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Qabanbay batyr. 53, Astana, Kazakhstan
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Towards Smart Sustainable Cities – Integrated Approaches, Nazarbayev University / 15-16 of June 2017

A multi-dimensional view on modelling of urban decentralized multi-energy systems

Dr. Georgios Mavromatidis, gmavroma@ethz.ch

Chair of Building Physics, ETH Zurich, Switzerland
Laboratory for Urban Energy Systems, Empa Duebendorf, Switzerland

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

EMPA
Materials Science & Technology

sccer | future energy efficient buildings & districts

Schweizerische Eidgenossenschaft
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Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
Commission for Technology and Innovation CTI
Innovation Promotion Agency

Introduction

- Switzerland has a series of ambitious energy & environmental goals outlined in the country’s Energy Strategy 2050

- Eight Swiss Competence Centers for Energy Research (SCCERs) are established by the Commission for Technology and Innovation (CTI) to guide the country’s energy transition

- Buildings: a key component of the Swiss energy system
  - 50% of Switzerland's primary energy[1]
  - 40% of Switzerland’s CO_2 emissions[2]

- SCCER Future Energy Efficient Buildings & Districts (SCCER FEEB&D)
  - Vision: *“Develop solutions for the Swiss building stock to reduce its environmental footprint by a factor of three by 2035”*

[1] SFOE (2012). Energy in Buildings. Swiss Federal Office of Energy (SFOE). Available from: http://www.bfe.admin.ch/themen/00507/00607/?lang=en#.
[2] IEA (2012). Energy Policies of IEA Countries – Switzerland. International Energy Agency (IEA), Paris, France.

SCCER FEEB&D - Project structure

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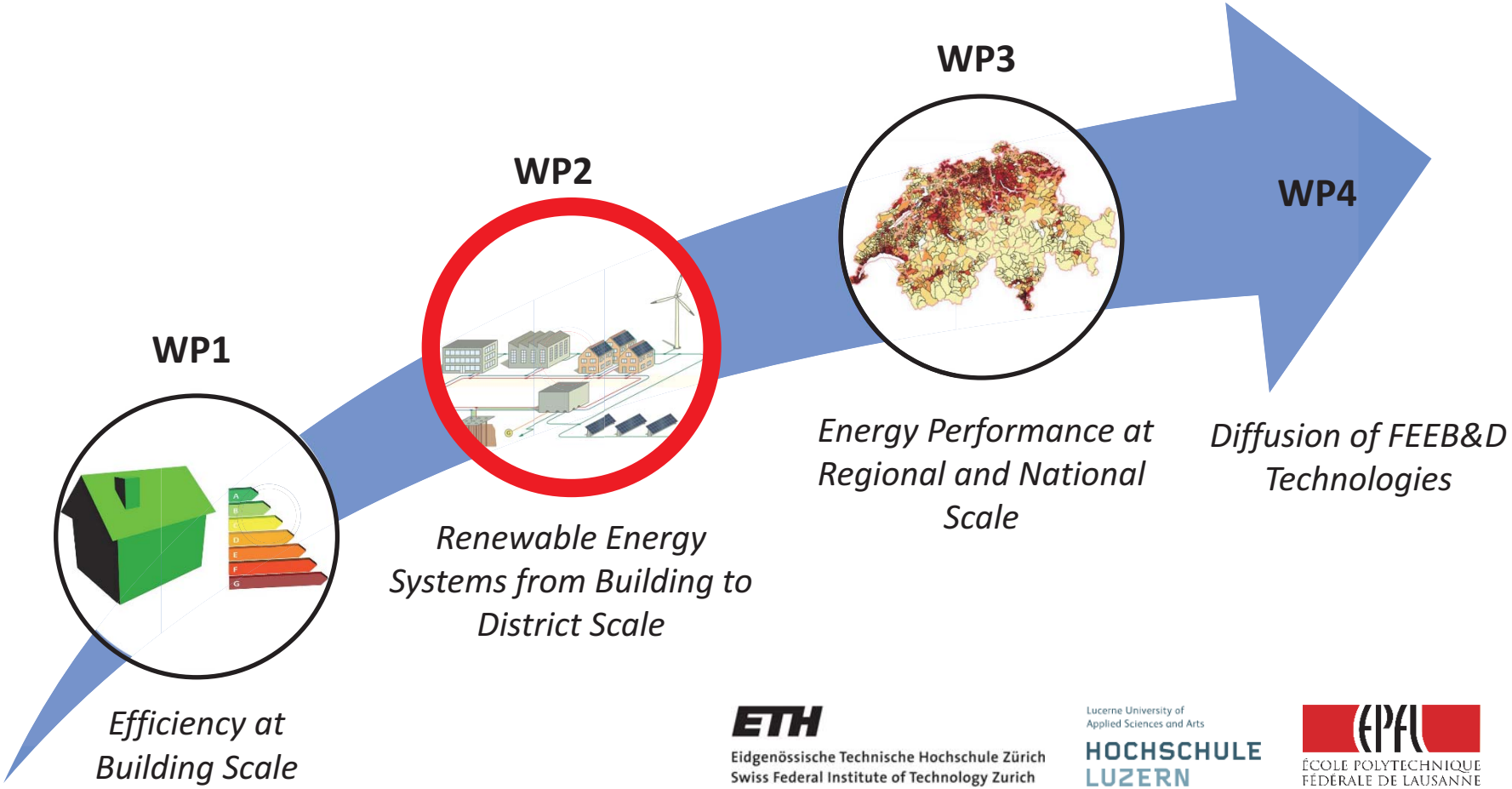


ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

Lucerne University of Applied Sciences and Arts HOCHSCHULE LUZERN

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

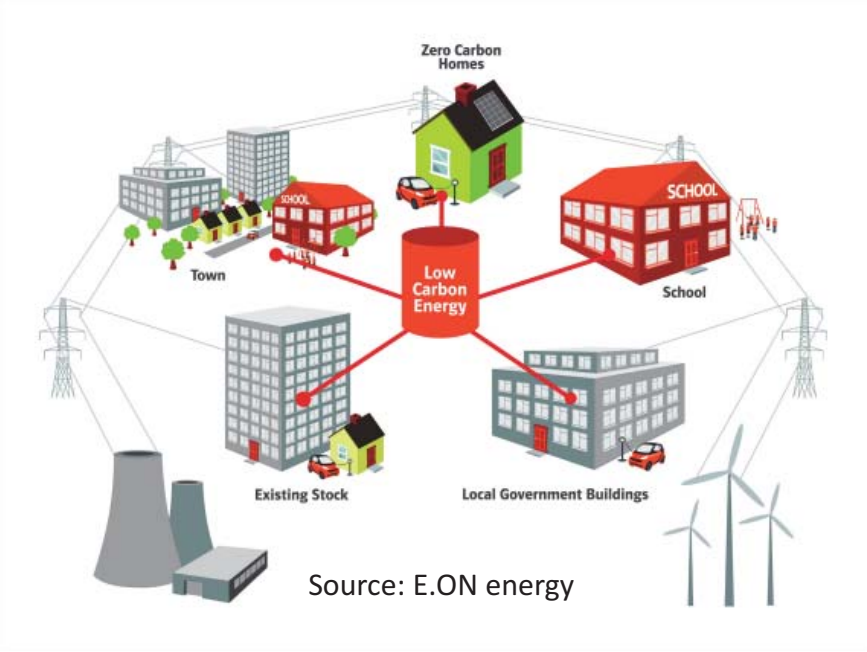
EMPA Materials Science & Technology

n|w Fachhochschule Nordwestschweiz Pädagogische Hochschule

UNIVERSITÉ DE GENÈVE

Distributed multi-energy urban energy systems

- Distributed multi-energy systems (DES) definition[3,4]: *“a system where energy is made available close to energy consumers with multiple integrated energy vectors (e.g. electricity, biomass, natural gas etc.) and multiple sectors (e.g. heating, cooling, electricity, transport etc.)”*



Source: E.ON energy

[3] Di Somma, M., Yan, B., Bianco, N., Graditi, G., Luh, P.B., Mongibello, L., Naso, V., 2015. Operation optimization of a distributed energy system considering energy costs and exergy efficiency. Energy Conversion and Management 103, 739–751.
[4] Mancarella, P., Ceseña, E.A.M., 2016. Tutorial 2 – Multi-Energy Systems – An introduction to the smart grid beyond electricity. IEEE International Energy Conference (ENERGYCON) 2016, Leuven, Belgium

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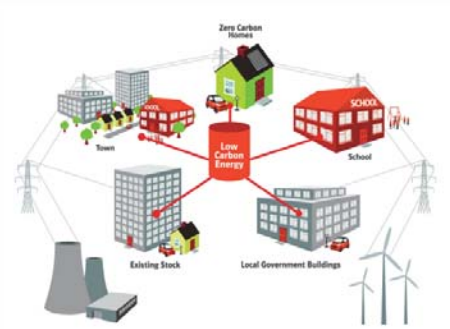
- Main characteristics
  - Organization of multiple buildings in integrated energy entities
  - Incorporation of locally available renewable sources and efficient generation and storage technologies

- Why an urban dimension?
  - High urban energy demand density
  - Co-existence of diverse energy consumers
  - Potential of urban renewable energy



[3] Di Somma, M., Yan, B., Bianco, N., Graditi, G., Luh, P.B., Mongibello, L., Naso, V., 2015. Operation optimization of a distributed energy system considering energy costs and exergy efficiency. Energy Conversion and Management 103, 739–751.
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Distributed multi-energy urban energy systems

- The design of distributed multi-energy urban energy systems is a challenging and multi-faceted task

- Research at the Chair of Building Physics, ETH Zurich and the Laboratory for Urban Energy Systems, Empa Duebendorf investigate the multiple dimensions of these systems within SCCER FEEB&D

