EMPOWERING EMERGING NUCLEAR NATIONS: WASTIMATE'S APPROACH FOR SMALL MODULAR REACTOR RADIOACTIVE WASTE MANAGEMENT

IAEA-CN-327-134

KLIIMAMINISTEERIUM

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Co-funded by the European Union

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Wastimate – what it is and what can it do?

For nuclear newcomer nations, early planning of the nuclear fuel cycle is critical.

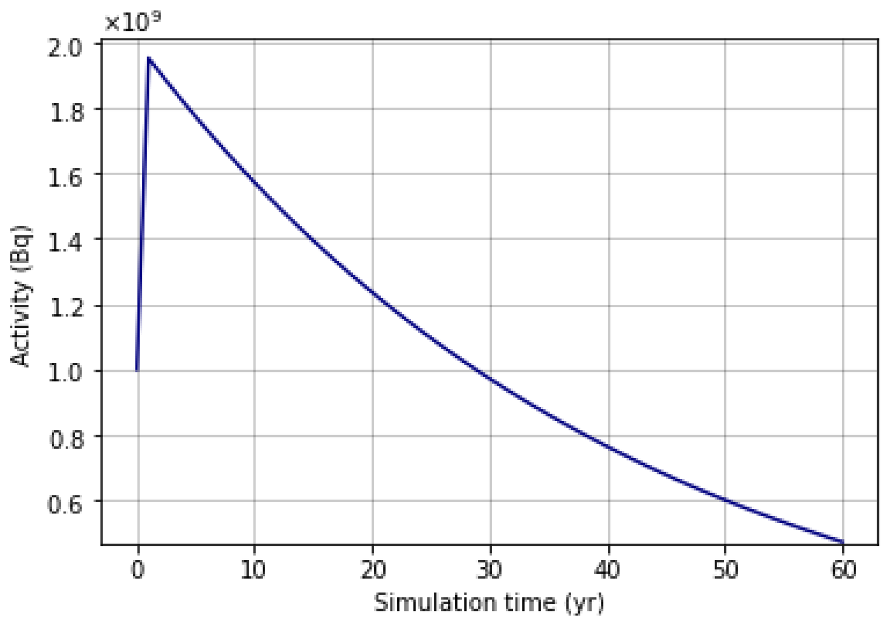
One solution to address the challenges of early planning

- **Wastimate!**
  - **Purpose**: Tracks movement and decay of radioactive materials in waste management systems.
  - **Open-Source**: Written in Python for ease of use and installation.
  - **No GUI**: Uses a modular, class-based approach for creating and running simulations.

Wastimate →

"Hello World!" of Wastimate

```
WastePackage  = Package(Mass=1, Inventory={"Sr90":1e9}, mode="activity")
DisposalNode  = Node([WastePackage])
ModelUniverse = Universe(stepsize=1*60*60*24*365) + DisposalNode
ModelUniverse.simulate(timesteps=60)
ModelUniverse.plot(DisposalNode, variable="activity", time_units="yr")
```



Sudden increase in the activity in the first model step:

- Ingrowth of Sr-90 daughter nuclide Y-90, **activity doubles**

***Fig. 1**: Activity of WastePackage in time as generated by the "Hello World!" Wastimate prompt.*

To verify Wastimate and demonstrate the basic functionality, two benchmarks were used:

SNF benchmark

300 MWe BWR

34 bundles per year	Burnup of 50 GWd/tU

↓

Spent fuel pool

Maximum pool capacity of 8 operational years

↓

Dry storage cask

Decay heat limit of 40 kW per canister (89 bundles)

↓

Geological disposal

Decay heat limit of 1.5 kW per package (12 bundles)

Wastimate requires waste production rates and isotopic composition as an input. For spent nuclear fuel, OpenMC[1] depletion module was used to estimate the isotopic description of the SNF.

SNF model was created by replicating the OECD/NEA's "Burn-up Credit Criticality Safety Benchmark Phase III-C" study[2].

