UNIVERSITY OF BERGEN

Bergen Offshore Wind Centre

Vindenergi - faktagrunnlag

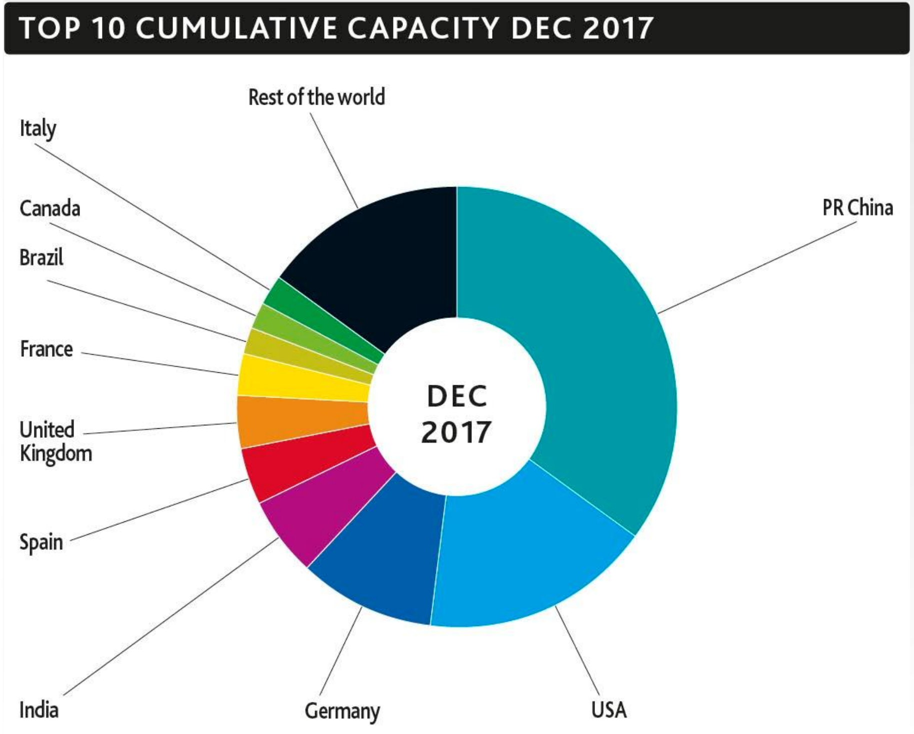
Finn Gunnar Nielsen
Geophysical Institute

UNIVERSITETET I BERGEN

Innhold

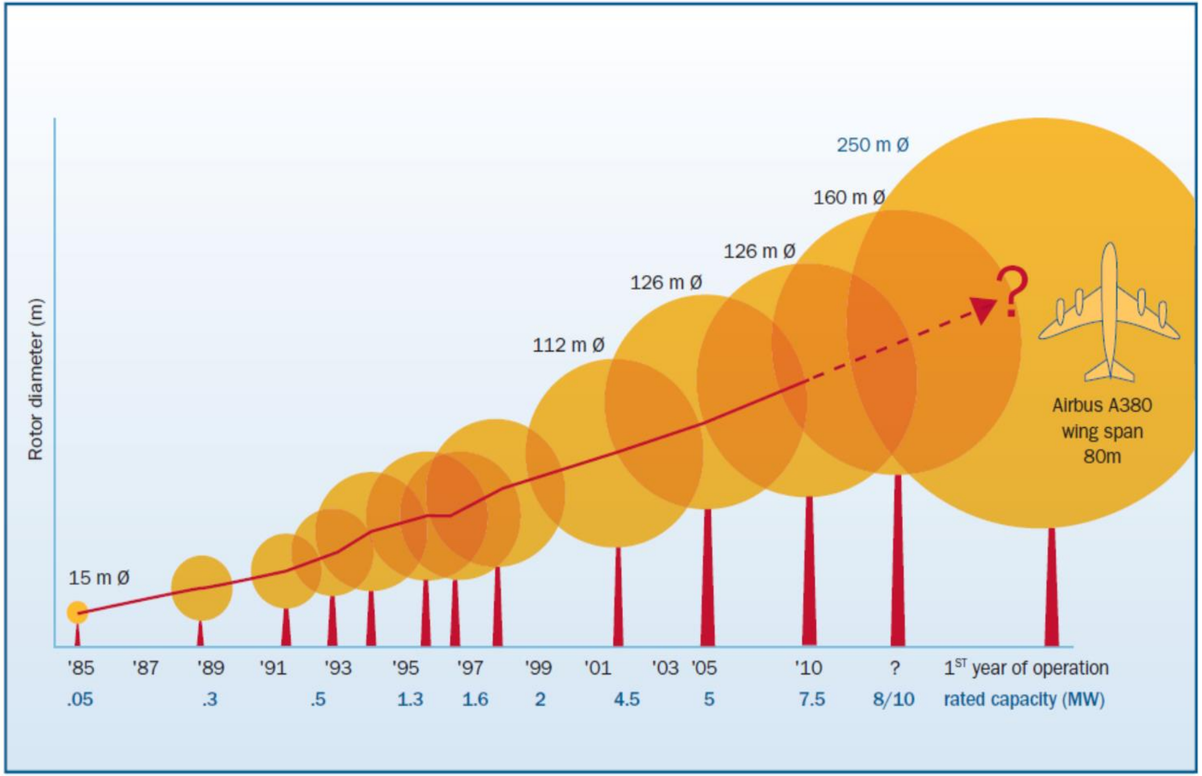
- Energien i vind – ressurser i Norge.
- Noen begreper:
  - Kapasitetsfaktor – fulldriftstimer – energikostnad.
- Typiske vindparker
- Arealbruk land – sjø.
- Kostnadsutvikling - Eksterne kostnader.
- Vind til havs – mulighetene
- Bergen Offshore Wind centre

Vindenergi i verden (2017)



Installert på land:	495 GW
Havvind:	19 GW
Norsk vannkraftsystem:	33,8 GW

Vindturbiners størrelse



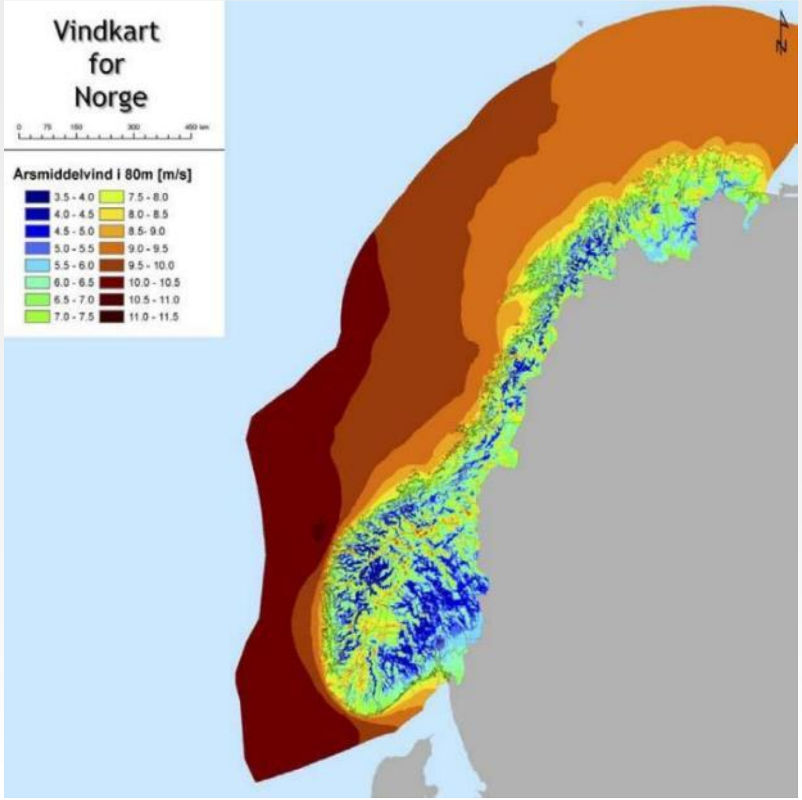
Mars 2018:

GE lanserer 12 MW, 220m offshore turbin

16.01.19:

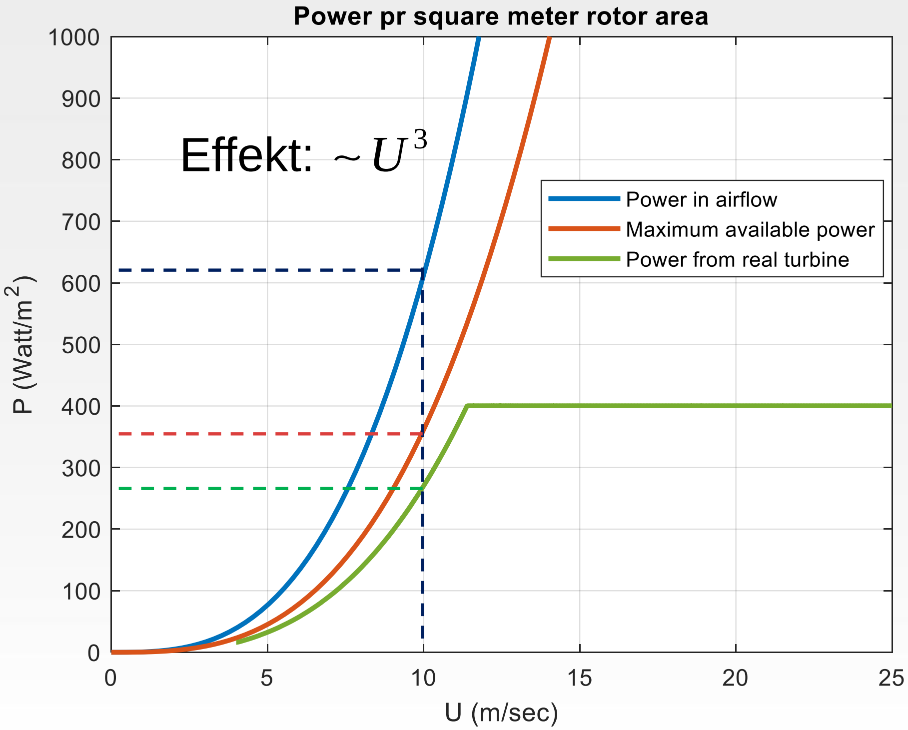
Siemens Gamesa lanserer 10MW 193m offshore turbin