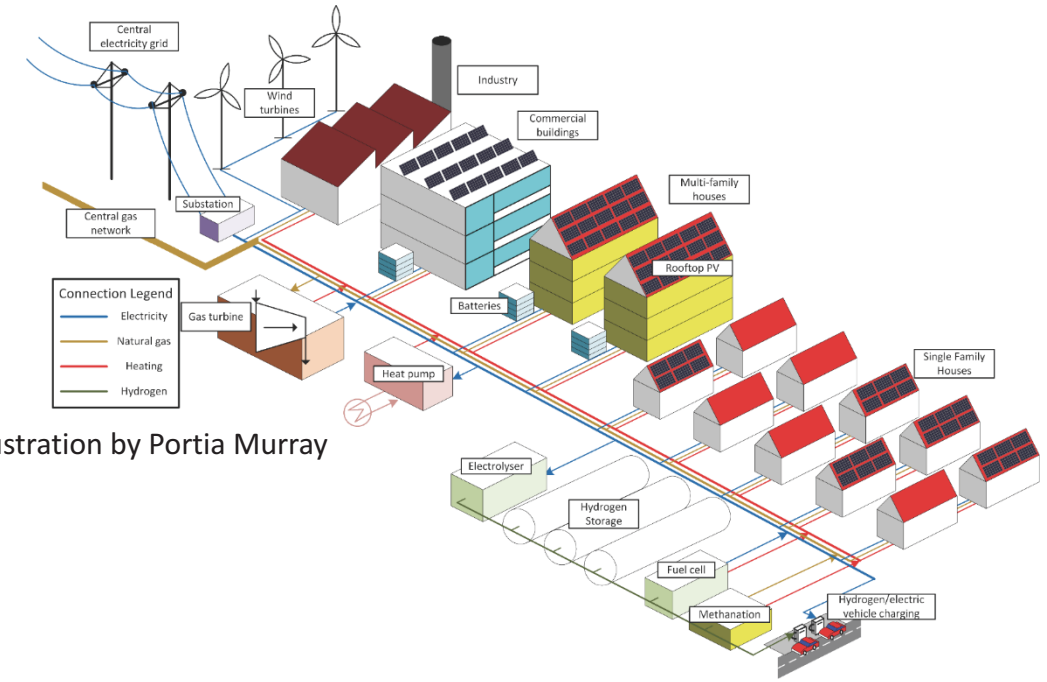


Illustration by Portia Murray

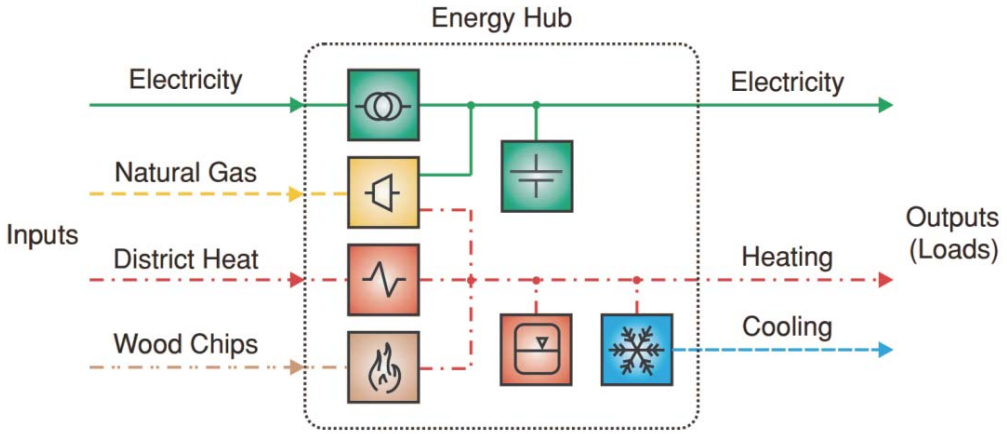
Research highlights

Distributed multi-energy urban energy systems

Chair of Building Physics, ETH Zurich
Laboratory for Urban Energy Systems, Empa

The ‘energy hub’ concept

- Modelling & Optimization framework for the interactions between multiple energy carriers and energy technologies[5]



- Used to optimize the supply, conversion and storage of multiple energy streams
  - Optimal design & optimal operation problems
  - Minimization of economic, environmental or energetic criteria

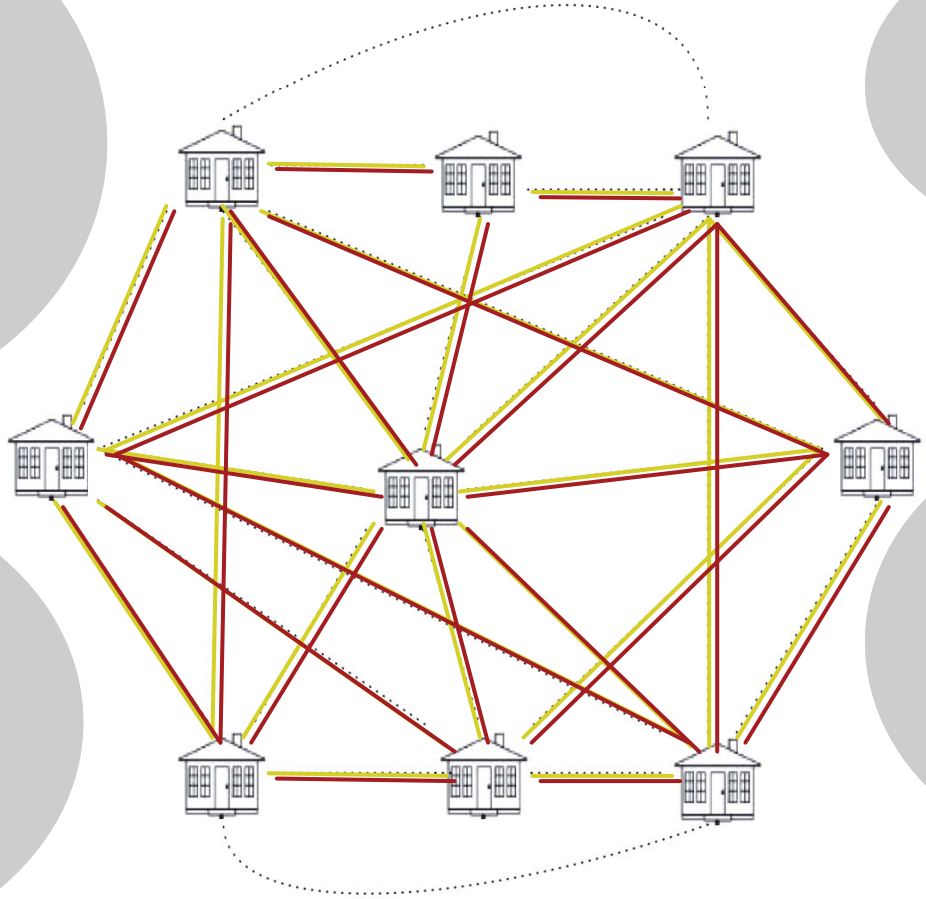
[5] Geidl, M., Koeppel, G., Favre-Perrod, P., Klockl, B., Andersson, G., Frohlich, K., 2007. Energy hubs for the future. IEEE Power and Energy Magazine 5, 24–30.

Electrical and thermal networks low-carbon urban areas

In order to achieve low carbon urban areas...

... should the networks be pure electrical so that electricity is used both for electricity and heating demand?

... what is the optimal network layout?

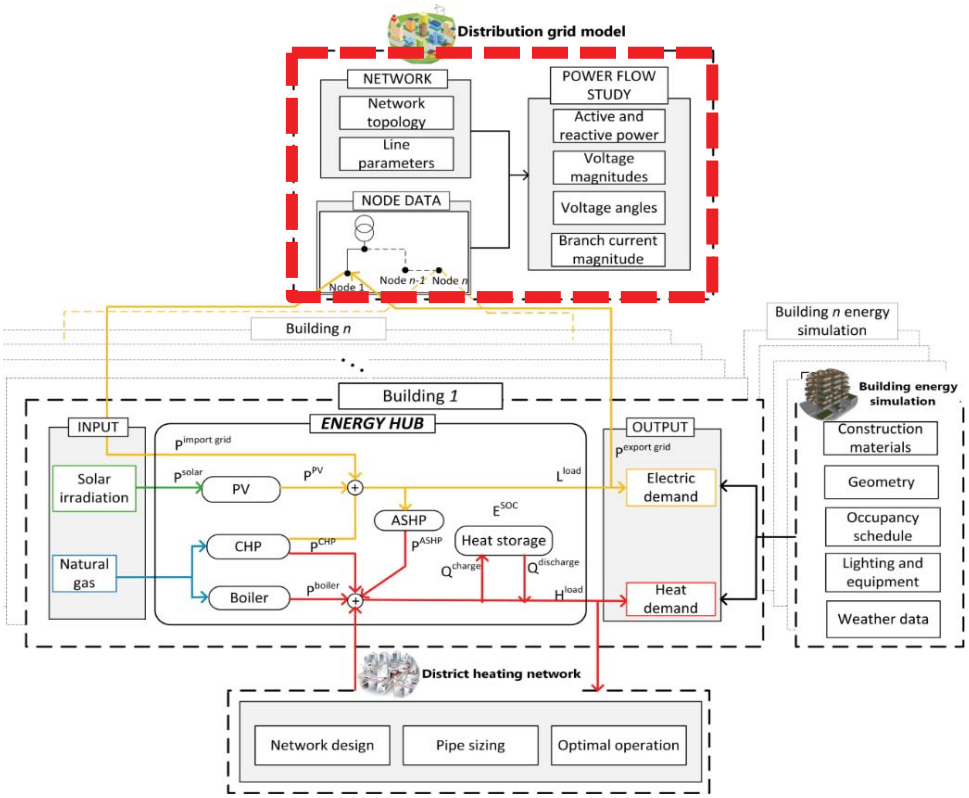


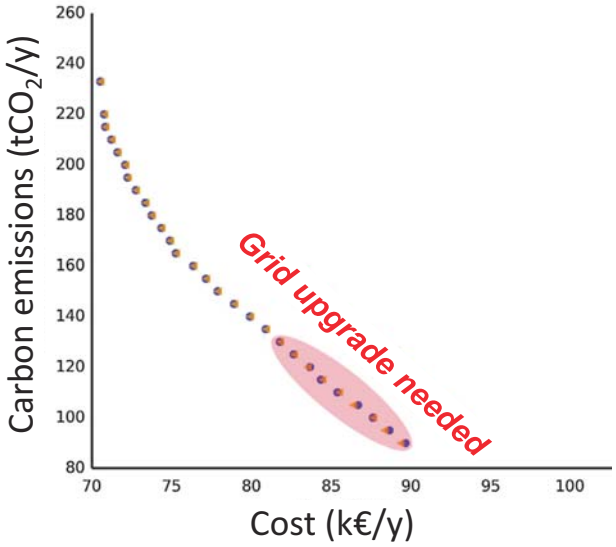
...when should buildings be connected by heating network in addition to electrical grid?

