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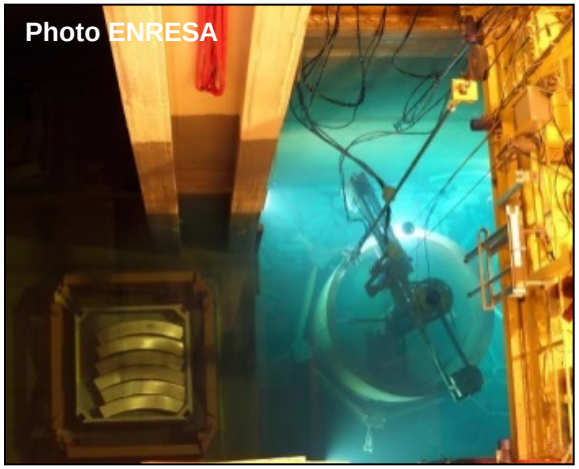
Immediate Dismantling of a Large Fleet of LWR NPPs: Consequences for Spent Fuel and Waste Management

IRSN
EUROSAFE 2016

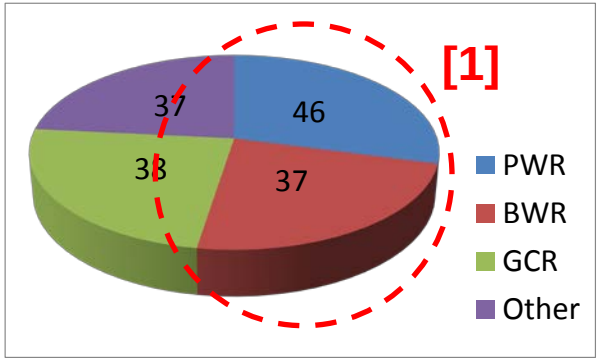
Plan of the Presentation

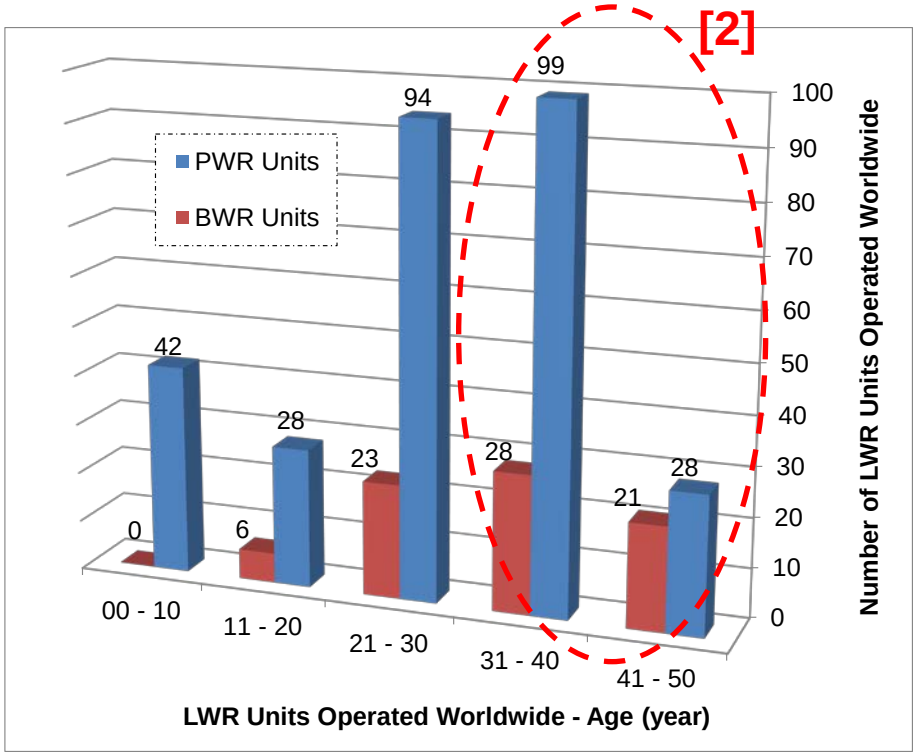
- Introduction / Initial Finding
- Issues / IRSN Analysis Approach
- IRSN case study
- Generic NPP Decommissioning
- Schedule to Phase Out the Fleet
- Annual Flow of Removed SNF
- Annual Flows of Produced RW
- Conclusion



Introduction / Initial Finding

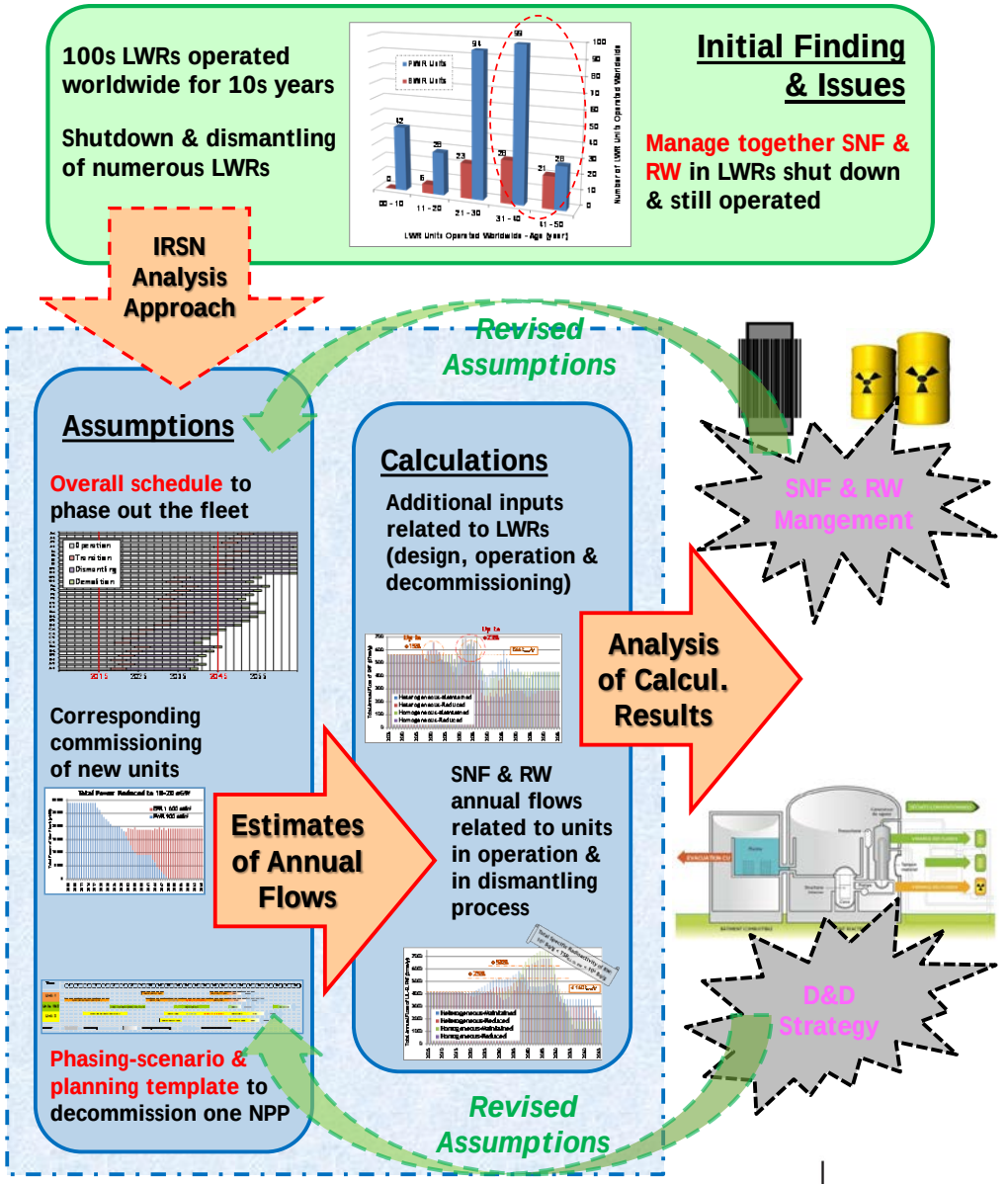
- These last 60 years
  - More than 380 PWRs & 110 BWRs commissioned worldwide
- Today
  - A large part of these LWRs:
    - are permanently shut down, in dismantling process or decommissioned **[1]**
    - have been operated for greater than 30 years **[2]**
- In future perspectives
  - Permanent shutdown of the LWRs still in operation at a similar rate to that of their commissioning
  - Simultaneous dismantling of numerous LWRs





