

CITIES Consortium Meeting

September 2018

Status and Innovation Activities

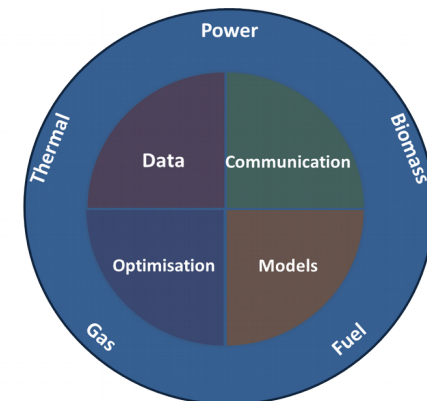
Henrik Madsen

Center Manager

Hypothesis

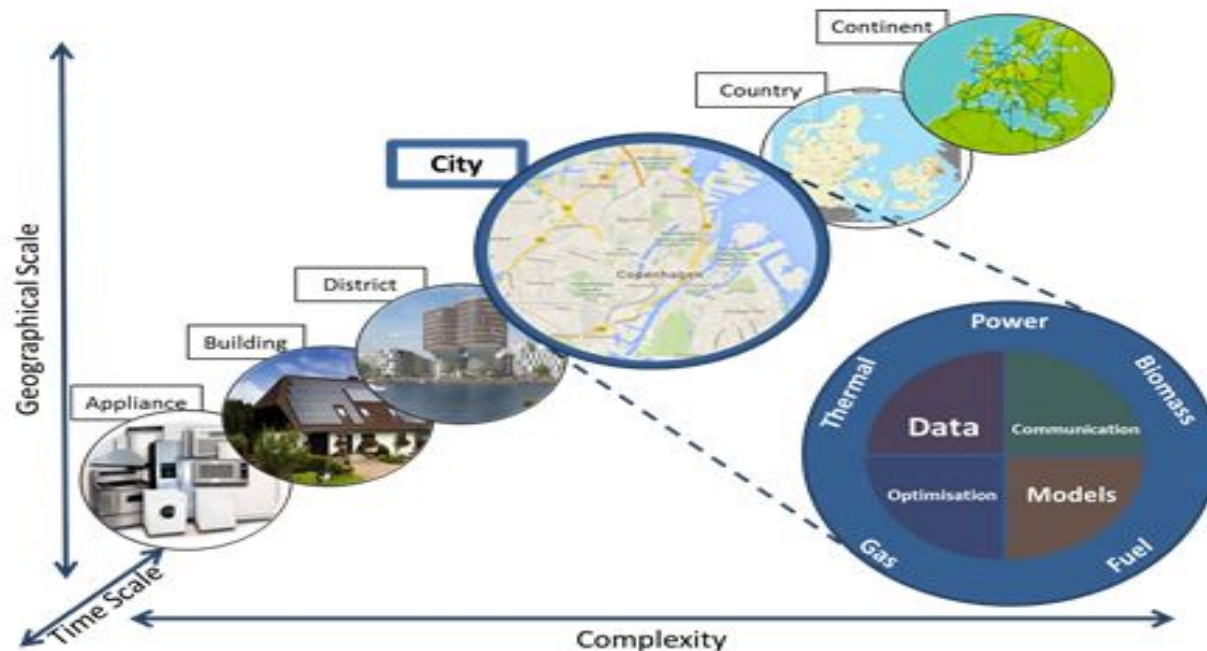
The **central hypothesis** of CITIES is that by **intelligently integrating** currently distinct energy flows (heat, power, gas and biomass) in urban environments we can enable flexibility for integrating large shares of renewables, and consequently obtain substantial reductions in CO₂ emissions.

Intelligent integration will enable lossless 'virtual' storage and flexibility on a number of different time scales.



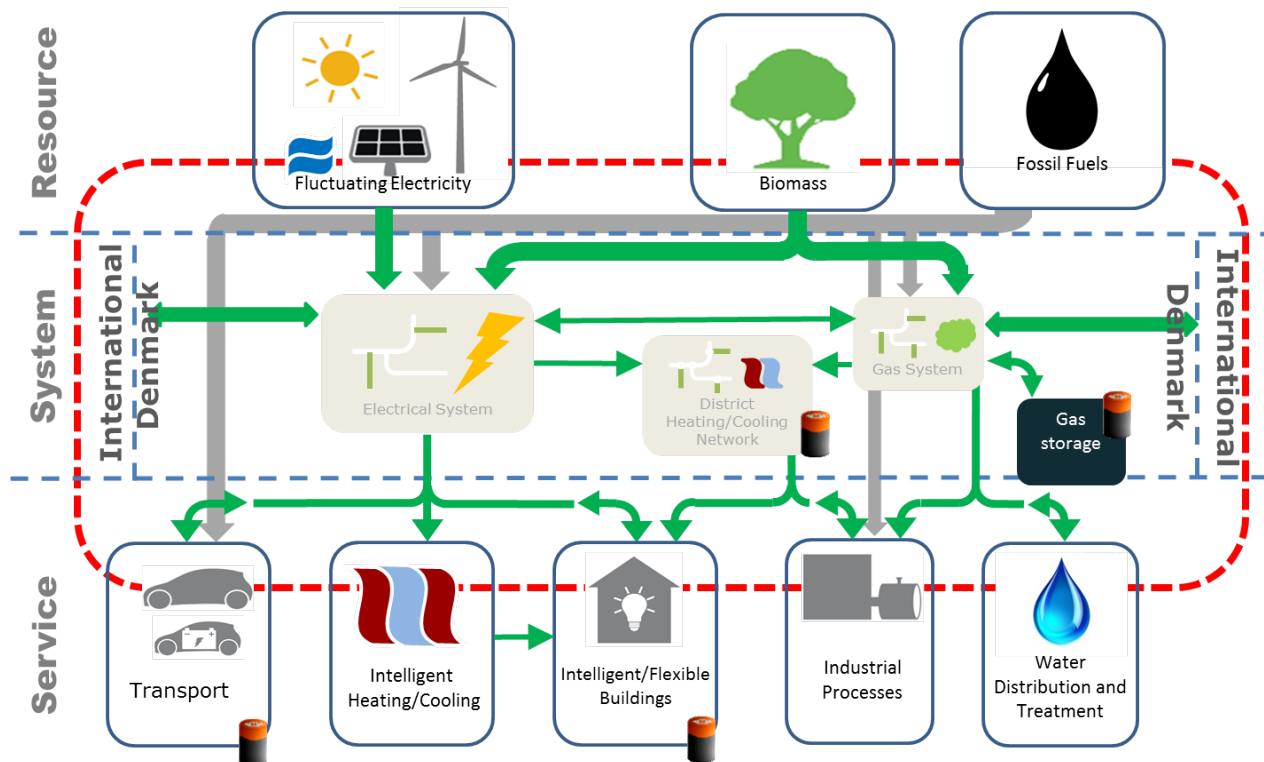
Scientific Objective

To establish **methodologies** and **ITC solutions** for **design and operation** of integrated electrical, thermal, fuel pathways at all scales.



