PHD TOPIC OF THE EUROPEAN SEED PROGRAM

Control of HVAC systems of a building: towards ambient air conditioning, at the lowest energy and environmental cost

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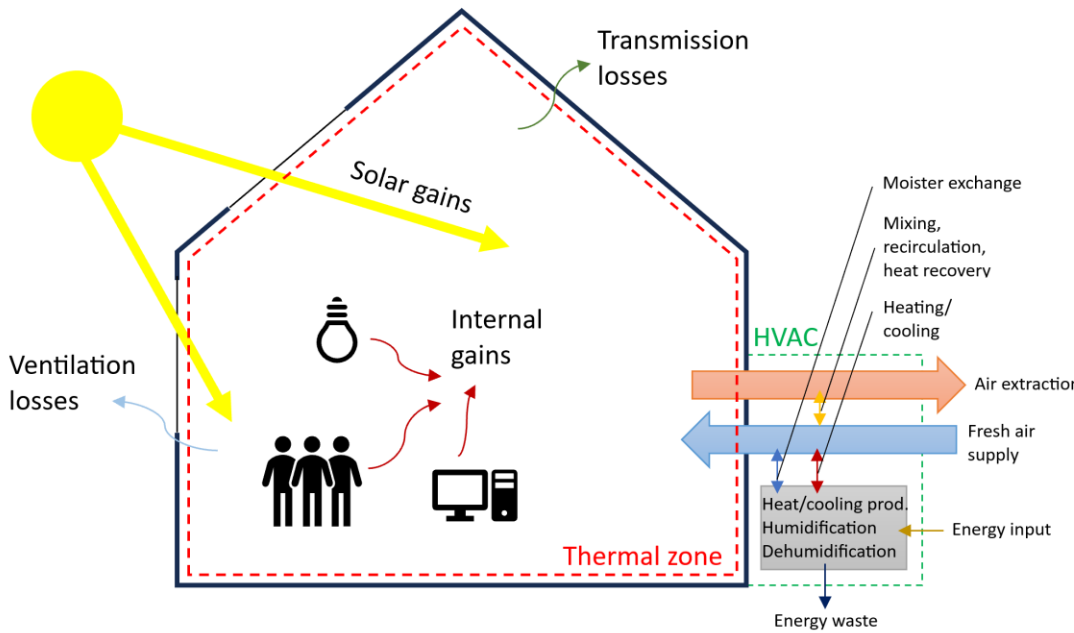
SUMMARY

HVAC (Heating, **Ventilation**, and **Air Conditioning)** is a system or technology used in buildings to control the indoor climate, including temperature, humidity, and air quality.

- **Heating (H):** responsible for maintaining a comfortable temperature in the indoor space during colder seasons..
- **Ventilation (V):** replacing air within a space to ensure a continuous supply of fresh, oxygen-rich air. Proper ventilation helps remove pollutants, odors, and excess moisture, contributing to indoor air quality.
- **Air Conditioning (AC):** responsible for cooling indoor spaces during warmer weather. Air conditioning systems also help control humidity levels, contributing to comfort.

