



Quantum computing and technologies at EDF R&D, an overview

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Our view of the “quantum context”

- ⦿ **The “Second Quantum Revolution” makes us three promises :**
 - An increase in computing power and sensor accuracy
 - A better future cybersecurity... and a threat to today’s
 - A reduction in the energy consumption of computing resources
- ⦿ **To what extent and when will these promises be kept?**
 - Very difficult to say, because major technological challenges remain in order to build robust large scale quantum devices
- ⦿ **Very significant progress in a few years, both in terms of quantum algorithmics and of quantum hardware**
- ⦿ **You must not miss the train and try to take it on afterwards ...**
 - Potentially (very) important impact on a limited number of uses, but very widespread in our businesses
 - Specialized and rare skills

Our position and objectives

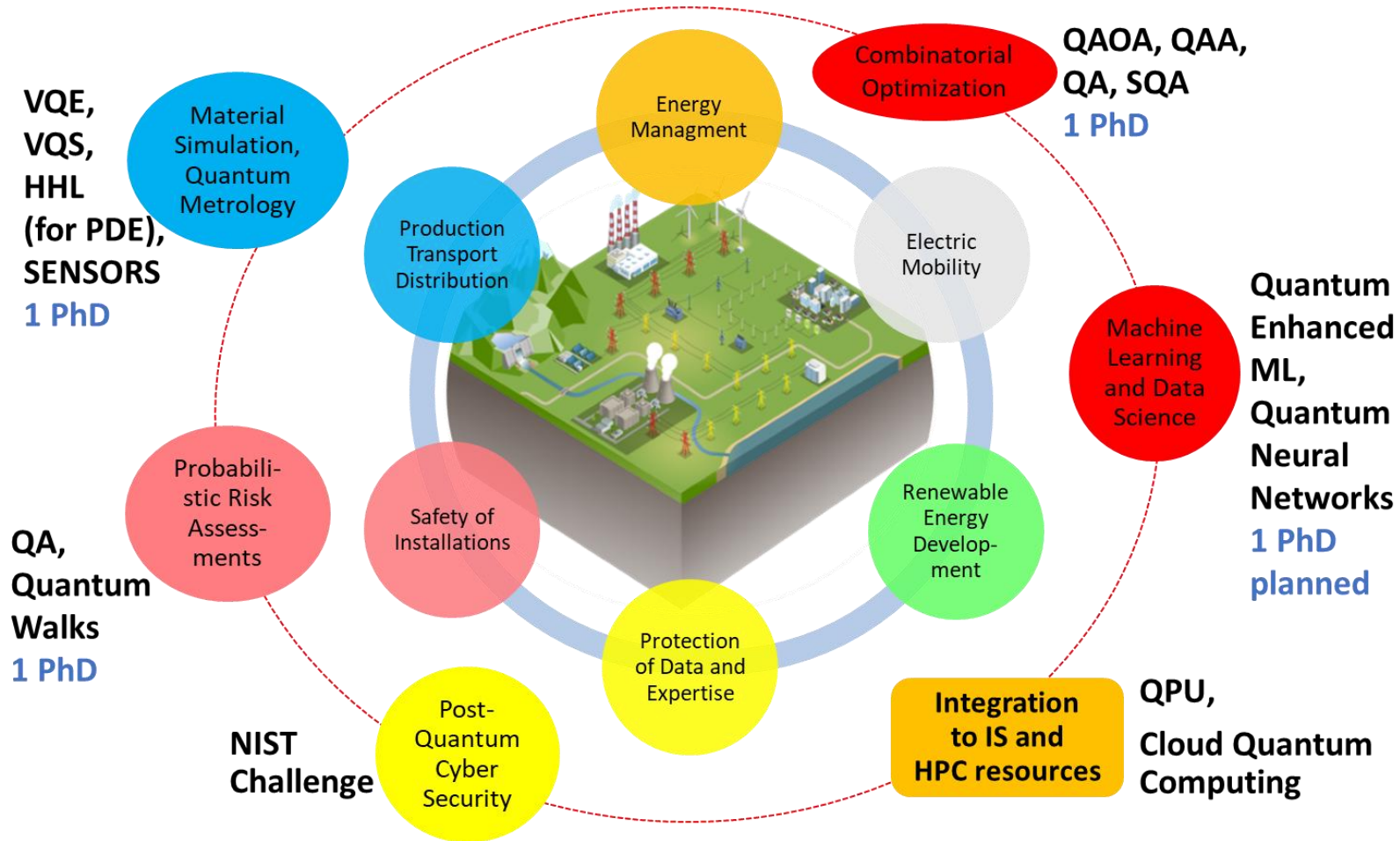
- ⦿ Increase internal skills in the field
- ⦿ Identify the relevant use-cases for EDF businesses
- ⦿ Experiment with available quantum technologies through proof-of-concept, relying on academic and industrial partnerships.
- ⦿ Enlighten our operational divisions on disruptive applications of quantum technologies