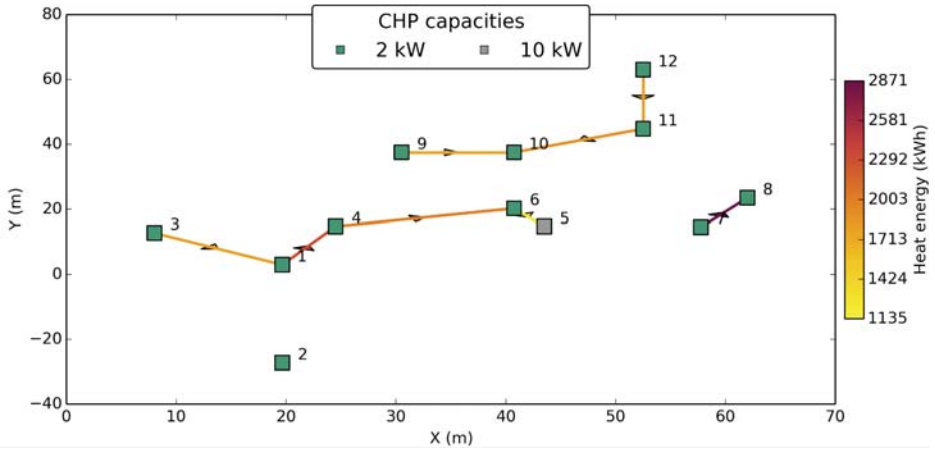
... what energy technologies should be installed in each building?

B. Morvaj, Holistic optimisation of distributed multi energy systems for low carbon urban areas. PhD Thesis. ETH Zurich, 2017.

Distribution grid model integrated with energy hub framework







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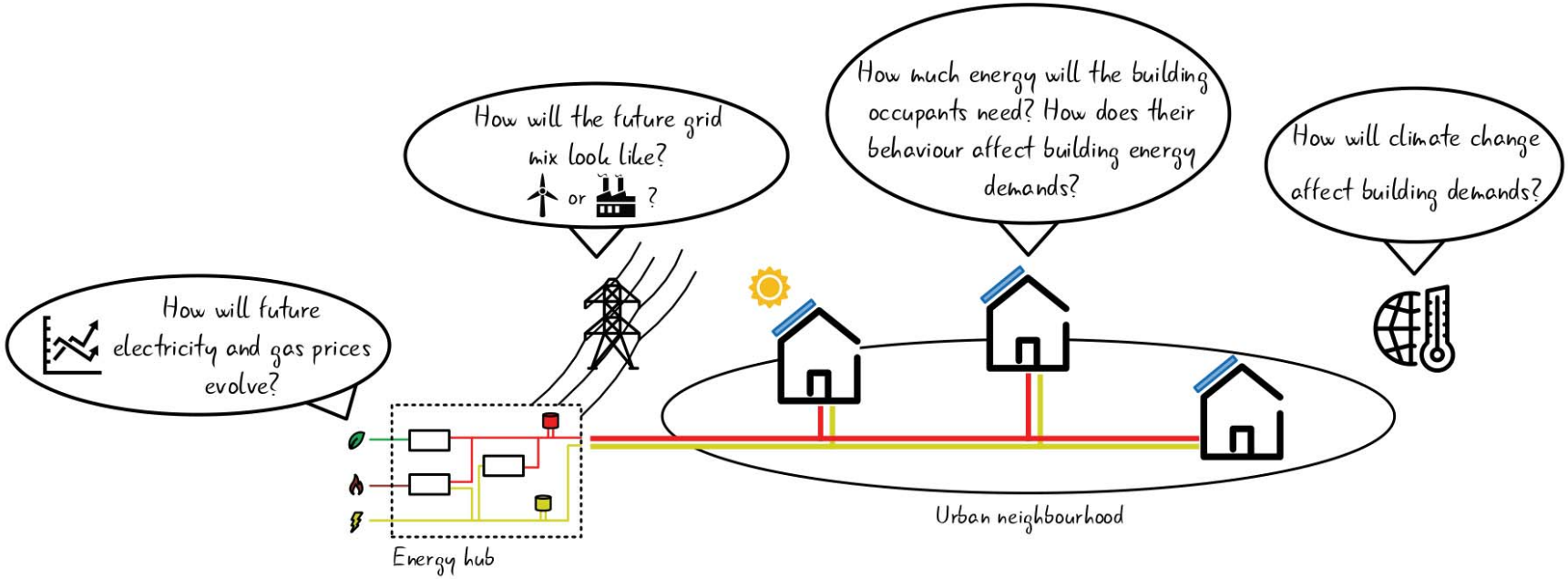
Uncertainty & the design of distributed urban energy systems



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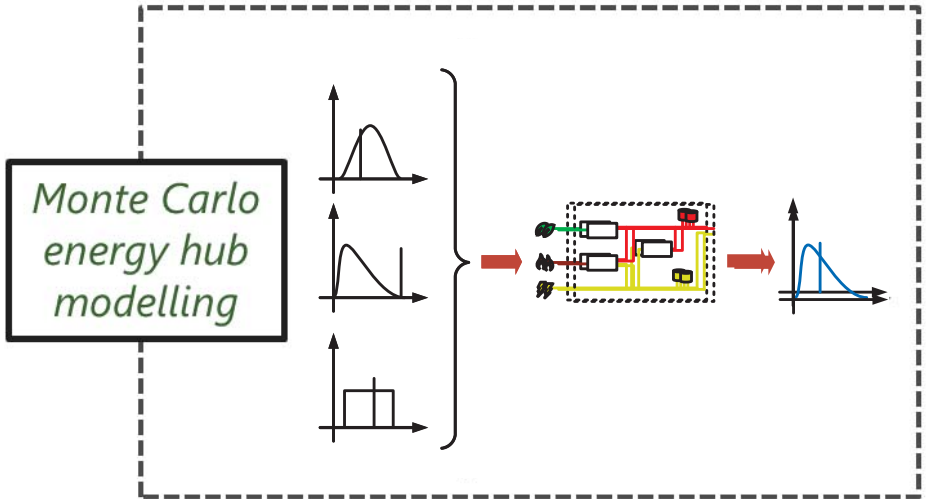
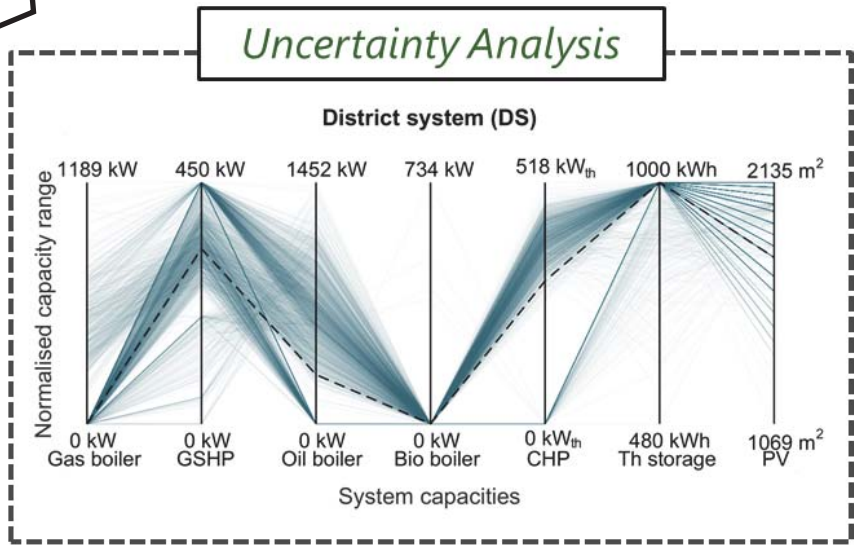
Uncertainty & the design of distributed urban energy systems

“What are the impacts of uncertainty?”



Examine patterns in optimal design variations

Deterministic designs might be suboptimal!