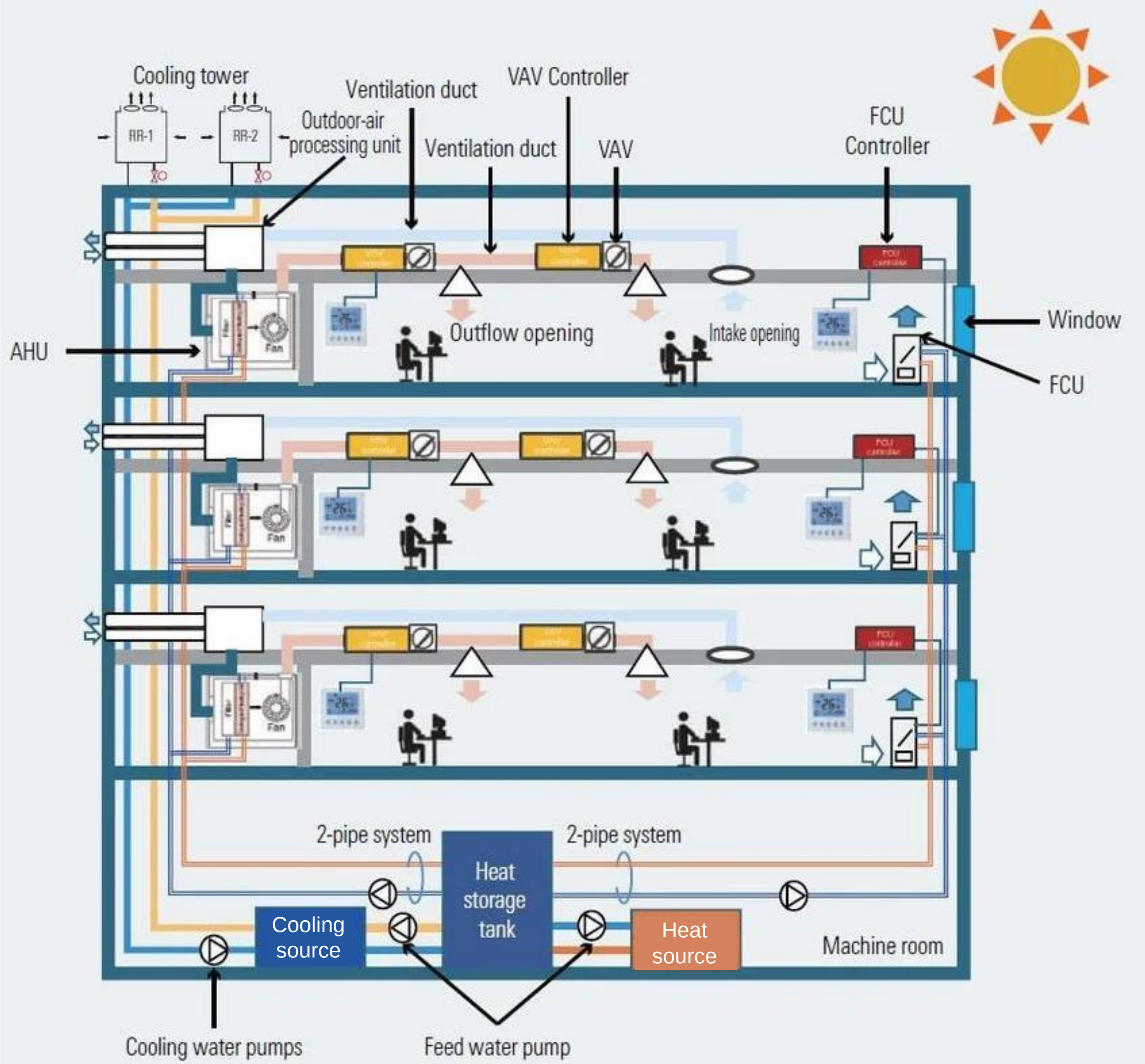


1. HVAC SYSTEM

1.2. key concepts

Main components:

- Energy production systems
- Air processing units
  - FCU: Fan Coil Unit
  - AHU: Air handling Unit
- Distribution systems
  - Pipes and ducts
  - Pumps and fans
- Monitoring and Control systems



