

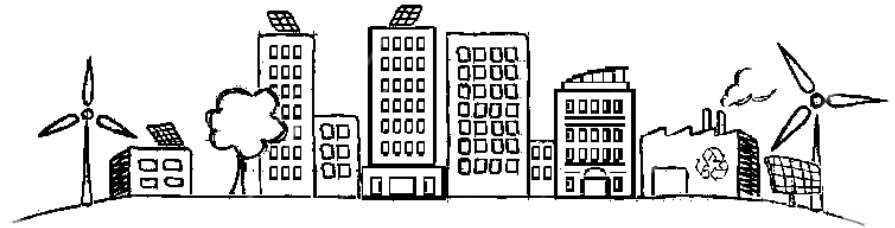
Energy Demand Flexibility in Buildings and Energy Systems



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Agenda

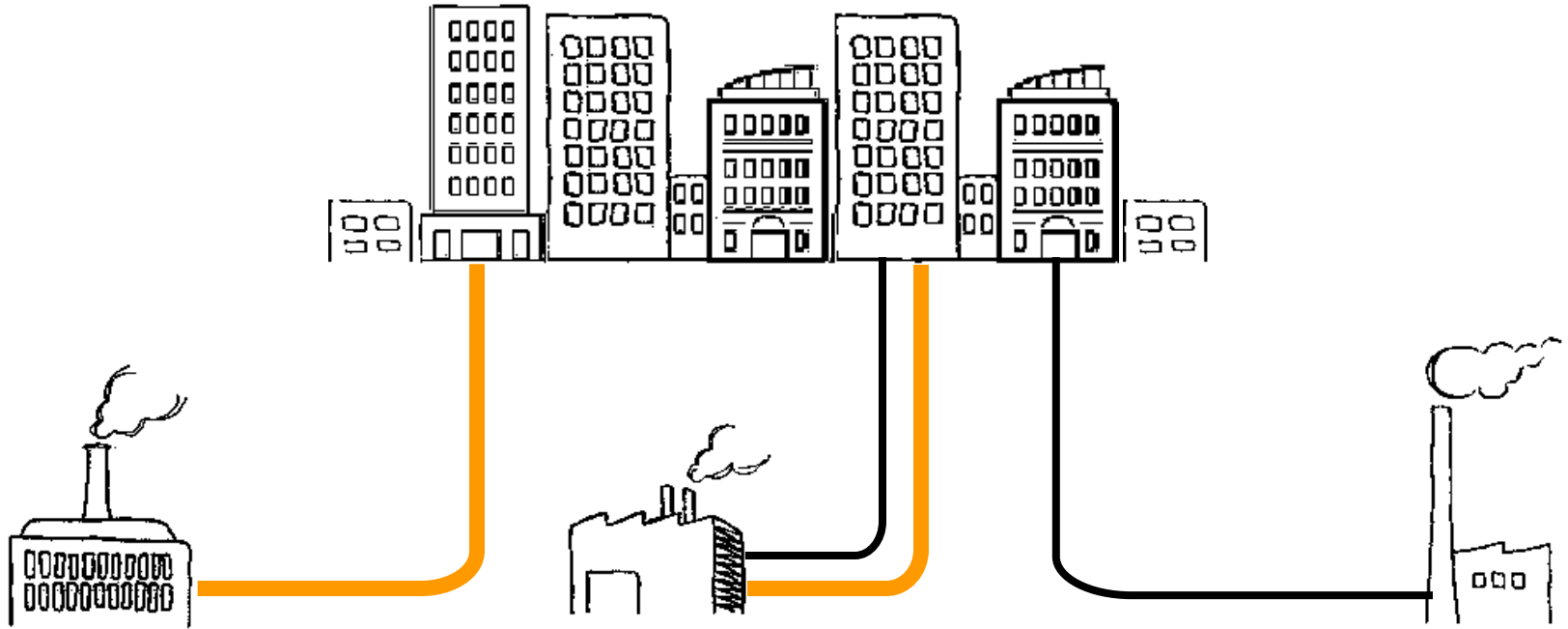
- Background
- Flexibility definitions
- Flexibility indicators
- Need for integrated approach
- Flexibility sources in built environment
- Conclusions



