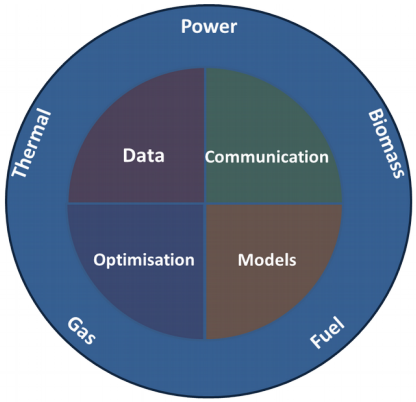
CITIES and Center Denmark
A National Digitalization Hub for a Smart and Fossil-free Society



Henrik Madsen

Applied Mathematics and Computer Science

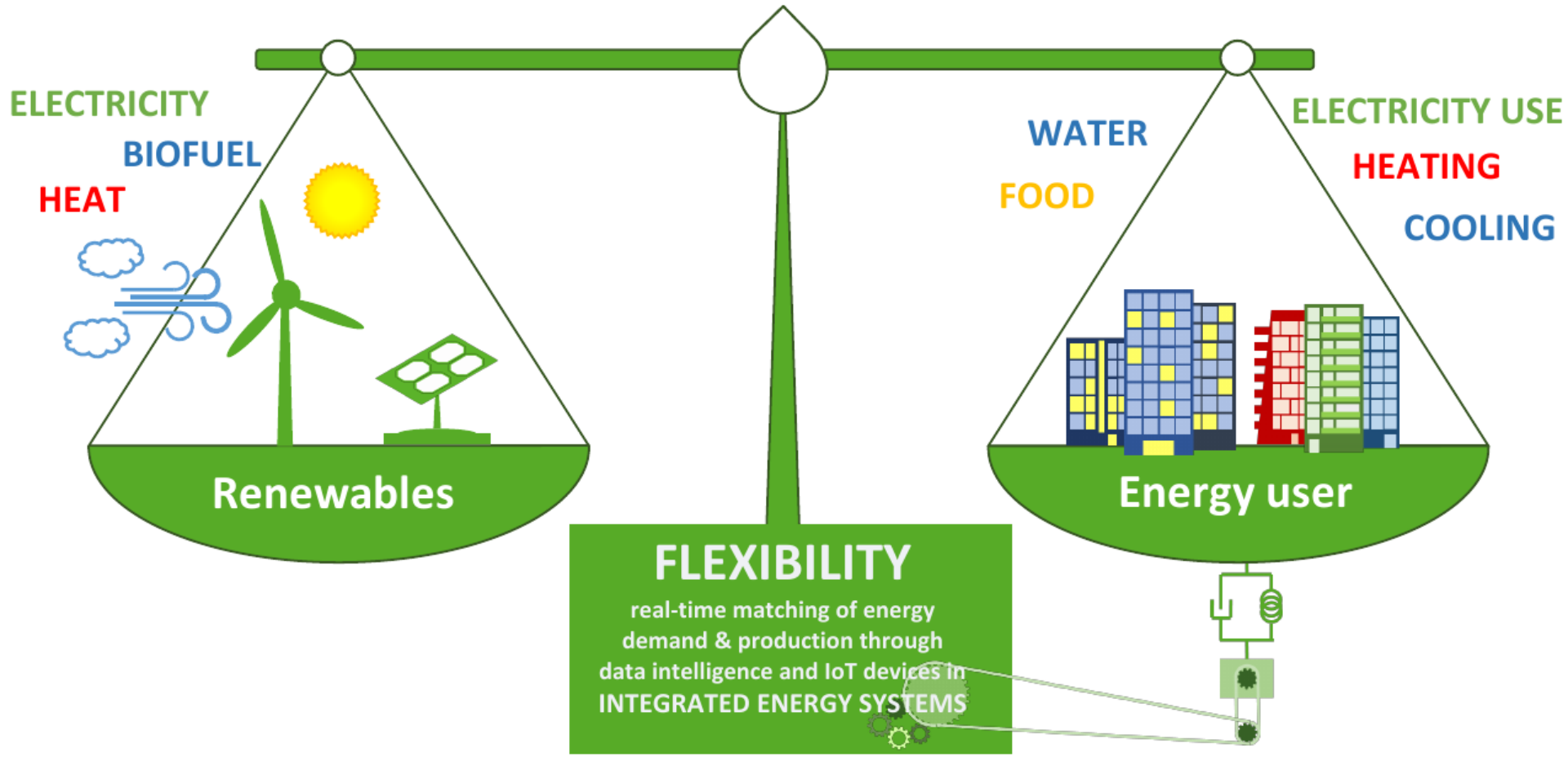
Technical University of Denmark

http://www.smart-cities-centre.org

http://www.henrikmadsen.org

A few CITIES and SmartNet presentations at Energinet and DE during the past 2 month

The Challenge: Denmark Fossil Free 2050



Challenges

Preparatory study on Smart Appliances

European Commission

Ecodesign Preparatory Study performed for the European Commission

Welcome | Project summary | Planning & Meetings | Documents | Register for website | Register for meeting | Contact & Consortium

Home > Project summary

Project Summary

The Ecodesign Preparatory Study on Smart Appliances (Lot 33) has analysed the technical, economic, market and environmental aspects with a view to a broad introduction of smart appliances and to develop adequate policy approaches supporting such uptake.

The study deals with Task 1 to 7 of the Methodology for Energy related products (MEErP) as follows:

- Scope, standards and legislation (Task 1, Chapter 1);
- Market analysis (Task 2, Chapter 2);
- User analysis (Task 3, Chapter 3);
- Technical analysis (Task 4, Chapter 4);
- Definition of Base Cases (Task 5, Chapter 5);
- Design options (Task 6, Chapter 6);
- Policy and Scenario analysis (Task 7, Chapter 7).

An executive summary of the project results can be downloaded here.

Throughout the study, new relevant aspects have come up which will be covered in a second phase of the Preparatory Study:

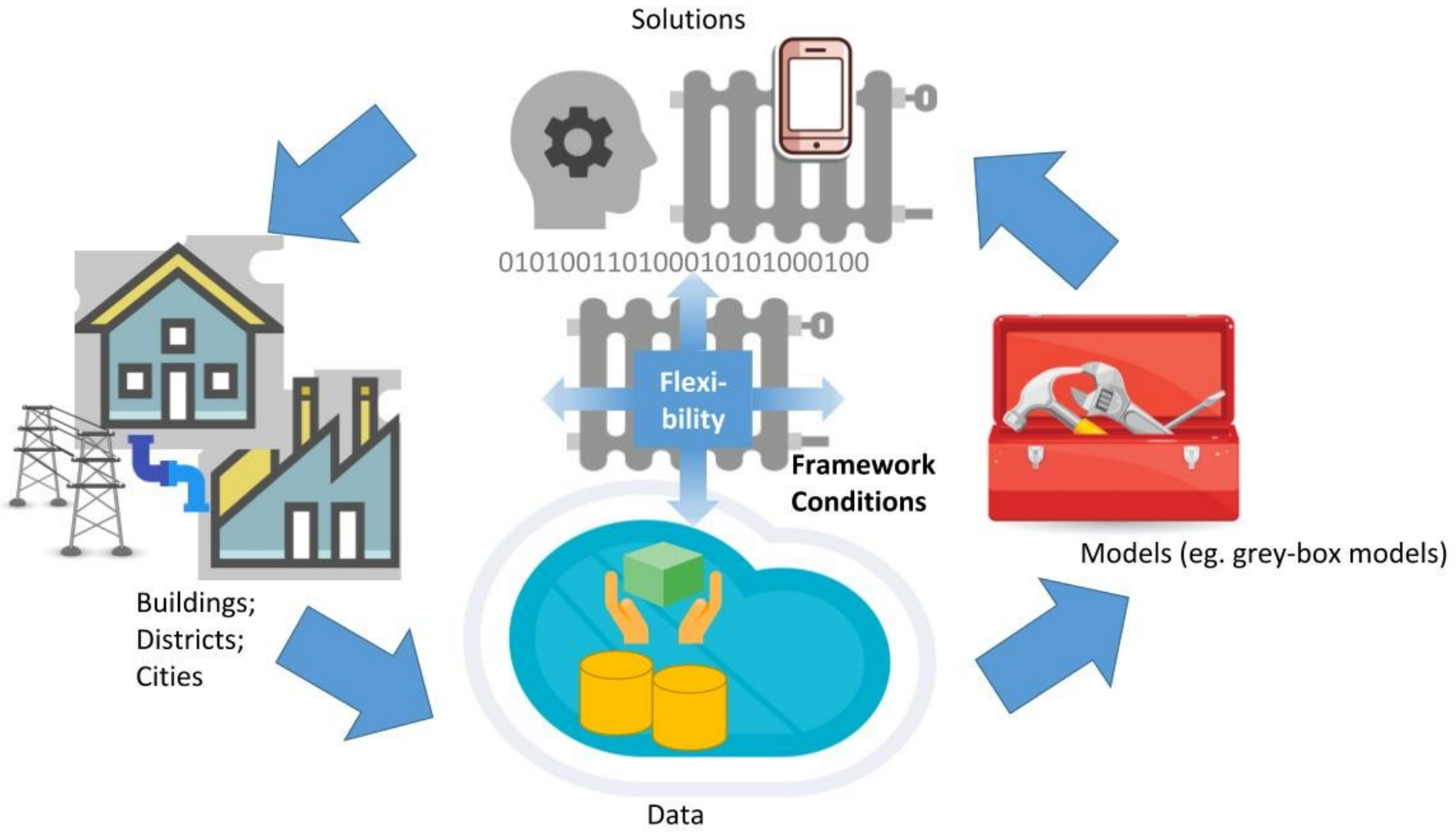
- Chargers for electric cars: technical potential and other relevant issues in the context of demand response.
- The modelling done in the framework of MEErP Task 6 and 7 will be updated with PRIMES data that recently became available, and with the EEA-countries.
- The development and assessment of policy options that were identified in the study will be further elaborated and deepened.

