Offshore Windfarms: Status and life cycle assessment of alpha ventus

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- **Present status of offshore wind energy use**
- **Cumulated energy and ecobalances**
- **Results of the wind park alpha ventus**
- **New developments**

Structure of my presentation

- **Present status of offshore wind energy use**
- **Cumulated energy and ecobalances**
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Structure of my presentation

Enercon 16 – December 1987 (Norddeich/Germany), 55 kW power

Source: Eilert Voß, Archiv Wattenrat

Beginning of wind use – Germany 1987

Wind energy use worldwide (values rounded)		
	Rated Capacity [GW]	Share worldwide [%]
	2019	2019
China	236,40	36,3
USA	105,57	16,2
Germany	61,4	9,4
India	37,51	5,8
United Kingdom	23,34	3,6
France	16,64	2,6
Brazil	15,45	2,4
Canada	13,41	2,1
Sweden	8,8	1,4
Remaining countries	132,12	20
total	**~ 651**	**~ 100**

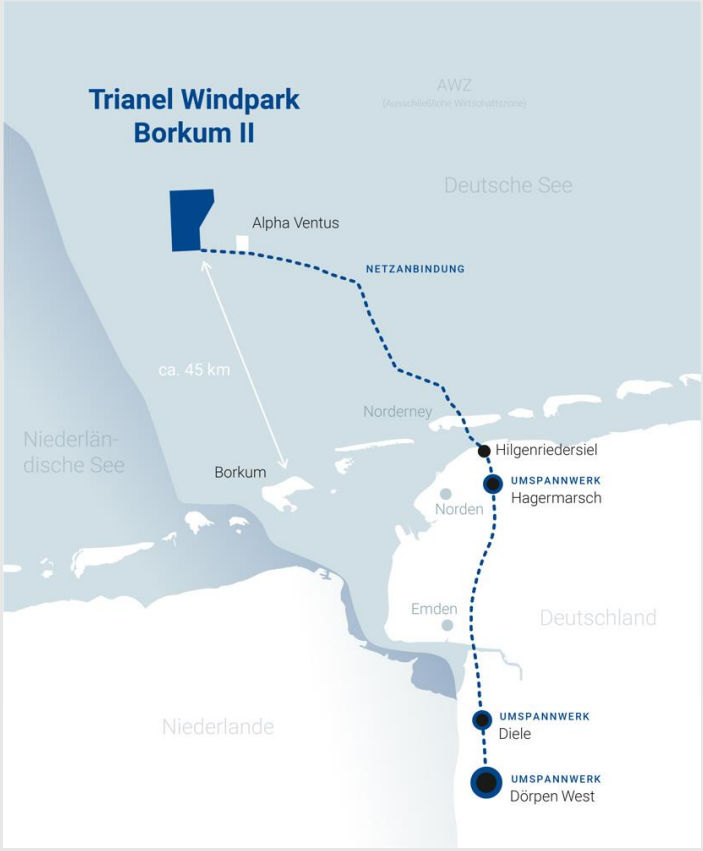
In 2021 4 GW of offshore wind power will be added across europe – in Germany only 3,1 GW by 2025.

Germany detailed: ~ 53 GW & Onshore ~ 8 GW Offshore (2019)

Compared to Germany in 2003: only 14,6 GW Onshore

Sources: https://www.volker-quaschning.de/datserv/windinst/index.php

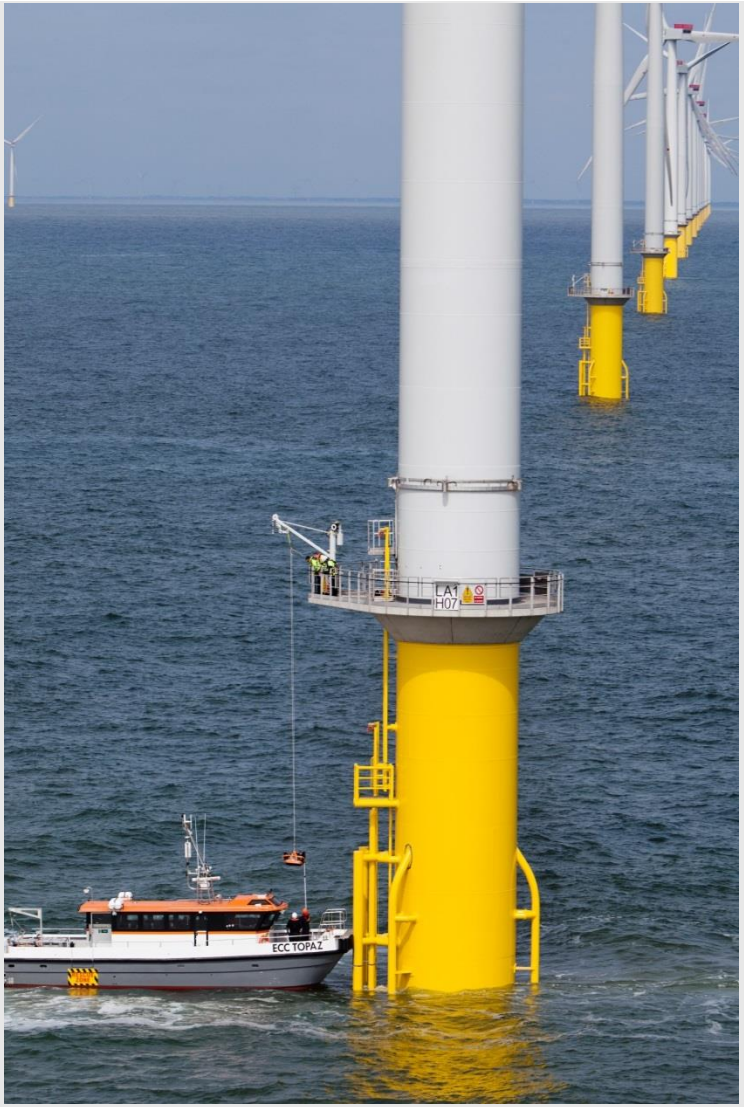
Worldwide wind use – present status



Source of the graphic: Trianel Windpark Borkum II
https://www.trianel-borkumzwei.de/

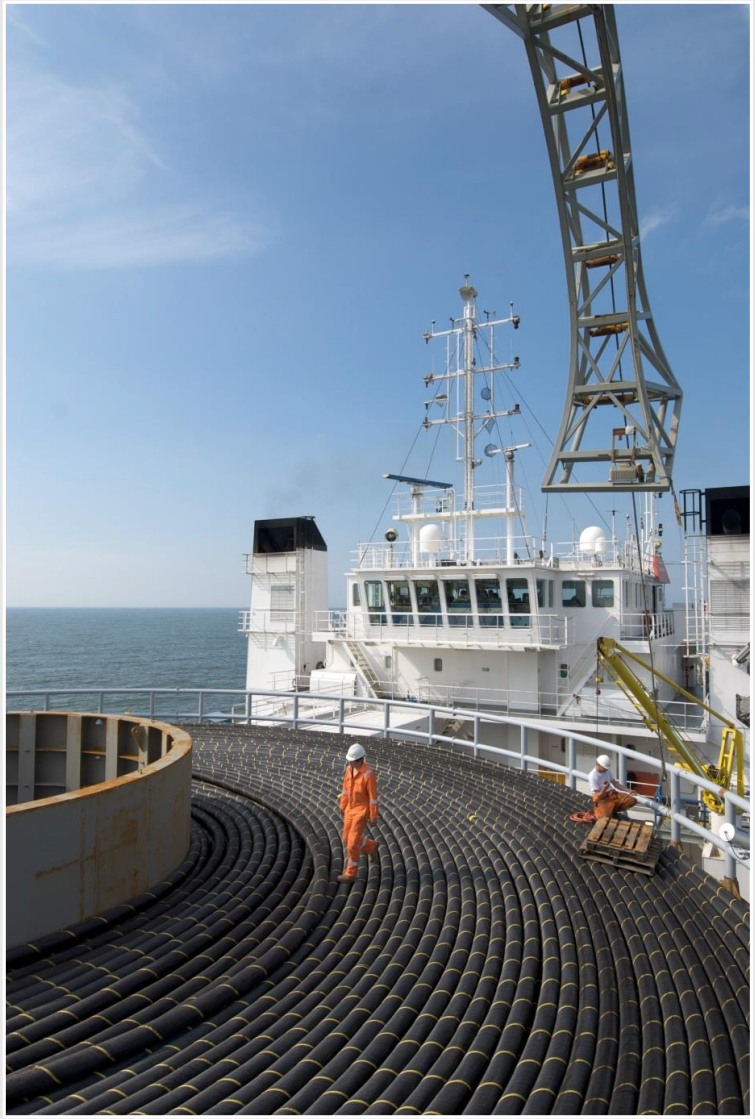
Location of „Windpark Borkum II“ of the „Trianel“ company and „alpha ventus“ at the north sea

Source: http://www.siemens.com/press/pool/de/pressebilder/2013/photonews/300dpi/PN201308/PN201308-04_300dpi.jpg



Source: http://www.siemens.com/press/pool/de/pressebilder/2013/photonews/300dpi/PN201308/PN201308-05_300dpi.jpg

Offshore windpark, transformer station and entrance



Sources: Tennetso, entnommen aus: VDI Ingenieurforum, Ausgabe 2/2012

Laying DC/AC cables at the sea

Source: „Energiewende: Festland-Konkurrenz hängt Offshore-Windparks ab“; Spiegel Online; http://www.spiegel.de/wirtschaft/soziales/Offshore-windparks-verlieren-an-windraeder-an-land-a-889943.html; 21.03.2013

