CITIES Final Consortium Meeting
Achievements and Recommendations

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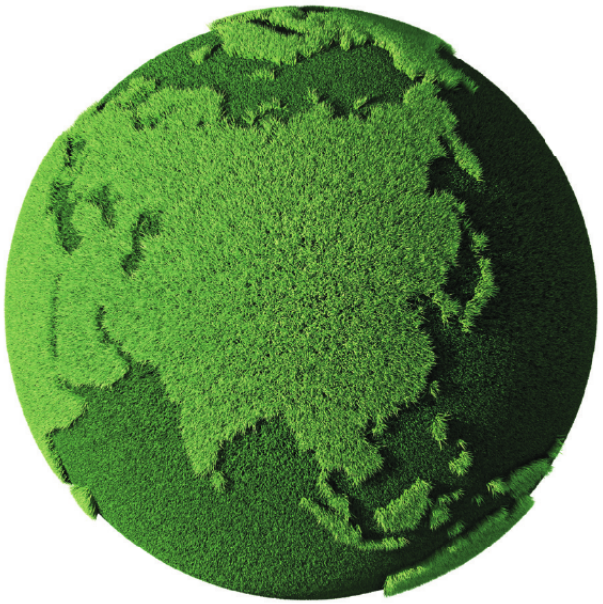
DTU Compute

CITIES' Vision on Accelerating the Green Transition

COULD WE BE
100% FOSSIL-FREE
TOMORROW?

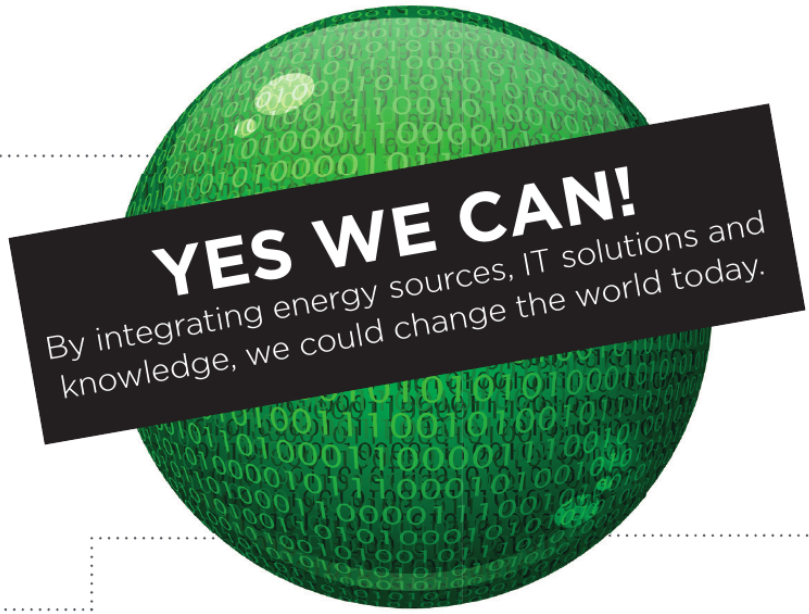


1. Linking energy sources

By linking traditionally separate energy systems it is possible to optimise renewable energy use, which will reduce the dependency on fossil fuels and cut CO2 emissions. The total amount of energy from renewable energy sources fully covers the world's existing and future energy needs.

2. Intelligent IT solutions

Linking is to take place via intelligent IT solutions which can handle and process large volumes of data. The total volume of knowledge is a prerequisite for being able to analyse, predict and utilise both energy production and energy needs. This makes it possible to switch between energy sources, depending on what is available and appropriate at any given time.



3. Knowledge sharing

The total volume of knowledge and data across sectors, public and private stakeholders and research institutions is enormous, but also highly compartmentalised. A crucial component in creating a fossil-free future is therefore integration and the willingness to work towards a common goal – for the benefit of consumers, society and the environment.

CITIES paves the way for a fossil-free future

Okay, we admit it: We won't be 100% fossil-free tomorrow. But it is both thought-provoking and motivating that it might be possible in theory. Just as the potential for utilising renewable energy sources such as solar, wind and biomass is enormous, there is an impressive amount of knowledge, advanced solutions, investments and best practice within each of the individual fields of energy.

