**Memo: Model for fuel fabrication in EG29**

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**Introduction**

This memo presents the modeling results of cases 1.1 to 1.3 of the EG29 scenario, induced by the use of a plutonium equivalent model for the fuel fabrication. Case 1 of the EG29 calculation involves the modeling of a single MOX-PWR at steady-state (see figure 1). Case 1 is subdivided into three sub-cases corresponding to calculations of increasing fidelity:

* 1: without isotopic composition,
* 2: with isotopic composition and no decay,
* 3: with isotopic composition and decay.



Figure 1 Schematic of Pu mass flow for Case 1

**Part 1:**

The first part of this memo is dedicated to the comparison between fixed ratio mix and pu-equivalent theory for the fuel fabrication process.

**Calculation:**

Two variations on fuel-building were calculated for each sub-case (1.1 to 1.3). The first calculation used a standard mixing fab (in Cyclus, the cycamore::mixer). This mixed the E3” and the J1” streams using a constant mixing ratio to build the MOX fuel for the PWR, labeled “M”. The second calculation used plutonium equivalent theory to determine the mixing fraction of each stream to build the MOX fuel, labeled “W”.

**Results:**

The difference on J1’’ and E3’’ between all 6 calculations can be observed on Figure 2. First on should only consider in this study the time between 15 and 75y, as the calculation need almost 12y to rich an equilibrium and the first reactor is replaced at 80y (explaining the different fluctuations observed).

For both stream (J1’’ and E3’’), the 2 cases without decay are similar in the 2 calculation methods (W and M). When decay is taking into account, one can observe a small reduction of the plutonium content in J1’’ stream directly due to 241Pu decay.

Nevertheless, when using the plutonium equivalent theory for the fuel fabrication and considering decay (“case 3\_W”), one can observe a slight continuous decrease of the amount of plutonium in J1’’ stream and a small continuous increase in E3’’. This is because, the fuel fabrication process use slightly less material from the J1’’ stream than expected, causing an accumulation of plutonium. This accumulation gives more time to the 241Pu to decay causing an increasing degradation of plutonium quality (through the increasing fraction of 241Am) which reduce even more the amount of J1’’ require. The degradation of the J1’’ plutonium is balanced by the increase of the amount of E3’’ stream used in the fuel fabrication process, the E3’’ plutonium been composed of mainly 239Pu.

