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Examples of SCALE uses at Studsvik Sweden

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Background

Our customers need:

- To ensure safety during fuel transports and handling, in the interim storage, in lab and even in final repository.
- Earlier: conservative estimates good enough
- Now: realistic values requested

Types of calculations:

• Spent fuel composition, activity, residual heat, A2 value	SCALE – ORIGEN, TRITON	
• Criticality analysis	MCNP	SCALE – KENO VI
• Activation products, corrosion products	Own codes	
• Radiation shielding	MCNP	SCALE – MONACO

Example of recent projects and SCALE codes involved

1. New fuel design –influence on the back-end of the fuel cycle, **TRITON, ORIGEN** (6.1)

2. Spent fuel in Sweden – prognosis for the back end of the nuclear fuel cycle, **ORIGEN** (6.1)

3. Fuel transports – various fuel types in various forms, **ORIGEN** (6.1, 6.2)

1. New BWR fuel design – problem description

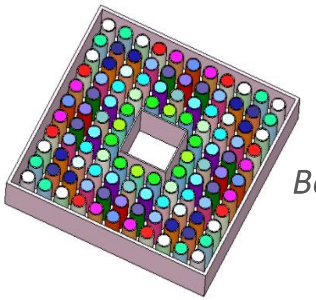
The goal is to ensure safety during handling of the spent fuel assemblies

How does the new compare to the existing fuel types in terms of

- activity
- decay heat
- neutron source term
- gamma source
- nuclide inventory

1. New BWR fuel design - solution

- Generate Dancoff factors with **MCDANCOFF** (SCALE 6.1)



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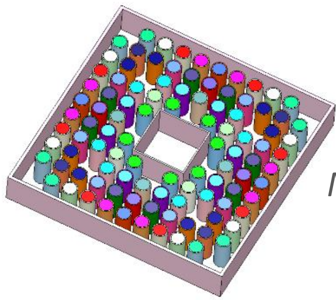

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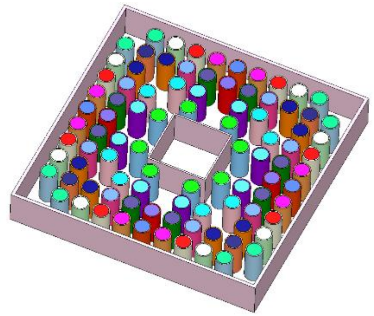

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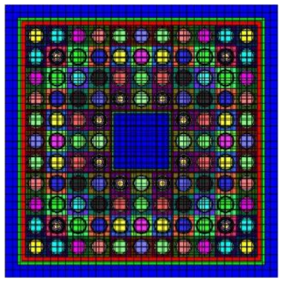
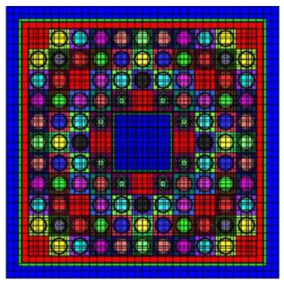
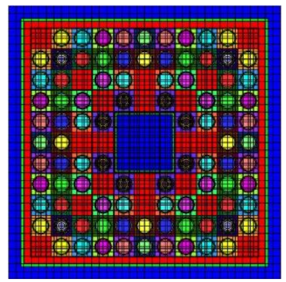
- Prepare set of cross sections for various water densities and enrichments with **TRITON** (SCALE 6.1)