Almost no Flexibility

Center Denmark

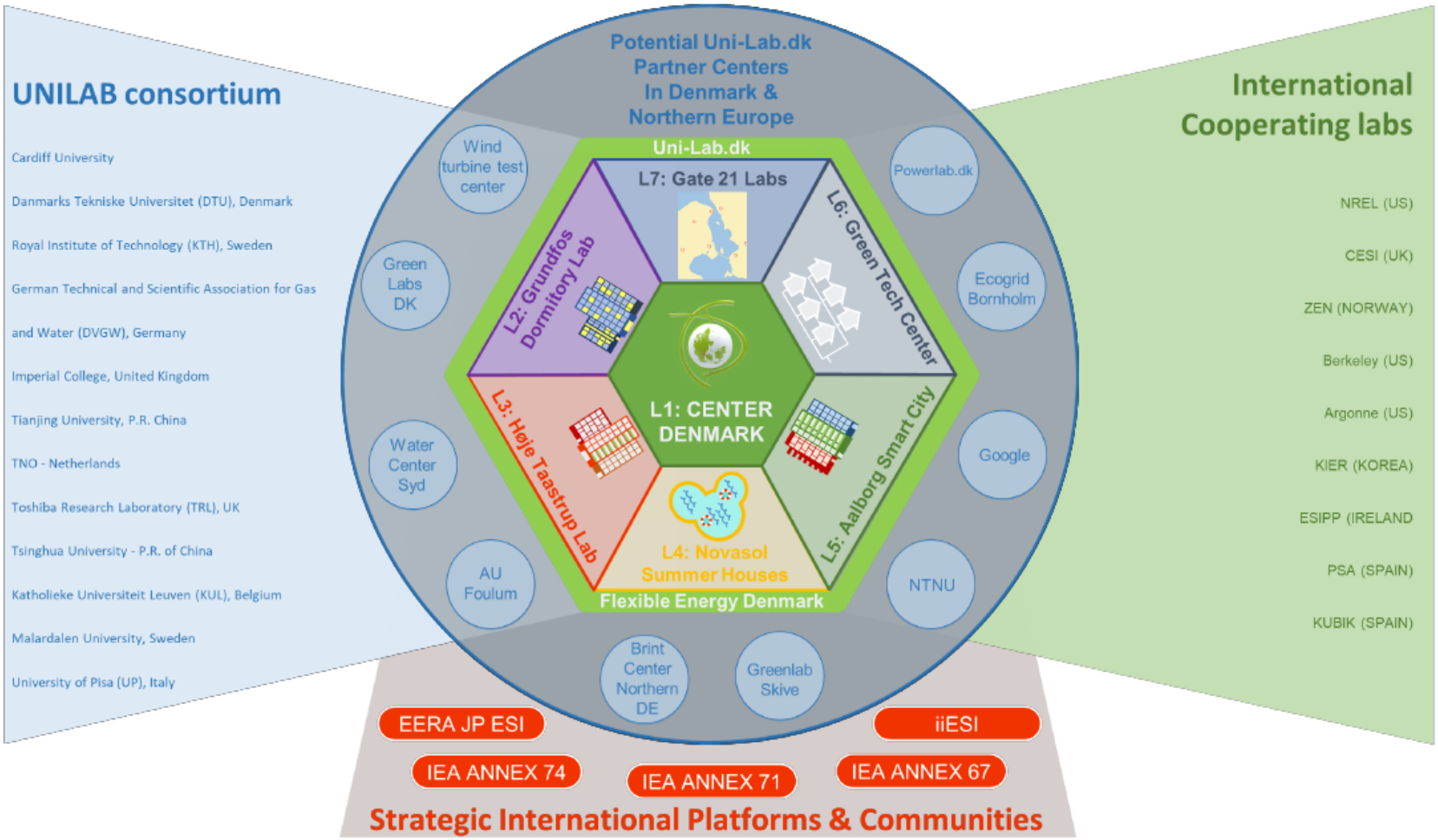
- A digitalization hub for data intelligent control of integrated energy systems for large scale integration of fluctuating renewable energy
- Tests have to be representative – and scaling is important
- The suggested national digitalization hub is Center Denmark; located around 10 min from Energinet.dk (10.000 m2 facilities for Research, Education, Development and Testing - plus Dissemination)
- The Societal objective is to establish a realistic and concrete pathway to a fossil-free society
- The Scientific objective is to establish methodologies and solutions for the future intelligent and integrated energy system using digitalization and a smart energy hub
- The Commercial perspective is to being able to idenfy and test solutions which can form the background for commercial success stories. We believe that this setup has the unique characteristics for being the ultimate smart energy hub for test and demonstration of future smart energy solutions

Flexibility enabled using data intelligence (FED project)



