- ✔ ***DCM determines optimal flex activation within this dynamic pool***
  - ✔ ***Based on flexibility order***
  - ✔ ***Coordination of prosumption for collective objective***
- ✔ ***DCM interacting with DSO/BRP using USEF[1] inspired information exchanges***



1: https://www.usef.energy/

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Overview

- ***Dynamic Coalition Manager: what and why?***
- ***DCM multi-agent platform***
- ***DCM building blocks & services***
- ***DCM activity flow***
- ***Summary***

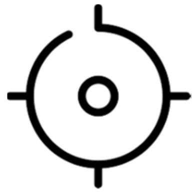
DCM

Building blocks & services

- ***Collector***
  - ***Baseline consumption & flexibility***
  - ***Aggregates forecasts***

- ***Planner***
  - ***Determines optimal flex activation***
  - ***Cluster optimization***
  - ***Offering service to grid or market***

- ***Dispatcher***
  - ***Disaggregate flexibility***
  - ***Distributed optimization (ADMM[1])***



1: Stephen Boyd, Neal Parikh, Eric Chu, Borja Peleato and Jonathan Eckstein (2011), "Distributed Optimization and Statistical Learning via the Alternating Direction Method of Multipliers", Foundations and Trends® in Machine Learning: Vol. 3: No. 1, pp 1-122. http://dx.doi.org/10.1561/2200000016

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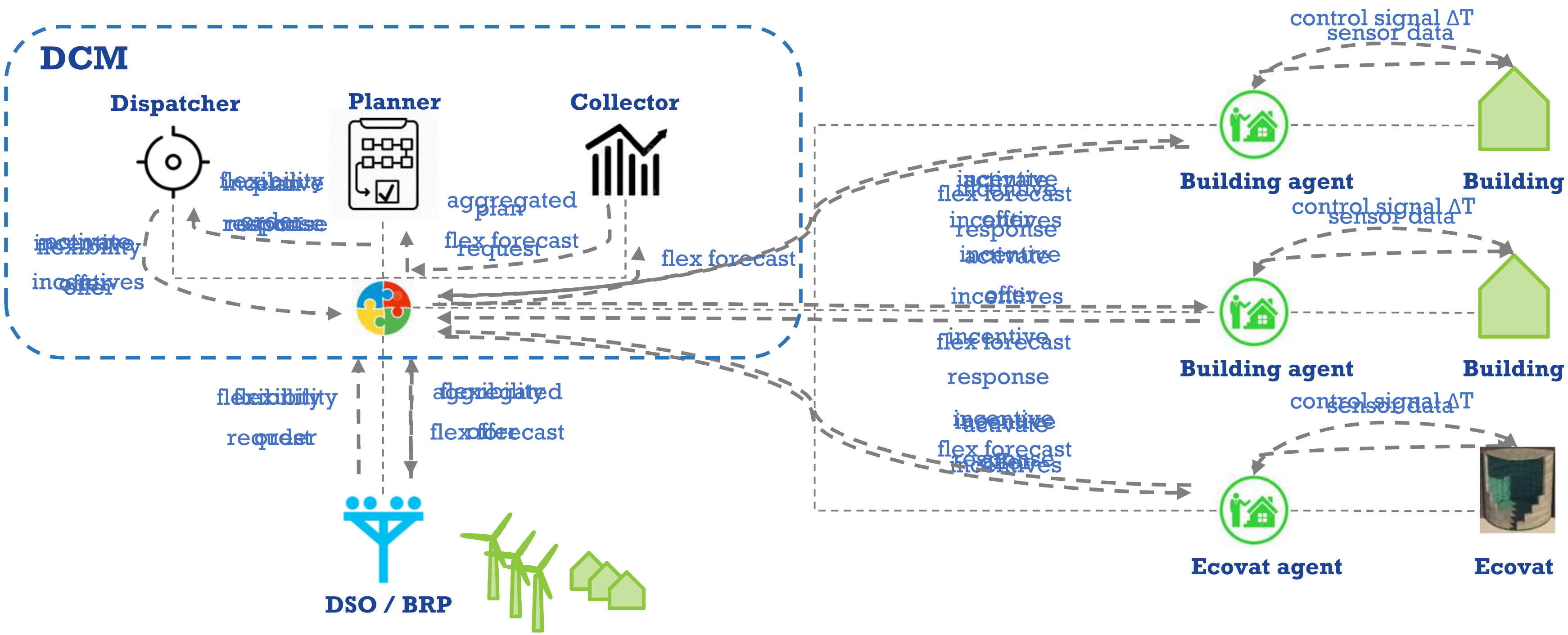
DCM-centric Multi-agent activity flow



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Summary

- ✔ ***Automated way of flexibility negotiation***
- ✔ ***Dynamic cluster of flexibility providers***
- ✔ ***Flexibility providers are in control***
- ✔ ***Location-aware aggregation/disaggregation***

Thanks for your attention

davy.geysen@vito.be

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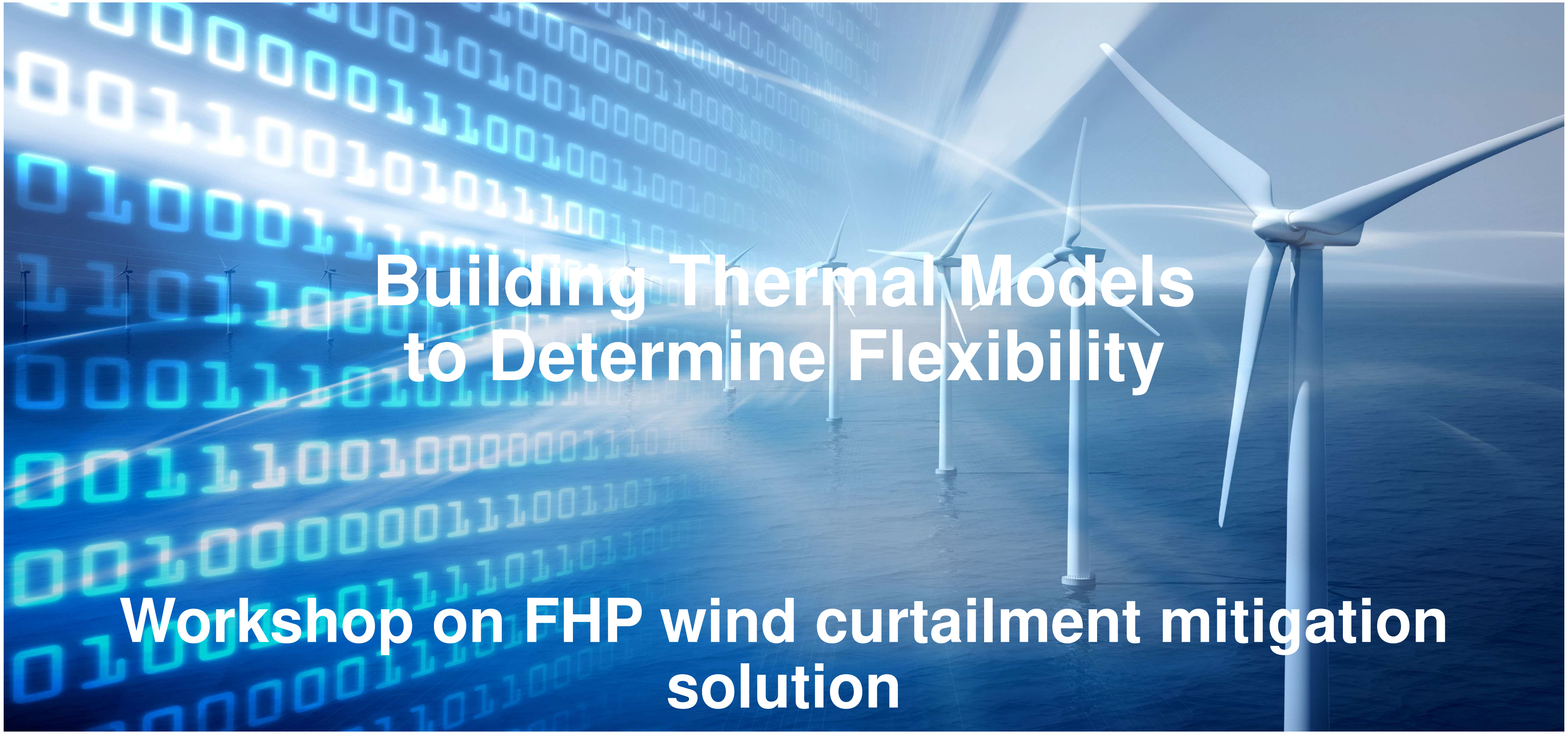
5.5 Annex 3.5. Building modelling and control strategies. Zdenek Schindler



Building Thermal Models to Determine Flexibility

Workshop on FHP wind curtailment mitigation solution

Zdeněk Schindler - Honeywell

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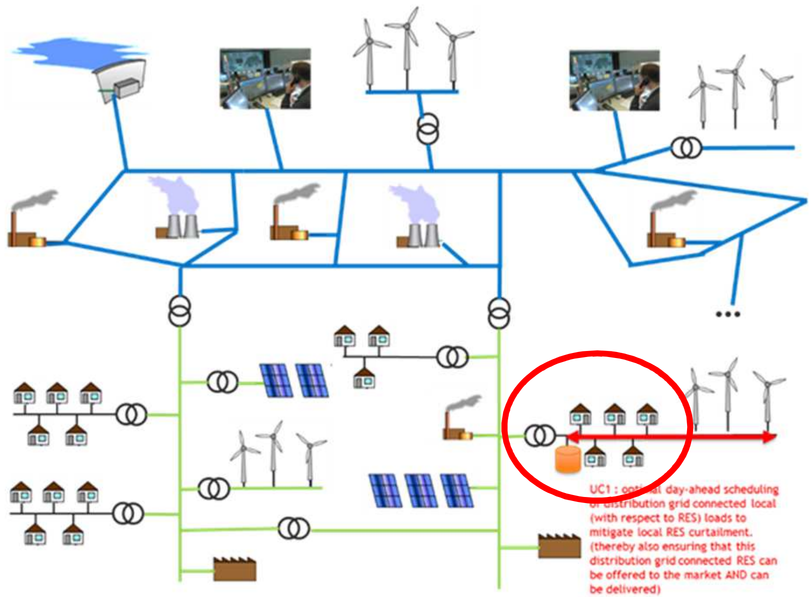
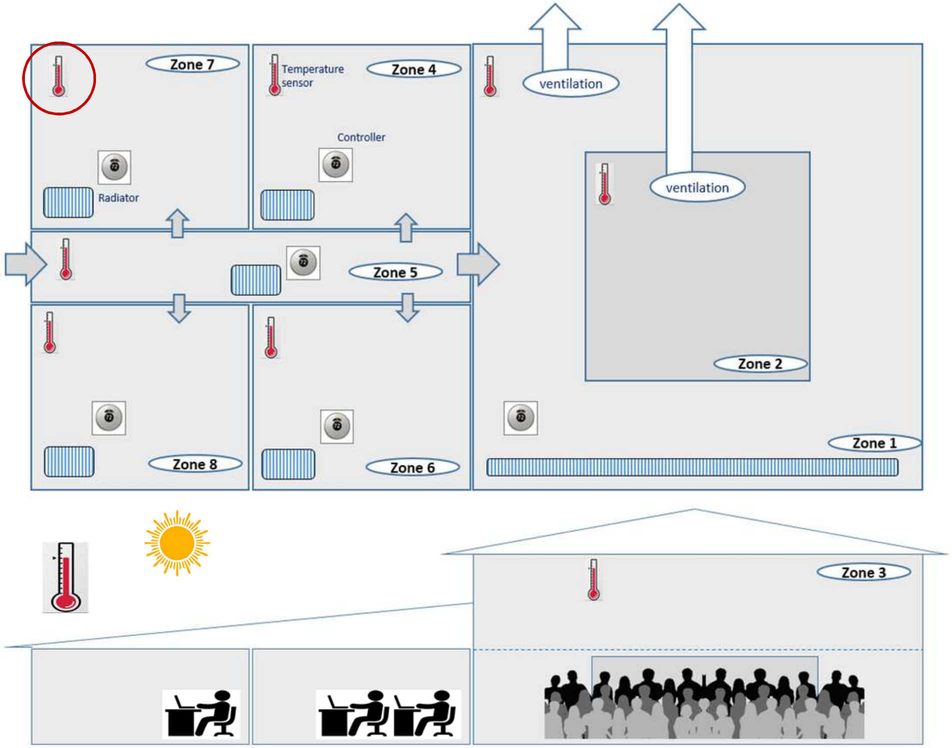
Motivation

- Flex Trading instead of Explicit Demand Response
- Thermal inertia of buildings, which provide Implicit Demand Response



Building Thermal Model



Dynamic models compute

- Indoor zone temperatures
- Heat flows

Principle influences / inputs :

- Weather
- Heating and cooling power
- Ventilation
- Occupancy & indoor heat gains

Building Thermal Model

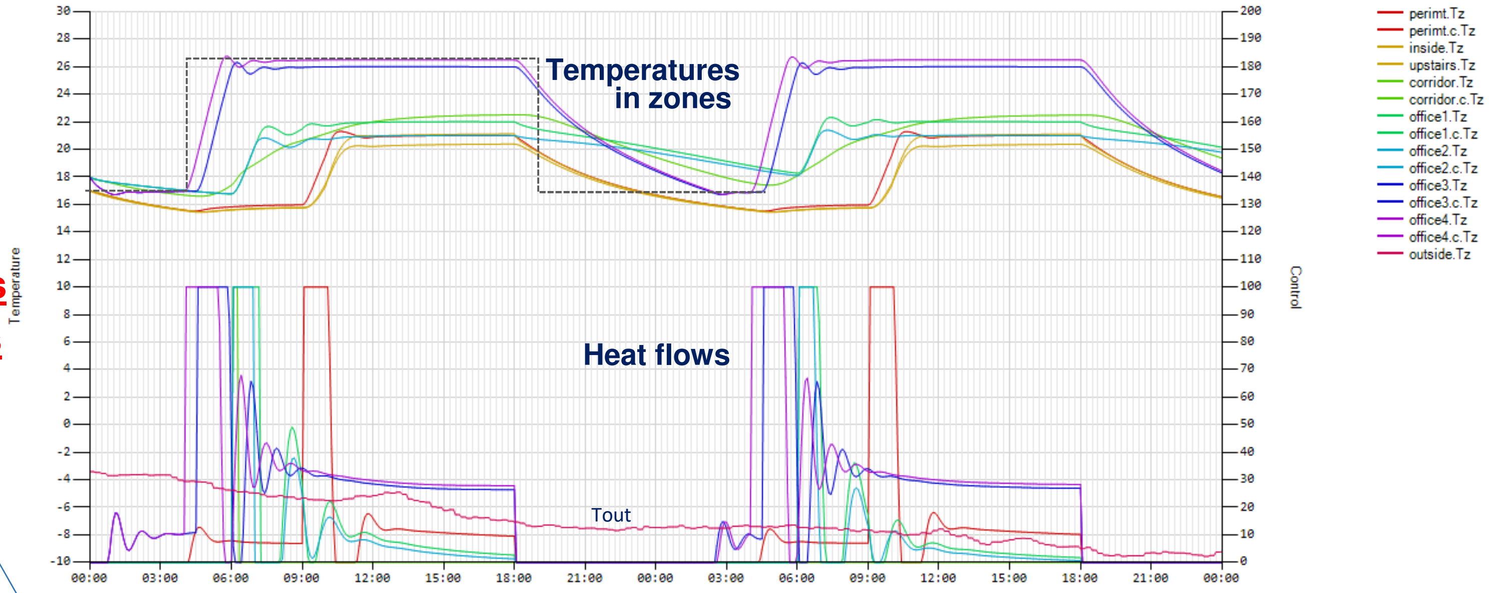
Example of first principles model with approximations

State space ODE model, 2 days simulation

The model has

74 state variables

> 100 parameters



Too complex for use …

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Building Thermal Model

FHP uses simple grey or black box models:

+ Small number of parameters for calibration

+ Easier for control

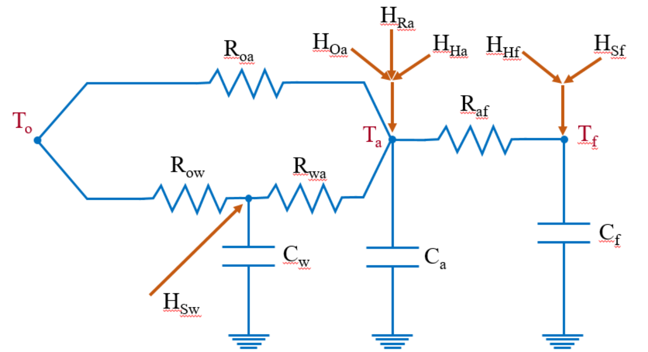
-- Narrow confidence region

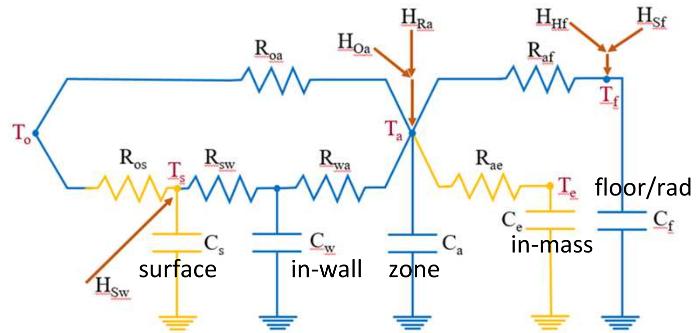
- Lower accuracy in dynamic response
- Lower granularity of results
- Often ambiguous model parameters

Grey Box Models

Model structure

- *Linear state space model*
  of low order (electrical RC analogy)
- *Several basic states,*
  thermal inertias in integral form:
  - *Outer wall states* T_w (T_s)
  - *Indoor air mass* T_a
  - *Indoor heating masses* T_f
  - *Indoor passive masses* T_e
- *Inputs = influences:*
  - *Outdoor temperature* T_o
  - *Solar irradiation* H_S
  - *Occupancy (gains)* H_O
  - *Explicit heat losses by ventilation* H_R





Grey Box Models

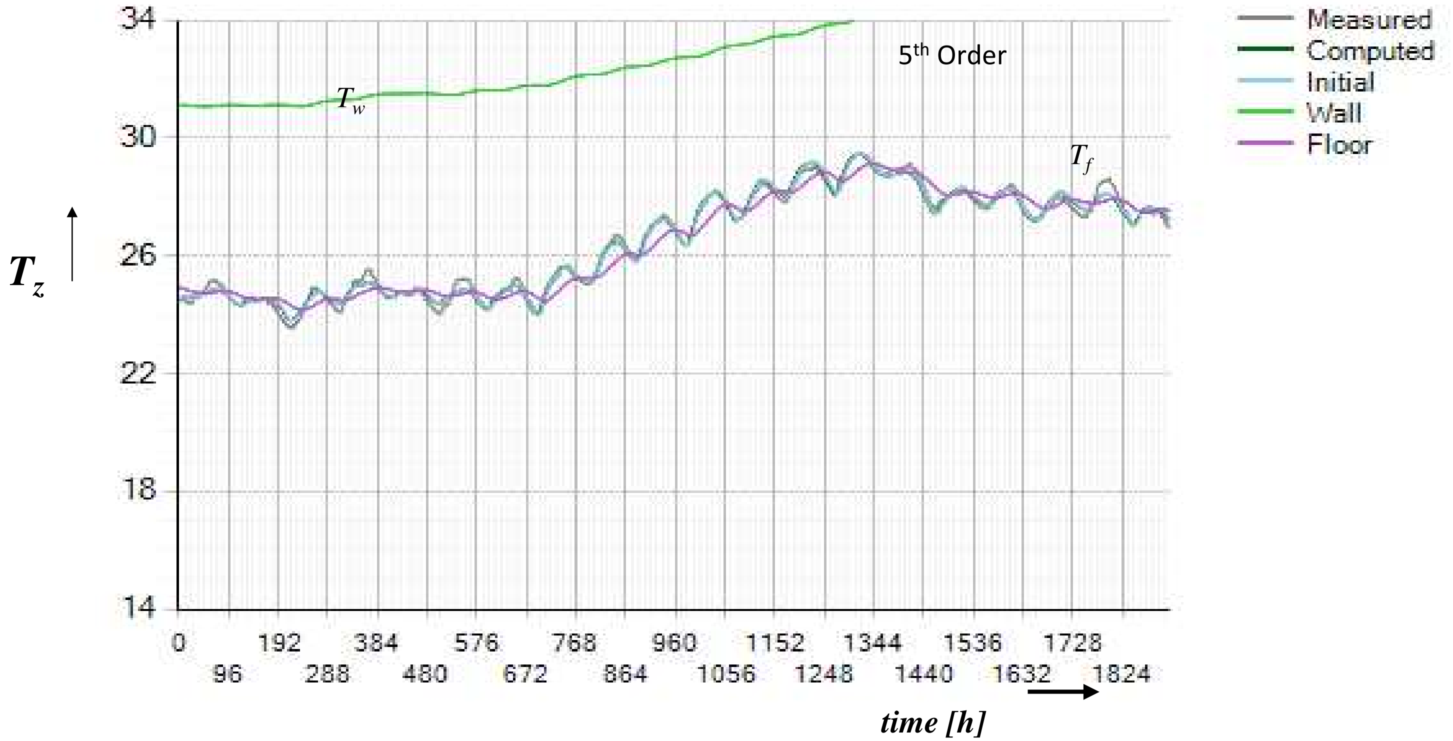
Experimental calibration of model parameters of RISE building

- R, C parameters and initial hidden states determined by nonlinear mathematical programming
- Data from experimental villa in Sweden: influences + zone temperatures T_a in summer, autumn, winter, spring
- 5 Models: 4 seasonal plus yearlong parameters

- Results:
  - Seasonal model better that the general one
  - 5th order better than 3rd order (Improvement in RMSE: 16.1%)

Grey Box Models
Simulated temperature profile

Summer temperature series, no heating



Grey Box Models
General findings

Calibrated model:

- Calibration is sensitive to initial estimates of parameters … multiple minima of parameters

- Model often smoothens temperature profiles

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Black Box Models
Modelling Concept

Two black box thermal models investigated

- **Time Series ARIMAX:** N-lagged autoregressive model
  The future is modeled as repetitive sequence of selected past events
- **Machine Learning:** Clustering and self learning regression models
  Learned relationships between inputs and outputs used to predict future behavior

Feature selection (Outdoor temp, Solar Irradiation, Indoor Temp, Heat Power, Temp Increase)

→ **Data collection (historical time series)**

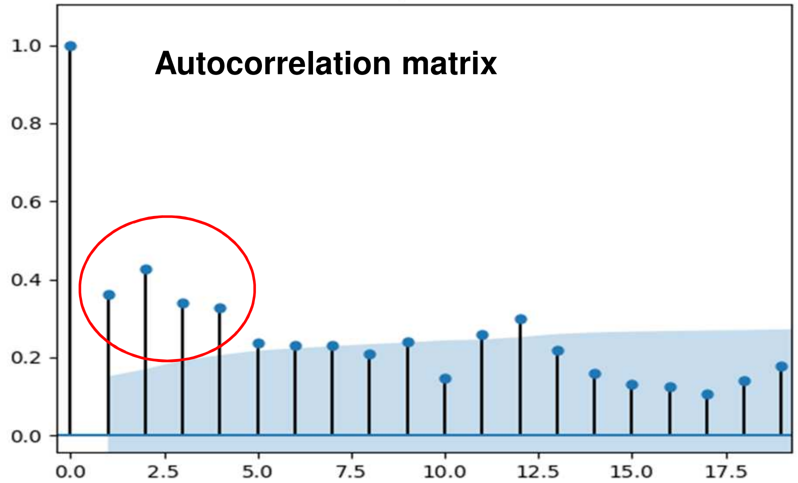
→ **Model training**

Model application

Black Box Models - Time Series Model

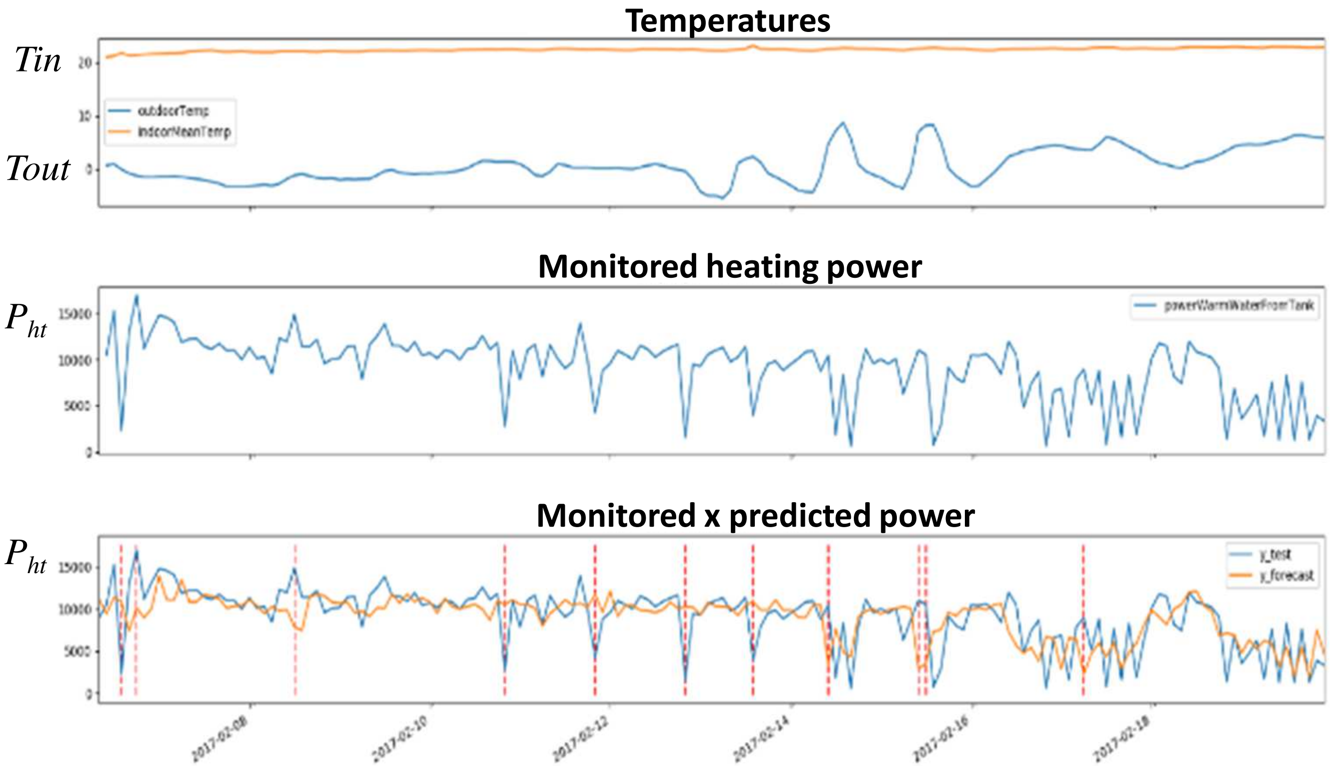
Experiments with RISE building data

- Winter period data resampled to 2h
- Best lags selected: t-1, t-2, t-3, t-4
- Determine the autoregressive terms
- Include exogenous variable (= Outdoor temperature)