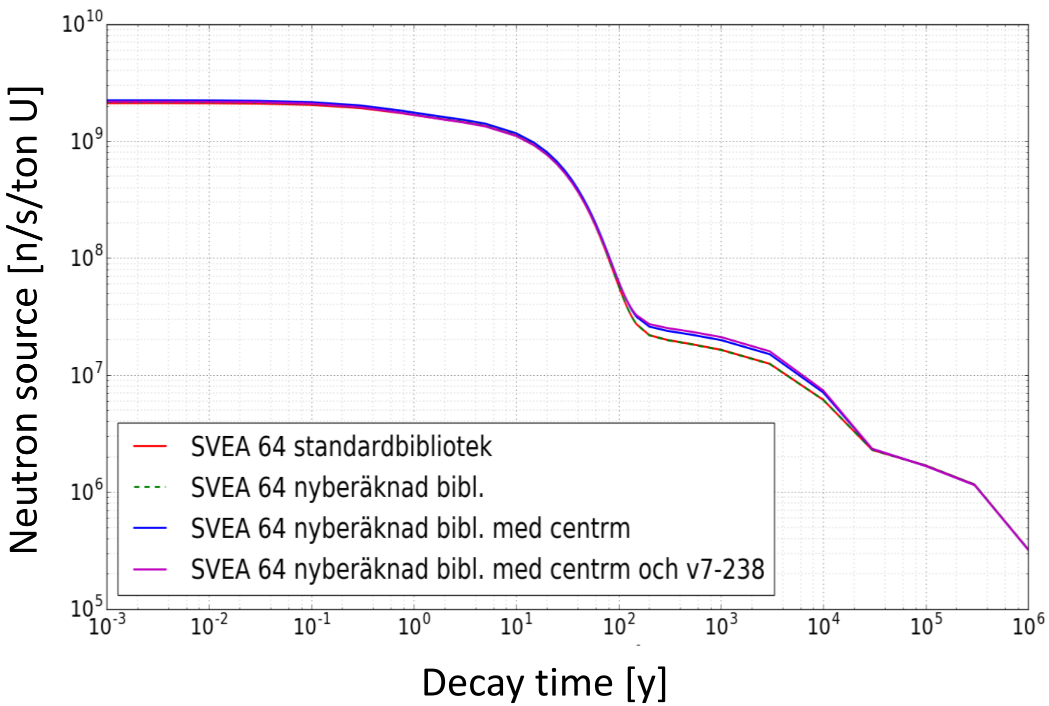




- Use **ORIGEN** (SCALE 6.1) to get the result: activity, decay heat, neutron and gamma source terms

1. New BWR fuel design - solution

Activity, decay heat and gamma source term were similar to the results for older types of fuel, but there was a visible difference in the neutron source term between 100 and 10 000 years.



After some more calculations involving only existing SVEA 64 fuel, we identified some possible reason for the discrepancies.

- NITAWL, CENTRM and CENTRM + v7-238 were used

SCALE 6.1.

2. Spent fuel in Sweden – problem description

The goal is to obtain realistic estimates. Swedish

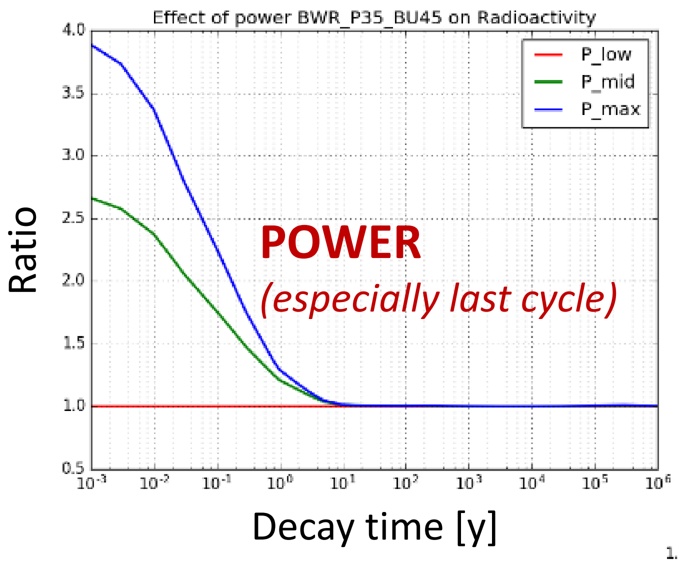
Project done in collaboration with Nuclear Fuel and Waste Management Co, SKB

For large number of BWR and PWR fuel assemblies with various designs, enrichments, burnups, irradiation histories

