中国科学技术大学

Open Source Modelling and Optimisation of Energy Infrastructure at Urban Scale

Final presentation

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Outline

Section 1

Energy, Infrastructure, City

Motivation

Questions about Germany's Climate Action Plan 2050 (BMUB 2015/16)

1. How can the almost complete transition from fossil fuels to renewable energy sources for electricity generation be accomplished by 2050?

http://www.klimaschutzplan2050.de/en/action-areas/energy-sector/

Motivation

Questions about Germany's Climate Action Plan 2050 (BMUB 2015/16)

1. How can the almost complete transition from fossil fuels to renewable energy sources for electricity generation be accomplished by 2050?
2. How can we build acceptance for a timely grid expansion?

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Motivation

Questions about Germany's Climate Action Plan 2050 (BMUB 2015/16)

1. How can the almost complete transition from fossil fuels to renewable energy sources for electricity generation be accomplished by 2050?
2. How can we build acceptance for a timely grid expansion?
3. What proportion of fossil fuel burning power stations do we need for a transitional period, and for how long?

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Motivation

Questions about Germany's Climate Action Plan 2050 (BMUB 2015/16)

1. How can the almost complete transition from fossil fuels to renewable energy sources for electricity generation be accomplished by 2050?
2. How can we build acceptance for a timely grid expansion?
3. What proportion of fossil fuel burning power stations do we need for a transitional period, and for how long?
4. Which role do decentralised energy supply concepts play?

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Questions about Germany's Climate Action Plan 2050 (BMUB 2015/16)

1. How can the almost complete transition from fossil fuels to renewable energy sources for electricity generation be accomplished by 2050?
2. How can we build acceptance for a timely grid expansion?
3. What proportion of fossil fuel burning power stations do we need for a transitional period, and for how long?
4. Which role do decentralised energy supply concepts play?
5. How can the electricity and heating/cooling markets be more closely integrated [⋯]?

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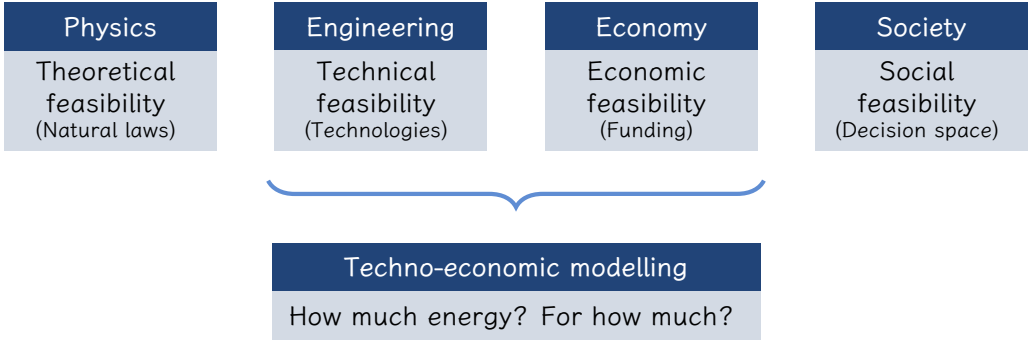
Perspective

Physics	Engineering	Economy	Society
Theoretical feasibility (Natural laws)	Technical feasibility (Technologies)	Economic feasibility (Funding)	Social feasibility (Decision space)

Perspective

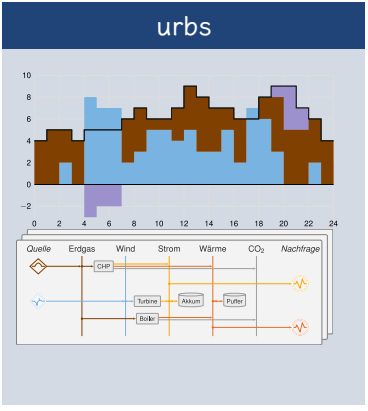


Section 2

Mathematical modelling, optimisation, case study

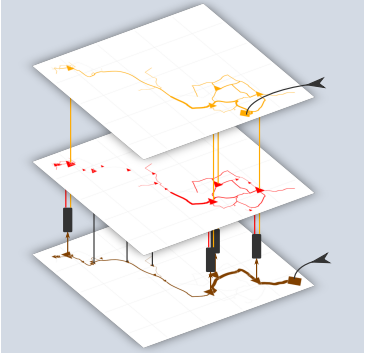
Model overview

urbs



https://github.com/tum-ens/urbs

rivus



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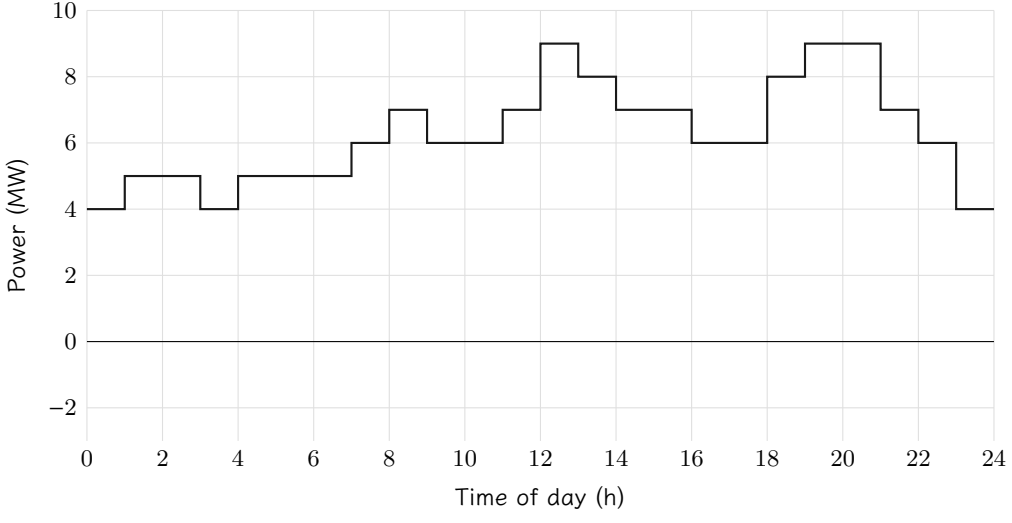
urbs

Principle illustrated



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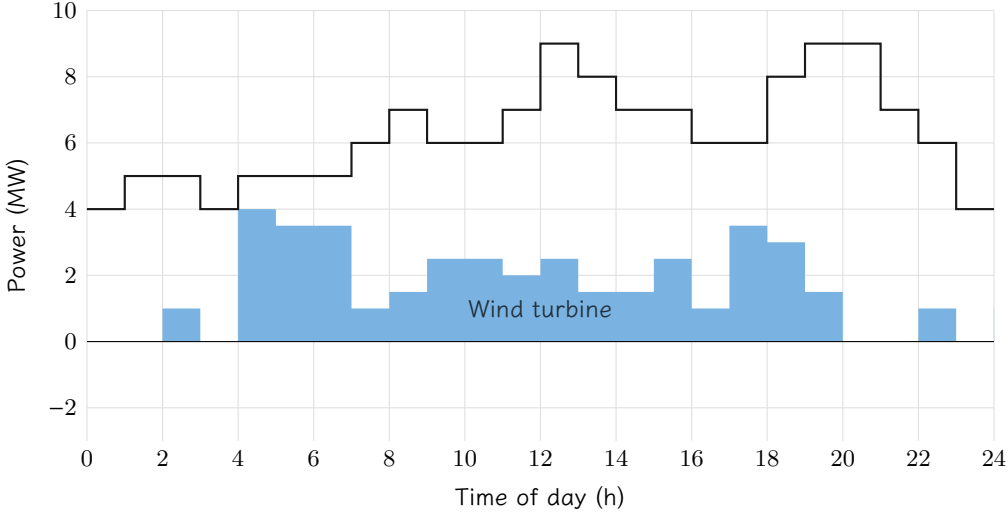

