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Intermediate Results from the Research Project SeeOff

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SeeOff

Strategieentwicklung zum effizienten Rückbau von Offshore-Windparks

Development of efficient strategies for offshore wind farm decommissioning

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

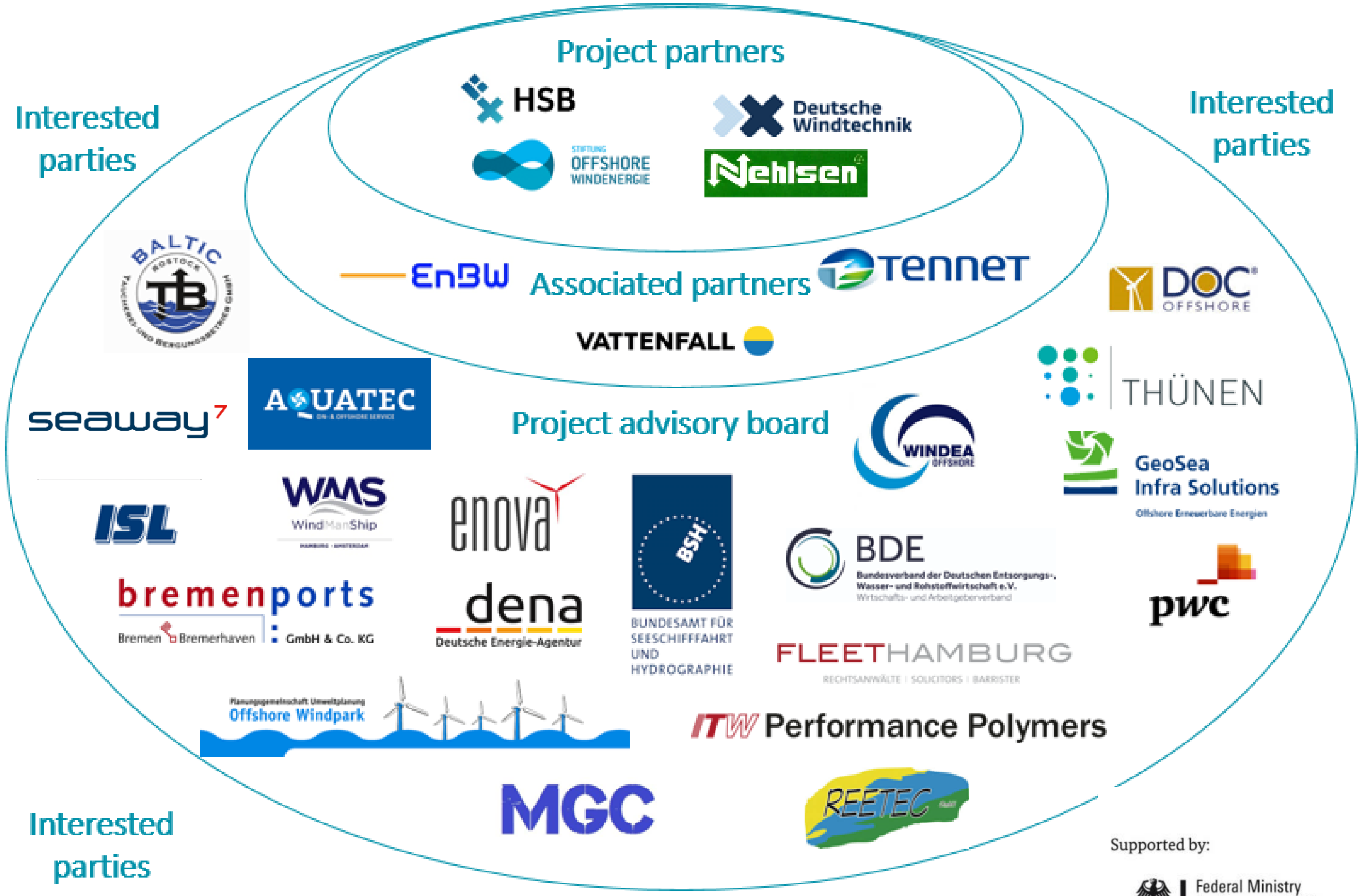
Agenda

- About our project
- The reference offshore windfarm
- Considered decommissioning scenarios
- Preview of intermediate results
  - campaign durations and high-level campaign plan
  - GHG emissions
  - Recycling rate
- Summary and Outlook

The Project SeeOff

SeeOff *Development of efficient strategies for offshore wind farm decommissioning*

- **Project duration:**
  3.5 years (November 1st 2018 – April 31st 2022)
- **Project coordination:** Prof. Dr.-Ing. Silke Eckardt
  City University of Applied Sciences Bremen
- **Project objectives**: Development and assessment of efficient **Decommissioning Strategies**
- **Strategies** shall
  - comply with **legal requirements**,
  - be **cost efficient**,
  - ensure **safety at work**,
  - ensure **environmental protection, low GHG emissions** and **resource efficiency**
  - be **publicly accepted**.



