Tractebel Engineering

# A pragmatic methodology to assess the fuel burnup effects in licensing of LBLOCA analyses for Belgian NPPs

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# Outline

- Introduction
- Licensing of LBLOCA analyses in Belgium
- Consideration of burnup effects
- Methodology and applications
- Conclusions

# Introduction

- LBLOCA reanalyses required in Belgium

  ➡ to support the licensing of

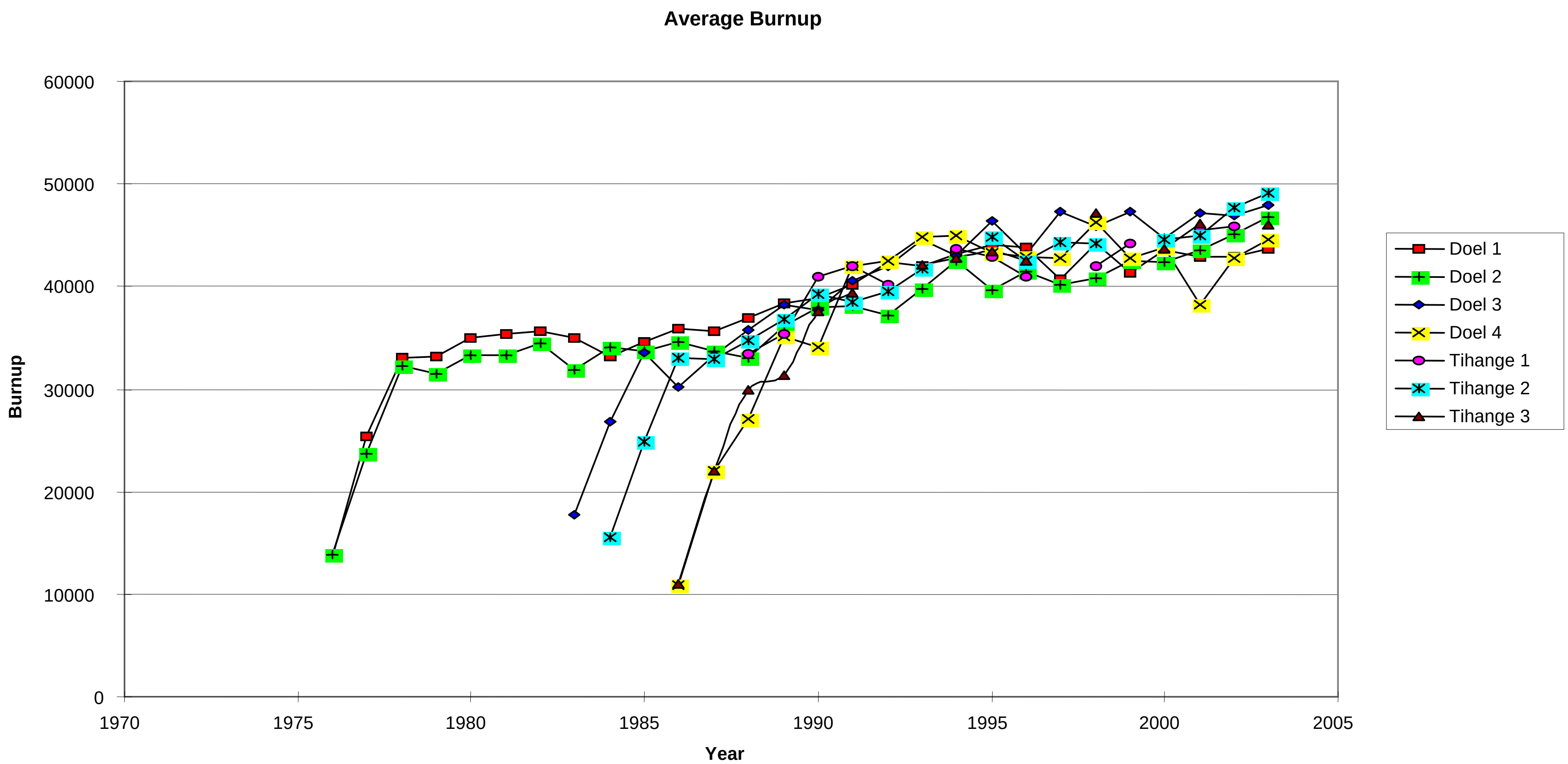
  - Major plant modifications: UPI conversion, SG plugging, SG replacement (SGR), etc.
  - Power uprate (PU)
  - Fuel cycle extension (CE): from 12 months to 15 or 18 months, …
  - MOX fuel
  - Periodic safety reassessment (RSR)

