



Smart Cities as Systems of Systems: an energy and grid perspective

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□ Cities important for energy?

- Size: cities occupy 2% of the world's land...
- But almost 75% of Europe's population lives in cities (55% worldwide, growing)
- Cities consume almost 70% of the world's energy
- Cities account for more than 70% of global CO₂ emissions.

□ So, yes, cities are important, also from an energy point of view...

□ Should they be (energy-)smart?



□ What are we taking about?

- The smart city paradigm originally aims at relating the city's physical infrastructures with human capital and social life

□ How?

- thanks to the widespread use of new communication technologies, mobility, the environment, energy efficiency

□ To do what?

- to improve the quality of life and meet the needs of citizens, companies and institutions

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□ Smart or digital cities?

- Digital cities = lots of digital services
- Smart cities = ICT
 - + better infrastructures
 - + sustainable economic development
 - + wise management of natural resources
 - + energy efficiency
 - + people commitment
 - + participatory action

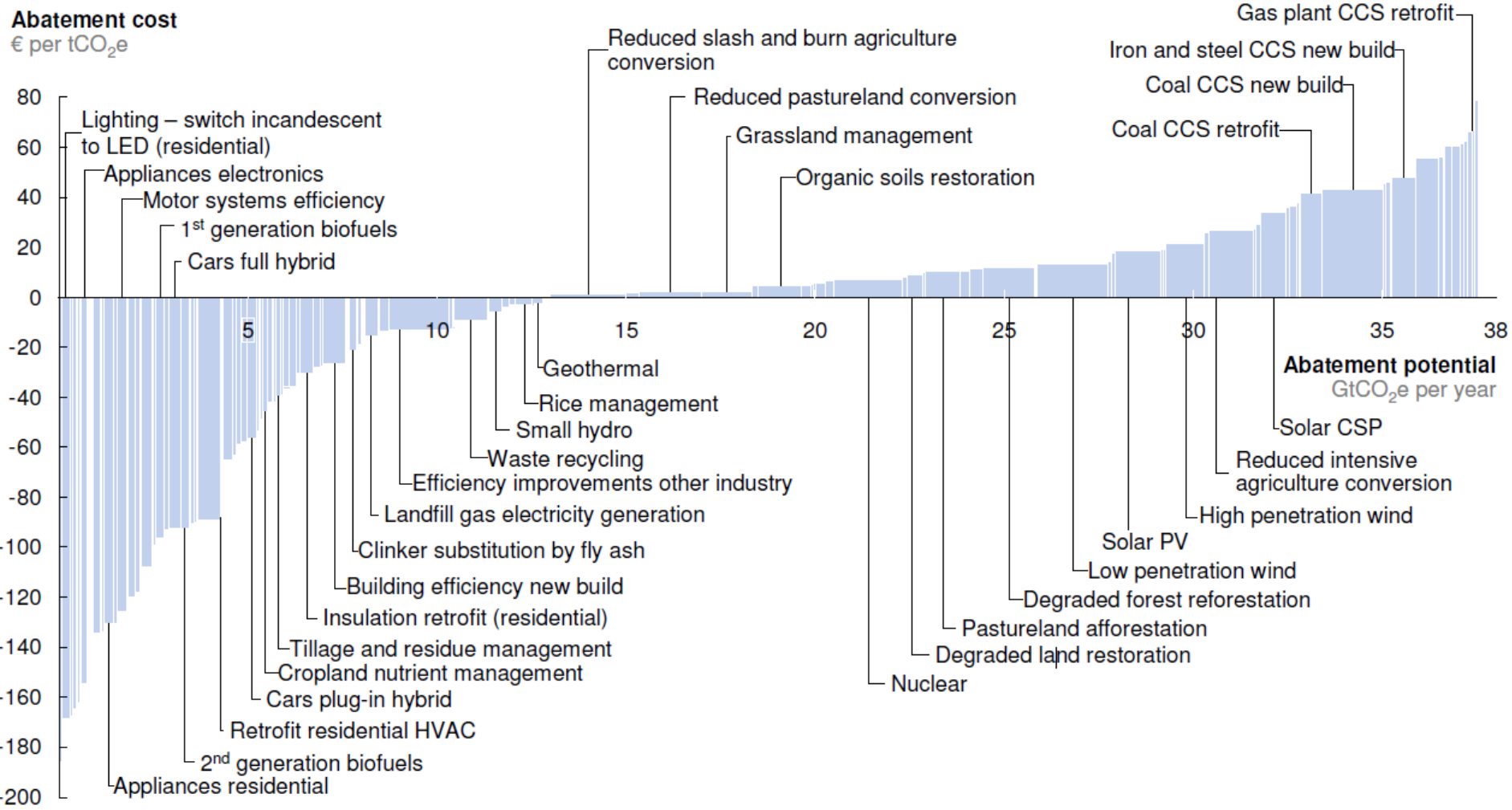


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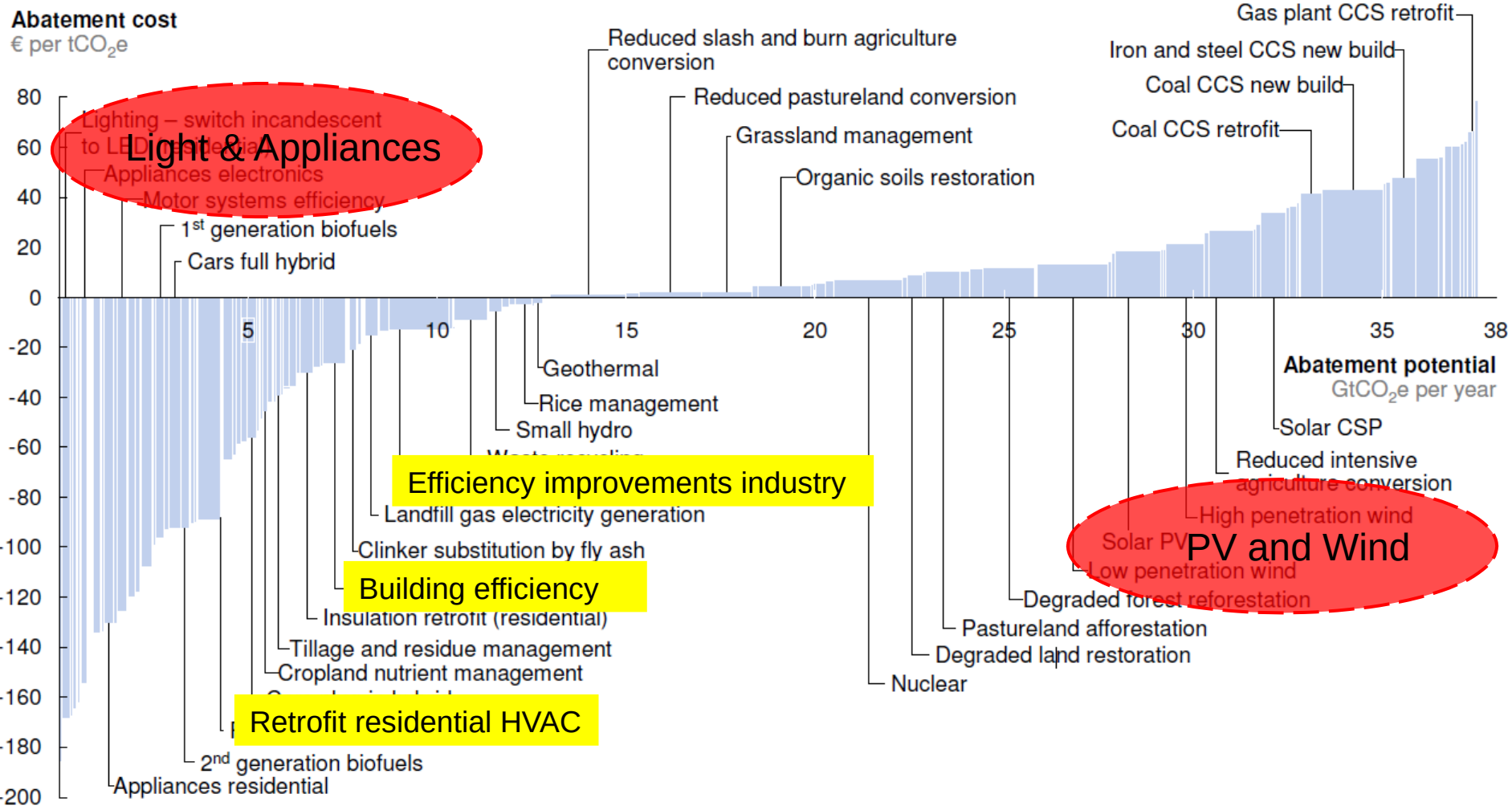
Abatement costs for CO₂ (€ / tCO₂) - 2030