Offshore wind park „Bard 1“

Source: Helmut Müller; Sonne, Wind und Wärme 4/2012

Improvement of protection against corrosion

- Present status of offshore wind energy use
- **Cumulated energy and ecobalances**
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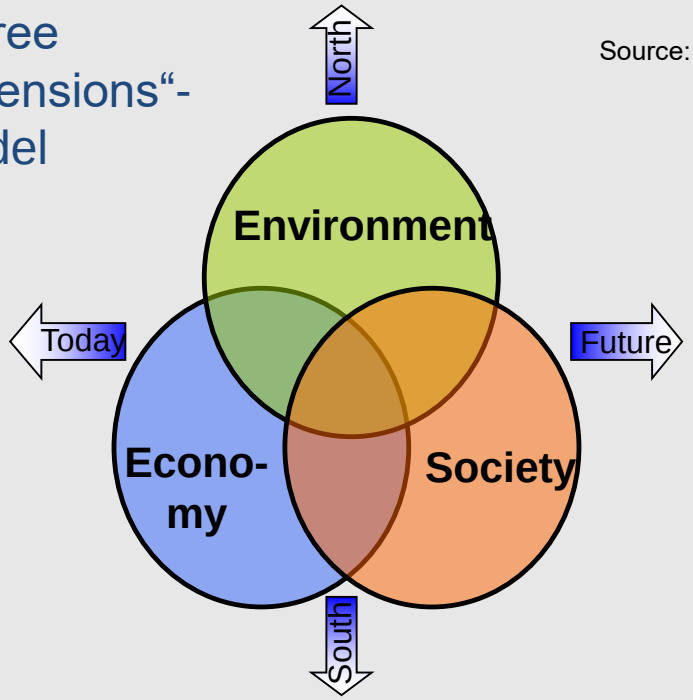
Structure of my presentation

Sustainability approach and models

"Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

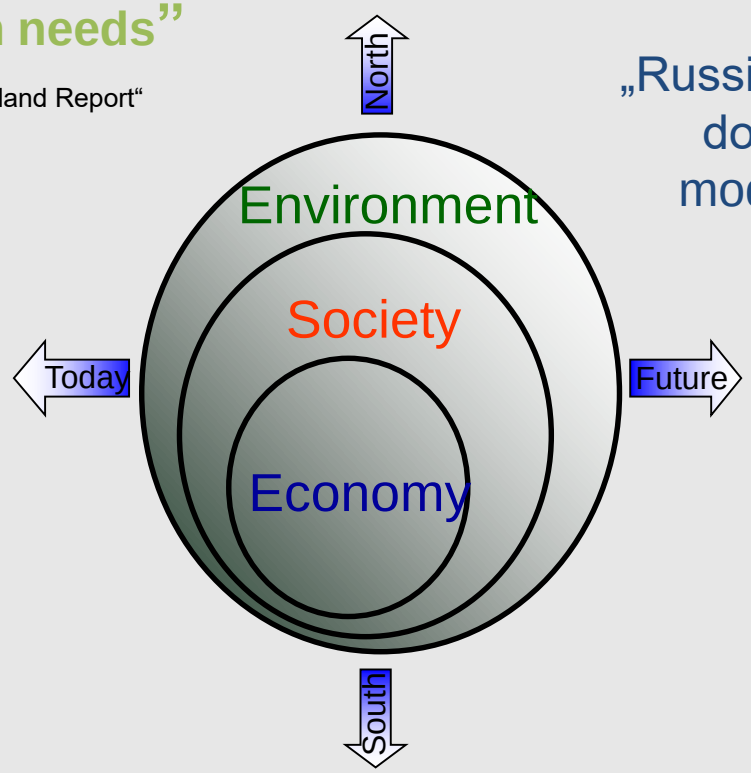
Source: UN 1987 „Brundtland Report"

