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Electrical versus thermal energy transport for future sustainable districts

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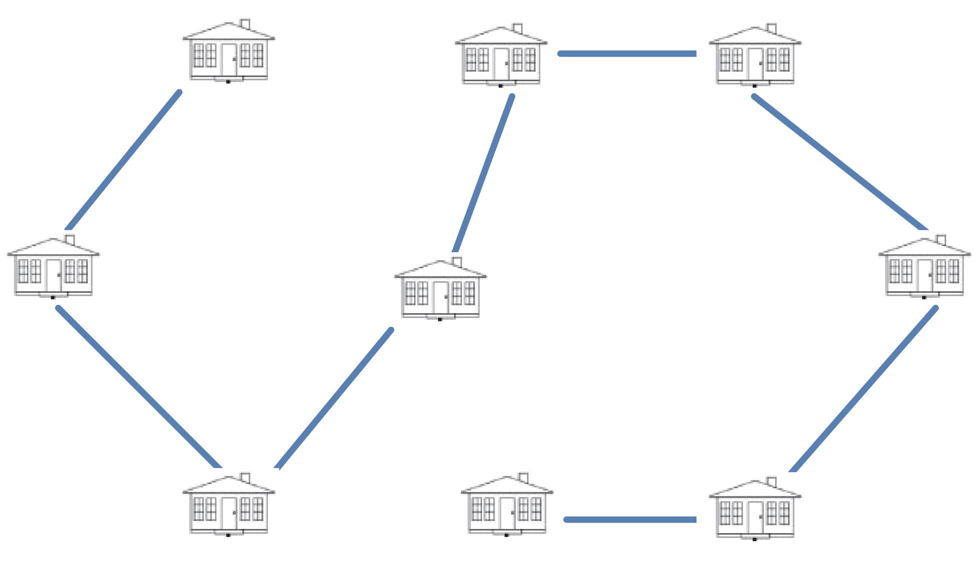
Resarch context

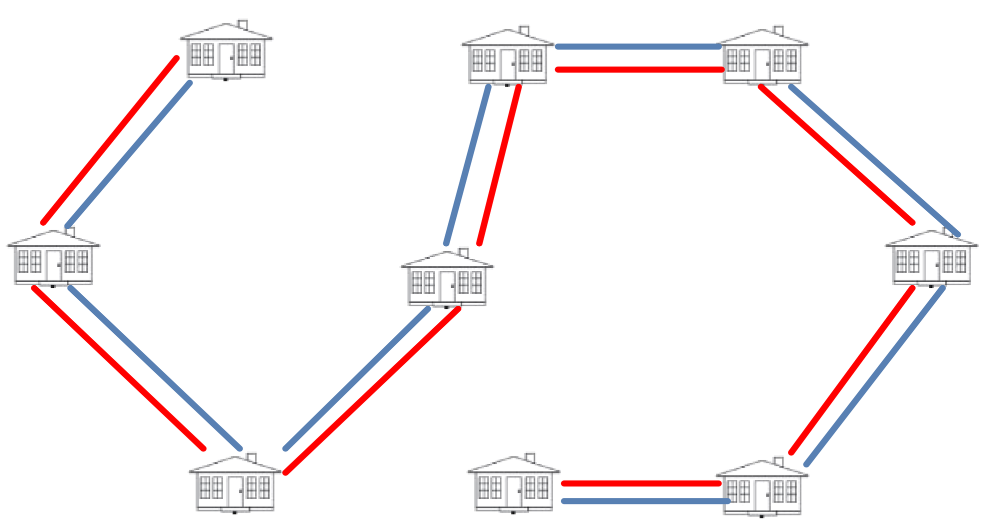
There are many challenges for the energy networks of the future: more renewables at all scales, necessity of storage, inclusion of mobility, renewal of infrastructure, and the impact of local measures like demand side management.
Should future district-scale energy networks be based on thermal or electrical distribution of energy?

Thermal energy networks can better use available sources of heat, and energy may be more easily stored, but over large distances they can be expensive and have high thermal and pumping losses. Electricity networks can use existing infrastructure, and remain efficient over longer distances, but may need to be upgraded to cope with the higher penetration of renewables.