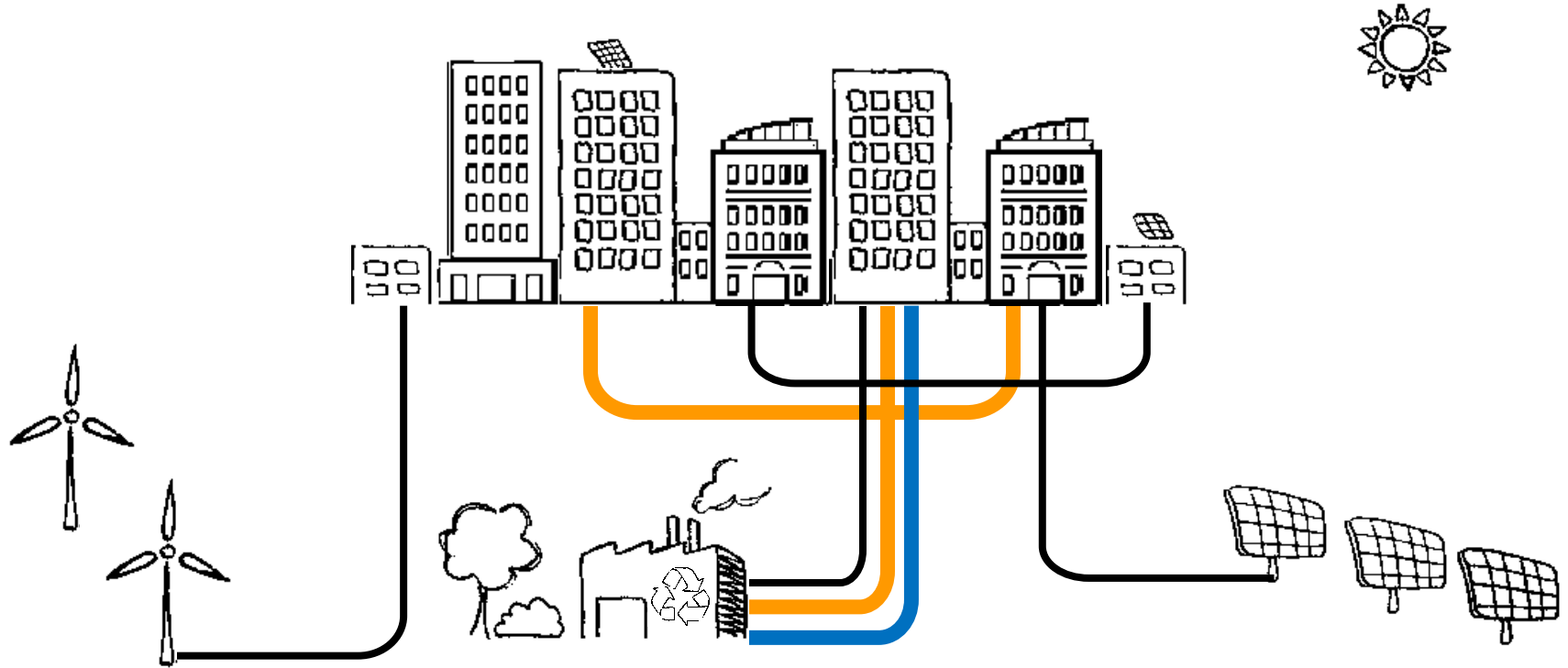
Background



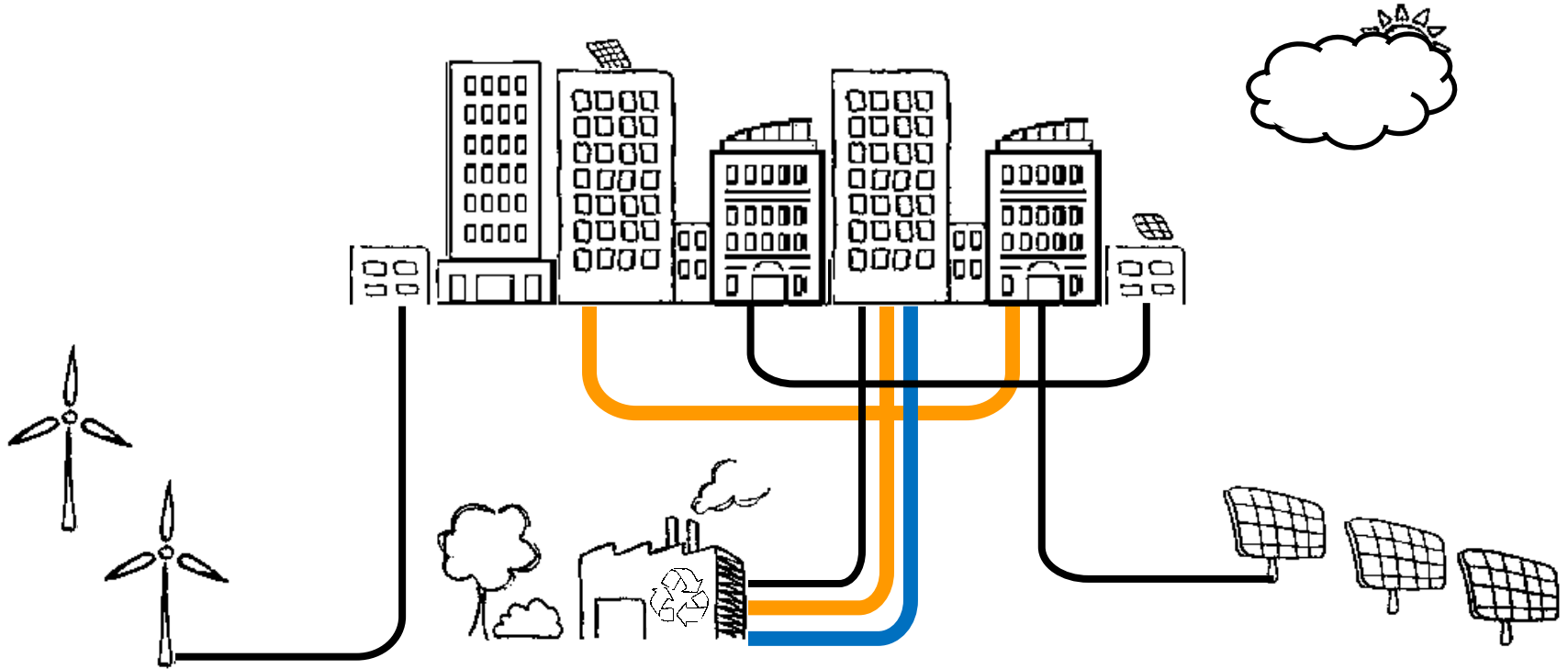
Background



Background



Background



Definitions

Ability of the system to react to the changes in supply and demand

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Ability of the system to react to the changes in supply and demand

Supply side

Demand side

Ability to balance the changes in energy consumption and fluctuation in renewable generation

Ability of the demand side to deviate consumption from a plan or reference state

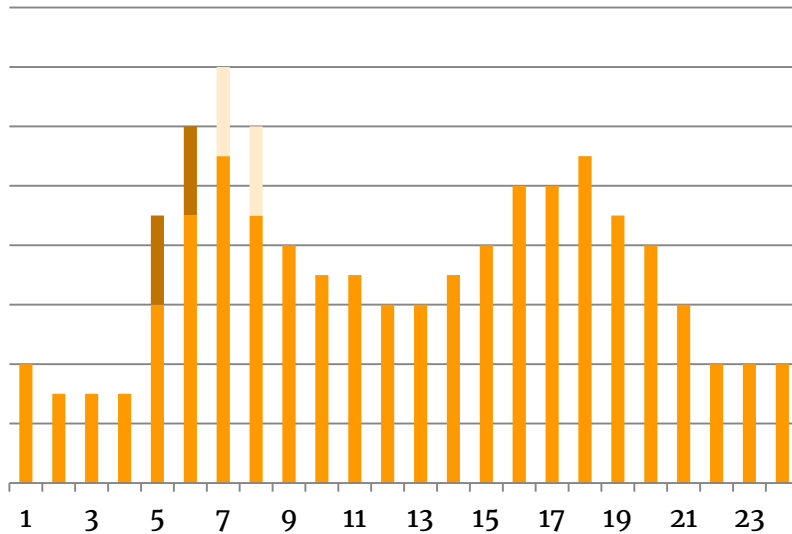
Definitions

Ability of the system to react to the changes in supply and demand					
Supply side			Demand side		
Ability to balance the changes in energy consumption and fluctuation in renewable generation			Ability of the demand side to deviate consumption from a plan or reference state		
Power and discharge time of storage technologies	Start-up and ramp-up time of generation technologies	...	Ability of a building to shift the use of certain amount of energy in time	Ability of the demand side to reduce the peak demand (peak shaving)	...