Movement of packages can be limited based on mass, inventory, activity, dose, or heat of the package or node. Technical criteria are set by the waste package requirements or applicable legislation.

Modeling results in node and package mass, activity, or decay heat distribution in time.

Wastimate calculations were verified by manually tracking individual packages and comparing the results.

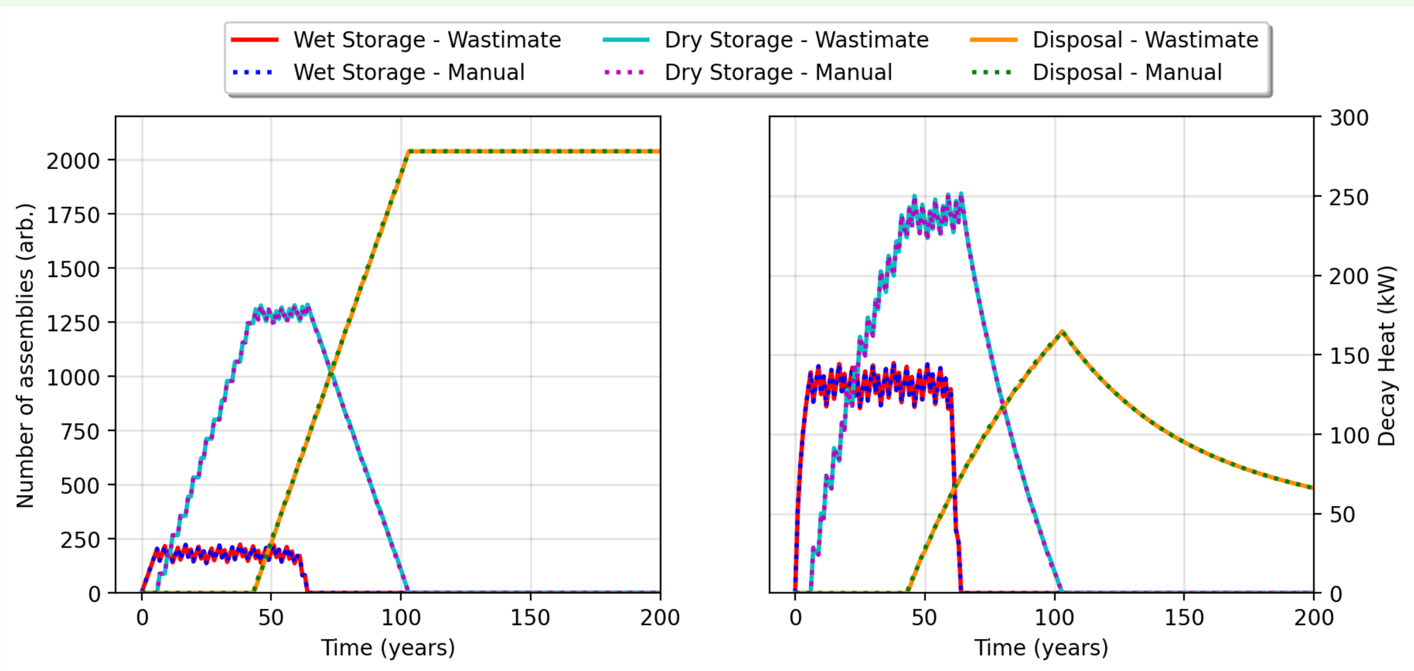


***Fig. 2**: SNF quantity and total decay heat output of wet, dry storage and final disposal node.*

LLW benchmark

LLW benchmark demonstrated the modeling of continuous waste quantities using two built-in Wastimate methods:

- **Combine**: Merges packages into larger collections.
- **Separate**: Homogenizes node contents and moves a fraction to a new node.

Nuclide concentrations can be inputted as statistical distributions using SciPy[3].

