Studsvik

Options for Steam Generator Decommissioning

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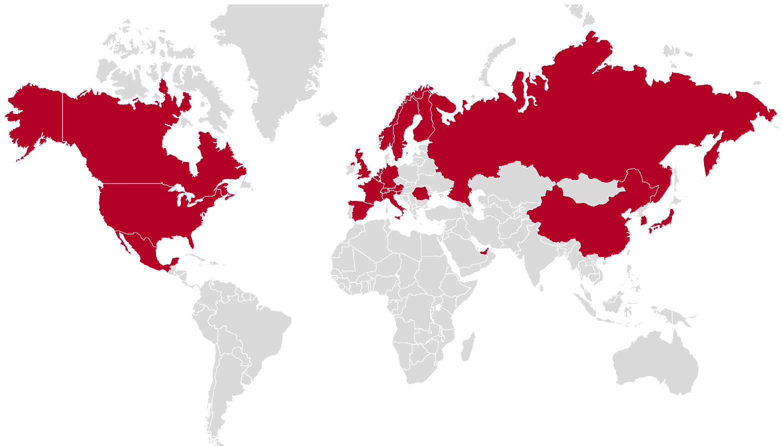
Leading supplier of specialist nuclear & radiological services

Employees
800

Sales SEK
1.0 billion
Listed on Nasdaq Stockholm

Radwaste Treated
40,000t

Global presence with subsidiaries in
7 countries



- Operating Nuclear facilities
- Decommissioned Nuclear facilities
- Research facilities
- Minerals and Petrochemical companies

Studsvik metals treatment & recycling facility in Sweden

Metal treatment and melting facility	Large components treatment facility
	
Licensed capacity 5000 ton/year	Capacity ~2000 ton/year

Studsvik supporting facilities in Sweden

Supporting Infrastructure

Harbour on Baltic Sea Coast within
Studsvik Nuclear Licensed Site

Large components temporary storage
Storage area 1200 m^2

Studsvik supporting facilities in Sweden

Incineration & Pyrolysis Facility

Environmental & Hot Cell Laboratories

Background to Steam Generator Decommissioning

In Europe >200 steam generators have to be treated or disposed of in the future

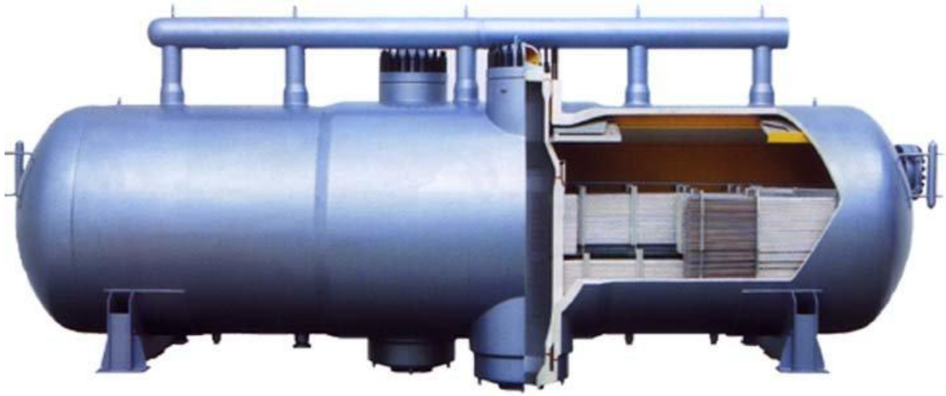
Steam generators in operation:
- for future interim storage
- for future final disposal
- for future on/off site treatment

Steam generators in interim storage:
- from exchange projects in the past
- from ongoing dismantling projects

Types of PWR Steam Generators

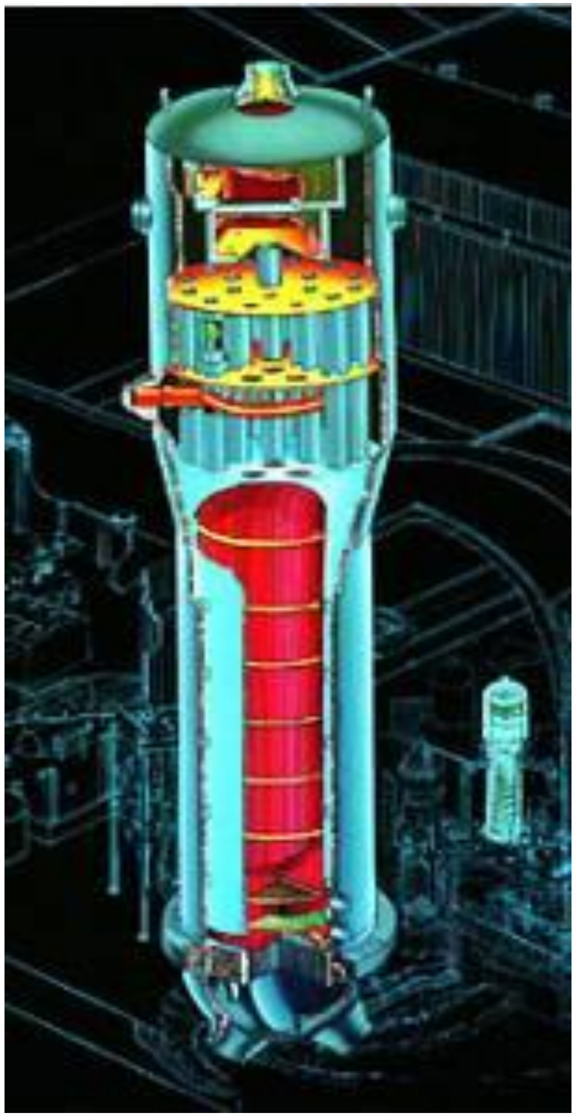
<u>Once Through Steam Generators</u>
Straight-tube SG
Generates superheated steam as the feed-water flows through in a single pass.
Reactor coolant flows in the tubes.