„Three dimensions"-model

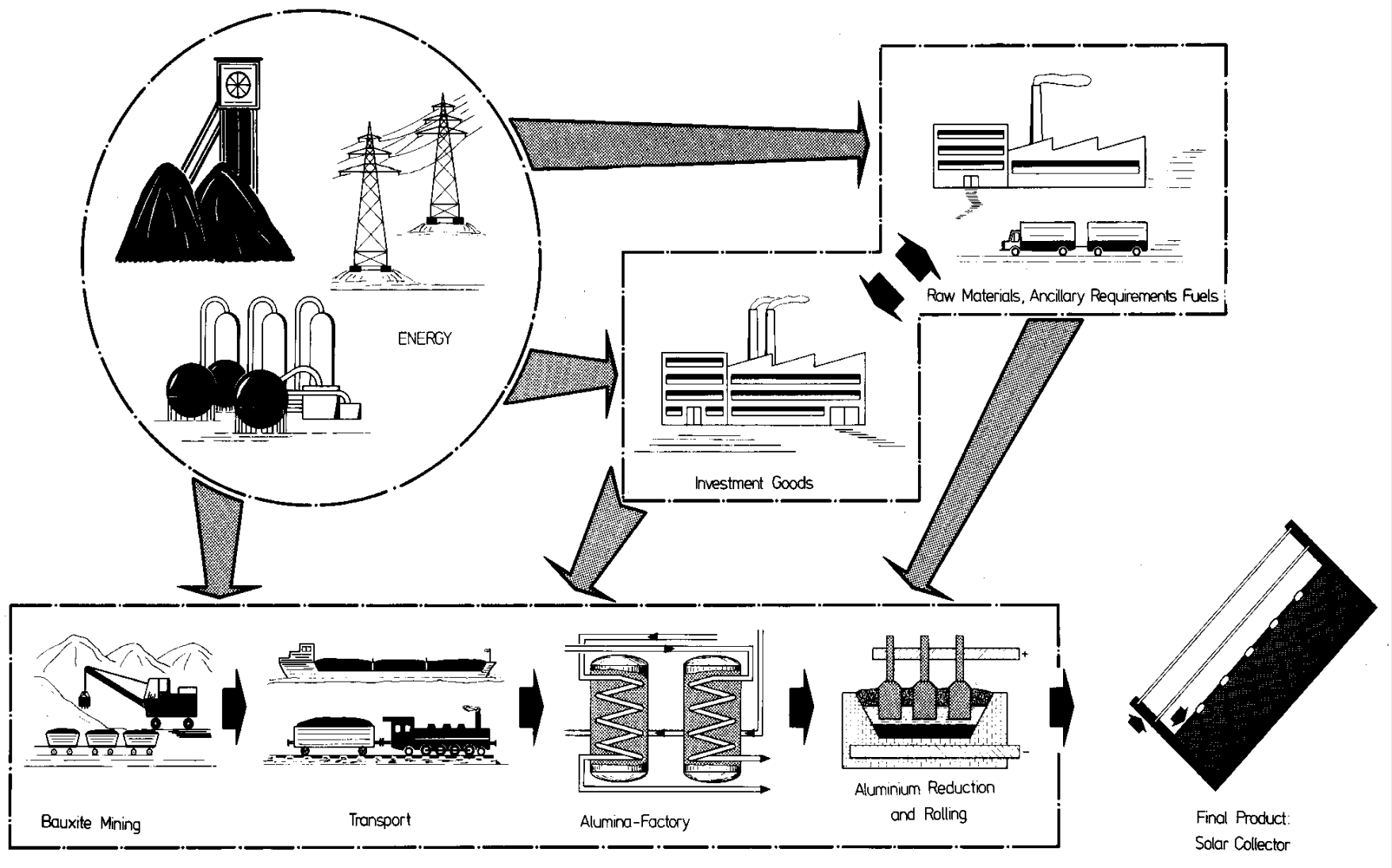


source: SIA 2000, modified

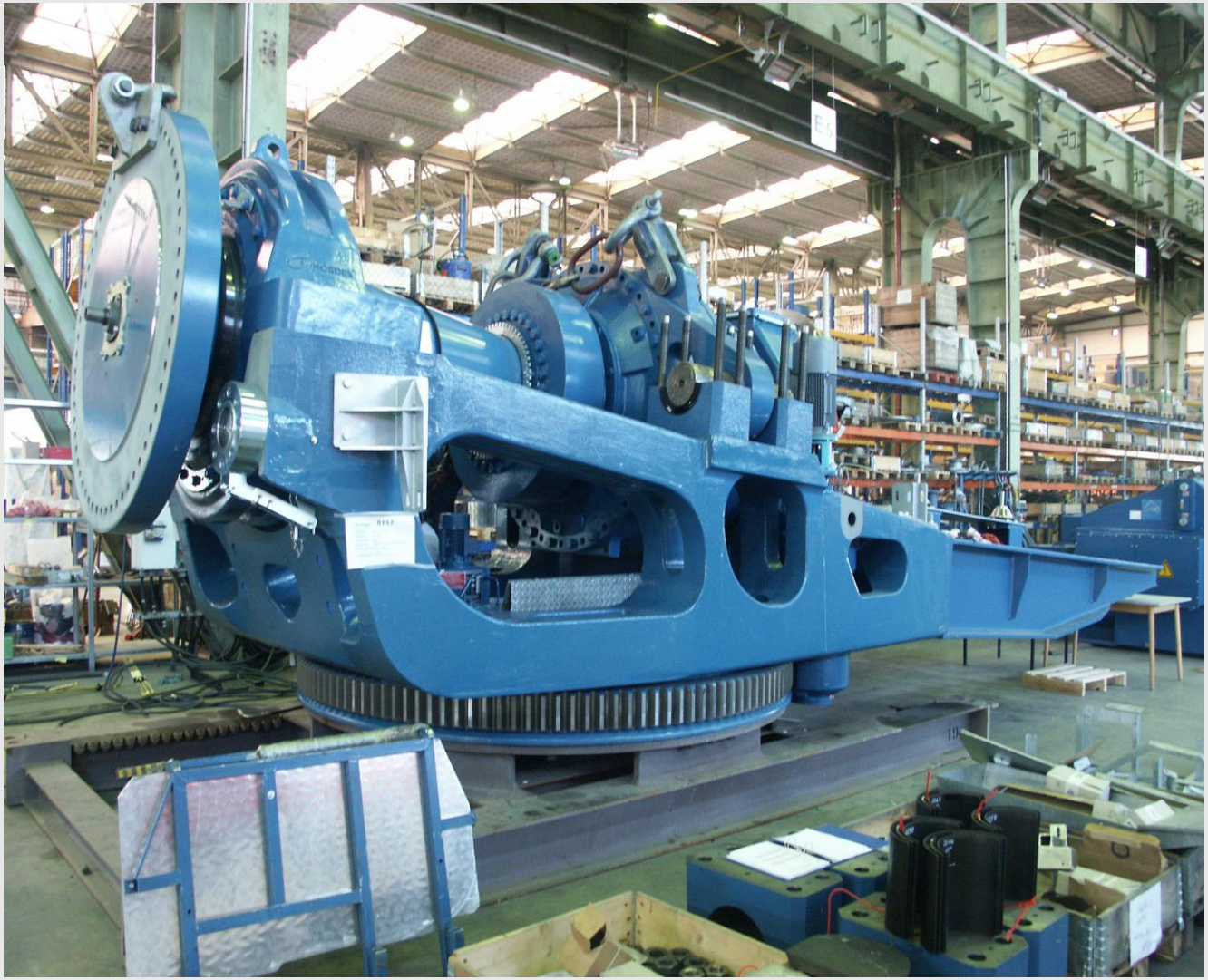
„Russian doll"-model



source: Levett 1999, modified



Example of Process-Chain-Analysis



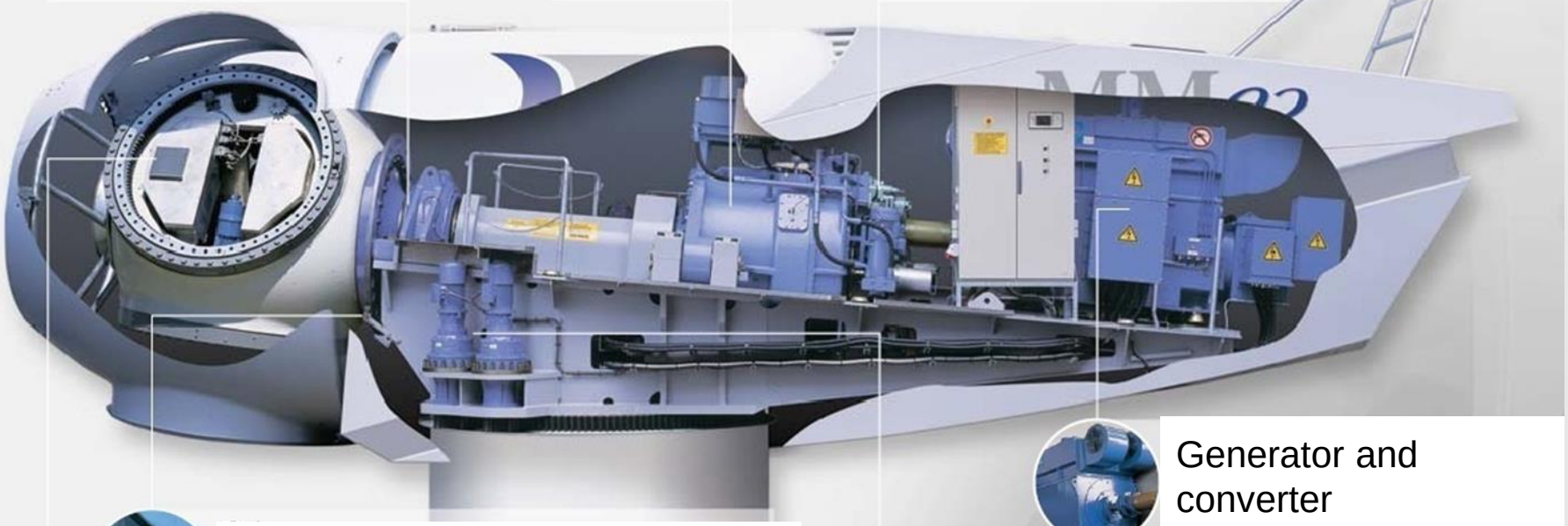
Source: Nordex AG

Assembling of a wind converter by Nordex AG

Rotor bearing / rotor shaft

Gearbox

Holding brake

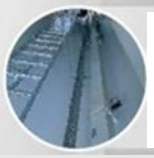


Generator and converter

Protection against lightning strikes

Azimuth constellation

Pitch system and rotor hub



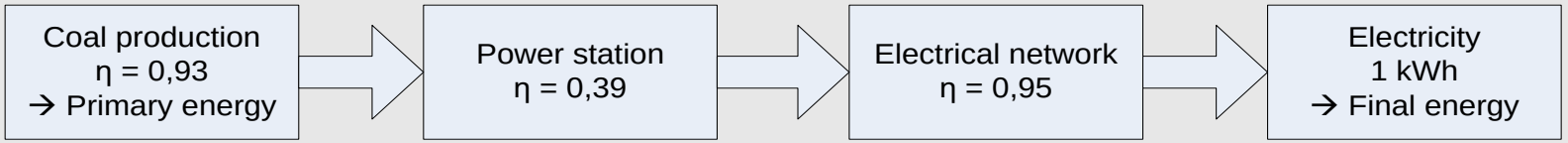
Conductor rail and tower

Nacelle of a 2 MW wind turbine with gearbox (by Repower Systems)

Example: Overall Efficiencies of Supply for final energy carrier

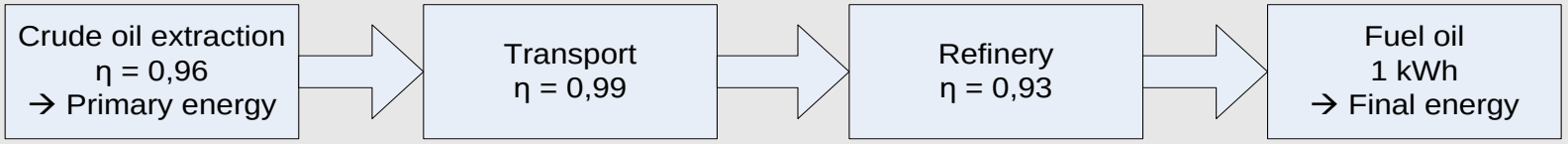
- Problem: different forms of energy must be made comparable.

  ↳ Electricity, oil-products, etc. are count back on primary energy with typical (country-specific) process chains.



- The primary energy equivalent of electricity is 2,90 kWh (Overall Efficiencies of Supply g_{el}).

  Overall Efficiencies of Supply: $g_{Electricity} = \frac{1}{\eta_{total\ about\ chain}}$



- The primary energy equivalent of oil is 1,13 kWh (Overall Efficiencies of Supply g_{oil}).

Comment:
If there are enough information, you can devide the primary energy equivalent in a fossil, regenerative and nuclear share.

Process chain for final energy carrier

Effect-Class	Massflow	Effect Indicator (load factor)
Energy resource	Energy consumption	All forms of energy count back on primary energy equivalent (CED); if possible differentiate between fossil, nuclear & renewable
Water- and Air-Pollution	Pollutants in effluents and air	Critical Volume (Emission devided by critical value = „dilutionsvolume“)
Waste volume	Solid waste	Volume, subdivided into default classes e.g. solids dump, domestic waste dump, hazardous waste dump
Greenhouse effect	Climate-damaging gases e.g. CO_2, N_2O, CFC	Conversion by Global-Warming-Potential-Factors (GWP) into CO_2-Equivalent
Ozone depletion	CFC	Conversion by Ozone-Depleting-Potential-Factors (ODP) on R11
Photooxidants	Gases, which add to photochemical ozone production (CO, NO, NO_2, C_xH_y)	Conversion by Effect-factors on kg ethylene (C_2H_4)-equivalent (POCP)

Possible effect-classes and – indicators in Life Cycle Analysis (1)

Effect-Class	Massflow	Effect Indicator (load factor)
Soil acidification	Air emissions, which add to acidification	Conversion of emissions (SO_2, NO_x, NH_3, O_3) by effect-factors into kg-sulfur dioxide (SO_2)-equivalent (AP). The disposal potential of H^+-ionic is used as reference.
Eutrophication	Fertilizing emissions in water, soil and air	Conversion by effect-factors into kg-phosphate (PO_4)-equivalent (EP)
Humantoxicity	Emissions with effects on human health	Conversion by effect-factors into equivalent number kg-bodyweight (amount pollutant [kg] devided by toxicological limit [mg/kg]) (HTP) The limits are different between the absorption by water, air und foodstuff Problem: resilient numbers for limits
Ecotoxicity	Emission with effects on the stability of ecosystems	Analog humantoxicity with equivalent number kg-soil/water Problem: resilient numbers for limits

Possible effect-classes and – indicators in Life-Cycle Analysis (2)

- Present status of offshore wind energy use
- Cumulated energy and ecobalances
- **Results of the wind park alpha ventus**
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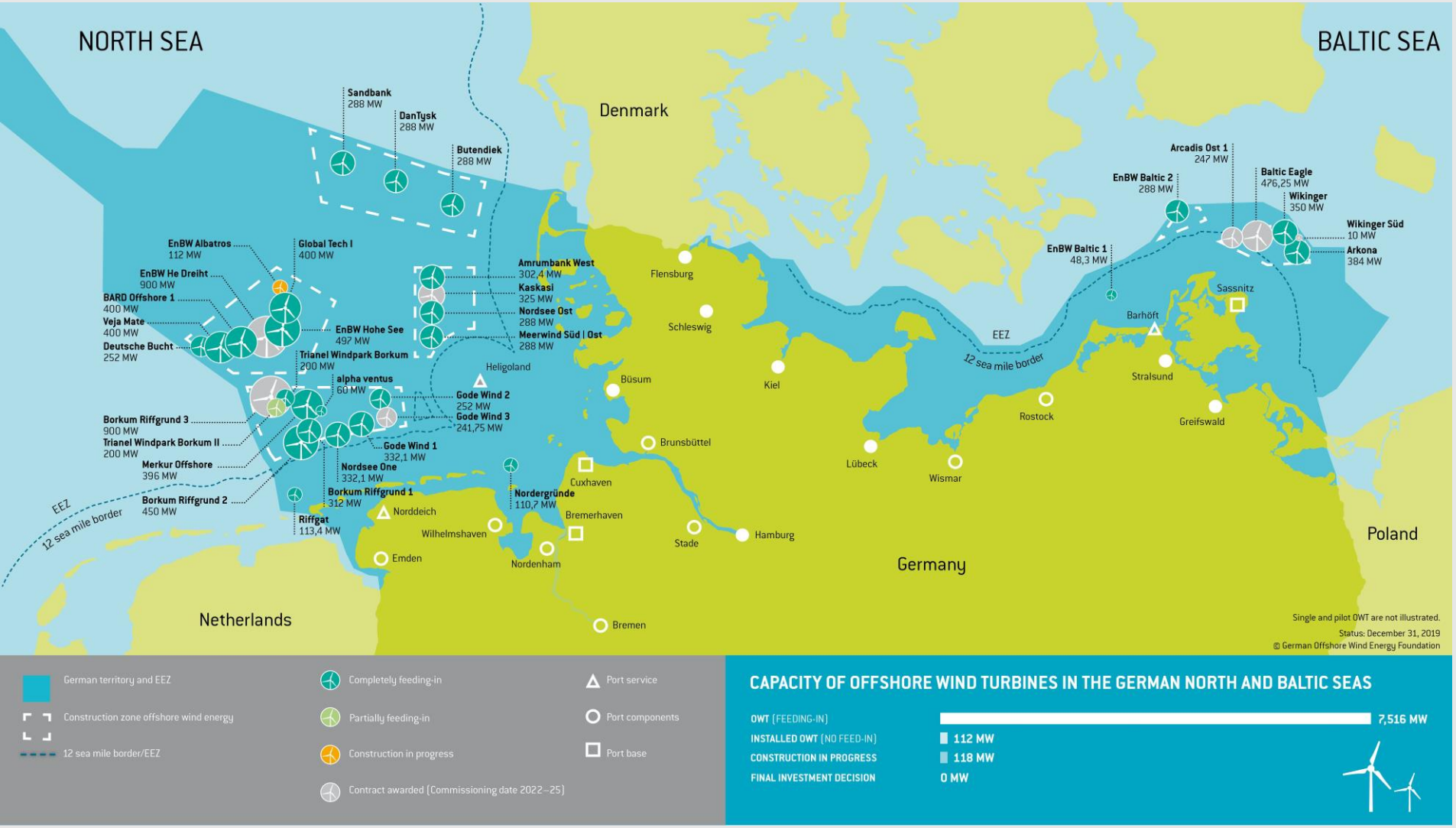
Structure of my presentation



