hybrid GEOTABS

Controlling the power of the ground by integration

DESIGNING hybridGEOTABS
COMFORT SUPPLIED IN A SUSTAINABLE WAY!

Thursday 17th December 2020 – 10.00 CET

HOUSEKEEPING RULES

- The webinar will be recorded
- The slides will be made available on http://www.hybridgeotabs.eu/publications/presentations
- All attendees are muted by default
- Use Q&A section to send your questions

  (to Everyone – not privately)

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TOPIC	TIME	PRESENTER
The hybridGEOTABS concept and project	15 mins	Eline Himpe, Ghent University
hybridGEOTABS challenges for designers	30 mins	Wim Boydens, Boydens Engineering
hybridGEOTABS design methodology	30 mins	Jelle Laverge, Ghent University
BREAK	10 mins	
Tools for feasibility study and pre-design	30 mins	Pascal Simoens, Boydens Engineering
MPC for HVAC-designers	20 mins	Damien Picard, University of Leuven
Conclusions/Q&A	20 mins	Liz Ellston, Climate Futures

Moderators: Liz Ellston (Climate Futures)
Technical management: Spyridon Pantelis (REHVA)

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Documentation and materials coming on www.hybridgeotabs.eu

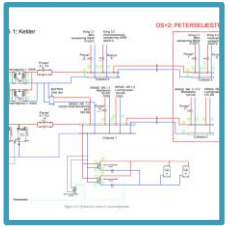
Knowledge Centre

Enhanced Geothermal Response Test

Cos

& policy report

Hydraulic schemes for hybridGEOTABS solutions



R&D: Radiant heating/cooling panels with **PCM**

Generic documentation for **TENDERING**

Energy Dashboard

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SOCIAL MEDIA AND CONTACT

linkedin.com/showcase/hybridgeotabs-project

linkedin.com/groups/13510727

facebook.com/hybridGEOTABS

@hybridGEOTABS

@hybridGEOTABS

YouTube hybridgeotabs

youtube.com/channel/UCQDBfhimW-bqATt31u8xQVg

email: hybridgeotabs@ugent.be

www.hybridgeotabs.eu

All project outcomes will become available via the website!

Subscribe to our quarterly newsletter to stay up to date!

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THANK YOU!

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HVAC-concept and EU-H2020 project

GHENT UNIVERSITY

dr. ir.-arch. Eline Himpe

Postdoctoral researcher & project manager

hybridgeotabs@ugent.be

Designing hybridGEOTABS Training (webinar)

17 December 2020

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What is hybridGEOTABS?

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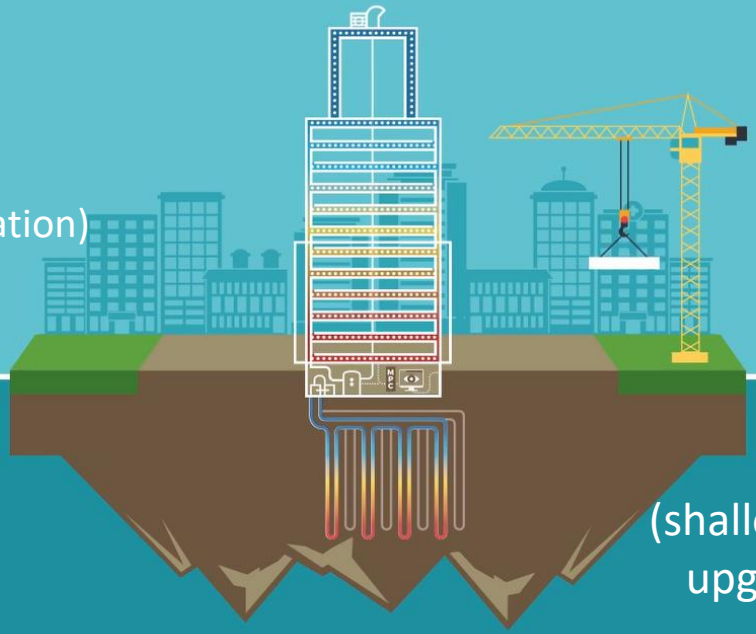
GEOTABS CONCEPT

TABS

Thermally Activated Building System

(e.g. Concrete Core Activation)



GEO

(shallow) **geothermal energy** upgraded using **heat pump**

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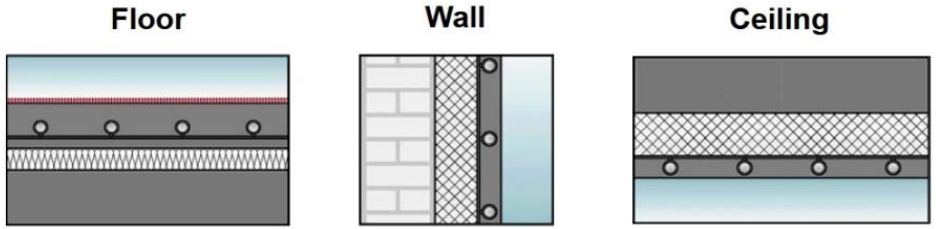
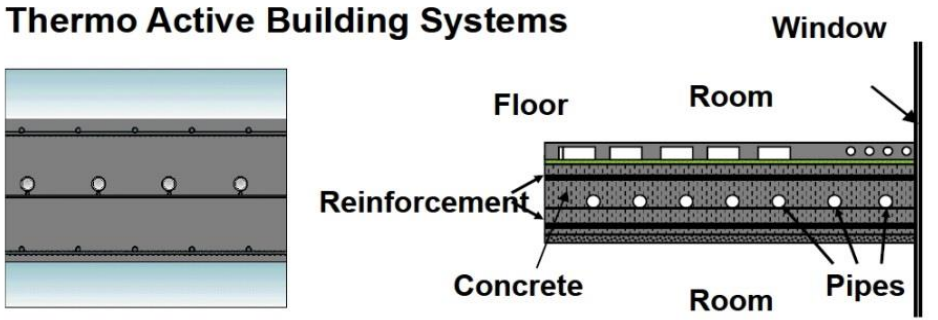
RADIANT HEATING AND/OR COOLING SYSTEMS





- Sensible heating and cooling emission
- > 50% radiant heat transfer
- ➢ **High thermal comfort & IEQ**
- Uniform temperature distribution
- Minimising risk of draught (↔ all-air systems)
- Quiet operation
- Increased room height (↔ suspended ceilings…)
- Flexibility of space (↔ radiators, FCU…)

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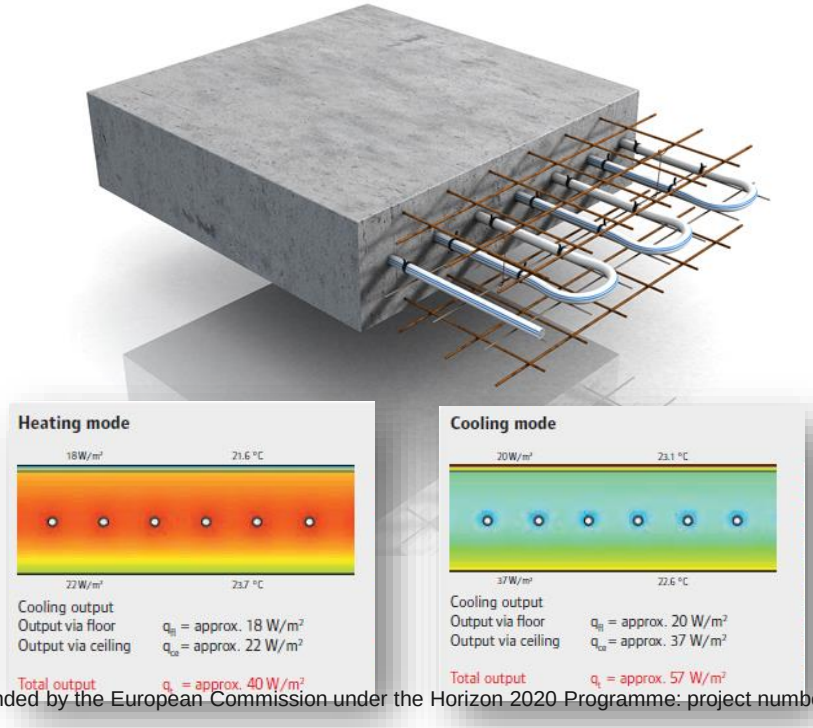
Source: B. Olesen (DTU)

THERMALLY ACTIVATED BUILDING SYSTEMS



- High thermal inertia
- ➢ **Short-term energy storage (day)**
  - Load shifting
  - Peak shaving
  - Grid flexibility
- \+ Large emission surface
- ➢ **Low-temperature heating (22-28°C)**

& High-temperature cooling (15-22°C)

- Self-regulating effect

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Source: B. Olesen (DTU); Q. Wang (Uponor)

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Infrax/Fluvius offices, Brussels (BE)

School in Libeznice (CZ)

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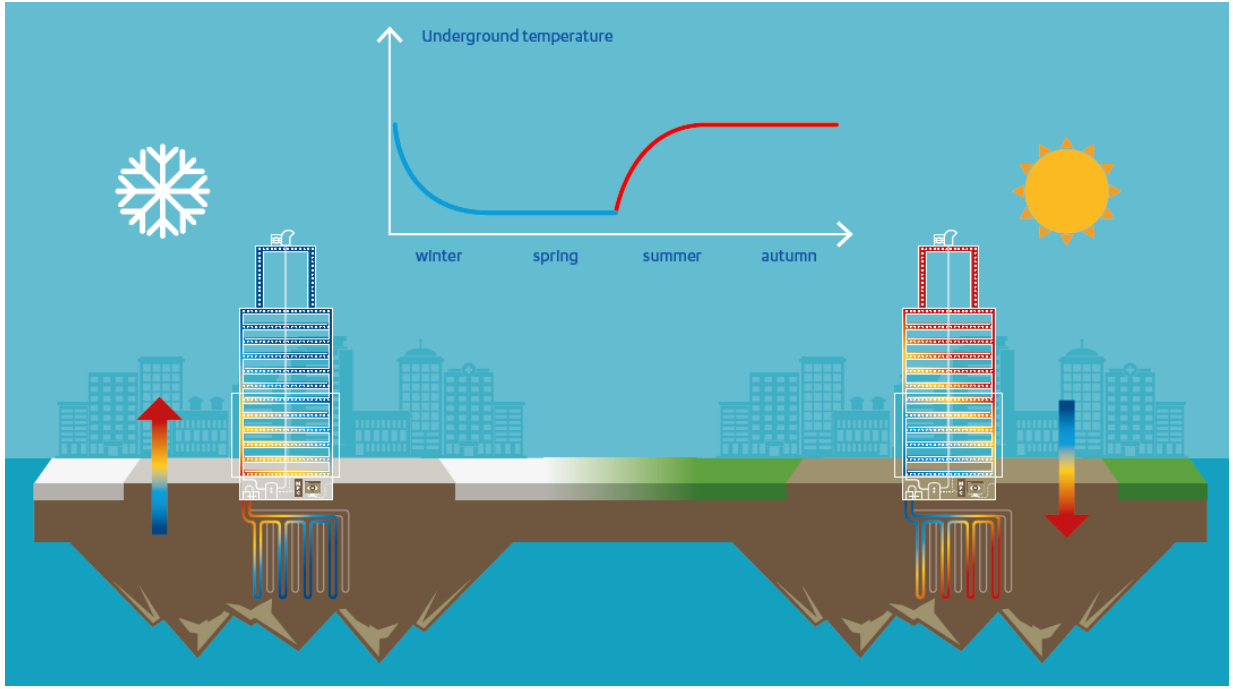
GEOTHERMAL ENERGY



- Renewable, zero-carbon energy source
- Low-temperature source (± 10°C in C-EU)
- High storage capacity
- **Seasonal energy storage**

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"EVERY BUILDING DESERVES A SHARE OF GEOTABS"

TABS

- Low temperature heating **(24°C-28°C)** & high temperature cooling **(16°C-20°C)**

GEOthermal

- Low-temperature source **(8°C-15°C)**

HEAT PUMP

- ➢ **Small ΔT**
- Active heating/cooling: COP↗
- Passive cooling (bypass)
- **High energy-efficiency all year**

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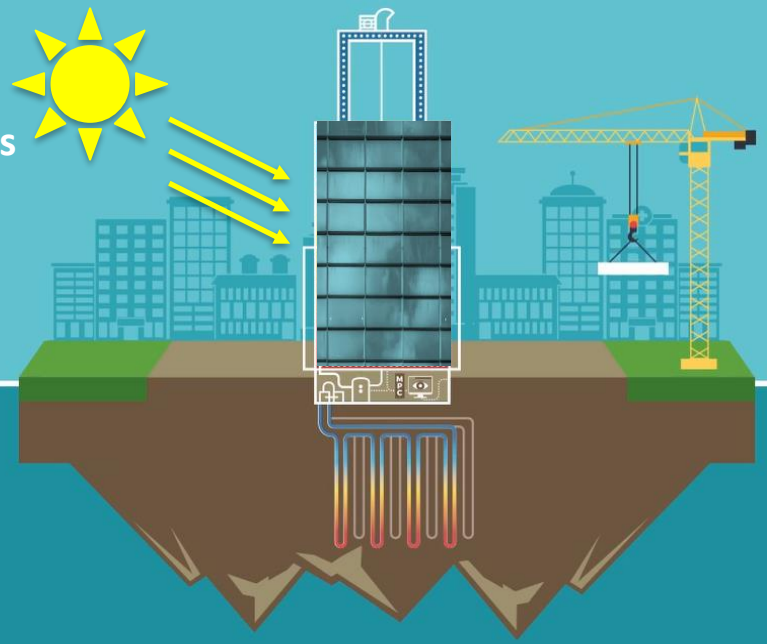
Controlling the power of the ground by integration

"EVERY BUILDING DESERVES A SHARE OF GEOTABS"

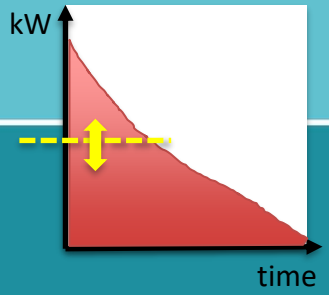
TABS

- Intra-day demand shifts
  Heating ↔ cooling?



GEOthermal

- Feasibility?
  (technical; financial)



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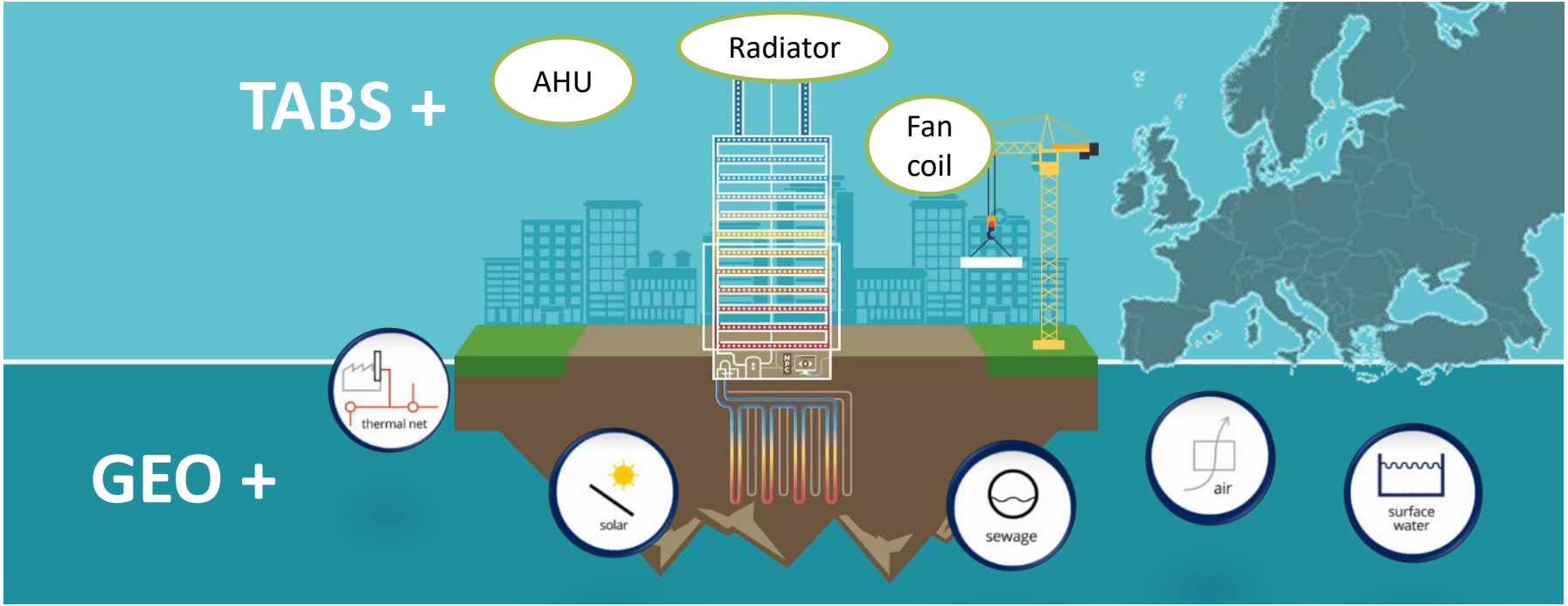
Controlling the power of the ground by integration

hybrid: broaden applicability & sustainable +



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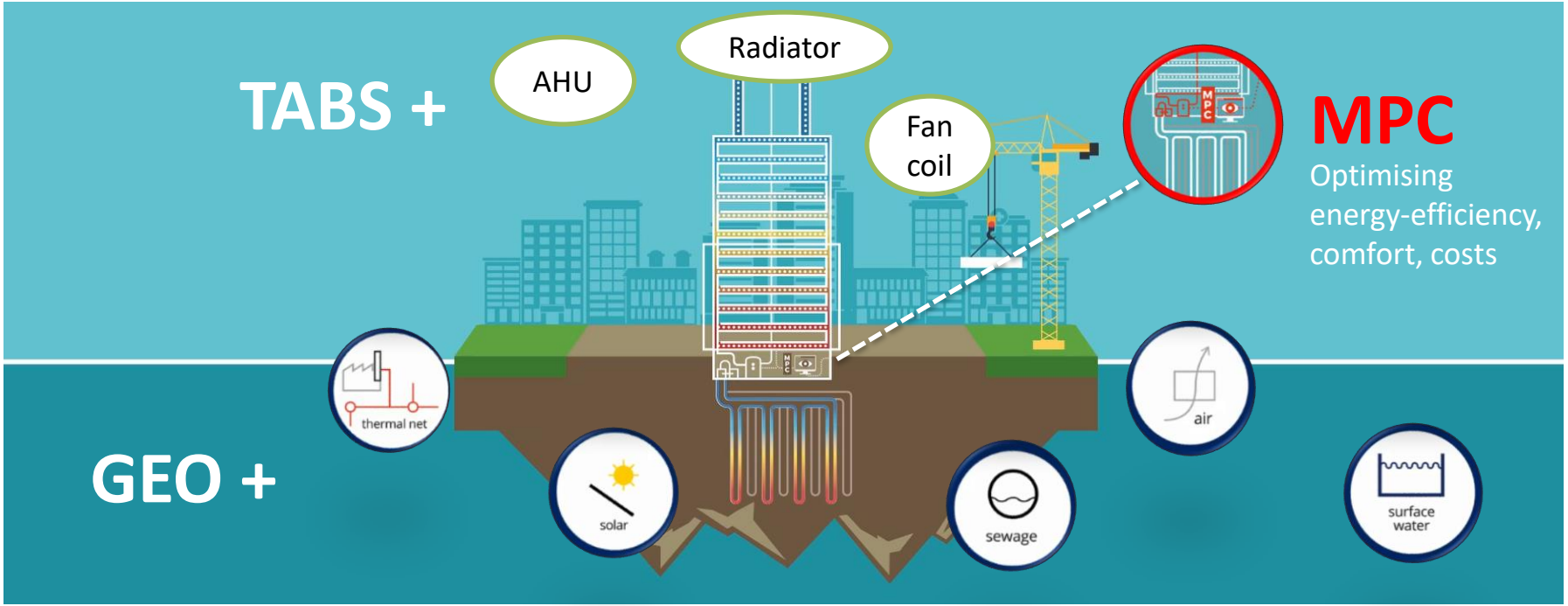
Model Predictive Control: integrator & optimiser



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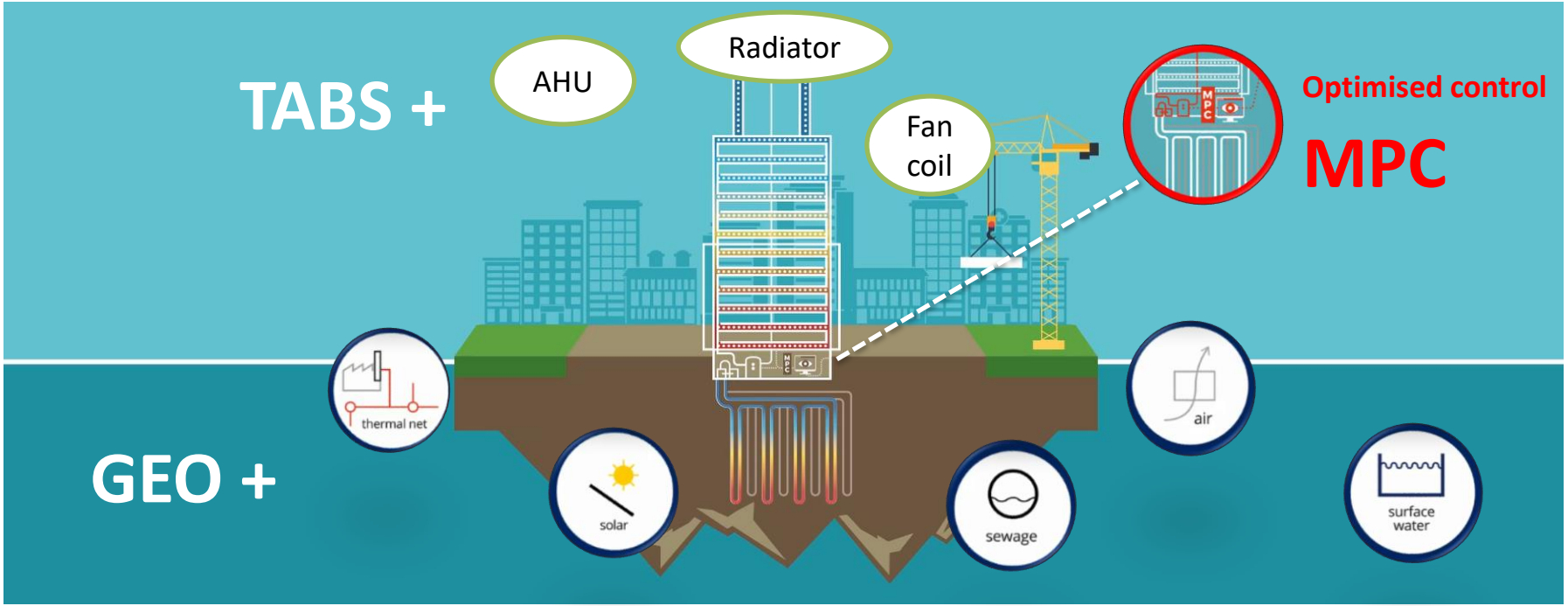
This is hybridGEOTABS



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Optimise

How to design hybridGEOTABS?

MPC needs to be (further) developed…
and tested in real buildings!

What does it cost?

Demonstrate

Energy savings realised?

How good is comfort?

Commercial attractiveness?

Exploitation materials

Exploit

How to bring it to the market?

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Controlling the power of the ground by integration

hybridGEOTABS project

Model Predictive Control and Innovative System Integration of GEOTABS in Hybrid Low Grade Thermal Energy Systems

Sept 2016 – Feb 2021

Horizon 2020 Research and Innovation Action 723649

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723649. The original project acronym is "MPC-.GT".

hybrid GEOTABS

Controlling the power of the ground by integration

PROJECT CONSORTIUM

SME – INDUSTRY – ACADEMIC - DISSEMINATION

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hybrid GEOTABS

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PROJECT CONSORTIUM

SME – INDUSTRY – ACADEMIC - DISSEMINATION

Geoter GEOTHERMAL ENERGY

boydens engineering

GHENT UNIVERSITY

DTU

REHVA

Federation of European Heating, Ventilation and Air-conditioning Associations

LEMON • CONSULT • ENERGY • EFFICIENCY • ENGINEERING

ENERGOKLASTR

KU LEUVEN

climate futures

uponor

VIESSMANN climate of innovation

Maastricht University

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723649. The original project acronym is "MPC-.GT".

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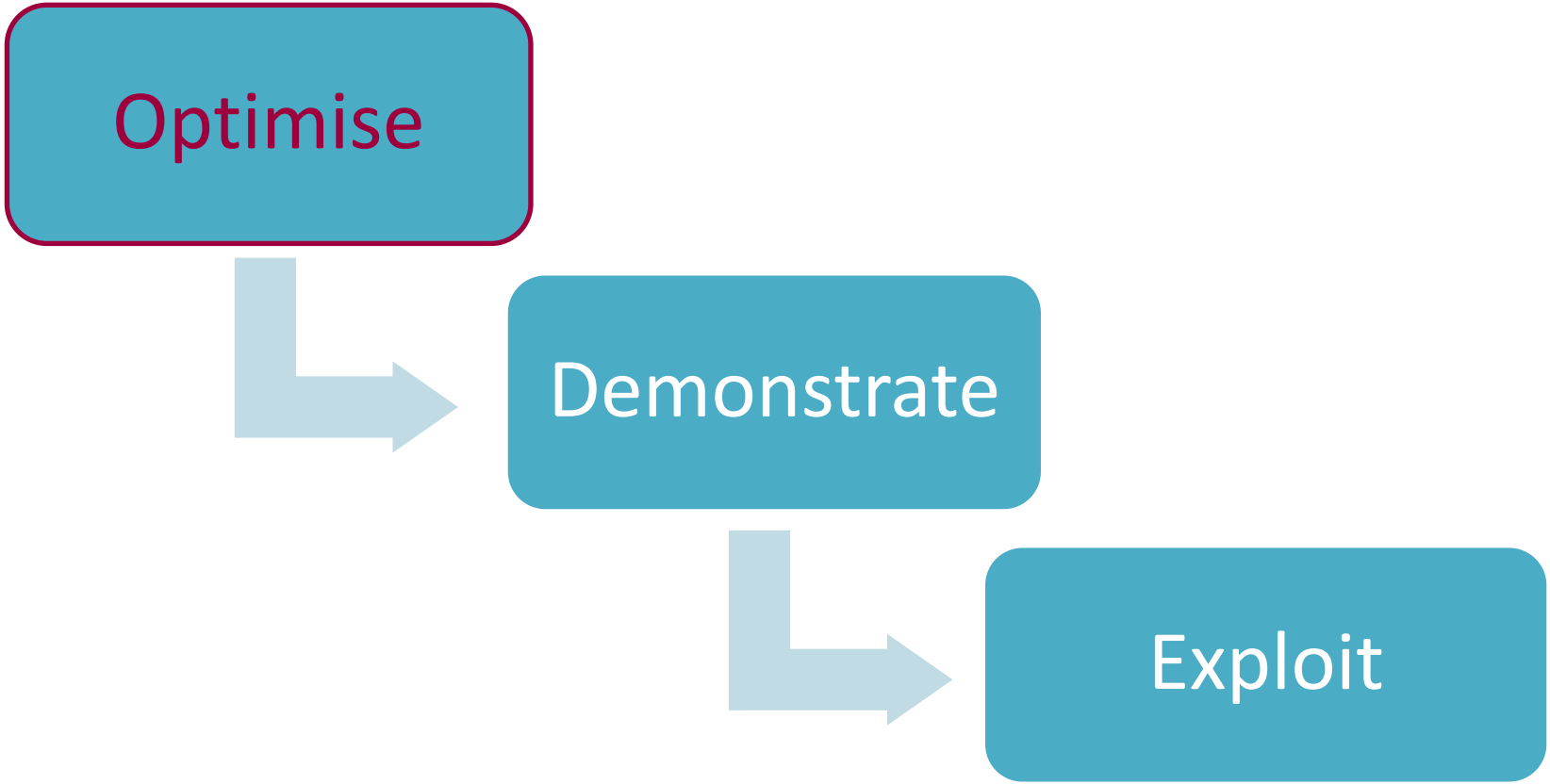
Controlling the power of the ground by integration



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HOW TO DESIGN HYBRIDGEOTABS?

