D. Rochman

Examples of assembly burnup derived from in-core measurements

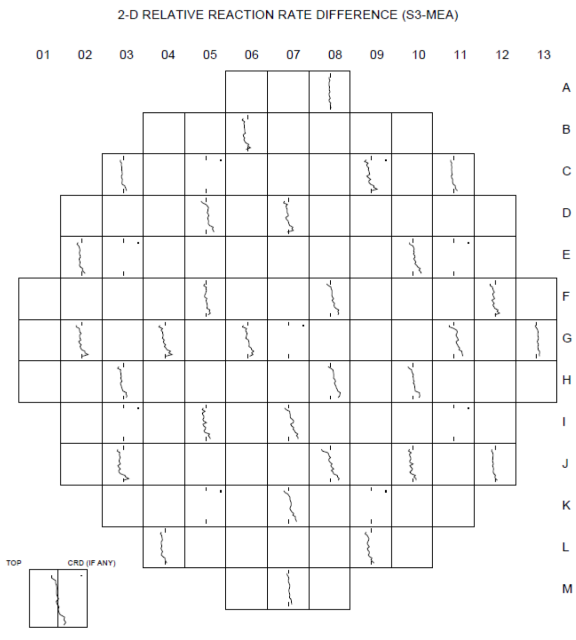
Ad-hoc meeting on burnup, WPNCS, NEA Paris, June 28, 2023

Introduction

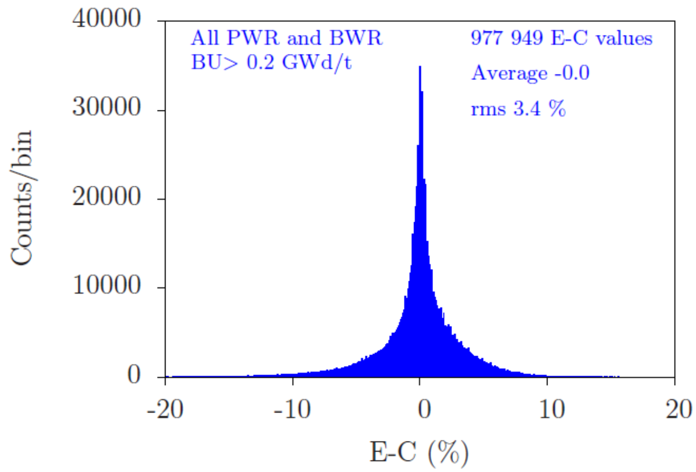
- Assembly burnup is a key **calculated** quantity for Spent Fuel Characterization
- It is **not measured**
- It impacts criticality-safety, decay heat, nuclide concentrations, safeguard quantities

- It can be derived from reactor in-core reaction rate measurements
- Measured reaction rates in 3D ⟶ derived node reactivity, power, burnup

- What are the biases and uncertainties on these burnup values ?