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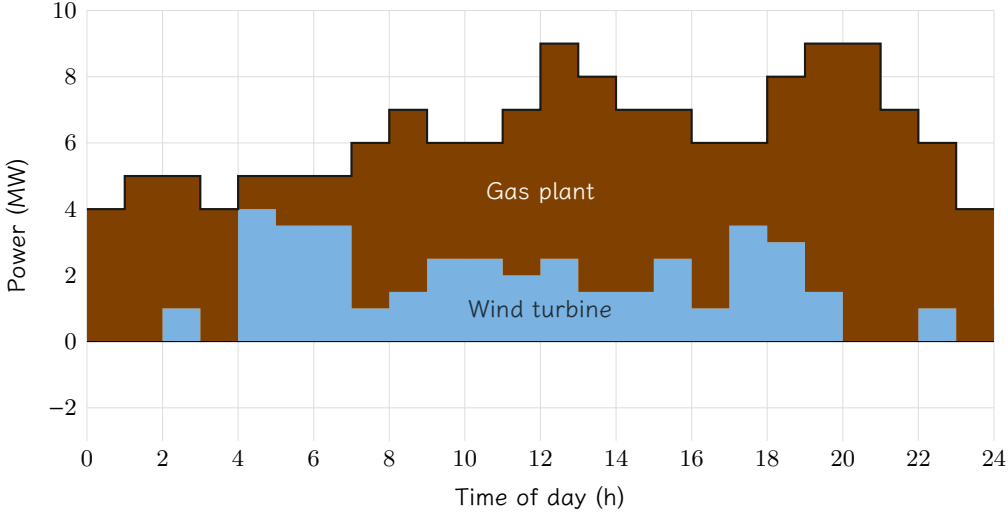

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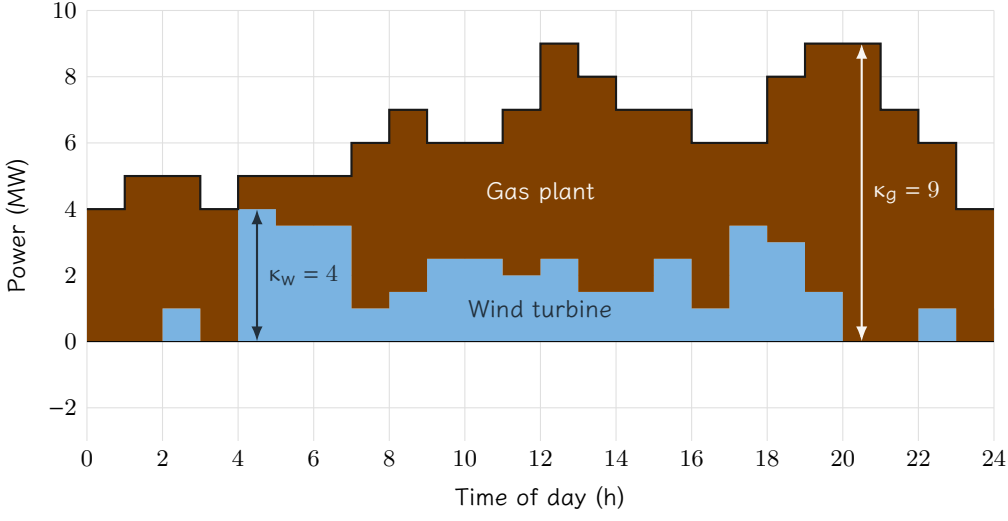

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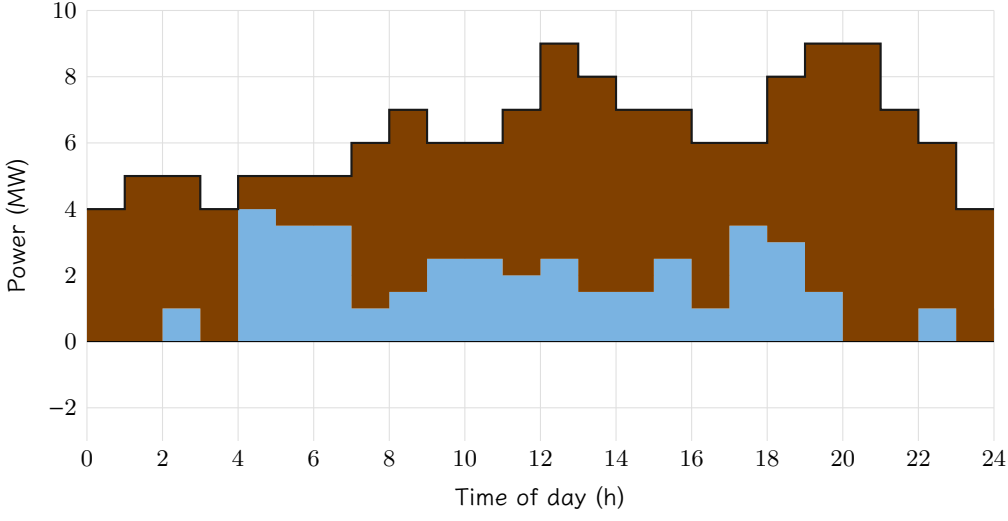

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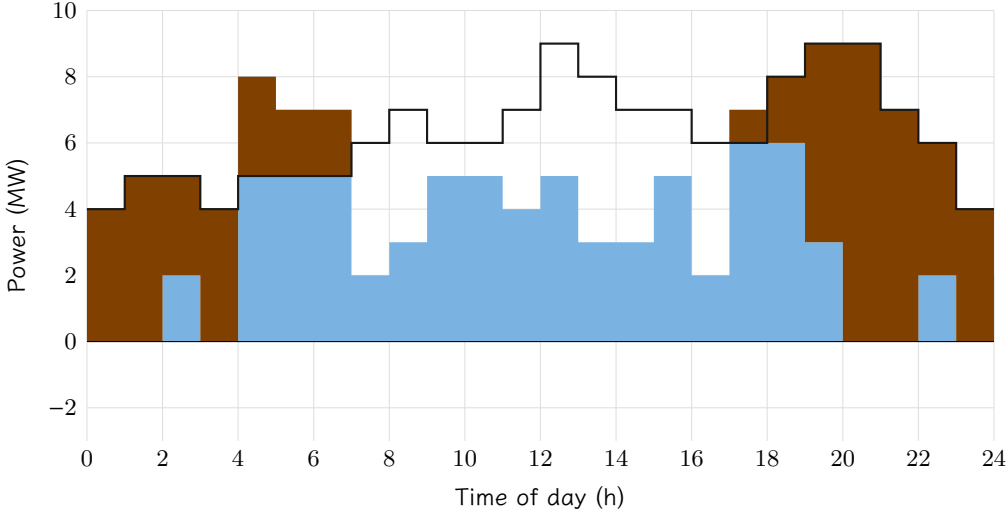

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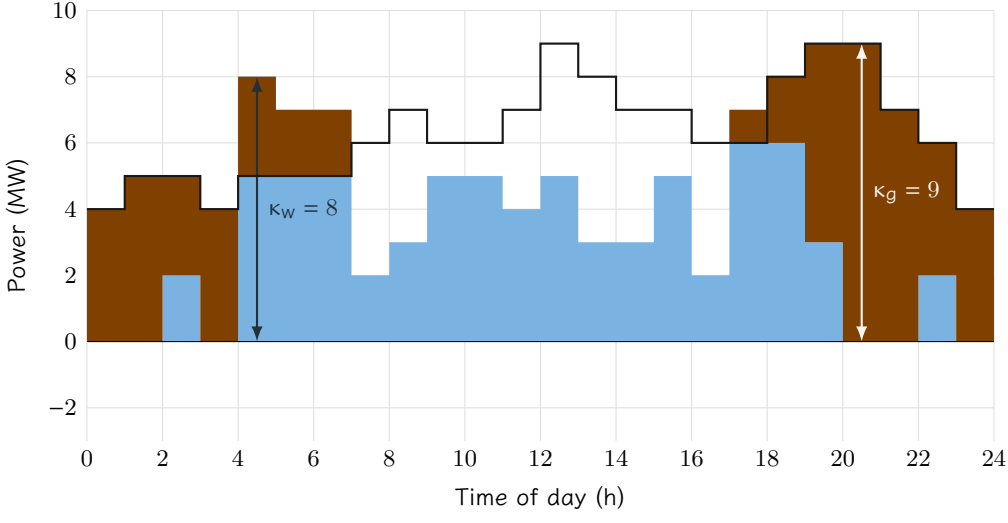