- Optimise the sizing of key components
- Allow to assess feasibility of hybridGEOTABS already in feasibility study and pre-design!
- Easy-to-use: reducing *(pre-)design costs*

- Input: building properties
- Output: sizing, behaviour, performance, cost

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Controlling the power of the ground by integration

Optimise

Demonstrate

Exploit

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Controlling the power of the ground by integration

CASE-STUDY BUILDINGS

- Buildings > 1000 m²
- Typologies:
  - Offices
  - Schools
  - Multi-family
  - Elderly homes
- EU (climate, building stock)

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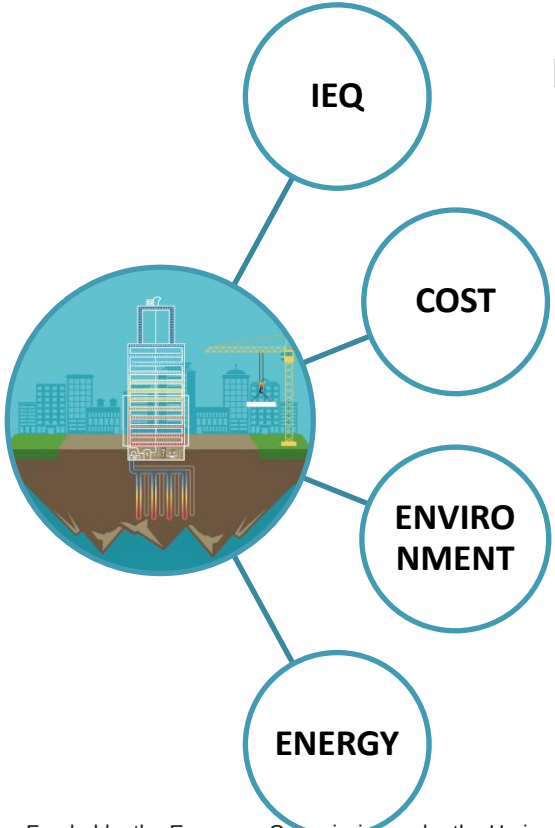

High thermal comfort and IEQ

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source:
O Kazanci (DTU); R Kramer (MU)

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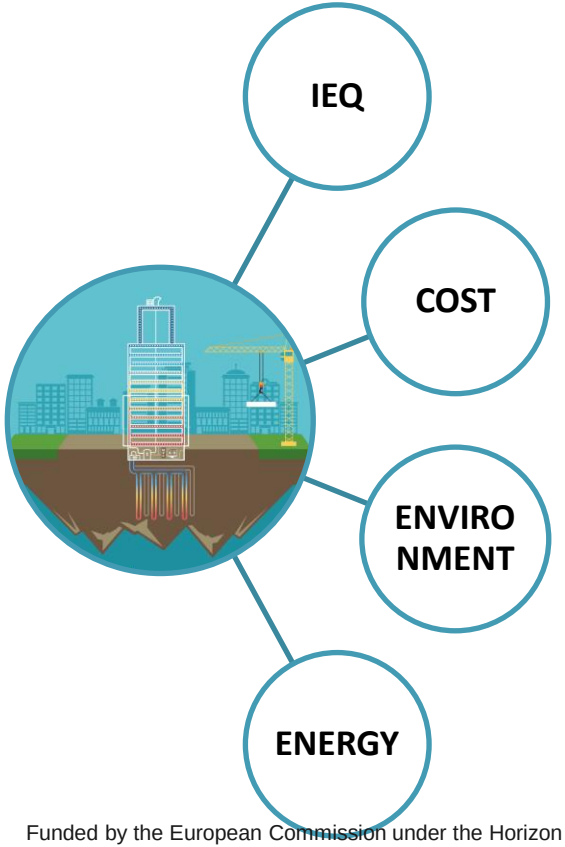
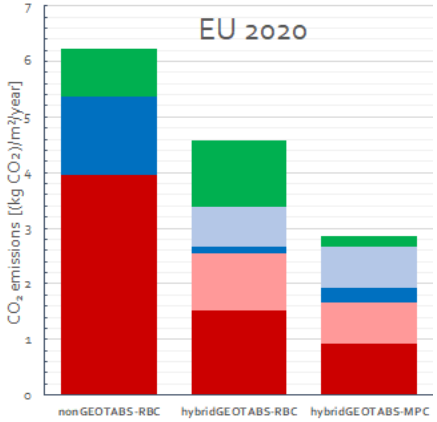
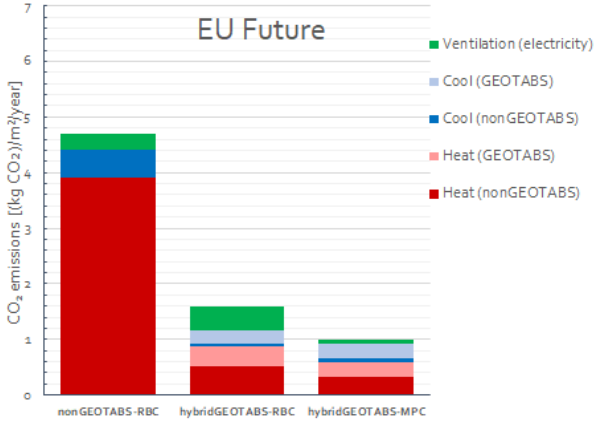


Electricity EU average in 2020:
260 gCO2/kWh



Electricity EU future + pioneering countries:
90 gCO2/kWh



> 50% of CO2-savings compared to standard non-RES (excl. additional RES)

source:
Josué B Bastero (Ghent University),
Iago C Figueroa (KU Leuven)

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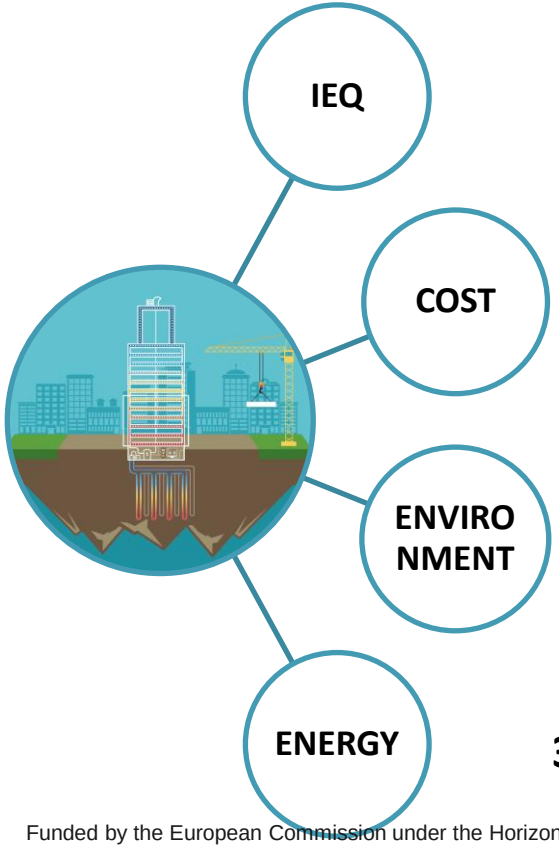

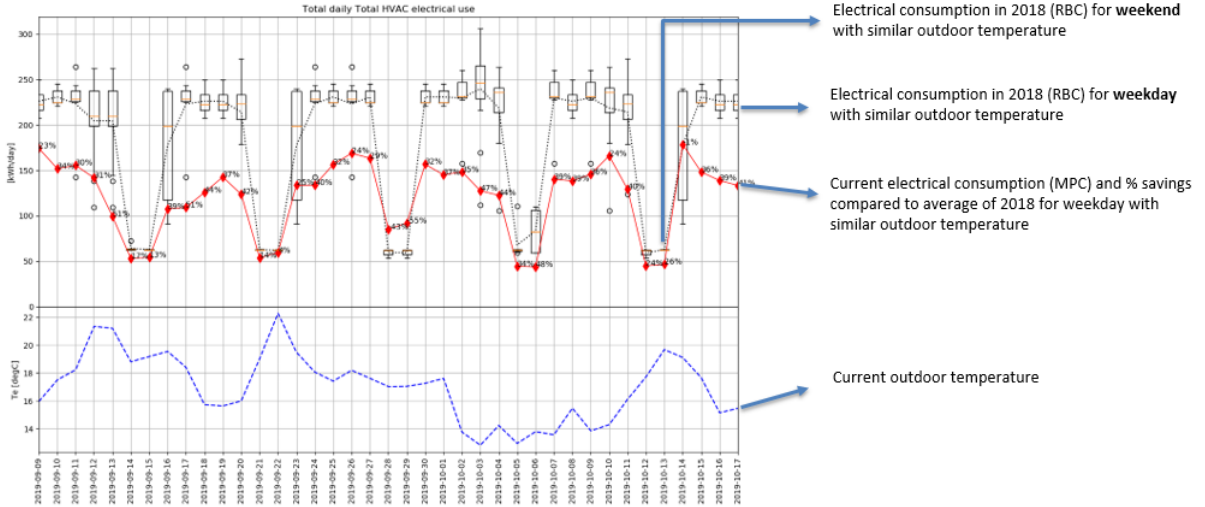

30% of energy savings thanks to MPC

source:
D Picard (KU Leuven)

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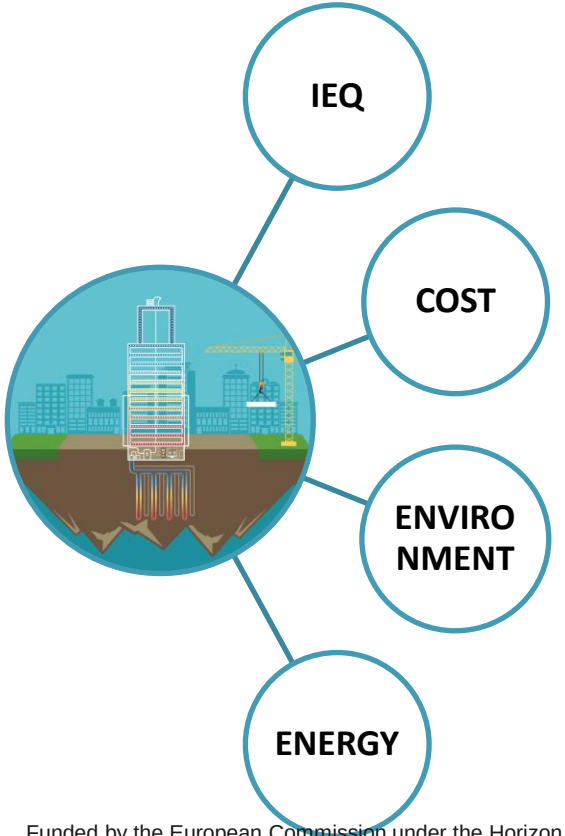
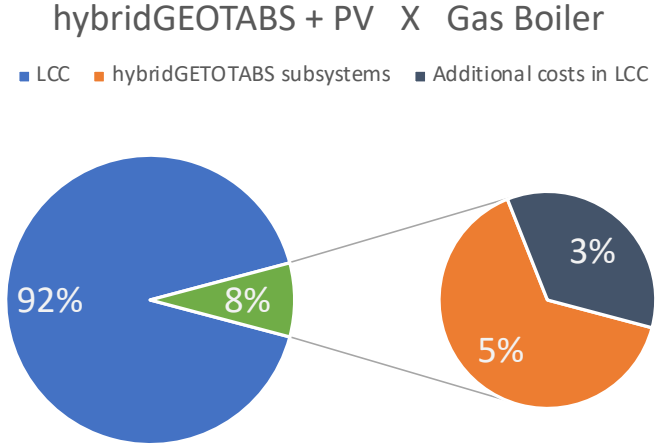


Life Cycle Cost: +1-5% compared to standard non-RES



source:
L Ferkl (EK)

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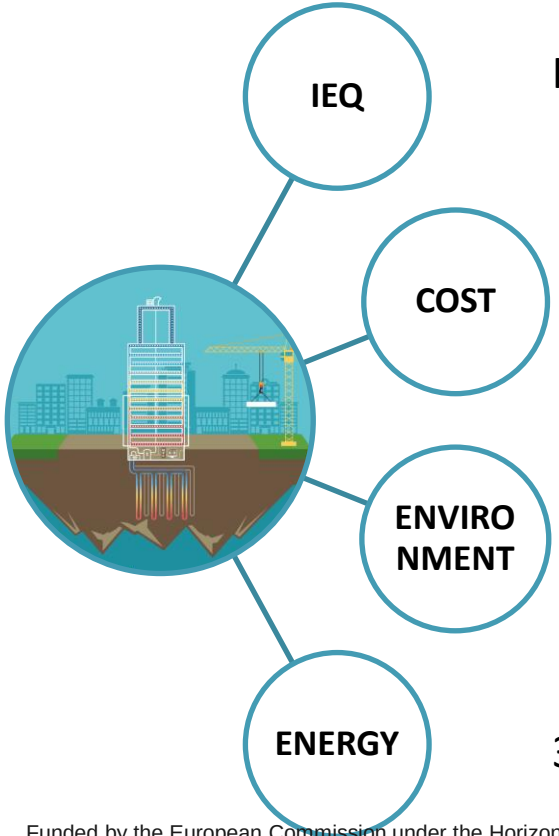

High thermal comfort and IEQ

Life Cycle Cost: +1-5% compared to standard non-RES

> 50% of CO2-savings compared to standard non-RES (excl. additional RES)

30% of energy savings thanks to MPC

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CONTACT

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hybridGEOTABS challenges for designers

hybridGEOTABS training module (webinar)
17 December 2020

prof. ir. Wim Boydens, boydens engineering
CSTO project partner

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lessons learned

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Involved designers

boydens engineering

Geoter GEOTHERMAL ENERGY

LEMON • CONSULT

Involved industries

ENERGOKLASTR

VIESSMANN

uponor

REHVA Federation of European Heating, Ventilation and Air Conditioning Associations

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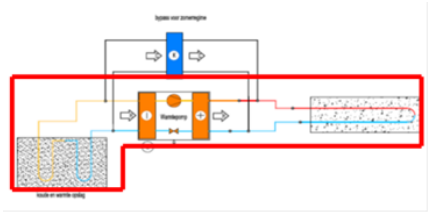
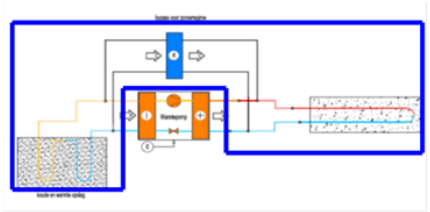
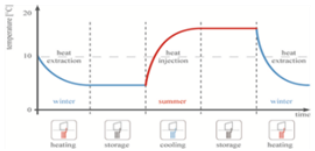
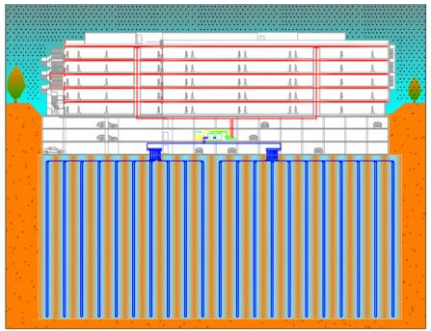
The GEOTABS evaluation from a design perspective: Why? **Strong** points

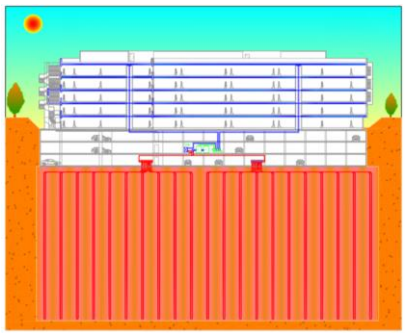
- Simple and logic to explain
- Seasonal storage
- Passive cooling mode
- Renewable heat share integrated, upgradable
- No local emissions
- Less building design constraints than a combustion solution











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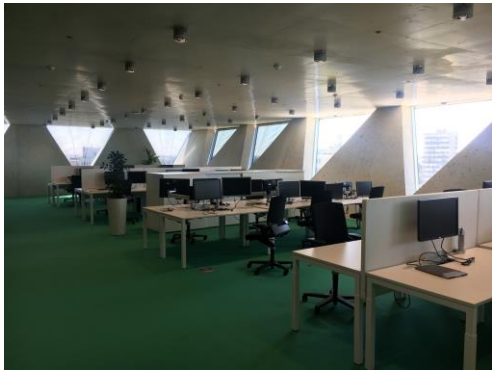
The GEOTABS evaluation from a design perspective: Why? **Strong** points

- High comfort (radiation) & self regulating effect (building integrated storage)
- Robust & flexible
- No installation noise
- Low maintenance
- Lifespan similar as the building
- Freedom of space and height



Antwerp province house,interior view,
Picture: boydens engineering
Arch. XDGA

Libeznice school,interior view,
Copyright: Photograph: **Andrea Thiel Lhotáková Arch. Ing. Arch. A. H. O. Hofmeister, Projektil Architekti**

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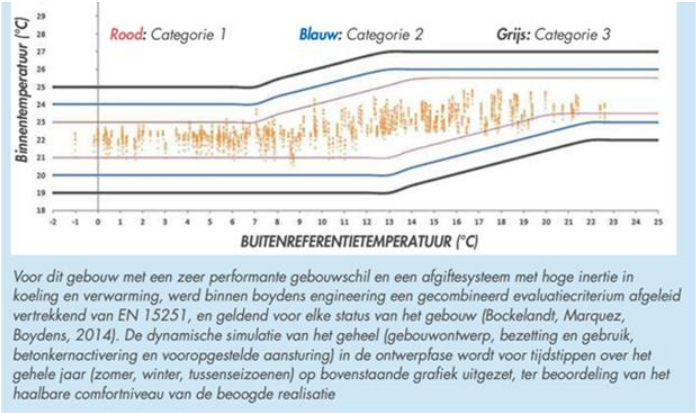
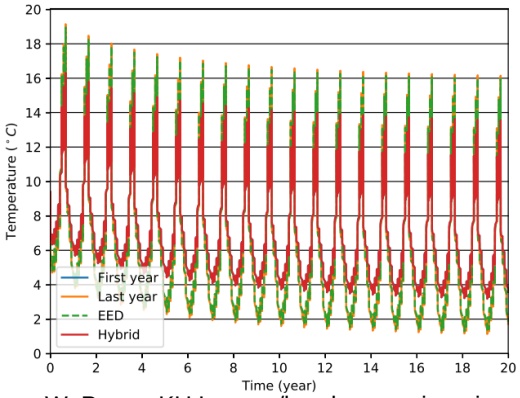
The GEOTABS evaluation from a design perspective: Woww! **challenging** points

- Intensive early design
  (e.g. simulation based)
  for performance assessment



Voor dit gebouw met een zeer performante gebouwschil en een afgiftesysteem met hoge inertie in koeling en verwarming, werd binnen boydens engineering een gecombineerd evaluatiecriterium afgeleid vertrekkend van EN 15251, en geldend voor elke status van het gebouw (Bockelandt, Marquez, Boydens, 2014). De dynamische simulatie van het geheel (gebouwontwerp, bezetting en gebruik, betonkernactivering en vooropgestelde aansturing) in de ontwerpfase wordt voor tijdstippen over het gehele jaar (zomer, winter, tussenseizoenen) op bovenstaande grafiek uitgezet, ter beoordeling van het haalbare comfortniveau van de beoogde realisatie

- Ground balance assessment?
  Interaction with building design?
- Impact of control? (combining power & storage)



W. Peere, KU Leuven/boydens engineering

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The GEOTABS evaluation from a design perspective: Woww! **challenging** points

- Individual room setpoints?
- Design of borehole field, cost-optimality?
- Fair comparison with competing concepts, not only price based but including environmental cost

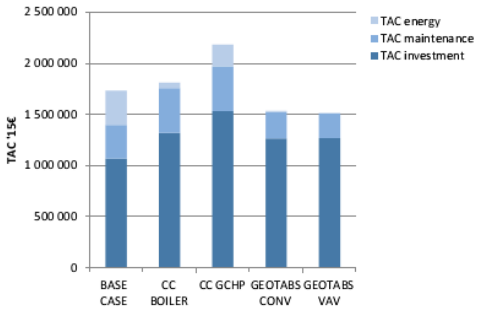
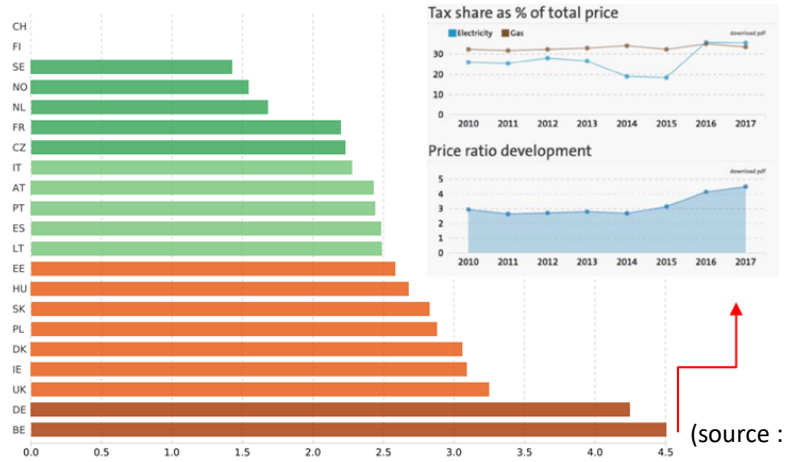


Figure 10.7: Total actual cost over a period of 20 years

Cornelis-Vermeulen, Ugent 2015

Energy price ratios across Europe



(source : EHPA, energy price gap in Europe)

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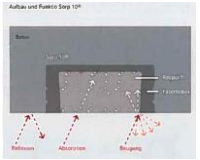
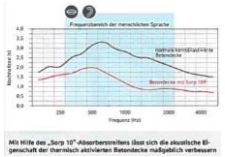
The GEOTABS evaluation from a design perspective: Woww! **challenging** points

- Fine tuning of control, commissioning of a dynamic system, expert task
- Proven solutions, but ‘new’ for installers and control firms, intensive supervision
- Robust comfort, but optimising energy use is the challenge
- Changing cooling to heating mode…
- Room acoustics





integrated absorbers (Uponor)

City office of Torhout (G Debruyne architects)

Herman Teirlinck Building (Neutelings Riedijk Arch)

Offices Van Roey (arch R Schellen)

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hybrid GEOTABS

Controlling the power of the ground by integration

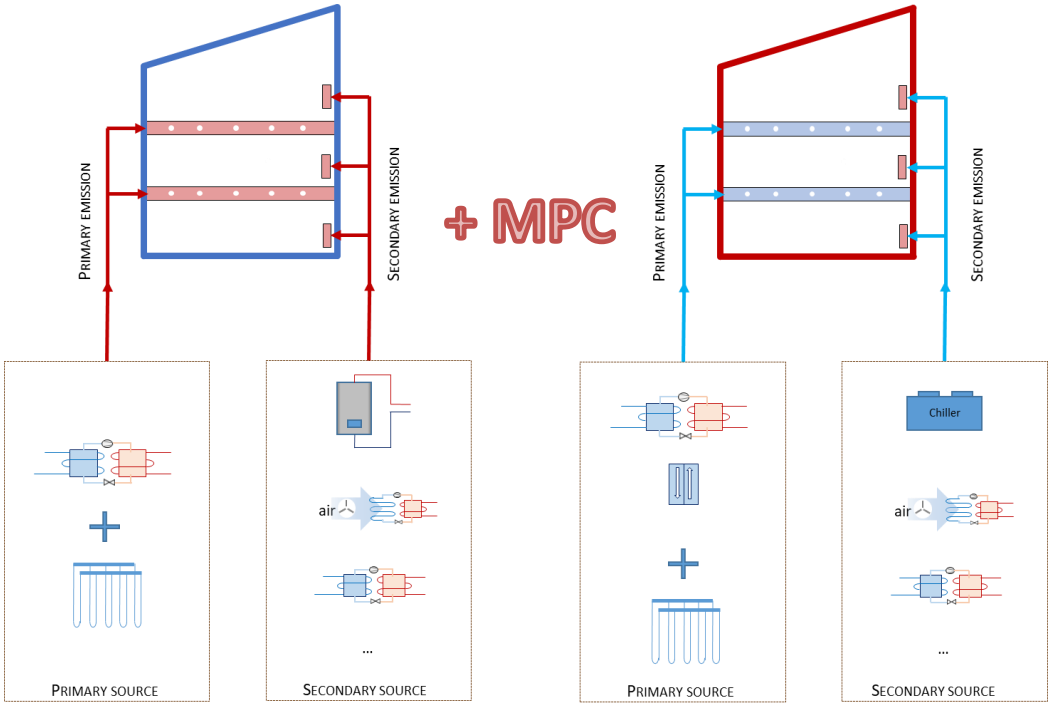
The GEOTABS evaluation from a design perspective:

Solutions within hybridGEOTABS

…

What is hybridGEOTABS?