Concepts

Integration based on *ICT solutions* (big data analytics, IoT, AI, automated learning, ..) leading to methods for *operation* and *planning* for future energy systems



Goals (from the application)

- To educate 11 Phd's and 4.5 PostDocs
- 30-40 journal papers
- 6 PhD summerschool events
- Dissemination through media and broad-audience events
- A dynamic and public website
- Models and strategies for integrated energy systems
- CITIES Innovation Centre (in parallel to CITIES)
- Support activities related to green/smart cities projects
- Establish an international network

Main priorities 2018

(from SC meeting Dec. 2017 and IAB)

- **Decision from SC meeting in December 2017:**

- An extension of the project with one year until end 2020.**

- Find the best team for the last 3 years (focus on partners for Demo Projects)**

- **More Demo Projects as kick-off for CIC**
- **Even more focus on framework conditions and testzones – CITIES Task Force group lead by Adam, Nina, Frank, Torben and Henrik**
- **Workshop(s) related to the CEM/MI in Copenhagen/Malmö.**
- **Workshop related to DSO (and TSO) issues**
- **Workshop related to regional planning and how to handle risks in planning**
- **Collaborate with Innovation Hubs (CLEAN, Climate KIC, INNO-SE, TI, ..)**
- **Make results more understandable for everyone (public media)**
- **Define an organisational structure for CIC**
- **Join international networks + international influence**

Status

(May 1st, 2018)

Status (April 1st, 2018)

Some KPIs, statistics and dissemination results:

- Approx. 50 scientific oriented presentations (2017 only)
- Approx. 90 journal papers published (until April 1st, 2018)
- In 2017 (see annual report): 90 publications (25 in preparation)
- 19 Workshops
- 9 PhD summer/winter-schools
- 2-3 extra PhD's (collaboration with Indonesia, Malaysia, DSOs, ...)
- More than 16 Demo Projects
- Several successful H2020, EUDP, ... applications related to CITIES (see later on)

Status (April 1st, 2018)

- Hiring of PhDs has been finalized
- Hiring of PostDocs is almost finalized
- First four PhD students have defended their thesis
- More Demo Projects (now 16 in total)
- CITIES Innovation Center (www.citiesinnovation.org) is established
- DTU has selected 'Smart and Integrated Energy Systems' as a topic for sector development
- Data management and sharing platform is developed
- Input on how to design Energy Taxes (and Tariffs)
- Suggestions for national Test Zones (with a focus on integrated energy systems)

Status (April 1st, 2018)

Some KPIs, statistics and dissemination results:

- Part of national Big Data Center (incl. Science Cloud for CITIES)
- National IoT Center (lead of Smart Energy division)
- Center Denmark (Data Intelligent and Integrated Energy Systems)
- Established Uni-Lab.dk (facilitating labs and lab testing)
- Data Intelligent District Heating Systems initiatives (Danfoss, Niras, EMD, ENFOR,..), (DF, GrønEnergi, Damvad, Kamstrup), (ABB, Rambøll, ENFOR, ..)
- Several successful EUDP, ForskEL, Inno+, .. applications related to CITIES
- Several successful EU applications related to CITIES:
 - Smart Cities Accelerator (Interreg V),
 - SmartNet (H2020),
 - uGRIP (ERA-NET SmartGrid+),
 - Integrated Energy Systems – A pathway for Europe (H2020),
 - FlexCOOP (H2020)

International Collaboration

- Our partners – TecNALIA, NREL, AIT, NTNU, LU, UCD, Samsung, ...
- Member of Advisory Board or Partner in many International Projects;

The largest being:

Energy Systems Integration Partnership Programme (ESIPP) –
Ireland – 120 mill dkr

Centre for Energy Systems Integration (CESI) – UK – 300 mill dkr
(project partner)

Research Centre on Zero Emission Neighbourhoods in Smart Cities
(ZEN) – Norway – 400 mill NOK – (partner)

In all cases the project has a strong link to CITIES

- 6 EU projects building on results from CITIES
- COST TD1207 ‘Mathematical Optimization in the Decision Support Systems for Efficient and Robust Energy Networks.

Budget and Accounts

- Total expenditure

Budget (entire project)	70.283.186 dkk
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Accounts 2014-2017	43.996.018 dkk
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- DSF grant

Budget (entire project)	43.971.679 dkk
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Accounts 2014-2017	27.808.485 dkk
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- Self-financing

Budget (entire project)	26.311.507 dkk
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Accounts 2014-2017	16.510.714 dkk
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- Note 1: A lot of variation between partners. Some partners tend not to report actual self-financing!

- Note 2: A bit behind with the expenditures; but nice self-financing in general

Economy – some comments

- **A good balance between Grant and Co-financing**
- **We are slightly behind the plan with respect to economical spendings (as already mentioned in May 2017 and at the SC meeting in December 2018)**
- **An extension of the project with one year until end 2020.**
- **Co-financing is increasing (mainly due to more Demo Projects).**
- **Partners have improved in reporting of the actual co-financing**
- **Large variations in the economic figures for the individual partners.**

New Partners

New partners	co-finans	grant
Krüger	85 000	30 000
Kampstrup	650 000	-
Hvide Sande Fjernvarme	120 000	80 000
VEKS	300 000	80 000
North Q	120 000	60 000
City of Zagreb	448 000	100 000
Tomorrow	200 000	100 000
NovaSol	240 000	80 000



CITIES

Project management



- Alfred Heller has left DTU. Replaced by Mark Danneman (DTU Byg)
- Increased focus on public oriented dissemination
- A public media expert was hired April 1st for ensuring an increased focus on dissemination (unfortunately he got sick ...)
- Homepage www.smart-cities-centre.org
- Twitter (@CITIES_Centre)
- **CITIES Innovation Center (CIC)** (incl. Homepage...)
- International influence:
 - EU Commission, EU JRC, DG Energy
 - EERA JP ESI
 - Global: UVIG (Summer schools / Meetings / Workshops)
 - Global: IEA (Annex 58, 66, 67, 71 and 73)
- Innovation Networks:
 - INNO SE – CLEAN, Climate KIC, TI

Some Highlights



- New planning tools (Jakob Zinck Thellufsen)
- A number of new software, hardware and cloud based solutions (eg. for control) (eg John et.al)
- Large flexibility potentials demonstrated - in particular for **IT-Intelligent Integ. Energy Systems**
- Smart-Energy Operating-System (SE-OS) (Big Data, IA, IoT, Controllers,..)
- Energy/power markets (new solutions/design/optimization)
- AS4.0 – a control based approach for smart grids (incl. ancillary services) (Giulia)
- Storage solutions (virtual by integrated energy systems, physical) (Mark, Karl, ...)
- **Flexibility Function** – A new approach for characterizing the flexibility (Rune, Armin, Rishi)
- **Flexibility Index** – A method for calculation the flexibility (with/without Framework conditions)
- Methodologies and tools for optimal operation under uncertainty (also bidding..) (Ign, AA, Dani.)
- Digitilization of District Heating (District Heating v.4.0)
 - Damvad Analytics: Data-intelligent TO control: 700-1400 mill dkr annual savings
- Optimal energy mix for various cities/islands/... (Dominik)
- Segmentation of energy (DH and Power) meter data (Alex, Peter)
- Science Cloud for CITIES (Per S., Xuifeng, Razgar, Peder, Davide, Alfred,)
- CITIES Innovation Centre (Isabel, Magnus, ...)
- Center Danmark (under construction)
- Uni-Lab.dk (under construction)

Task Force on Framework Conditions

- Task Force was established at the SG meeting in December 2016
- Focus: Demonstration of **flexibility and intelligence**, product testing, Test and Lab, Design of *Energy Taxes, Tariffs, Test Zones, Markets and Framework conditions*
- Consists of AVA, Grøn Energi, TI, DTU, Danfoss, Grundfos, Kamstrup, Aarhus K., Kamstrup, Region Midtjylland – core group: *Nina, Adam, Frank, Torben, Henrik*
- **Suggestion for a new design of energy taxes (published eg in Ingeniøren)**
- **Suggestions for thematic Test Zones**
- Meetings with the Ministries (EFKM and Tax. M.)
- Meetings with ‘Energistyrelsen’
- Meetings with IFD and EUDP
- Meetings with members of parliament (energiordførerne)
- **We got influence on ‘Energiaftalen’ !!** (now we need the right implementation of the agreement)

På vej mod nye rammebetingelser: Tematiske Testzoner

Udarbejdet af Task-Force gruppe omkring
rammebetingelser (2017-18)

(Danfoss, Grundfos, Kamstrup, AVA, Grøn
Energi, Teknologisk Institut, DTU)

Demo Projects

CITIES – Demo Project

- **Purpose:** To ensure an efficient and fruitful collaboration between smart cities projects (Sønderborg, Tjæreborg, Frederikssund, Odense, Aarhus, Copenhagen,..), companies, research organisations, and universities.
- Use test facilities (eg at Grundfos, Danfoss, PowerLab.dk, TI, Tecnia (Kubik), ...)
- At least two Work Packages must participate
- Linked to new partner projects (EUDP, Innovation Centre, H2020, etc.)
- Linked to external existing and planned Smart Energy/Cities projects
- Use of high performance computing facilities (eg NREL-ESIF and DTU-HPC)
- Described on our homepage.



