HEAT TRANSFER SIMULATION IN A SPENT NUCLEAR FUEL REPOSITORY USING ANSYS AND OPENFOAM

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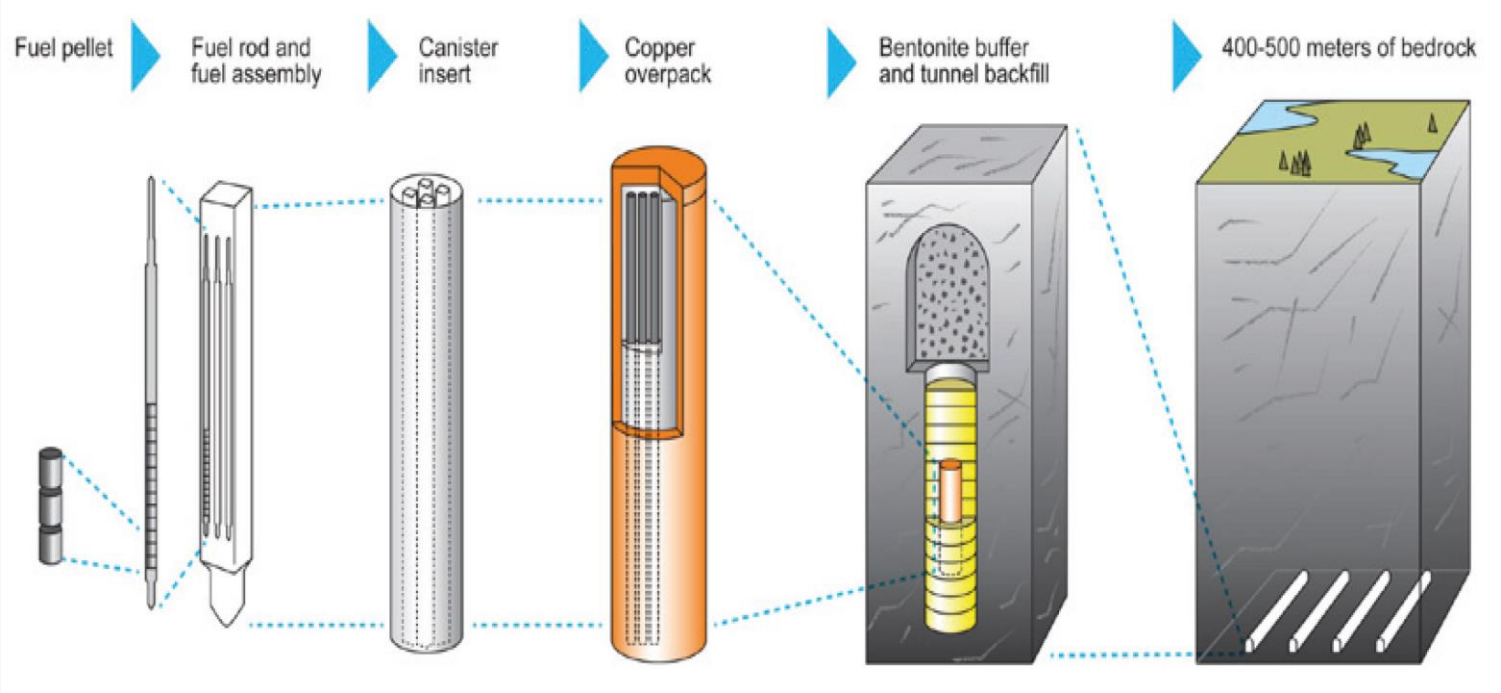
Introduction

- Geological disposal:
  - Most accepted method for the disposal of High-Level Waste -> Multibarrier principle



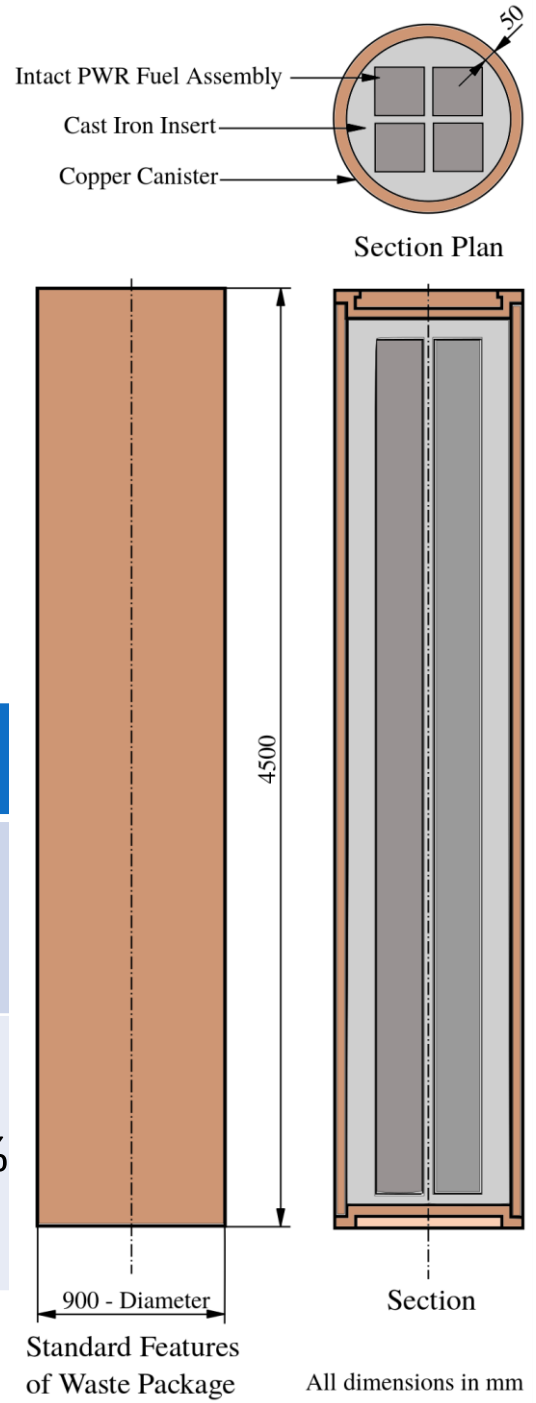
Posiva (2012)

