



Vindkraft på land og til havs

Finn Gunnar Nielsen
Geophysical Institute
Bergen Offshore Wind Centre
<https://www.uib.no/en/bow>





Innhold

- De store utfordringene
- Trenger vi mer energi?
- Utvikling innen vindenergi,
 - På land
 - På havet
 - Norges muligheter
- Hva gjør UiB



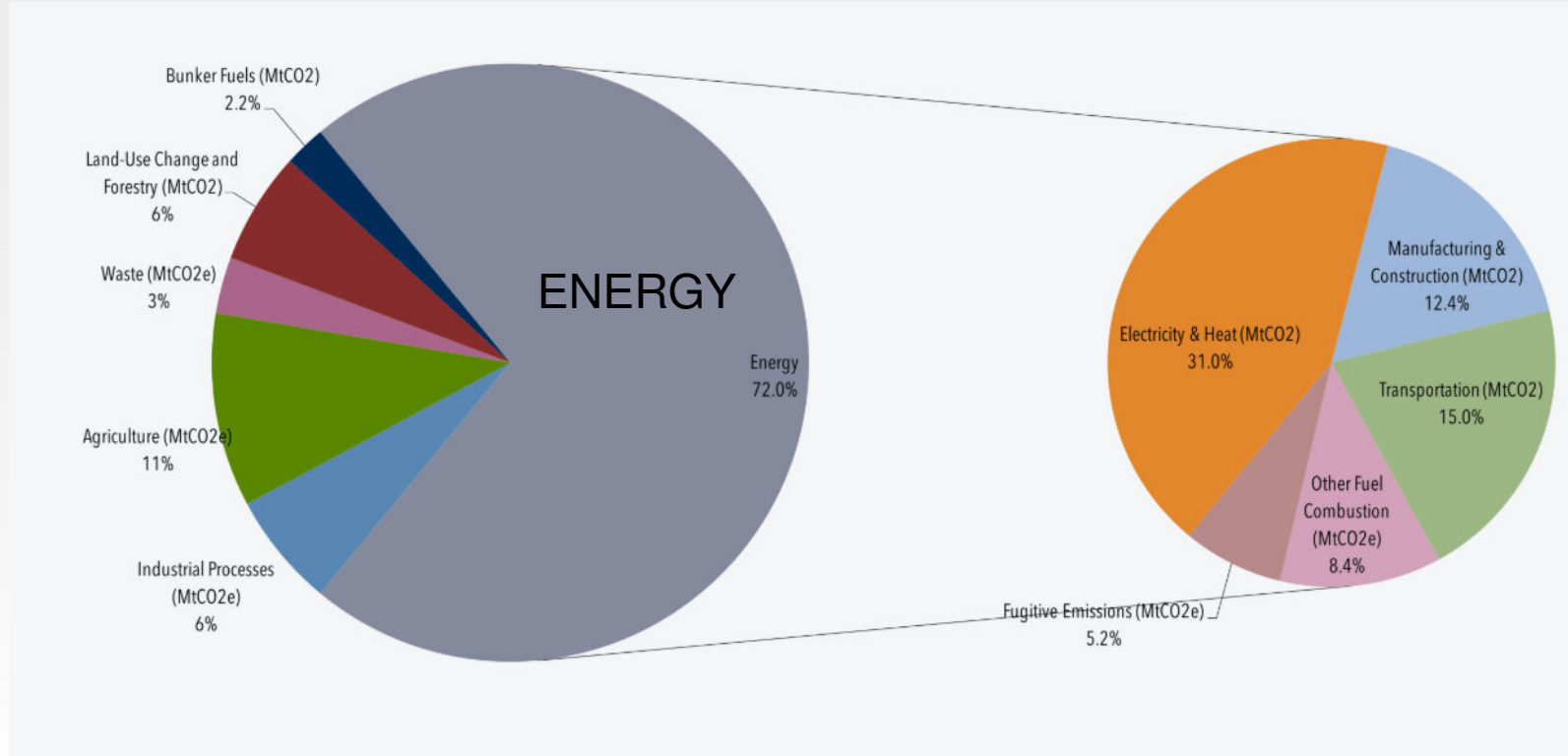
De store utfordringene



Sustainable Development Goals



Menneskeskapte drivhusgasser



Reduksjon av utslipp



- Verdens energiproduksjon og -bruk må legges om
 - Fornybar energi
 - Energieffektivisering
 - Elektrifisering
- “Green Deal”: Karbonnøytralt EU i 2050!



Vindkraft (TWh/år)



NVE	2019	2040
Norge:	10	26
Norden:	53	161

Statnett: Ny fornybar i Norge: 30 – 50 TWh/år



Litt om enheter



Effekt

- 1kW
- 1MW = 1000kW
- 1GW = 1000MW
- 1TW = 1000GW

- Norsk vannkraft: 34 GW

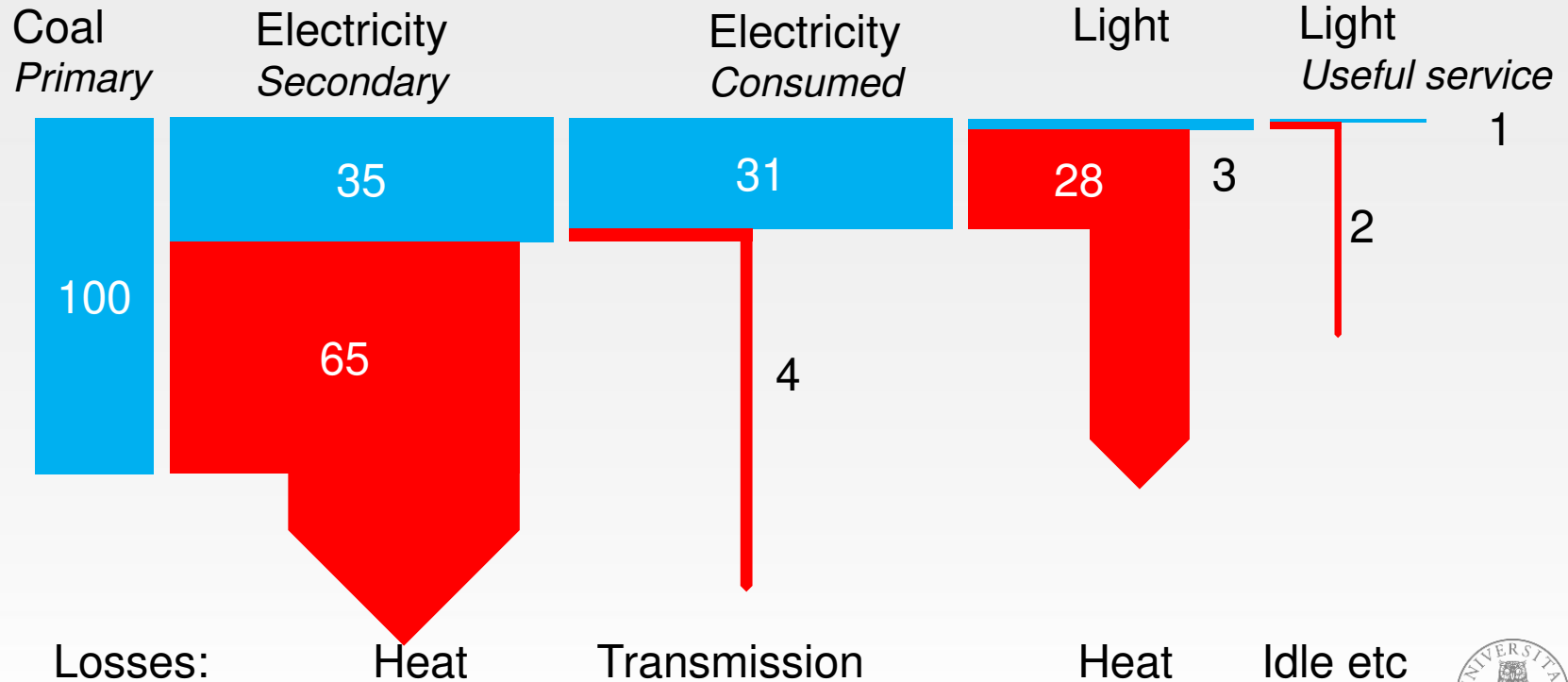
Energi

- 1kW i 1 time: 1kWh
- 1kW i ett år : 8760kWh
- 1MWh = 1000kWh
- 1GWh = 1000MWh
- 1TWh = 1000GWh