Black Box Models - Time Series Model

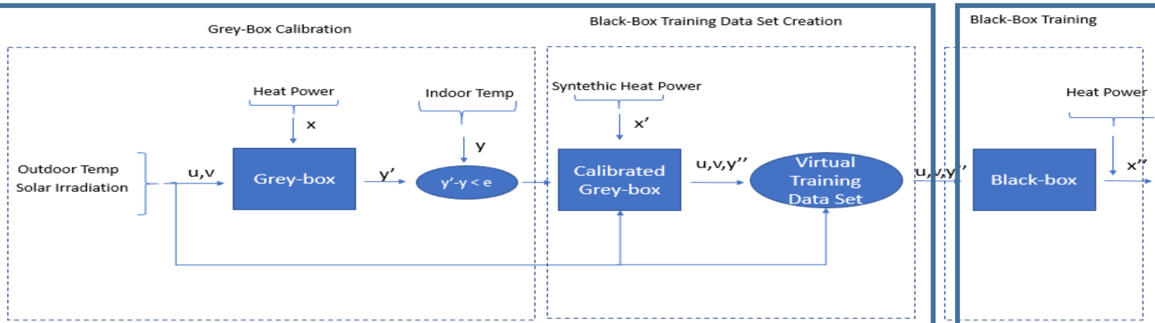
Prediction results with RISE building data



Black Box Models - Machine Learning Model

Experiments with building data

- **Not enough historical data for training – data temporarily substituted by data generated with grey box model**
- **Grey box data will be gradually substituted by real monitoring data**



INPUTS	OUTPUTS
Supplied heat power	Indoor building average temperature
Outdoor temperature	Indoor temperature for one of the zones
Solar Irradiation	

TRAINNING FEATURES				TARGET FEATURE
Outdoor temp	Solar Irradiation	Indoor Temp	Heat Power	Temp. Increase

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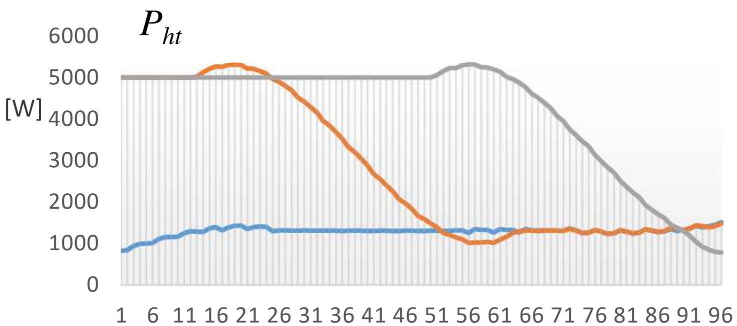
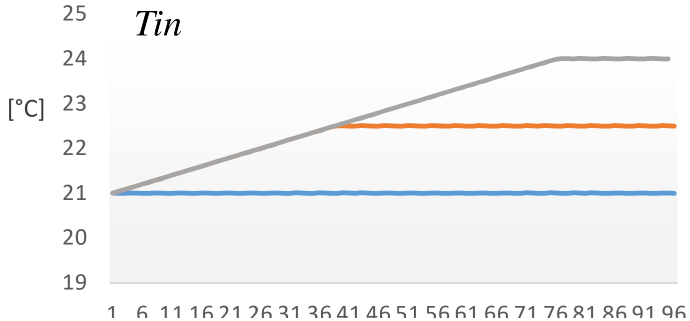
Black Box Models - Machine Learning Model

Modeling results





96 periods (24h)

Estimated indoor temperatures and consumption for

- **21ºC (blue),**
- **22.5ºC (orange) requested at t=0,**
- **24 (grey) requested at t=0**

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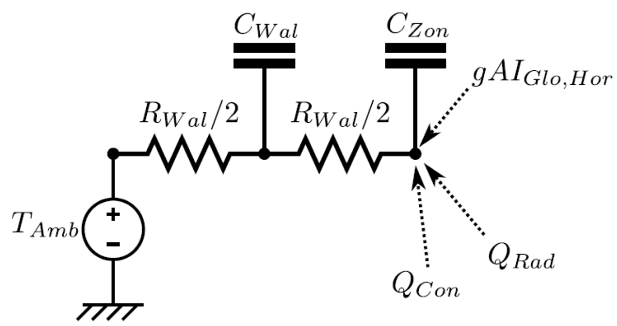
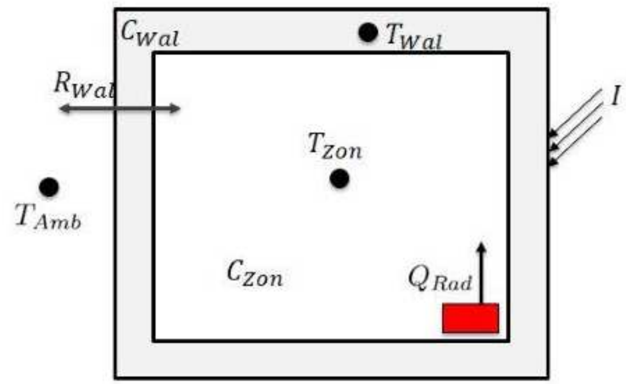
Gray Box Model
Pilot testing

Hangar building

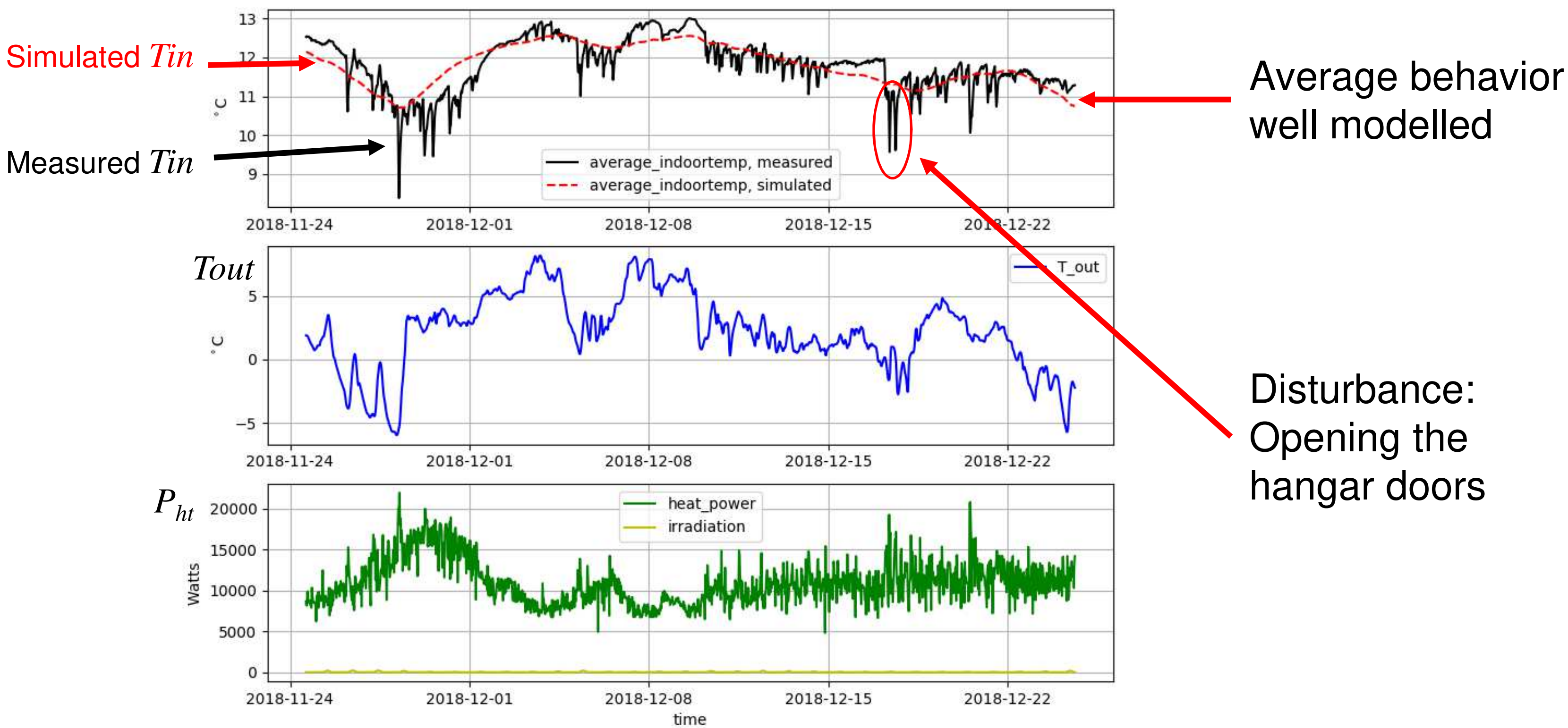
- Single-zone 2nd order model chosen
- Calibration with 30 % to 45% data
- Resampling applied to consolidate and synchronize data
- Minimization of RMSE of the modelled indoor temperature
- Validation of models parameters on remaining data





Gray Box Model

Pilot testing result



Building Heating Control

Optimal baseline and flexibility with grey box model

- Heating and cooling determined by economic optimal control
- Inputs – forecasts of
  - Weather
  - Significant influences
  - Power price
  - Required thermal comfort
- Outputs
  - Baseline energy demand
  - Flexible energy demand - altered prices and extended thermal comfort
- Nonlinear conversion of heat to power (COP)

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Building Heating Control

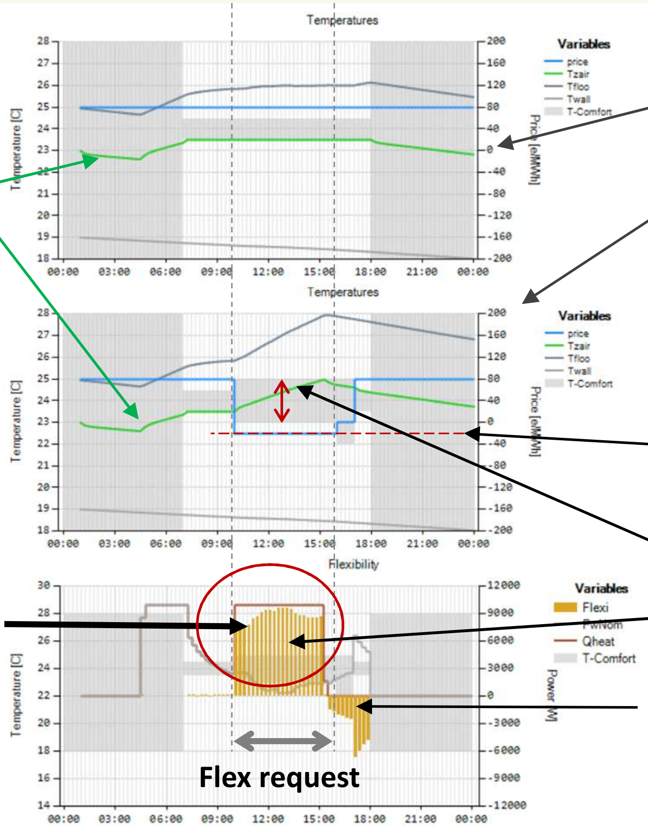
Optimal baseline and flexibility with grey box model

Baseline

Tin

Demand with negative price

Flexibility orange frame



Optimal baseline

Flexibility - Optimal increase of consumption between 10:00 – 16:00

Negative energy price

Slightly compromised comfort for increased flexibility

Potential increase of consumption (orange bars)

Rebound effect

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Conclusions

- Simulations using grey box models provide acceptable match with measured baseline, depending on chosen complexity and available data
- Flexibility may need adding a safety margin not to violate pre-specified constraints in real environment
- Expert free modeling needs to be further validated in practice

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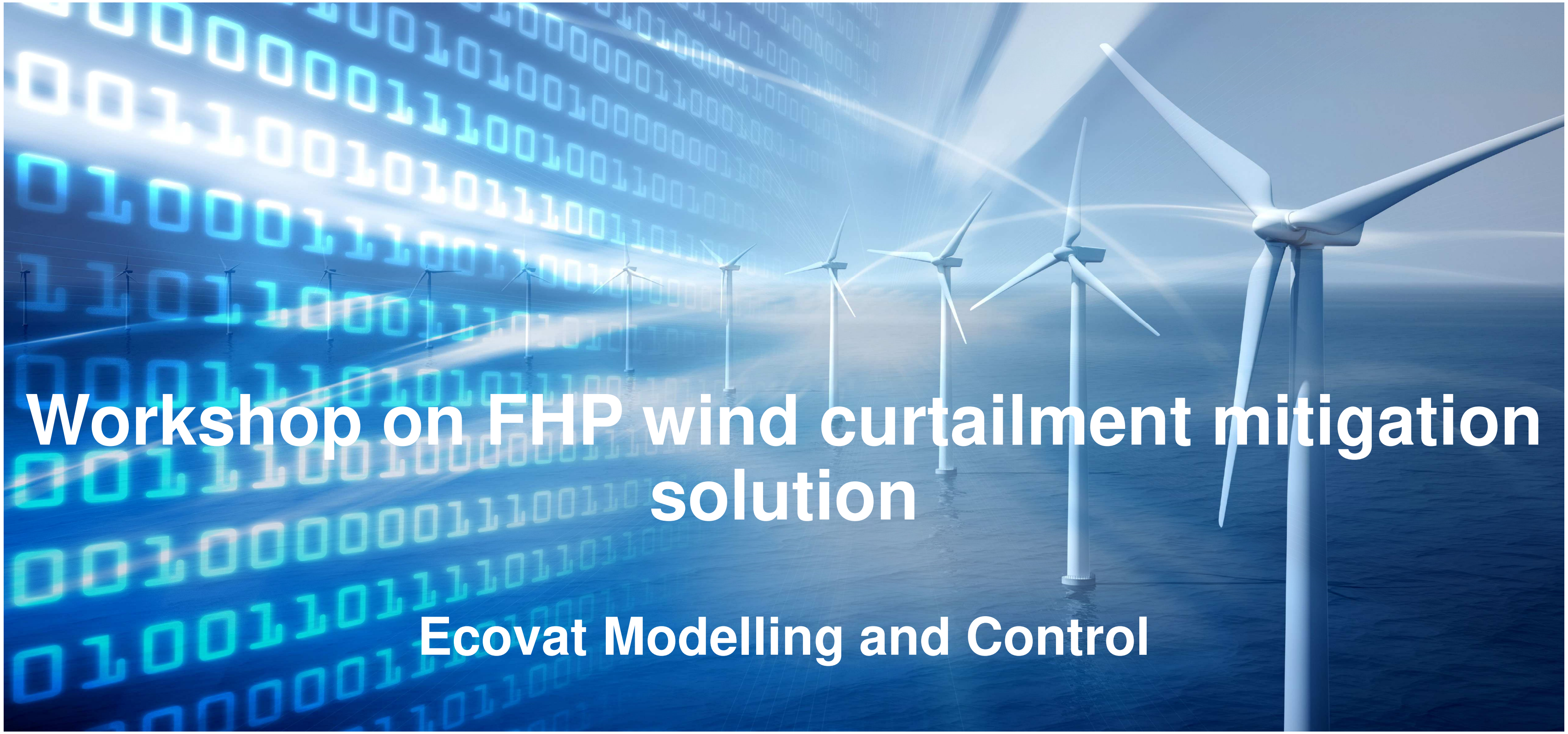
5.6 Annex 3.6. Ecovat modelling and control. Wiet Mazairac



Workshop on FHP wind curtailment mitigation solution

Ecovat Modelling and Control

Wiet Mazairac - Ecovat

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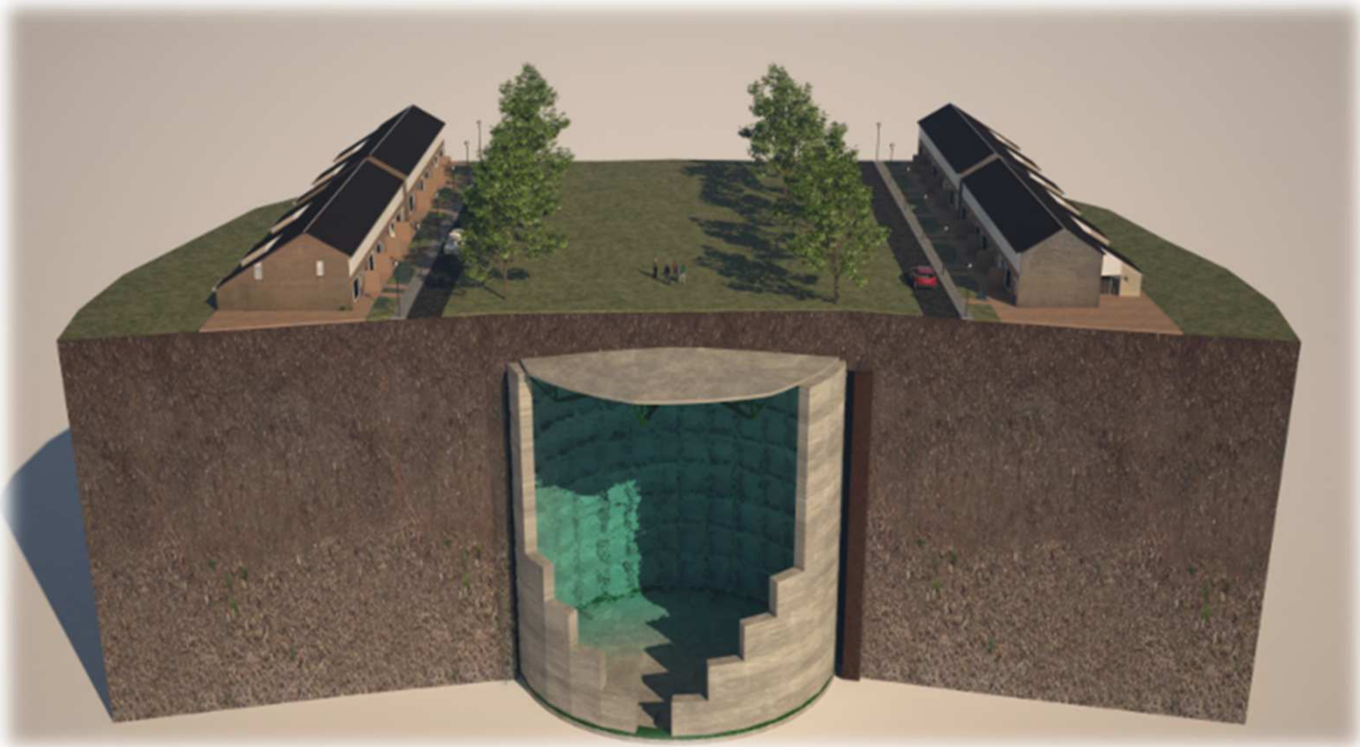
Ecovat Modelling and Control

Contents

- ✓ ***Ecovat Introduction***
- ✓ ***Pilot Site in the Netherlands***
- ✓ ***FHP System***

Ecovat Modelling and Control

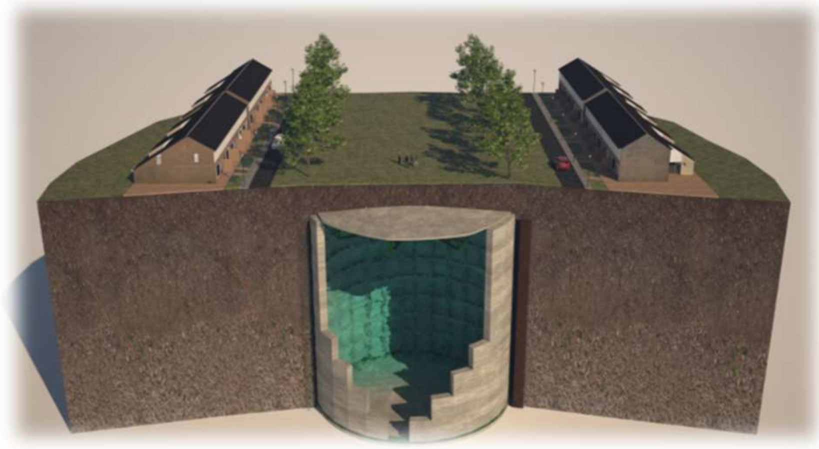
Ecovat Introduction



Ecovat Modelling and Control

Ecovat Introduction

- ✓ ***Ecovat***
  - ✓ ***Thermal energy storage***
  - ✓ ***Heat and cold***
  - ✓ ***Subterranean***



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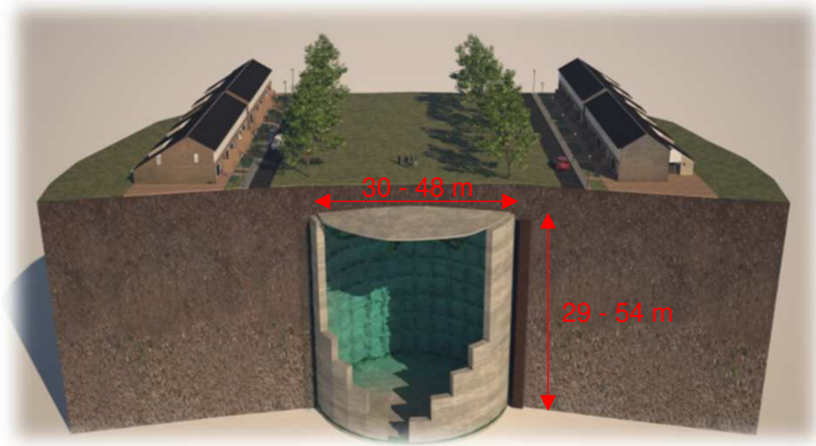
Ecovat Modelling and Control
Ecovat Introduction

- ✓ ***Ecovat***
  - ✓ ***Thermal energy storage***
  - ✓ ***Heat and cold***
  - ✓ ***Subterranean***

  - ✓ ***Diameter: 30 - 48 m***
  - ✓ ***Height: 29 - 54 m***
  - ✓ ***Volume: 20.000 - 100.000 m^3***



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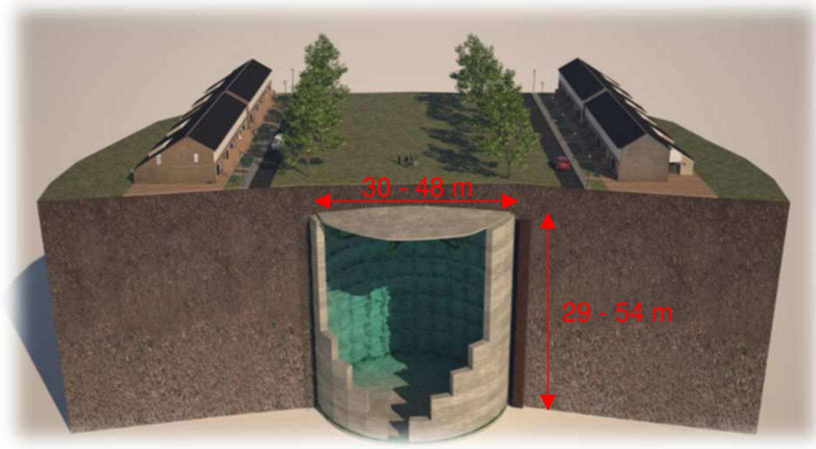
Ecovat Modelling and Control