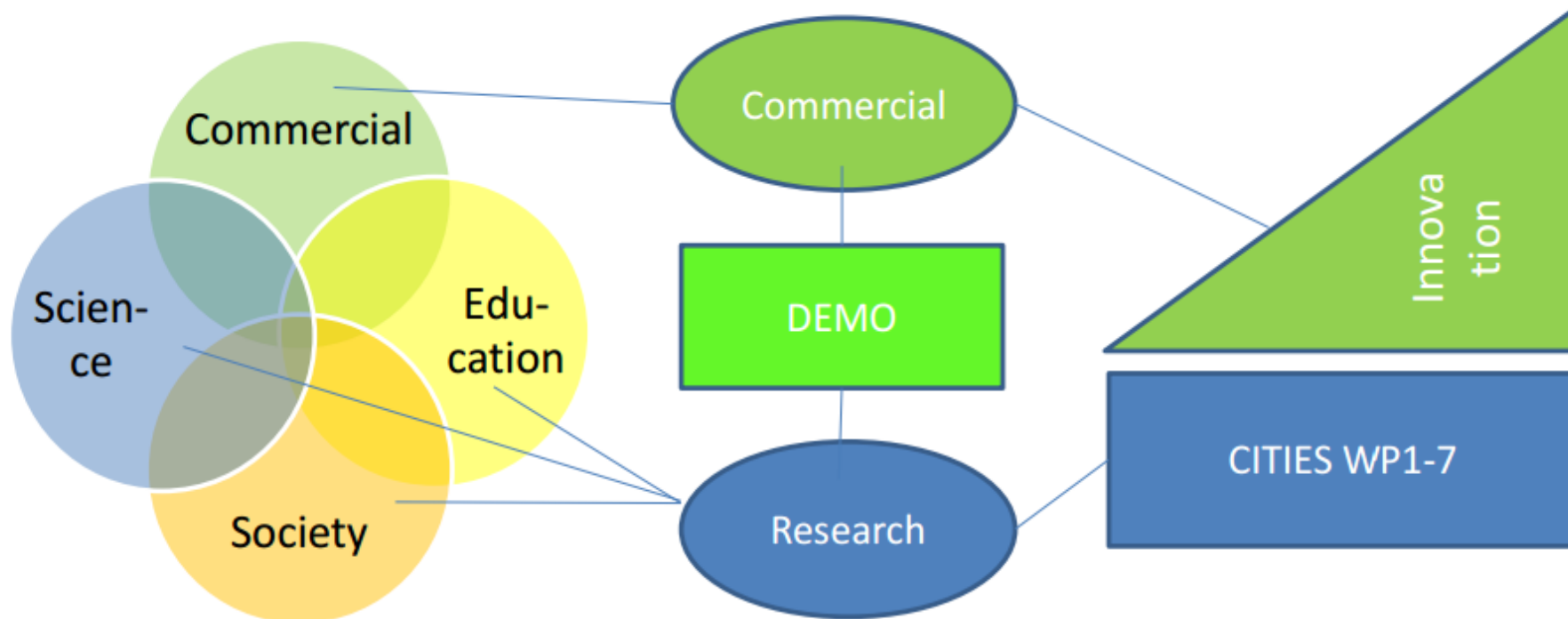
CITIES

Innovation Center



CITIES Innovation Center

CITIES
Objectives





CITIES INNOVATION CENTER

Integrated energy systems powered by intelligent data

[100% BY 2050](#)[ABOUT US](#)[TOPICS](#)[PROJECTS](#)[EVENTS](#)[PARTNERS](#)

We pioneer the green transition in a unique partnership with the industry, academia and state-actors.

100% renewable urban energy systems, is 100% possible. We are actors from the Danish industry, academia and public sector pioneering the green transition through integrated energy systems powered by intelligent data. Join us now for a safer and greener future.

LATEST ARTICLES

TWITTER



CITIES

Centre for IT Intelligent Energy Systems

Center Denmark



center**danmark**
intelligent energi

-
- National Centre for Research, Education, Innovation, Test and Demonstration with a focus on data intelligent and integrated energy systems, physical and virtual storage, and water and food systems coupling
 - From research to business in a real-life test environment with a main focus on the environment, people and nature