▪ McKinsey, 2010, GHG Abatement Cost Curve

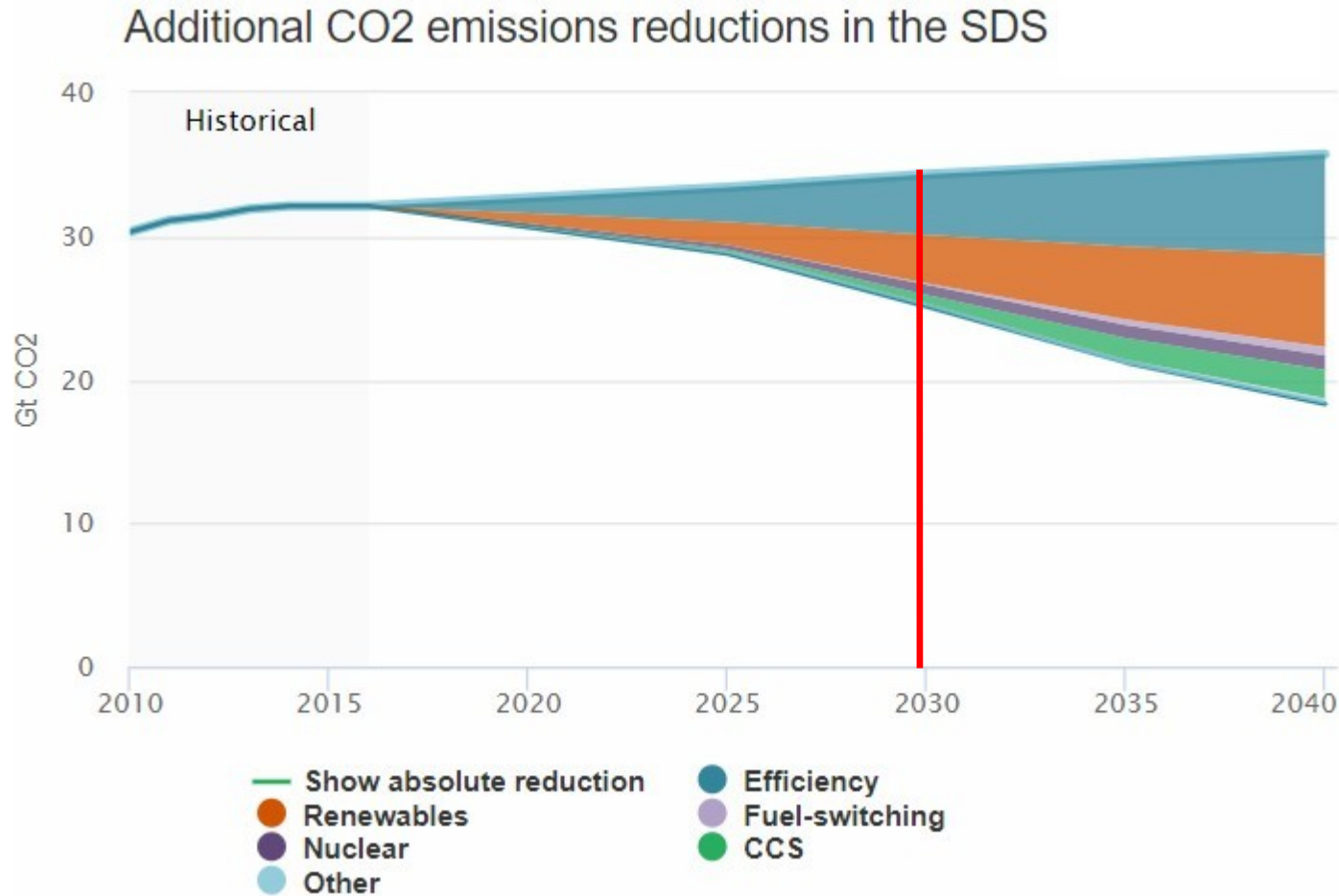


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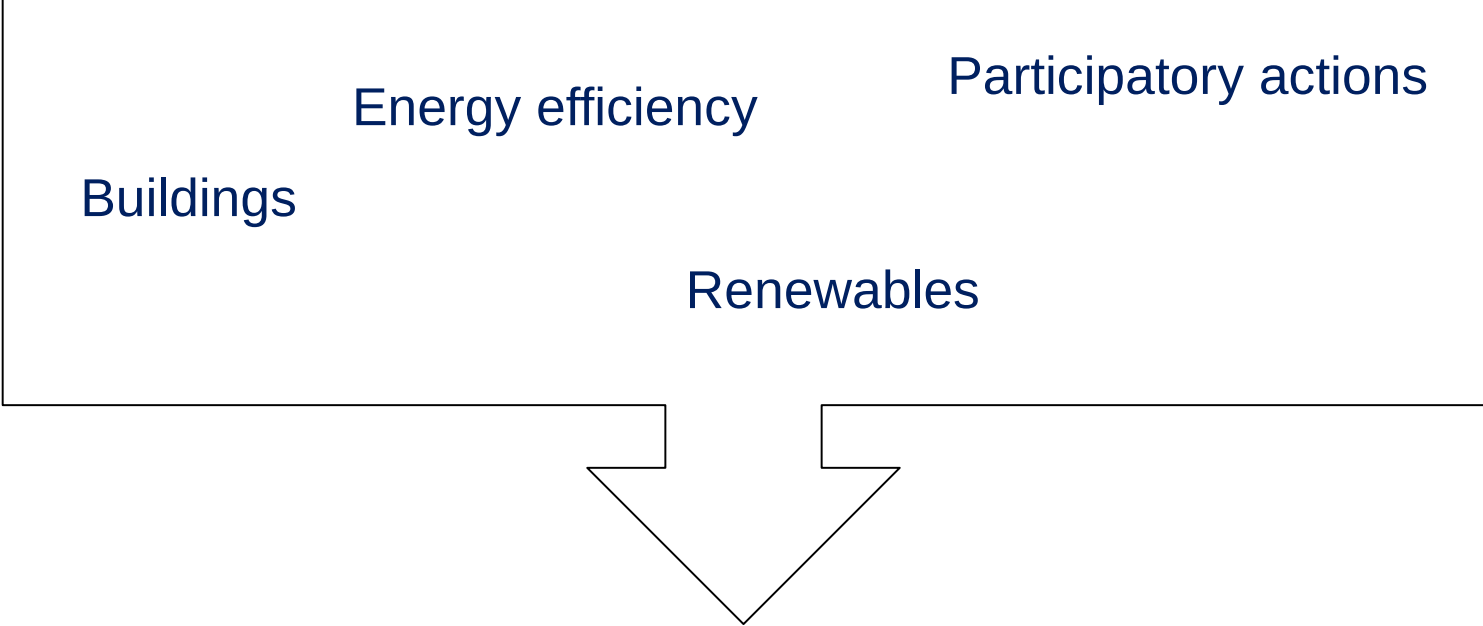
What is needed for sustainable development scenario by 2030