Ecovat Introduction

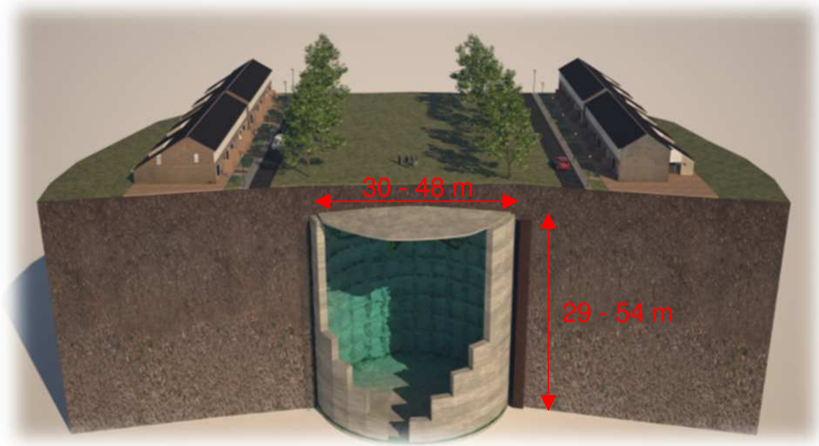
- ✓ ***Ecovat***
  - ✓ ***Temperature: 5 - 95 °C***
  - ✓ ***Efficiency: 90% over 6 months***



Ecovat Modelling and Control
Ecovat Introduction

- ✓ ***Ecovat***
  - ✓ ***Temperature: 5 - 95 °C***
  - ✓ ***Efficiency: 90% over 6 months***

  - ✓ ***Heat capacity: 1,2 - 5,7 GWh***
  - ✓ ***Capacity: > 500 houses***



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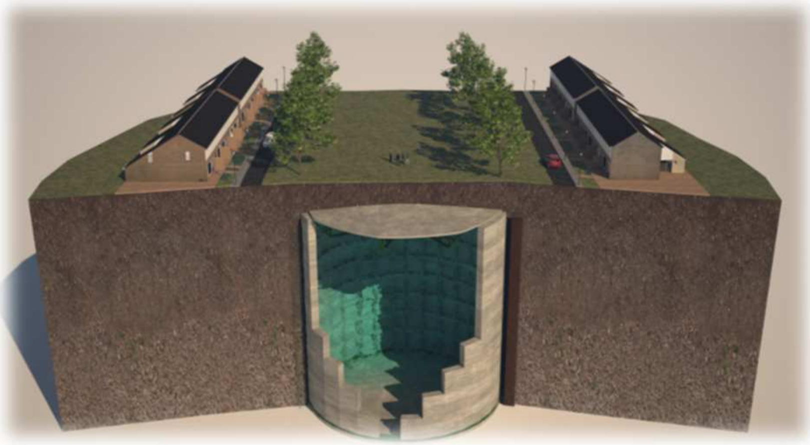
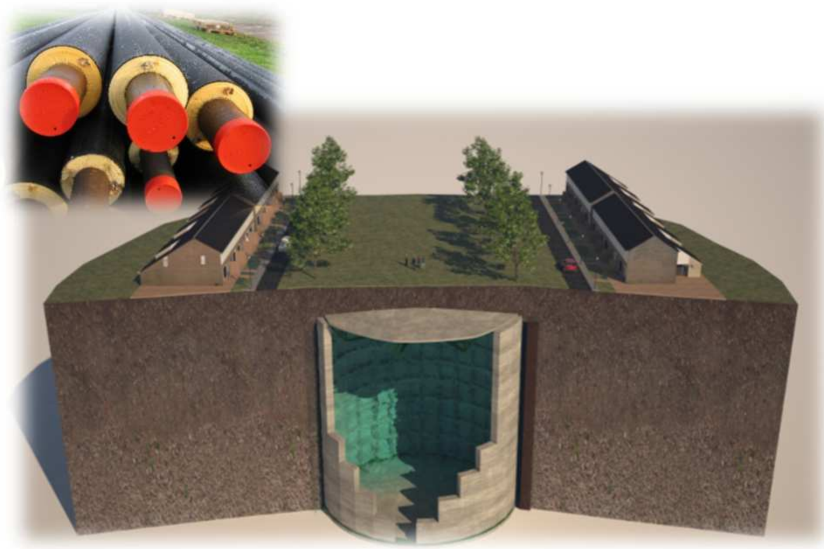
Ecovat Modelling and Control
Ecovat Introduction

- ✓ ***Ecovat Energy System***
  - ✓ ***Not only a Vessel***



Ecovat Modelling and Control
Ecovat Introduction

- ✓ ***Ecovat Energy System***
  - ✓ ***Not only a Vessel***
  - ✓ ***Heating and Cooling Network***



Ecovat Modelling and Control

Ecovat Introduction

- ✓ ***Ecovat Energy System***
  - ✓ ***Not only a Vessel***

  - ✓ ***Heating and Cooling Network***
  - ✓ ***Local Renewable Energy Sources***

Ecovat Modelling and Control

Ecovat Introduction

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  - ✓ ***Local Renewable Energy Sources***
  - ✓ ***Energy Efficient Buildings***

Ecovat Modelling and Control

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  - ✓ ***Control Software***

Ecovat Modelling and Control
Ecovat Introduction

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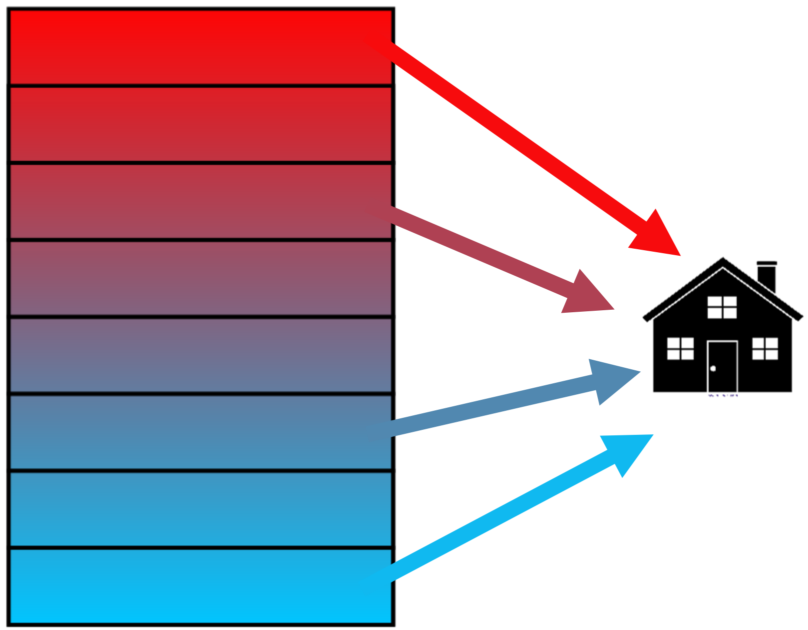
  - ✓ ***Local Renewable Energy Sources***
  - ✓ ***Energy Efficient Buildings***

  - ✓ ***Control Software***
  - ✓ ***Energy Market Interface***

Ecovat Modelling and Control

Ecovat Introduction

- ✓ ***Ecovat***
  - ✓ ***Heating and Cooling***
  - ✓ ***Different Temperatures***



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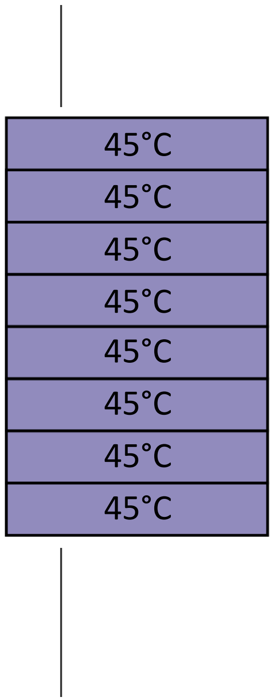
Ecovat Modelling and Control

Ecovat Introduction

- ✓ ***Ecovat***
  - ✓ ***Heating and Cooling***
  - ✓ ***Different Temperatures***

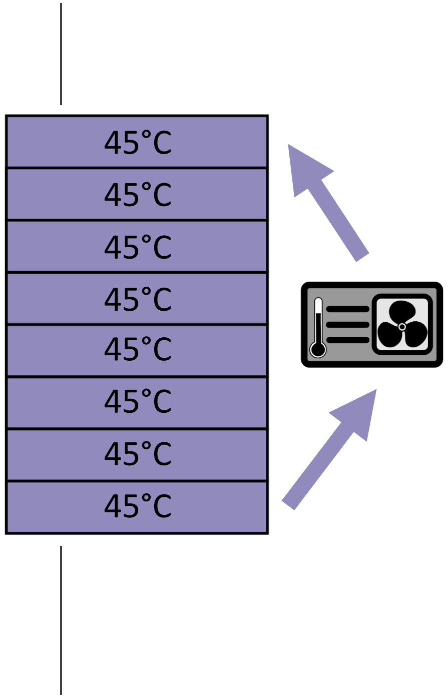
  - ✓ ***Temperature Control***
  - ✓ ***Stratification Control***



Ecovat Modelling and Control
Ecovat Introduction

- ✓ *Ecovat*
  - ✓ *Heating and Cooling*
  - ✓ *Different Temperatures*

  - ✓ *Temperature Control*
  - ✓ *Stratification Control*



Ecovat Modelling and Control
Ecovat Introduction

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  - ✓ ***Different Temperatures***

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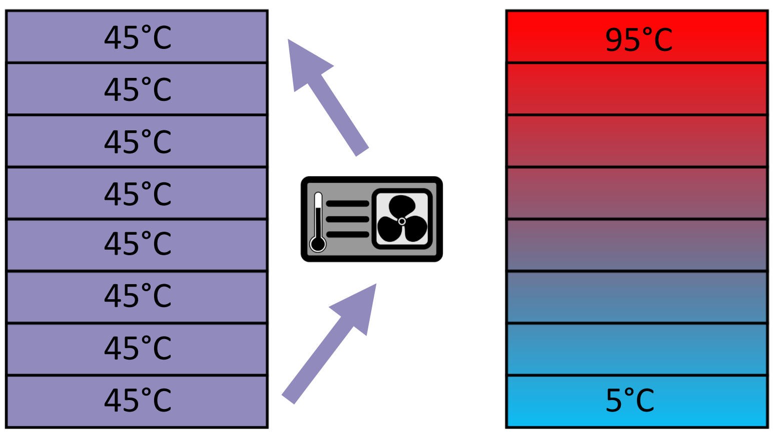
  - ✓ ***Stratification Control***



Ecovat Modelling and Control
Pilot Site in the Netherlands

- ✓ ***Pilot site***
  - ✓ ***Diameter: 11 m***
  - ✓ ***Height: 15,5 m***
  - ✓ ***Layers: 5***

  - ✓ ***Volume: 1500 m³***
  - ✓ ***Heat Capacity: 90 MWh***

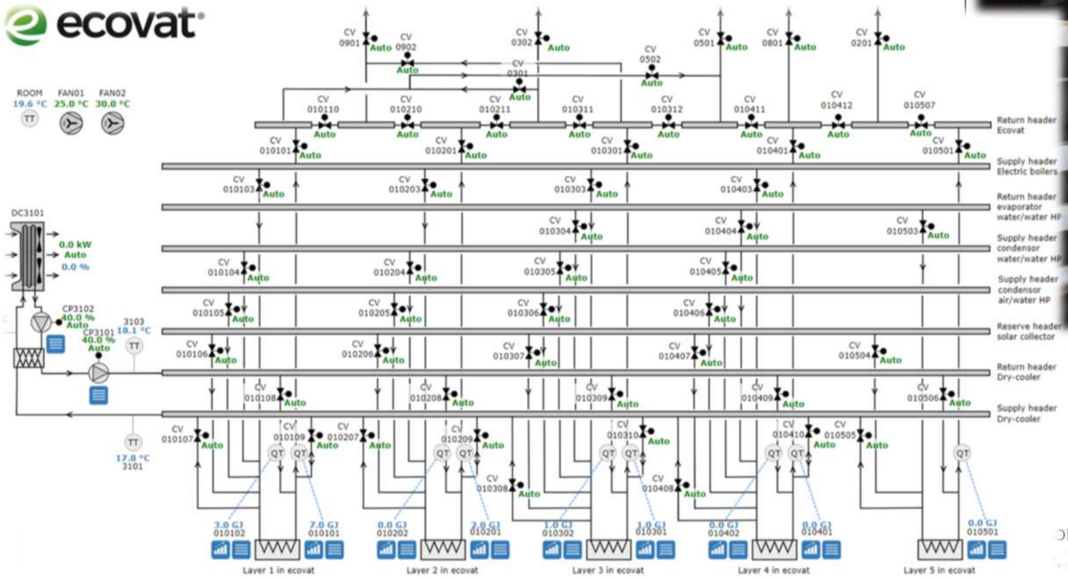
Ecovat Modelling and Control
Pilot Site in the Netherlands

- ✓ ***Pilot site***
  - ✓ ***Resistor***
    - ✓ *6 x 28 kWt = 168 kWt*
  - ✓ ***Air/Water Heat Pump***
    - ✓ *8 kWt*
  - ✓ ***Water/Water Heat Pump***
    - ✓ *6 kWt*

Ecovat Modelling and Control
Pilot Site in the Netherlands

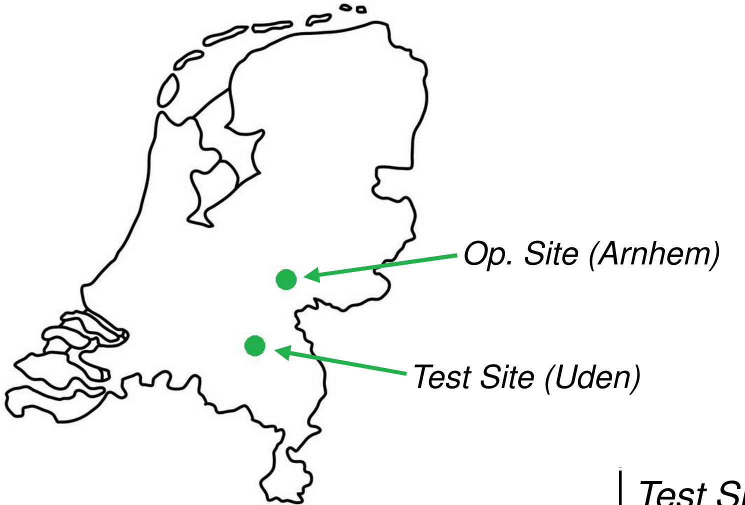
- ✓ ***Pilot site***
  - ✓ ***Valve Matrix***
    - ✓ *58 valves*

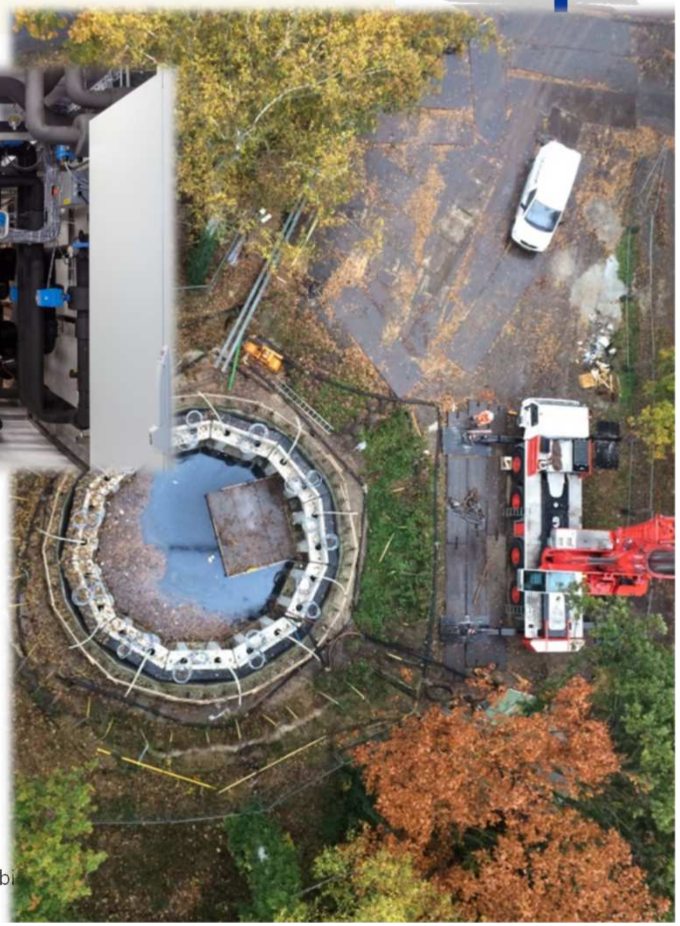
ecovat



Ecovat

Future Operational Site





	Test Site	Operational Site
Volume [m³]	1.500	20.000
Resistor [kW]	168	300
Air Heat Pump [kW]	8	630
Water Heat Pump [kW]	6	400
Connected Houses	0	500

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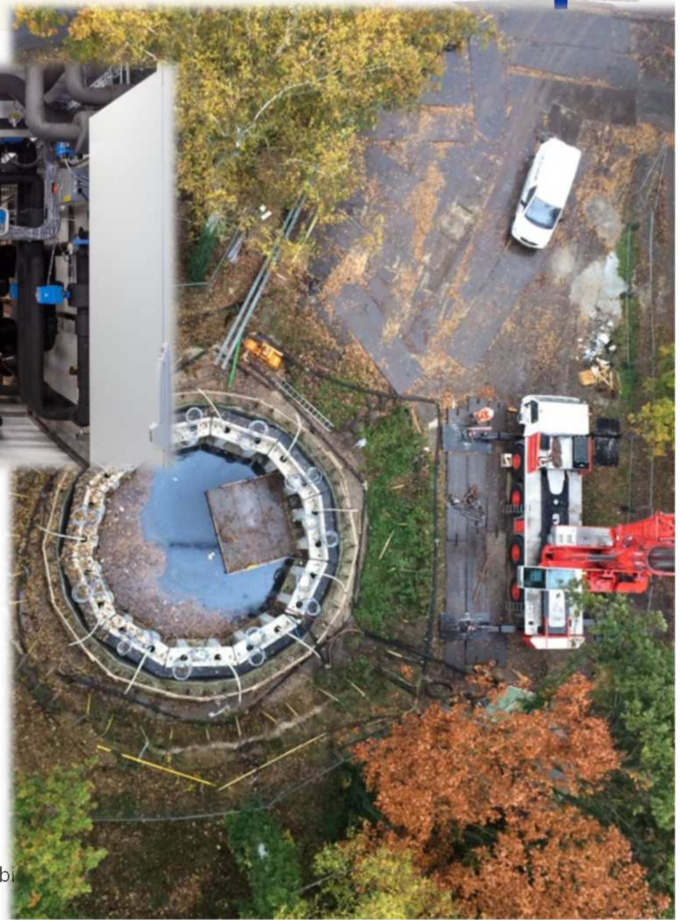
Ecovat
Future Operational Site

- ✓ ***Test Site:***
  - ✓ ***Thermal Efficiency Validated***
- ✓ ***Operational Site:***
  - ✓ ***Start Build in Q2 2019***
  - ✓ ***500 Houses***



	Test Site	*Operational Site*
Volume [m³]	*1.500*	*20.000*
Resistor [kW]	*168*	*300*
Air Heat Pump [kW]	*8*	*630*
Water Heat Pump [kW]	*6*	*400*
Connected Houses	*0*	*500*

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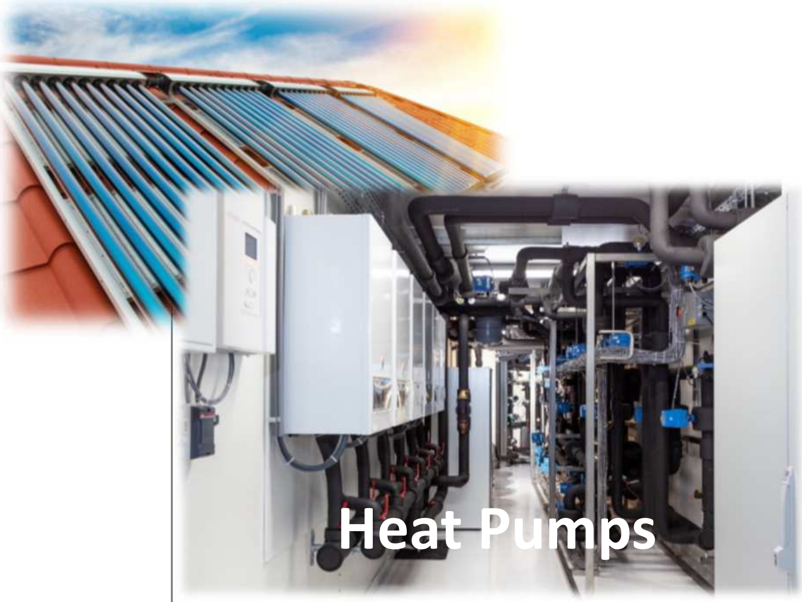
Ecovat Modelling and Control
Ecovat and renewable generation

- ✓ ***Sources***
  - ✓ ***Local***
    - ✓ *Renewable Energy Sources*

Ecovat Modelling and Control

Ecovat and renewable generation

- ✓ ***Sources***
  - ✓ ***Local***
    - ✓ *Renewable Energy Sources*
  - ✓ ***Exchange Market***
    - ✓ *Day-Ahead*
    - ✓ *Intraday Market*



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Ecovat Modelling and Control

Ecovat and renewable generation

- ✓ ***Sources***
  - ✓ ***Local***
    - ✓ *Renewable Energy Sources*
  - ✓ ***Exchange Market***
    - ✓ *Day-Ahead*
    - ✓ *Intraday Market*
  - ✓ ***Imbalance Market***

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Ecovat Modelling and Control
Ecovat and renewable generation

- ✓ ***Services***
  - ✓ ***High Power/Storage Capacity***
  - ✓ ***Balancing Services***
  - ✓ ***Long Term***
  - ✓ ***Short Term***

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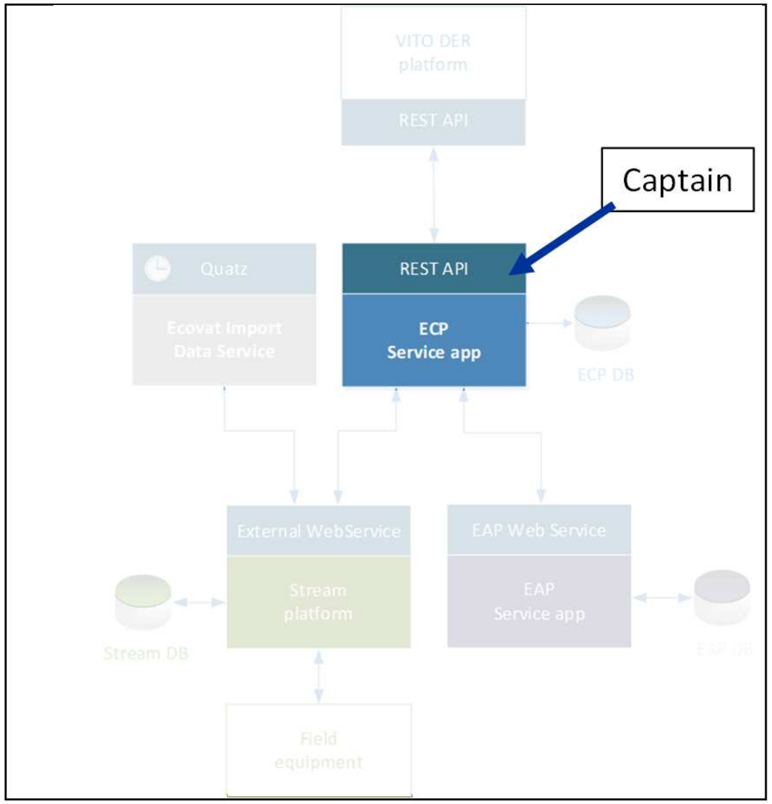
Ecovat Modelling and Control

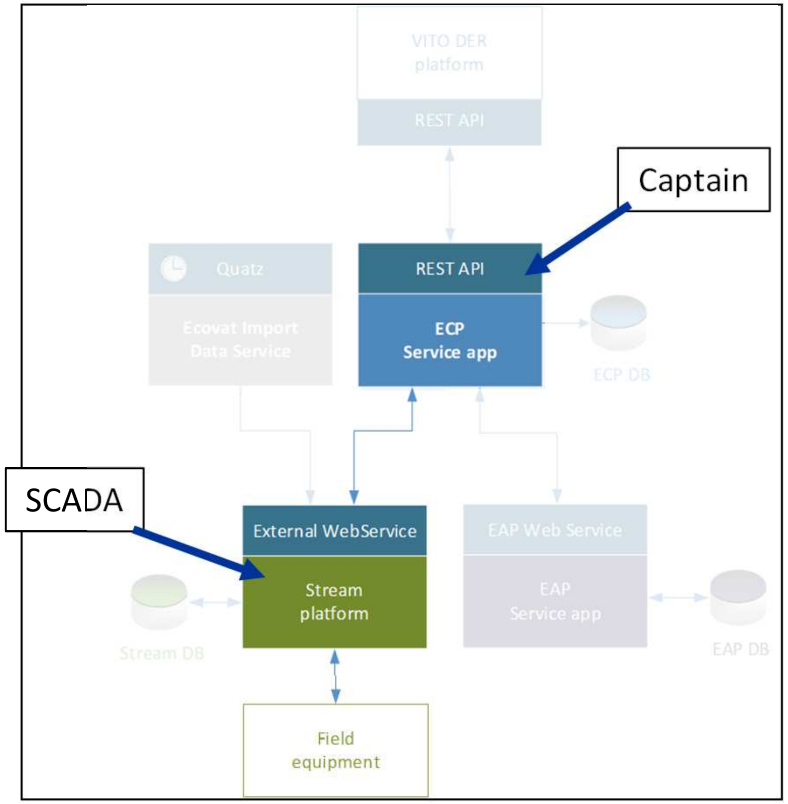
Ecovat and the FHP System

- ✓ ***Software Components***
  - ✓ ***Ecovat Control Program (ECP)***
    - ✓ *Captain, communicates with FHP aggregator (DCM)*



