TU Delft PowerWeb Institute & TU Delft Urban Energy

Propelling the Evolution of Smart Grids and Buildings

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SPECTRAL

A Kropaarstraat 12
1032 LA Amsterdam
The Netherlands

T + 31 (0)20 737 1628
E info@spectral.energy
W www.spectral.energy

About us

Dmitry Surugin

Smart Building Engineer

Milan Milinković

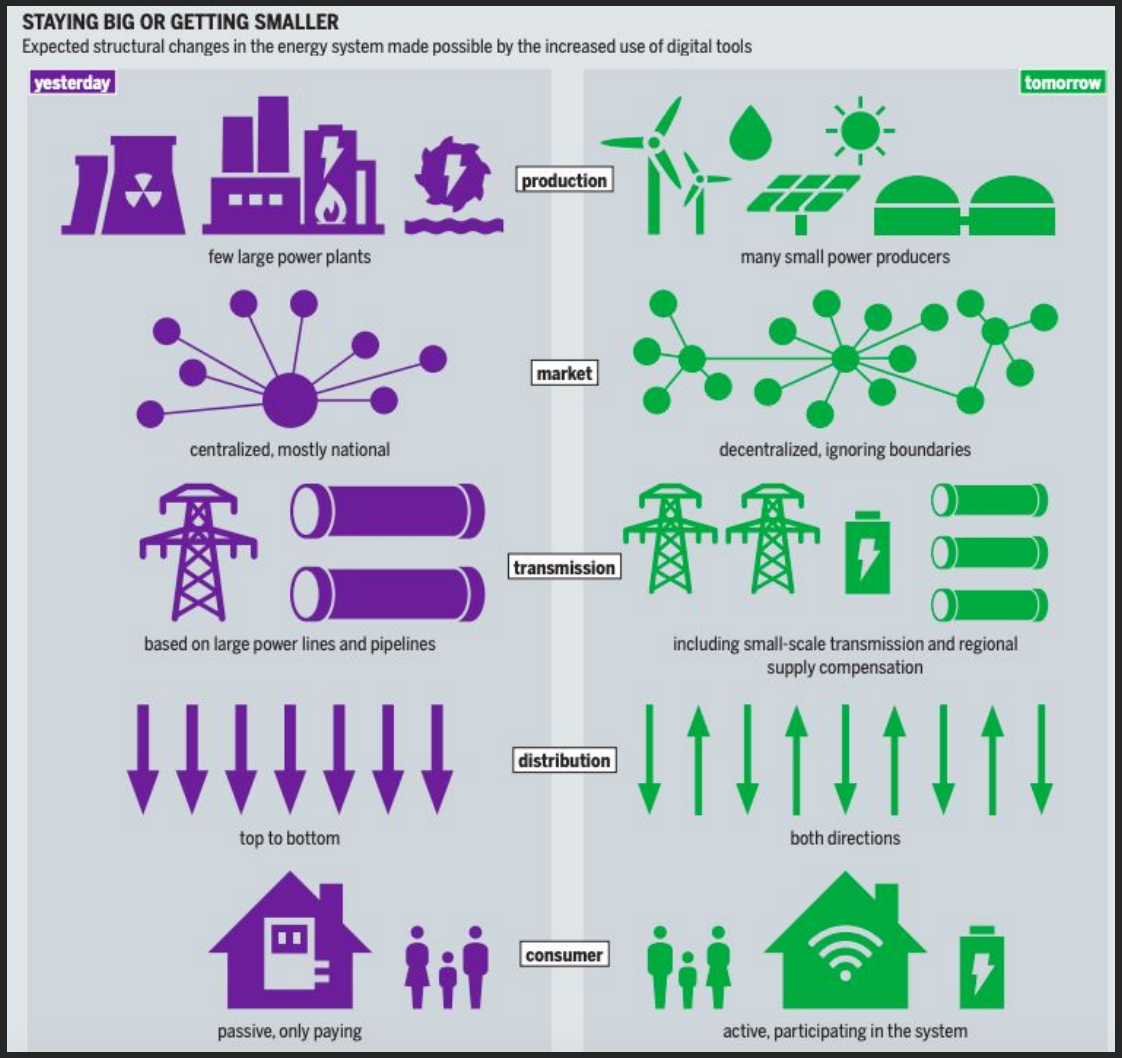
Smart-Grid Architect

Agenda

- Energy transition. Smart grids and smart buildings
- Spectral projects & innovative solutions: smart microgrids, buildings and energy assets
- Smart Energy Control Systems (SEC)
- Smart Building Platform (SBP)
- SBP & SEC convergence. Local Energy Market Pilot.

Sustainable energy transition

structural system changes



Source: https://gef.eu/wp-content/uploads/2018/04/energyatlas2018_facts-and-figures-renewables-europe.pdf

Issues with integration of renewables

- Randomness & intermittency of weather conditions
- Demand-supply mismatch (peaks & imbalances) / power grid stability issues
- More renewables → high price volatility, need for good predictions
- Energy storage & DR for peak-shaving & load shifting (smoothing)

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Evolution of the energy sector

OUR FOCUS AREAS

» Making energy systems smarter & more resource-efficient

» Unlocking the values of renewables through flexibility

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Quality of life & sustainability

Spectral - dedicated team with a mission

Future where sustainable energy is secured and accessible to all, serving as the supporting pillar of our civilization

To build the ICT backbone of our future, sustainable energy system

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Sustainable energy transition

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Core Application Areas

Hybrid Renewable /
Virtual Power Plants

Smart-Grids

Smart Buildings

Spectral Energy Control Systems

- Advanced control platform aiming to unify the flexibility across sustainable assets
  - Observability
  - Controllability
  - Abstraction
- Facilitate asset integration & centralize control
- Unlock revenues & new value propositions
- Adapt to various constraints & use cases
- Unify and (virtually) aggregate assets
- Scale and enable direct market access

WindFlex

Taking control of renewables

- Cloud platform that enables (manufacturer-agnostic) plant aggregation
  - Advanced real-time asset monitoring
  - Abstracting the active power control
  - Statistical analysis and KPI tracking
  - Financial calculations and invoicing
- Cloud (or local) integrations with renewable plants
- Imbalance price forecast for turn-key solution
- Wind farms - 150 MW onboarded & 100 MW to be added this year
- Solar parks - 300 MW to be added this year

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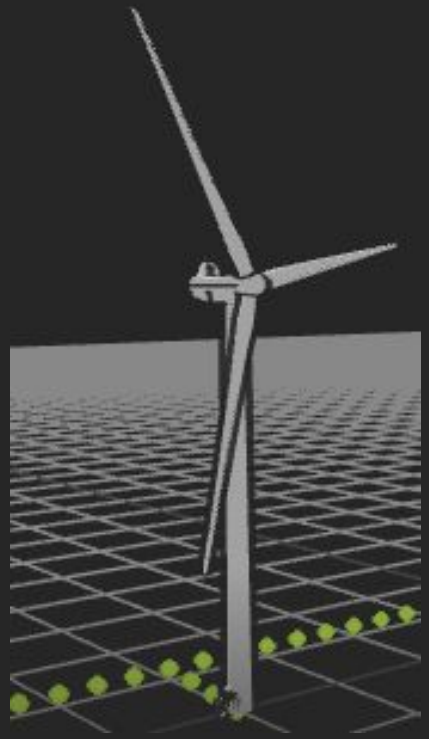
Sometimes Less is Actually More

Curtailment service

- How can curtailment be sustainable?
- The grid is still catching up with renewables
  - Grid congestion issues
- The intermittency of renewable energy
  - Grid balancing issues
- Passive balancing
  - Steering plants on the imbalance market
- Active balancing
  - Aggregating plants for aFRR provision



