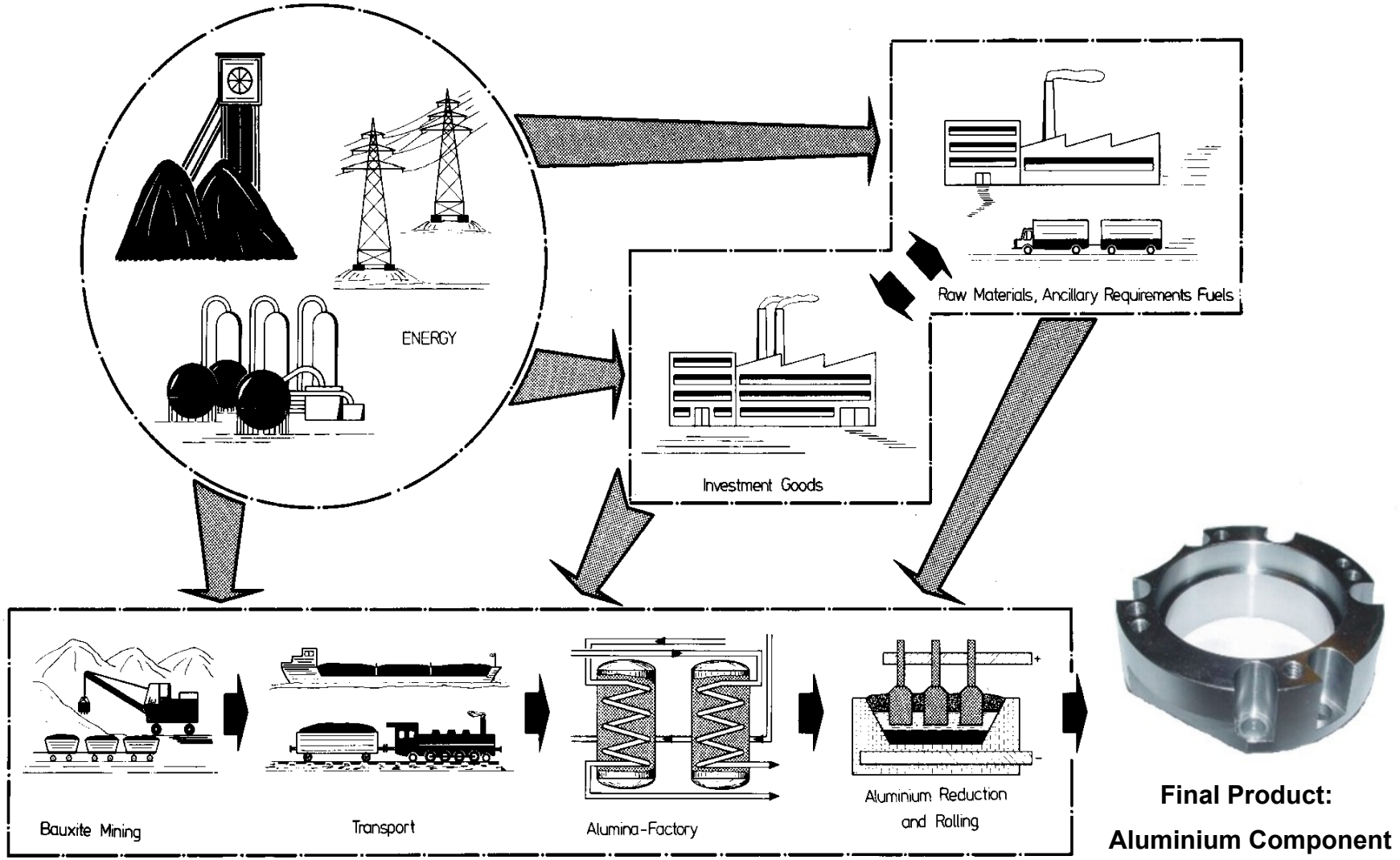
Life Cycle Assessment of the German offshore windpark alpha ventus

International School on Energy, 17-23 July 2014, Varenna, Lake Como

Structure of my presentation

- **Cumulated Energy and Ecobalances**
- Results of the wind park alpha ventus

Example of Process-Chain-Analysis



Final Product:

Aluminium Component

Process chain for final energy carrier

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.