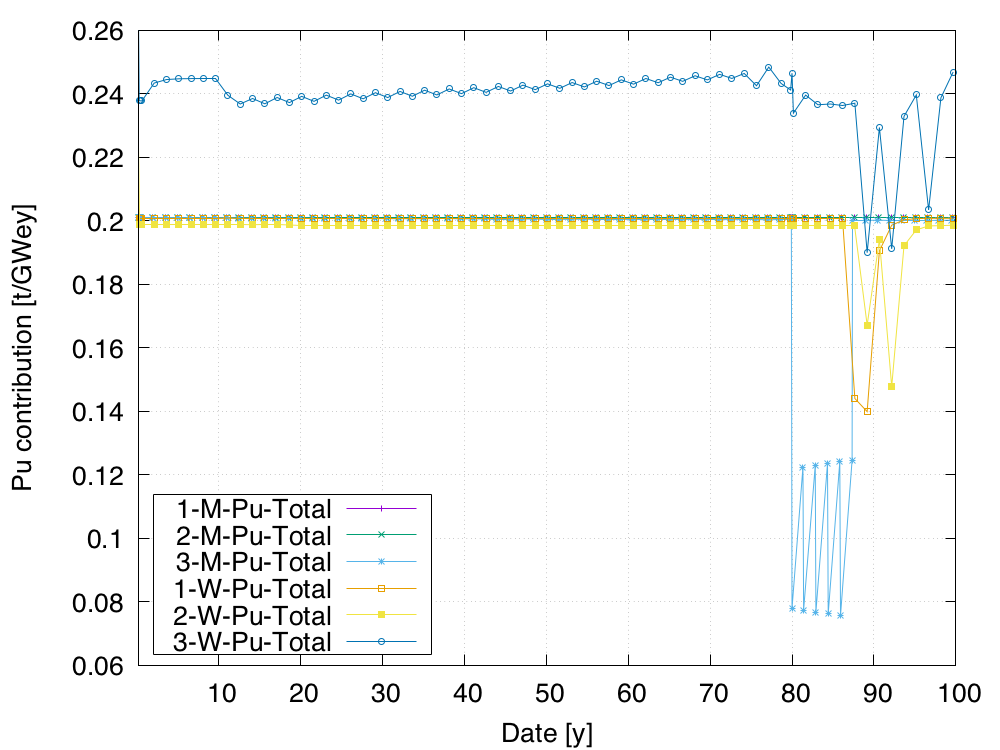
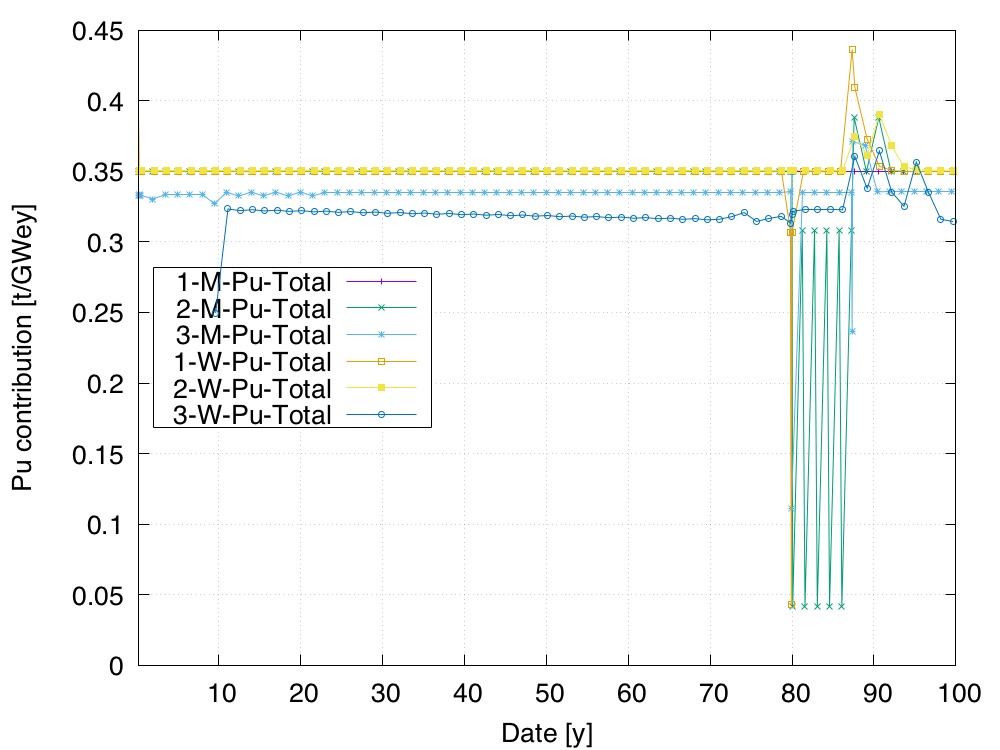


Figure 2 Evolution of Pu contribution on J1” stream on the left, and E3’’ on the right

Case 1.3, which includes isotopic compositions and decay, behaves drastically different than the other two sub-cases. For the fixed mixing ratio calculation (M), the fluctuations are caused by the decay of Pu241 in the J1” stream. The E3’’ stream, which contains very few short-lived plutonium isotopes, is not impacted by the decay.

For the calculation using the plutonium equivalent model (W), the decay of Pu241 has a cyclic impact on the fabrication of the MOX fuel. As the Pu241 is transmuted to Am241, the plutonium from the J1” stream has a reduced “reactivity potential”, forcing the increase of the E3” stream amount in the mix from 0.210 tPu/y to almost 0.3 tPu/y.

**Part 2:**

The second part of this memo is dedicated to the comparison of the plutonium fraction in the fresh PWR-MOX fuel predicted using different kind of models. The model used can be divided in two categories, the one able to mix any stream to another (fix mixing ratio and pu-equivalent based model) and the one allowing only to mix a plutonium stream into a uranium stream.