Objectives

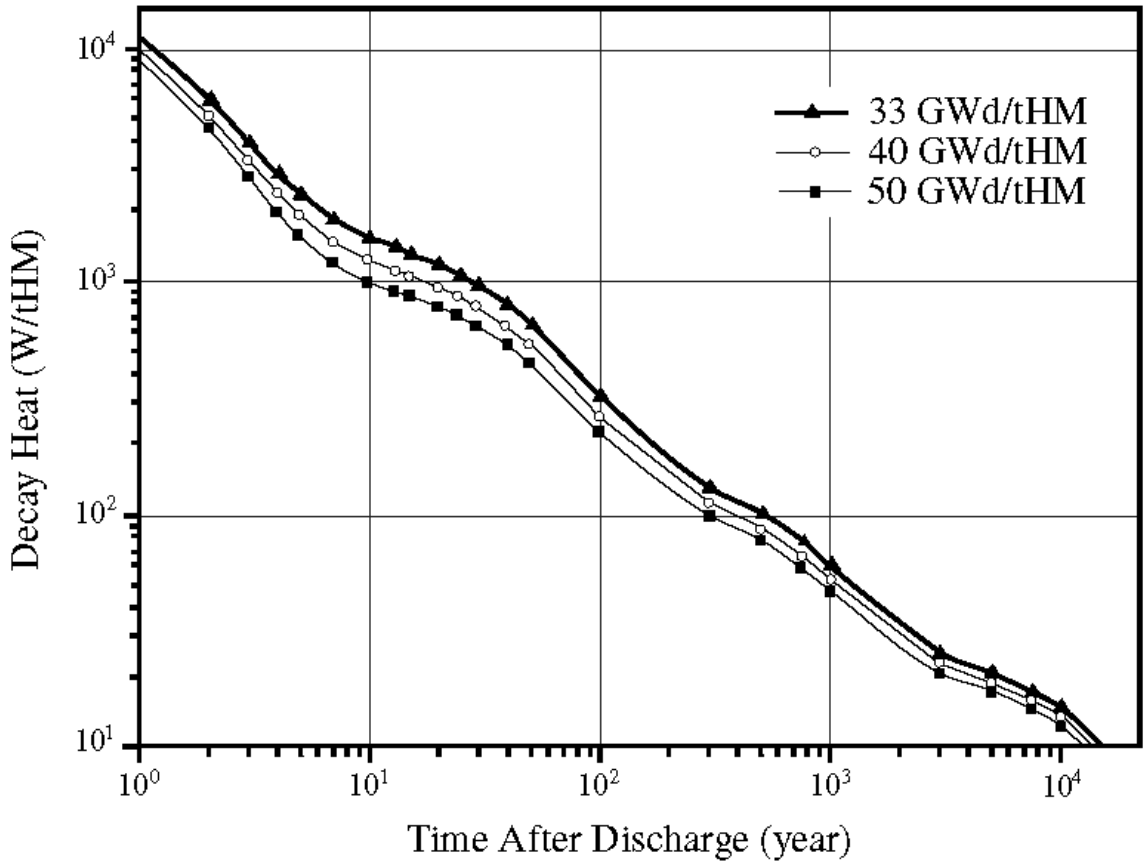
- Compare the heat transfer simulation in a spent nuclear fuel repository using Ansys , OpenFOAM and a benchmark (peer-reviewed-paper)

Methodology - SF types:

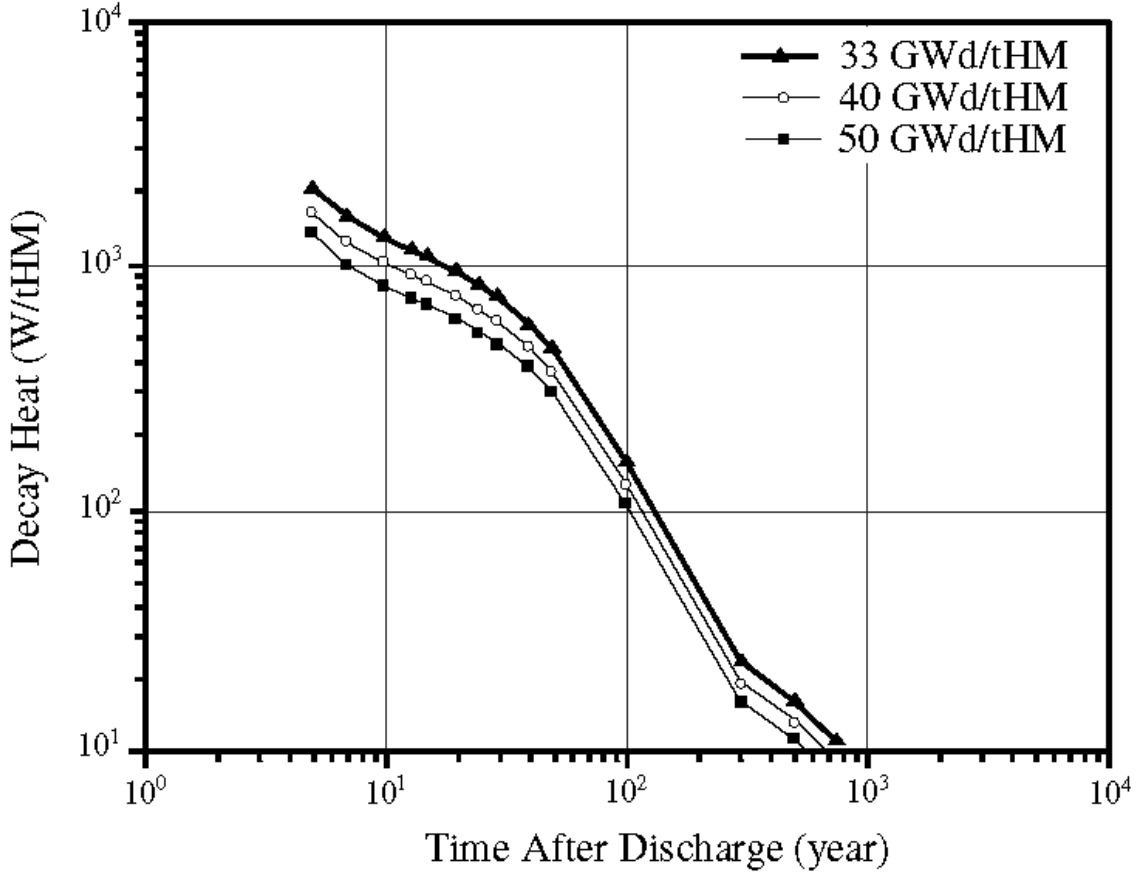
	SUOX			SMOX		
Burnup (GWd/tHM)	30	40	50	30	40	50
Fuel Enrichment/total fissile content	3.3%	3.8%	4.56%	4.064%	4.852%	6.045%