Indicators

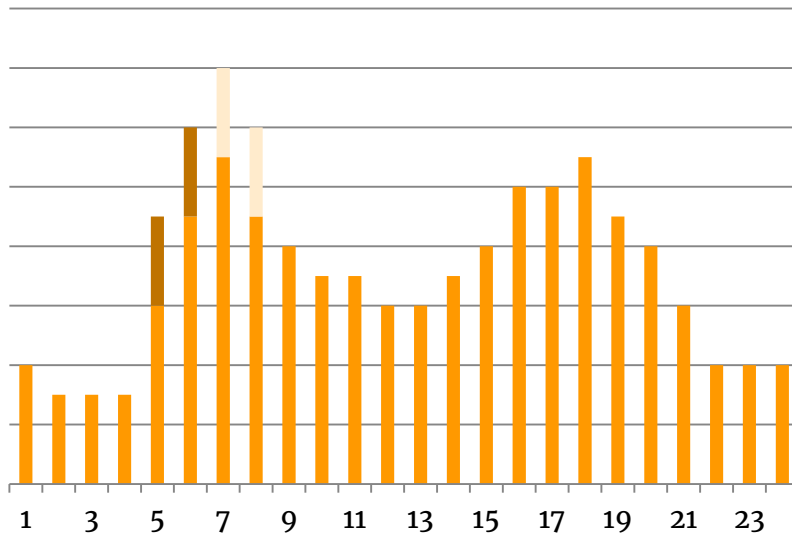
Indicators

Technical – e.g. energy shifted over timespan



Indicators

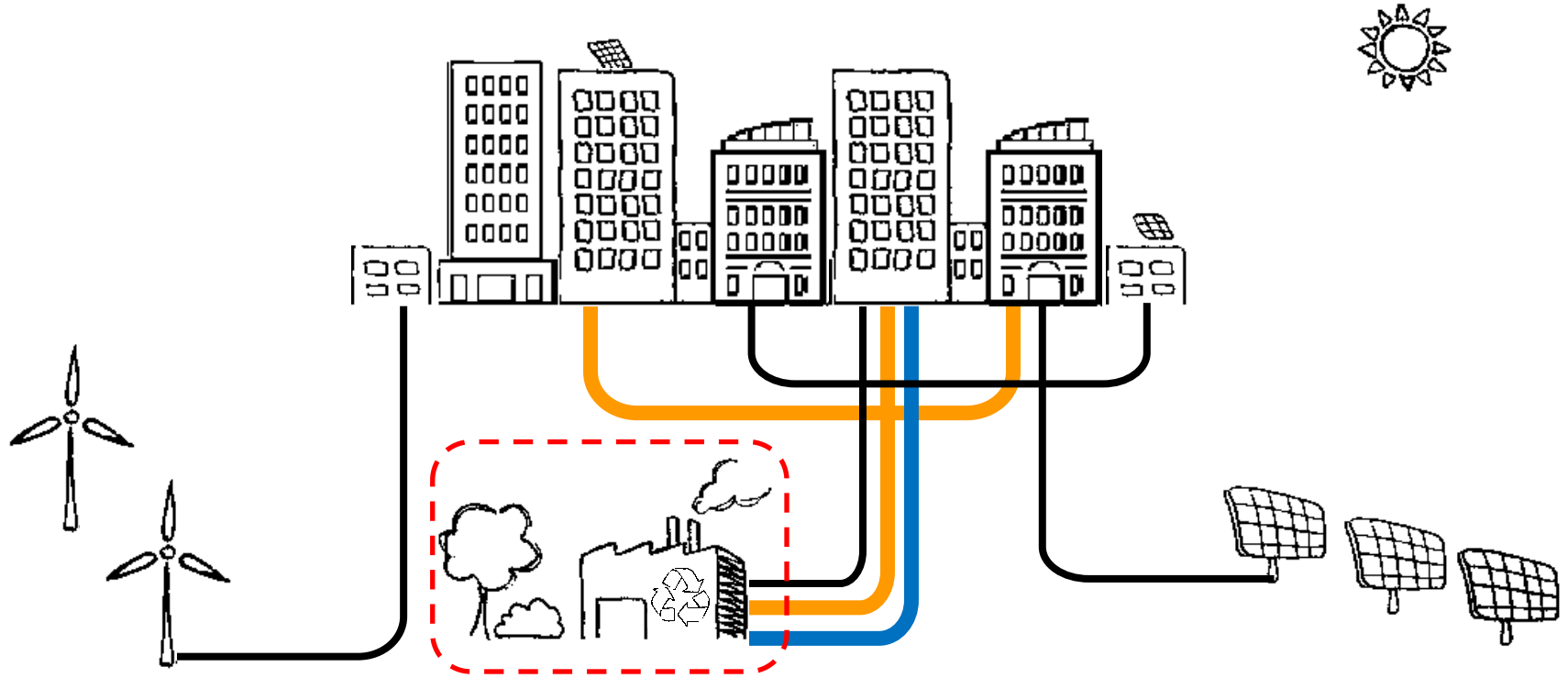
Technical – e.g. energy shifted over timespan