The (needed) transformation

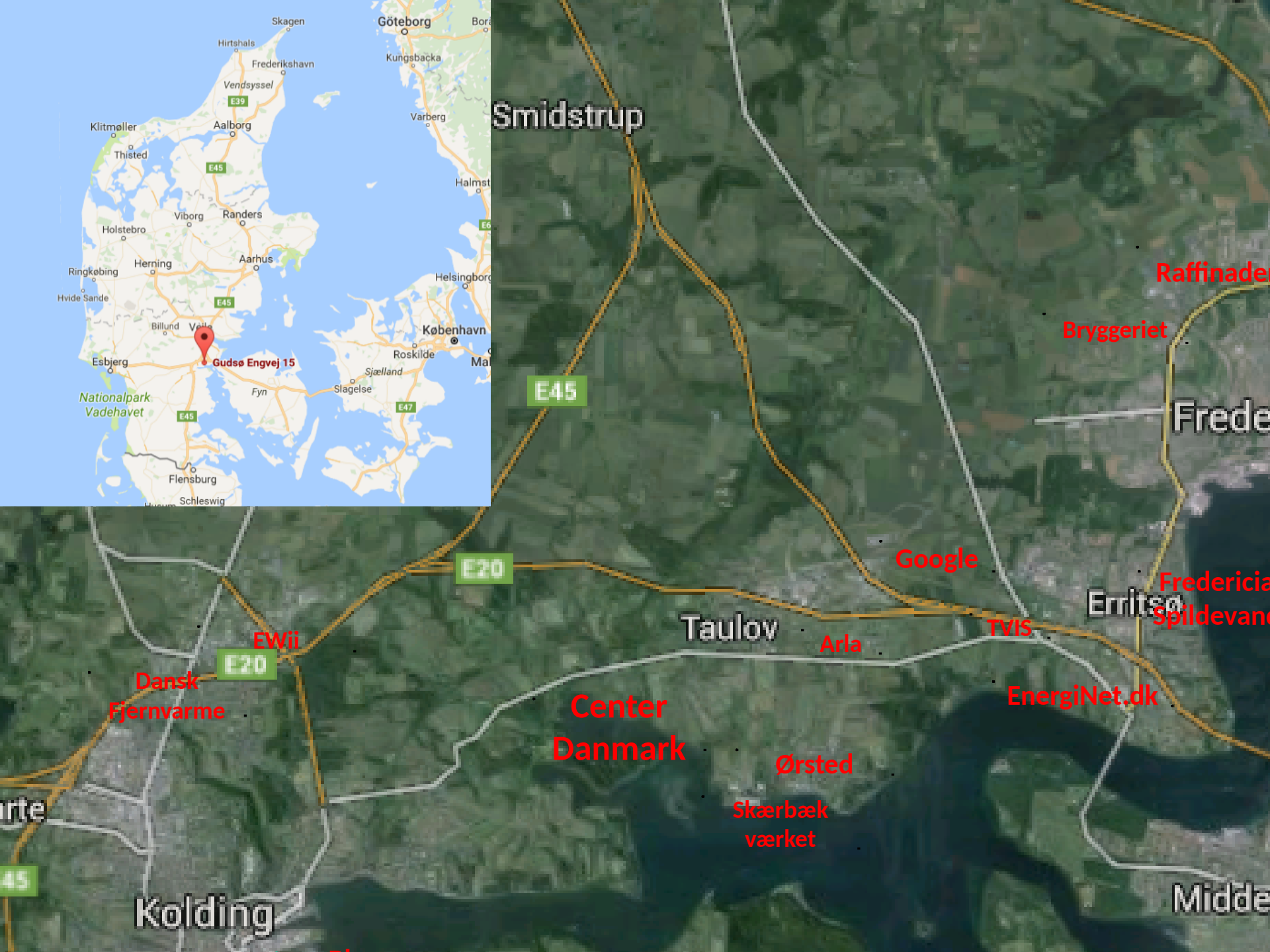


- A procedure for data intelligent control of integrated energy systems
- The test center has to be representative – and scaling is important
- A first national step would be to establish Center Denmark near Fredericia (10.000 m2 facilities for Research, Education, Development and Testing - plus Dissemination)
- Supported by DTU, AAU, SDU, Energinet, NEAS Energy, EWII, Danish DH Association, Trefor,
- The Societal objective is to establish a realistic, representative 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
- 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 area has the unique characteristics for being the ultimate representative facility for test and demonstration of future smart energy solutions



CITIES

Centre for IT Intelligent Energy Systems





Taulov

Oddersted

Gammel
Mølle og
bydel

SMART CITY
in Smart Societies
Anno 2030

Center
Danmark

Eksisterende
Boliger

Husmands
stedet

Gudsø
Gård

Naturområde med stier

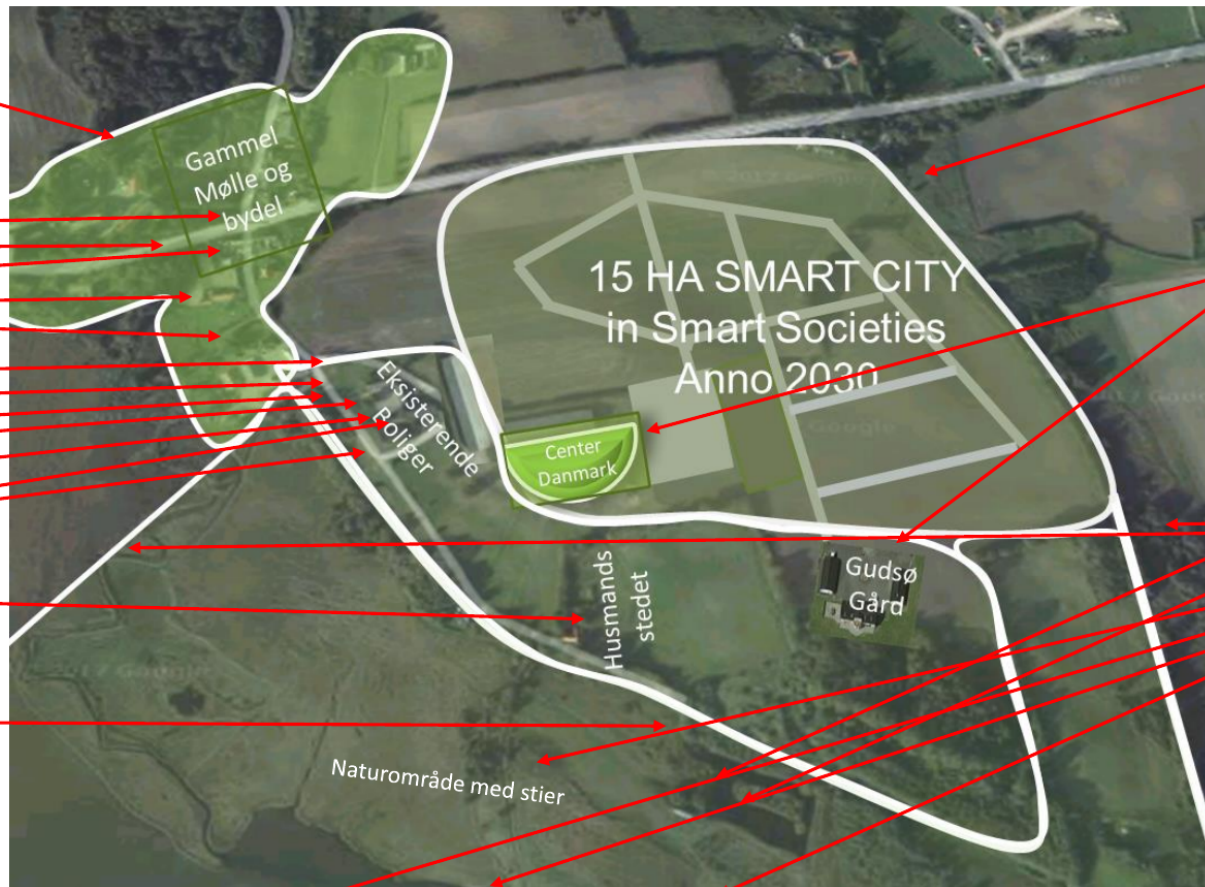
Google

Kort

A mixture of old and new buildings (smart city anno 2030)

Ældre bygninger :

1. Møllen: Urban Farmning
 1. Bygning 228 m²
 2. Bygning 590 m²
 3. Bygning 290 m²
 4. Bygning 230 m²
 5. Bygning 155 m²
2. Privathus, 183 m²
3. Privathus, 153 m²
4. Privathus, 166 m²
5. Gård 140 m²
6. Gård 4-længet 231 m²
 1. Udbygninger 1200 m²
7. Rækkehus 140 m²
8. Rækkehus 130 m²
9. Depot 140 m²
10. Kontor 110 m²
11. Lager 450 m²
12. Erhverv produktion 450 m²
13. Ridehal 1700 m²
14. Produktion Øko Gødning
15. Privat hus 160 m²
16. Husmandssted 110 m²
 1. Erhverv 70 m²
 2. Produktion 25 m²
 3. Kølerum 5 m²
 4. Klimarum 10 m²
17. Shelter 60 m²



