Aspects of quantum science and sustainability

2026 Edition

What is this class about ?

- In **QSE** we face the development of new technologies for the future. These have transformative or even disruptive potential.

- We want these new techs to develop in the “right way” for the benefit of society and mankind:
  - *Ethical use of the technology*
  - *Fair access and in particular across countries*
  - *User awareness and user education*
  - *Sustainable development and use*

- **Case of AI**: although concepts and development was lurking for many years, the technology exploded suddently (after long winters).
  Will the above points be matched and how ? (that is the question).

- In this class: we will discuss topics related to above points for a sustainble development of QSE in a broad sense.

- EPFL has introduced disciplinary sustainability classes in all master programs and general one s at Bachelor level.

- First edition of this class experimented last year was very sucessful. I hope this year also!

Logistics

Course: Wednesdays 14h15 - 16h00

Room INM 11

We explore the intersection of quantum technologies and sustainability. Topics: 1) GESDA and open quantum institute initiative on UN Sustainable Goal Developments; 2) Fundamental aspects of thermodynamics of computation and analysis of energy consumption in current NISQ and near term quantum devices; 3) Broader discussion of computing and storage challenges related to AI; 4) Projects on use cases through personal student work.

The course will also feature guest lectures and some may be announced during the semester.

Students will choose to work in small teams on projects related to potential applications of quantum technologies or quantum enabling technologies to sustainability challenges.

***EPFL lecturers*:** nicolas.macris@epfl.ch , adrian.ionescu@epfl.ch

***Guest lecturers 2026 edition*:** audrey.himmer@cern.ch, philipp.kammerlander@cern.ch , alex bernasconi, philippe.caroff@epfl.ch, marieke.hood@gesda.global Geneva Science and Diplomacy Anticipator www.gesda.global and Open Quantum Institute CERN

Other guest: TBA

Final assessment: based on participation in class, project work, and presentation at the end of semester.

An overview of the subjects the 2026 program

Part I: GESDA, OQI, QDG

Guests: Philipp Kammerlander, Alex Bernasconi, and Audrey Himmer, Marieke Hood (TBC)

THE GENEVA SCIENCE AND DIPLOMACY ANTICIPATOR

gesda

USE THE FUTURE TO BUILD THE PRESENT

"To develop an instrument of **anticipation** and **action**

- by favoring **public-private partnerships of international scope**
- and **projects**
  - to provide solutions to current and future technological challenges
  - turn them into **opportunities**
  - and **widen the circle of beneficiaries of advances in science and technology**"

SDGs

OQI
Open Quantum Institute

https://sdgs.un.org/goals

Quantum Diplomacy Game

Governance of Revolutionary Technology

Participant Guide

Originally developed by Andrew Chen, Kristiann Allen, Grant Mills and Naomi Simon-Kumar for INGSA/GESDA. Adapted by Marga Gual Soler and Marianne Schoerling from the GESDA Foundation for the Open Quantum Institute (OQI).

Geneva · January · 2025


THE WORLD TODAY


Think creatively about the world you want to help create


Quantum Diplomacy Game

Part II: Topics in thermodynamics of computation

- Introduction to fundamental aspects
- Resource estimations for full stack NISQ devices

Lects: Nicolas Macris

The Thermodynamics of Computation—a Review

Charles H. Bennett

IBM Watson Research Center, Yorktown Heights, New York 10598

R. Landauer

Irreversibility and Heat Generation in the Computing Process

Abstract: It is argued that computing machines inevitably involve devices which perform logical functions that do not have a single-valued inverse. This logical irreversibility is associated with physical irreversibility and requires a minimal heat generation, per machine cycle, typically of the order of kT for each irreversible function. This dissipation serves the purpose of standardizing signals and making them independent of their exact logical history. Two simple, but representative, models of bistable devices are subjected to a more detailed analysis of switching kinetics to yield the relationship between speed and energy dissipation, and to estimate the effects of errors induced by thermal fluctuations.

Demons, Engines and the Second Law

Since 1871 physicists have been trying to resolve the conundrum of Maxwell's demon: a creature that seems to violate the second law of thermodynamics. An answer comes from the theory of computing

by Charles H. Bennett

PRX QUANTUM **3,** 020101 (2022)

Perspective

Quantum Technologies Need a Quantum Energy Initiative

Alexia Auffèves*
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Quantum technologies are currently the object of high expectations from governments and private companies, as they hold the promise to shape safer and faster ways to extract, exchange, and treat information. However, despite its major potential impact for industry and society, the question of their energetic footprint has remained in a blind spot of current deployment strategies. In this Perspective, I argue that quantum technologies must urgently plan for the creation and structuration of a transverse quantum energy initiative, connecting quantum thermodynamics, quantum information science, quantum physics, and engineering. Such an initiative is the only path towards energy-efficient, sustainable quantum technologies, and to possibly bring out an energetic quantum advantage.

