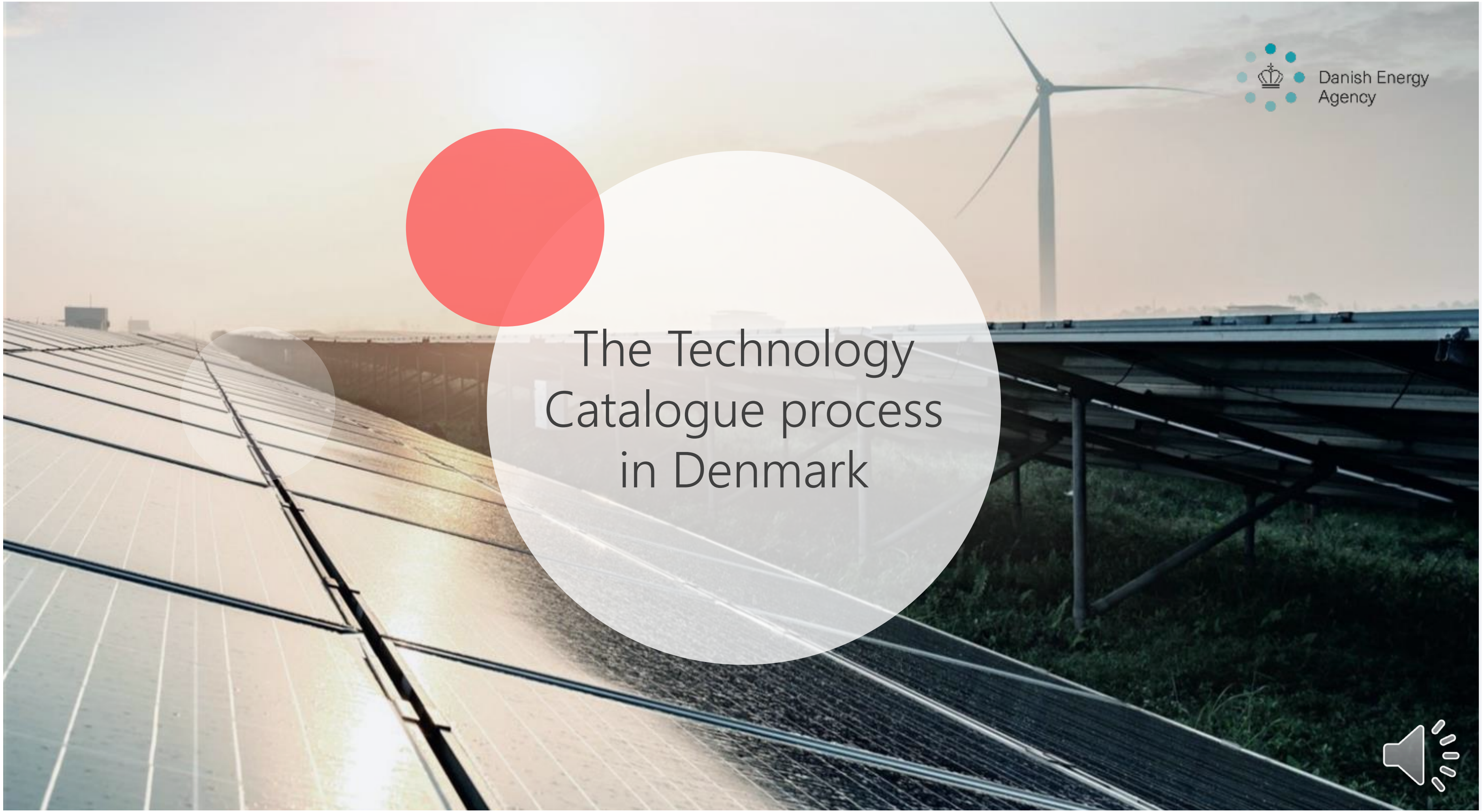
Danish Energy Agency

The Technology Catalogue process in Denmark



Session 1 : Overview of data collection and the Technology Catalogue process in Denmark

*The **objectives** of this session are:*

- *To learn about the importance of a national set of technology data*
- *To understand the necessity of common reference points within energy systems planning*
- *To provide background knowledge for the two-week seminar*

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"The primary objective of publishing technology catalogues is to establish a uniform, commonly accepted and up-to-date basis for energy planning activities."