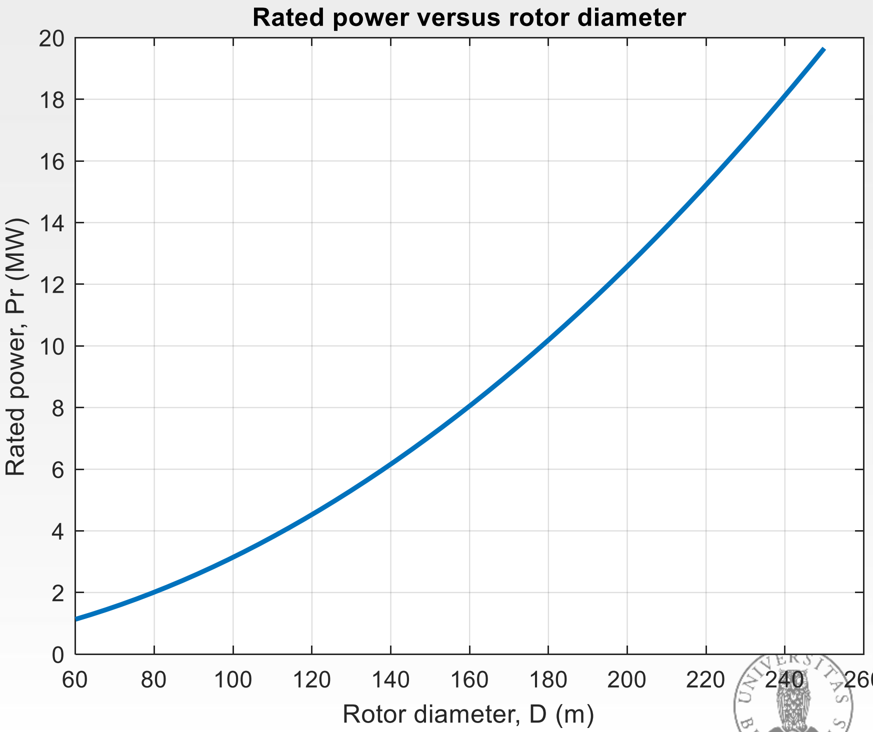
Vindressurser (80 m høyde)



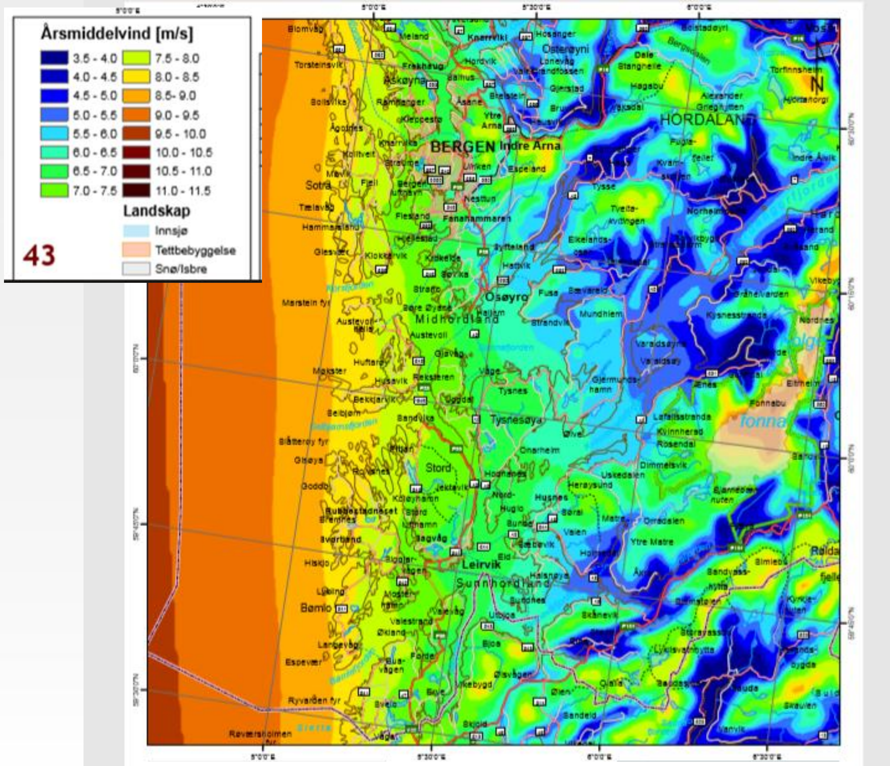
http://www.nve.no/Global/Publikasjoner/Publikasjoner%2020 09/Oppdragsrapport%20A%202009/oppdragsrapportA9-09.pdf

Effekten (energien) i vind

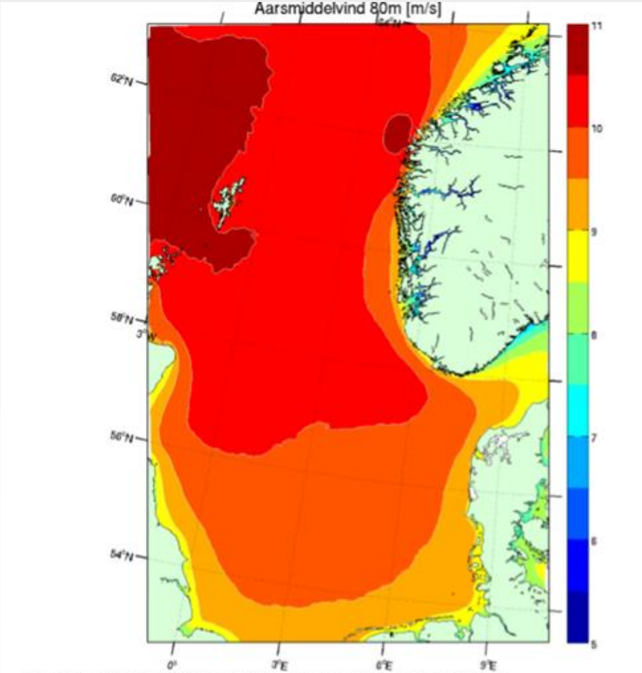




Regionale ressurser (80 m høyde)



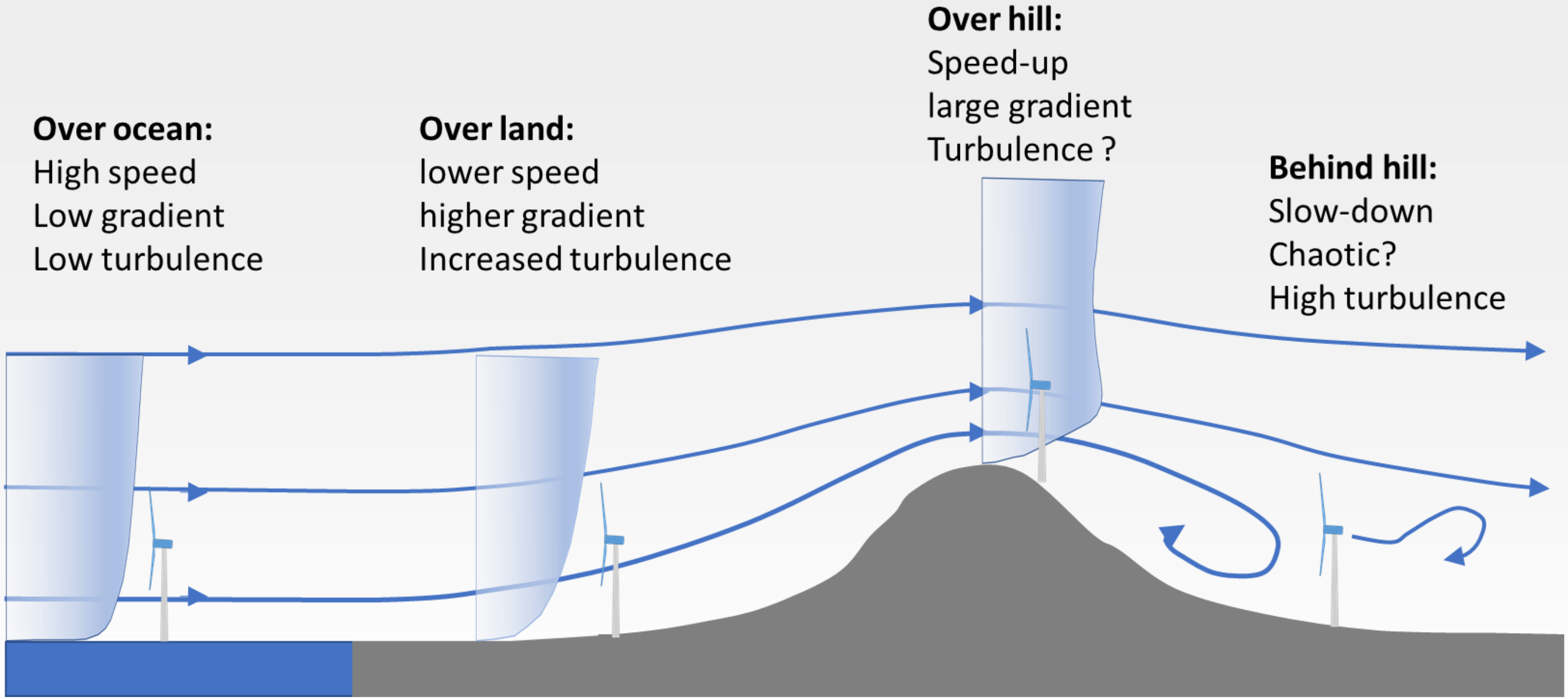
https://www.nve.no/media/2462/vind_80m_kartbok1a_4140.pdf



Figur 2 Årsmiddelvind i 80m høyde. Basert på 4km modellsimulering fra WRF.