Coal production
η = 0,93
à Primary energy
→
Power station
η = 0,39
→
Electrical network
η = 0,95
→
Electricity
1 kWh
à Final energy

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

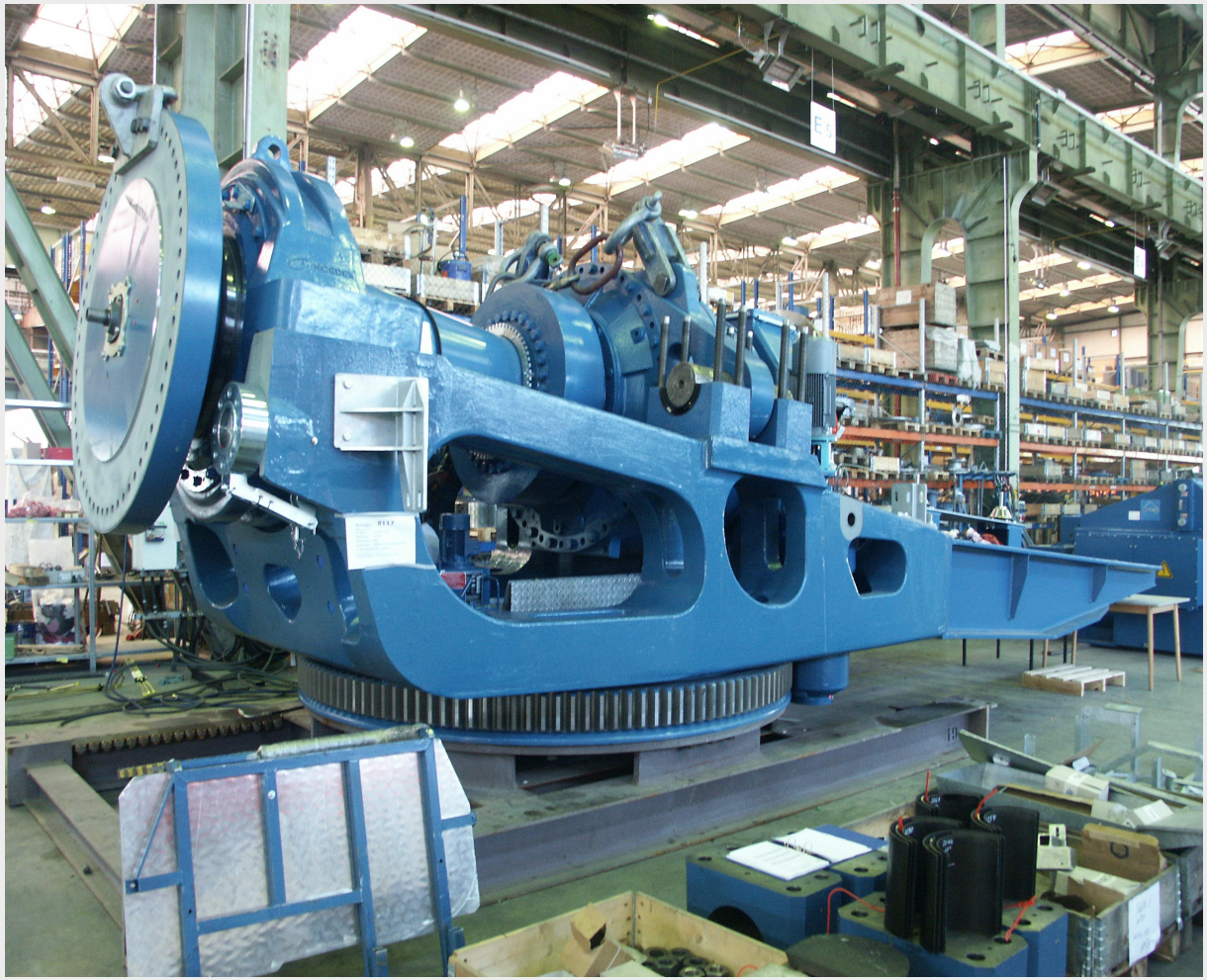
  Overall Efficiencies of Supply: $g_{Electricity} = \frac{1}{\eta_{total\ about\ chain}}$

Crude oil extraction
η = 0,96
à Primary energy
→
Transport
η = 0,99
→
Refinery
η = 0,93
→
Fuel oil
1 kWh
à Final energy