# Power Uprates in Belgian NPPs

| Unit | Initial Power (MWth) | Power Uprate | | Uprated Power MWth |
|---|---|---|---|---|
| | | Project | Uprate | |
| **Doel 3** | 2785 | SGR (1993) | +10% | 3064 |
| **Tihange 1** | 2665 | SGR (1995) | +8% | 2875 |
| **Tihange 2** | 2785 | PUCE (1995) | +4.3% | 2905 |
| | | SGR (2001) | +10% (total) | 3064 |
| **Doel 2** | 1192 | SGR (2004) | +10%* | 1311 |

- *Scheduled for July 2004*

# Cycle Extension in Belgian NPPs



# Licensing of LBLOCA analyses in Belgium

- Objectives
  - Verification of the ECCS performance
  - Verification of the 10 CFR 50.46 (b) criteria
  - Determination/Verification of the Technical Specifications LOCA Fq limit

    ➡ **for a reference core and fuel to avoid cycle specific LBLOCA studies**
  - Supply of the reference T/H boundary condtions and key fuel safety paramters

    ➡ **for cycle specific reload safety evaluation (RSE)**

# Licensing of LBLOCA analyses in Belgium

- Approach
  - Verify the *same* acceptance criteria (maintain the global safety margins)
  - Use *approved* methdologies (Appendix K evaluation model, SECY, or acceptable best estimate evaluation model with superbounded I/B conditions)
  - Take advantage of *advanced* technologies (if necessary, use of best estimate codes and methods)
  - Take account for *improved* and *proven* knowledge (burnup effects, etc.)

# Licensing of LBLOCA analyses in Belgium

- Approved methodologies
  - **Appendix K methodology** : S-RELAP (Doel 3), <u>W</u>COBRA-TRAC UPI (Doel 2)
  - **SECY superbounded methodology** : <u>W</u>COBRA-TRAC UPI (Doel 2)
  - **BE superbounded methodology** : <u>W</u>COBRA-TRAC (Tihange 1)
  - **Deterministic *superbounded* methodology** : CATHARE-GB (Tihange 2)

# Consideration of fuel burnup effects

- Traditional methods

  - Fuel rod data calculated by acceptable **fuel rod performance codes**:

    PAD, COPERNIC, etc.

  - Determination of the fuel stored energy (or volume averaged temperature VAT), rod internal pressure, initial oxidation, etc.

    as a function of burnup (BU) and linear heat generation rate (LHGR)

  - The corresponding fuel conditions at the **maximum stored energy** are used as input data to the fuel rod model in the LBLOCA codes

  ➡ no implicit sensitivity studies on the BU effects

# Consideration of fuel burnup effects

- Traditional analyses (before ’90)