Rapport nr 10/2009
Analyser av offshore modellsimuleringer av vind:
http://publikasjoner.nve.no/oppdragsrapportA/2009/oppdragsrapportA2009_10.pdf

Wind from sea to land



Kapasitetsfaktor / full-last timer

- Kapasitetsfaktor: $C_p = \dfrac{\text{Årlig energiproduksjon}}{\text{Teoretisk maximum produksjon}} = \dfrac{AEP}{P_{turbine} \cdot 8760}$

- Full-last timer: $T = \text{Antall timer med full last for å oppnå årsproduksjonen}$

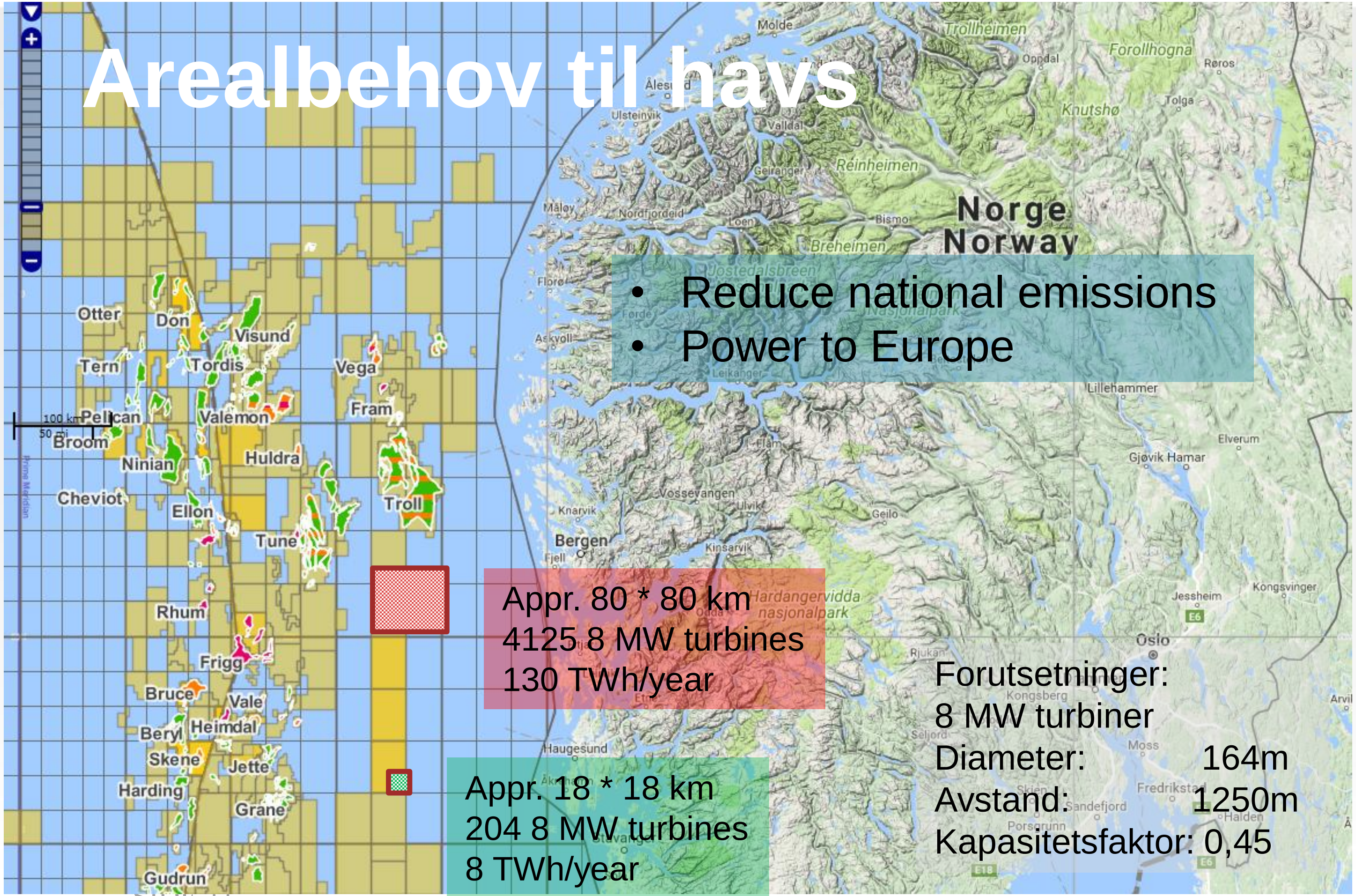
$$= \frac{\text{AEP}}{P_{turbine}} = C_P \cdot 8760$$

Eksempler 2017

	Innstallert effekt (GW)	Produksjon (TWh)	Kapasitets-faktor	Gjennom-snittlig turbin-størrelse (MW)	Referanse
Norge	1,165	2,85	0,32	2,5	Vindinfo.no
Midtfjellet	0,110	0,325	0,34	2,5	Midtfjellet.no
Midtfjellet estimat 2018	0,150	0,434	0,33	2,73	Midtfjellet.no
EU offshore	15,78 (4149 turbiner)	55,3[1]	0,29 – 0,48	5,9[2]	Windeurope.org
Hywind Scotland (1. år)	0,030	0,147	0,56	6,0	Equinor.com
Sheringham Shoal (UK)	0,317	Ca 1,1	Ca. 0,40	3,6	http://www.sheringhamshoal.co.uk/

1): Antatt Cp = 0.4
2): Gjelder nye turbiner i 2017

Arealbehov til havs



- Reduce national emissions
- Power to Europe

Appr. 80 * 80 km
4125 8 MW turbines
130 TWh/year

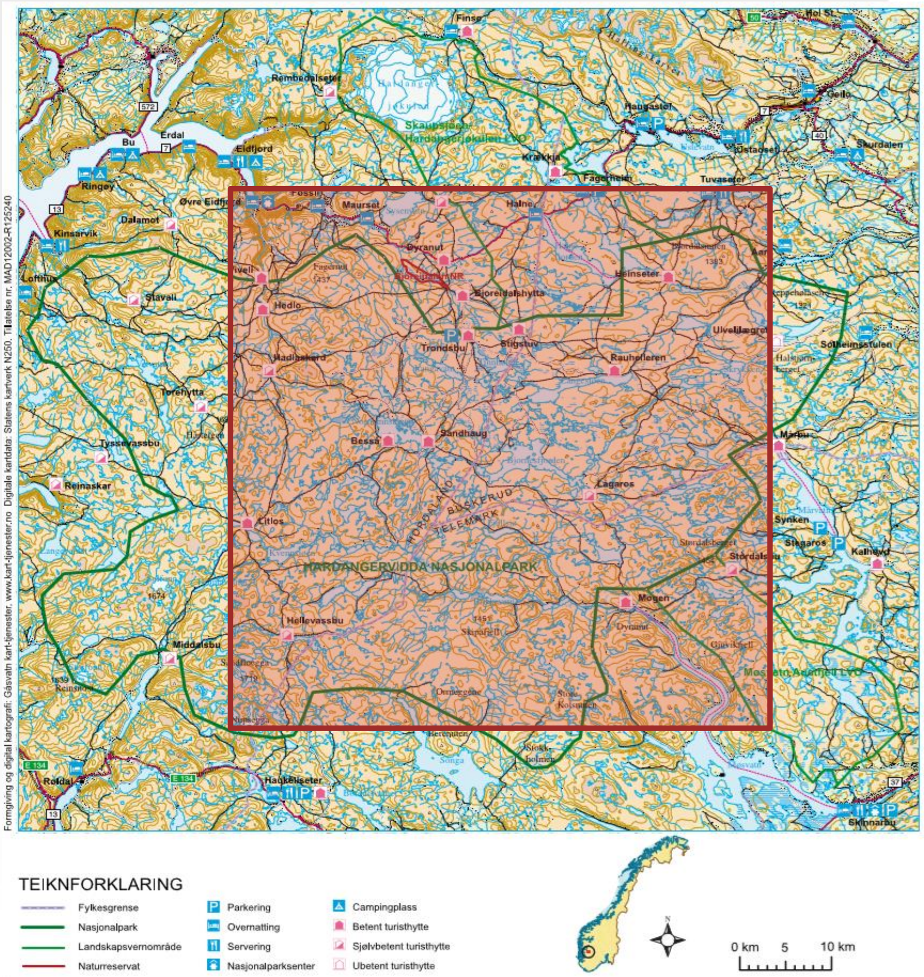
Appr. 18 * 18 km
204 8 MW turbines
8 TWh/year

Forutsetninger:
8 MW turbiner
Diameter: 164m
Avstand: 1250m
Kapasitetsfaktor: 0,45

Arealbehov land

Appr. 60 * 60 km
11200 4 MW turbines
130 TWh/year

Forutsetninger:
4 MW turbiner
Diameter: 110 m
Avstand: 550 m
Kapasitetsfaktor: 0,33



Energikostnad

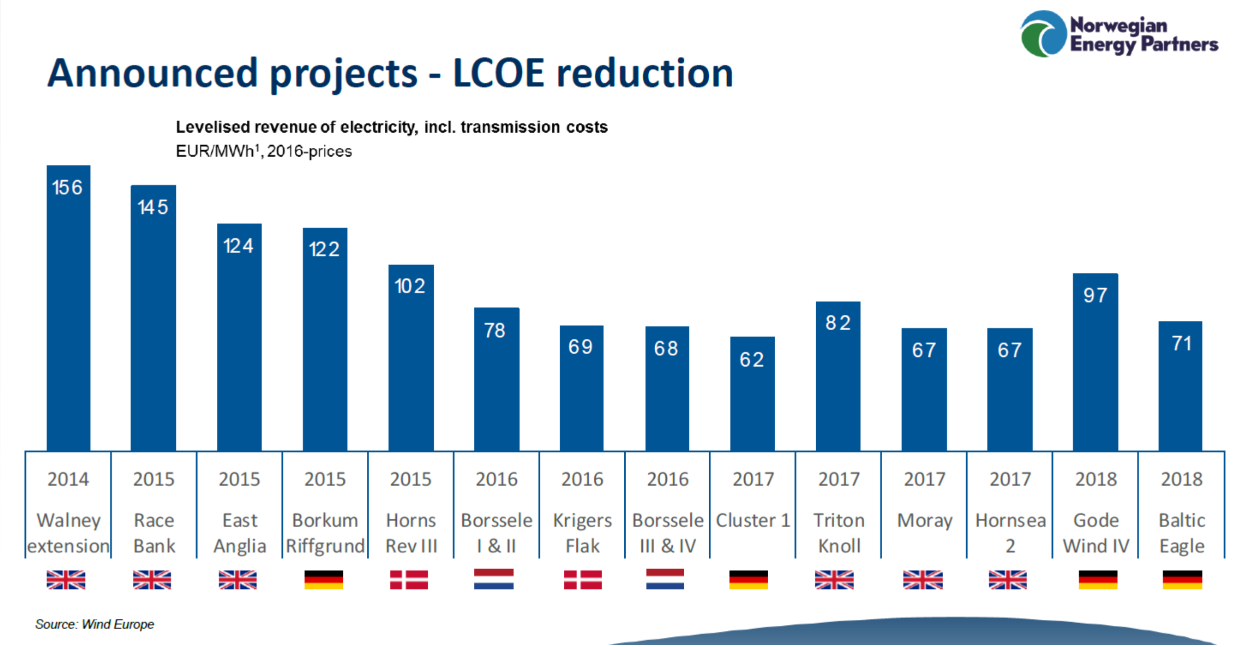
Gjennomsnittlig energikostnad (Levelized cost of energy):

$$LCOE = \frac{\text{Investeringer} + \text{sum(drift \& vedlikehold)}}{\text{sum(Levert energi)}}$$