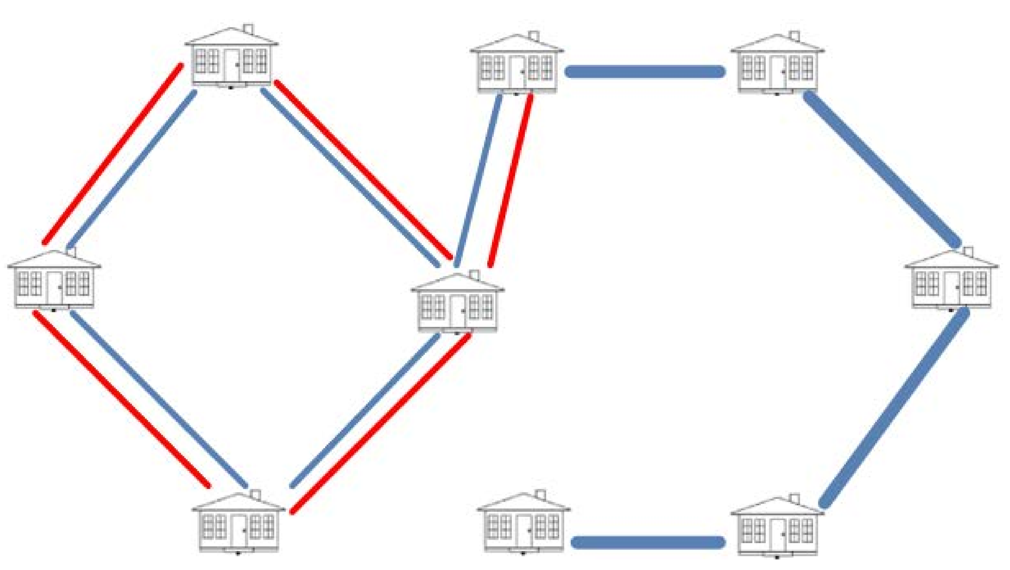
There are three basic cases for how the buildings in the future district energy networks can be connected:



Existing electrical network



Install heating network

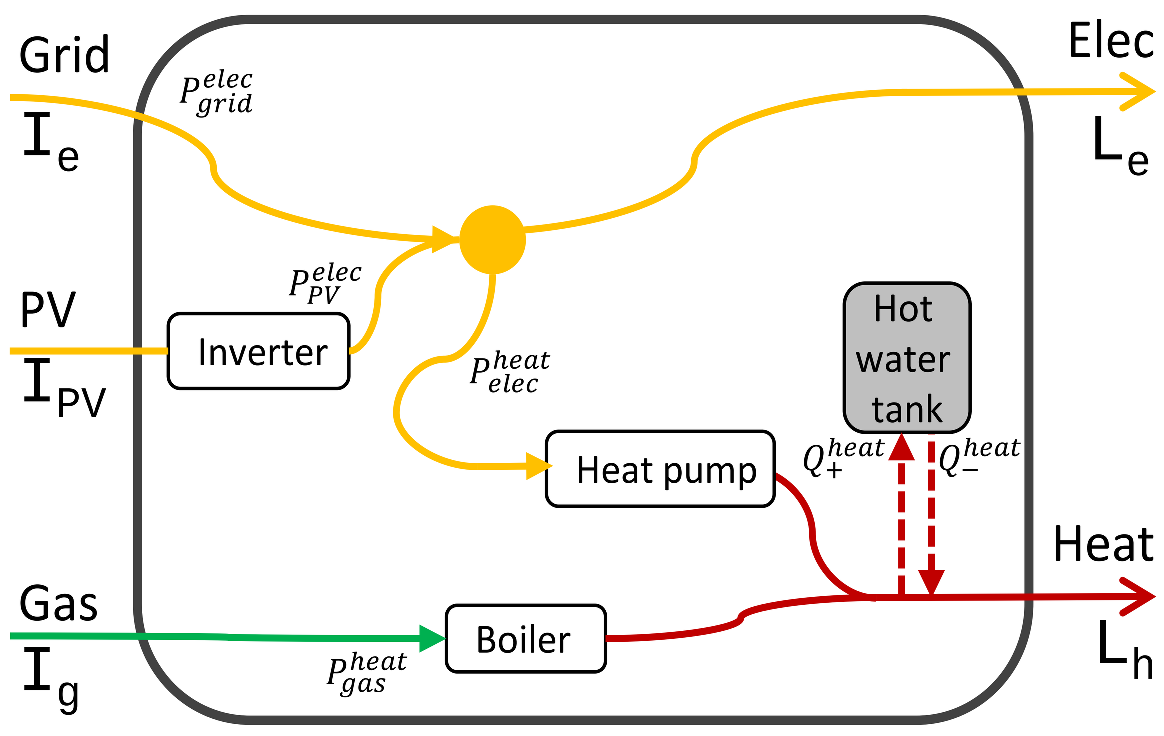


Combination of new heating network and improved electrical networks

Heating network
Electricity network

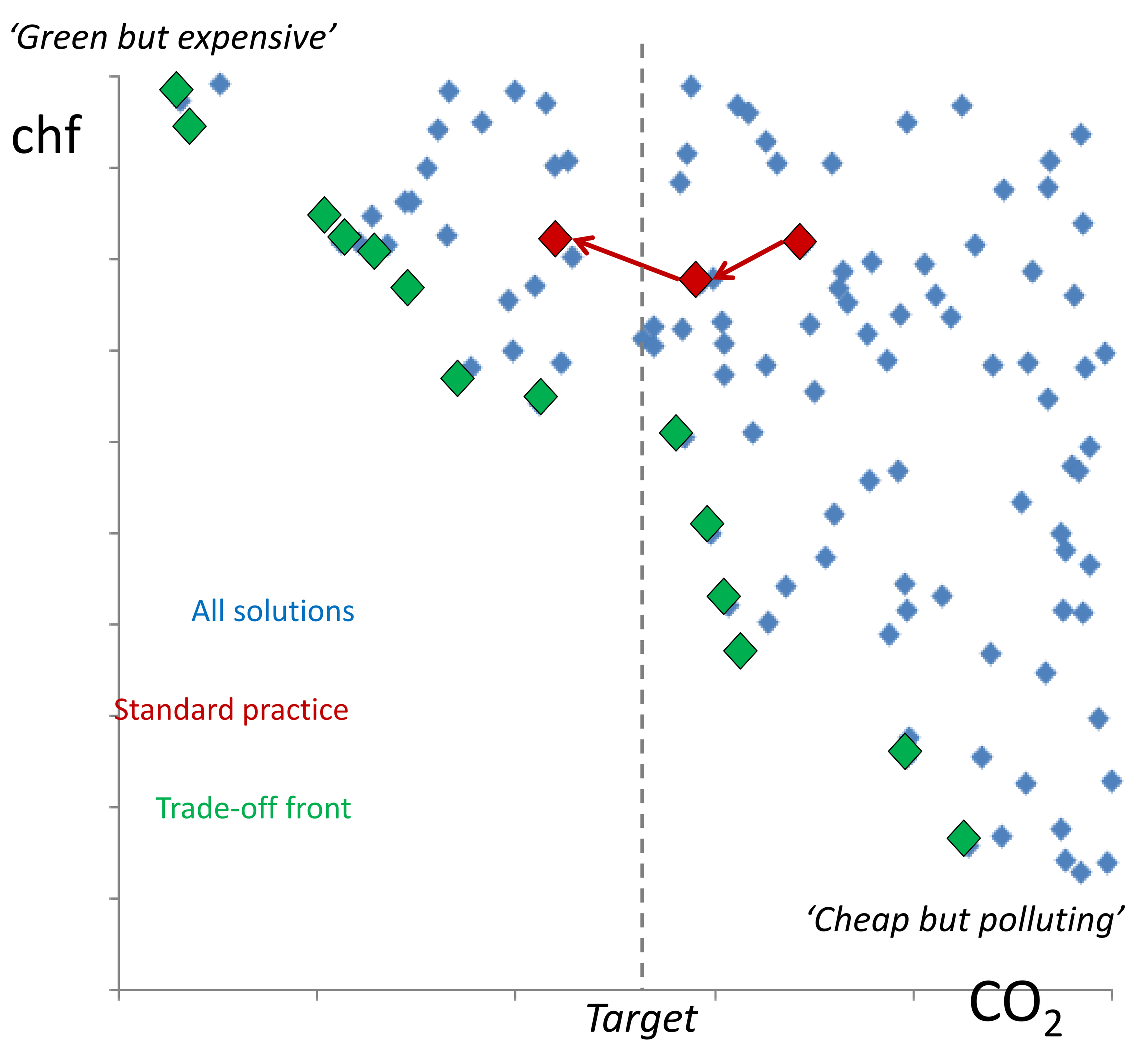
Networks of buildings are key to future sustainable districts