What is missing is integration –
and that is what we focus on in CITIES.

With Denmark as a fantastic live lab, support from Innovation Fund Denmark and extensive cooperation with leading Danish and global companies, researchers, engineers, computer scientists and project managers are working hard to pave the way for a fossil-free future.

By establishing and running an integrated research centre, covering all aspects of the energy system, CITIES will make a significant contribution to the Danish target of being 100% fossil-free by 2050.

Facts, goals, and KPIs

CITIES facts

- CITIES = Center for IT-Intelligent Energy Systems
- Period of operation: January 1st, 2014 – December 31st, 2020

- 39 Danish partners
- 9 international partners (Korea, US, Spain, Austria, Australia, Ireland)

- Investement from IFD (DSF): 44.0 mill dkr
- Total budget: 70.7 mill dkr
- Extra financing: Approx. 5.1 mill dkr

Goals
(from the application)

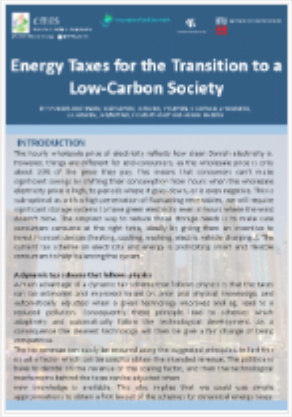
- 30-40 journal papers
- 6 PhD summerschool events
- To educate 11 Phd's and 4.5 PostDocs
- Dissemination through media and broad-audience events
- A dynamic and public website
- Models and strategies for integrated energy systems
- CITIES Innovation Centre (in parallel to CITIES)
- Support activities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

Some KPIs (October 2020)

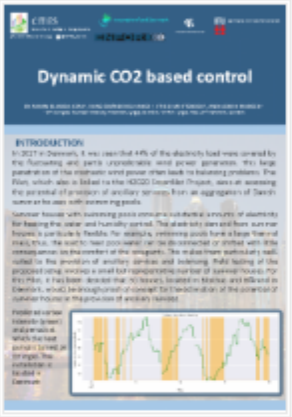
- 290 scientific publications
- 130 journal papers
- 6 book chapters
- 25 brochures with solutions
- 14 PhD Summer Schools
- 25 PhDs and Postdocs
- 27 Workshops
- 12 PhD summer/winter-schools
- More than 20 Demo Projects
- Several successful H2020, IFD, EUDP, … applications related to CITIES

  (Ex. 3 Grand Solution projects – FED, HEAT 4.0 and CoolData)

CITIES Solutions Brochures

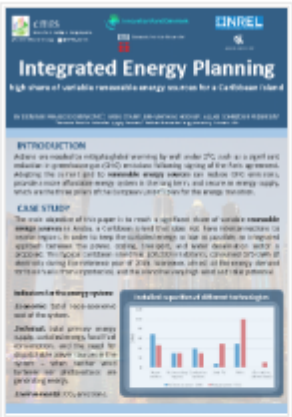


Energy taxes for the transition to a low-carbon society



Dynamic CO2 based control

Stability of electricity smart meter clusters



Integrated energy planning for a carribean island

Potential of district cooling

Clustering based analysis of residential district heating data

Highlights

Possible Savings ‘Tomorrow’ (CO2 + Costs)

- 800 mill dkr annually in Denmark by data-driven temperature optimization (tons of CO2 savings)
- 10 – 30 pct savings by predictive control of heat pumps
- 5 – 15 pct savings by integrating forecasts in smart house controllers
- 10 – 40 pct improvements of electricity and heat load forecasts
- Up to 10 pct savings by optimal operations of CHP and DH plants
- 5 – 12 pct savings by smart wastewater treatment
- 10 – 20 pct savings on cooling for supermarkets
- Up to 90 pct savings on cooling for data centers
- BUT …… see the Recommendations
- Many digital solutions for better modelling (digital twins, grey-box), forecasting, and control (world record in algorithms for control). These solutions are ready for industrial integration
- ……. many more solutions and results will be shown today and tomorrow by CITIES WP-leaders and partners

CITIES solutions can revert the ice hockey stick

CITIES

Digitalization and
Energy Systems Integration

70 pct reduction

33 pct reduction (since 1990..)