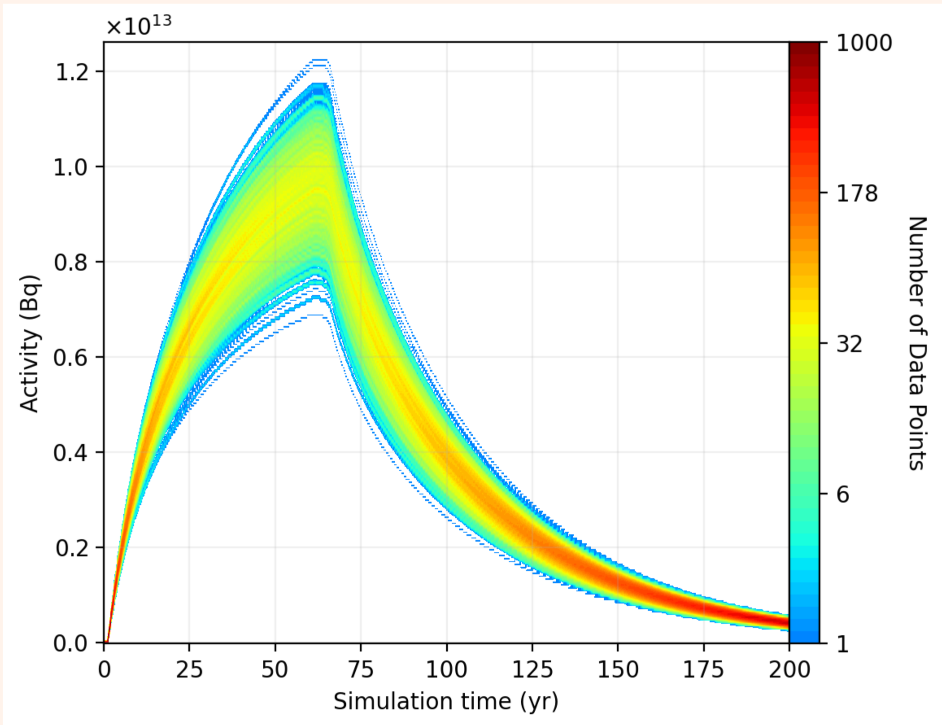


***Fig. 3**: Activity distribution of the near-surface disposal node in time over 1000 simulations.*

300 MWe BWR

61 m^3 of concentrated sludges per year

↓

Liquid Storage Tank

Waste processing rate-based limit

↓

Near-surface disposal

Transportation-based radionuclide activity limits

↓

Waste package release

Activity-based radionuclide release criteria

Results - Estimated design-based criteria

SNF benchmark summary

- First transfer: **89 assemblies** to dry storage after **7 years**.
- Wet storage capacity: **250 assemblies** + entire reactor core
- Dry storage: **15 canisters** for 89 assemblies (total 1335).
- Packaging rate: **3 packages** of 12 assemblies/year.

LLW benchmark summary

- Waste volume in tank: ~**320 m^3** by end of reactor cycle.
- Disposal facility capacity: 3660 m^3 of liquids or **2925 grouted waste packages**.
- **First package** meets clearance criteria after **550 years**
- Release activities **delayed due to Cs-137**, followed by Sr-90.

References

[1] ROMANO, P. K., HORELIK, N. E., HERMAN, B. R., NELSON, A. G., FORGET, B., et al., OpenMC: A State-of-the-Art Monte Carlo Code for Research and Development, Annals of Nuclear Energy 82 (2015) 90–97

[2] Burn-up Credit Criticality Safety Benchmark Phase III-C, Nuclear Science NEA/NSC/R(2015)6, OECD (2016)

[3] VIRTANEN, P., GOMMERS, R., OLIPHANT, T. E., HABERLAND, M., REDDY, T., et al., SciPy 1.0: Fundamental Algorithms for Scientific Computing in Python. Nature Methods 17(3) (2020) 261-272.