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Hybrid (RES + ESS) Power Plants

United we stand

- Hybrid power plants - making the best of both worlds
  - Flexibility - storage allows us to “tame” the intermittent resources
  - Cost synergie - sharing infrastructure & extending value propositions
- Mission-critical control systems with stacked control proposition

  - Peak power management and cable pooling
  - Provision of balancing services (FCR & aFRR)
  - Secondary commercial functions
  - Capitalizing on local (renewable) resources
- Abstracting site constraints and operating requirements on the local level
- Redundant control and data logging services ensuring high reliability

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Hybrid (RES + ESS) Power Plants

Hartel II - 10 MW Battery System

Hybrid (RES + ESS) Power Plants

Hellegatsplein - Mobile Battery Station

Hybrid (RES + ESS) Power Plants

Rhino - 2 x 6 MW Battery System

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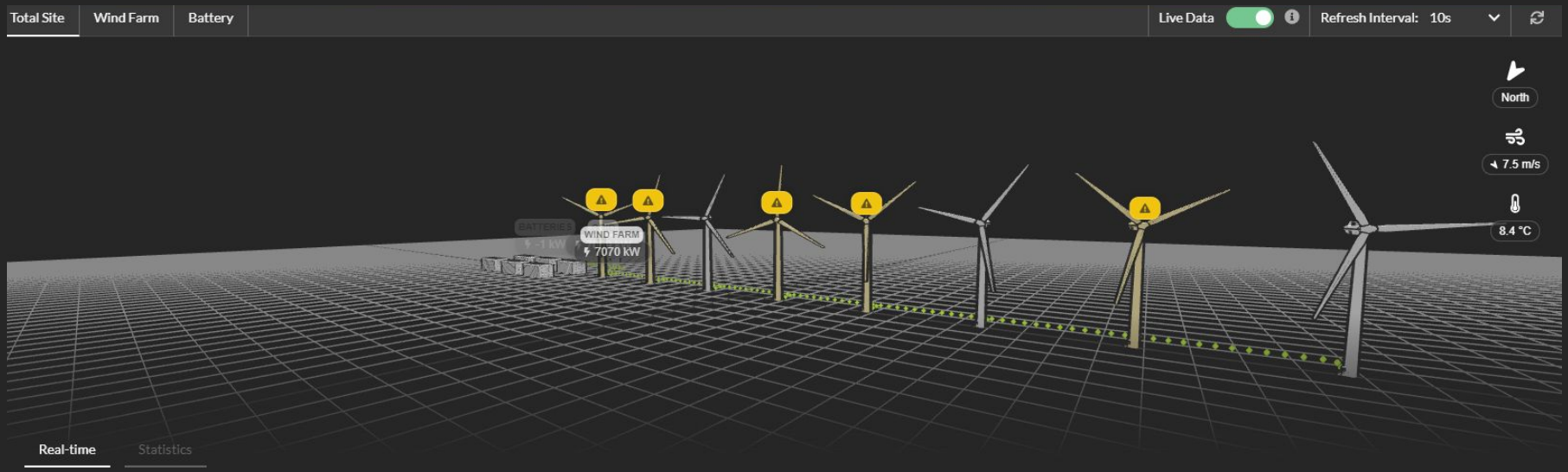
SECS Monitoring Platform



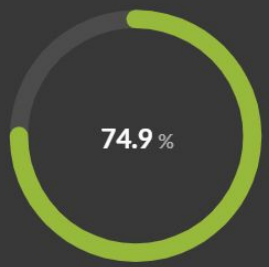
Wind Farm Status

Windturbine	Status	Control Status	Internal Temperature
T2	OK	OK	28.5 °C
T3	Warning	OK	28.8 °C
T4	OK	OK	28.3 °C
T5	Warning	OK	28.7 °C
T6	Warning	OK	28.8 °C
T8	OK	OK	30.6 °C
T9	Warning	OK	30.4 °C
T10	Warning	OK	27.8 °C

Battery System Status

Container	Status	Converters	Temperature
1	ON	6	8 °C
2	ON	6	11 °C
3	ON	6	9 °C
4	ON	6	12 °C
5	ON	6	10 °C
6	ON	6	12 °C

Battery State of Charge



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Smart Community Platform

Don't forget about the little guy

- Smart-grid solutions propelling the evolution of energy positive districts
  - Source energy from your neighbors & support local economy
  - Increase efficiency and reduce transportation losses
  - Reduce grid dependency and help balance the grid
- If it was just a simple matter of scaling...
- Local flexibility to the rescue
  - Electric Vehicles & Energy Storage
  - Renewables Resources
  - Heating Systems
- Empower local prosumers to take an active role in the energy transition

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Smart Community Platform

Don't forget about the little guy

Virtual Power Plants

Strength is in numbers

- Proving a concept is definitely fun, but it is not sufficient
- Virtual Power Plants - regroup your forces & unify the potential

- Clustering is the way to go:
  - Reduce dependencies
  - Improve predictability
  - Optimize your fleet

> There is strength in numbers, but organizing those numbers is one of the great challenges.
>
> John C. Mather

- Scalability - the devil is in the details...

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Unlock the Power of Data

Dealing with Uncertainty

- Data-driven modelling & machine learning applications in smart-grids
  - Modelling the assets and their limitations
  - Promised vs. delivered and KPI tracking
  - Improving forecasts and balancing
  - Optimizing operation and planning ahead
  - Exchange knowledge between projects
- Testing has never been easier
  - Digital twin - help us model the behavior of complex systems
  - Predictive Twin - estimate the future state of those systems
  - Digital Playground - our actions have no consequences

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SECS Recap

Renewables on steroids

- Take control of renewables
  - Facilitate integration
  - Abstract the control
- Harvest the flexibility
  - Unlock the value of flexibility
- Push the grid to its limits
  - Lift the constraints
  - Optimize the operation
  - Support the grid

What are the next steps?

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Why switching to renewables is not sufficient?

building energy consumption should be reduced

- Life-Cycle Assessment (LCA) & Energy Payback Time (EPBT)
- Population growth followed by load increase
- 10-40 % losses due to inefficient HVAC control (offsets all the green energy in the Netherlands)

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Why is technology in buildings so far behind?

- Not on the forefront of the user
- Massive long-term multi-year investment
- Need for IT/OT hybrid skill set

Old paradigm:

- Ad-hoc custom control implementation
- Act only when complaints received
- Micromanage every little aspect
- Solve same problem in different sylos

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Enabling technologies for smart buildings