- The great role is for energy efficiency and renewable (almost 50% each)

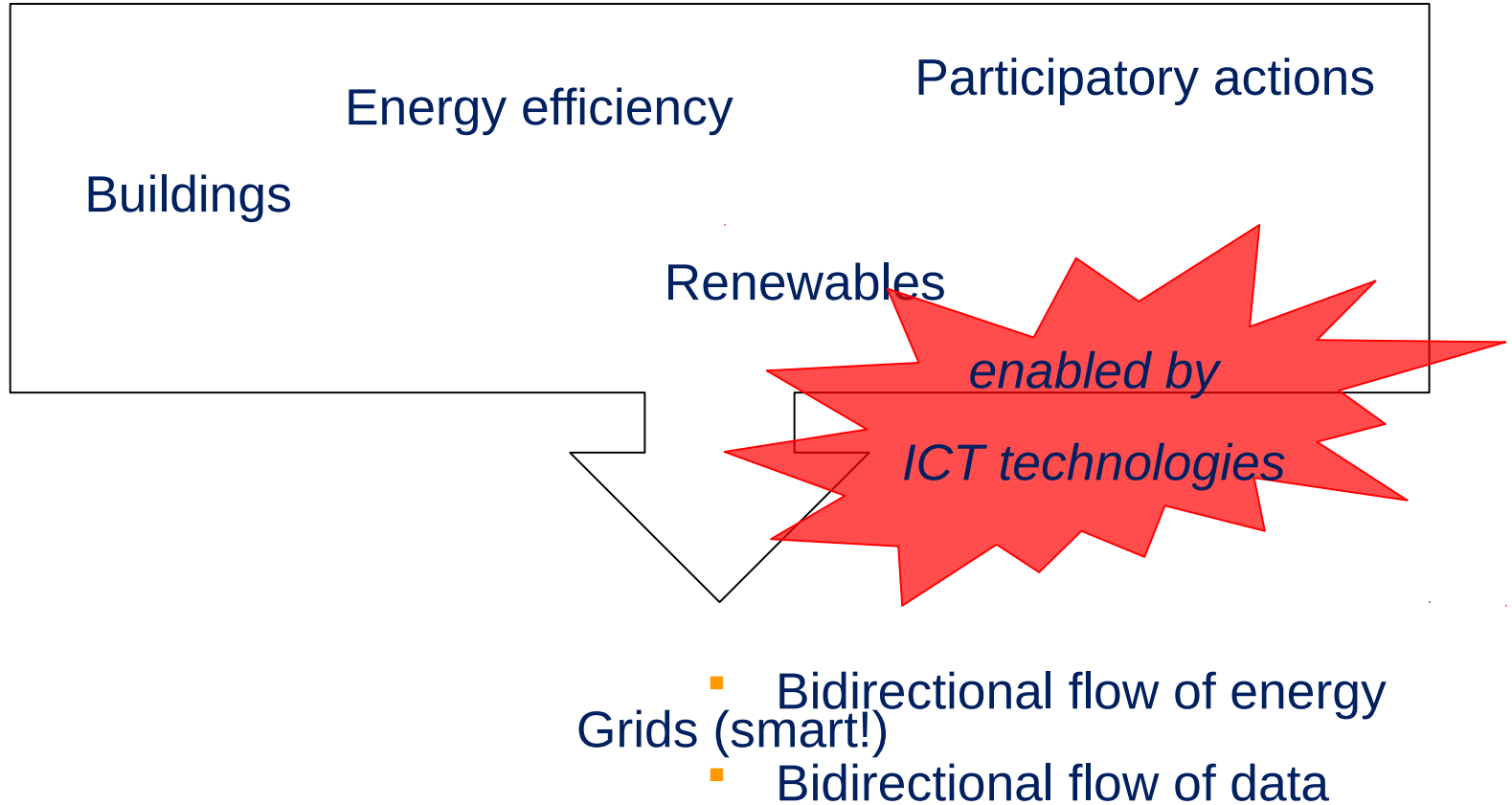


A possible future concrete action





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