Source: https://www.offshore-stiftung.de/en/media-library

Offshore wind energy in Germany in 2019

Panorama of wind park alpha ventus

- **12 Wind energy converter, each 5 MW**
- **Operation time 20 years**
- **Lifetime foundation 20 years**
- **Capacity Factor 45% (load duration 3900 h/a):**

  incl. maintenance- and failure times, power consumption of WEC and transmission platform inside wind park

- **Maintenance and services:**

  Change of 1/2 gearbox per station and operation time

  Change of 1,25 rotor blades per station and operation time

  120 helicopter transports per year for the wind park

  180 ship transports per year for the wind park

BMU-Forschungsplattform FINO 1, © Germanischer Lloyd

Life Cycle Analysis wind park alpha ventus: Reference system

Photo:. Große Böckmann

Tripod of wind park alpha ventus

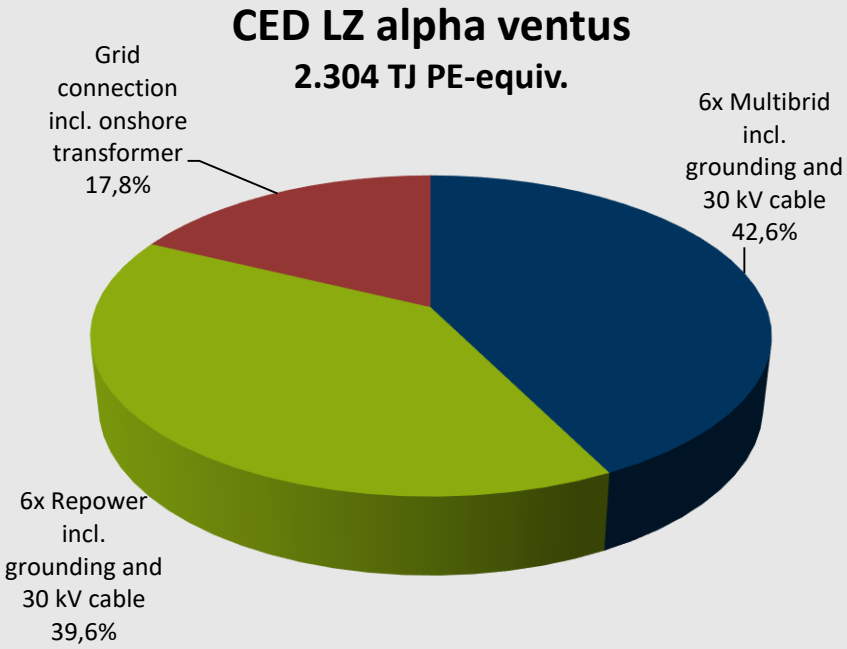
Transporting a Tripod

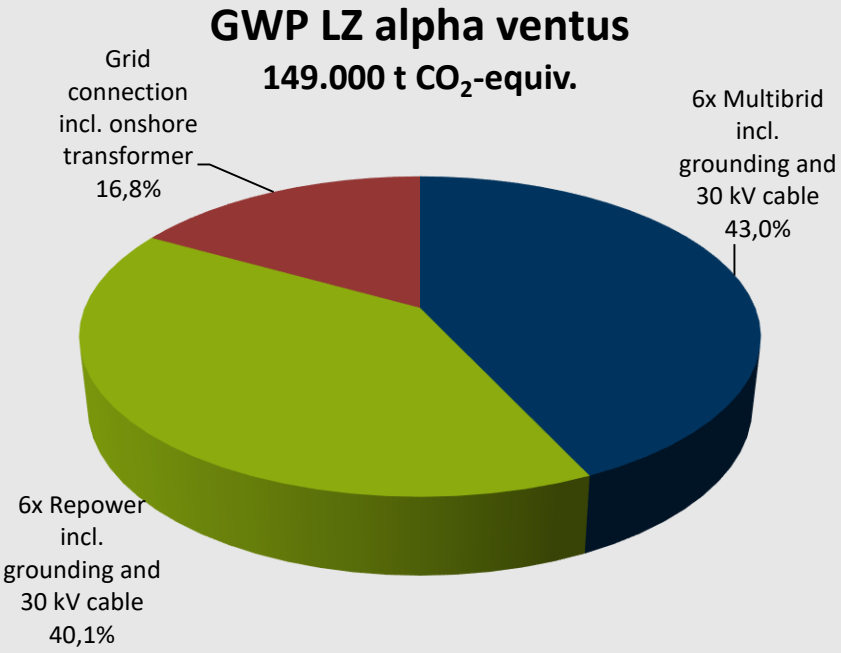
Jackets of wind park alpha ventus

Montage of a cabin – wind park „alpha ventus“

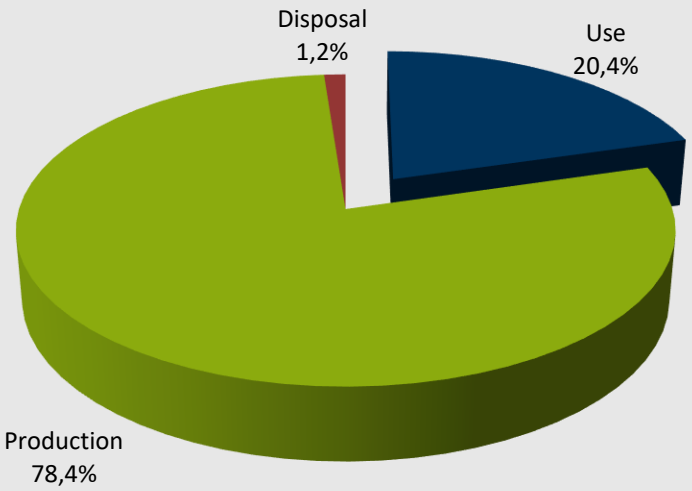
Results wind farm alpha ventus

CED and GWP – Life cycle – by elements

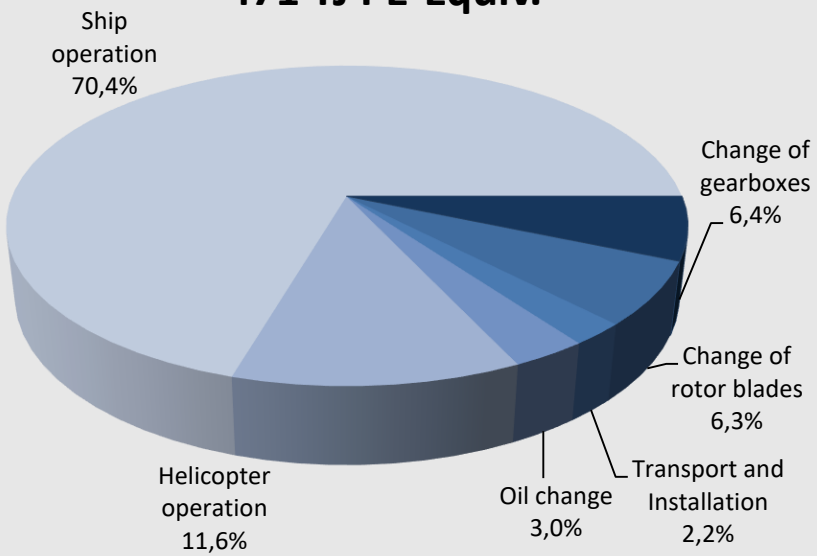




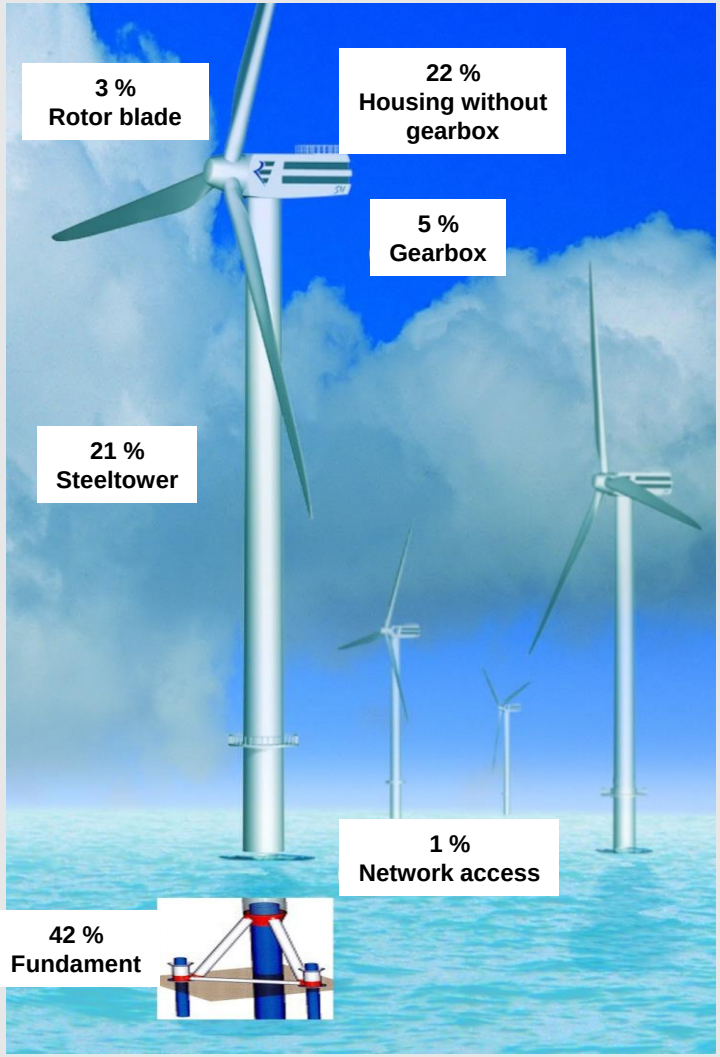
CED over life cycle alpha ventus
2.304 TJ PE-Equiv.