<u>Recirculating Steam Generators</u>
U-tube heat exchanger bundle
Steam separation at the top
Reactor coolant flows in the tubes.



<u>Horizontal Steam Generators</u>
Horizontal U-tube heat exchanger bundle.
Reactor coolant flows in the tubes.

Typical Steam Generator Characteristics



Total weight:	310 t
Weight steam dome:	110 t
Volume:	430 m^3
Diameter:	3,4 - 4,4 m
Length:	20 m
Tubes:	4700 (in total ~75 km)
Contaminated surface:	approx. 5000 m^2
Plugged tubes:	depending on operational history
Activity inventory:	up to several TBq
Dose rate	up to several mSv/hr

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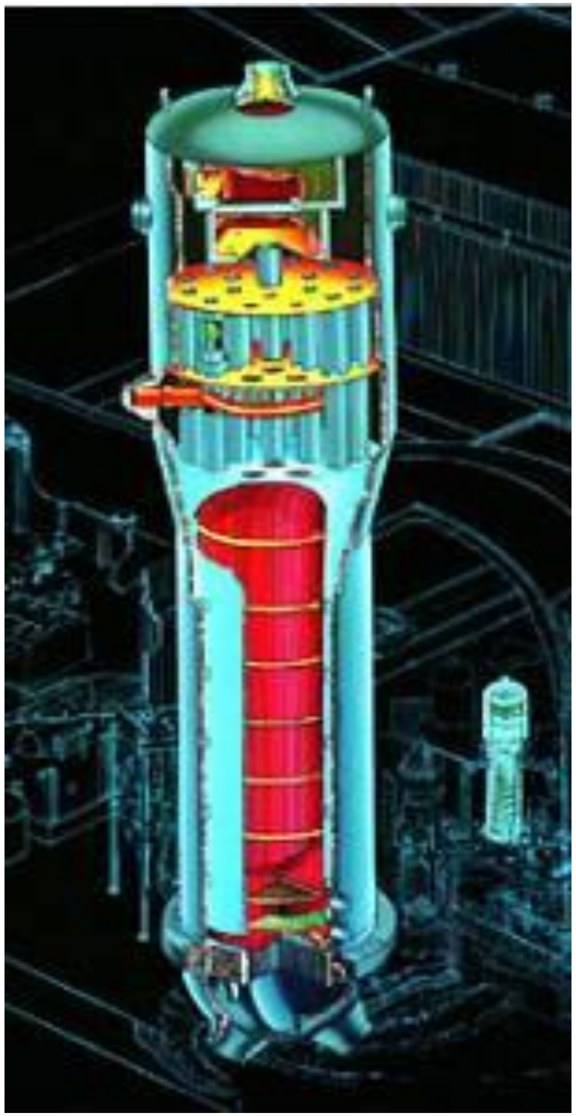
Challenges for Treatment and Disposal



- Minimising the collective dose
- Dismantling and physical handling of large items
- Decontamination
- Dealing with waste from decontamination (high activity load)
- Tubes
  - cutting
  - pulling
  - dealing with plugged tubes
  - dealing with U-bends
  - volume reduction of tubes
- Tube Plate & Water Chambers
  - decontamination
  - segmentation
- Minimising of the disposal volume of waste

Importance of Pre-Decommissioning data

Besides steam generator drawings, activity and dose rate data, other technical and operational data has to be evaluated before treatment:

Weight:	XX	ton
Length:	XX	m
Diam. Tube section	XX	"
Diam. Steam Dome	XX	"
Outer shell thickness:	XX	mm
Inner shell thickness	XX	"
Steam dome	XX	ton
Tube plate:	XX	"
Diameter:		mm
Thickness:		"
Plating material	?	
Sludge pail	XX	mm/ton
Water Chamber:	XX	ton
Material	?	
Wall thickness	XX	mm
Plating material	?	

