Applying Reinforcement Learning to IFMIF-DONES HVAC optimisation

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IFMIF-DONES ESPAÑA

UNIVERSIDAD DE GRANADA

Ciemat

RL4AA

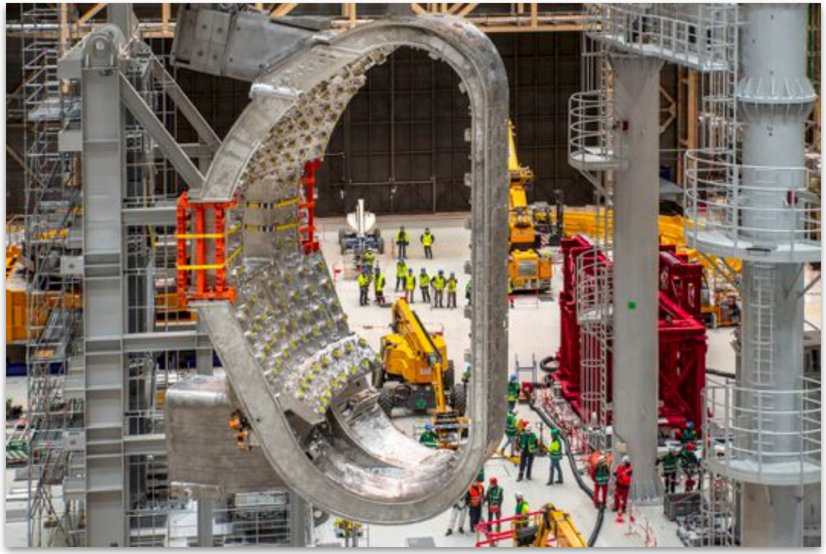
About me...

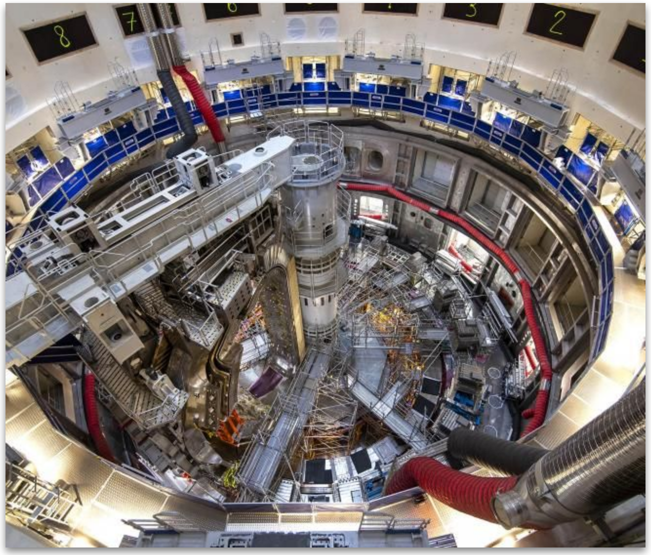
Antonio Manjavacas

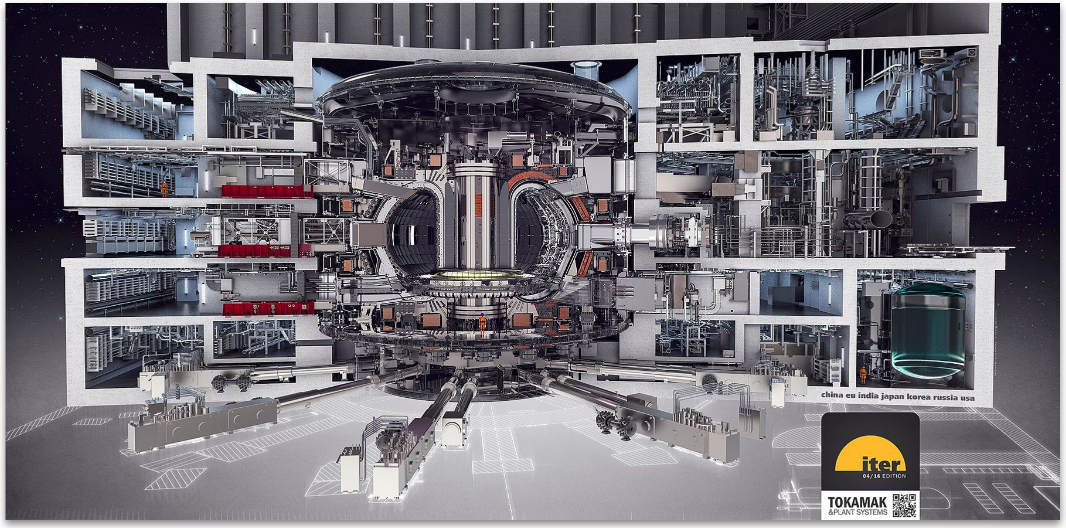
- PhD fellow at **University of Granada** & **IFMIF-DONES** (2022–2025)
- "*Deep Reinforcement Learning for Generative Design of Safety Elements in IFMIF-DONES*"
- Member of **SAIL** (Sustainable Artificial Intelligence Lab)
  - Reinforcement Learning for HVAC control (see **Sinergym**)
  - Physics-based models for power prediction
  - Grid operation with Reinforcement Learning

What about fusion?