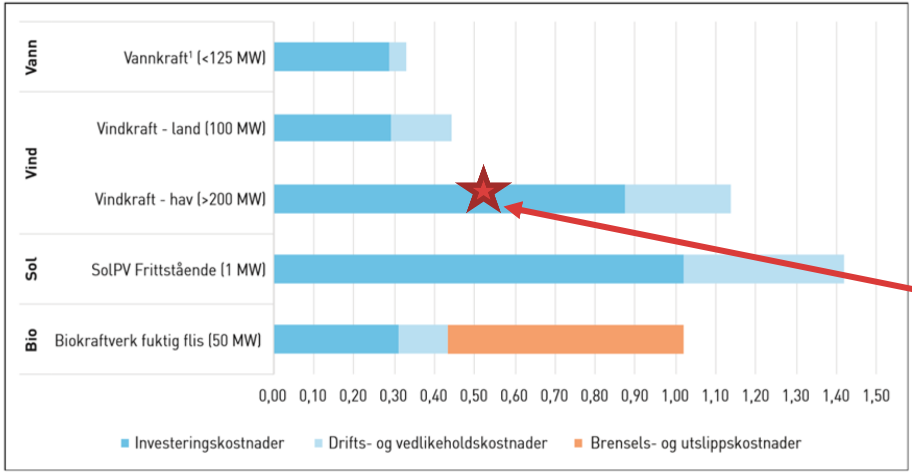
NB diskontering. Valg av rentenivå viktig!

Kostnader – auksjoner

- Tyskland (2017), landvind: 0,38 NOK/kWh (snitt)
  0,22 NOK/kWh (minimum)



Kostnadsutvikling havvind

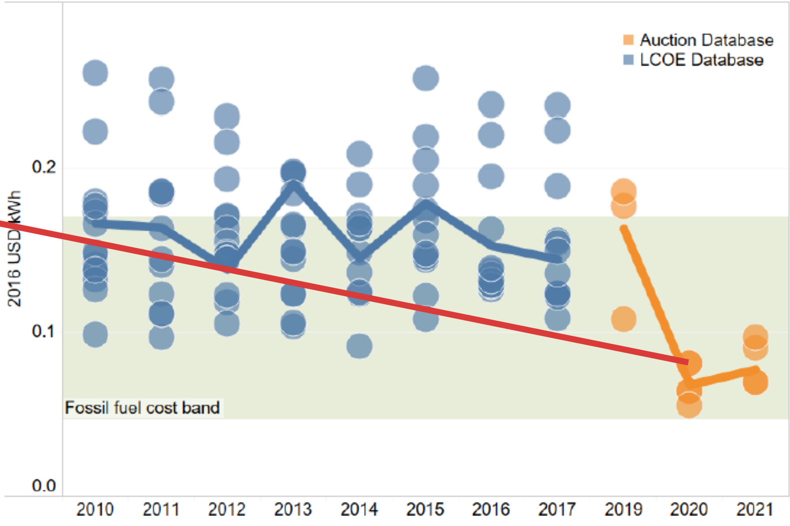


Figur 12.2 Kostnader ved kraftproduksjon fra ulike teknologier i Norge, kroner/kWh.

Biokraftverk er representert med den mest kostnadseffektive varianten.
Kilde: NVE

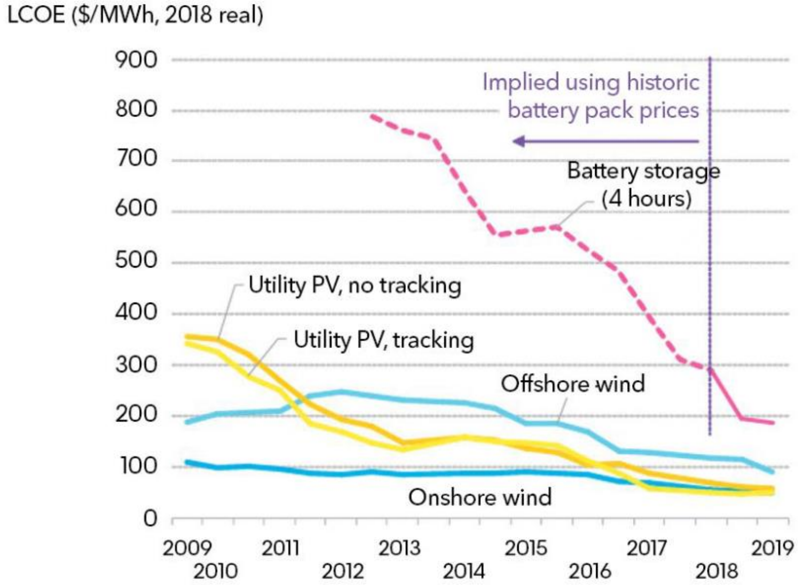
Energimeldingen 2015 -16

Figure 1: Global levelised cost of electricity from offshore wind farms by year of commissioning, 2010-2021



Source: IRENA, 2018a.

Nyere kostdata



Source: BloombergNEF. Note: The global benchmark is a country weighed-average using the latest annual capacity additions. The storage LCOE is reflective of a utility-scale Li-ion battery storage system running at a daily cycle and includes charging costs assumed to be 60% of whole sale base power price in each country.

BloombergNEF 26 mars, 2019:

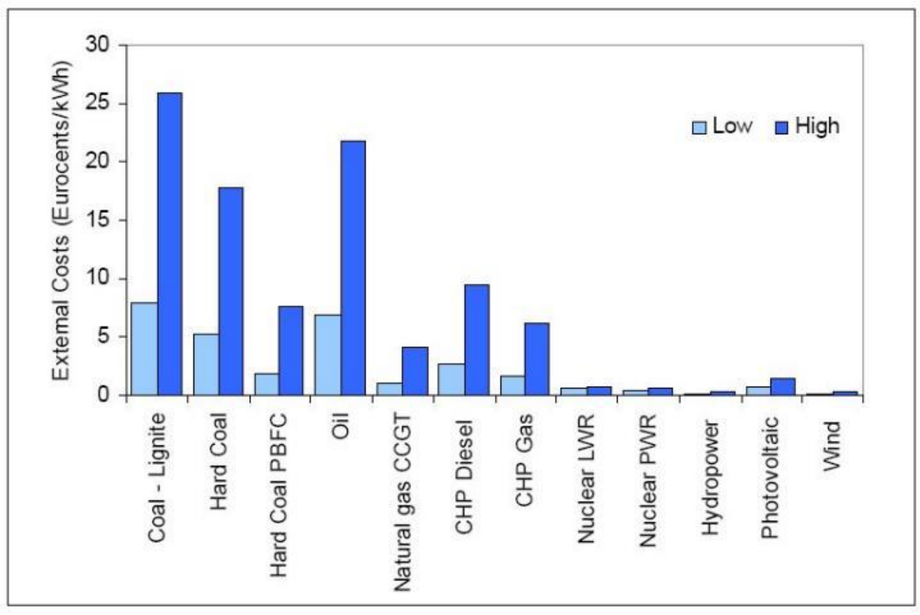
Siste år:

- Kostnader for Lithium-ion batterier ned 35%
- Kostnader for havvind ned 24%

Source: https://about.bnef.com/blog/battery-powers-latest-plunge-costs-threatens-coal-gas/

Eksterne kostnader

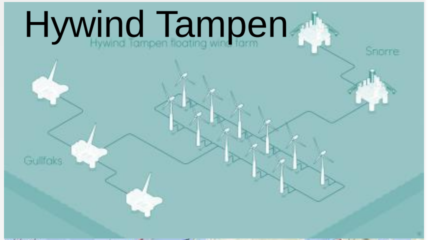
- Hva skal inkluderes?
  - Klimaeffekter
  - Helseeffekter
  - Biologisk mangfold
  - Konflikter i arealbruk
  - …
- Hvordan verdisette og veie ulike hensyn?

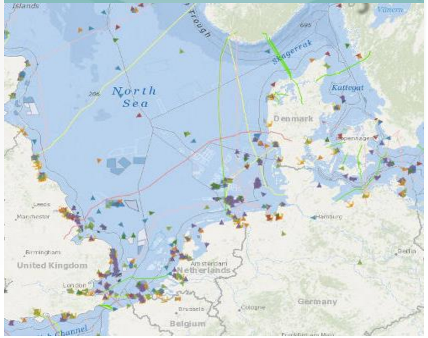


- Se f.eks.
  - European Env. Agency http://www.eea.europa.eu/data-and-maps/indicators/en35-external-costs-of-electricity-production-1
  - IPPC SREEN, Special report on renewable energy (2011)

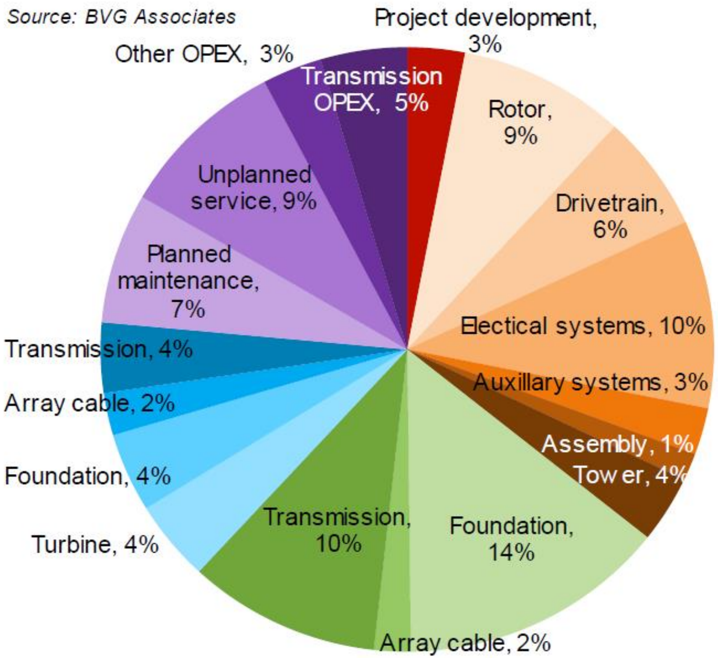
The role of offshore wind in Norway

- New industrial opportunities
- Reduce Norwegian emissions (on- and offshore)
- Contribute in a future North-European power market





Hva kan vi levere?