Technological axes of the French National Quantum plan, and their respective investments

NISQ	LSQ	Quantum Communications	Post-Quantum Cryptography	Ancillary technologies (cryogenics, lasers ...)	Quantum Metrology	TOTAL 2021-2025
352 M€	432 M€	325 M€	156 M€	292 M€	258 M€	1815 M€
↓	↓	↓	↓	↓	↓	
EDF's position : Actor – User		Watch	Watch/User	Watch	Watch/User	



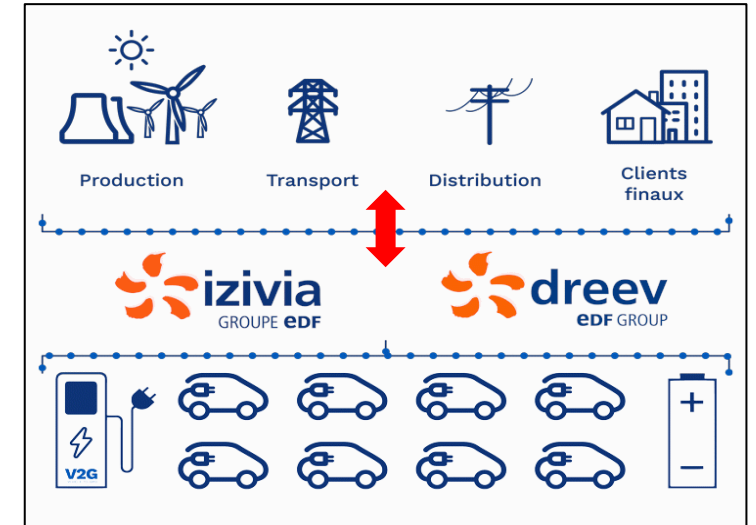
Our use-cases under study



- ⊙ We seek for potential « quantum advantages » in these fields, in terms of performances and energy consumption
- ⊙ Exploring NISQ, without waiting for LSQ!

Quantum optimization for electric mobility (PhD with LORIA)

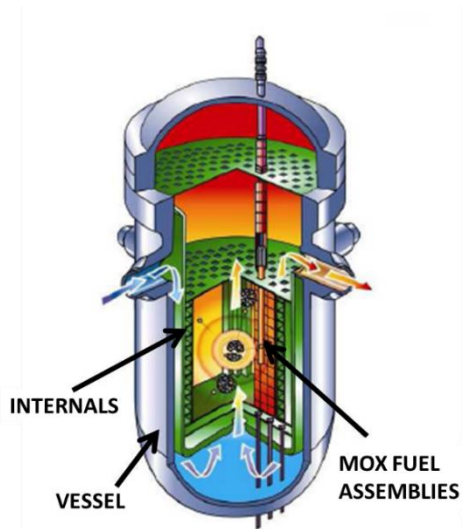
- Smart-charging/V2G, a key feature for the thriving of electric mobility : considering EV not only as a *power demand* addressed to the grid (*charge*) but also as a *power resource* for the grid (*store, discharge*)
- Work in progress on hybrid classical/quantum methods for hard combinatorial optimization problems in this field
 - Minimization of the completion time of charging tasks with priorities
 - Maximization of non-overlapping charging intervals under a group constraint
 - Optimization of a huge number of EV charges/discharges to contribute to the stability of the frequency of the Grid (*Frequency Containment Reserve*)
- First encouraging results obtained applying the “Quantum Approximate Optimization Algorithm” (QAOA) on real instances of these problems, but of limited size
- To be confirmed on real-size instances on the forthcoming larger scale quantum devices



C. Dalyac, L. Henriot, E. Jeandel, W. Lechner, S. Perdrix, M. Porcheron et M. Veshchezerova, «Qualifying quantum approaches for hard industrial optimization problems. A case study in the field of smart-charging of electric vehicles,». *European Physical Journal EPJ Quantum Technol.*, vol. 8, n° 112, 2021

Others use-cases in progress

- Quantum simulation for material ageing (PhD with Institut d'Optique)