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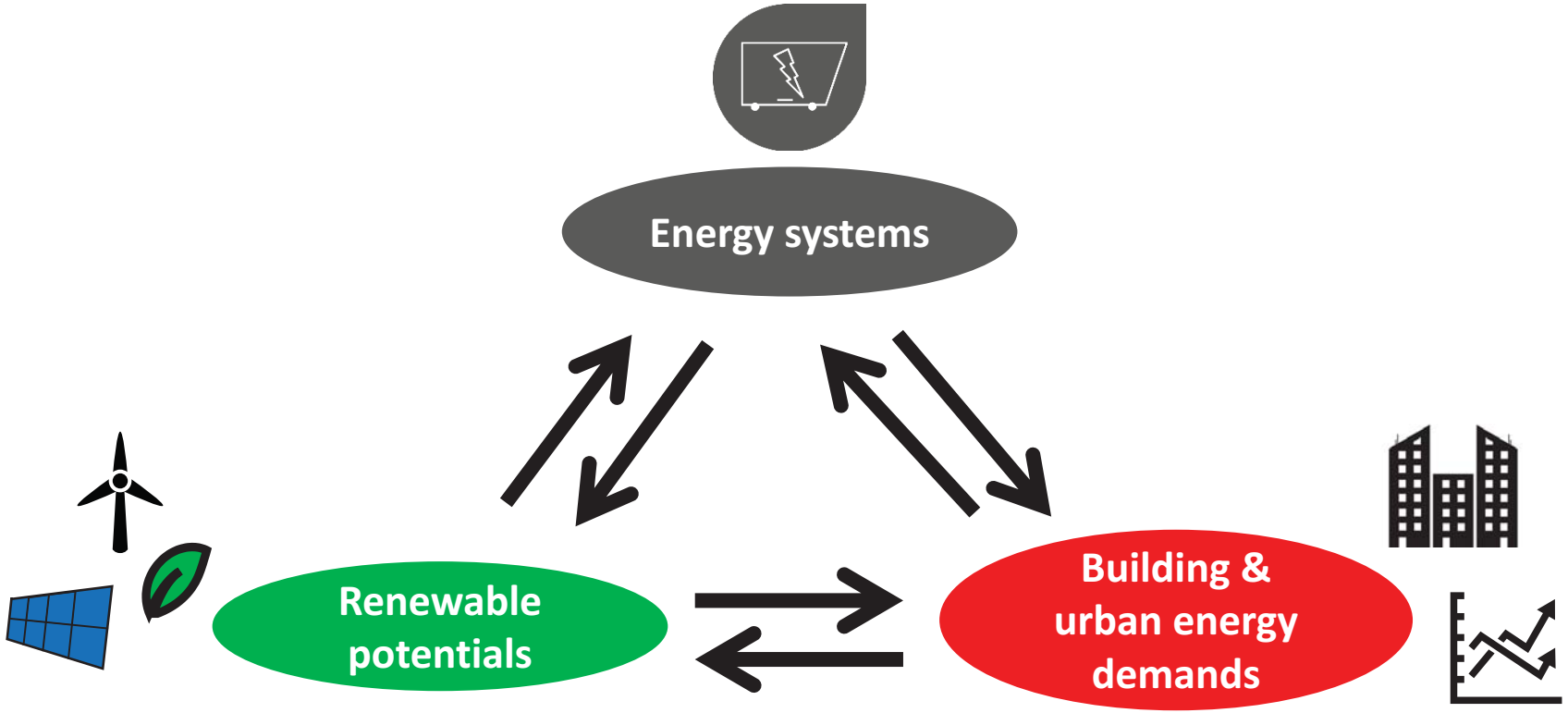
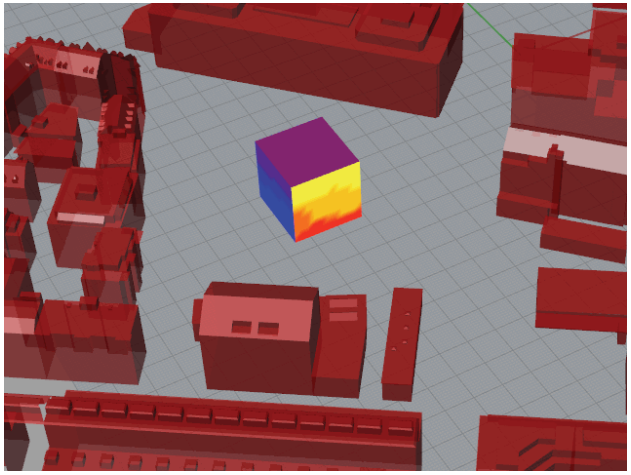
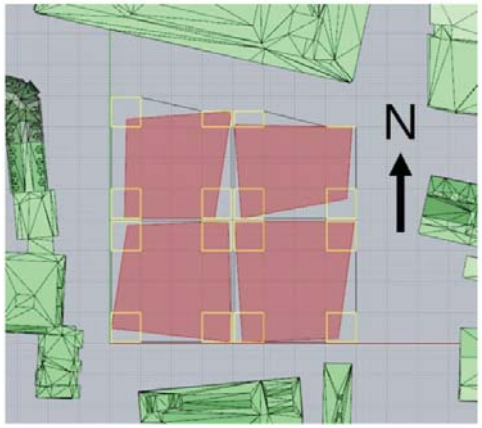
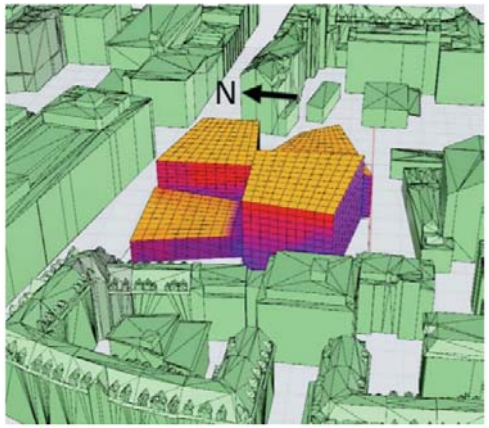
Interactions between urban design & energy systems



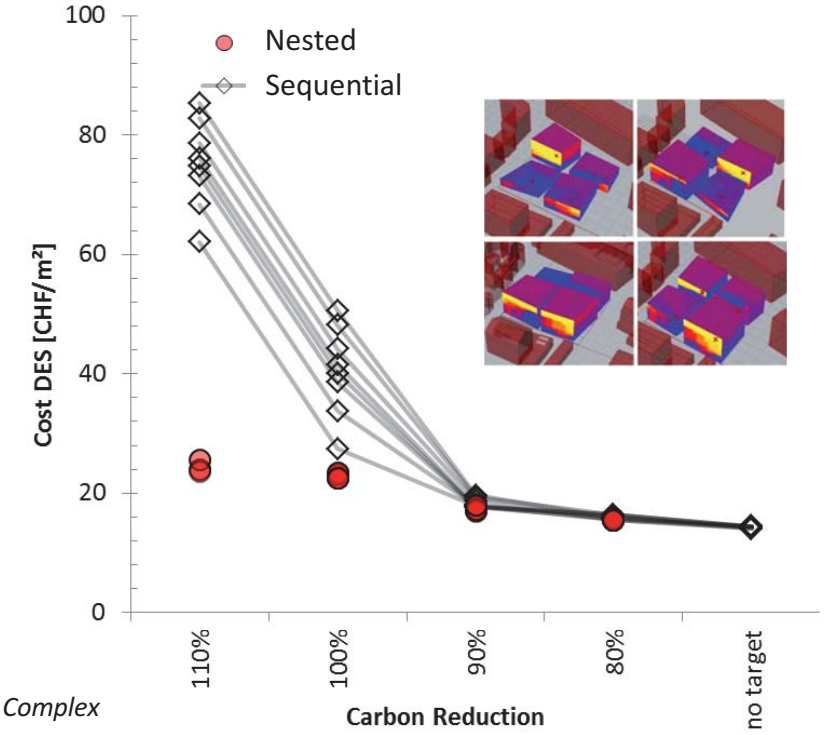
Interactions between urban design & optimal energy systems







Simultaneous optimization of urban & building design and energy systems



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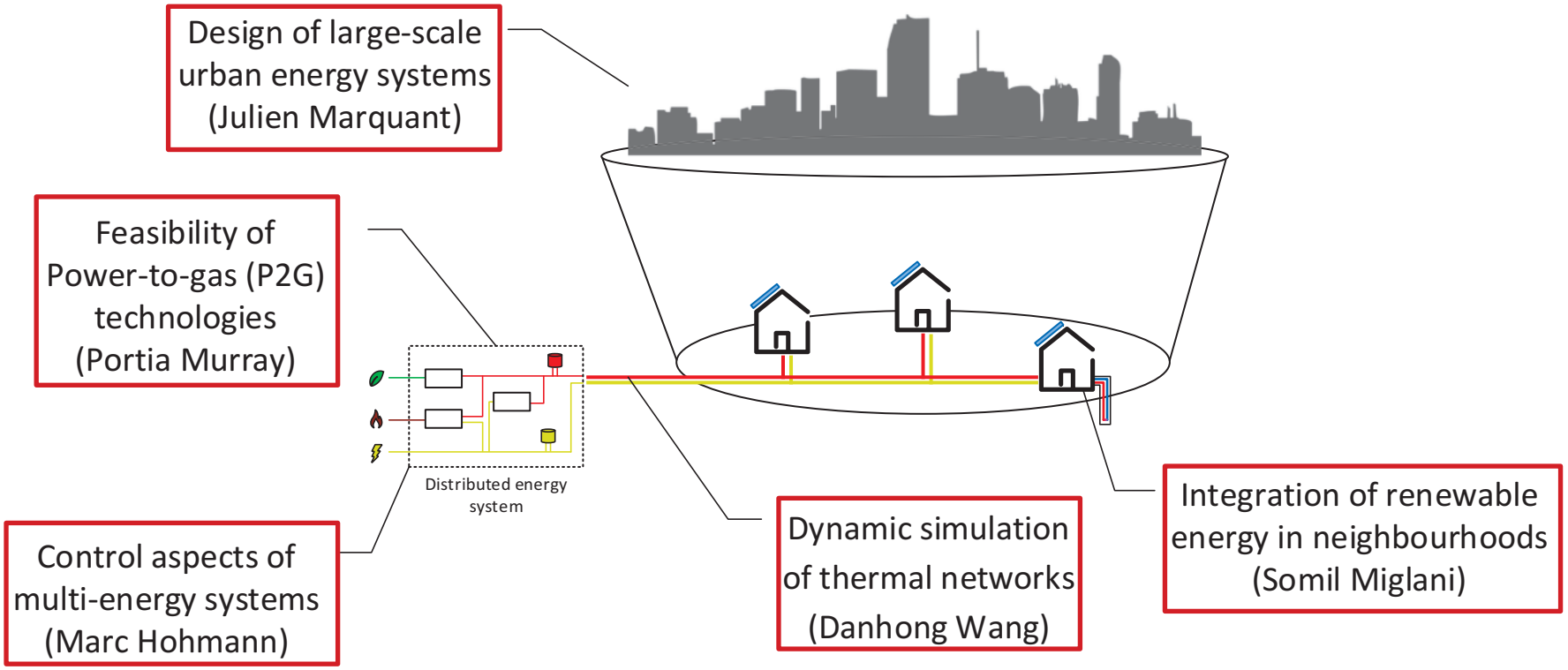
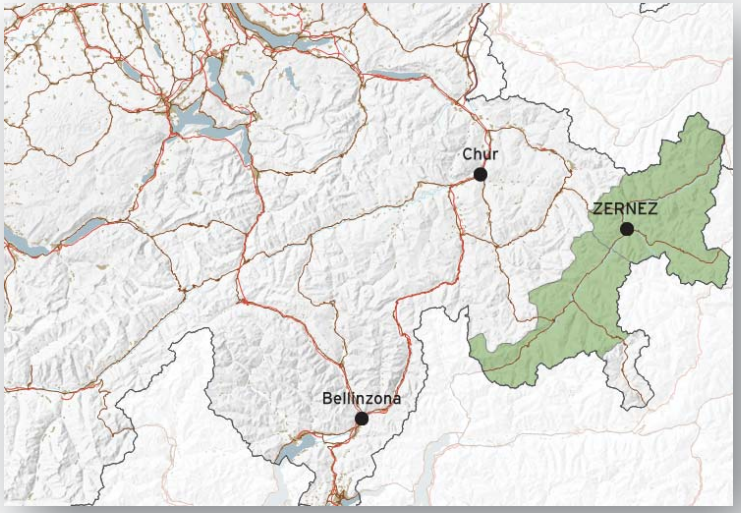
Other modelling research topics