Buildings play a key role in energy networks: they include both demand and supply aspects, require multiple energy streams (electricity, heating, hot water, cooling), and exhibit complex spatial and temporal relationships. These systems can be represented by the energy hub, a framework for defining different types of energy vectors, aimed at efficiently transferring multiple energy flows. It can describe any configuration of generation, conversion and storage elements.



Energy inputs I (supply) must be managed via conversion and storage to give outputs L (demand).

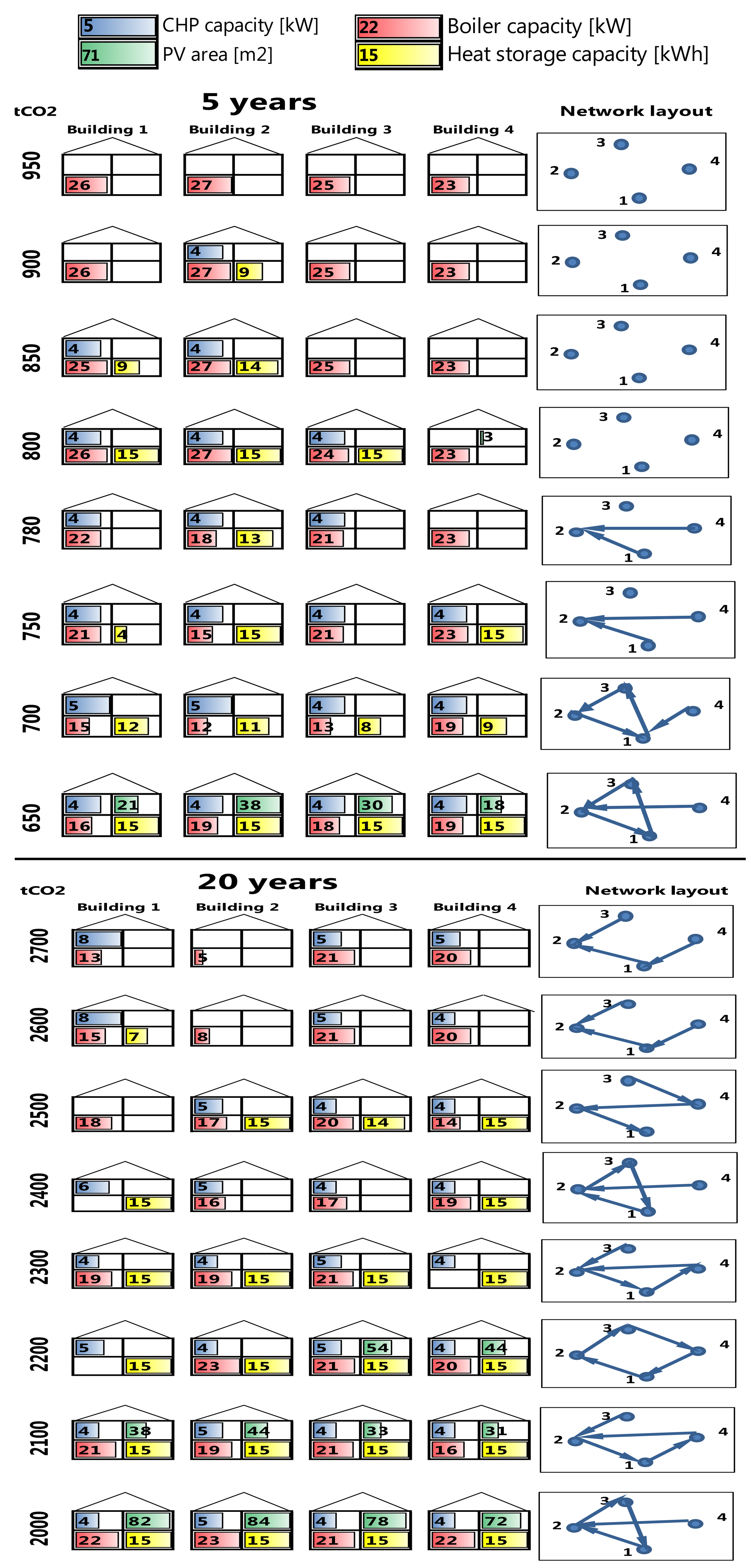
Interconnected buildings in future sustainable districts result in more complex system design challenges, because they combine at least two types of energy services (heat and electricity) that were traditionally separated. It becomes necessary to select the optimal number and capacity of equipment, as well as an optimal operation so that they match the load profiles of consumers. Multi-objective optimization, where more than one objective function is optimized simultaneously, e.g. costs and emissions, is useful in addressing such challenges.



