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Nuclear Power and Nuclear Safety Post Fukushima

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DPG – AKE – AGA: Nuclear Energy and Security

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Agenda

1 Status of Nuclear Power Today

2 Review - Fukushima Daiichi

3 National and International Reactions

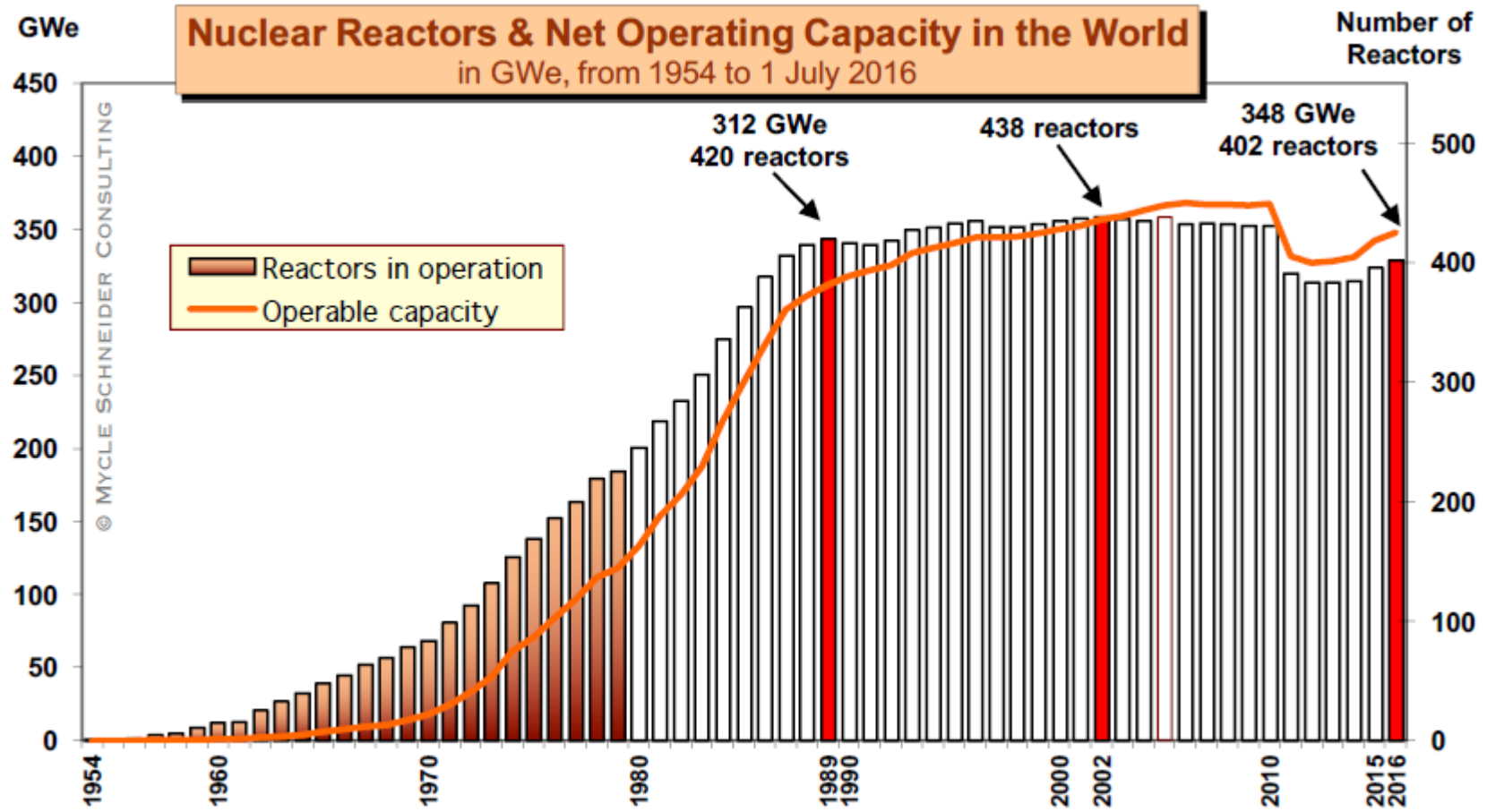
4 Persisting Problems: Quality Control, Precautionary Measures, Unexpected Phenomena