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SeeOff – Reference Offshore Wind Farm

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Turbine (WTG):	**80 x SWT 3.6 120**
Foundation (FOU):	**Transition Piece (TP) with grouted connection to Monopile (MP)** MP: 680 t, length 65 m, diameter max. 6m, wall thickness max. 126 mm; TP: 250 t, length of 27 m
Water Depth:	**between 20m and 30m**
Inter Array Cable (IAC):	**33kV (length approx. 100 km)**
Scour Protection:	**2 layer (Filter: 20 – 200 mm, Armour: 350 – 550 mm)**
Offshore Substation: (OSS)	**Weight approx. 3,000 t** **Jacket foundation, approx. 850 t**
Harbour:	**Bremerhaven (for a better comparability just one harbor assumed)**

System Boundary: 1. Reference offshore wind farm, incl. AC export cable connection to converter,
2. From dismantling/ decomissioning (offshore) to secondary raw material (onshore)

System Boundery - Process Overview

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1 Offshore Dismantling/Decommissioning

Area of responsibility: OWF

- 1.1 Dismantling of WTG
- 1.2 Dismantling of WTG foundation
- 1.3 Decommissioning of inter-array cable
- 1.4 Dismantling of OSS
- 1.5 Decommissioning of scour protection

2 Waste Management Onshore

2.1 Dismantling and preparation at the harbour

- 2.1.1 Pretreatment of rotor blades
- 2.1.2 Dismantling of nacelle
- 2.1.3 Dismantling of tower
- 2.1.4 Dismantling of WTG foundation
- 2.1.5 Dismantling of OSS foundation

[…]

2.2 Processing and disposal

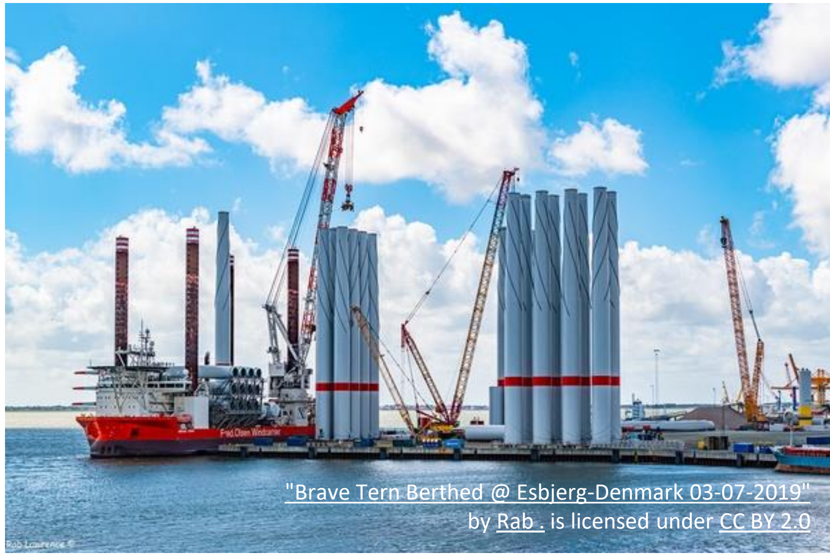
- 2.2.1 Processing of glassfibre reinforced plastics
- 2.2.2 Processing of carbonfibre reinforced plastics
- 2.2.3 Processing of metal scrap
- 2.2.4 Processing of cables
- 2.2.5 Processing of construction waste

[…]

Sekundärrohstoff

Wind Turbine Generator (WTG)

	Base Scenario WTG	Alternative Scenarios WTG
Concept	„Reverse Installation“ Dismantling in reverse installation order, interface is tower/TP flange	./.
Logistics	Jack-Up Vessel (JUV (WTG)) for both dismantling and transport	JUV (WTG) for dismantling; feeder vessel for transport (Deck Carrier) **(S1)**



SeeOff – Decommissioning Scenarios

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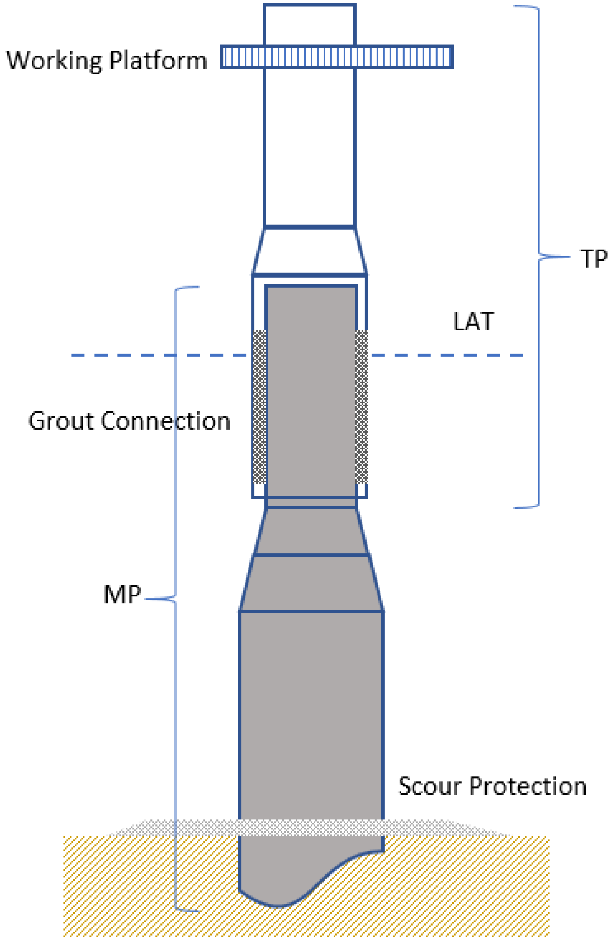
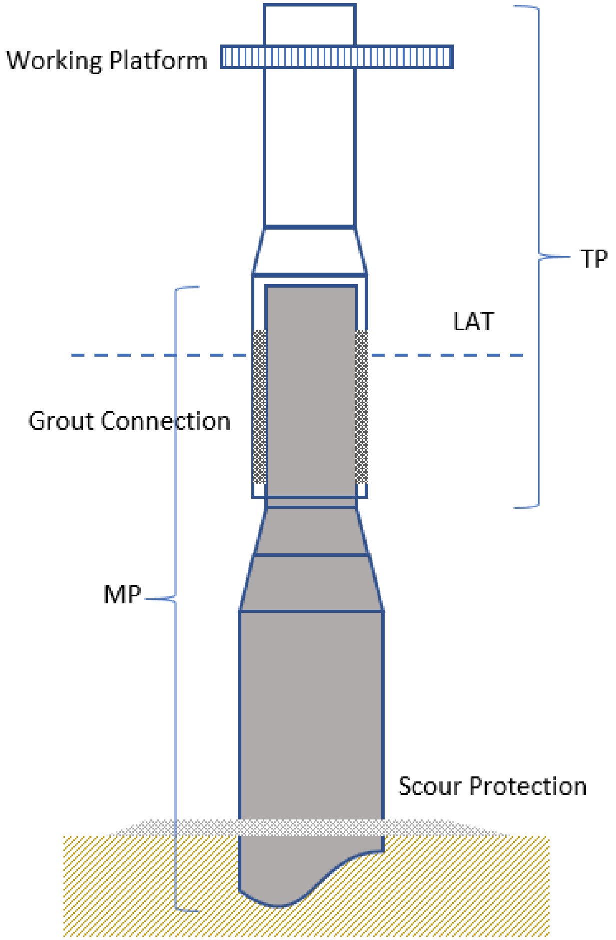
WTG-Foundation (WTG-FOU)