Issues / IRSN Analysis Approach

- Issues
  - **Manage together SNF and RW** in the LWRs permanently shut down and still in operation
- IRSN analysis approach
  - Use of estimates of annual flows of SNF and RW notably based on:
    - alternative **overall schedules** to phase out the fleet of LWRs
    - generic **phasing-scenario and planning template** (PS-PT) to decommission one NPP

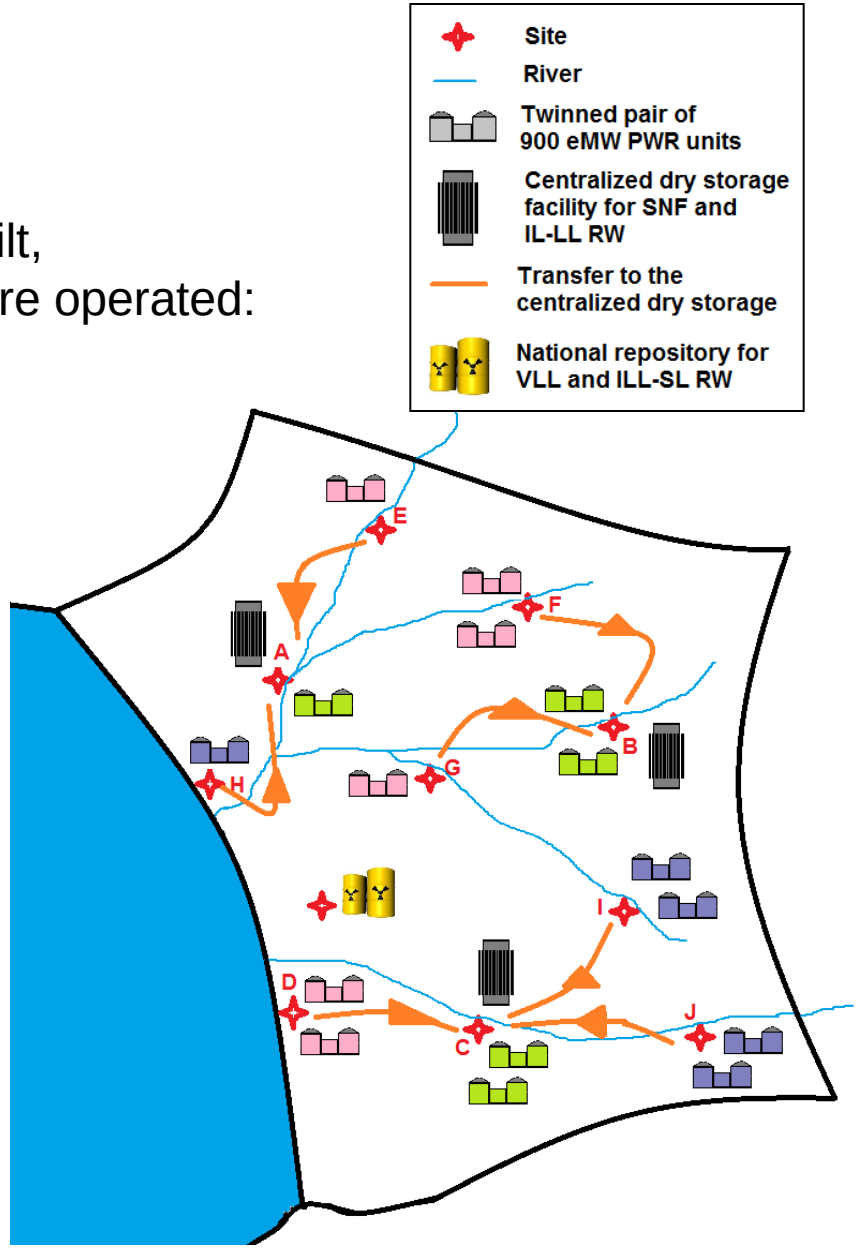


IRSN Case Study

- Illustration of the approach
  - An illustration (case study) has been built, considering a “dummy” country where are operated:
    - 16 twinned pairs of 900 eMW PWRs
      - located in 10 NPPs (A to J)
    - 3 centralized dry storage facilities
      - located in the 3 older NPPs (A, B & C)
    - 1 national repository

Type[a]	Commissioning years	Number in operation	Sites of units	Units designation[b]
0	Late 70’s / Early 80’s	5	A, B & C	[A-1, A-2], [B-1, B-2], [B-3, B-4], [C-1, C-2] & [C-3, C-4]
1	Early / Mid 80’s	6	D, E, F & G	[D-1, D-2], [D-3, D-4], [E-1, E-2], [F-1, F-2], [F-3, F-4], & [G-1, G-2]
2	Mid / Late 80’s	5	H, I & J	[H-1, H-2] [I-1, I-2], [I-3, I-4], [J-1, J-2] & [J-3, J-4]