Methodology - SF types:



SMOX



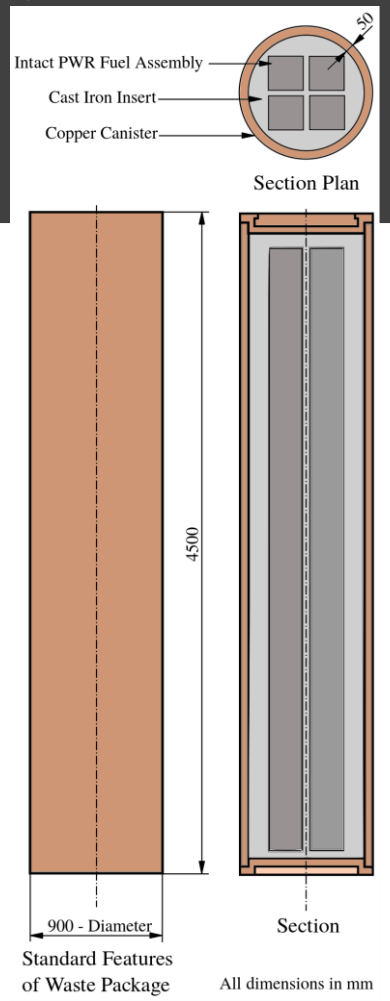
SUOX

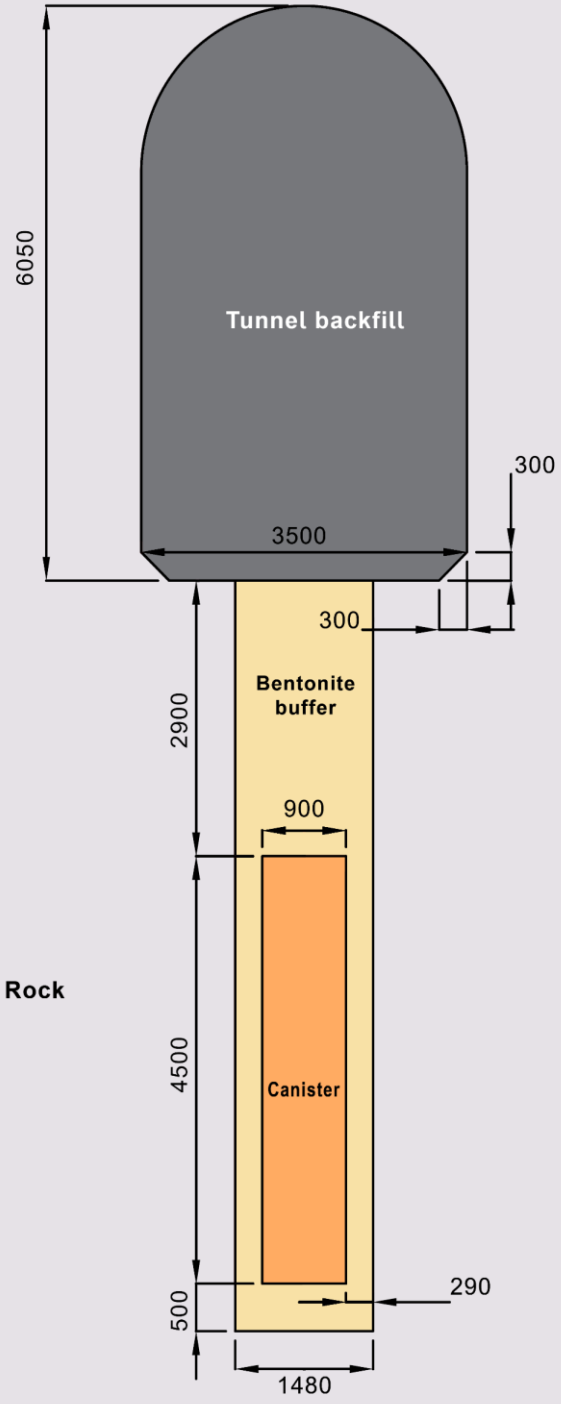
Methodology - Decay Heat Equation

$$Q_t = \sum_{i=1}^{4} A_i e^{-b_i t}$$

Waste Type	SUOX			SMOX		
Burnup GWd/tU	33	40	50	33	40	50
A1	990.18	1219.81	1535.27	1131.78	1495.38	2100.53
A2	120.73	138.18	157.3	703.28	865.25	1058.92
A3	14.27	15.76	48.54	390.09	552.25	660.44
b1	11.6	13.02	27.2	116.68	138.58	177.22
b2	0.00166	0.00167	0.00152	0.00152	0.00155	0.00159
b3	0.00013	0.00014	0.00869	0.00692	0.00788	0.00765
b4	$3.3175\ 10^{-5}$	$3.2642\ 10^{-5}$	$5.5445\ 10^{-5}$	$6.7581\ 10^{-5}$	$6.9608\ 10^{-5}$	$8.0955\ 10^{-5}$