	Base Scenario WTG FOU	Alternative Scenarios WTG-FOU
Concept	**2 cuts:** First cut: internal cut below TP, Abrasive water jetting technology (AWJ) Second cut: MP internal cut, min. 1 m below seabed, AWJ technology,	**2 cuts:** First cut: internal cut below TP, AWJ technology Second cut: MP internal cut, 3-5m above seabed, AWJ technology, **Alternative** Second cut with diamond wire cutting machine (DWCM)
		One cut + Vibratory extraction (S8): cut below TP with AWJ; complete retrieval of MP by vibratory extraction
Logistics	Shuttle concept with JUV (WTG-FOU)	JUV (WTG-FOU) for dismantling, feeder vessel for transport (Deck Carrier) **(S2+3)**



Scour Protection

	Base Scenario Scour Protection	Alternative Scenarios Scour protection
Concept	Removal of stones with cable dredger	No removal of scour protection
Logistics	Multipurpose vessel with cable dredger (Cargo Barge for transport)	./.



SeeOff – Decommissioning Scenarios

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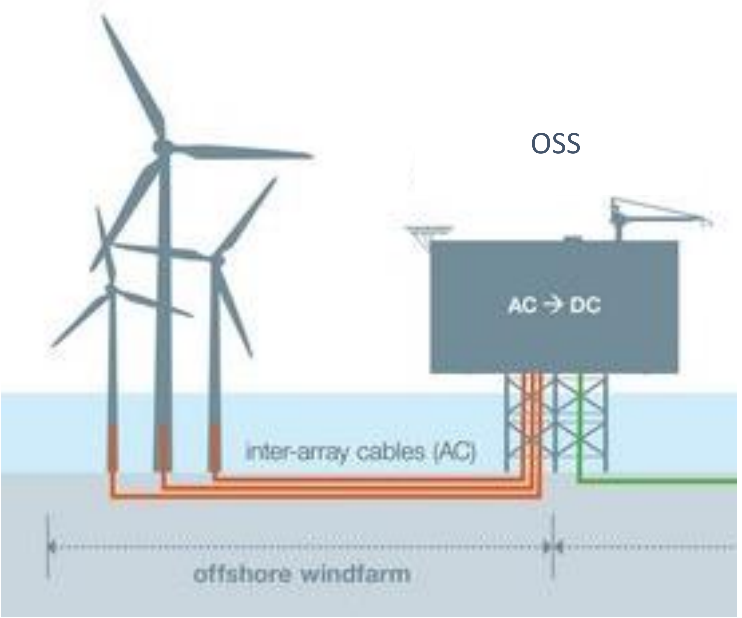
Inner Array Cable (IAC)

	Base Scenario IAC	Alternative Scenarios IAC
Concept	Complete removal of all cables	Removal of cables around FOU, burial of cable end and no removal of buried cables
Logistics	Walk to work (W2W) Vessel and Cable Lay Vessel	W2W Vessel and JUV (cable, support)



(Quelle: https://www.tennet.eu/news/detail/tennet-develops-innovative-submarine-cable-with-suppliers/)

Selection

1. Campaign Planning -> to estimate decommissioning project duration and duration of single campaigns as well as for cost simulation
2. Green House Gas (GHG) Emissions -> CO_2-Equivalents
3. Resource Efficiency -> Recovery Rate

Scenarios considered:

- Base scenario: WTG dismantling with JUV and „reverse installation"; Logistics: shuttle transport with JUV
- Scenario 3: dismantling as Base scenario; Logistics: Feeder concept with feeder vessels
- Scenario 8: complete removal of monopile foundation with vibratory extraction; logistics as base case