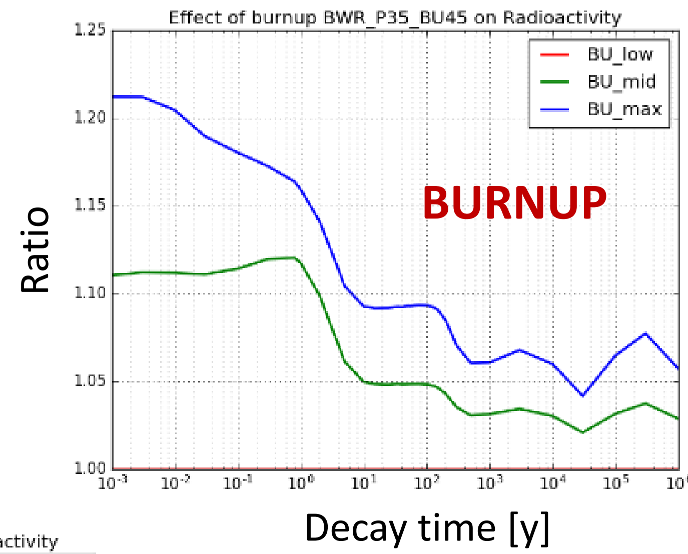
- identify factors that have the largest influence on the result
- calculate radioactivity, decay heat , neutron source term , gamma source, nuclide inventory
- estimate uncertainties in the results

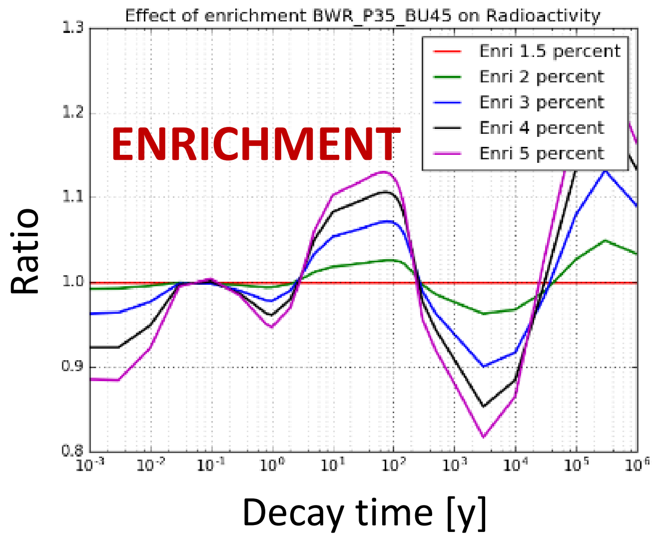
2. Result – which parameters have major influence?

... example radioactivity, average burnup 45 MWd/kgU, power 3.5 MW/assembly



Power, burnup and enrichment varied in their typical range

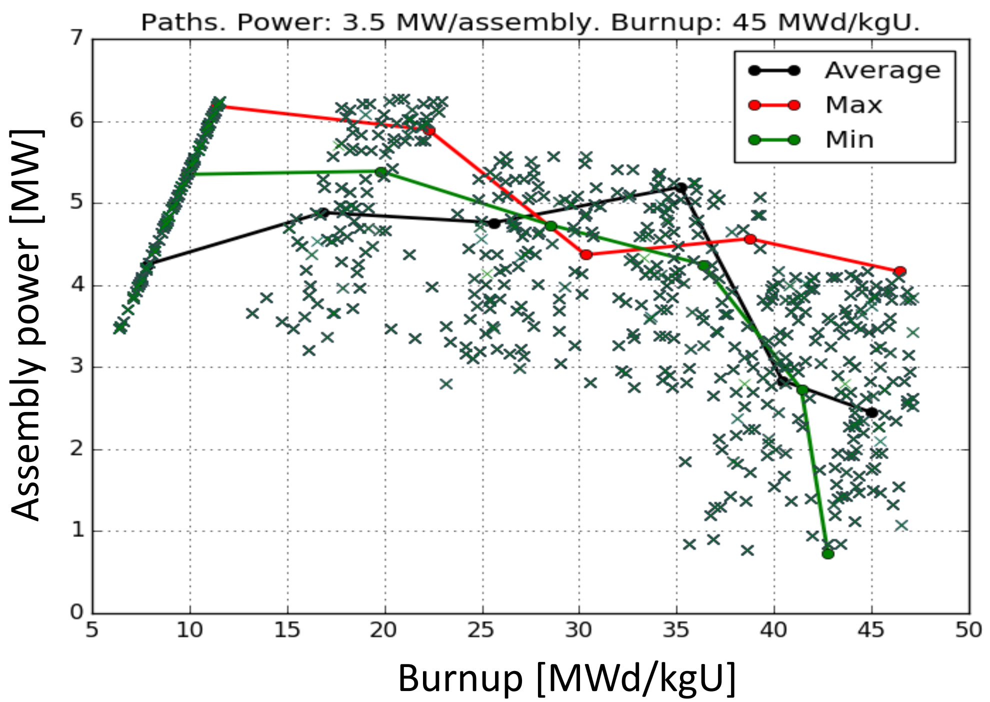




Where are these uncertainties from in reality?