CED Use alpha ventus
471 TJ PE-Equiv.



Results wind park alpha ventus: CED – Life Cycle and use time

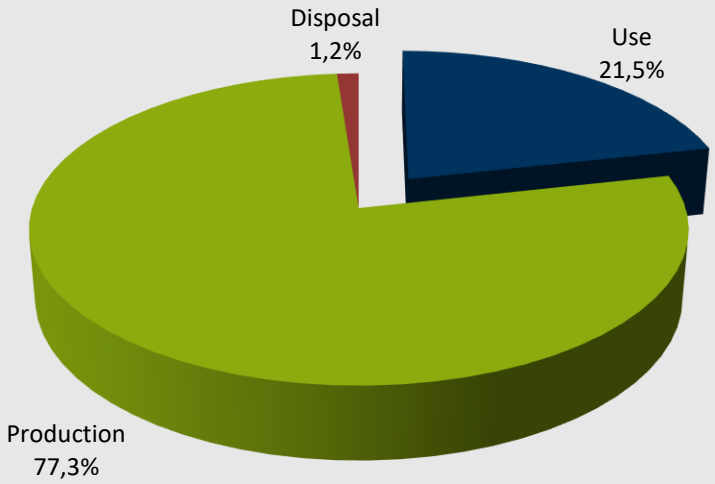


Source:
Picture: REPOWER;
Data: LEE

Structure of cumulative energy demand of an offshore-plant (5 MW)

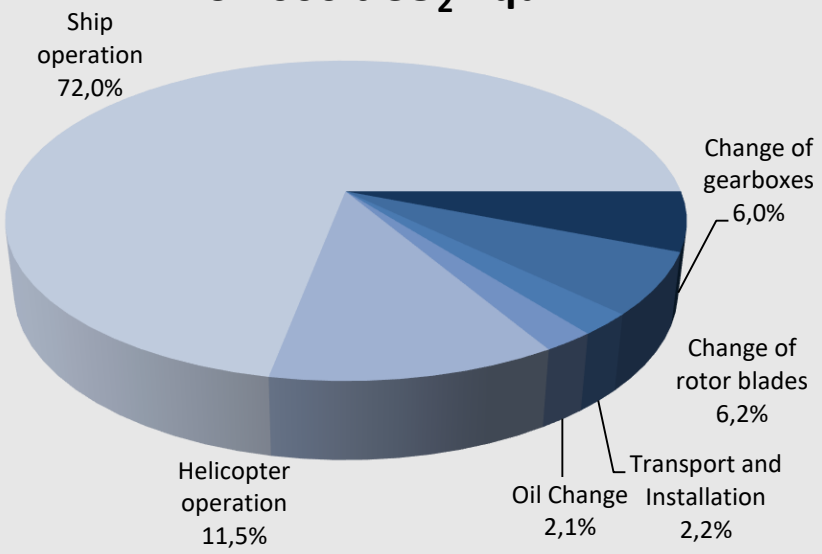
GWP over life cycle alpha ventus

149.000 t CO_2-Equiv.

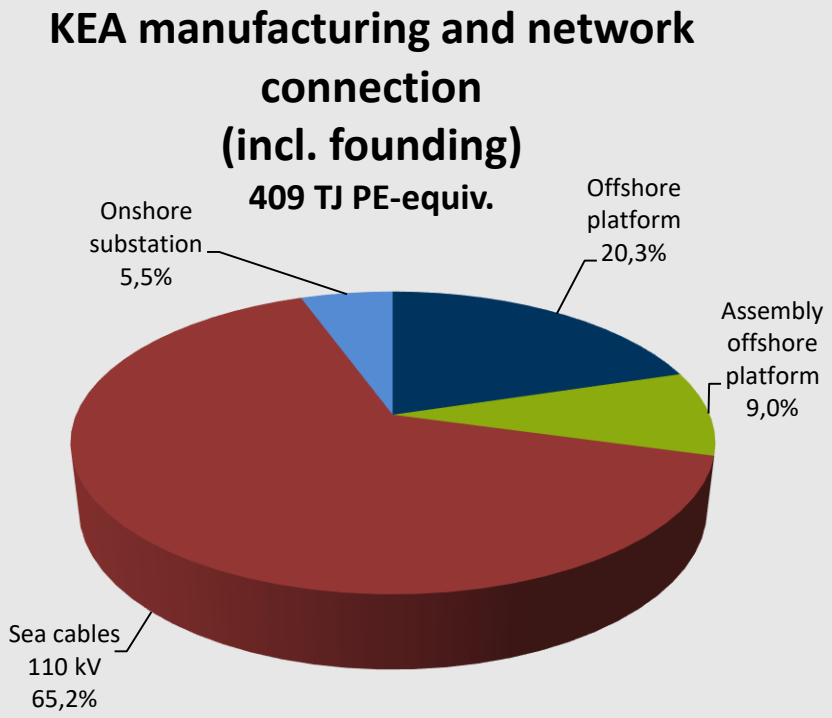


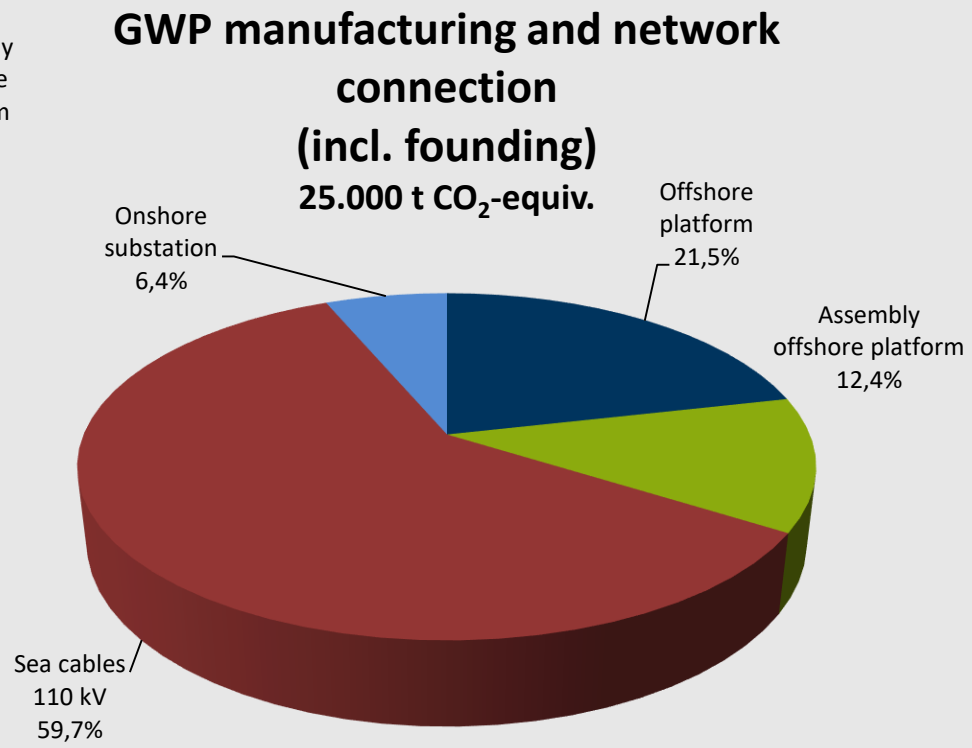
GWP Use alpha ventus

32.000 t CO_2-Equiv.