DOI: 10.1103/PRXQuantum.3.020101

PRX QUANTUM **4,** 040319 (2023)

Optimizing Resource Efficiencies for Scalable Full-Stack Quantum Computers

Marco Fellous-Asiani[1,2,*] Jing Hao Chai,[2,3,4] Yvain Thonnart[5] Hui Khoon Ng,[6,3,7,†]
Robert S. Whitney[8,‡] and Alexia Auffèves[2,3,7,§]

18–22 May 2026 • ICFO Auditorium • Castelldefels (Barcelona, Spain)

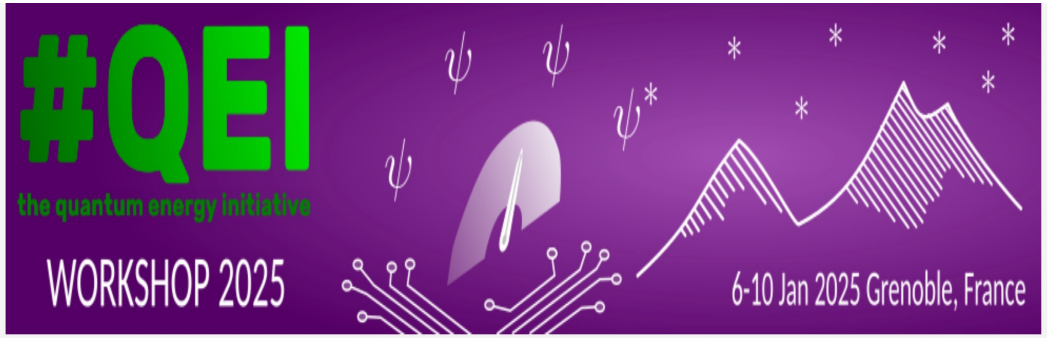
Quantum Energy Initiative Workshop

The third Quantum Energy Initiative Workshop will happen at ICFO, Castelldefels (Barcelona, Spain) from the 18th to the 22nd of May 2026. **Save the date !**

Register (free) External links

Launched in August 2022, the Quantum Energy Initiative is fostering a worldwide community of experts willing to develop scientific approaches to evaluating and minimizing the physical resource costs of emerging quantum technologies. This requires the synergy of a broad range of expertises, from fundamental quantum physics to enabling technologies, from hardware to software, from research to industry.

Building on the strong foundations at the first workshop (Singapore, Nov 2023), and second workshop (Grenoble, Jan 2025), this third workshop will bring together highly renowned speakers of all these areas, to provide their vision on these exciting and essential questions. It will also leave time for discussions and crossed-fertilization to the build new methodologies and roadmaps.



Workshop: QEI 2023 (Singapore, Nov 2023)

#QEI workshop 2023 nov 20-24 Singapore
the quantum energy initiative

Part III: Computing and storage challenges related to AI

Lects: Adrian Ionescu

Sustainability of Edge to Cloud Computing

Adrian M. Ionescu, Nanolab, EPFL

- Source of optimization problems
- Related to SDGs

Sustainability challenges for energy harvesting and Digital Twins

Adrian M. Ionescu, Nanolab, EPFL

Part IV: Personal work in teams

Rest of semester devoted to your personal project work:

Projects Instructions :

i) Form teams of 2 or 3 per project (to be updated).

ii) During the last two weeks you will be presenting your projects to the rest of the class and handover your slides. Each presentation will last approx 30 minutes and discussed with the whole class. Presence in these two last sessions is mandatory.

iii) The project can be any topic of *your choice* related to the themes of the class (discussed or not discussed in class). Below is a list of suggestions to help you out, but you may have other ideas.

iv) We are available during course hours on Wednesdays 14h15 – 16h if you want to discuss your progress. However you should first make an appointment with us a few days before.

Last two weeks teams present their projects

2025 edition presentations:

1) Douaa Salah, Edoardo Spigarolo, Constantin Wehrbach [OQI Use Case: Multi-objective Food Optimization Model] (relates to SDG no 2 Zero Hunger) *Abstract: see pdf file below.*

2) Emma Berenholt, Alexandra Golay, Paul Gregory [Quantum Reservoir Computing for Market Forecasting: An Application to Fight Food-Price Crisis] (relates to multiple SDGs) *Abstract: see pdf file below.*

3) Simon Deconihout and Andrew Sutcliffe [Affordable and Clean Energy Using Quantum Computing] (relates to SDG 7 affordable energy) *Abstract: see pdf below*

1) Antoine Pignalosa, Ata Krichene, Yuchen Lu,
[Energy consumption comparison for different quantum computing platforms]
Abstract: see below.

2) Nathan Pacey, Cherilyn Christen, Lindon Zymberi, [Energy Analysis of Classical and Quantum Algorithms for the Traveling Salesman Problem; relates to SDG 9 & 11 in particular] ***Abstract: see below.***