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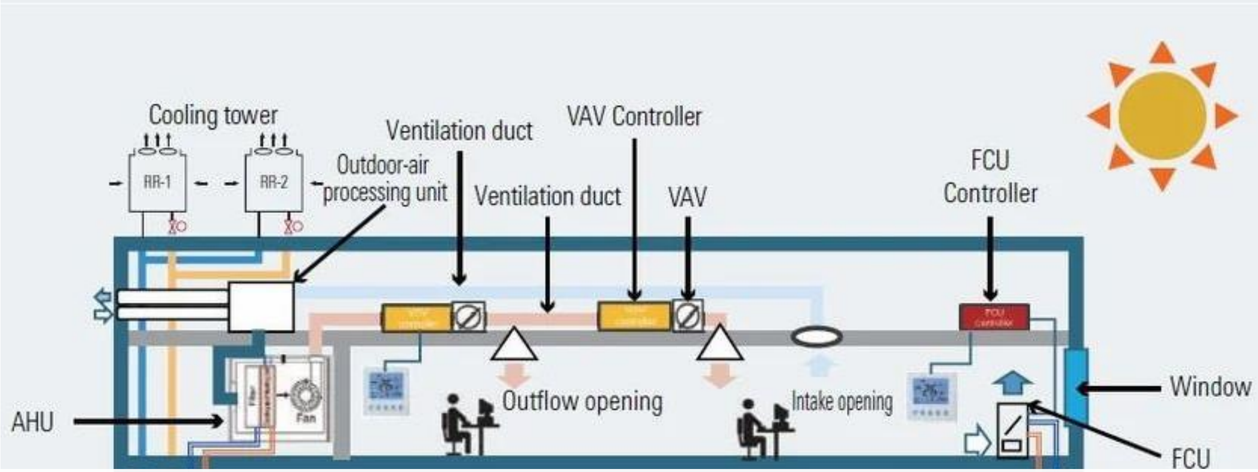
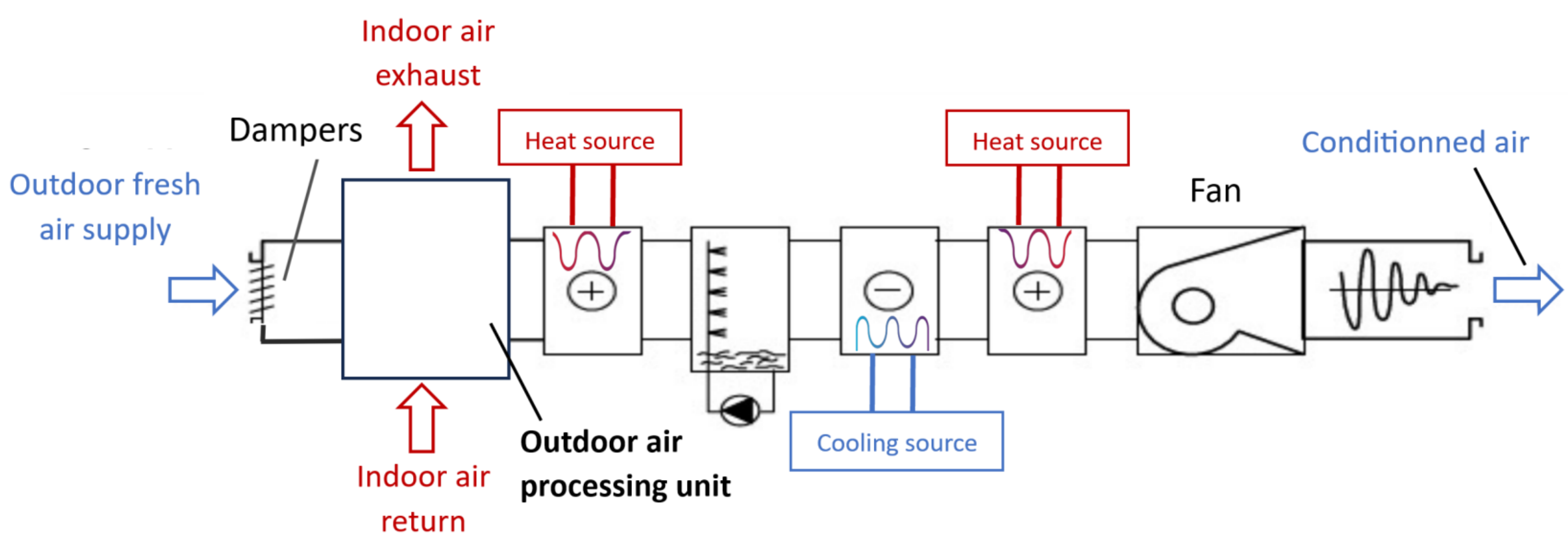
1. HVAC SYSTEM