Bias: E – C with rms per plant, cycle, position…



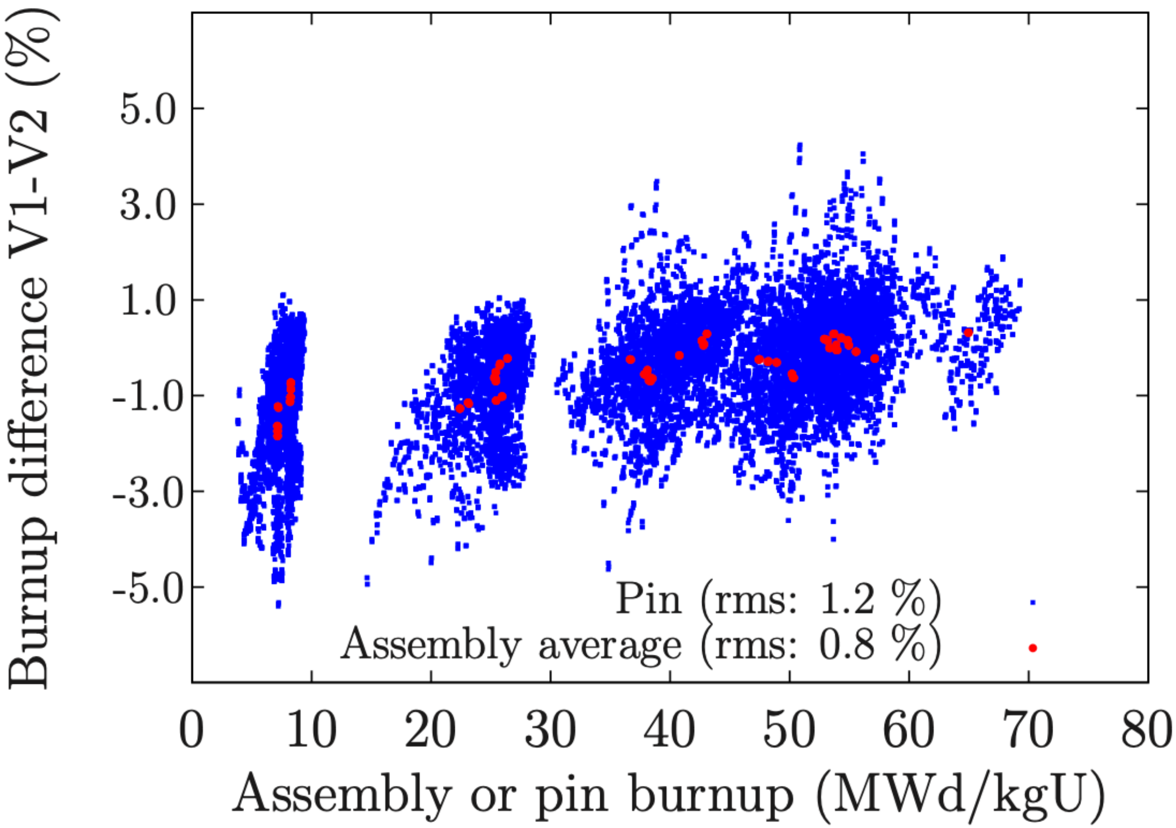
Introduction

- Derived assembly burnup depends on
  - Core simulator
  - Measurement (e.g. $^{235}U(n,f)$ fission chamber, ^{51}V activation)
  - Conversion factors (rates to burnup)
  - Human errors

- Different methods can be used to derive biases and uncertainties on burnup
  1. Changing simulator (or version)
  2. Adjust assembly burnup to lower biases for follow-up calculations
  3. Adjust design calculation with online core power tracking
  4. Compare offline C and E reaction rates
  5. Correct known human errors
  6. Classical uncertainty propagation