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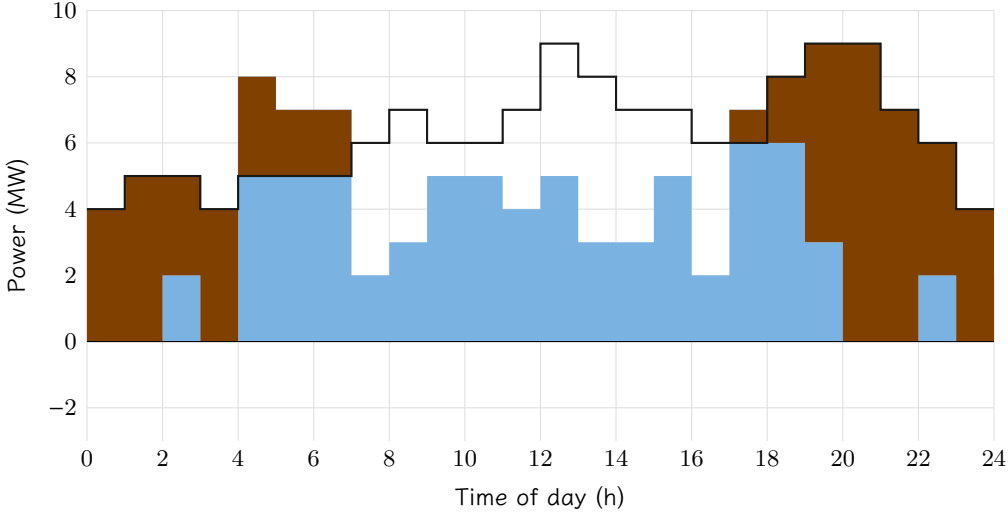

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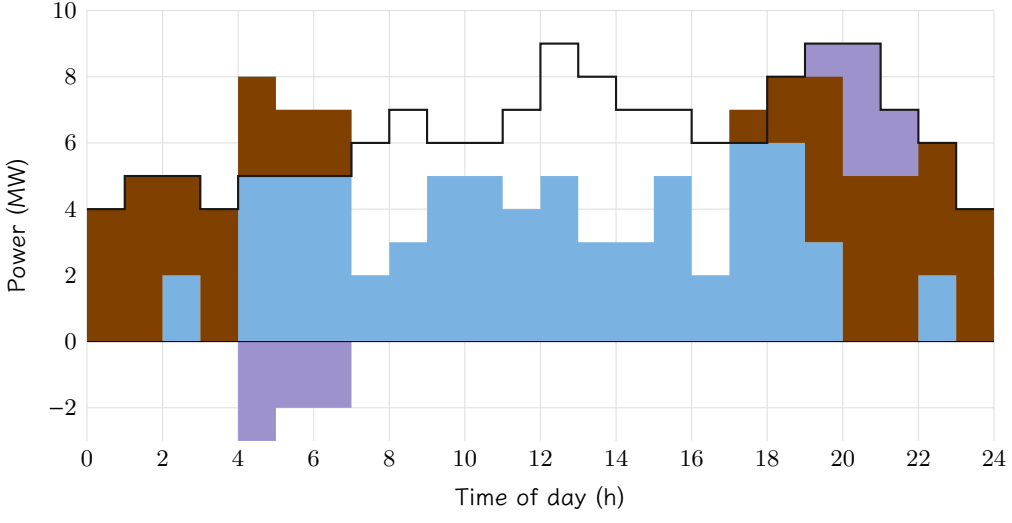

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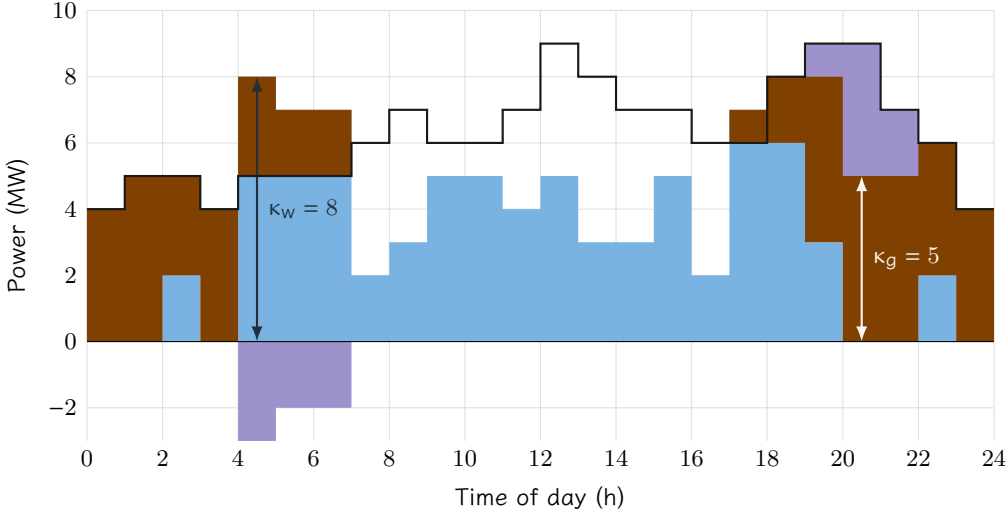

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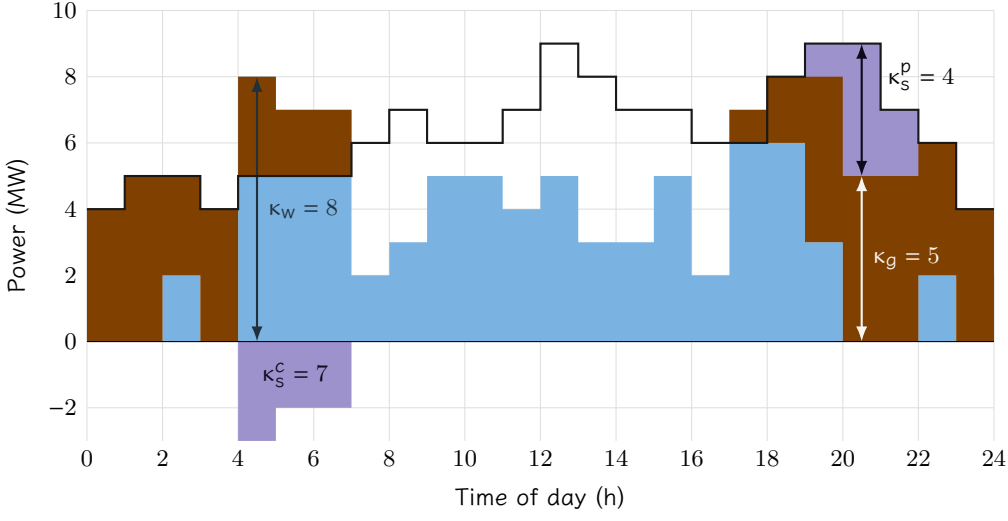

Notation as mathematical optimisation problem

Sets	$t \in T,\ p \in P,\ s \in S,\ \ldots$
Parameters	d_t

Notation as mathematical optimisation problem

Sets	$t \in T,\ p \in P,\ s \in S,\ \ldots$
Parameters	$d_t,\ k_p^{fix},\ k_s^{fix,c},\ k_s^{fix,p}$

Notation as mathematical optimisation problem

Sets $t \in T,\ p \in P,\ s \in S,\ \ldots$

Parameters $d_t,\ k_p^{fix},\ k_s^{fix,c},\ k_s^{fix,p},\ k_p^{var},\ k_s^{var},\ \ldots$

Notation as mathematical optimisation problem

Sets	$t \in T,\ p \in P,\ s \in S,\ \ldots$
Parameters	$d_t,\ k_p^{fix},\ k_s^{fix,c},\ k_s^{fix,p},\ k_p^{var},\ k_s^{var},\ \ldots$
Variables	$\kappa_p,\ \kappa_s^c,\ \kappa_s^p$

Notation as mathematical optimisation problem

Sets	$t \in T,\ p \in P,\ s \in S,\ \ldots$
Parameters	$d_t,\ k_p^{fix},\ k_s^{fix,c},\ k_s^{fix,p},\ k_p^{var},\ k_s^{var},\ \ldots$
Variables	$\kappa_p,\ \kappa_s^c,\ \kappa_s^p,\ \epsilon_{pt},\ \epsilon_{st}^{in},\ \epsilon_{st}^{out},\ \epsilon_{st}^{con},\ \ldots$