5 „Human Induced External Hazards“

1

Status of Nuclear Power Today

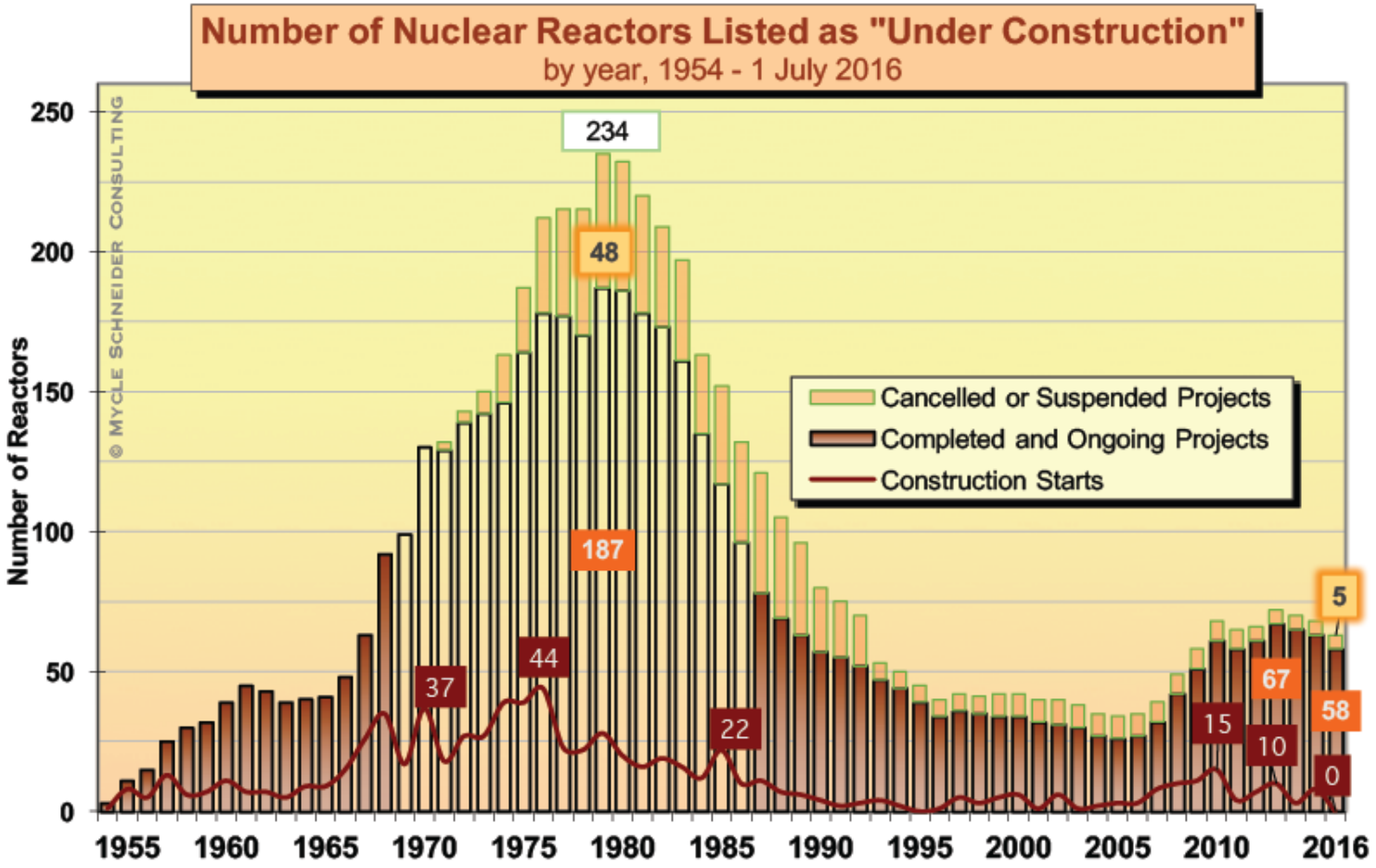
Nuclear Power Development



Sources: IAEA-PRIS, MSC, 2016

Quelle: Schneider World Nuclear Industry Status Report 2016

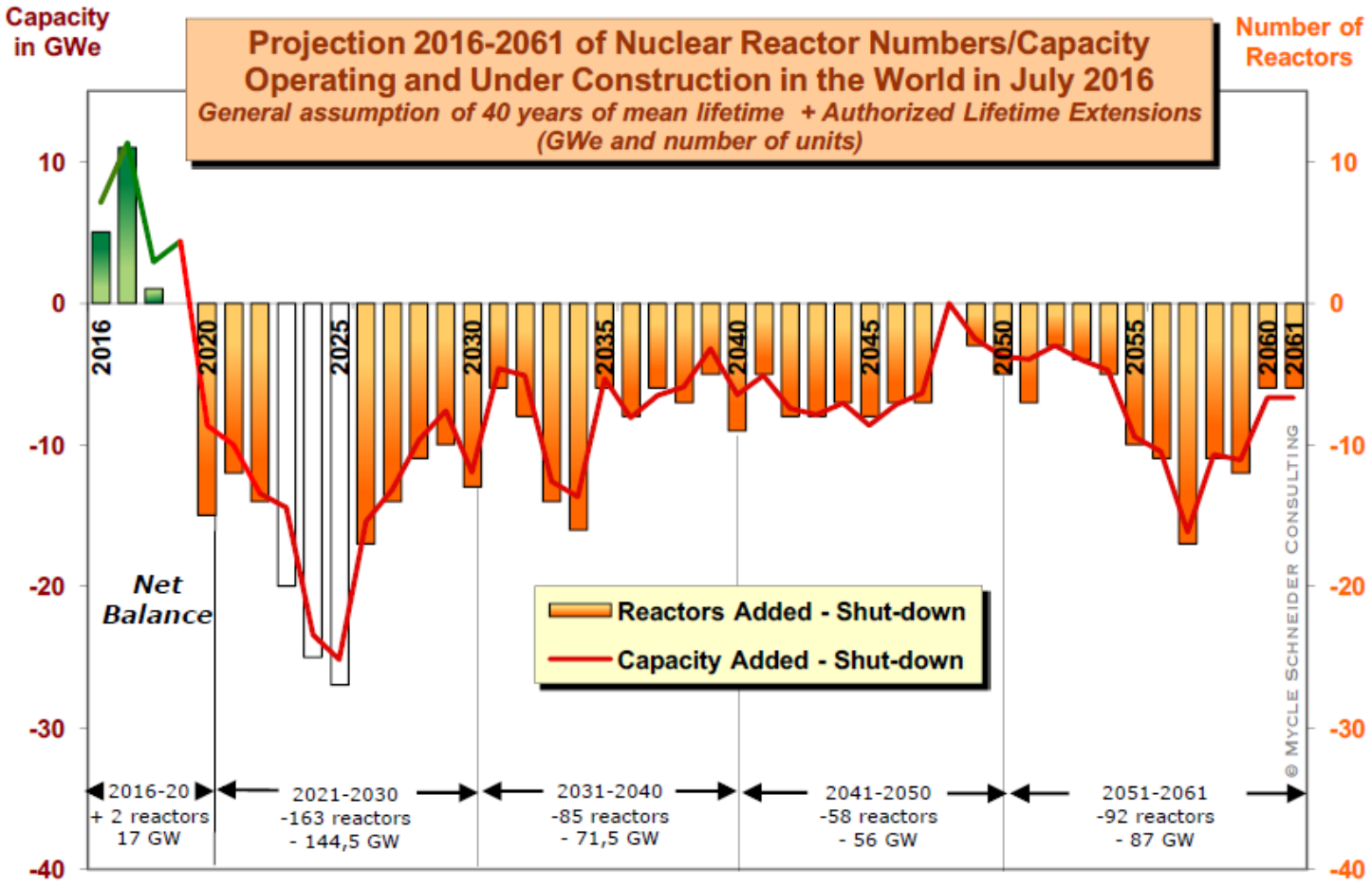
Reactors under Construction



Sources: IAEA-PRIS, MSC 2016

Quelle: Schneider World Nuclear Industry Status Report 2016

Projected Deployment



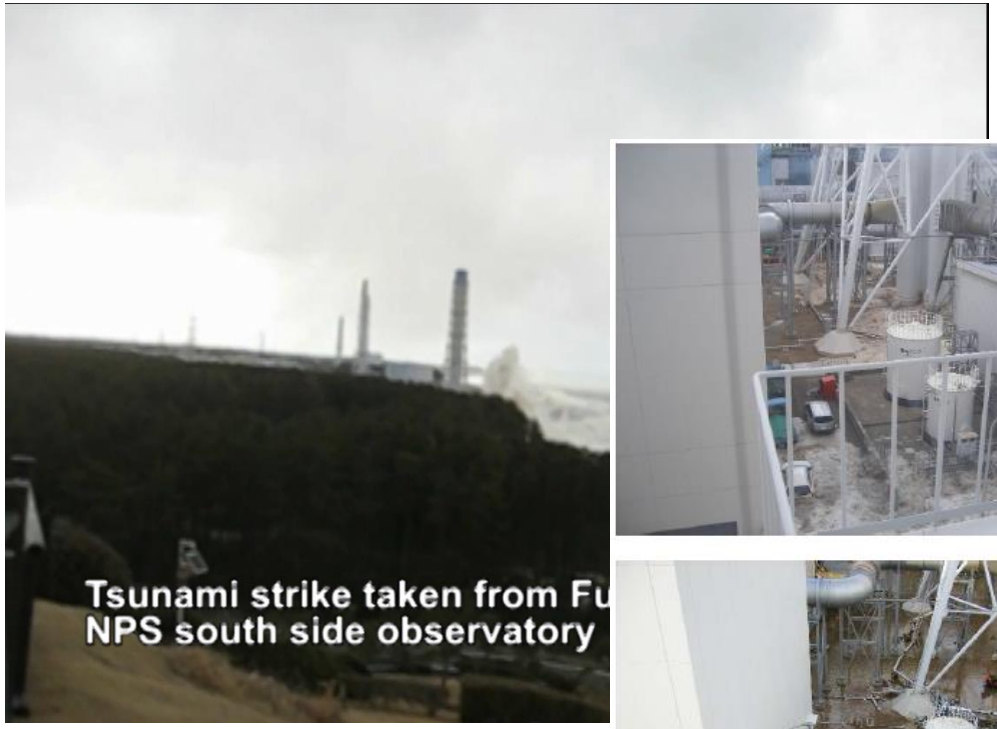
Sources: IAEA-PRIS, WNA, various sources compiled by MSC 2016