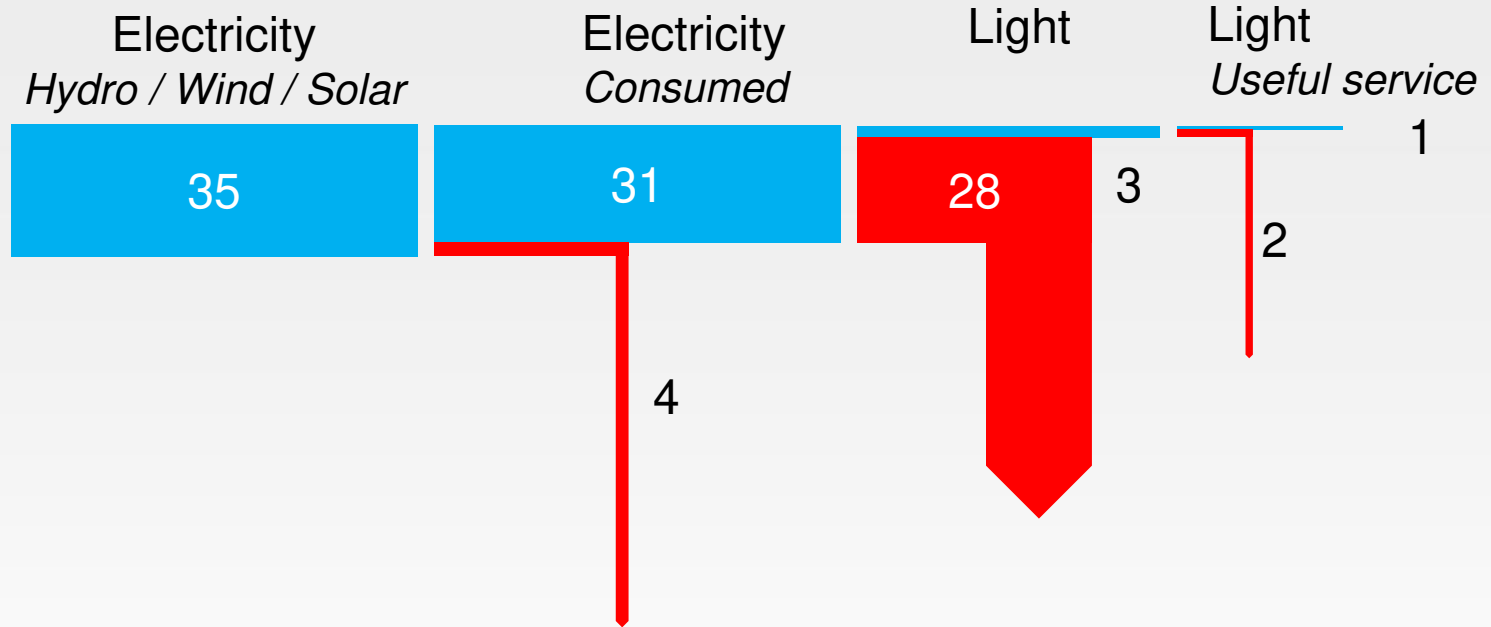
- Norsk vannkraft: ca. 140TWh/år
- 1 Norsk husholdning ca 20MWh/år



From coal to light - incandescent light bulb



From renewables to light - incandescent light bulb



Losses:

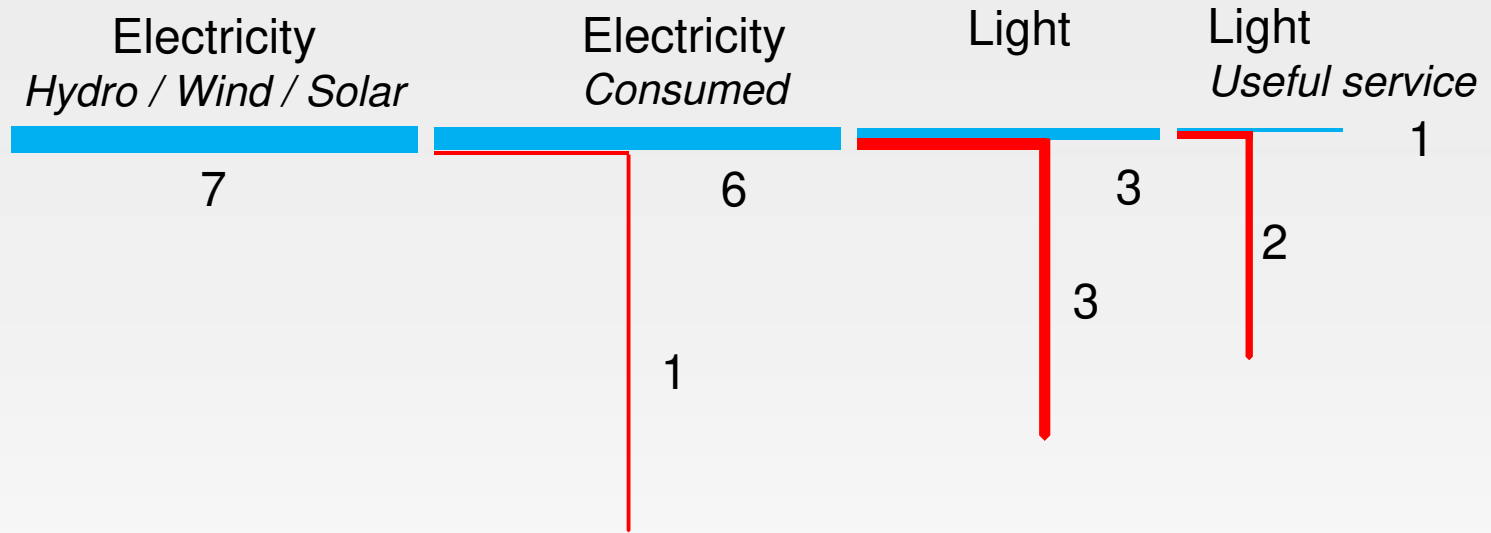
Transmission

Heat

Idle etc



From renewables to light - LED light bulb



Losses:

Transmission

Heat

Idle etc



Primær energi eller energitjenester?



Kullkraft →
glødelyspære

100

Fornybar →
glødelyspære

35

Samme tjeneste!



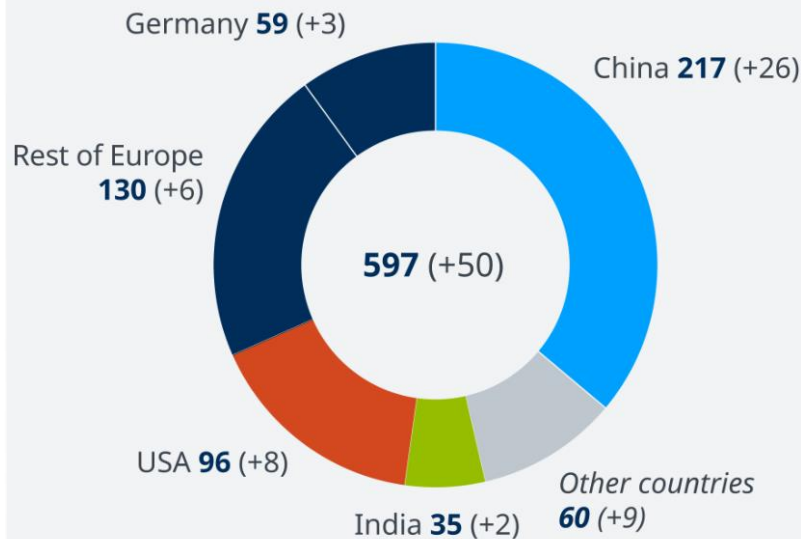
Fornybar →
LED lys

7

Wind Globally (Installed power)



Total power in gigawatts (installed in 2018)



Sources: WWEA, WindEurope

© DW

- Onshore (2018): 573 GW
- Offshore (2018): 24 GW
 - Europe: 19 GW
 - Asia: 5 GW
- Nuclear power(globally): 392 GW
- Norwegian hydropower: 34 GW

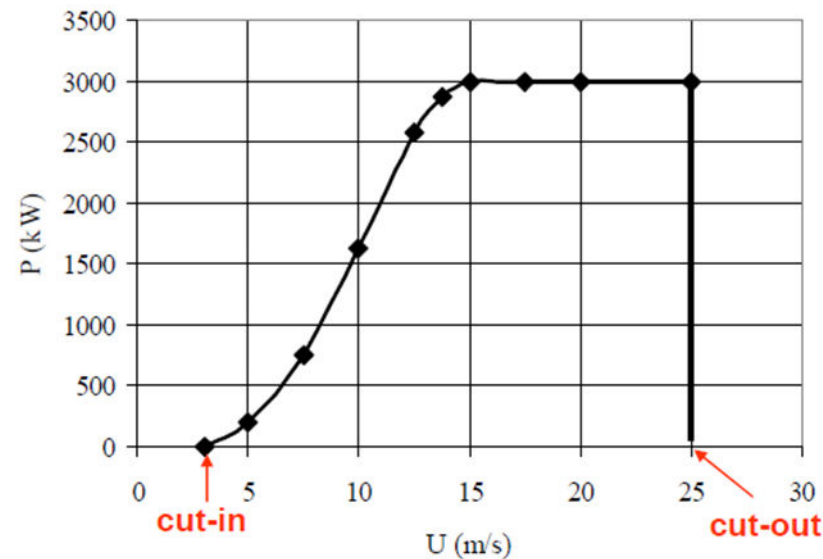
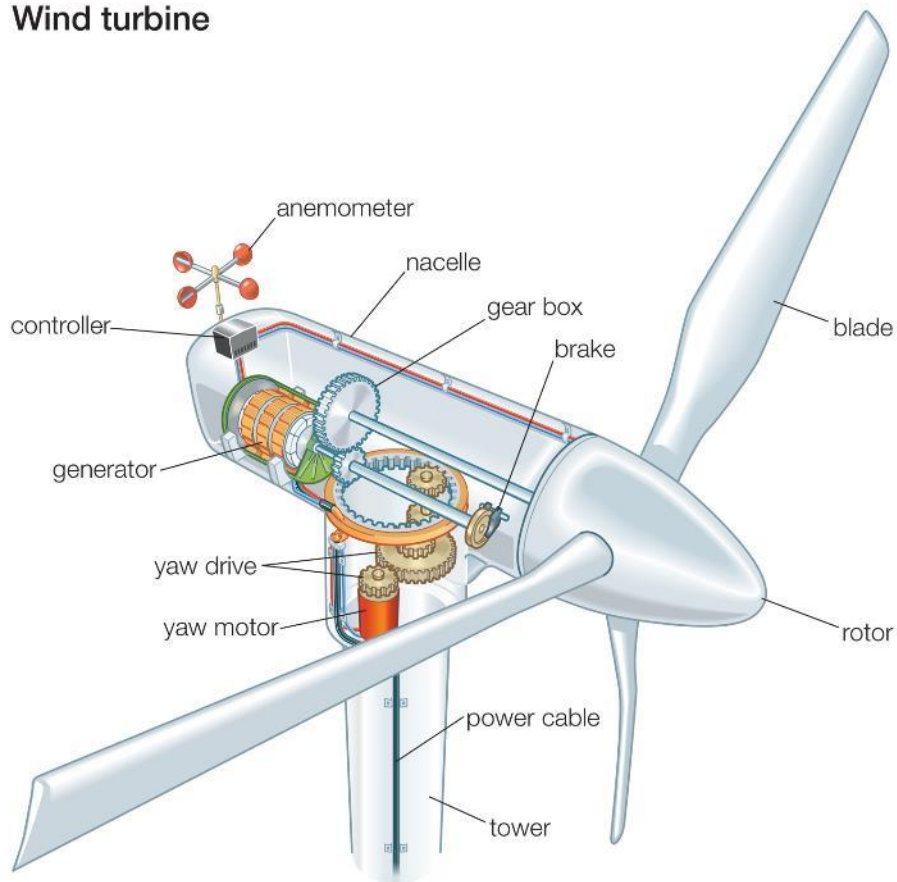
Sources: IRENA / WindEurope (2019)