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

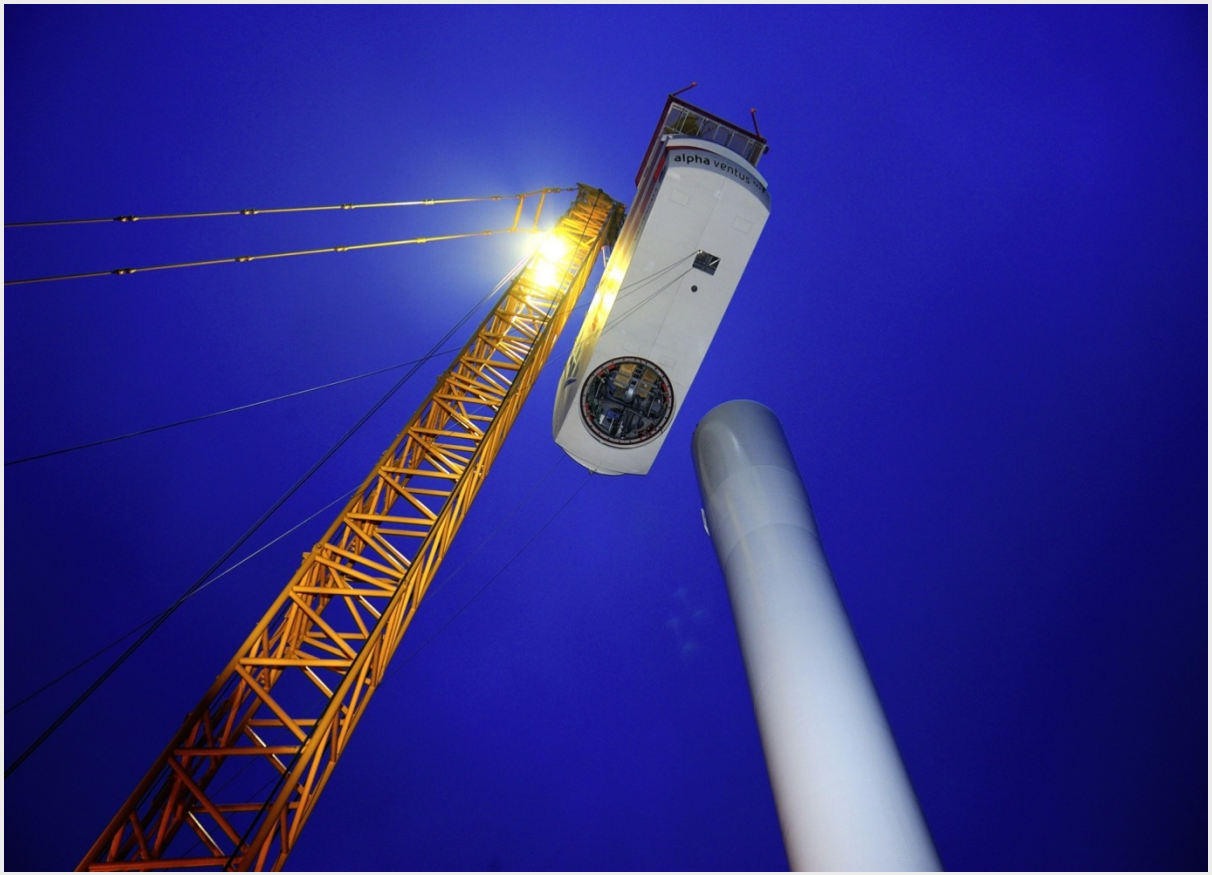
<u>Comment:</u>
If there are enough information, you can devide the primary energy equivalent in a fossil, regenerative and nuclear share.

Assembling of a wind converter by Nordex AG



Source: Nordex AG

Montage of a cabin - windpark alpha ventus



Structure of my presentation

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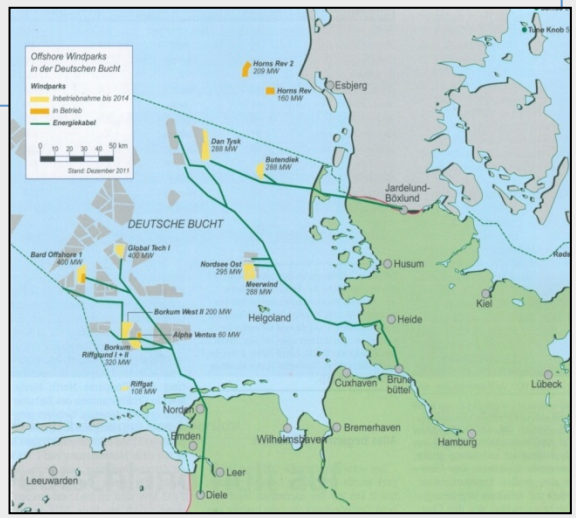
- **Results of the wind park alpha ventus**