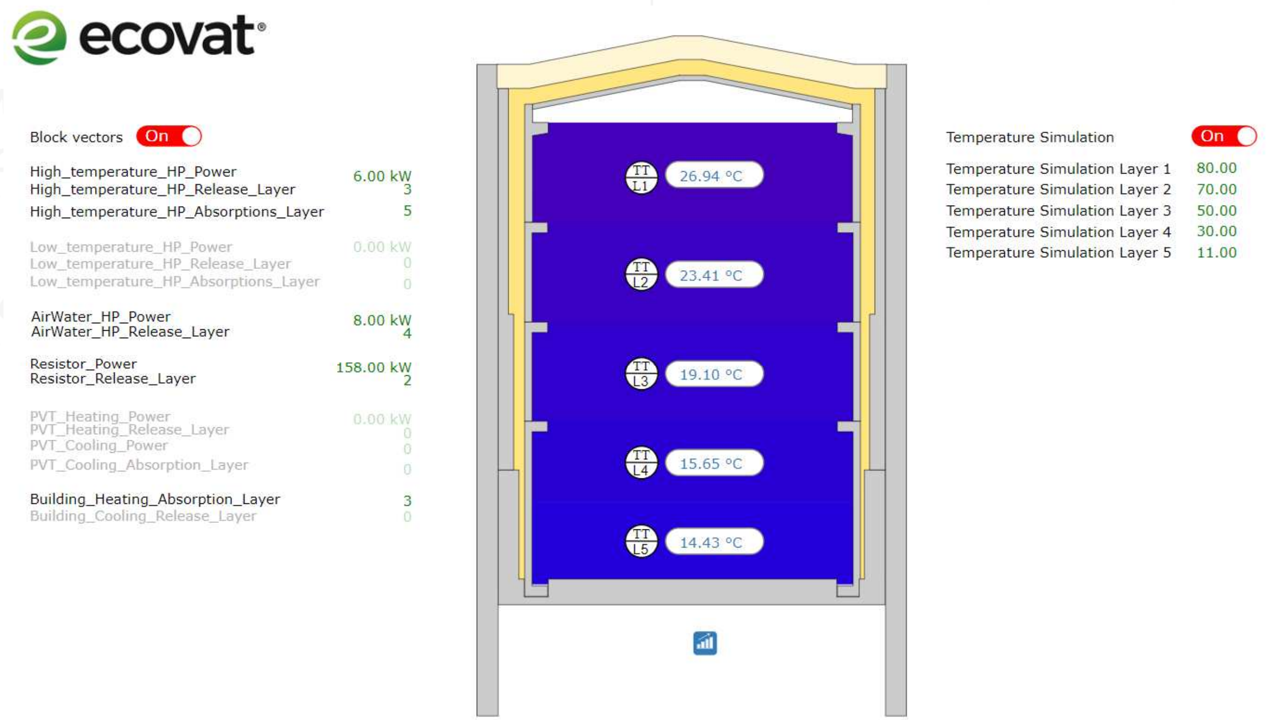
Ecovat Modelling and Control
Ecovat and the FHP System

- ✓ ***Software Components***
  - ✓ ***Ecovat Control Program (ECP)***
    - ✓ *Captain, communicates with FHP aggregator (DCM)*
  - ✓ ***Stream***
    - ✓ *SCADA, communicates with field equipment*



Ecovat Modelling and Control

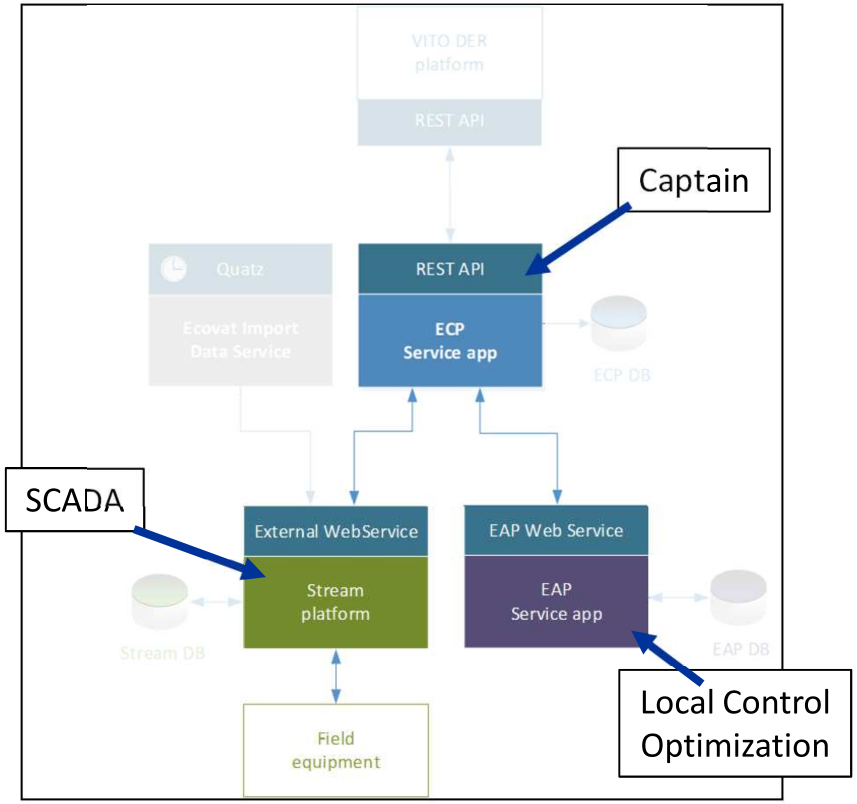
Ecovat and the FHP System



Ecovat Modelling and Control

Ecovat and the FHP System

- ✓ ***Software Components***
  - ✓ ***Ecovat Control Program (ECP)***
    - ✓ *Captain, communicates with FHP aggregator (DCM)*
  - ✓ ***Stream***
    - ✓ *SCADA, communicates with field equipment*
  - ✓ ***Ecovat Advice Program (EAP)***
    - ✓ *Local Control Optimization, answers to ECP*



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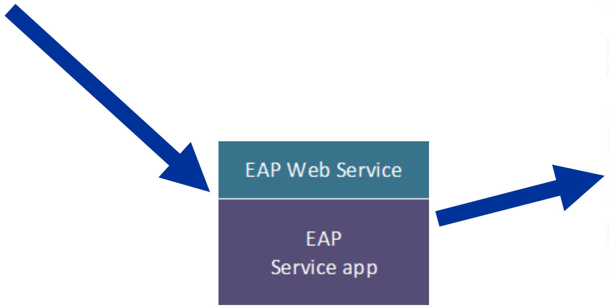
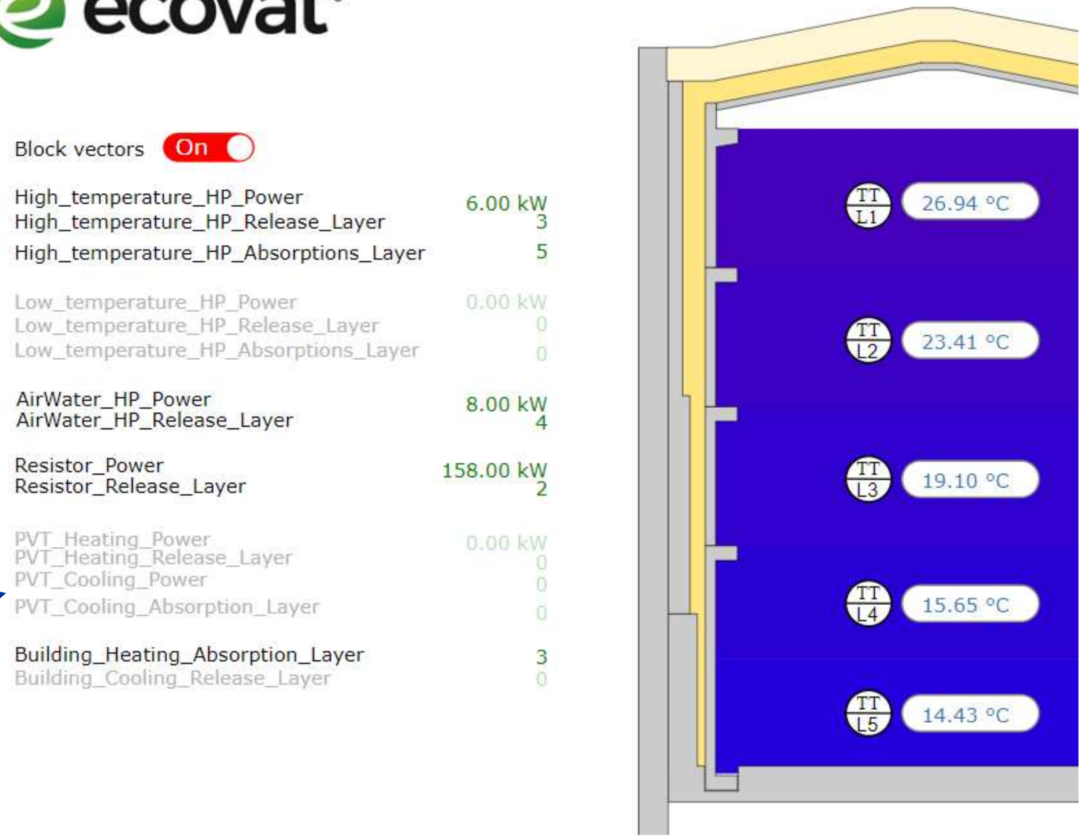
Ecovat Modelling and Control

Subsection title

ecovat

- ✓ ***Energy Price?***
- ✓ ***State of Charge?***
- ✓ ***Date?***
  - ✓ ***Summer: Low Demand***
  - ✓ ***Winter: High Demand***





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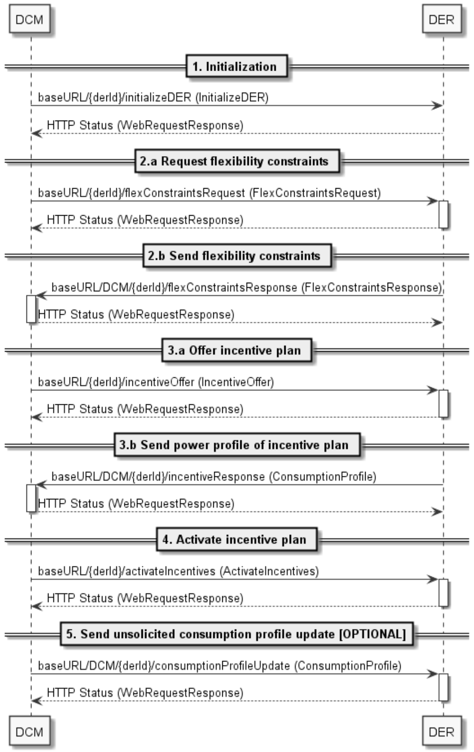
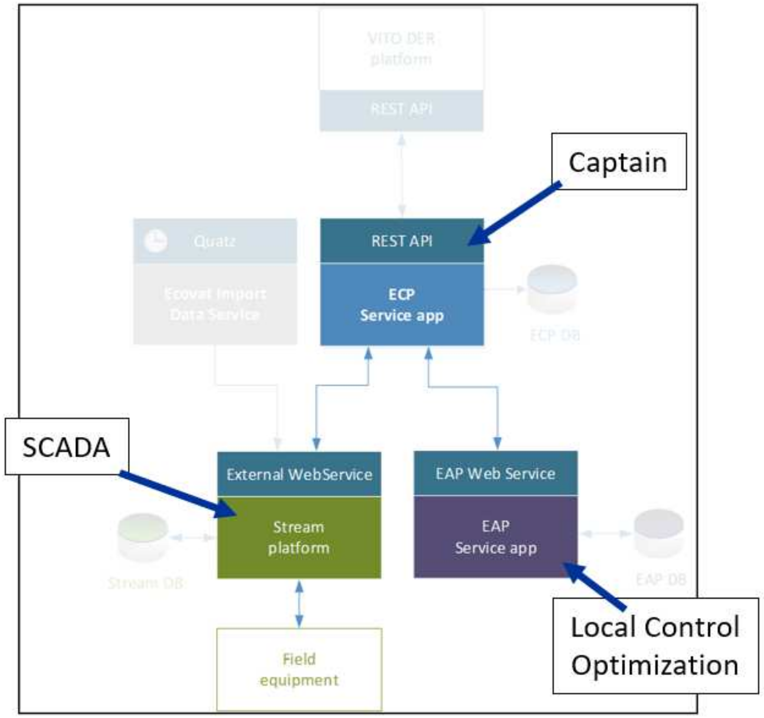
Ecovat Modelling and Control

Ecovat and the FHP System





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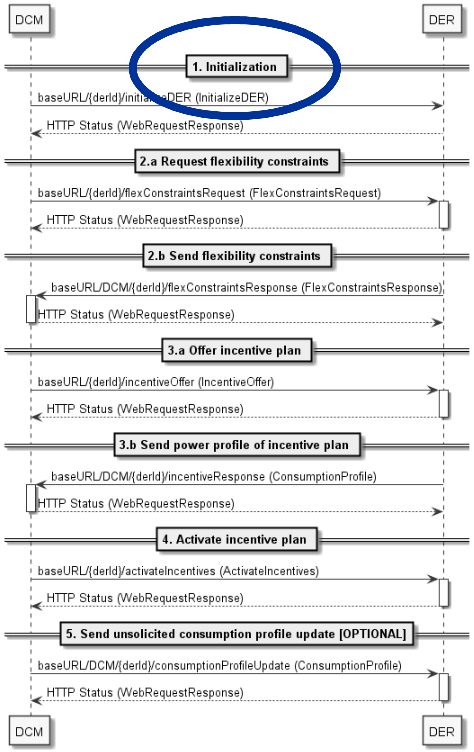
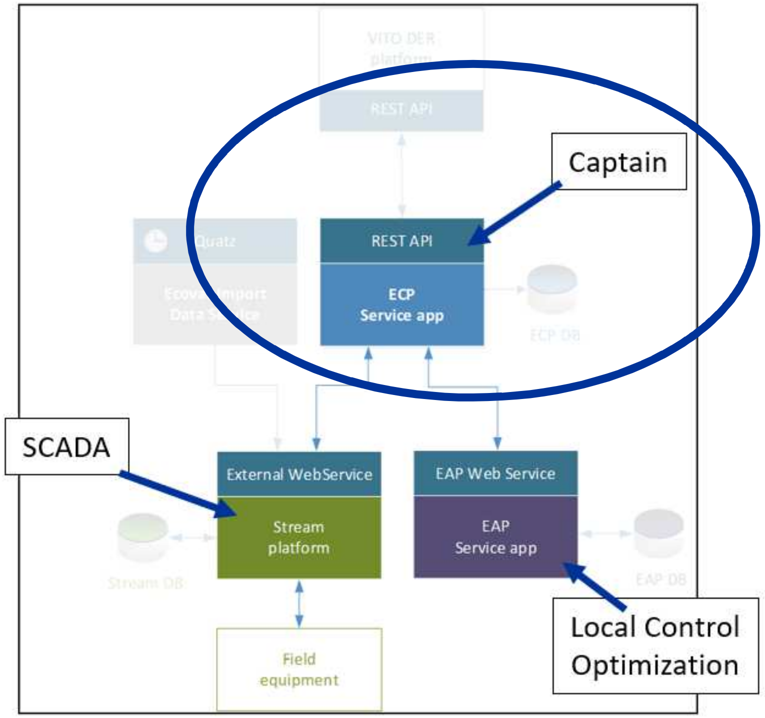
Ecovat Modelling and Control

Ecovat and the FHP System





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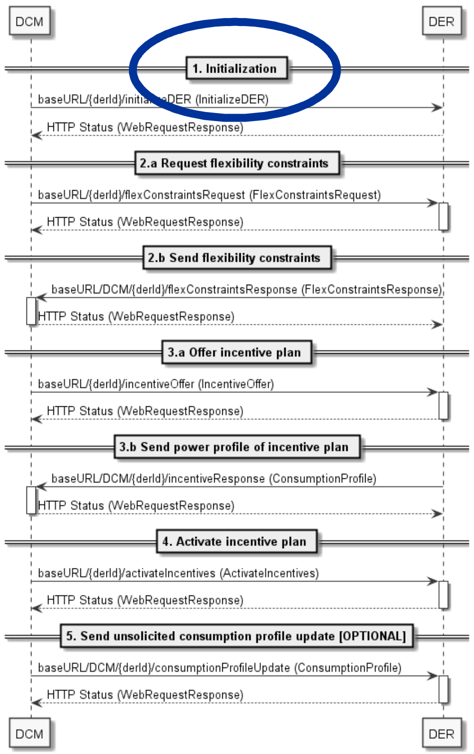
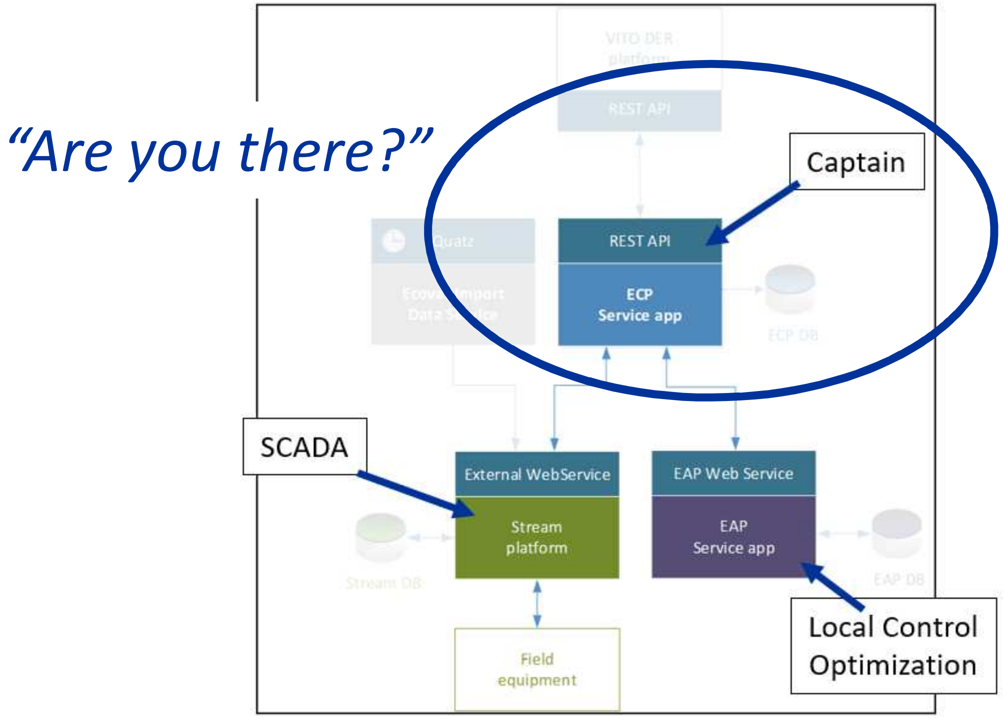
Ecovat Modelling and Control

Ecovat and the FHP System





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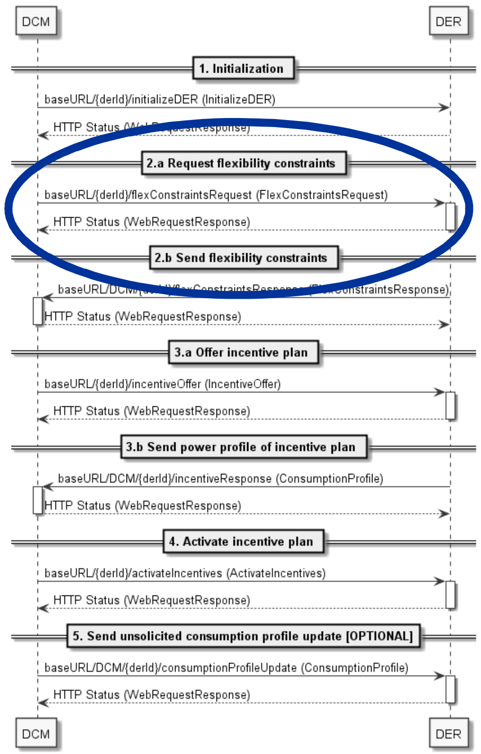
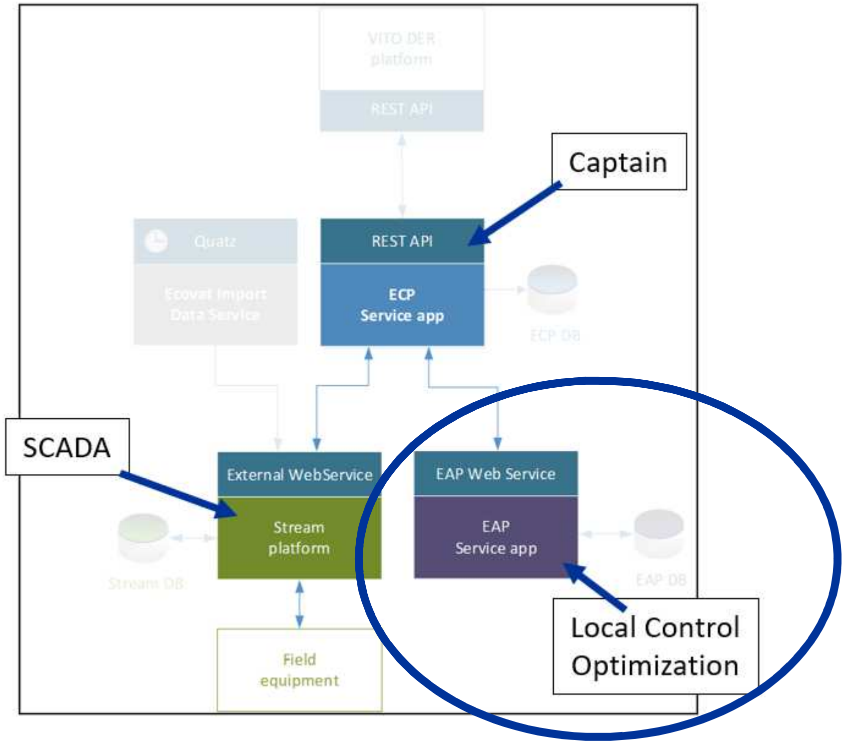
Ecovat Modelling and Control

Ecovat and the FHP System





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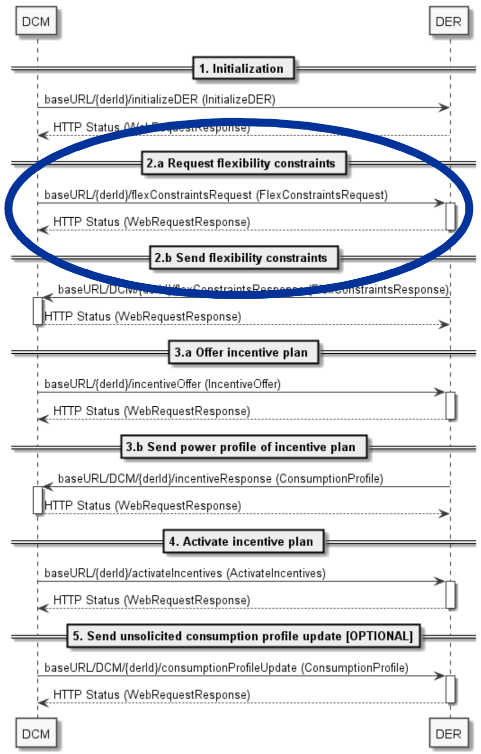
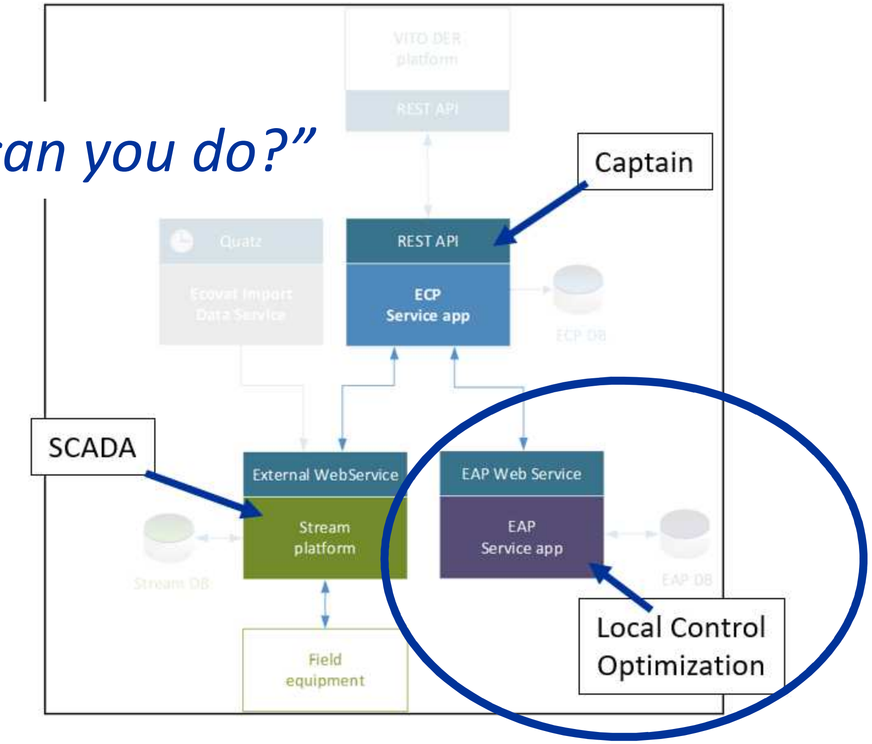
Ecovat Modelling and Control

Ecovat and the FHP System



"What can you do?"



