# Intelligent Aggregation and Markets

## CITIES - WP4

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*(with acknowledgements to all those who contributed)*

# Outline

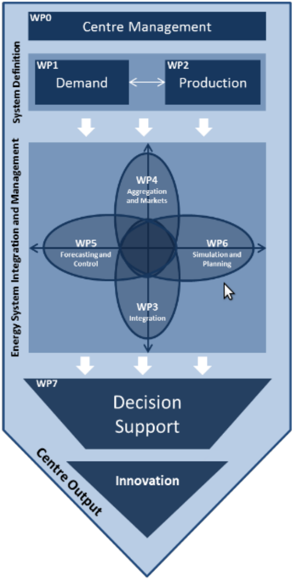
- **An overview**
- **Our state of the art**
- **Activities in CITIES - WP4**

# Background and overview

- **The Devil is in the detail (!)**

- The challenge is about how to best represent the detailed operation and conditions in **aggregated simulations** of the entire complex and integrated energy system, e.g.,
    - Detailed distribution of the available flexibility in time and space
    - Local bottlenecks in the energy infrastructures
    - Local voltage profiles in the power grid,
    - Local temperature profiles in the heat grid, etc.
- In parallel, how would a **multi-carrier energy market** work?
- Finally, how does that **feed back to the planning level/problems**?

# In the CITIES workflow...




- WP4 - Intelligent aggregation and markets is one of the central Work Packages
- It has strong ties with a number of other WPs
- Risk and challenges (a personal opinion):
  - topics are really broad and loosely defined
  - identified overlap with other WPs (at least WPs 3, 5 and 7)
  - need for common test cases and datasets shared by WPs

# It has all been done before...

From 2007 (ETH Zurich):




## Optimal Power Flow of Multiple Energy Carriers

Martin Geidl, *Student Member, IEEE*, and Göran Andersson, *Fellow, IEEE*

***Abstract*—This paper presents an approach for combined optimization of coupled power flows of different energy infrastructures such as electricity, gas, and district heating systems. A steady state power flow model is presented that includes conversion and transmission of an arbitrary number of energy carriers. The couplings between the different infrastructures are explicitly taken into account based on the new concept of energy hubs. With this model, combined economic dispatch and optimal power flow problems are stated covering transmission and conversion of energy. A general optimality condition for optimal dispatch of multiple energy carriers is derived, and the approach is compared with the standard method used for electrical power systems. Finally, the developed tools are demonstrated in examples.**

***Index Terms*—Cogeneration, energy hub, multiple energy carriers, natural gas, optimization methods, power conversion, power generation dispatch, power system modeling, power transmission.**

### I. Introduction

NOWADAYS, power flow in different energy infrastructures such as electricity and natural gas systems is mostly considered to be independent. Motivated by different reasons, a number of recent publications suggest an integrated view of energy systems including multiple energy carriers, e.g., electricity, natural gas, and district heating, instead of focusing on systems with a single energy carrier. One incentive for that is given by the increasing utilization of gas-fired and other distributed generation, especially co- and trigeneration [1], [2]. The conversion of power between different energy carriers establishes a coupling of the corresponding power flows resulting in system interactions. For example, a gas turbine can be used for simulta-

While approximated flow models are used for instance in [8] for optimizing the flows through an energy supply chain, [9] and others employ detailed steady state power flow equations for natural gas and electricity appropriate for dispatching a real system.

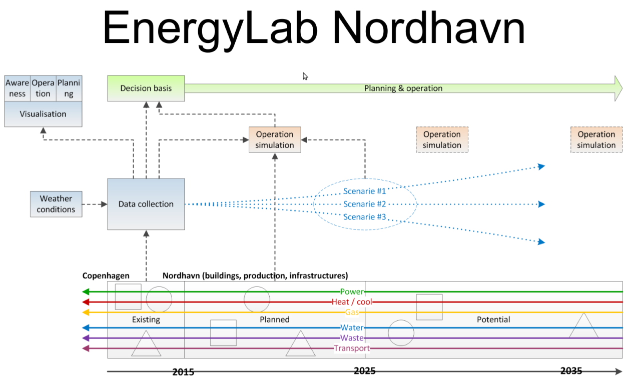
The approach presented in this paper aims at a general modeling and optimization framework for energy systems including multiple energy carriers. Based on the novel concept of energy hubs, it enables simple analysis of couplings and interactions between the different infrastructures. Similar to the standard economic dispatch approach for electricity generators, a general optimality condition can be derived for optimal dispatch of multiple energy carriers. For the specific energy carriers, steady state power flow models can be used within the same framework, enabling the formulation of an optimal power flow problem. The flexibility of the model opens a diversity of potential applications, which will be discussed later in this paper.