ITER







2020-2025
Main assembly phase

2022
Torus completion*

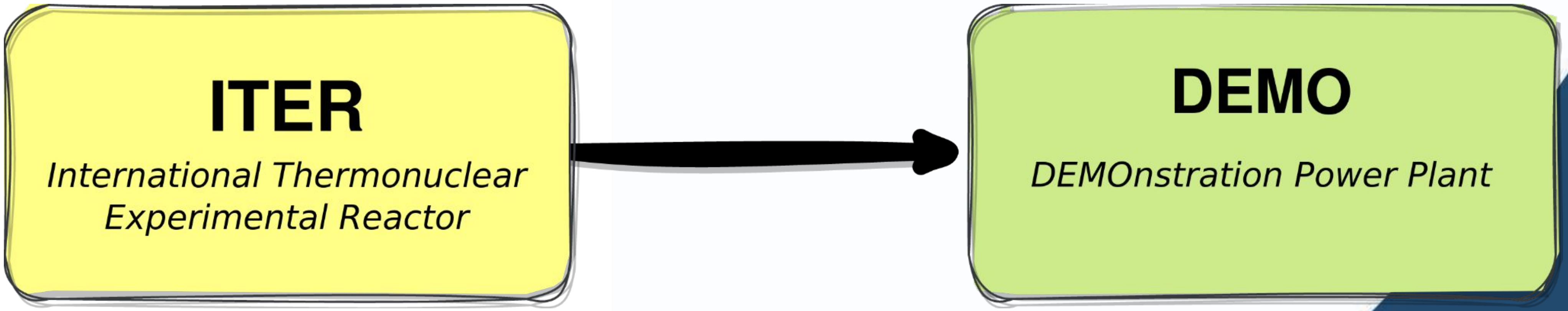
2024
Cryostat closure*

2024-2025
Integrated commissioning phase

Dec 2025
First Plasma*

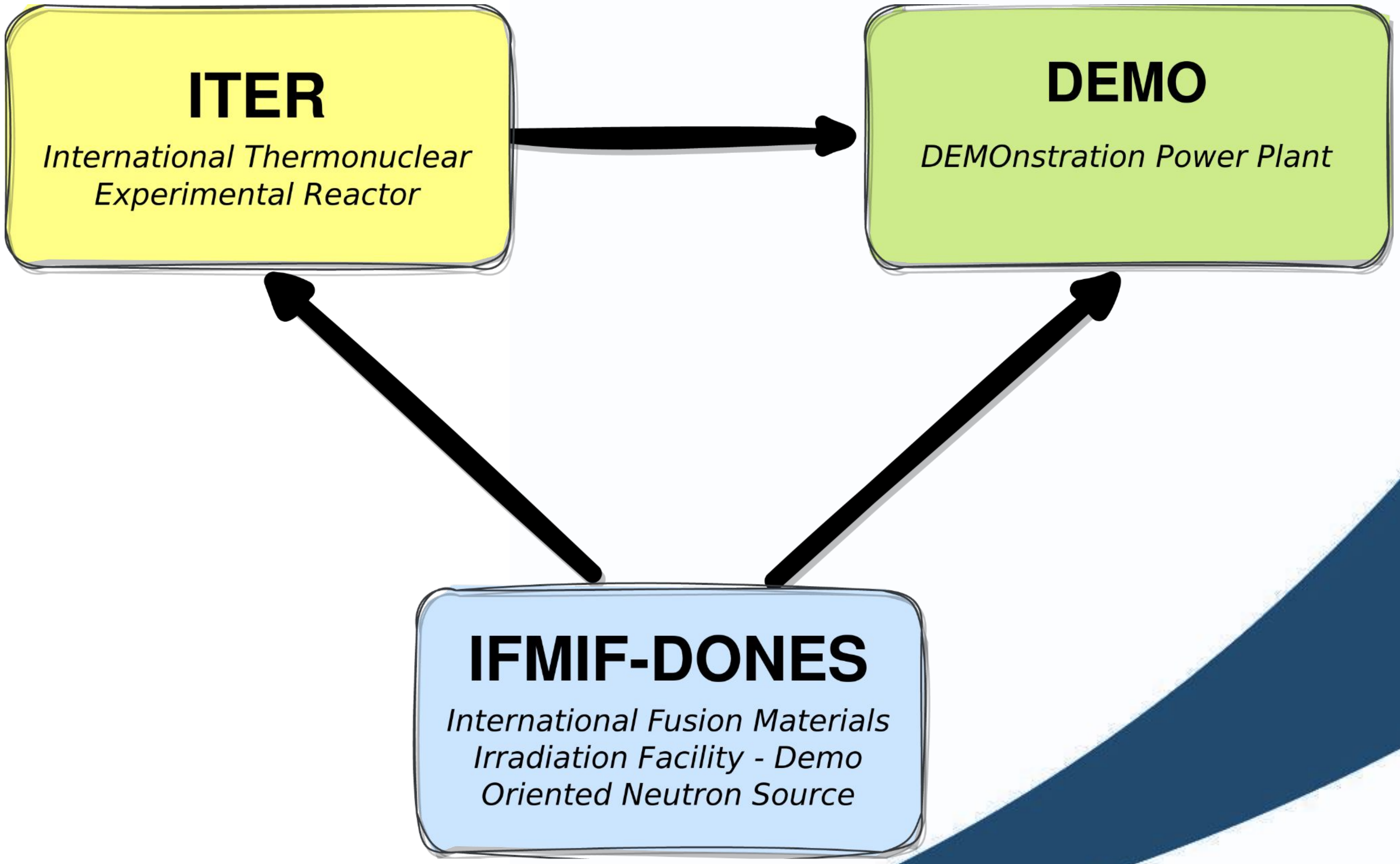
2025-2035
Progressive ramp-up of the machine

2035
Deuterium-Tritium Operation begins


ITER
International Thermonuclear Experimental Reactor
DEMO
DEMOnstration Power Plant

1990s: the materials scientific community promotes the development of a **neutron source** for the qualification of materials to be used in future **fusion reactors** (**DEMO**).