  *BOL is the most limiting time in life*

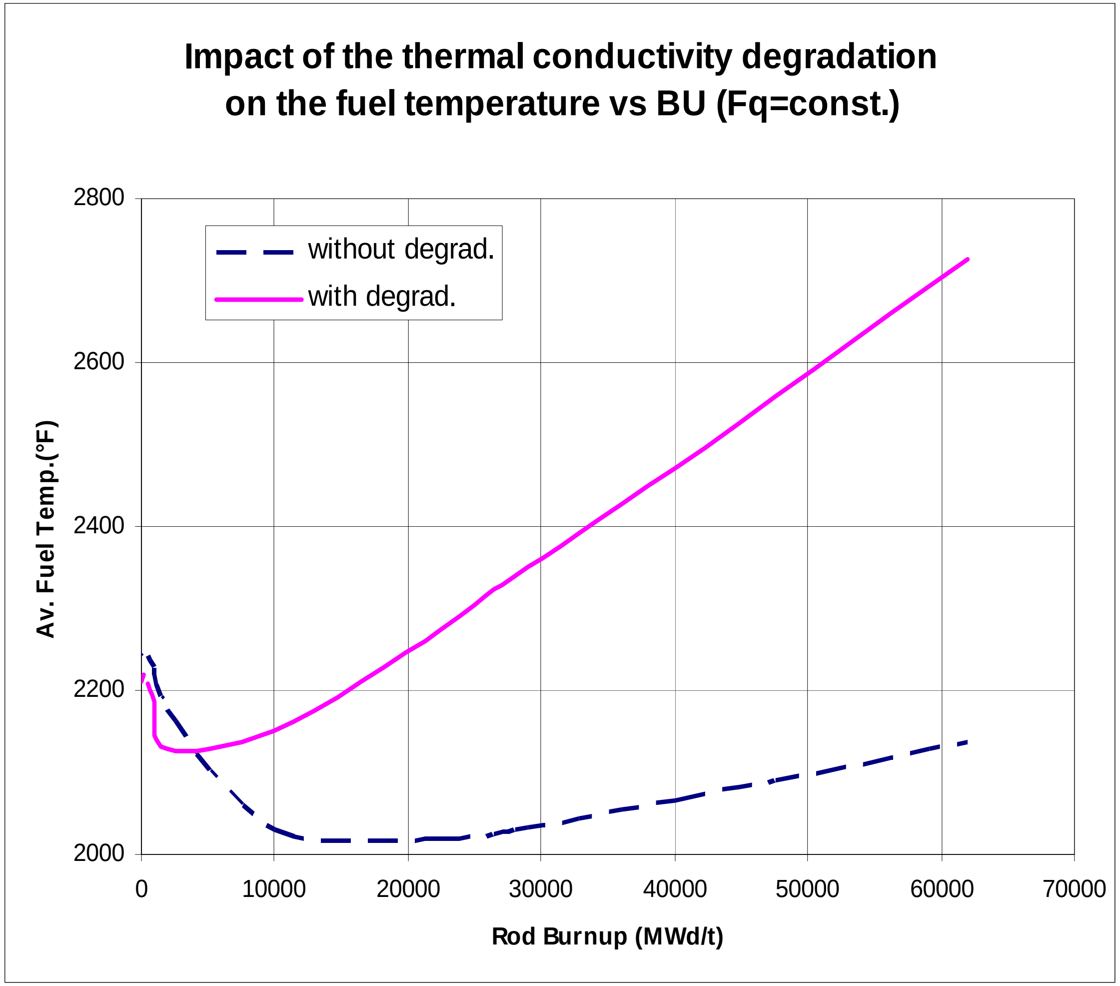
  - The fuel thermal conductivity decreases at low and intermediate BU
  - The maximum stored energy occurs at BOL when *maximum densification* occurs

- New trends (after ’90)

  *Higher burnups may be more limiting*

  - The fuel thermal conductivity degradation at higher BU – Halden tests (’91)
  - Higher initial oxidation and rod internal pressure at higher BU
  - The maximum stored energy occurs at EOL *for a constant Fq,* or at intermediate BU if crediting the *reduction of Fq* at higher BU

# Consideration of fuel burnup effects



# Consideration of fuel burnup effects

- Requirements from AVN (*The Belgian Authorized Inspection and Licensing Body*)
  - Fuel rod performance codes: take account for high BU effects

    ➡ to be validated for the whole range of  BU (up to 62 GWd/t rod ave.)
  - Reference LBLOCA analysis: cover the whole range of BU up to EOL

    ➡ to take limited credit on the reduction of Fq only at EOL (currently limlited at 55 GWd/t assembly ave.)
  - Generic demonstration of sufficient margin of the enveloping Fq to LOCA Fq limit