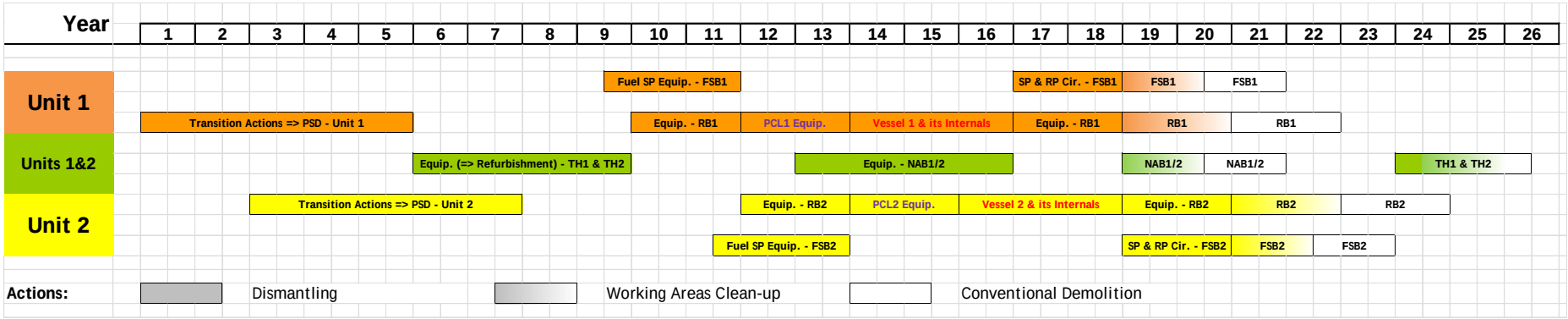
a: design evolution to improve operation and safety.
b: [X-i, X-i_{+1}], twinned pair of 900 eMW PWR units No. i and i_{+1}, located on site X.



Generic NPP Decommissioning

- Assumptions taken into account
  - Generic PS-PT to decommission one NPP are based on assumptions consistent with the national context (legislative and regulatory framework notably) => for example for France, strategy of a dismantling as soon as possible
  - Other assumptions and inputs which are used to establish the generic PS-PT are related to LWRs design and experience feedback of their operation and decommissioning
- For the case study
  - Generic PS-PT are defined to decommission:
    - NPP with 2 PWRs (figure below)
    - NPP with 4 PWRs

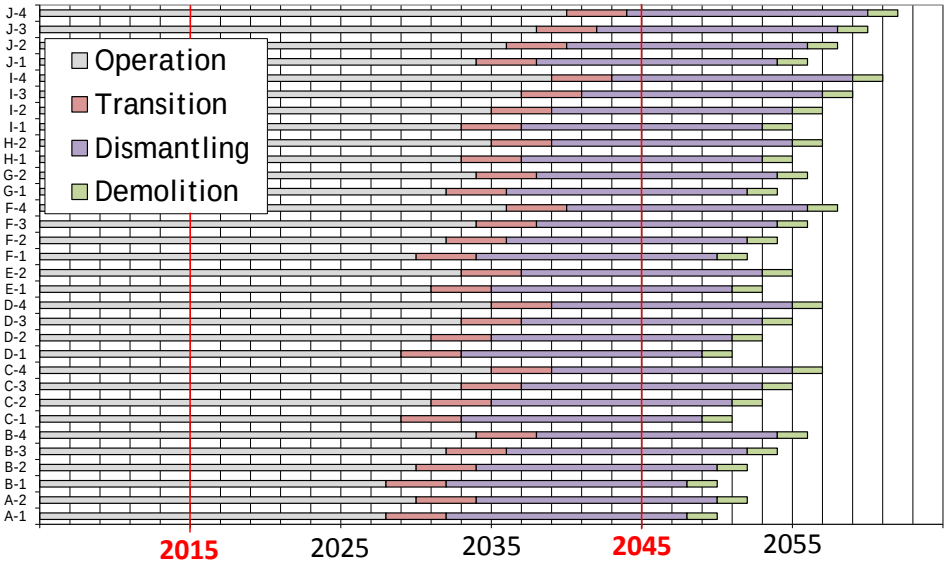
PSD: Permanent ShutDown
RB: Reactor Building
FSB: Fuel Storage Building
NAB: Nuclear Auxiliaries Building
TH: Turbine Hall
SP: Storage Pool
RP: Reactor Pool
PCL: Primary Circuit Loops

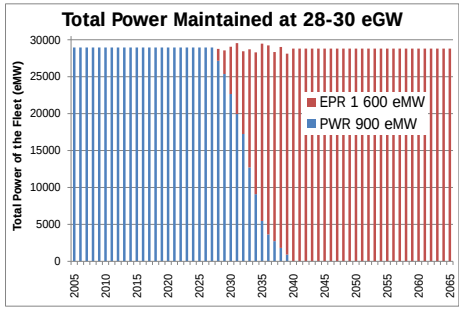


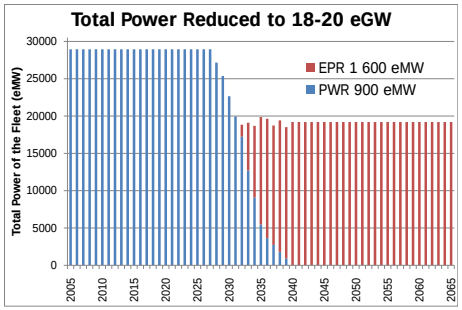
Schedule to Phase Out the Fleet

- Use of alternative assumptions
  - To build a theoretical and realistic overall schedule to phase out all the LWRs of the fleet
  - To take into account the renewal of the nuclear units, by the commissioning of new reactors
- For the case study
  - Homogeneous overall schedule:
    - lifespan of each PWR **similar and approximately equal to 50 years**
    - total nuclear power maintained at 28-30 eGW or progressively reduced to 18-20 eGW (EPRs commissioning is supposed)