- An irradiation facility with material samples being exposed to fusion-like radiation conditions.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International Thermonuclear Experimental Reactor
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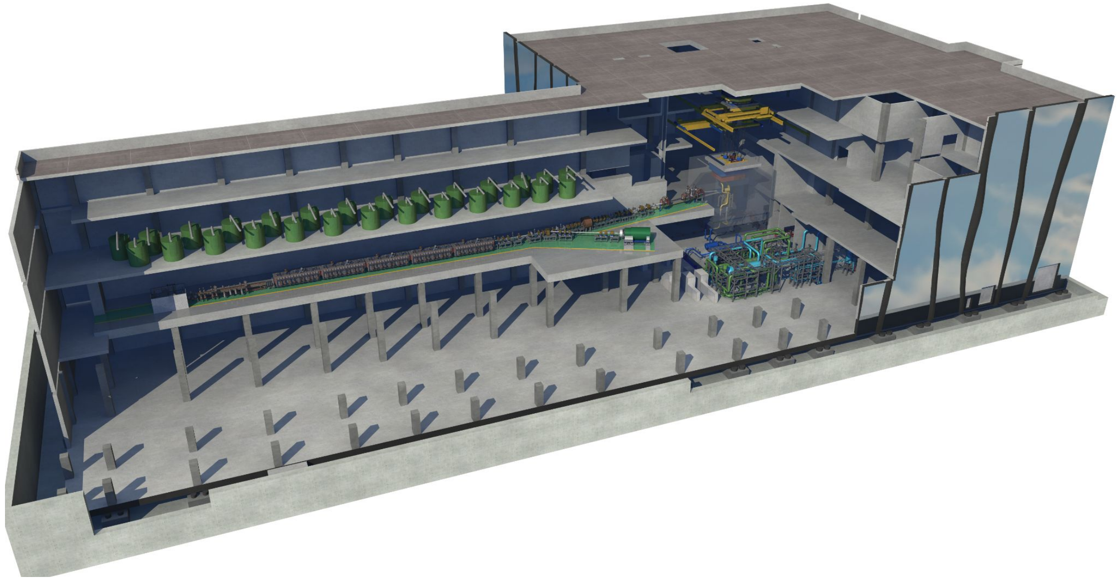
IFMIF-DONES
International Fusion Materials Irradiation Facility - Demo Oriented Neutron Source

IFMIF-DONES

International Fusion Materials Irradiation Facility – DEMO Oriented Neutron Source

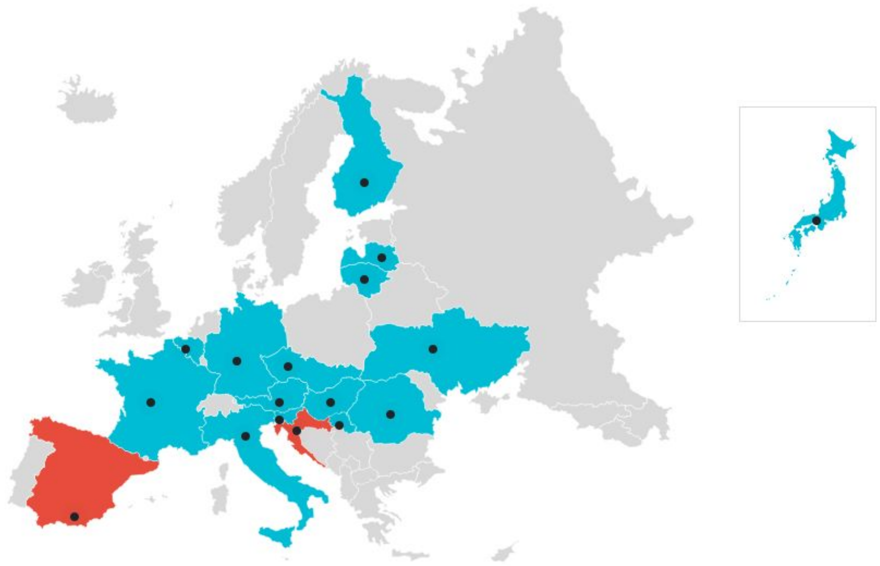


- **Deuteron linear accelerator** with a maximum initial dose of 20 dpa, and up to 50 dpa in its second phase.
- 100 dpa with two 40 MeV and 125 mA beam linear accelerators once the facility is upgraded to **IFMIF**.
- Granada (Spain).