    ➡ to avoid systematic verification of Fq (BU) for RSE

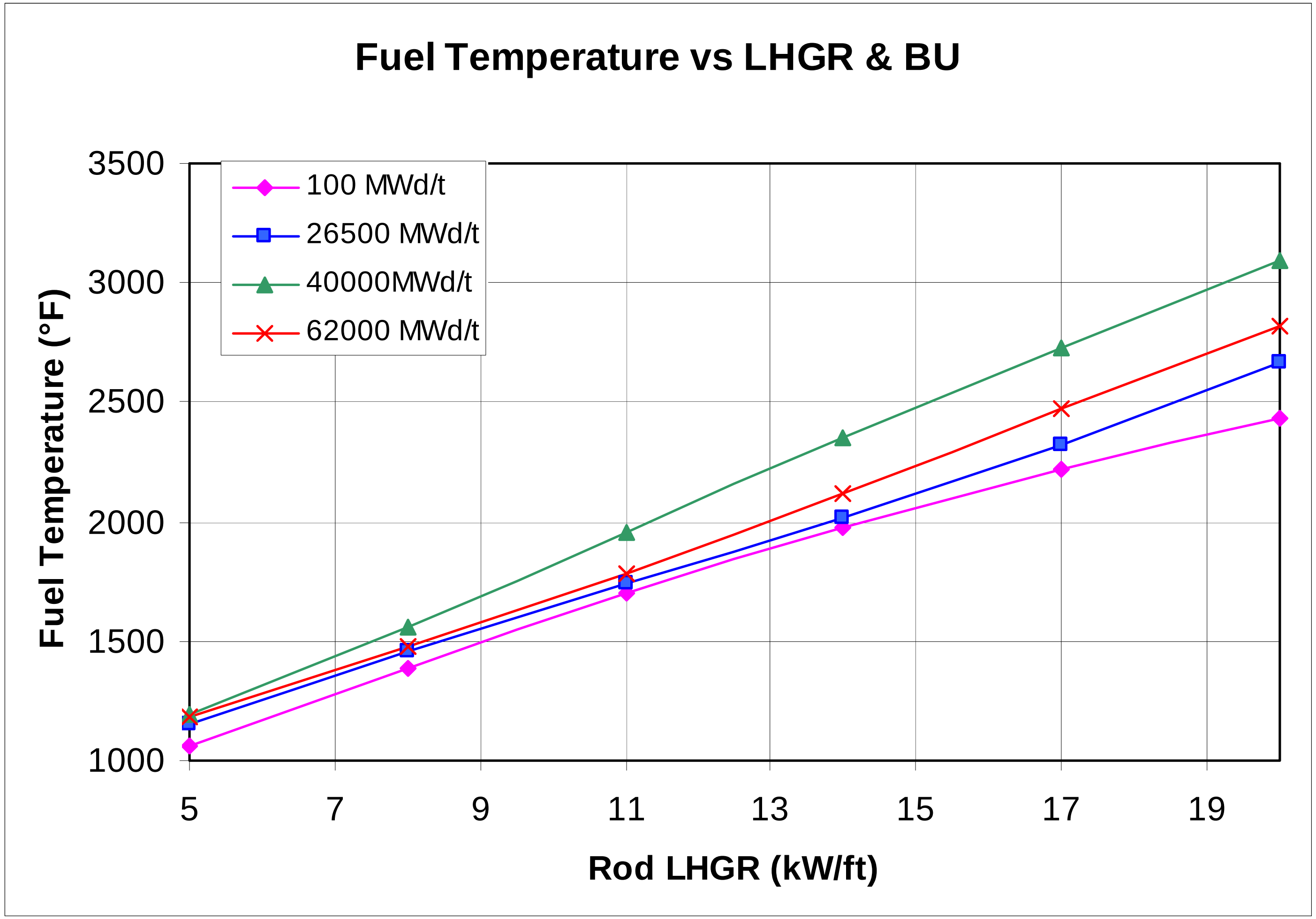
# Methodology and applications

- Step 1 : Perform fuel rod data calculations at selected BU points (BOL, 1-3 intermediate BU, EOL)
  - volume averaged temperature (VAT),
  - rod internal pressure,
  - initial oxidation,
  - etc.

  as a function of linear heat generation rate (LHGR)

  ➡ **evaluation of the BU effects**

# Methodology and applications



# Methodology and applications

- Step 2 : Perform LBLOCA analyses at 3 BU points
  - BOL (maximum densification)
  - a well chosen intermediate BU with the same Fq as BOL
  - EOL (62 GWd/t) with a reduced Fq determined based on the BOL results and the calculated fuel rod data at EOL