Homogeneous Overall Schedule



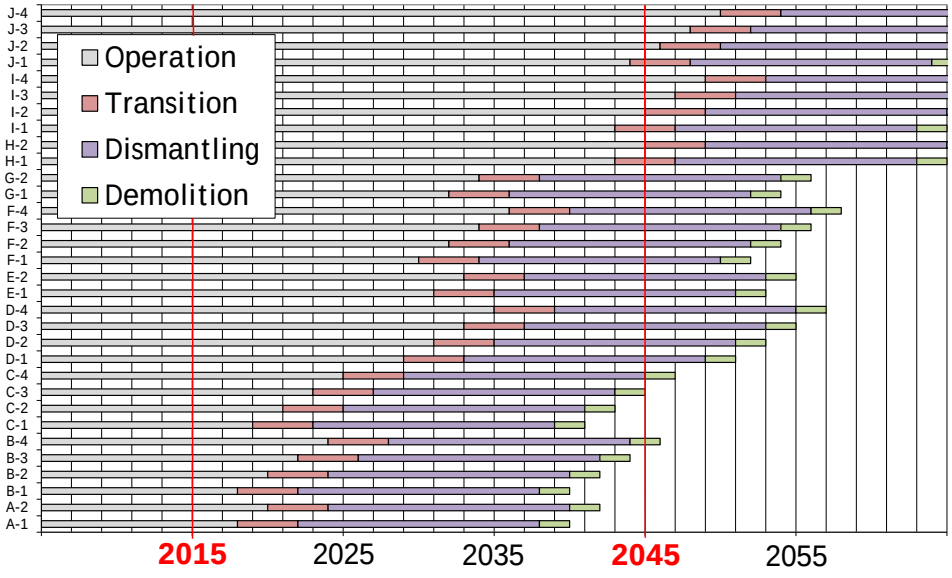


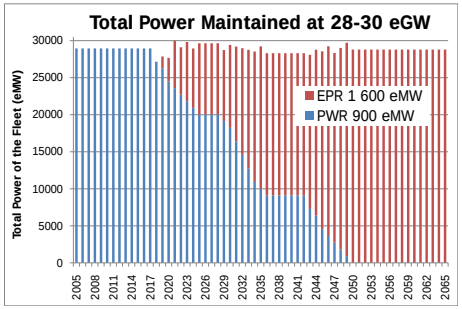


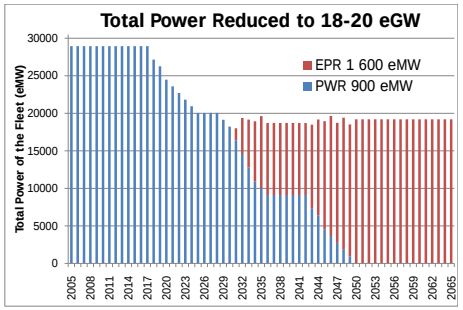
Schedule to Phase Out the Fleet

- Use of alternative assumptions
  - To build an overall schedule to phase out all the LWRs of the fleet
  - To take into account the renewal of the nuclear units
- For the case study
  - Heterogeneous overall schedule:
    - lifespan of each PWR **depending on its design and approximately equal to 40, 50 and 60 years** respectively for types 0, 1 and 2
    - total nuclear power maintained at 28-30 eGW or progressively reduced to 18-20 eGW (EPRs commissioning is supposed)

Heterogeneous Overall Schedule







Annual Flow of Removed SNF

↗ Main Additional Assumptions & Inputs

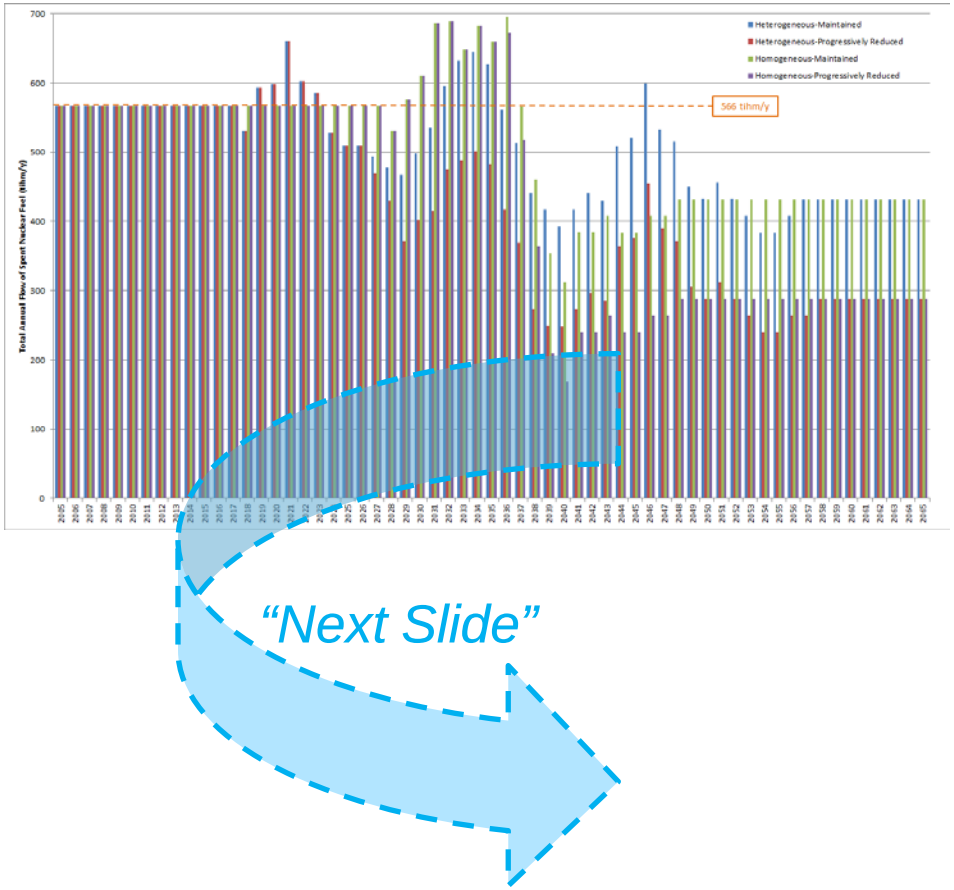
- Total annual flow of SNF
  - Depends on SNF amounts removed each year from each LWR in operation (current fleet and new LWRs) and from each LWR permanently shut down (during the transition period)
  - Needs additional assumptions and inputs, related to operation of the LWRs, irradiation of their nuclear fuel (core management) and SNF amount stored in the deactivation pool when the LWRs are permanently shut down
- Additional assumptions & inputs for each LWR
  - Coefficient of productivity
  - SNF amount definitively unloaded each year from the core and those annually removed from the deactivation pool
  - Core management evolutions and possible facility modifications during the operating period
  - Total amount of SNF to remove during the transition period