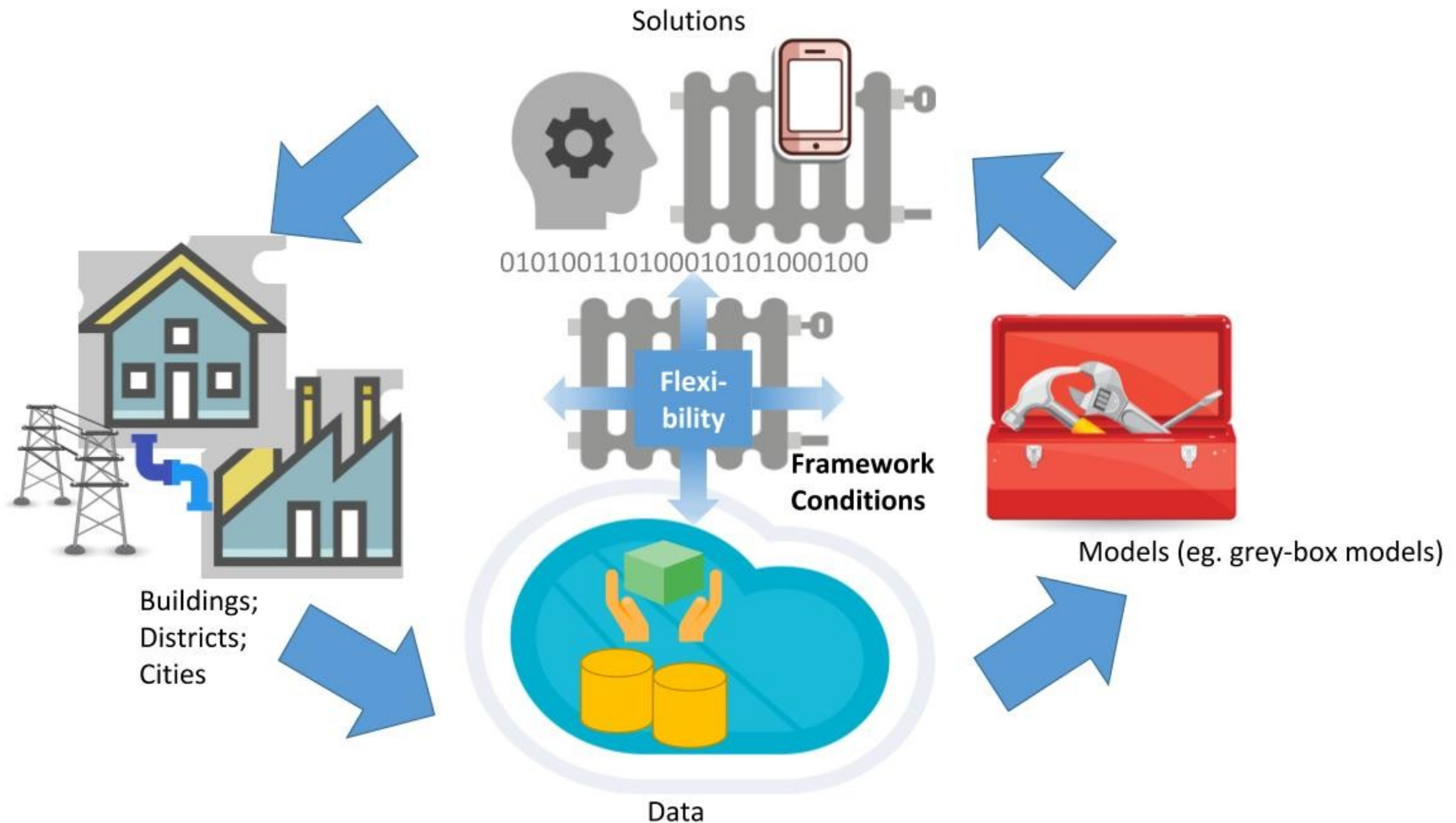
Nye bygninger :

1. Smart City 2030
 1. Urban Farmning
 2. Rækkehuse
 3. Parcel huse
 4. Kollegie værelser
 5. Undervisningsbygning
 6. Laboratorier
 7. Mini Industri
2. Center Danmark 4800 m²
3. Ny Gudsøgård 2600 m²
 1. Privat hus 280 m²
 2. Erhverv 280 m²
 3. Stald 280 m²

Natur, miljø & Dyreliv:

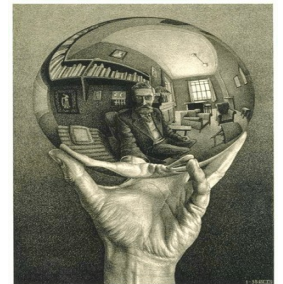
1. Åer
2. Sø
3. Skov
4. Eng
5. Hav
6. Natursti
7. Shelters

Flexibility enabled using data intelligence



Center Denmark: Data Intelligent Energy Systems

- Automatic and self-cal. methods based on Big Data analytics and AI
- 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



Results

A few examples

Results – some examples

- Software:

 - HPMPC: A toolbox for High-Performance MPC

 - MPC-R: A toolbox for MPC in R

 - CTSM-R: A toolbox for semi-physical modelling in R

- Modelling and Planning tools

 - Modelling tools for aggregated loads – info about flexibility

 - Multiple Execution Tool (MultiNODE) for EnergyPLAN

 - Ancillary service handling in smart grids

 - Sifre (Energinet.dk) - incl. tests in Sønderborg

- Hardware

 - SN-10 Smart House Controller

- Data Analytics and Energy Informatics

 - WEB-service for forecasting (load, wind, solar,...)

 - Cloud based model predictive control (incl. price- and CO₂-based control)

 - Smart-Energy Operating-System (SE-OS)

[Demo projects](#)[Software solutions](#)[Work Packages](#)[Partners](#)[Events](#)[Communications](#)[Publications](#)[Vacant positions](#)[Contacts](#)

Software solutions

Software for combined physical and statistical modelling

Continuous Time Stochastic Modelling (CTSM) is a software package for modelling and simulation of combined physical and statistical models. You find a technical description and the software at CTSM.info.

Software for Model Predictive Control

HPMPC is a toolbox for High-Performance implementation of solvers for Model Predictive Control (MPC). It contains routines for fast solution of MPC and MHE (Moving Horizon Estimation) problems on embedded hardware. The software is available on [GitHub](#).

MPCR is a toolbox for building Model Predictive Controllers written in R, the free statistical software. It contains several examples for different MPC problems and interfaces to opensource solvers in R. The software is available on [GitHub](#).