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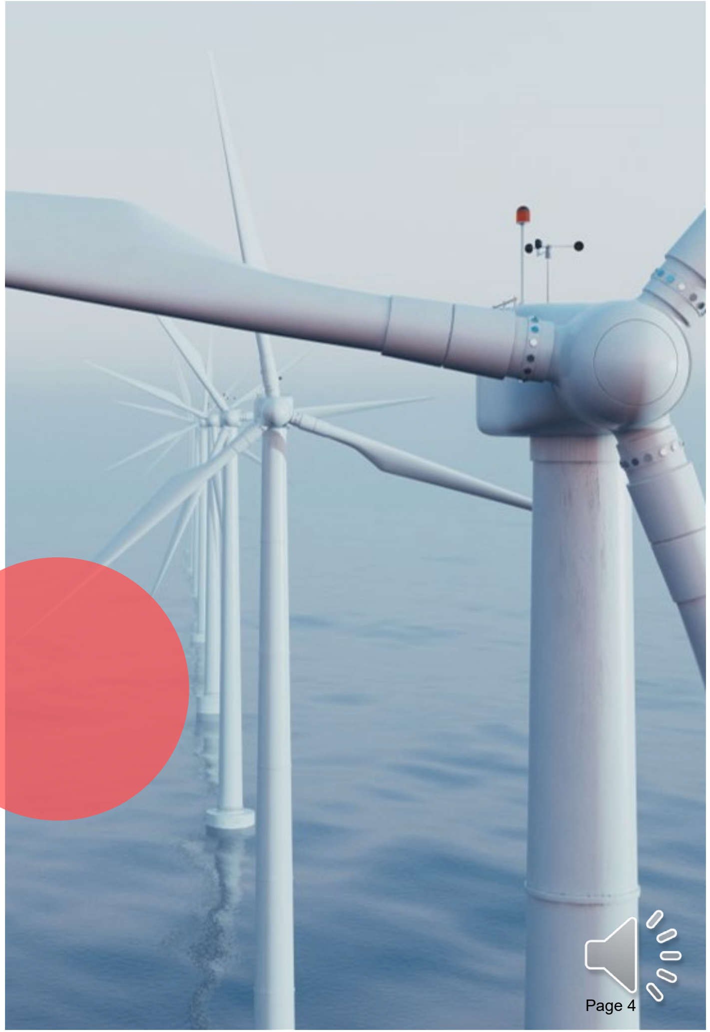
Agenda

- *Purpose*
- *Product*
- *Process*
- *Lessons learned*




Danish Energy
Agency
Purpose!

A Long Tradition of Energy Planning

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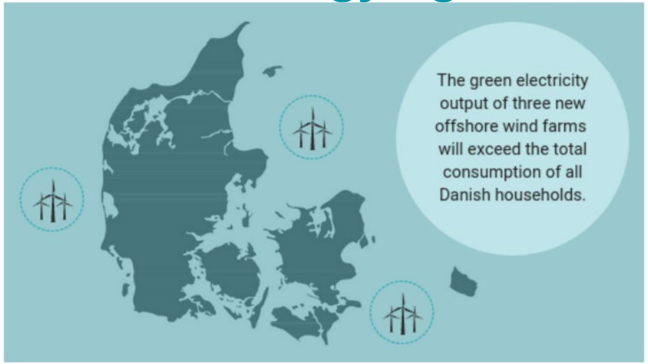
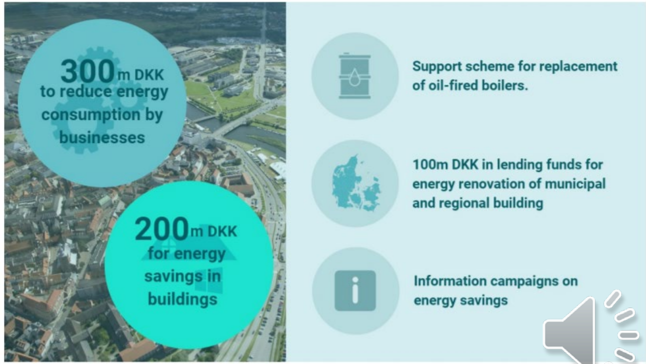
2018 Energy Agreement