Assumptions

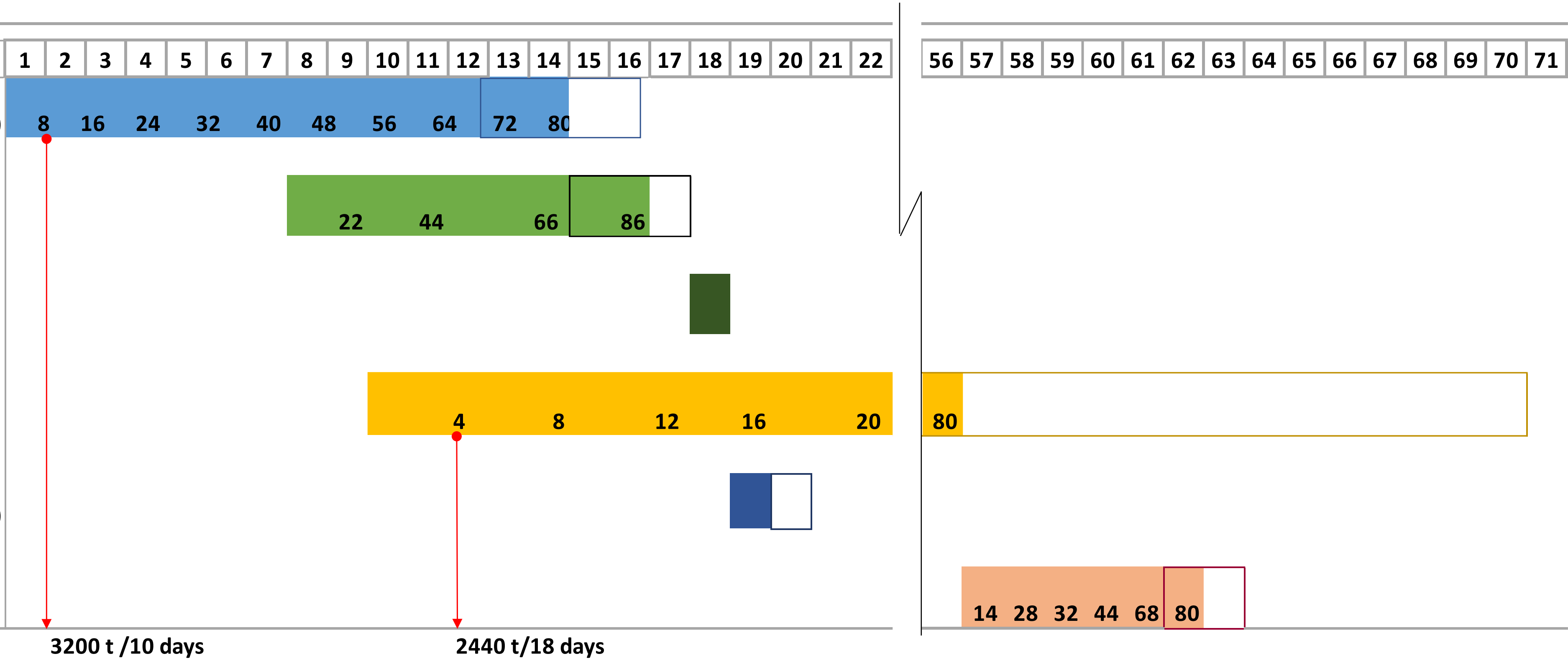
- Number of simultaneous processes at site (decom of WTG, IAC, FOU) are not limited
- Consideration of weather risks by means of safety factors on process durations depending on process activity type
- Consideration of process risks by using range in process activity durations

Base Scenario

Base Scenario

Process	Duration p.unit	Duration total
Dismantling WTG	1,1-1,5 d	14,5 w (12-16)
Removal of IAC	0,6-0,9 d	8,6 w (7-10)
Removal of export cable	3-4 d	1 w (0,8-1,1)
Dismantling Foundation	2,8-5,3 d	46 w (32-60)
Dismantling OSS	8,6-13,3 d	1,6 w (1,2-1,9)
Removal of Scour protection	0,5-0,6 d	6 w (5,3-6,5)

∑ Weight landing at port in tmax



SeeOff – Campaign Planning (offshore activities)