Latest news

Summer School at DTU, Lyngby,
Denmark – July 4th-8th 2016

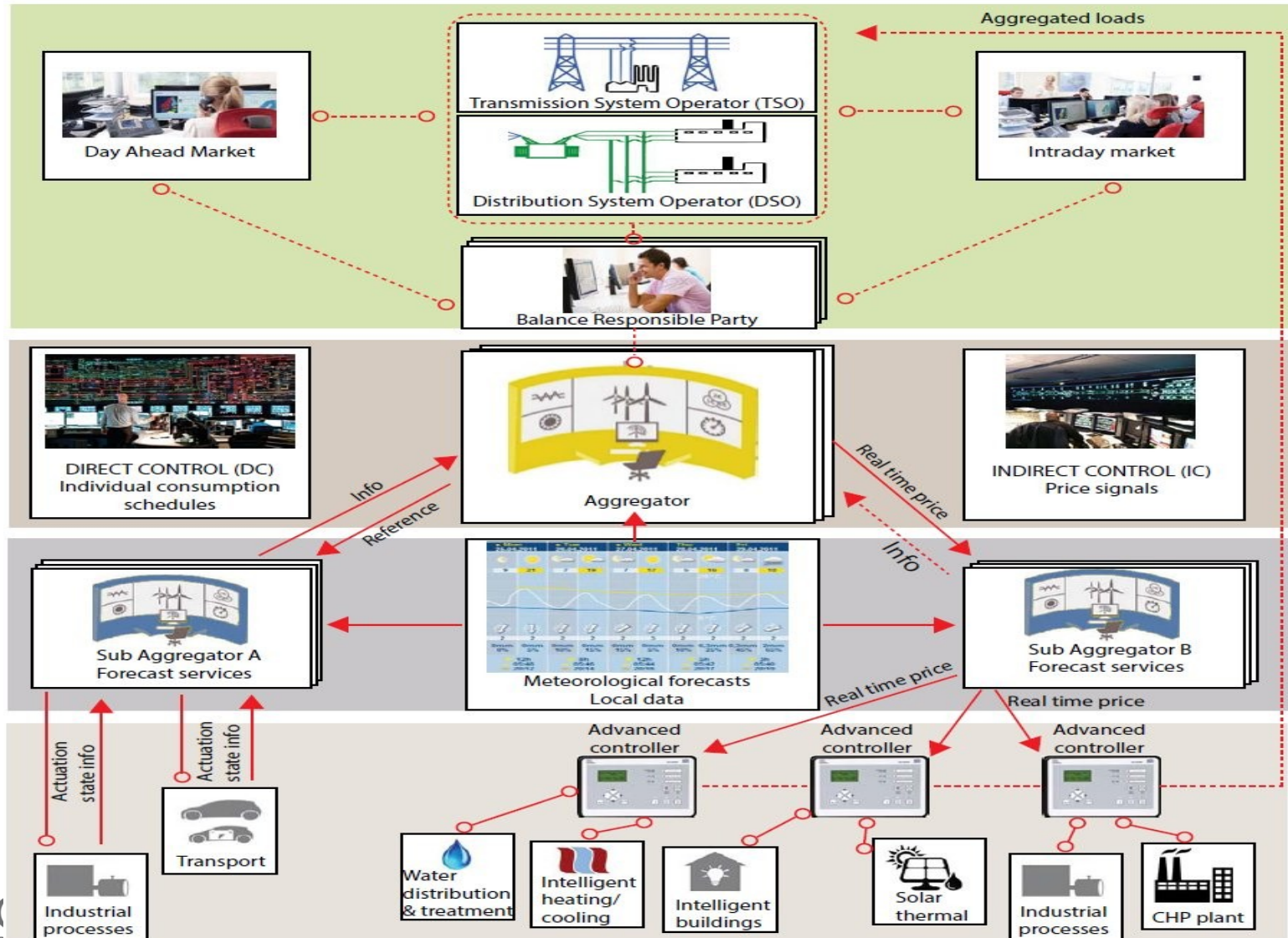
Summer School – Granada,
Spain, June 19th-24th 2016

Third general consortium
meeting – DTU, May 24th-25th
2016

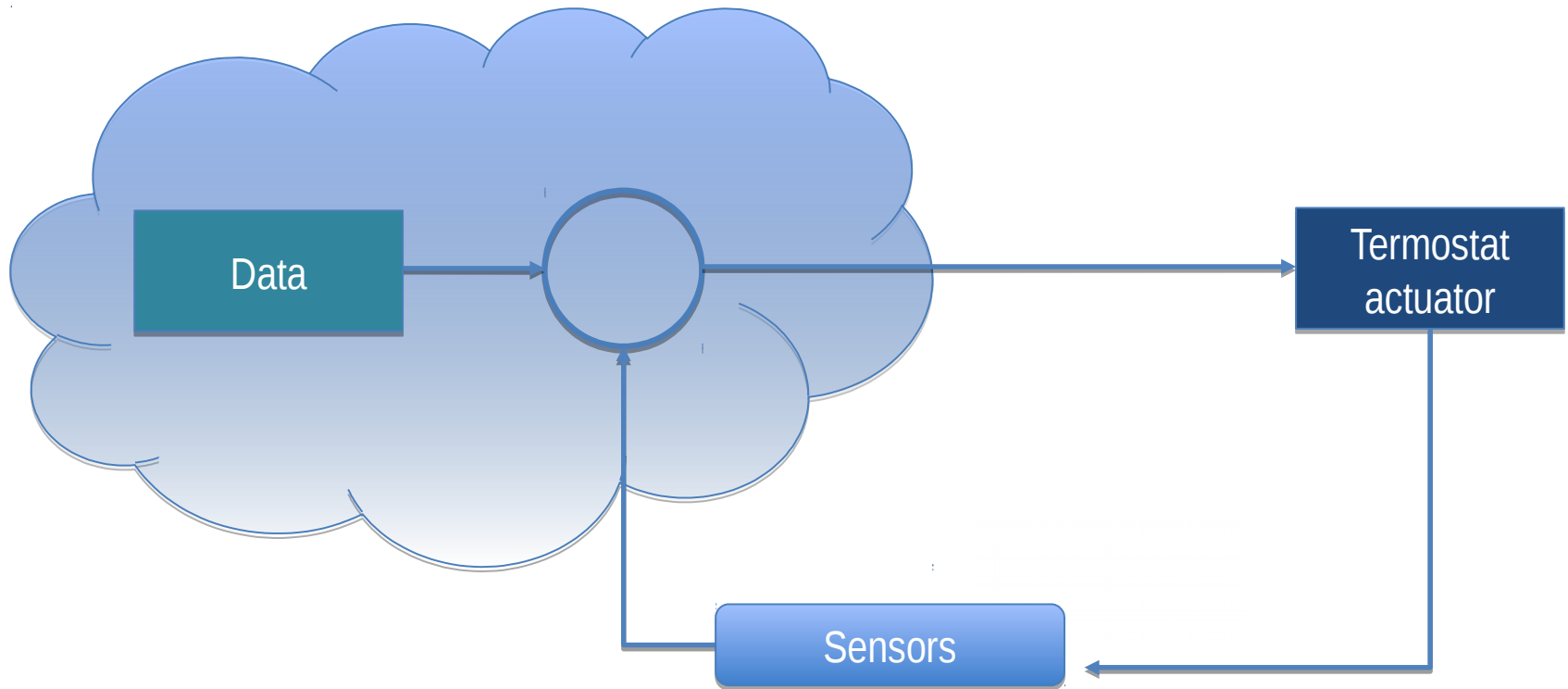
Smart City Challenge in
Copenhagen – April 20th 2016

