R&D UK Centre

Hot gas/steam release in Gas circulator Hall

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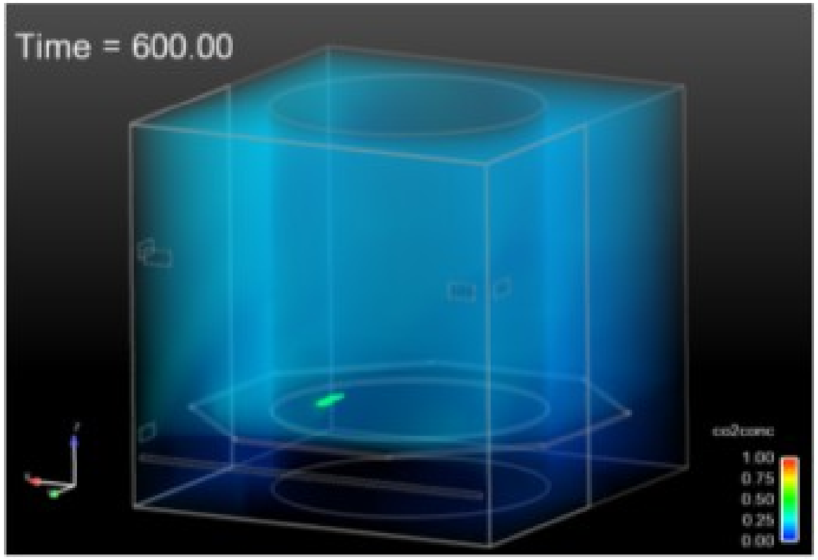
5 April 2018

Objectives



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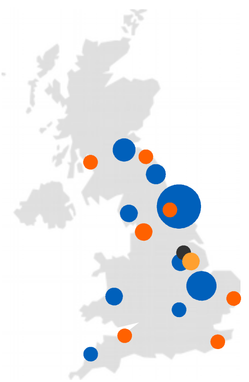
EDF Energy in the UK



- Nuclear
- Wind farms
- Coal
- Gas

Amount

1 10

8
nuclear power stations
(**14 AGRs, 1 PWR**)

31
wind farms
(including
1 **off-shore**)

2 + 1
coal gas
powered stations

2
EPRs
in project at
Hinkley Point

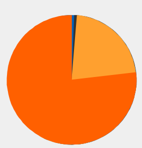
Sales & marketing

52.8 TWh
electricity sold

25.7 TWh
gas sold

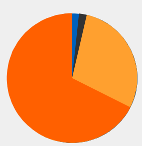
5.8 million
customers

Generation 72.5 TWh



- Nuclear **77%**
- Coal **22.5%**
- Combined cycle gas and cogeneration **0.2%**
- Other renewables **0.3%**

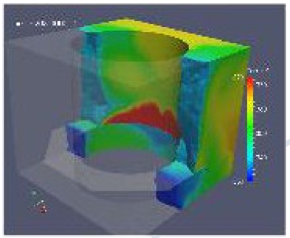
Installed capacity 13 GWe



- Nuclear **67.6%**
- Coal **31%**
- Gas **0.7%**
- Other renewables **0.7%**

EDF Energy R&D in the UK

People, Processes & Buildings



Nuclear

Energy Systems

Local delivery of Global Value

100 people (FTE)

40 PhD

£40m of investment in R&D

Environment and Natural Hazards

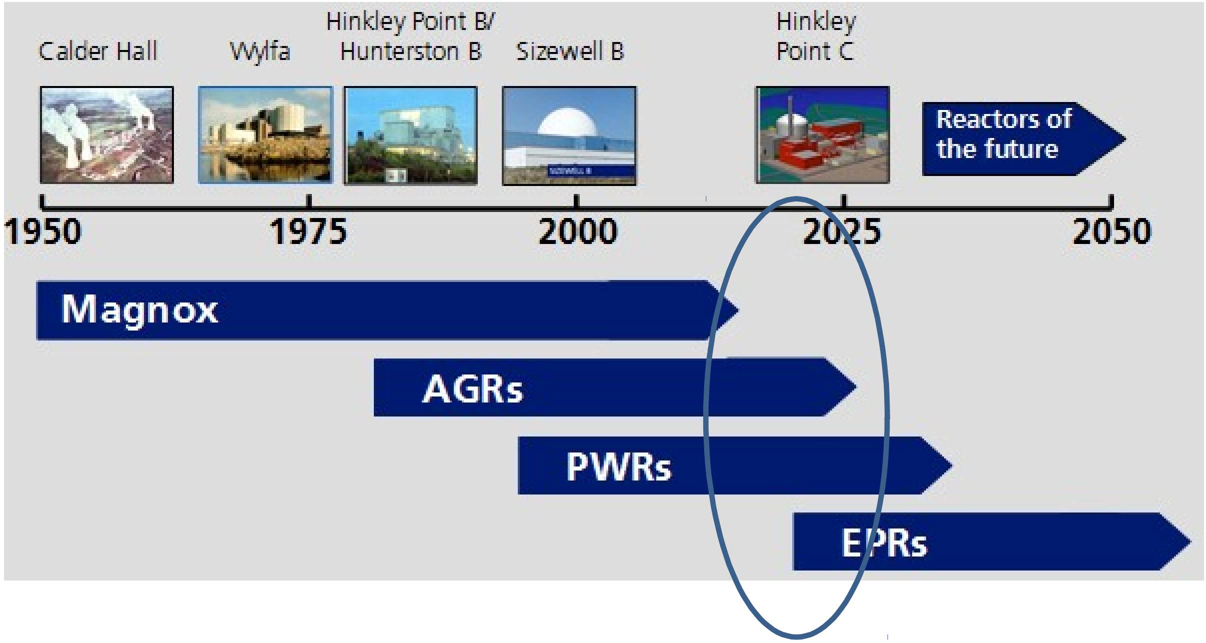
Digital Innovation

Renewables

Part of EDF Group International R&D Centres (500m€ investment per annum, 2100 people)

Open Innovation

Nuclear energy in the UK – a turning point

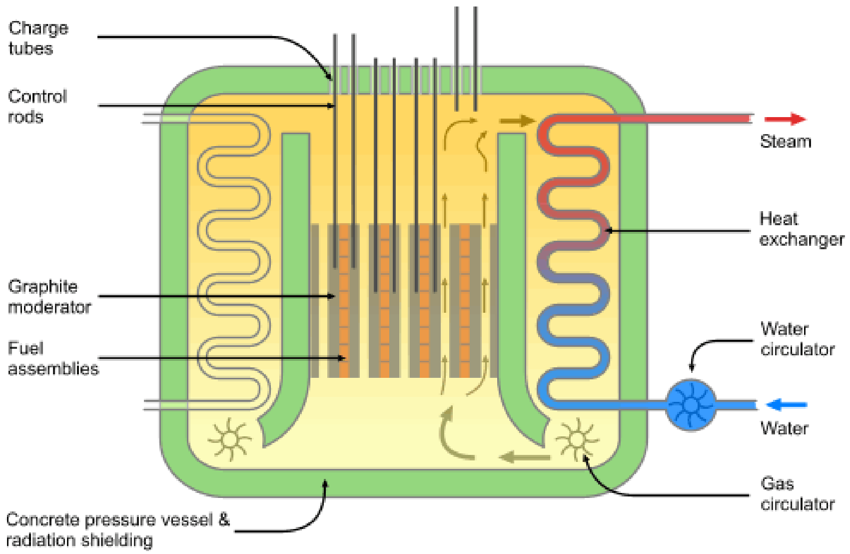


Today: Nuclear has provided safe and secure electricity in the UK for over half a century. Today it contributes 20% of supply.