➡ **Verification of the 10CFR50.46 acceptance criteria**

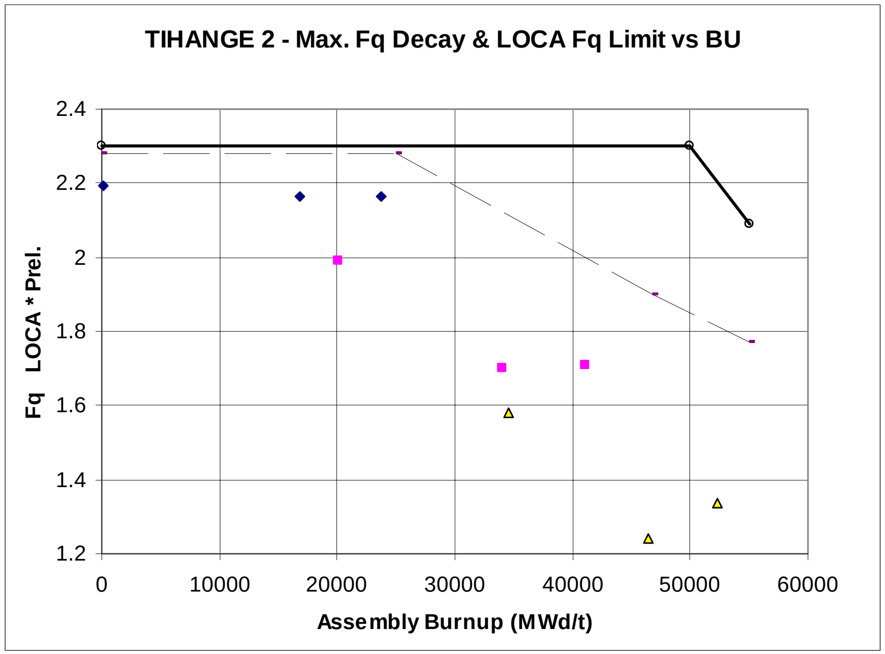
➡ **Determination of the LOCA Fq limit as a function of BU**

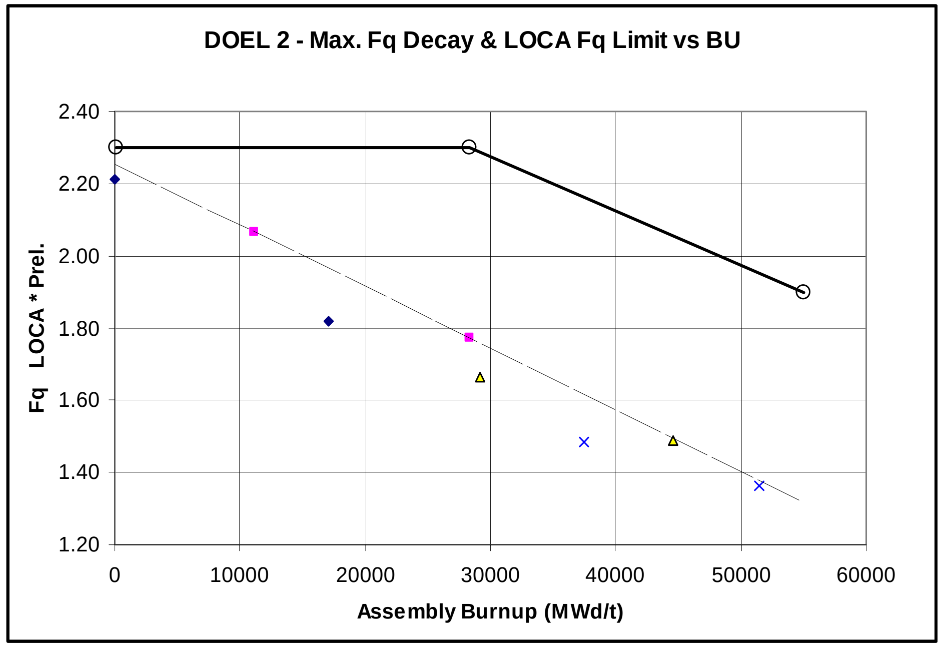
# Methodology and applications

## Step 3 : Determination of the enveloping Fq limit

- Perform power capability studies for several cycles and various reloading patterns