2020 **2030**

Highlights (1)

- **New planning tools** - Also short-term flexibility in long-term planning
- A number of new software, hardware and cloud based solutions
- **Large flexibility potentials demonstrated**
- **Smart-Energy Operating-System** (SE-OS) (Big Data, IA, IoT, Controllers,..)
- Energy/power markets (new solutions/design)
- **AS 4.0** – a control based approach for smart grids (incl. Ancillary services)
- Storage solutions (also virtual storage enabled by digitized and integrated energy systems)
- **Flexibility Function** – A new approach for characterizing the flexibility
- **Flexibility Index** – A method for calculation the flexibility (with/without Framework conditions)

Highlights (2)

- **New controllers** for smart energy systems - implemented also as a cloud solution
- Methodologies and tools for **optimal operation under uncertainty** (also bidding..)
- Methodologies for optimal biomass contract management (with Ørsted)
- **Digitilization of District Heating (District Heating v.4.0)**
- **Smart (waste)water** handling
- **CITIES Innovation Centre**
- **Uni-lab.dk** (test and living labs)
- **Center Denmark** (established 20 February 2019 - AAU, AU, SDU, DTU coordinated).
- **You will learn about some of the main results during this conference**

Recommendations

Recommendations
Energy Systems Operation

- Digitalization and data-driven operation of integrated energy systems are key to the green transition
- We must prioritize digitalization in the energy system
- System solutions for sector coupling and Power2X (incl. Power2Heat) should be focussed and barriers for those solutions must be eliminated
- Prioritize virtual storage solutions enabled by digitalization and sector coupling
- National initiatives for digital and sector coupling should be supported and expanded
- Test Zones must be representative and scalable

Recommendations
Energy Systems Planning

- Models and methods for planning must be critically assessed. Are sector coupling and flexibility integrated and modelled properly?
- Investment planning models should be developed
- Cities and municipalies should play a major role
- Transparency and democracy have to be prioritized

Recommendations
Smart Buildings and Districts

- Designed solutions must respect consumer preferences, e.g. in relation to automatic self-acting solutions.
- Smart controllers should offer users preferences regarding energy efficiency, CO2 efficiency and cost efficiency.
- The design of ICT (information and communications technology) solutions must be robust.
- Buildings should be prepared for energy flexible operation
- Buildings should be prepared for supporting grids operations
- A data-driven alternative to the Smart Readiness Indicator must be considered
- Data-driven approaches for energy labelling and energy performance characterization must be adapted
- Smart buildings shall preferably adopt forecasting

Recommendations
Markets

- Coordination of energy markets (heat, gas and electricity) should be further rethought, so they harness flexibility and reward those providing it.
- Market designs should be thought of in a more flexible manner to allow for a wealth of alternative business models.
- Future markets should readily accommodate the uncertainty and variability of renewable energy generation, storage, flexibility and decentralization
- New methods for describing the flexibility can be implemented in control solutions as an operational alternative to low level markets.
- The role of technical aggregators in energy markets should be considered and investigated.

Recommendations
Policy

- We need to use strategic energy planning to aim for emission goals.
- We must remove barriers for sector coupling and use of excess heat.
- New CO2-related energy taxes need to be established now.
- New dynamic tariff structures should be tested and established
- Tests of regulatory conditions and solutions should carried out in test zones ensuring that the tests are representative for, and scalable to, the entire Danish society

New permanent website for CITIES software and solutions

CITIES

Topics Material About us Contact

Centre for IT-Intelligent Energy Systems

CITIES is a research project about smart cities and smart energy systems

CITIES ends ultimo 2020

Supported by Innovation Fund Denmark

In CITIES we have shown how to integrate energy systems powered by intelligent use of data