1.2. key concepts



Typical air handling unit



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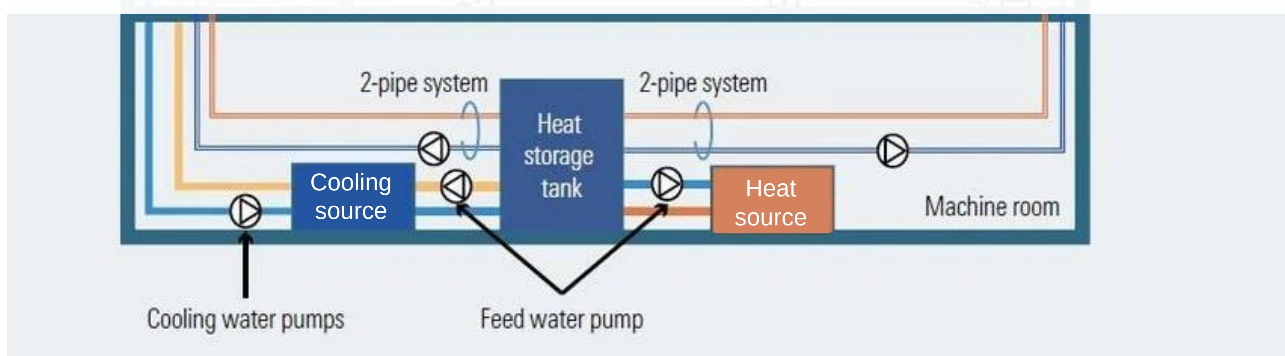
Heat and cooling Production technologies:

- Boilers
- Combined Heat and Power units (CHP)
- Combined Cooling, Heat and Power (CCHP)
- Compression Heat pumps (HP) and chillers: air source, geothermal
- Absorption Heat pumps and chillers

Energy sources

- Gas
- Biomass, biofuels and waste
- Electricity: grid, PV and wind
- Geothermal
- Ambient air
- …



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Two levers towards sustainable and decarbonized systems:

- Usage of renewable energy and decarbonized sources
  - Intermittent sources and time dependent energy availability
  - Time-variant energy tariff on the grid
  - An increased reliance on demand response
- Increase the efficiency to consume less energy and reduce emissions
  - Usage of more complex combination of technologies to optimize the usage of the primary energy
  - Optimize operations for continual reduction of energy consumption and GHG emissions

➡ **Advanced control strategies taking into account developments in these systems and their environment**

2. CHALLENGES & OBJECTIVES

2.1. Challenges (2/2)

- **A complex system…**
  - **Nonlinear behavior of the systems:** partial load efficiencies, Hexs, flow mixing
  - **Different dynamics and time scales:** building's envelope, energy production dynamics, Hexs dynamics
  - **Large scale buildings:** a big number of components and independent thermal zones

➡ **Difficulty in obtaining a realistic and tractable model, yet necessary for an effective control method !**

- **A complex trade-off between comfort, energy consumption & GHG emission…**
  - Comfortable thermal and hygrometric environment can be already a challenge: distributed sensors and actuators, not necessarily co-localized.
  - Energy costs and environmental concerns must be taken into account in the control problem !

Scientific objectives:

- **Leading-edge control strategy for HVAC:** predictive optimal control techniques, that take benefits from the knowledge of the future tracking point, weather forecast, ect…
  - Trade-off between comfort / energy consumption & GHG emissions
  - Need for **fast**, **realistic** and **calibrated** models of the HVAC and the building; current research aim to promote physical and parametrized model of sufficient complexity. Very few work on physics-informed machine learning…
  - Methodological challenge; implementation of the predictive control law at low computational cost and guaranteed robust performance
- **Perspective with reinforcement learning approach**
  - Data-based approach; Data-driven approach; no expected model of the process?
  - Practical concerns: Prohibitive quantity of data and learning time needed, data availability
  - One solution: direct control-policy learning, but physics-informed?

Operational objective:

Implementation of the control strategy on a real HVAC system:

- Veolia will provide a real case study selected from their managed buildings
- Need to adapt the method to the real system: available sensors and actuators, available data and information, etc…
- Necessity to limit the scope of required modification: pragmatic approach
- Combining data and physics need to be guided by the reality of the case study

An interdisciplinary challenge !