Life Cycle Assessment wind park alpha ventus

Reference system



- 12 Wind energy converter, each 5 MW

  (6 of Multibrid and 6 of REpower company)

- Operation time 20 years

- Lifetime foundation 20 years

- Capacity Factor 45% (load duration 3900 h/a):

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

- 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

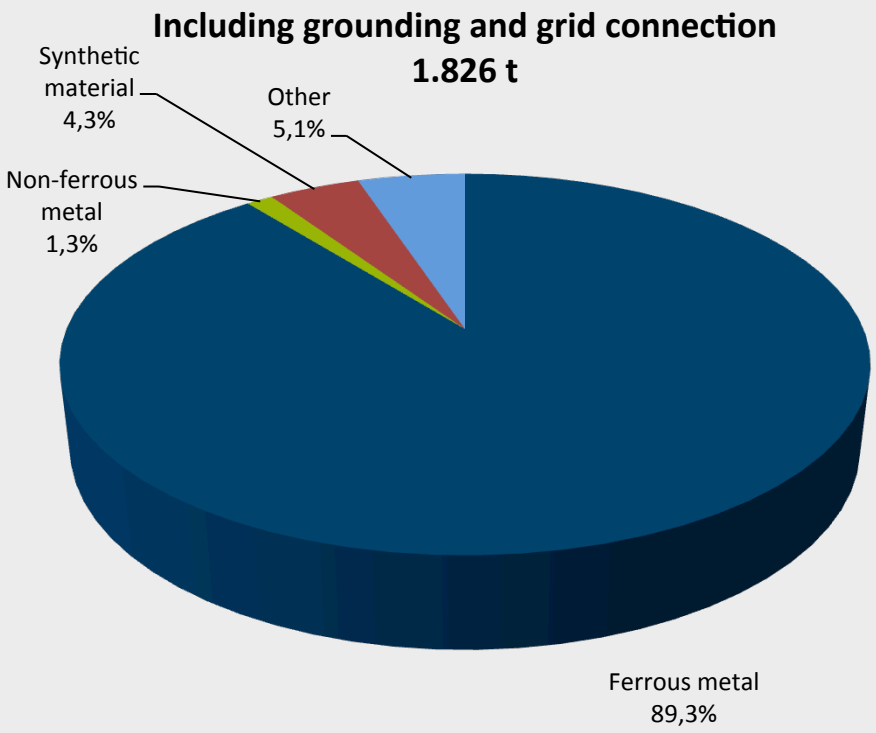
Fundaments for windmills for alpha ventus

Tripods for the Multibrid windmills

Jackets for the Repower windmills

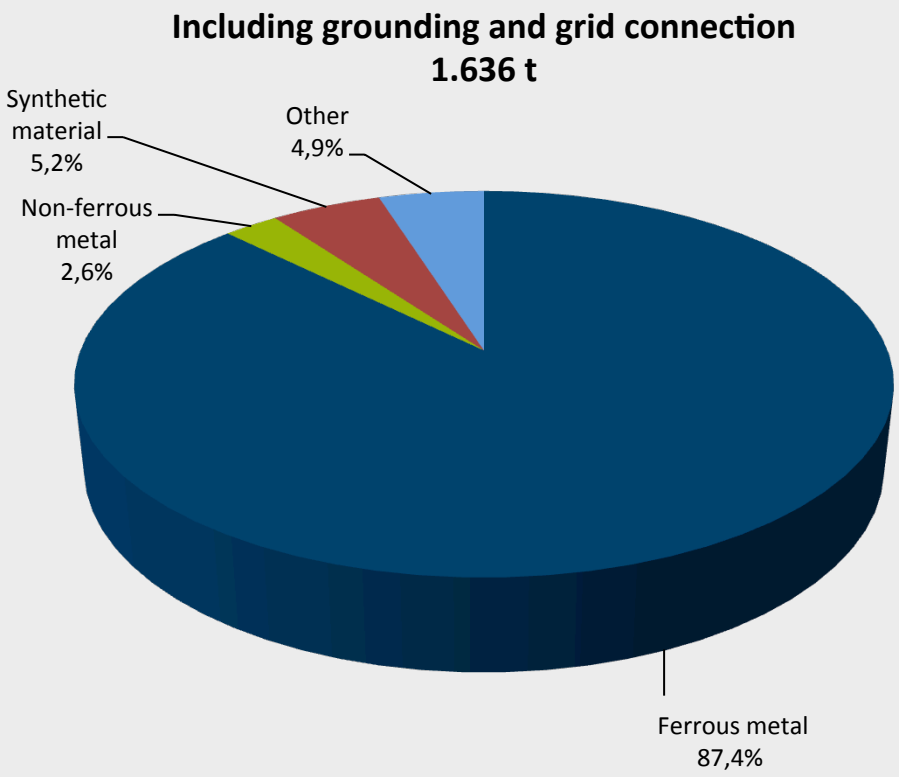
Results production of 1x *Multibrid M5000*