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Ecovat Modelling and Control

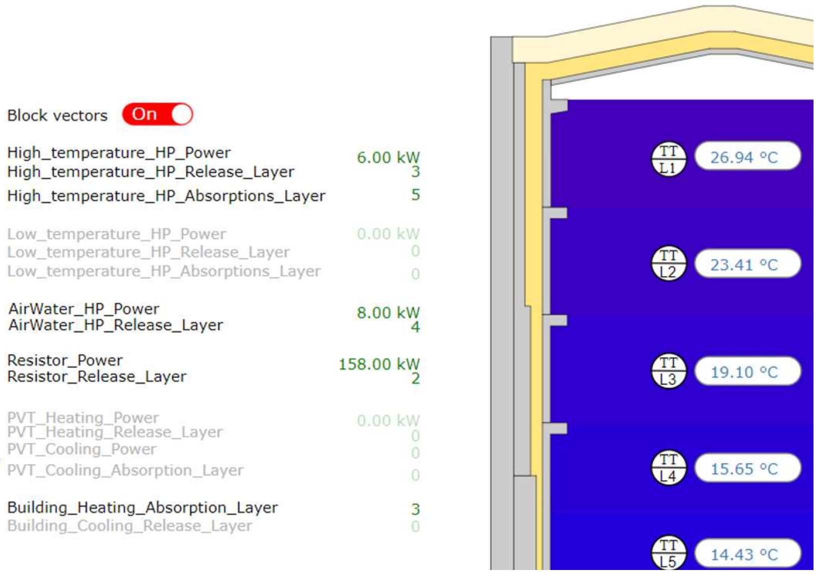
Ecovat and the FHP System

For Lower Bound: Extremly High Price
For Upper Bound: Extremely Low Price

Actual SOC

Now

- ✓ ***Energy Price?***
- ✓ ***State of Charge?***
- ✓ ***Date?***
  - ✓ ***Summer: Low Demand***
  - ✓ ***Winter: High Demand***



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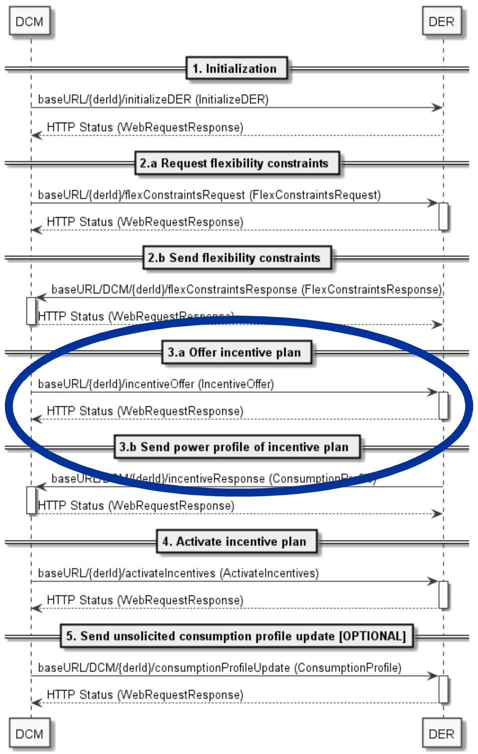
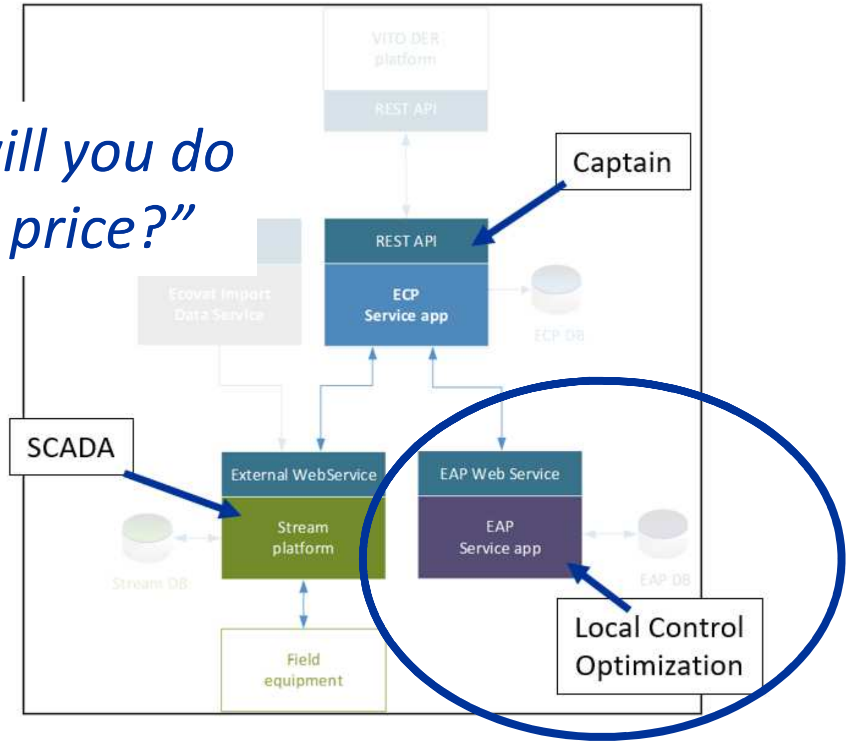
Ecovat Modelling and Control
Ecovat and the FHP System



"What will you do for this price?"



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Ecovat Modelling and Control

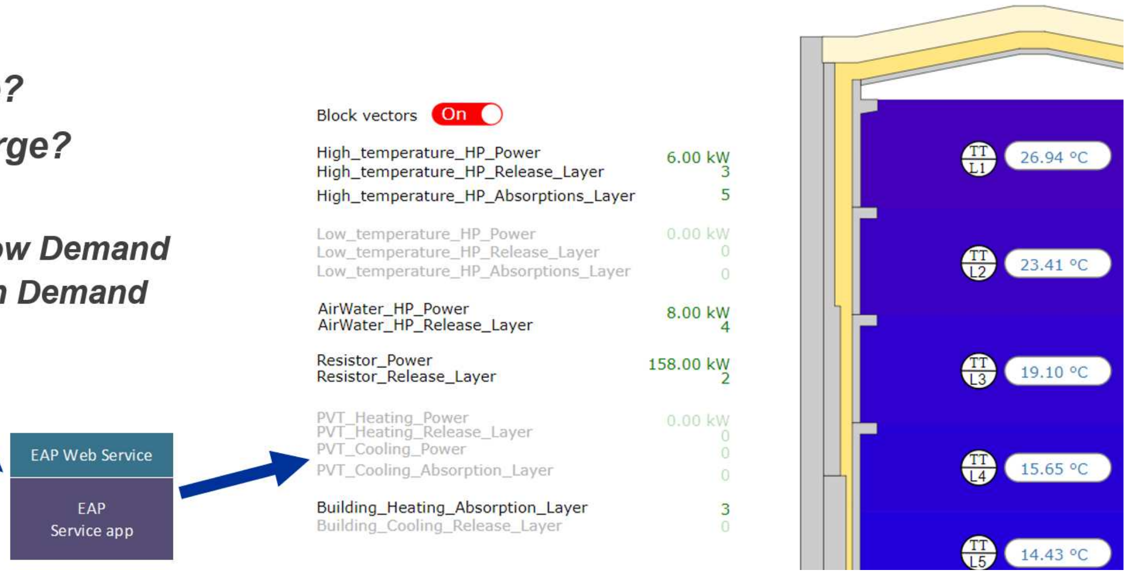
Ecovat and the FHP System

Incentive Price

Actual SOC

Now

- ✓ *Energy Price?*
- ✓ *State of Charge?*
- ✓ *Date?*
  - ✓ *Summer: Low Demand*
  - ✓ *Winter: High Demand*



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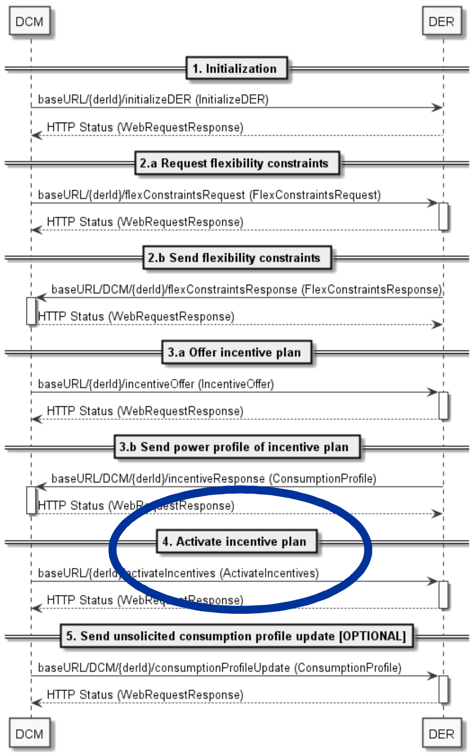
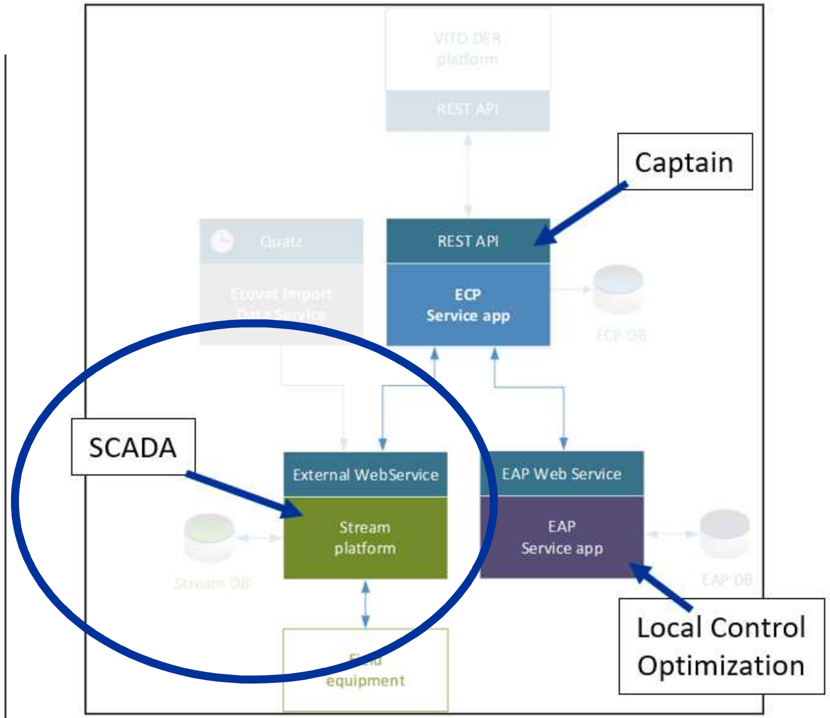
Ecovat Modelling and Control

Ecovat and the FHP System





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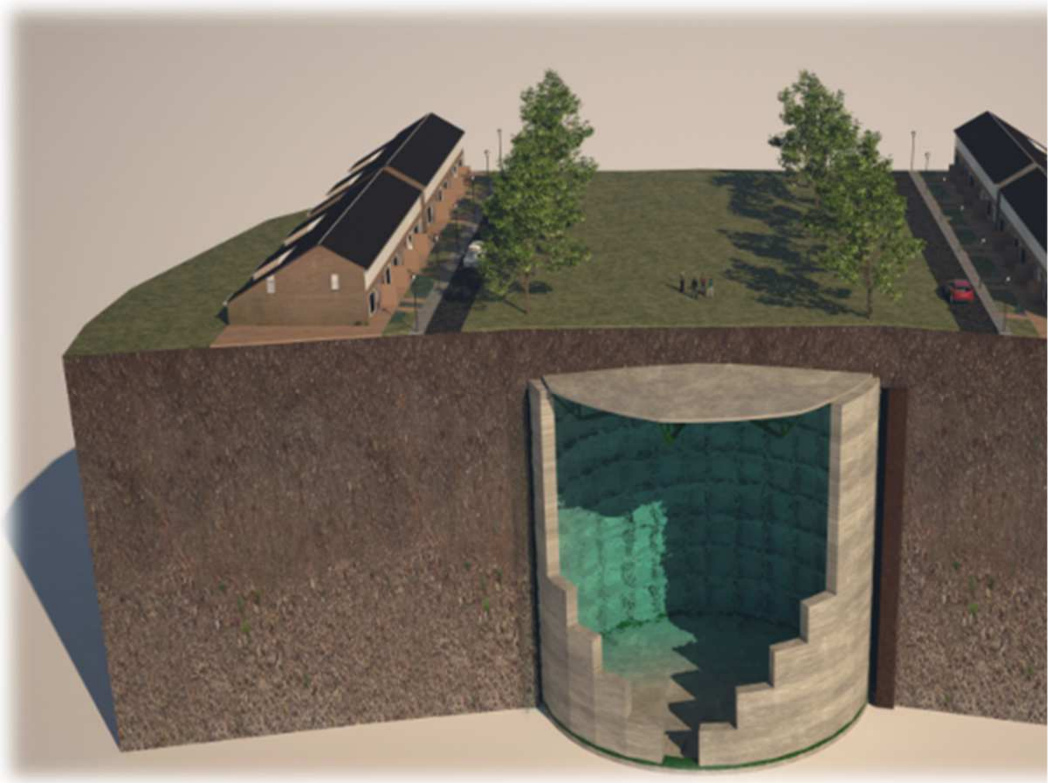
Ecovat Modelling and Control
Ecovat and the FHP System

- ✓ *Ecovat*
  - ✓ *Conversion and Storage Hub in Multi-Carrier Energy Systems*
  - ✓ *Not only Seasonal Storage of Heat and Cold*
  - ✓ *Offers Balancing Services*
  - ✓ *Prevents (Wind) Curtailment*



ecovat

Europese Unie

OPoost
operationeel programma oost

Europees Fonds voor Regionale Ontwikkeling

De hieronder genoemde activiteiten worden mede mogelijk gemaakt door de Europese Unie

Kijk voor meer informatie over het subsidie-programma op:

www.op-oost.eu

ecovat

Ecovat Software 2.0–2.2

- Centrale sturing voor het Ecovat -

Ecovat heeft een prototype gerealiseerd van een Ecovat thermisch opslagvat (hardware-1.0) met een softwarematig besturingssysteem (software-1.0).

In dit project wordt deze software doorontwikkeld met (1) focus op professionalisering van software en IT-infrastructuur, (2) beheer(s)baar maken van de daily-operations van de assets en (3) onderzoek naar (toepassing op) internationale markten, High Frequency Trading en Hoge Temperatuuropslagsystemen.

EFRO

Het operationeel programma (OP) EFRO Oost-Nederland is een gezamenlijk subsidieprogramma van de provincies Overijssel en Gelderland en werkt aan structurele versterking van de economie. Oost-Nederland zet de EFRO-middelen in op innovatiestimulering en koolstofarme economie. Het doel is dat meer Oost-Nederlandse MKB-bedrijven meer omzet halen uit nieuwe producten.

Thanks for your attention

wiet.mazairac@ecovat.eu

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5.7 Annex 3.7. DSO Optimal Flexibility Dispatch. Shahab Shariat

DSO Optimal Flexibility Dispatch

Workshop on FHP wind curtailment mitigation solution

Shahab Shariat Torbaghan - VITO

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DSO Optimal Flex Dispatch

Goal

- ✓ Solve challenges caused by increasing share of intermittent RES
- ✓ Use flexibility from assets connected to the distribution grid
- ✓ Activate flexibility in an optimal and grid-secure manner

➡ **Location-aware flexibility activations**

- ✓ Grid is no copper plate
- ✓ Location-aware activations of flexibility will not cause grid problems
- ✓ Location-aware activations make optimal use of available assets and available grid infrastructure and capacity

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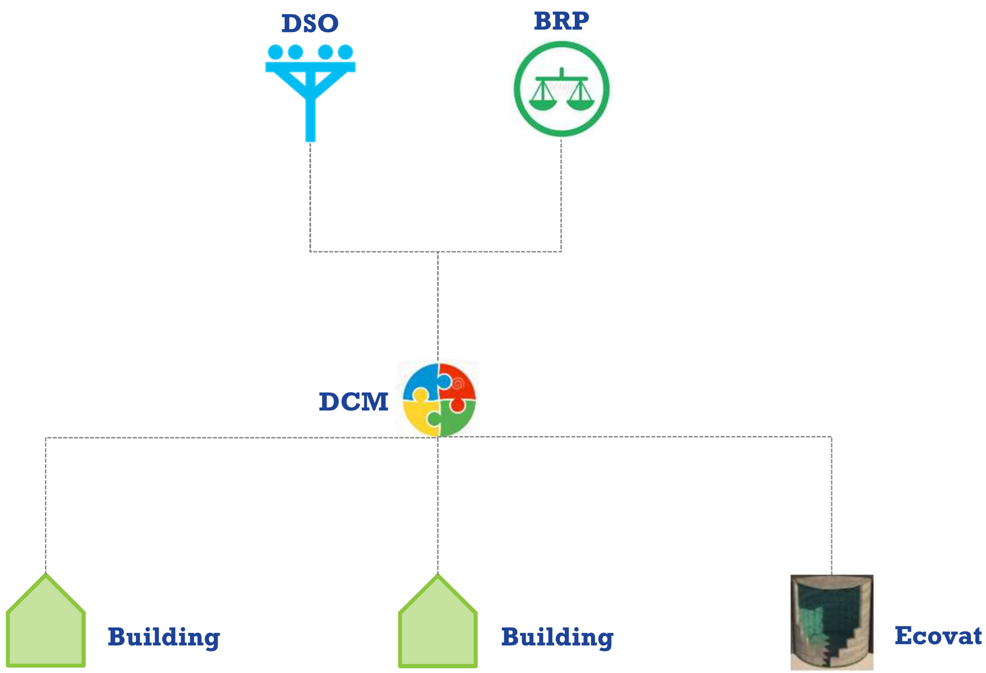
DCM

Multi-agent platform



1: https://www.usef.energy/

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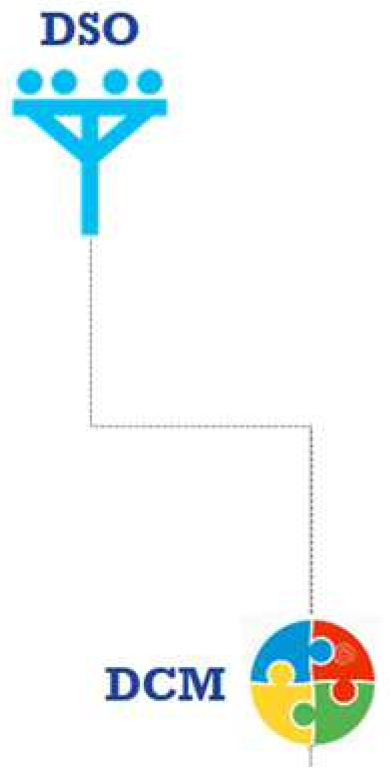
Role of the DSO

2 use cases investigated:

1. Provide **dynamic operational boundaries** (i.e. a safe band) for a DCM so that grid limitations are not violated.

2. Provide an **optimal grid-secure flex activation profile** for a DCM.



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Option 1: Adaption of operational boundaries of DCM

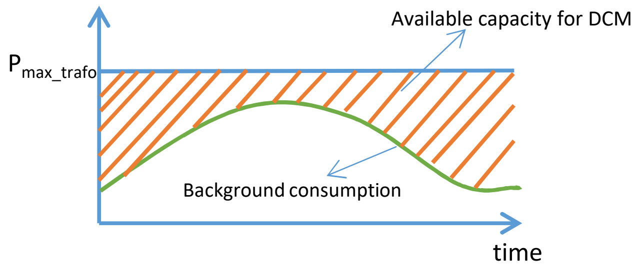
- DSO provides 'safe band' for flex activations.
  - ✓DCM activations are grid secure when within safe band

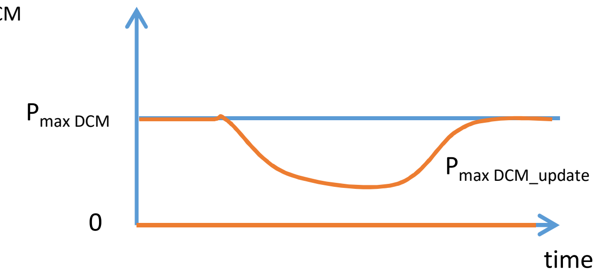
- Used when the grid limitations are capacity limits at the substation level :
  - ✓Substation investments or upgrades are avoided when a large new installation with flexibility is installed.
  - ✓New assets are granted access to the grid, without the need to wait for grid upgrades
  - ✓Better use of available grid capacity

Note! Calculation can only been done when 1 DCM involved in assessment.

Option 1. Dynamic Operational Boundaries

- Information flow:
  – DSO has an indication of the ‘background’ consumption/production on the substation
  – DSO reviews and if needed adjusts flex boundaries of DCM





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Option 2. Optimal Flexibility Dispatch

- DSO determines optimal flexibility activation plan
  - Taking into account available/forecasted flexibility from DCMs
  - Taking into account voltage limits at all nodes in the network, and all current limits through all branches in the network
  - Possible objective: minimal RES curtailment, minimal losses, minimal flex utilization, …
  - The Optimal Flex Dispatch for each DCM respects the available flexibility boundaries of each DCM

OFD Formulation

- Objective Function
- S.t.
  - Voltage bounds
  - Apparent power (relaxed)
  - Flexibility and power bounds
  - Ohm's law defining power flows
  - Flow limits
  - Power balance

$$
\begin{aligned}
(\epsilon^{p}_{i,j,t}): \quad p_{i,j,t} = {} & \left(g^{sh}_{i,j} + g^{s}_{i,j}\right)/t^{m}_{i,j} \cdot w_{i,t} \\
& - \left(g^{s}_{i,j} \cdot t^{k}_{i,j} - b^{s}_{i,j} \cdot t^{i}_{i,j}\right)/t^{m}_{i,j} \cdot w^{r}_{i,j,t} \\
& - \left(b^{s}_{ij} \cdot t^{k}_{i,j} + g^{s}_{i,j} \cdot t^{i}_{i,j}\right)/t^{m}_{i,j} \cdot w^{i}_{i,j,t},
\end{aligned}
$$

$$(\underline{\phi^{w}_{i,t}}, \overline{\phi^{w}_{i,t}}): \quad \underline{w_{i,t}} \leq w_{i,t} \leq \overline{w_{i,t}}, \; i \in \Omega_N, t \in \Omega_t \qquad (2)$$

$$(\underline{\phi^{r}_{i,j,t}}, \overline{\phi^{r}_{i,j,t}}): \quad \underline{w^{r}_{i,j,t}} \leq w^{r}_{i,j,t} \leq \overline{w^{r}_{i,j,t}}, \; (i,j) \in \Omega_E, t \in \Omega_t \qquad (3)$$

$$(\underline{\phi^{i}_{i,j,t}}, \overline{\phi^{i}_{i,j,t}}): \quad \underline{w^{i}_{i,j,t}} \leq w^{i}_{i,j,t} \leq \overline{w^{i}_{i,j,t}}, \; (i,j) \in \Omega_E, t \in \Omega_t \qquad (4)$$

$$
\begin{aligned}
(\epsilon^{p}_{j,i,t}): \quad p_{j,i,t} = {} & \left(g^{s}_{i,j} + g^{sh}_{i,j}\right) \cdot w_{j,t} \\
& - \left(g^{s}_{i,j} \cdot t^{k}_{i,j} + b^{s}_{i,j} \cdot t^{i}_{i,j}\right)/t^{m}_{i,j} \cdot w^{r}_{i,j,t}
\end{aligned}
$$

$$
\begin{aligned}
(\lambda^{p}_{i,t}): \quad & \sum_{(i,j)\in\Omega_E} p_{i,j,t} - \sum_{(i,j)\in\Omega_{E^r}} p_{i,j,t} = \sum_{g\in\Omega_{G_i}} p^{g}_{i,t} - \sum_{d\in\Omega_{D_i}} p^{d}_{i,t} \\
& - g^{sh}_{i} \cdot w_{i,t}, \qquad i \in \Omega_N, t \in \Omega_t \qquad (16)
\end{aligned}
$$

$$
\begin{aligned}
(\lambda^{q}_{i,t}): \quad & \sum_{(i,j)\in\Omega_E} q_{i,j,t} \sum_{(i,j)\in\Omega_{E^r}} q_{i,j,t} = \sum_{g\in\Omega_{G_i}} q^{g}_{i,t} - \sum_{d\in\Omega_{D_i}} q^{d}_{i,t} \\
& + b^{sh}_{i} \cdot w_{i,t}, \qquad i \in \Omega_N, t \in \Omega_t \qquad (17)
\end{aligned}
$$

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Case study 1

Ecovat: safe operational boundaries

- Connected to substation with dedicated feeder
- Upgrade of substation required to host nominal capacity Ecovat

What are the operational boundaries of ECOVAT so that there is no need for a substation upgrade?