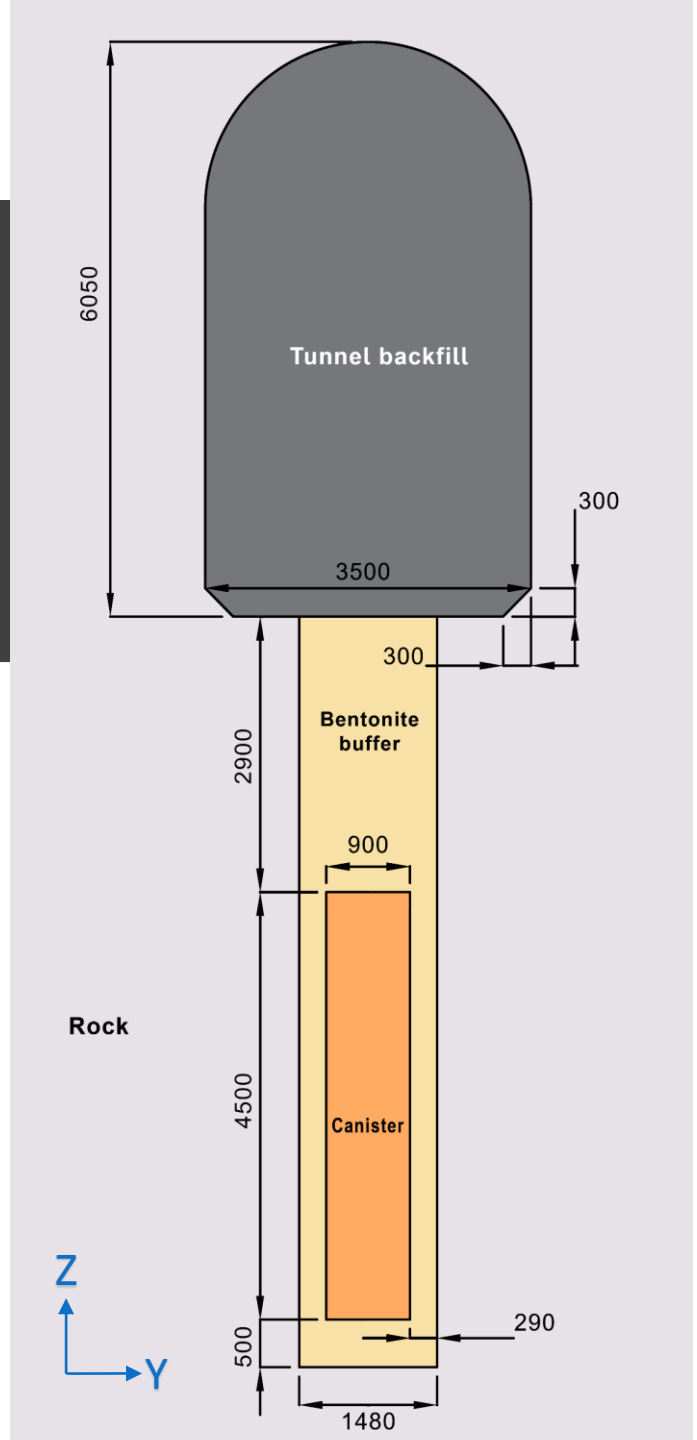
Methodology - Materials thermal properties





Material	Properties	Values
Spent fuel/HLW	Density (kg/m3)	2000
	Thermal Conductivity (W/m ºC)	0.135
	Specific Heat (J/kg ºC)	2640
Cast Iron Insert	Density (kg/m3)	7200
	Thermal Conductivity (W/m ºC)	52
	Specific Heat (J/kg ºC)	504
Copper Canister	Density (kg/m3)	8900
	Thermal Conductivity (W/m ºC)	386
	Specific Heat (J/kg ºC)	383
Bentonite	Density (kg/m3)	1970
	Thermal Conductivity (W/m ºC)	1
	Specific Heat (J/kg ºC)	1380
Backfill Material	Density (kg/m3)	2270
	Thermal Conductivity (W/m ºC)	2.0
	Specific Heat (J/kg ºC)	1190
Rock	Density (kg/m3)	2650
	Thermal Conductivity (W/m ºC)	3.2
	Specific Heat (J/kg ºC)	815

Methodology - Materials thermal properties



SF Type	Fuel Burnup [GWd/tHM]	Distance Dh [m]
SUOX	33	3.90
	40	5.54
	50	10.0
SMOX	33	3.0
	40	4.8
	50	13.0