Tubing:	XX	Tubes
Material:	Inconel?	
Weight:	XX	ton
Length:	XX	m
Surface, total:	XX	m^2
Diameter:	ID / OD	mm
Expanding roll length/depth	xx/xx	mm
Welded to tube plate	Y/N	
Tubes-Plugged	XX	Tubes
Kind of Plugs: Double Welded, Expander	?	
Tubes pulled	XX	"
Tubes with steel wire	XX	"
Sleeves	XX	"
Tube Support plates:	XX	Plates
Weight	XX	ton

Comparison of Options

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Options for On-site treatment

On-site treatment	
Option 1	Treatment in the containment
Option 2	Treatment in purpose-built local on-site waste treatment centre (WTC)

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Options for On-site treatment

Option 1	Treatment in the containment
Advantages	**Disadvantages**
Lower cost compared with new treatment facilities	Lack of working space in the containment
No external SG transport necessary	High initial cost of learning and development
Possibility to utilize own staff for segmentation	Blocking of other decommissioning activities
Large SG segments can be removed for decontamination and free-release measurements	Long treatment time inside the containment
	Uncertainty regarding the total costs
	Extended, total decommissioning time and cost
	Significant conventional and radiological exposure risks
	Increased regulatory requirements
	Requires external material and waste buffer storage
	Extensive decontamination and free release measurement programme

Options for On-site treatment

Option 2	Treatment in purpose-built local on-site waste treatment centre (WTC)
Advantages	**Disadvantages**
Only short on-site SG transport distance	Capital cost for build & equipping facilities
Equipment available on the market	Time for permitting and licensing
Early SG removal means limited interferences with other dismantling activities in the containment	High initial cost of learning and methodology development
Large SG segments can be sent for free release measurements	SG removal from the containment
Early site release date	Extensive measuring program for free releasing of the SG parts
Utilization of own staff for segmentation	

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Options for Off-site treatment

Off-site treatment	
Option 1	Direct disposal of the SG as an entire component, or disposal of the tube bundle part only
Option 2	Segmentation of entire SG and packaging in suitable packages for direct disposal
Option 3	Treatment with the target to minimize the secondary waste volumes for disposal by melting, free-release and recycling

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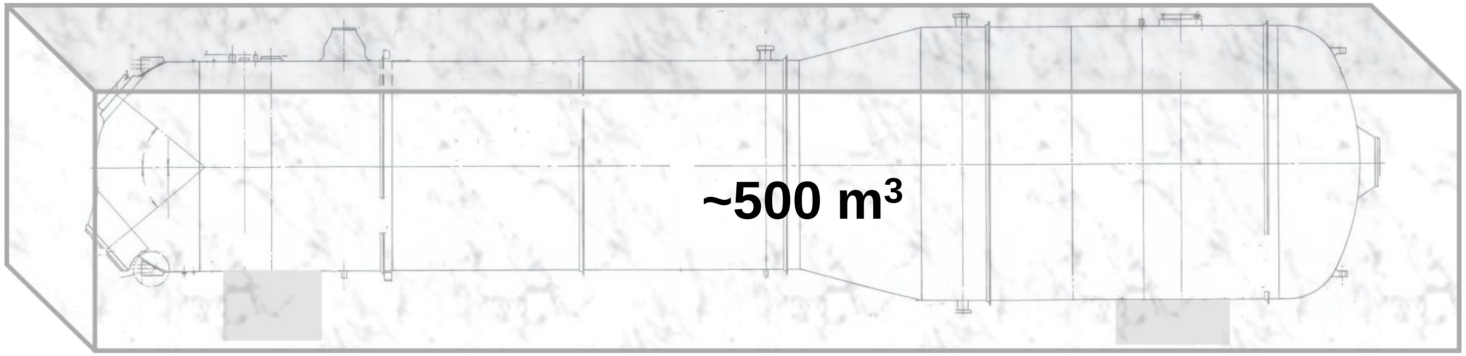
Options for Off-site treatment

Option 1	Direct disposal of the SG (entire component or tube bundle part only)
Advantages	**Disadvantages**
Minimal processing meaning fast and simple process	Large volumes of waste for disposal and associated cost
Reduces or removes on-site/project risks related to time plan and available space	Not in-line with environmental policies and guidelines
Limited conventional and radiological exposure risks	Off-site transport challenge
	Needs sites to accept large components for disposal

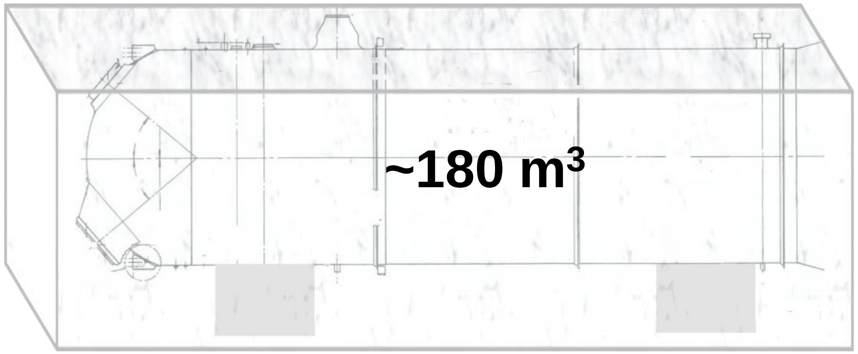
Options for Off-site treatment - Waste Volumes

