# Transmission Expansion Planning by Quantum Annealing

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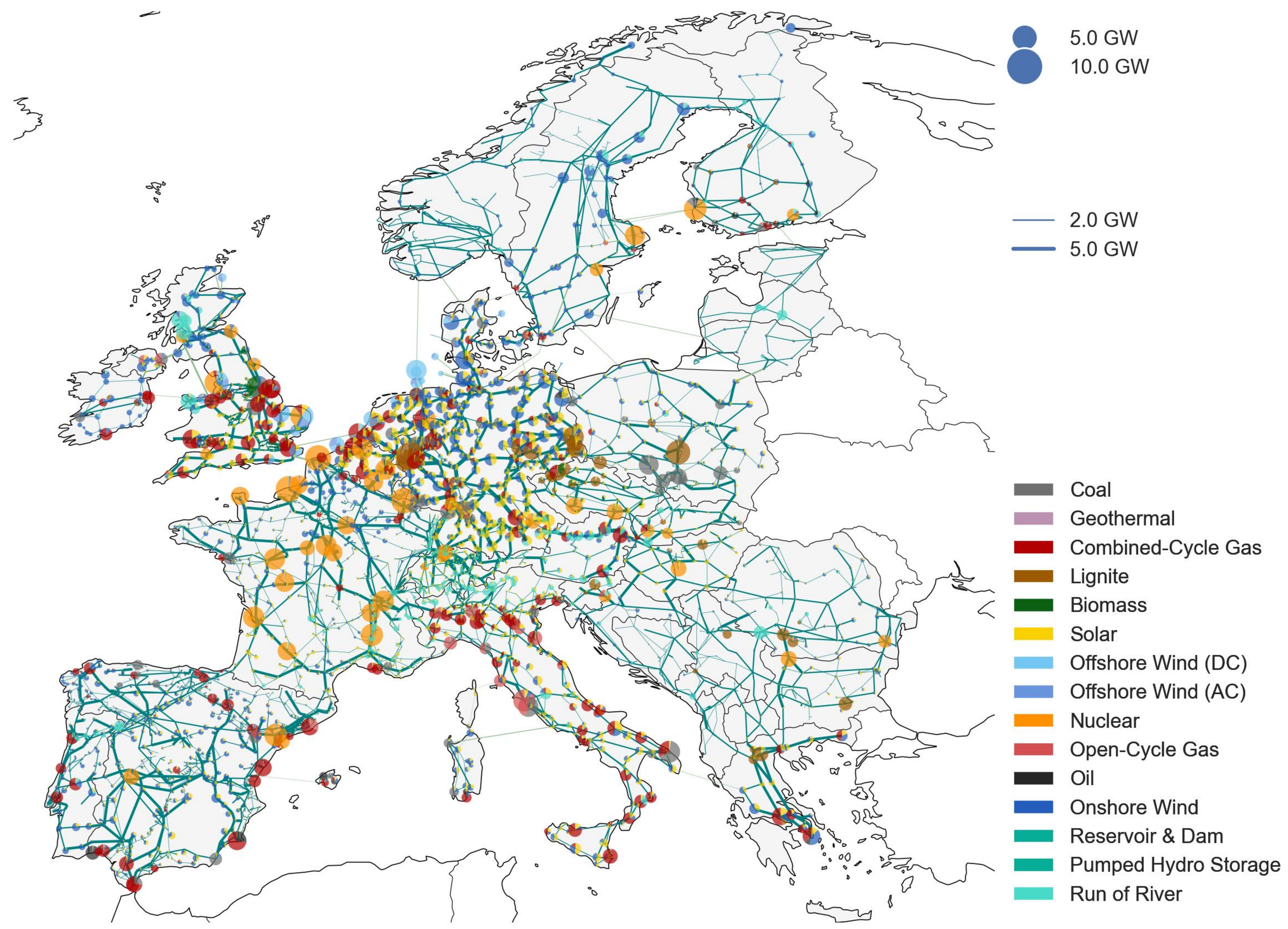


**Figure 1: Clustered transmission expansion network model of Europe as modelled by PyPSA-EUR [1].**

Energy system models are getting larger and more complex due to the integration of decentralized weather-dependent renewable energy sources, intermittent loads, sector coupling and the increase of storage components. For instance, the renewable energy produced by the integration of solar panels in dwellings is intended to be integrated to the grid if the consumers are not using it. However, the grid infrastructure is not evolving accordingly to the new energy paradigm. As a consequence, the efficiency of solar panels has to be decreased or the excess of energy has to be discarded. An analogous situation occurs with other renewable sources such as wind turbines.

An accurate expansion planning would solve these problems by redirecting the excess of energy to where it is required or by storing it so that it can be used later, e.g., to charge an electric car.

## Objectives

Study the advantage of using quantum computers to solve real-world energy optimization problems. Concretely, we want to answer the following questions for the TEP:

1) How big can a TEP problem be so it is fully solvable by nowadays quantum annealers?
2) How can hybrid methods be implemented in the TEP problem?
3) Benchmarking of classical solvers versus hybrid quantum-classical methods.

