# Modelling, Simulation, and Validation of Urban Energy Systems

## Chair

Arjen van der Meer – TUD

## Presentation 1

### Holistic testing for Urban Energy Systems Coupling and Integration

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Traditionally, heat and electricity supply are managed as independent infrastructures. However, where district heating networks are available, the coupling electricity and heat systems can facilitate more efficient overall energy system operation. For district heating systems the benefits include loss reduction through lower operating temperatures and the potential to increase efficiency by decentralized infeed and integration of renewable sources; the electricity networks can gain from a dynamic operation of heat loads and networks offering flexibility, which is valued for a range of purposes such as the integration of renewable energy or avoidance of grid capacity investments.

Coming generations of urban energy systems planners thus will have to break with the established siloed view of urban energy infrastructures. Considering that urban infrastructure has lifecycles of many decades, solutions should be well validated, which is harder to achieve when solutions operate cross disciplinary boundaries. Approaches are required that facilitate the cooperation of infrastructure planners from different engineering disciplines and encourage involvement of various stakeholders.

Constructing these multi-disciplinary systems is challenging, as engineering design of systems is guided by abstractions specific to each respective engineering discipline. A common language for the specification of systems, a common way of coupling engineering and simulation tools and a shared approach to the validation are necessary cornerstones of such a cooperation. Human-scale laboratory implementations of a coupled electricity and heat infrastructure will allow experimentation and validation of operation concepts for coupled and integrated system operation, besides being suitable for purposes of involving non-technical stakeholders.

As a step to address these challenges, we summarise the key system concepts from district heating and electricity supply, and outline an approach for system validation by coupling simulation tools and physical validation environments. The approach involves the separation of use cases for design and test cases for validation, clarification of system components and boundaries as well as test criteria. The proposed approach is illustrated on a case study of multi-energy systems; the validation requirements are then mapped to a coupled simulation environment, as well as to the SYSLAB multi-energy systems laboratory.

## Presentation 2

# Recent developments in simulation-based assessments of integrated urban energy systems

AUTHOR: E. Widl et al.

KEYWORDS: energy system integration, urban energy systems, holistic assessment, model-based assessment, co-simulation, optimization

ABSTRACT: Simulation-based assessments are a cost- and time-effective way of evaluating various aspects of large energy systems. For instance, they can help in the design process of energy systems, where they provide insights into technical or economic questions. Or they can be used for developing operational strategies and controllers for increasing the efficiency of energy systems. Unfortunately, in the case of integrated urban energy systems the required simulation-based assessments remain a challenge, from both a methodological as well as a technical perspective. This is not only due to the size of the considered systems but also due to the fact that they comprise and integrate subsystems that are related to different engineering domains (e.g., electric grids and heat networks) and different stakeholders. However, recent work demonstrates how co-simulation approaches can be successfully utilized in this context, enabling detailed technical multi-domain assessments for urban energy systems. Moreover, it has been shown how they can be combined with optimization approaches for holistic assessments, which also target planning and economic aspects. This presentation aims to show and compare different case studies, highlighting the advantages and shortcomings of the different simulation and optimization approaches and how they can be applied in a way to exploit synergies between them. The case studies also demonstrate how these approaches aid the involved stakeholders in understanding the associated risks and potentials, paving the way for early adopters to implement innovative concepts in the context of integrated urban energy systems.

## Presentation 3

# Characterizing the energy metabolic pattern of urban systems with MuSIASEM: the case of Barcelona

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**Abstract**

Cities are the local engines of economic development but their dynamics are supported by the convergence of large flows of material and energy resources from all around the world: they are extremely open and adaptive dissipative systems. Urban metabolism is characterized by the specific mix of paid work activities carried out in the city and the heterogeneity of activities expressed in leisure and residential sector. Most global cities have externalized their energy consumption, pushing out their industries to peripheral metropolitan areas or remote regions, and have become service cities. Many urban activities are carried out by non-residents (commuters, tourists). This poses epistemological challenges to defining system boundaries: Who is consuming energy, to do what, when and where?

We present results from an analysis of Barcelona's energy metabolism, a global city characterized by an important service sector, based on an application of Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM). This novel tool characterizes the energy metabolic pattern of the different socio-economic sectors and neighborhoods of the city by studying biophysical flow/fund relations. Indeed, functions (end-uses) performed in the city are at the end of the chain of production and consumption, and are reflected in the use of space, human time allocation and energy carriers. The tool is used both in diagnostic and simulation mode to support an informed discussion about polies related to energy transition, energy poverty, and energy sufficiency. Recognizing the complexity of the urban system, we propose the concept of energy performance rather than energy efficiency to inform urban policies.

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**Key Words**: Energy, end-use matrix, urban metabolism, societal metabolism, MuSIASEM, energy efficiency, energy performance.

## Presentation 4

## Optimization modeling of regional energy systems considering coordination mechanisms

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Keywords:

Renewable energy sources, regional energy system modeling, optimization methods, coordination mechanisms

Abstract:

Dutch regional municipalities increasingly take an active role in the transition to more sustainable and autonomous energy supply systems, using local energy sources like wind, solar and biomass. The ambition, on the one hand, concerns how an optimal local energy supply system can be

designed such that local energy targets can be realized with minimum dependence on the national energy grids. On the other hand, it is of importance to consider the coordination mechanisms between actors such as municipalities, local communities and grid operators, since they will influence the technical configuration of the system.

In the literature about renewables-based regional energy systems, the technical optimizations are done mostly from a central planner point of view. Therefore, there lacks a study on the optimization models for regional renewable energy planning that has a comprehensive view on coordination mechanisms and their influence on the system performance.

The objective of this work is to enhance the formulation of mathematical optimization models for self-sufficient regional energy systems by taking coordination mechanisms into account, in order to understand their influences on the system performance.

In this paper, a toy model for making optimal long-term investment decisions in electricity generation and transmission will be presented. Two coordination mechanisms, namely one with a central planner, and the other one with a regional market, are considered. In addition, the different modeling approaches for rural and urban energy systems will be discussed.

Initial results show that the coordination with a central planner has the least system cost. In the market-based coordination, it is recognized that the degree of shared information and of market participation influences the problem formulation. This results in the cost differences for different coordination mechanisms and for different actors, and thus gives policy implications in the choice of coordination mechanisms and in cost allocation.