The nuclear industry is well established across the lifecycle (operations, new build and decommissioning), and is firmly supported by world-class science and technology, a robust regulatory regime and strong international collaborations.

State of the project

Advance Gas-cooled Reactor (AGR)



Schematic diagram of the AGR core

- Designed and Operated in the UK
- 14 AGRs owned and operated by EDF Energy
- Coolant: Carbon dioxide

Objective of the project

- Better understanding of Loss Of Coolant Accident scenario (LOCA)
- Establish a bank of CFD results
- Guidance for operators concerning the CO_2 level of exposure

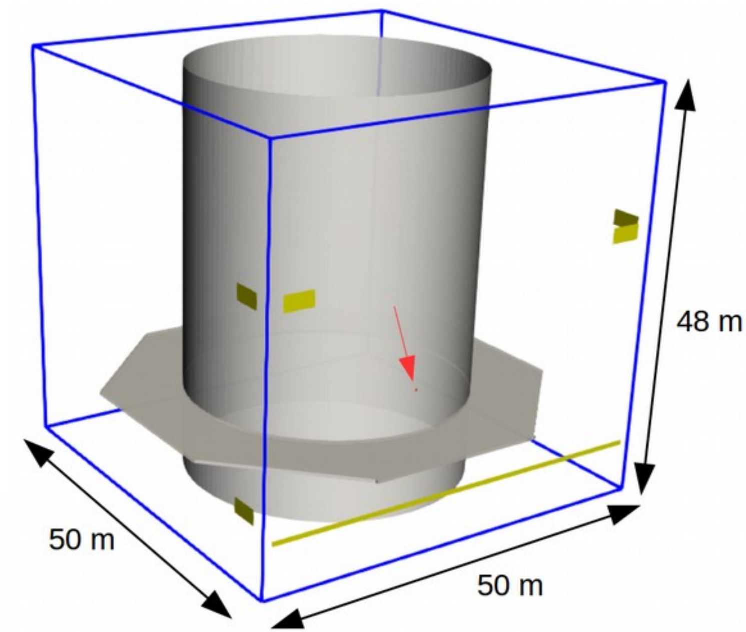
CO_2 level

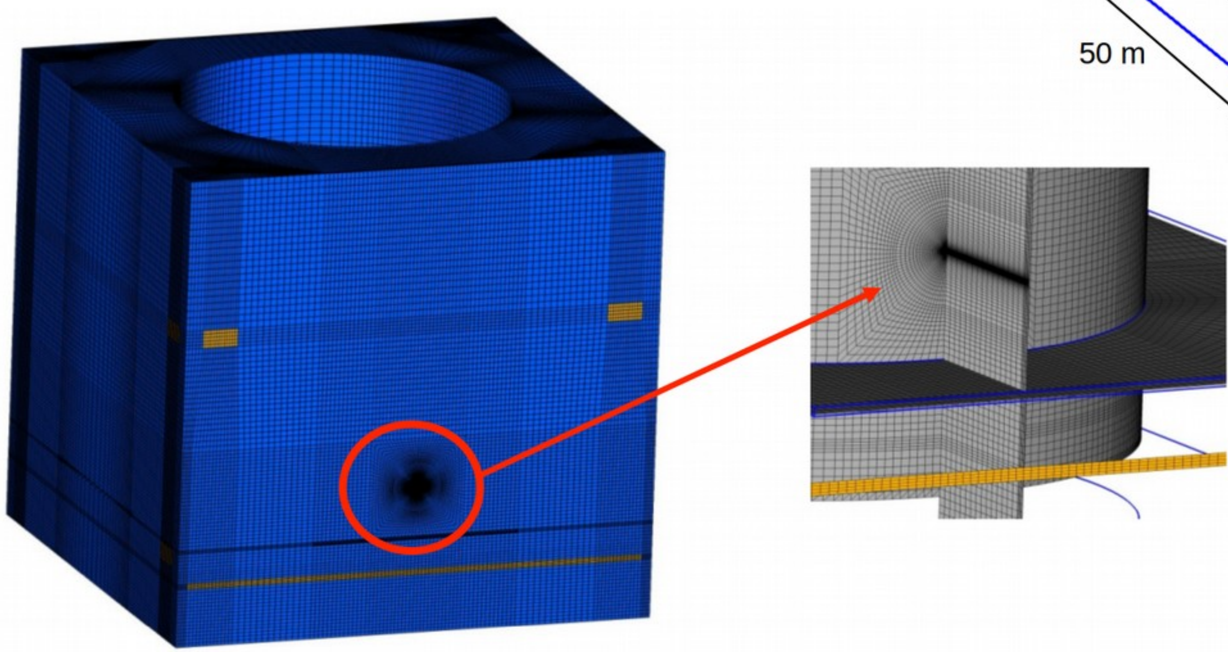
0.04%	In air
3%	Legal limit (15min)
10%	Visual trouble
15%	Fainting
25%	Respiratory arrest

Hot gas release in gas circulator hall

- Adiabatic walls
- Vents (~60 m^2)
- Hot gas release (CO_2)

$$\dot{m} = \dot{m}_0 \exp(-\alpha t)$$



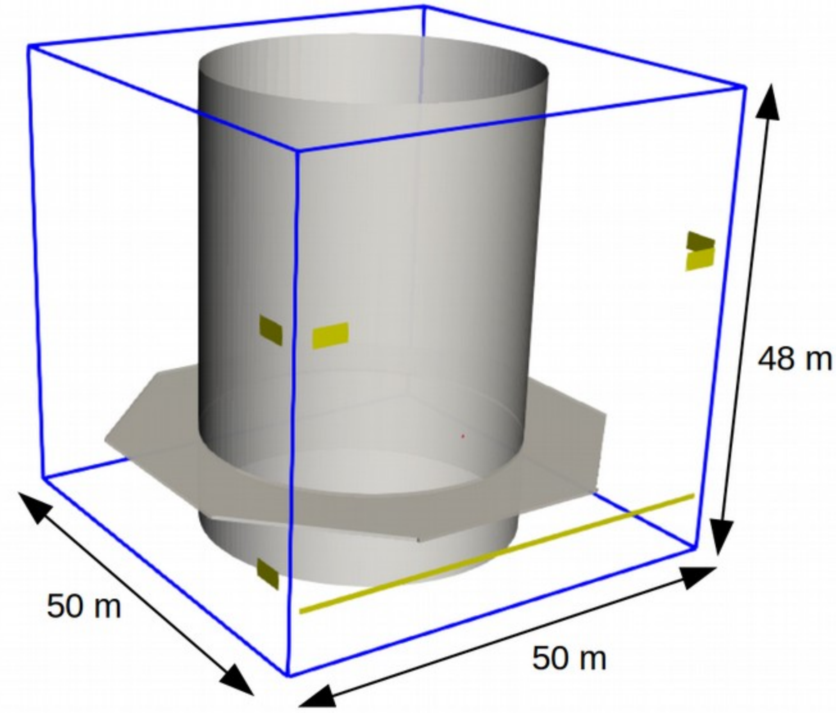


- Base mesh (1 million cells)