Methodology - Step end time and time steps utilized

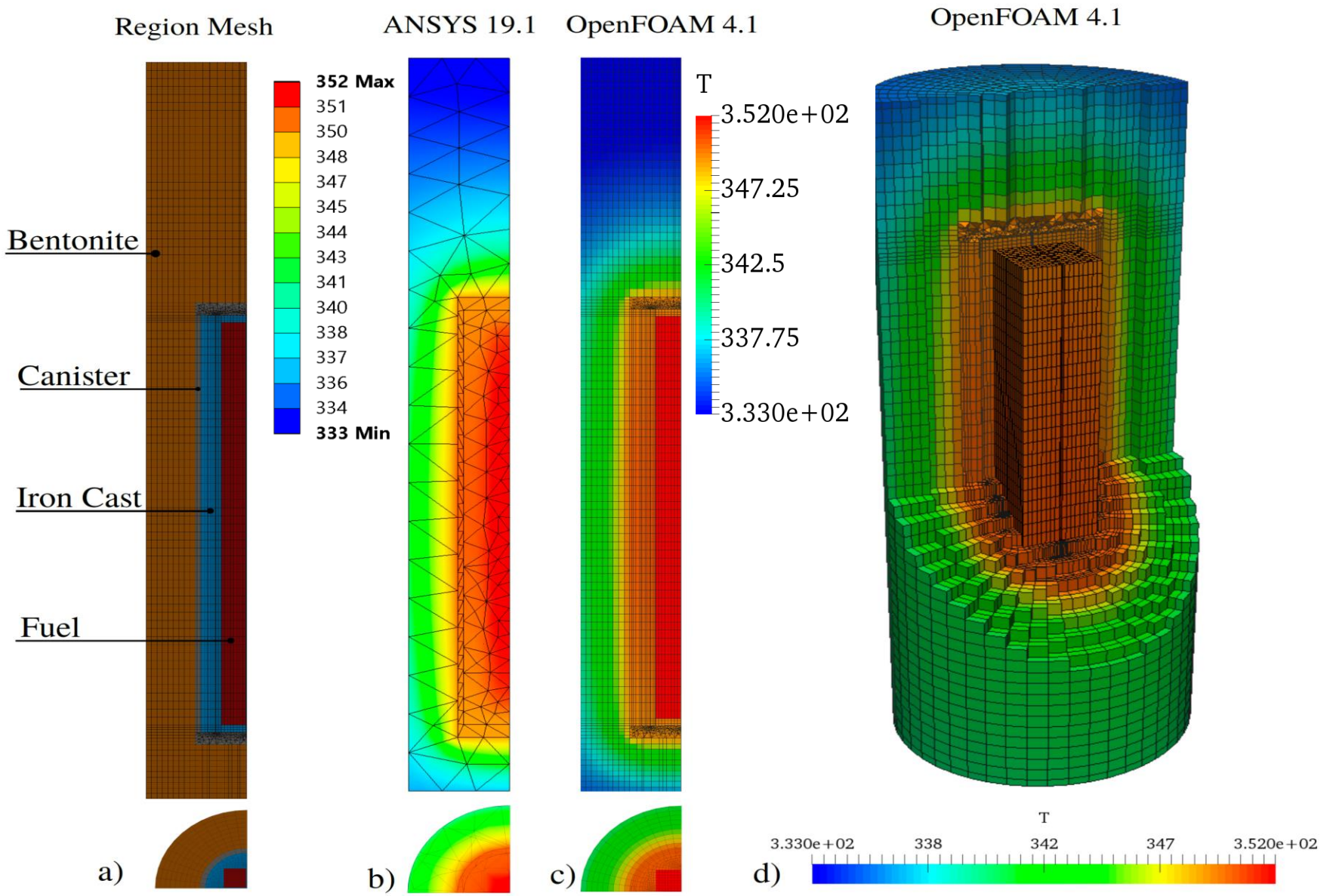
Step end Time (seconds)	Time Step (seconds)
86,400	180
2,592,000	10,800
28,927,800	259,200
631,152,000	7,889,400

