Coordination of district-level smart energy systems: multi-objective considerations

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Presented by: Edward O'Dwyer
Overview

• Real-time control and coordination potential & challenges
• Energy management aspects of the Sharing Cities H2020 project
• Development of Sustainable energy management tool and open-source simulation environment
• Application in Sharing Cities case studies
Multi-vector energy systems: real-time control & coordination

Shift demand

Store energy

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Potential for real-time control in energy system transition

- IoT integration technologies
- Communication networks
- Advanced control (e.g. MPC)
- Data-science/ML/AI
- Big-data & software advances
- Increased technological diversity
- Environmental and economic imperatives
Challenges, considerations and trade-offs

- Resource availability
- Infrastructural limitations
- Complexity and context
- Enacting optimal control actions
- System-benefits vs individual-benefits
- Environmental vs. economic
- Robustness & resilience vs. max potential
What is Sharing Cities?

- Sharing Cities is a project funded by the EU’s Horizon 2020 research and innovation programme.
- Three lead cities (London, Lisbon and Milan) and three follower cities (Bordeaux, Burgas and Warsaw).
- It will provide a better, common approach to making smart cities a reality.
- Total cost is €25million
Greenwich Assets & Smart City Architecture

Coordination Layer
Evaluate high level system constrain satisfaction
Mitigate excess by reformulating constraints of lower-level sub-problems

Building heat opt (QP, LP or MILP):
Minimise energy/£/CO₂
Subject to: Heat network constraints

Forecasting (e.g. occupancy)
Method: Any classification algorithms, ANNs, etc.

Demand-side modelling (e.g. building dynamics)
Method: Regression, SysID, etc.

Electrical-side opt (LP or MILP):
Minimise £/CO₂/export
Subject to: power network constraints

Forecasting (e.g. EV forecast)
Method: Classification algorithms, ANNs, etc.

Demand-side modelling (e.g. battery)
Method: Regression, SysID, etc.

System parameters, set-points etc.

Datastore
Measurements (feedback from assets)
Forecasts (weather, energy prices, etc.)
Cloud-based architecture

- External data
- SEMS core
- SEMS integration
- Web services
- Web frontend
- Digital twin

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- Subsystem 1: Data acquisition & control (e.g. SCADA)
- Subsystem n: Data acquisition & control (e.g. SCADA)

Real systems
Twin: simulation architecture

Ptolemy II (component models)

- Water Source Heat Pumps
- Boilers
- Thermal Stores
- Pumps
- Valves
- Low-level controllers

Electricity Grid
- Gas Network
- Environmental Variables

Electric Vehicles
- e-bikes
- Photovoltaic cells

EnergyPlus (building model)
- Building dimensions
- Material Properties
- Heating schedules
- DHW consumption
- Occupancy

Heat network flow
Heat network return

Python (control algorithms)

- Measurements & forecasts
- Web application framework
- Set-point recommendations

Adaptive modelling
- Use-case 1 MPC
- Use-case n MPC

Coordination layer
Heat network management

• MPC applied to building energy problem – minimise weighted combination of £ & CO2 subject to soft comfort constraints
• Improved environmental performance conflicts with economic performance
• Digital twin provides decision makers specific information about otherwise arbitrary looking problem
PV/EV coordination

- Delaying charge of fleet vehicles to increase utilisation of local PV resource
- More delay leads to more utilisation: what is the desired balance?

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<thead>
<tr>
<th></th>
<th>PV Utilisation</th>
<th>Renewable</th>
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</thead>
<tbody>
<tr>
<td>Uncoordinated</td>
<td>54</td>
<td>45</td>
</tr>
<tr>
<td>Coordinated</td>
<td>61</td>
<td>51</td>
</tr>
</tbody>
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Power grid restrictions

- Better coordination can allow for reduced infrastructural development
- This comes at an operational cost

<table>
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<tr>
<th>Limit Violation reduction</th>
<th>Operational emission increase</th>
<th>Operational cost increase</th>
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<tbody>
<tr>
<td>Coordinated</td>
<td>97 %</td>
<td>20.8 %</td>
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Conclusions

- Technologies and techniques for real-time of district-level energy systems carry great potential

- Coordination challenge – competing/conflicting objectives

- Integration of intelligent energy management software and simulation environments enable more informed real-time decision-making
Thank you!

Funded by the H2020 Sharing Cities project

www.sharingcities.eu