Guest lecture by Pierluigi
Mancarella at DTU, April 6th
2016

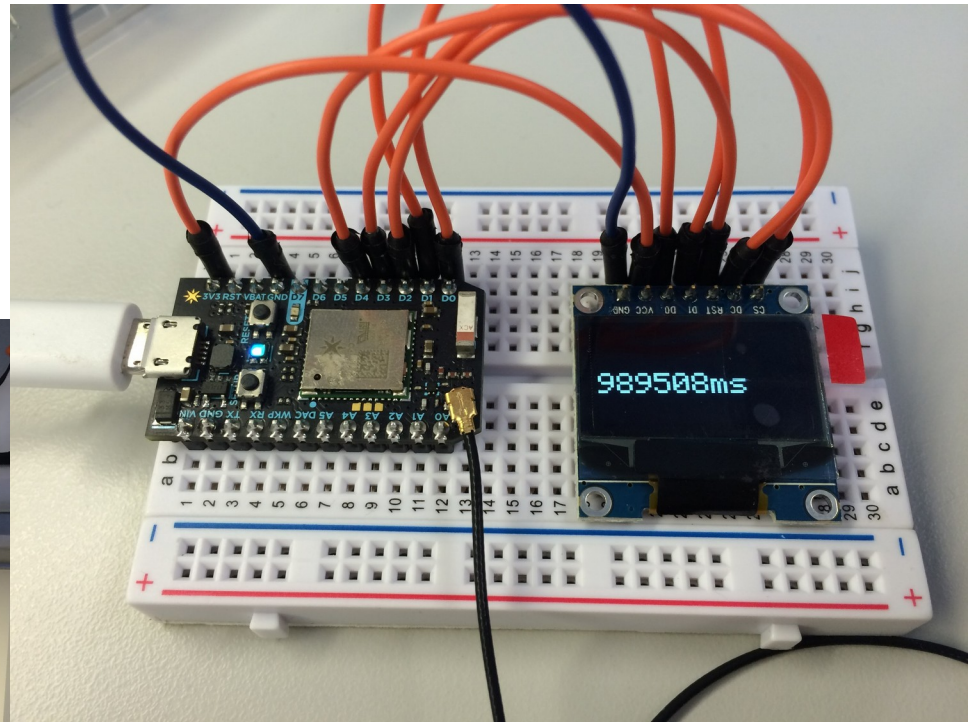
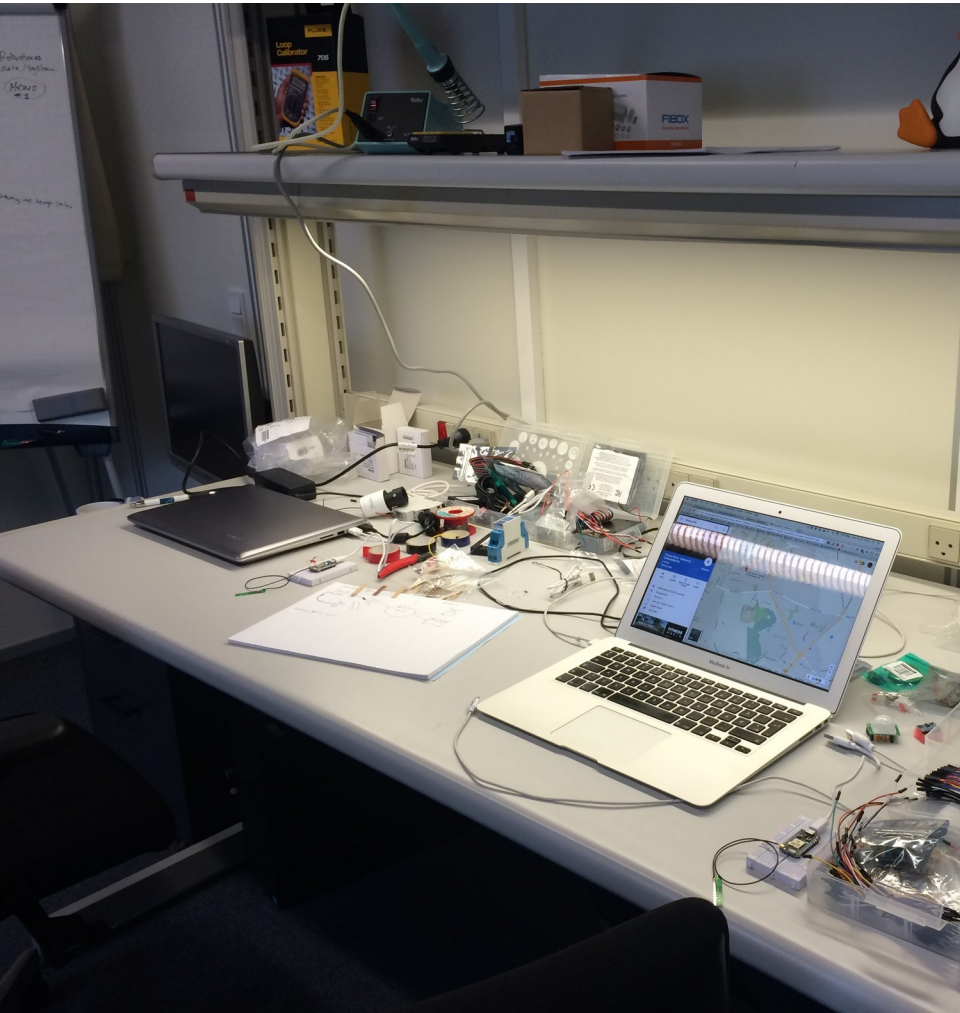
Smart-Energy OS



SE-OS and a WEB-based control platform

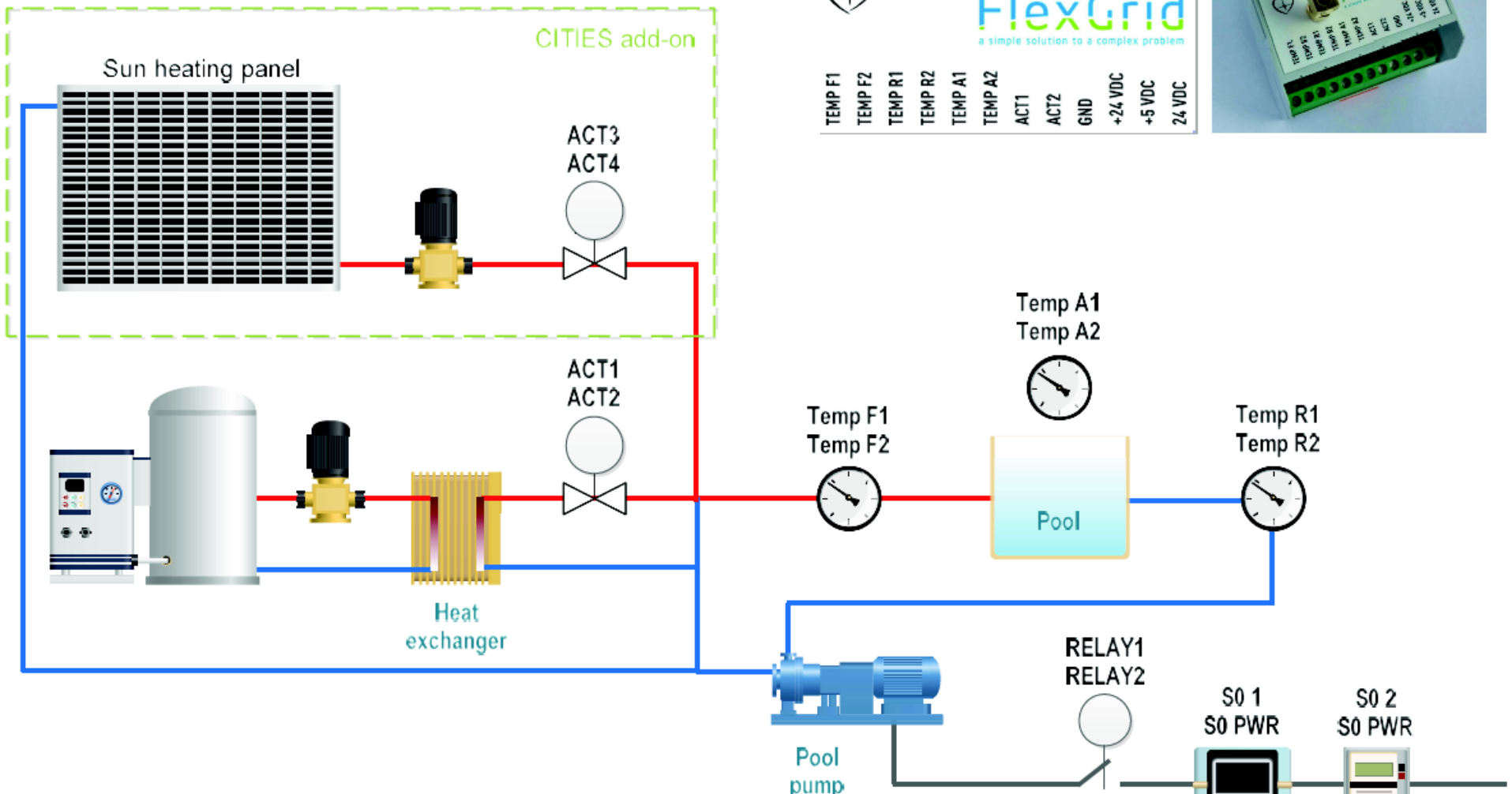
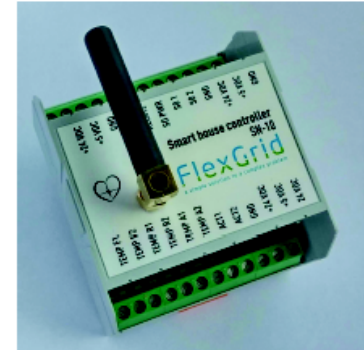