Vindturbiner



Wind turbine



$$P_{wind} : U^3$$



Vertikal akse turbin



Darreius



Source: Ghada Aboufares 2015 [Performance Characteristics of a Vertical Axis Wind Turbine Operating in Different Environmental Conditions](#)

Source: Siemens: <https://news.cision.com/siemens-process-industries-and-drives/r/siemens-helps-make-vertical-axis-wind-turbine-a-reality,c9783370>



Ekstotiske løsninger –Makani (Google)

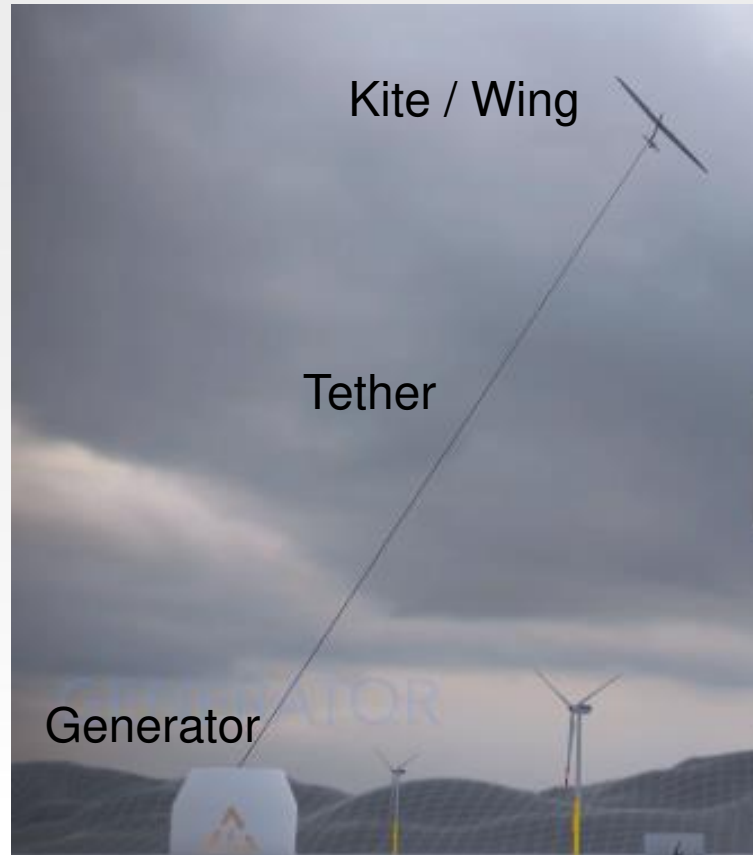


Makani's first offshore energy kite flight, Karmøy aug. 2019



Kilde: <https://www.youtube.com/watch?v=F6NW0QeKLZA>

Kitemill (Voss)



Kilde: <https://www.kitemill.no/>



Vindparker på land



**Wind Farm, Kern
County, Tehachapi, CA. 1996**



Nederland, 2019

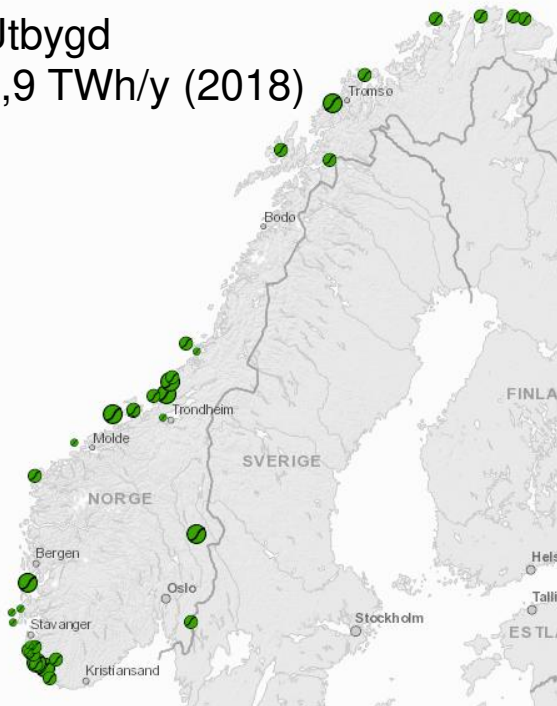


Midtfjellet vindpark, Fitjar, 2017

Vindkraftanlegg Norge, 31.12.2019



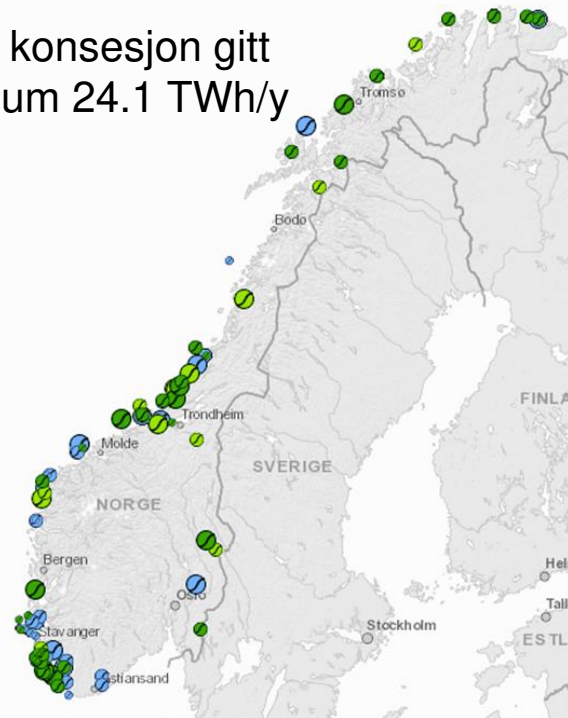
Utbygd
3,9 TWh/y (2018)



+ under utbygging



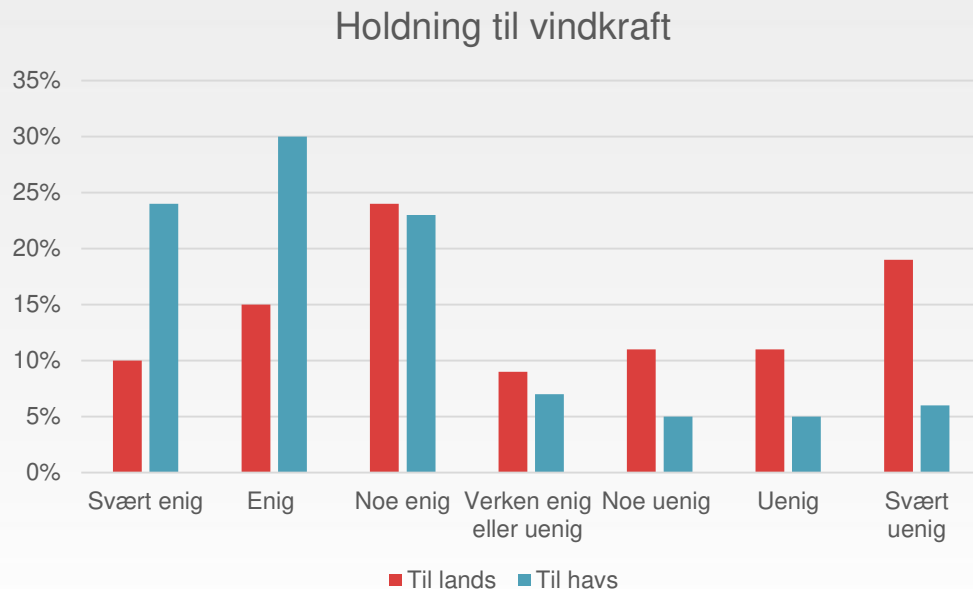
+ konsesjon gitt
Sum 24.1 TWh/y



Holdninger til vindkraft, høsten 2019



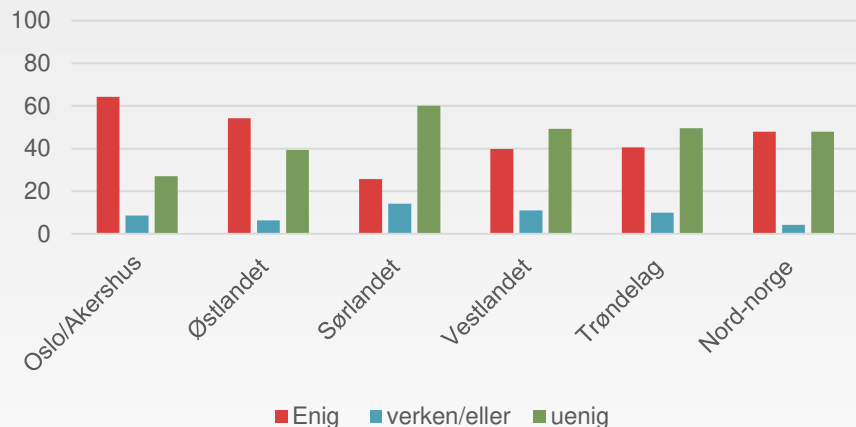
“Bør det bygges flere vindmøller på land / til havs i Norge?”