Quelle: Schneider World Nuclear Industry Status Report 2016

2

Review - Fukushima Daiichi

Tsunami: Total Station Blackout



Quelle: TEPCO/MEXT

Fukushima Daiichi, March 2011

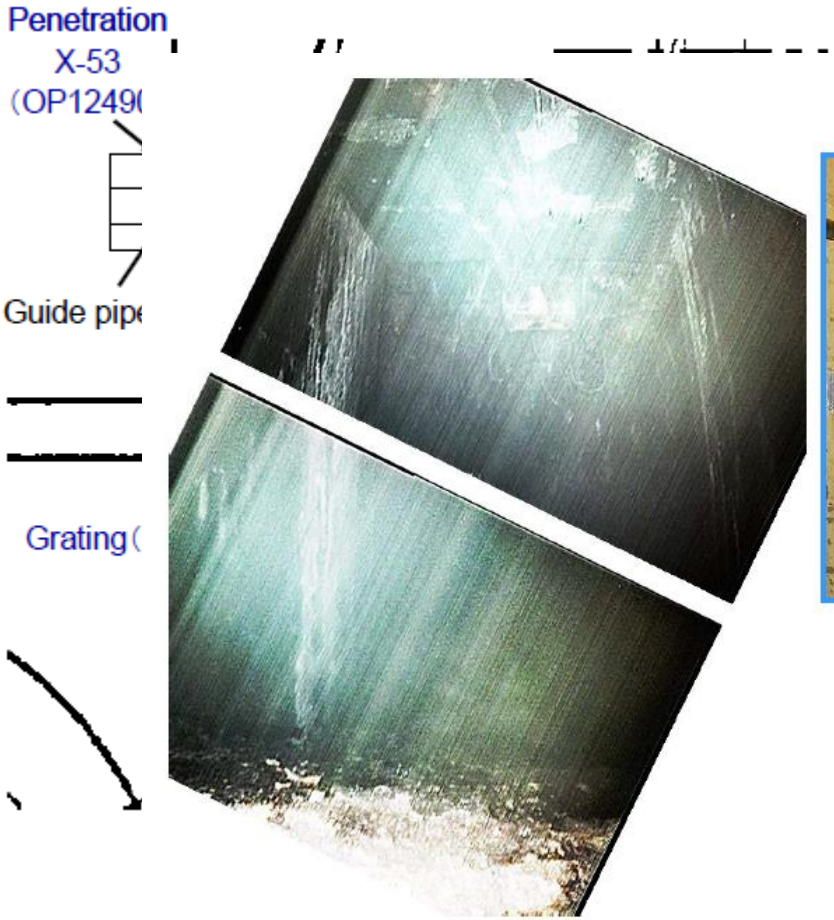
Quelle: TECPO

Fukushima Today: Unit 4

- Unit 4:
  - Until 22.12.2014 all spent fuel elements removed

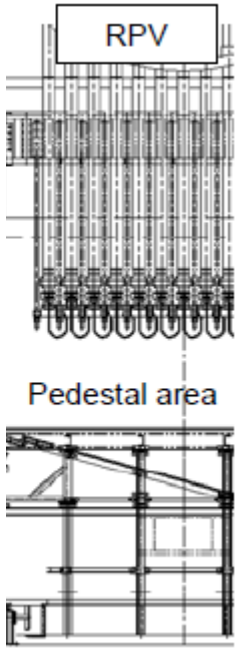
Quelle: TEPCO

Fukushima Today: Unclear Conditions of Molten Cores in Unit 1-3



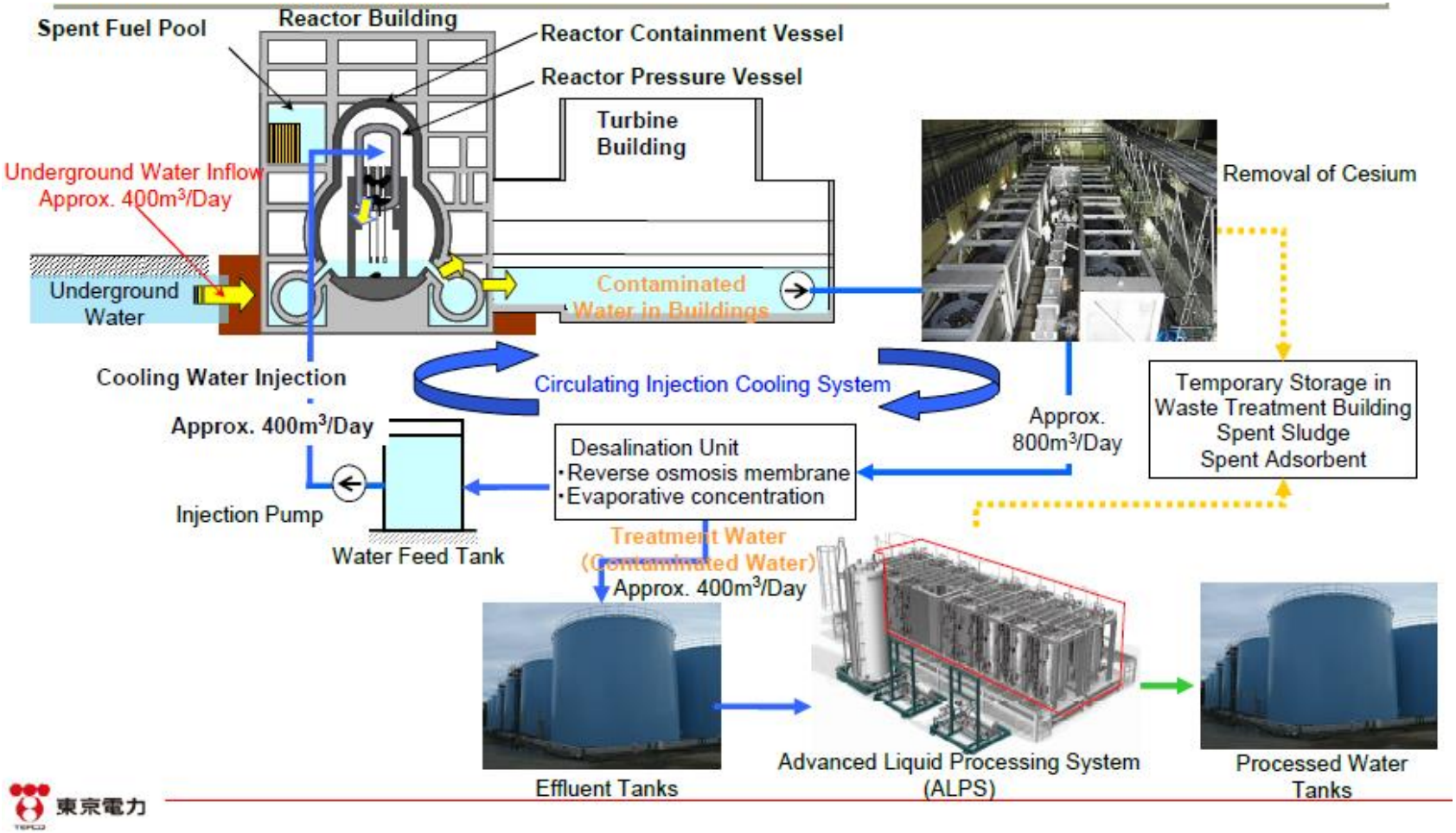
(Reference information)