Lab testing



Smart Control of Houses with a Pool

PilotB SN-10 signal overview
revision 1.0 (CITIES add-on)



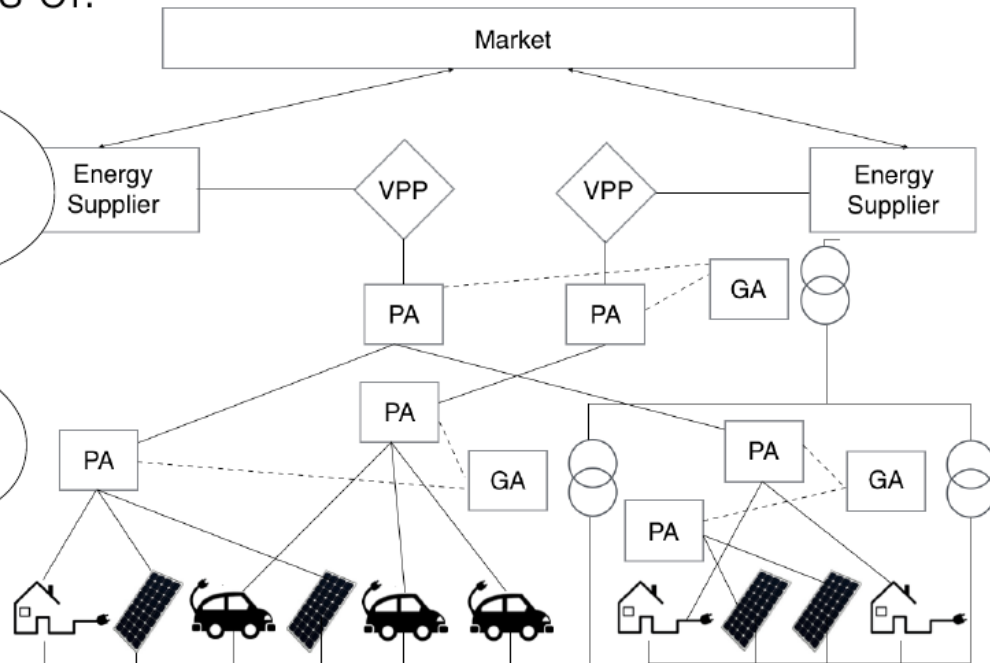
Coordinating flexible resources

Market-based approach

The market-based approach consists of:

I. Aggregating DERs through the support of an agent.

II. Formulating bids to submit to the market.



However, such approach raises several concerns due to the fact that the AS market provisioned in this approach is:

Static
Linear **Deterministic**

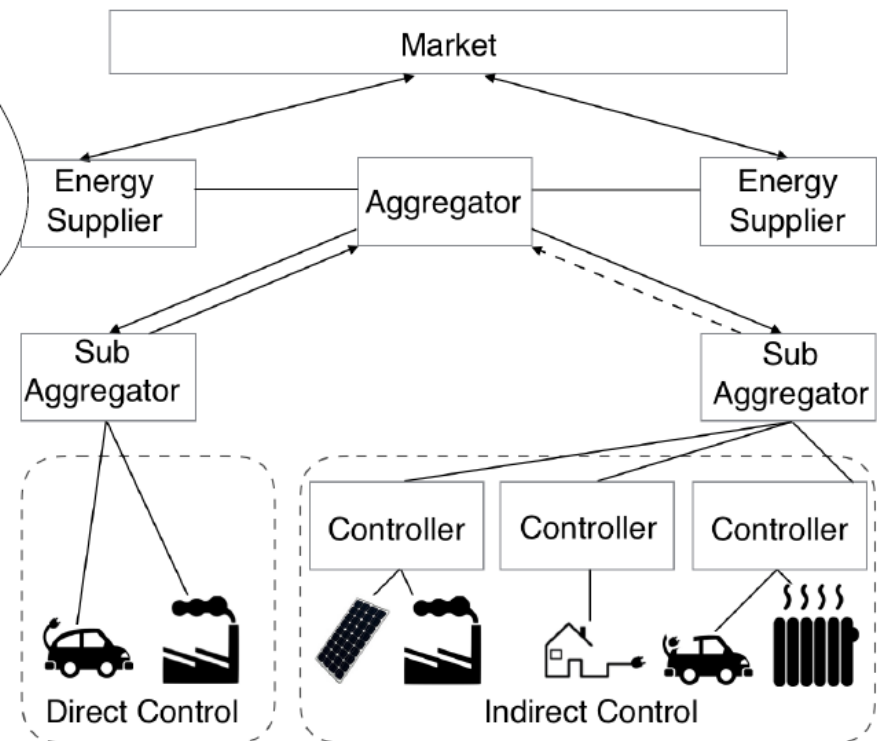
Coordinating flexible resources

Control-based approach

The control-based approach is formulated in two steps:

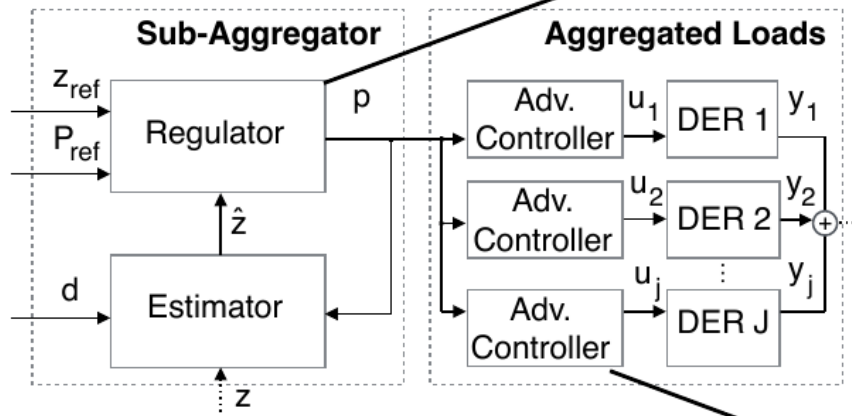
I. A **control problem** at the sub-aggregator level, to determine the appropriate Control (Price) signal to address ancillary services issues.

II. A **model-predictive control** at the consumer's level acting upon receiving the control signal.



Proposed methodology

Control-based methodology



$$\min_p \quad \mathbb{E} \left[\sum_{k=0}^N w_{j,k} \|\hat{z}_k - z_{ref,k}\| + \mu \|p_k - p_{ref,k}\| \right]$$

$$\text{s.t.} \quad \hat{z}_{k+1} = f(p_k)$$

We adopt a control-based approach where the **price** becomes the driver to **manipulate** the behaviour of a certain pool flexible prosumers.

$$\min_u \quad \mathbb{E} \left[\sum_{k=0}^N \sum_{j=1}^J \phi_j(x_{j,k}, u_{j,k}, p_k) \right]$$

$$\text{s.t.} \quad x_{k+1} = Ax_k + Bu_k + Ed_k,$$

$$y_k = Cx_k,$$

$$y_k^{\min} \leq y_k \leq y_k^{\max},$$

$$u_k^{\min} \leq u_k \leq u_k^{\max}$$



This Consortium Meeting

Consortium Meeting

- CITIES results presented in poster sessions
- High-level keynote presentations
- Smart Grids, Markets, Smart Cities/Societies, Energy Storage Solutions
- Discuss regulatory framework (energiaftalen)
- Research needs (incl. panel debate)
- Discuss Innovation Activities (*SysLab+, CIC, Center Denmark, Sector development*)