Base Model

Modelling of the pipes

- Not explicitly taken into account
- Volumetric heat source term
- Heat release 3.6MW
- Positioned between the drip tray and the top vents



Release description

- Mass flow decaying in time
- Breach diameter: 7.6cm → 37.2cm
- Sonic speed to avoid pressure waves
- Incompressible model
- Temperature 300C

Gas properties

- Variable gas properties (X)
- 1 additional transport equation for CO_2 mass fraction (Y_{CO_2})

$$\frac{1}{X_{mix}} = \frac{Y_{CO_2}}{X_{CO_2}} + \frac{1 - Y_{CO_2}}{X_{Air}}$$

General properties

- Unsteady flow (1 hour real time)
- κ-ω SST turbulence model
- 1 phase flow

Results **Reference model - global**

- CO2 concentration

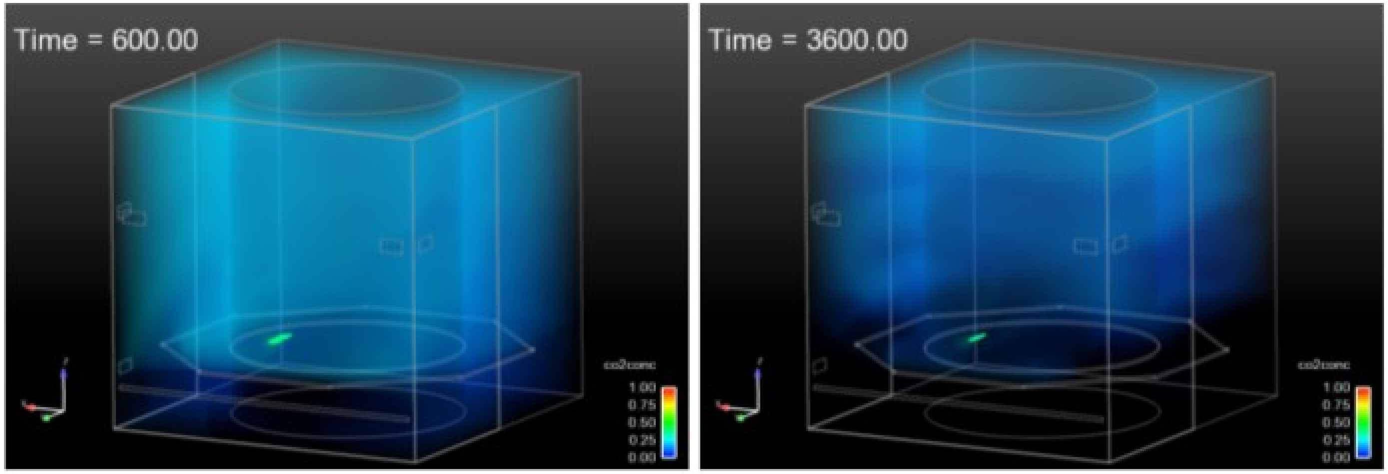


Figure 16: CO_2 concentration at different times.

- Temperature

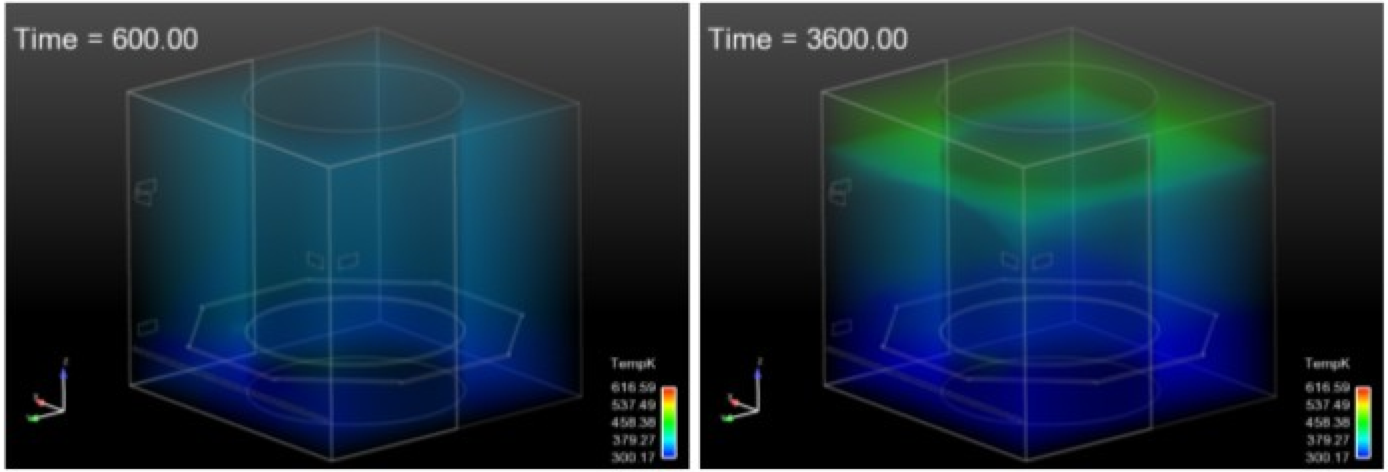
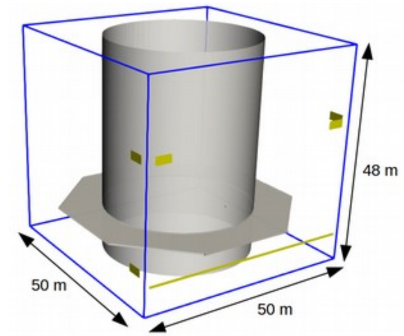
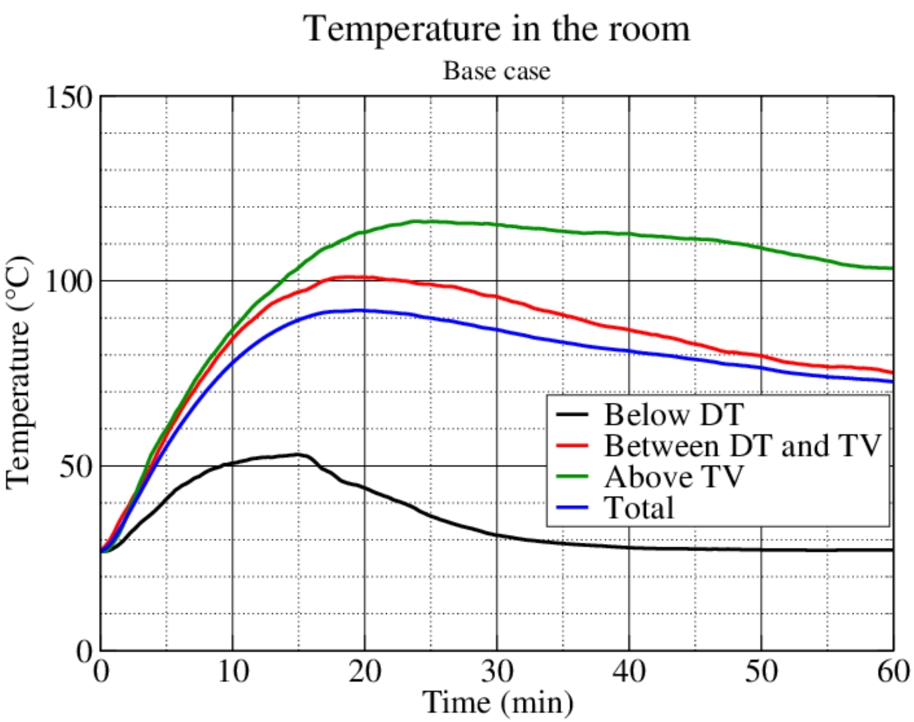