Option 1	Direct disposal of the SG (entire component or tube bundle part only)
Disposal volume each Steam Generator:	Approx. 500 m^3 for whole SG Approx. 180 m^3 tube bundle part only

Outer dimensions ~20 x 5 x 5 m



Outer dimensions ~11 x 4 x 4 m

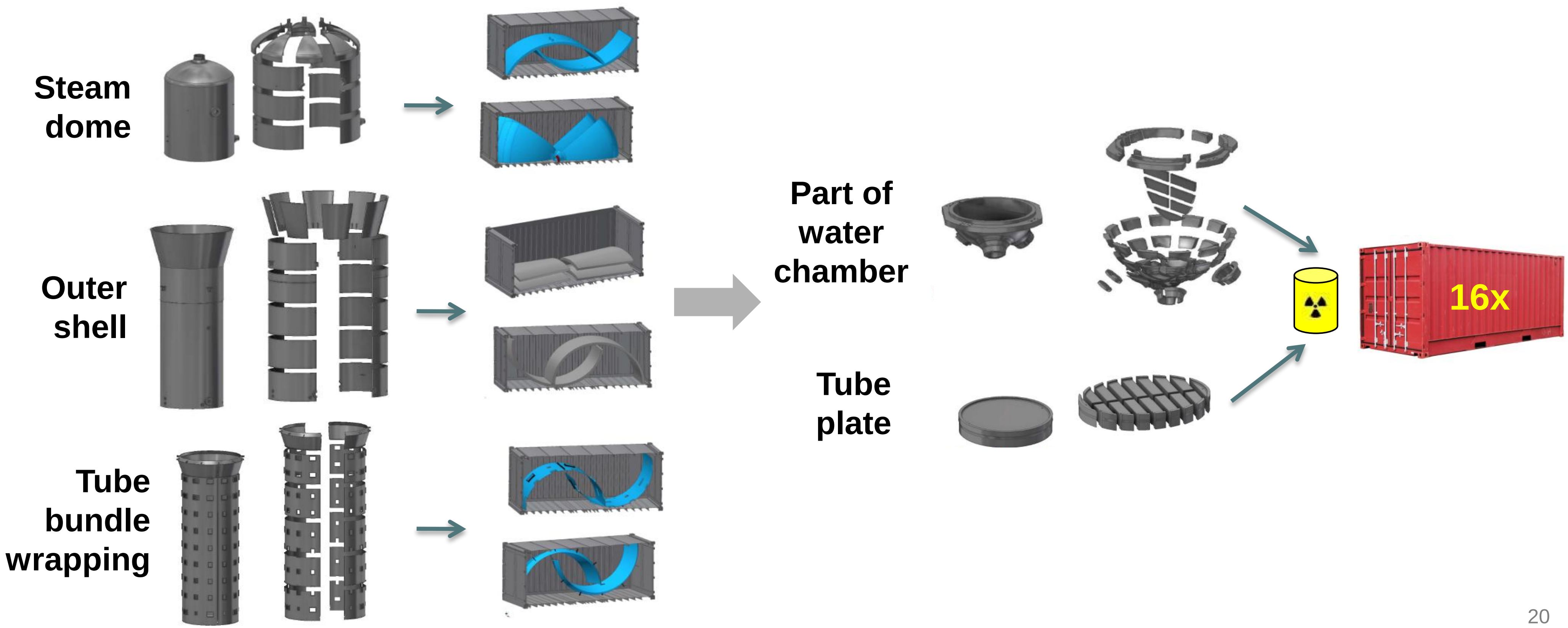


Options for Off-site treatment

Option 2	Segmentation of entire SG and packaging in suitable waste containers for direct disposal
Advantages	**Disadvantages**
Process only involves segmentation and packaging	Large volumes of waste for disposal and associated cost
Reduces on-site/project risks related to time plan and available space	Not in-line with environmental policies and guidelines
Limited conventional and radiological exposure risks	Needs sites to accept metal for disposal

Options for Off-site treatment – Waste Volumes

Option 2	**Segmentation of entire SG and packaging in suitable waste containers for direct disposal**
	Disposal volume each Steam Generator: **Approx. 16 ISO (20ft) containers, approx. 600 m^3**