Notation as mathematical optimisation problem

$$
\begin{aligned}
\text{Sets} \quad & t \in T,\ p \in P,\ s \in S,\ \dots \\
\text{Parameters} \quad & d_t,\ k_p^{fix},\ k_s^{fix,c},\ k_s^{fix,p},\ k_p^{var},\ k_s^{var},\ \dots \\
\text{Variables} \quad & \kappa_p,\ \kappa_s^c,\ \kappa_s^p,\ \epsilon_{pt},\ \epsilon_{st}^{in},\ \epsilon_{st}^{out},\ \epsilon_{st}^{con},\ \dots \\
\text{Objective} \quad & \min \sum_{p \in P} \left(k_p^{fix} \kappa_p + \sum_{t \in T} k^{var} \epsilon_{pt} \right) + \\
& \sum_{s \in S} \left(k_s^{fix,c} \kappa_s^c + k_s^{fix,p} \kappa_s^p + \sum_{t \in T} k_s^{var} \left(\epsilon_{st}^{in} + \epsilon_{st}^{out} \right) \right)
\end{aligned}
$$

Notation as mathematical optimisation problem

$$
\begin{aligned}
\text{Sets} \quad & t \in T,\ p \in P,\ s \in S,\ \dots \\
\text{Parameters} \quad & d_t,\ k_p^{fix},\ k_s^{fix,c},\ k_s^{fix,p},\ k_p^{var},\ k_s^{var},\ \dots \\
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& \sum_{s \in S} \left(k_s^{fix,c} \kappa_s^c + k_s^{fix,p} \kappa_s^p + \sum_{t \in T} k_s^{var} \left(\epsilon_{st}^{in} + \epsilon_{st}^{out} \right) \right) \\
\text{Constraints} \quad & \text{s.t. } \forall t \in T\text{:} \quad \sum_{p \in P} \epsilon_{pt} + \sum_{s \in S} \left(\epsilon_{st}^{out} - \epsilon_{st}^{in} \right) = d_t \\
& \dots
\end{aligned}
$$

Standard form of linear optimisation problems (LP)

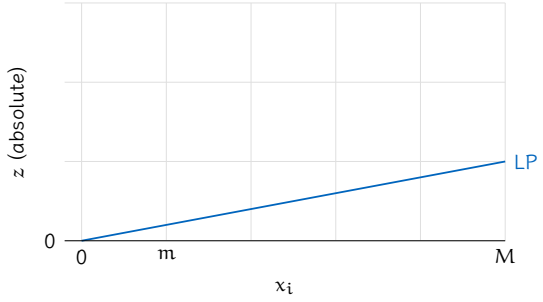
Generic form

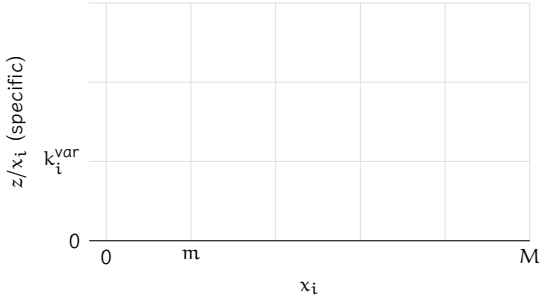
$$\min_{\mathbf{x}} \; z = \mathbf{c}^{\mathsf{T}}\mathbf{x}$$

$$\text{s.t. } \mathbf{A}\boldsymbol{x} \leqslant \mathbf{b}$$

$$\text{with } \boldsymbol{x} \in \mathbb{R}^{n},\ \mathbf{A} \in \mathbb{R}^{m \times n},$$
$$\mathbf{b} \in \mathbb{R}^{m},\ \mathbf{c} \in \mathbb{R}^{n}.$$

Mixed-integer linear programming (MILP)

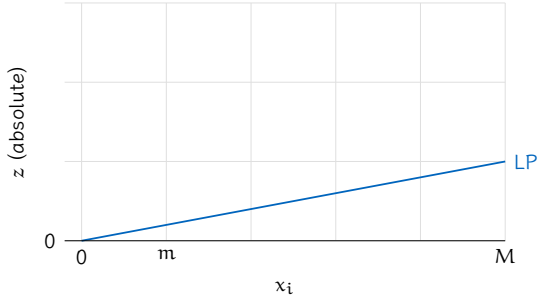




LP $z = k_i^{var} x_i$

$x_i \leqslant M$

Mixed-integer linear programming (MILP)



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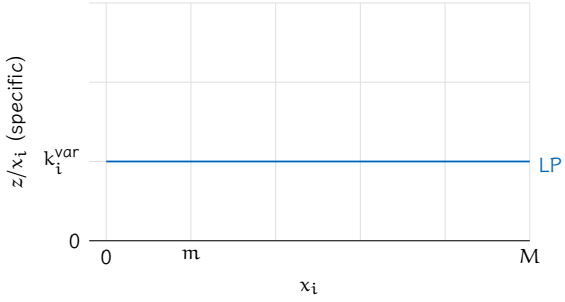
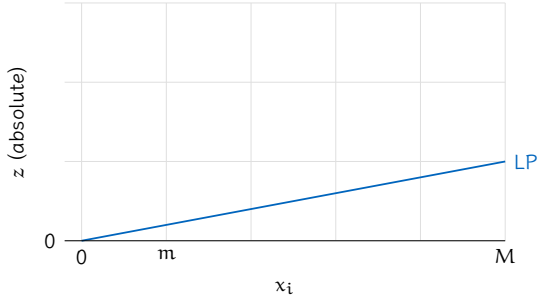
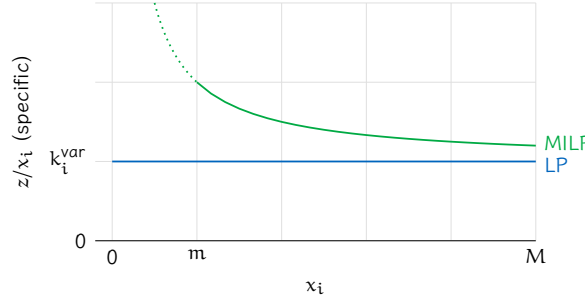


LP $\frac{z}{x_i} = k_i^{var} \equiv \text{const}$

Mixed-integer linear programming (MILP)





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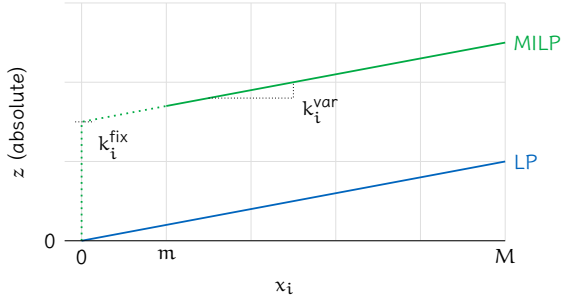
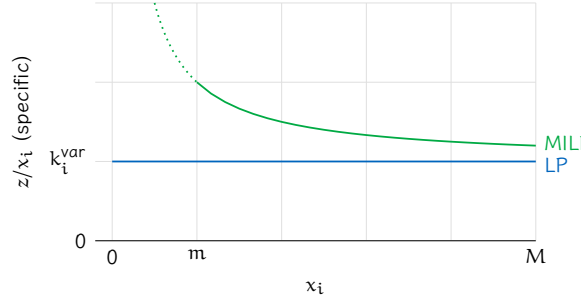
$x_i \leqslant M$

LP $\frac{z}{x_i} = k_i^{var} \equiv \text{const}$

MILP $\frac{z}{x_i} = k_i^{var} + \frac{k_i^{fix}}{x_i}$

Mixed-integer linear programming (MILP)





LP $\quad z = k_i^{var} x_i$

$x_i \leqslant M$

MILP $\quad z = k_i^{fix} y_i + k_i^{var} x_i$

$y_i \in \{0, 1\}$

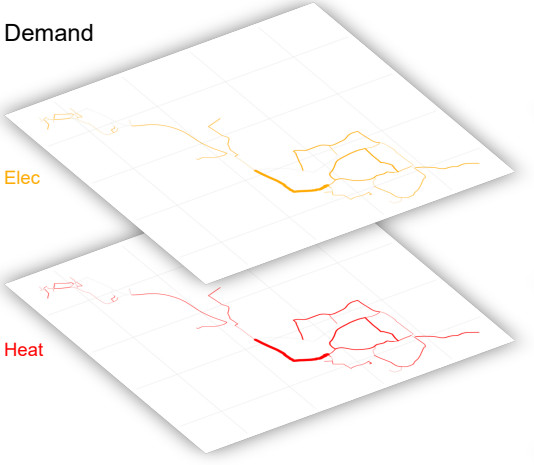
$m\, y_i \leqslant x_i \leqslant M\, y_i$