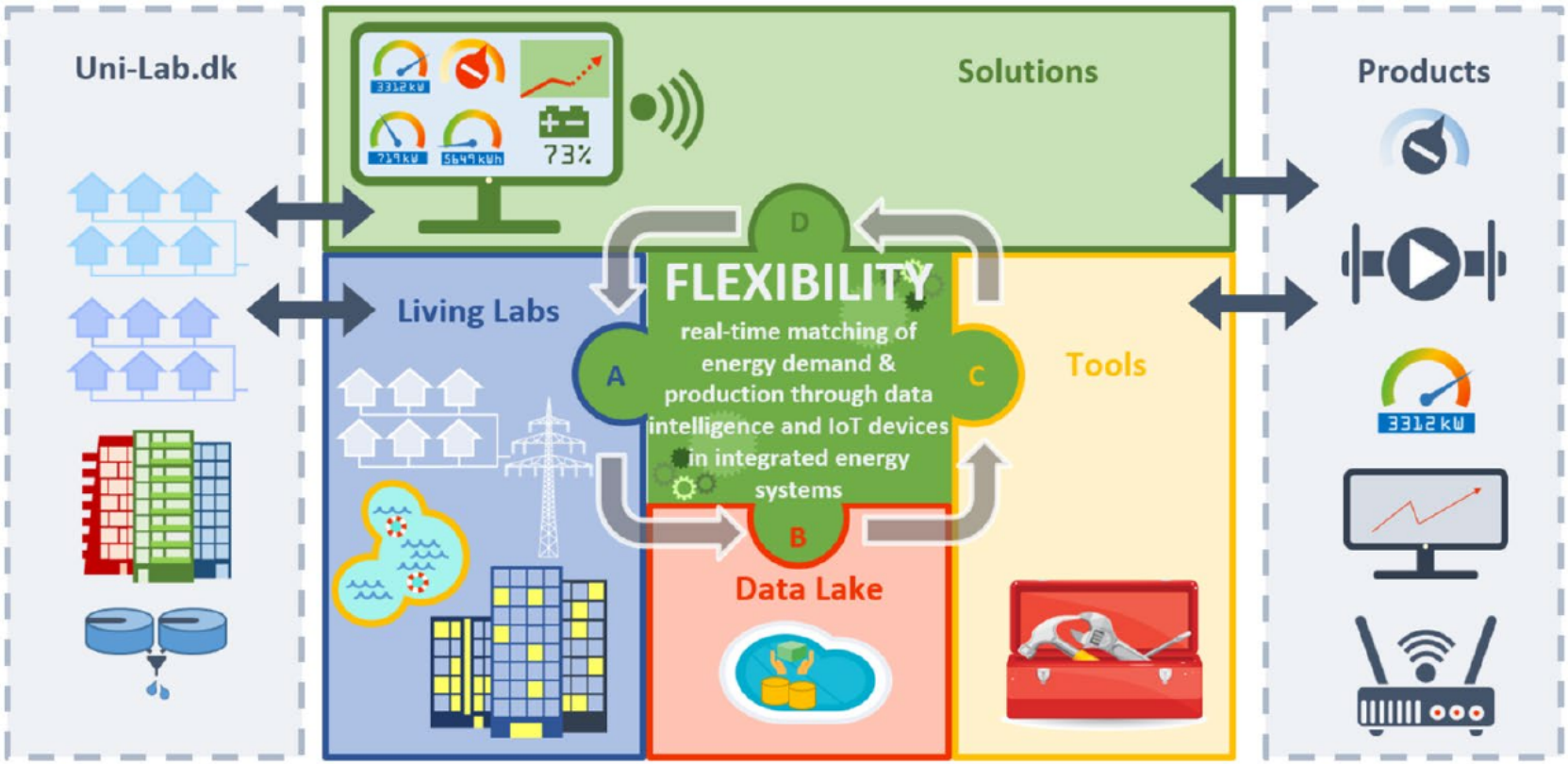
CITIES is a strategic research project funded by Innovation Fund Denmark (formerly by the Danish Strategic Research Council) through the grant 1305-00027B with a project runtime from 2014 to 2020. The research in CITIES focuses on methodologies and solutions for smart energy systems to facilitate the green transition to a fossil-free energy system.