Annual Flow of Removed SNF

↗ Results of the Estimates for the Case Study

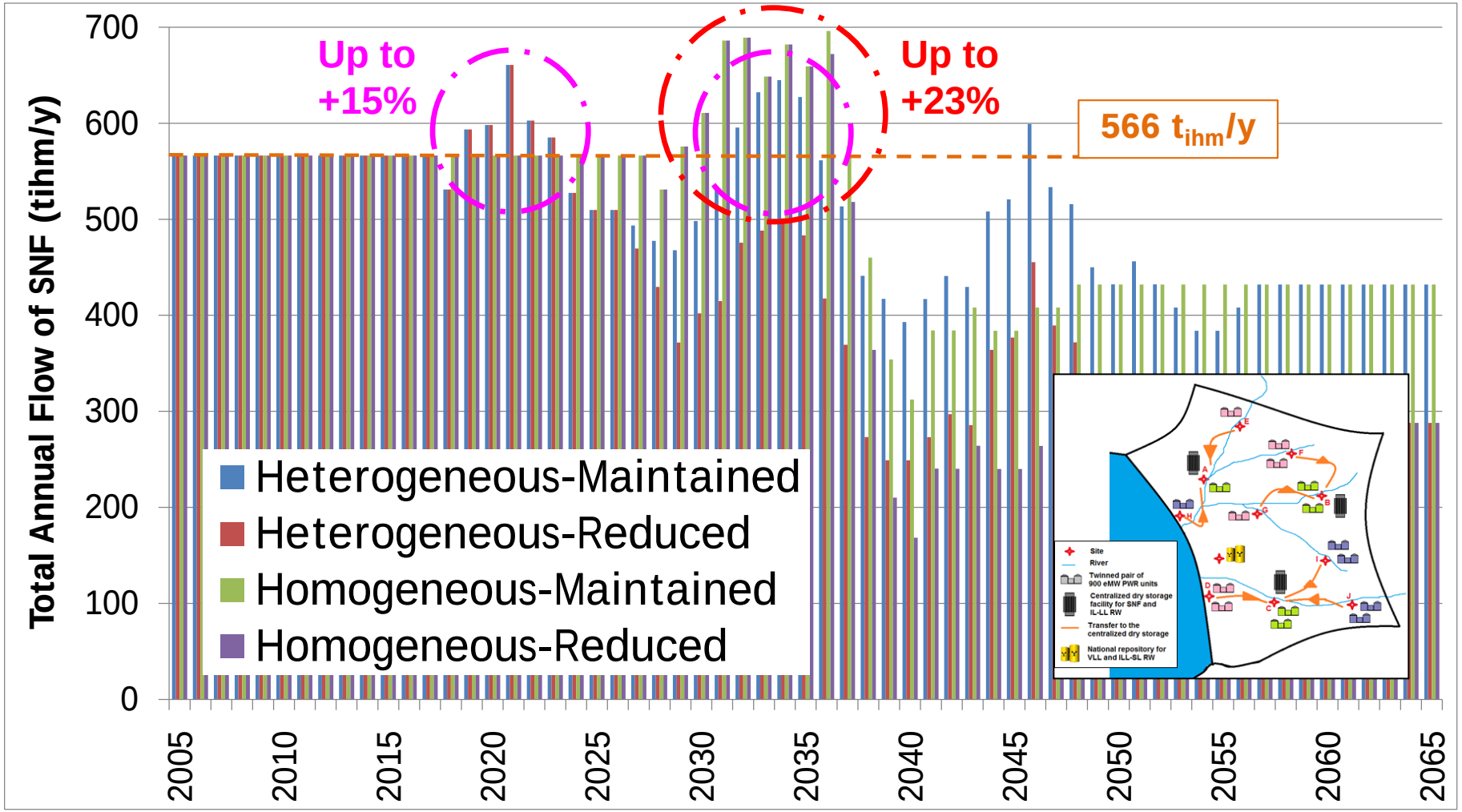
- Consequences of the phase out of the fleet
  - When all 900 eMW PWRs are in operation:

    SNF flow = 566 t_{ihm}/y
  - Heterogeneous overall schedule for the phase out => SNF flow increases up to +15% for a few years around 2020 then around 2030
  - Homogeneous overall schedule for the phase out => SNF flow increases up to +23% for a few years around 2030 only



Annual Flow of Removed SNF

↗ Results of the Estimates for the Case Study



Annual Flows of Produced RW

↗ Main Additional Assumptions & Inputs

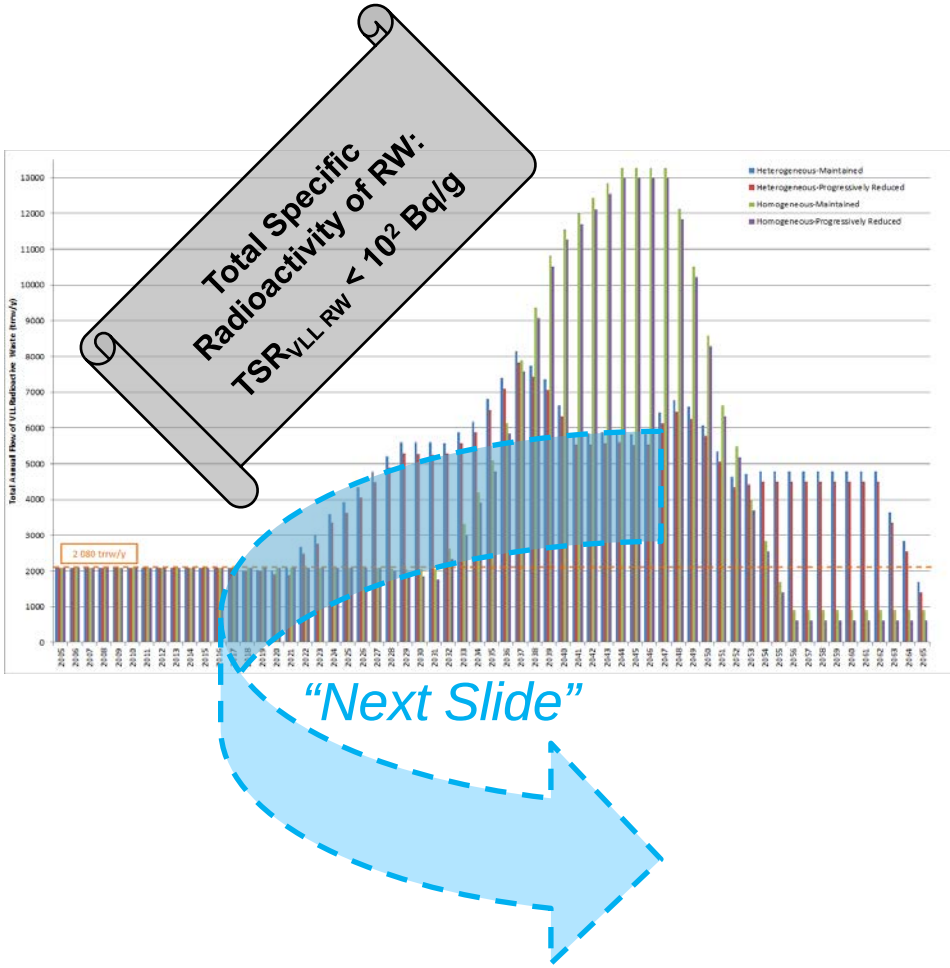
- Total annual flows of RW
  - Depend on RW amounts produced each year by each LWR in operation (current fleet and new LWRs) and by each LWR permanently shut down (during transition, dismantling and clean-up periods)
  - Need additional assumptions and inputs, related to RW produced by the LWRs in operation, physical inventory of the facilities, activation and contamination of the equipment and working areas
- Additional assumptions & inputs for each LWR
  - Flows of operating RW (taken from the operating experience feedback)
  - Amounts of activated dismantling RW (estimated on the basis of neutron transport and materials activation calculations)
  - Amounts of contaminated dismantling and clean-up RW (use of the physical inventory of equipment and working areas combined to the operating and decommissioning experience feedback)