Material balance



Results production of 1x REpower 5M

Material balance



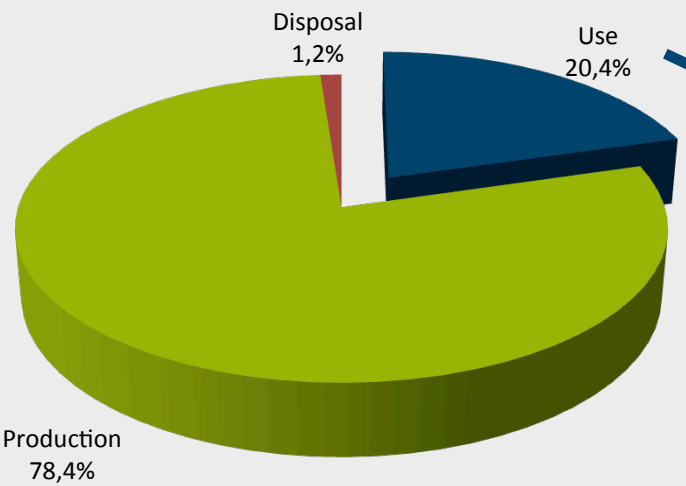
Results of the wind park alpha ventus

Cumulated Energy Demand(CED) and Global Worming Potential (GWP)

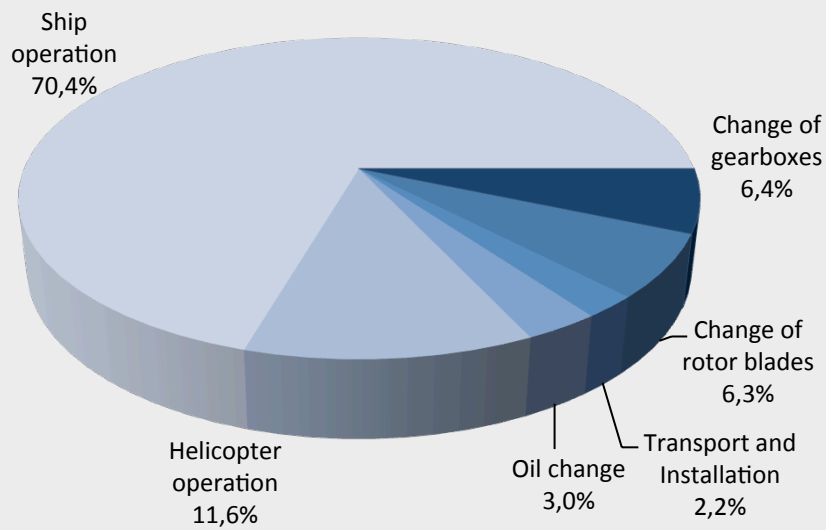
Results wind park alpha ventus

Cumulated Energy Demand (CED) – Life Cycle and use time

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



CED Use alpha ventus
471 TJ PE-Equiv.