Long-Term Energy Planning

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Input	Energy system models	Output
• Demand projection • Fuel price projections • Technology data • Historical data (statistics and existing stock)	• General Equilibirum Models (e.g. TIMES) • Hourly dispatch models (e.g. Balmorel) • Stochastic model for assessment of security of supply (e.g. SISYFOS)	• Frozen Policy Projections • Energy Outlook Reports • Explorative Scenarios • Analyses for e.g. policy recommendations

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How is the Technology Catalogue Used in DEA?

- Yearly Danish Energy Outlook
- Grid Planning
- National Energy and Climate Plans for the EU
- *AD hoc calculations*
  eg. subsidy level assessment

→ *The common point of references of all the socio-economic analyses*

How is the Technology Catalogue Used in DEA?

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  eg. subsidy level assessment

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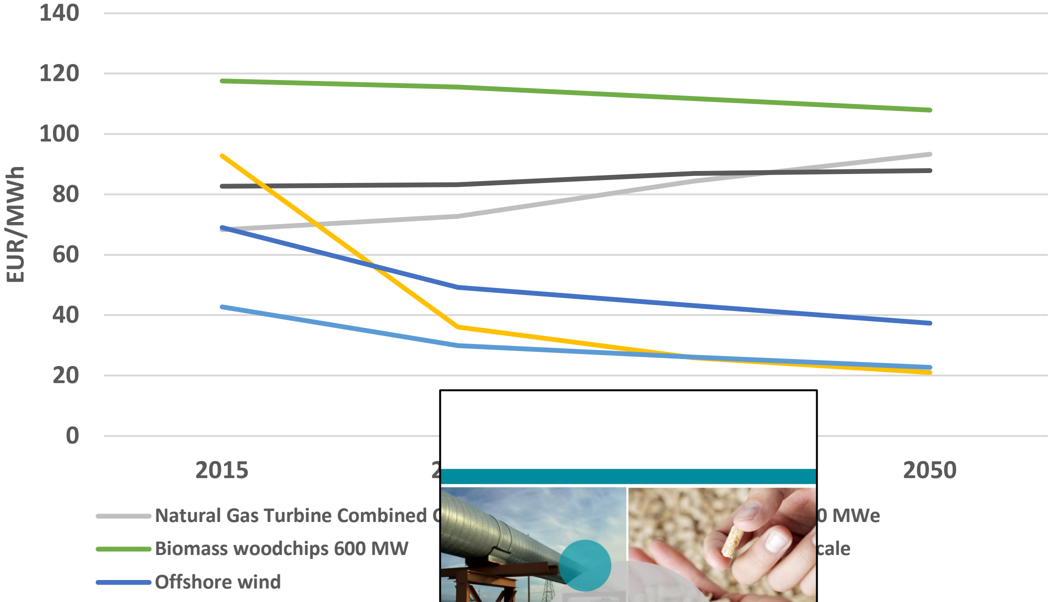
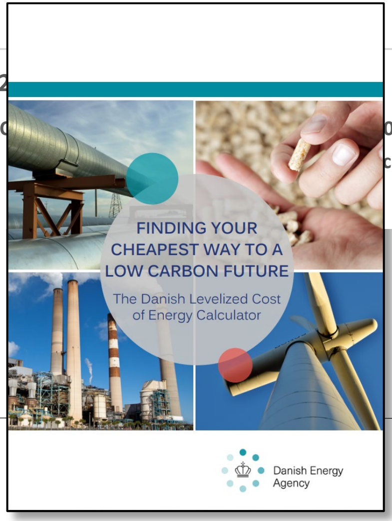
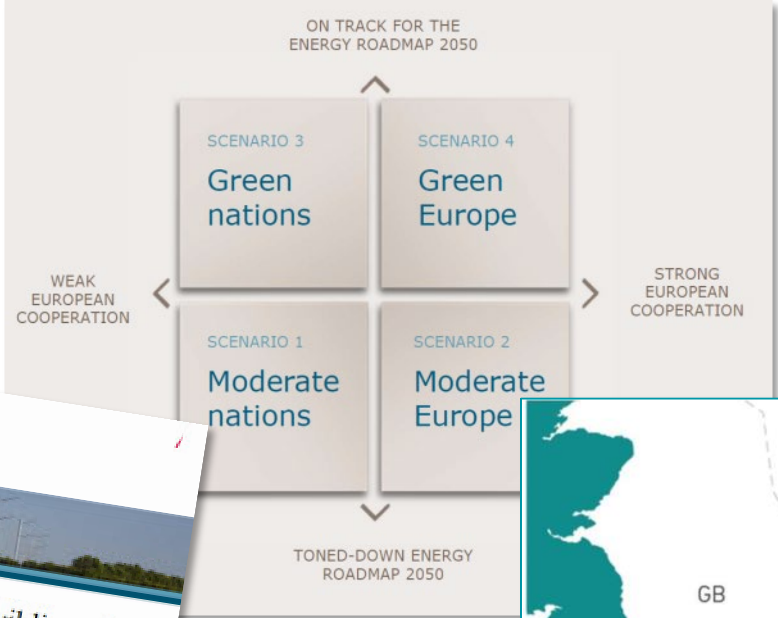