Vindenergi viktig for Norge

Antall årsverk 2017

	Vannkraft	Havbasert vind	Solenergi	Landbasert vind	Bioenergi	Totalt verdikjede
Leverandører	1 538	1600	923	668	221	4950
Utbyggere	368	4	107	42	70	591
Rådgivning og FoU	1 095	26	91	68	149	1430
Totalt på segment	3002	1630	1122	778	439	**6971**

Omsetning 2017 (mrd kr)

	Vannkraft	Solenergi	Havbasert vind	Landbasert vind	Bioenergi	Totalt verdikjede
Leverandører	4,30	2,77	3,67	1,52	0,91	13,16
Utbyggere	1,02	0,81	0,20	0,09	0,21	2,33
Rådgivning og FoU	1,38	0,13	0,02	0,11	0,18	1,81
Totalt på segment	6,70	3,70	3,88	1,72	1,30	**17,30**

Kilde: Menon Economics, okt. 2018: Kartlegging av omsetning, sysselsetning, eksport og utenlandsomsetning i fornybarnæringen i Norge i 2017.

RAPPORT

Hywind Tampen - Samfunnsmessige ringvirkninger

OPPDRAGSGIVER
Equinor

EMNE
Konsekvensanalyse

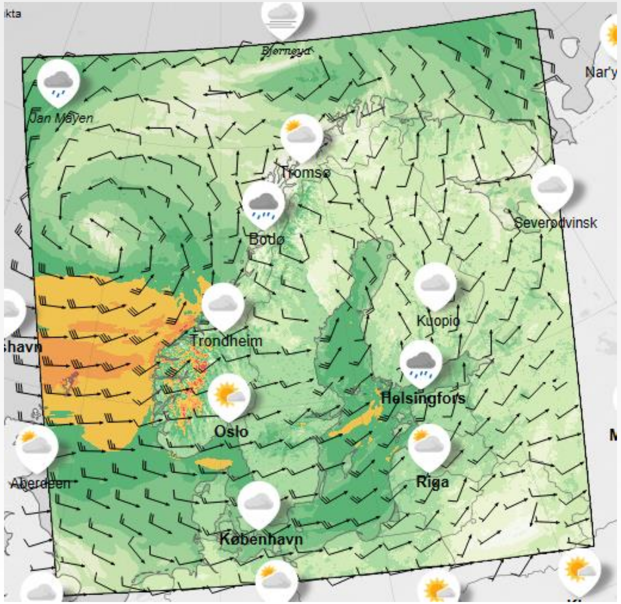
DATO / REVISJON: 21. februar 2019 / Endelig
DOKUMENTKODE: 10209499-TFP-REA-RAP-001

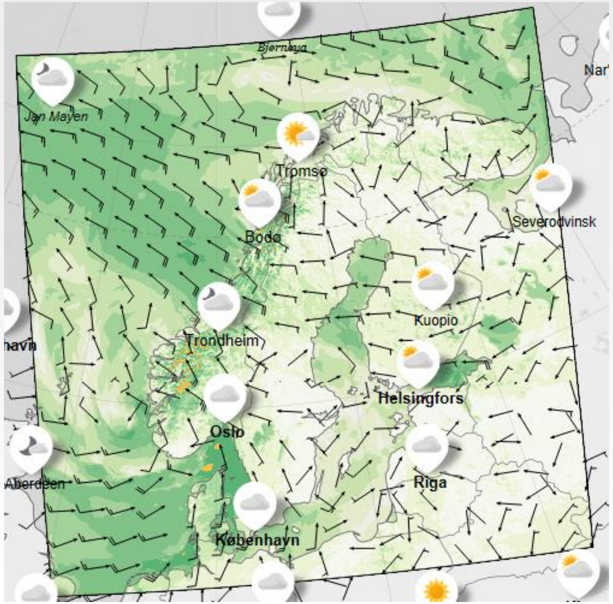
Avhengig av hvor store markedsandeler norske bedrifter tar, vil en potensiell etablering av flytende havvind på 1 GW i Norge kunne gi ringvirkningseffekter på mellom 8 000 og 15 000 årsverk og bidrag til BNP på 9,4 – 17,6 milliarder kroner i Norge samlet sett til og med 2030. Tilsvarende vil en vekst i markedet for flytende vindkraft utenfor Norge opp til 11 GW mot 2030 kunne gi ringvirkninger i Norge på 8 000 - 28 000 årsverk og bidrag til BNP på 9-31 milliarder kroner.

https://www.multiconsult.no/spennende-fremtid-med-flytende-havvind/

Norwegian and mid-European winds have low correlation

- 19.06.2018 kl 11:00 9.09.2018 kl 06:00





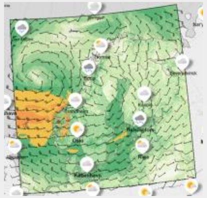
Bergen Offshore Wind Centre (BOW)

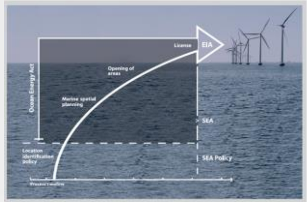
A multidisciplinary approach to offshore wind

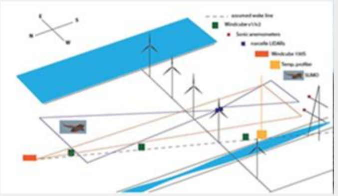
BOW is:

- A resource centre contributing with Research and Education at a high international level.
- Addresses aspects related to resources, environment, and technical solutions, as well as legal, economic and social aspects of offshore wind energy.
- Provides professional support and advices to industry, authorities and the society at large.
- Use the wide range of competences within a multi-disciplinary University.

Focus areas of Bergen Offshore Wind Centre







Wind resources

- **Resource mapping**
  - Map and understand wind at various spatial and time-scales.
  - Wind boundary layer over sea
  - Infrastructure for observations
  - Stability and turbulence evaluations
  - Establish detailed numerical models
- **Inside the wind farm**
  - Wake models and multiple wakes
  - Importance of stability on wake flow

Site evaluation

- **Environmental issues**
  - Mapping of ecology
  - Mapping of soil properties
  - Interaction wind, waves and current.
- **Planning issues**
  - Use of areas, combined use, conflict handling
  - Dynamic response of wind turbines
  - Turbine localization and cable routing
  - Sustainable finance
- **Law issues**
  - Jurisdiction, national / International laws.
  - Integration of offshore wind in the power market

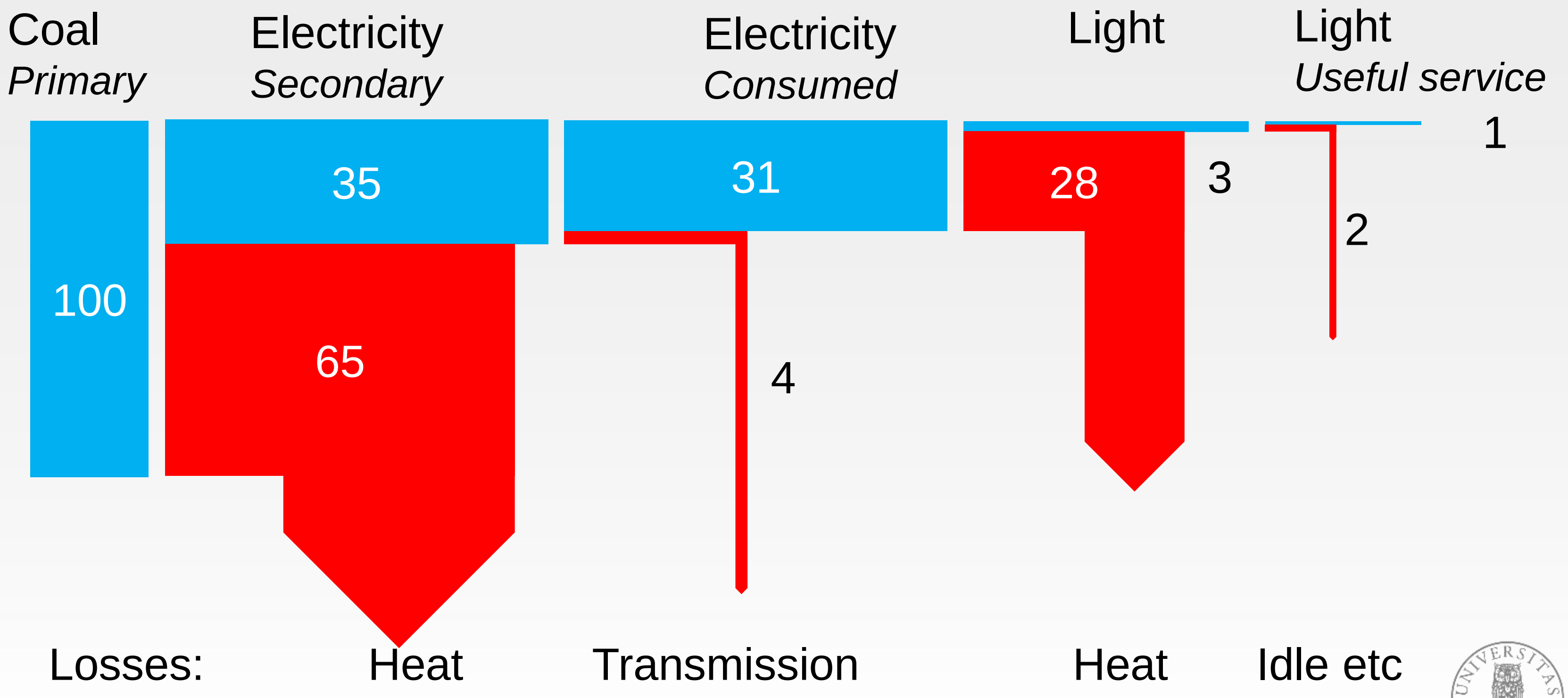
Wind farm operations

- **Production forecasts**
  - Prognosis & Now-casting
- **Marine operations**
  - Operational windows
  - Optimum scheduling
- **Information handling**
  - Collection and analysis of «big data». Visualization and digitalization
  - Decision support systems