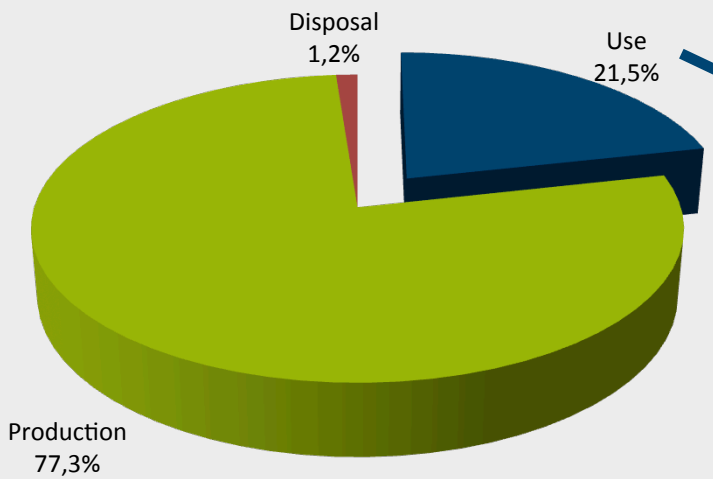


Results wind park alpha ventus

Global Warming Potential (GWP) – Life Cycle and use time

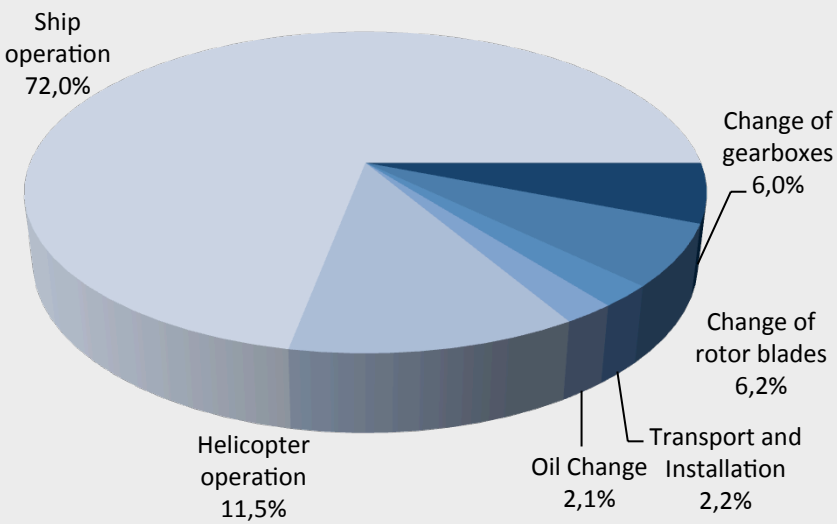
GWP over life cycle alpha ventus

149.000 t CO_2-Equiv.