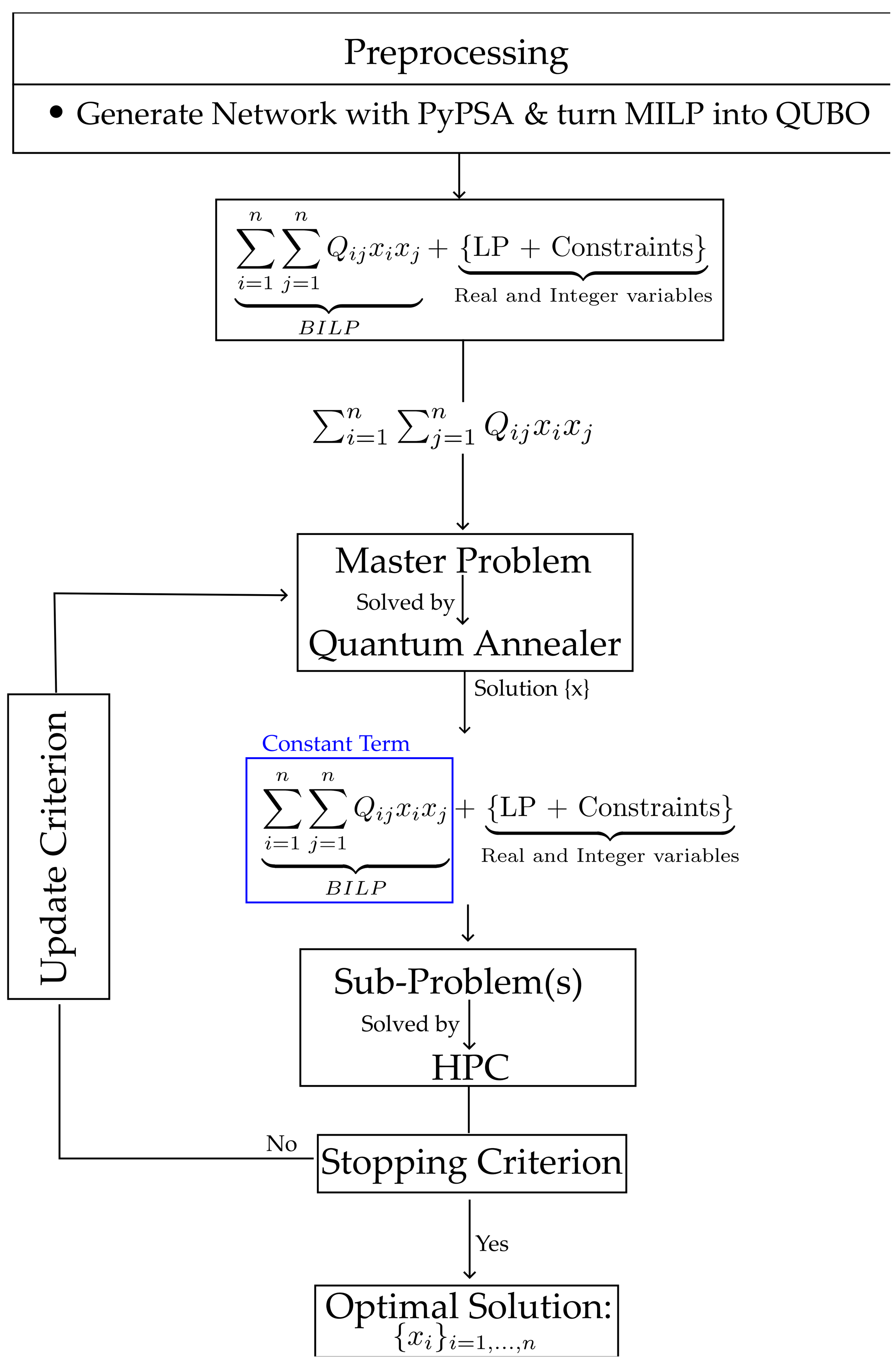


**Figure 2: Scheme of quantum-classical hybrid approach.**

## Motivation

In this work, we tackle the transmission expansion planning (TEP) problem [2], which is a mixed-integer linear problem (MILP) with NP complexity that aims at finding the optimal way to expand the capacity and connections of an energy system. Due to computational problems, usually, the scope and granularity of the models are reduced using clustering algorithms. For this reason, any computational time reduction will have substantial implications in closing the granularity gap between what the current models can solve and the desired resolution needed by energy system operators. Furthermore, preliminary studies, [3] and [4], indicate a possible speed-up by using hybrid quantum-classical techniques for larger problems.

## Ongoing Research

The TEP problem can be written as

$$\mathcal{H} = \underbrace{\sum_{i=1}^{L} c_i^{(\text{iv})} l_i}_{\text{Investment Cost}} + \underbrace{\sum_{t}^{T}\sum_{j=1}^{G} c_j^{(\text{oc})} g_{j,t}}_{\text{Operational Cost}}$$

subject to:

$$0 \le g_{j,t} \le g_j^{\max}, \qquad \forall j, t$$

$$D_k(t) = \sum_{j=1}^{G} g_{j,t}, \quad \forall\, t, k$$

where $c_i^{(\text{iv})}$ represents the investment cost of line $l_i$, $c_j^{(\text{oc})}$ is the operational cost of generator $g_j$, $D_k$ is the energy demand at node $k$ and $t$ is the time index.

We are studying the different ways of splitting a the TEP Hamiltonian into a master problem and a sub-problem according to (Figure 2), so that we can couple quantum solvers with classical solvers.

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**References:**

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