Annual Flows of Produced RW

↗ VLL RW - Results of the Estimates for the Case Study

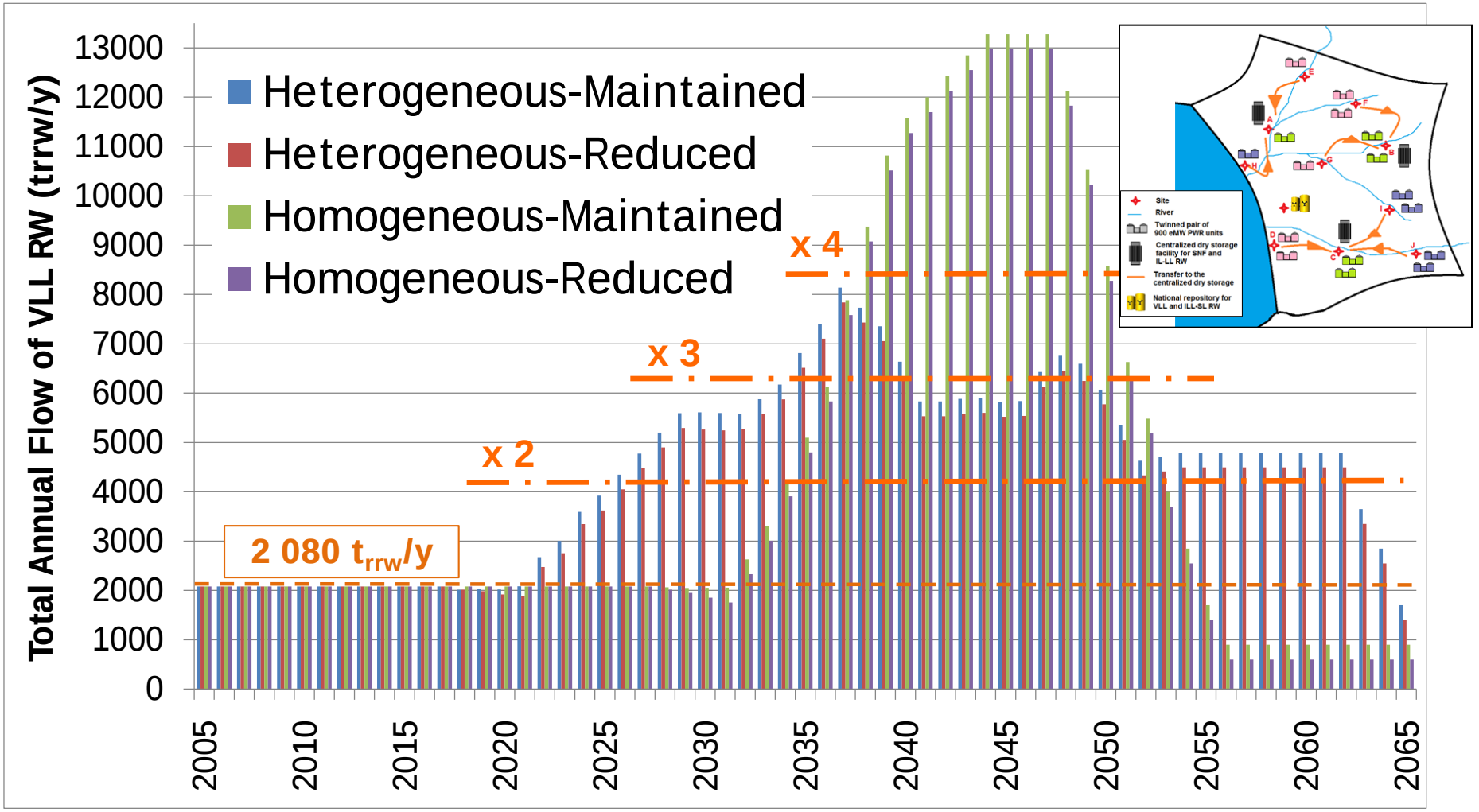
- Consequences of the phase out of the fleet
  - When all 900 eMW PWRs are in operation:

    VLL RW flow = 2 080 t_{rrw}/y
  - VLL RW flow increases by a factor 2 to 6 over 2 to 3 decades after 2025 or 2035, essentially according to the overall schedule considered to phase out the fleet of 900 eMW PWRs