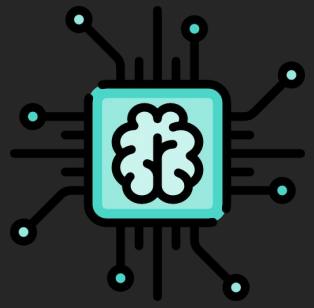
"Game-changers" for the industry

Cloud storage & CPU

Cellular infrastructure

Weather APIs

Open protocols

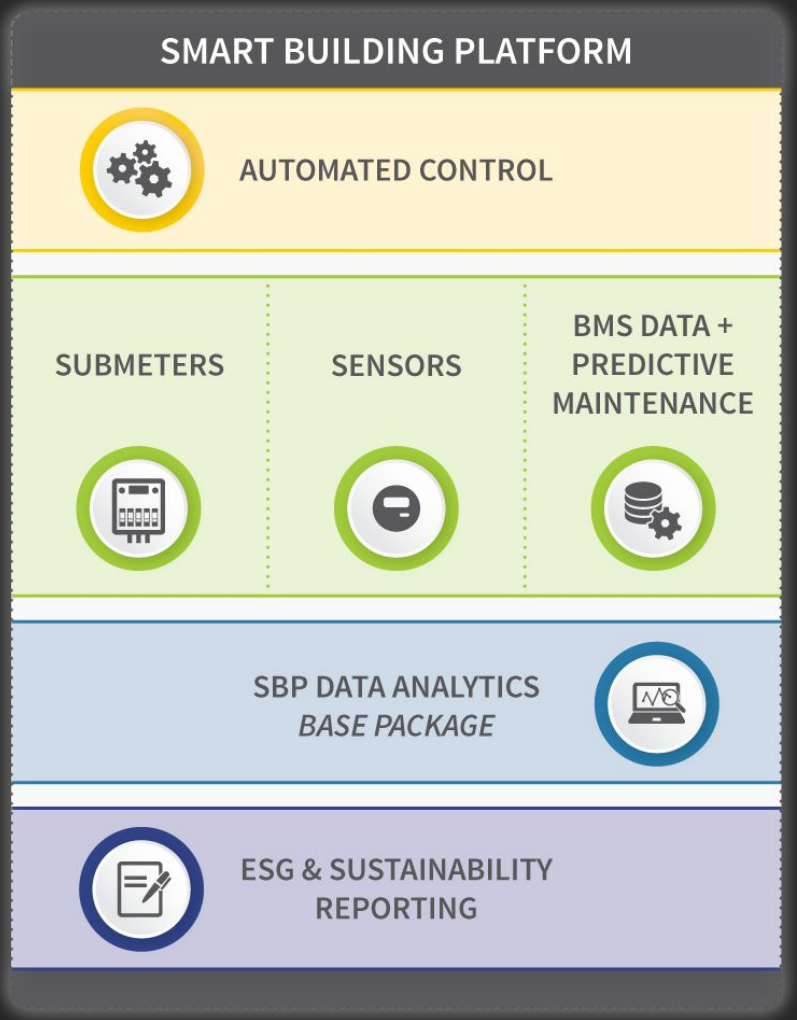


Cheap & customizable hardware

Infrastructure & data are already there → it's a harvest time!

Smart Building Platform

Key features of our software overlay solution



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Automotive vs building industry

“Front-glass view”

- Looking around
- Processing information
- Adjusting actions

What would happen if it reacted post-factum?

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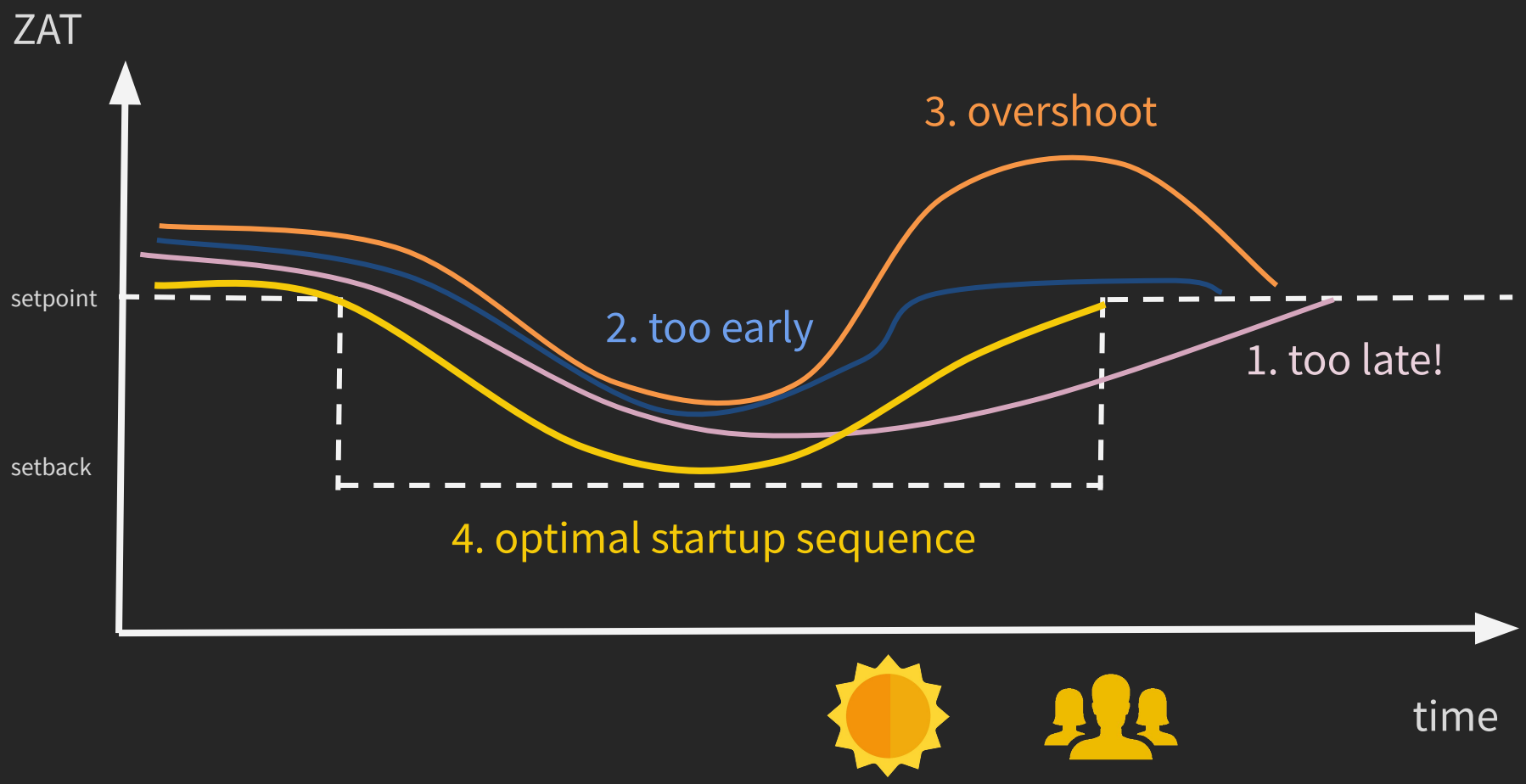
What is the value of predictive control for buildings?