LP $\quad \dfrac{z}{x_i} = k_i^{var} \equiv \text{const}$

MILP $\quad \dfrac{z}{x_i} = k_i^{var} + \dfrac{k_i^{fix}}{x_i}$

rivus

Principle illustrated



rivus

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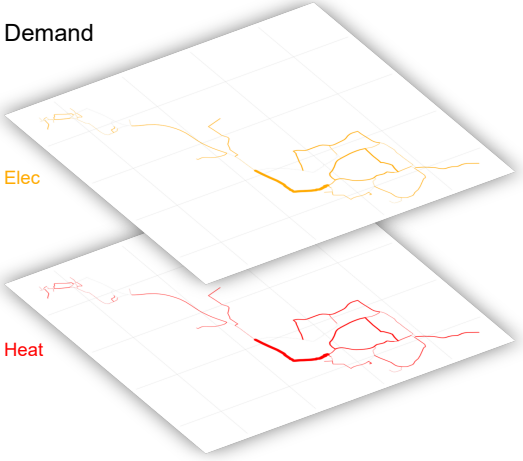
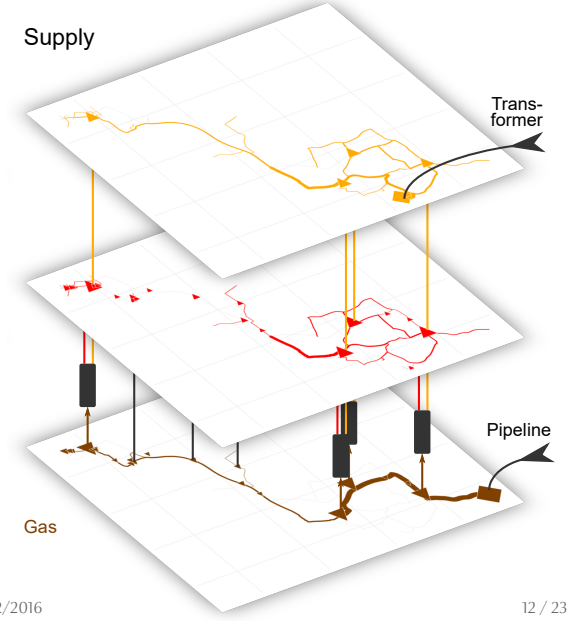
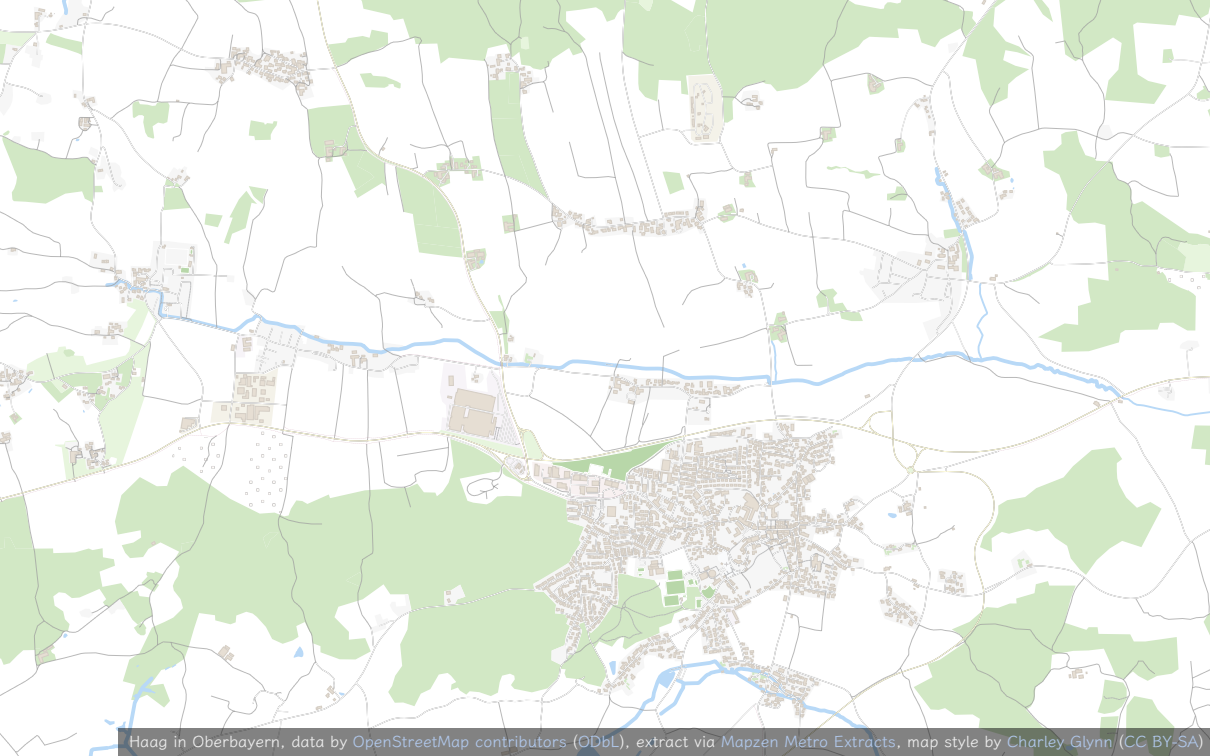
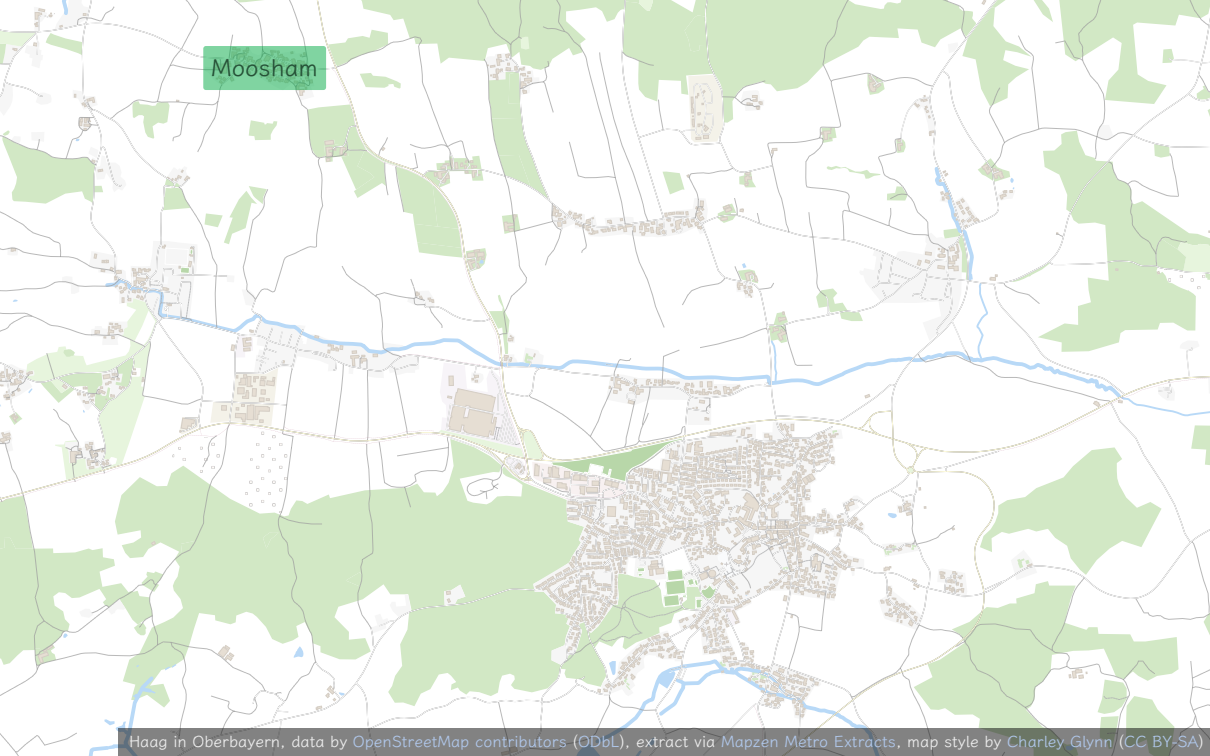
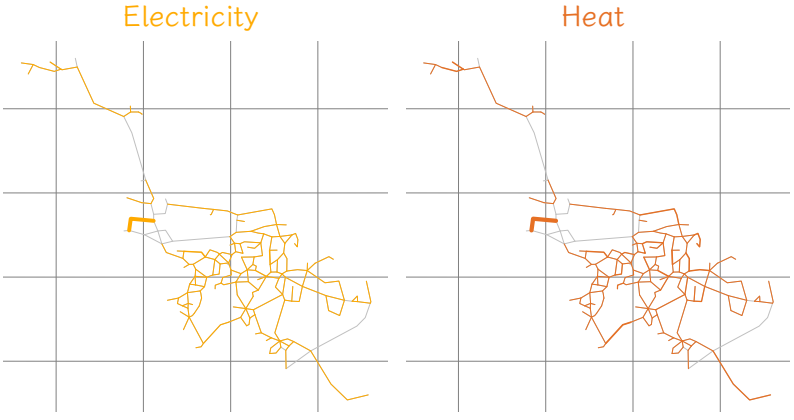