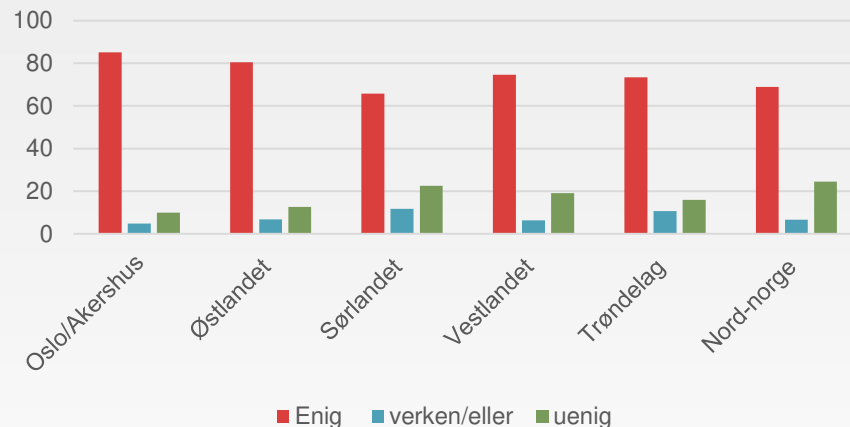
Holdninger til vindkraft, høsten 2019



Utbygging av vind på land



Utbygging av vind til havs



Kilde: Medborgerpanelet v/ E. Tvinnereim



IEA ser potensialet til havs!



iea

About

News & Events

Publications

Our Work

Countries

Statistics & Data

Home » Newsroom » News » 2019 » October

Offshore wind to become a \$1 trillion industry

25 October 2019



Europe is set to be the engine of growth for this flourishing renewable energy technology, followed closely by China and others.
(Photograph: ABB)

“One trillion dollars” »

10 000 milliarder kr. » “oljefondet”

The Ocean as a Solution to Climate Change

Five Opportunities for Action



However, new analysis¹ has identified five ocean-based climate action areas that can help in the fight against climate change. These are:



OCEAN-BASED RENEWABLE ENERGY: reduce barriers to scaling up offshore wind (fixed and floating turbines) and invest in new, innovative ocean-based energy sources such as floating solar photovoltaics, wave power, and tidal power.

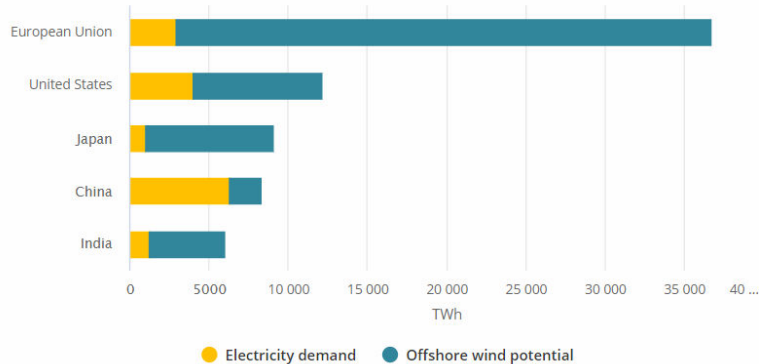


IEA 21.10.19:



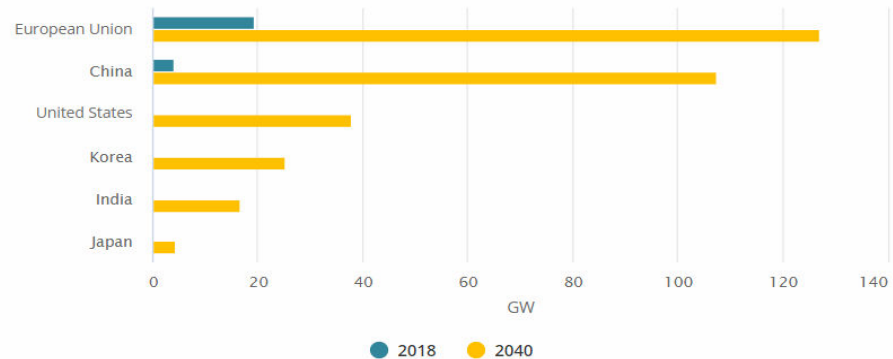
“Offshore wind currently accounts for just a tiny fraction of global power generation, but its potential growth over the next two decades is huge, according to the upcoming Offshore Wind Outlook 2019 that will be released Friday. (25.10.19)”

Offshore wind technical potential and electricity demand in 2018



IEA. All rights reserved.

Installed capacity of offshore wind, 2018 and 2040, Stated Policies Scenario



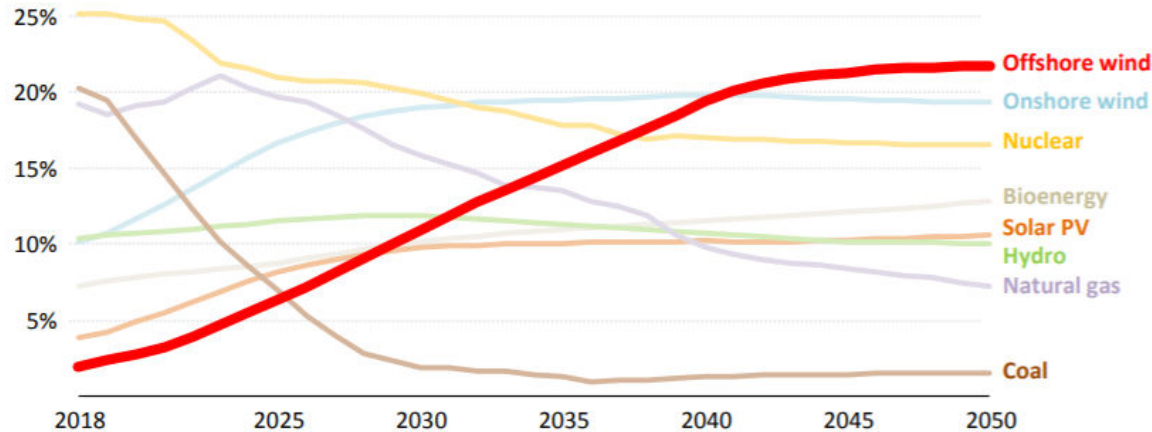
IEA. All rights reserved.



A carbon neutral Europe puts offshore wind in front



Shares of electricity generation by technology in the European Union, Sustainable Development Scenario



Offshore wind is set to become the largest source of electricity in the European Union by 2040, complementing other renewables towards a fully decarbonised power system

IEA 2019. All rights reserved.

iea



In depth: The EU's plan to become the first climate-neutral continent

Published on 03/12/2019, 4:26am

Source: ClimateHome News



Our energy, our future

How offshore wind will help Europe go carbon-neutral

20

september
2019

Equinor satser 50 milliarder på vindkraft til havs
utenfor Storbritannia

 KJELL RØNNINGSBAKK  FORNYBAR ENERGI, NYHETER GRATIS  0

Wind
EUROPE

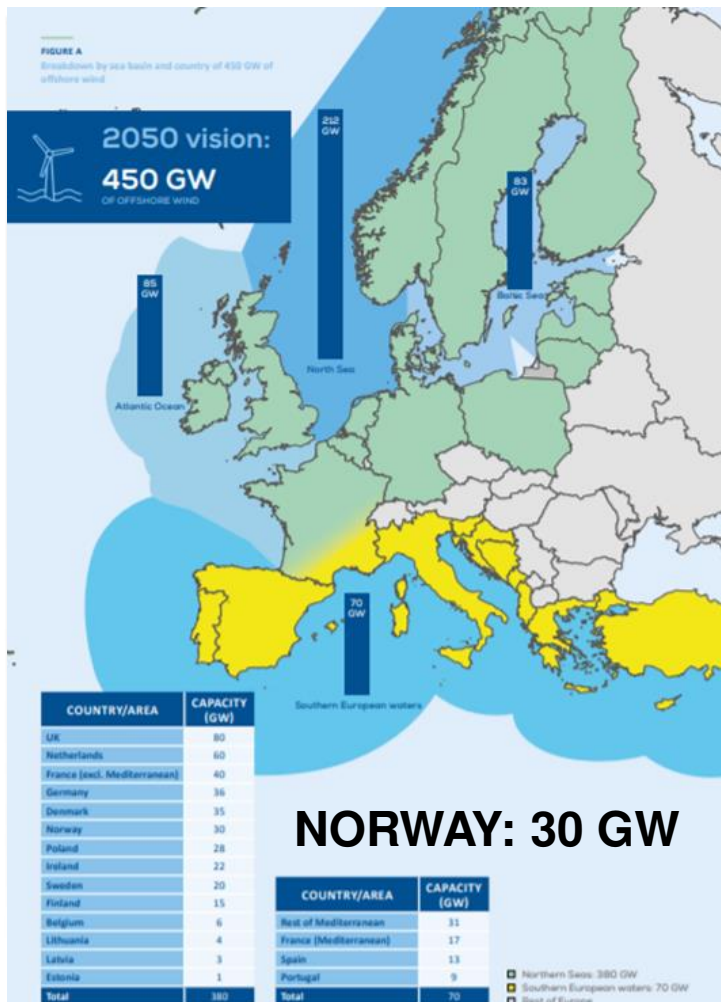
10 December 2019

WindEurope at COP25: This is how wind energy can help deliver a
climate-neutral economy



FIGURE A

Breakdown by sea basin and country of 450 GW of offshore wind



POLICY RECOMMENDATIONS

To overcome the aforementioned challenges and to reach 450 GW of offshore wind by 2050, WindEurope makes the following calls on policymakers:

1.