Pedestal opening of Unit-5



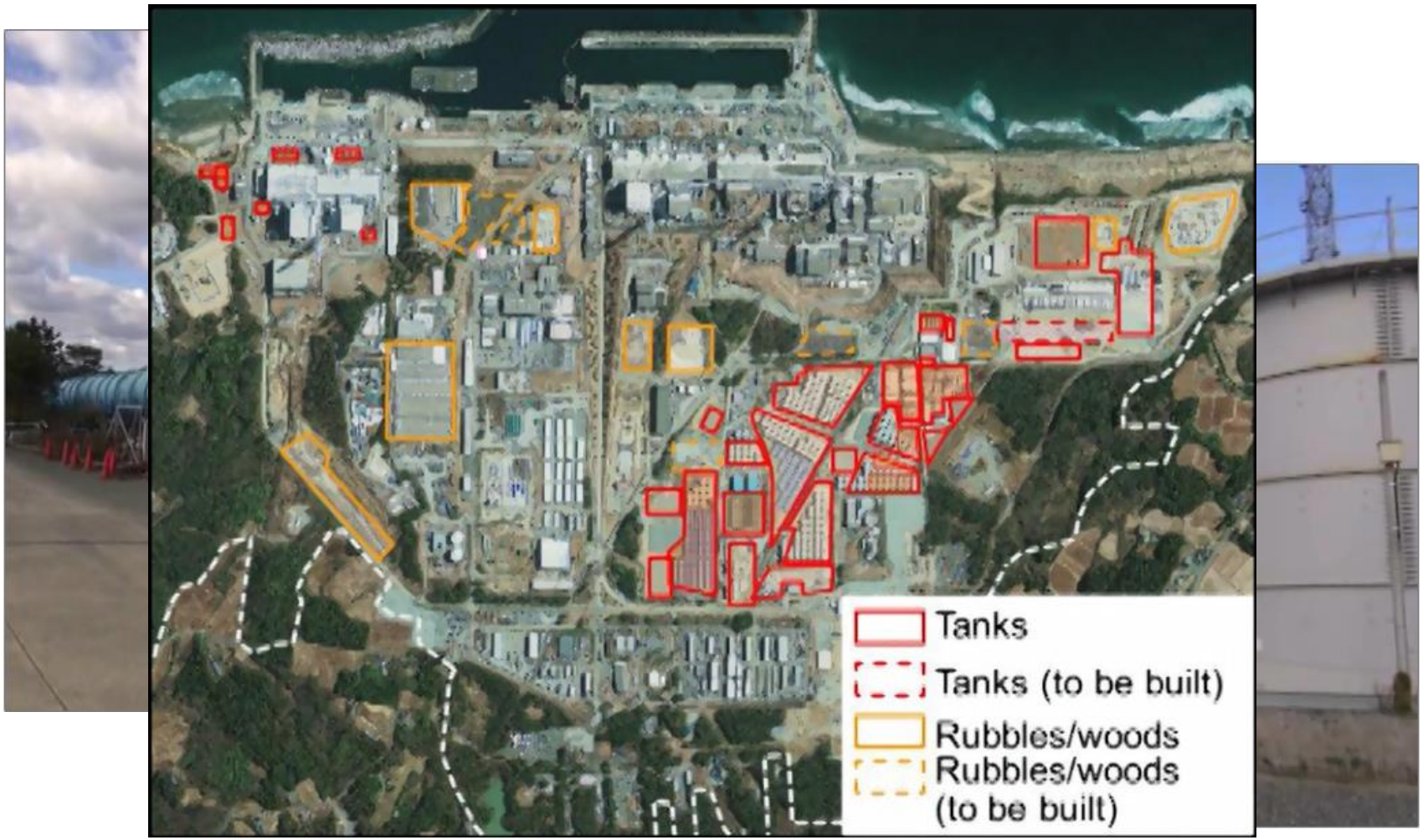
Quelle: TEPCO

Fukushima Today: Continuous Cooling in Open Cycle



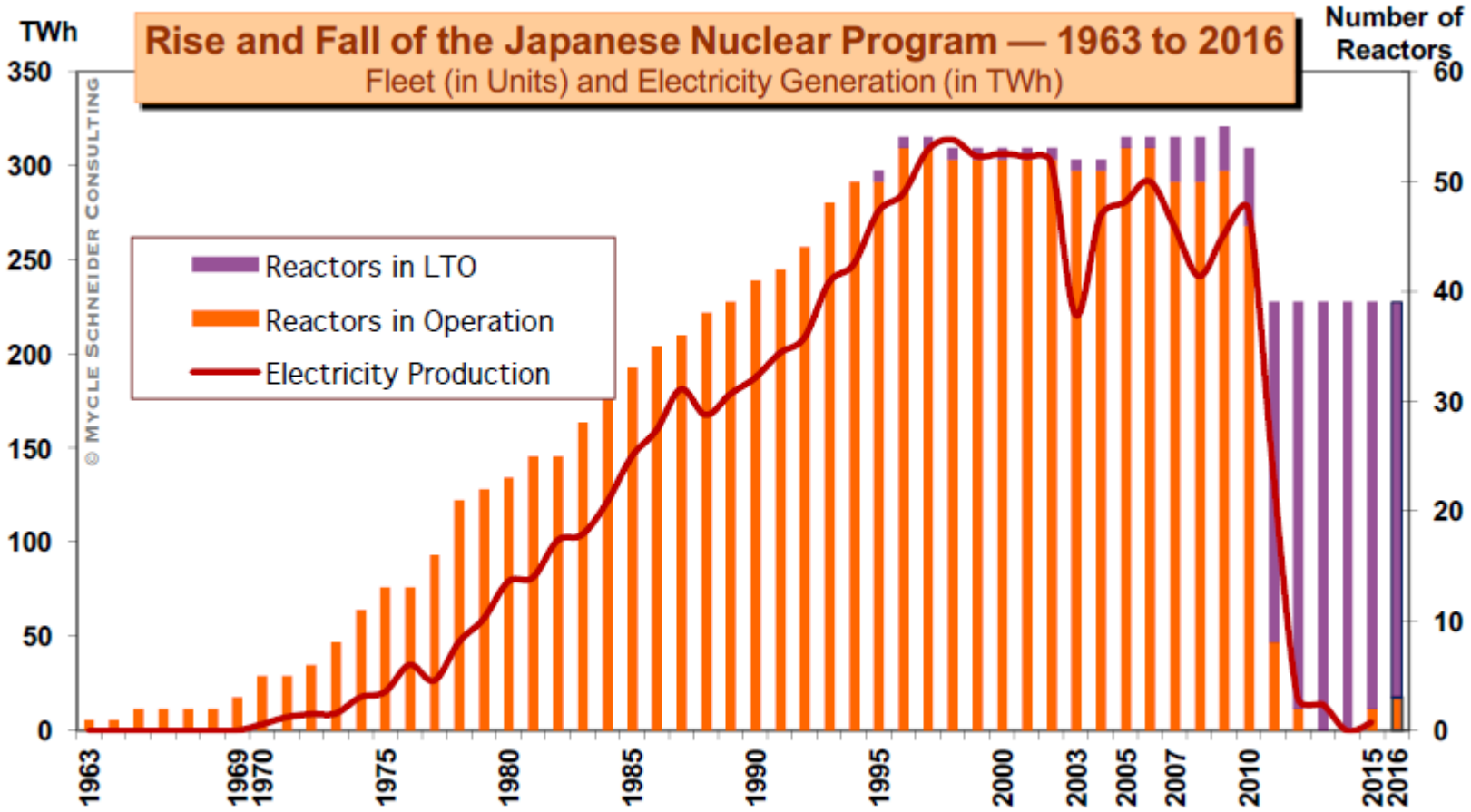
Quelle: TEPCO

Large Amounts of Contaminated Water Accumulate



Quelle: TEPCO

Nuclear Power in Japan



Sources: IAEA-PRIS, MSC, 2016

Quelle: Schneider World Nuclear Industry Status Report 2016

3

National and International Reactions

EU-Stresstest

24./25.03.2011: The European Council declared:

"the safety of all EU nuclear plants should be *reviewed, on the basis of* a *comprehensive and transparent risk assessment ("stress tests"); …“*

Quelle: EUCO 10/11 (paragraph 31)

Methodology of the EU-Stresstest

- Description of design basis of NPPs
- Check of safety margins in the design basis and existance of cliff-edge-effects
- Identification of weaknesses and options for improvement
  - Take reactor core and spent fuel pools into account
  - Take all plant states into account (full power, shutdown)

But:

- Focus on „Robustness“
- Design basis was addressed only indirectly

Scope of the EU-Stresstest

- Natural hazards
  - Earthquakes
  - Flooding
  - Extreme metereological events
- Postulated loss of safety functions
  - Station blackout (SBO)
  - Loss of heat sink (also in combination with SBO)
- Severe Accidents
  - Preventive and mitigative accident management measures

But: no „comprehensive“ review (internal events, human factors, precautionary measures …)

Recommendations in Joint Statement

ENSREG and the EU-Commission identify four major areas for safety improvements

- Issuing WENRA guidance with the contribution of the best available EU expertise on assessment of natural hazards and margins …
- Underlining the importance of Periodic Safety Review
- Implementing the recognised measures to protect containment integrity
- Minimising accidents resulting from natural hazards and limiting their consequences

51 additional recommendations