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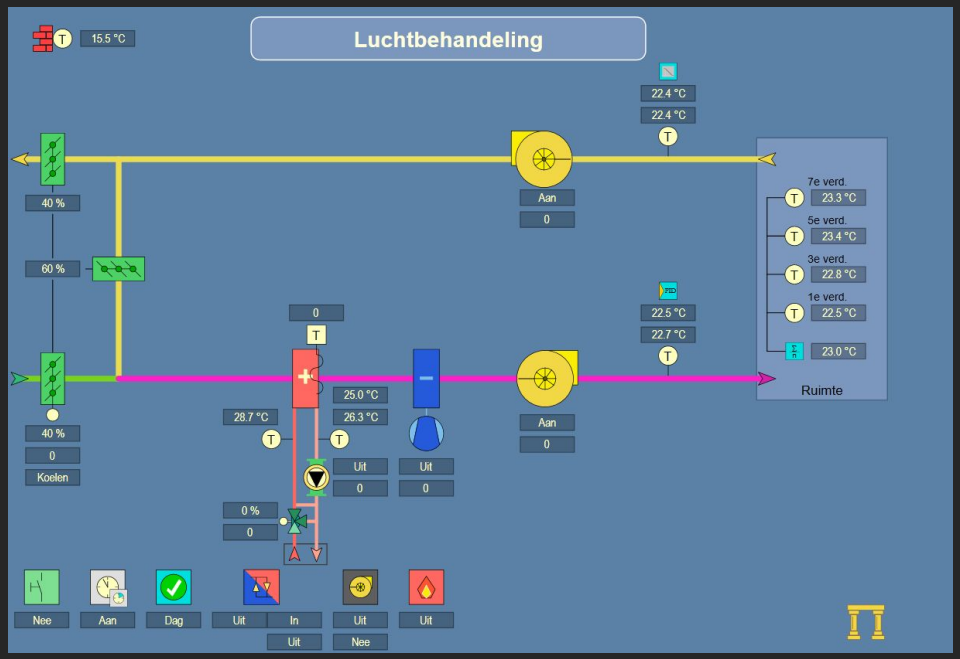
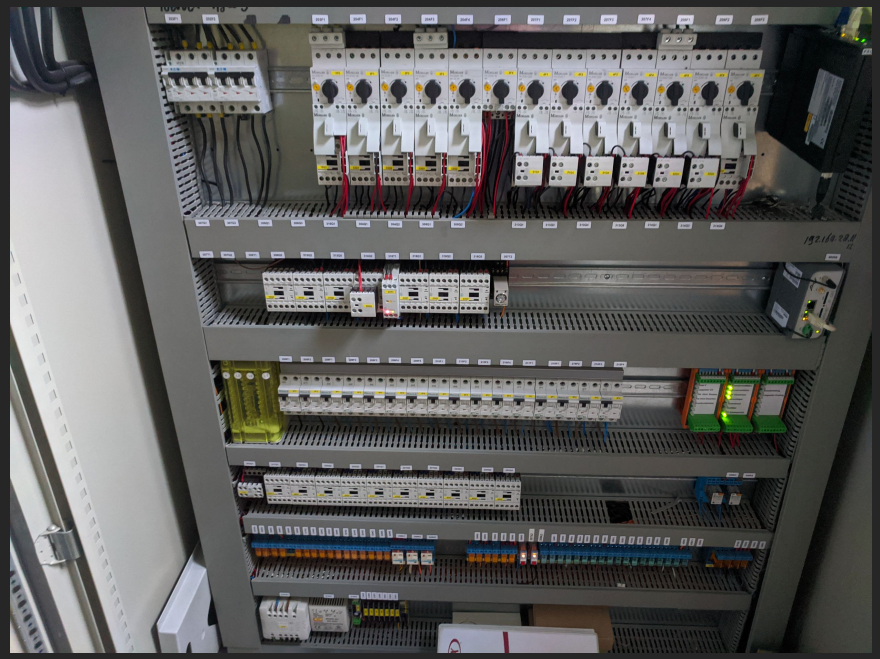
Smart Building Platform

prerequisites for the automated control

1. Onboarding - collecting building info & HVAC specs, installing gateway & connecting to BMS (as a plugin/overlay on top)





Smart Building Platform

prerequisites for the automated control

1. Onboarding - collecting building info & HVAC specs, installing gateway & connecting to BMS (as a plugin/overlay on top)
2. Energy audit & commissioning, installing sensors & energy submeters
3. Pulling, processing and storing time-series data, congregating APIs
4. Data modelling (creating “building topology” - giving context to it), mapping registers, setting up monitoring & alerting

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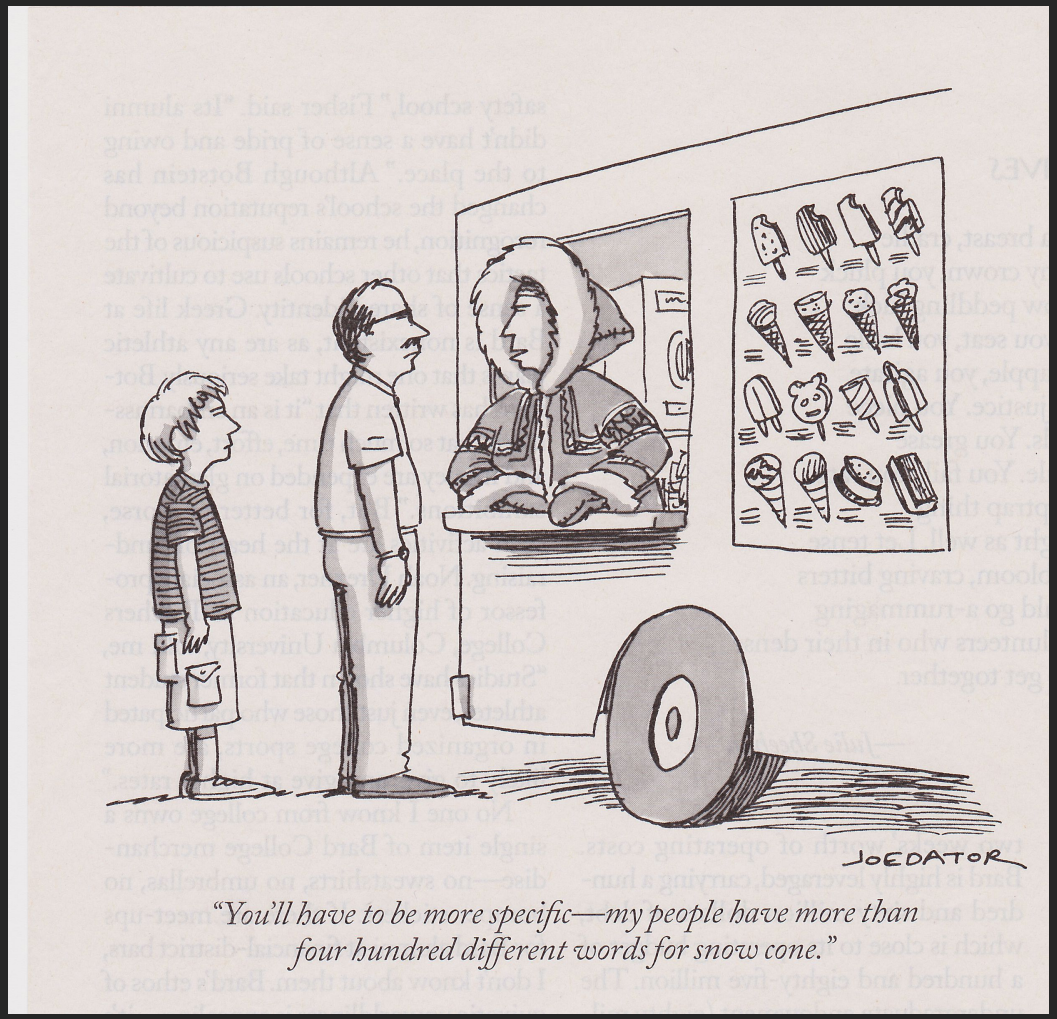
Data modeling & Interoperability



"You'll have to be more specific—my people have more than four hundred different words for snow cone."

- Naming convention / taxonomy:

"Deep rainforest green" vs RGB

- Need for HTML-like unified standard
- 100 words for snow / palm - define proper "abstraction level"
- Data model / ontology:

describe points & relationships

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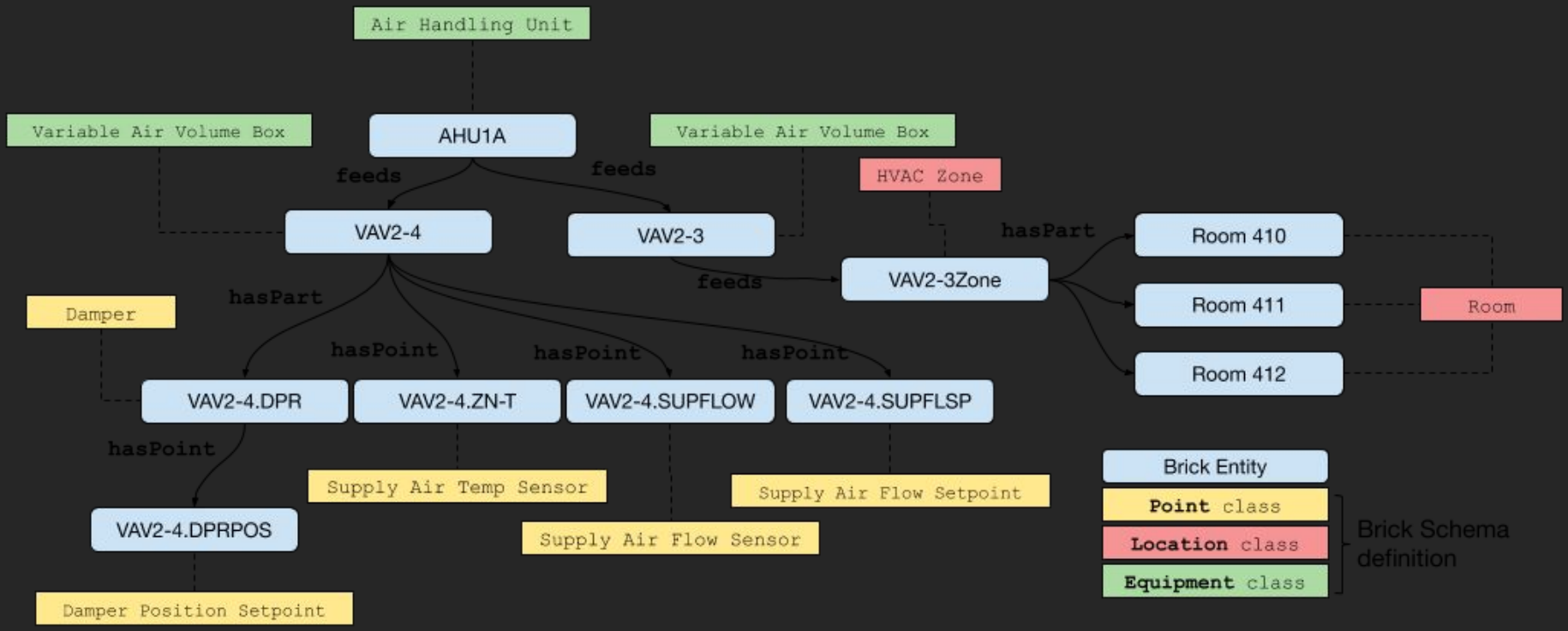
Data models, ontologies & taxonomies

BRICK schema, Haystack project, Google digital buildings



Source: brickshema.org

Smart Building Platform

prerequisites for the automated control

1. Onboarding - collecting building info & HVAC specs, installing gateway & connecting to BMS (as a plugin/overlay on top)
2. Energy audit & commissioning, installing sensors & energy submeters
3. Pulling, processing and storing datastreams, congregating APIs
4. Data modelling (creating “building topology” - giving context to it), mapping registers, setting up monitoring & alerting
5. Deploying fault detection & diagnostics, setting up automated functional performance tests (FPTs). Using newly installed sensors for getting reliable feedback from the building.

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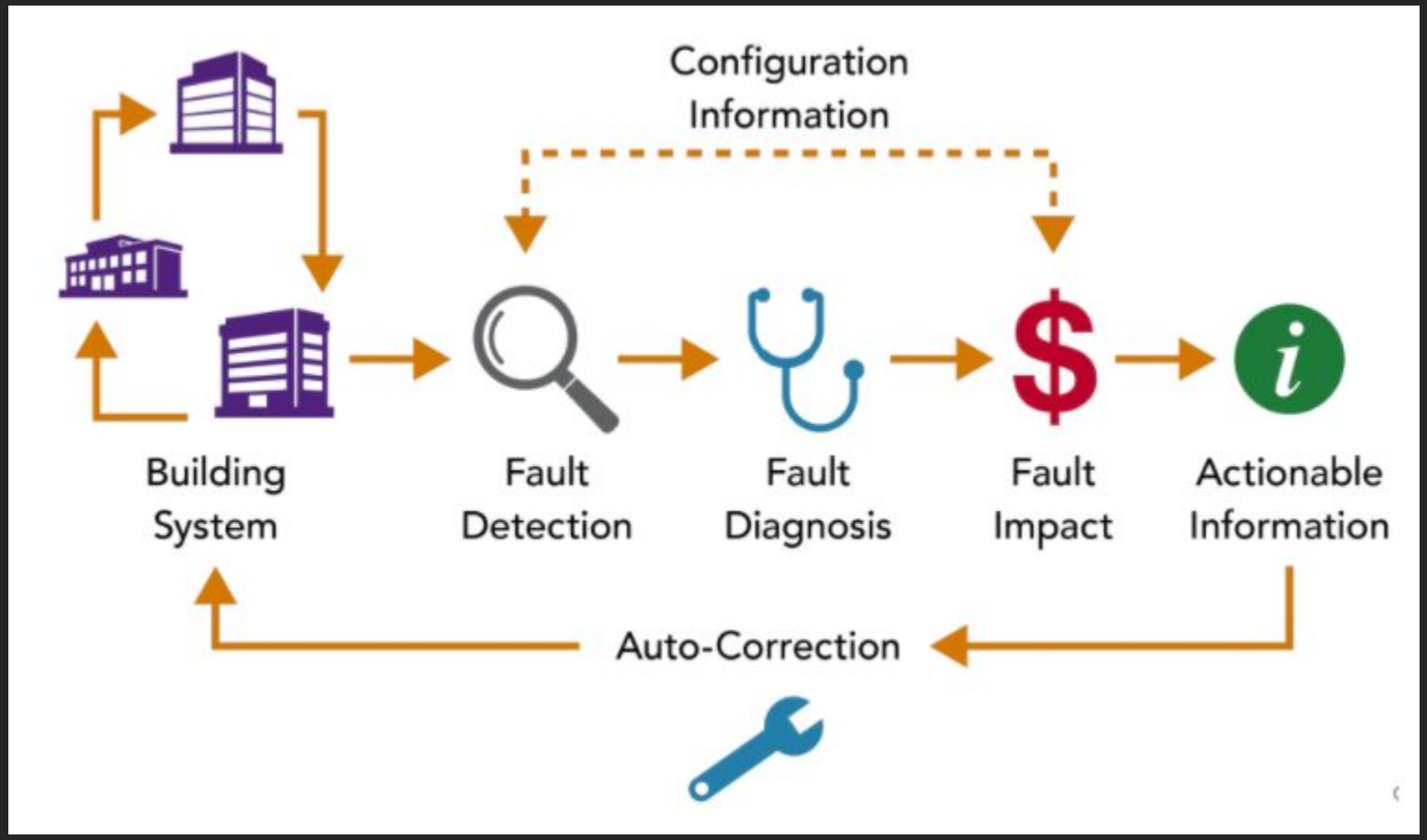
Fault Detection & Diagnostics



Source: https://www.pnnl.gov/building-grid-integration

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Smart Building Platform

5 stages of active control

1. Reactive control: reconfiguring BMS using its existing capabilities. Set up basic control practices, start with three S: setpoints, schedules, sequences.
2. Setting up advanced control strategies using the python-based “reactive control toolbox” (ASHRAE GPC 36 - Trim & Respond). Dynamically adjusting setpoints every 10 minutes.
3. After few weeks: training thermal model & adding predictive control strategies (e.g. “optimal start-up/shut-off time”)
4. Using “digital twin” for MPC - implementing rolling horizon optimization on top of tuned RC-model with day-ahead forecasts, prices, comfort constraints
5. Grid-Interactive Efficient Buildings (GEBs) - managing load flexibility