Annual Flows of Produced RW

↗ VLL RW - Results of the Estimates for the Case Study

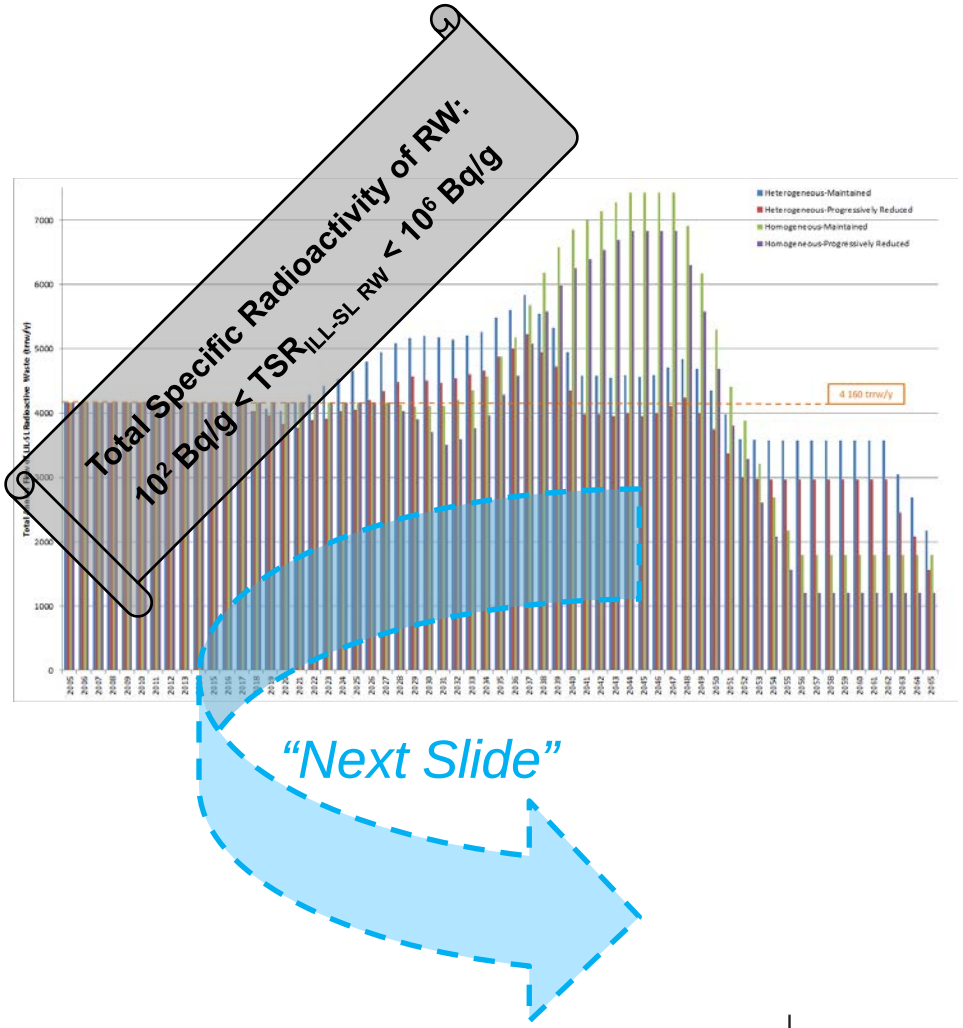


Annual Flows of Produced RW

↗ ILL-SL RW - Results of the Estimates for the Case Study

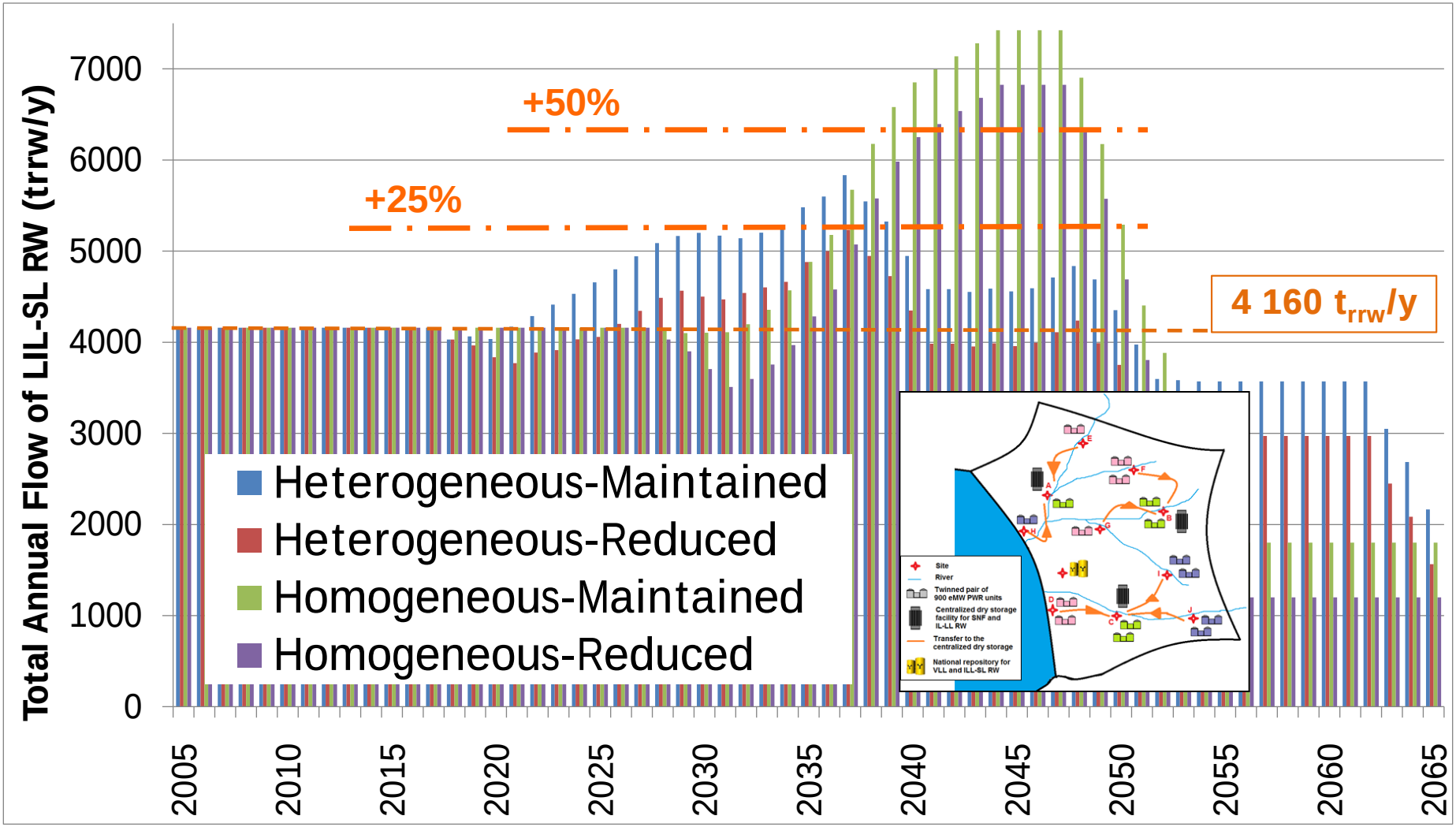
- Consequences of the phase out of the fleet
  - When all 900 eMW PWRs are in operation:

    ILL-SL RW flow = 4 160 t_{rrw}/y
  - ILL-SL RW flow increases between +10% and +60% over 2 to 3 decades after 2025 or 2035, according to:
    - first, the overall schedule considered to phase out the fleet
    - second, the total nuclear power considered for the country in the future



Annual Flows of Produced RW

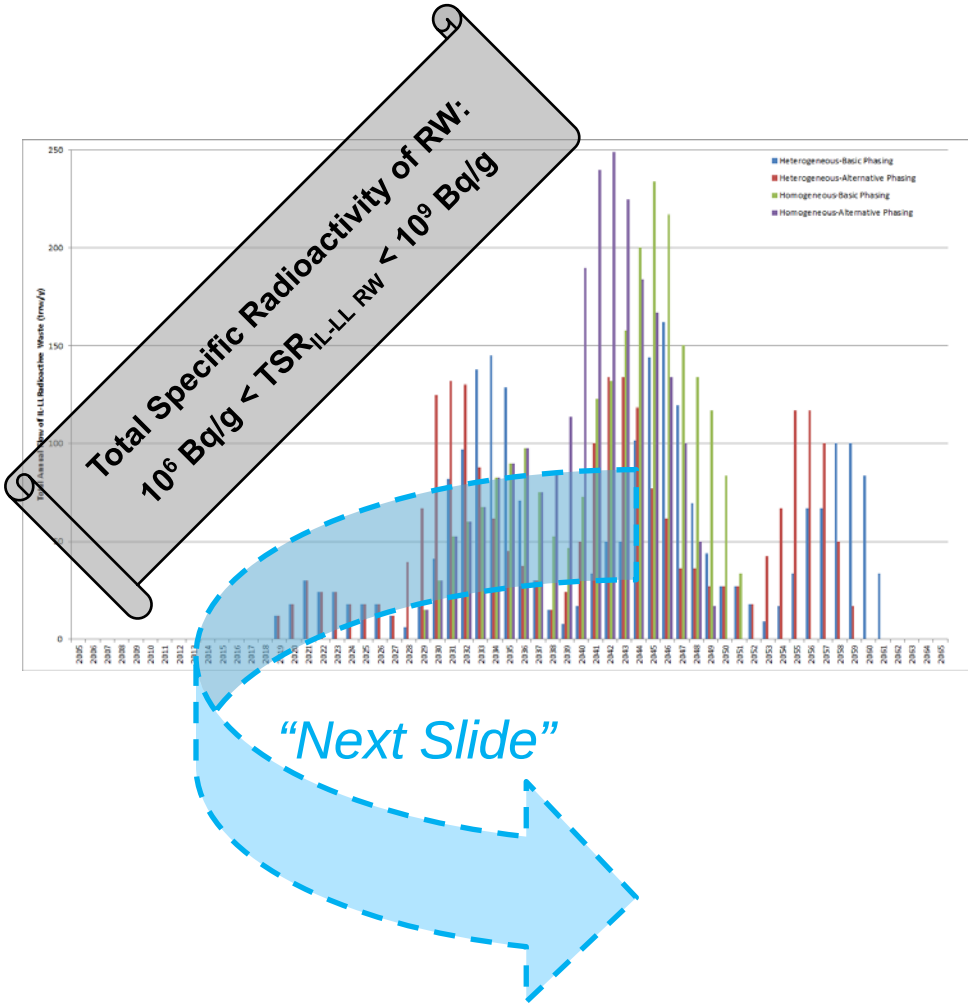
↗ ILL-SL RW - Results of the Estimates for the Case Study