This paper is organized in six sections. After this introduction, the concept of energy hubs is presented in Section II. Based on this concept, models for describing flow and conversion of multiple energy carriers are developed in Section III. Optimal dispatch and optimal power flow problems in systems employing multiple energy carriers are then investigated in Section IV. In Section V, the presented approach is demonstrated in examples. Finally, Section VI summarizes and concludes this paper.

### II. Energy Hub Concept

# Ongoing activities (at DTU Elektro)

## EnergyLab Nordhavn




**... as one of the smart cities initiatives combining research, development, and demonstration**

# Ongoing activities (at DTU Elektro)

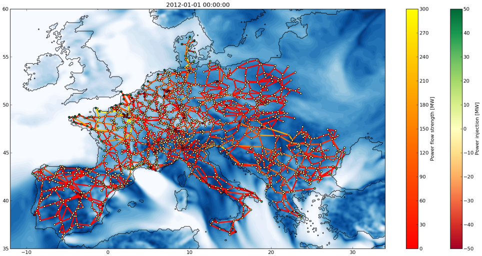
**'5s' - Future Electricity Markets** (DSF)

- **Vision**: *Proposal and benchmarking of new approaches to market design allowing for a very large penetration of stochastic power generation, while respecting power system operations constraints and stimulating a healthy environment for investment.*

- **In practice**, some of the key aspects include
  - *market-clearing mechanisms*
  - *plurality of markets* (energy, capacity, ancillary services) possibly co-optimized
  - enabling and rewarding the more *pro-active role of electricity demand*
  - assessing *impact on investment* and our future power system
  - *bridging the gap* between "theoretical proposals" and practical implementation

- **More generally**: foster and develop cutting-edge electricity market expertise in Denmark to support education, industry and increase in social welfare

# Some ongoing developments



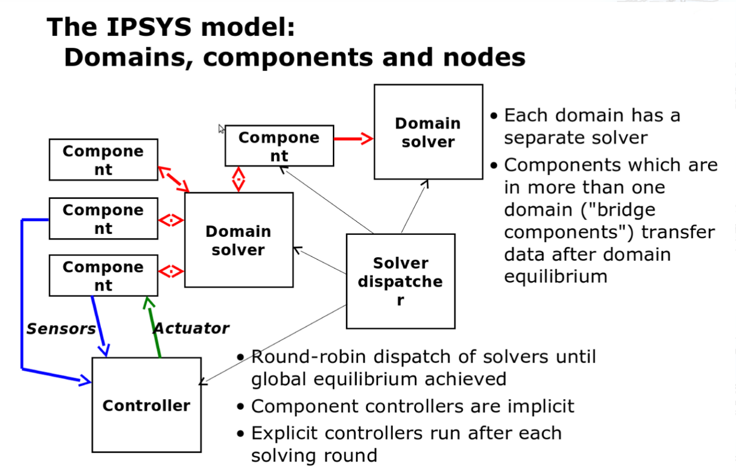

(courtesy of Tue V. Jensen, DTU Elektro)

- **Looking at the big picture:**
    - Simplified dataset for EU-wide transmission system, stochastic meteorological drivers, supply and consumption
    - Research on nodal pricing, dynamic zoning, etc.

- **Probabilistic auctions:**
    - Proposing new types of auctions (for forward markets) with probabilistic offers, on both demand and supply side
    - The cost of handling uncertainty is anticipated and defines an “uncertainty rent” for the system operator

- **Energy and services:** description of new joint markets, permitting to better reward various players for their support to power system operations

- Extension here to multi-carrier energy markets in a cities framework




Focus on control and operations for various **component types** (eg., battery, EV, heat consumer, etc.) and **domain types** (El, gas, water, etc.). Geared towards practical implementation!

# Activities in WP4

The work in this WP is to be mainly based on 3 Ph.D. projects:

- **Ph.D. 1:** *Classification and aggregation of active and flexible energy components* (main superv.: Henrik Bindner; 2014-2017)
  - Methods to aggregate active energy units' energy flexibility
  - Characterisation and classification of active and flexible energy units
  - Aggregated models at generic, statistical and scalable levels
- **Ph.D. 2:** *Multi-carrier energy markets* (main superv.: Pierre Pinson; 2015-2018)
  - New market structures and mechanisms for multi-carrier energy systems
  - Accounting for operational constraints and uncertainties on both supply and demand side (related to the city-limited setup).
- **Ph.D. 3:** *Institutional aspects of multi-carrier energy systems* (main superv.: Frede Hvelplund; 2016-2019)
  - Identify institutional challenges and barrier as well as proposals to overcome these
  - Cross-sectoral organization between different supply systems as well as institutional set-ups

All these projects link to other WPs (5,6,7).

# Thanks for your attention!