But: not a single European plant had to shut down (temporarily) due to safety deficits identified during EU-Stresstest

Quelle: Joint statement of ENSREG and the European Commission. 26 April 2012

Some Exemplary Results for Germany

- Enhance DC (up to 10 hours) and AC-Availability (after 10 hours)
  - Mobile diesel generators and connection points
- Independant, divers heat sink
- Improvements of filtered venting (with respect to SBO and loss of DC, if necessary)
- Additional feedline to the spent fuel pool
- Implementation of severe accident management guidelines

Example France

- Implementation of „FARN“ (Force d'Action Rapide du Nucléaire)
  - Availability of external supply within 24 hours after event
  - At each french NPP site
  - With mobile equipment and specially trained personal

Example France

- „Hardened Safety Core“
  - One additional redundancy
  - Ensure heat removal and criticality control for events „more severe than the design basis“
  - One additional (mobile) diesel generator
  - One large additional stationary diesel generator (until 2019)
  - Independant pump with alternative water supply to ensure (after 2019)
    - steam generator feedwater and
    - low pressure water injection to reactor core/spent fuel pool

But:

- no relevant improvments with respect to design basis

Remember …

Root-Causes of Fukushima Accident according to TEPCO included:

- it was assumed, that severe accidents have a low chance of occurrence
- there were concerns about liability issues and public anxiety if severe accident measures were implemented and
- there was a fear of plant shut down for the time until measures are implemented

→ Mandatory, timely and comprehensive implementation of identified safety improvements necessary

Quelle: Tepco Nuclear Reform Special Task Force: Fundamental Policy for the Reform of TEPCO Nuclear Power Organization. October 12, 2012

4

Persisting Problems: „Quality Control“, Precautionary Measures, Unexpected Phenomena

