



#### **CITIES Consortium Meeting, May 2017**

## **Status and Innovation**

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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 large shares of renewables, and consequently obtain substantial reductions in CO2 emissions.

**Intelligent integration** will enable lossless 'virtual' storage 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 (analytics, IoT, AI, automated learning, ...) leading to methods for operation and *planning* for future energy systems









- 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 international networks

# Status (May 1<sup>st</sup>, 2017)

Budget and Accounts	DTU
CITIES	
Total expenditure	
Budget (entire project)	70.283.186 dkk
Accounts 2014-2016	31.524.979 dkk
DSF grant	
Budget (entire project)	43.971.679 dkk
Accounts 2014-2016	18.886.330 dkk
Self-financing	
Budget (entire project)	26.311.507 dkk
Accounts 2014-2016	12.700.000 dkk

- 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





#### Some KPIs, statistics and dissemination results:

- 60+ scientific oriented presentations (2016 only)
- 47 journal papers published (about 70 papers incl. submitted journal papers)
- In total about 130 papers, chapters, reports, etc.
- 14 Workshops
- 6 PhD summer/winter-schools
- 3-4 extra PhD's (Indonesia, Malaysia, DSOs, ...)
- Several successful H2020, EUDP, ... applications related to CITIES (see next page)







#### Some KPIs, statistics and dissemination results:

- Part of national Big Data Center (incl. Science Cloud for CITIES)
- Part of new IoT Center
- Focus group on regulatory conditions (Adam, Frank, Henrik, Region Midtjylland, Danfoss, Grundfos,....)
- Data Intelligent District Heating Systems initiative (Danfoss, Grundfos, EMD, ENFOR,..)
- Several successful EUDP, ForskEL, Inno+, .. applications related to CITIES
- Several successful EU applications related to CITIES:

Smart Cities Acceletor (Interreg V),

SmartNet (H2020),

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uGRIP (ERA-NET SmartGrid+),
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Integrated Energy Systems – A pathway for Europe (H2020),

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FlexCOOP (H2020)
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## **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

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

## **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, Tecnalia (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 Cities projects
- Use of high performance computing facilities (eg NREL-ESIF and DTU-HPC)
- Described on our homepage.



# CITIES Innovation Center



# DTU

### **CITIES Innovation Center**





Search ...

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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.





# Results A few examples



#### **Results – some examples**

DTU

UDMDC: A toolboy for High-Dorfo

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 Data Management Systems (OS, DATA, REP)

#### CITIES

Centre for IT-Intelligent Energy Systems in cities



#### 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



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



## Lab testing ....



## **Smart Control of Houses with a Pool**



#### Coordinating flexible resources Market-based approach



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

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#### Coordinating flexible resources Control-based approach

The control-based approach is formulated in two steps:



#### Proposed methodology Control-based methodology



#### Proposed methodology Structures for the electricity price



#### Main advantages of the proposed methodology

Several advantages can be identified for such methodology:

- It takes into account stochasticity, non-linearity and dynamics.
- It is able to solve all the ancillary services' problems in one set.
- It exploits the **potential** of flexible resources at the prosumers' level of **any size**.
- It is **fast** and fully **automated** at different levels.
- It facilitates the integration of the different energy carriers.

## This Consortium Meeting





- CITIES results presented in poster sessions
- High-level keynote presentations
- Long-term and seasonal storage
- Regulatory framework and markets
- Innovation activities (incl. panel debate)
- Discuss with other leading smart energy projects
- Discuss CITIES Innovation Center