Methodology - Codes

ANSYS® Academic Student 2019 R1

OpenFOAM©

Methodology - Meshing

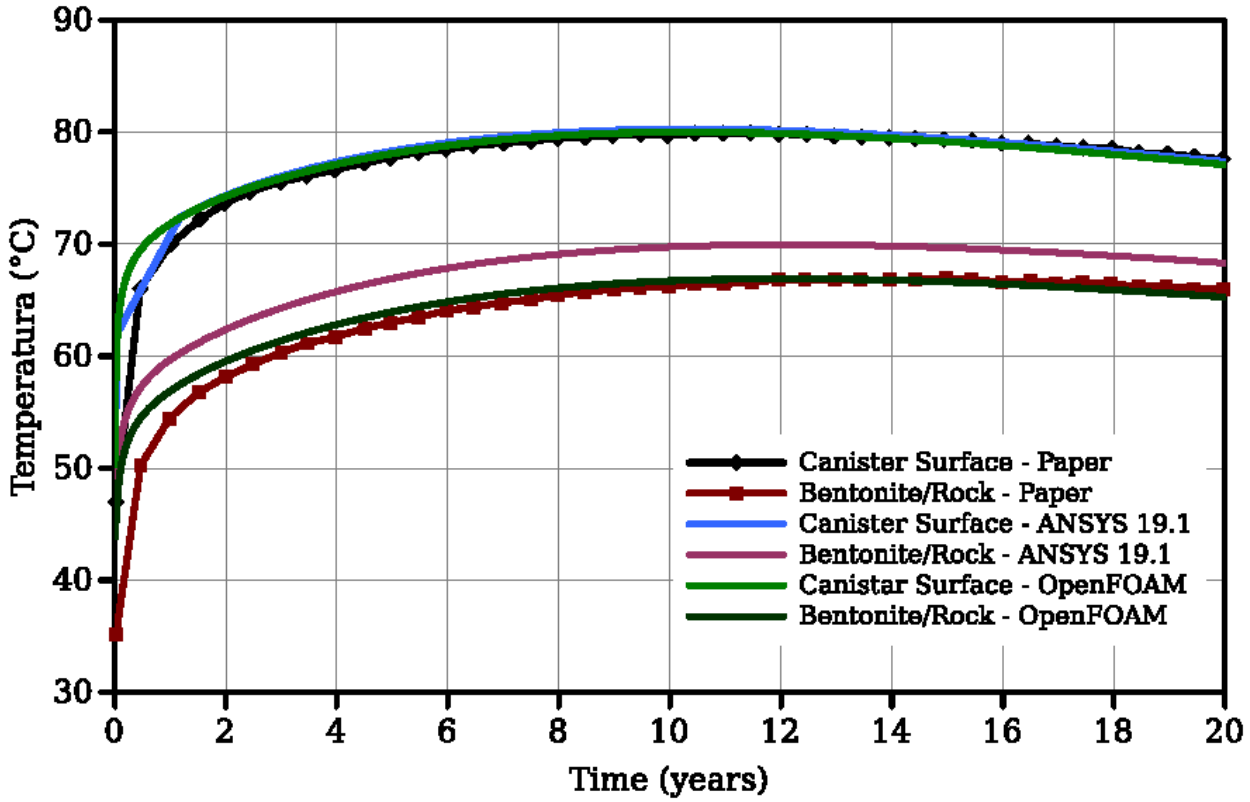


Methodology - Limitations

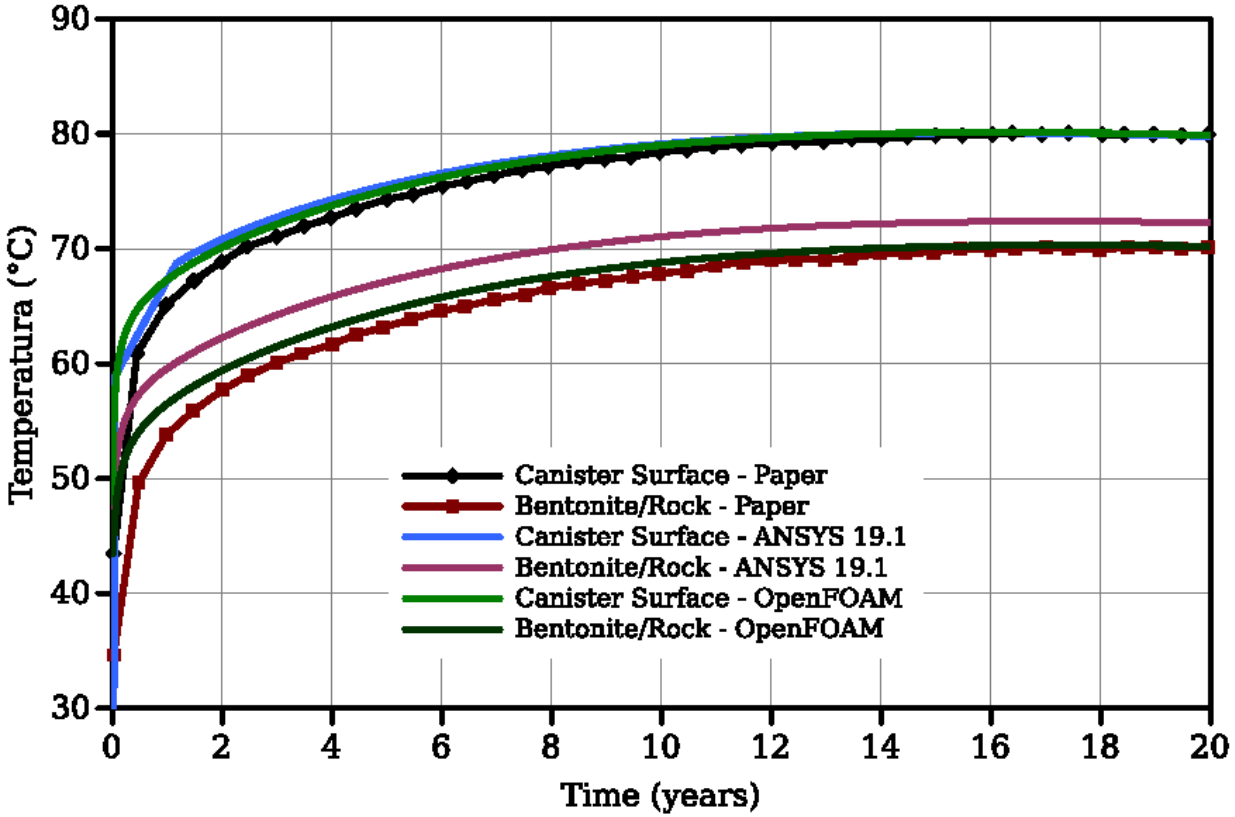
Numerical limitation on Ansys: 32k nodes/elements;

Unknown temporal discretization and meshing of the benchmarck.