Haag in Oberbayern, data by OpenStreetMap contributors (ODbL), extract via Mapzen Metro Extracts, map style by Charley Glynn (CC BY-SA)



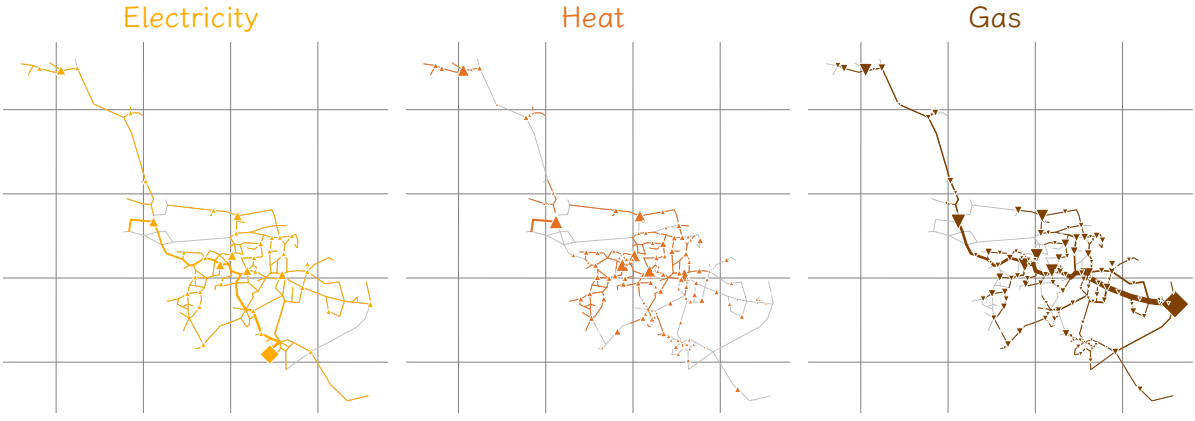
Input data rivus



Light industry (Schletter) biggest single consumer

https://github.com/tum-ens/rivus/data/haag15

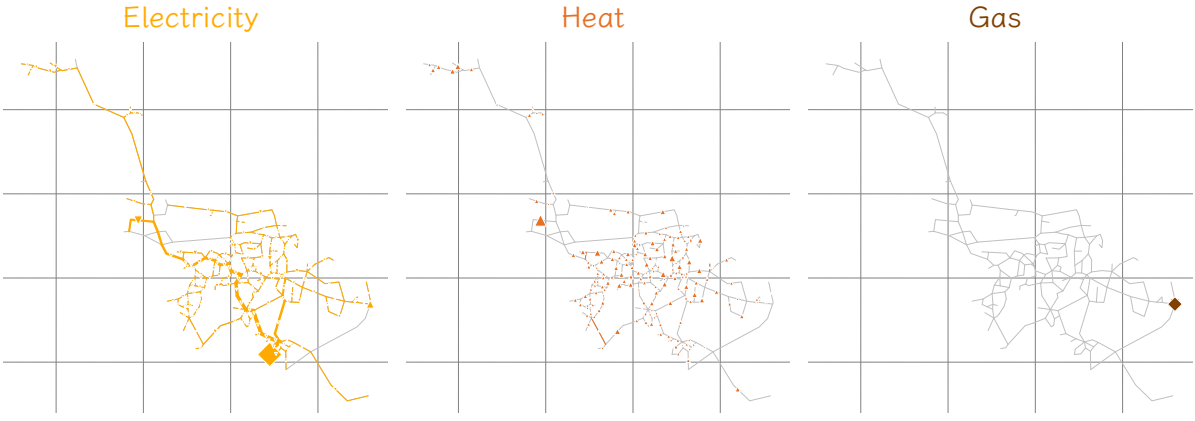
Result rivus -- Capacities in scenario base



Full networks for electricity and gas, several local heating networks

https://github.com/tum-ens/rivus/runhg15.py:scenario_no_electric_heating()

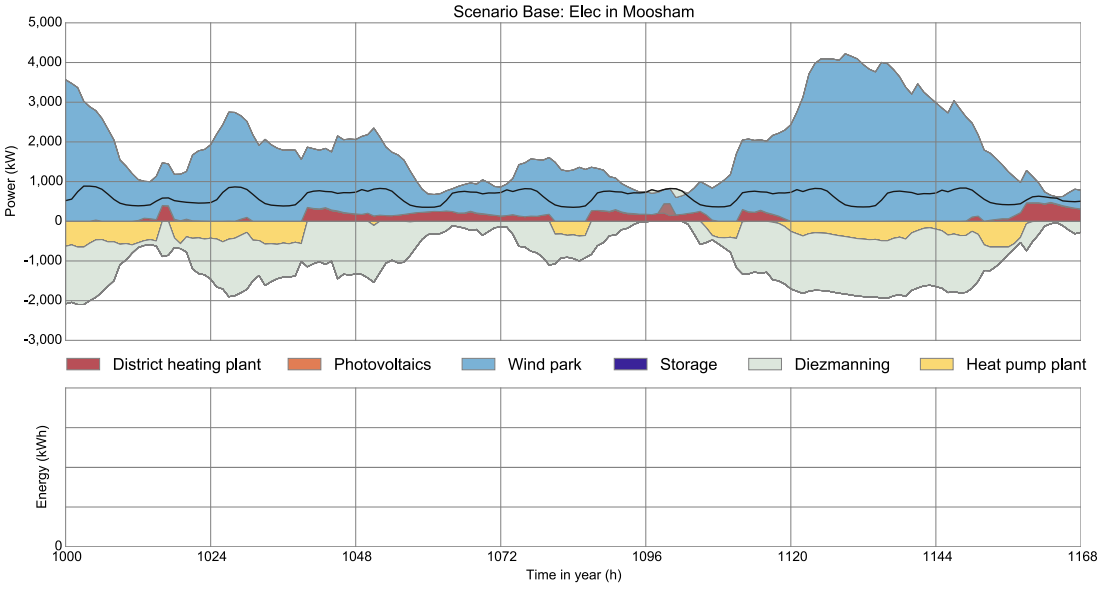
Result rivus -- Capacities in scenario future



Strong electricity grid, no gas network, only heat pumps

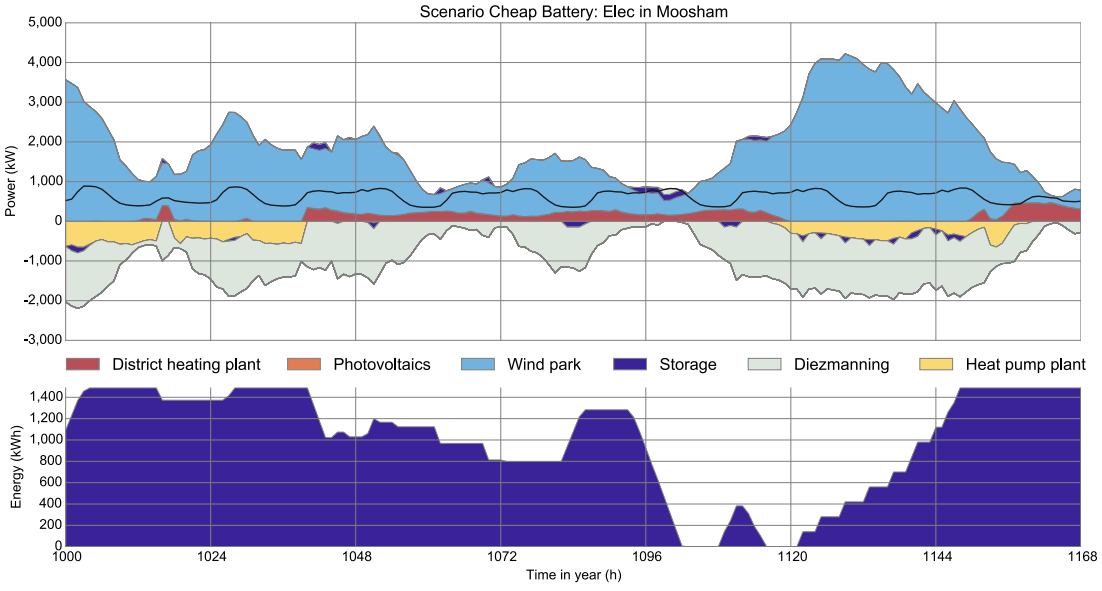
https://github.com/tum-ens/rivus/runhg15.py:scenario_renovation()