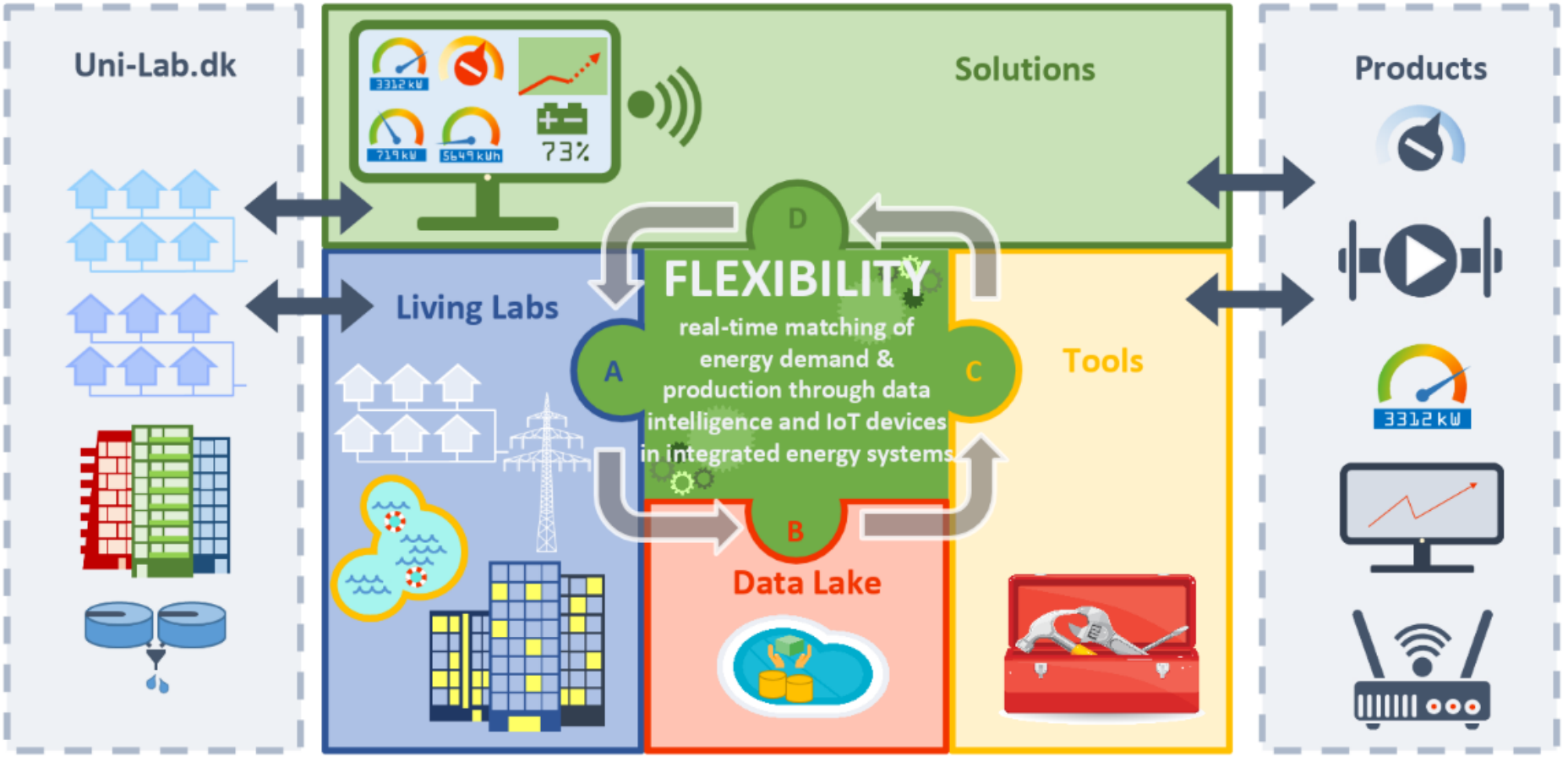
Uni-Lab.dk

Center Denmark, Living Labs, Partnerships

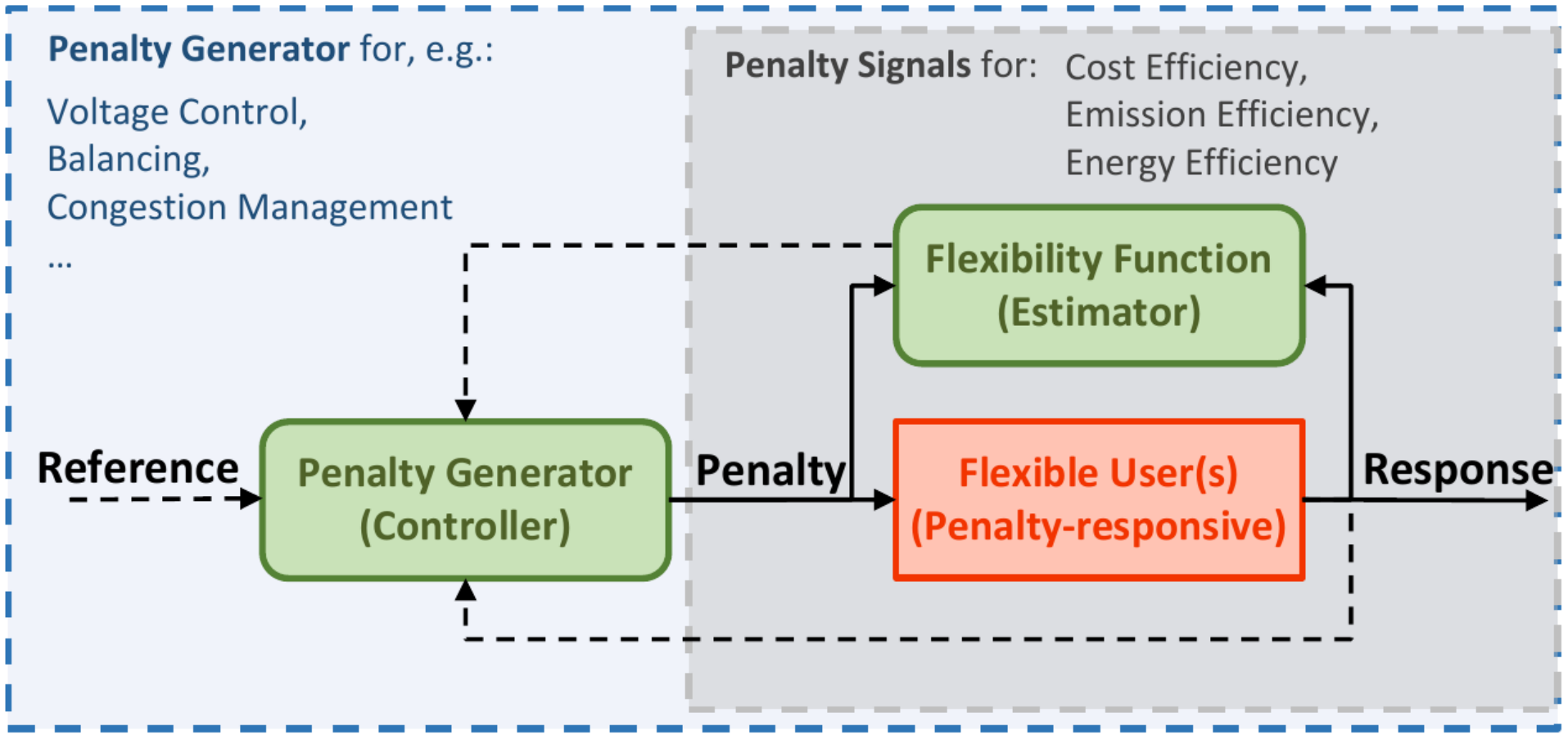


Digital Hub – Flexible Energy Denmark

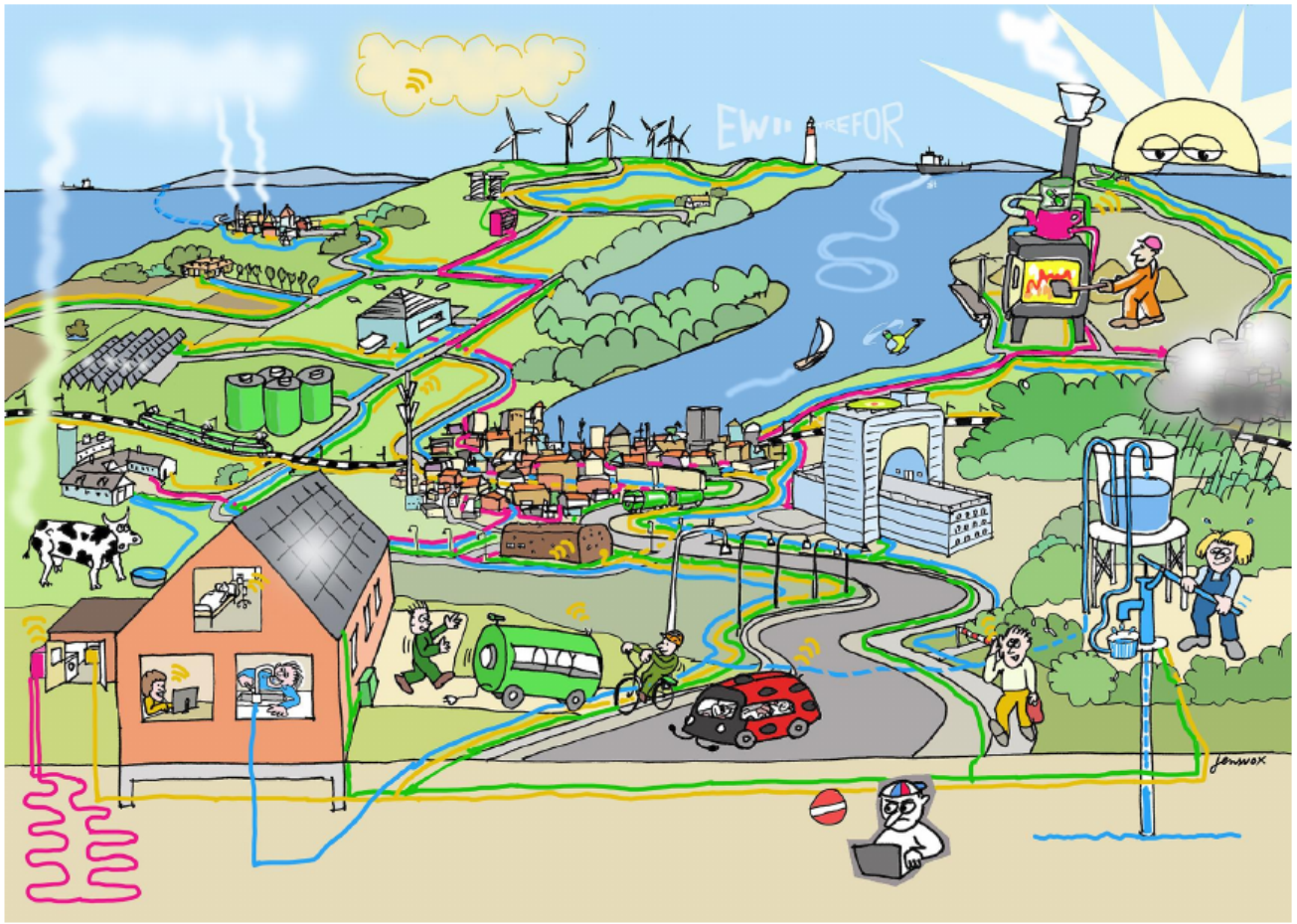
Circularity in the development of digital energy systems



A FED example: Flexible Users and Penalty Signals

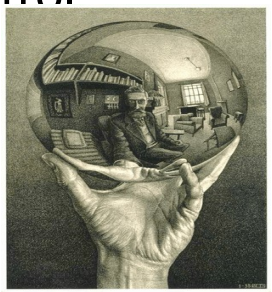


EWII: One digitally integrated multi-utility



CITIES / Center Denmark: Digitalization Hub for Smart Energy Systems

- Automatic and self-cal. methods based on Data Lake and AI
- Storage solutions are essential – batteries, PCM, etc.
- Prosumer integration strategy and methodologies
- Labs – Virtual, HiL, Live
- Peer-to-peer communication (incl. blockchain)
- Nested sequence of systems – systems of systems
- Hierarchy of optimization (or control) problems
- Control principles at higher spatial/temporal resolutions
- Cloud or Fog (IoT, IoS) based solutions – eg. for forecasting and control
- Facilitates energy systems integration (power, gas, thermal, …)
- Allow for new players (specialized aggregators)
- Simple setup for the communication and contracts
- Harvest flexibility at all levels