To deal with this challenge ask for: HVAC engineering, physical modeling (energy, thermodynamic, fluid), model reduction, dynamical system theory, and artificial intelligence (optimization, Machine learning)

4. PARTNERS

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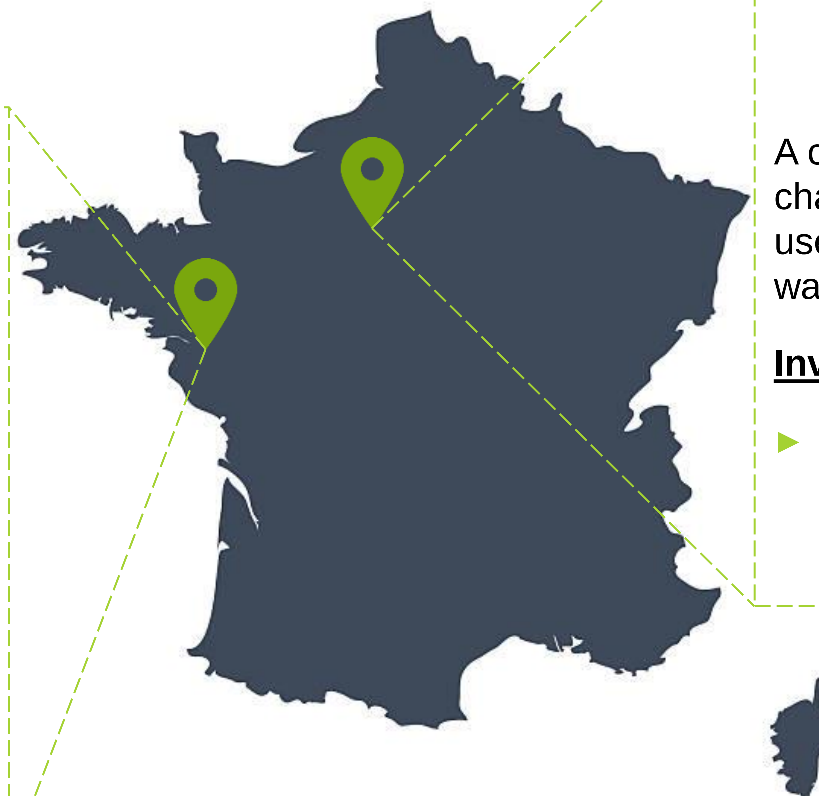
A leading technological university

Involved departments:

- **“Automation, Production and Computer Sciences”**
- **Department “Energy and Environmental Systems »**



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A company that provides game-changing solutions that are both useful and practical for water, waste and energy management.

Involved department:

- **Sientific and Technological Expertise department (S&TE)**

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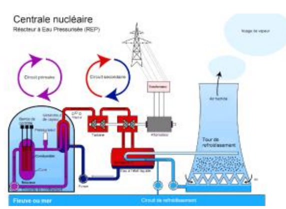
3.1. IMT Atlantique: “Automation, Production and Computer Sciences”

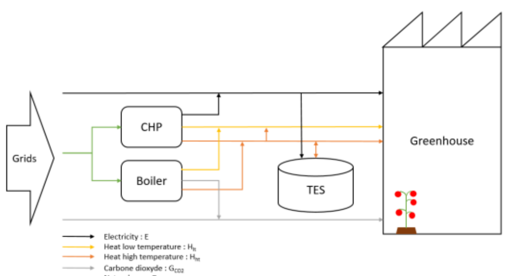
Department: around 45 Permanent academic staff, including 20 professor, and 25 PhD students

https://www.imt-atlantique.fr/en/about/departments/dapi/research

Three main themes:

- *Software engineering and distributed systems*.
- *Optimisation and decision-making*.
- ***Cyber-physical system:*** *team CODEx* (Command, Observation, Diagnostic and Experimentation), who will be involved in this PhD





Research: dynamical systems, robust and optimized control and observers, neural network based predictive control.