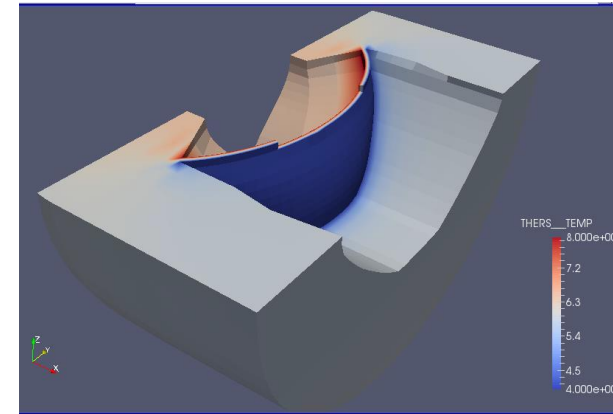


Nuclear Power Plants



Batteries

- Quantum algorithmics for solving PDEs in mesh-based simulators (Collab. with Thales)



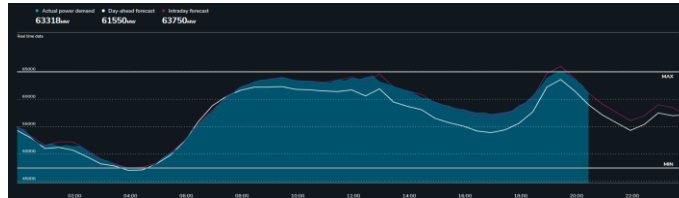
Dams

Others use-cases in progress

- Quantum Machine Learning for forecasting of energy prices, consumption, ENR production ; for load curves completion and customer clustering ... (PhD with CentraleSupélec)

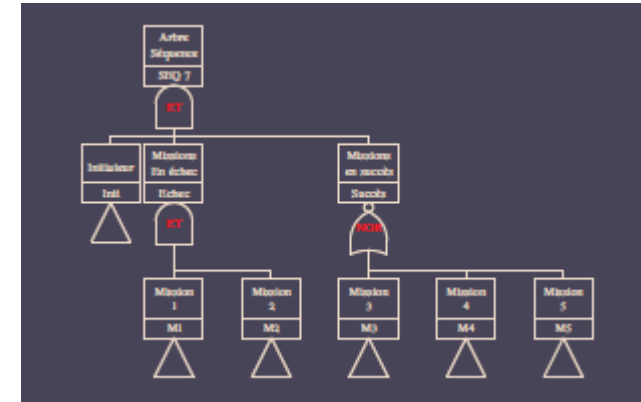


ENR production



Load curves

- Quantum algorithmics for Probabilistic Risk Assessments (PhD with LIPN)



Fault trees

Not alone !

Partnerships and quantum ecosystem are essential for us

- ⊙ Three PhD in progress, a new one to begin this year. Co-advising labs : [Loria/University of Lorraine](#), [LIPN/Paris Nord](#), [Institut d'Optique Saclay](#), [Centrale-Supélec](#) (planned)
- ⊙ Collaboration with the startup [Pasqal](#), in particular in the [Quantum Pack of the region Ile de France](#)
- ⊙ Partner of two European projects of the “[H2020 FET-Quantum Flagship](#)”: [PASQuanS](#) (Programmable Atomic Large-Scale Quantum Simulation) and [NEASQC](#) (NExt ApplicationS of Quantum Computing)
- ⊙ Collaborations under construction with industrial and academic partners: [Thales](#), [Ecole Normale Supérieure](#), [Centrale-Supélec](#), [Safran](#), [Airbus](#)...
- ⊙ Collaborations with [Atos-Bull](#) on use-cases, access to the [Quantum Learning Machine](#) at the [CRRT](#)
- ⊙ Exchanges with [D-wave](#), and test of its Quantum Annealer
- ⊙ Contacts with actors of the quantum ecosystem, from startups to big companies: [Quandela](#), [C12](#), [CryptoNext](#), [Alice&Bob](#), [Xanadu](#), [QC-Ware](#), [Nvidia](#), [IBM](#), [Microsoft](#), [Google](#)...
- ⊙ Participation in working groups with other industrial companies involved: [CIGREF](#), [CCRT/TERATEC/TQCI](#)...
- ⊙ Support to the [Quantum Hub of Paris-Saclay](#), and academic quantum training programs ([Arteq](#), [Quarmen](#))
- ⊙ Hearing by the French government as part of the development of the [French National Quantum Plan](#)
- ⊙ Contribution to the [European Commission](#) groups on “[Industrial applications of Quantum Technologies](#)” and “[European Competence Framework for Quantum Technologies](#)”
- ⊙ Presentation of our activities in various meetings/conferences and in the specialized media

Thank you !

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