- **GEOTABS** (primary system)
- + Secondary system
- + MPC (model predictive control)



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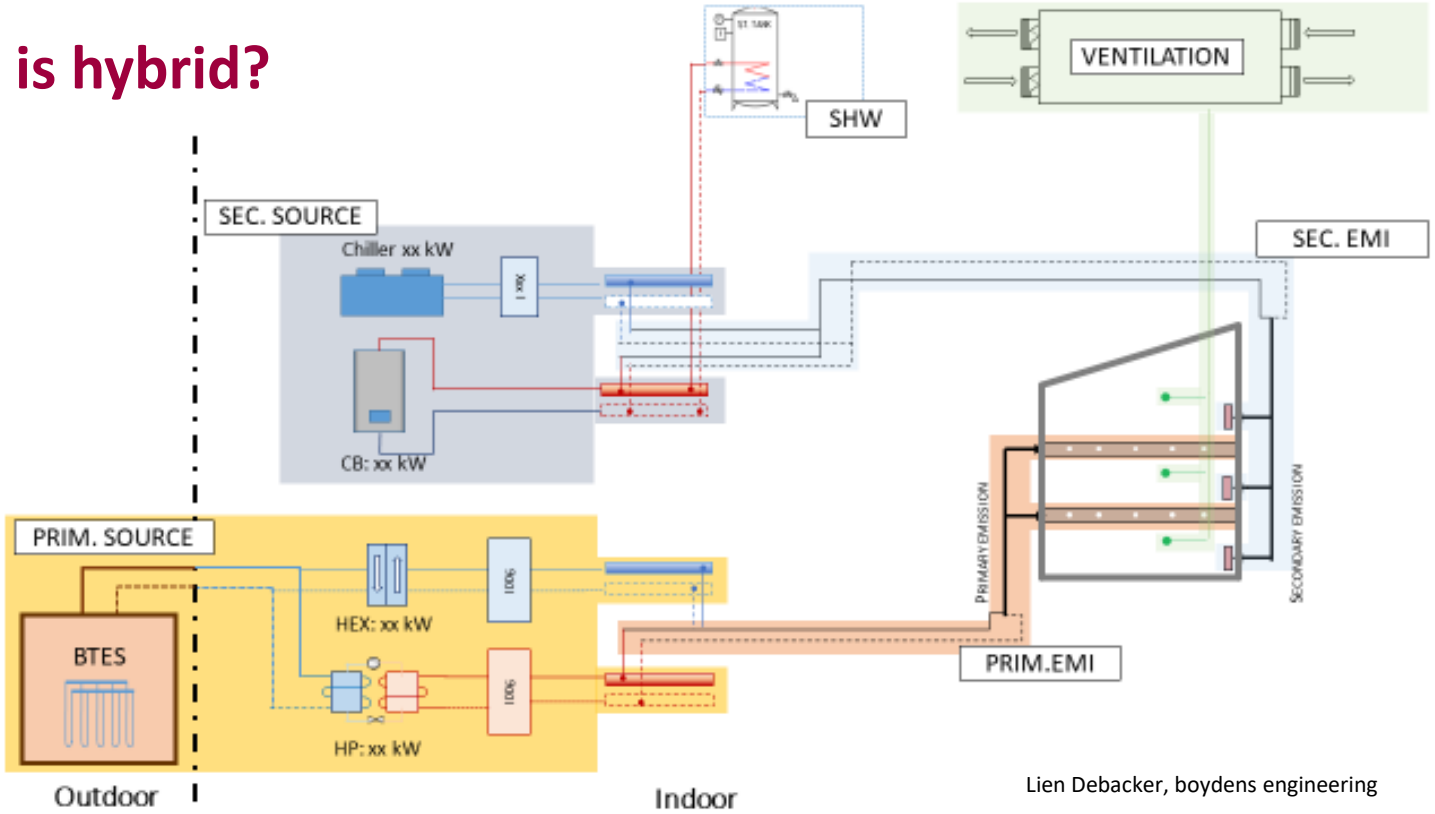
hybrid GEOTABS

Controlling the power of the ground by integration

What is hybrid?



Lien Debacker, boydens engineering

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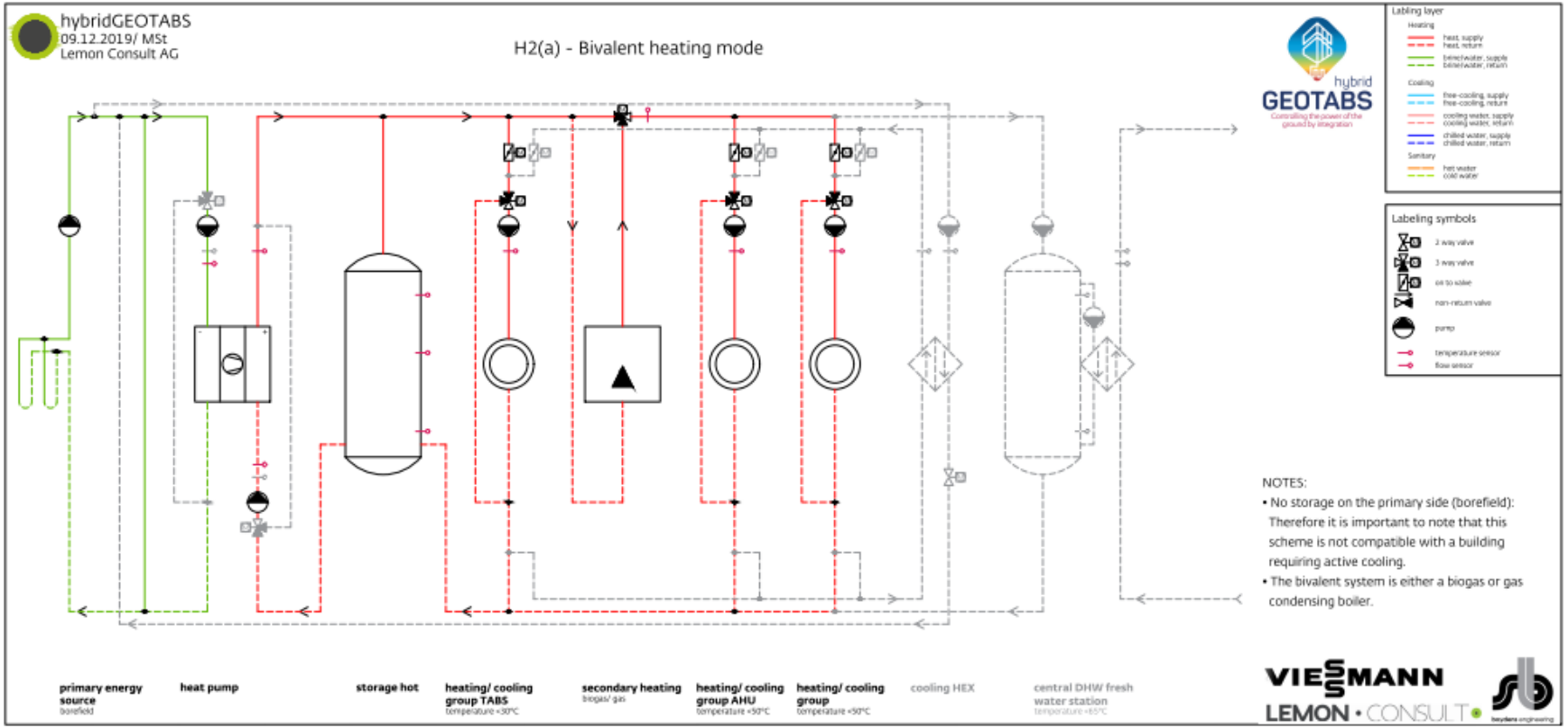
Hydronic scheme of hybridGEOTABS (hybridGEOTABS Hydraulic Schemes)



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The GEOTABS evaluation from a design perspective:

Solutions within hybridGEOTABS …

What is **solved** by going **hybrid**?

- Create a fast early design tool for assessing and comparing performance
- Ground balance assessment? **Interaction with building design?**
- Impact of control?
- **Individual room setpoints?**
- Design of borehole field, **cost-optimality?**
- Fair comparison with competing concepts
- Fine tuning of control, commissioning of a dynamic system, expert task
- **Proven solutions, but 'new' for installers and control firms, intensive supervision**
- Robust comfort, but optimising energy use is the challenge

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What is MPC?

Model Predictive Control

The targeted performances are optimised (objective function)

Using a system (white box) model & predictions

Elaborated @ KU Leuven, Thermal Systems simulation, prof Lieve Helsen

Optimally operating a modelled system

⬇

Optimal design integrating optimal control

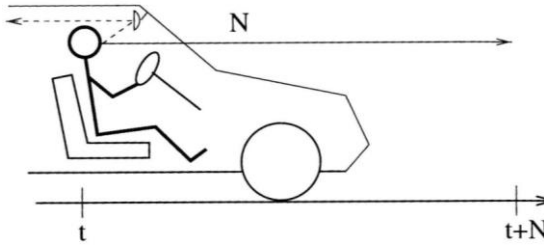
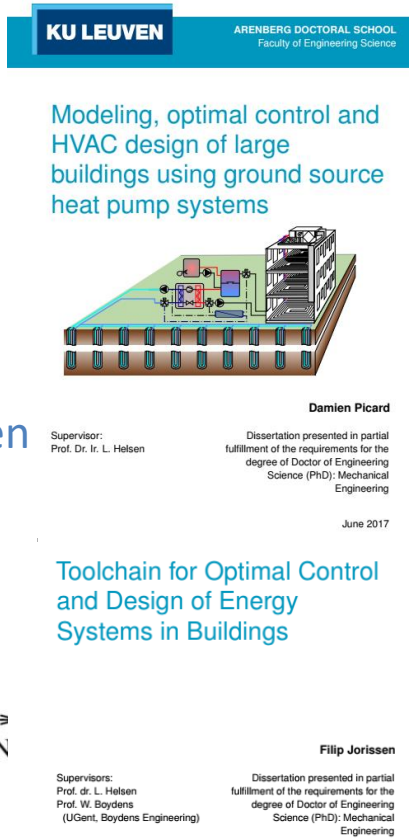


Figure 1.3: MPC analogy
[E.F Camacho and C. Bordons, Model Predictive Control]


KU LEUVEN
ARENBERG DOCTORAL SCHOOL
Faculty of Engineering Science

Modeling, optimal control and HVAC design of large buildings using ground source heat pump systems

Damien Picard

Supervisor:
Prof. Dr. Ir. L. Helsen

Dissertation presented in partial fulfillment of the requirements for the degree of Doctor of Engineering Science (PhD): Mechanical Engineering

June 2017

Toolchain for Optimal Control and Design of Energy Systems in Buildings

Filip Jorissen

Supervisors:
Prof. dr. L. Helsen
Prof. W. Boydens
(UGent, Boydens Engineering)

Dissertation presented in partial fulfillment of the requirements for the degree of Doctor of Engineering Science (PhD): Mechanical Engineering

April 2018

Funded by the European Commission under the Horizon 2020 Programme: project number 723649 (proposal name “MPC-;GT”)

The GEOTABS evaluation from a design perspective:

Solutions within hybridGEOTABS …

What is solved by going hybrid? What is **solved** by **MPC** approach?

- Create a fast early design tool for assessing and comparing performance
- Ground balance assessment? Interaction with building design?
- **Impact of control?**
- Individual room setpoints?
- Design of borehole field, cost-optimality?
- Fair comparison with competing concepts
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Going for a predesign and feasibility tool in early design stage

Starting from GEOTABS as a building component

Every building deserves a share of GEOTABS (no matter what function, which architecture)

How can I mimic the early design of the building?

What does the ideal operating GEOTABS deliver?

What is still needed from a secondary system? How do they collaborate?

TCO analysis? Environmental analysis?

Comparing different **concepts on a fair level playing field** in early design

(conventional non GEOTABS as a start baseline)

Funded by the European Commission under the Horizon 2020 Programme: project number 723649 (proposal name “MPC-;GT”)

Going for a predesign and feasibility tool in early design stage

Starting from GEOTABS as a building component

Every building deserves a share of GEOTABS (no matter what function, which architecture)

How can I mimic the early design of the building? **Simulated database of generated buildings**

What does the ideal operating GEOTABS deliver? **Base load splitting algorithm**

What is still needed from a secondary system? How do they collaborate?

TCO analysis? Environmental analysis? **Cost correlation from real designs & standards**

Comparing different **concepts on a fair level playing field** in early design

(conventional non GEOTABS as a start baseline)

hybridGEOTABS TOOL 1.0

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Solutions within hybridGEOTABS …

What is solved by going hybrid? What is solved by MPC approach? What is **solved** by **the tool**?

- **Create a fast early design tool for assessing and comparing performance**
- **Ground balance assessment?** Interaction with building design?
- Impact of control?
- Individual room setpoints?
- **Design of borehole field**, cost-optimality?
- **Fair comparison with competing concepts**
- Fine tuning of control, commissioning of a dynamic system, expert task
- Proven solutions, but ‘new’ for installers and control firms, intensive supervision
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hybrid GEOTABS

Controlling the power of the ground by integration

From GEOTABS to hybridGEOTABS

- Hand in hand research and practice
- Novel approach with living database
- Optimising costs, environmental impact and efforts of designers
- Opening the Knowledge Centre **ener**CORE for broadening and enriching the methods

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hybrid GEOTABS

Controlling the power of the ground by integration

Learn more at

info@bs2021.org

www.bs2021.org

dedicated impact day for dynamic practice & research sept 1

IBPSA NVL

KU LEUVEN

GHENT UNIVERSITY

boydens engineering

daidalos peutz

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hybrid GEOTABS

Controlling the power of the ground by integration

hybridGEOTABS design method

Prof. Jelle Laverge
Project leader

GHENT UNIVERSITY

hybridgeotabs@ugent.be

Training for designers (webinar)

17 December 2020

hybrid GEOTABS

Controlling the power of the ground by integration

The principles behind the hybridGEOTABS design method

HOW TO ESTIMATE DESIGN POWER AND ENERGY FLOWS IN EARLY DESIGN?

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hybrid GEOTABS

Controlling the power of the ground by integration

GEOTABS: the sustainable core of the building HVAC

TABS

- Low temperature heating (24°C-28°C) & high temperature cooling (16°C-20°C)

GEOthermal

- **Low-carbon renewable energy source**
- Low-temperature source (8°C-15°C)

HEAT PUMP

- **Small ΔT**
- Active heating/cooling: COP↗
- Passive cooling (bypass)
- **High energy-efficiency all year**

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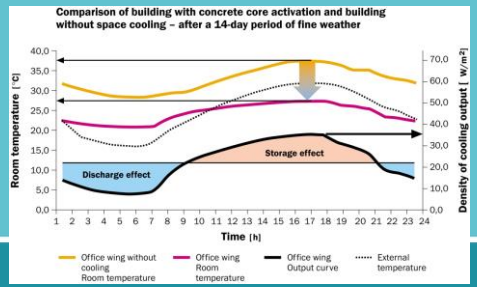
hybrid GEOTABS

Controlling the power of the ground by integration

GEOTABS: the sustainable core of the building HVAC

TABS

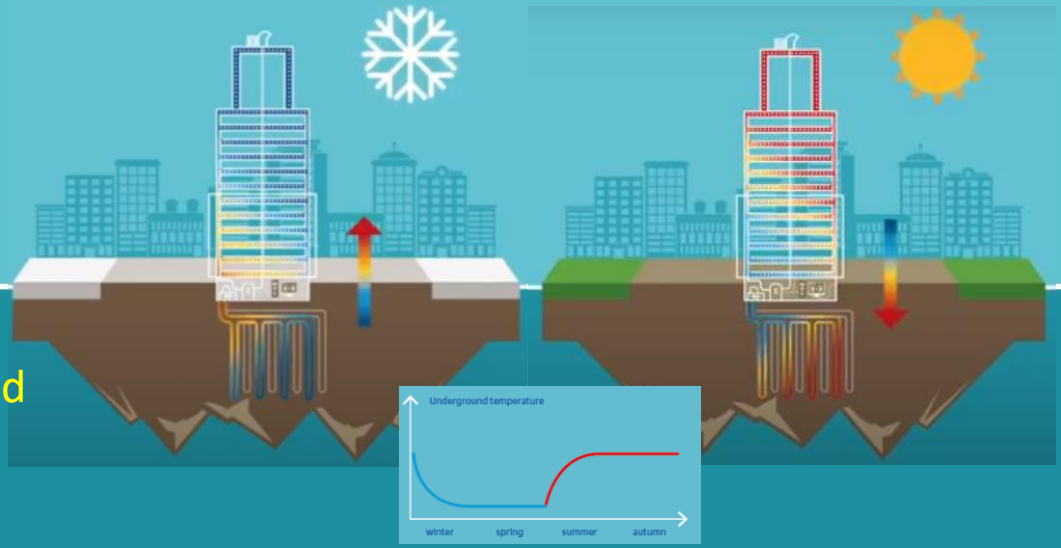
- Short-term energy storage



flexibility in the smart grid
load shifting capacity
peak shaving capacity

GEOthermal

- **Seasonal energy storage**



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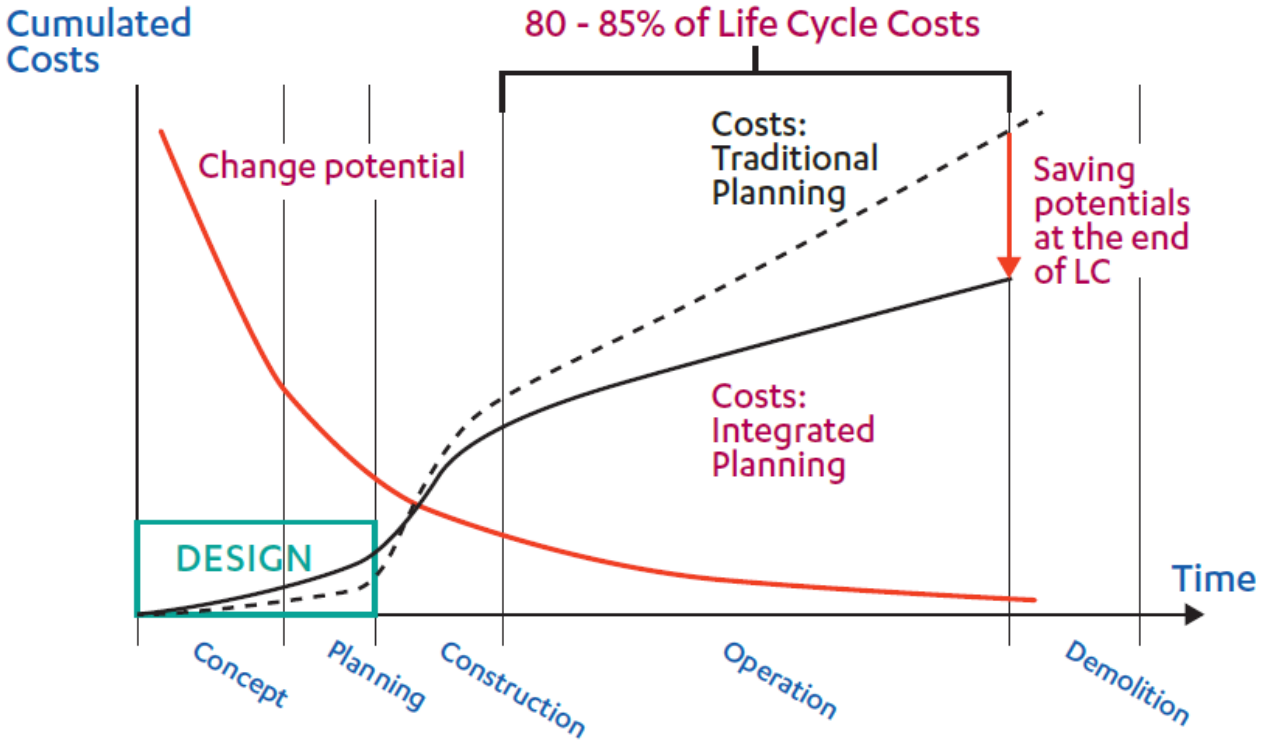
hybrid GEOTABS

Controlling the power of the ground by integration



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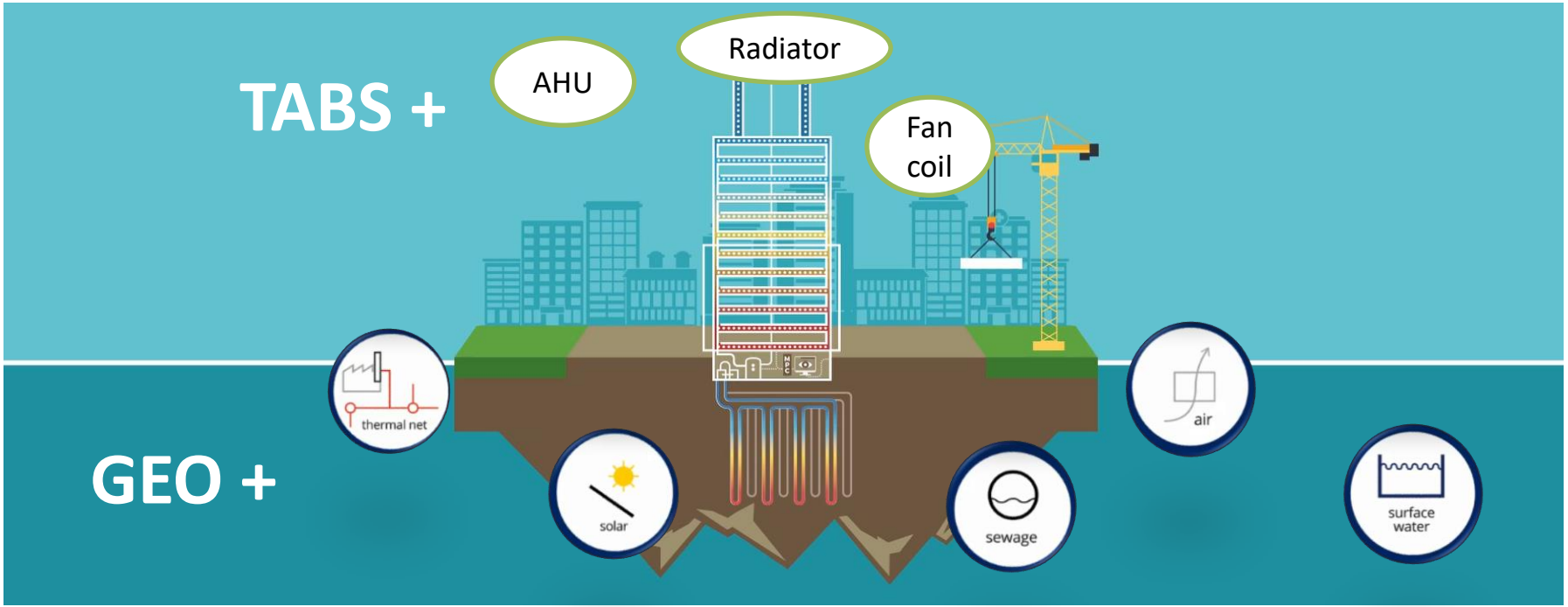
hybrid GEOTABS

Controlling the power of the ground by integration

hybridGEOTABS: broaden applicability & sustainable +



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WISHLIST

- Every buiding deserves a share of GEOTABS, but what share?
- Sizing of main hybridGEOTABS components
- Cost estimate
- Performance estimate

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hybrid GEOTABS

Controlling the power of the ground by integration

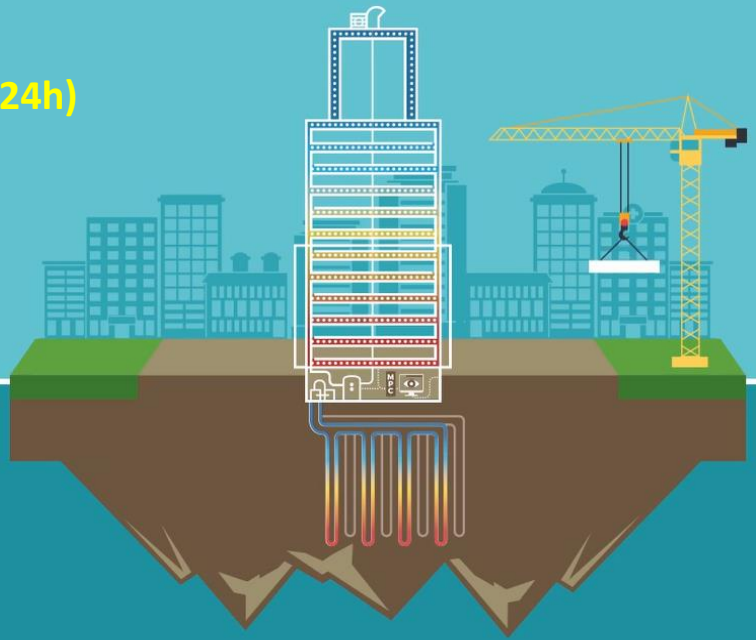
GEOTABS: the challenges for design

TABS

- High time constant (10-24h)

GEOthermal

- Yearly balance?