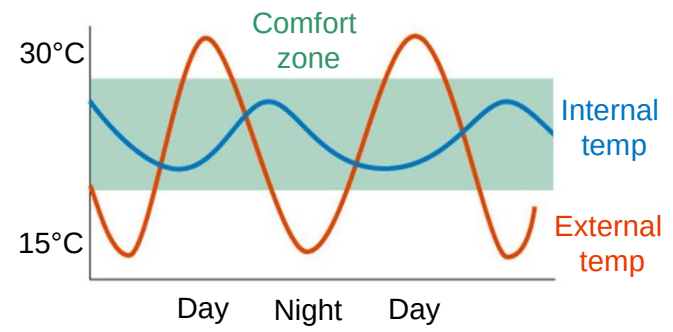
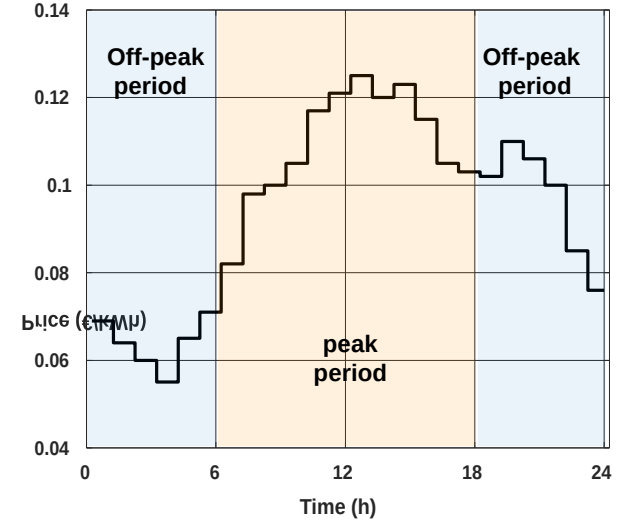
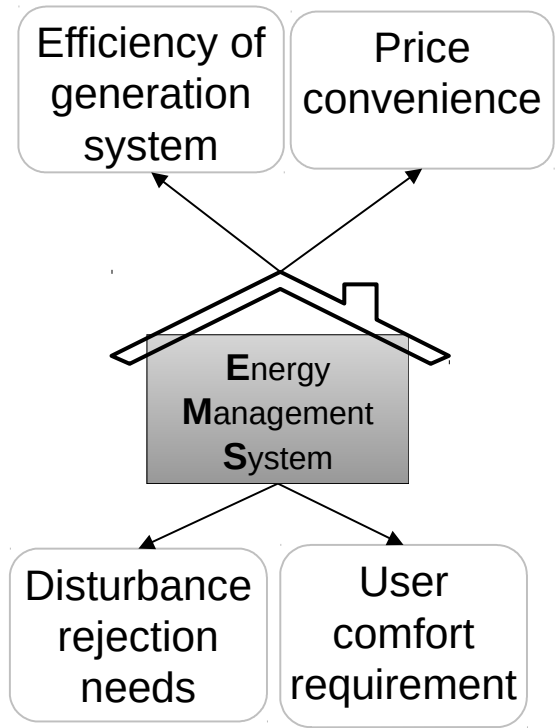
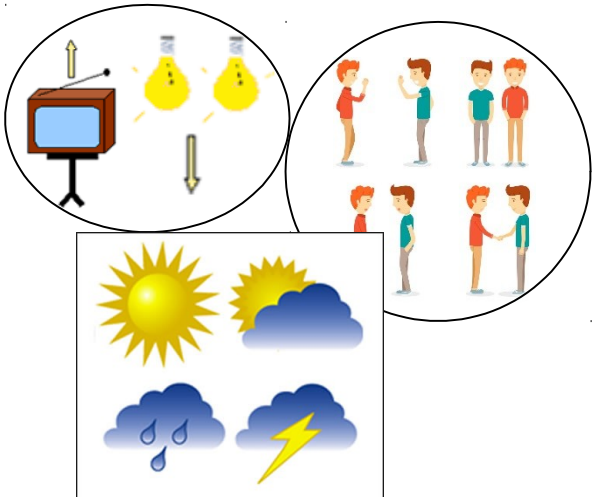
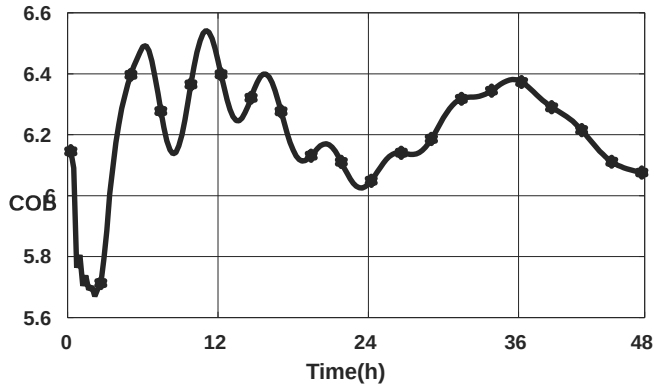