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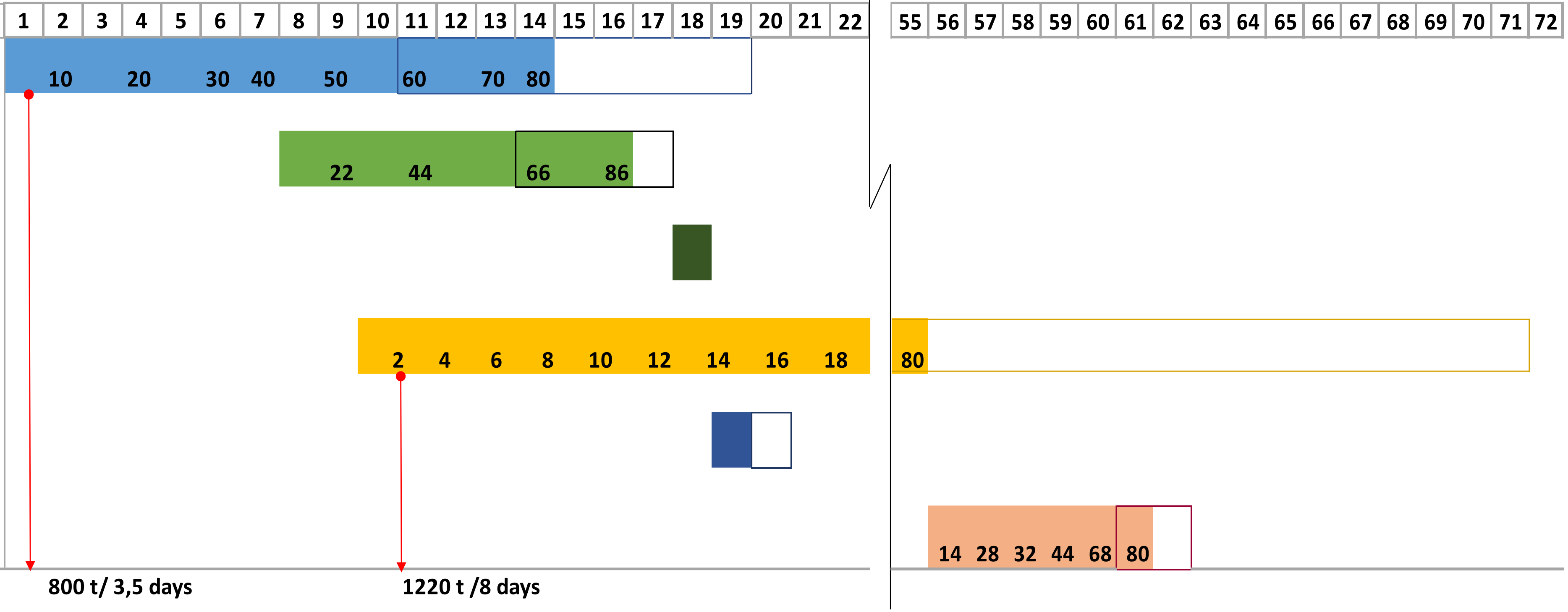
Scenario 3: as Base Szenario; logistics: Feeder concept with feeder vessels

S3: Decommissioning of WTG and FOU with feeder concept

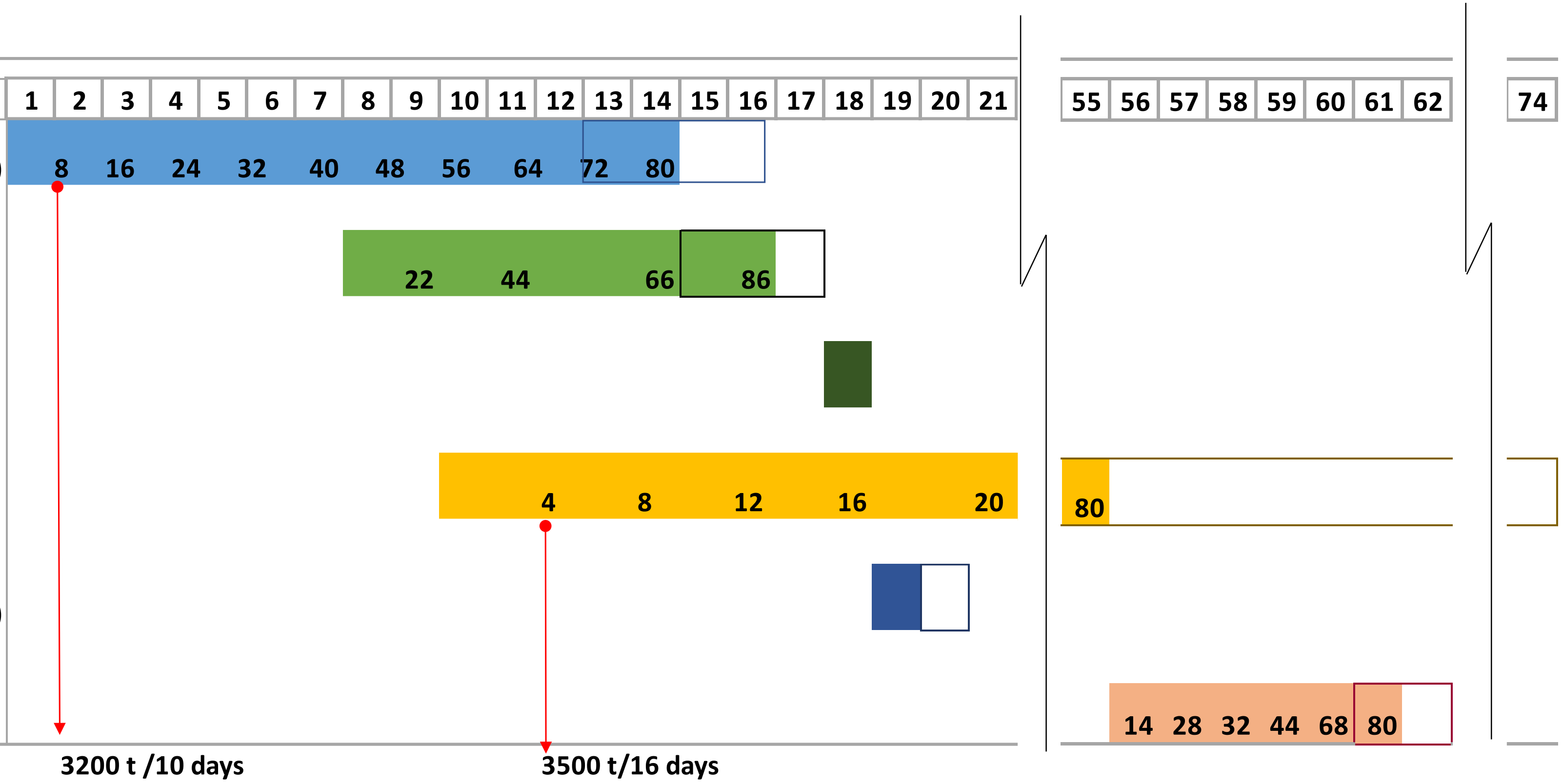
Process	Duration p.unit	Duration total
Dismantling WTG	0,9-1,7 d	14 w (11-20)
Removal of IAC	0,6-0,9 d	8,6 w (7-10)
Removal of export cables	3-4 d	1 w (0,8-1,1)
Dismantling Foundation	2,7-5,3 d	45 w (31-61)
Dismantling OSS	7,5-12 d	1,4 w (1,1-1,7)
Removal of Scour protection	0,5-0,6 d	6 w (5,3-6,5)
∑ Weight landing at port in tmax		