Results

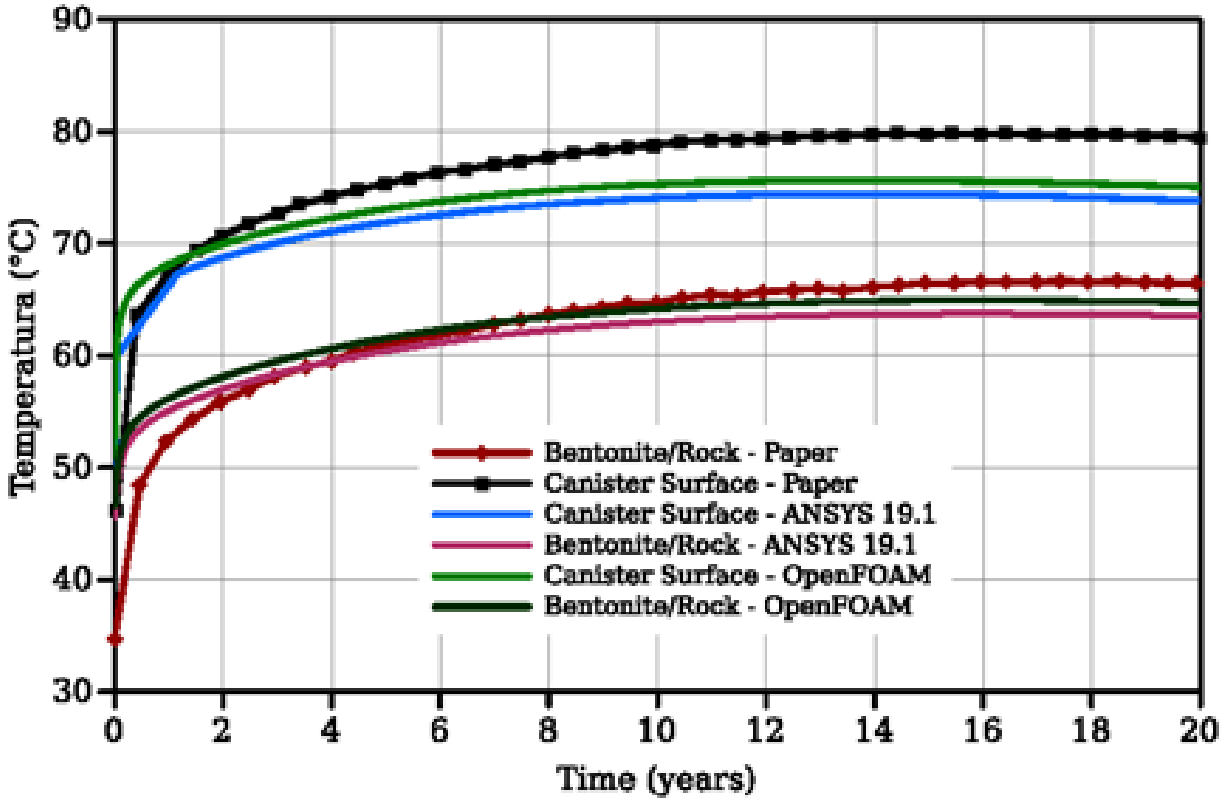


Temperature over time on the canister surface and at the bentonite/rock interface, SMOX 33 GWd/tHM.

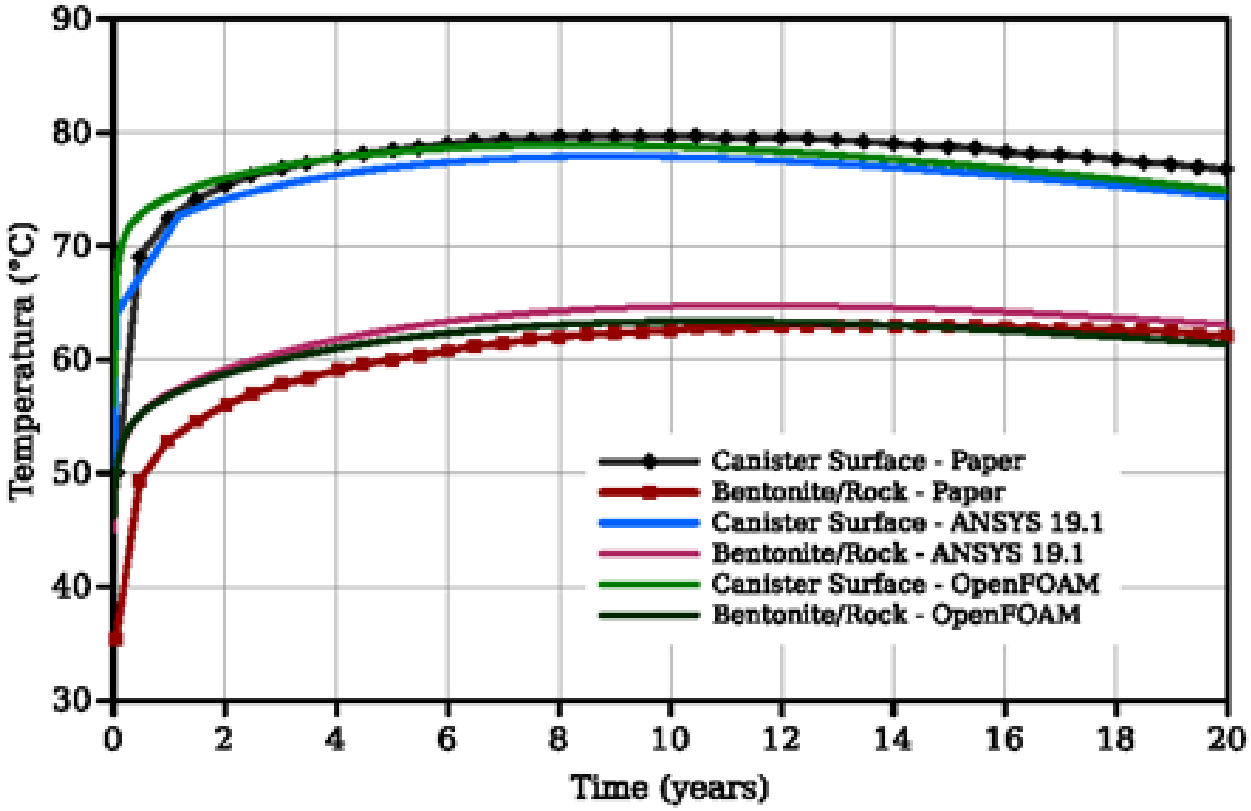


Temperature over time on the canister surface and at the bentonite/rock interface, SUOX 33 GWd/tHM.

Results



Temperature over time on the canister surface and at the bentonite/rock interface, SMOX 40 GWd/tHM.



Temperature over time on the canister surface and at the bentonite/rock interface, SUOX 40 GWd/tHM.