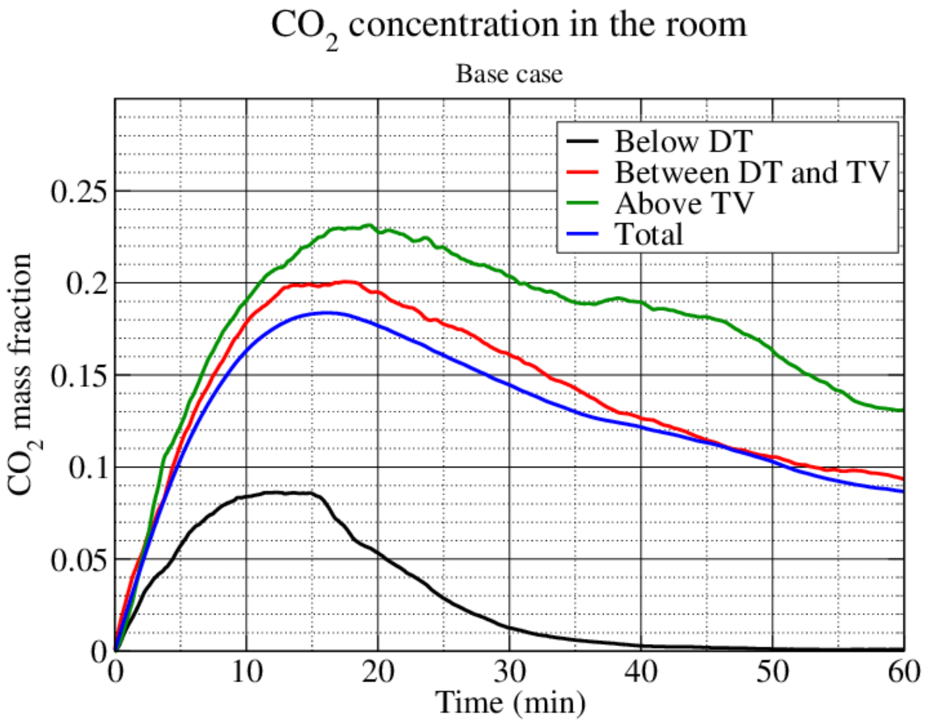
Figure 17: Bulk temperature at different times.

Base model - general

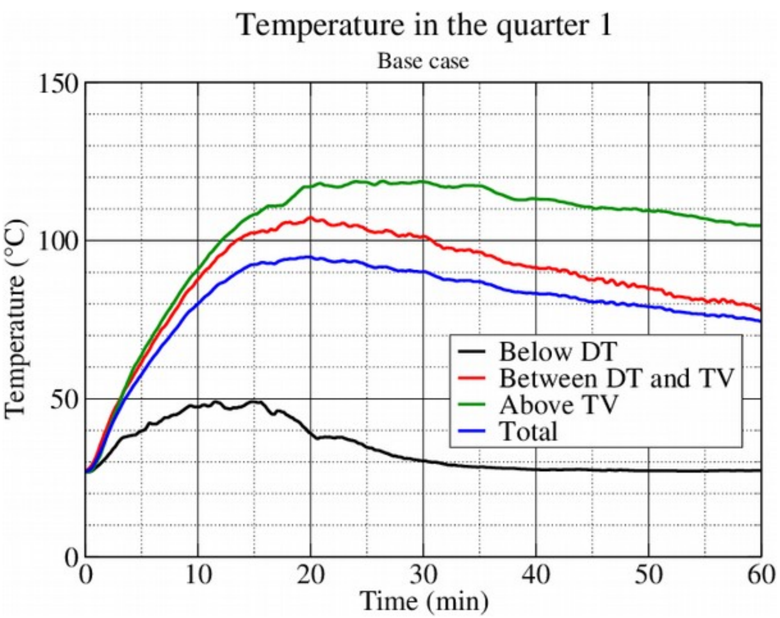
- Previous work done on sensitivity studies:
  - Mesh
  - Turbulence model
  - Time step
  - Pressure-Velocity coupling
  - Energy source term