➡ **Determine the maximum attainable Fq as a function of BU**

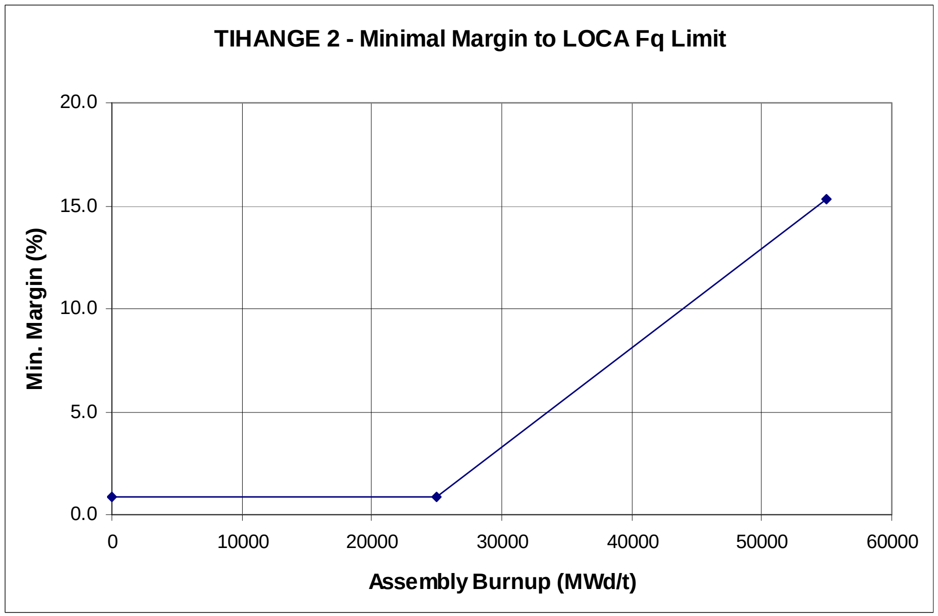


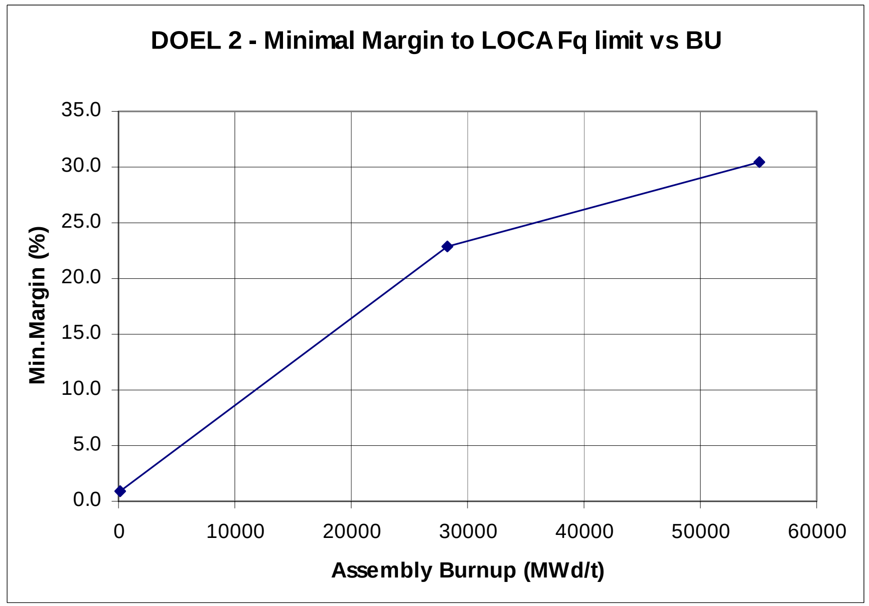



# Methodology and applications

- Step 4 : Demonstration of the margin to LOCA Fq limit at high BU

    ➡ **sufficiently large to avoid systematic verification of Fq (BU) for RSE**



# Conclusions

- The fuel high burnup effects are considered in the recent licensing of LBLOCA analyses in Belgium
- Due to the fuel thermal conductivity degradation, a reduction of Fq at high BU need to be credited to assess the BU effects
- A limited reduction at EOL only is accepted by the Belgian Authorized Inspection and Licensing Body (AVN) to avoid systematic verification of the Fq (BU) for RSE
- A pragmatic methodology is thus developed and successfully applied to the Tihange 2 and Doel 2 PUSGR projects