Result urbs -- 1 week electricity in scenarios base



https://github.com/ojdo/urbs/tree/haag15/`rivhg15.py:scenario_base()`

Result urbs -- 1 week electricity in scenario cheap battery



https://github.com/ojdo/urbs/tree/haag15/rivhg15.py:scenario_cheap_battery()

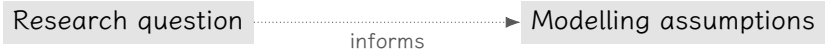
Section 3

Sustainable model use

Optimisation model workflow

Research question

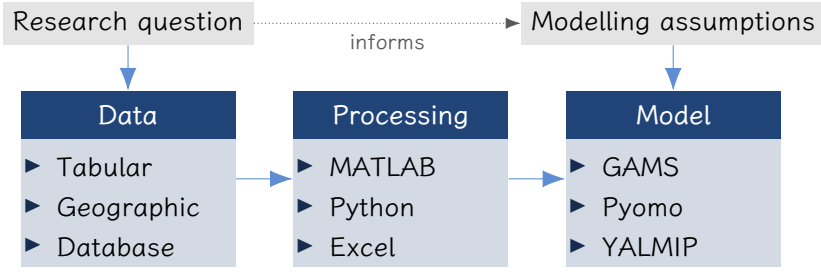
Optimisation model workflow



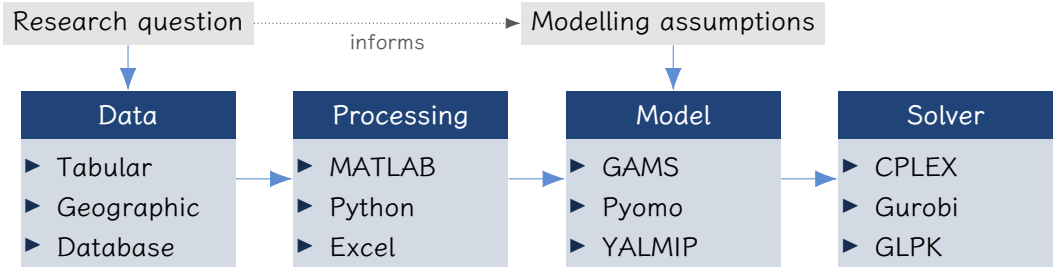
Optimisation model workflow

Optimisation model workflow

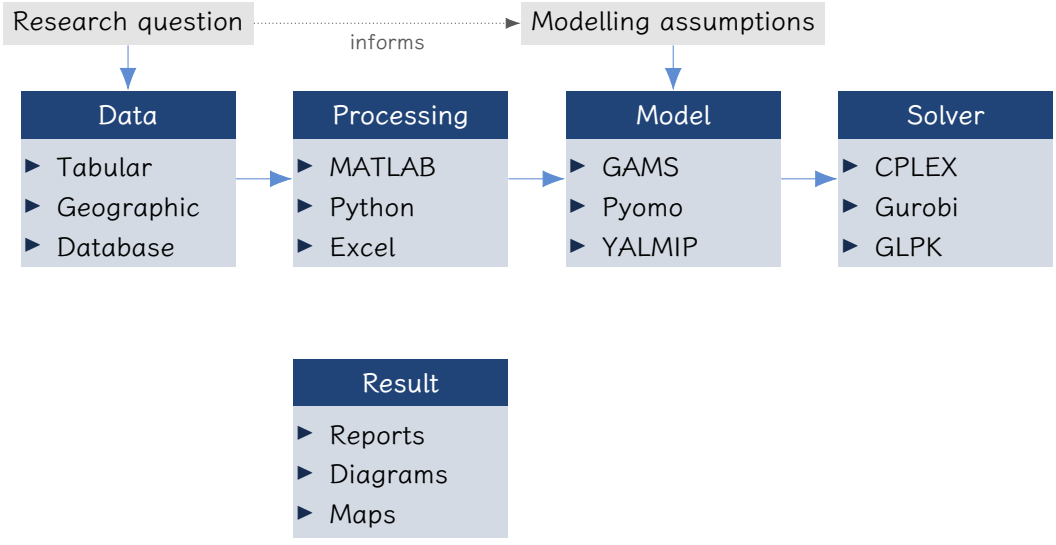
Optimisation model workflow



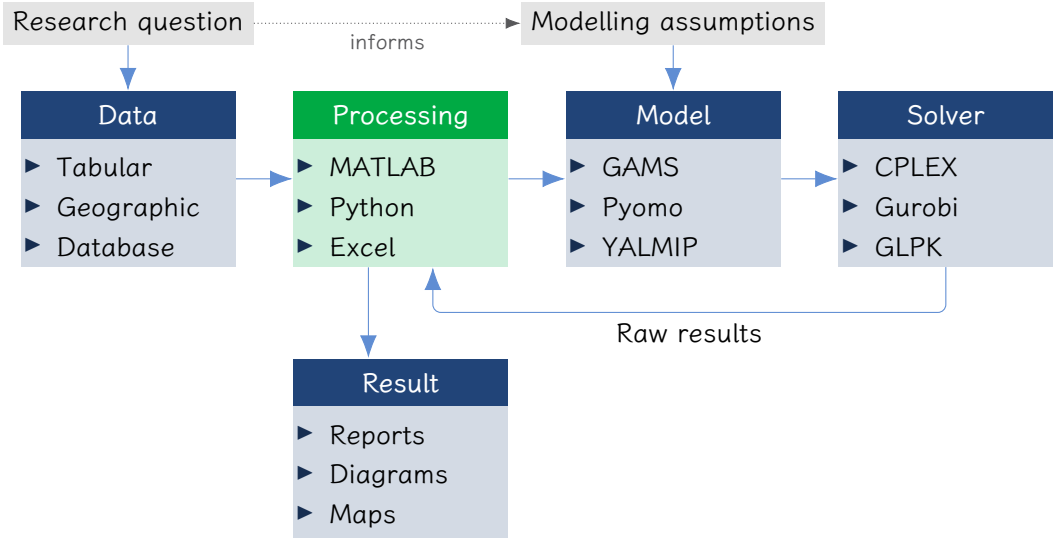
Optimisation model workflow



Optimisation model workflow



Optimisation model workflow



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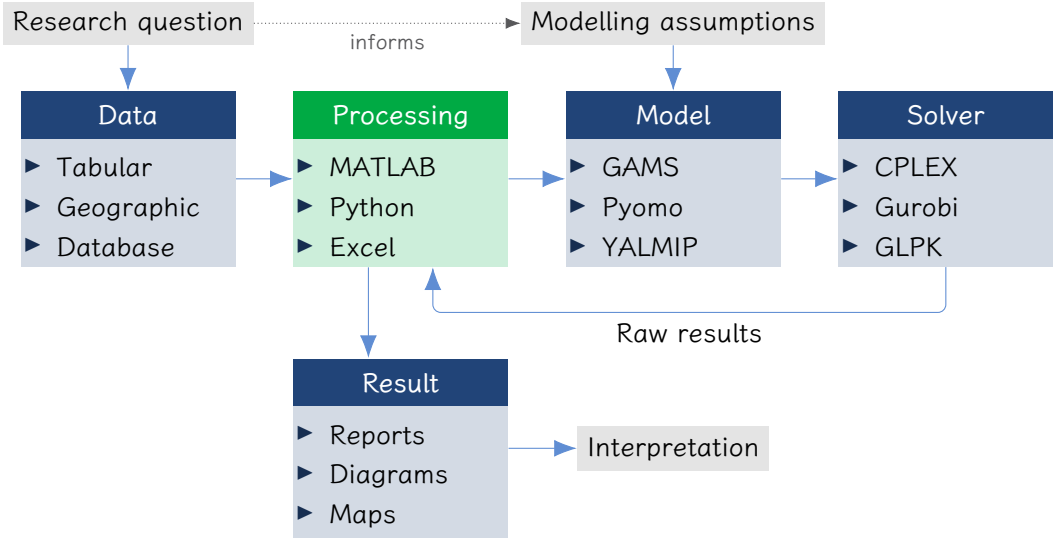
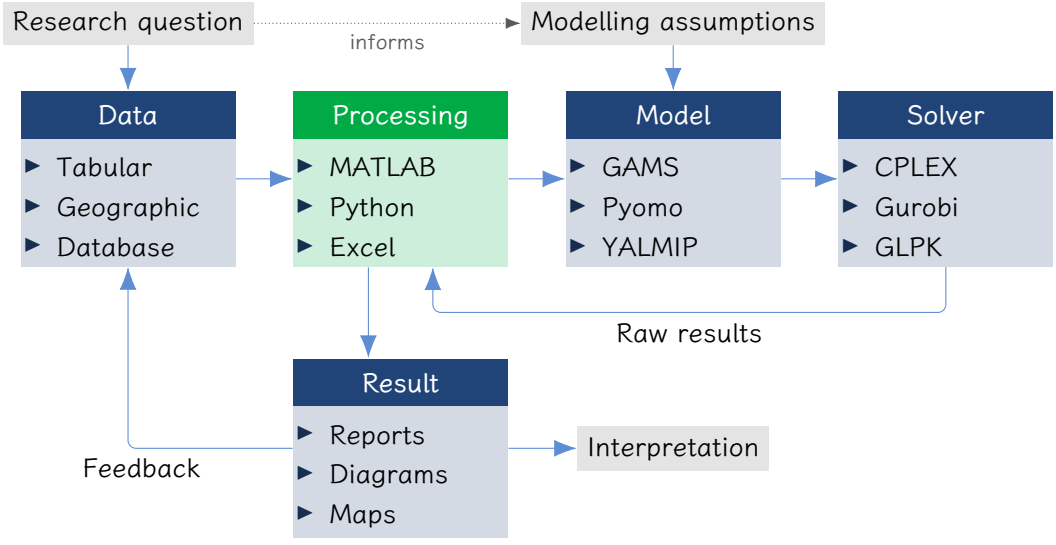


Optimisation model workflow



Distributed version control for scientific work