Results of the LCoE calculator to compare competitiveness across selected technologies now and projected for the future

How does Energinet (TSO) use the Technology Catalogue?

- Long term planning scenarios
- Grid Development Plan and other official reports
- Business cases e.g. on inter-connectors



Examples of how others use it

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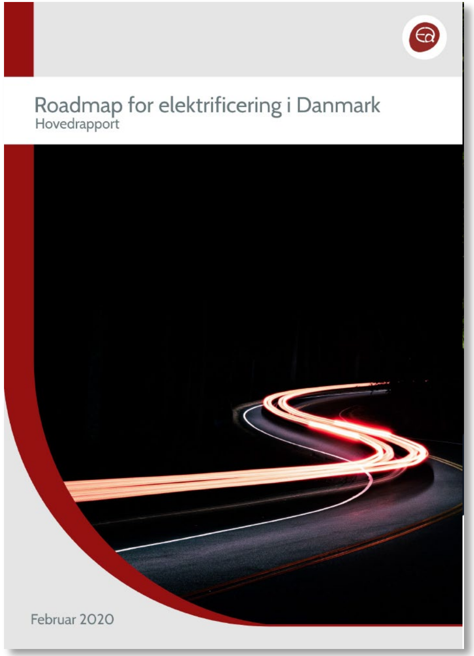
Independent energy systems analyses consultancies