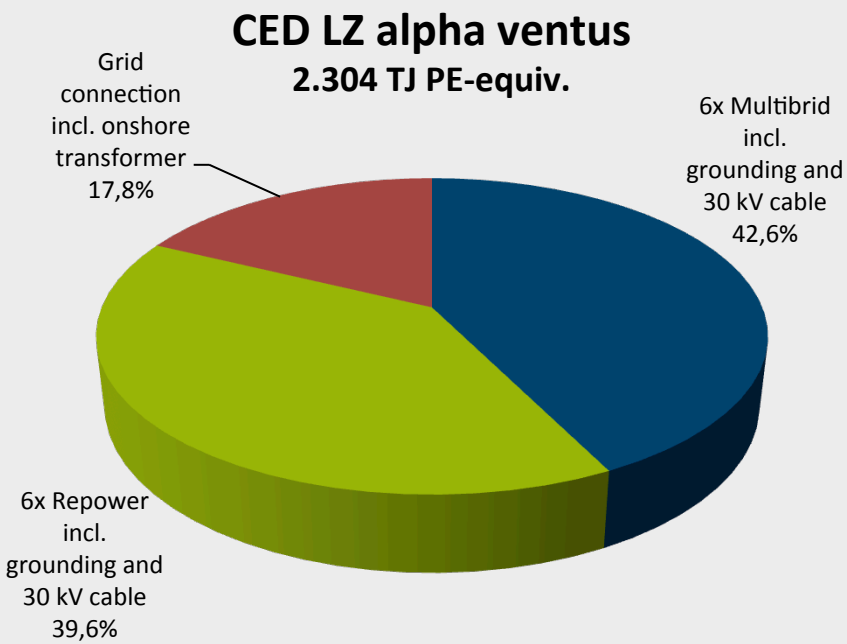
GWP Use alpha ventus

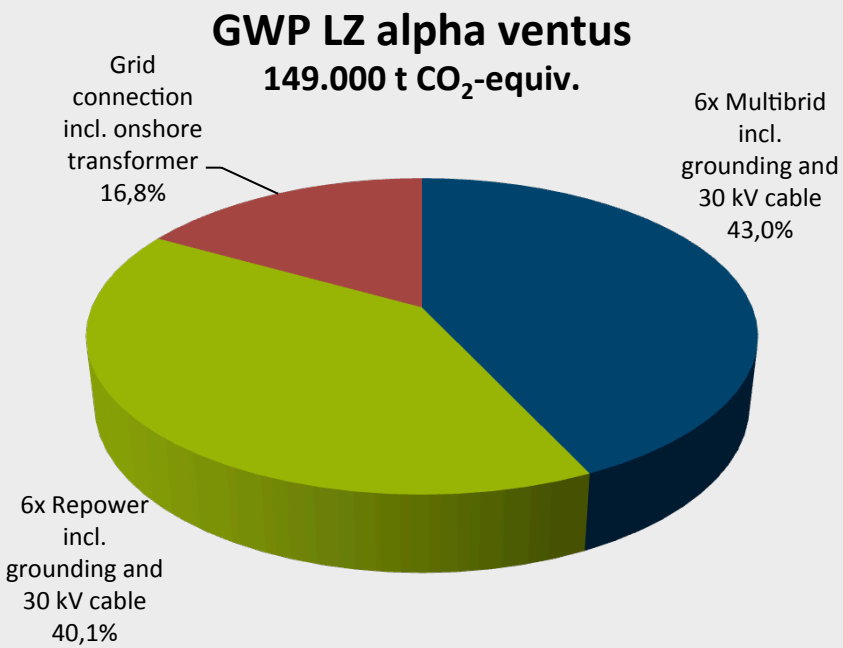
32.000 t CO_2-Equiv.



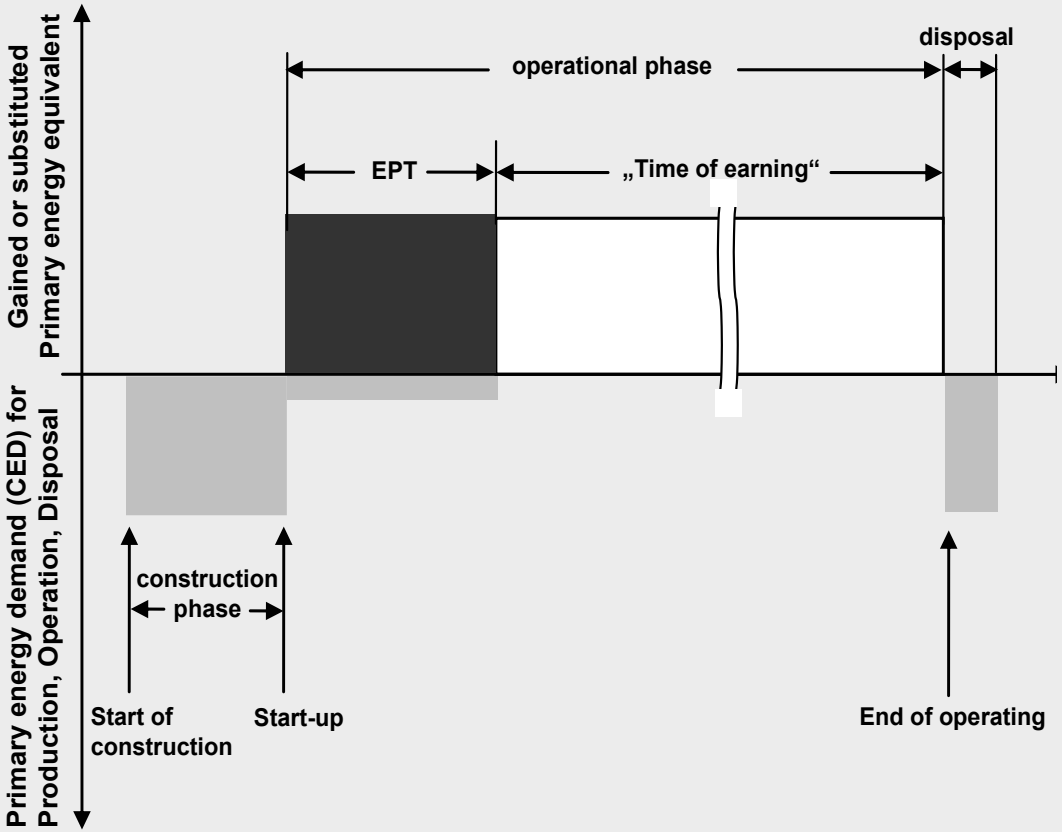
Results wind farm alpha ventus

CED and GWP – Life cycle – by elements





Energy Payback Time (EPT)