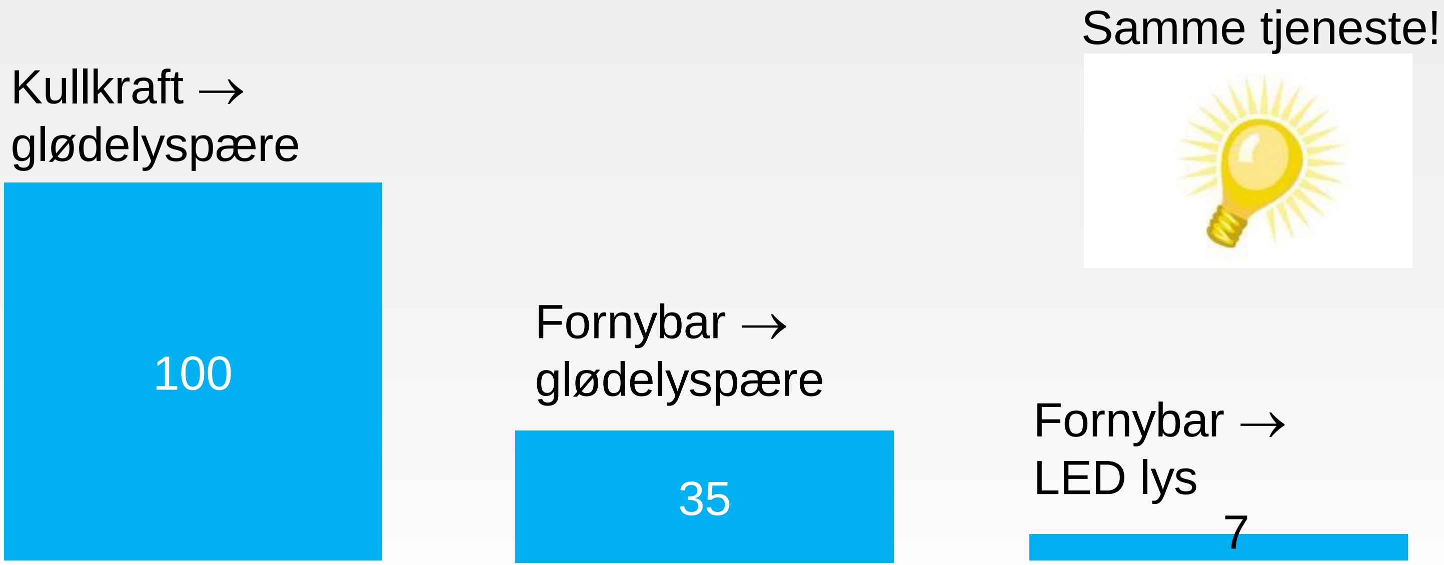
Energiomstilling

- Fra fossil til fornybar – Karbon-nøytralt Europa i 2050!
  - Er kvotehandel et egnet virkemiddel?
- Energieffektivisering
- Elektrifisering

From coal to light - incandescent light bulb



Primær energi eller energitjenester?

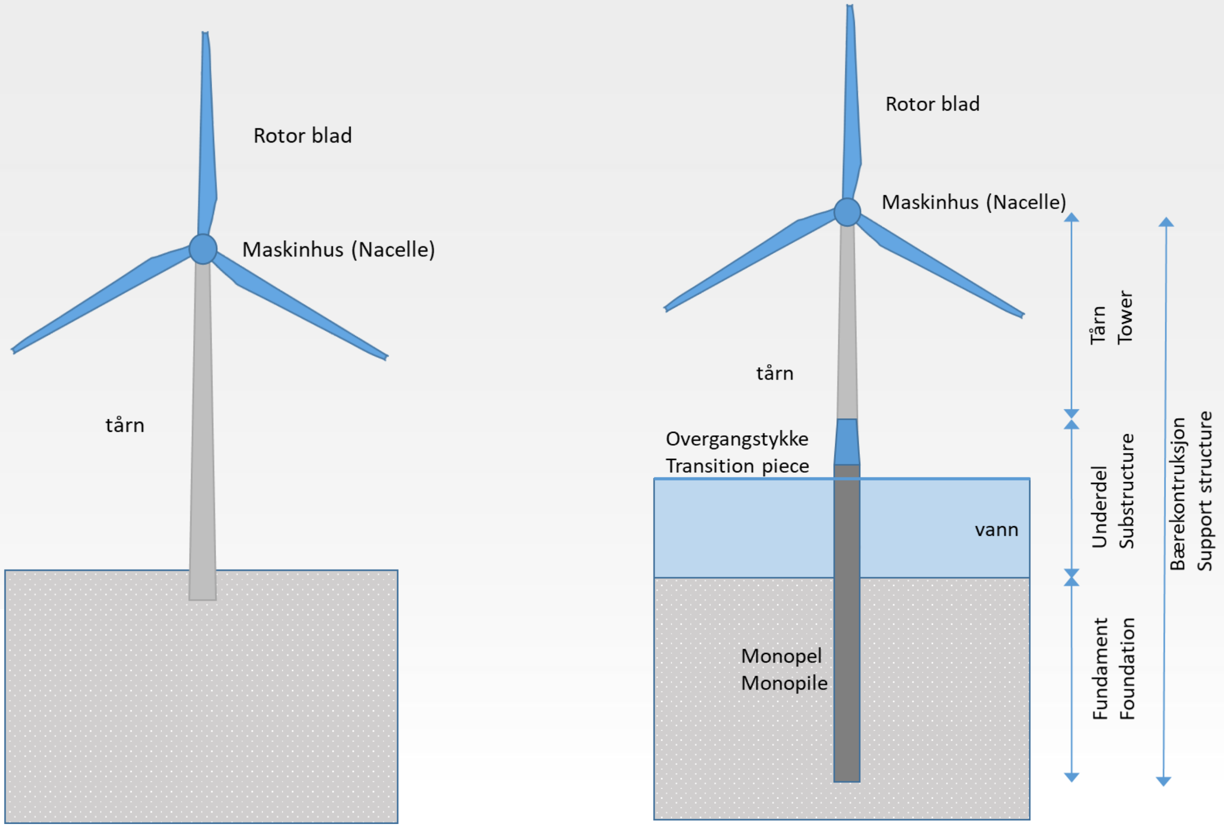


UNIVERSITY OF BERGEN

Bergen Offshore Wind Centre

Tillegg

Navn på turbindeler



BOW

Units

- Energy, E: Joule (J) = Newtonmeter (Nm)
- Power: P = dE/dt: Newtonmeter/sec (Nm/s)= Watt (W)
  - 1 kW = 1000W
  - 1kWh = 3600Ws = 3600J
  - 1 year: 8760.25 hours, i.e. 1kW average power means 8.76kWh/y

Notations and reference values

Prefixes (SI system)

Kilo	k	10^3
Mega	M	10^6
Giga	G	10^9
Tera	T	10^{12}
Peta	P	10^{15}
Exa	E	10^{18}
Zetta	Z	10^{21}

Some revant quantities

- Norwegian Hydropower plants:
- Installed power: approx. 33 GW
- Yearly production: 145 TWh,
- I.e. «capacity factor» =

$$145000 / 33 * 8760 = 0.50$$

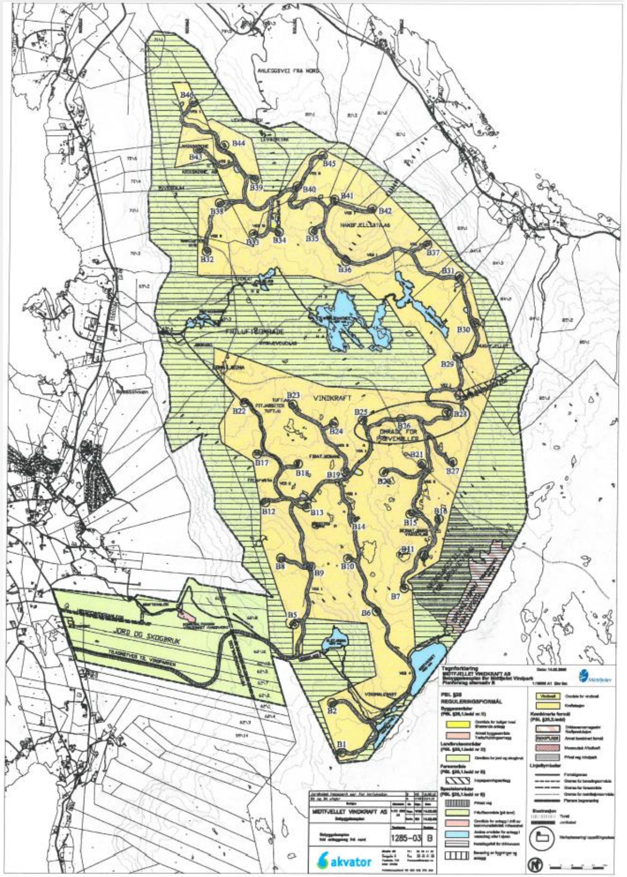
Conversion of units

	kJ kiloJoule	kWh kiloWatthours	BTU British Termal Units	toe Ton oil equivalents
kJ	1	0.2778×10^{-3}	0.9478	23.39×10^{-9}
kWh	3600	1	3.412×10^{3}	85.99×10^{-6}
BTU	1.055	0.2931×10^{-3}	1	25.20×10^{-9}
toe	41.87×10^{6}	11.63×10^{3}	3.968×10^{7}	1

Note: Definition of non-SI units may vary

Eksempel Midtfjellet (Fitjar)

- Årlig produksjon 433,7 GWh
- 34 vindturbiner av typen N90, 2500kW
- 10 vindturbiner av typen N100, 2500kW
- 11 vindturbinar av typen N117, 3600kW
- Totalt: 149,6 MW , Cp = 0,33
- Parkens areal ca 8 km^2



Kilde: Midtfjellet.no

Testaktivitet ved Karmøy

⊕ Vis bildetekst

HYWIND DEMO

Equinor selger verdens første flytende vindmølle til Unitech

Selskapet skal bruke Hywind Demo til å teste ut ny type høyspentkabel for strøm fra havinstallasjoner

AV THOMAS FØRDE ENERGI 8. JAN. 2019 - 12:29

WINDPOWER OFFSHORE

Search

Home | News & Analysis | Countries | WPO Intelligence | Expert Papers

Business & Finance | Technology | Policy & Markets | Project Development | Operations & Maintenance

NORWAY

Stiesdal's TetraSpar set for demonstration

5 October 2018 by Craig Richard

NORWAY: Innogy and Shell will collaborate with Stiesdal Offshore Technologies (SOT) to build a demonstration project using the TetraSpar floating foundation concept.

