We begin by introducing the project through the lens of the paper *"Quantum Computing for Energy Systems Optimization: Challenges and Opportunities."* This paper lays the foundation for understanding how quantum methods could transform decision-making in complex energy systems. Alongside this, we present two real-world problem statements from the Open Quantum Institute Challenge: one focused on Smart Grid Management, and the other on the Optimal Layout of Wind Turbines. These challenges reflect urgent, practical needs in the energy transition. To frame our work in a broader global context, we also reference the 17 Sustainable Development Goals (SDGs) established by the United Nations. These goals aim to guide global development toward sustainability, equity, and resilience. Among them, our focus is on SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 13 (Climate Action)—each directly connected to energy optimization and technological innovation. Our topic supports these goals by aiming to optimize energy systems for lower emissions, better reliability, and improved infrastructure planning.

As an introduction to quantum energy optimization, we looked first at the facility allocation problem. In its classical form, this involves assigning facilities to locations with constraints (like only one facility per site). To map this to a quantum version, we reformulate it as a QUBO (Quadratic Unconstrained Binary Optimization) problem. Constraints are encoded into the cost function using large penalty constants (A), allowing us to use quantum annealing systems like D-Wave. These systems apply the adiabatic theorem: by starting in the known ground state of an initial Hamiltonian and slowly evolving to a target Hamiltonian, we aim to land in the ground state representing the optimal solution.

We now turn to a more advanced application: the Unit Commitment (UC) problem, which determines which power generation units should be turned on or off over a planning horizon. This depends on demand variation across time, seasons, and location. Generators differ in startup costs, running costs, and efficiency, making this a complex problem—even before introducing uncertainty.

With renewables, things get harder. Their fluctuating output requires more frequent updates to the plan, and since they're used first, the cost of starting or stopping backup generators becomes even more critical. Batteries can help smooth this, but they add more variables. The result is a large-scale, non-convex, mixed-integer optimization problem—in fact, NP-hard. The next step is to explore a quantum approach using Benders decomposition, to break the problem into tractable parts and potentially achieve more scalable optimization using quantum resources. Results of the paper [3] are discussed at the end.

Ref:
[1]: 2305.08482 (classical methods)
[2]: 2003.00254v1 (naive quantum solution)
[3]: Hybrid quantum annealing decomposition framework for unit commitment (current quantum solution)