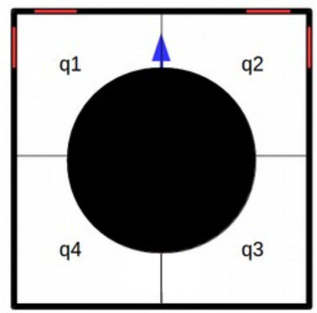


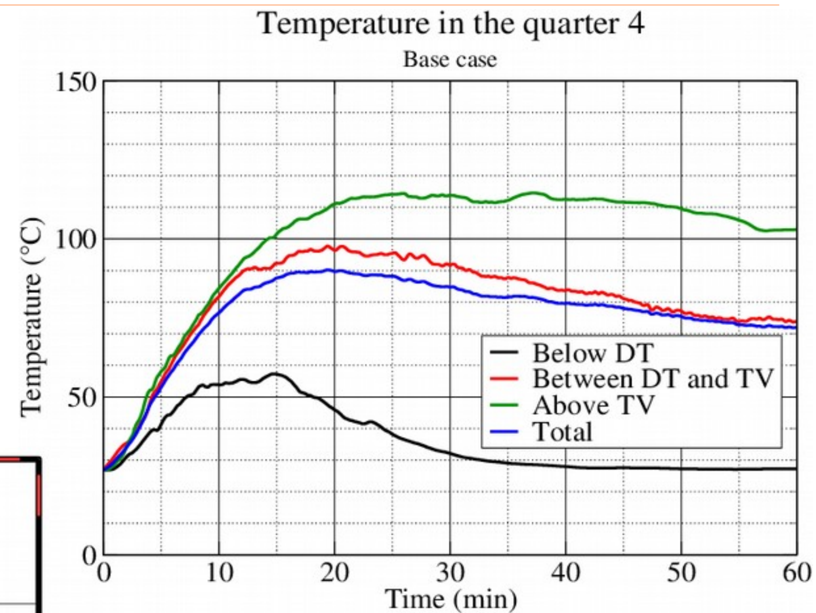


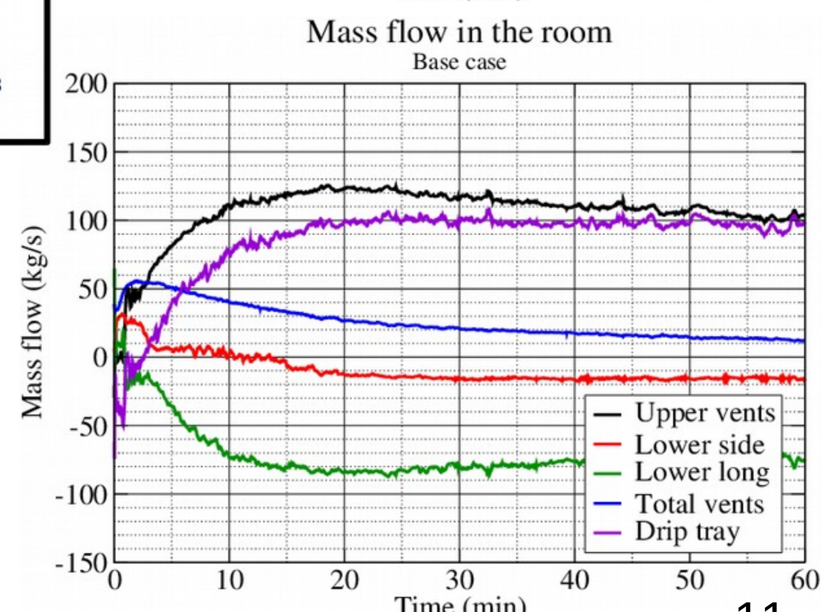


Results Base model - details





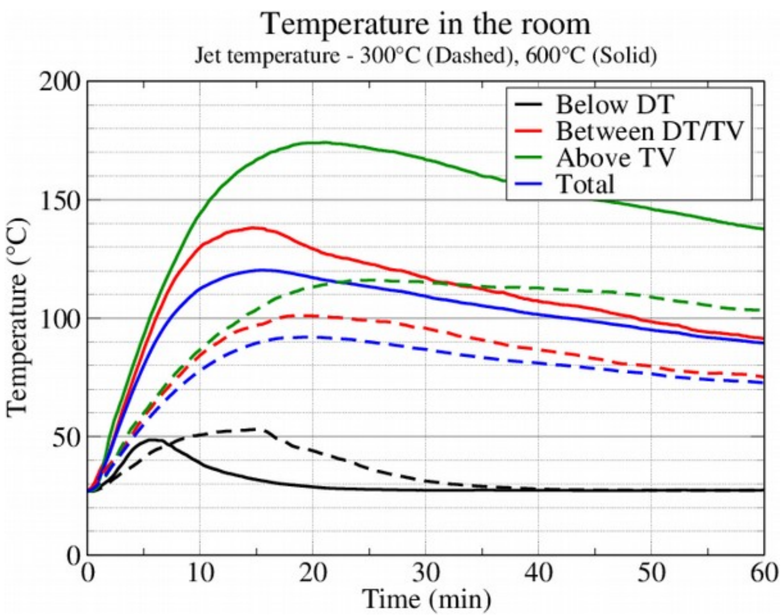


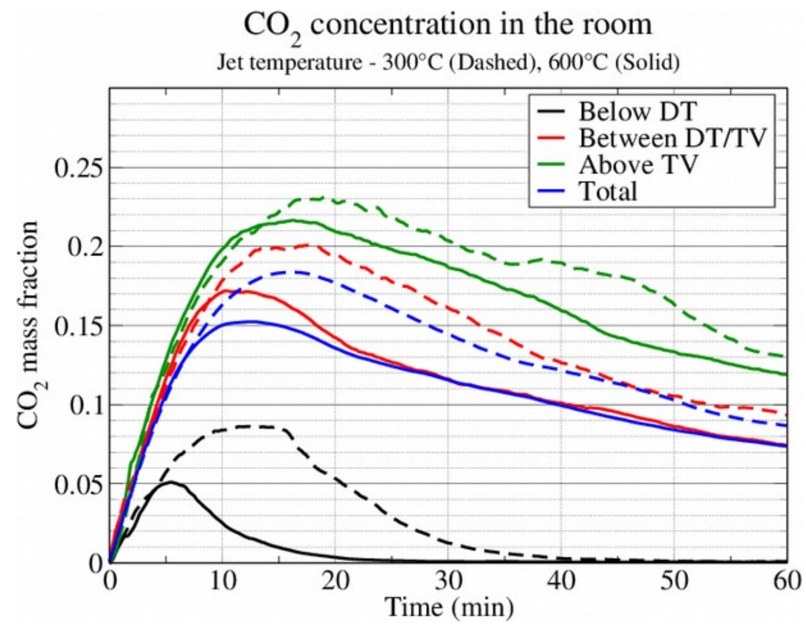


- Same temperature profile
- Local temperature difference up to 10°C

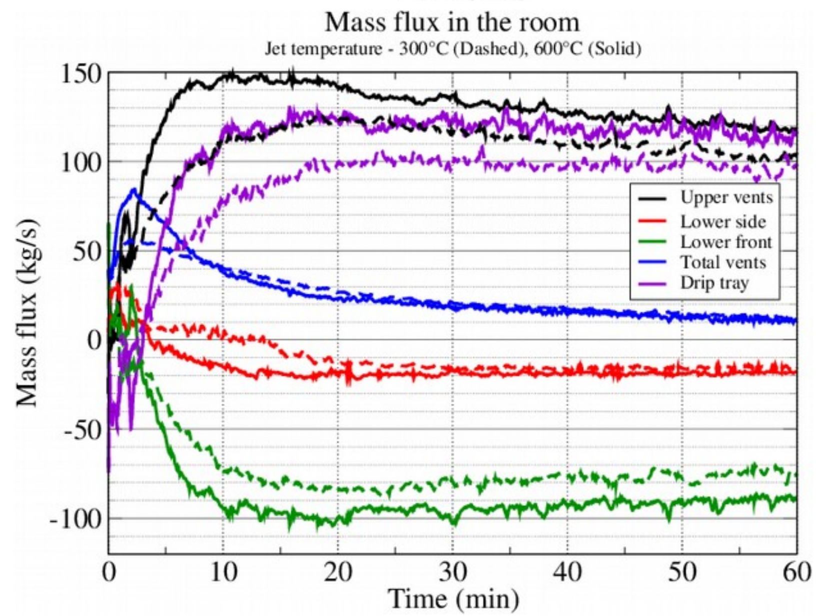
- At the beginning all the vents expel some gas
- After 10 minutes a ventilation loop from bottom to top occurs