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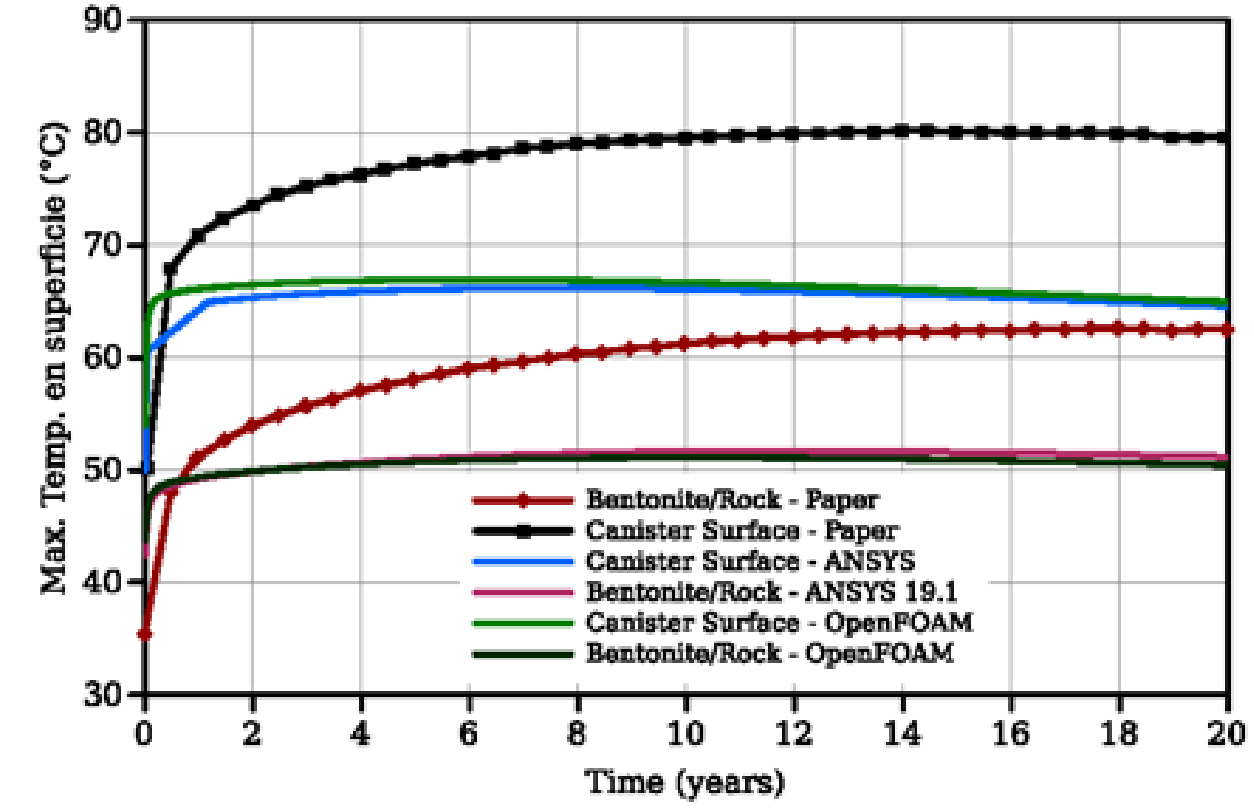
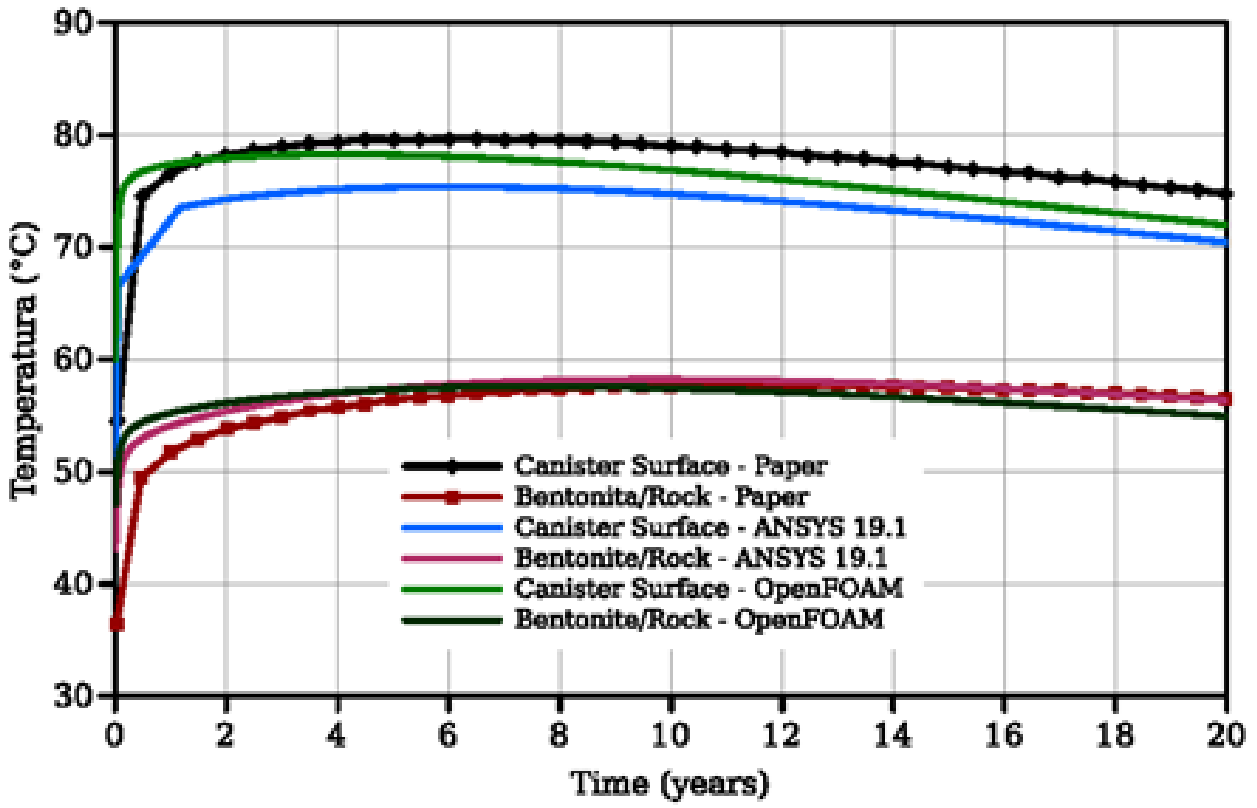


Temperature over time on the canister surface and at the bentonite/rock interface, SMOX 50 GWd/tHM.



Temperature over time on the canister surface and at the bentonite/rock interface, SUOX 50 GWd/tHM.

Conclusions

- Low meshing resolution didn’t interfere with the simulation of the physical phenomena;
- Possible typesetting error on the benchmark;
- Higher temporal discretization is preferable, specially at the beginning of the simulation.

Further Studies

- Mesh refinement studies;
- New SF;
- Brazilian geothermal gradients -> Evaluation of the optimal canister and tunnel spacing at the repository.

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Acknowledgements

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CONICET

Thank you!

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