Applications:

- Autonomous vehicles (on & off road)
- multi-energy and industrial process control

Energy transition: sustainable energy or low carbon

- Distributed management of multi-energy systems
- Nuclear energy production control
- Energy optimization

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3. PARTNERS

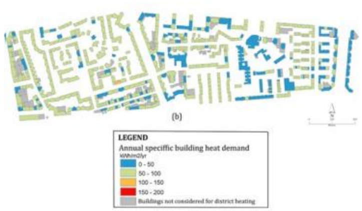
3.2. IMT Atlantique: “Energy and Environmental Systems”

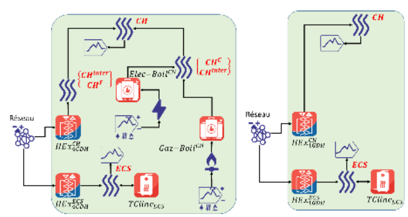
Department: around 60 Permanent academic staff, including 25 professors, 9 administrative and technical staff, and ~25 PhD students

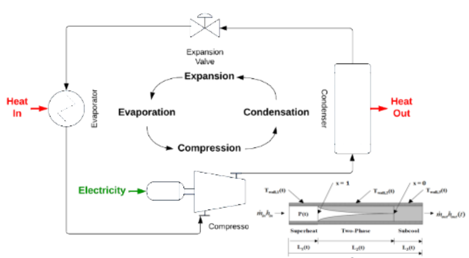
https://www.imt-atlantique.fr/en/about/departments/energy-and-environmental-systems/research

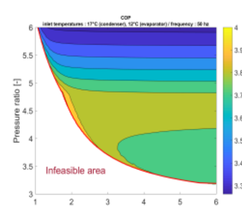
Three main teams:

- *Team TEAM: Water Air Metrology Processing*
- *Team VERTE: Energy and resources recovery from residu and emission processing*
- ***Team OSE:*** Optimization – systems - Energy, who will be involved in this PhD









Research: Energy systems modelling (demand, conversion, storage and distribution), model reduction, optimization methodologies for energy integration

Applications:

- Multi-energy systems and their interaction with energy networks
- Optimization of design of multi-energy systems
- Optimization of management and control energy systems

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3. PARTNERS

3.3. Veolia

3 MAIN BUSINESSES IN NUMBERS

WATER

111 million people supplied with drinking water

97 million people connected to wastewater systems

4,130 drinking water production plants managed

3,506 wastewater treatment plants managed

WASTE

46 million people provided with collection services on behalf of municipalities

61 million metric tons of treated waste

533,759 business clients

823 waste processing facilities operated

ENERGY

44 TWh produced

46,922 thermal installations managed

680 heating and cooling networks managed

2,716 industrial sites managed

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3.3. Veolia

SOLUTIONS TO ADDRESS OUR MAIN CHALLENGES

DECARBONIZATION

Veolia designs solutions for the climate that decarbonize our lifestyles and production methods and adapt them to the consequences of climate disruption.

ECONOMY & REGENERATION OF RESOURCES

Veolia invents green energy systems, recovers waste in the form of materials or energy, and promotes the recycling and reuse of wastewater and plastics.