Results TC1: Jet temperature – 600C instead of 300C

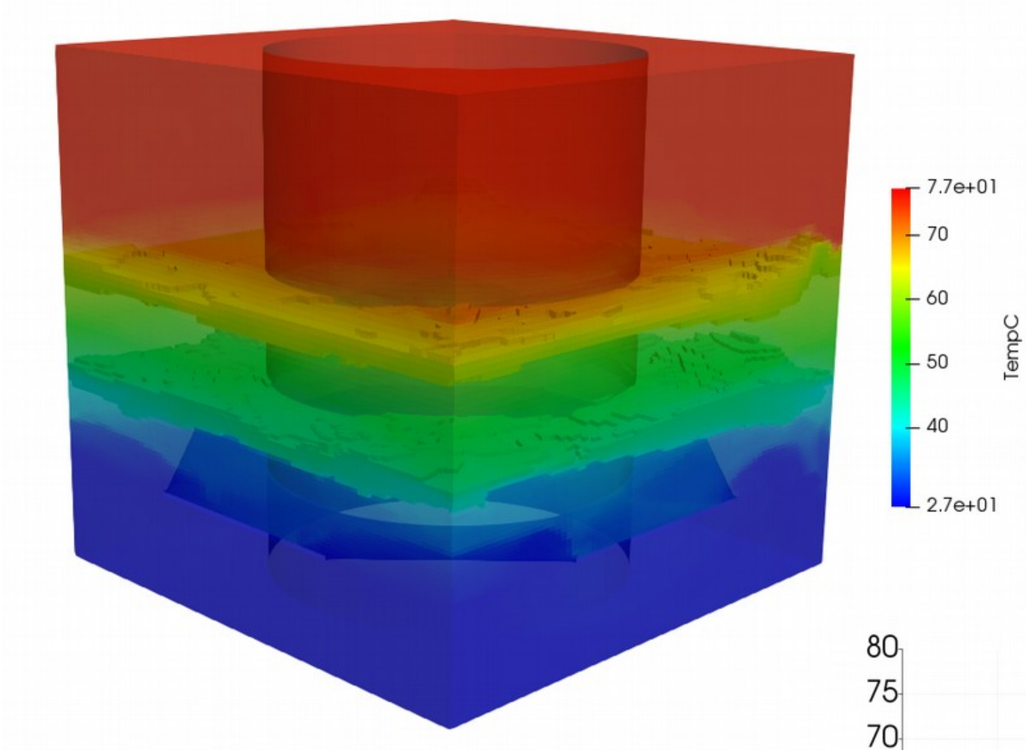


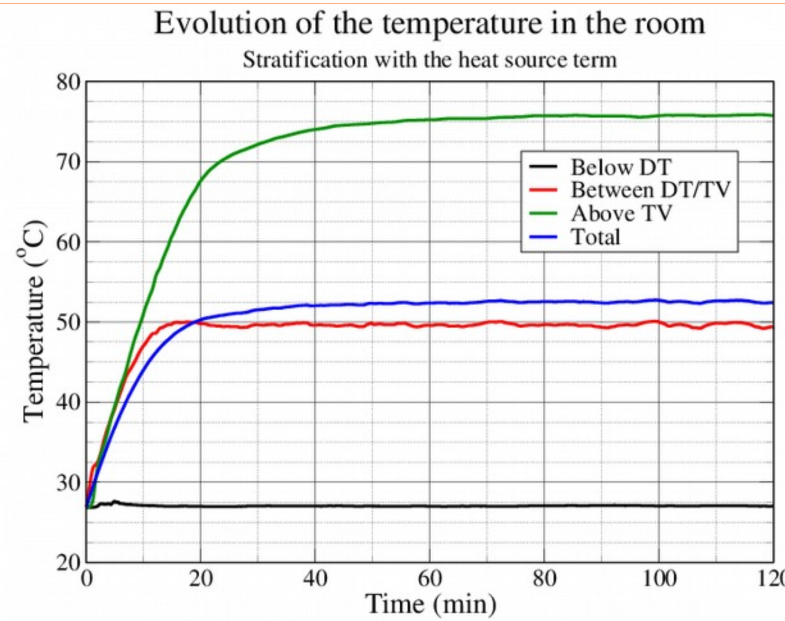


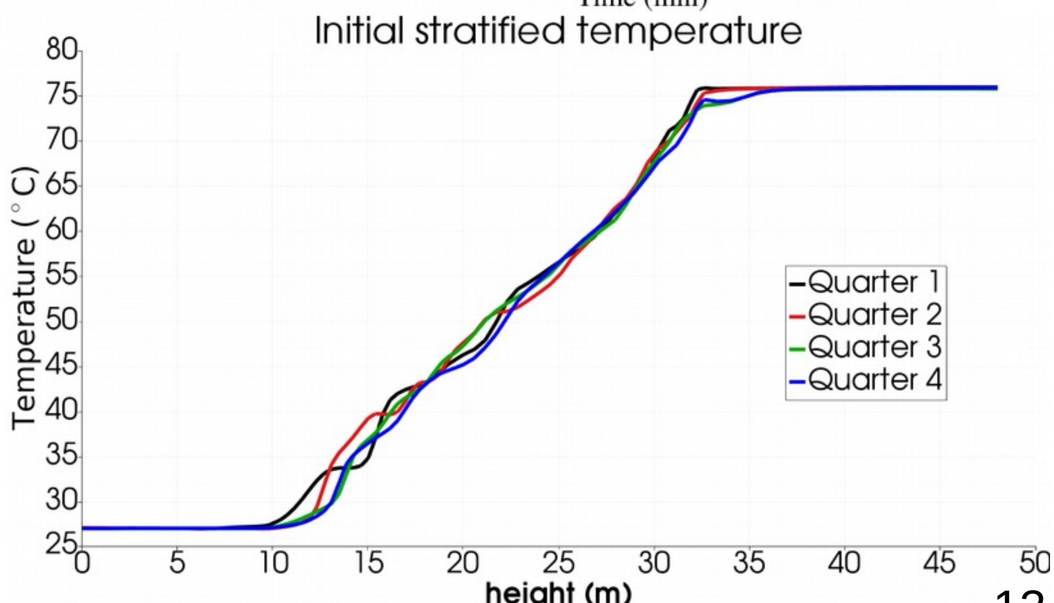
- Significant effect of the drip tray
- Ventilation loop is stronger
- Increase in Temperature
- Reduction of the CO_2 concentration