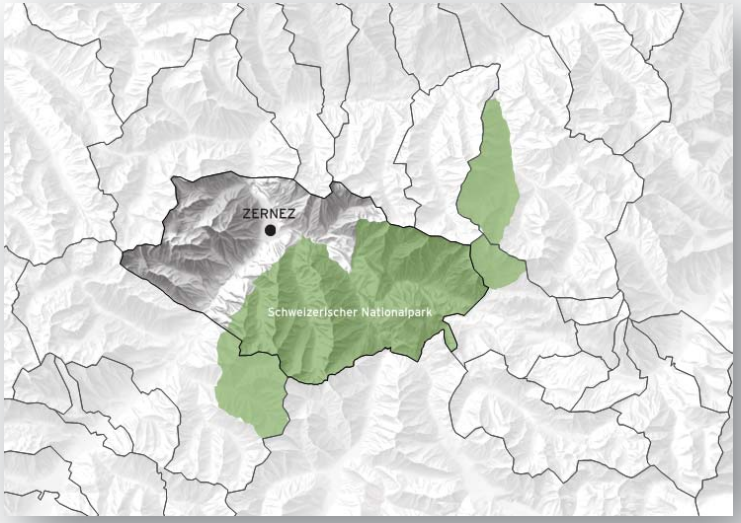



Zernez
Designing an energy
sustainable community

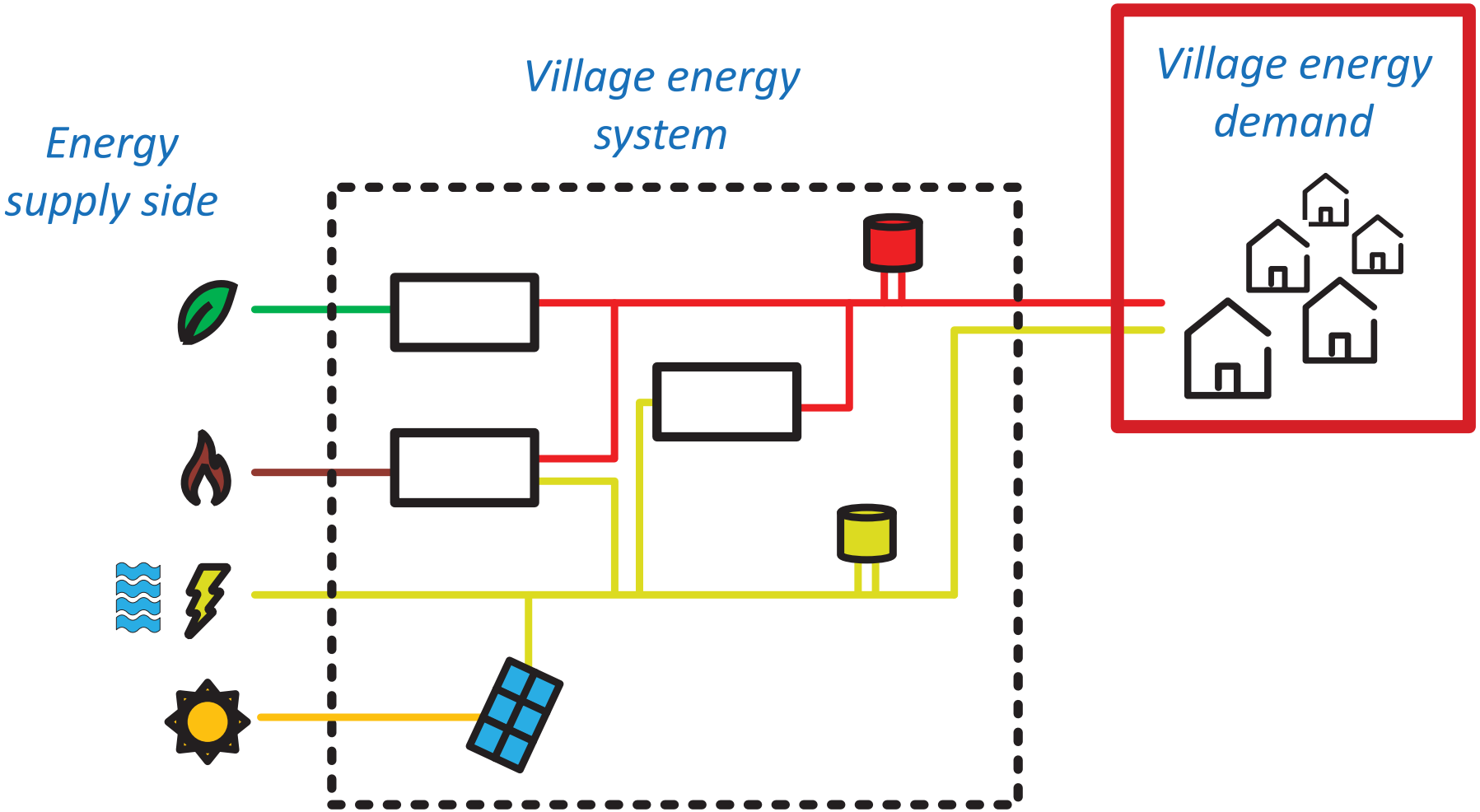
Zernez, Switzerland

- Small alpine village at Canton Graubunden
  - Elevation: 1‘474m
  - Population: 1‘153 citizens
  - ~ 300 buildings
- Ambitious goals by 2050
  - Eliminating use of fossil fuels
  - Achieve 100% supply of energy demands with local renewable energy