3

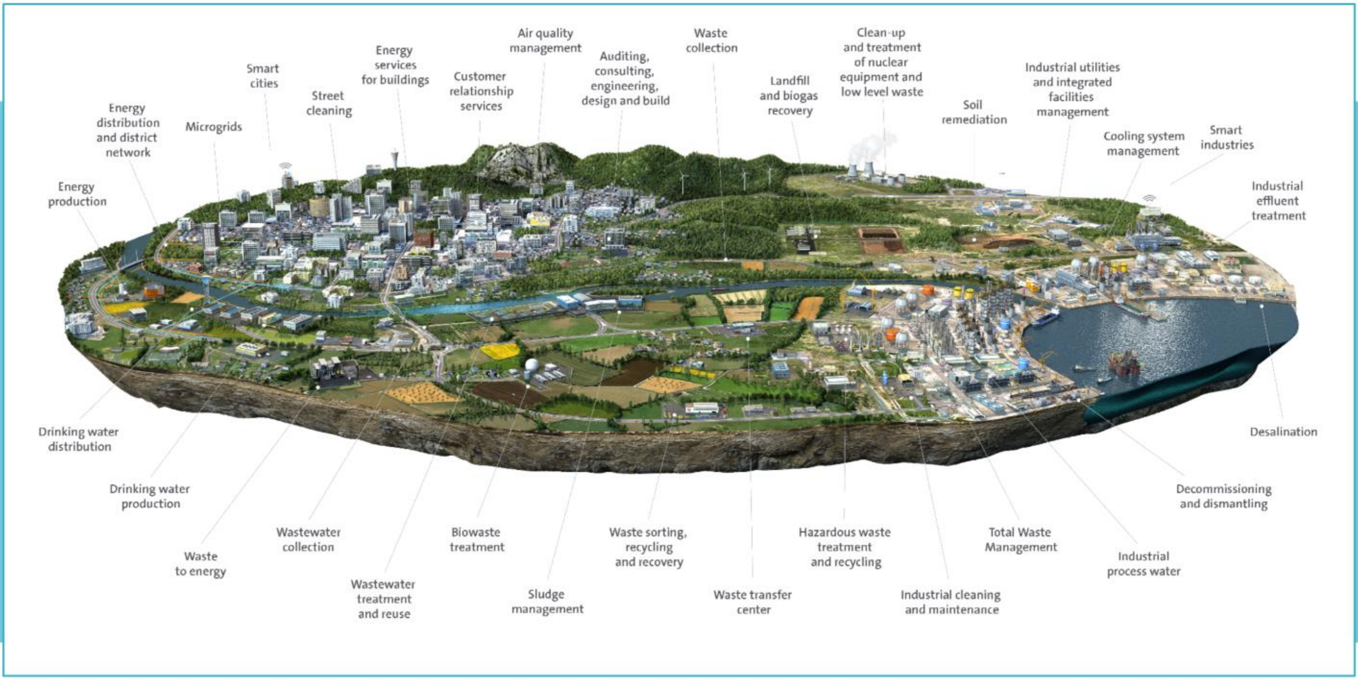
DEPOLLUTION

Water, soil, air... Veolia offers a range of solutions to treat all types of pollution. The Group is a recognized player in the treatment of hazardous waste and degraded soil, and is a specialist in indoor air quality.

3. PARTNERS

3.3. Veolia

A WORLD OF SOLUTIONS FOR LOCAL AUTHORITIES & INDUSTRIES



Discover our solutions on our Website:
activities.veolia.com

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THE SCIENTIFIC & TECHNOLOGICAL EXPERTISE DEPARTMENT

250 research engineers and technicians

160 project or innovation sheets (available in the Research Project Library)

S&TE

4 research sites including **30** specialized laboratories

4 Centres of expertise scientific & technological

+150 technical & scientific assistance on operational sites

+130 research pilots available and tested at Research sites or operational sites

The S&TE department is responsible for :

- Developing strategic research projects in the Water / Waste / Energy fields
- Providing BUS with scientific and technical skills via Scientific & Technical Assistances
- Offer services to boost innovation

Starting date : September 2024

PhD Timeline

- 24 months at IMT Atlantique (Nantes)
- 9 months at Veolia (Aubervillier)

3 months a research collaboration with an international academic partner

General information
https://www.imt-atlantique.fr/en/research-innovation/phd/seed

Application process:
https://www.imt-atlantique.fr/en/research-innovation/phd/seed/application

⚠ Please respect the application process and the deadlines

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4. PRACTICAL ASPECTS OF THE PHD

4.2. working conditions

Living allowance (= gross salary including all French wage costs) → 3700€ per month

Mobility allowance (mandatory for all students): support to settle in → 70€ per month

Family allowance: only for students in family-like situations) → 130€ per month

Directly transferred to the PhD students

Research, travel and mobility costs: covers infrastructure, software, etc., research-related costs, notably travel (conferences, workshops), and financial support for mobility periods at international or non-academic partners → 500€ per month

Training expenses: support to execute training program (7 pillars) → 125€ per month

Managed globally by the PMB

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