EUROfusion

IFMIF-DONES ESPAÑA

IFMIF-DONES

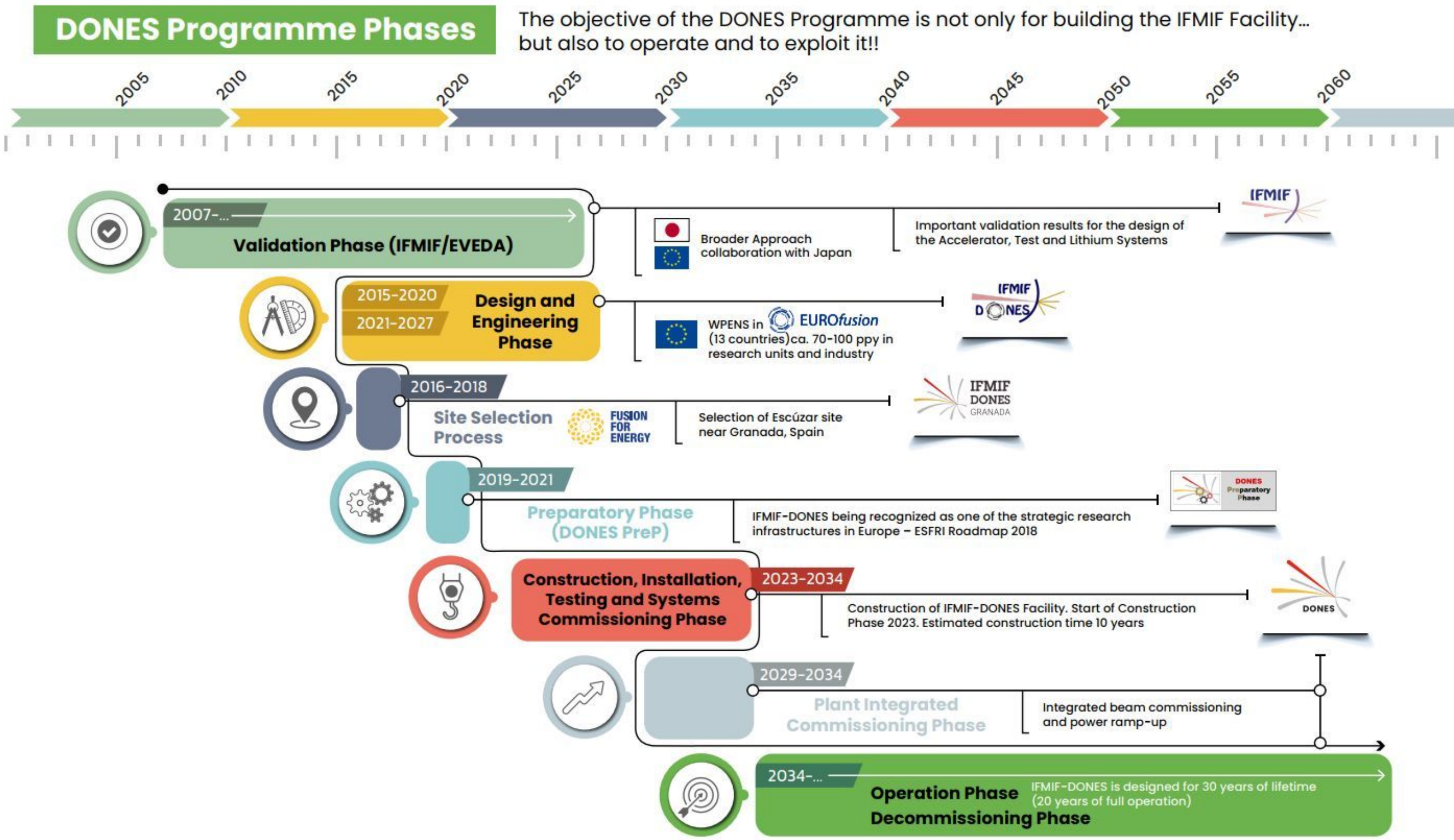


■ **Partners**

Spain
Croatia

■ **Observers**

Austria
Belgium
Czech Republic
Finland
France
Germany
Hungary
Italy
Japan
Latvia
Lithuania
Romania
Slovakia
Slovenia
Ukraine
Euratom (F4E)



Particle accelerators are great…

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BUT

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…we have to build them **somewhere**,

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BUT

…we have to build them **somewhere**,

…ensuring **safety** conditions,

Particle accelerators are great…

BUT

…we have to build them **somewhere**,

…ensuring **safety** conditions,

…in an **efficient** way

Safety

IFMIF-DONES is a critical infrastructure where **safety** systems and protocols will play a fundamental role.

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Potential **tritium** releases, **radiation** doses, **Li** fires...

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- **Detritiation** systems
- Inertized rooms → **dynamic confinement.**
- **Purification** and **controlled evacuation** of gases to the environment.

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Potential **tritium** releases, **radiation** doses, **Li** fires...

- **Detritiation** systems
- Inertized rooms → **dynamic confinement**.
- **Purification** and **controlled evacuation** of gases to the environment.

Dynamic confinement

ISO 17873

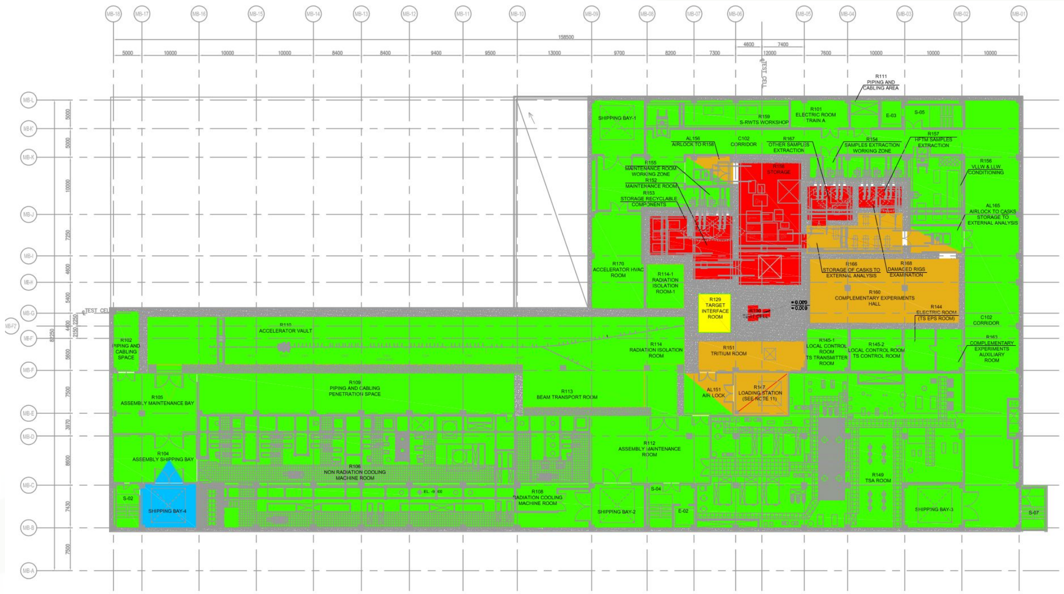
Criteria for the design and operation of ventilation systems for nuclear installations other than nuclear reactors

- **Dynamic confinement** prevents the release of hazardous substances throughout the building, keeping them contained within their respective enclosures.
- It relies on **different rooms maintained at different pressures**, based on their potential contamination levels.
- Confinement classes: C1, C2, C3, and C4.