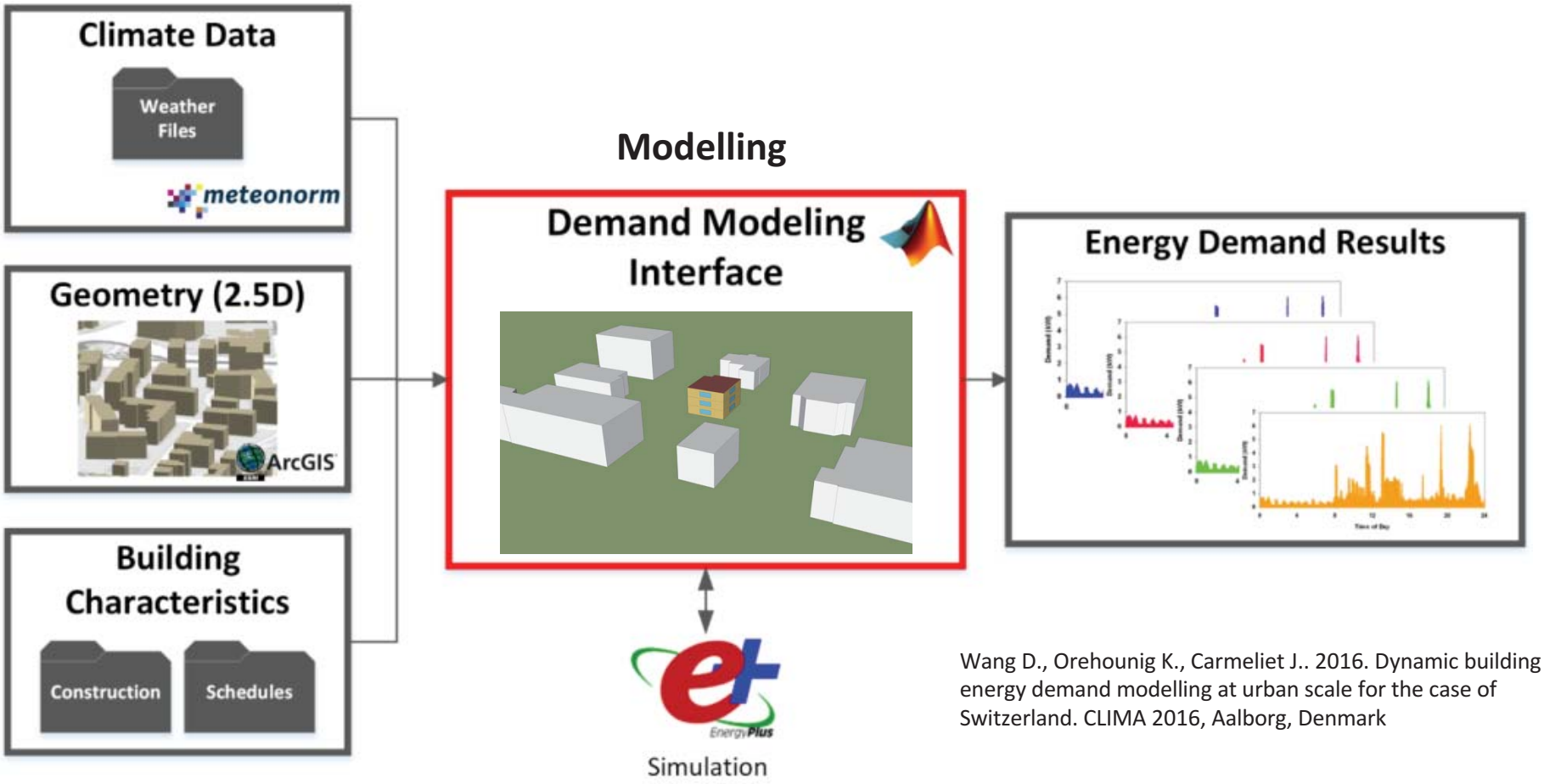


Community energy system design



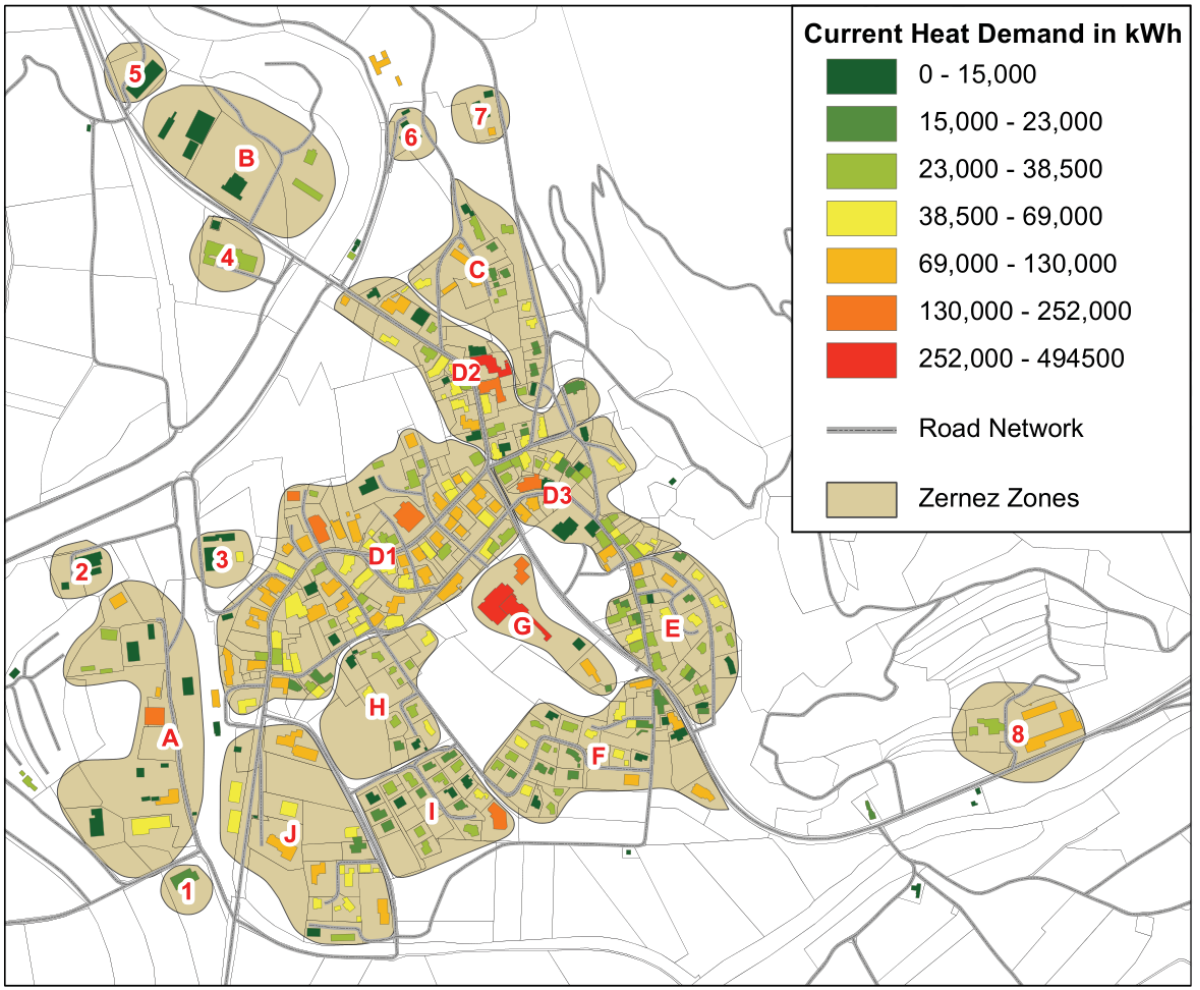
Dynamic building energy demand modelling

Building data



Wang D., Orehounig K., Carmeliet J.. 2016. Dynamic building energy demand modelling at urban scale for the case of Switzerland. CLIMA 2016, Aalborg, Denmark

Geospatial analysis of building energy demands & potential for building retrofits



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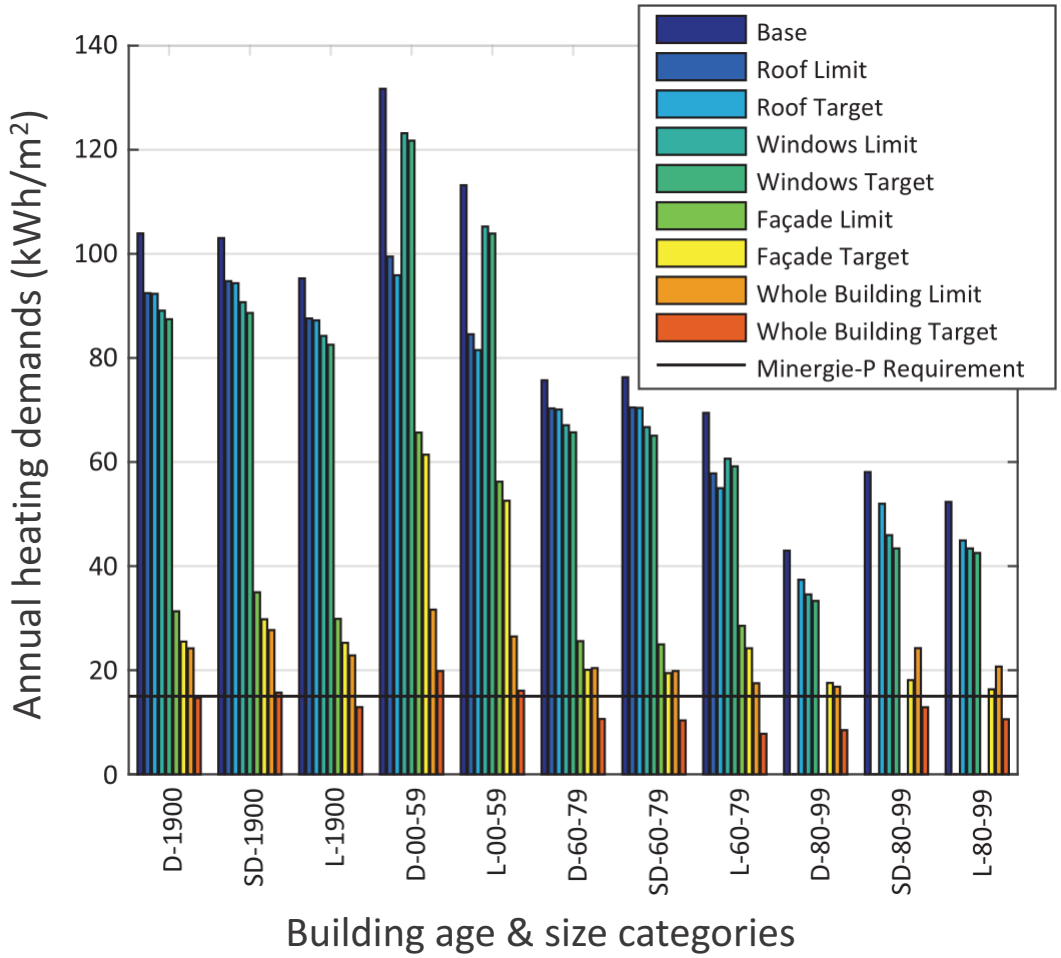

R. Wu, G. Mavromatidis, K. Orehounig, J. Carmeliet, Multiobjective optimisation of energy systems and building envelope retrofit in a residential community, Applied Energy. 190 (2017) 634–649.