Example „Quality Control“ – Part I

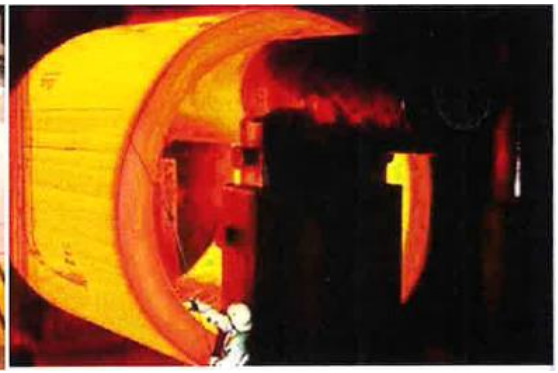
- In 2012 unexpected indications during ultrasonic inspections of reactor pressure vessels of Doel 3 / Tihange 2
  - First safety case in 2013: restart of reactors
  - Unexpected experimental results in 2014, again, both plants are shut down
  - New safety case in 2015, FANC gives o.k. for restart
- In 2015, following the discussion in Doel 3/Tihange 2, unexpected indications are found in RPV of Beznau 1 and 2
  - Beznau 2 can restart in 2015
  - Beznau 1 safety case not yet approved by regulator

Production of a Reactor Pressure Vessel

Stahl schmelzen

Vakuum Entgasung

Rohling giessen

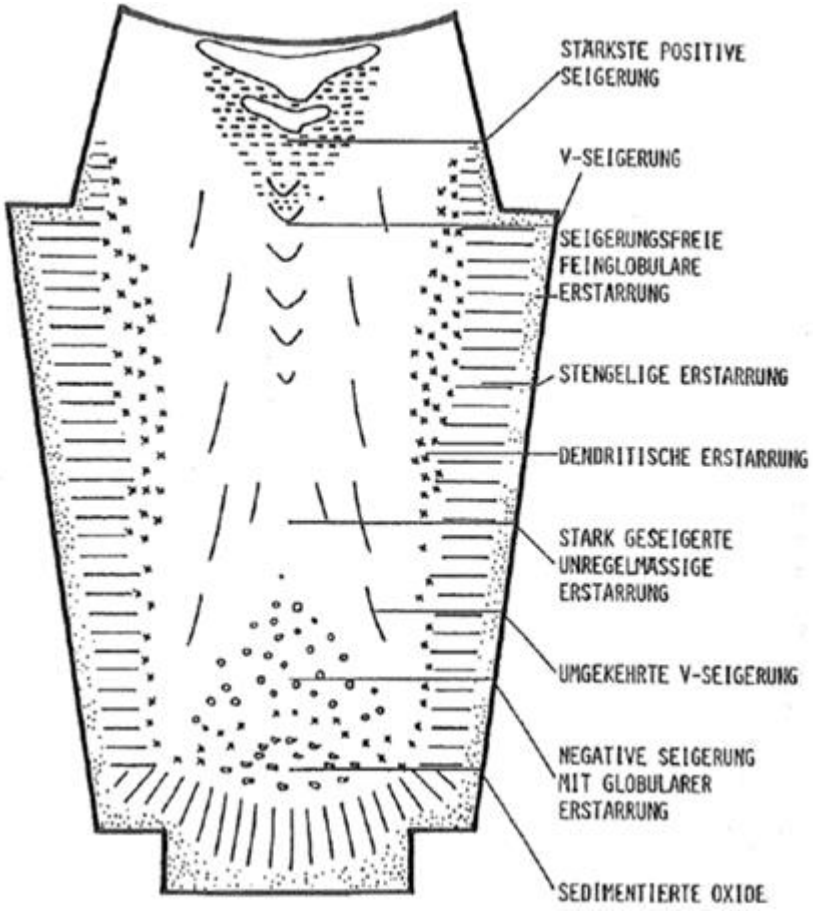


Quelle: axpo 2015

Creusot Forge

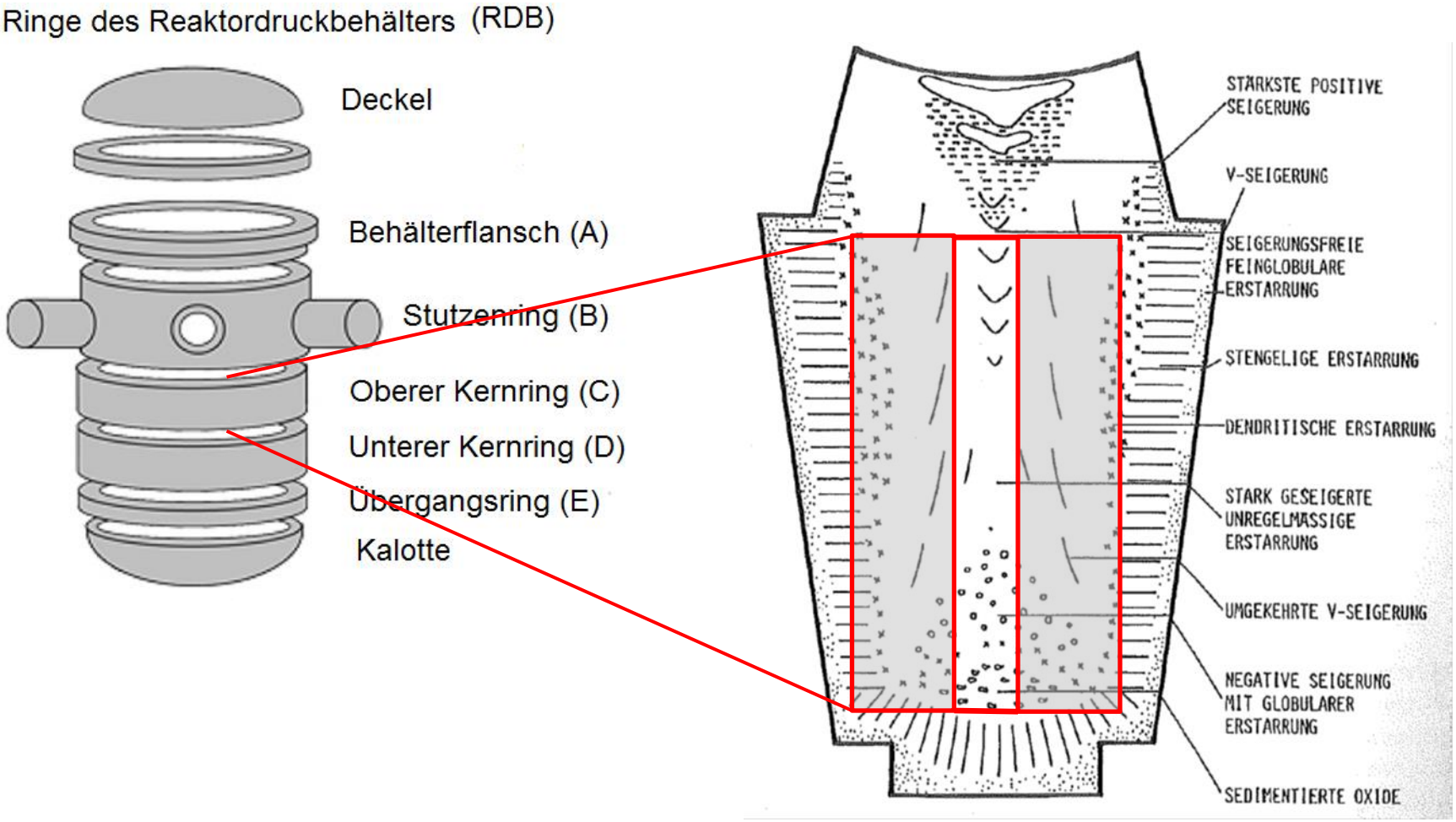
Quelle Areva

Inhomogenities



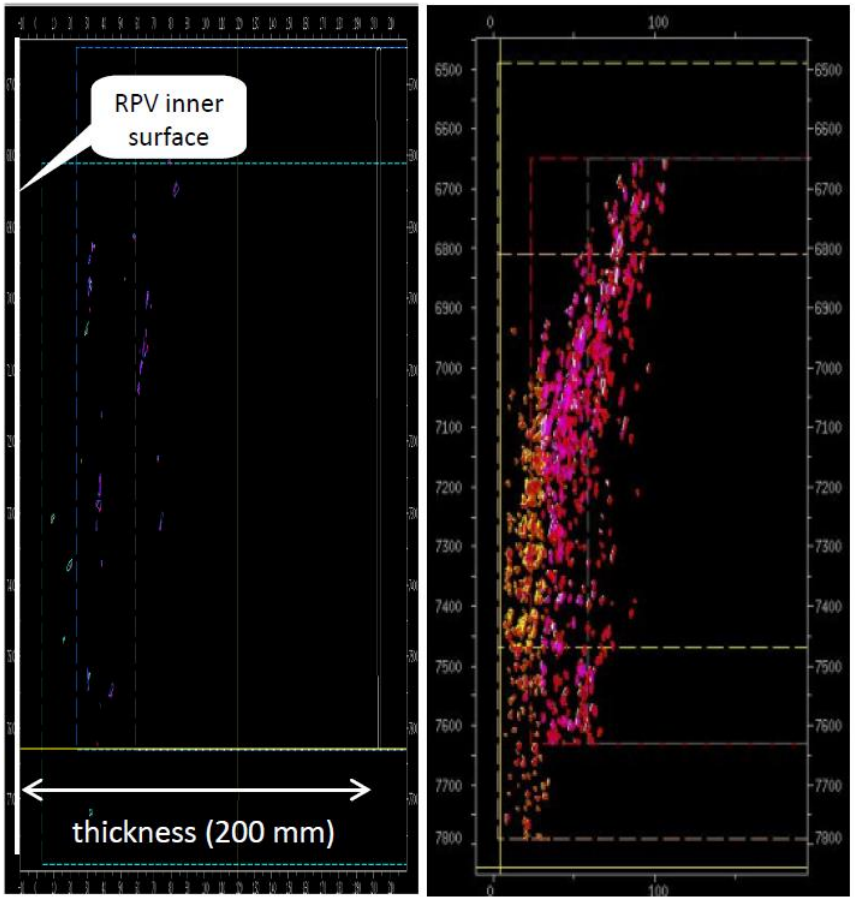
Quelle: Areva 2013

Extraction of Parts for Reactor Pressure Vessel



Quelle Abbildung: Öko-Institut, AREVA

Hydrogen Flake Distribution in Doel 3



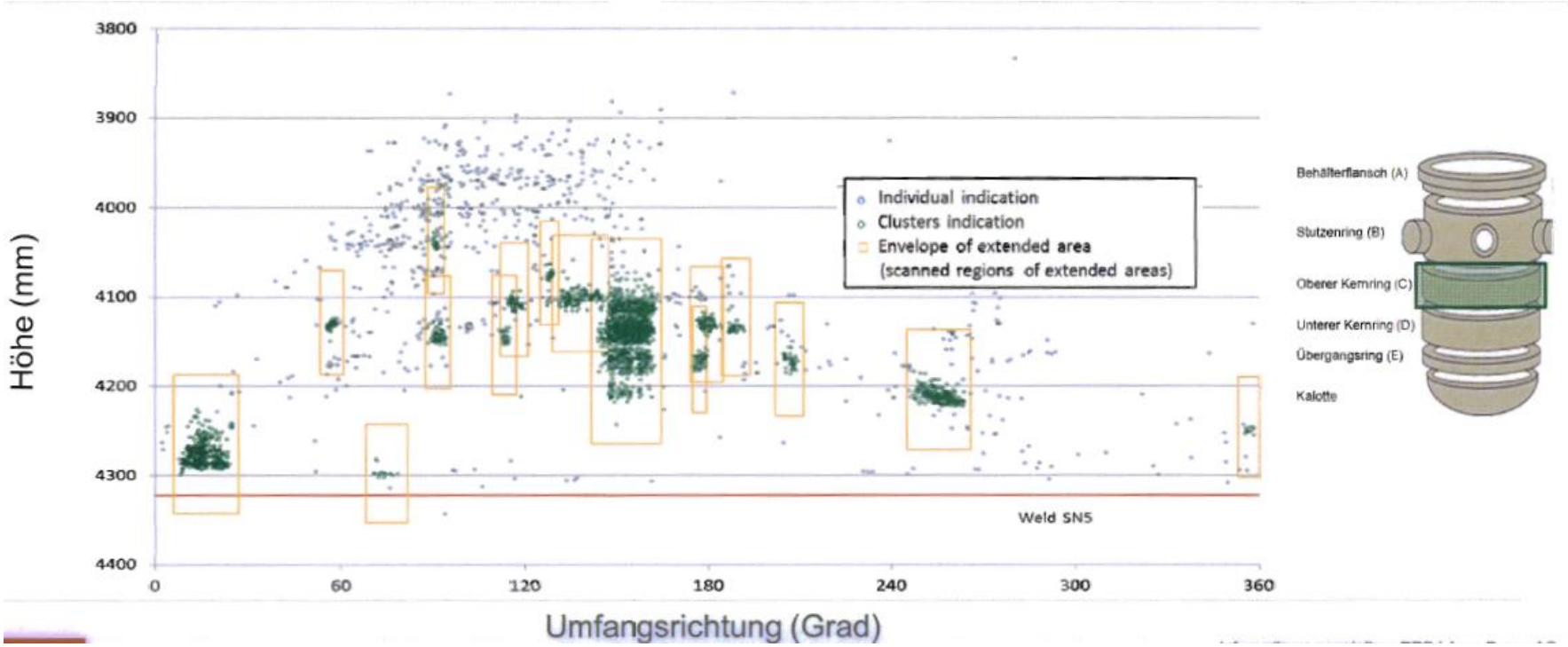
- Left: Cross section of RPV
- Right: All indication of a 20° ring segment ar projected onto one plane