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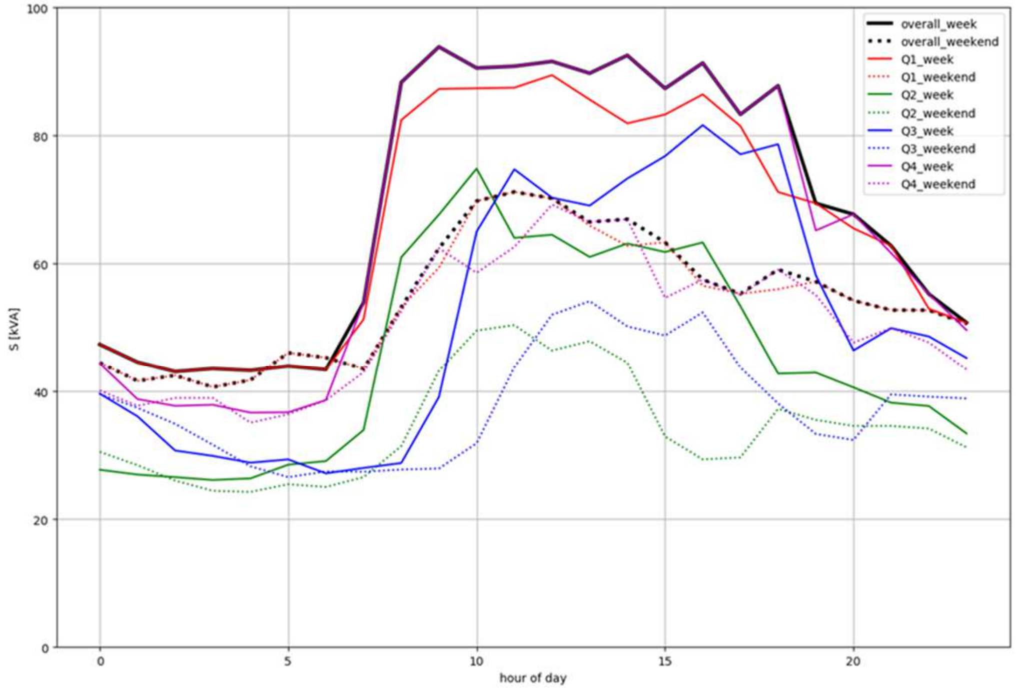
Case study 1

Background consumption at substation?

- Maximal background consumption varies:
  - Week-weekend
  - Seasonal



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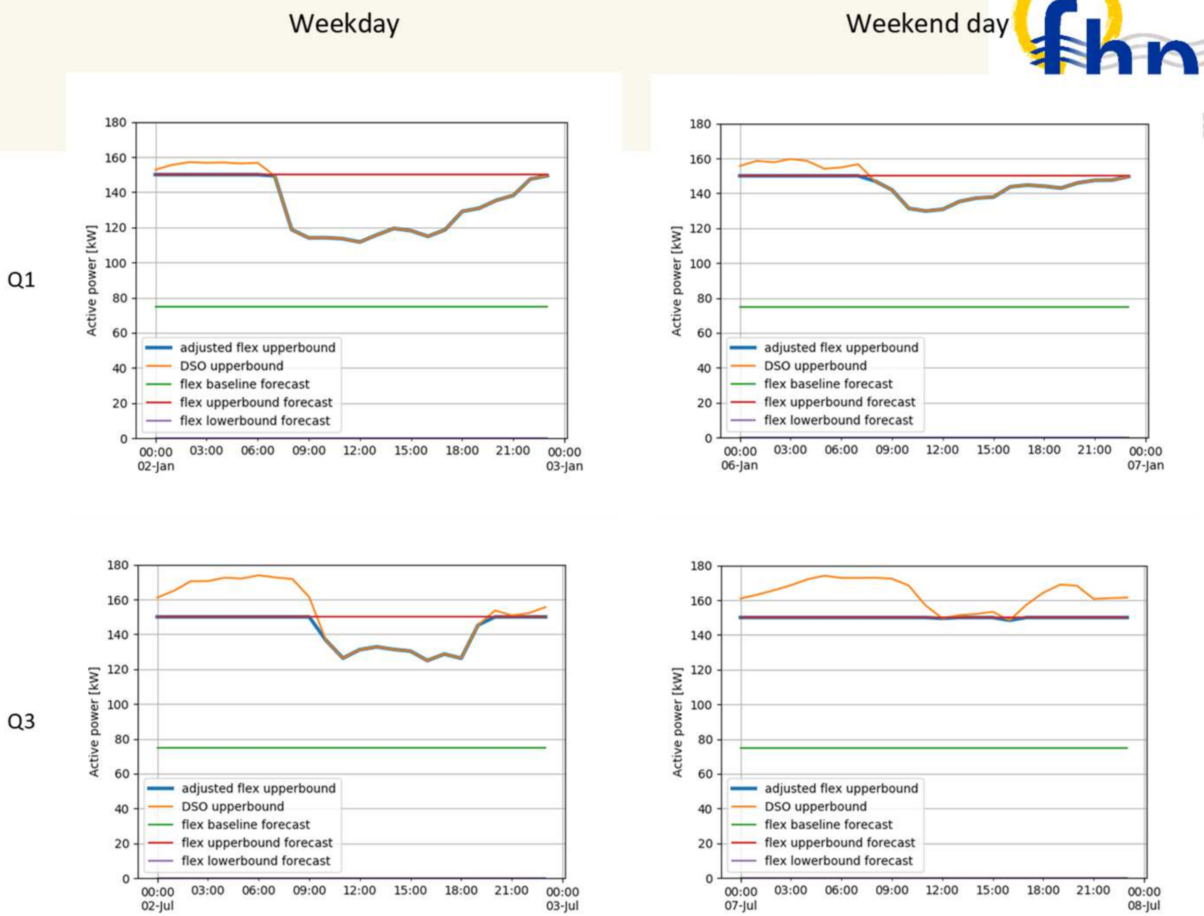
Case study 1

Adjusted flexbounds

- Adjustment depends on:
  - Week-weekend day
  - Season

➡ Flexbounds for ECOVAT to prevent substation investments.



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Case study 2

Ecovat: optimal flexibility dispatch

- What if ECOVAT is connected to an existing feeder?

➡ What is the optimal flexibility activation plan for ECOVAT within the existing feeder?

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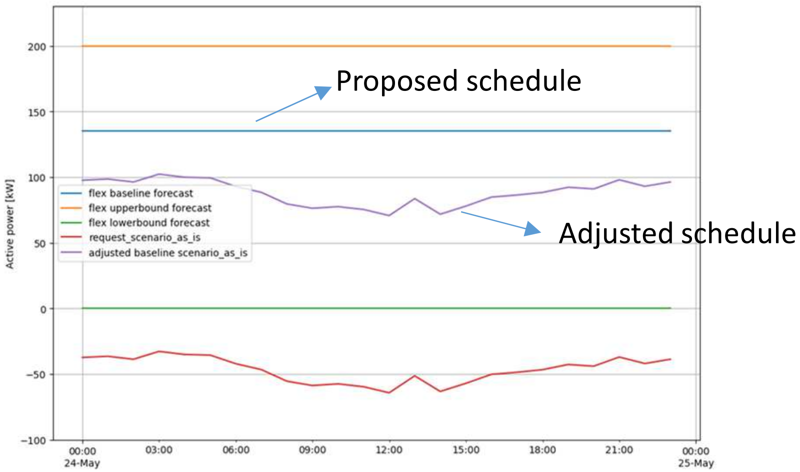
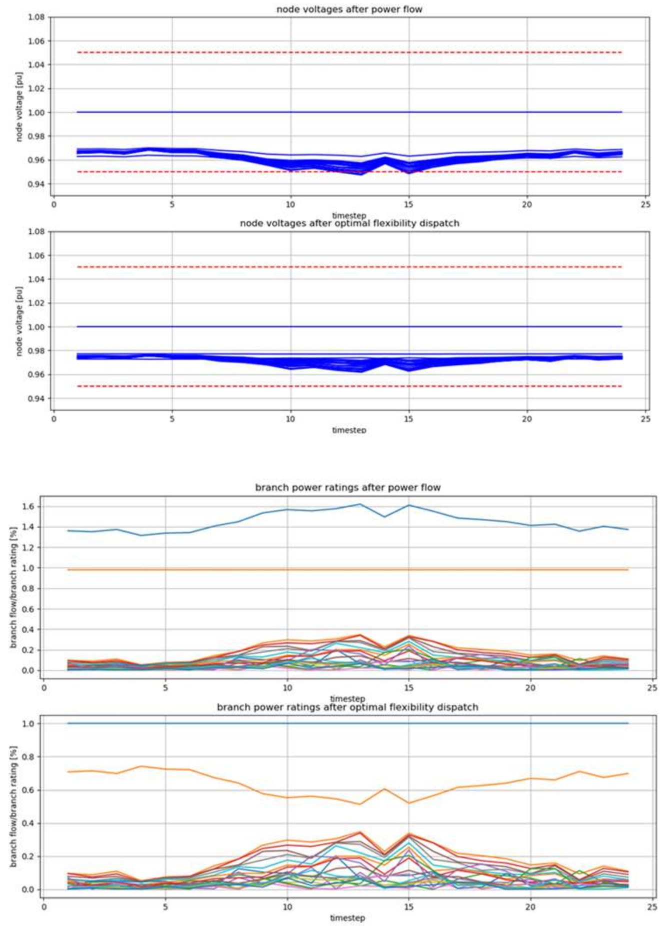
Case study 2

Optimal flexibility dispatch

- DSO optimizes operational schedule of ECOVAT





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Conclusions

2 options to fill in role of DSO in Optimal Flexibility Dispatch:

Option 1: DSO sets the constraints

- benefits
  - straightforward, easy to implement
  - not so far from current practice
- restrictions
  - only one DCM

Option 2: DSO advises use of flexibility

- Benefits
  - multiple DCMs
- restrictions
  - more complex implementation
  - requires an evolution in the role of the DSO: passive → active

Conclusions

Optimal flexibility dispatch

- Enabling DSO to coordinate the utilization of flexibility allows for:
  - \+ Avoided substation/feeder investments or upgrades when a new installation with flexibility is installed.
    - ➔ decrease of network-related costs
  - \+ New assets are granted access to the grid, without the need to wait for grid upgrades.
    - ➔ existing grid capacity does not block introduction in the market of new assets.
  - \+ Better use of available grid capacity
    - ➔ Increase of social welfare

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5.8 Annex 3.8. Application of genetic algorithms for BRP flexibility allocation. Laura Lazaro

Application of genetic algorithms for BRP flexibility allocation

Workshop on FHP wind curtailment mitigation solution

Laura Lázaro – TECNALIA

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Overview

Application of genetic algorithms for BRP flexibility allocation

- ✓ ***Optimization problems at the BRP application***
- ✓ *Introduction to genetic algorithms*
- ✓ *Mapping and resolution of the optimization problems*

Application Of Genetic Algorithms For BRP Flexibility Allocation

Optimization problems at the BRP application

- ✓ One of the obligations of the BRP role, is to sell the **expected generation** of DER producers.

- ✓ The BRP has to assess if it is convenient for its business to pay for flexibility to the DCMs instead of compensating to the DER Producers for the curtailed energy.
  - The **BRP would compensate** to the DER producer for the **loss of opportunity** of selling its energy**.**
  - The BRP **negotiates the flexibility** with the DCM that would minor the curtailment at an affordable price.

- ✓ **<u>Challenge of the design in FHP</u>**: Provide the technology so that all involved roles can achieve a certain **benefit**, compared to the nowadays situation in which commercial **curtailment is endorsed**.

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Overview

Application of genetic algorithms for BRP flexibility allocation

- ✓ ***Optimization problems at the BRP application***
  - ✓*systemDERCurtailmentMitigation* use case
- ✓ ***Introduction to genetic algorithms***
- ✓ ***Mapping and resolution of the optimization problems***

Application Of Genetic Algorithms For BRP Flexibility Allocation

Optimization problems at the BRP application:
***systemDERCurtailmentMitigation* use case**

✓ ***Objective:***

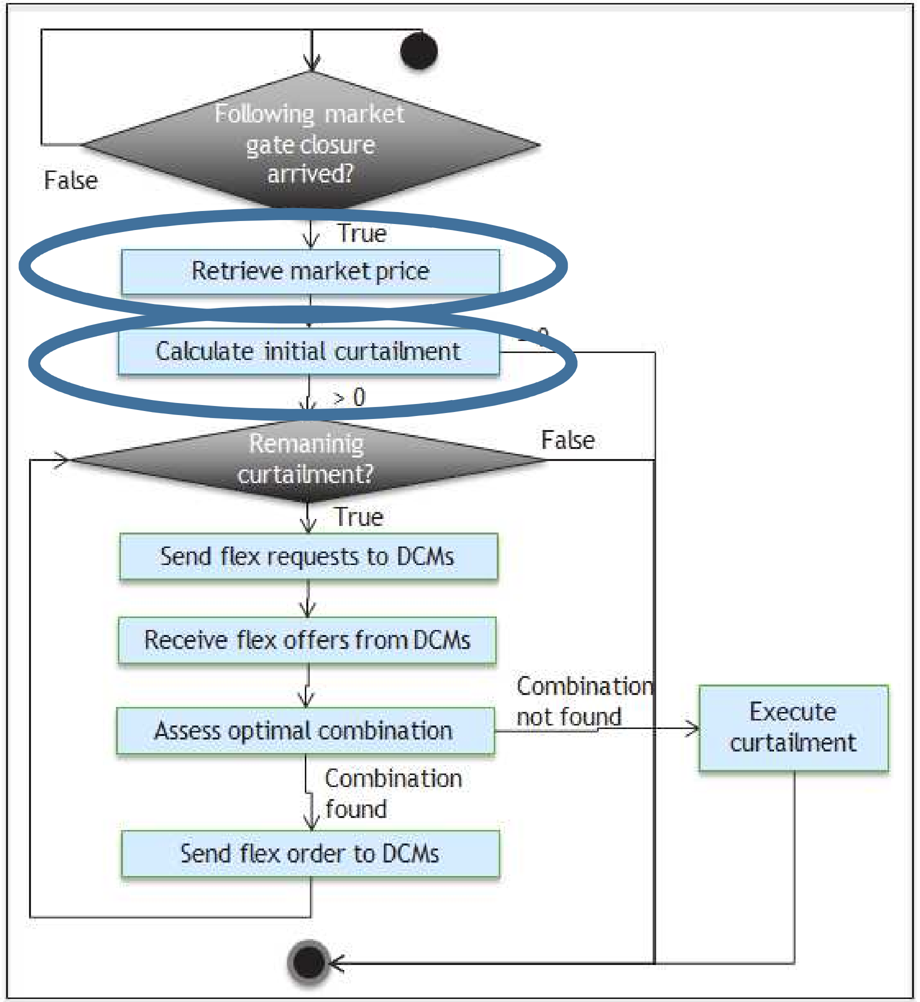
Limit the curtailment of system-level RES by using heating/cooling flexibility of buildings and Ecovat thermal storage systems.

Application Of Genetic Algorithms For BRP Flexibility Allocation

Optimization problems at the BRP application

RetrieveMarketPrice: The BRP retrieves the day ahead market price for each PTU of the following day.

CalculateInitialCurtailment: Once the BRP has retrieved the day ahead market prices, it can assess for which DER producers in its portfolio it would have to address commercial curtailment.



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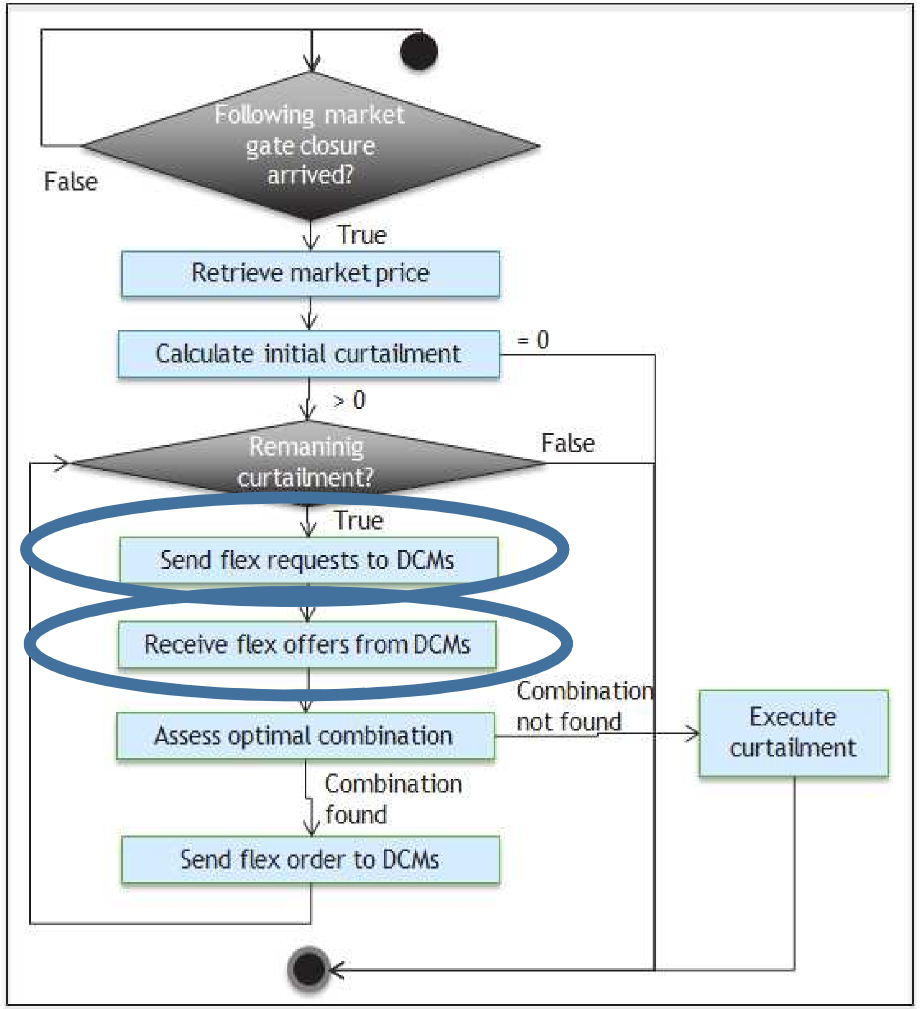
Application Of Genetic Algorithms For BRP Flexibility Allocation

Optimization problems at the BRP application

FlexRequest: The BRP queries to all DCMs in its portfolio about their possibilities to increase their consumption in those PTUs where **curtailment is expected up** to the value of **the remaining curtailment.**

FlexOffer: Each DCM can present one flex offer to the BRP, being the offered flex value equal or smaller than the requested flex value.

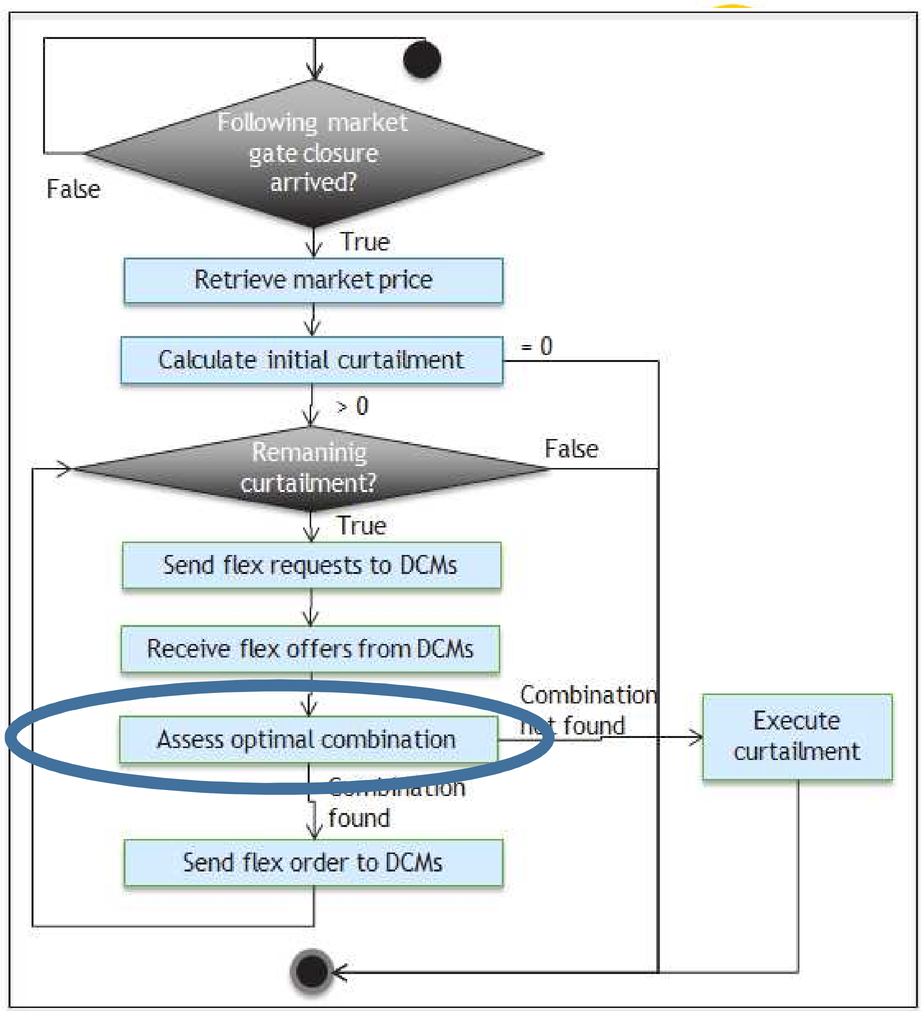


Application Of Genetic Algorithms For BRP Flexibility Allocation

Optimization problems at the BRP application

AssessCurOptimalCombination: Decide how much flex the BRP will order in this iteration loop for each DCM associated to each DER, to **minimize the cash flow of the BRP**, which is the sum of what it has to pay to **DER producers** due to **commercial curtailment** and what it has to pay to **DCMs for flex**

$$\sum_{DER} CompensationPrice * (DERRemainingCurtailment - FlexDEREnergy) + \sum_{AGR} OfferedAGRPrice * FlexAGREnergy$$



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Application Of Genetic Algorithms For BRP Flexibility Allocation

Optimization problems at the BRP application

AssessCurOptimalCombination

Compensation that the BRP has to pay to the DER producer if the DER is commercially curtailed

Total energy per DER that would be commercially curtailed if flex is no longer negotiated

FlexDEREnergy ≤ DERRemainingCurtailment

$$\sum_{DER} CompensationPrice * (DERRemainingCurtailment - FlexDEREnergy)$$

$$+ \sum_{AGR} OfferedAGRPrice * FlexAGREnergy$$

Price that the BRP has to pay to the DCM for the flex (increase of consumption) that enables the avoidance of DER curtailment.

Increase of production of the DER producer

Flex that is ordered to each DCM

Overview

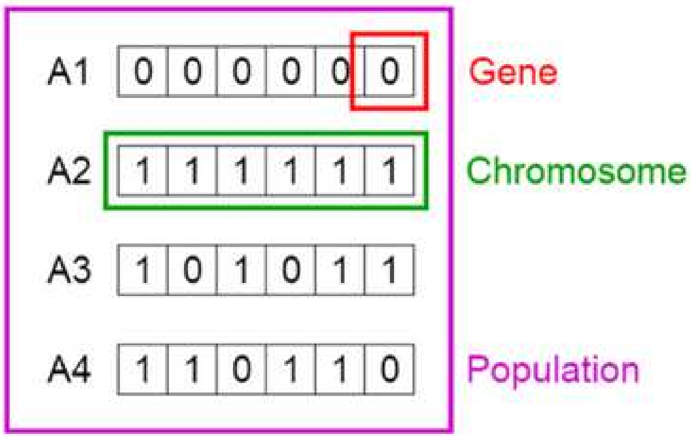
Application of genetic algorithms for BRP flexibility allocation

- ✓ *Optimization problems at the BRP application*
- ✓ ***Introduction to genetic algorithms***
- ✓ *Mapping and resolution of the optimization problems*

Application Of Genetic Algorithms For BRP Flexibility Allocation

Introduction To Genetic Algorithms

- ✓ A **genetic algorithm (GA)** is an optimization method inspired by the evolution of species and natural selection. It reflects the process of natural selection where the **fittest individuals are selected for reproduction**.



Chromosome:

- Potential solution
- Made of genes
- It is generally represented as binary strings

Gene:

- Simple bit in a chromosome

Population:

- Pool of possible solutions

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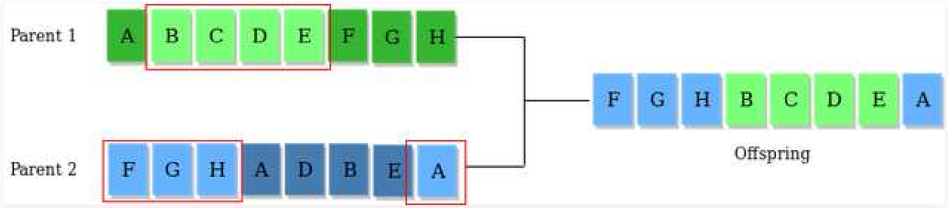
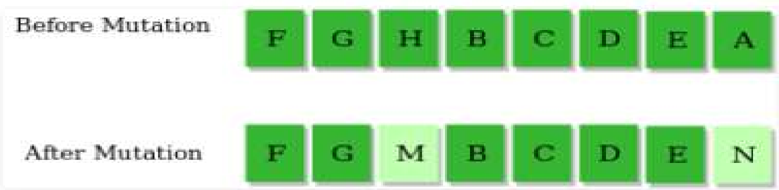
Application Of Genetic Algorithms For BRP Flexibility Allocation

Introduction To Genetic Algorithms

- ✓ Two significant phases of GA:
  - **Crossover:** For each pair of parents to be mated, a crossover point is chosen at random from within the genes. Offspring are created by exchanging the genes of parents among themselves until the crossover point is reached.