Table 3 — Guide to depression values

Nature of room or area	Depression value [a]	Containment class
Non-controlled rooms or areas free from contamination	Atmospheric pressure or small overpressure	Unclassified
Supervised areas with low levels of surface or airborne contamination	Less than 60 Pa	C1
C1 should be uncontaminated in normal operations		
Controlled areas with moderate levels of surface or airborne contamination	80 to 100 Pa	C2
Controlled areas with high levels of surface or airborne contamination	120 to 140 Pa	C3
Controlled areas with very high levels of surface or airborne contamination	220 to 300 Pa	C4
Areas which are not accessible except under specific circumstances		

[a] Compared to the reference pressure.



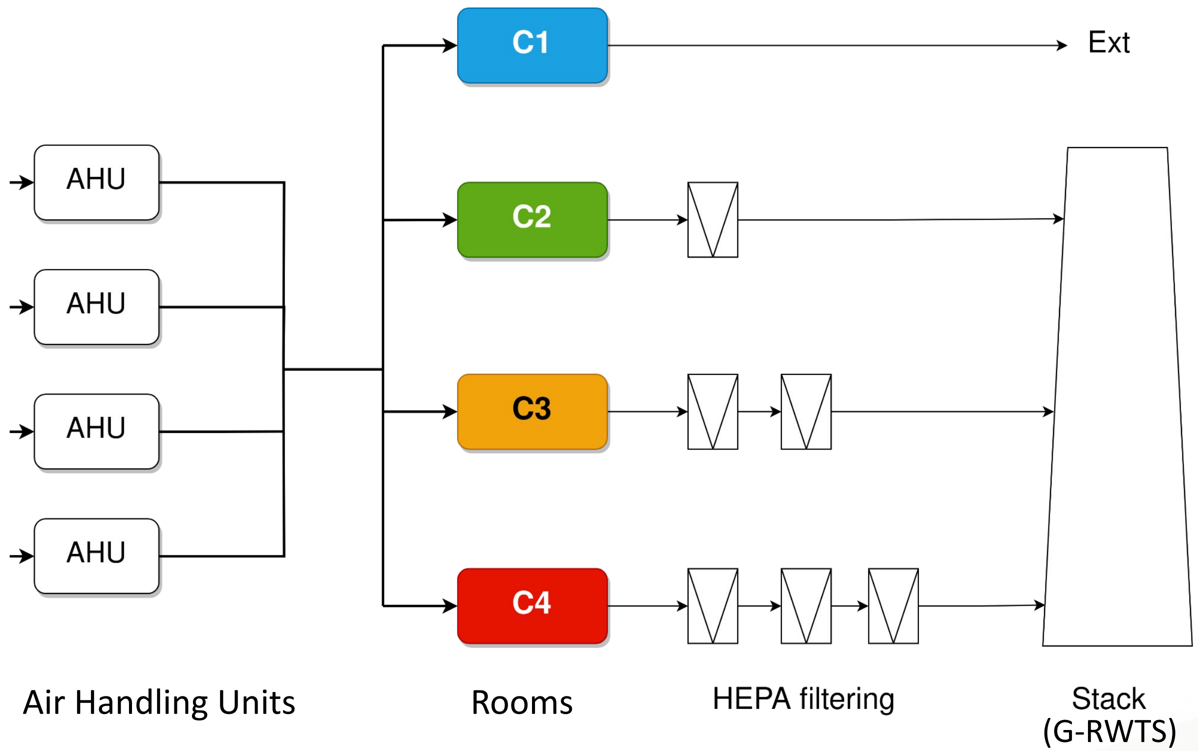
Nuclear HVAC

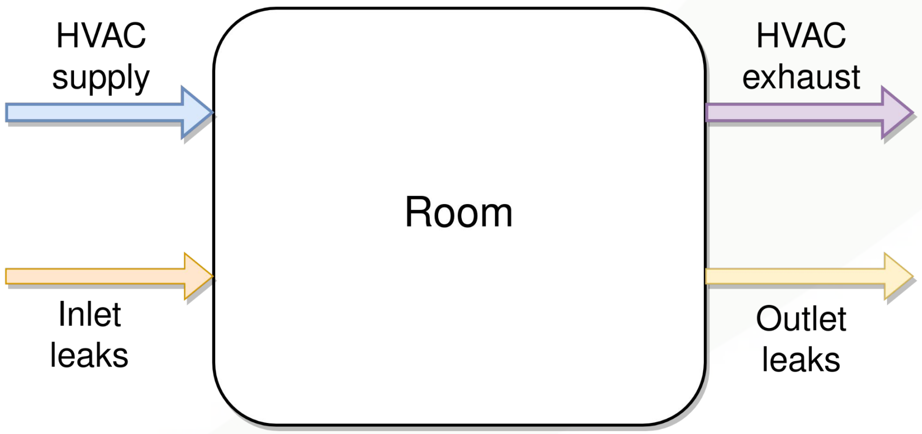
HVAC

Heating, Ventilation, and Air Conditioning system

Dissipation of gases with non-radiological risk.

Ensures stable pressures (**dynamic confinement**).





MELCOR

Computer code designed to model and simulate **accidents** leading to **radiological** release at nuclear facilities.

A MELCOR model of the **IFMIF-DONES** main building is under development.

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Sandia National Laboratories

A MELCOR model of the **IFMIF-DONES** main building is under development.

HVAC **design decisions** match the design decisions in the **simulation model**.

Generation / evaluation of design alternatives in the simulated environment → Real system implementation

Reinforcement Learning

- **Deep Reinforcement Learning** has emerged as an outstanding competitor to conventional control methods.
    - HVAC control, particle accelerators, fusion domain.
- MELGYM: a Gymnasium environment for continuous control in MELCOR simulations.