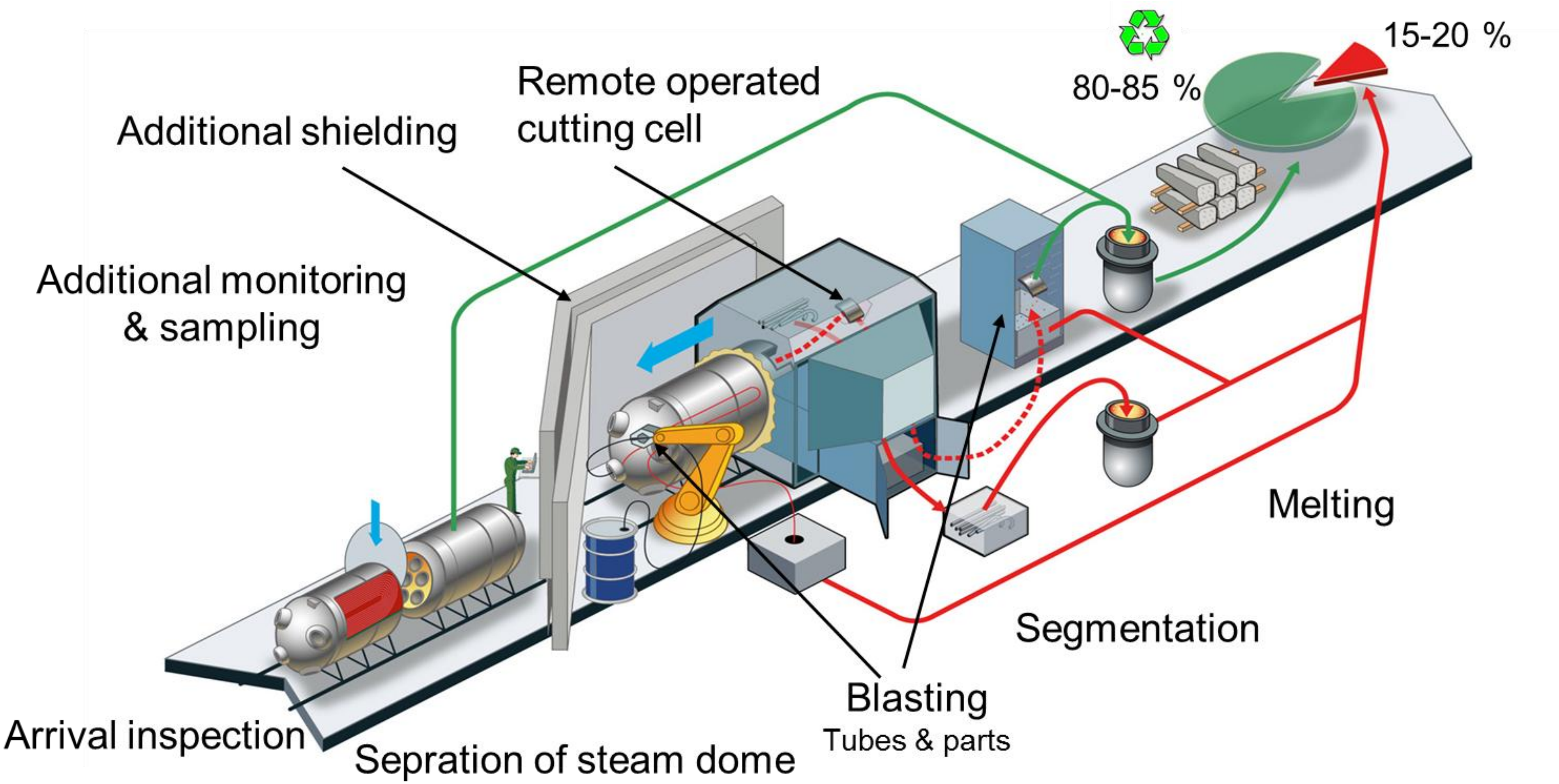
Options for Off-site treatment

Option 3	Treatment with the target to minimize the secondary waste volumes for disposal by melting, free-release and recycling
Advantages	**Disadvantages**
Proven, fast and reliable process	Off-site transport challenge, international
Minimises waste for final disposal to a small fraction	Limitations on SG total activity inventory, with pre-decontamination or decay storage required
Costs are bounded for the transport and treatment	
Meets environmental policy and guide lines. Waste hierarchy & Best Available Technique.	
Reduces or removes on-site/project risks related to time plan and available space	
Conventional and radiological exposure risks managed in a purpose-built facility	

Options for Off-site treatment

Option 3	Treatment with the target to minimize the secondary waste volumes for disposal by melting, free-release and recycling

Disposal volume each Steam Generator: Approx. 36 m^3 (= 8%vol.)



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Options for Off-site treatment – Waste Volumes

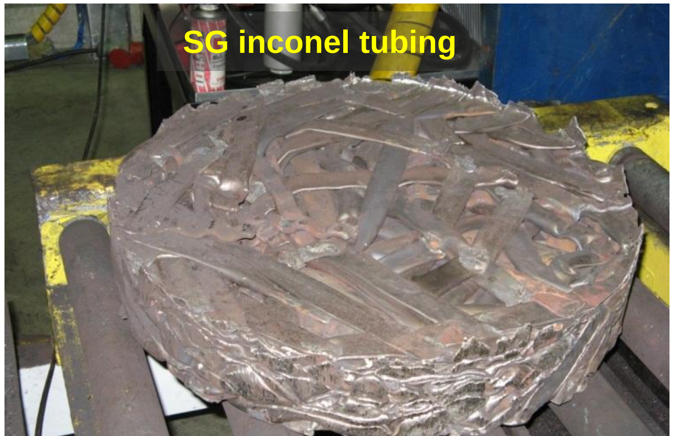
Option 3 **Treatment with the target to minimize the secondary waste volumes for disposal by melting, free-release and recycling**