- **Building will become basic nodes of the future smart (micro) grid**
 1. They can use electrical energy for space conditioning (HVAC)
 2. Exploiting their thermal inertia they can decouple user comfort profile from electrical profile
 3. User comfort may be modulated by the user himself (participatory action)



Buildings and grids



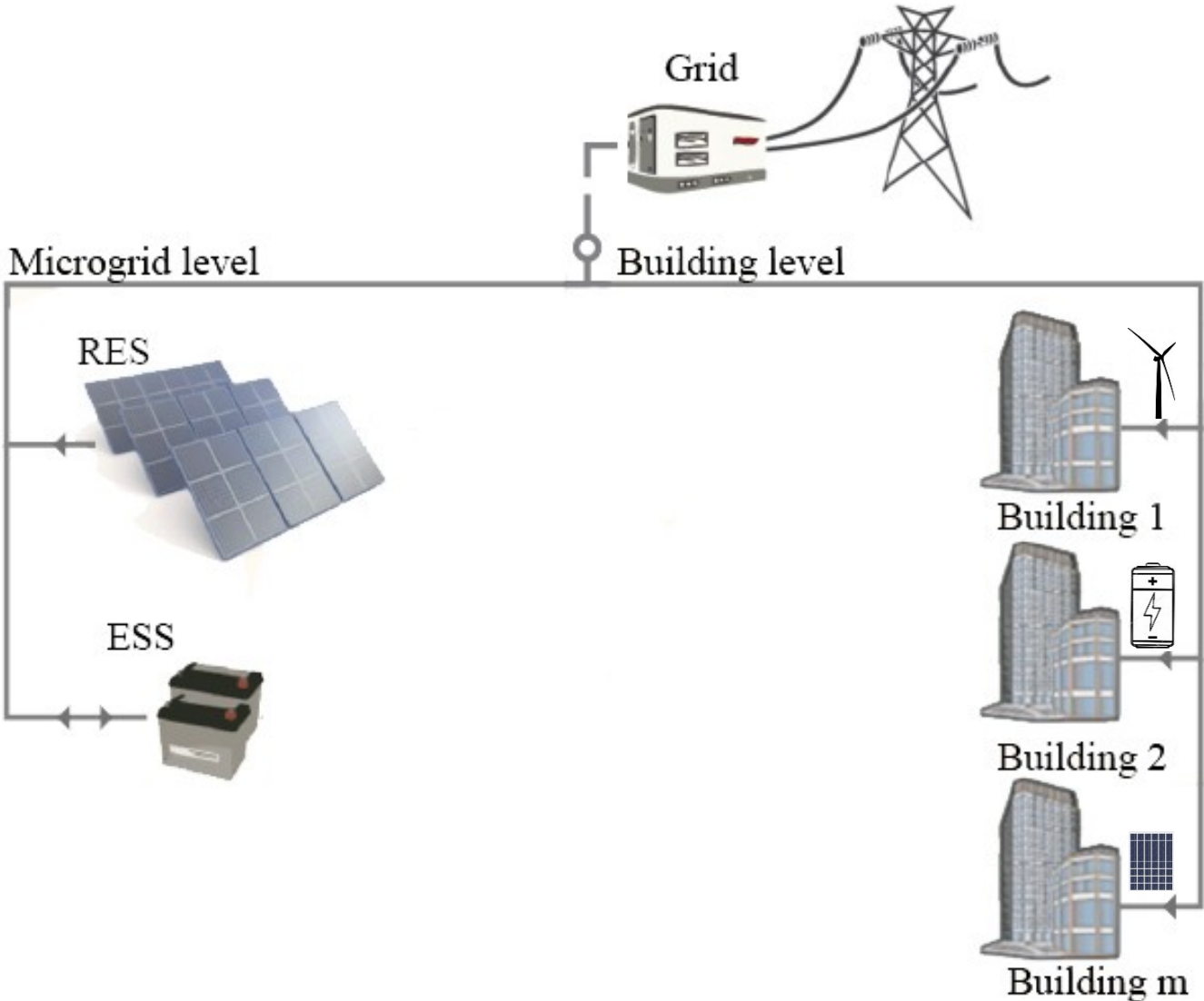


From buildings to grid



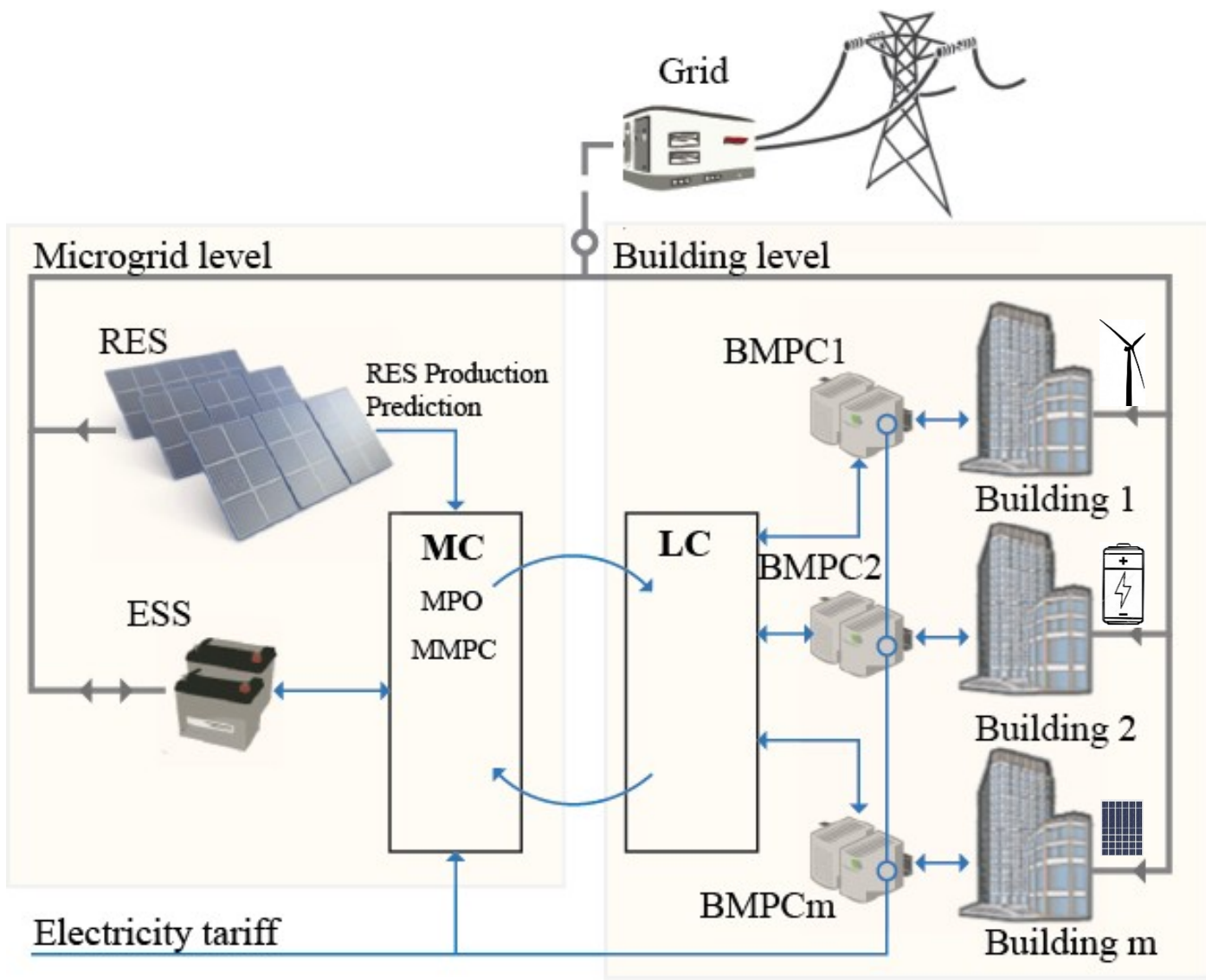


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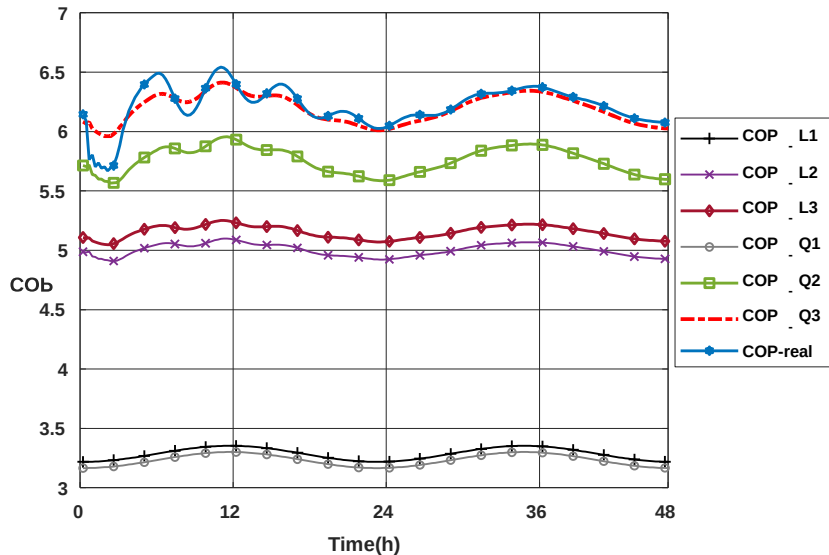