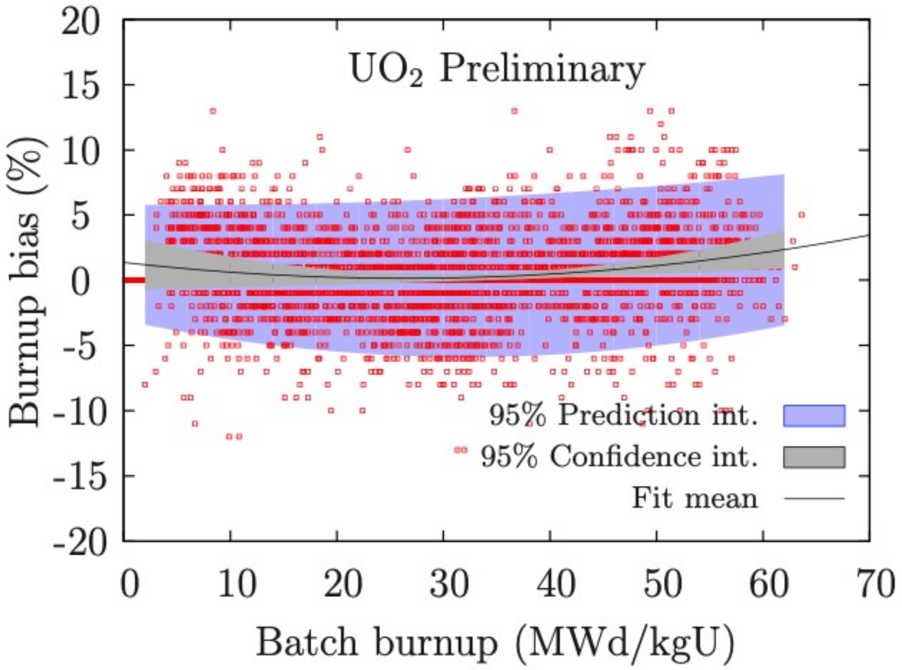
1. Changing simulator version

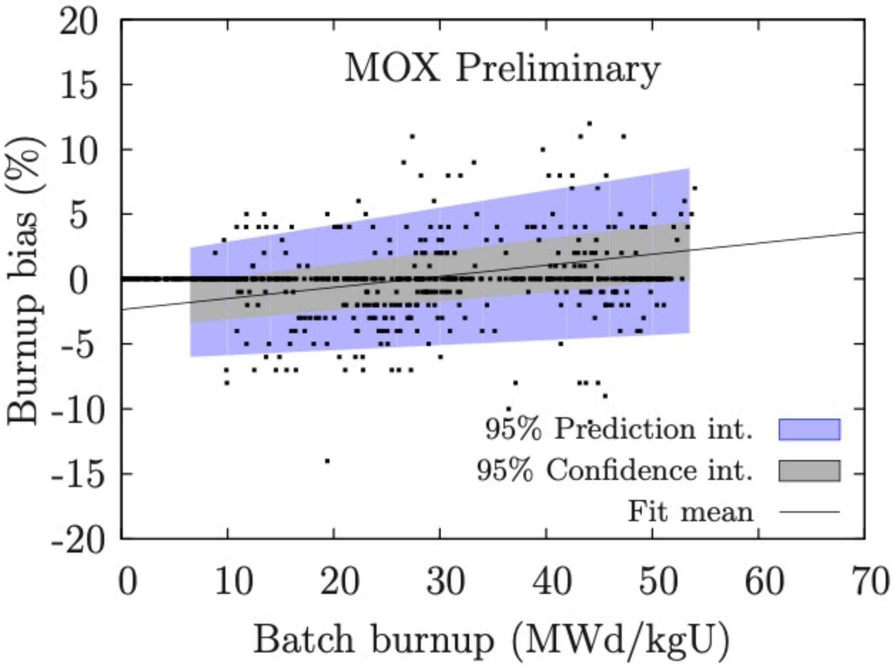
- See example in the SG12 report (Fig. 6)
- Using two different versions of the same core simulator



2. Adjust assembly burnup to lower E-C

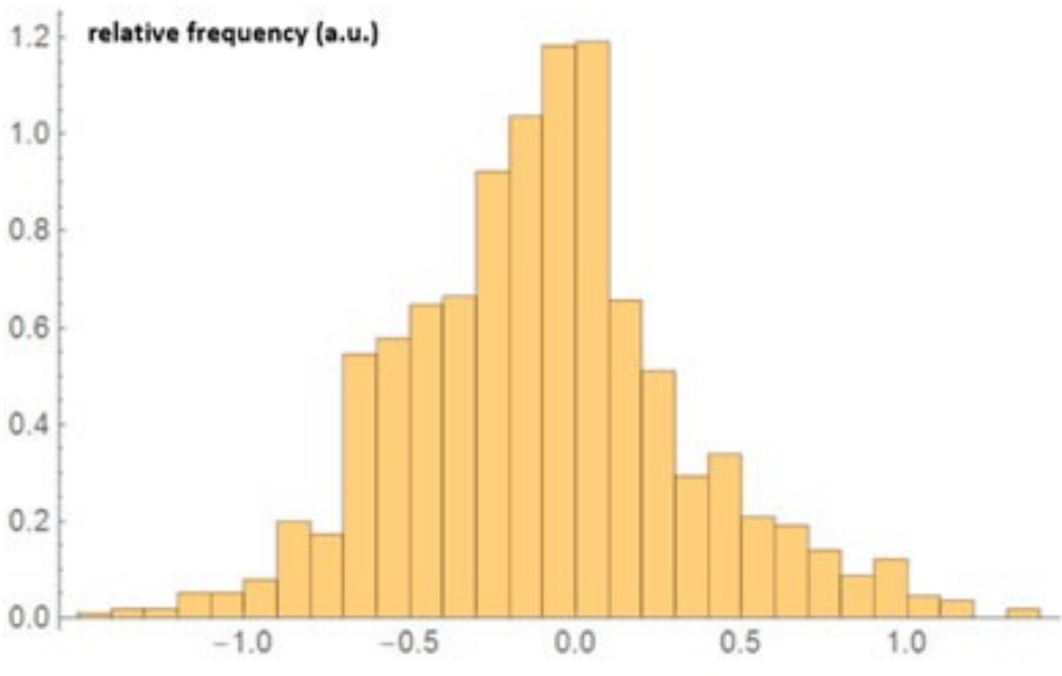
- Change assembly burnup batch to improve E-C (Measured – Calculated reaction rates), unpublished (yet)