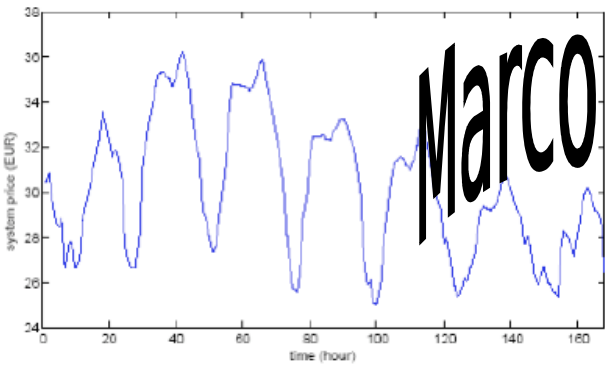


COMPETITIVE BIDDING AND STABILITY ANALYSIS IN ELECTRICITY MARKETS USING CONTROL THEORY

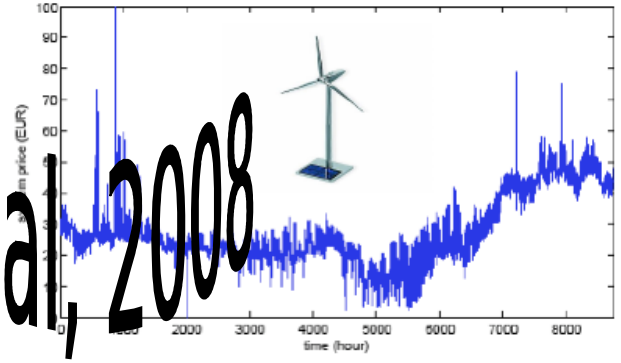
Main idea: **applying control theory to the study of power markets**

Advantages in handling effectively

Dynamics



Uncertainty



Marco Zugno et.al, 2008

control theory provides ways of modeling the dynamics which is intrinsic in energy markets

↓

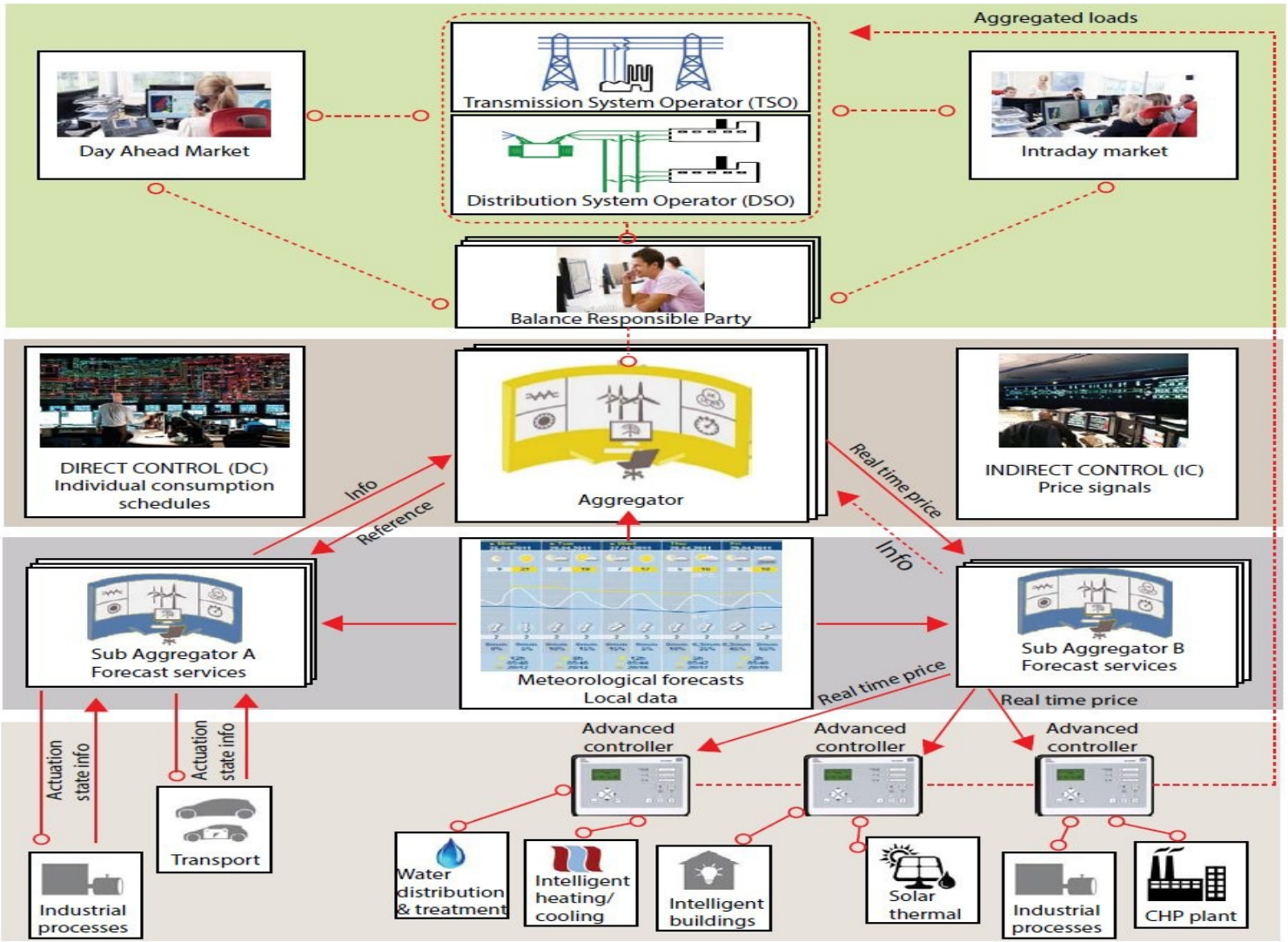
it is possible to develop advanced bidding strategies which exploit the inclusion of the dynamics in the model

stochastic control theory allows for taking into account different sources of uncertainty (wind, ...)

↓

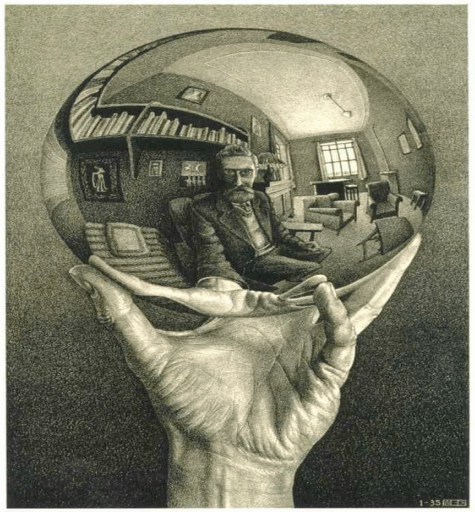
it is possible to develop bidding strategies which are optimal with respect to the stochastic characteristics of the market

Smart-Energy OS



Smart Energy Solutions
Some Demo Projects in CITIES:

- Control of WWTP (ED, Kruger, ..)
- Heat pumps (Grundfos, ENFOR, ..)
- Supermarket cooling (Danfoss, TI, ..)
- Summerhouses (NEAS, ENDK, Nyfors, ..)
- Green Houses (NeoGrid, ENFOR, ...)
- CHP (Ørsted, EMD, Fj. Fyn, ...)
- Industrial production (several, ..)
- EV (Eurisco, ...)
- .....