Disposal volume each, 310 Mg, Steam Generator: Approx. 36 m^3 (= 8%$_{vol.}$)

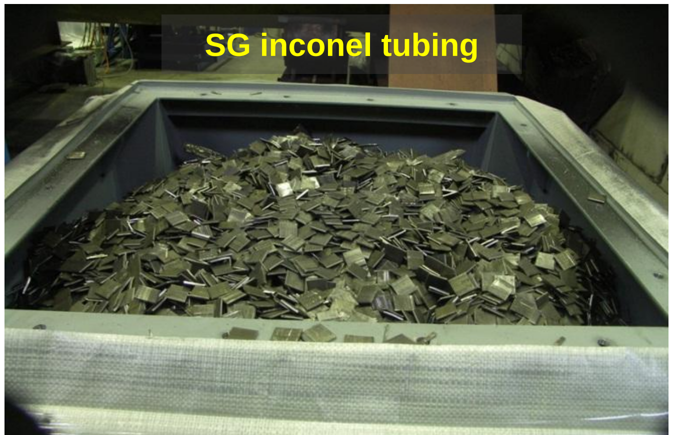
Slag from melting

Slag from cutting

Dust from blasting & melting



Pellet of compacted tubing



Chopped & flattened tubing

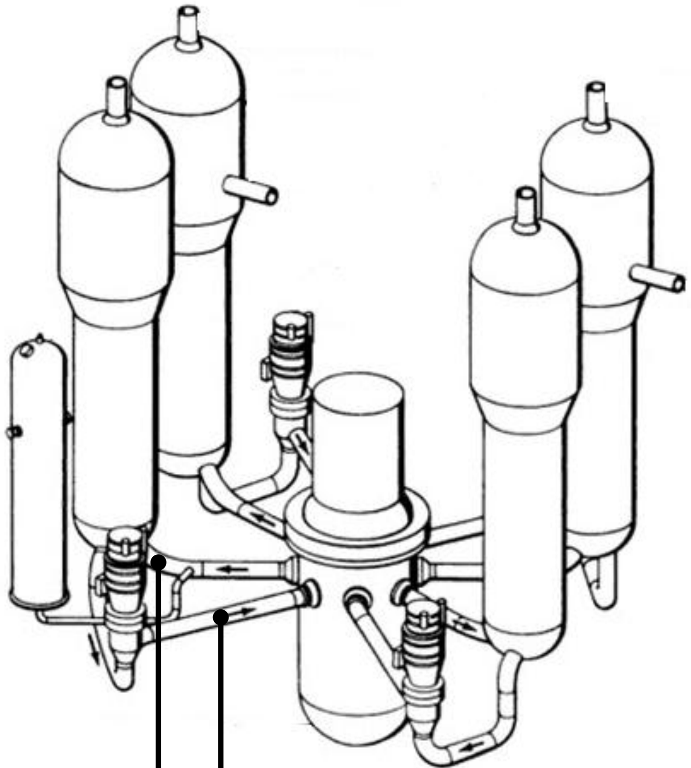
Ingots of melted tubing

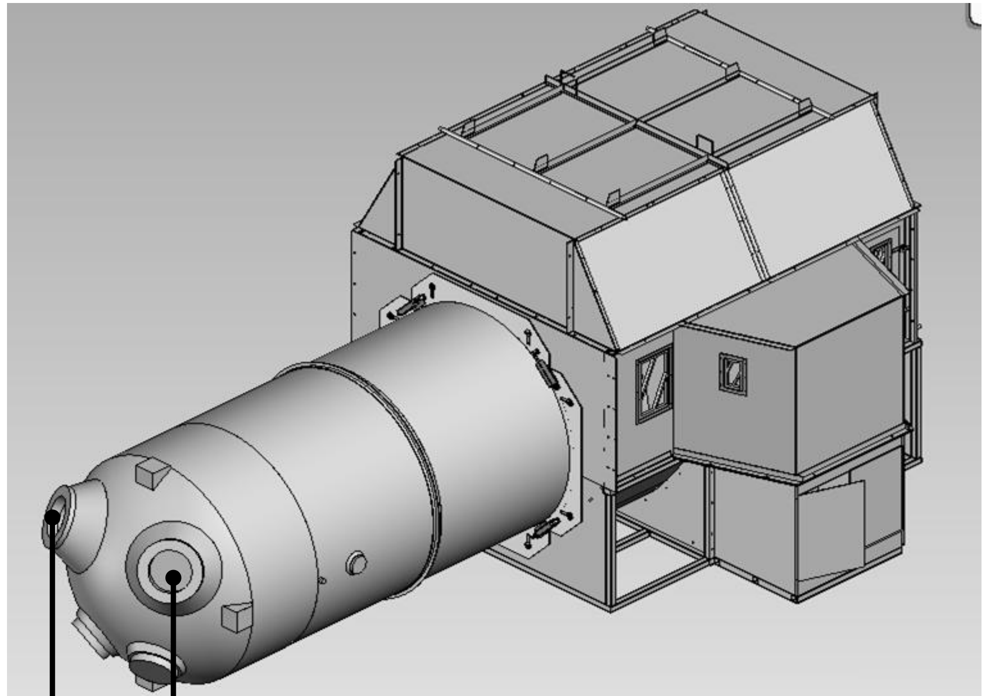
The role of prior decontamination

- In-situ decontamination is a logical first step to reduce gross contamination, dose rate and facilitates off-site transport and treatment
- A number of standard processes are available
- The decontamination factor (DF) for the chemical decontamination improves feasibility for the final treatment on or off-site and reduces the total inventory transport, both ways
- On occasions where SGs have been in storage for many years, decay storage of 20-30 years is sufficient to achieve the same goals without prior decontamination
- It is possible, but more difficult, to treat SGs without prior decontamination or decay

The role of prior decontamination

