Optimal Planning of Integrated Electricity, Gas and Heat Systems for Smart Cities

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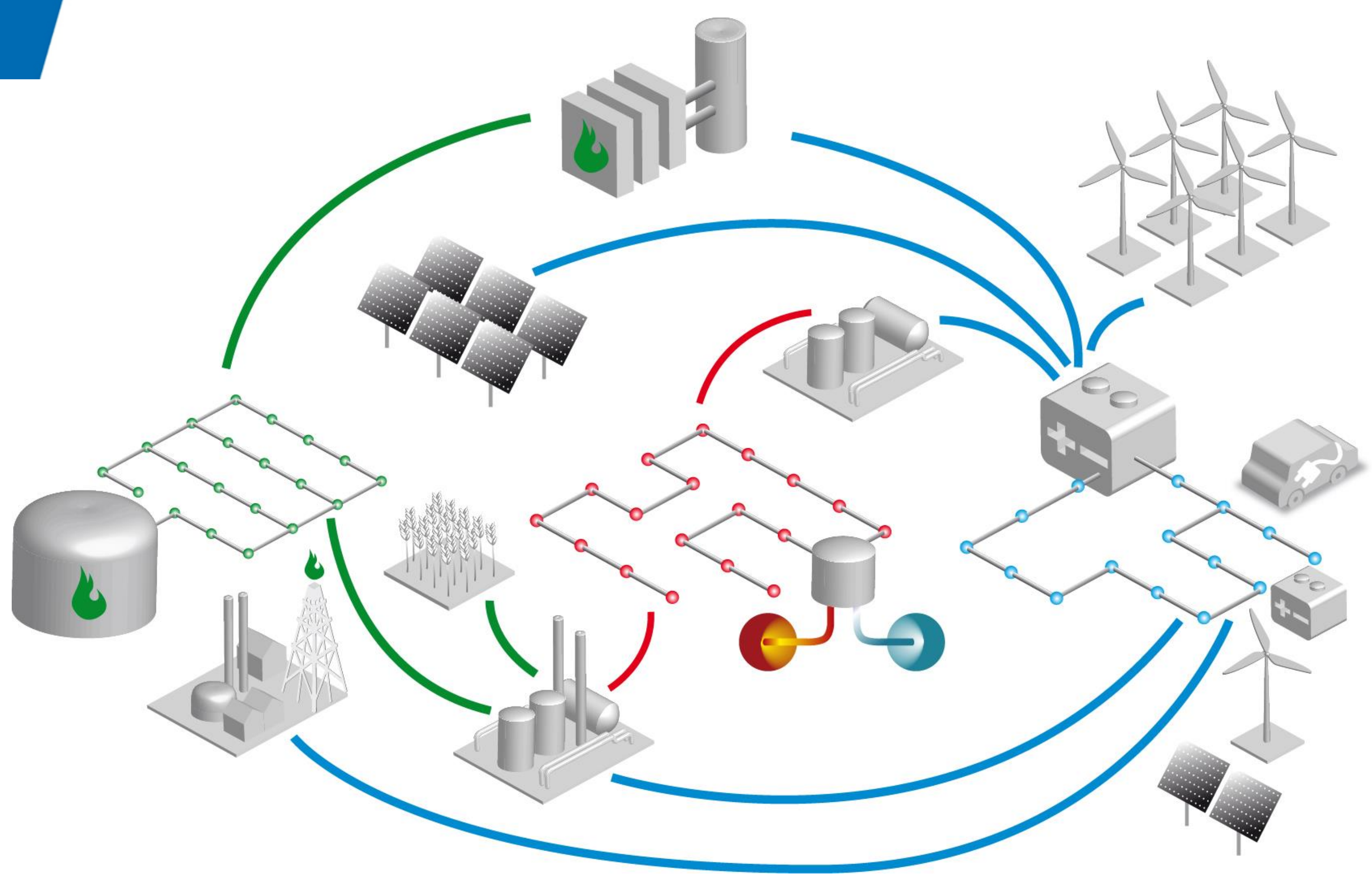
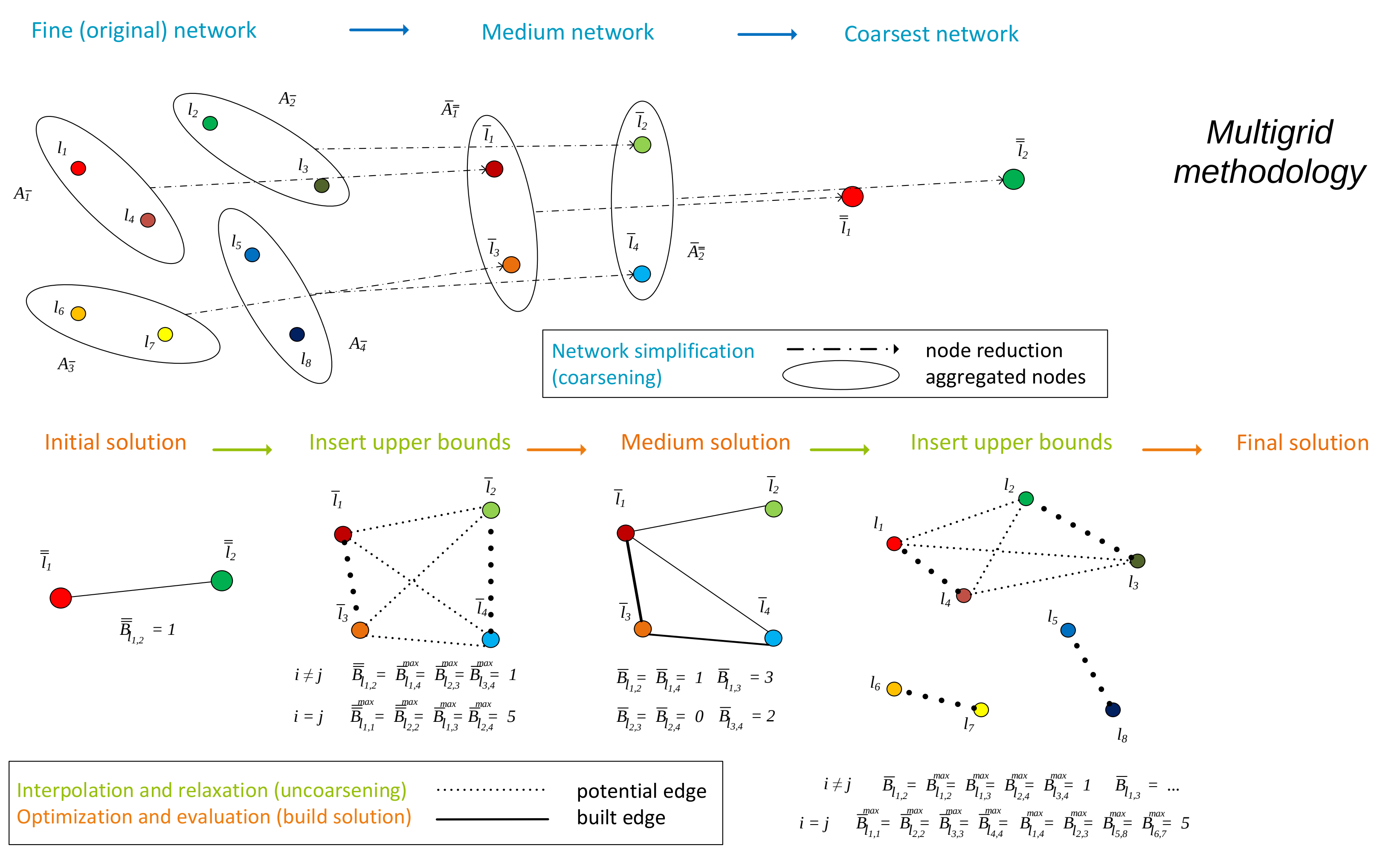