CITIES INNOVATION CENTER

Integrated energy systems powered by intelligent data

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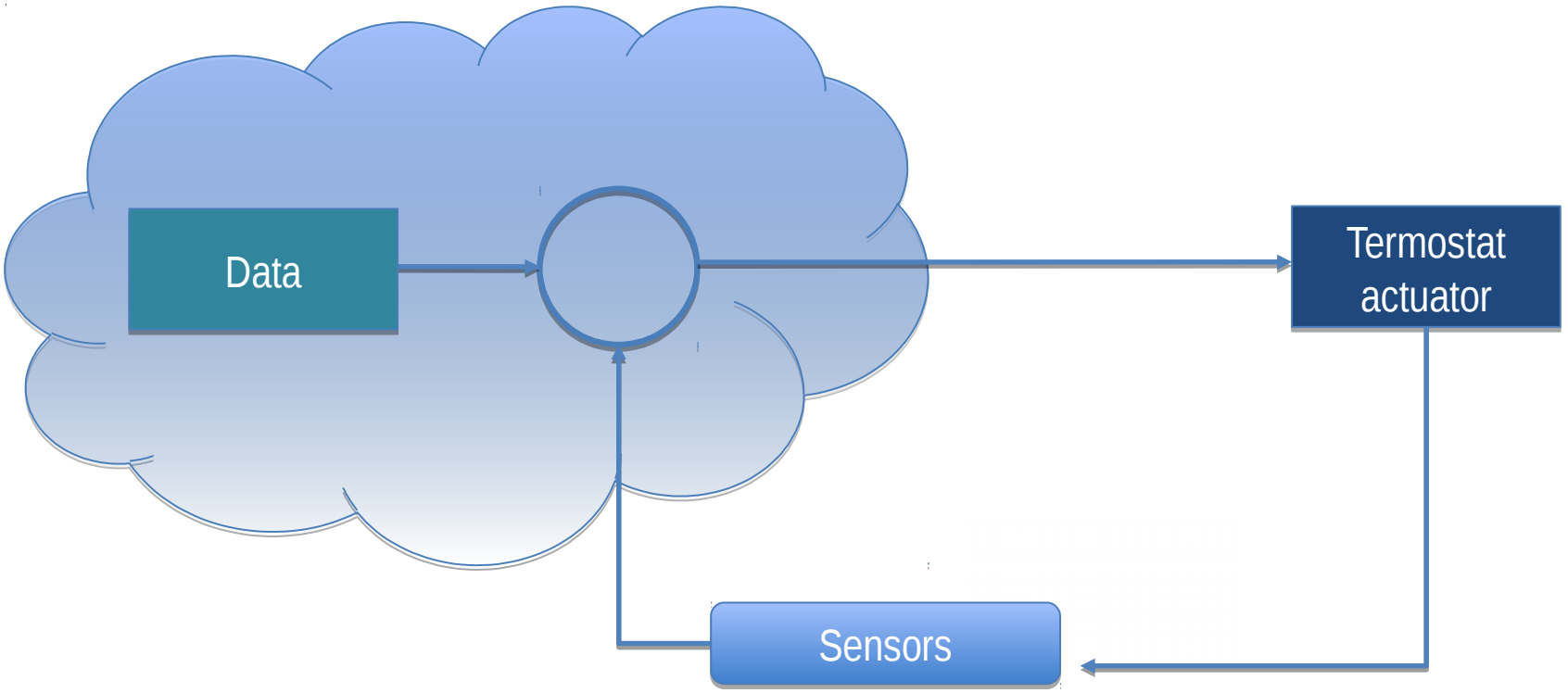
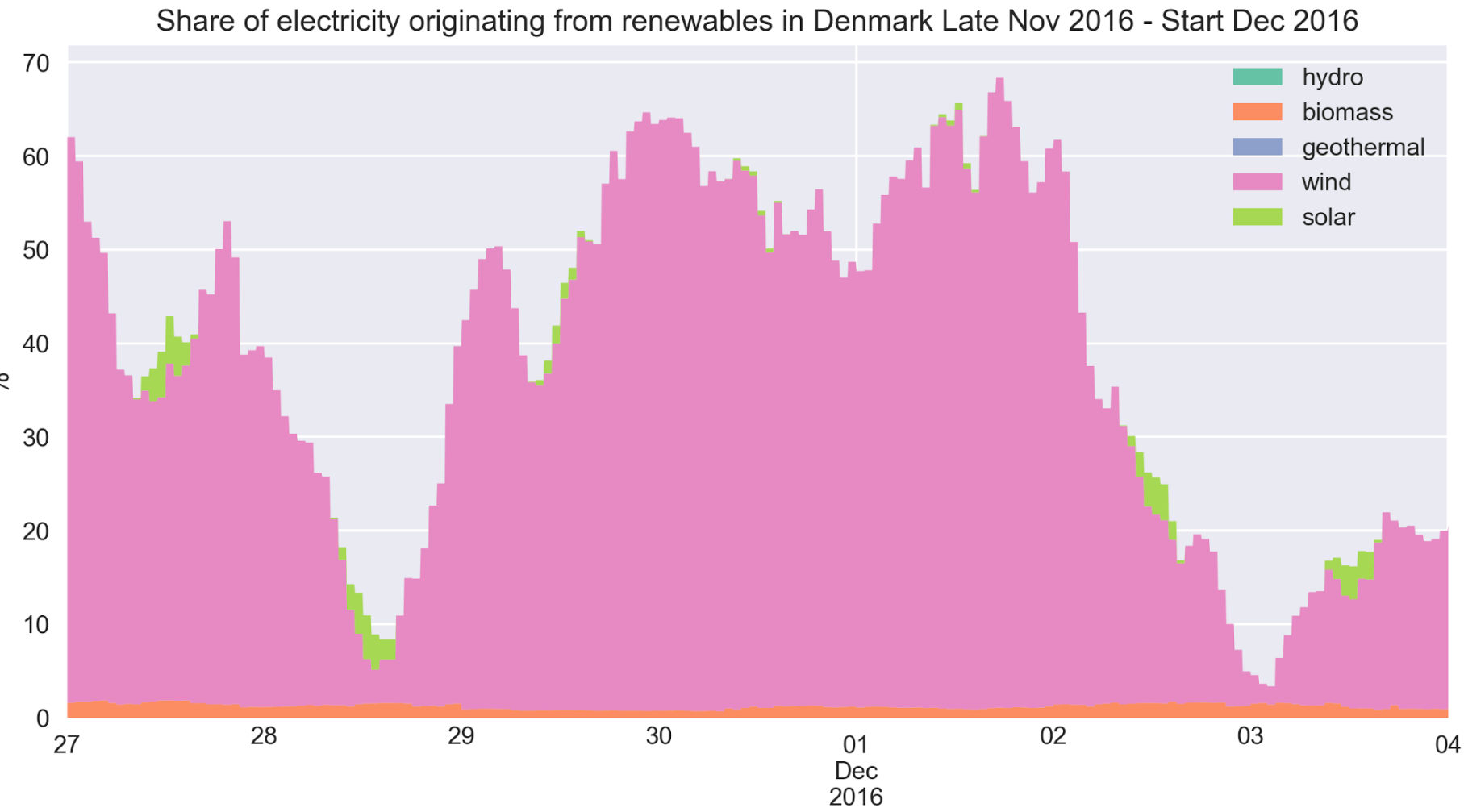
Topics

SE-OS
Control loop design – **logical drawing**



Case study No. 1

Control of heat pumps for swimming pools (CO2 minimization)



Source: pro.electicitymap.org

Smart Grid Control of Smart Buildings

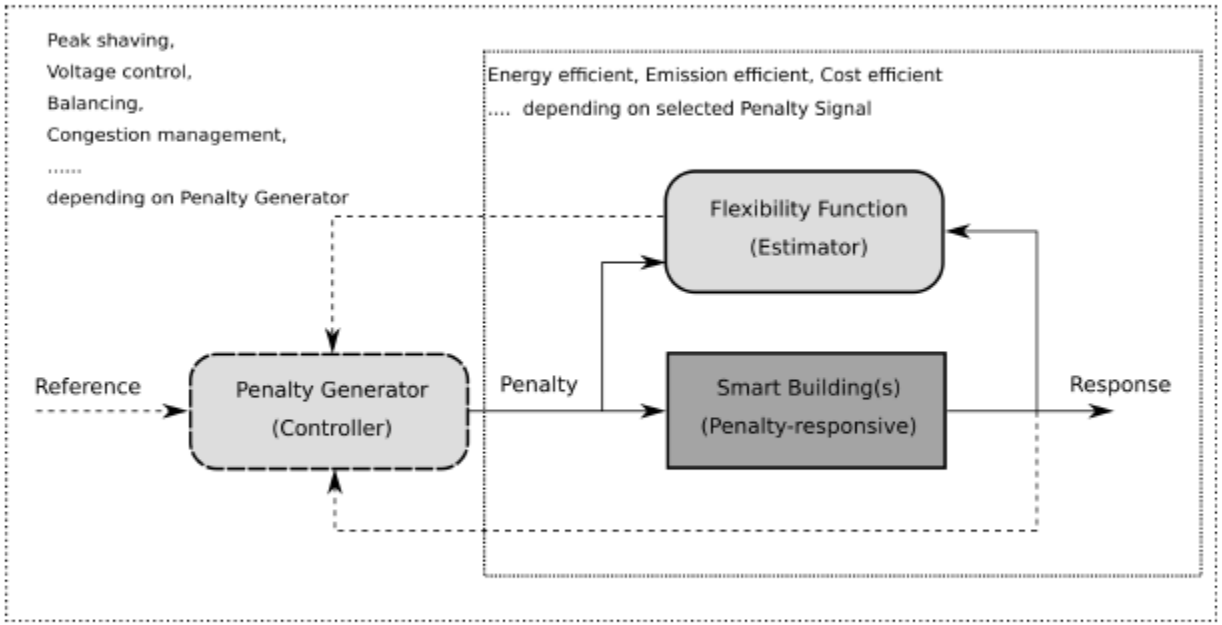
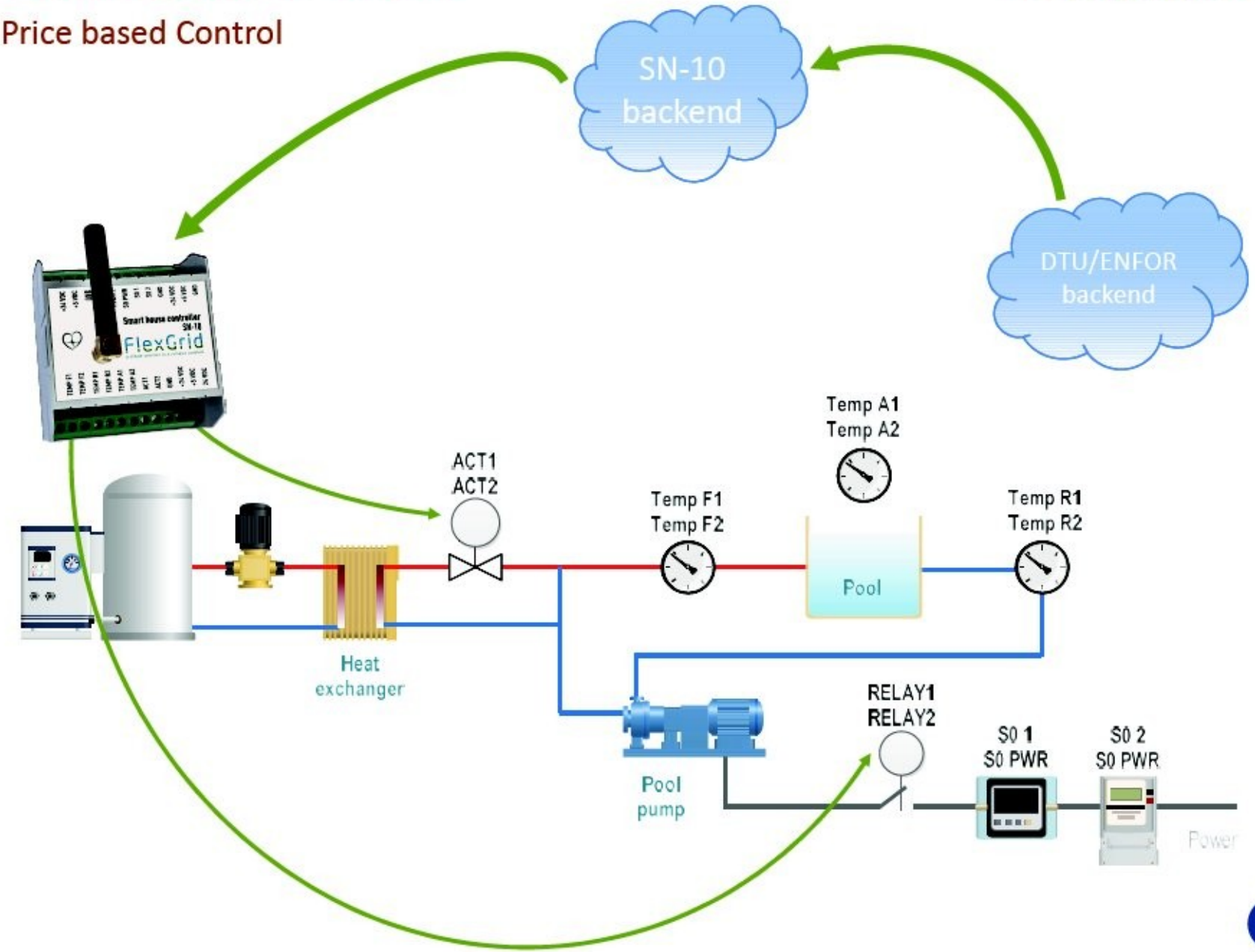