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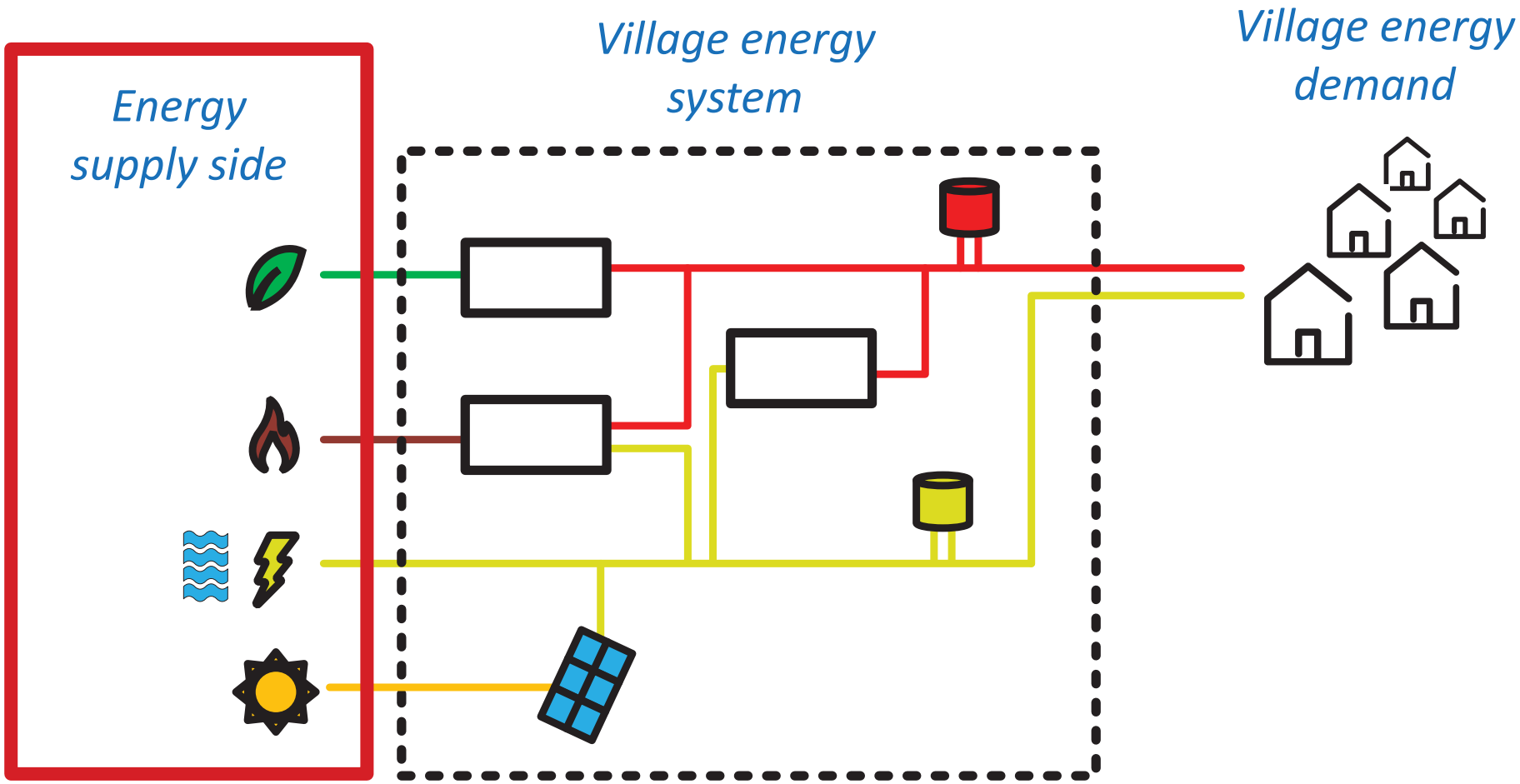
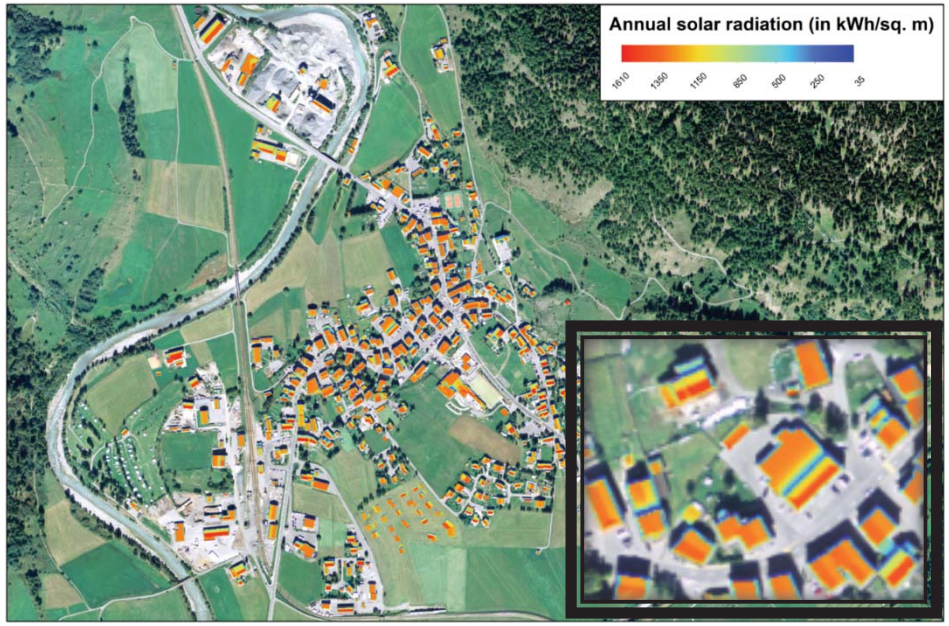
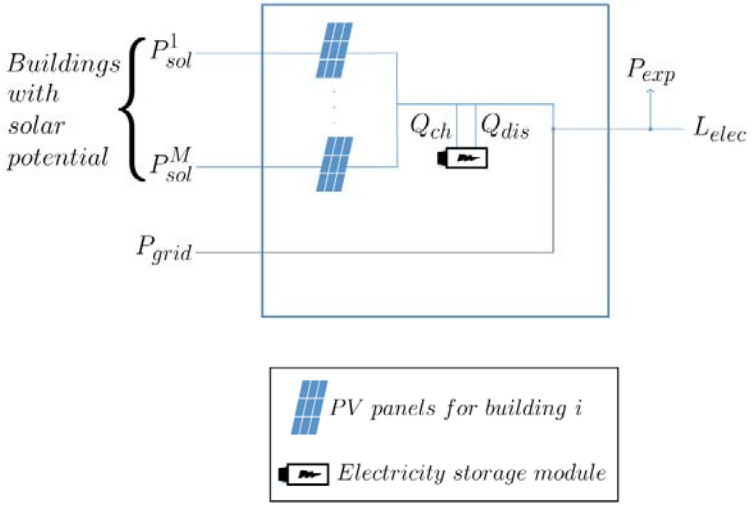


Evaluation of photovoltaic integration potential

What is Zernez’s solar potential and what are the optimal roofs for photovoltaic installations?





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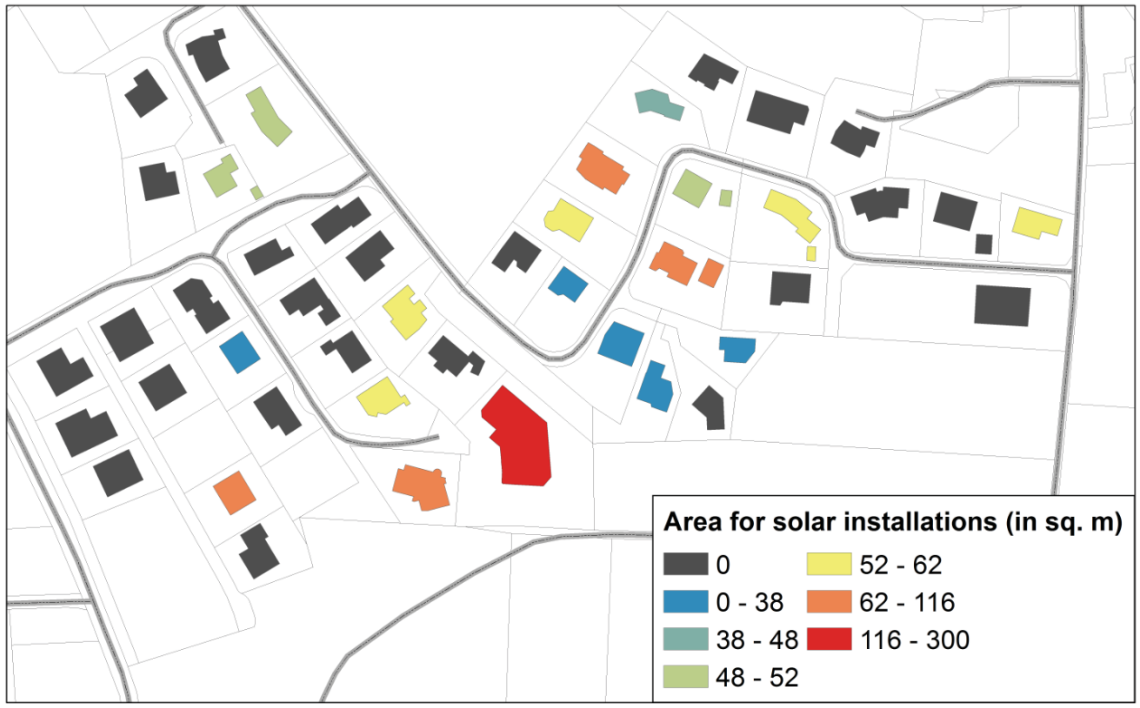