HEAT PUMP

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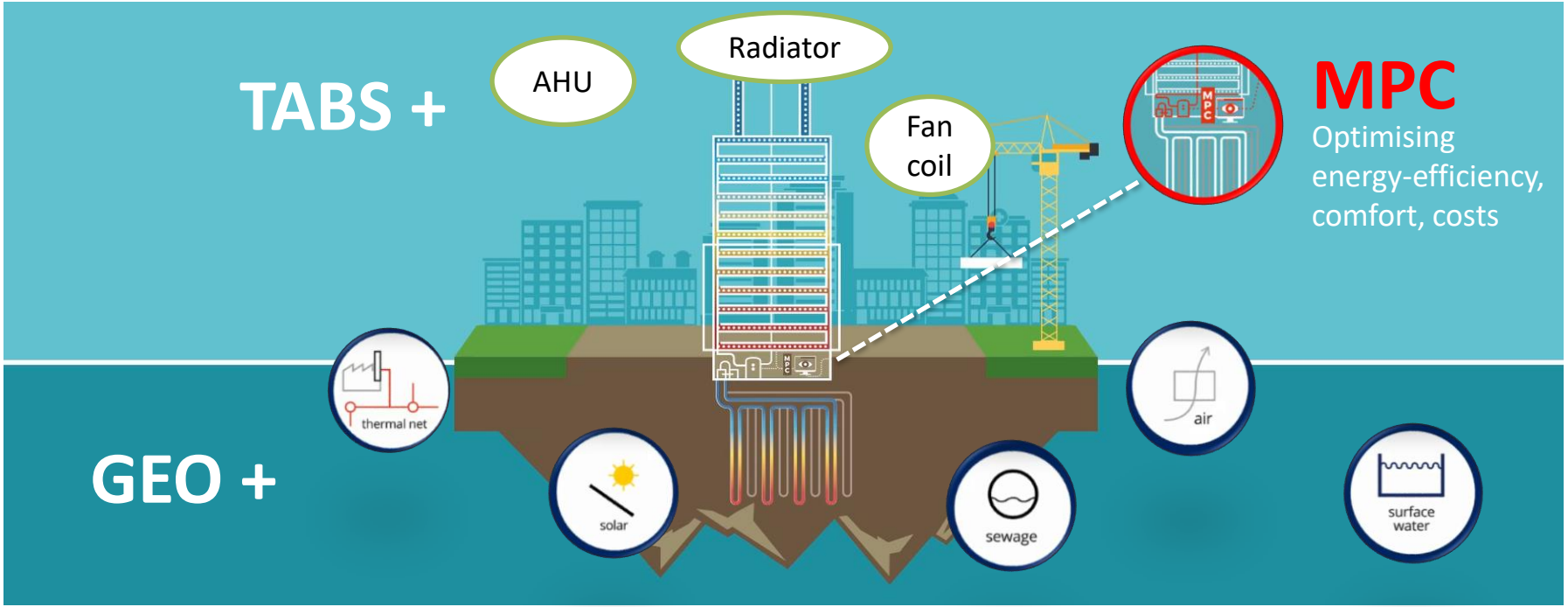
hybrid GEOTABS

Controlling the power of the ground by integration

MPC: integrator & optimiser



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DESIGN METHOD DILEMMA

- What are critical conditions?
- Detailed analysis in early stage?
- How to account for control?

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hybrid GEOTABS

Controlling the power of the ground by integration

Avoiding case-by-case detailed simulations in early design

'BIG DATA' AND PRECALCULATED ARCHETYPES FOR EARLY DESIGN

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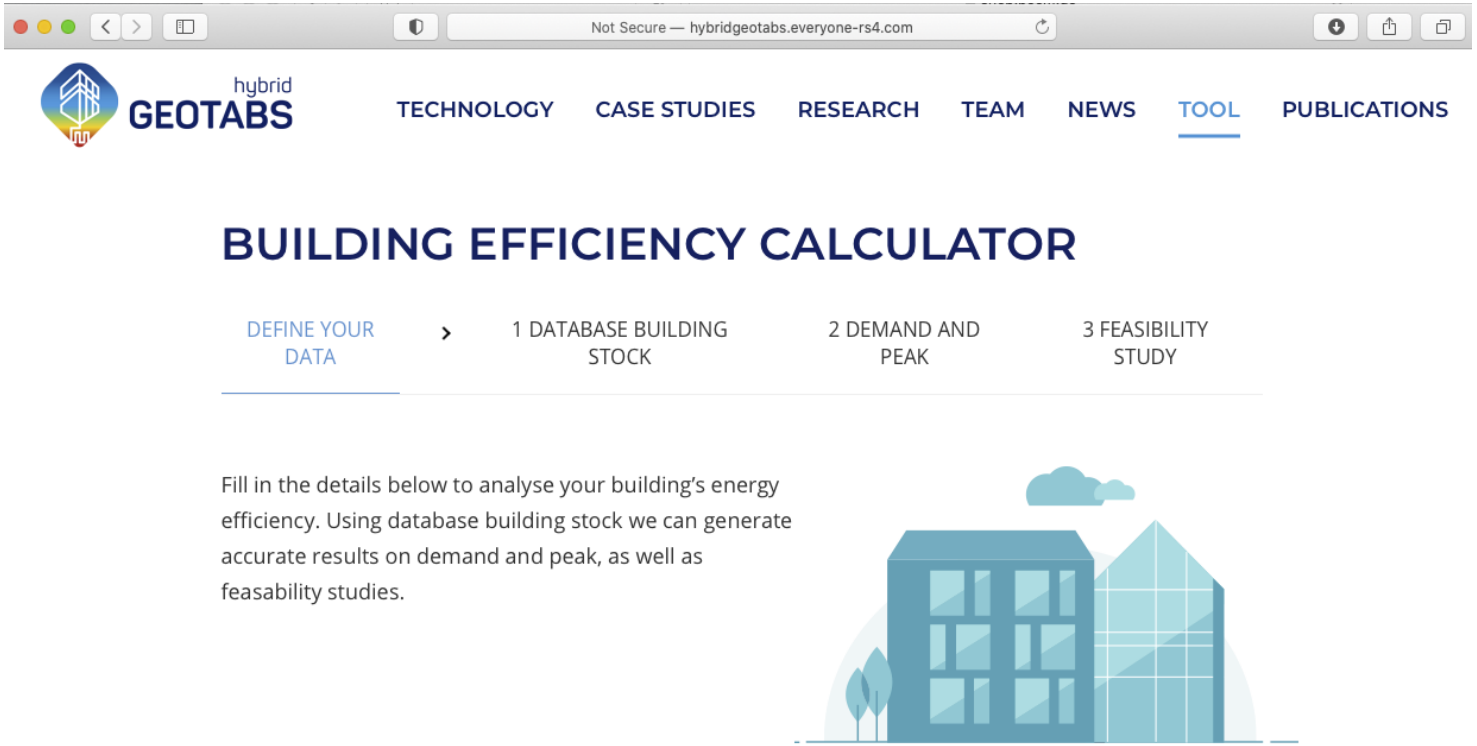
hybrid GEOTABS

Controlling the power of the ground by integration



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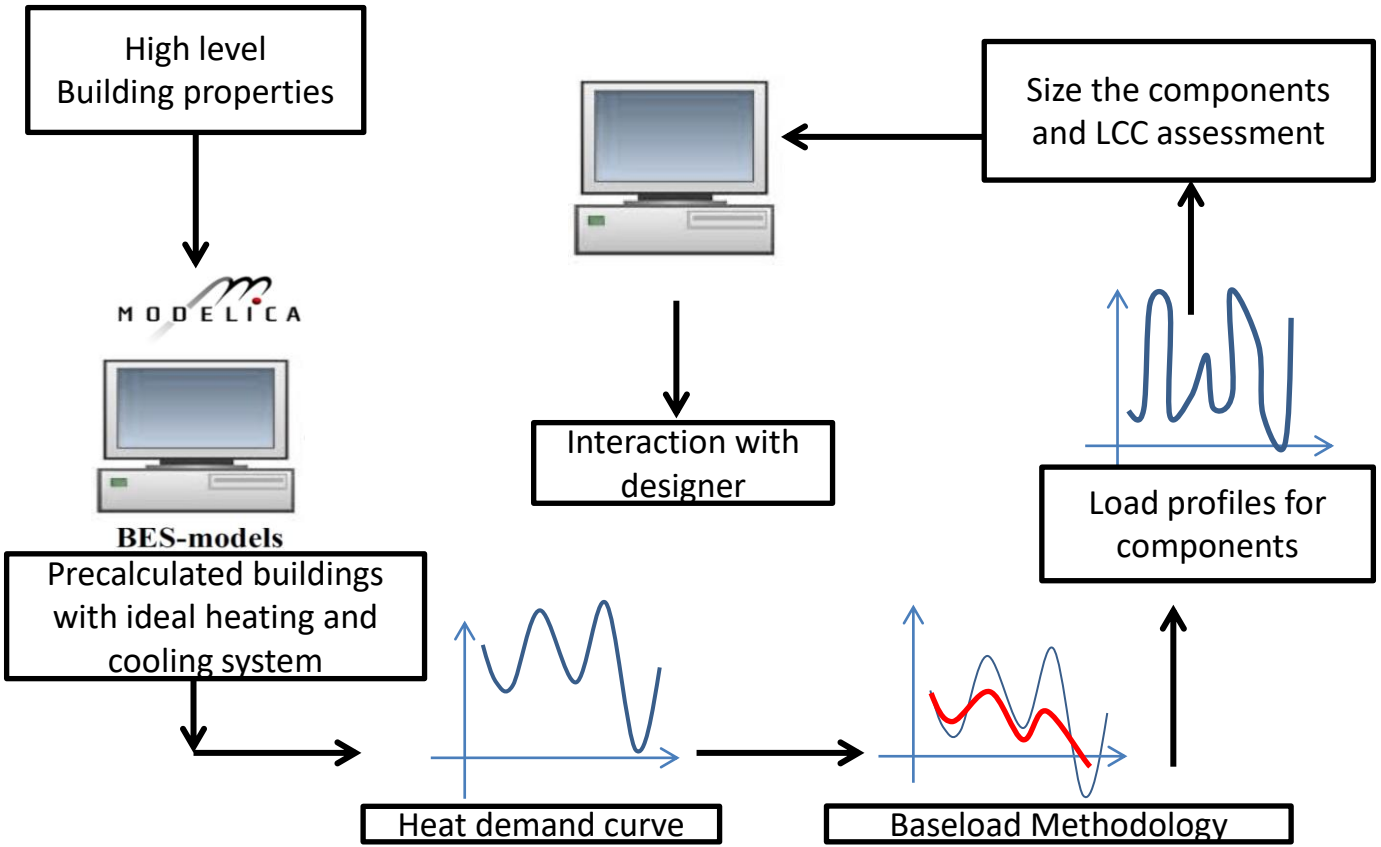
hybrid GEOTABS

Controlling the power of the ground by integration



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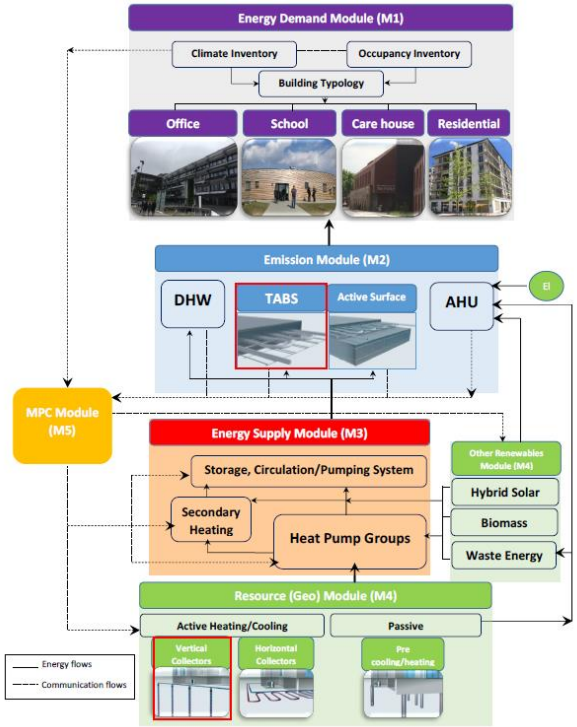
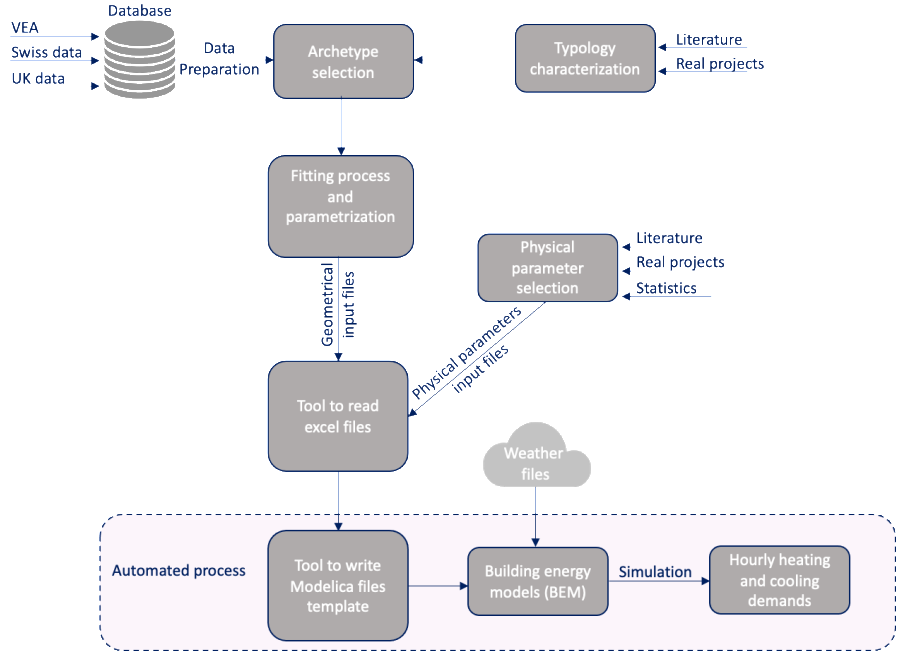
hybrid GEOTABS

Controlling the power of the ground by integration

hybrid GEOTABS System Scheme Model





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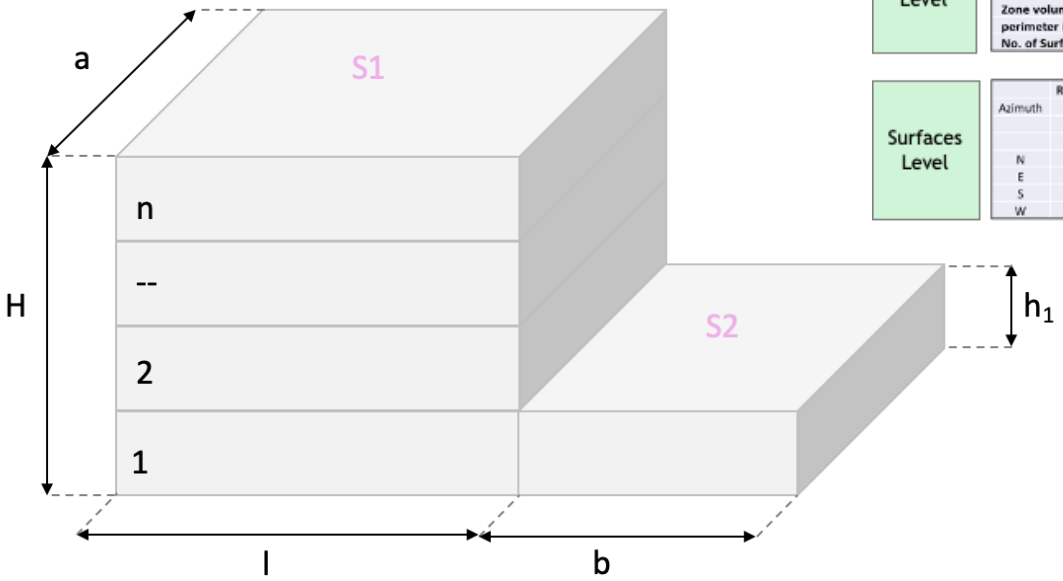
ASSUMPTION 2: 'NEAR' OPTIMAL CONTROL



Zones Level

Building Level	Restaurant	Kitchen	Stairs	Toilets	lobby	Meeting rooms
Zone no.	1	2	3	4	5	6
Zone height (m)	3,7	3,7	3,7	3,7	3,7	3,7
Zone area (m²)	32	15	16	15	66	87
Zone volume (m³)	117,64	55,84	57,6	55,84	242,84	320,53
perimeter (m)	22712	16045	16361	16045	33379	38080
No. of Surfaces	10	8	8	8	12	9

Surfaces Level

	Restaurant							
Azimuth		Length	Width/Height	Area	Windows	Doors	Areaa_no_op	Connections
	Ceiling	6,345	5,011	32				Con_OP_OF_SC_1_FLO
	Floor	6,345	5,011	32				
N	Wall A	5,011	3,7	19		1,755648	17	Con_Kit_C
E	Wall B	6,345	3,7	23	3,66		20	
S	Wall C	5,011	3,7	19	3,66		15	
W	Wall D	6,345	3,7	23		1,755648	22	Con_LOB_B

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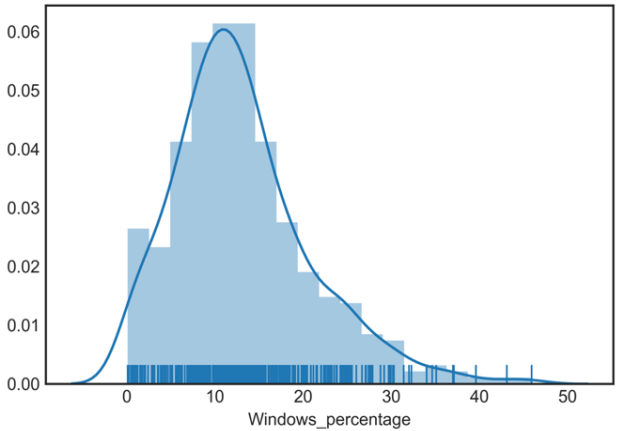
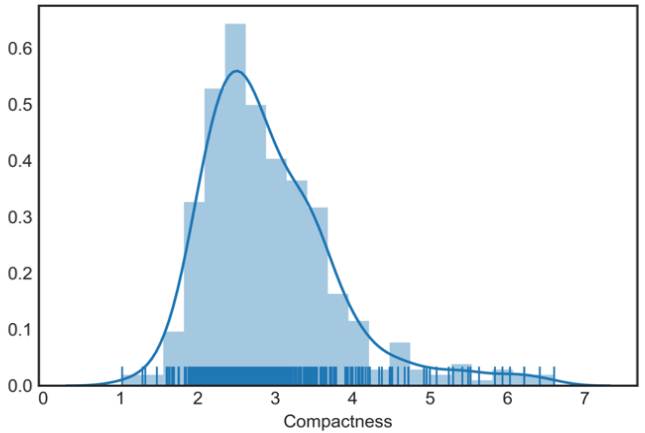
source: Rana Mahmoud (Ghent University)

PROPERTY DISTRIBUTIONS IN THE STOCK





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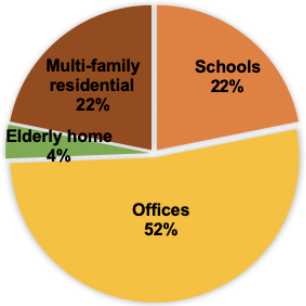
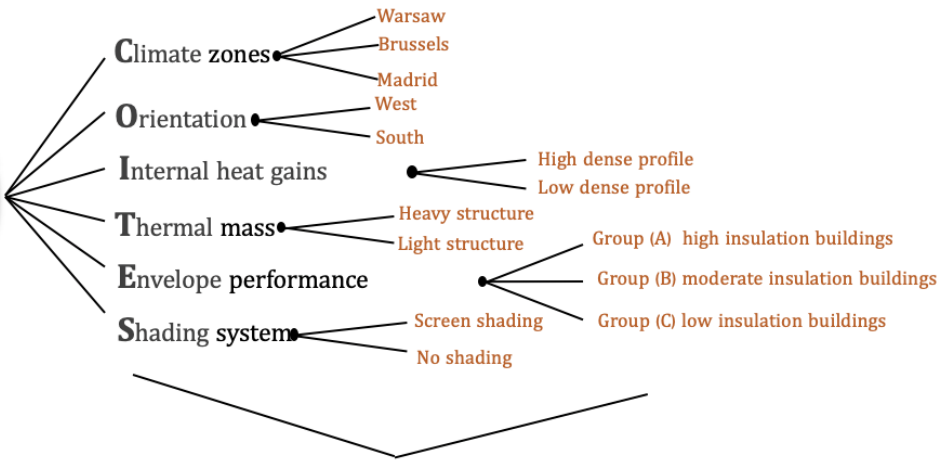
source: Rana Mahmoud (Ghent University)

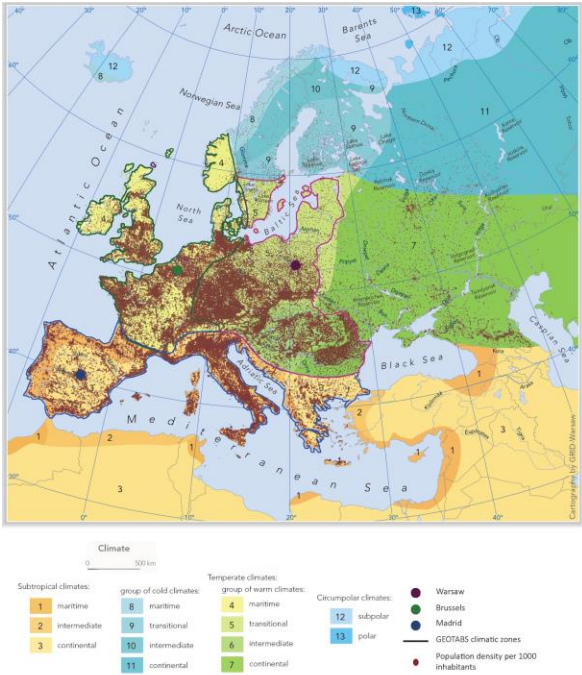
REPRESENTING THE hybridGEOTABS STOCK IN EU



4 Building typologies
ca. 1000 geometries



144 Building physical combinations



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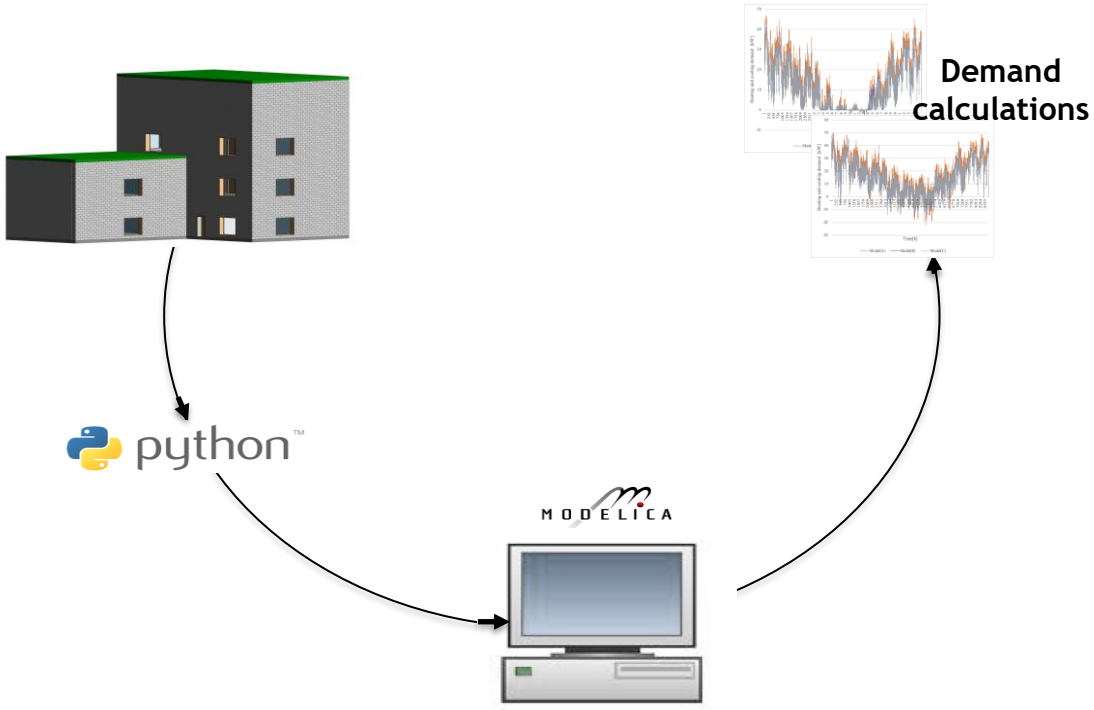
source: Rana Mahmoud (Ghent University)

RESULT: DATABASE OF DEMAND PROFILES



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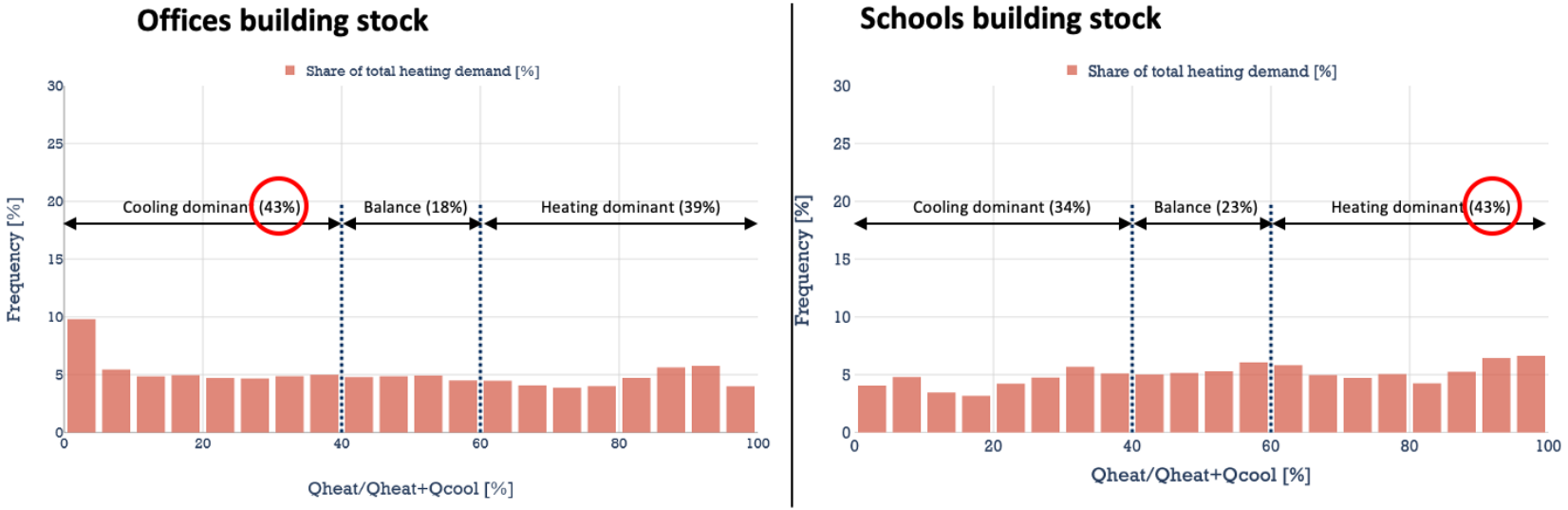
source: Rana Mahmoud (Ghent University)

HEATING AND COOLING DOMINATED



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source: Rana Mahmoud (Ghent University)

hybrid GEOTABS

Controlling the power of the ground by integration

Deciding how to size the GEOTABS and the secondary systems

HOW TO SPLIT THE HEATING AND COOLING DESIGN LOADS?