In situ decontamination Full System Chemical Treatment	Off-site decontamination using Dry Abrasive Method





Mobile Decont skid

Waste: Several m^3 of resins

Remote Decont' Equipment

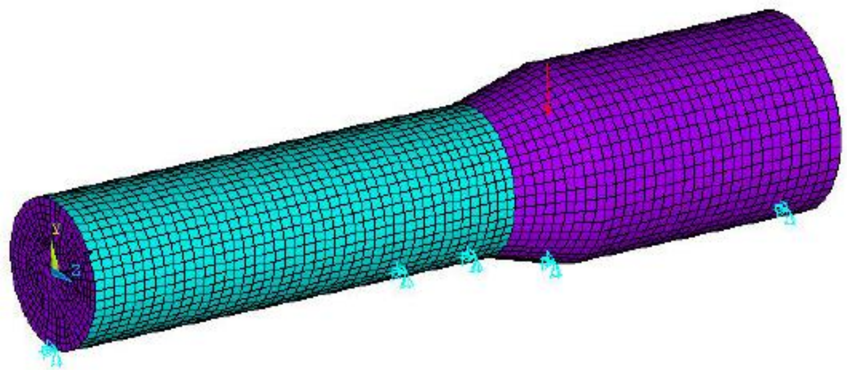
Waste: <<1m^3 metal-dust & oxides

Planning for off-site shipments

- Lifting and transport is routine experience for the heavy lift industry
- Feasibility studies are useful to increase customer confidence and dispel myths
  - Licensing and planning
  - On-site heavy handling
  - Transportation routes (road, sea, rail)
- Feasibility studies should also focus on stakeholder engagement
  - This can be a positive factor when managed proactively

For contamination values according to SCO-II or for special arrangements:

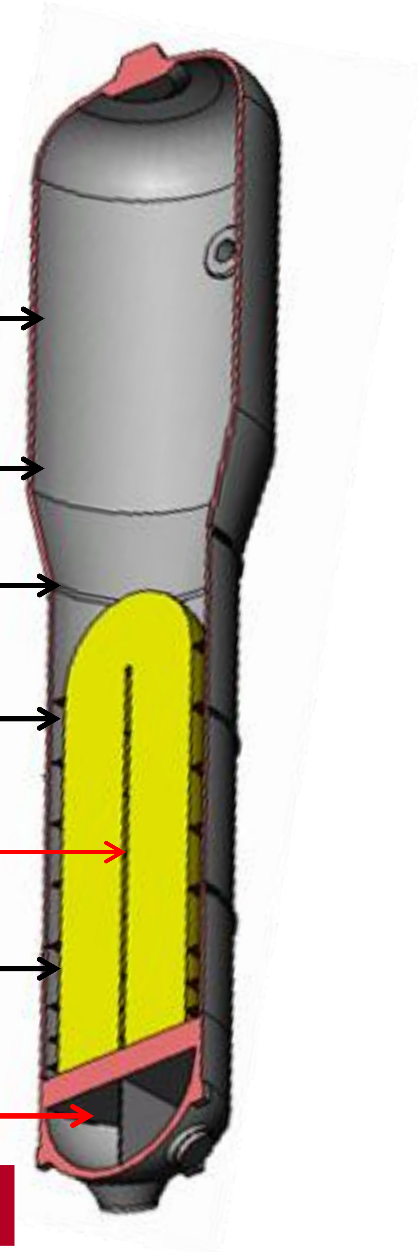
- IP2 classification of the goods itself is required
- Component design approval certificate is required
- Simulations of horizontal and sloped drop tests



Proven Experience of Transport

Treated Steam Generators in Studsvik - Radiology

After chemical decontam. mSv/h	
<0,001	
<0,001	
0,03	
0,1	
0,3	
0,02	
7	
0,1	**~TBq**