Danish Climate Council

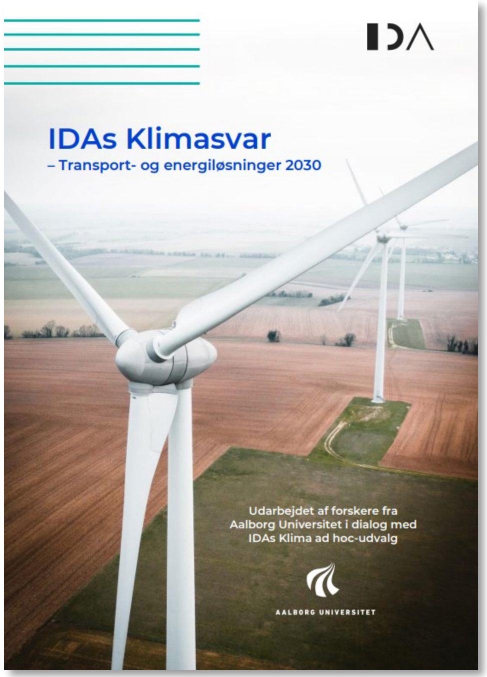
The Danish Society of Engineers (IDA) & universities

”Roadmap for electrification in Denmark”



”70% reduction of emissions by 2030 in Denmark”

”IDA’s climate response”



Why do we need a <u>Danish</u> Technology Catalogue?

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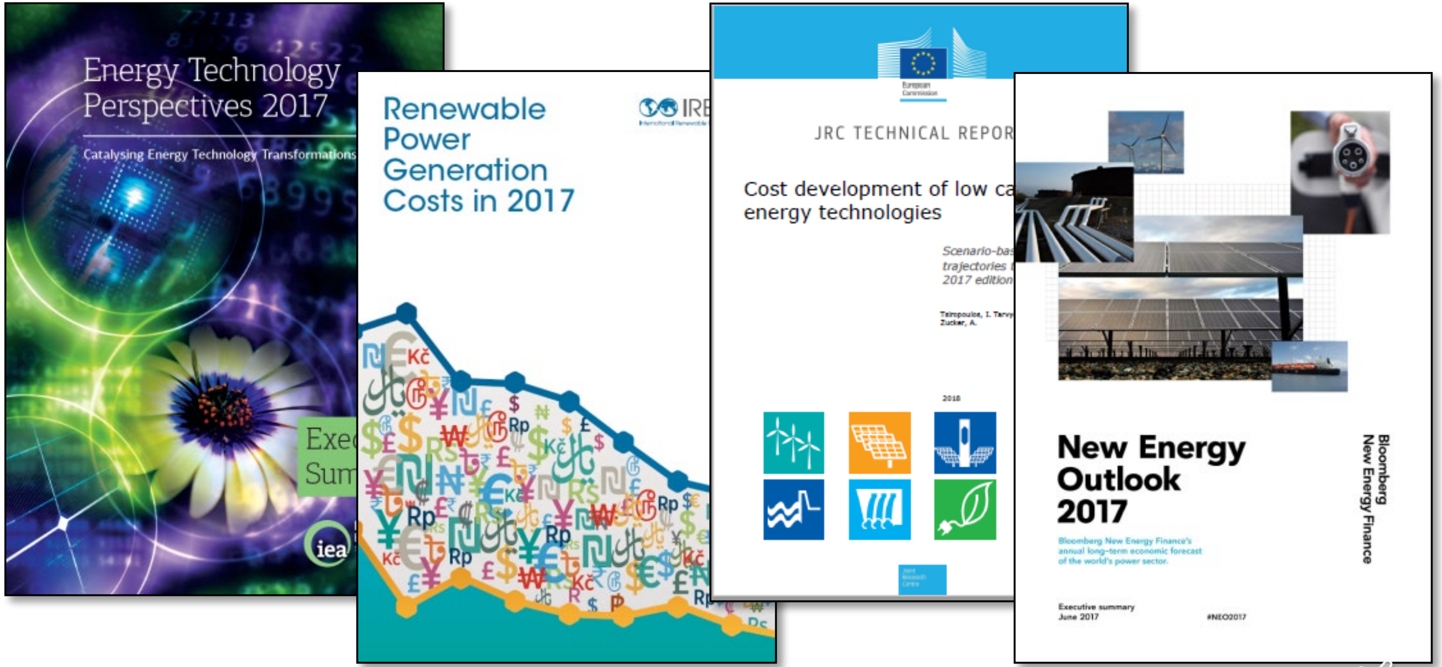
We already have …