Figure 8: Smart buildings and penalty signals.

How does it work?

Price based Control



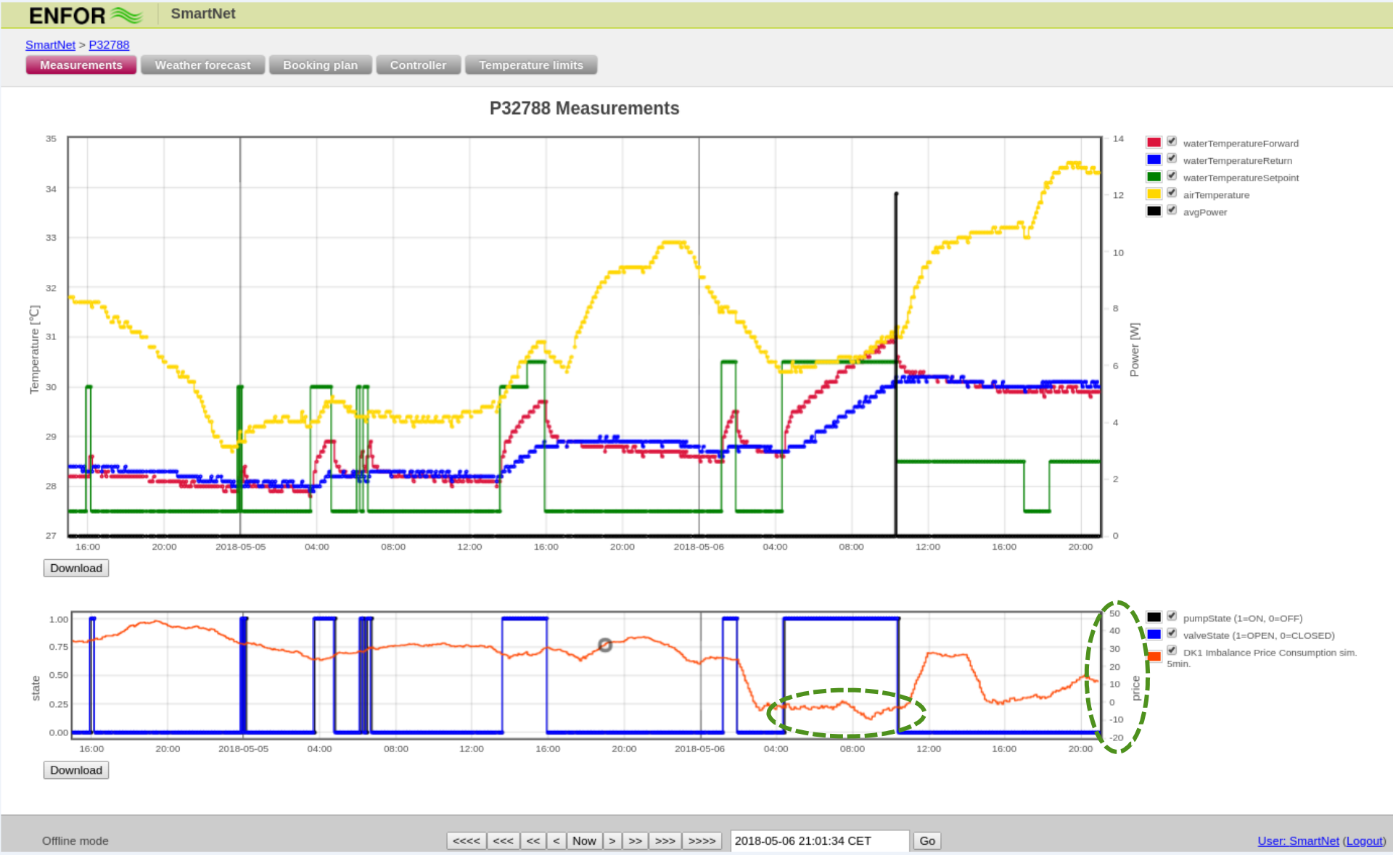
Web Portal

SmartNet

	Postal Code	First Measurement	Latest Measurement	Avail.	+48h	Latest Control Fcs.	TempRet	TempSetPnt	TempRetMin	TempRetMax	Adaptive	Setpoint Endpoint	Accepted at Endpoint
A3067	6857 Blåvand	2018-03-01	2018-09-19 18:40:00	1	0	2018-09-19 20:25:00	31.5 °C	30.0 °C	26.0 °C	30.0 °C	no	sn10.flexgrid.dk	2018-09-19 18:35:00
A3074	6857 Blåvand	2018-03-01	2018-09-19 22:20:00	0	0	2018-09-19 22:20:00	28.2 °C	27.5 °C	28.0 °C	30.0 °C	yes	sn10.flexgrid.dk	2018-09-19 22:20:00
A3128	6857 Blåvand	2018-03-01	2018-09-19 22:20:00	0	0	2018-09-19 22:20:00	30.7 °C	28.5 °C	28.0 °C	30.0 °C	no	sn10.flexgrid.dk	2018-09-19 22:20:00
A3306	6857 Blåvand	2018-09-18	NA	1	1	*Not enabled*	-	-	-	-	no	sn10.flexgrid.dk	-
A3763	6857 Blåvand	2018-09-18	2018-09-19 22:20:00	1	1	*Not enabled*	-	-	-	-	no	sn10.flexgrid.dk	-
P32013	6857 Blåvand	2018-03-01	2018-09-19 22:20:00	0	0	2018-09-19 22:20:00	28.9 °C	27.5 °C	28.0 °C	30.0 °C	no	sn10.flexgrid.dk	2018-09-19 22:20:00
P32037	6857 Blåvand	2018-03-01	2018-09-19 22:20:00	0	0	2018-09-19 22:20:00	30.0 °C	28.5 °C	28.0 °C	30.0 °C	no	sn10.flexgrid.dk	2018-09-19 22:20:00
P32071	6857 Blåvand	2017-11-22	2018-09-19 22:20:00	0	0	2018-09-19 22:20:00	27.5 °C	30.0 °C	28.0 °C	30.0 °C	no	server.flex-control.com	2018-09-19 22:20:00
P32121	6857 Blåvand	2017-11-10	2018-09-19 22:20:00	1	0	2018-09-19 22:20:00	27.1 °C	30.0 °C	26.3 °C	30.0 °C	no	server.flex-control.com	2018-09-19 22:20:00
P32286	6857 Blåvand	2018-03-01	2018-09-19 22:20:00	0	0	*Not enabled*	-	-	-	-	no	sn10.flexgrid.dk	-
P32359	6857 Blåvand	2018-03-01	2018-09-19 22:20:00	0	0	2018-09-19 22:20:00	28.3 °C	27.5 °C	28.0 °C	30.0 °C	yes	sn10.flexgrid.dk	2018-09-19 22:20:00
P32424	6857 Blåvand	2018-03-01	2018-09-19 22:20:00	1	0	2018-09-19 22:20:00	29.7 °C	27.0 °C	24.3 °C	32.0 °C	no	sn10.flexgrid.dk	2018-09-19 22:20:00
P32512	6857 Blåvand	2018-03-01	2018-09-19 22:20:00	0	0	2018-09-19 22:20:00	29.0 °C	27.5 °C	28.0 °C	30.0 °C	no	sn10.flexgrid.dk	2018-09-19 22:20:00
P32641	6857 Blåvand	2018-03-01	2018-09-19 22:20:00	0	0	2018-09-19 22:20:00	28.6 °C	27.5 °C	28.0 °C	30.0 °C	yes	sn10.flexgrid.dk	2018-09-19 22:20:00
P32731	6857 Blåvand	2018-03-01	2018-09-19 22:20:00	0	0	2018-09-19 22:20:00	28.7 °C	27.5 °C	28.0 °C	30.0 °C	no	sn10.flexgrid.dk	2018-09-19 22:20:00
P32787	6857 Blåvand	2018-03-01	2018-09-19 22:20:00	0	0	2018-09-19 22:20:00	24.9 °C	27.5 °C	28.0 °C	30.0 °C	no	sn10.flexgrid.dk	2018-09-19 22:20:00
P32788	6857 Blåvand	2018-03-01	2018-09-19 22:20:00	0	0	2018-09-19 22:20:00	28.3 °C	27.5 °C	28.0 °C	30.0 °C	yes	sn10.flexgrid.dk	2018-09-19 22:20:00
A07395	9480 Løkken	2018-01-26	2018-09-19 22:20:00	0	0	2018-09-19 22:20:00	29.9 °C	28.5 °C	29.0 °C	31.0 °C	yes	sn10.flexgrid.dk	2018-09-19 22:20:00
A11305	9480 Løkken	2017-11-08	2018-09-19 22:20:00	0	0	2018-09-19 22:20:00	25.1 °C	27.5 °C	28.0 °C	30.0 °C	yes	sn10.flexgrid.dk	2018-09-19 22:20:00
D7395	9480 Løkken	2018-01-25	2018-09-19 00:30:00	0	0	2018-09-19 02:15:00	30.5 °C	29.5 °C	30.0 °C	32.0 °C	no	sn10.flexgrid.dk	2018-09-19 00:25:00
A14526	9490 Pandrup	2017-03-28	2018-09-19 22:20:00	0	0	2018-09-19 22:20:00	32.0 °C	30.0 °C	30.0 °C	32.0 °C	no	sn10.flexgrid.dk	2018-09-19 22:20:00
A13957	9492 Blokhus	2017-03-28	2018-09-19 22:20:00	1	1	2018-09-19 22:20:00	29.1 °C	27.0 °C	25.0 °C	30.0 °C	no	sn10.flexgrid.dk	2018-09-19 22:20:00
A12216	9493 Saltum	2017-03-28	2018-09-19 22:20:00	1	1	2018-09-19 22:20:00	32.9 °C	30.0 °C	20.0 °C	32.0 °C	yes	sn10.flexgrid.dk	2018-09-19 22:20:00
A12486	9493 Saltum	2018-01-25	2018-08-22 12:45:00	0	0	*Not enabled*	-	-	-	-	no	sn10.flexgrid.dk	-
A12979	9493 Saltum	2017-11-08	2018-09-19 22:20:00	0	0	2018-09-19 22:20:00	28.4 °C	30.0 °C	30.0 °C	32.0 °C	no	sn10.flexgrid.dk	2018-09-19 22:20:00
D7105	9493 Saltum	2017-03-28	2018-09-08 13:05:00	1	1	2018-09-08 14:50:00	-0.1 °C	23.1 °C	25.0 °C	32.0 °C	yes	sn10.flexgrid.dk	2018-09-08 13:00:00
D7227	9493 Saltum	2016-09-26	2018-09-19 22:20:00	1	0	2018-09-19 22:20:00	29.0 °C	27.0 °C	25.0 °C	32.0 °C	no	sn10.flexgrid.dk	2018-09-19 22:20:00
D7320	9493 Saltum	2017-03-28	2018-09-19 22:20:00	0	0	2018-09-19 22:20:00	29.9 °C	31.5 °C	32.0 °C	34.0 °C	no	sn10.flexgrid.dk	2018-09-19 22:20:00
D7811	9493 Saltum	2017-03-28	2018-09-19 22:20:00	1	0	2018-09-19 22:20:00	29.2 °C	31.5 °C	24.3 °C	32.0 °C	yes	sn10.flexgrid.dk	2018-09-19 22:20:00
C7224	9690 Fjerritslev	2018-01-25	2018-08-29 01:20:00	0	0	2018-08-29 02:50:00	29.2 °C	27.0 °C	25.0 °C	32.0 °C	yes	sn10.flexgrid.dk	2018-08-29 01:15:00