2. Spent fuel in Sweden – solution

- **Average power per assembly, final burnup** +/- 5% and historical data are used to generate possible power histories for ORIGEN calculation
- Power history that yields maximum and minimum is selected. Average is in between (no weighting for the actual number of assemblies that undergo these paths)



In this example

- *3.5 MW/assembly,*
- *45 MWd/kgU*

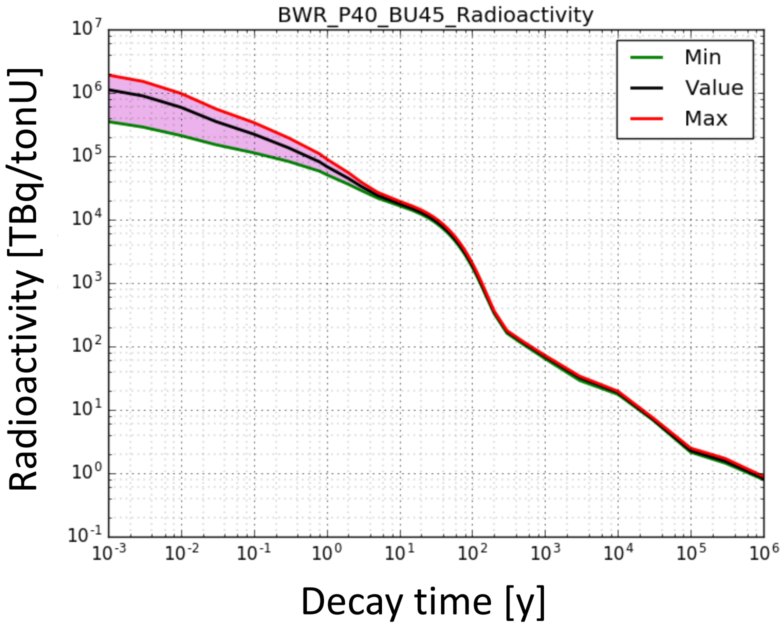
2. Spent fuel in Sweden – solution

- ORIGEN inputs are created to calculate minimum, maximum and average. For various axial zones and water densities. For every requested combination of power and burnup.
- Results for axial zones are re-composed to create complete fuel assemblies.
- Calculations for varying enrichment are done and added to the result. Earlier “conservative” estimates may be exceeded.
- Plots and totals are produced.
- ORIGEN Output files are mined for data to be stored in the database (*in this project Access - not recommended!*).

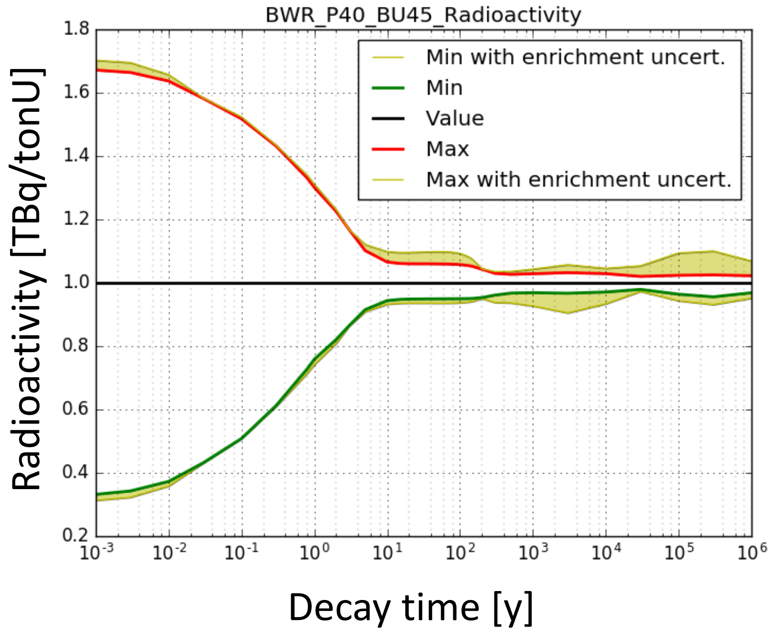
2. Result – Radioactivity

… in this example a reactor with power 4MW/fuel element. Average burnup: 45 MWd/kgU

The large uncertainty **up till 10 years** after offload from reactor is due to the **uncertainty in the irradiation history**, most importantly the power the assembly experienced in the last cycle. Generally, the power in the last cycle can vary between 0.1 and 1.2x average power.