  - **Mutation:** to maintain diversity within the population and prevent premature convergence some of the bits in the bit string are changed randomly.



Application Of Genetic Algorithms For BRP Flexibility Allocation

Introduction To Genetic Algorithms

Basic structure of GA:

1. **Start:** Generate random population of *n* chromosomes.
2. **Fitness:** Evaluate the **fitness score** (fitness function solution) of each chromosome and determines how fit an individual is. The fitness function is used to give preference to the individuals with good fitness scores.
3. **New Population:** Create a new population by repeating following steps:
   a. **Selection**: Select two parent chromosomes from a population. The better fitness score, the bigger chance to be selected.
   b. **Crossover**: With a *crossover probability* cross over the parents to form new offspring (children).
   c. **Mutation**
   d. **Accepting** Place new offspring in the new population
4. **Replace** Use new generated population for a further run of the algorithm
5. **Test:** If the end condition is satisfied, **stop**, and return the best solution in current population

Overview

Application of genetic algorithms for BRP flexibility allocation

- ✓ *Optimization problems at the BRP application*
- ✓ *Introduction to genetic algorithms*
- ✓ ***Mapping and resolution of the optimization problems***

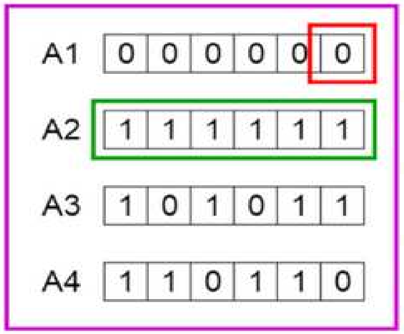
Application Of Genetic Algorithms For BRP Flexibility Allocation

Mapping and resolution of the optimization problems

Genes: One for each Aggregator/ Offer. When Gene = 1 -> Offer selected.

Chromosome: String of bits that represents the combination of the selected offers.

Fittest Function: The fittest function will calculate **the price to pay** for the selected options in each chromosome. The optimal solution will be the one which **cash flow is the smaller** in absolute value.



No offers selected option

All offers selected

Selected Offers: 1,2,4,6

Selected Offers: 2,3,5,6

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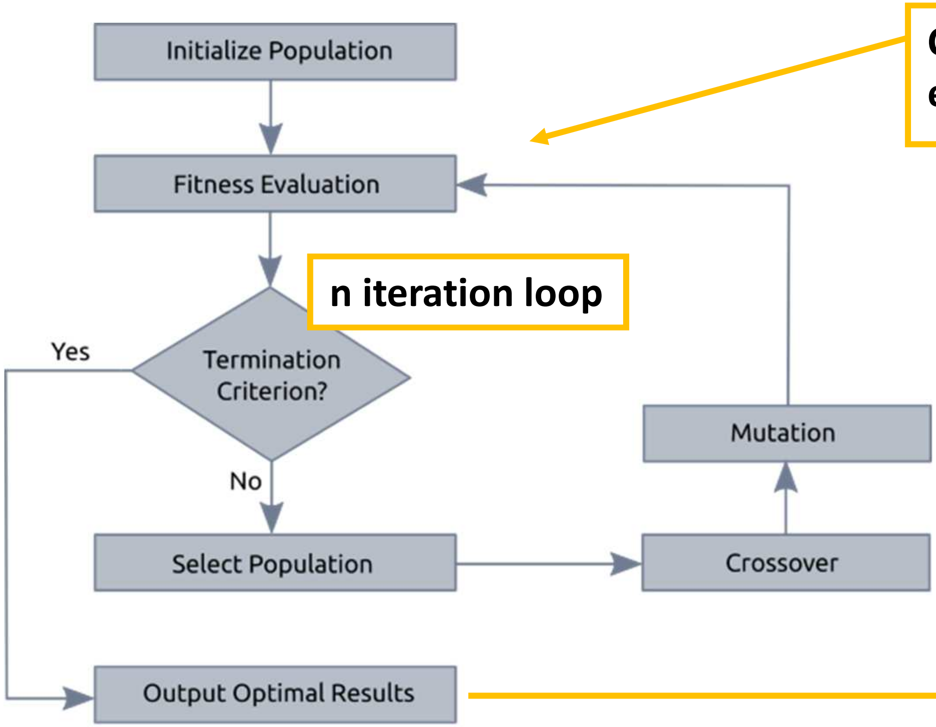
Application Of Genetic Algorithms For BRP Flexibility Allocation

Mapping and resolution of the optimization problems



Calculate the Cash flow of the BRP for each chromosome of the population

$$\sum_{DER} CompensationPrice * (DERRemainingCurtailment - FlexDEREnergy) + \sum_{AGR} OfferedAGRPrice * FlexAGREnergy$$

Selection of Offers that minimize the BRP cash flow

Thanks for your attention

laura.lazaro@tecnalia.com

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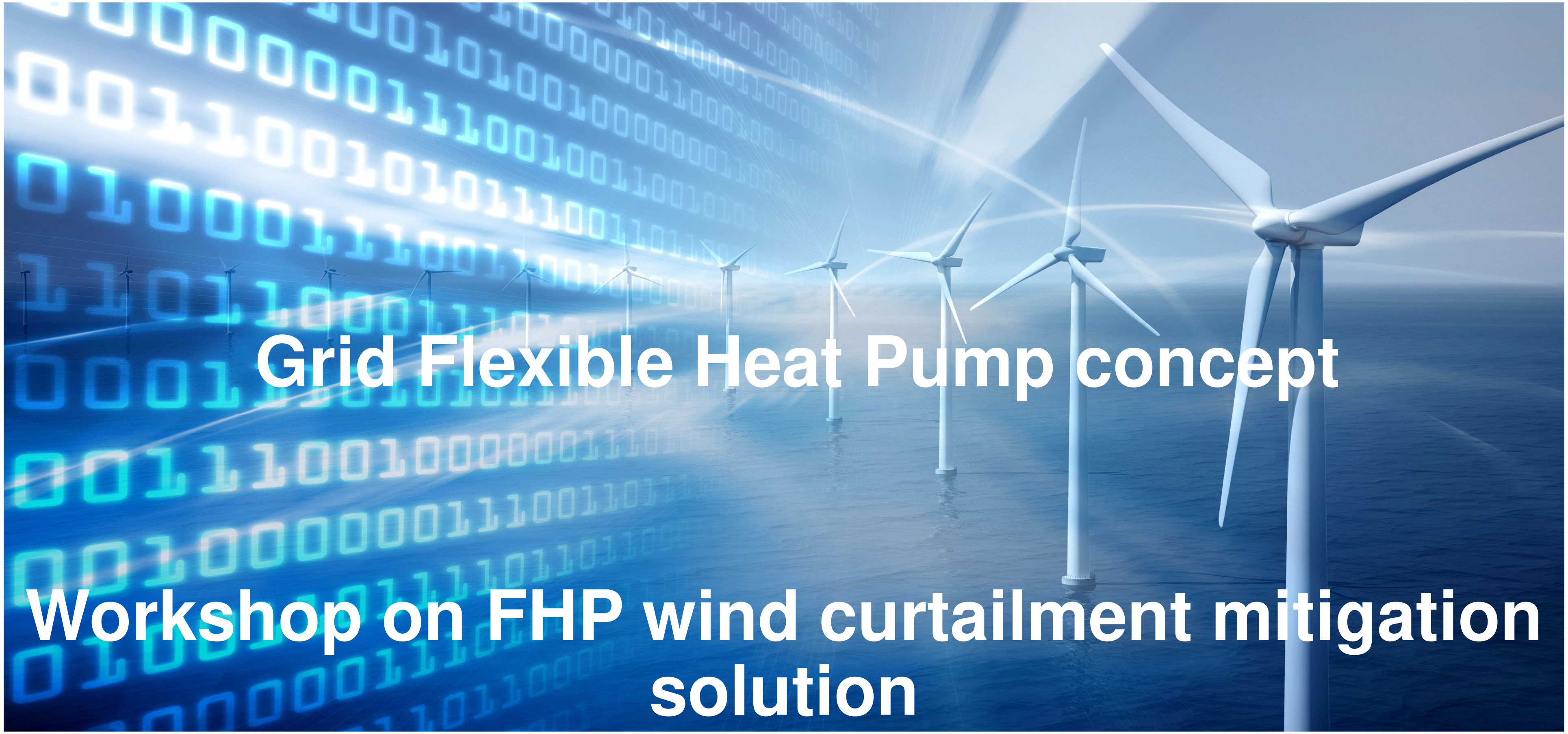
5.9 Annex 3.9. Grid Flexible Heat Pumps. Markus Lindahl



Grid Flexible Heat Pump concept

Workshop on FHP wind curtailment mitigation solution

Markus Lindahl- RISE Research Institutes of Sweden

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FHP project is funded by European Union under the grant agreement no. 731231.

Grid flexible Heatpump concept

Presentation overview

- ✓Introduction heat pumps
- ✓Laboratory test grid flexible heat pump control
- ✓Results and recommendations

✓ A grid flexible heat pump: A heat pump (HP) that can be asked to follow a electricity consumption profile in a direct manner

Introduction heat pumps

Heating

- ✓ Space heating (focus in FHP-project)
- ✓ Domestic hot water (DHW)
- ✓ Industrial
- ✓ District heating

Compressor

- ✓ On/off
- ✓ Variable speed compressor

- ✓ $COP = \frac{Heating\ capacity}{power\ input}$

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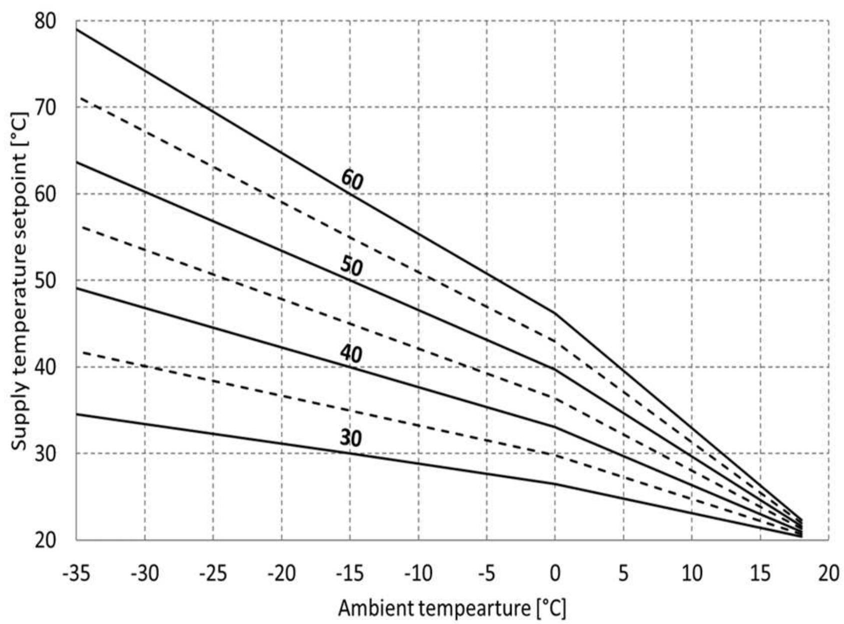
Internal steering of a heat pump

- ✓ Heat production depends on:
  - ✓Outdoor temperature
  - ✓Indoor temperature

- ✓ Heating curve gives the supply temperature

Example of heating curves



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Smart grid ready standard

- ✓ Smart grid ready (SG ready) is a standard for smart control
  - ✓ Defined by the German Bundesverband Wärmepumpe e.V.
- ✓ The activation of each mode is done based on how two terminals are open (0) or closed (1)

Four different heat pump working modes:

1. Blocking mode (1:0)
2. Normal mode (0:0)
3. Low price mode (0:1)
4. Over capacity mode (1:1)

Variation of heating capacity

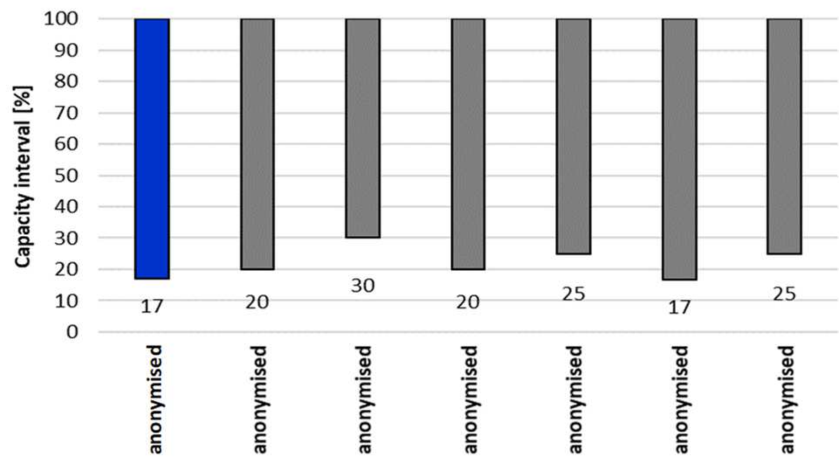
Heating provided and electricity consumption can change in three ways:

- ✓Start/stop compressor
- ✓Change compressor speed
- ✓Start/stop electric auxiliary heater

Survey (4 large Swedish HP manufacturers)

- ✓Bosch (IVT)
- ✓Enertec (CTC)
- ✓Nibe
- ✓Thermia

Compressor capacity range



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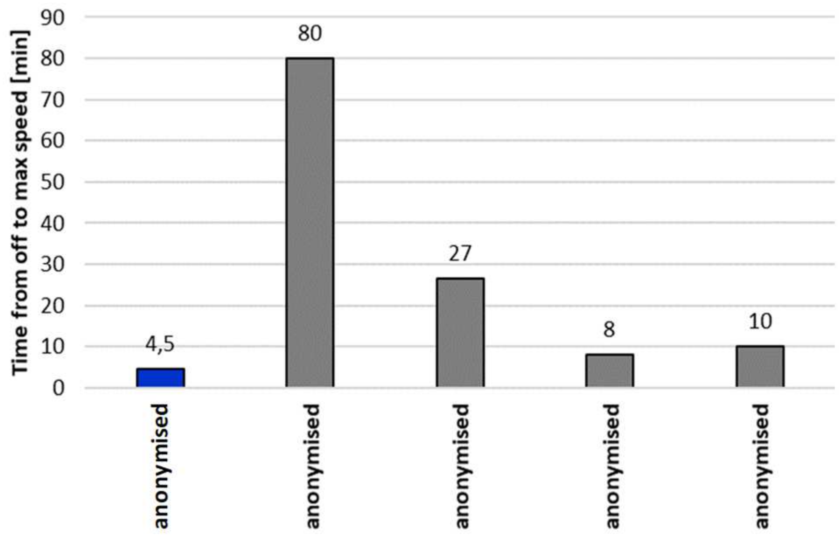
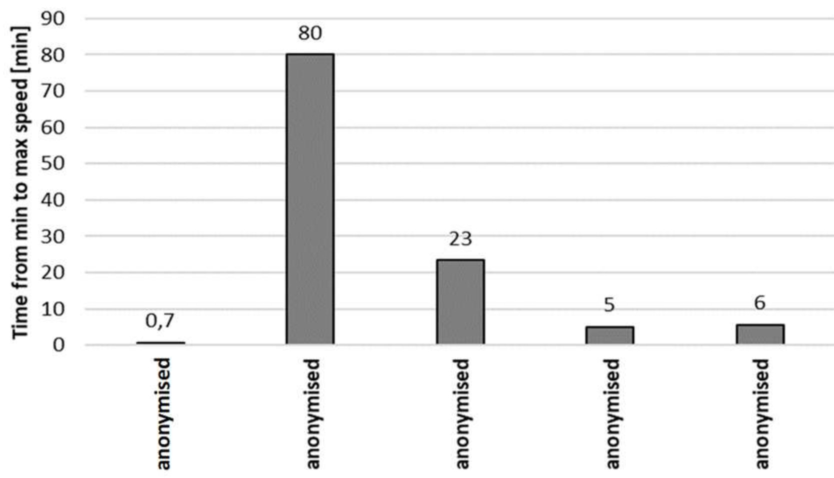
Variable speed compressors

Time from compressor off to full speed



Time from lowest compressor speed to full speed

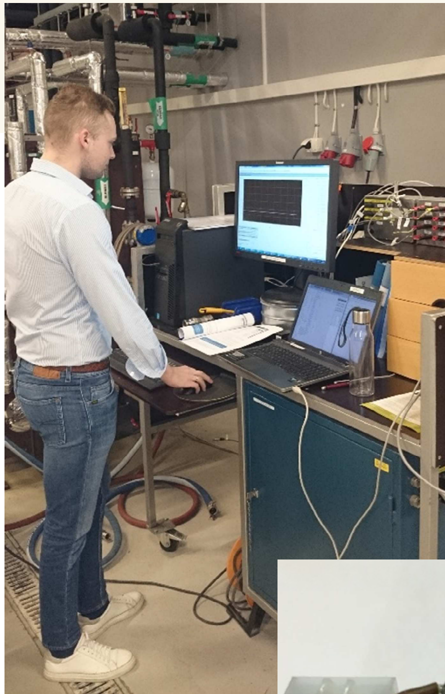


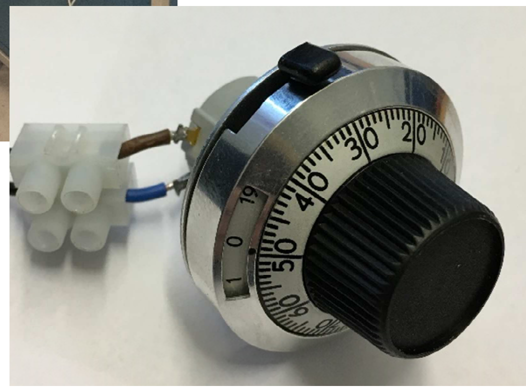
Laboratory tests

- ✓ Ground source heat pump
- ✓ Single family house
  - ✓12 kW heating capacity
  - ✓Elec. auxiliary heater
- ✓ Variable speed compressor

Controlling the heat pump

- ✓ Direct control of compressor speed (Grid Flex HP approach)
  - ✓ The heat pump compressor was controlled via an external computer.
  - ✓ Manually or automatic
- ✓ Indirect control (traditional approach)
  - ✓ Temperature sensor override
  - ✓ Precision potentiometer used to set the outdoor temperature.
  - ✓ Manually by a test engineer

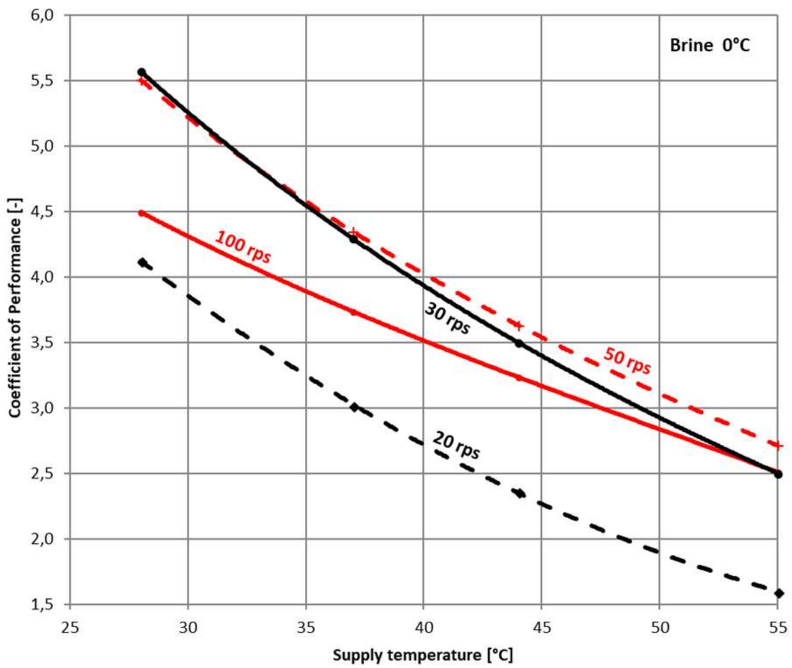




Heating performance

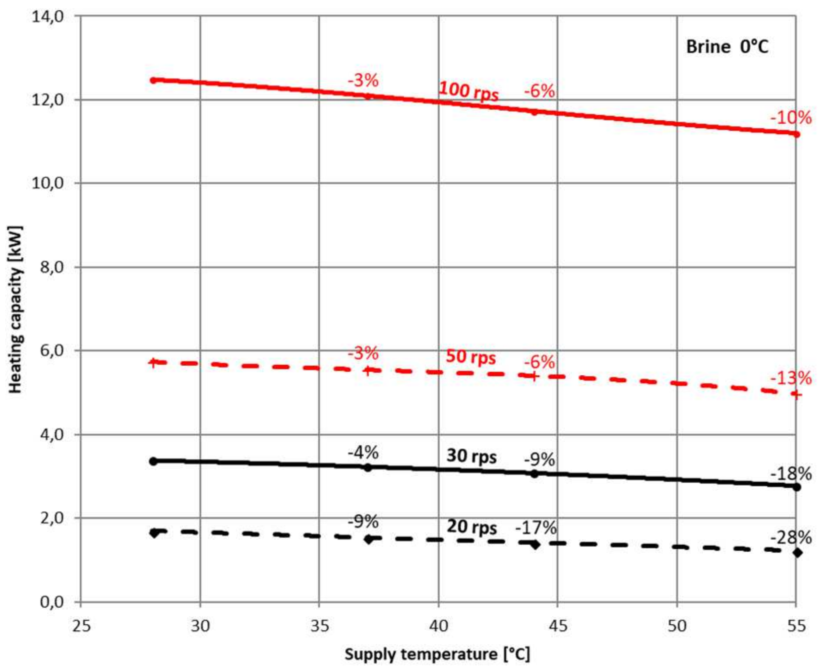
COP

- function of supply temperature



Heating produced

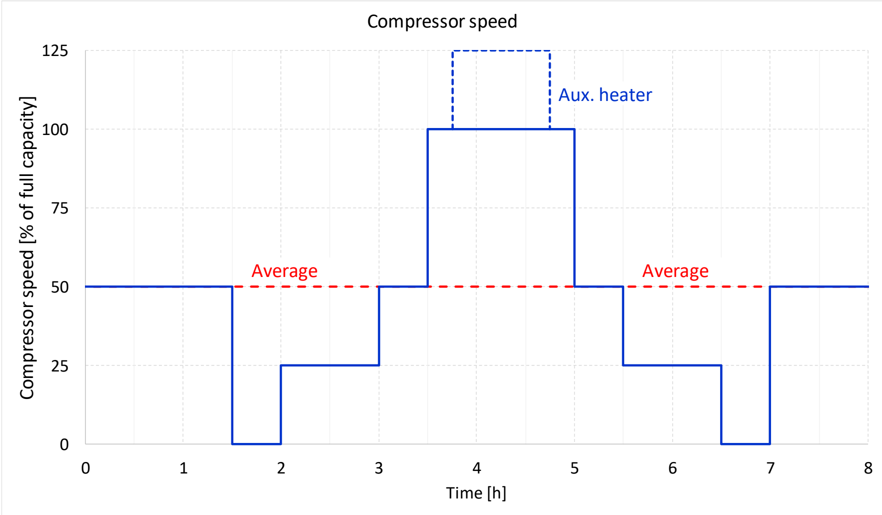
- function of supply temperature



Test cycle for grid flexible heat pumps

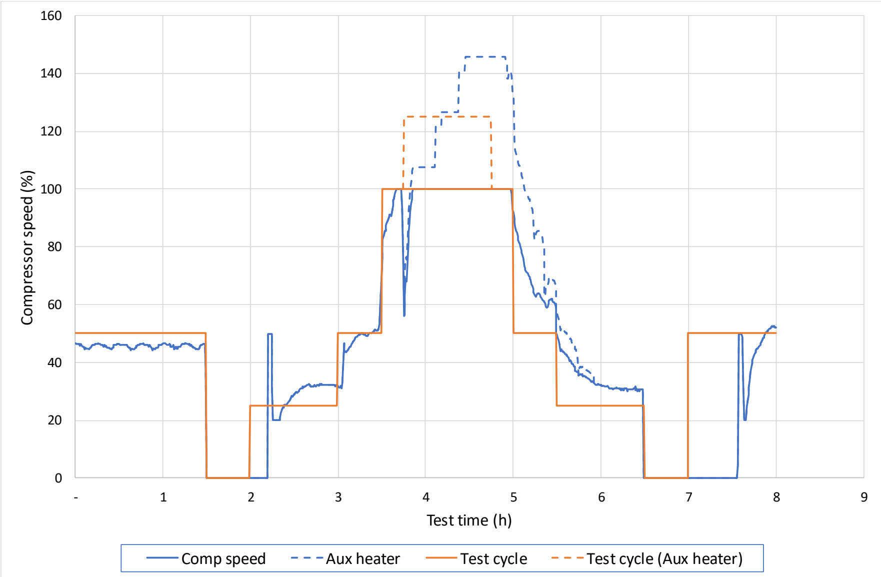
Purpose:

- ✓ How well can we follow the test cycle
- ✓ Impact on COP
  - ✓ Compared to stable conditions
- ✓ Test to steer a number of functions externally
  - ✓ Turning on and off the heat pump
  - ✓ Increasing the heating capacity in steps
  - ✓ Working on maximum capacity
  - ✓ Decreasing the heating capacity in steps
  - ✓ Turning on and off the axillary heater
  - ✓ Adjusting the heating capacity of the auxiliary heater

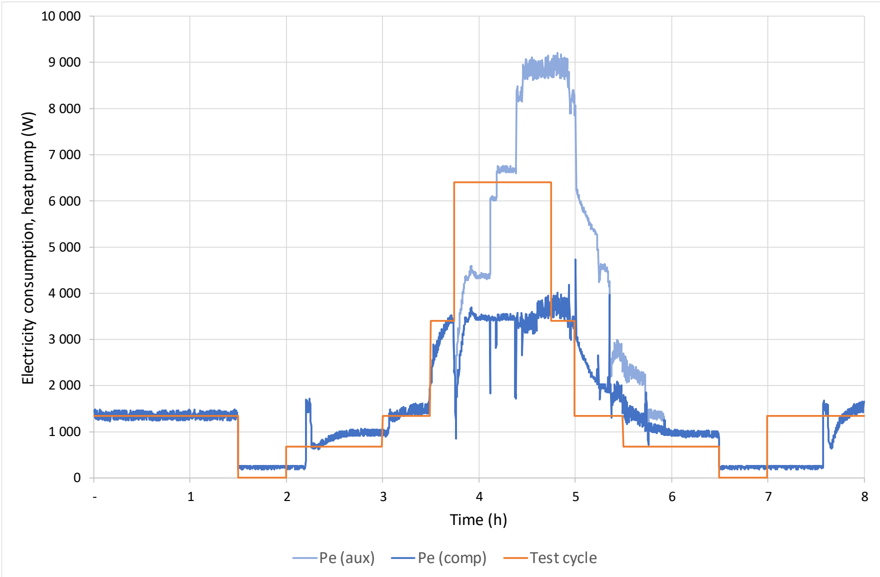


Indirect control

Compressor speed

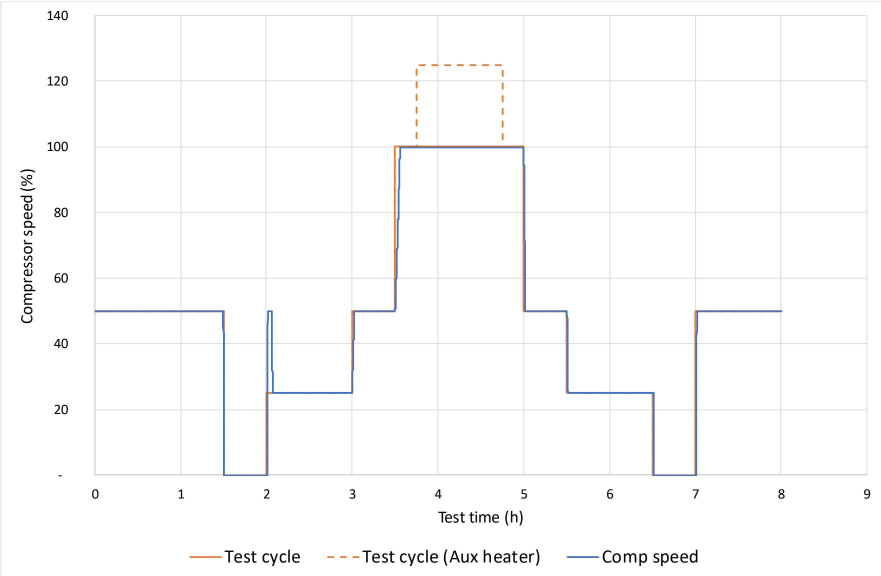


Elec. consumption

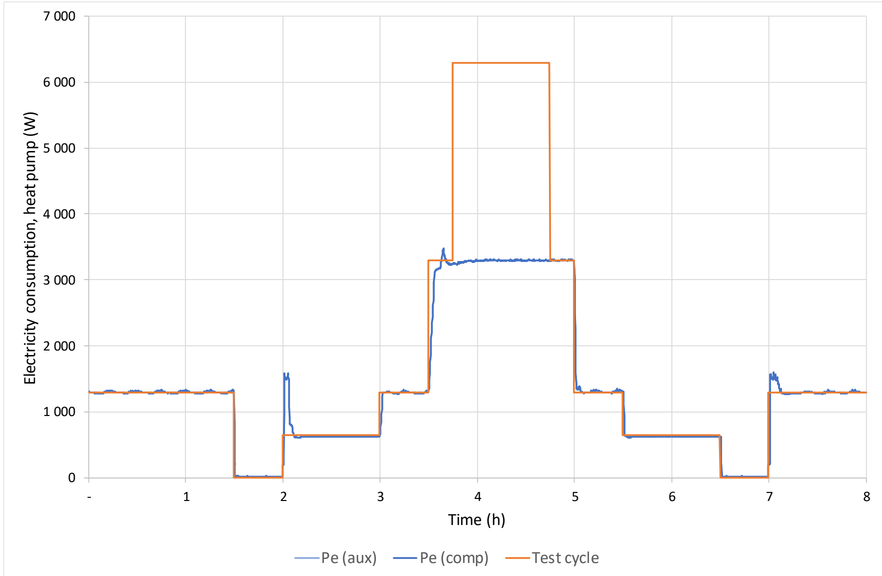


Direct control

Compressor speed



Elec. consumption



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Evaluation of results

KPI	Description
KPI_1:	Average deviation from test cycle
KPI_2:	Time within ±3% of the test cycle
KPI_3:	Time within ±10% of the test cycle
KPI_4:	Decrease COP

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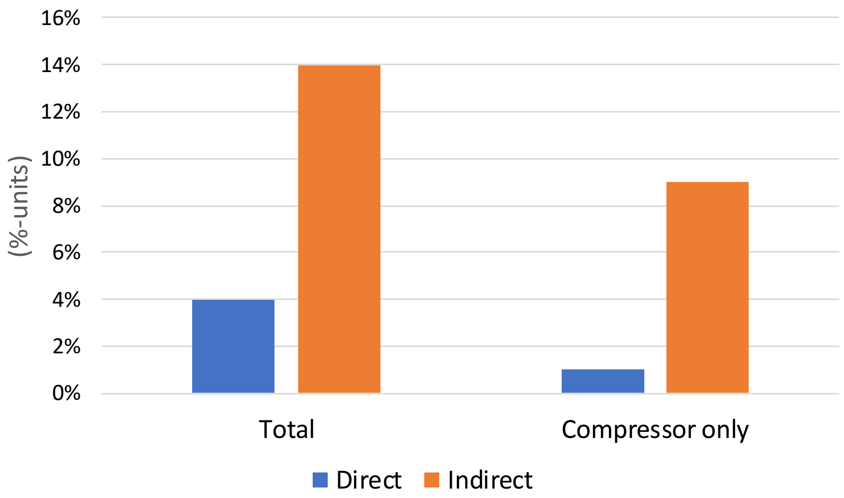
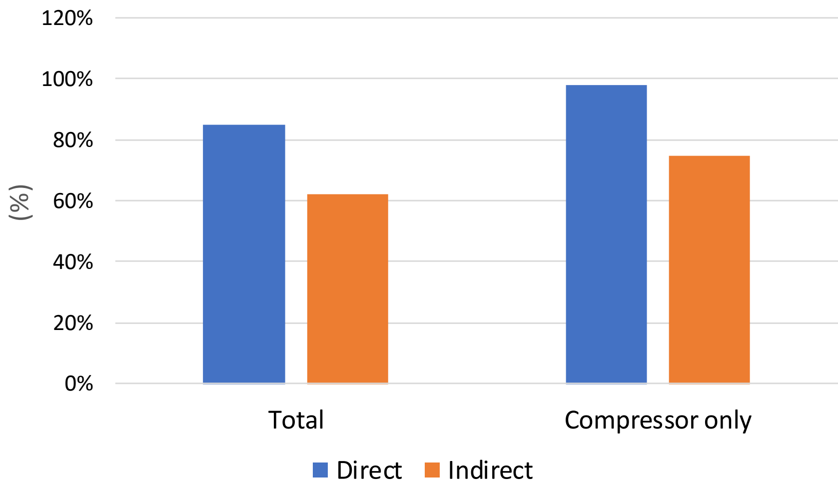
Results
- How close did the heat pump followed the test cycle

Average deviation from test cycle



Time within ±10% of the test cycle

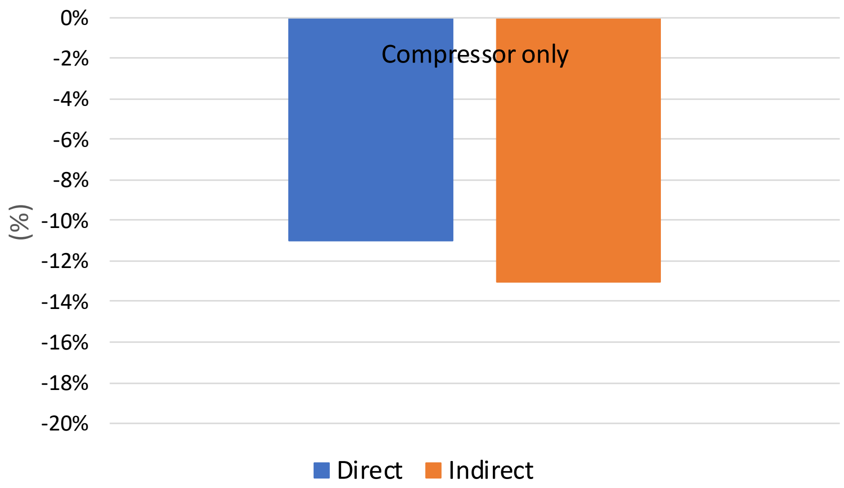


Results
- Impact on heat pump efficiency (COP)

- ✓ COP decreases 10-15% using the flexible test cycle
  - ✓ Compared to stable conditions
    - ✓ 50% compressor speed
  - ✓ Looking at the compressor only
    - ✓ (Auxiliary heater excluded)
- ✓ First indication, more tests are needed

Decrease in COP

-Compared to stable conditions



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Recommendations for external control

Older heat pumps or non-premium heat pumps sold today:

- ✓ Outdoor temperature sensor override
- ✓ Works on more or less all heat pumps

Premium heat pumps sold today and future heat pumps

- ✓ Indirect control of the temperature settings by adjustments of the heating curve or similar
- ✓ Using web-API, many premium heat pumps sold today are connected to the internet
- ✓ a web interface or an app makes it possible for the owner to make changes related to the heat pump settings at a distance

Future heat pumps

- ✓ Direct control (as proposed in Grid Flex HP concept)
- ✓ Fastest control, better accuracy
- ✓ Requires standardization e.g. through EEBus or similar

Heat pump design for flexibility

- ✓ Oversized heat pump systems gives higher flexibility
  - ✓ Larger investments costs
  - ✓ Risk for lower system efficiency, due to many hours on low part load
  - ✓ Economic compensation for offering the flex service is needed
- ✓ Available flexibility depends on the heating demand and thereby the outdoor temperature
- ✓ Large differences in how fast the compressor speed can change between different HP models
  - ✓ Survey in Sweden: 40 s – 80 min from min to max speed
  - ✓ Probably technically possible with quick changes in compressor speed

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Summary

- ✓ Laboratory testing has shown that the HPs electricity consumption can be controlled in different ways:
  - ✓ Indirect control
  - ✓ Direct control
- ✓ Indirect control via temperature sensor override
  - ✓ Works on most heat pumps
- ✓ Direct control gives better control of the HP to steer in detail
  - ✓ Today there are no standard protocol on how to control the heat pump directly
- ✓ Large differences in how fast the compressor speed can change between different HP models
- ✓ Laboratory tests indicates that COP will decrease:
  - ✓ Total electricity consumption (kWh) will increase using the HP for flex service => Economic compensation needed

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Thanks for your attention

Markus Lindahl, RISE

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5.10 Annex 3.10. Lessons learned from pilot demonstration. Marcus Steen

Results from the Swedish pilot sites

Workshop on FHP wind curtailment mitigation solution

Marcus Steen – Karlshamn Energi AB

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Results from the Swedish pilot sites

Difficulties arised and solutions provided in the pilot set-up

Presentation overview

- ✓ ***Introduction***
  - ✓***Karlshamn municipality***
  - ✓***Karlshamn Energi AB***
- ✓ ***Residential premises***
- ✓ ***Industrial premises***
- ✓ ***Technical installations***
- ✓ ***Summary***

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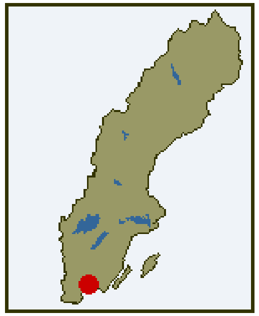
Introduction

The municipality of Karlshamn and Karlshamn Energi AB

- ✓ ***Karlshamn municipality***
  - ✓ ***City of Karlshamn***
- ✓ ***Karlshamn Energi AB***
  - ✓ ***Multi-utilities company***
  - ✓ ***DSO - local electricity grid***
  - ✓ ***Local RES***
  - ✓ ***District heating***
  - ✓ ***Municipal water and sewage***
  - ✓ ***Broadband connection***



Residential premises
pilot set-up

Residential premises in the city centre

- ✓ ***Multiy family buildings***
  - ✓ ***Premise 1***
    - ✓ ***3 apartments, total of 316 m2.***
    - ✓ ***GSHP – Nibe F1155-12 3-12kW***

Residential premises
pilot set-up

Residential premises in the city centre

- ✓ ***Multiy family buildings***
  - ✓ ***Premise 2***
    - ✓ ***8 apartments, total of 688 m2.***
    - ✓ ***AWHP – Mitsubishi 3-10kW***
    - ✓ ***Electric Cartridge 15 kW backup***
    - ✓ ***Oil burner 37-50 kW backup***

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Residential premises
pilot set-up

Residential premises in the city centre

- ✓ ***Multiy family buildings***
  - ✓ ***Premise 3***
    - ✓ ***5 apartments, total of 250 m2.***
    - ✓ ***GSHP – Nibe F1155-12 3-12kW***

Industrial premises
pilot set-up

Industrial buildings

- ✓ ***Premise 1***
  - ✓ ***Logistics company – 3 large buildings***
  - ✓ ***GSHP – 3-10 kW***
  - ✓ ***AAHP - 4 smaller, 1-3 kW each***
  - ✓ ***Oil burner – 200 kW, mostly for tap water***

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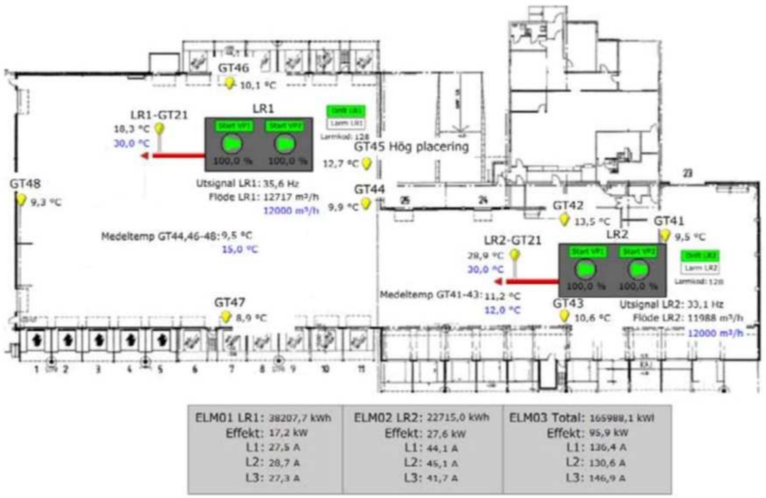
Industrial premises
pilot set-up

Industrial buildings

- ✓ ***Premise 2***
  - ✓ ***Logistics company, partly manufacturing***
  - ✓ ***ASHP - 4 Mitsubishi AAHP 2-10kW each***



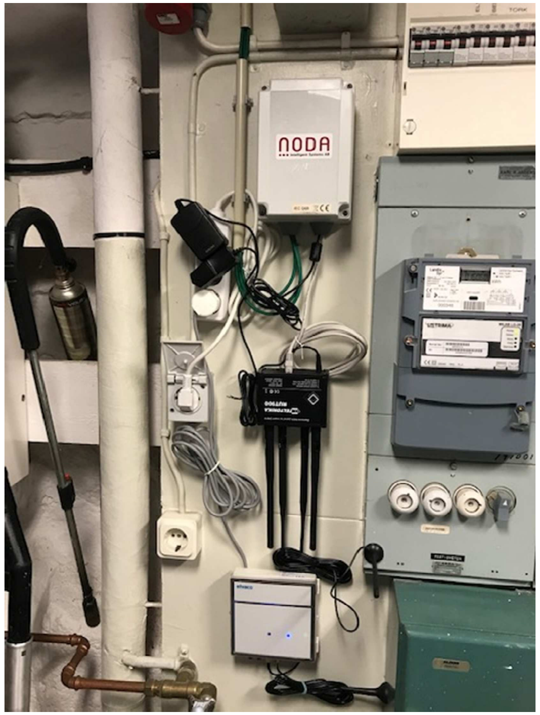
Industrial premises
pilot set-up

Industrial buildings
- ✓ **Premise 3**
  - ✓ **ASHP – several small ASHP 1-3 kW**

Solutions for pilot set-up

technical installations

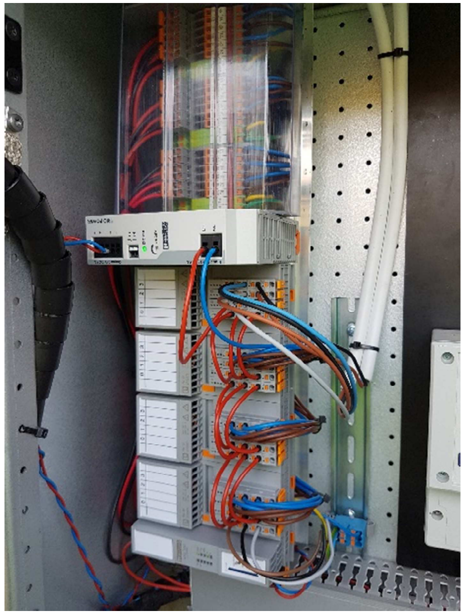
- ✓ *Temperature sensors*
- ✓ *One wire sensors*
- ✓ *NODA IEC*
- ✓ *Energy meter sensors*
- ✓ *Communication - Wifi / GPRS*



Solutions for pilot set-up
technical installations

- ✓ ***Substation installation***
  - ✓ ***Grid monitoring for the industrial premises***





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Summary
Difficulties in the pilot set-up

Difficulties in the pilot set-up

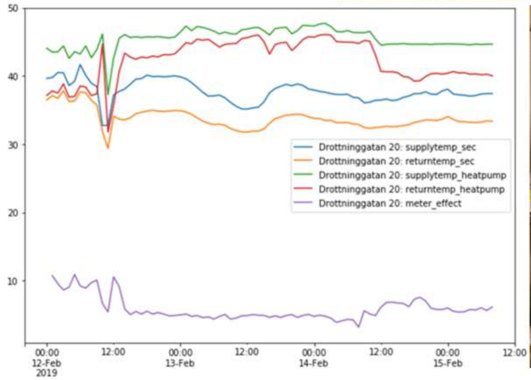
- ✓ ***Limited scope of premises for the pilot***
- ✓ ***Voluntary premises tends to have some sort of issues from start***
  - ✓ ***Often need for energy efficiency***
- ✓ ***Very complex and diversified energy systems***
  - ✓ ***Most premises don't look the same***
- ✓ ***Some technical installations is to cost expensive***
  - ✓ ***Mass flow indicators***
- ✓ ***Human behaviour causes noise, makes analysis hard***

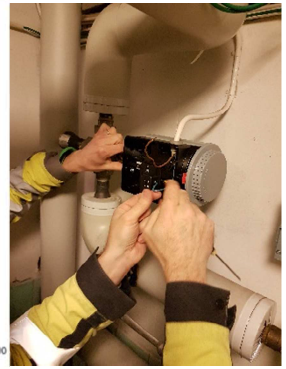
Summary

Findings in the pilot set-up

Findings in the pilot set-up

- ✓ ***Good communication with premise owners***
  - ✓ ***Common interest in a successful pilot***
  - ✓ ***Be prepared to solve problems***
- ✓ ***Planning of sensor placing is crucial***
- ✓ ***Temperature override works well***





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5.11 Annex 3.11. Steps for further research and exploitation. Martin Borgqvist

Steps for further research and exploitation

Workshop on FHP wind curtailment mitigation solution

Martin Borgqvist - NODA

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The scope


Buildings
Seasonal thermal storages
Heat pumps
Location aware aggregations of flexibility
Electricity markets

Highlights of findings and outcomes

Buildings Seasonal thermal storages Heat pumps	Location aware aggregations of flexibility	Electricity markets
• Using flex from power-to-heat-systems is possible • Self-learning models can be used for flex estimation • Heat pumps today are not designed for flex services	• Platform for flex trading that empowers providers • Tool to calculate revenue for flex provision • Flex dispatch-algorithm for grid benefits • Flex-bid selection algorithm	• Renewable energy is lost every year due to curtailment • This curtailed energy comes with a cost • FHP shows how to make use of this energy instead of losing it

Focus of future exploitation

Grid active automation systems

Steps for further research and exploitation

- Black-box and grey-box thermal models
- Model predictive controllers for heat pump optimisation
- Flexibility trading tools for buildings and seasonal thermal storages
- Standard for grid flexible heat pump interfacing

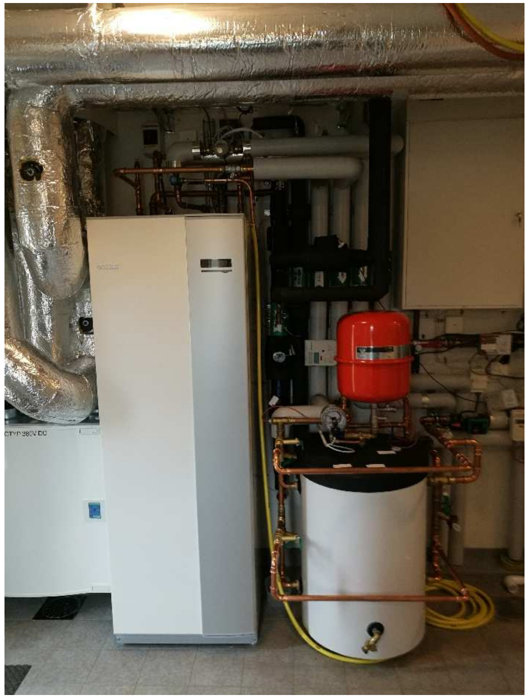
Using flexibility in seasonal thermal storages

Steps for further research and exploitation

- Improve existing pre-engineering services by including building models in the process

Grid flexible heat pumps

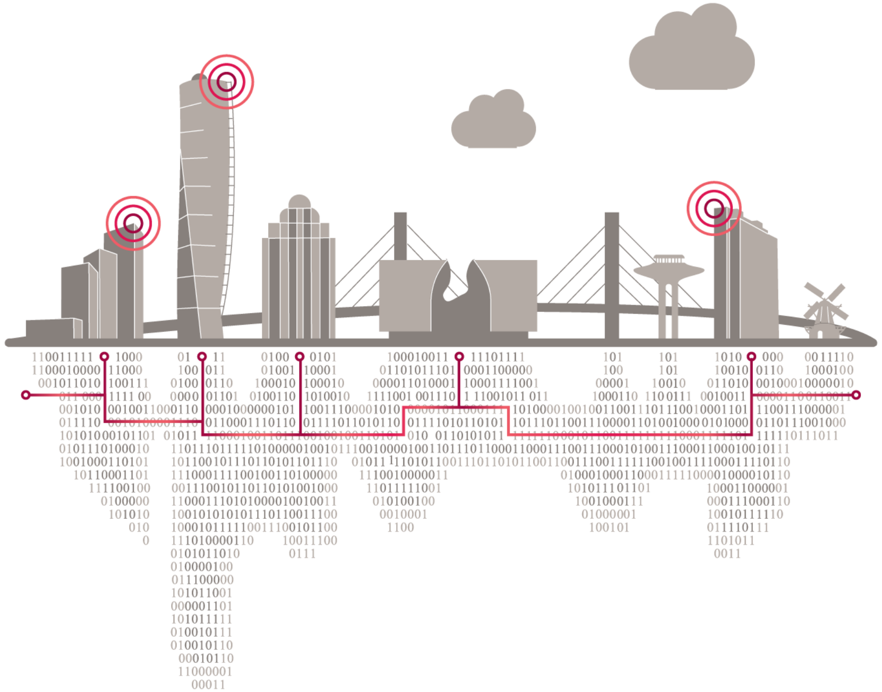
Steps for further research and exploitation



- Service for independent third party testing of grid flexible heat pumps

Flexibility management

Steps for further research and exploitation



- Algorithms for curtailment mitigation and imbalance management
- Services for thermal flexibility harvesting
- Flexibility dispatcher for grid active buildings

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