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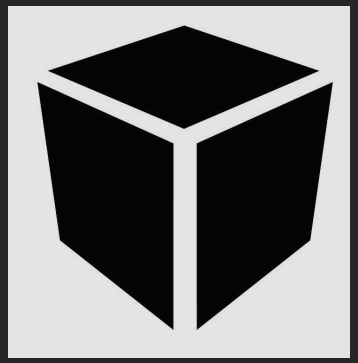
Thermal models for building control

data driven



Black-box models

Physical processes in real buildings are too complex to be captured

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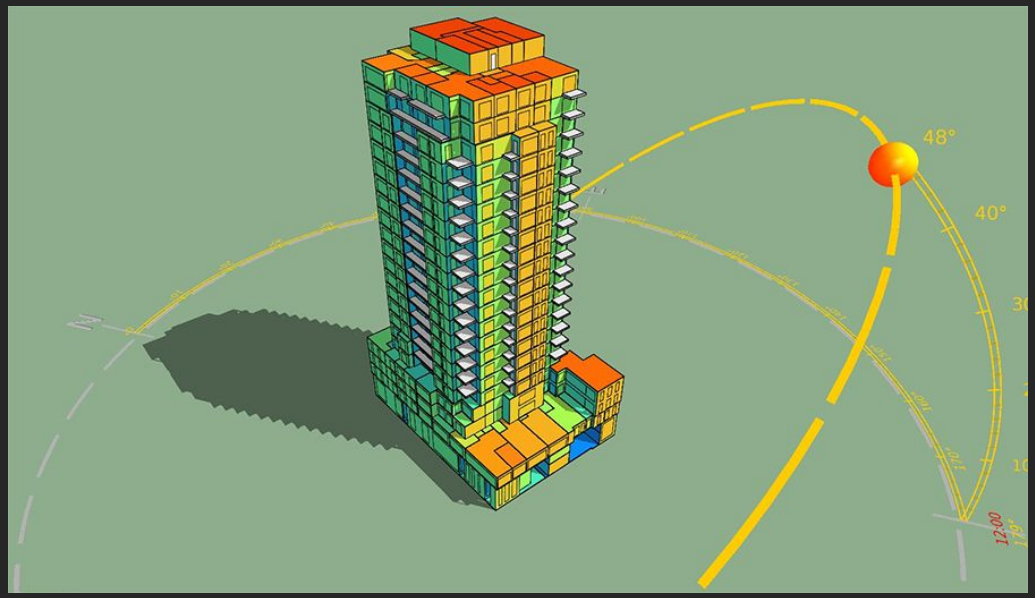
Building Energy Modelling & Performance Simulation

white-box approach



- 3D-building geometry
- Typical meteorological data
- Building constructions
- Plant/occupancy profiles
- Internal heat gains
- Ventilation rates
- HVAC systems

- Need for calibration simulations (e.g. data from energy meters, temperature sensors)
- Need for the runtime operation & optimisation (e.g. coupling E+ with BCVTB)

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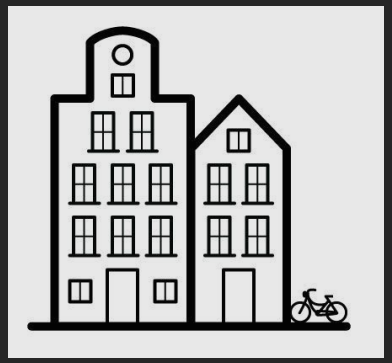
Thermal models for building control

physics-based



White-box models - building performance simulations

The prior knowledge of building is not comprehensive enough

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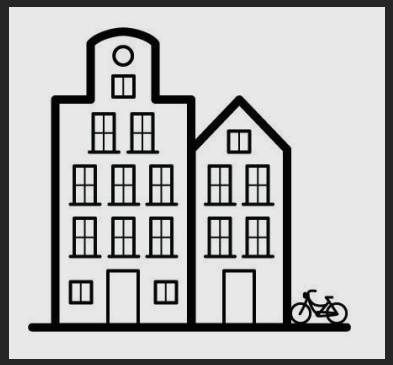
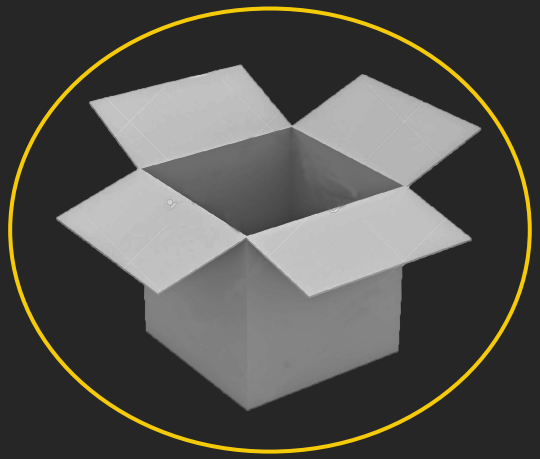
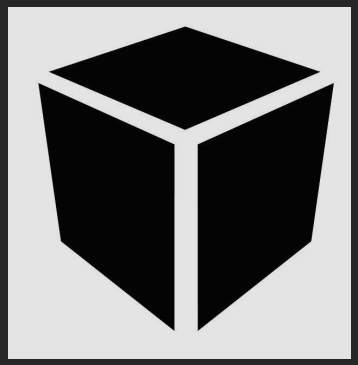
Thermal models for building control

physics-based & data driven







Grey-box

Effective to achieve a suitable characterisation of buildings' thermal response of buildings in a short time

ML to tackle the gap between predicted & actual performance

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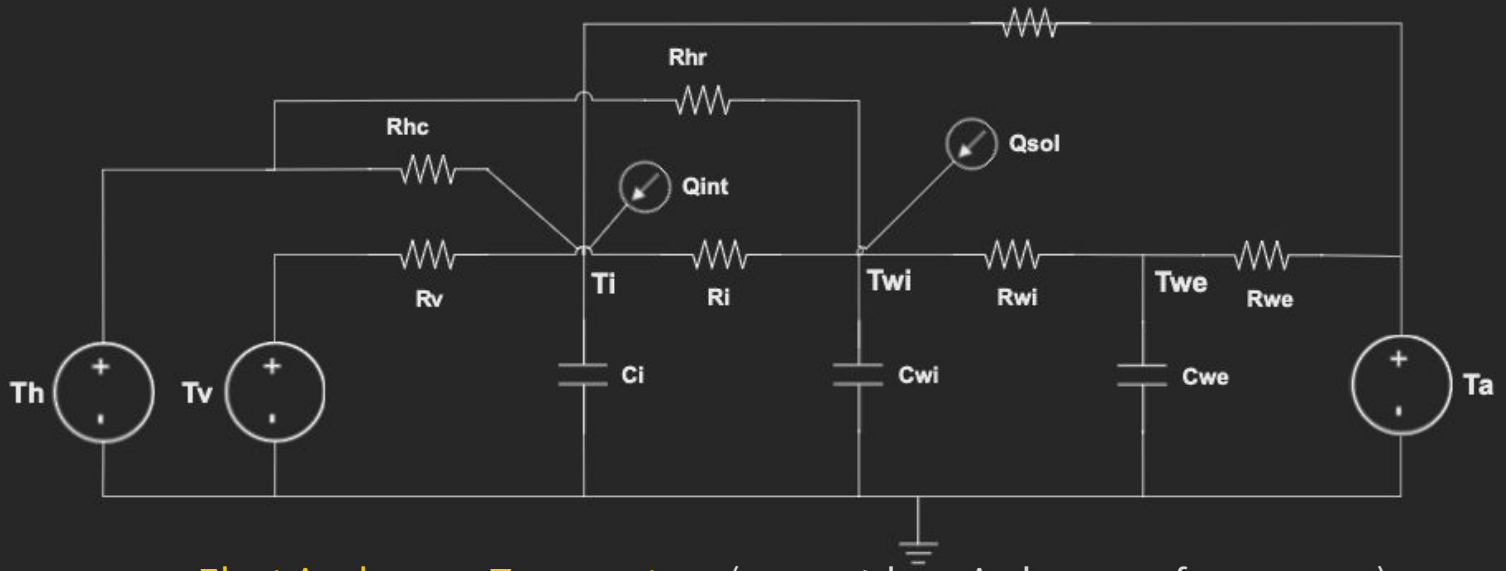
Grey-box building models for MPC