Cities beyond smart grids

Cities emit >70% of the world's greenhouse gases and are expected to contain >80% of the world's population in 2050. This increases their resource intensity and simultaneously puts them at high risk from climate change consequences. Hence, many cities across the globe have committed to stringent carbon targets; accelerating the integration of renewable energy. Given the intermittent nature of most renewables, smart grid solutions are explored to ensure a balanced power system. However, the world's current final energy consumption is just ~20% electric. To enable a sustainable energy transition across demand types with a predominantly renewable electric supply, it is imperative to explore solutions integrating the entire energy system.



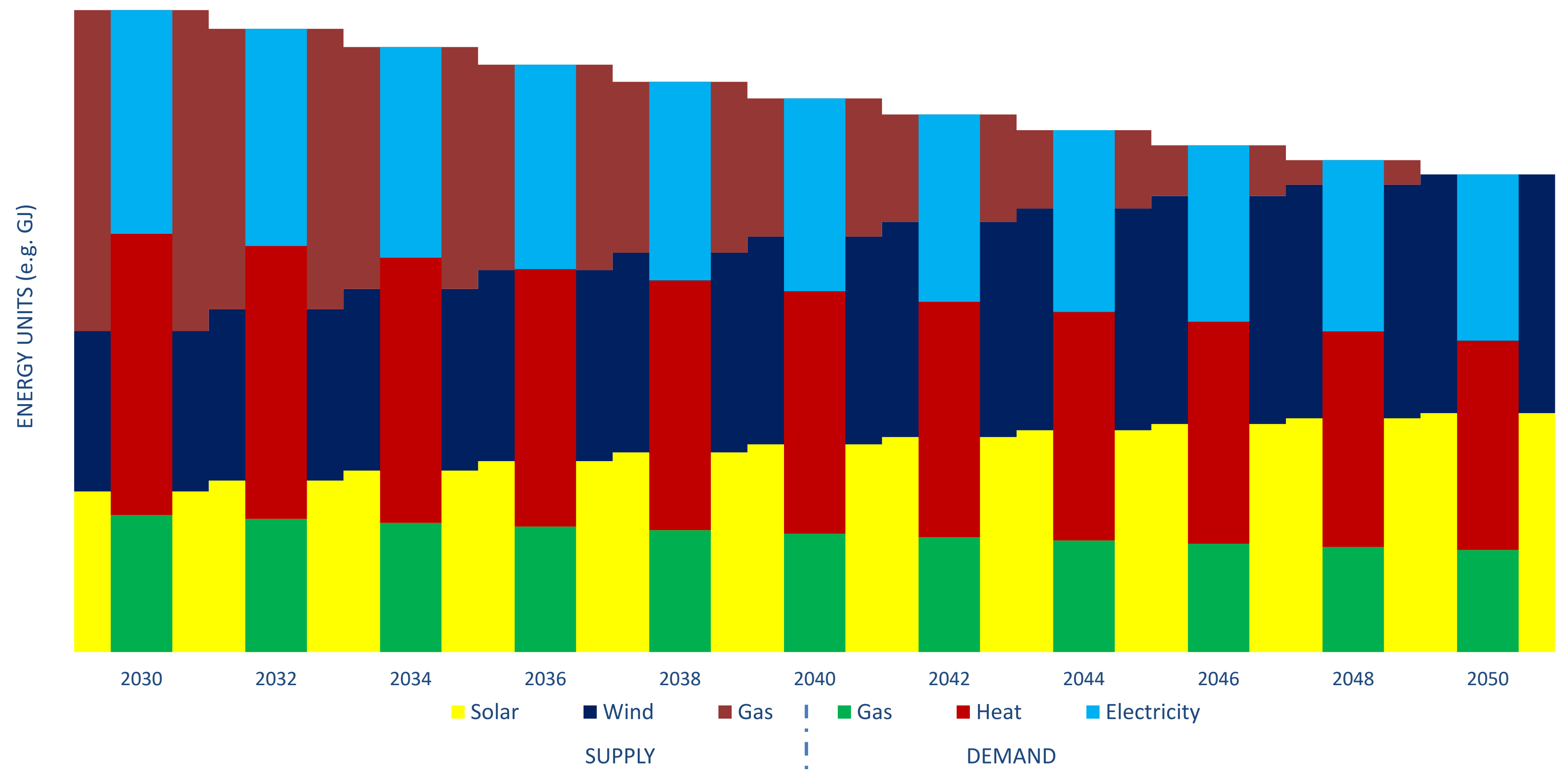
Multigrid methodology

Results for Dutch city

Using asset data from a Dutch DSO, a 110 node network is reduced to a 28 and then a 7-node network. The reduced network is solved as shown on the right, and then the upper bounds are translated to the 28-node network, which is solved in turn. This process is repeated for the 110 node network. The two multigrid solutions are compared with the closed-form non-multigrid solutions. Though the total cost increases, the CPU time is reduced significantly:

- *28 nodes – 1.25% more expensive, 64% CPU time savings*
- *110 nodes – 7.2% more expensive, 54% CPU time savings*