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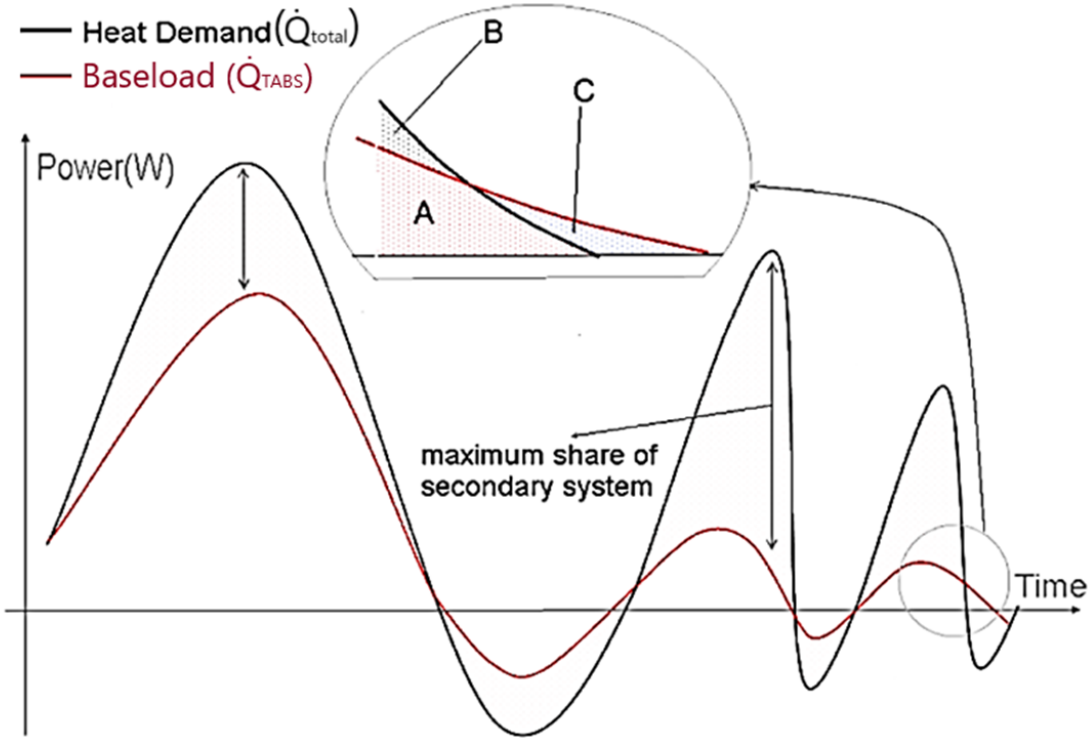
hybrid GEOTABS

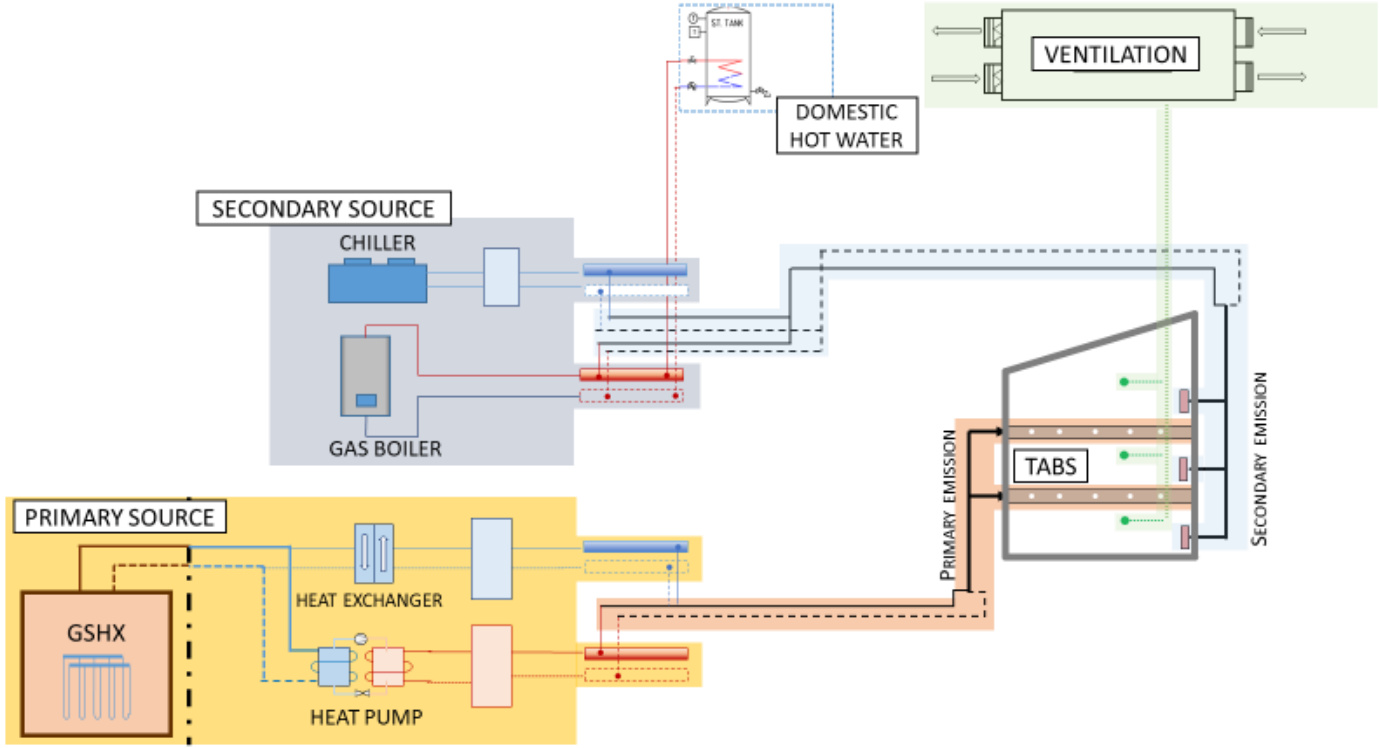
Controlling the power of the ground by integration



Funded by the European Commission under the Horizon 2020 Programme: project number 723649 (proposal name “MPC-;GT”)

source: Mohsen Sharifi (Ghent University)

ASSUMPTION 1: SPLIT SYSTEMS



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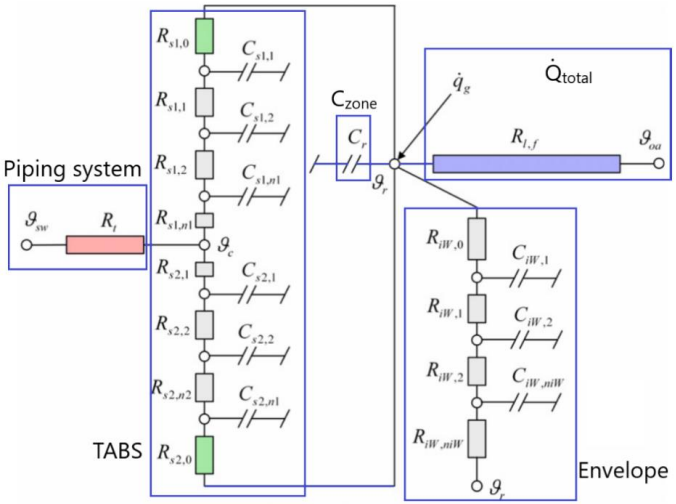
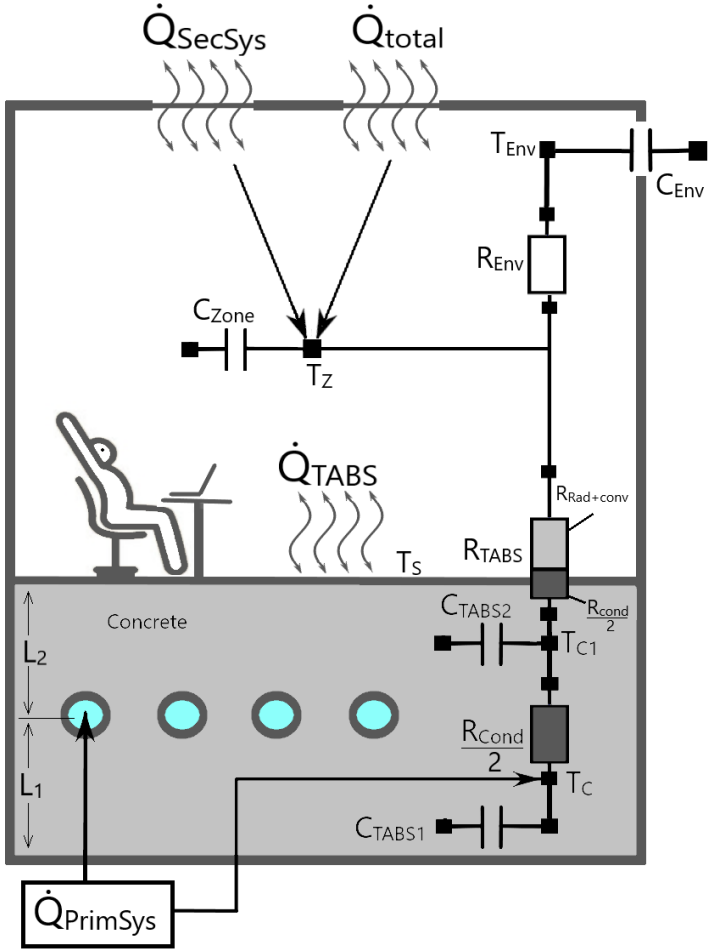
hybrid GEOTABS





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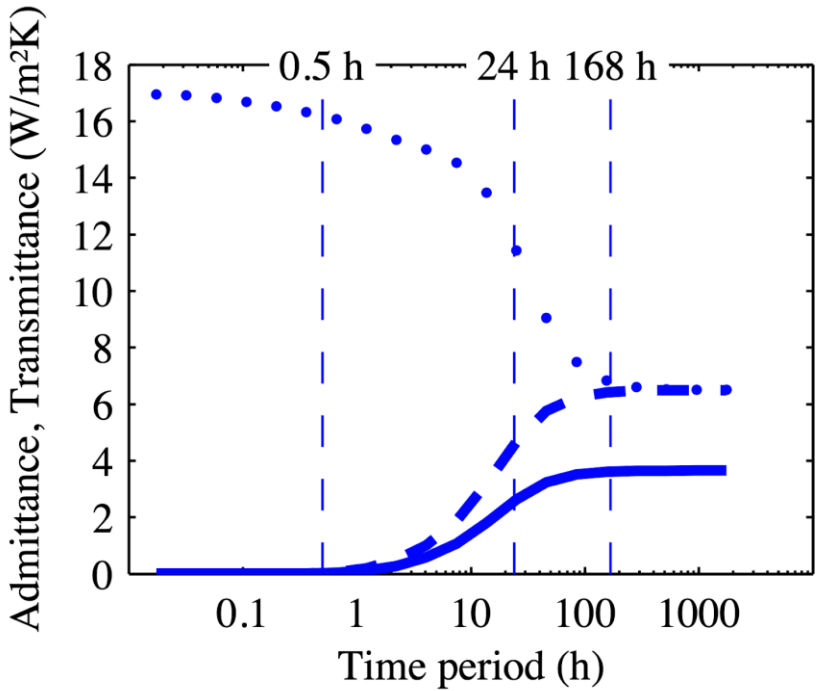
ASSUMPTION 2: 'NEAR' OPTIMAL CONTROL



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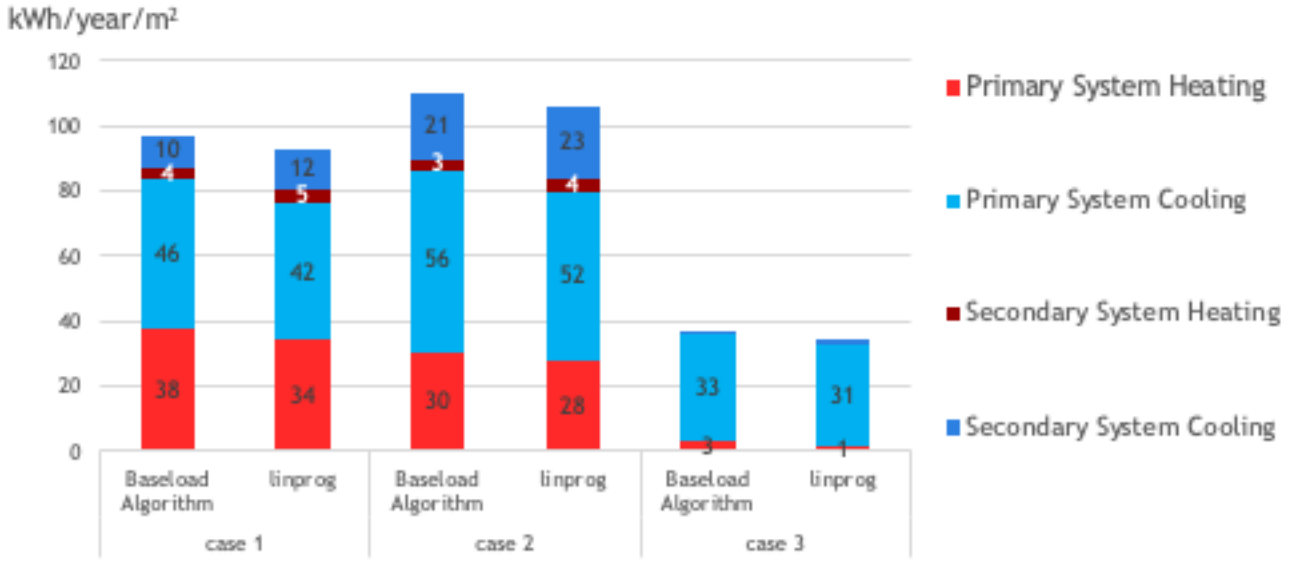
source: Maarten Sourbron (KU Leuven)

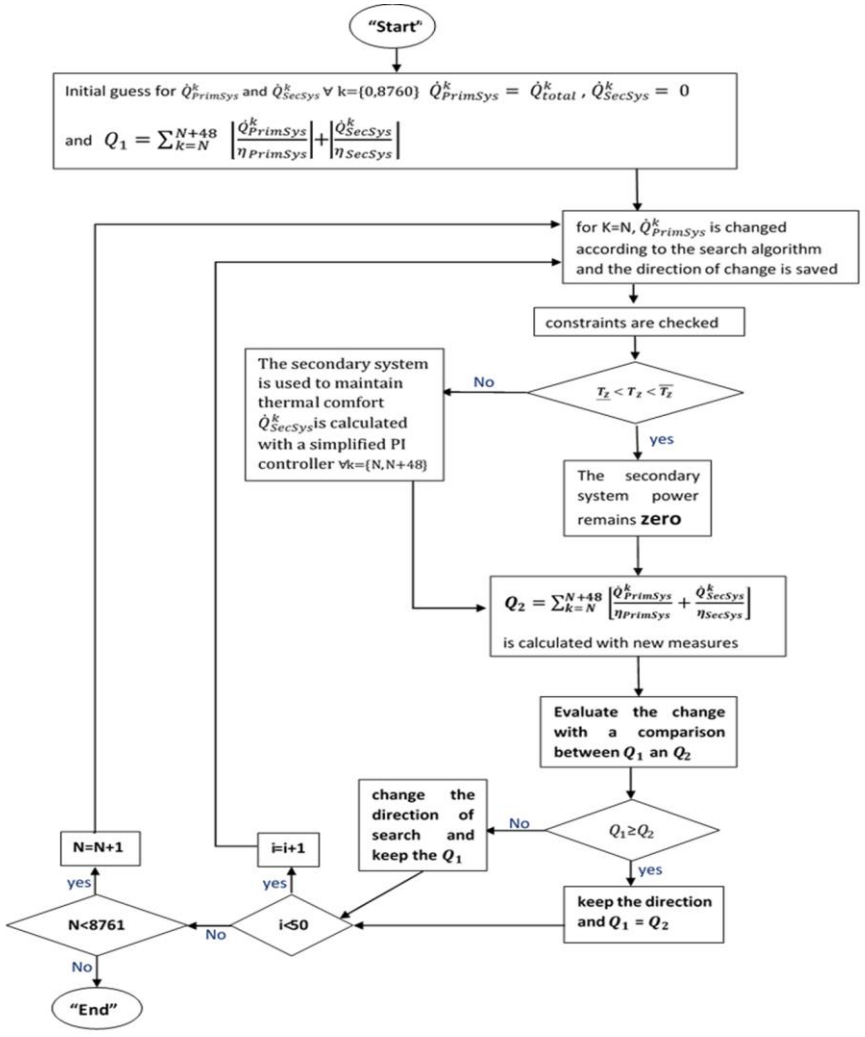
ASSUMPTION 2: 'NEAR' OPTIMAL CONTROL



Funded by the European Commission under the Horizon 2020 Programme: project number 723649 (proposal name "MPC-;GT")

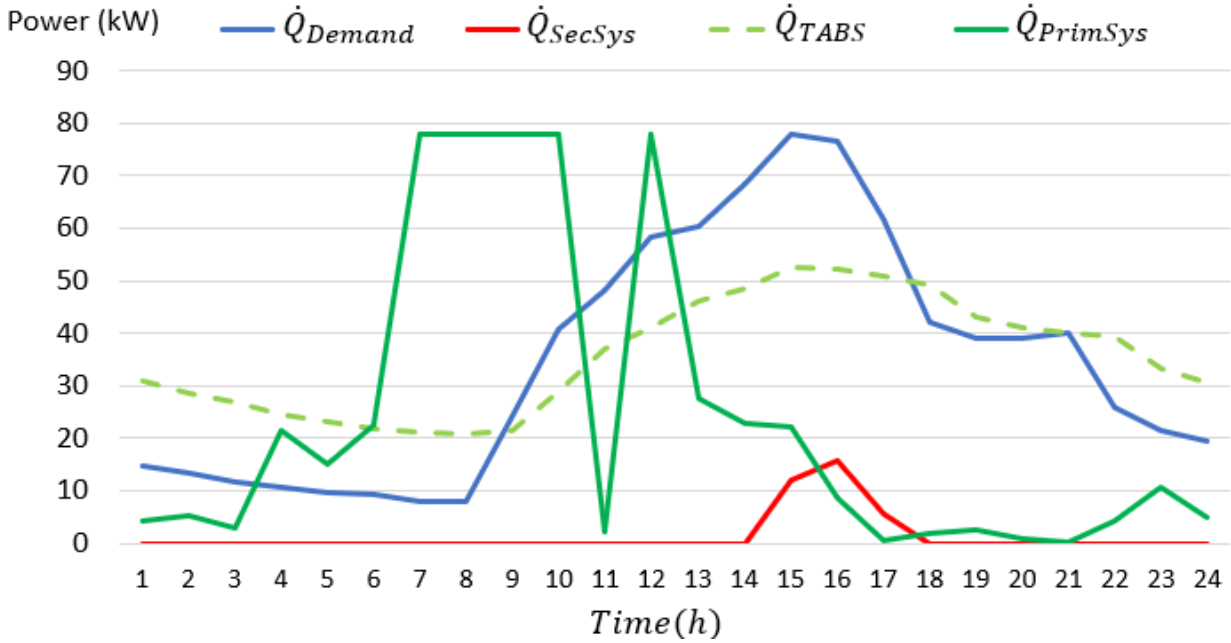
source: Mohsen Sharifi (Ghent University)

hybrid GEOTABS



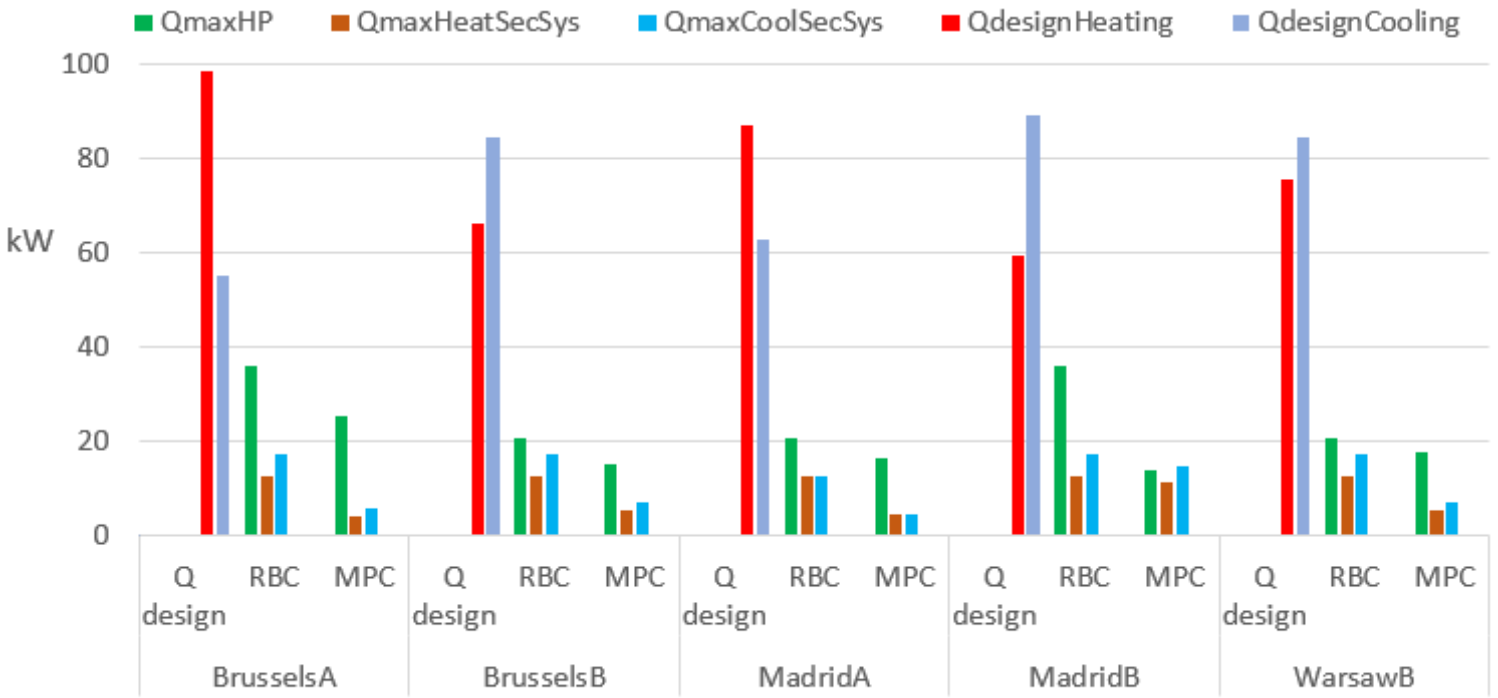
Funded by the European Commission under the Horizon 2020 Programme: project number 723649 (proposal name "MPC-;GT")

ASSUMPTION 2: 'NEAR' OPTIMAL CONTROL



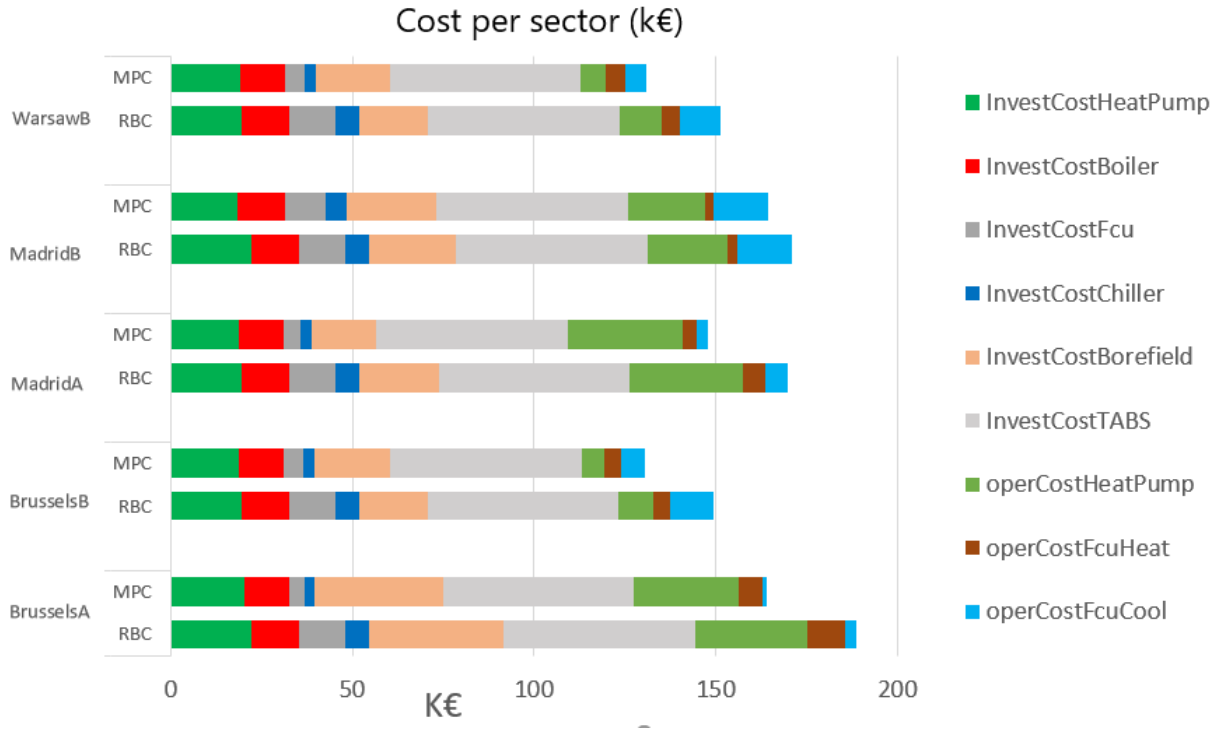
Funded by the European Commission under the Horizon 2020 Programme: project number 723649 (proposal name "MPC-;GT")

RESULTS: component sizing



Funded by the European Commission under the Horizon 2020 Programme: project number 723649 (proposal name “MPC-;GT”)