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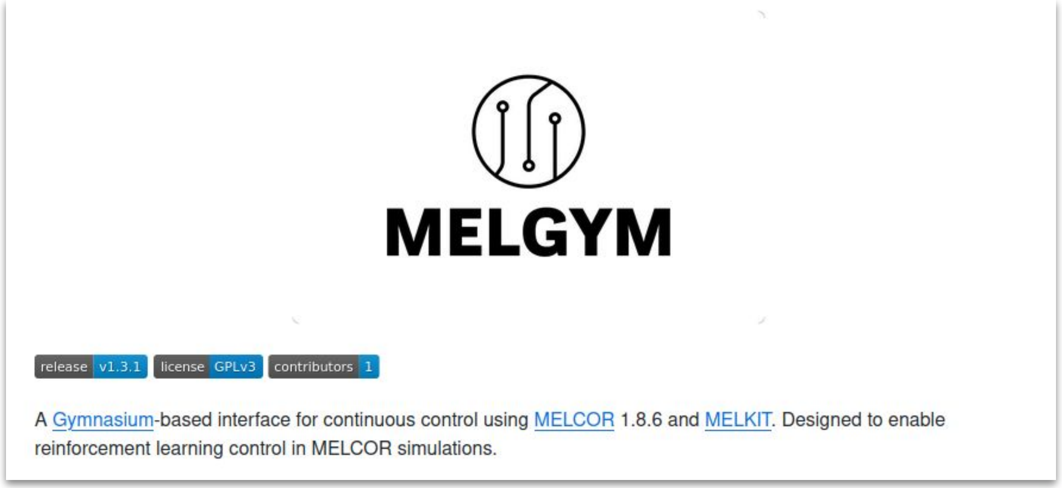
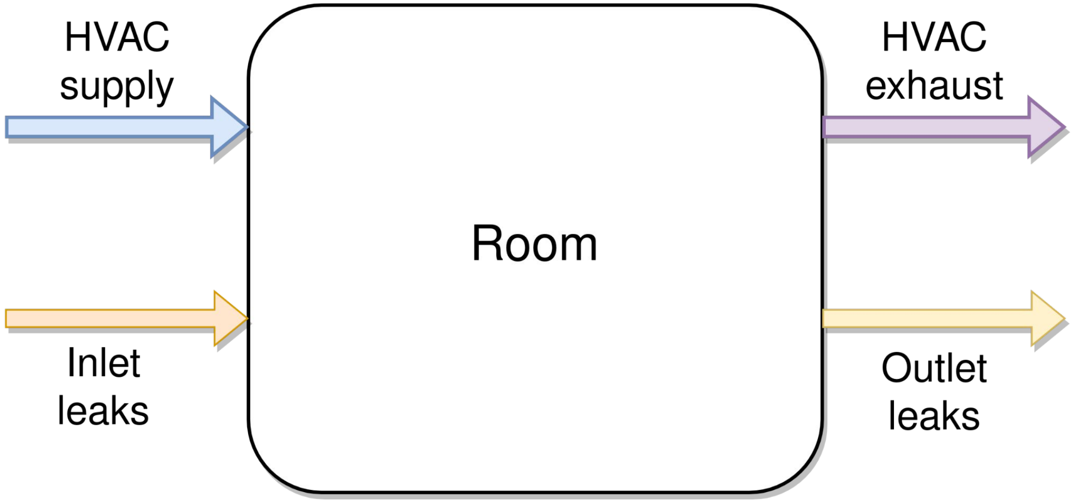
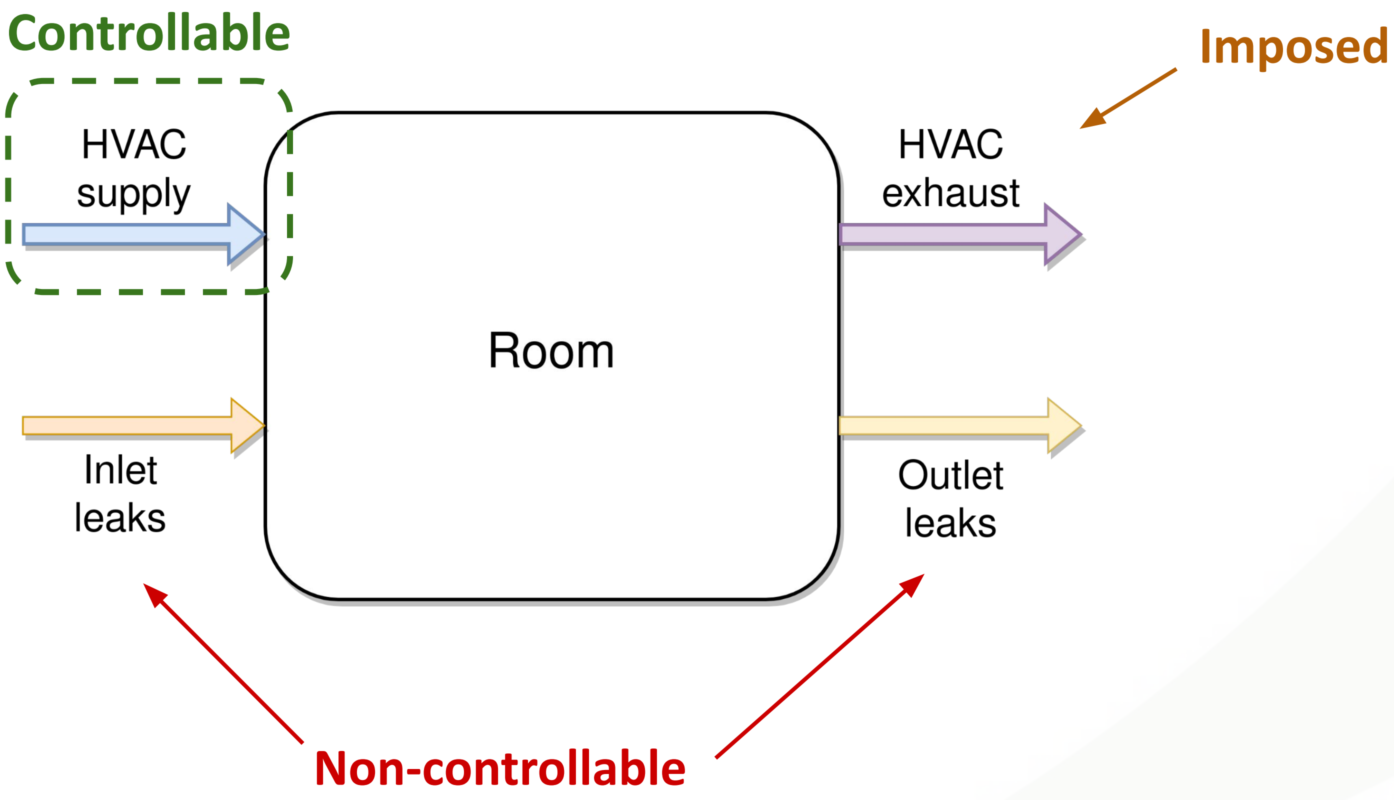