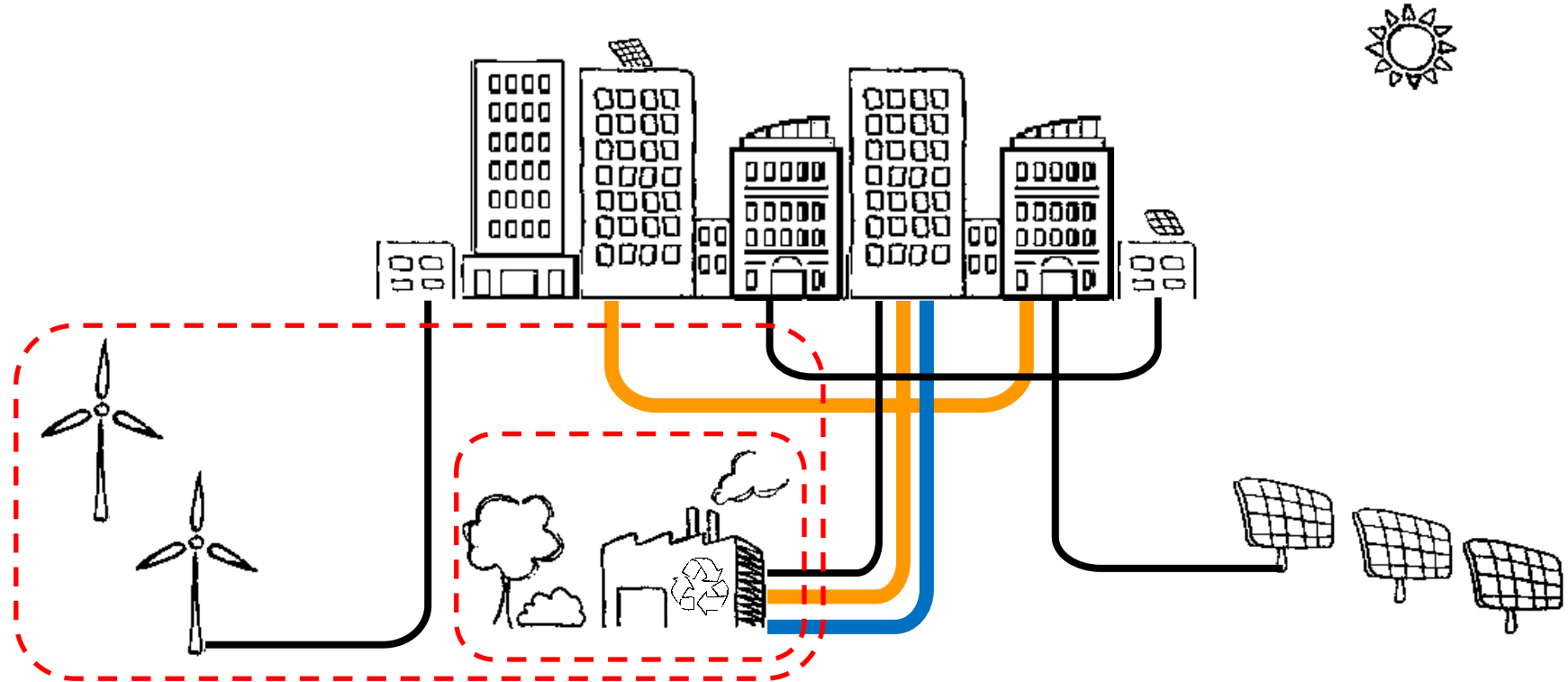
Economic – e.g. procurement costs avoided