Result with uncertainty minimum and maximum.



Uncertainty interval.

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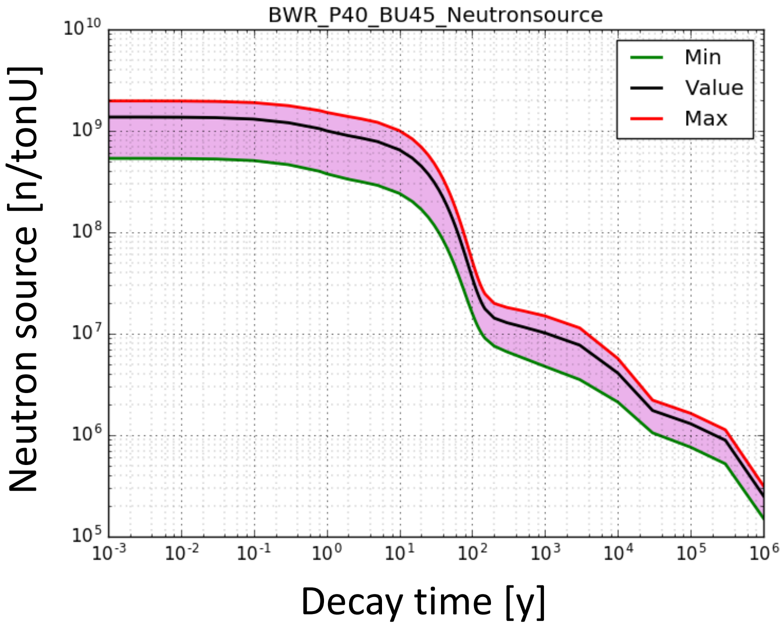
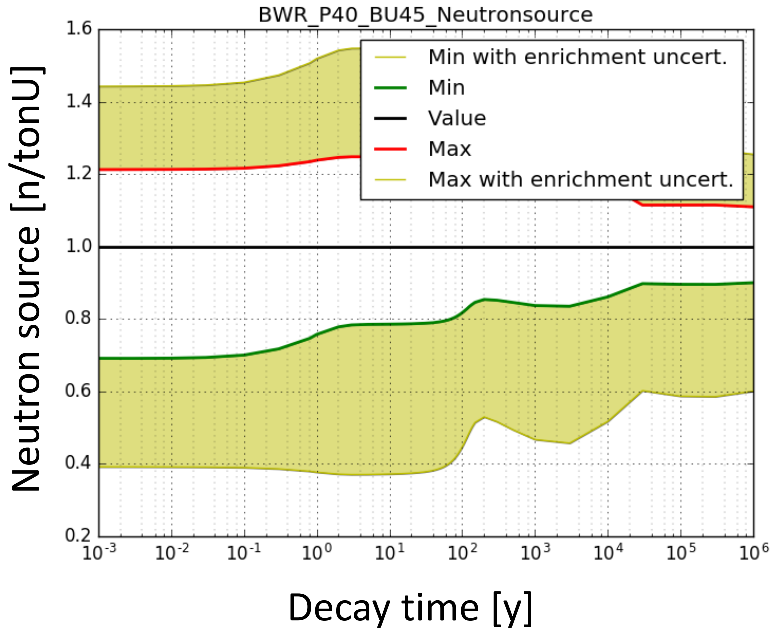
2. Result – Neutron source term

Uncertainty is governed by uncertainty in burnup and enrichment. The uncertainty changes little with the decay time in comparison to the uncertainty in radioactivity, gamma source term and decay heat.



Result with uncertainty minimum and maximum.



Uncertainty interval.