RC-circuits as a core (thermal-electric equivalent)



Electric charge - Temperature (e.g. outdoor, indoor, surfaces, mass)

Voltage - Temperature difference (e.g. outdoor-indoor, supply-indoor, heater-indoor)

Electric current - Heat gains / losses (e.g. solar gains, internal gains from equipments, occupants)

Electrical capacitance - Heat capacity (e.g. of air, of thermal mass)

Electrical resistance - Thermal resistance (constant - walls, windows and variable - valves & dampers)

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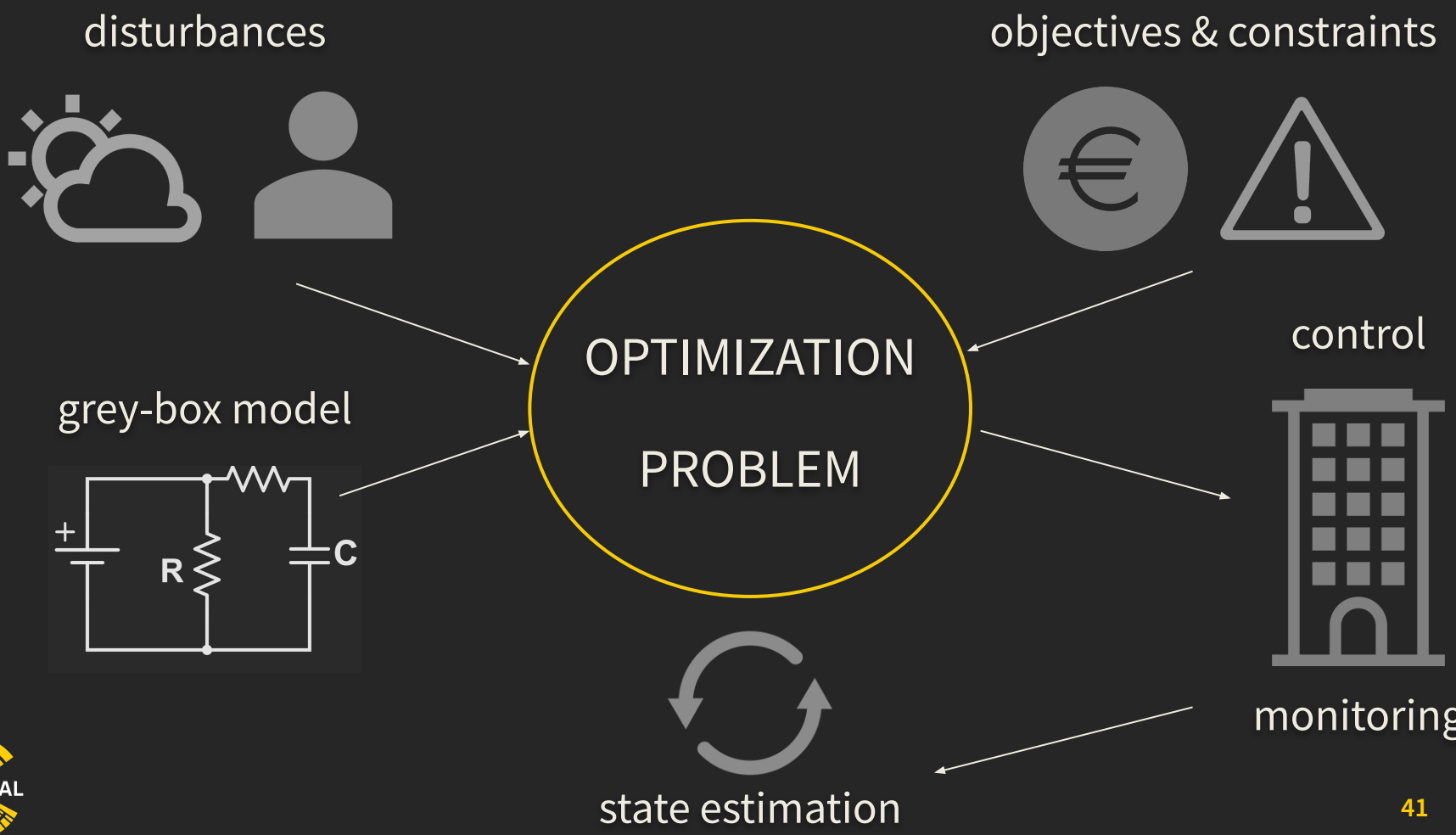
Grey-box building models for MPC

MPC framework



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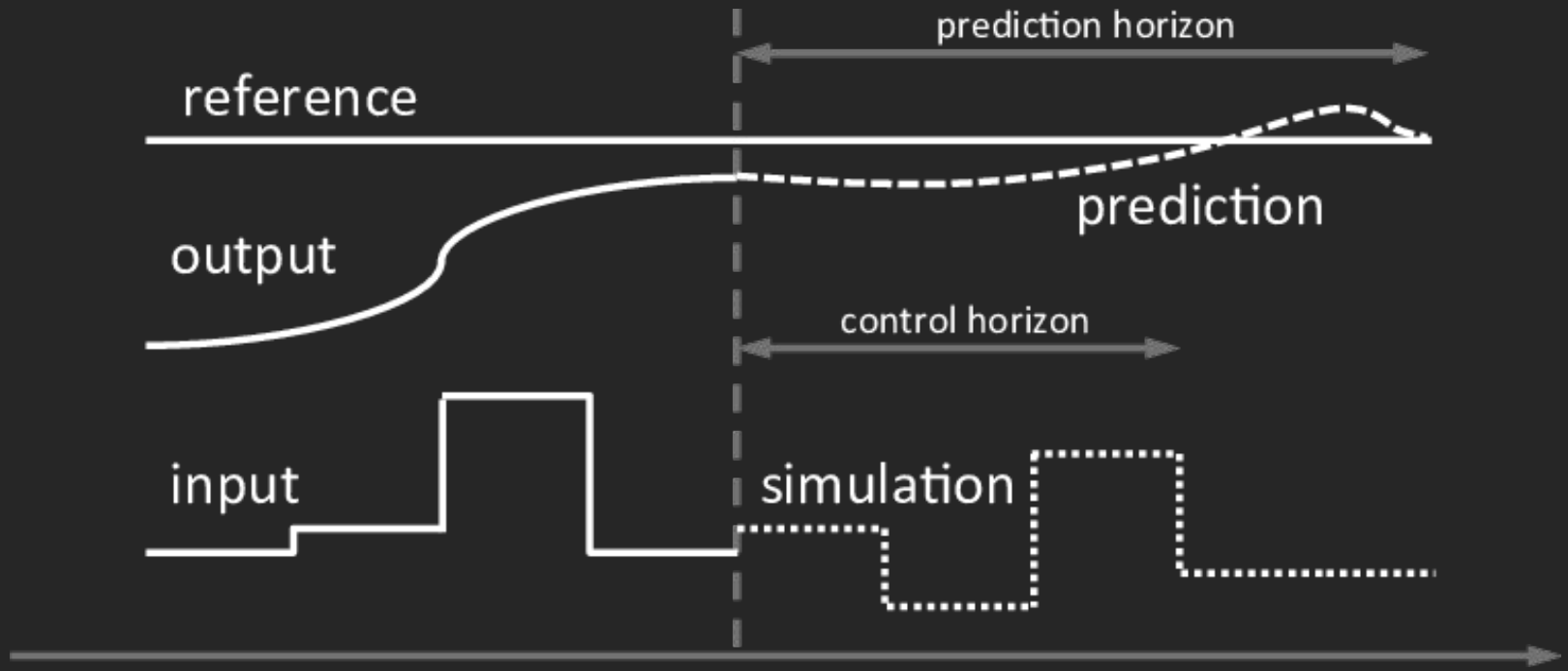
Grey-box building models for MPC

Moving horizon optimization



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SBP - lessons learned

- Scalability/replicability is a key. Challenge is to design provider-agnostic decoupled standardized system. Data models are crucial.
- Unlock the data from all sylos, apply analytics, enable synergies
- Start simple (“three S”) with low-hanging fruits, then add complex algorithms based on ROI
- Train O&M staff on how technology works. They should use it as a helpful tool, rather than fighting it. Not to replace, to improve the process. O → M. “FIx an issue” instead of “find an issue”.