$$flexibility_{PC} = \frac{PC_{\max} - PC}{PC_{\max} - PC_{\min}}$$

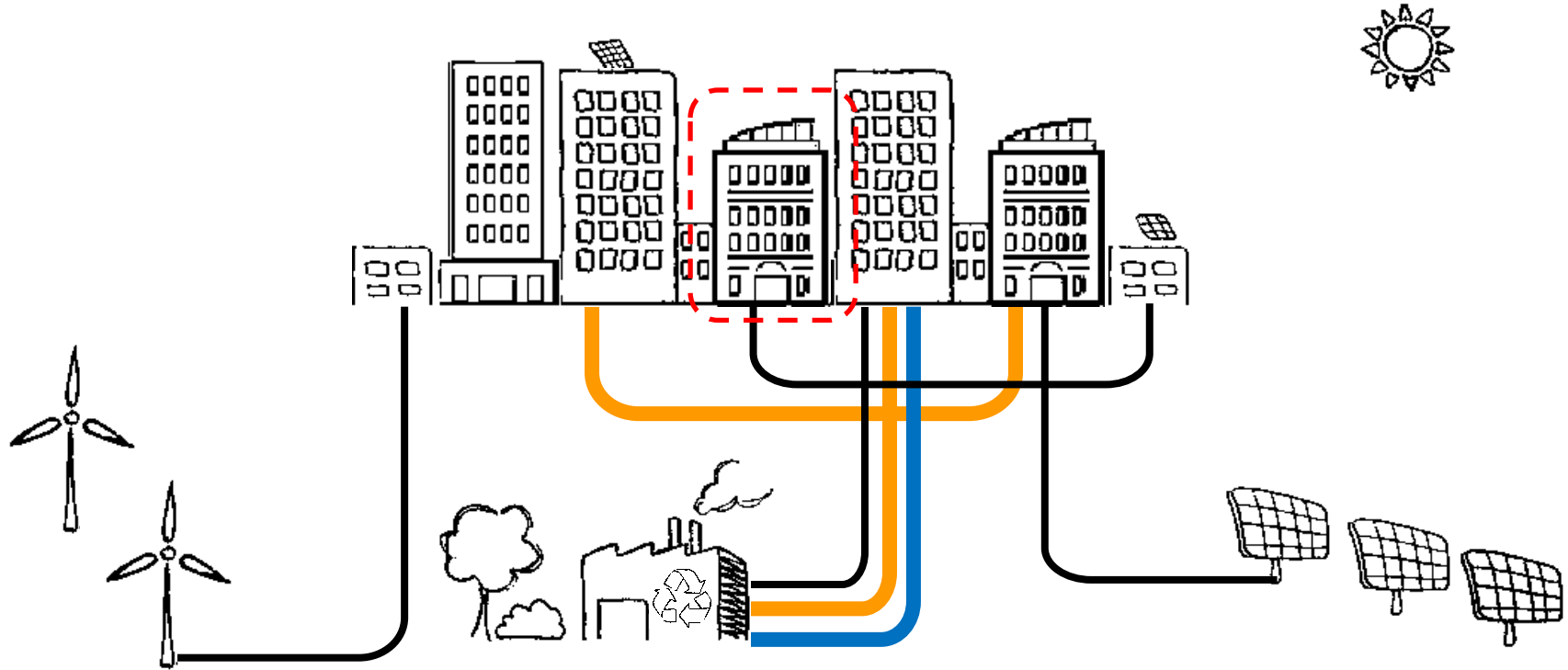
Need for the integrated approach



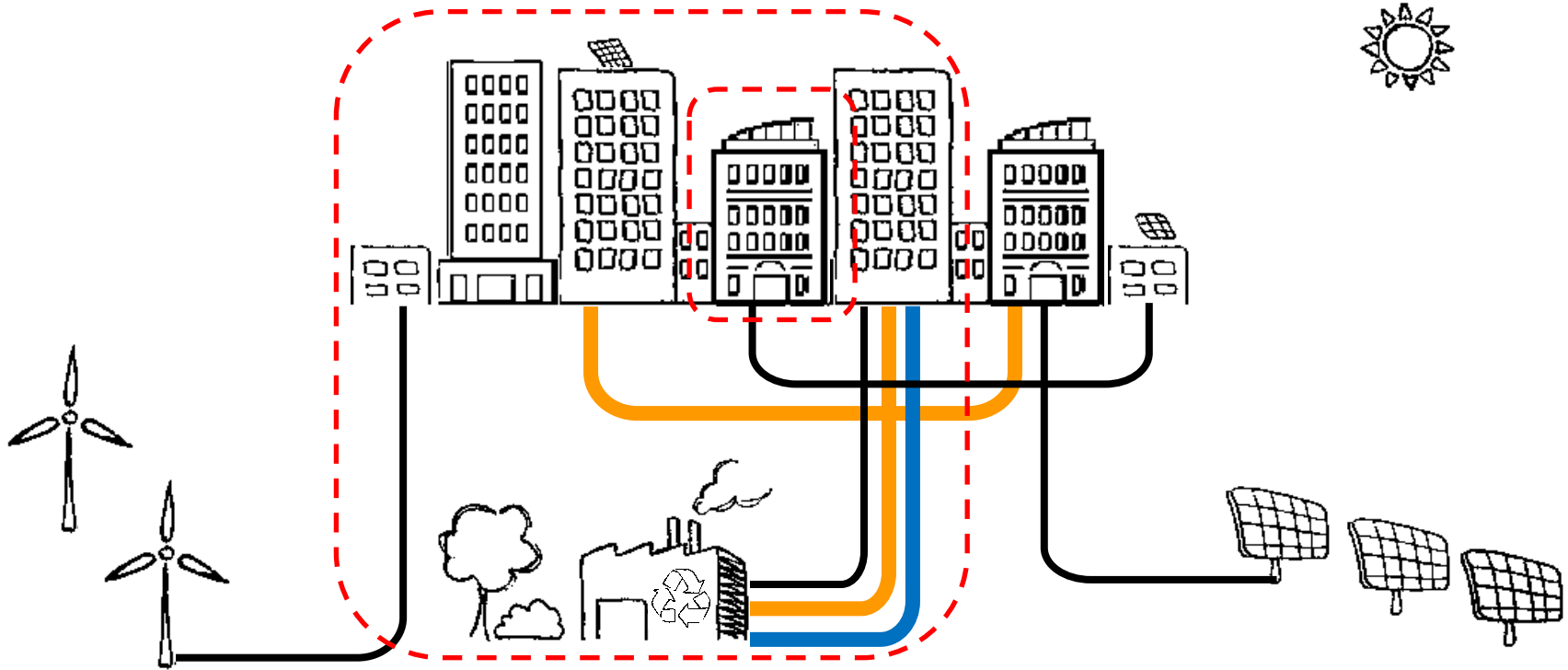
Need for the integrated approach



Need for the integrated approach



Need for the integrated approach



Flexibility sources in built environment

Flexibility sources in built environment

Sensible thermal energy storage



https://commons.wikimedia.org/wiki/File:Fernw%C3%A4rmespeicher_Theiss.JPG

Flexibility sources in built environment

Sensible thermal energy storage



https://commons.wikimedia.org/wiki/File:Fernw%C3%A4rmespeicher_Theiss.JPG

Latent thermal energy storage



<https://en.wikipedia.org/wiki/File:Handwaermer12.jpg>

Flexibility sources in built environment

Cold thermal energy storage



<http://hpac.com/air-conditioning/energy-storage-works-wind-turbine-cut-energy-costs>; Photograph by Ros Kavanagh