Figure 4.6 Indications recorded in the lower core shell of the Doel 3 RPV

Quelle: Electrabel 2012, Doel 3, Fig. 4.6

Indications in Beznau 1 (2015/2016)

Distributions of indications in one RPV Ring



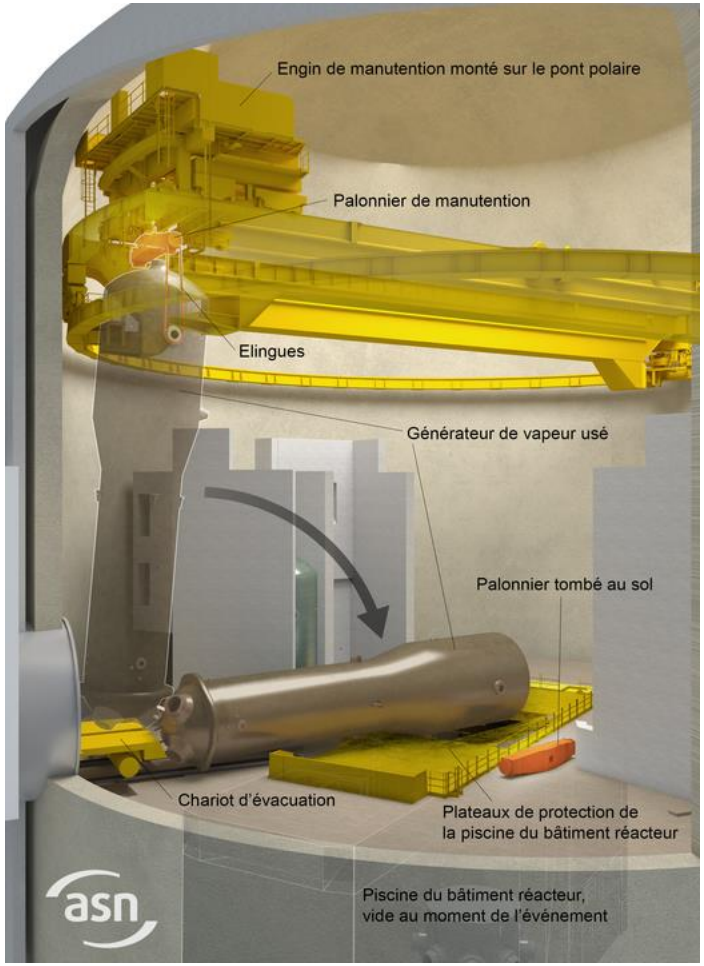
Example „Quality Control“ – Part II

- 2015: ASN informs about irregularities in RPV of Flamanville 3
  - Parts of RPV show carbon segregations beyond specifications
  - Assessment of safety implications ongoing
  - Check of production history at Creusot Forge
    - In total 400 „irregularities“ identified (including deviations from internal specifications up to intentional falsifications)
    - Before 1990: 20 steam generators in 8 NPPs made in Le Creusot
    - After 1990: 26 steam generators in 12 NPPs made at JCFC
    - Other manufacturers and other customers (outside France) are also affected

Examen de tous les composants forgés à la demande de l'ASN

25 octobre 2016 OPECST 6

Example „Precautionary Measures“



- Specific events shall be excluded by „precautionary measures“ (highest quality, high reliability)
- Example „load drop“
  - 10.07.2016, RPV droped to the ground at Belarus VVER-1200 during construction
  - 31.03.2016, Paluel 2, drop of steam generator while exchange takes place

→ While events shall be excluded, they continue to happen

Quelle: ASN

Example „Unexpected phenomena“

- Since several years increase in neutron flux oscillations in spanish and german PWRs
  - 11.04.2013: RSK-Statement on „PWR neutron flux oscillations“
- Other „quality control issues“ with respect to fuel elements and core components
  - 18.03.2015: RSK-Statement on „Deformations of fuel assemblies in German pressurised water reactors (PWRs)”
  - 18.05.2016 : RSK-Statement on „Damage to fuel assembly alignment pins and core components”
- 2016: In Leibstadt, several fuel elements with increased oxidation detected → probably local dryout effects during normal operation

→ Even for the reactor core, new and unexpected phenomena appear even today

5

„Human Induced External Hazards“

Nuclear Power Plants and Terrorism – Is there a Threat?

- Sweden 2012: civil protesters enter NPP – remain undetected for serveral hours
- France: over months, drones fly over NPPs – counter measures do not help, no responsible person identified yet
- Belgium:
  - August 2014: possible sabotage of steam turbine in NPP
  - 2014: known islamic fundamentalist identified working in high security area in NPP since 2012
  - After Paris attacks: NPPs being evacuated, videos of director of nuclear research facility found in terrorist‘s house

Nuclear Power Plants and Terrorism – Is there a Threat?

- Ukraine:
  - May 2014: approx. 20 armed activists enter nuclear facility – to protect it against hostile forces
  - November 2015: transmission towers of national grid attacked – loss of external grid at nuclear power plant
- Germany April 2016: computer virus „Conficker“ and comparable viruses located in safety relevant computer systems in operating BWR plant

Nuclear Power Plants and Terrorism – Kinds of Threats

Different kinds of threat to be taken into account

- War-like situations with direct or indirect consequences for nuclear power plants
- Terror attacks from the outside (who, how many, what capabilities?)
- Terror attacks from insiders (permanent staff, temporary workers?)
- Cyber attacks

- Different threats require different approaches
- Threats might change over (relatively short) timeframes
- For cyber security: see next talks!!

Some Conclusions

Conclusions I

- Nuclear Power still relevant contributor to worldwide electricity production, but in decline
- Fukushima again showed risks associated with current nuclear power plants
- EU-Stresstest was
  - Substantial and new review of safety issues
  - But: no „comprehensive“ review!
- Relevant differences in safety status between european NPPs have been identified
- Important safety improvements have been recommended
  - Timeline for implementation?
  - Obligatory character of recommendations?

Conclusions II

- Persisting Problems
  - Still, severe problems come to light with respect to
    - „Quality Control“ issues,
    - Preventive measures
    - New and unexpected phenomena
    - …
  - Nuclear security issues
  - Regulatory standing?
  - Financial situation of manufacturers and operators??
  - …

Fazit

Naoto Kan (ehem. Japanischer Premierminister)
Foreign Affairs, 08.03.2012:

“I have thought very hard about the types of safety measures necessary to prevent any such disaster from happening again. However, when one weighs these measures against the tremendous risks, it is clear that no amount of precautions will make a country completely safe from nuclear energy. I have reached the conclusion, therefore, that the only option is to promote a society free of nuclear power.”

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Vielen Dank für Ihre Aufmerksamkeit!
Thank you for your attention!

Haben Sie noch Fragen?
Do you have any questions?