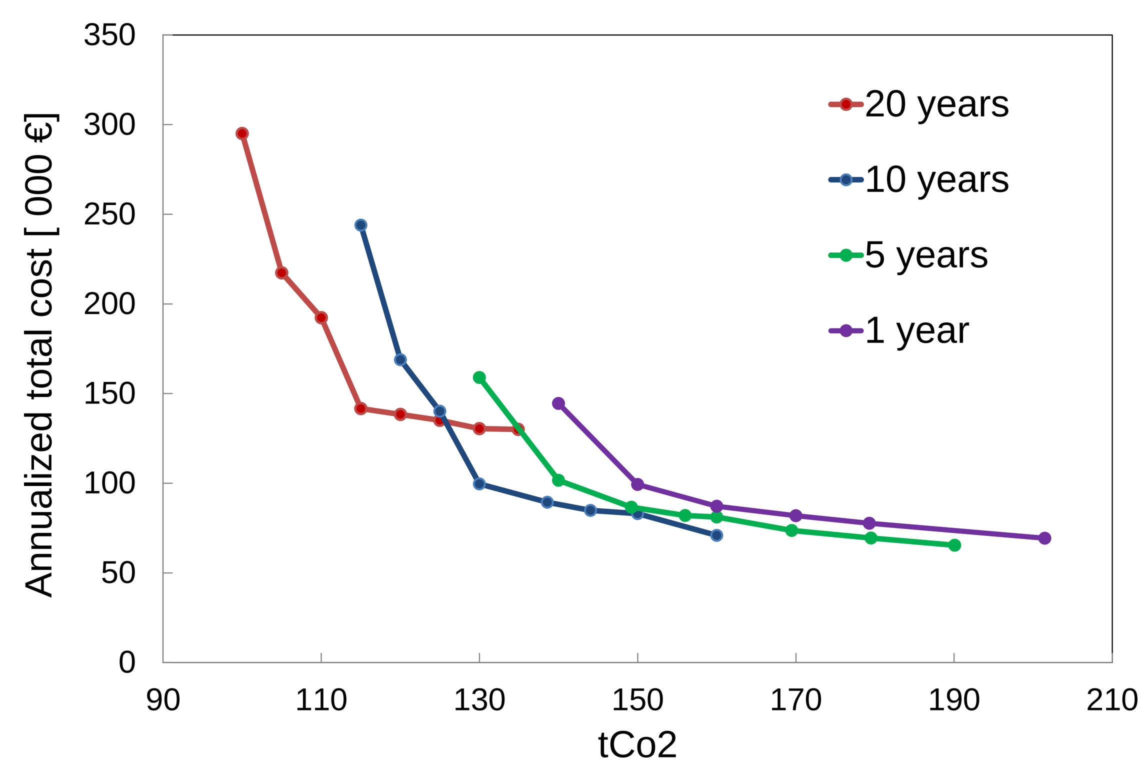
Optimised trade-off front of solutions for two objectives: carbon emissions and cost.

Preliminary results

A simple optimization model of a small district has been used to analyze the interactions between buildings and to determine the optimal technologies and network layouts for different scenarios. Mixed integer linear programming was used to optimize network layout and equipment capacities for 4 buildings with spatial relations.



Network layouts and equipment capacities depend on both emissions targets and time horizon



Bigger emissions reductions can be achieved with higher costs and longer time horizon.