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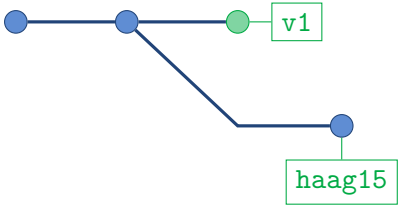

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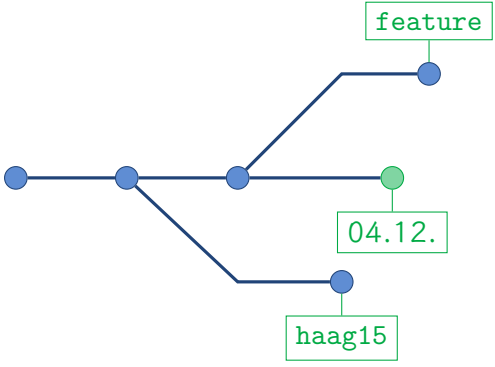
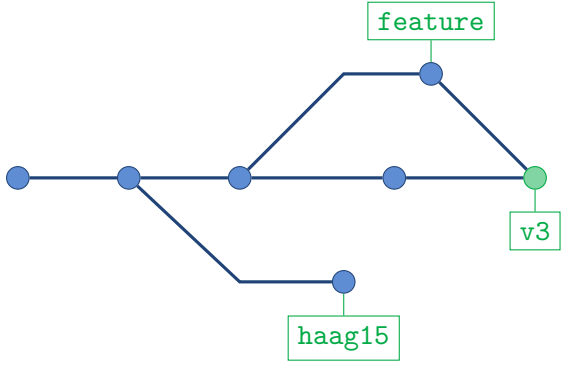
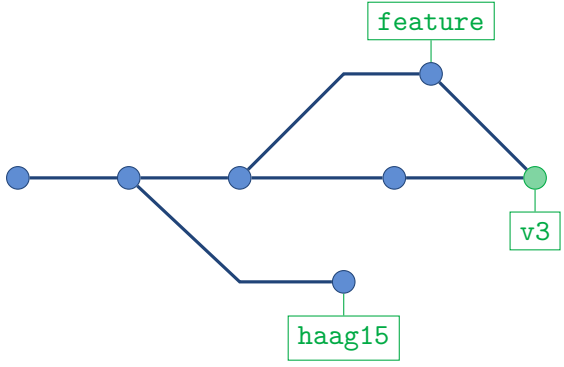


Distributed version control for scientific work



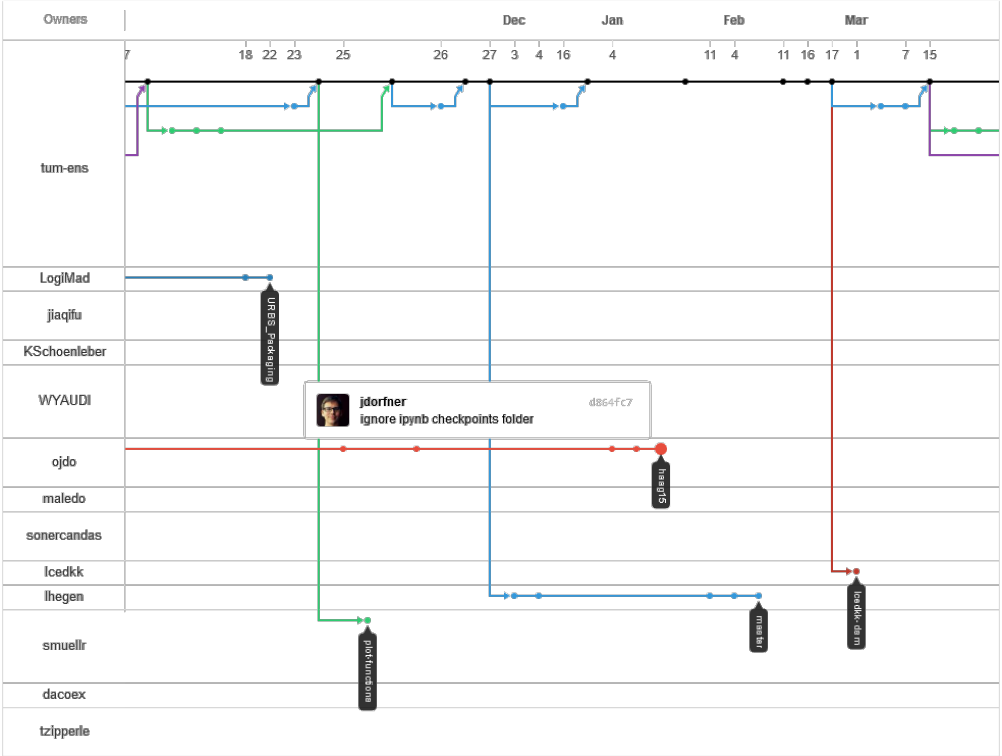
Distributed version control for scientific work



Collaboration

Development

Archival


Owners
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LogiMad
jiaqifu
KSchoenleber
WYAUDI
ojdo
maledo
sonercandas
Icedkk
lhegen
smuellr
dacoex
tzipperle
URBS_Packaging
jdorfner
d864fc7
ignore ipynb checkpoints folder
master
master
plotfunctions
master
Icedkk-dam

Conclusion

Infrastructure

Engineering

Technical feasibility (Technologies)

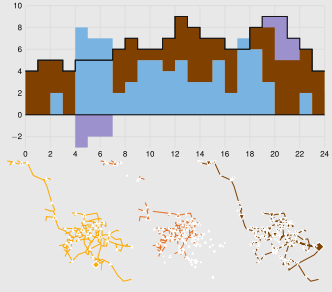
Economy

Economic feasibility (Funding)

Techno-economic modelling

How much energy? For how much?

Modelling



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