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SBP - lessons learned

- Make FDDs focused and actionable: no one want “how messed up is my building” report. Avoid false positives. SaaS = selling... a project? a product? an outcome!
- Safety factor: connectivity loss → soft landing on BMS sequences
- Provide ever-increasing value, keeping up with the times (e.g. “pandemic mode”)
- It’s not enough to think “behind the meter”. Aggregate portfolio into Virtual Power Plant (VPP). Respond to grid events & price signals.

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(Future) Spectral Tech Ecosystem

SBP & SECS convergence

- Enabling the transition towards a clean and sustainable energy system
  - Flexible Generation - taking control and unlocking flexibility
  - Efficient Distribution - overcoming the obstacles and decreasing losses
  - Responsive Consumption - following the system conditions
- SECS Platform
  - Extending the generation
  - Optimizing the transmission
- SBP Platform
  - Optimizing the consumption
  - Harvesting (thermal) flexibility
- Enable the power system to maintain balance during uncertainty
- Electricity markets are based on supply-driven wholesale models...

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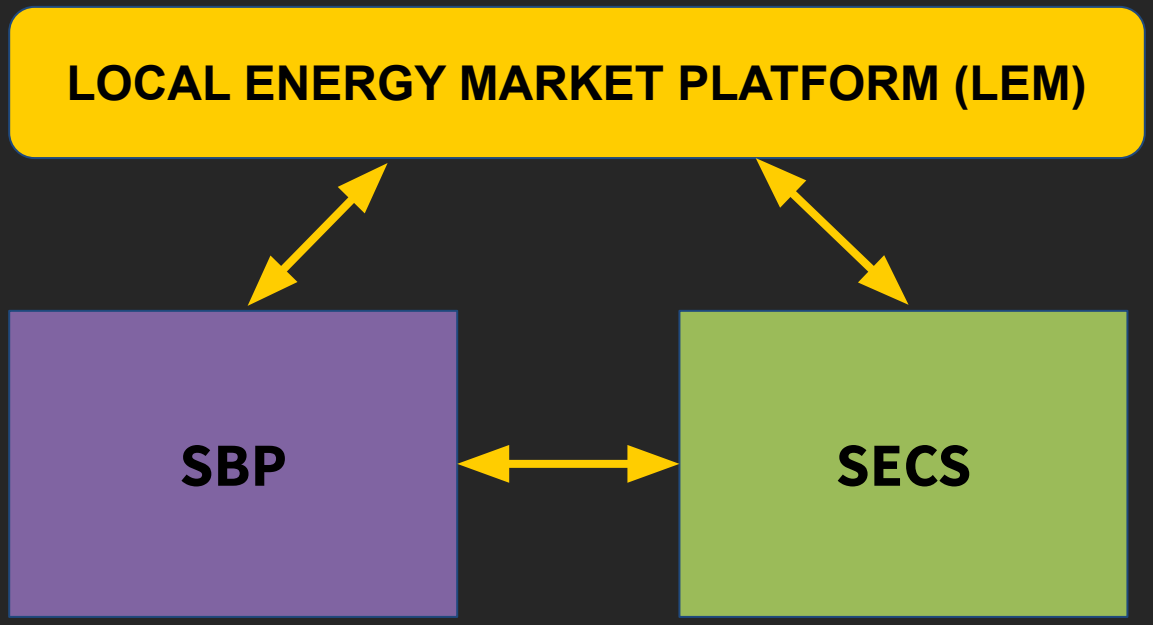
(Future) Spectral Tech Ecosystem

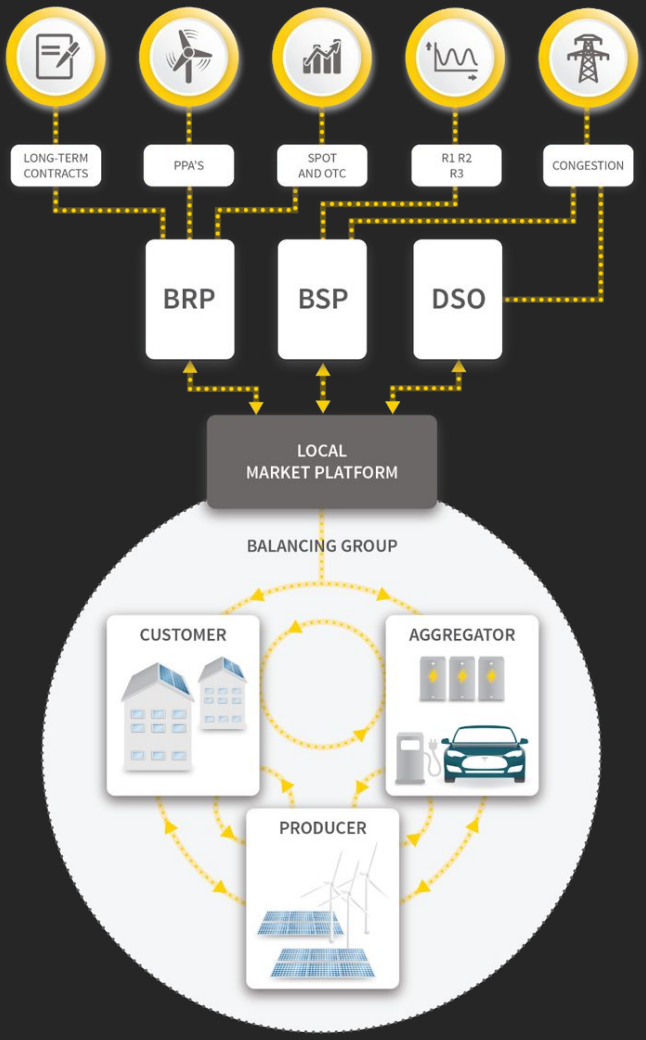
SBP & SECS convergence



Atelier - Local Energy Market Pilot

Energy Positive District in Amsterdam

- Local Market Platform as a **gateway to wholesale** and balancing **markets**
- **Two-way** communication and **dynamic pricing** based on wholesale market participation
- Greater **transparency** and **control** over energy supply



- **Automated trading** of PPA's, smart flex contracts, and P2P energy exchange
- Deployment of **local energy services** (eg. congestion relief for the DSO)
- **Seamless integration** of new customers, producers, and aggregators

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Conclusions

Developing technological solutions propelling the evolution of smart grids and buildings that will enable the sustainable energy transition!

Thank you!

Dmitry V. Surugin
Smart Building Engineer

dmitry@spectral.energy
+31 (0)6 42 72 38 63

www.spectral.energy

Milan Milinković
Smart-Grid Architect

milan@spectral.energy
+31 (0)6 34 15 72 38

www.spectral.energy

Questions?

If you have any additional questions you can follow our trusty T Rex

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