Governments should set ambitious maritime spatial planning policies to deliver 450 GW by 2050.

2.



Governments should ensure that permitting and other relevant authorities have the necessary expertise and resources to consent enough sites.

3.



Governments should accelerate the expansion of the necessary on- and offshore grid infrastructure.

4.



The EU should elaborate a regulatory framework for offshore hybrid projects.

5.



Governments should accelerate the electrification of transport, heating and industrial processes.

6.



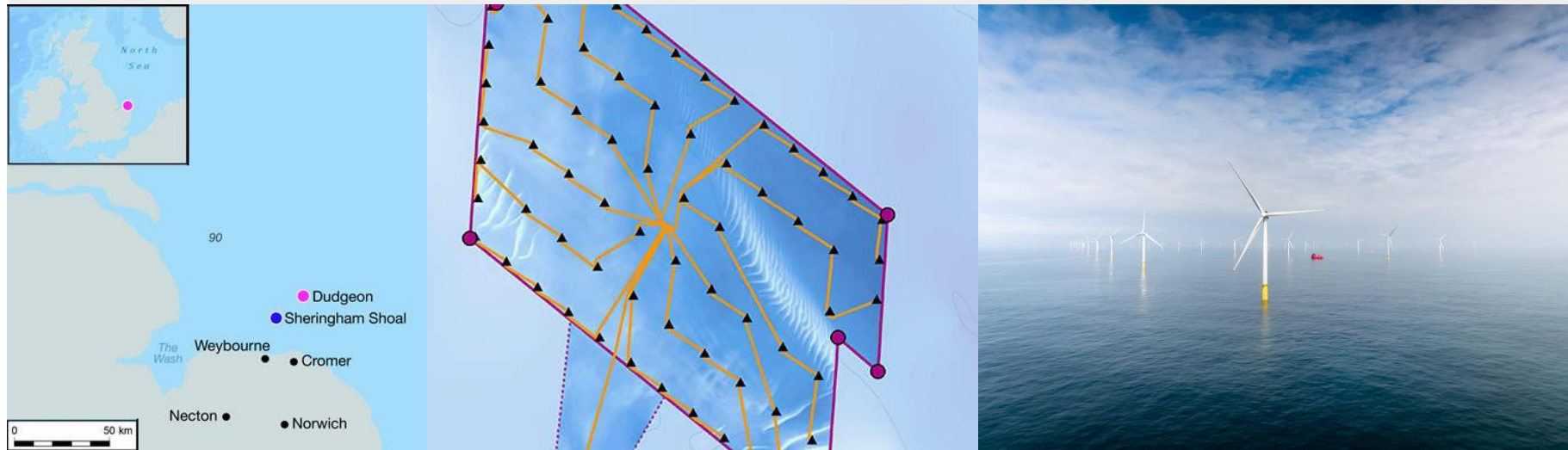
Governments should ensure visibility and confidence in volumes and revenue schemes.



Source:
WindEurope Nov
2019



Havvindpark - Dudgeon



Kilde: Equinor

67stk. 6 MW turbiner, 402MW

NRK 21.11.19



EU-bank struper den norske gassen som skulle redde Europa

Den europeiske investeringsbanken (EIB) skal ikke finansiere fossil energi etter 2021, og struper samtidig gassen som ifølge Norge skulle «redde Europa fra kull».



Iselin Elise Fjeld
Journalist

Publisert i dag kl. 06:09
Oppdatert for 44 minutter siden

Regjeringen ser potensialet, men...



Statsministeren inviterte til toppmøte om havvind ved UiB

På sitt toppmøte for havvind ved UiB peika statsminister Erna Solberg som ein av dei viktigaste ressursane for landet. – Vindkraft til havs vil vere ein viktig ressurs for mange marknader framover, og vil gi grunnlag for næringsutvikling og -arbeidsplassar her heime, sa statsministeren.



TOPPMØTE OM HAVVIND: Statsminister Erna Solberg kaste inn til toppmøte om havvind på Hørfarane ved UiB. Photo: Jens H. Amdam, UiB

Bergens Tidende

BT Magasinet

Sport

Kultur

Meninger

17. september

Hallelujamøte om havvind

Erna Solberg ble møtt med et unisont ønske om å komme raskt i gang med utbygging av flytende havvind.

17. september



VILLE LYTTE: Statsminister Erna Solberg kom til vindkraftmøtet fulgt av rektor ved Universitetet i Bergen, Dag Rune Olsen, og leder for Havforskningsinstituttet, Sissel Rogne. ■ Bjørn Erik Larsen



Norge uten mål!