OBJECTIVE: simulate and validate **HVAC** different system design alternatives.

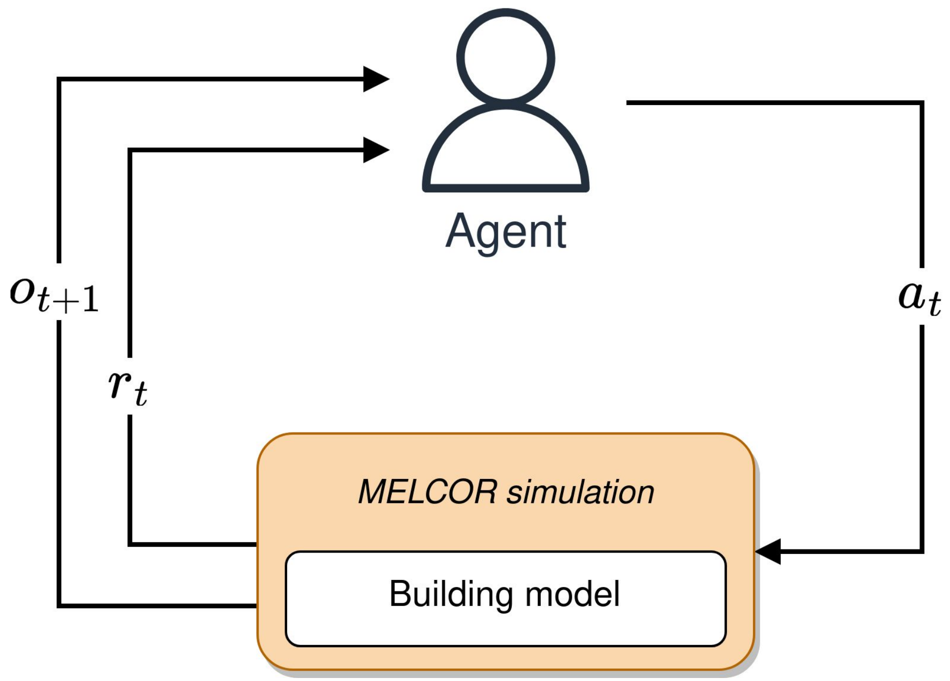
HVAC supply control



HVAC supply control

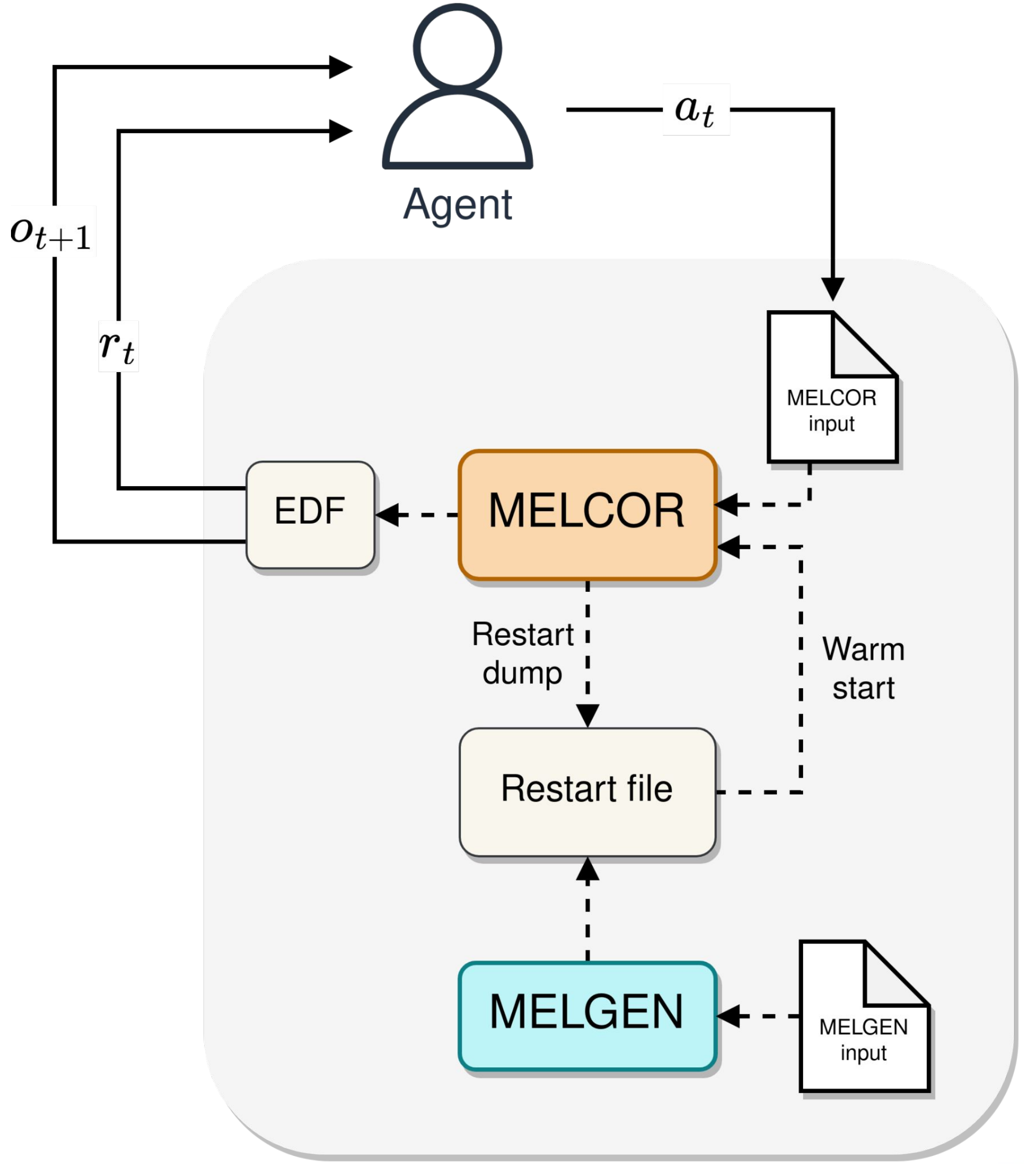


MDP



- **Observations**: current rooms pressures.
- **Actions**: HVAC air inlet flow rates.
- **Reward**: proximity to target pressure values.
- **Transition**: MELCOR simulation during *T* cycles.

Control loop