Example: CO2-based control

Example with negative power prices

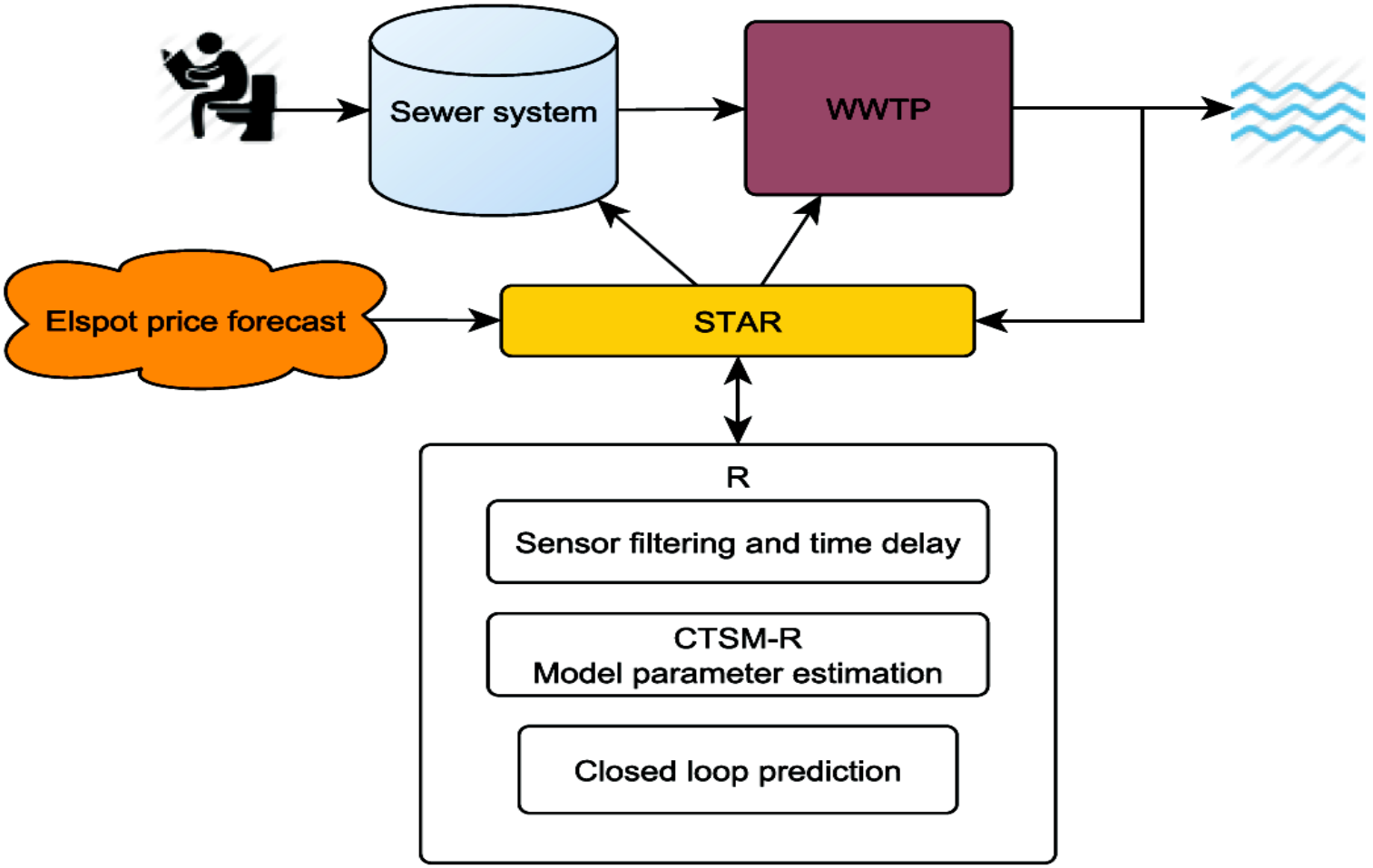


Case study No. 2

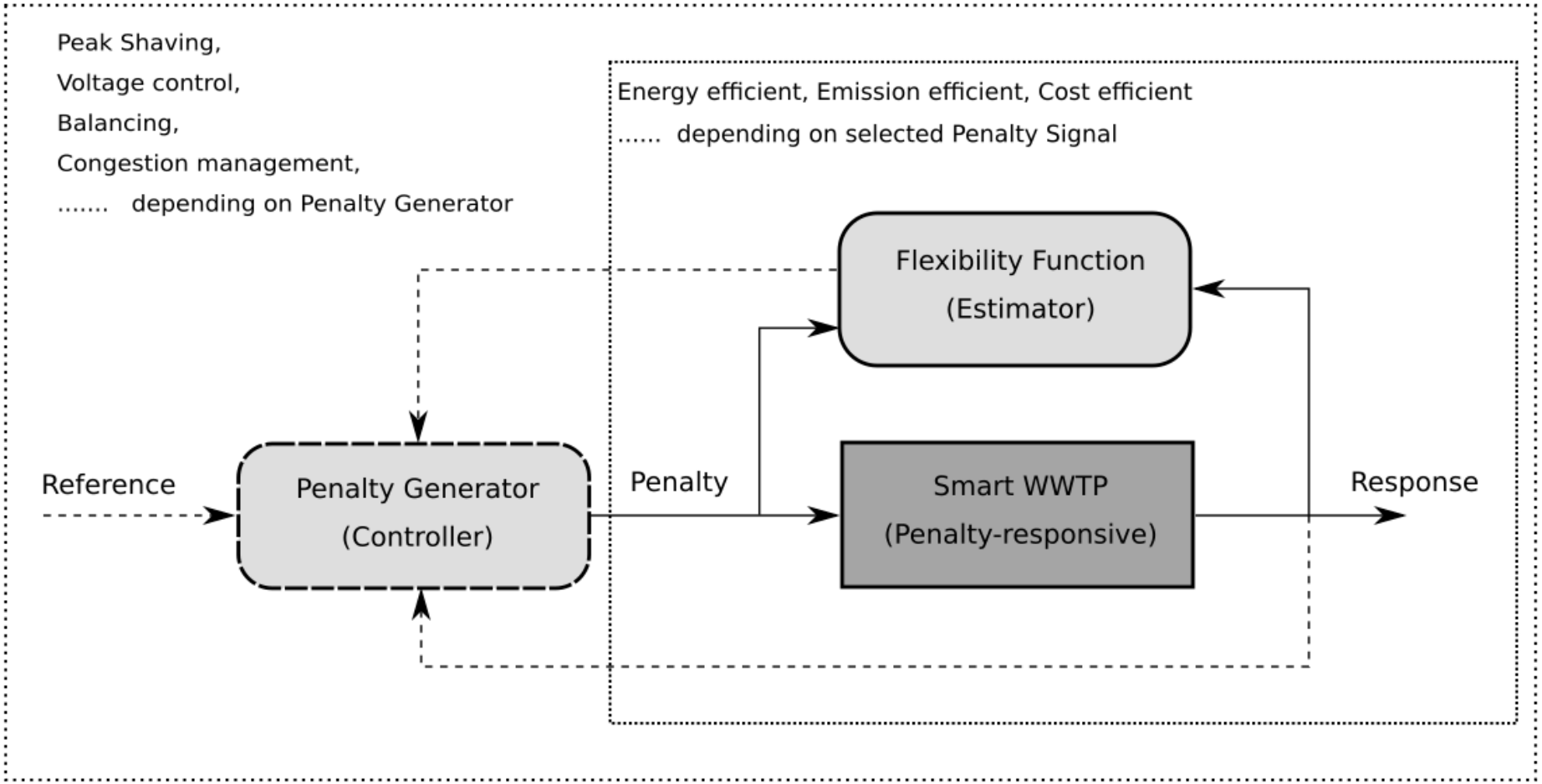
Wastewater Treatment Plants

Kolding WWTP

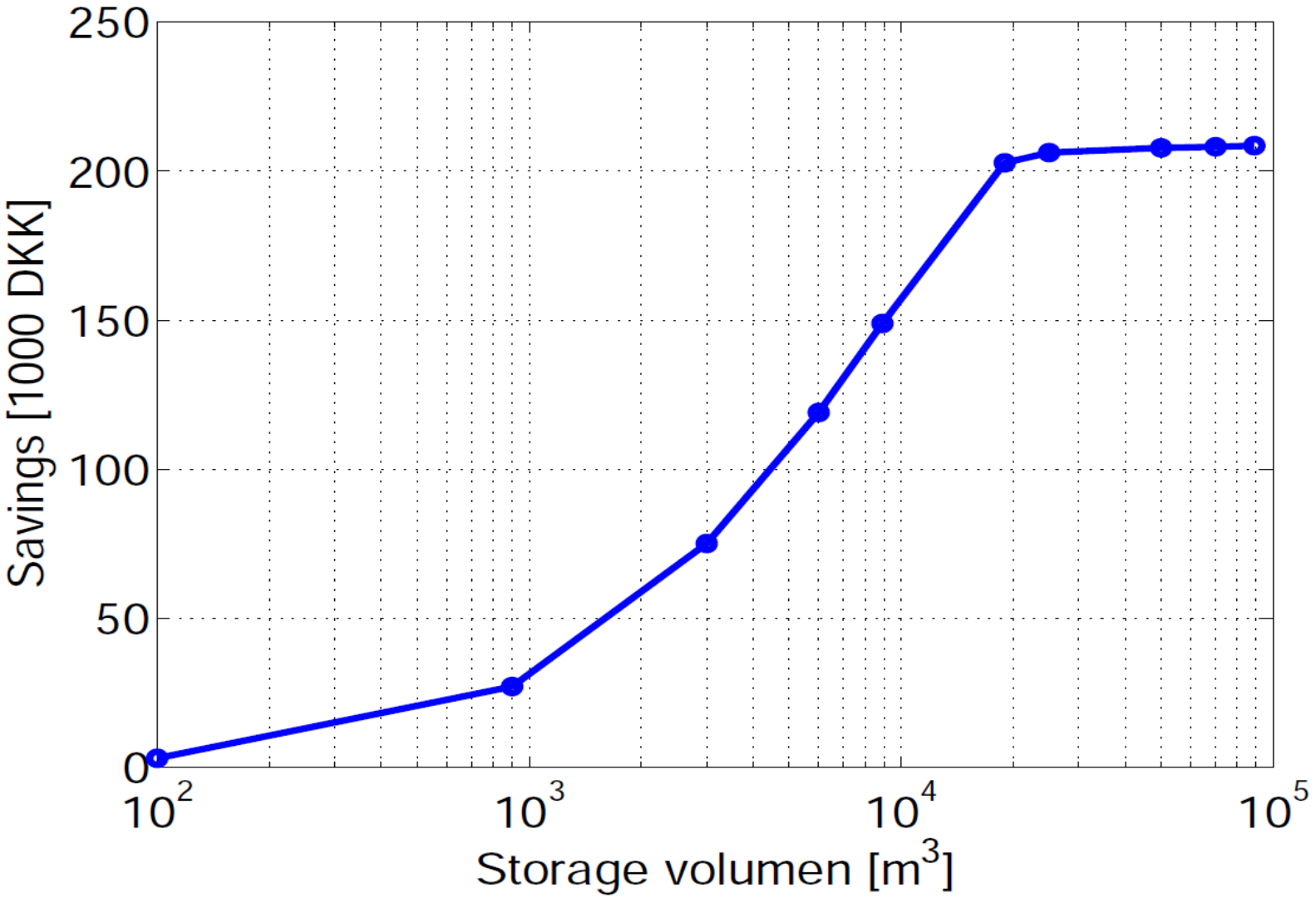
Energy Flexibility in Wastewater Treatment



Smart Grid Control of Wastewater Systems