RESULTS: costs



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hybrid GEOTABS

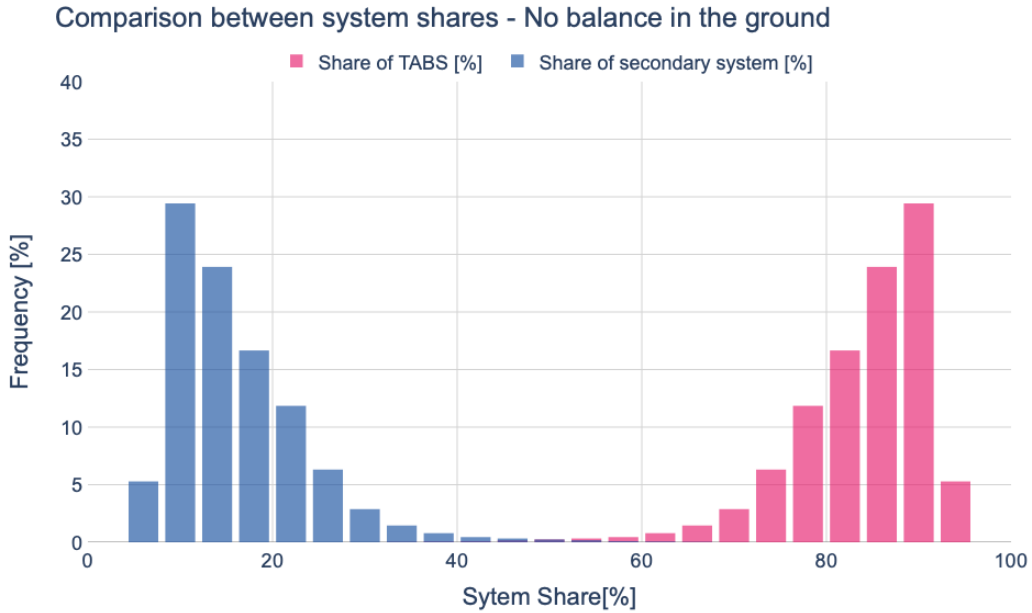
Controlling the power of the ground by integration

Providing the designer a ‘rule-of-thumb’ intuition

TYPICAL SHARES OF GEOTABS AND PERFORMANCE

Funded by the European Commission under the Horizon 2020 Programme: project number 723649 (proposal name “MPC-;GT”)

GEOTABS POTENTIAL (OFFICES)



Funded by the European Commission under the Horizon 2020 Programme: project number 723649 (proposal name “MPC-;GT”)

source: Rana Mahmoud (Ghent University)

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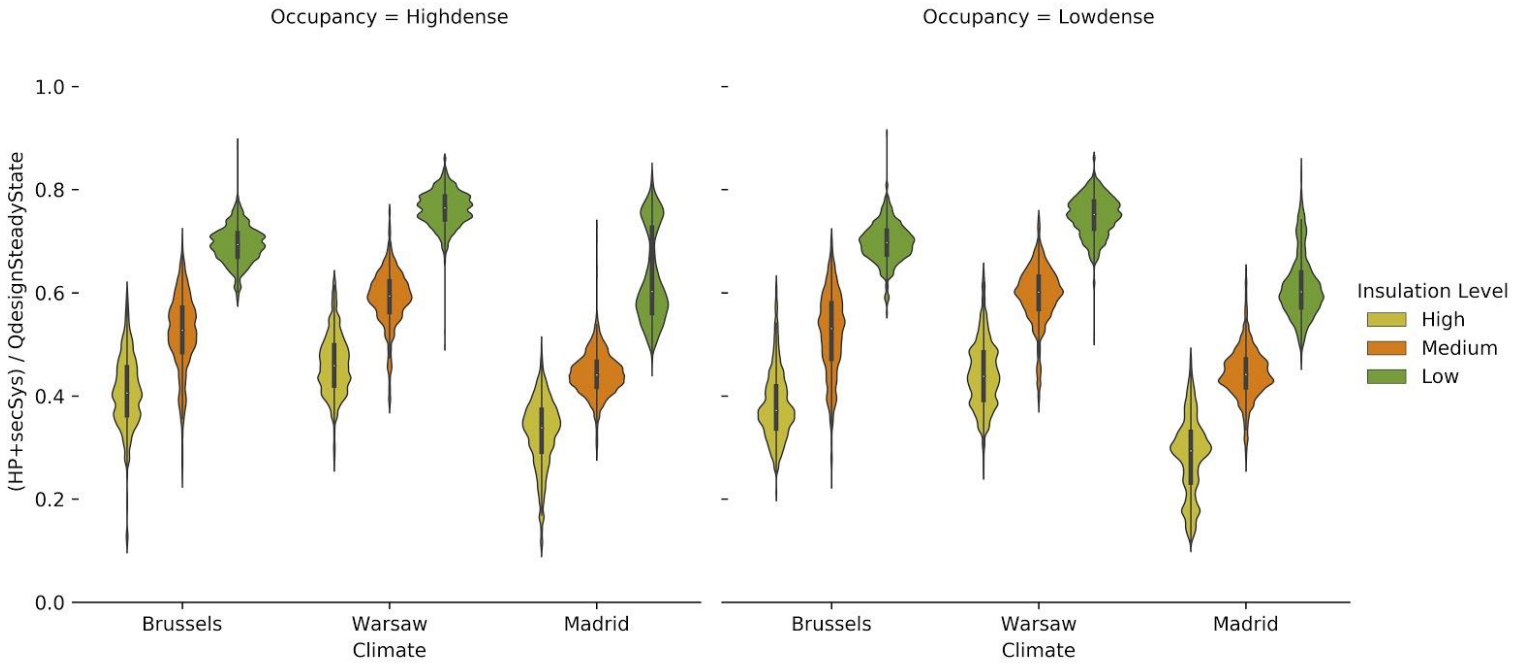


Funded by the European Commission under the Horizon 2020 Programme: project number 723649 (proposal name “MPC-;GT”)

source: Mohsen Sharifi (Ghent University)

hybrid GEOTABS

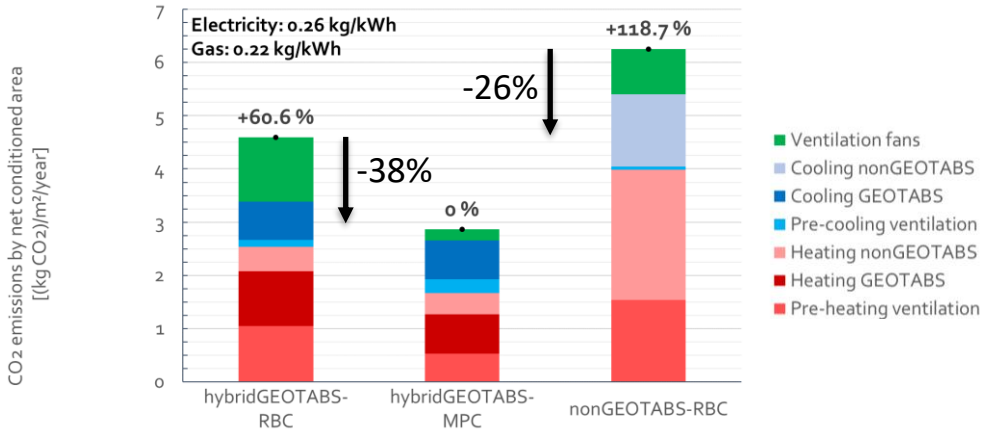
Controlling the power of the ground by integration

hybridGEOTABS in various climates and building typologies

WHAT IS THE POTENTIAL OF HYBRIDGEOTABS IN THE EU?

Funded by the European Commission under the Horizon 2020 Programme: project number 723649 (proposal name “MPC-;GT”)

CO_2 Emissions are reduced by more than 50%

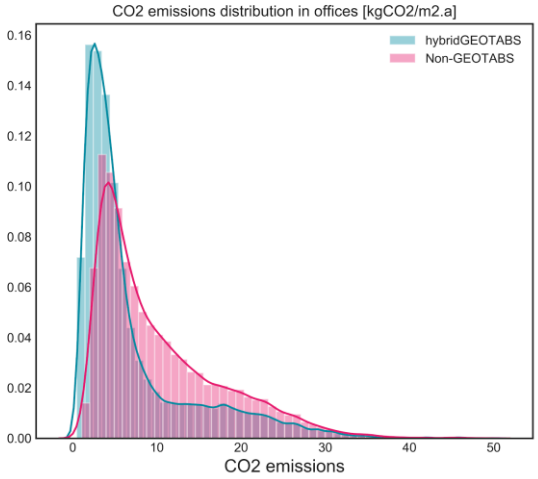


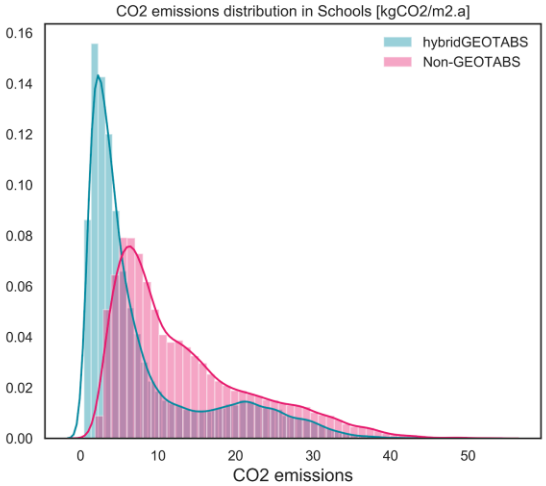
Electricity EU average in 2020

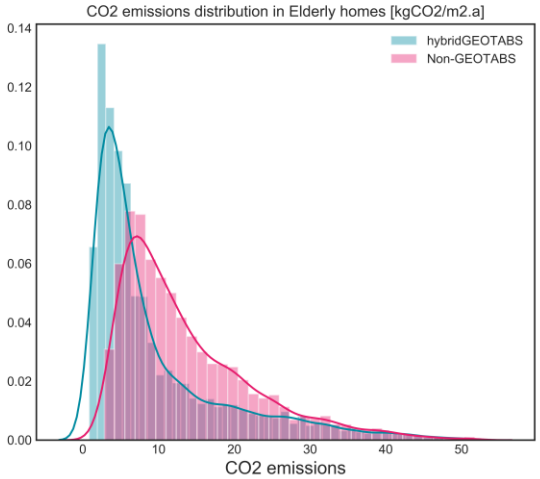
Funded by the European Commission under the Horizon 2020 Programme: project number 723649 (proposal name “MPC-;GT”)

source:
Josué B Bastero (Ghent University),
Iago C Figueroa (KU Leuven)

CO_2 Emissions reduced to about 5 kg/m².y



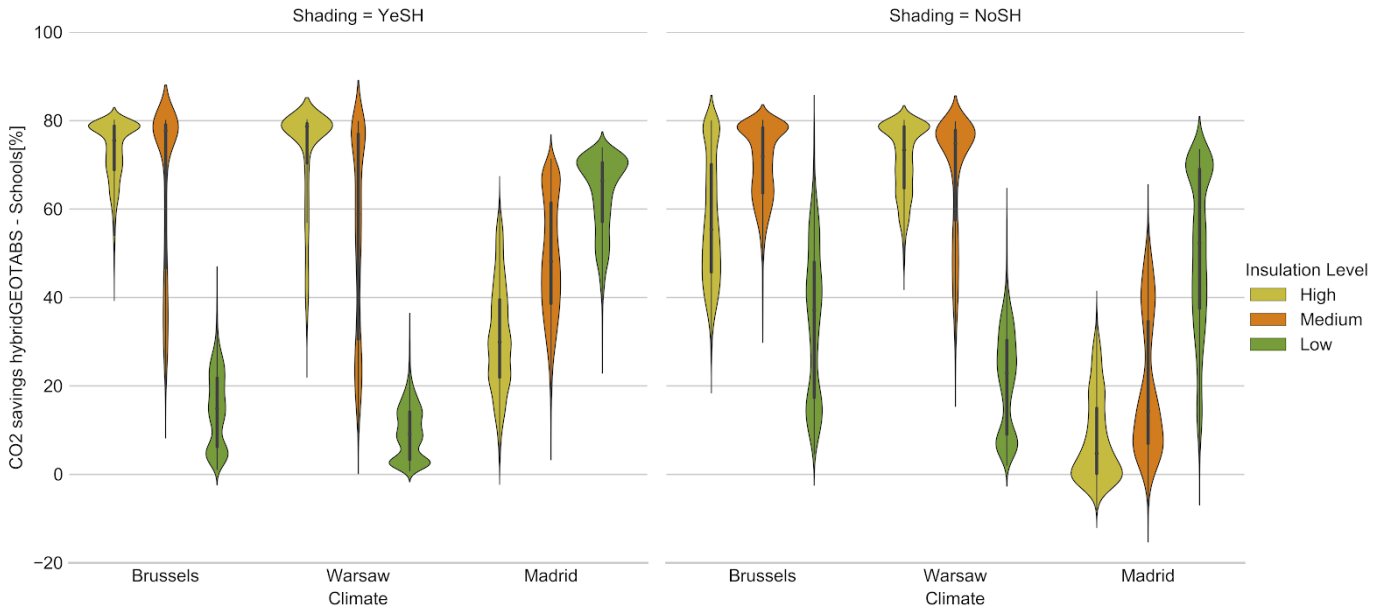




Funded by the European Commission under the Horizon 2020 Programme: project number 723649 (proposal name “MPC-;GT”)

source: Rana Mahmoud (Ghent University)

CO_2 Savings in EU building stock



Funded by the European Commission under the Horizon 2020 Programme: project number 723649 (proposal name “MPC-;GT”)

source: Rana Mahmoud (Ghent University)

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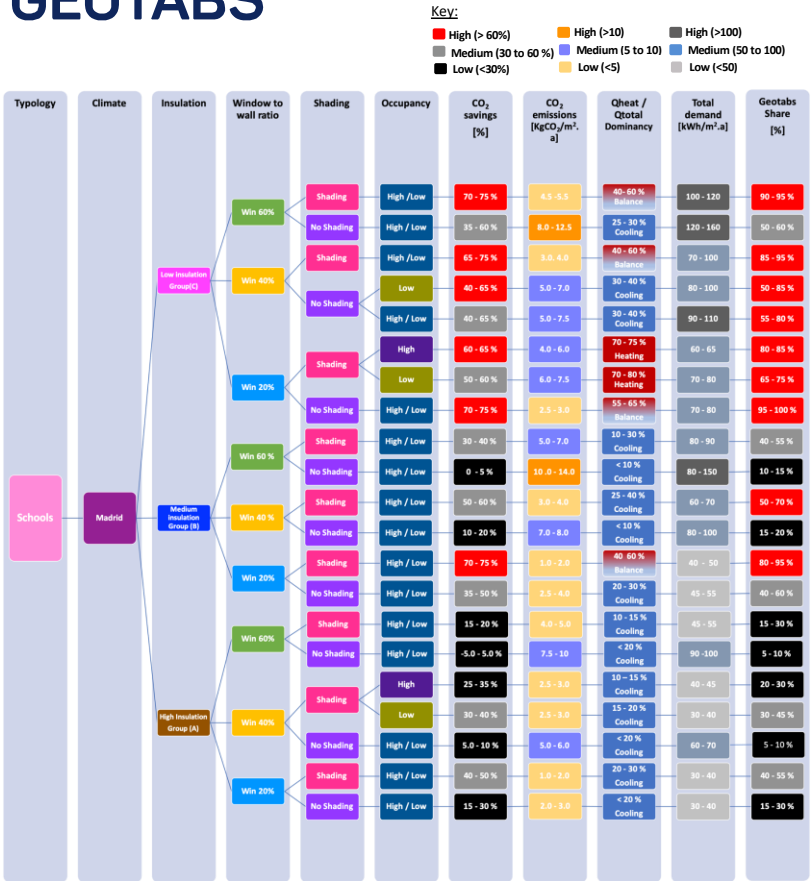
Controlling the power of the ground by integration



Funded by the European Commission under the Horizon 2020 Programme: project number 723649 (proposal name “MPC-;GT”)

source: Rana Mahmoud (Ghent University)

hybrid GEOTABS

Controlling the power of the ground by integration

hybridGEOTABS design method

Prof. Jelle Laverge
Project leader

GHENT UNIVERSITY

hybridgeotabs@ugent.be

Training for designers (webinar)

17 December 2020

hybrid GEOTABS

Controlling the power of the ground by integration

MODEL PREDICTIVE CONTROL FOR HVAC ENGINEERS

17/12/2020

KU LEUVEN

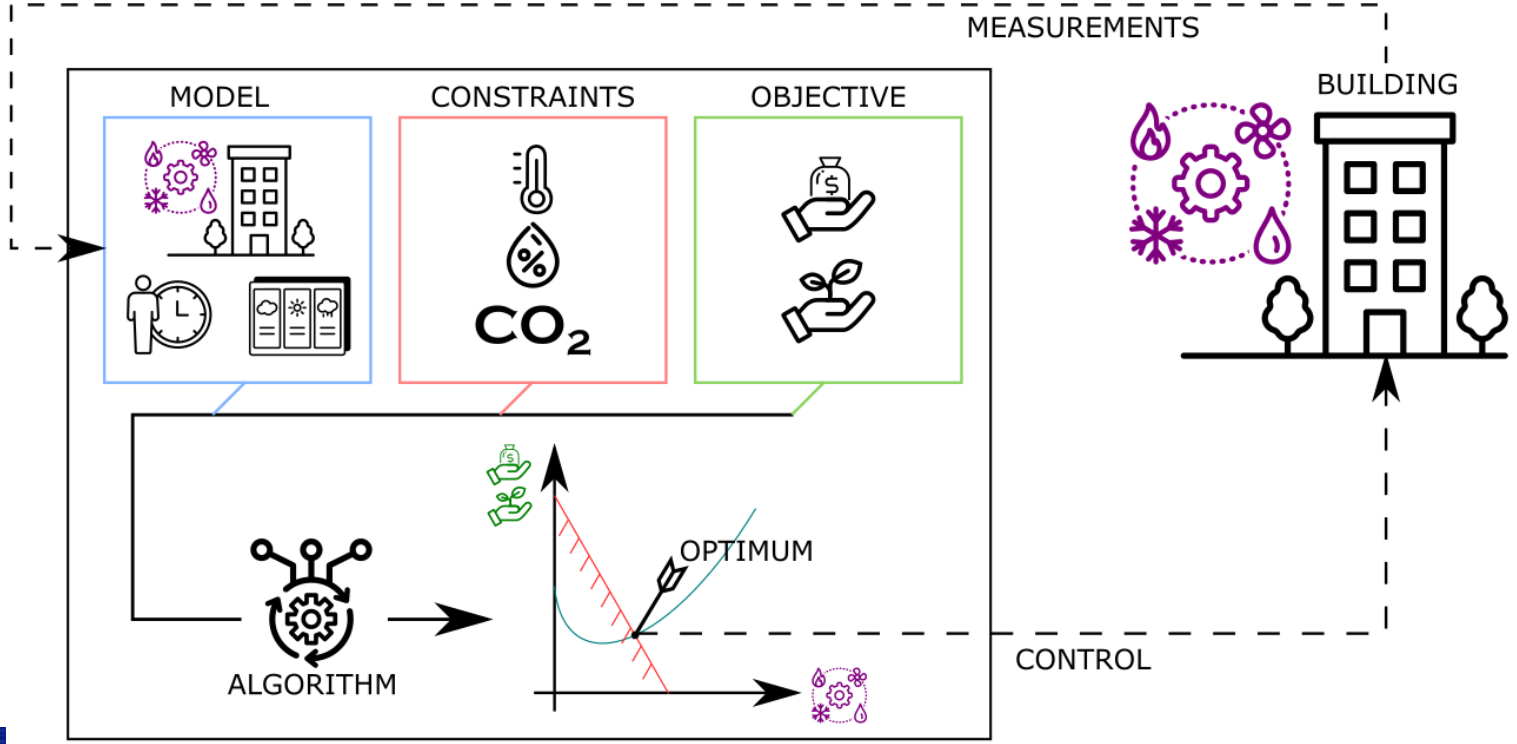
dr. ir. Damien Picard

Postdoctoral researcher

WHAT IS MODEL PREDICTIVE CONTROL (MPC)?

Funded by the European Commission under the Horizon 2020 Programme: project number 723649 (proposal name “MPC-;GT”)

WHAT IS MODEL PREDICTIVE CONTROL (MPC) ?



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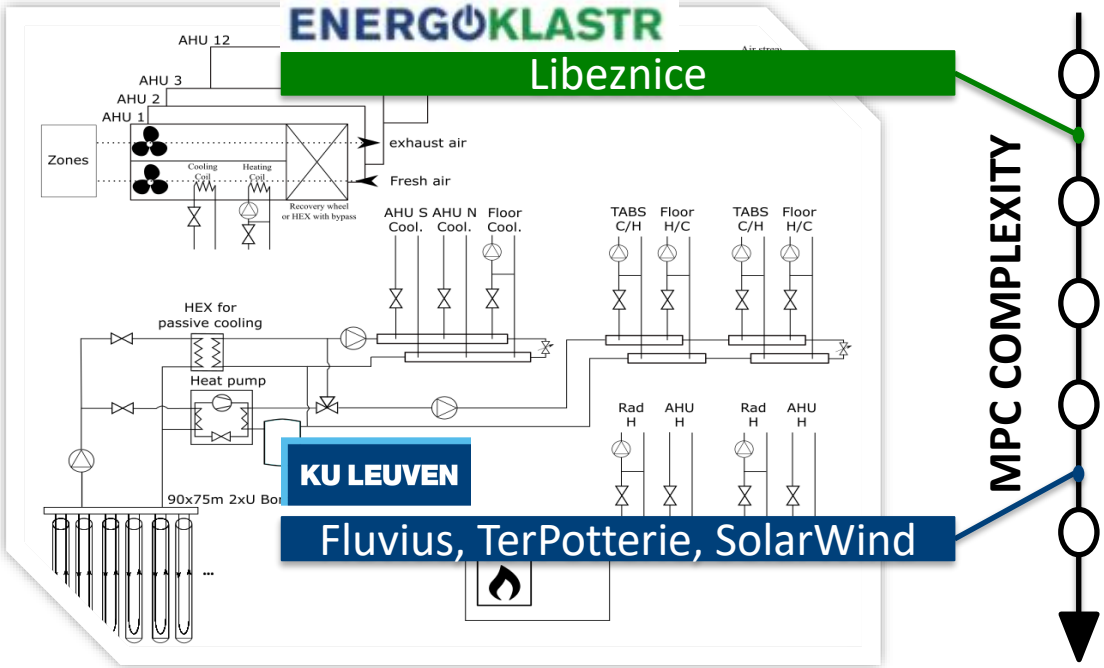
WHAT DOES MPC CONTROL IN A BUILDING ?



Temp/RH/CO_2 set points (HP, water supply, vent., …)

Pressure set points (pump, fan)

Modulation (heat pump, pump)

Valve/damper opening

On/off control (heat pump, pump, shading, …)

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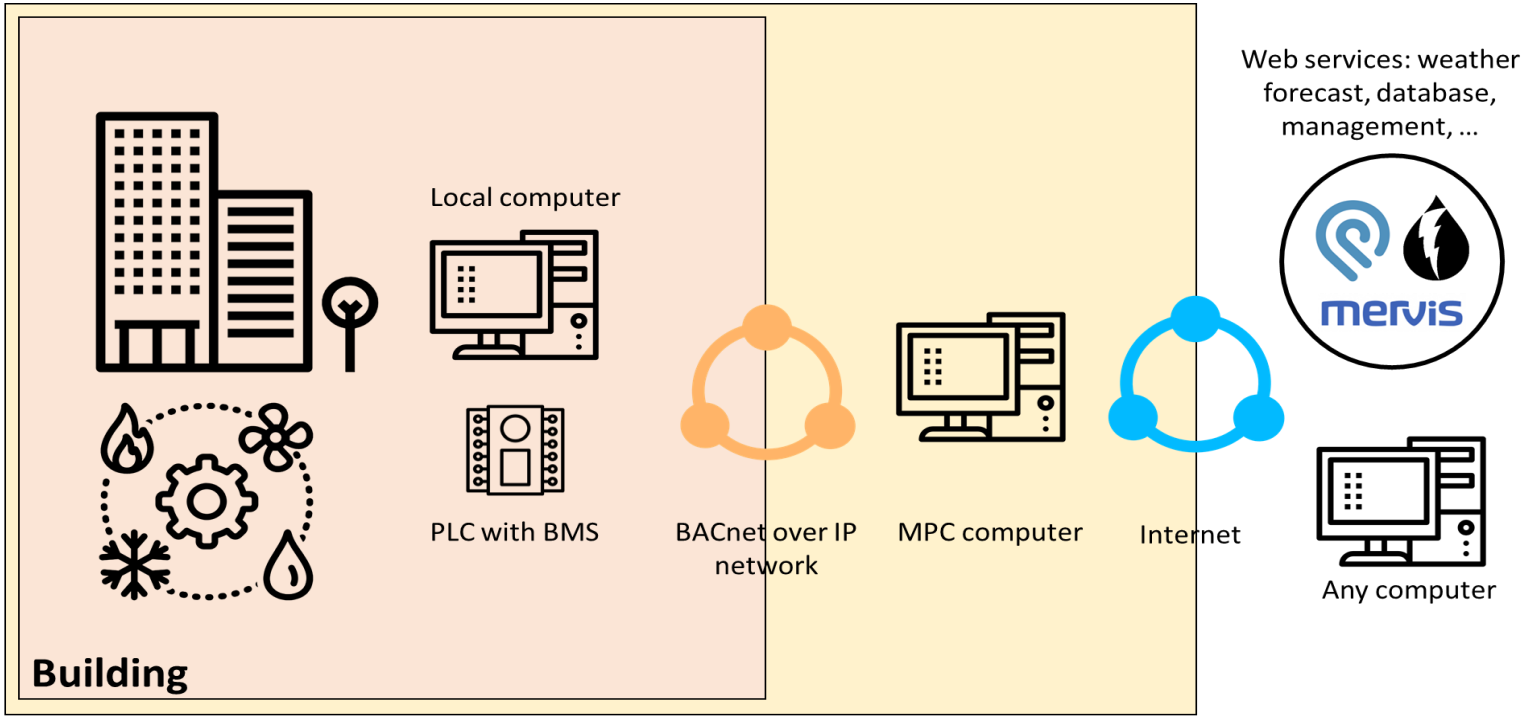
PRACTICAL IMPLEMENTATION FOR DEMO'S



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Controlling the power of the ground by integration

HOW TO MAKE THE BUILDING MORE SUITABLE FOR MPC?