Annual Flows of Produced RW

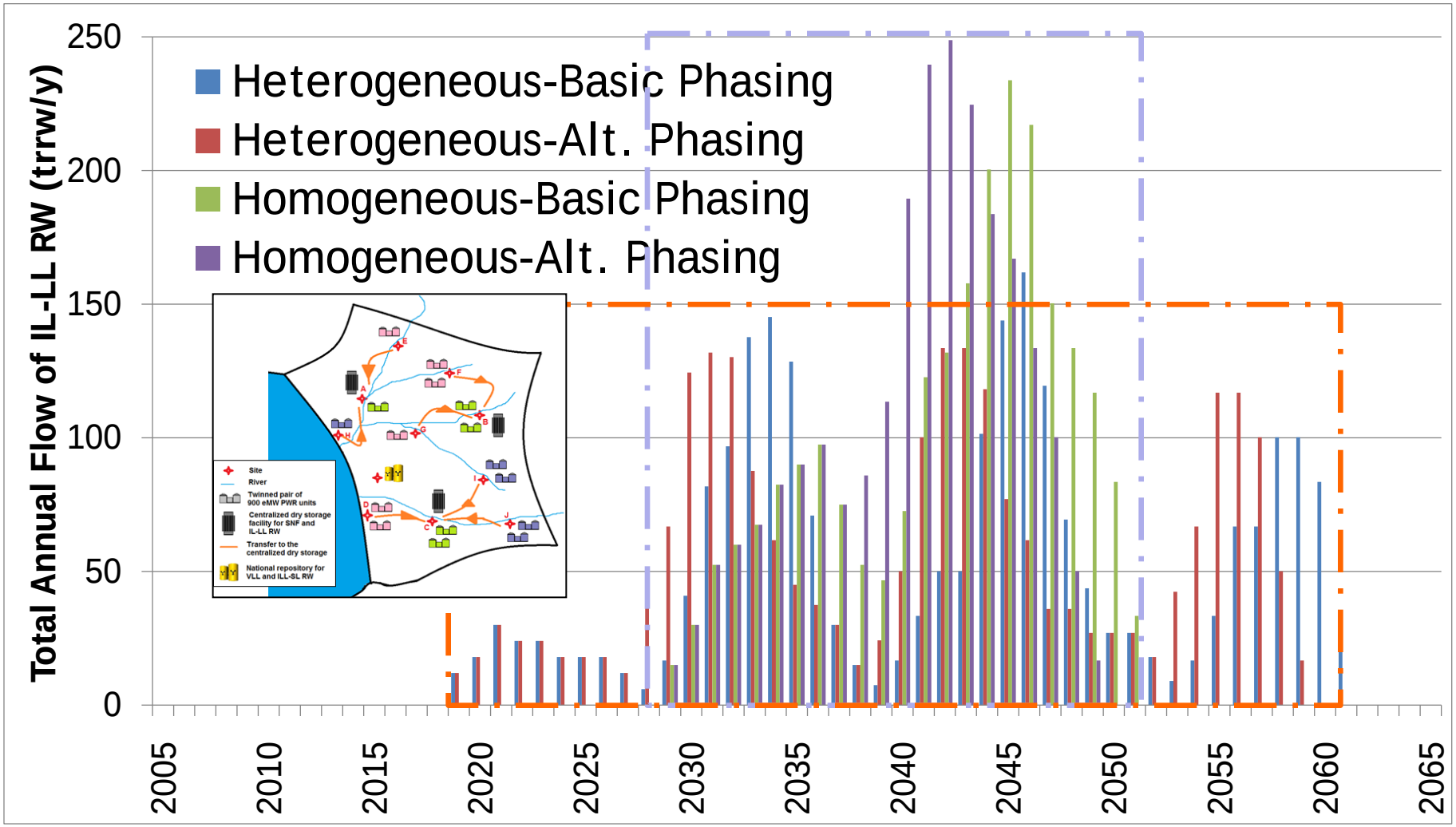
↗ IL-LL RW - Results of the Estimates for the Case Study

- Consequences of the phase out of the fleet
  - When the 900 eMW PWRs are in operation, their operating IL-LL RW are stored in their deactivation pools (FSBs)
  - Heterogeneous overall schedule to phase out the fleet => IL-LL RW flow rises up to 150 t_{rrw}/y over 4 decades after 2018
  - Homogeneous overall schedule to phase out the fleet => IL-LL RW flow rises up to 250 t_{rrw}/y over 2 decades after 2028



Annual Flows of Produced RW

↗ IL-LL RW - Results of the Estimates for the Case Study



Conclusion

- What is possible to do
  - The simultaneous management of SNF and RW generated in parallel by LWRs permanently shut down and LWRs still in operation, can be effectively analysed by considering the estimates of SNF and RW flows
  - On this basis, it is possible to identify some “key-factors” to decommission each LWR of NPPs and to phase out the fleet regarding SNF and RW management (and possibly adjust it)
- What should be kept in mind
  - This work needs to be done upstream the studies and implementation of the decommissioning actions
  - The question of “*who should do that?*” arises
  - Over issues are not addressed:
    - human resources (staff, skills and knowledge) necessary to perform all the decommissioning actions
    - construction and commissioning of the new LRWs needed to maintain the nuclear power

Thank you for your attention!

Merci de votre attention !

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