Results wind park alpha ventus: GWP – Life Cycle and use time



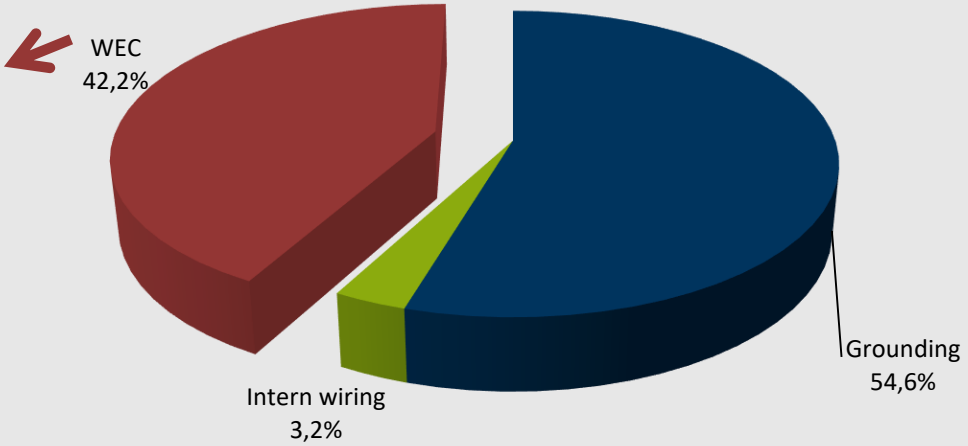


Results of manufacturing and network connection

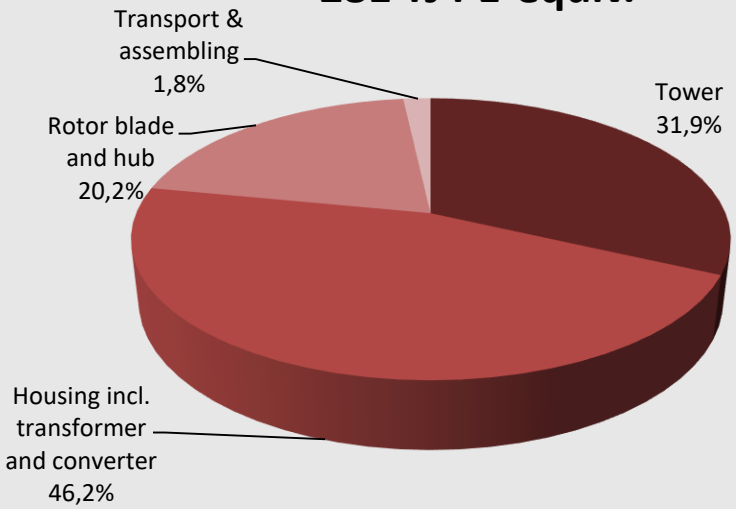
Results production 6x REpower 5M

Cumulated energy demand

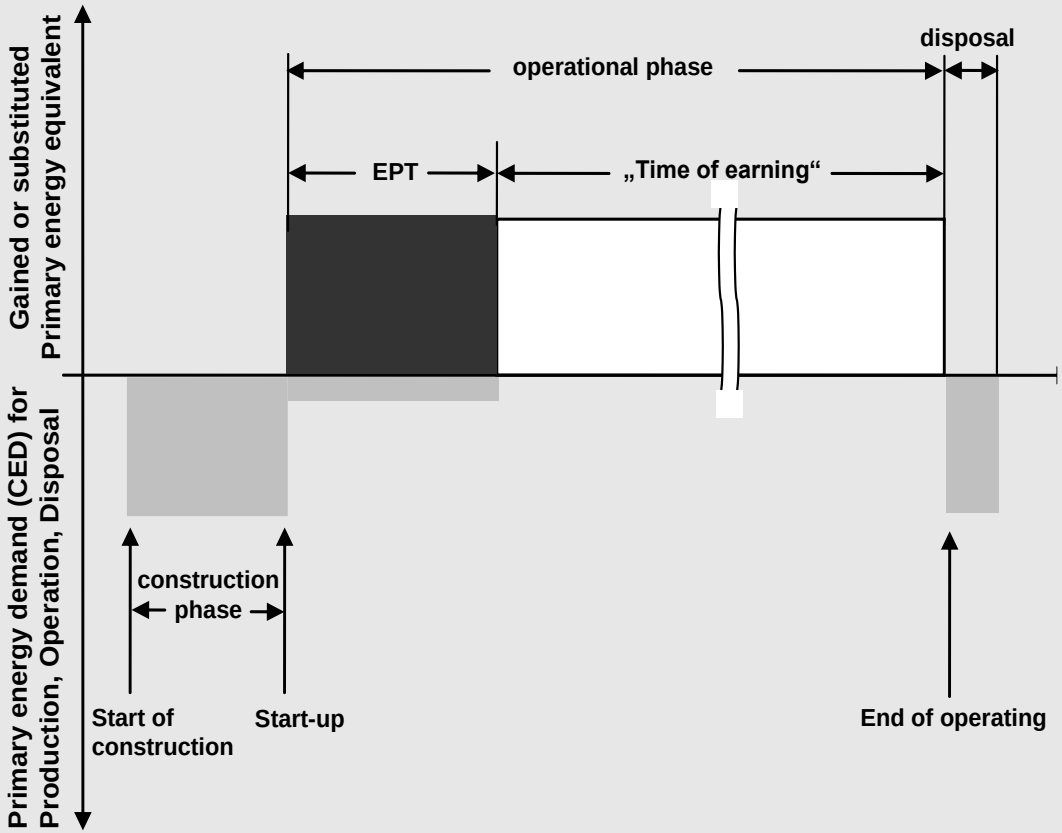
CED Production REpower (6x)
Wind farm elements
666 TJ PE-equiv.



CED Production WEA REpower
(6x excl. Grounding and cable)
281 TJ PE-equiv.



Results production 6x Repower 5M



Energy Payback Time (EPT):

Substituted fossil energy

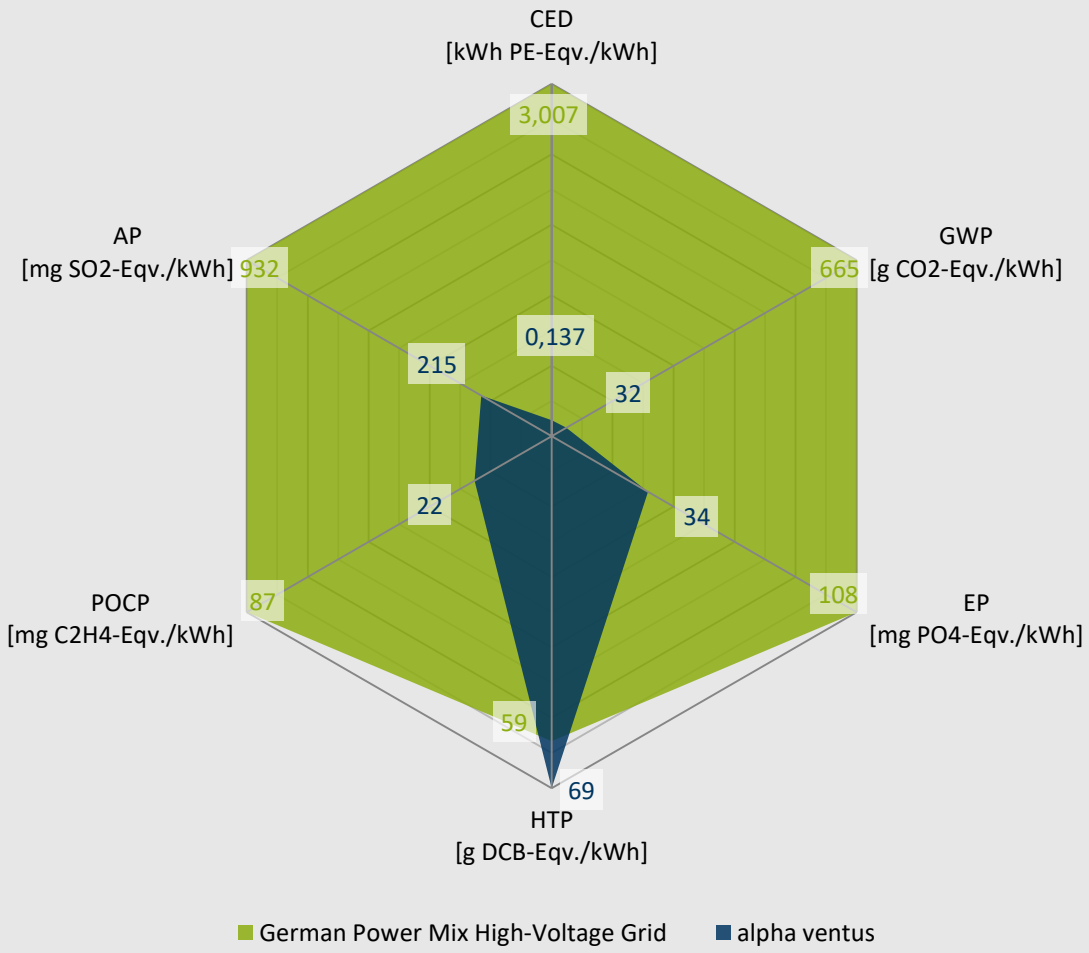
Energy supply for construction, operating and disposal

Energy Payback Time (EPT)

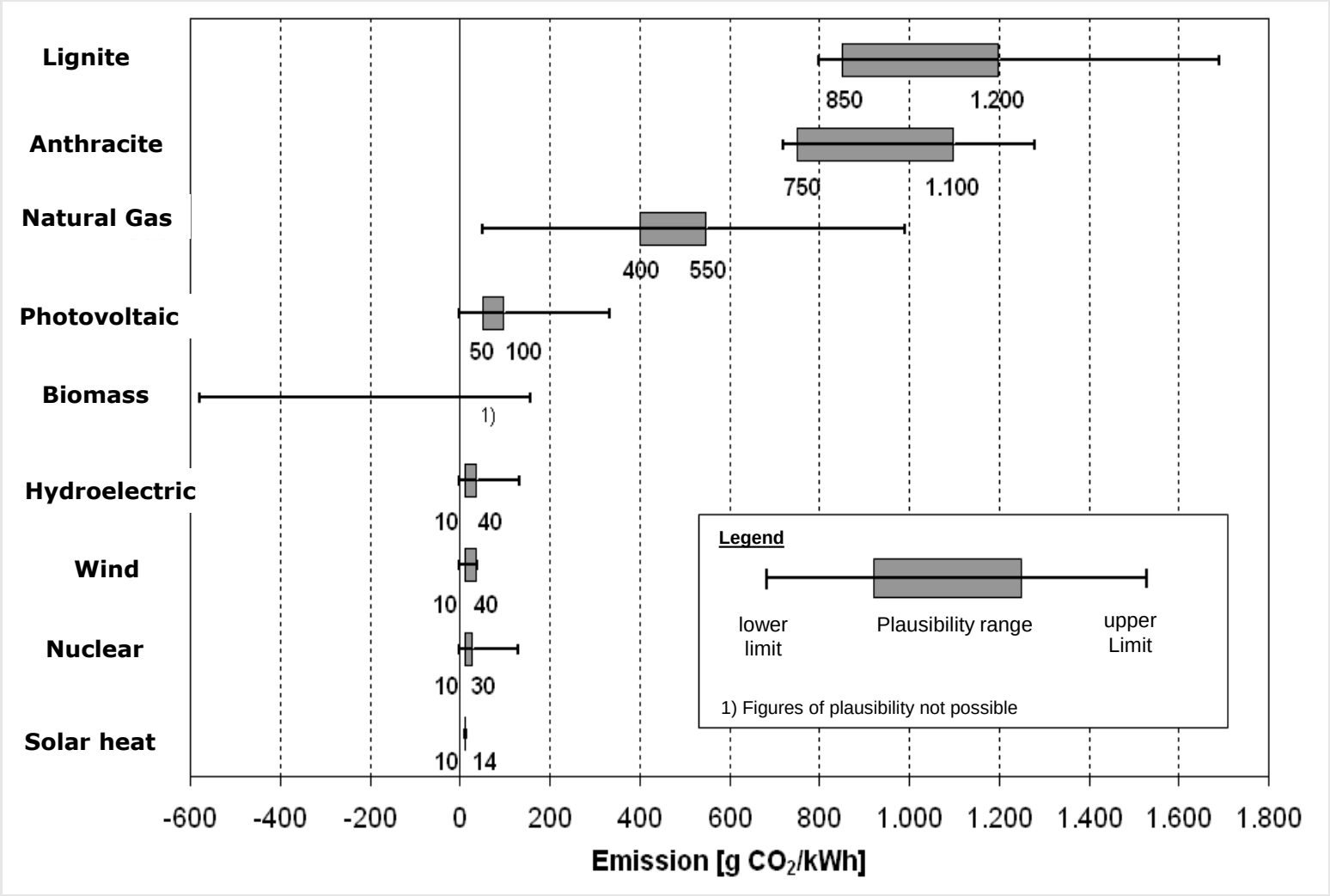
Case	Scenario	Produced Electricity about 20a	EPT (VDI 4661 definition)	CO_2 AZ_{VDI}
A	Reference system	4.680 GWh	8,8 Month	9,1 Month
B	Lifetime foundation 40 a	4.680 GWh	6,1 Month	6,3 Month
C	Capacity Factor 41%	4.320 GWh	9,5 Month	9,9 Month
D	Capacity Factor 48%	5.040 GWh	8,1 Month	8,5 Month
E	Maintenance cut in halve	4.680 GWh	8,7 Month	9,1 Month
F	Windpark beta 40 Wind energy converter same cable and transformer	15.600 GWh	7,4 Month	7,7 Month