Scenario 8: complete removal of monopile foundation with vibratory extraction

S8 - Complete removal of monopile

Process	Duration p.unit	Duration total
Dismantling WTG	1,1-1,5 d	14,5 w (12-16)
Removal of IAC	0,6-0,9 d	8,6 w (7-10)
Removal of export cables	3-4 d	1 w (0,8-1,1)
Dismantling Foundation	2,3-5,7 d	46 w (26-65)
Dismantling OSS	7,5-12 d	1,4 w (1,1-1,7)
Removal of Scour protection	0,5-0,6 d	6 w (5,3-6,5)



∑ Weight landing at port in tmax

Conclusion

- Similar overall project duration (process durations of the individual campaigns varies only slightly): approx. 60 to 70 weeks
- But: higher uncertainty regarding process durations for removal of monopile foundation with vibratory extraction
- Only small time reduction with feeder concept due to relatively short distance to shore (110nm)
- The process sequence must be coordinated with the dismantling capacities (cranes, storage areas, dismantling resources, etc.) at the port

Calculation of CO_2-Equivalents of the vessels

based on

- Vessel fuel consumption (at transit, operation, standby)
- Fuel type (Marine Gas Oil, Heavy Fuel Oil)
- Duration of the fuel consumption

Conversion factors for MGO and HFO derive from UK Government Conversion Factors for greenhouse gas (GHG) reporting (2021)

Global warming potential (GWP_{100}) of the Intergovernmental Panel on Climate Change (IPCC) were applied to calculate CO_2-Equivaltents (Stocker et al. 2013)

Pollutant	GWP_{100} in kg CO_2-eq/kg
CO_2	1
CH_4	28
N_2O	265

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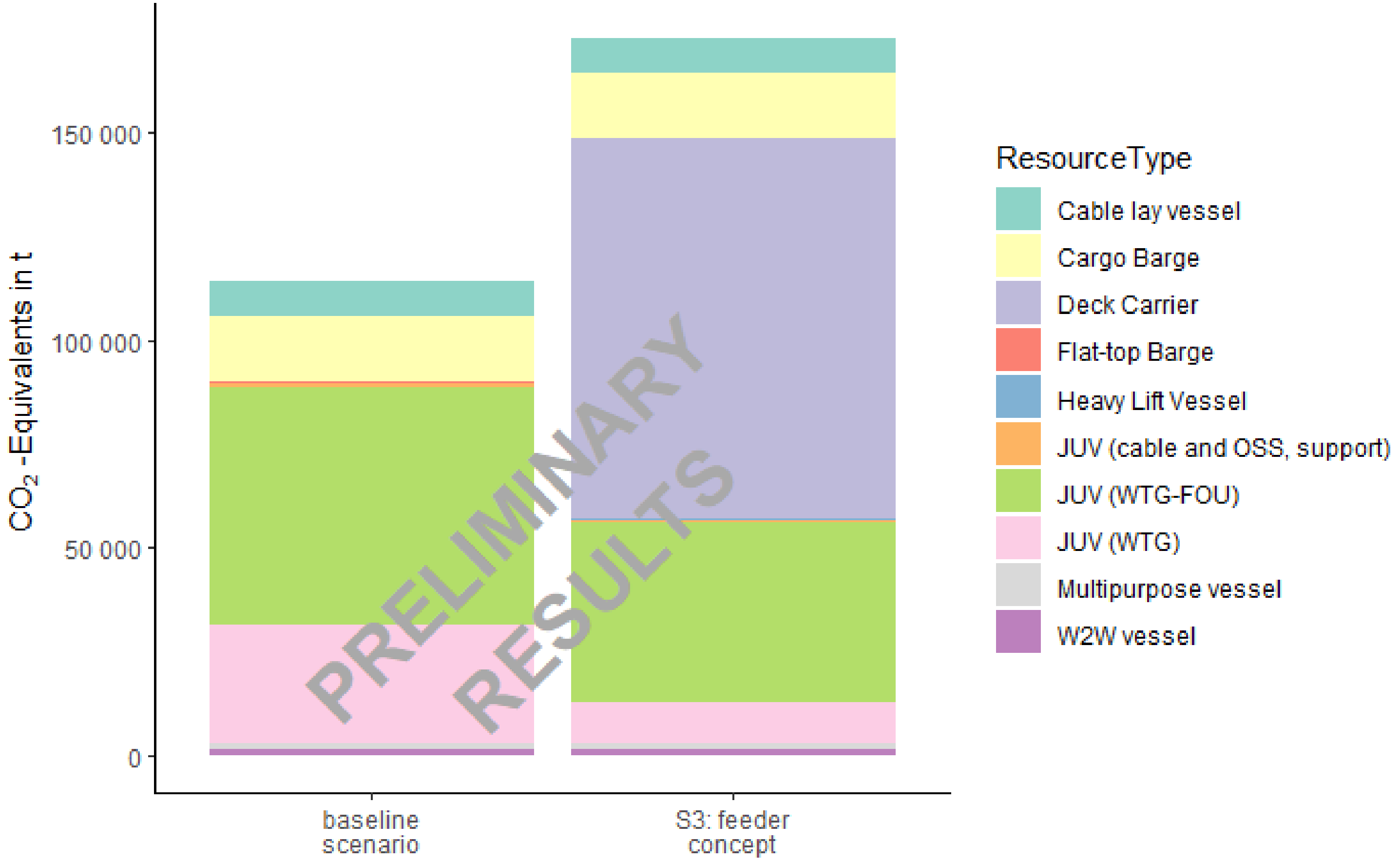
Mean CO_2-Equivalents of the vessels