3. Fuel transports – problem description

- Various fuel types from various types of reactors transported to and from our lab
- Undamaged, damaged, cut in pieces and re-encapsulated
- Often unknown irradiation history, but often long times since offload
- Often a conservative estimate is enough, but sometimes not

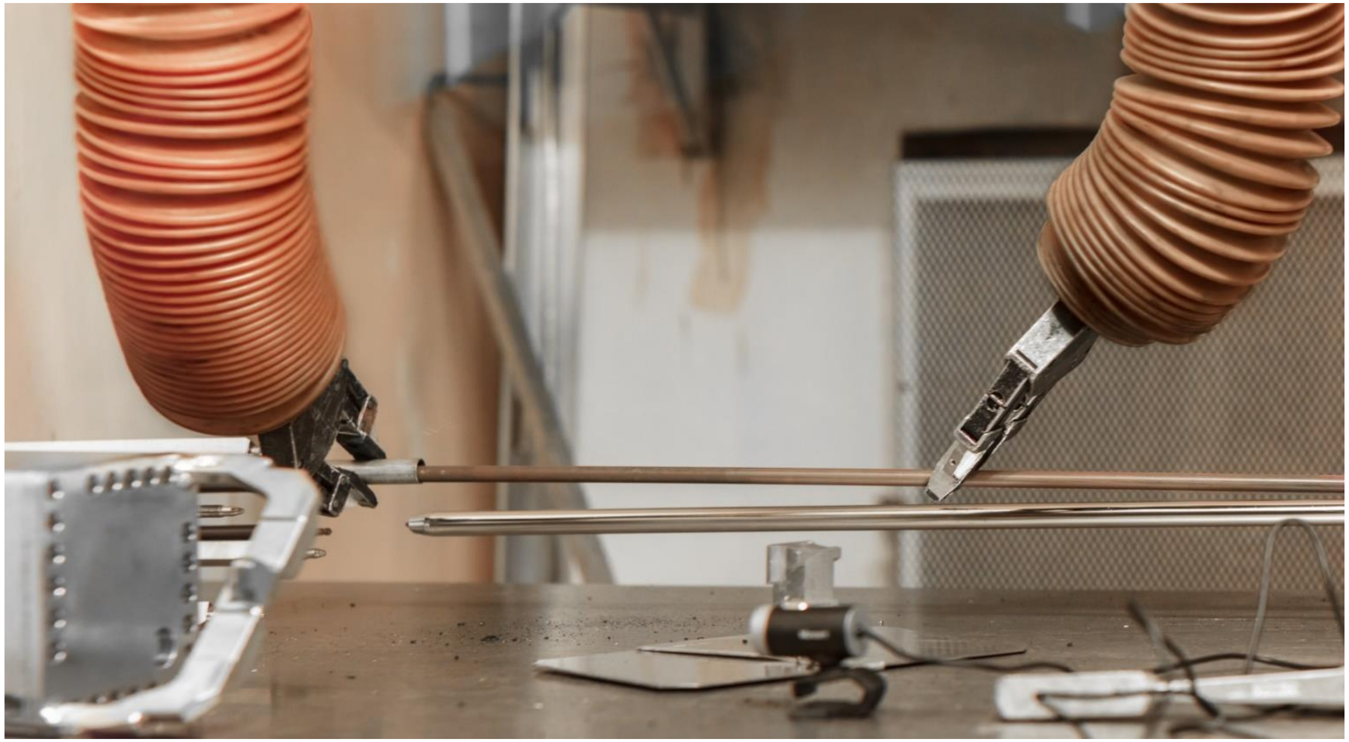
- Wanted results: radioactivity, decay heat , nuclide inventory, A2 value
- Comparison to the values in the transport package certificate and compliance check for various fuel loadings, optimization of loadings (send maximum heavy metal mass without exceeding…)
- Slightly different boundary conditions in each project, sometimes large number of units
- SQL database

3. Fuel transports – solution

- Constants such as A2 are already in the database
- Fuel data are entered into database
- Transport specifications are entered into the database
- Completeness check to identify values that need to be calculated is performed
- ORIGEN (6.2) are created, calculated and mined for data
- A2 values are calculated
- Results are written into the database

3. Fuel transports – solution

- When the database is complete, combine the fuels according to the transport specifications that live in another table in SQL. Using constants such as A2 values from other tables.
- Produce tables for report with results
- If needed, activation products and crud can be calculated separately



Summary

- Realistic estimates are requested by our customers
- "Conservative" calculations ….. not necessarily always conservative!

- We use mostly ORIGEN, nowadays SCALE version 6.2.
- In most projects, we handle large numbers of fuel assemblies and automatization in terms of input preparation, output reading and evaluation is necessary
- We started using SQL to store all the data

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