Norge med Hywind Tampen:
0.088GW





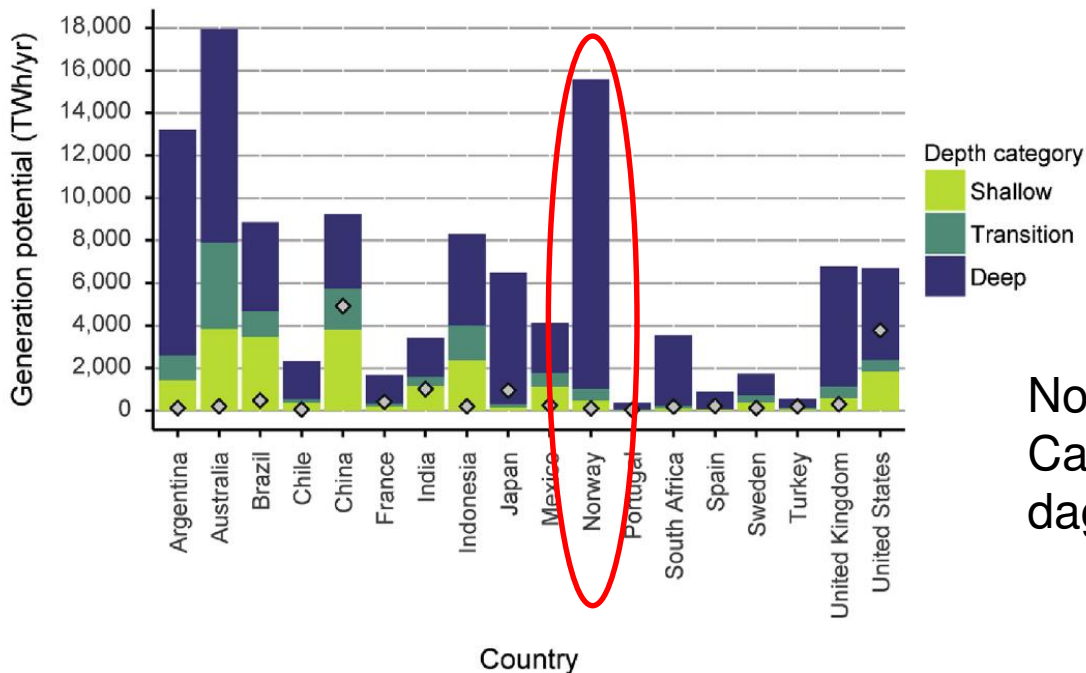
FGN Feb 2020

Havvindressurser



J. Bosch et al. / Energy 163 (2018) 766–781

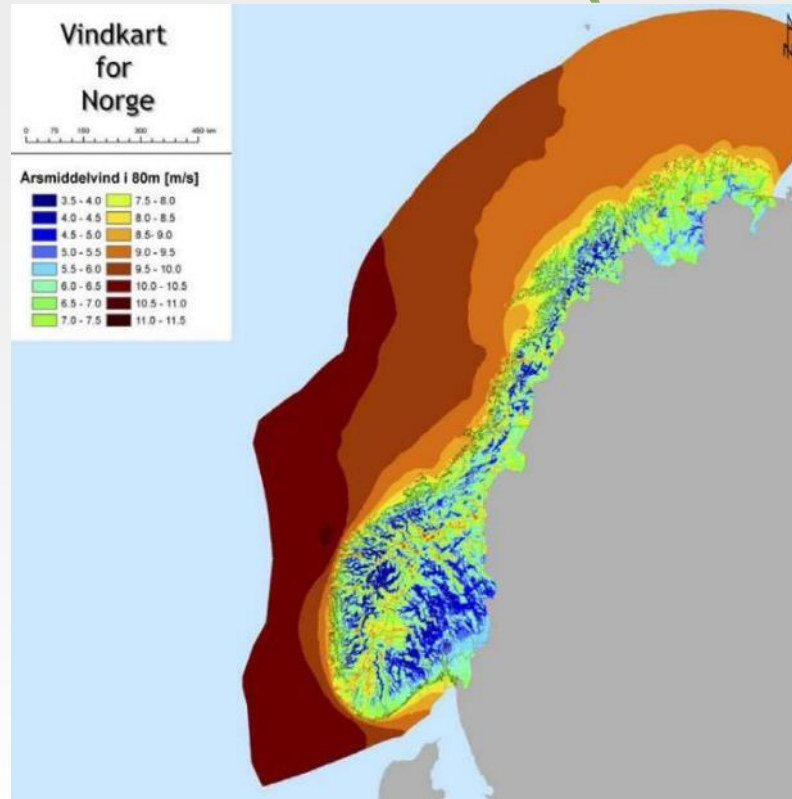
775



Norsk potensial:
Ca. 100 ganger
dagens vannkraft

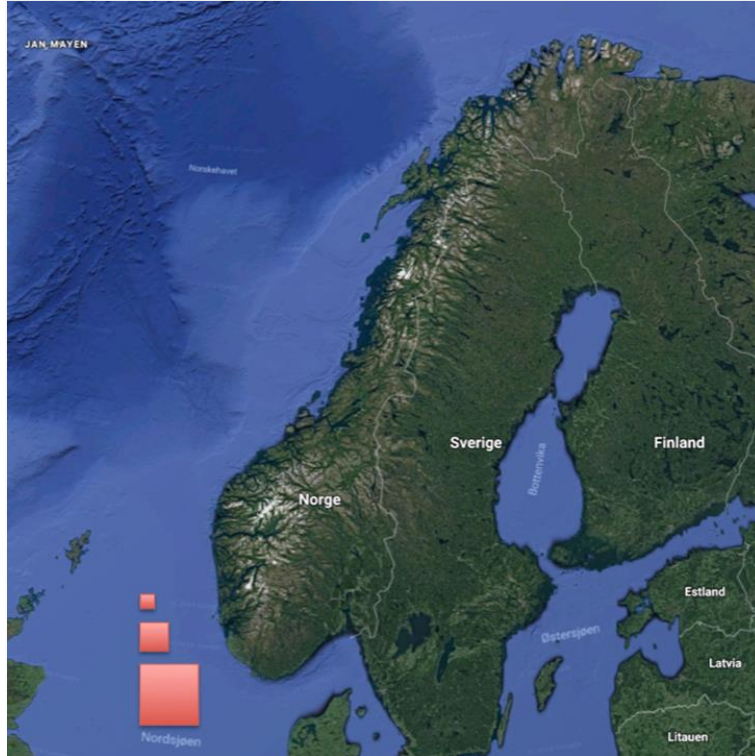
Fig. 7. Annual average energy production (AEP) potential of offshore wind farms for different depth categories for a selection of high producing countries (shown in alphabetical order). Depth categories are Shallow (0–40 m), Transitional (40–60 m) and Deep (60–1000 m). The estimated AEP is the average generation over all time slices, summed over all feasible areas of the country Exclusive Economic Zone, up to the prescribed depth limit. The overlaid point on each bar is the electricity generation in 2015 from Ref. [71] for comparison.

Vindressurser (80 m høyde)



$$P : U^3$$

Arealbehov



- 30 x 30 km: Vindkraft på land med konsesjon. (ca. 24 TWh/år)
- 70 x 70 km: All norsk vannkraft
- 140 x 140 km: Erstatte all norsk gass eksport (hensyntatt energikvalitet)

Map: Google Maps.

Havvindens rolle for Norge

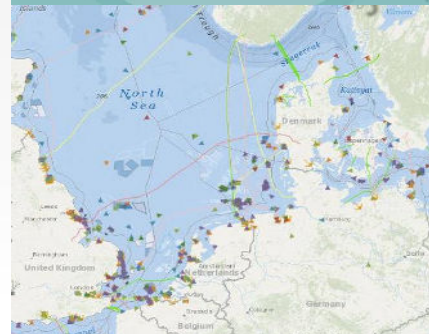
- Nye industrielle muligheter – vi har kompetansen.
- Redusere norske utslipp.
- Bidra i et fremtidig europeisk fornybart energimarked.



Fjellstrand



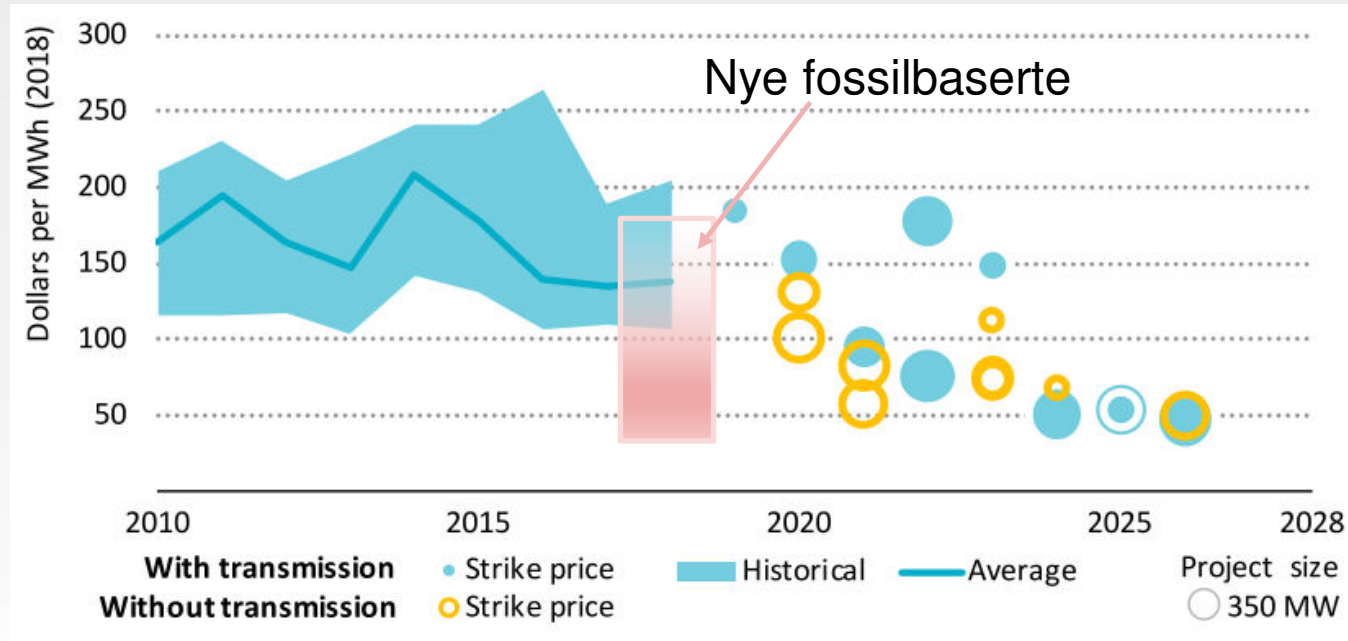
Hywind Tampen



Energikostnad for havvind i Europa



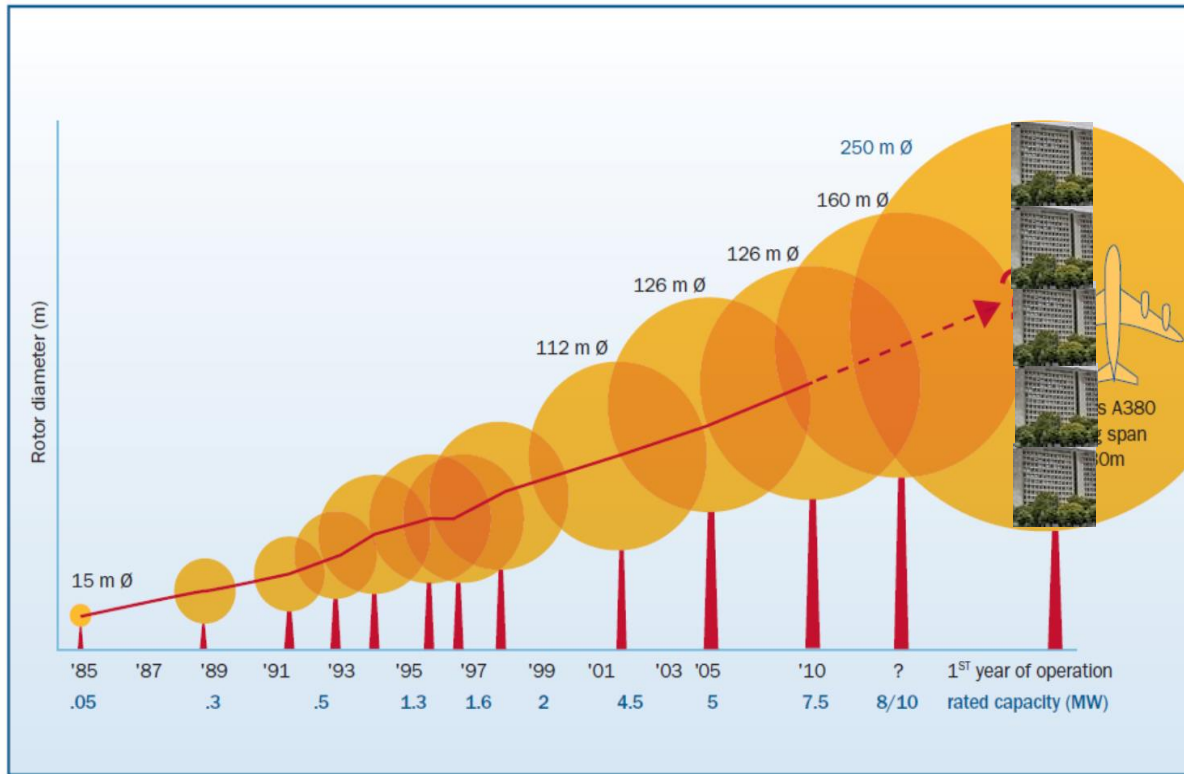
LCOE



Kilder: IEA, World Energy Outlook, 2019,
IRENA, Renewable energy costs, 2018



Vindturbiners størrelse



Mars 2018:

GE lanserer 12 MW, 220m offshore turbin

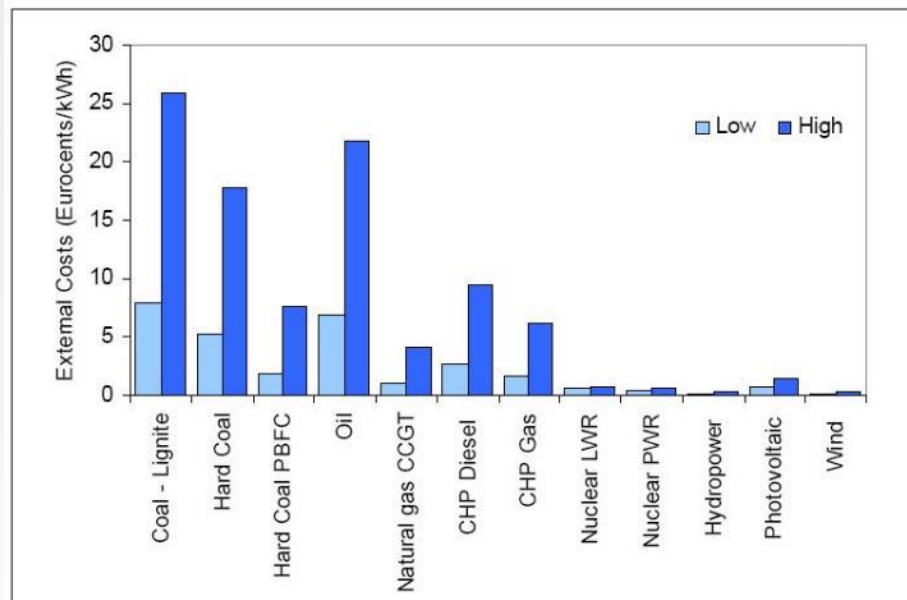
16.01.19:

Siemens Gamesa lanserer 10MW 193m offshore turbin

Eksterne kostnader



- Hva skal inkluderes?
 - Klimaeffekter
 - Helseeffekter
 - Biologisk mangfold
 - Konflikter i arealbruk
 - ...
- Hvordan verdsette 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)



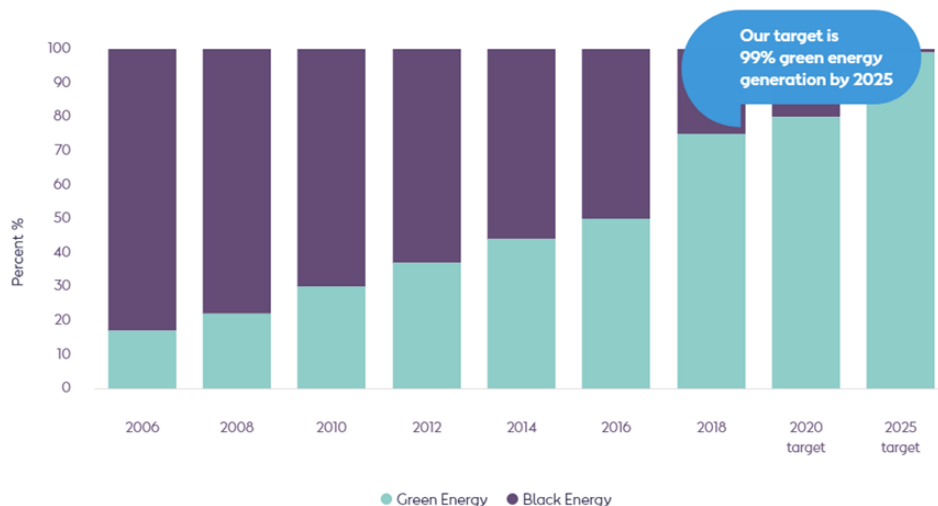
Hurtig omstilling er mulig – DONG - Ørsted



Green share of power

Green energy share in power and heat production

Energy sources in power and heat production



Prices of newly built power production technologies



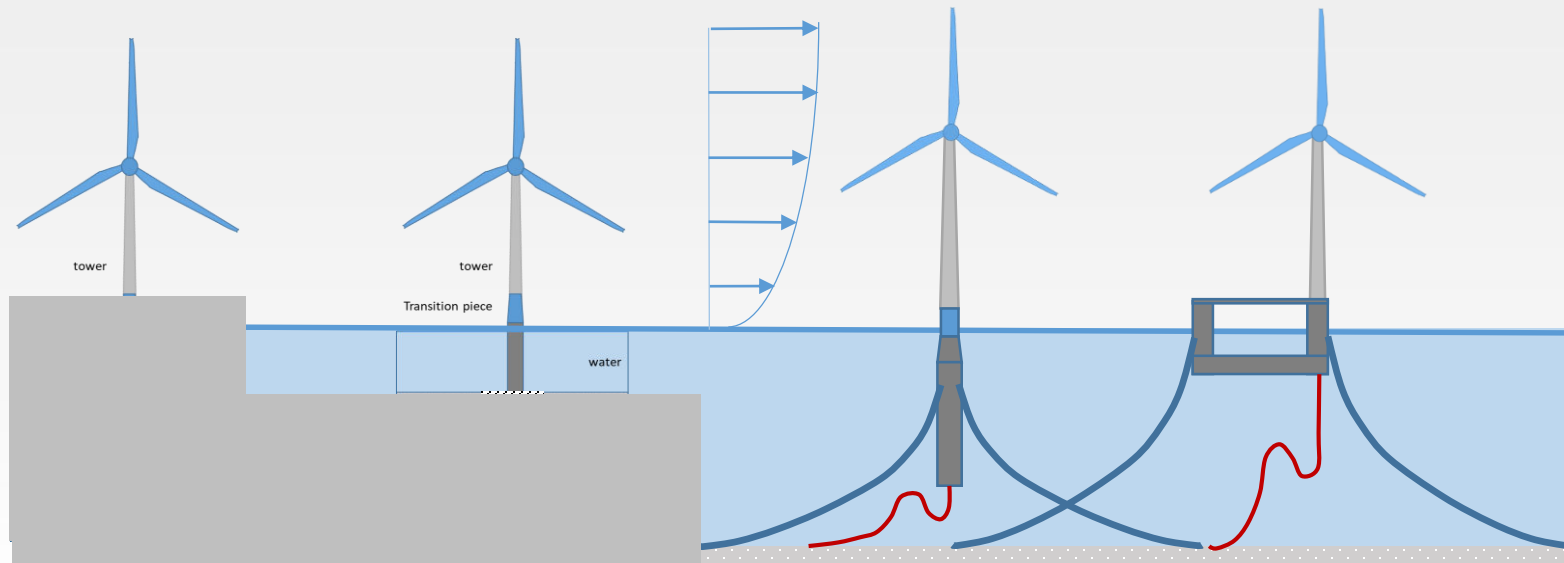
Source: Bloomberg New Finance (2016-prices), Year of FID

*Offshore: Hornsea 2, UK; **Nuclear: Hinkley Point, UK

Prices reflect North Western European market conditions, which express a global trend. Specific prices may vary across regions.



Dypt vann – nye løsninger



Hywind Scotland



Photo: Ørjan Richardsen, Wordcam/Equinor



Nye utfordringer



DN Dagens
Næringsliv

Meny

▼ D2

▼ Magasinet

▼ Dagens avis



Kjøp DN

Logg inn

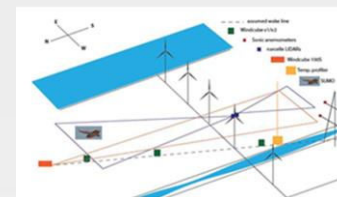
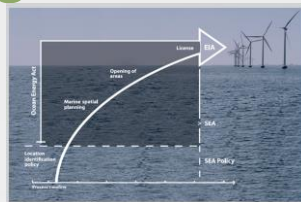
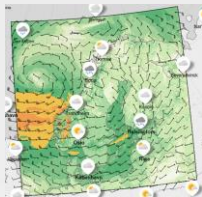
Her er vindfenomenet som rystet offshore-giganten

Har overvurdert energien som produseres av vindmølleparkene.

🕒 1 min Publisert: 06.11.19 — 09.10 Oppdatert: 15 dager siden

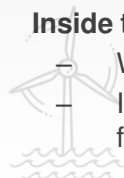


Focus areas of Bergen Offshore Wind Centre



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



Oppsummert

- Klimamålene krever mer fornybar energi
- Norge har en unike vindressurser
- Havvind kan bidra til norske utslippsreduksjoner og i et Europeisk energisystem
- Norge har kompetanse til å ta et internasjonalt lederskap på dypt vann.
- Det haster!

Vi har tjent oss rike ved å være en del av problemet –
La oss ta lederskap i å finne løsningene!