Results TC2.1: Initial stratification – Temperature stratification

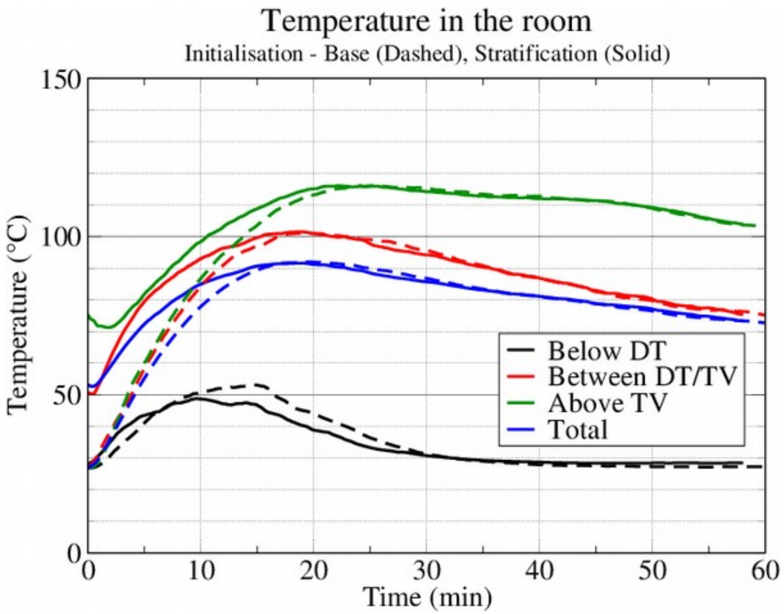


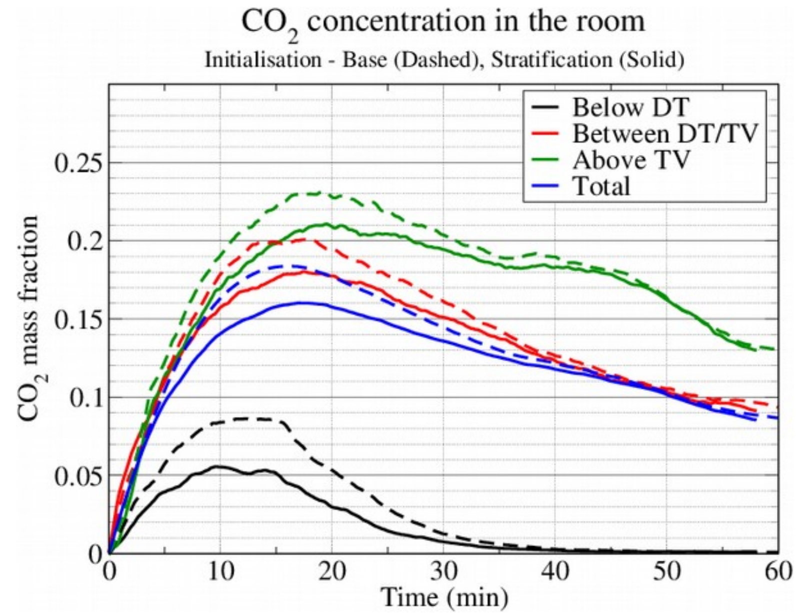


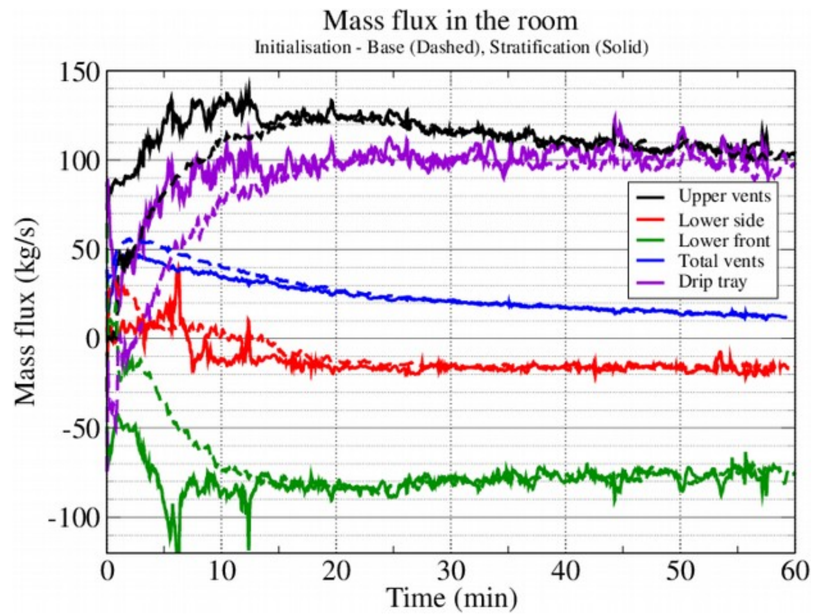


- Test without jet
- Current system codes don't take into account the initial state
- Results shown after 2 hours (45 minutes to get steady state)

Results TC2.2: Jet + Initial stratification – Comparison with basic initialisation



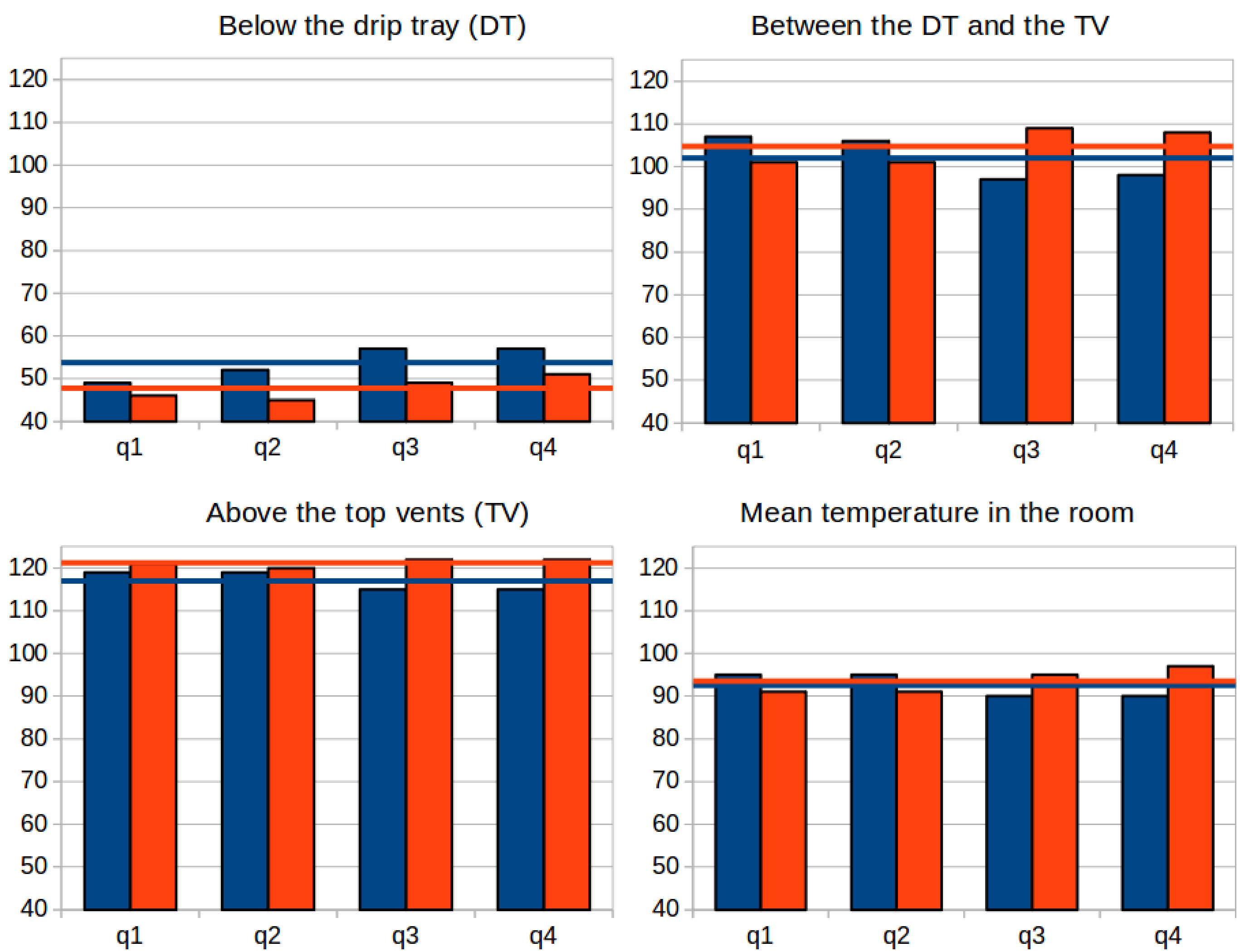


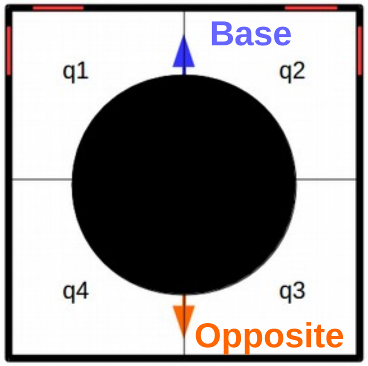


- Same temperature profile after 15 minutes
- Same mass flow profile after 15 minutes
- Initial ventilation loop allows to reduce the CO_2 concentration