For the first kind, the EG29 specification are applied as is (except for the fuel fabrication). For the second kind, the plutonium and uranium from J1’’ and E3’’ stream are separated. Then the plutonium from J1’’ and E3’’ are mixed according to the ratio provided in EG29 specifications. The model are used to determine what proportion of this J1’’/E3’’ plutonium stream are require to build the PWR-MOX fuel to achieve the EG29 specifications (LWR, 50GWd/t, 1/3 batching).

The different model used are:

* fix mixing ratio between J1’’ and E3’’ stream, (M)
* pu-equivalent based model to mix J1’’ and E3’’ stream, (W)
* Neural Network (NN) trained with irradiation stopped at a k∞ of 1.01 (mean k∞ of all batches), 3 batches, (MLP)
* NN with irradiation stopped at a mean a k∞ of 1.034, 3 batches, (MLP-STD)
* NN with irradiation stopped at a mean a k∞ of 1.034, 4 batches. (MLP-STD-2)

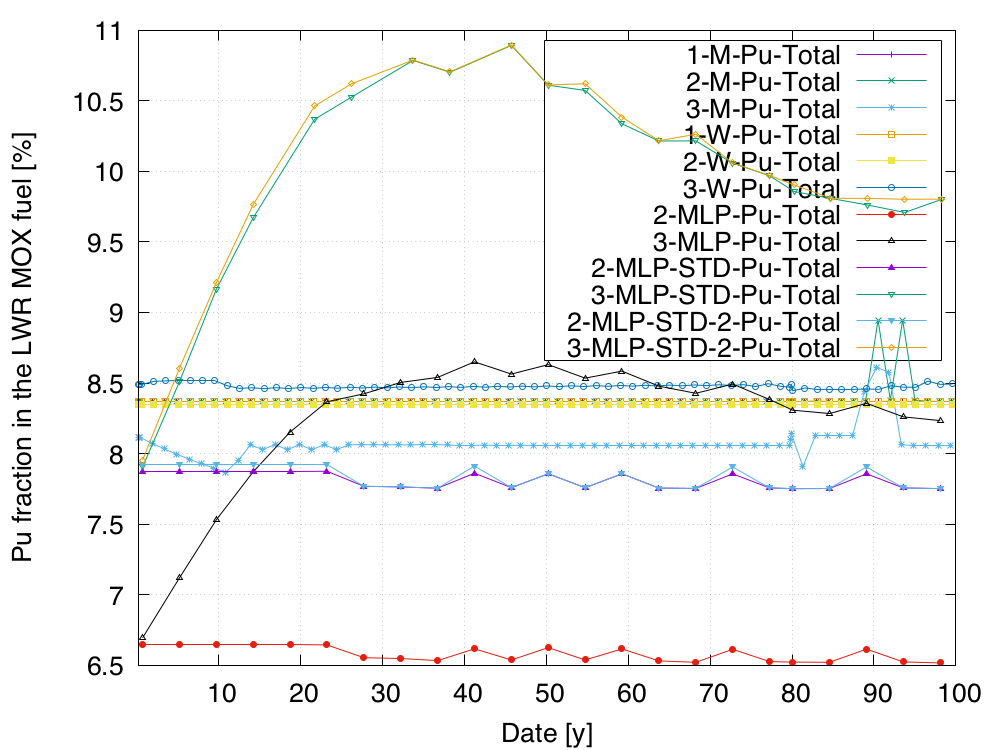


Figure 3 Evolution of Pu content in the fuel loaded in the PWR

On Figure 3, one can observe the evolution of the plutonium enrichment loaded in the PWR fuel depending of the model considered for the fabrication.

We can observe that the Neural network model using a k∞ of 1.01 clearly under estimate the the amount of plutonium require comparatively to the other models: the require reactivity is lower. There is no strong effect on the batching (3or 4) on the neural network models using a a k∞ of 1.034, which predict a an initial enrichment close to the one use on the more standard models: 7.9% versus 8.4%. The strongest difference appears when taking into account the decay: on all models the inclusion of the decay: with the decay of the 241Pu into 241Am the amount of plutonium require increase of about 2-2.5%.