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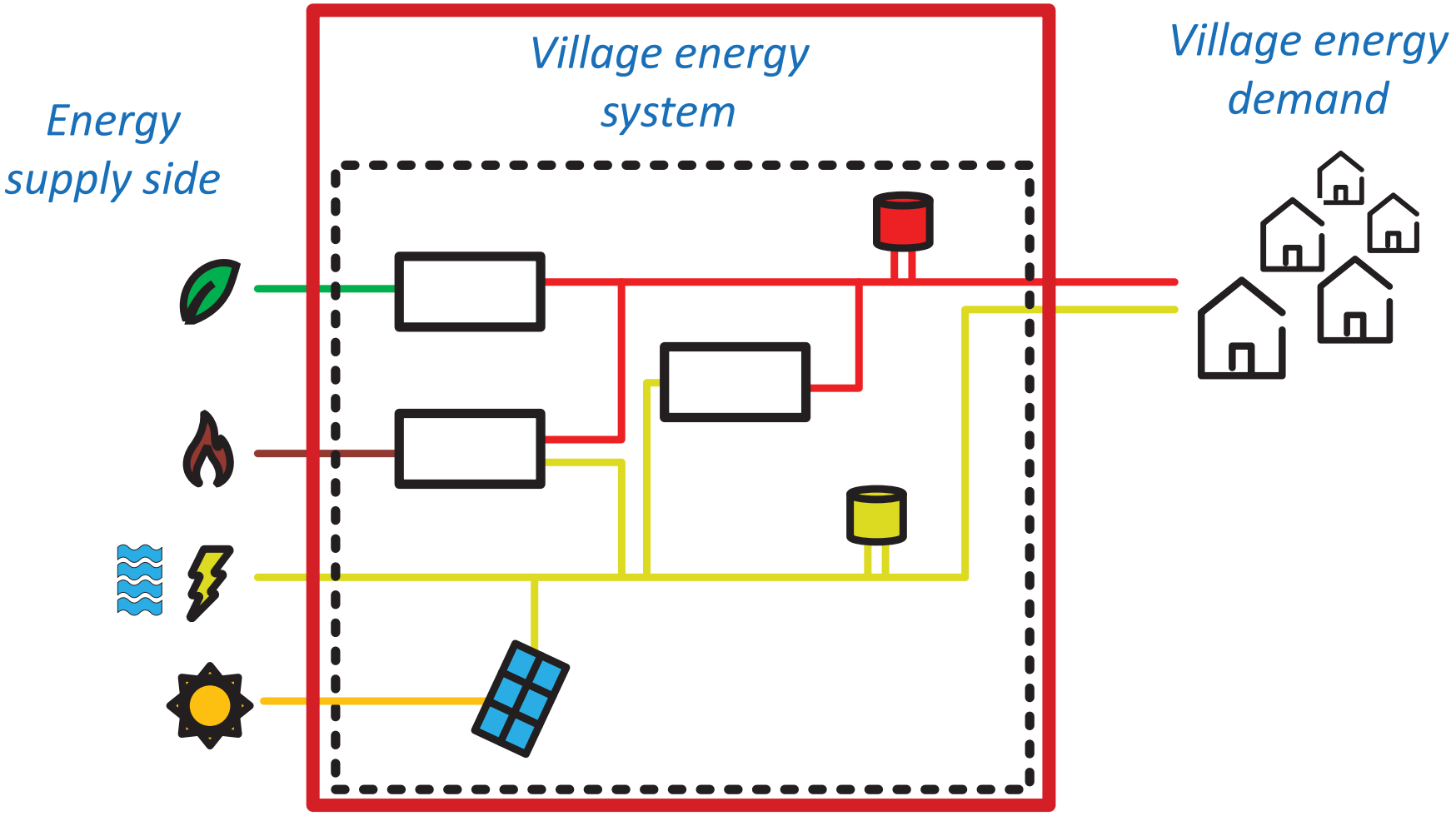
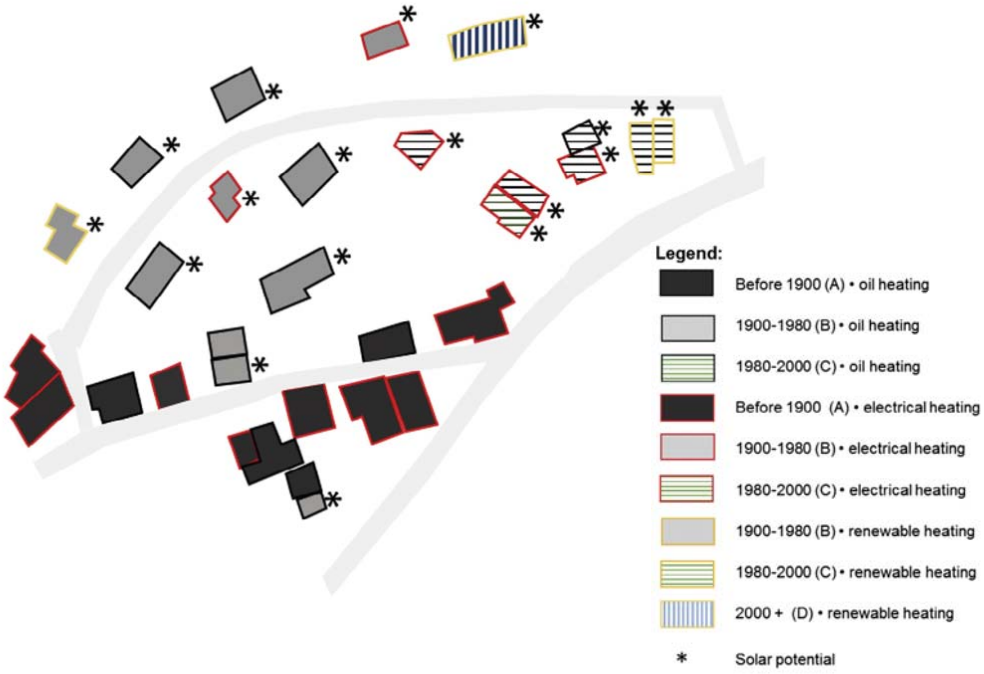
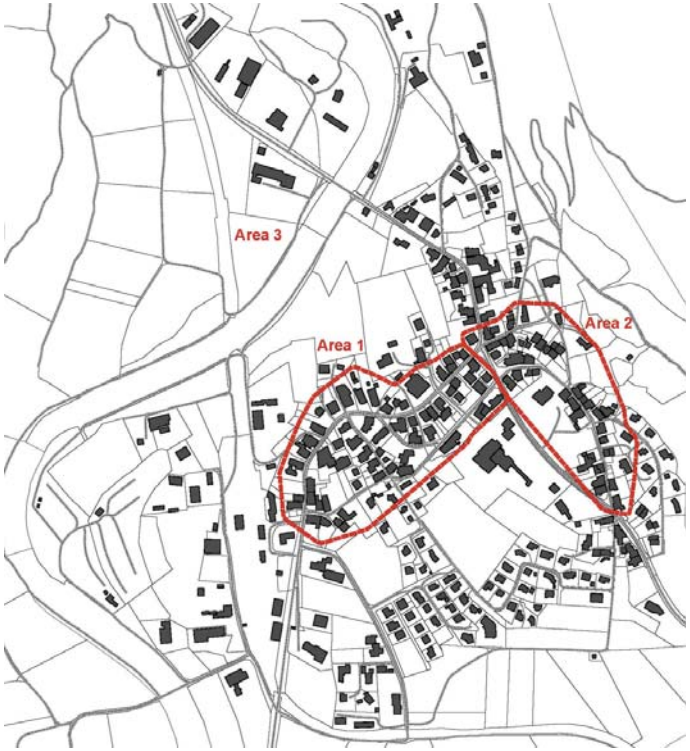


Design of Zernez’s energy system

Neighbourhood-scale



Community-scale



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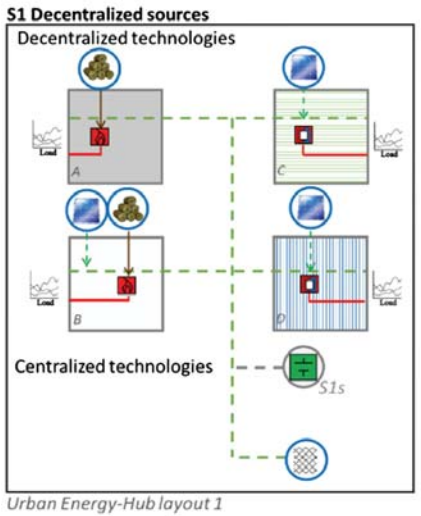
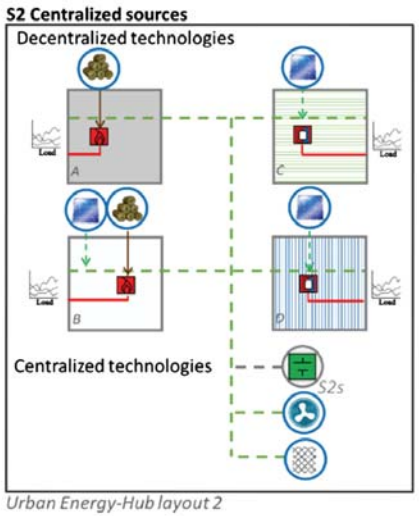
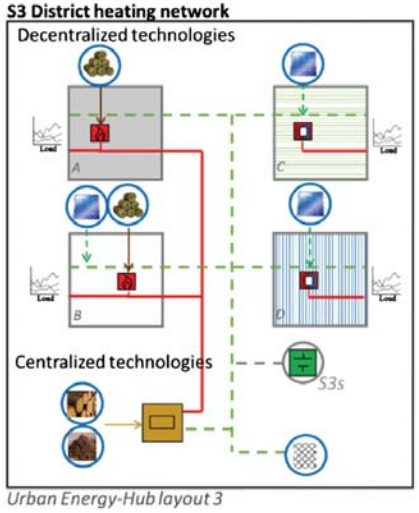


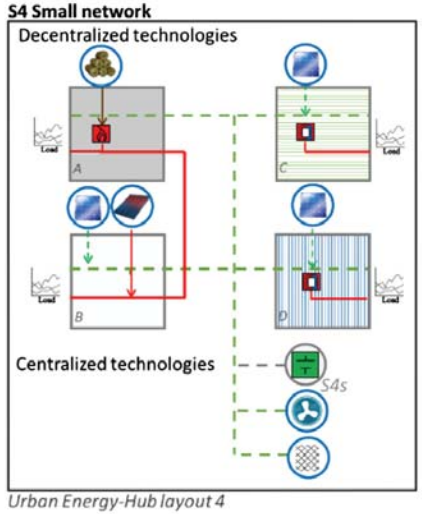
Decentralised technologies



Decentralised technologies + Micro-hydro



Decentralised technologies + CHP-powered district heating



Decentralised technologies + Micro-hydro + Small thermal network

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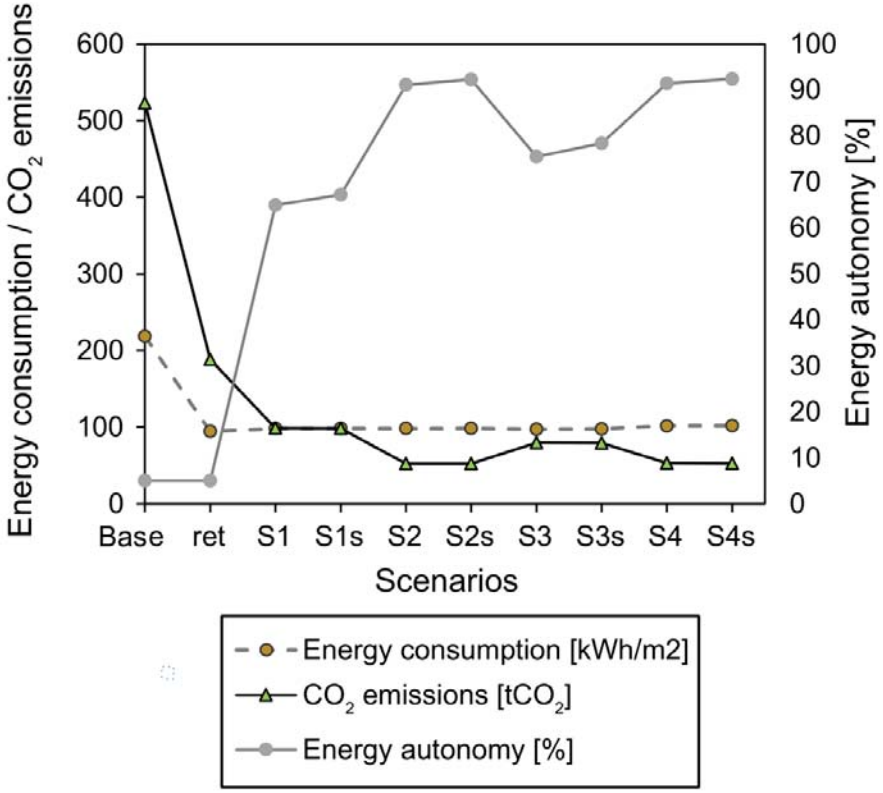

	Neighbourhood	Village
Energy autonomy	**92%**	**83%**
Energy consumption	**-55%**	**-62%**
CO_2 emissions	**-90%**	**-86%**

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Rural vs Urban conditions

Different settings – Same modelling approaches

Rural case: Zernez

Urban case: Zurich

Rural vs Urban conditions

Different settings – Same modelling approaches

Rural case: Zernez

Urban case: Zurich

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Swiss Confederation

Federal Department of Economic Affairs,
Education and Research EAER
Commission for Technology and Innovation CTI
Innovation Promotion Agency

Thank you for your attention

Georgios Mavromatidis

gmavroma@ethz.ch

Chair of Building Physics, ETH Zurich
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References

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