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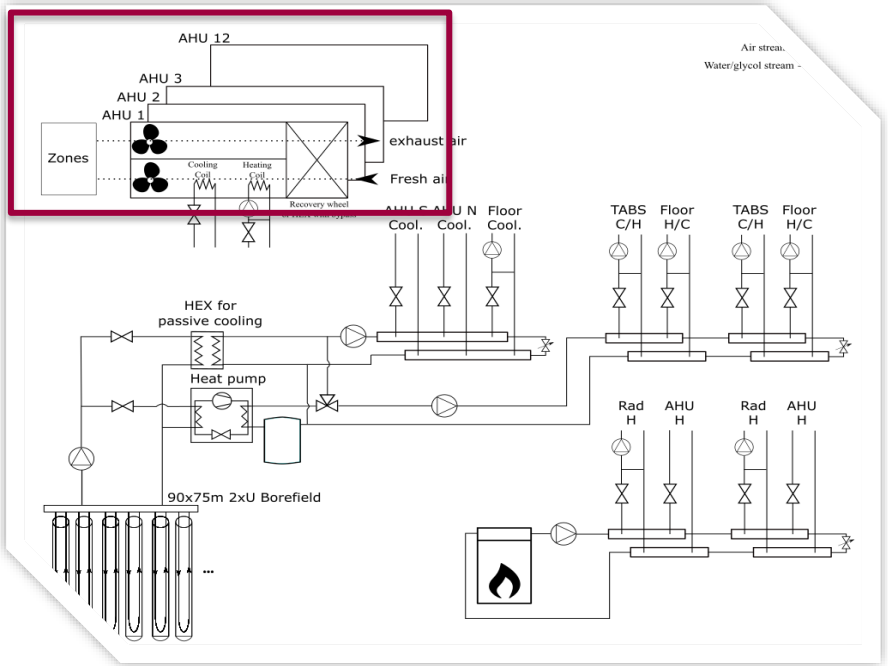
VENTILATION



	Fluvius	Ter Potterie
Ventilation flow	10 000	31 000 m^3/h
Building floor surface area	3000	10 000 m^2
Pressure drop	1000	1500 Pa
Fan power (supply + extraction)	6	26 kW
Fan daily energy use (12h, nominal)	67	310 kWh/day
Thermal power (5°C/21°C, rec. 70%)	16	51 kW
Daily thermal energy use	196	607 kWh/day
Total yearly cost (COP=4, 0,1€/kWh, 80days heating, 250day occ)	**2 058**	**8 964 €/year**

Components:

- Modulating fans
- VAV for zones with variable occupancy

Sensors:

- CO_2 and T per zone

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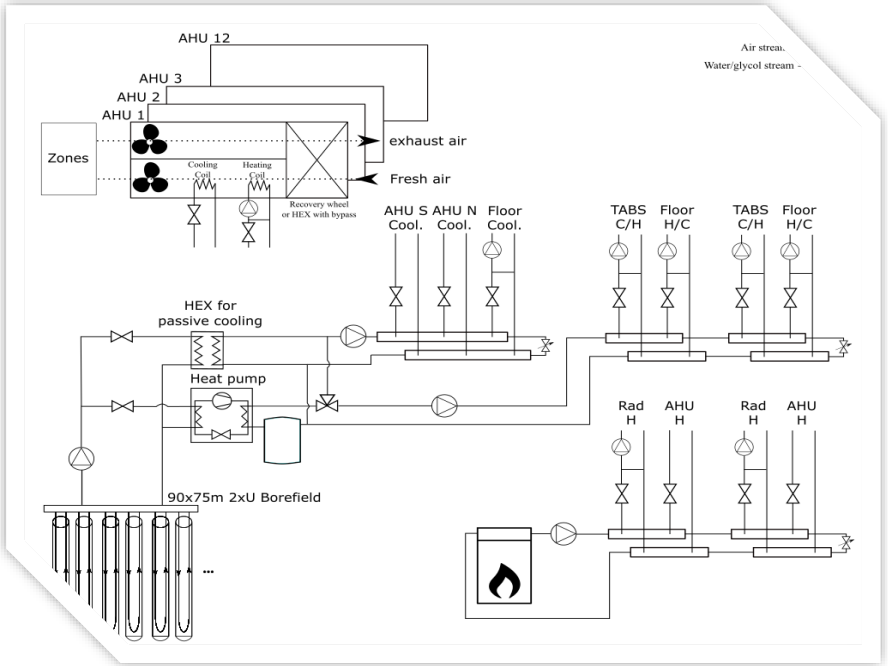
HYDRAULIC



	Fluvius	TerPotterie
Pressure drop (borefield + HP/HEX)	1.9	1.3 bar
Flow	28	90 m^3/h
Power	1.5	3.3 kW
Daily energy use (24h/day)	35	78 kWh/day
Total yearly cost (0,1€/kWh, 24/7, 200 days)	**709**	**1 560 €/year**

- Modulating pumps
- Controllable supply temperature for each TABS circuit by mixing
- Controllable flow for TABS sub-circuit using 2-way valves
- Recirculation from south zones to north zones

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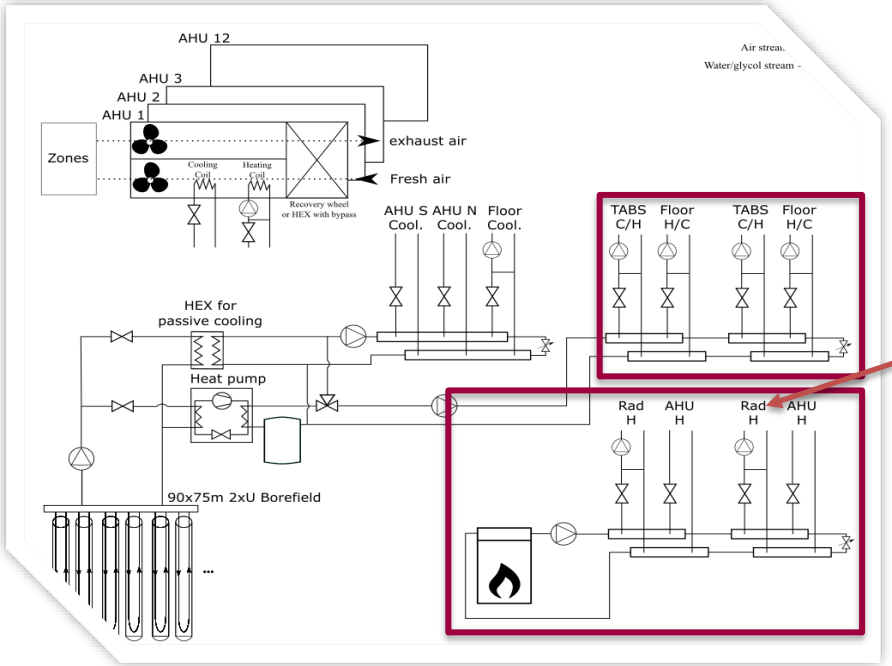
HYDRAULIC



- Combine slow (TABS) and fast (rad, VAV with heating/cooling coils,…) systems
  Careful: make them centrally controllable

Radiators with TRV: to avoid…

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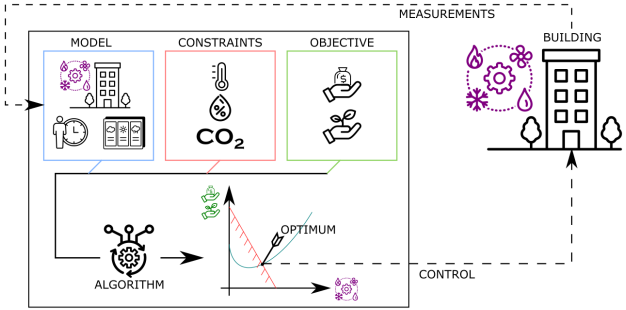

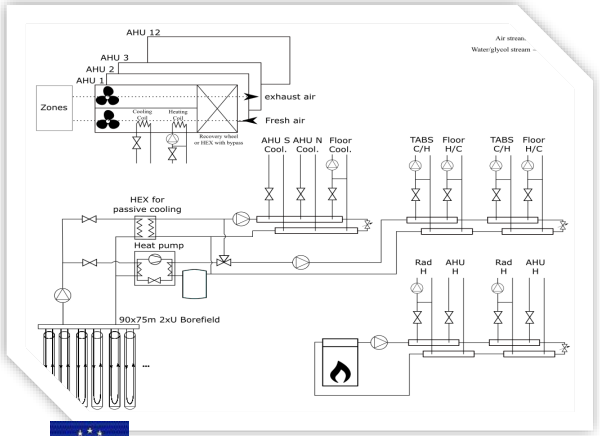

SENSORS

- Comfort:
  - **T, R.H., CO_2 sensors per zones**
- Hydraulics:
  - Temperatures in circuits
  - Calorimeters: try to capture the different energy flows. Careful with units, especially for cumulative values.
  - Electricity counter: TOT HVAC, VENT, HP, … .
  - Gas counter

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BUILDING MANAGEMENT SYSTEM REQUIREMENTS

- Easy remote access to BMS
- Unique point identifier for BMS, BACnet (or other communication protocol), and database, ideally listed in I/O list and (partially) visible on hydraulic schematics
- Open protocols. BACnet is a good choice (mature, widely supported, interesting features such as priority arrays, …). Ideally request the I/O BACnet objects in specs

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Controlling the power of the ground by integration

WHAT ARE INTERESTING FEATURES OF A BUILDING FOR MPC?

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WHAT ARE INTERESTING FEATURES OF A BUILDING FOR MPC?

INTERESTING

- Buildings with slow systems (TABS, large storage, …)
- Buildings with hybrid systems (trade off between slow/cheap and fast/expensive, trade off between machines with different time-dependent efficiencies or energy vector costs)
- Simultaneous heating and cooling demand (e.g. data center, north/south zones, …)
- Variable electricity price
- Highly modulating system with variable efficiencies

NOT INTERESTING

- Very narrow comfort bounds

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MAY I / SHOULD I SIZE MY HYDRAULIC COMPONENTS DIFFERENTLY, KNOWING THAT MPC WILL BE INSTALLED?

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MAY I / SHOULD I SIZE MY HYDRAULIC COMPONENTS DIFFERENTLY, KNOWING THAT MPC WILL BE INSTALLED?

YES

- Avoid reheating factors
- Consider simultaneity factors

NO

- Do not further downsize the system capacity as MPC is not yet a market mature technology

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PRELIMINARY RESULTS

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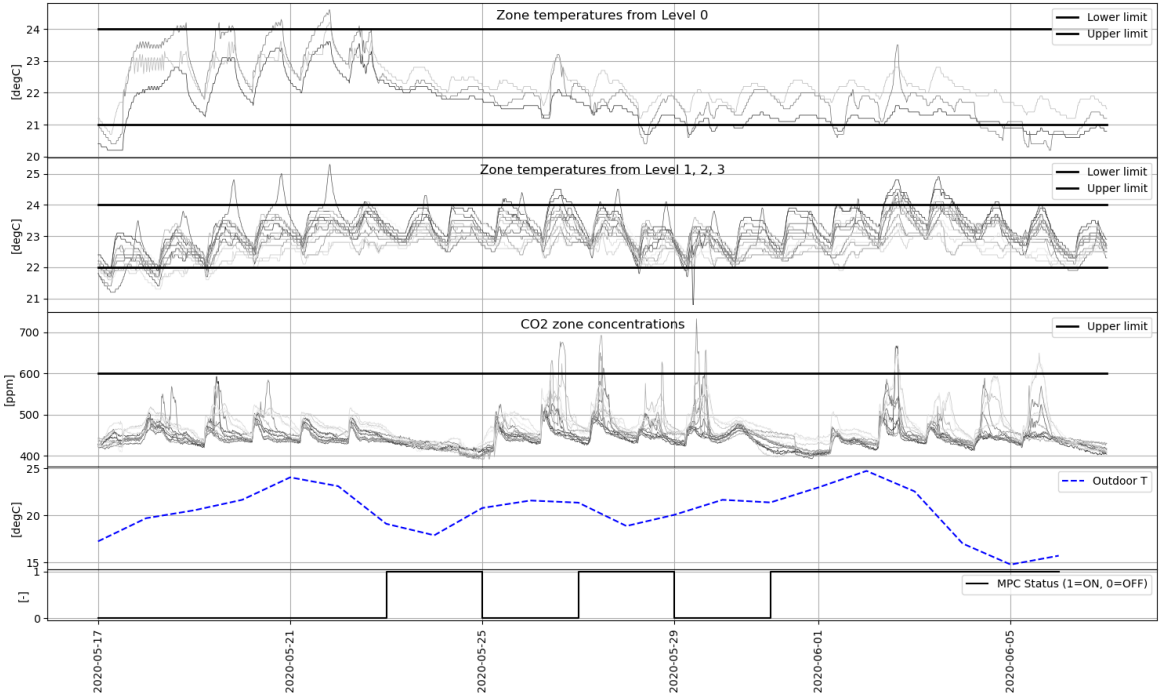
PRELIMINARY MPC RESULTS FOR FLUVIUS BUILDING

COMFORT



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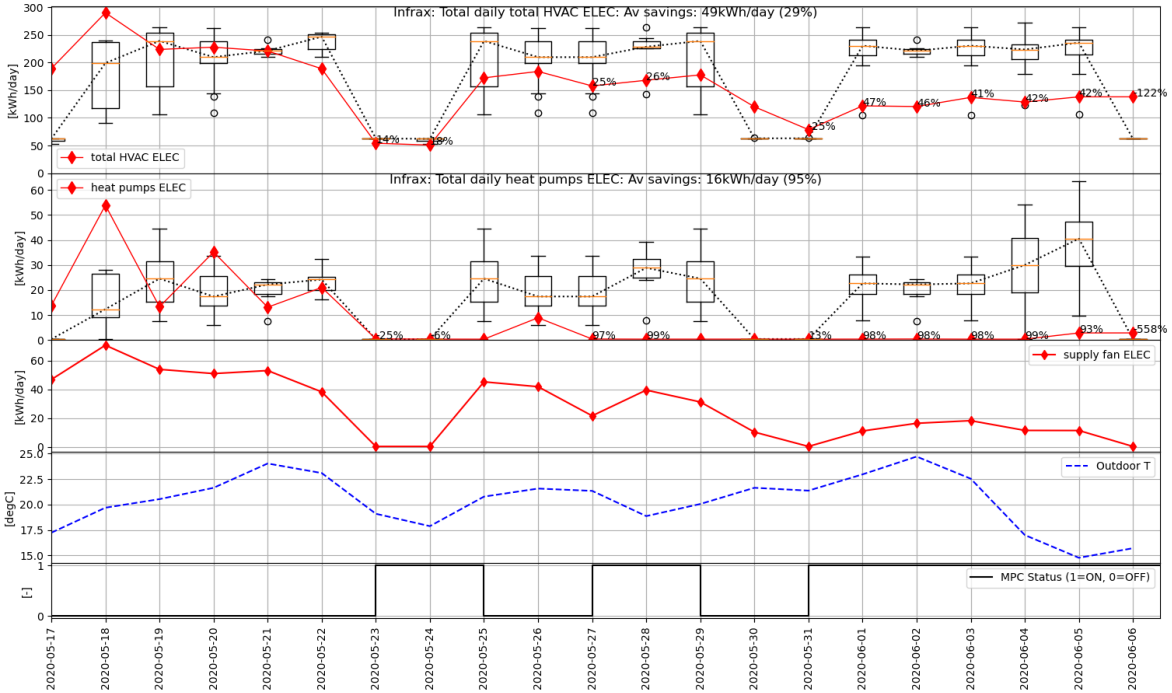
PRELIMINARY MPC RESULTS FOR FLUVIUS BUILDING

ENERGY



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SPECIAL THANKS!

CREATING A CLIMATE FOR GROWTH
PRIVA

boydens engineering

TECHNOLOGY

DeltaQ

fluvius.

mintus
zorg met een plus

schuler

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Controlling the power of the ground by integration

QUESTIONS?

For questions regarding the potential commercialization of white-box MPC in buildings and spin-off which is being created:

KU LEUVEN

Lieve.Helsen@kuleuven.be
Filip.Jorissen@kuleuven.be
Damien.Picard@kuleuven.be

For questions regarding the commercialization of grey-box MPC in buildings:

ENERGOKLASTR

cigler@feramat.com

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hybrid GEOTABS

Controlling the power of the ground by integration

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e: hybridgeotabs@ugent.be

www.hybridgeotabs.eu

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Controlling the power of the ground by integration

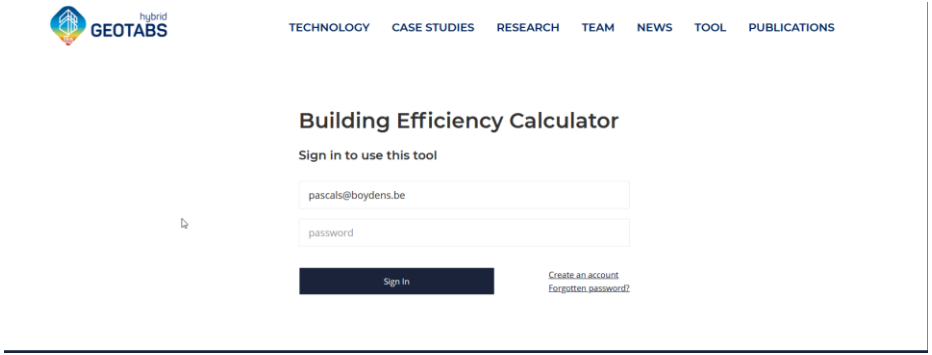
hybridGEOTABS Design Tool

hybridGEOTABS training module (webinar)

17 December 2020

Ing Pascal Simoens, boydens engineering

Project manager



- Web based intuitive usage
- 150.000 simulations
- Same building different configurations
- Quick estimated result

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Controlling the power of the ground by integration

BUILDING EFFICIENCY CALCULATOR

DEFINE YOUR DATA › 1 DATABASE BUILDING STOCK 2 DEMAND AND PEAK 3 FEASIBILITY STUDY

Fill in the details below to analyse your building's energy efficiency. Using database building stock we can generate accurate results on demand and peak, as well as feasability studies.

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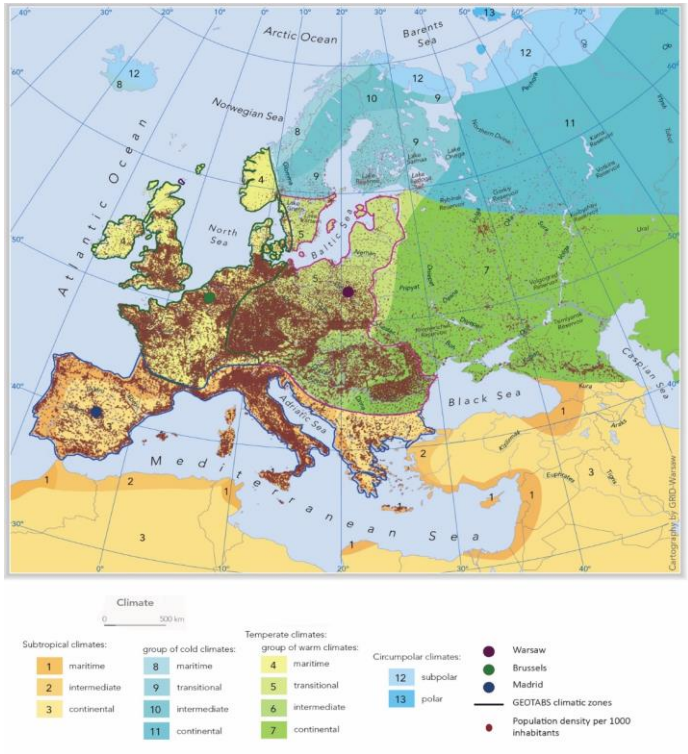
INPUT PARAMETERS

- Region:
  - Madrid, Brussels, Warsaw
- Typology:
  - Office
  - School
  - Elderly care home
  - Multi family
- Shading:
  - If present trigger: 150W/m²



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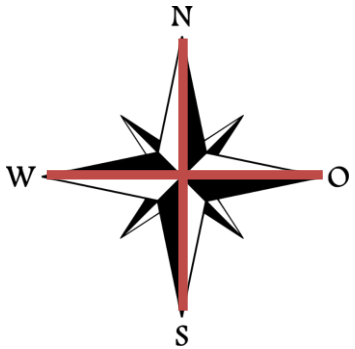
INPUT PARAMETERS

- Orientation:



- Insulation levels:

	U-Value opaque [W/m². K]	U-Value windows [W/m². K]	Airtightness at n50 value 1/h	G-value glazing
Group(A)	0.15	0.80	0.6	0.40
Group(B)	0.27	1.5	2.0	0.56
Group(C)	0.50	2.5	5	0.6

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INPUT PARAMETERS

- Thermal mass:
  - Lightweight construction:
    - 840 J/kgK
    - 550 kg/m³
    - Average building: 397 kg/m²
  - Heavyweight construction:
    - 1180 J/kgK
    - 2100 kg/m³
    - Average building: 630/m²

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- Internal heat loads:
  - Specific per typology

Type	High density office (1p/10 m²)	Low density office (1p/20 m²)
Occupancy	10.0 W/m²	5.0 W/m²
Lighting	8.0 W/m²	8.0 W/m²
Appliances	15.0 W/m²	5.5 W/m²
Total	33.0 W/m²	18.5 W/m²

Type of function	Occupant density	Watts per Person	Occupancy [W/m²]	Appliances [W/m²]	Lighting [W/m²]	Total [W/m²]
Classroom (high dense)	1/ 2.5 m²	75	30	4	8	42
Classroom (low dense)	1/3.5 m²	75	21.4	4	8	33
Study room	1/2.0 m²	74.5	37.3	8	8	53
Offices (single)	1/ 15 m²	100	6.7	12	8	27
Restaurant	1/2 m²	80	40.0	4	8	52

- Window to wall ratio:

Window to wall ratio	low	medium	high
Schools	20 %	40%	60%
Elderly	20%	35%	50%
	20 %	35 %	50 %

Once you have reviewed the above requirements to submit this form click apply changes. The form will refresh with all results filled. Once the form is finished calculating, tabs "Demand and Peak", "Feasibility Study" will be accessable. This may take up to 5 minutes to complete.

SUBMIT AND ANALYSE

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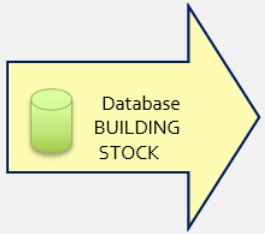
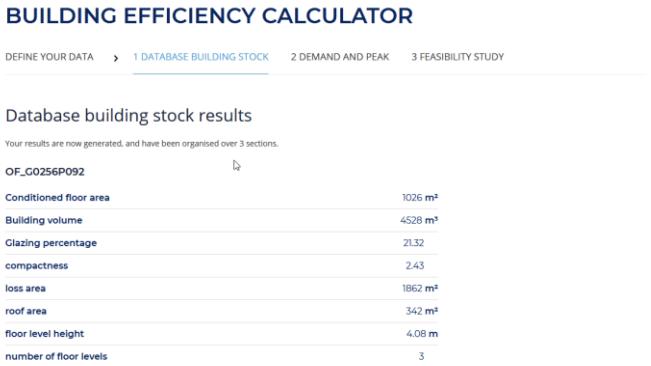
Controlling the power of the ground by integration

RESULTS



OF_G0256P030	Result
Conditioned floor area	1026 m²
Building volume	4528 m³
Glazing percentage	21.32%
compactness	2.43
loss area	1862 m²
roof area	342 m²
floor level height	4 m
number of floor levels	3



BUILDING EFFICIENCY CALCULATOR

DEFINE YOUR DATA › 1 DATABASE BUILDING STOCK 2 DEMAND AND PEAK 3 FEASIBILITY STUDY

Database building stock results

Your results are now generated, and have been organised over 3 sections.

OF_G0256P092

Conditioned floor area	1026 m²
Building volume	4528 m³
Glazing percentage	21.32
compactness	2.43
loss area	1862 m²
roof area	342 m²
floor level height	4.08 m
number of floor levels	3

OF_G0259P030	2.25	GroupB	2	1005 m²	4441 m³	Light	Lowdense	N	NoSH	58.91%	50236.00%	407.01%	196956.00%	OFFICE
OF_G0272P030	1.60	GroupB	2	1011 m²	3338 m³	Light	Lowdense	N	NoSH	22.00%	50550.00%	295.17%	208103.00%	OFFICE
OF_G0254P030	2.30	GroupB	3	1016 m²	4044 m³	Light	Lowdense	N	NoSH	34.93%	33858.00%	364.80%	175688.00%	OFFICE
OF_G0252P030	2.29	GroupB	2	1016 m²	4720 m³	Light	Lowdense	N	NoSH	40.44%	50813.00%	429.48%	206464.00%	OFFICE
OF_G0214P030	2.35	GroupB	3	1022 m²	3502 m³	Light	Lowdense	N	NoSH	28.24%	34056.33%	309.48%	149070.00%	OFFICE
OF_G0256P030	2.43	GroupB	3	1026 m²	4528 m³	Light	Lowdense	N	NoSH	21.32%	34212.00%	407.83%	186249.00%	OFFICE
OF_G0278P030	2.44	GroupB	2	1027 m²	7134 m³	Light	Lowdense	N	NoSH	30.56%	51345.00%	659.71%	292610.00%	OFFICE
OF_G0274P030	1.88	GroupB	2	1032 m²	3663 m³	Light	Lowdense	N	NoSH	33.59%	51616.00%	319.82%	195154.00%	OFFICE
OF_G0255P030	2.41	GroupB	2	1040 m²	5210 m³	Light	Lowdense	N	NoSH	25.86%	52004.00%	465.88%	216076.00%	OFFICE
OF_G0253P030	2.02	GroupB	2	1045 m²	3894 m³	Light	Lowdense	N	NoSH	38.09%	52228.50%	337.78%	192784.00%	OFFICE
OF_G0264P030	2.49	GroupB	2	1047 m²	5130 m³	Light	Lowdense	N	NoSH	29.33%	52352.00%	454.95%	205934.00%	OFFICE
OF_G0261P030	2.37	GroupB	2	1050 m²	4806 m³	Light	Lowdense	N	NoSH	14.73%	52480.00%	422.88%	203174.00%	OFFICE

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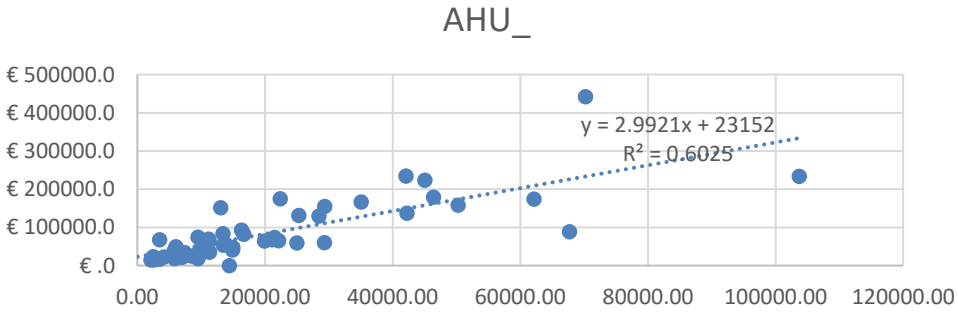
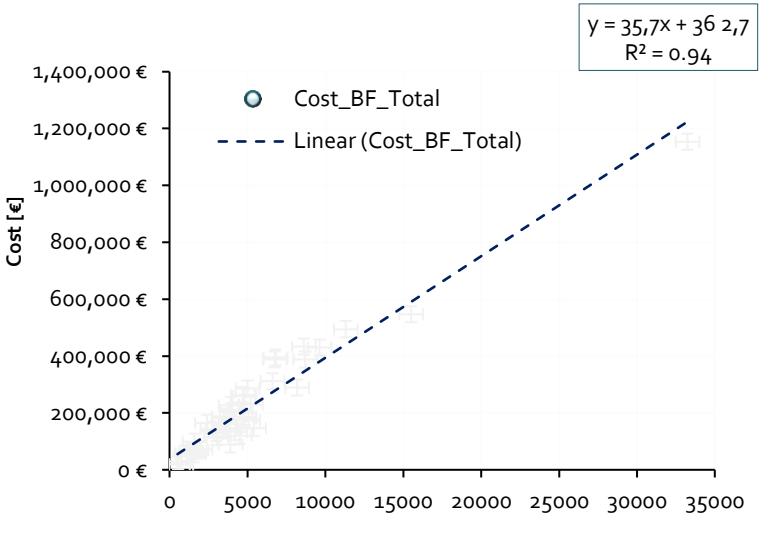
ECONOMIC

- Correlation of prices from different projects
- Evolution inflation
- Evolution CO_2 prices
- Lifetime of different systems
- PV panel for consumption of HVAC





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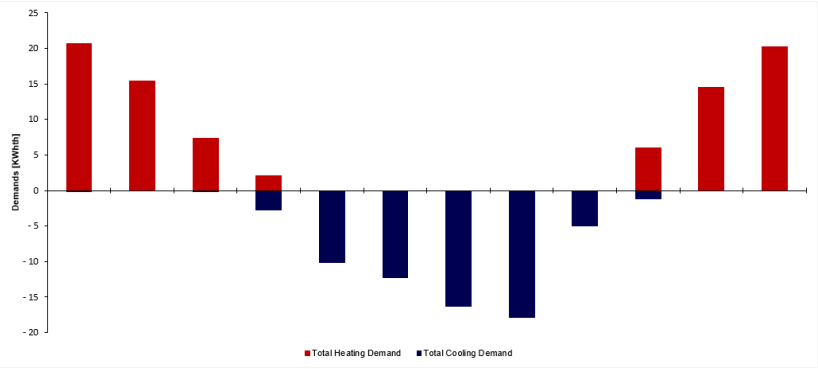
PEAK & DEMAND

Building Level

1. The heating and cooling demand of the building

The heating and cooling demand of the total building is calculated based on a multi-zonal dynamic energy simulation of the archetype of the building. No system characteristics are taken into account in the dynamic simulation. This includes that the heating and cooling demand is the instantenious demand at that time.