Reference System: 12 WEC - Lifetime Foundation 20 a – load duration 3900 h/a – Maintenance: ½ Gearbox, 15 Rotorplates, 120 Helicopter , 180 Ship transports

Energy and CO_2 Payback Time



Classification of the results: Comparison with German Power Mix (uniform ranking)



CO_2- emission of electricity generation in consideration of the whole chain - Comparison of different studies

Damaged nacelle „alpha ventus“ in april 2018

New nacelle „alpha ventus“

Sources: left: https://www.nwzonline.de/seite1/oldenburg-borkum-alpha-ventus-defekte-windpark-gondel-wird-getauscht_a_50,1,2528201113.html; right: https://energiewinde.orsted.de/koepfe-der-energiewende/zehn-jahre-offshore-wind-deutschland-irina-lucke-interview

Transporting the nacelle of a wind power station

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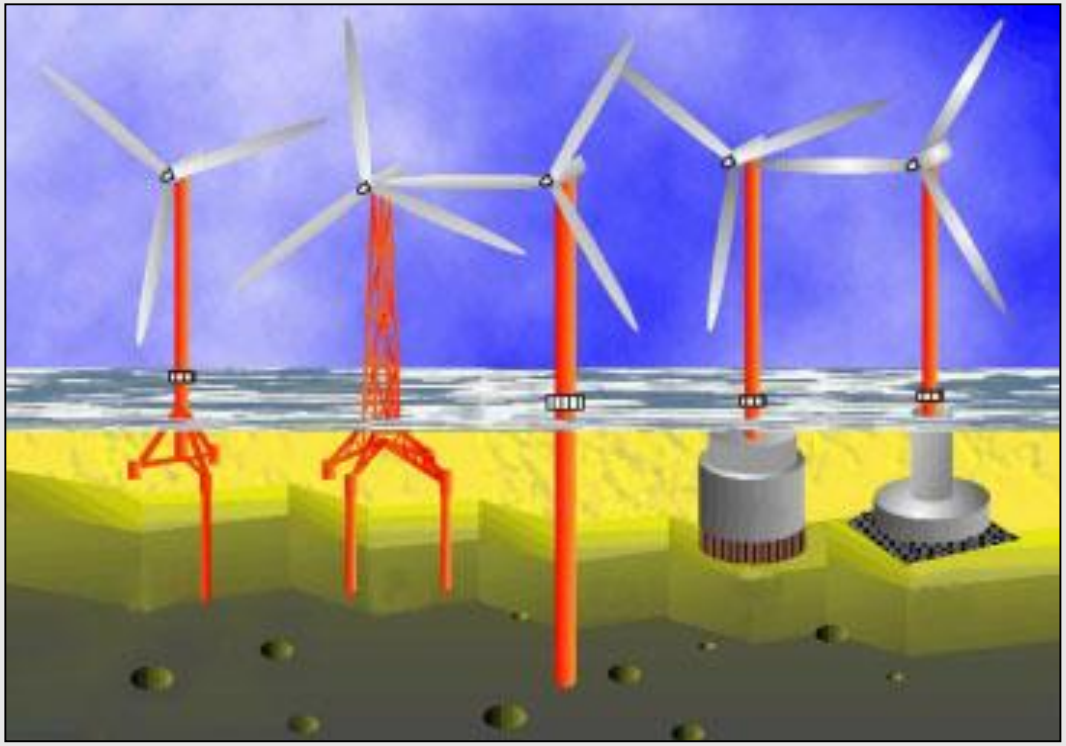
Structure of my presentation



Monopile

- until 20 m deep of water
- Steel- or concrete construction

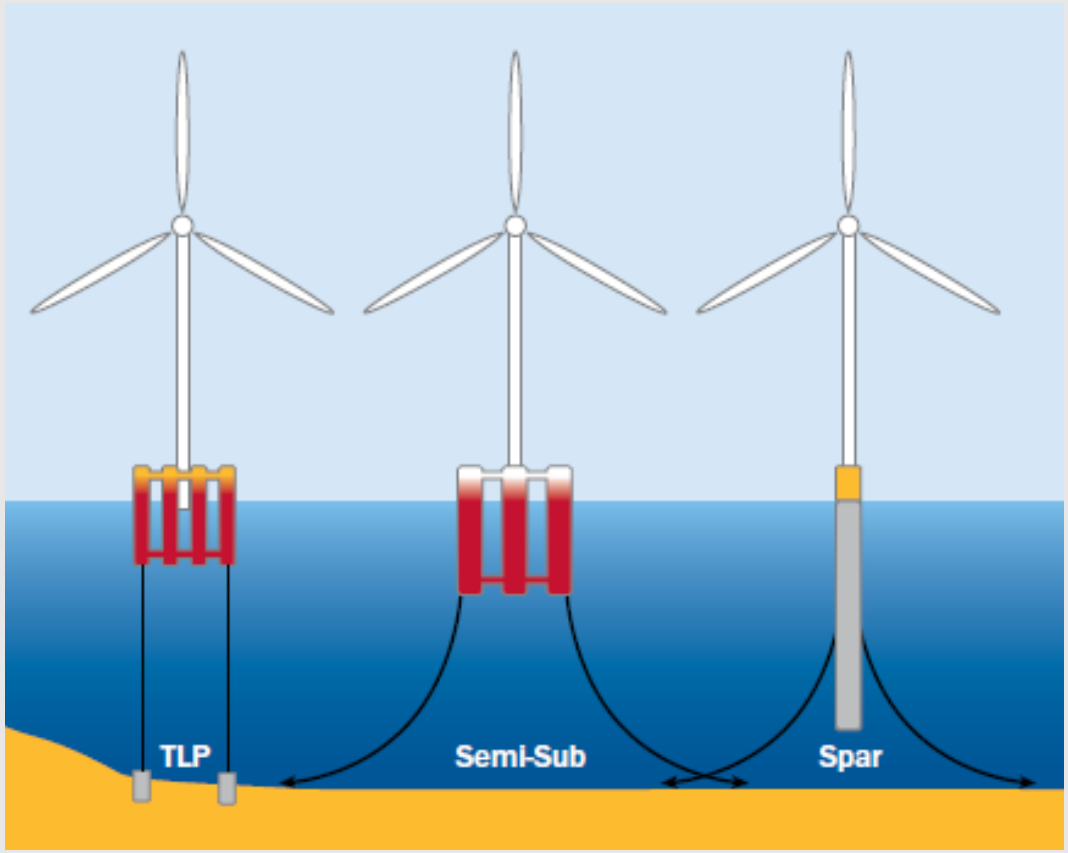
Gravity foundation

- until 10 m deep of water
- Steel- or concrete construction

Tripod, Jacket

- more than 20 m deep of water
- Steel construction

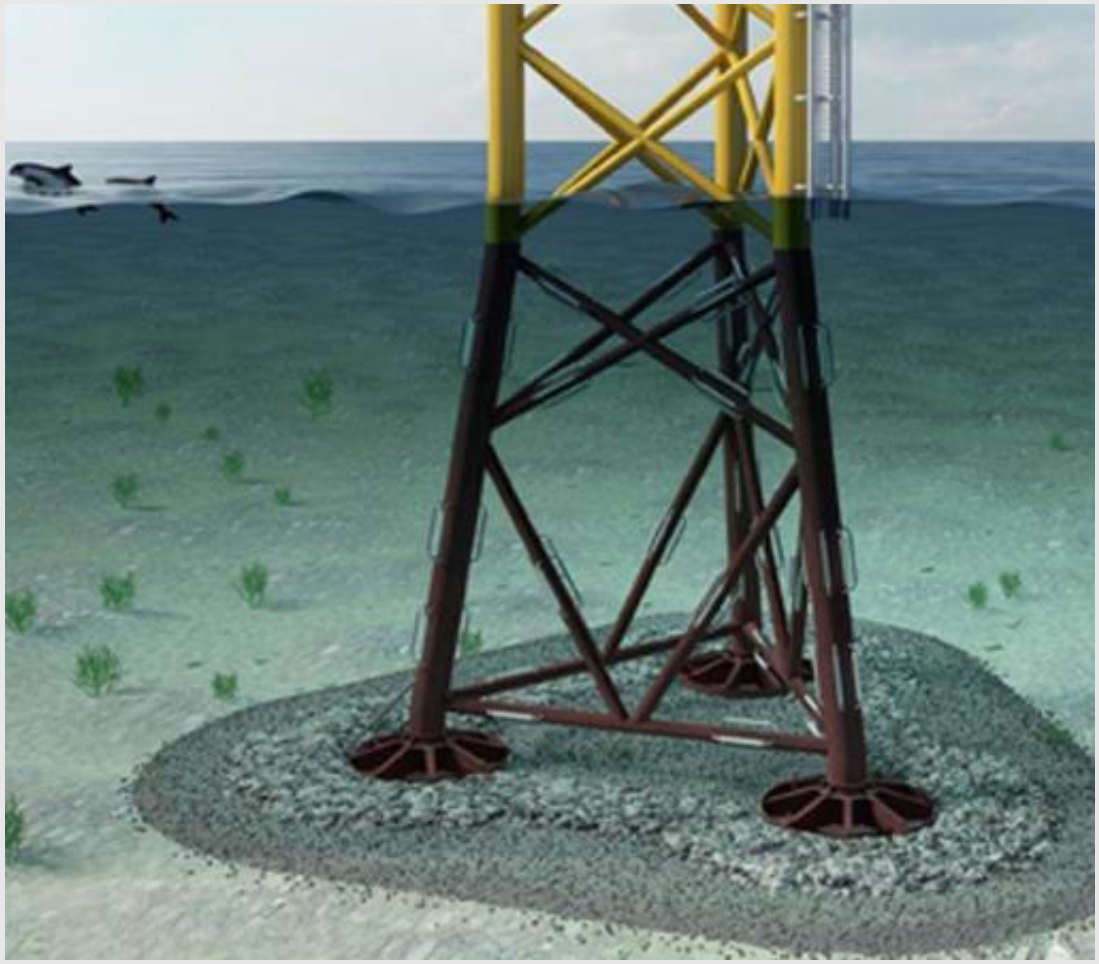
Possible foundations of offshore wind converters