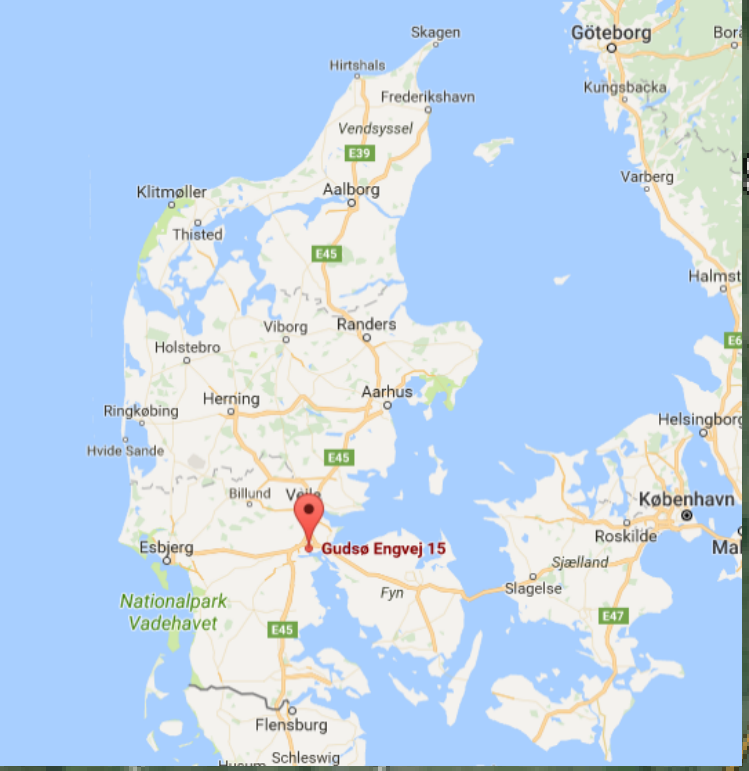


Sewer System Annual Elspot Savings



Center Denmark

Green transition paved by green innovation



Smidstrup

E45

Raffinade

Bryggeriet

Frede

E20

Google

Fredericia

Spildevand

Erritsø

Taulov

TVIS

Arla

EWii

E20

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Ørsted

Skærbæk
værket

Kolding

Midde