	From dynamic Simulation	
Total Heating Demand	121870 **kWh/year**	121870 **kWh/m.year**
Total Cooling Demand	-5704 **kWh/year**	-5704 **kWh/m.year**
Peak Demand for Heating	61 **kW**	61 **W/m²**
Peak Demand for Heating	30 **kW**	30 **W/m²**

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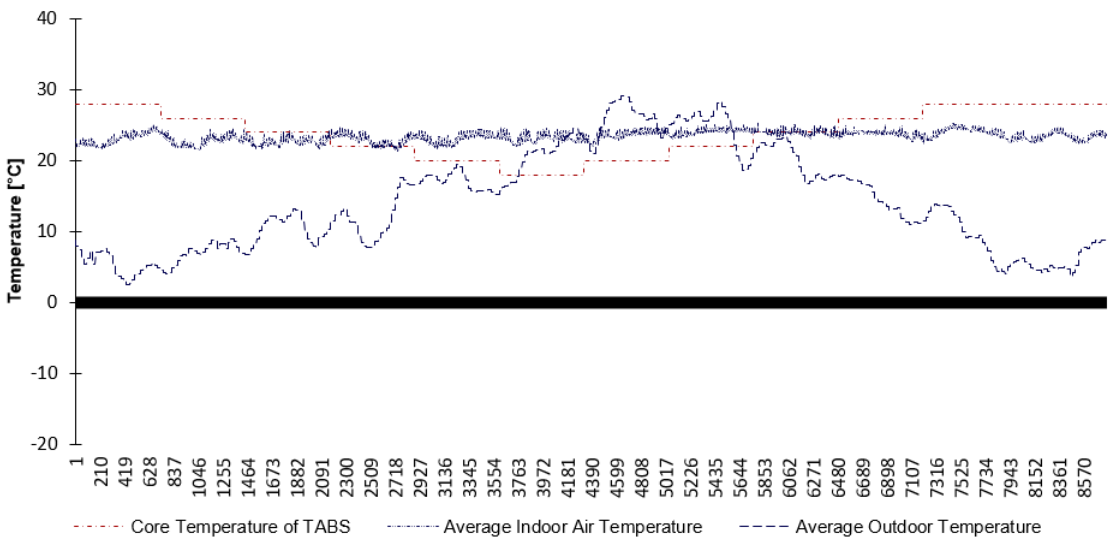
PEAK & DEMAND

- Stationary calculation
- MPC
- RBC
- Monthly setpoints

Month	Core Temperature of Tabs
jan	28
feb	26
mrt	24
apr	22
mei	20
jun	18
jul	20
aug	22
sep	24
okt	26
nov	28
dec	28



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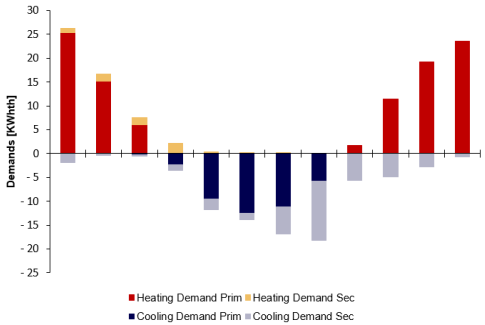
hybrid GEOTABS

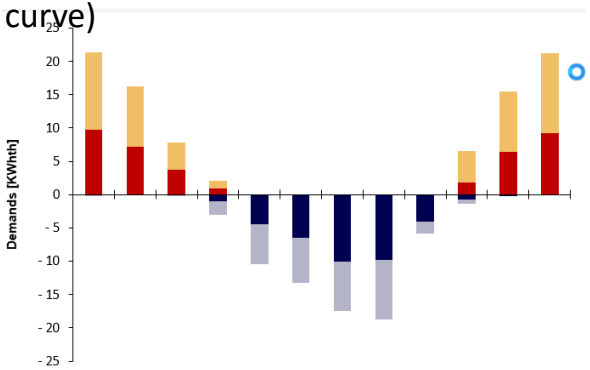
Controlling the power of the ground by integration

PEAK & DEMAND

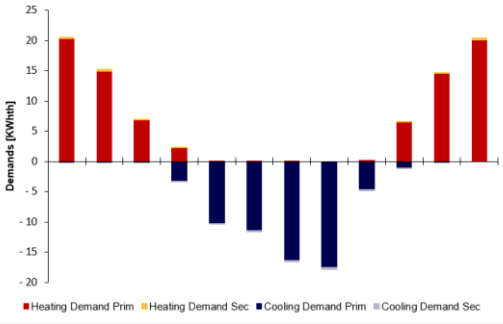
Monthly setpoints



Optimised RBC (derived heating curve)



MPC



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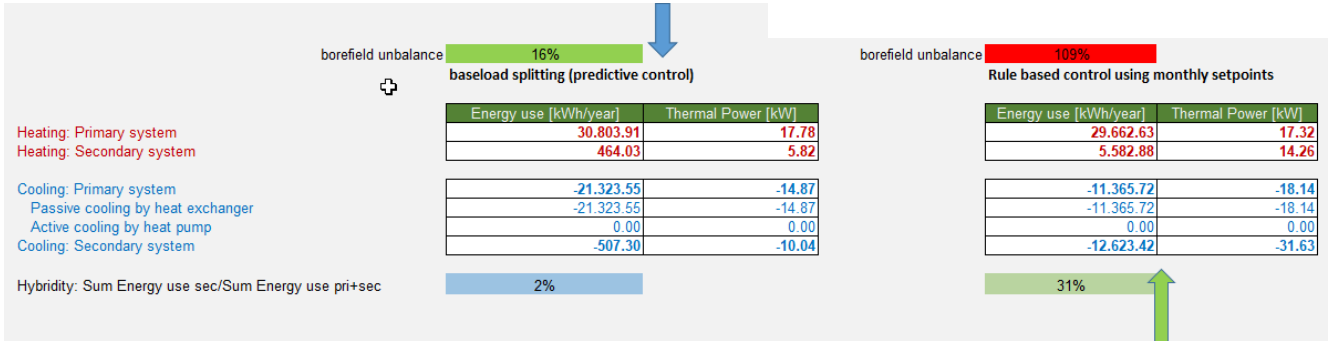
hybrid GEOTABS

Controlling the power of the ground by integration

PEAK & DEMAND

Solution following Baseload Splitting Algorithm

	Energy use [kWh/year]	Thermal Power [kW]
Heating: Primary system	121394.89	42.31
Heating: Secondary system	2007.73	18.25
Cooling: Primary system	-7216.82	17.04
Passive cooling by heat exchanger	-7216.82	17.04
Active cooling by heat pump	0	0
Cooling: Secondary system	-135.78	6.81
Hybritidy	-	



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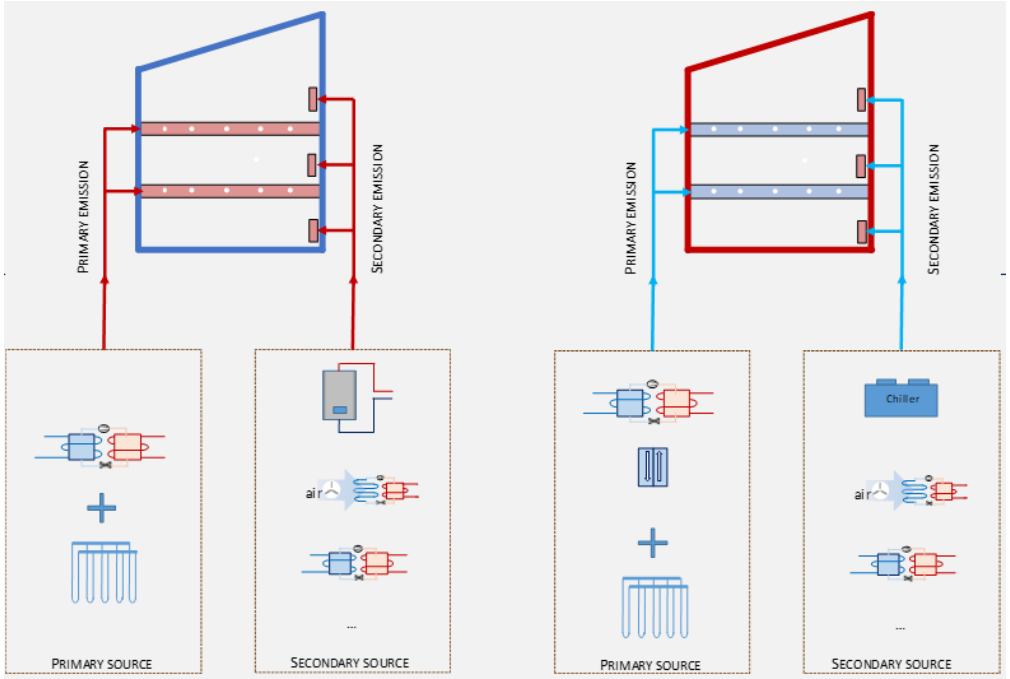
FEASIBILITY STUDY

- hybridGEOTABS system
  - Primary
    - Water-Water heat pump
    - Heat exchanger
    - Concrete core activation
  - Secondary
    - Based on classic system
- Classic system
    - Condensing gas boiler
    - Air-water chiller
    - Radiators
    - Cooling emission system



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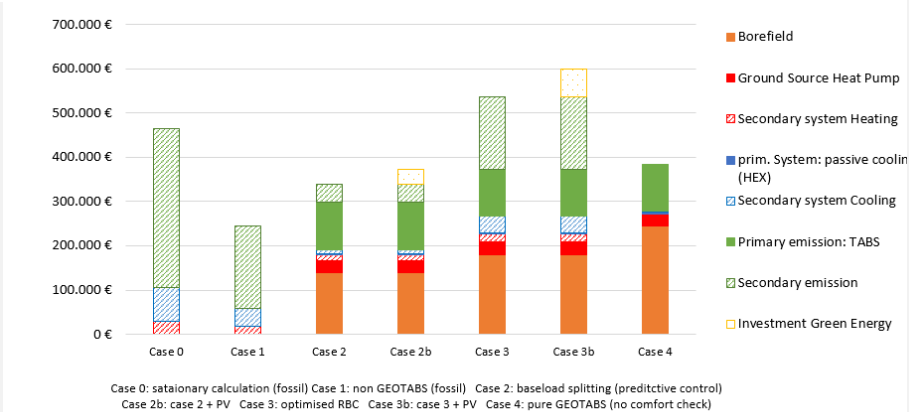
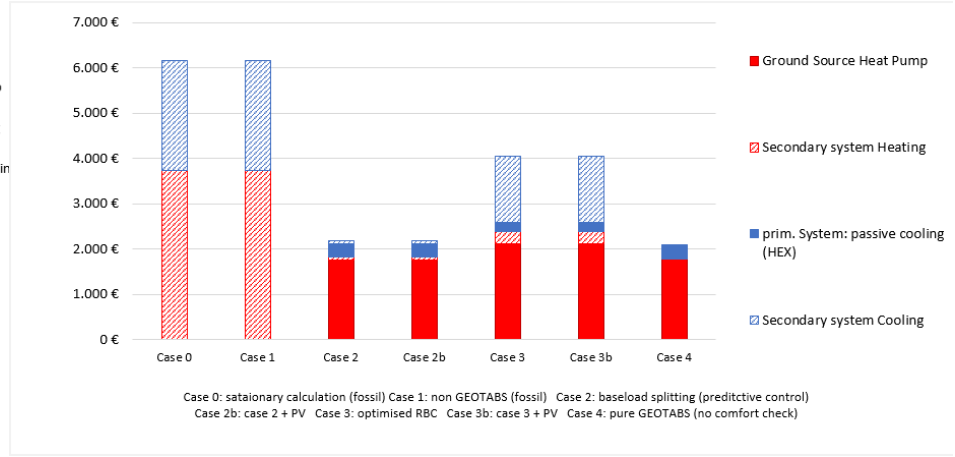
hybrid GEOTABS

Controlling the power of the ground by integration

FEASIBILITY STUDY
INVESTMENT vs. OPERATIONAL



Case 0: sataionary calculation (fossil) Case 1: non GEOTABS (fossil) Case 2: baseload splitting (preditctive control)
Case 2b: case 2 + PV Case 3: optimised RBC Case 3b: case 3 + PV Case 4: pure GEOTABS (no comfort check)



Case 0: sataionary calculation (fossil) Case 1: non GEOTABS (fossil) Case 2: baseload splitting (preditctive control)
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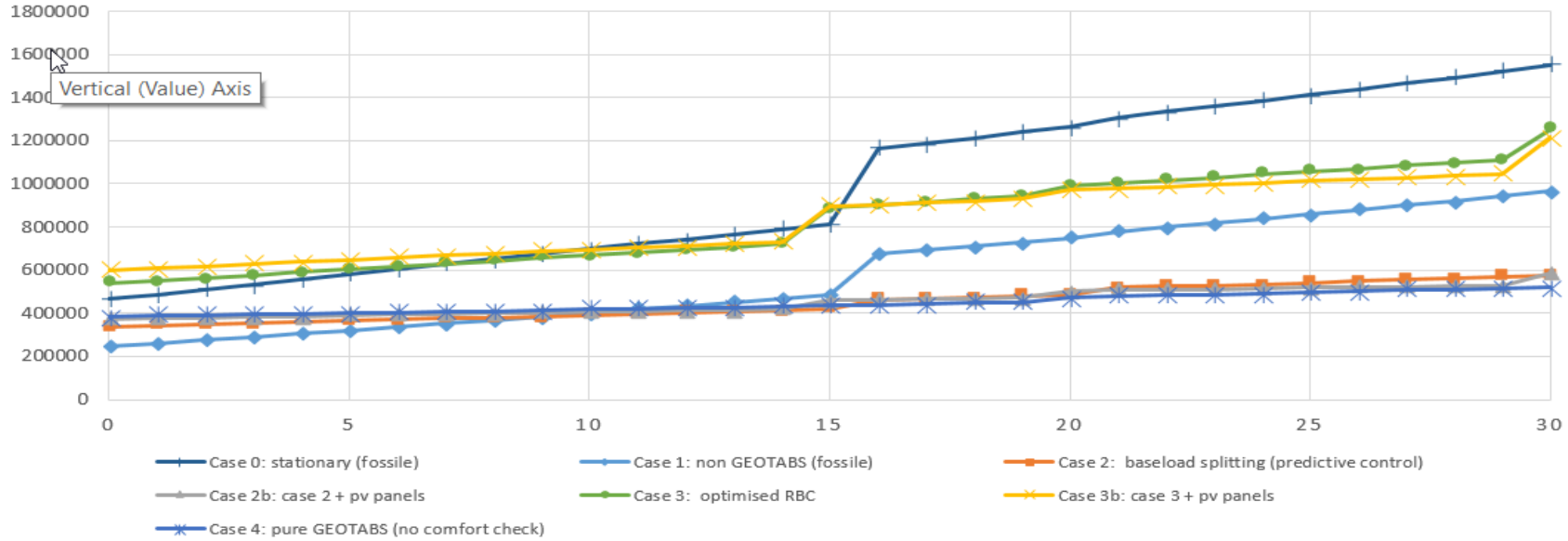
FEASIBILITY STUDY - TCO



- Investment cost based on real life cases
- Inflation rate
- Increase of energy cost above inflation rate
- Average lifecycle of equipment
- Maintenance cost

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hybrid GEOTABS

Controlling the power of the ground by integration

SAME BUILDING - TWO CONFIGURATIONS

BUILDING DATA

GENERAL

Region	Uccle
Building type	OFFICE

GEOMETRY

Conditioned floor area	5000 m²
Building volume [m³]	45000 m³
Glazing percentage	20%
Number of floors	2

Database BUILDING STOCK

OF_G0032P030	Result
Conditioned floor area	4822 m²
Building volume	19538 m³
Glazing percentage	18.58%
compactness	3.37
loss area	5797 m²
roof area	1206 m²
floor level height	4 m
number of floor levels	4

Building orientation longest facade facing	N

BUILDING ENERGETIC CHARACTERISTICS

Insulation level of the building	GroupB
U-value wall	
U-value glazing	
n50	
Solar Shading available ?	NoSH
Thermal mass of the building structure	Light
Internal heat gains	Lowdense

	GroupA	GroupB	GroupC
	0.15 W/m²K	0.27 W/m²K	0.50 W/m²K
	0.80 W/m²K	1.50 W/m²K	2.50 W/m²K
	0.60 l/h	2.00 l/h	5.00 l/h

BUILDING DATA

GENERAL

Region	Uccle
Building type	OFFICE

GEOMETRY

Conditioned floor area	5000 m²
Building volume [m³]	45000 m³
Glazing percentage	20%
Number of floors	2

Database BUILDING STOCK

OF_G0032P035	Result
Conditioned floor area	4822 m²
Building volume	19538 m³
Glazing percentage	18.58%
compactness	3.37
loss area	5797 m²
roof area	1206 m²
floor level height	4 m
number of floor levels	4

Building orientation longest facade facing	W

BUILDING ENERGETIC CHARACTERISTICS

Insulation level of the building	GroupC
U-value wall	
U-value glazing	
n50	
Solar Shading available ?	YeSH
Thermal mass of the building structure	Heavy
Internal heat gains	Highdense

	GroupA	GroupB	GroupC
	0.15 W/m²K	0.27 W/m²K	0.50 W/m²K
	0.80 W/m²K	1.50 W/m²K	2.50 W/m²K
	0.60 l/h	2.00 l/h	5.00 l/h

	baseload splitting (predictive control)		Rule based control using monthly setpoints	
	Energy use [kWh/year]	Thermal Power [kW]	Energy use [kWh/year]	Thermal Power [kW]
Heating: Primary system	85.575.64	58.43	102.699.51	80.97
Heating: Secondary system	1.136.90	16.89	6.364.82	44.22
Cooling: Primary system	-64.779.58	-48.52	-41.631.85	-79.27
Passive cooling by heat exchanger	-64.779.58	-48.52	-41.631.85	-79.27
Active cooling by heat pump	0.00	0.00	0.00	0.00
Cooling: Secondary system	-1.387.42	-25.20	-39.418.26	-105.46

	baseload splitting (predictive control)		Rule based control using monthly setpoints	
	Energy use [kWh/year]	Thermal Power [kW]	Energy use [kWh/year]	Thermal Power [kW]
Heating: Primary system	234.383.74	123.84	150.956.10	91.69
Heating: Secondary system	5.199.61	45.21	109.138.77	93.28
Cooling: Primary system	-55.471.07	-62.80	-33.064.41	-84.89
Passive cooling by heat exchanger	-55.471.07	-62.80	-33.064.41	-84.89
Active cooling by heat pump	0.00	0.00	0.00	0.00
Cooling: Secondary system	-1.435.87	-26.98	-32.344.35	-25.32

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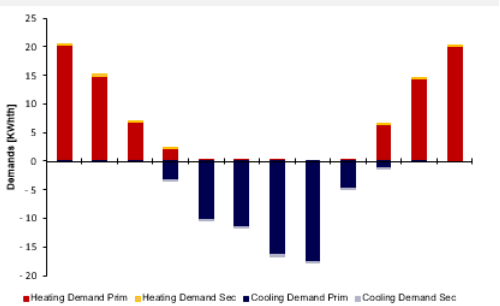
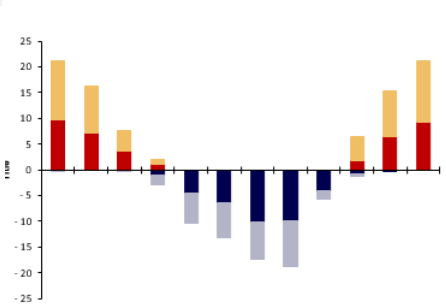
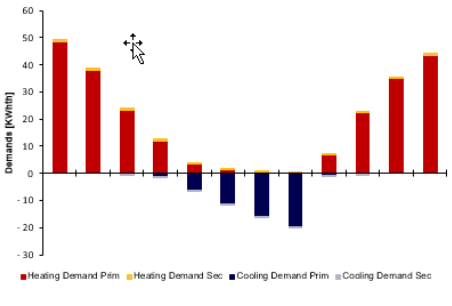
hybrid GEOTABS

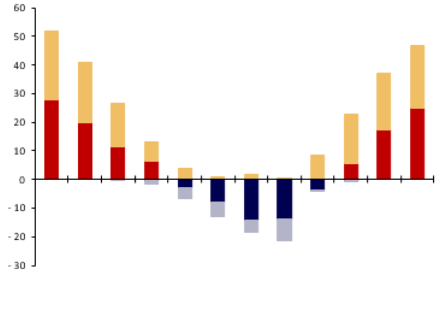
Controlling the power of the ground by integration

SAME BUILDING - TWO CONFIGURATIONS

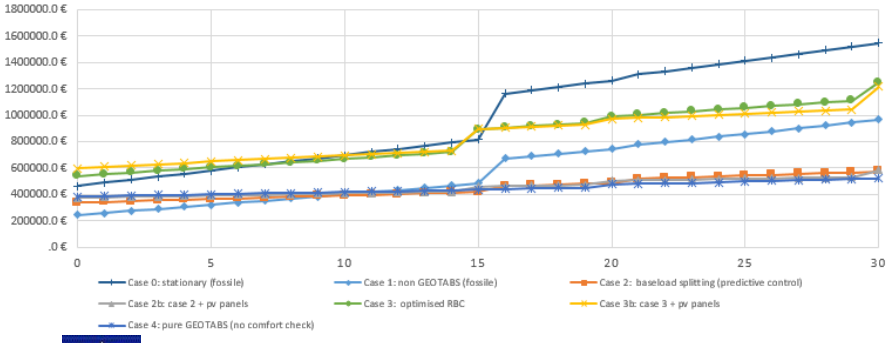




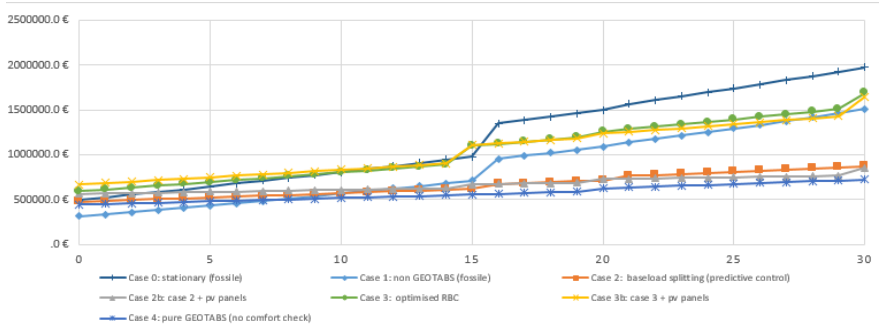




Case 0: stationary (fossile)	€	465.056.28	€	1.352.452.02	
Case 1: non GEOTABS (fossile)	€	244.778.32	€	863.895.14	
Case 2: baseload splitting (predictive control)	€	338.088.98	€	538.987.80	-€ 324.907.34
Case 2b: case 2 + pv panels	€	373.088.98	€	382.381.69	-€ 481.513.45
Case 3: optimised RBC	€	537.230.35	€	962.891.21	€ 98.996.07
Case 3b: case 3 + pv panels	€	596.830.35	€	914.842.48	€ 50.947.33
Case 4: pure GEOTABS (no comfort check)	€	384.007.37	€	282.135.02	-€ 581.760.11



Case 0: stationary (fossile)	€	492.861.00	€	1.771.024.84	
Case 1: non GEOTABS (fossile)	€	312.089.32	€	1.378.386.45	
Case 2: baseload splitting (predictive control)	€	475.615.22	€	829.976.19	-€ 548.410.26
Case 2b: case 2 + pv panels	€	561.015.22	€	561.191.22	-€ 817.195.22
Case 3: optimised RBC	€	593.180.03	€	1.378.797.70	€ 411.25
Case 3b: case 3 + pv panels	€	867.380.03	€	1.320.920.80	-€ 57.465.64
Case 4: pure GEOTABS (no comfort check)	€	445.058.90	€	449.552.49	-€ 928.833.96



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