- 39 Danish partners from academia and industry as well as 9 international partner institutions from the EU, Asia, Australia and the USA have investigated all aspects of the energy system and their interactions, including gas, power, district heating/cooling and biomass. The partners developed methods to forecast,

Center Denmark and Uni-Lab.dk

Center Danmark – Digitaliserings Hub

Circularity in the development of digital energy systems



Center Denmark – Control Room

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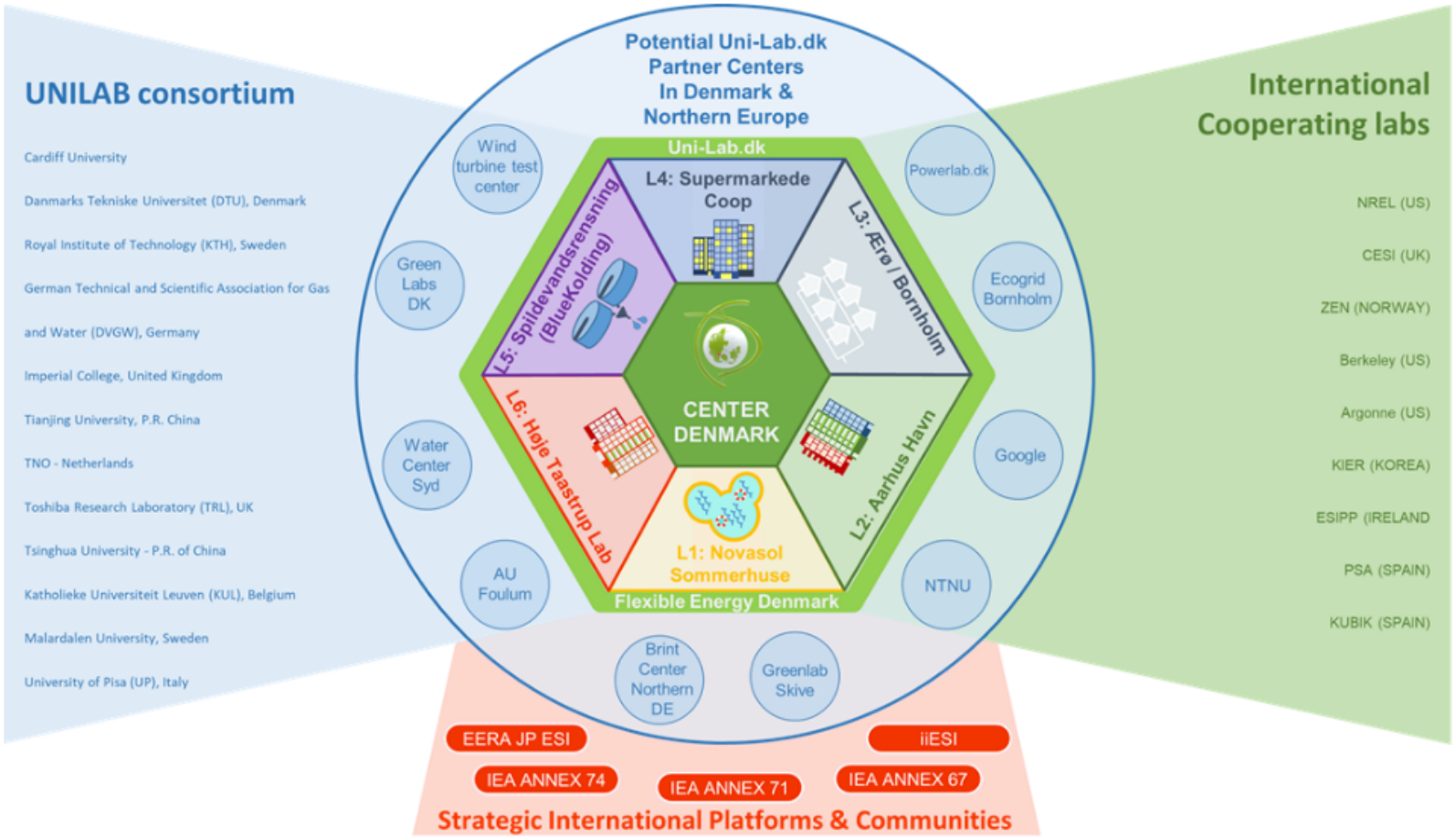
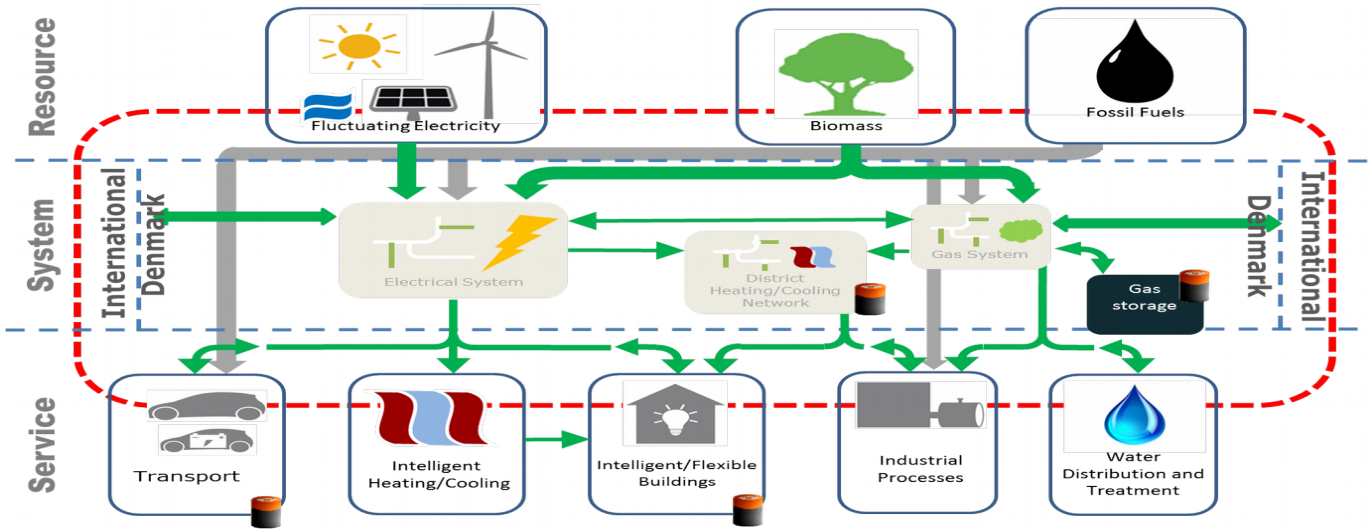