Baseline scenario:
113 857 t CO_2-Equivalents

Scenario 3 (Feeder concept):
172 290 t CO_2-Equivalents

Vessel	Baseline scenario	S3: feeder concept
JUV (WTG)	28 333 t	9 776 t
JUV (WTG-FOU)	57 045 t	4 2878 t
Deck Carrier	---	91 127 t



Resource Efficiency

Calculation of recovery rate based on recovery rate of construction and demolition waste (2011/753/EU):

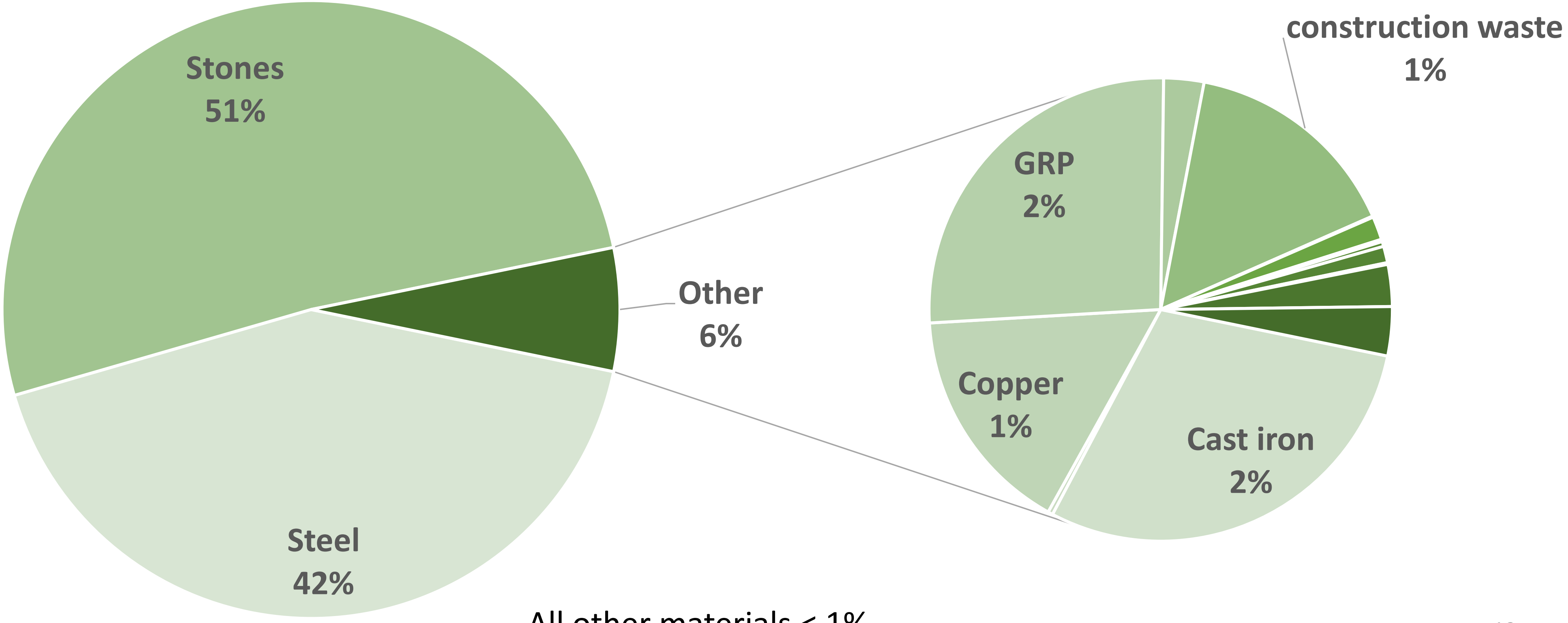
$$\text{Recovery rate of construction and demolition waste, in \%} = \frac{\text{Materially recovered amount of construction and demolition waste}}{\text{Total amount of generated construction and demolition waste}}$$

- Only construction and demolition waste brought ashore is considered
- Assumption: all materials and components are disposed