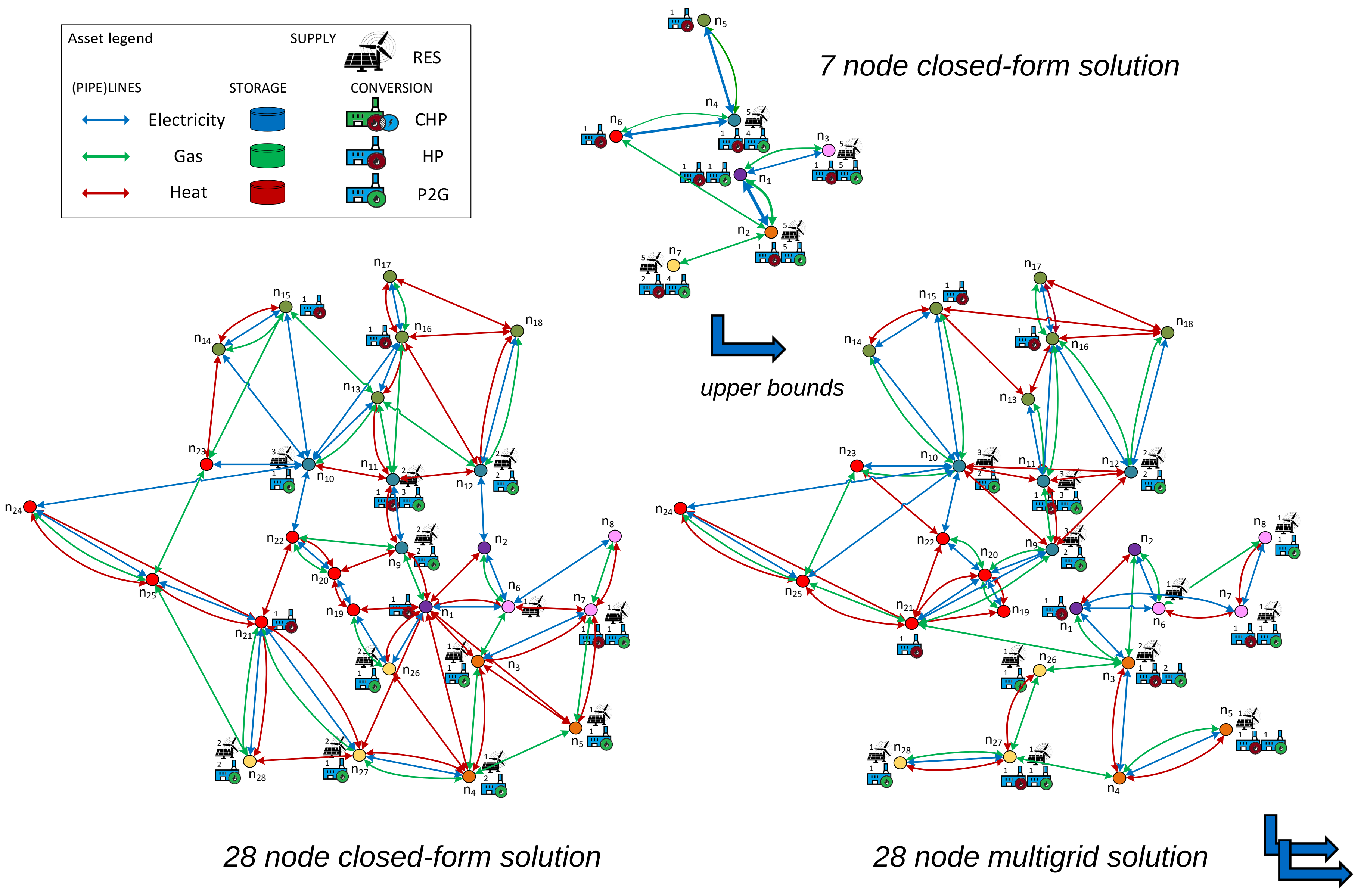
Moreover, the 110-node problem (technically 330 nodes) was the largest size to still have a closed-form solution. By applying the multigrid decomposition method, larger size problems can be tackled (e.g. more nodes, more time steps, more carriers).



Conceptual future city energy scenario 2030-2050

Decomposition using multigrid approach

At city level, the main energy infrastructures carry electricity, gas and heat. Fully integrating optimal planning of those networks –including asset capacity and location of conversions between carriers, respective storage of each carrier and (largely renewable) supply- is a mixed integer nonlinear problem. As this is N-P hard, the problem is linearized into an MILP. Yet when exploring city scales, the planning problem still lacks computational tractability. To manage that, a decomposition method is required. Multigrid decomposition is applied, because it is well suited for large-scale network problems (see left).



7 node closed-form solution

28 node closed-form solution

28 node multigrid solution

110 nodes
..~450 nodes,..

Conclusions and future research

Results show multigrid decomposition is an interesting approach for large-scale network problems, like the optimal planning of integrated electricity, gas and heat infrastructures. It is sensitive to the limitations of the initial solution and requires additional data processing steps.

Future work will use this approach to expand the current problem to energy transition scenarios as shown in the figure on the left. This will not just add timesteps, but also storage constraints and other technological development constraints. Further expansion options:

- Contingency testing for multi-energy systems, stochasticity, nonlinearity, adding other energy carriers (e.g. H_2), services (e.g. transportation) and developments (e.g. demand flexibility).

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