Energy Payback Time (EPT):

Substituted fossil energy

Energy supply for construction, operating and disposal

Energy and CO_2 Payback Time

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

Results of the wind park alpha ventus

All considered eco-indicators

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

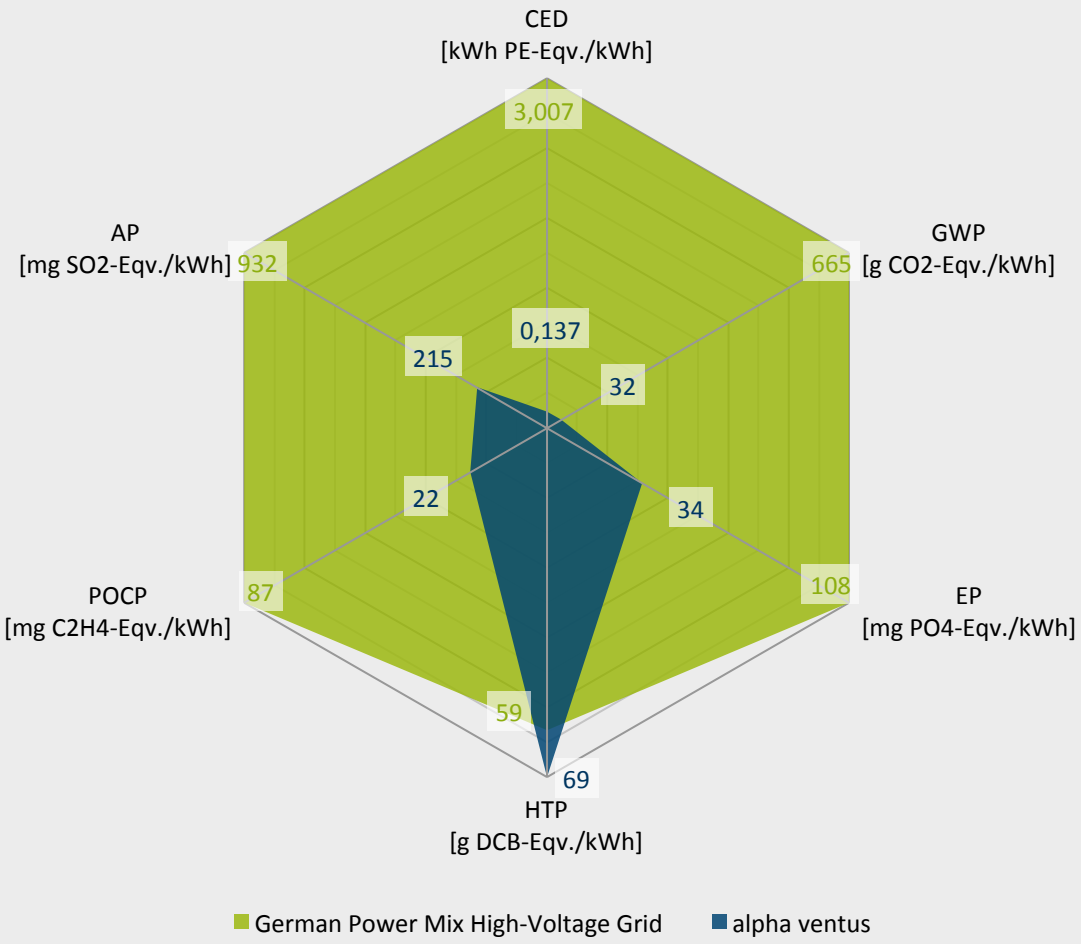
Effect-Class	Massflow	Effect Indicator (load factor)
Energy resource	Energy consumption	All forms of energy count back on primary energy equivalent (CED); if possible differentiate between fossil, nuclear & renewable
Water- and Air-Pollution	Pollutants in effluents and air	Critical Volume (Emission devided 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 (2)

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

Classification of the results

Comparison with German Power Mix (uniform ranking)



Conclusions

- Wind energy is very material intensive → that needs energy → emissions
- Life cycle assessment (ecobalances) give information about sustainability
- The energetic and CO_2 payback time for wind parks is less one year
- Electricity from wind is much more sustainable as electricity from fossils
- A sustainability check by life cycle analysis must be part of every planning of new energy systems

Thank you for your attention