  → no reuse

Mass balance of reference offshore wind farm

Overall mass: 228 171 t



All other materials < 1%

Resource Efficiency

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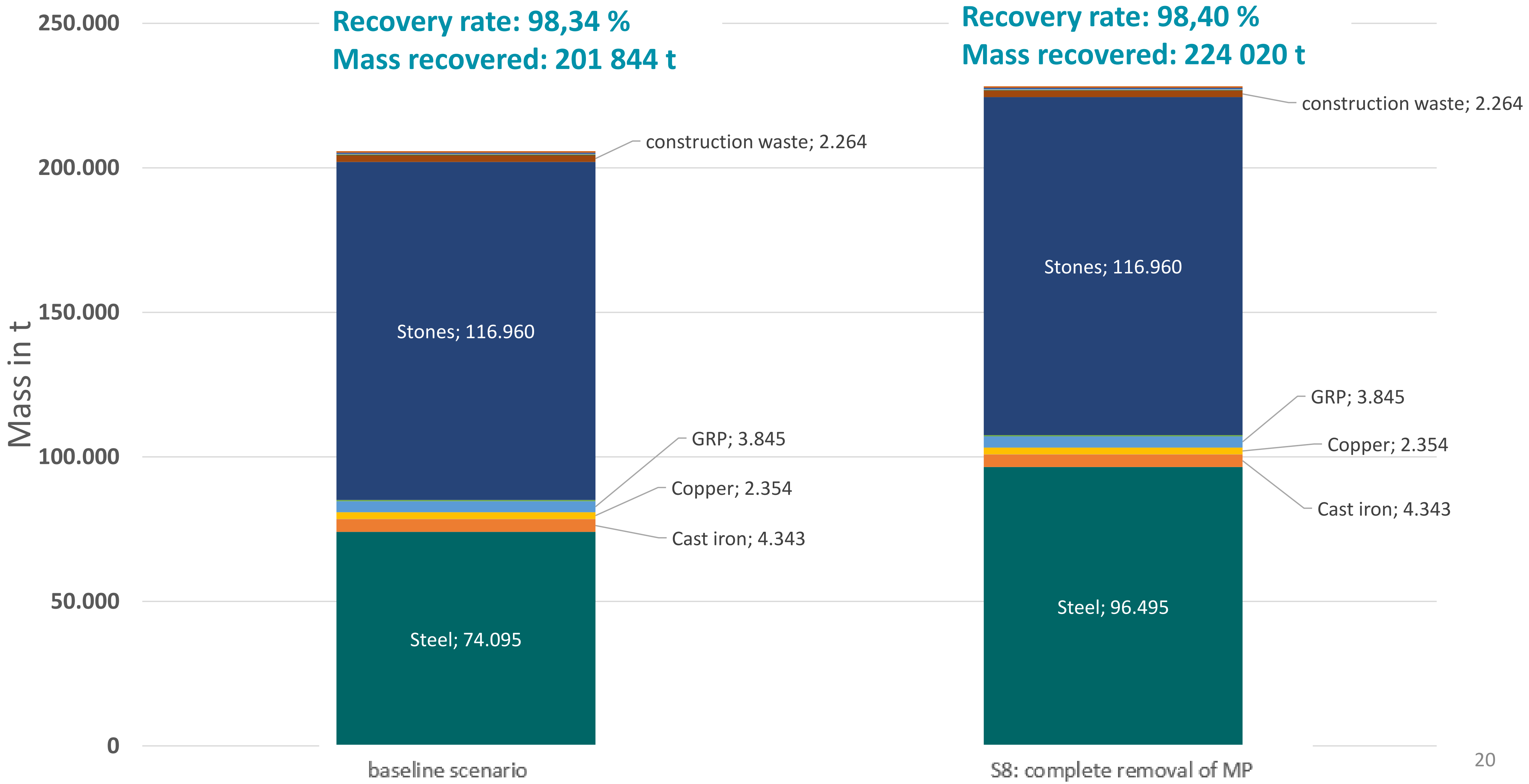

Summary and Outlook

- Durations vary only slightly between scenarios
- Vessel concept (shuttle vs. feeder concept) influences GHG emissions
- Complete removal of MP has only minor impact on overall recovery rate, but influences the amount of overall materials that will be recovered

→ Remaining indicators for costs, biodiversity and safety at work will be calculated

→ Indicators will be calculated for all scenarios

→ Results of individual indicator calculation are assessed in a multicriteria decision analysis

→ **Sustainable offshore wind farm decommissioning scenarios**

…. more Information on our website www.seeoff.de

1. Workshop and Conferences

- Workshop: Decommissioning of Offshore Wind Farms: Requirements, Objectives and Challenges, September 19th 2019
- Expert-Workshop: Scope of Offshore Wind Farm Decommissioning – Impacts on the marine environment, April 23rd 2021
- SeeOff Conference on Technologies for Offshore Wind Decommissioning, June 10th 2021

2. Presentations and Paper

- Zukunft Offshore Konferenz des Bundesverbands der Windparkbetreiber Offshore e.V. (BWO), April 3rd 2020, Berlin
- Offshore Decommissioning Congress, September 16th 2020
- End of Life Issues and Strategies Seminar, WindEurope, November 18th -20th 2020
- International Conference on The Decommissioning of Offshore & Subsea Structures DECOM 2020, December 07th - 08th 2020
- Wind Energy Science Conference, May 25th – 28th 2021
- Spielmann et al., 2021. Integration of sustainability, stakeholder and process approaches for sustainable offshore wind farm decommissioning. Renewable and Sustainable Energy Reviews, 147.

Thank you very much for your attention

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- UK Government Department for Business, Energy & Industrial Strategy (Hg.) (2021): UK Government GHG Conversion Factors for Company Reporting. conversion factors 2021: advanced set (for advanced users). https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2021 [Zugriff: 2021/08/24].