UNIVERSITY OF BERGEN

Bergen Offshore Wind Centre

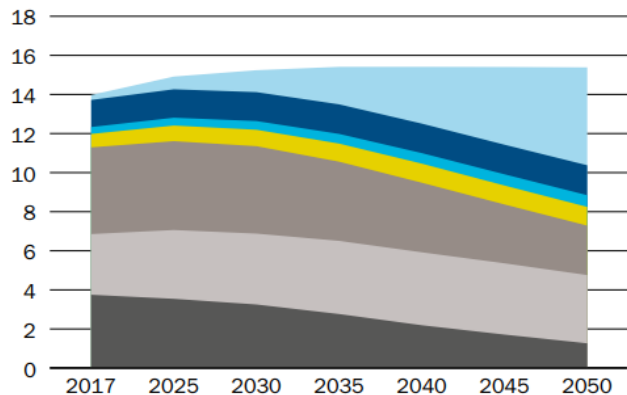


Statkraft, lavutslippsscenario, 2019



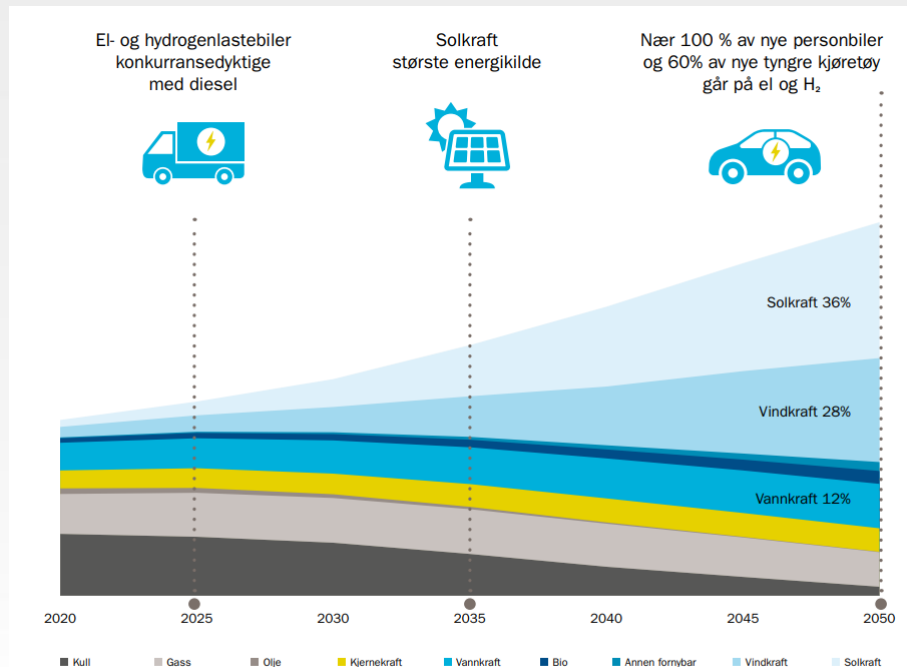
Etterspørsel etter primærenergi globalt

Mrd toe



■ Kull ■ Gass ■ Olje ■ Kjernekraft
■ Vannkraft ■ Bio ■ Sol og vind

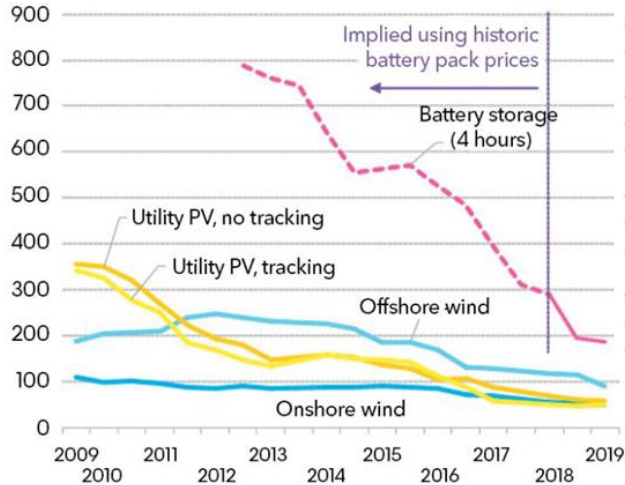
Figur 5. Global energibalanse i primærenergi fra i dag og fram til 2050. Lavutslippsscenario 2019 (mrd toe).



Bloomberg March 26, 2019



LCOE (\$/MWh, 2018 real)



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.

Battery Power's Latest Plunge in Costs Threatens Coal, Gas



March 26, 2019

London and New York, March 26, 2019 - Two technologies that were immature and expensive only a few years ago but are now at the center of the unfolding low-carbon energy transition have seen spectacular gains in cost-competitiveness in the last year.

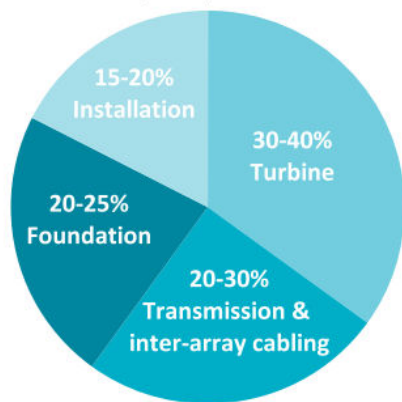
- Cost reductions last year:
- LCOE
 - Offshore wind: 24%
 - Onshore wind: 10%
 - Solar PV: 18%
- Lithium-ion batteries: 35 %



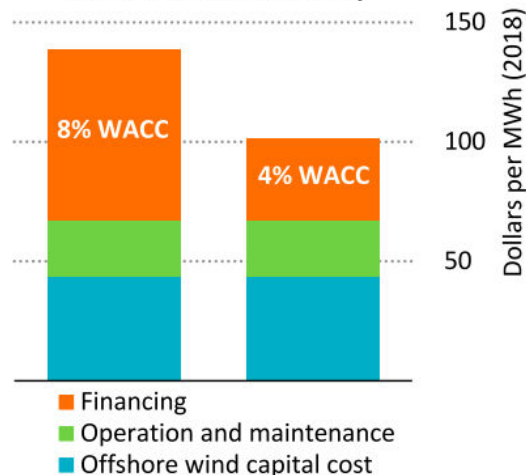
Kapitalkostnad er sentralt



Indicative shares of capital cost
by component



Levelised cost of electricity



Offshore wind generation costs are heavily influenced by the cost of capital and were about \$100/MWh for projects completed in 2018 based on low financing costs

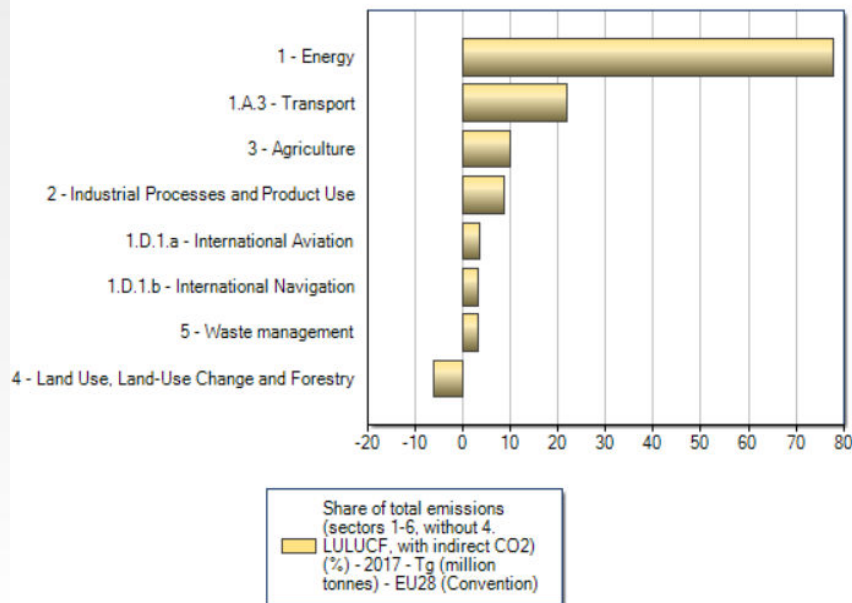
Notes: WACC = weighted average cost of capital; Transmission includes offshore substations.

Sources: IEA analysis based on IRENA (2019), IJGlobal (2019) and BNEF (2019).

Utslipp av drivhusgasser



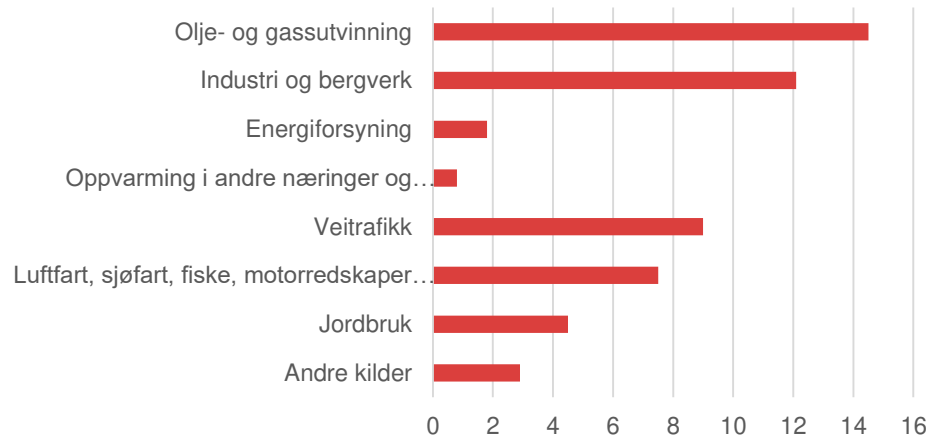
EU-28, 2017



<https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer>

Norge, 2018

Utslipp fra norsk territorium
Klimagasser (mill. tonn CO₂-ekvivalenter), SSB 2018



<https://www.ssb.no/natur-og-miljo/statistikker/klimagassn/aar-forelopige/2019-06-03?fane=tabell&sort=nummer&tabell=388501>