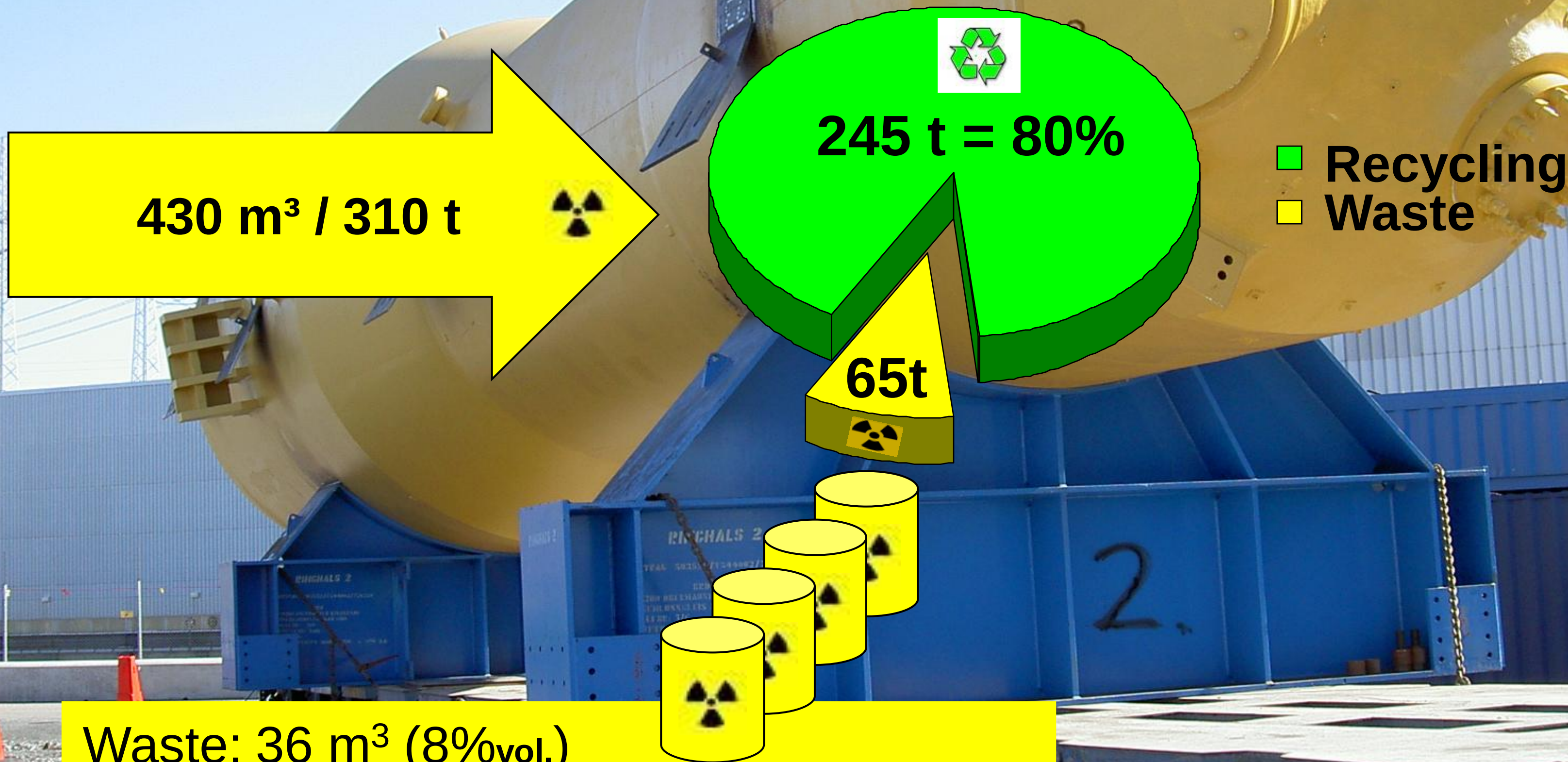


Treated Steam Generators in Studsvik – results, mean values

Steam Generators	Total	Volume, each SG			Weight, each SG			Dose/SG
	Treated units	Initial volume (m^3)	Waste for Final Storage (m^3 net)	Waste for Final Storage (% net)	Initial weight (Mg)	Recycling (Mg)	Recycling (%)	Collective dose (man mSv)

Steam Generator - results summary

Total treatment time of one 310 Mg Steam Generator: 8-12 weeks



Waste: 36 m³ (8%vol.)
- Slag, dust, blasting residues
- Melted/compacted tube bundle material

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Conclusion – Options for Steam Generator Decommissioning

- Radiological & technical data are important for efficient treatment
- On-site treatment in the containment is unproven and will be a logistical and radiological challenge, potentially extending decommissioning programmes & cost
- Treatment on-site eliminates transport but requires capital and a steep learning curve
- For all SG treatment options, prior decontamination supports efficient treatment and low collective-dose to the operators
- Several successful SG treatment projects have been demonstrated by Studsvik
- Recycling of SG metals up to 80% is possible, with waste volume reduction >90%
- Assuming direct disposal of whole SGs is not feasible, the Studsvik approach has the lowest disposal cost, lowest capital cost, fastest programme and best risk profile for the customer
- The number of SGs in future years means that knowledge-transfer to other local treatment sites will be required, as well as maximising the use of off-site treatment routes

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