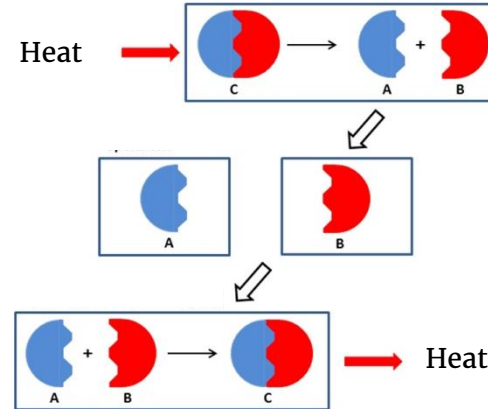
Flexibility sources in built environment

Cold thermal energy storage



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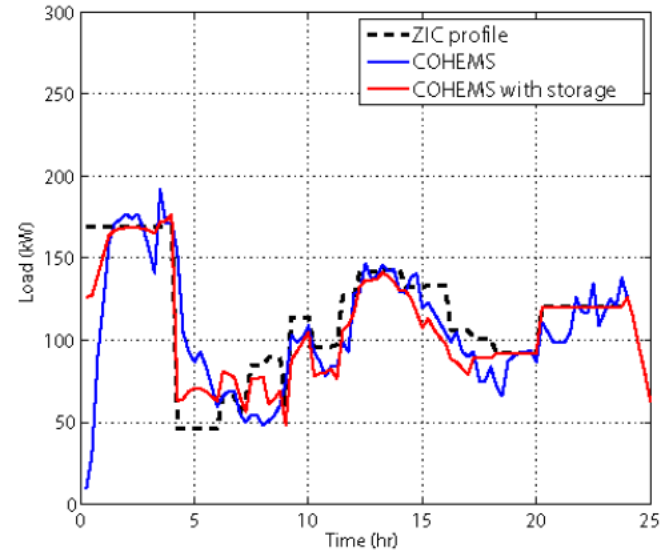
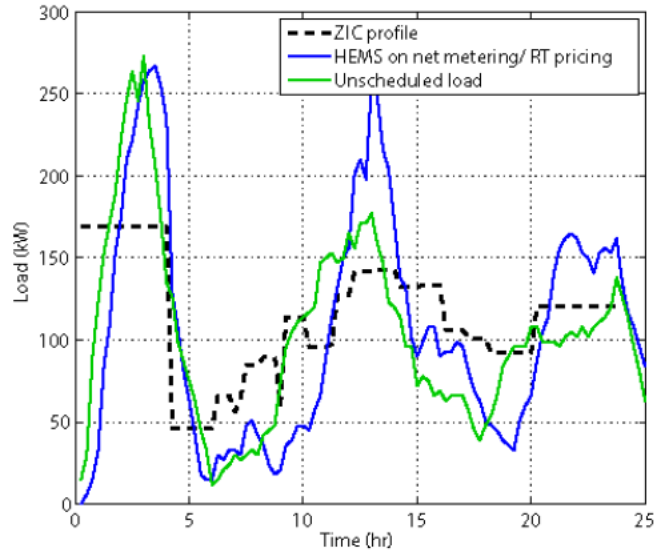
Thermochemical energy storage



http://forschung-energiespeicher.info/en/storing-heat/project-list/project-details//Waerme_auf_kleinstem_Raum_speichern/

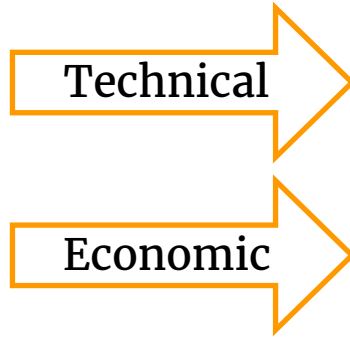
Flexibility sources in built environment

Control of appliances



Conclusions

No single definition
of flexibility



Energy shifted over time

Costs avoided due to shifting
consumption to periods with
low energy prices

Conclusions

- System integration increases its flexibility, but... characteristics of thermal side have to be accounted for!
 - ⇒ heat losses
 - ⇒ in case of storage in the building mass: occupants' comfort
- Large body of knowledge on energy storage in built environment that can be used in context of flexibility

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Thank you for attention

A panoramic view of the Toronto skyline at sunset. The CN Tower is the central focus, with its reflection clearly visible in the water. To its left is the Rogers Centre, and to its right are several other skyscrapers. The sky is a warm, golden color, and the water is calm with gentle ripples.

Questions?

(or please feel free to find me afterwards)