A couple of results from CITIES

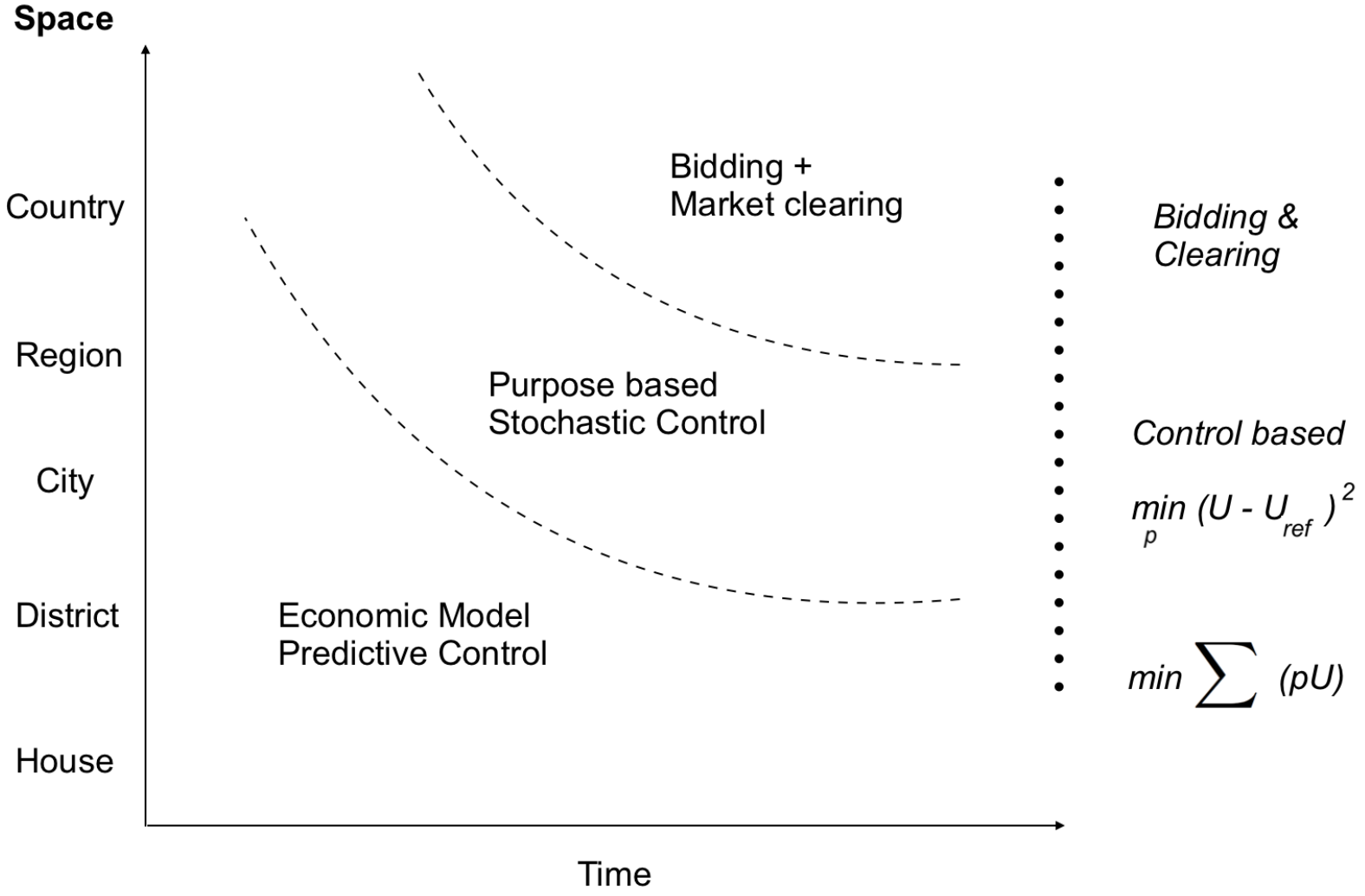
Example: CO2-based control (savings 15 pct)

Flexibility (or Virtual Storage) Solutions



- **Flexibility (or virtual storage) characteristics:**
  - Wastewater systems can provide storage 0.2-6 hours ahead
  - Supermarket refrigeration can provide storage 0.5-2 hours ahead
  - Buildings thermal capacity can provide storage up to, say, 2-10 hours ahead
  - Buildings with local water storage can provide storage up to, say, 2-18 hours ahead
  - District heating/cooling systems can provide storage up to 1-3 days ahead
  - DH systems can provide seasonal/long term storage solutions
  - Gas systems can provide seasonal/long term storage solutions

AS4.0 + SE-OS: Hierarchy of Optimatization and Control Problems



THANKS …

… to Innovation Fund Denmark (DSF-1305-00027B)

… to Hanne Kokkegård for all your help with news, articles, conferences, communication, etc.