3. Online core power tracking

- Figure 1 shows the difference between the theoretically determined fuel assembly burnup from core design calculations and the burnup determined from online core power tracking of several hundred fuel assemblies of a German Konvoi plant… one standard deviation of 1%.



BRIEF RESEARCH REPORT article
Front. Energy Res., 05 April 2023
Sec. Nuclear Energy
Volume 11 - 2023 | https://doi.org/10.3389/fenrg.2023.1143312

This article is part of the Research Topic
Computational Modelling for Spent Fuel Characterisation
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Note on the potential to increase the accuracy of source term calculations for spent nuclear fuel

Marcus Seidl[1]*, Peter Schillebeeckx[2] and Dimitri Rochman[3]

4. Compare off-line reaction rates

- Case 1: EPRI study

Determination of the Accuracy of Utility Spent Fuel Burnup Records (Interim Report)

TR-109929

Interim Report, May 1998

For assemblies discharged after one cycle of burnup, the uncertainty is 1.90%, after two cycles of burnup, the uncertainty is 0.97% and after three cycle of burnup is 1.02%. This decrease in uncertainty after two cycles of burnup is indicative of the self-correcting nature of burnup.

- Case 2: unpublished study on reaction rates

Root mean squares (rms) and standard deviations (STD) for the studied cases

Case	(E-C) rms (%)	(E-C) STD (%)
all LWR	2.9	2.9
BWR1	0.9	0.9
BWR2	0.9	0.9
PWR1/2	2.6	2.6
PWR3	4.8	4.7

5. Impact of human error

- Incorrect assembly segment was used from cycle 7 to 11.

Root mean squares (rms) for PWR1, cycle 5 to 16. One MOX segment was discovered uncorrect in cycle 7 to 11.

Cycle	Correct assemblies segments rms	Incorrect MOX segment rms	rms(Correct)/rms(Incorrect)
05	5.13	5.13	1.00
06	3.26	3.26	1.00
07	3.26	3.61	0.90
08	3.14	3.59	0.87
09	3.10	3.44	0.90
10	3.18	3.68	0.86
11	2.75	2.82	0.97
12	3.26	3.37	0.97
13	3.69	3.87	0.95
14	3.50	3.50	1.00
15	2.97	2.97	1.00
16	2.82	2.82	1.00

- In this case, wrong segment assignments lead to non-negligible differences in BU.

Conclusions

- Assembly and nodal burnup values are often (or always) provided by core simulators

- These simulators are also prone to biases (and uncertainties)

- In-core reaction rates can be used to estimate burnup biases

  – Results depends on methods, reactors, fuel types, core locations
  – Derived averaged biases on burnup are certainly > 1%
  – Local (node) biases are larger

- Uncertainties and biases from $BU_{core\ simulator}$ impact the nuclide concentrations, decay heat, criticality studies.

PAUL SCHERRER INSTITUT

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