Results TC3: Jet position – opposite side of the room

- Maximum temperature in the room





- Volumetric averages are similar
- Local maximum differs

Results **TC4: Wall heat transfer**

Wall properties

$$\rho = 2300$$
$$c_p = 900$$
$$\lambda = 2$$

Flux

$$q = h\left(T_{fluid} - T_{surface}\right)$$

Non-dimensionless number

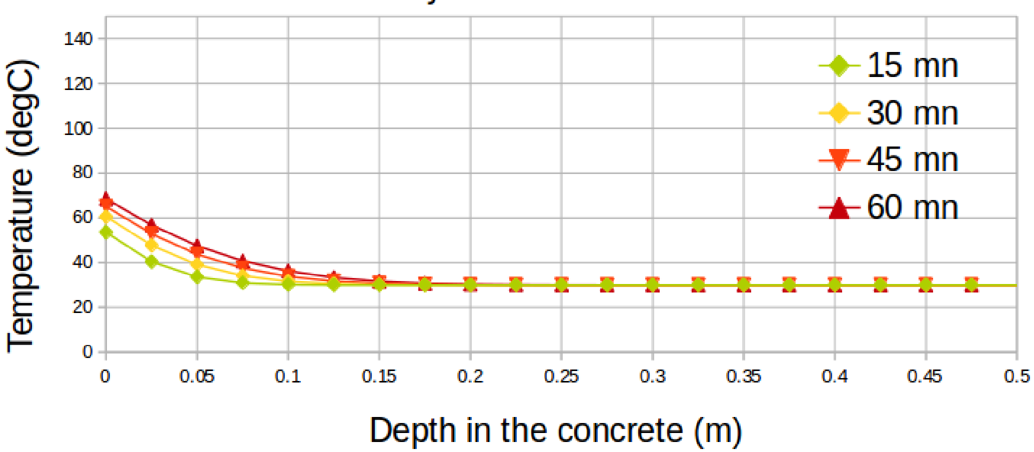
$$Bi = \frac{hL_c}{\lambda} = 0.39$$

$$Fo\left(1h\right) = \frac{\lambda t}{\rho c_p L^2} = 0.054$$

Previous work

1D code:
Maximum temperature
73 °C

Transient temperature in semi infinite concrete

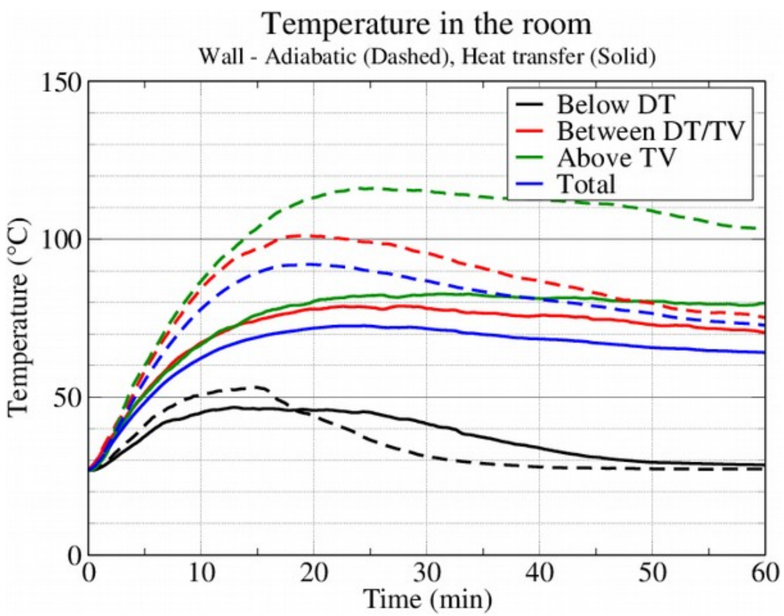


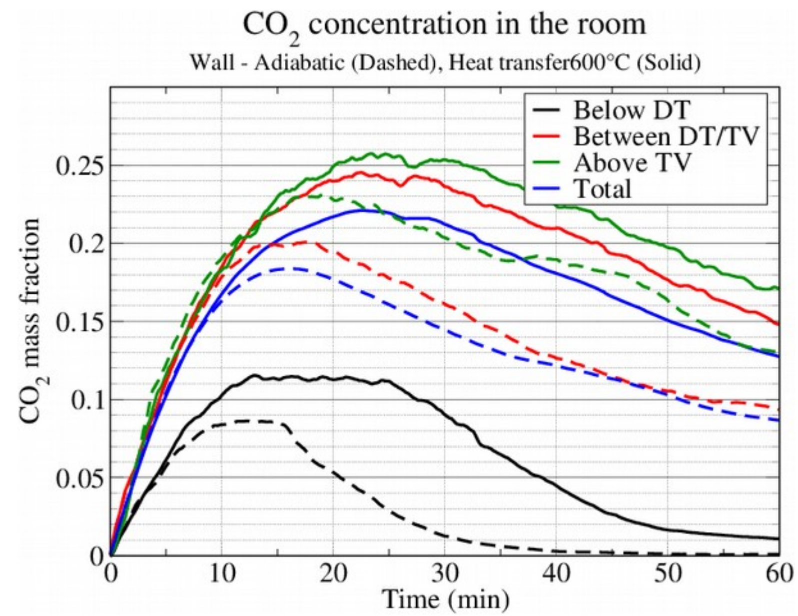
Choice in the model

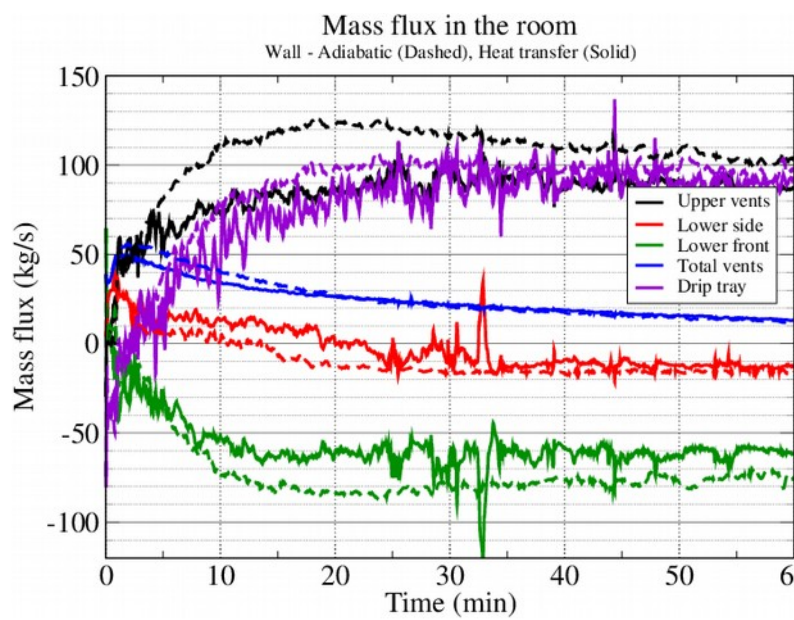
- Constant wall temperature
- Heat exchange coefficient

"Convection Heat Transfer", Vedat S. Arpaci and Poul S. Larsen, Prentice-Hall Inc

Results TC4: Wall condition







- Maximum temperature decrease by 30°C
- Ventilation loop weaker
- Increased CO_2 concentration

Conclusion

Project achievement

- CFD is showing more details regarding the gas and temperature distribution inside the room compared to current practices
- We are able to analyse different scenarios/assumptions
  - TC1 - 600^{o}C: Large difference in the first 30 minutes
  - TC2 - Stratification: Effects negligible after 60 minutes
  - TC3 - Jet at the opposite direction: Variation from the mean up to 5^{o}C
  - TC4 - Wall heat transfer: Large difference in temperature and CO_2 concentration

Perspective

- TC5: Wind condition at the exterior
- TC6: Forced ventilation
- TC7: Steam release
- TC?: Increase of release rate
- TC?: Better modelling of the release (compressible model)