… to all our partners (39 national and 9 international)

… to all our students, PhDs and PostDocs

… to the members of the Center Management Team

… to the WP-leaders

… to the Steering Board members

… to the International Advisory Board members

… to members of CITIES Task Force on regulatory framework conditions

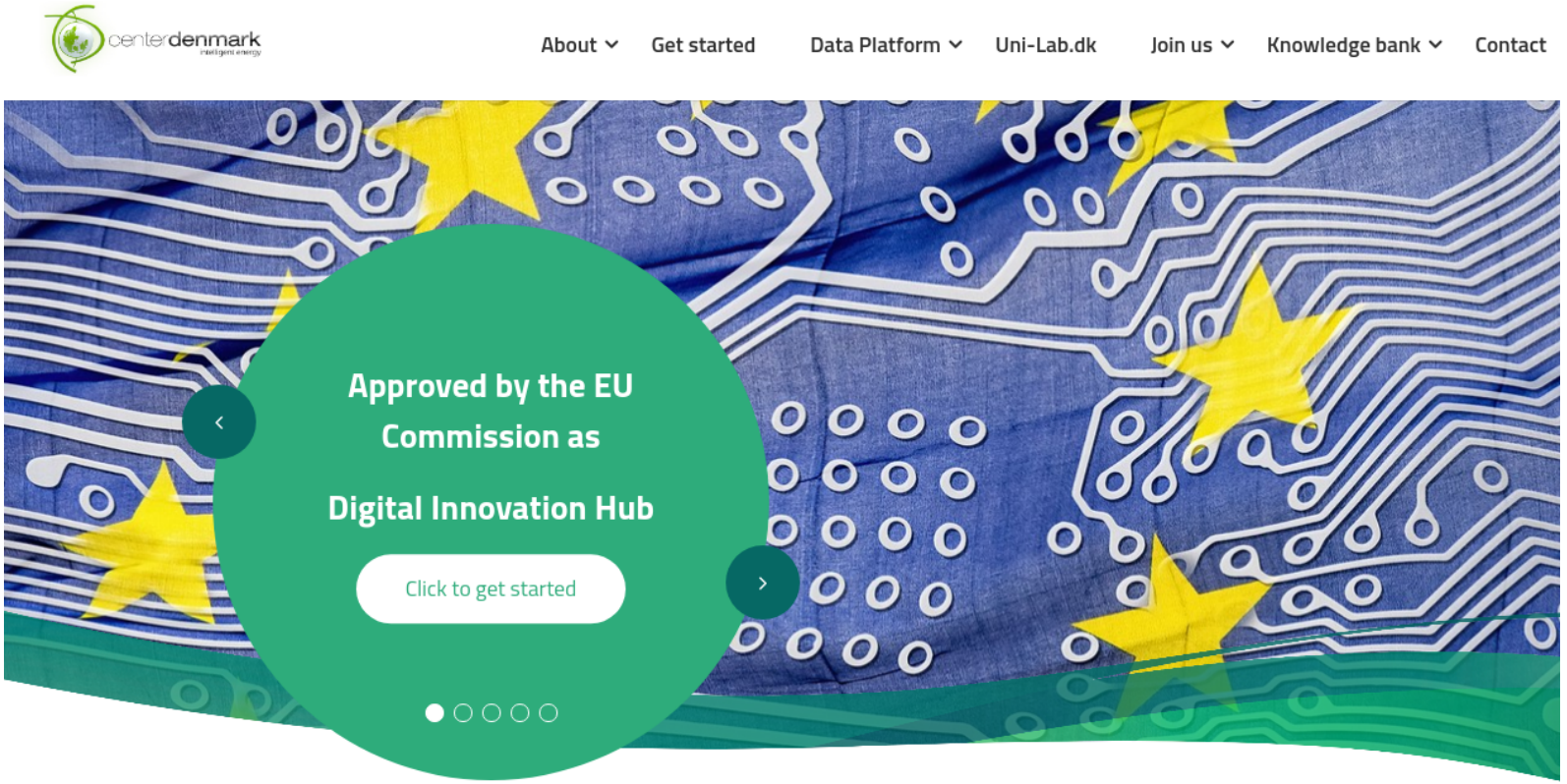
… to the Commission and Ministries for regular discussions

Acknowledgement:

Center Denmark

Become a partner – see www.centerdenmark.com

It will increase possibilities for eg. EU projects and support – also since Center Denmark is approved by the Commission



Center Denmark is an independent and non-profit national research center with the aim to unify and embed research results within the field of digitalization of energy systems and put