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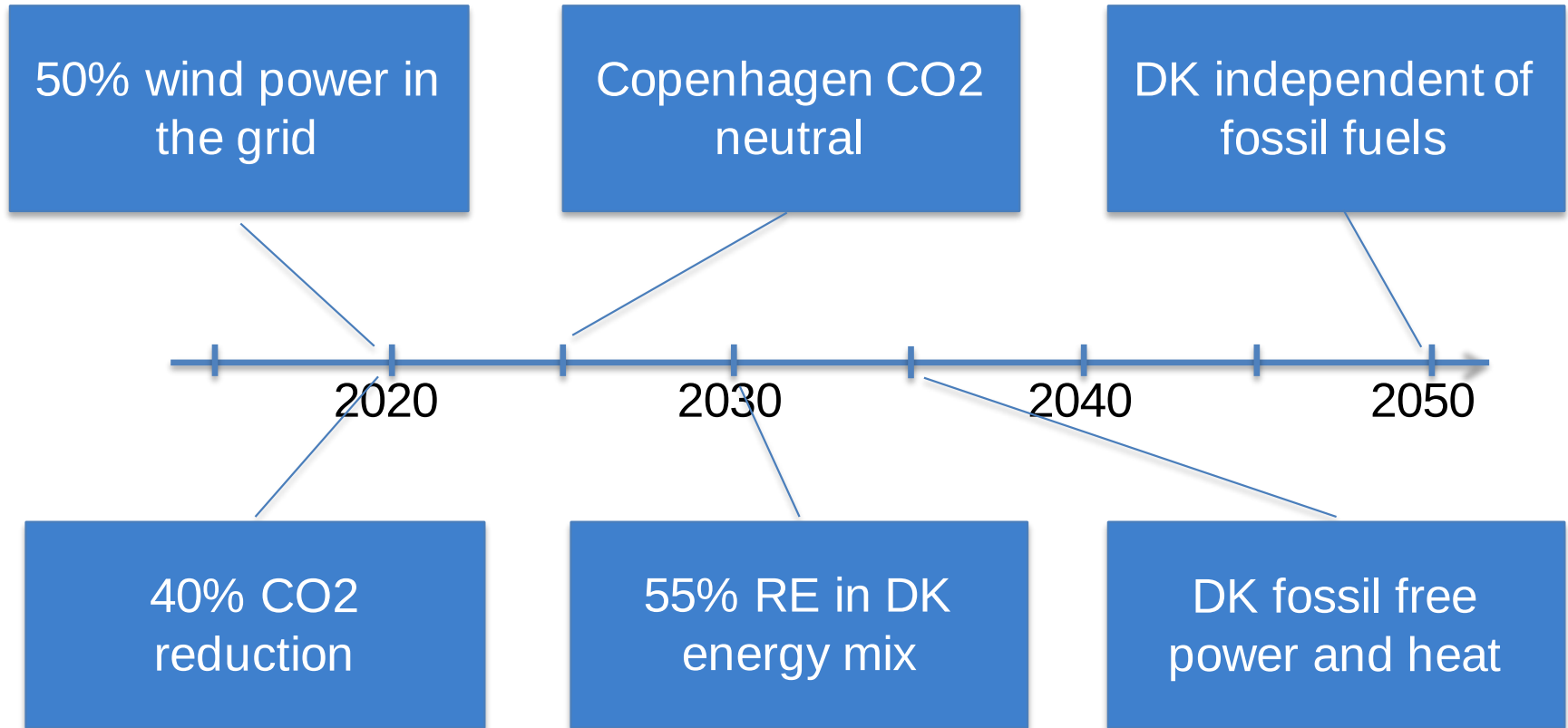
□ In many cases, technologies are already available

- The previous schemes (building and grid levels) have been simulated and tested in reality (distributed nonlinear realtime optimization – sampling time = few minutes)
- Remotly Control Thermostats (device)
- Heat pumps control (algorithmic optimization)



Parameters	Datasheet	
	Test 1	Test 2
COP	3,26	4,29
TB	35 °C	35 °C
Air temp.	2 °C	7 °C
ΔT water	5 °C	5 °C
Compressor	100 %	100 %
Water mass flow rate	0.5 kg/s	0.5 kg/s

Example of Copenhagen city and Denmark – national goals



- ❑ Storage - renewables not available when we need (PCM)
- ❑ User flexibility is not exploited at all in HVAC
- ❑ Home and building automation largely unexploited (money?)
- ❑ Keep on raising awareness in citizens: requires time
- ❑ Energy cloud – Energy as a service
- ❑ Blockchain technology?
- ❑ Privacy issues related to measured data
- ❑ Resilience to failures and disasters
- ❑ Cyber-security



Thank you for your attention