TLP = Tension-leg-platform
Semi-Sub = Semi-submersible platform

Source: Deep Water The next step for offshore wind energy, EWEA

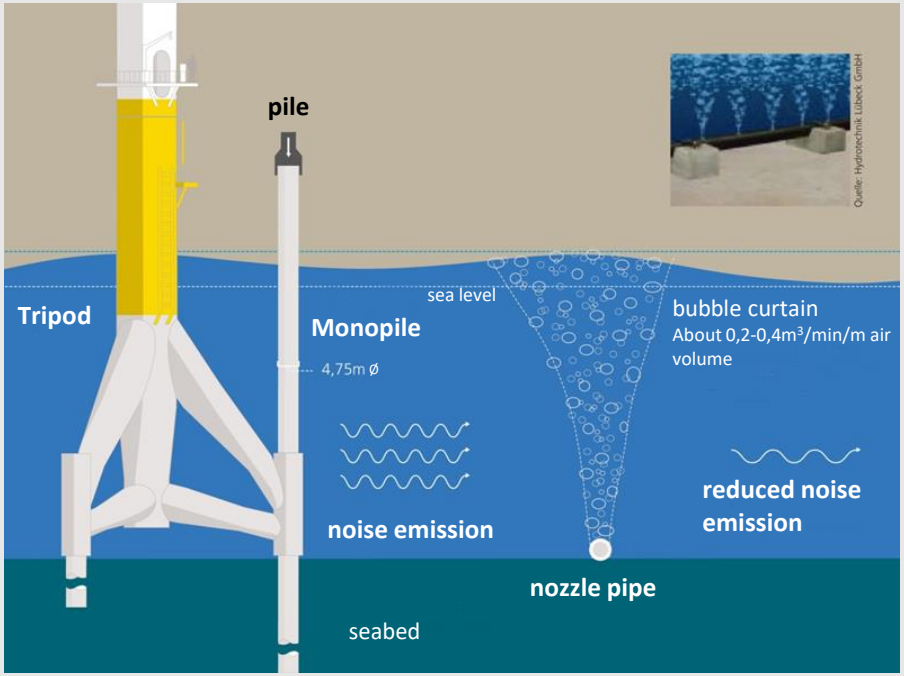
Floating offshore windparks under development



First SBJ was installed in june 2018 at Borkum/Germany

Source: ew Erneuerbare Energien Spezial, III/2014, ISSN: 1619-5795-D9785D; http://subseaworldnews.com/wp-content/uploads/2014/05/SPT-Offshore-Awarded-Foundation-Contract-for-Borkum-Riffgrund-1.jpg & https://www.energiefachmagazin.de/Branchen-News/Erstes-Suction-Bucket-Jacket-Fundament-installiert

Suction-Bucket-Jacket foundation

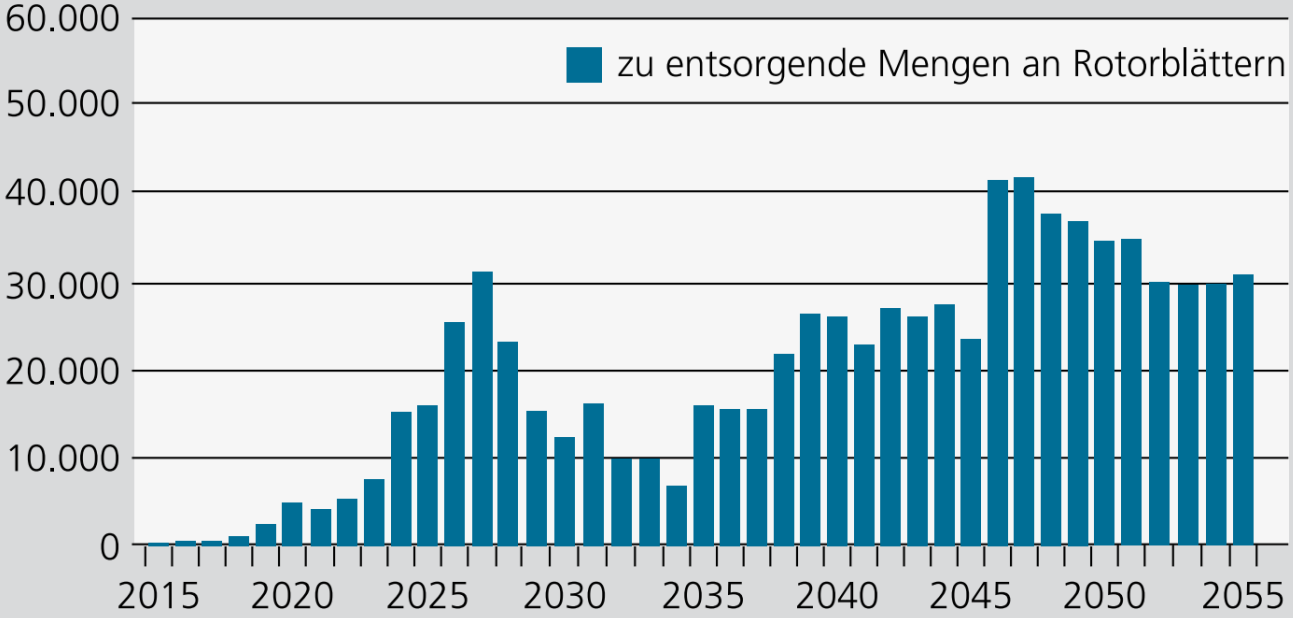


Source: left: Trianel; right: NVB, Nordhäuser Versorgungsbetriebe, entnommen aus: VDI Ingenieurforum, Ausgabe 2/2012

Bubble curtain as underwater noise protection during pile-driving

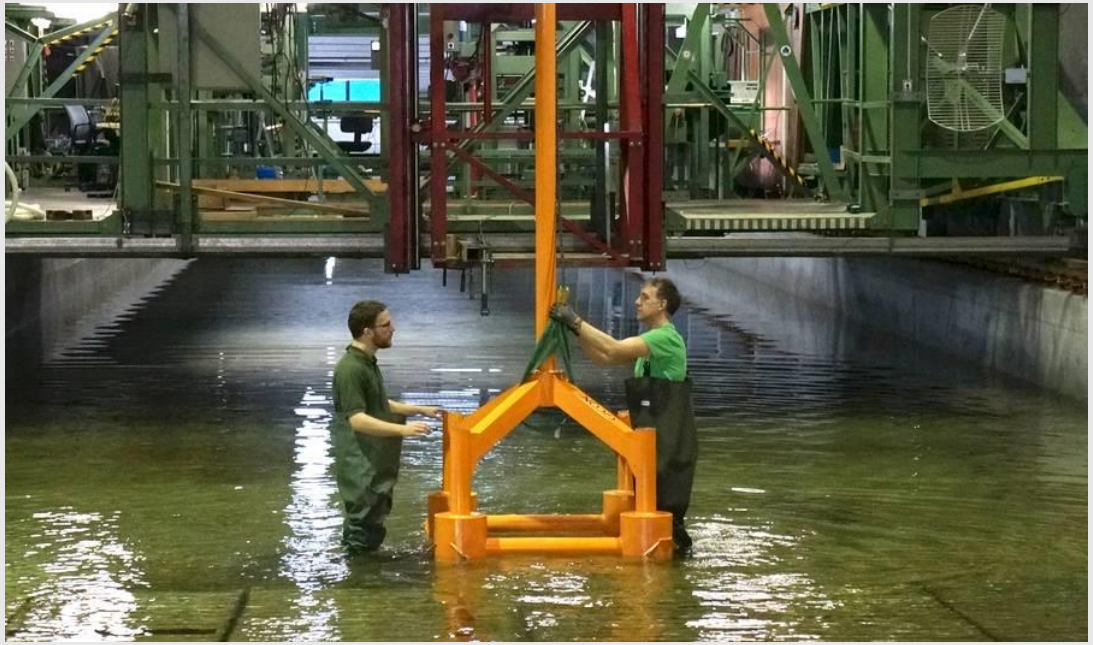
Source: „Germany's Troubled Offshore Wind Offensive"; Spiegel Online; http://www.spiegel.de/fotostrecke/photo-gallery-problems-with-germany-s-offshore-wind-plans-fotostrecke-86725.html; 09.04.2012

Installation of a wind turbine with a special construction ship



Source: Fraunhofer Institut für chemische Technologien ICT & TU Dresden

Number of debuilt wind rotor blades per year in Germany



Source: gicon-sof.de

Floating wind turbine: concept and planning in laboratory

Source: EnBW – Jan Oelker (Fotograf)

Prototype of a small floating wind „park“

- The use of wind energy is worldwide growing
- Wind energy is very material intensive → that needs energy
  → emissions
- Ecobalances give information about sustainability
- The energetic and CO_2 payback time for wind parks is about one year and less
- Electricity from wind is much more sustainable as electricity from fossils
- A sustainability check must be part of every planning of new energy systems

Conclusions

Thank you for your attention

www.lee.rub.de

Bild: http://www.cpmax.com/tl_files/content/leistungen/inspektionen/galerie/100629%20097_klein.jpg