The TetraSpar concept consists of a tubular steel main structure with a suspended keel (pic: DNV GL)

GOOGLE TRANSLATE

SHARE THIS

Tweet

Share

G+

in Share

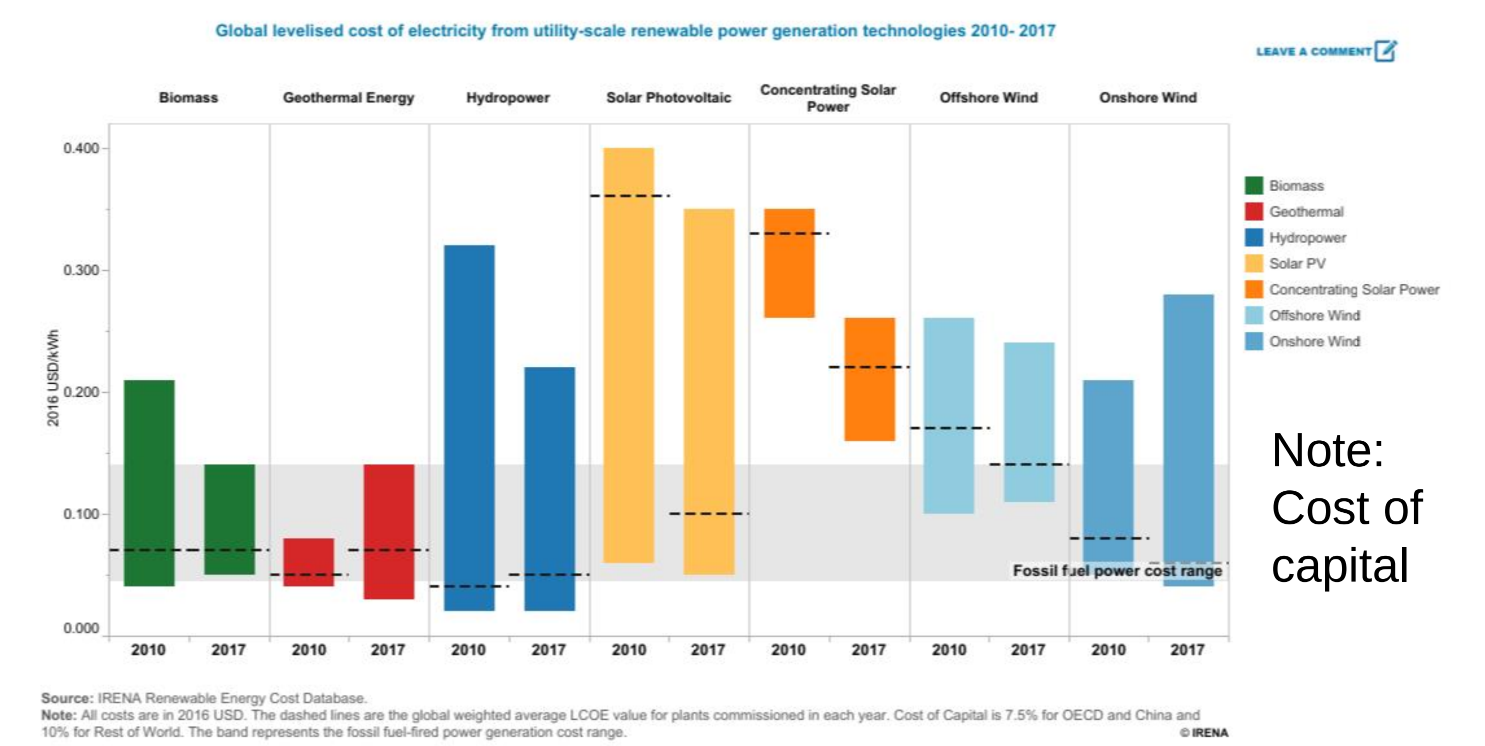
reddit this!

ATTACHMENTS

StiesdalOffshoreTechn

MORE ON THIS TOPIC

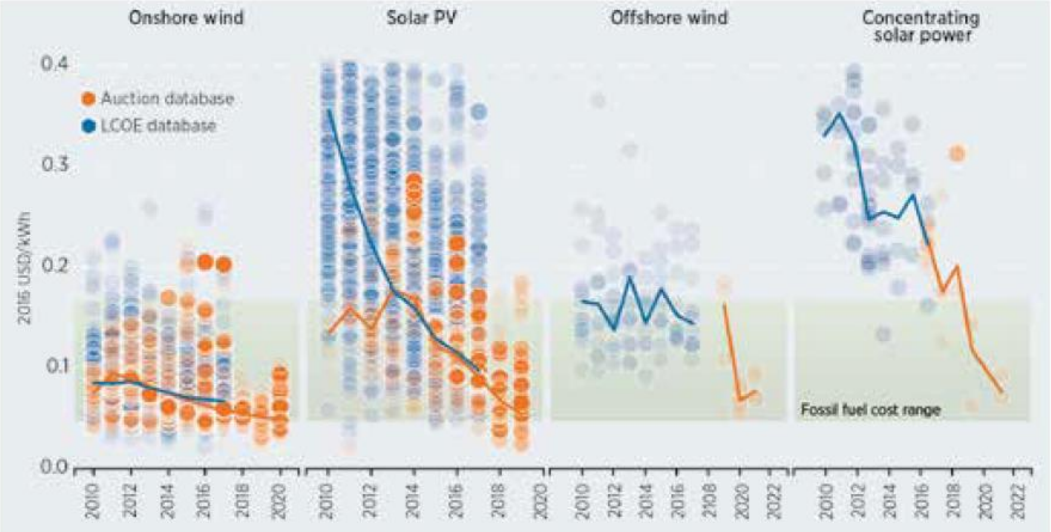
Energikostnad –fornybar energi



Note: Cost of capital

Kostnadsutvikling fornybar energi

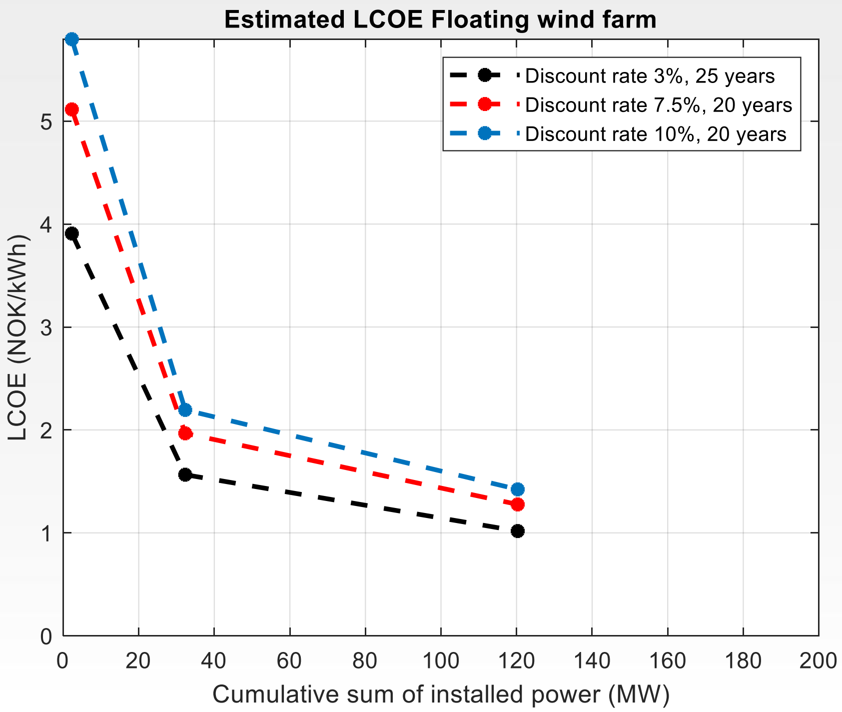
Figure 2: The levelised cost of electricity for projects and global weighted average values for CSP, solar PV, onshore and offshore wind, 2010-2022



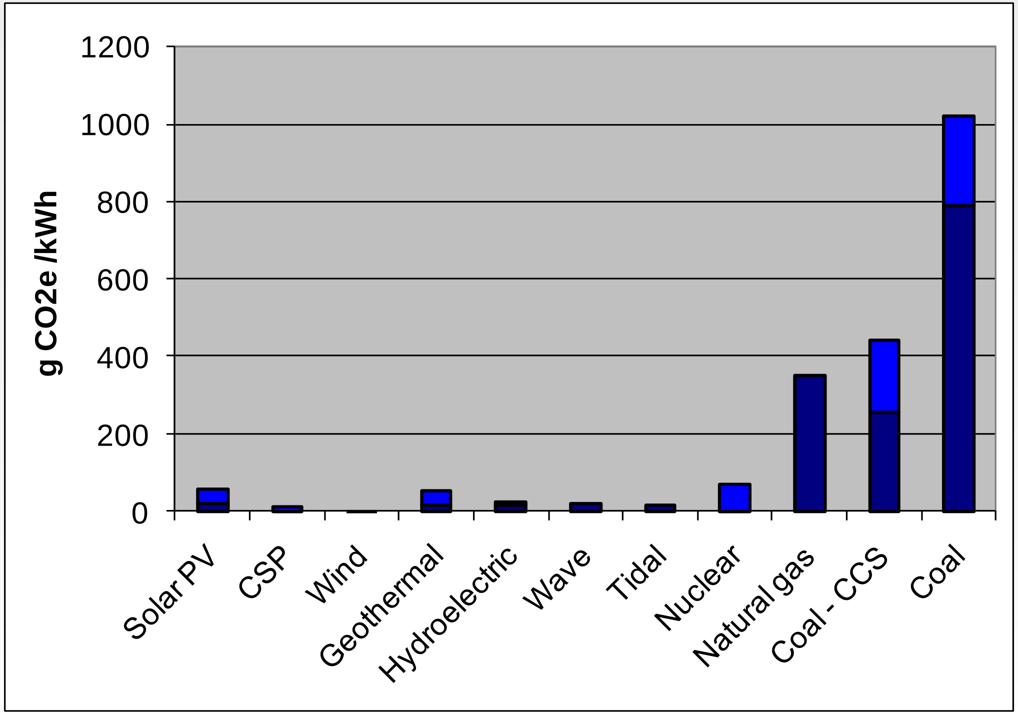
Source: *IRENA Renewable Cost Database and Auctions Database.*