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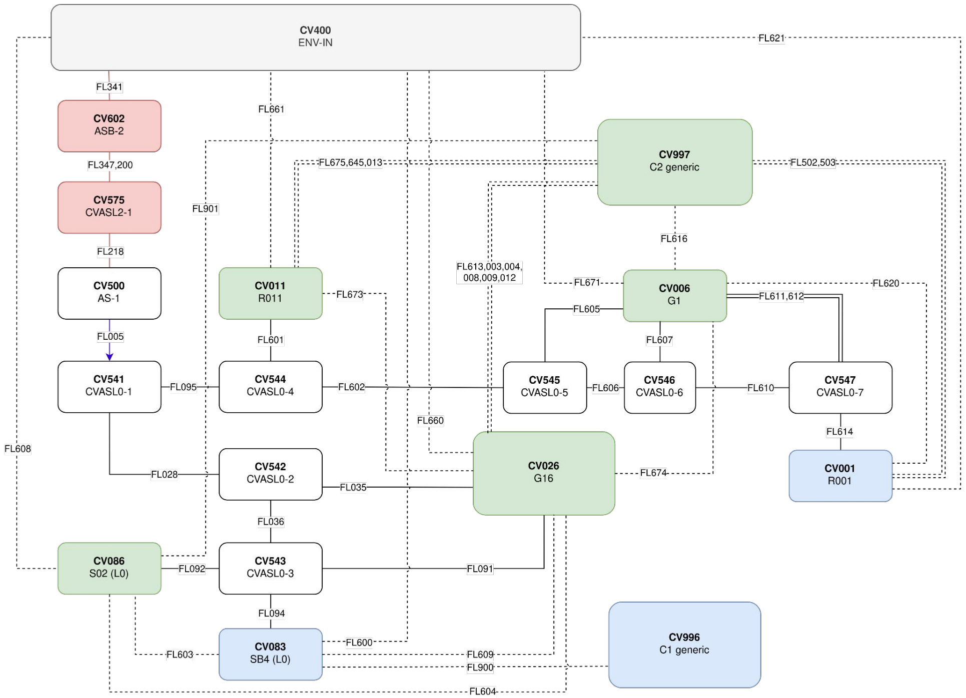
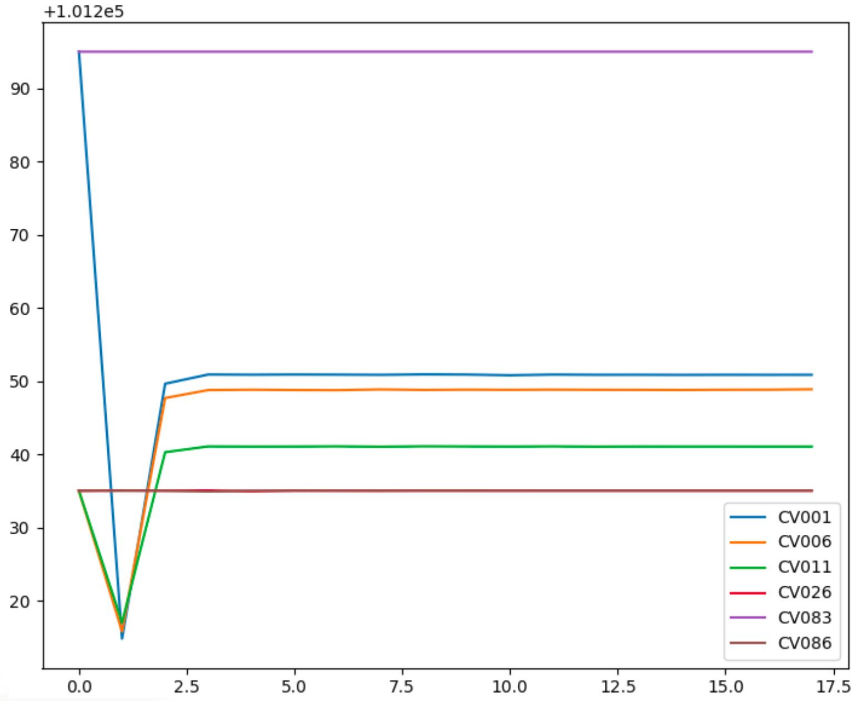
Preliminary results

- Initial **air inlets** assessment.
- HVAC **power consumption** estimates (*in progress*).
- Evaluation of different **leak rates** in critical rooms.





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"Una manera de hacer Europa"
AGENCIA ESTATAL DE INVESTIGACIÓN
Andalucía se mueve con Europa