Note: *Each circle represents an individual project or an auction result where there was a single clearing price at auction. The centre of the circle is the value for the cost of each project on the Y axis. The thick lines are the global weighted average LCOE, or auction values, by year. For the LCOE data, the real WACC is 7.5% for OECD countries and China, and 10% for the rest of the world. The band represents the fossil fuel-fired power generation cost range.*

Kostnad flytende havvind – grovt overslag

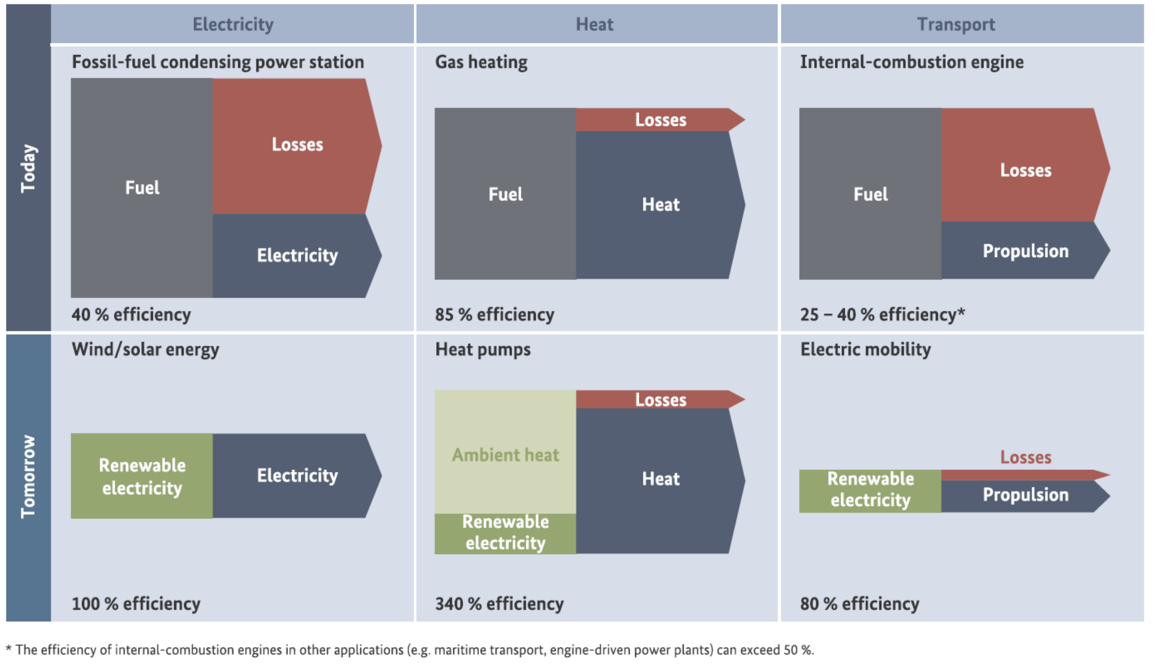


CO_2 avtrykk for el-kraft



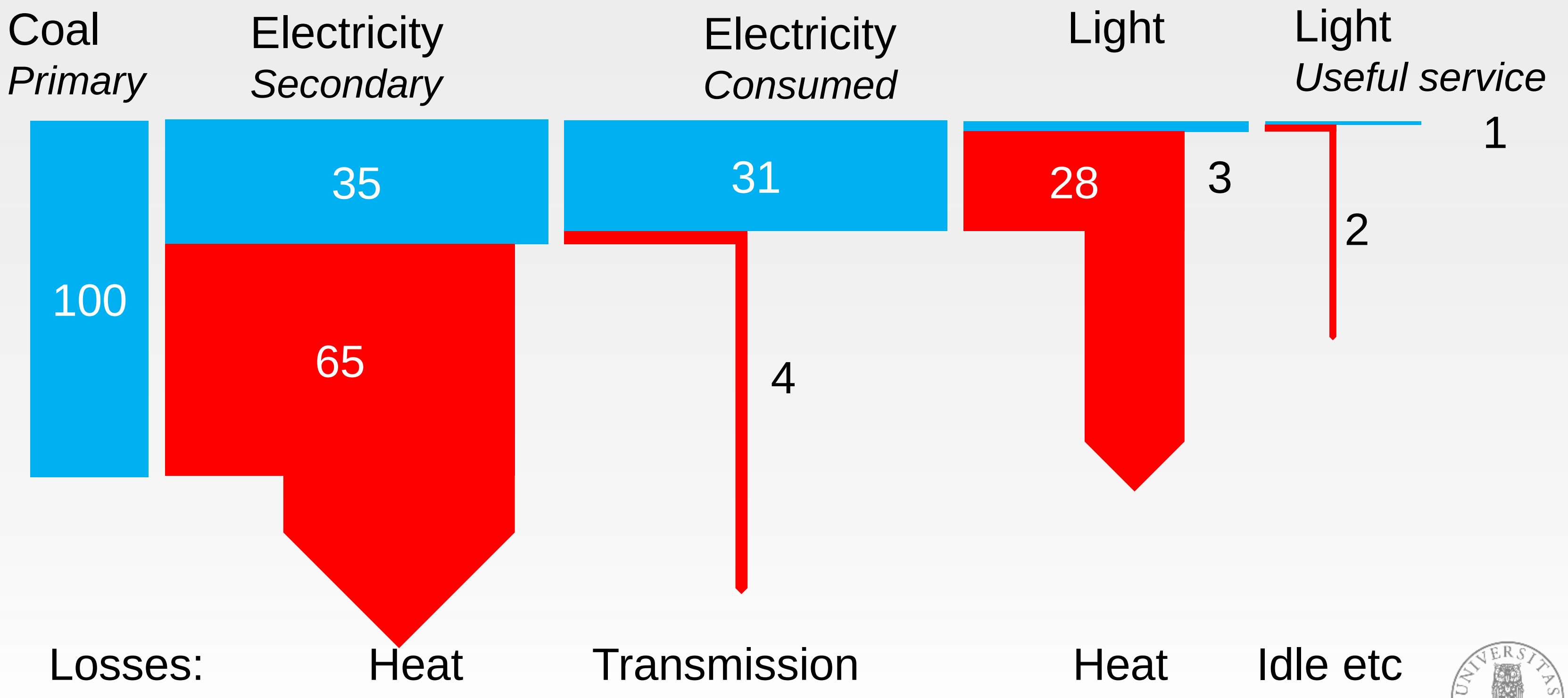
Source: M. Jacobson, Energy & Env. science (2009)

Primary energy versus energy services

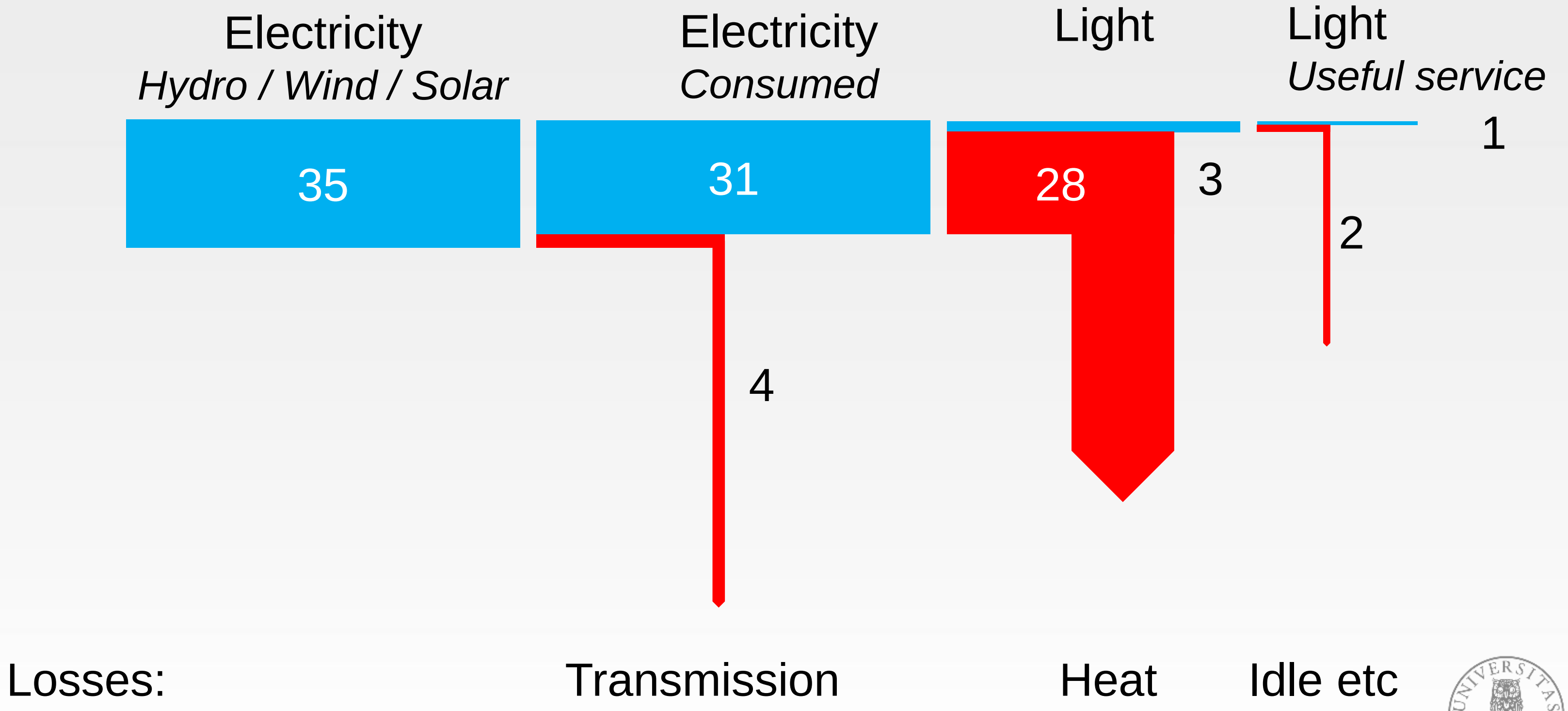


Source: Brown, T.W et al. (2018) Response to “Burden of proof”: A comprehensive review of the feasibility of 100% renewable-electricity systems”. Renewable and Sustainable Energy Reviews, 92 (2018) 834-847.

From coal to light - incandescent light bulb



From renewables to light - incandescent light bulb



From renewables to light - LED light bulb