- IEA
- IRENA
- BNEF
- JRC
- etc…



The advantages of a Danish Technology Catalogue

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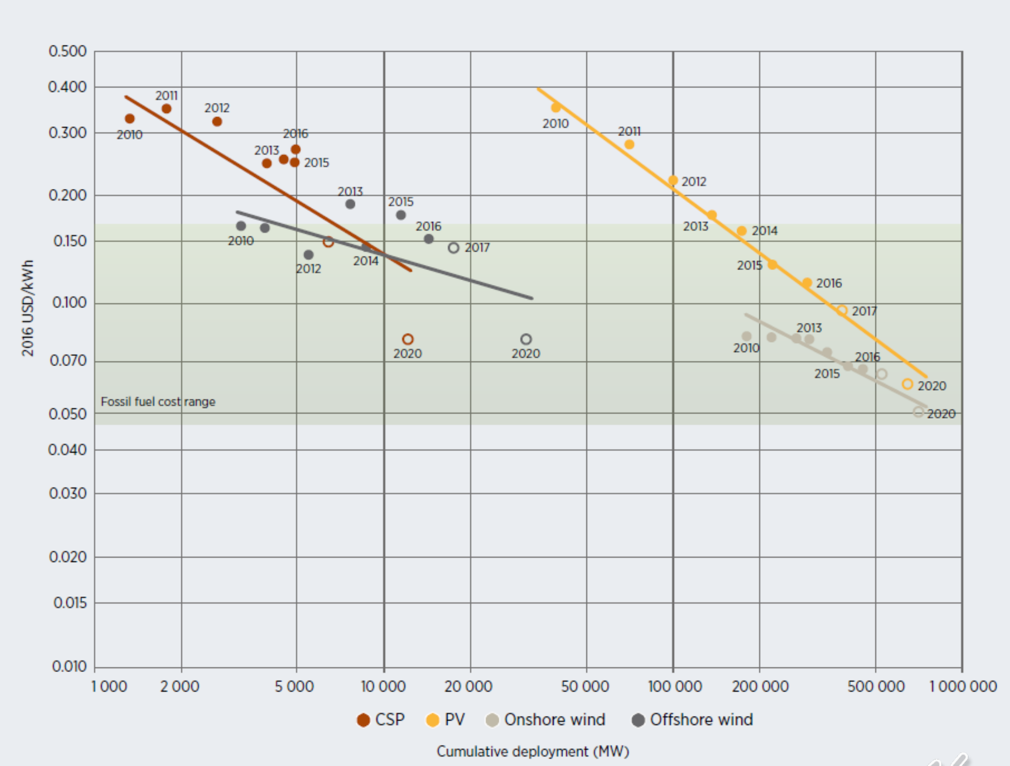
- Includes **local condition** incl. cost of labour, competitive situation, development of industry, etc.
  - Costs of installations are likely to be different across countries
  - Costs of equipment can vary based on the market setup
- **Technology 'preferences'** may differ and may not include the relevant technologies
  - E.g. another type of biogas plant is used in tropical climates than in DK
  - E.g. Some wind turbines are better suited for low wind speeds
- **Assumptions** differ across international sources
  - E.g. Included grid connection costs of offshore wind or not (cost boundary)
- International data may not be **accepted** by key Danish stakeholders
  - Important to get input from local stakeholder and have wide acceptance.

The risk of not using updated data

E.g. costs of solar power has more than halved within the last 5 years – an unexpectedly fast development!

By using outdated data one risks to implement non-optimal scenarios…

Or make false predictions of the development of the system.



Source: IRENA

Based on IRENA Renewable Cost Database and Auctions Database; GWEC, 2017; WindEurope, 2017; MAKE Consulting, 2017a; and SolarPower Europe, 2017a.

The risk of not using updated data of wind power in Denmark

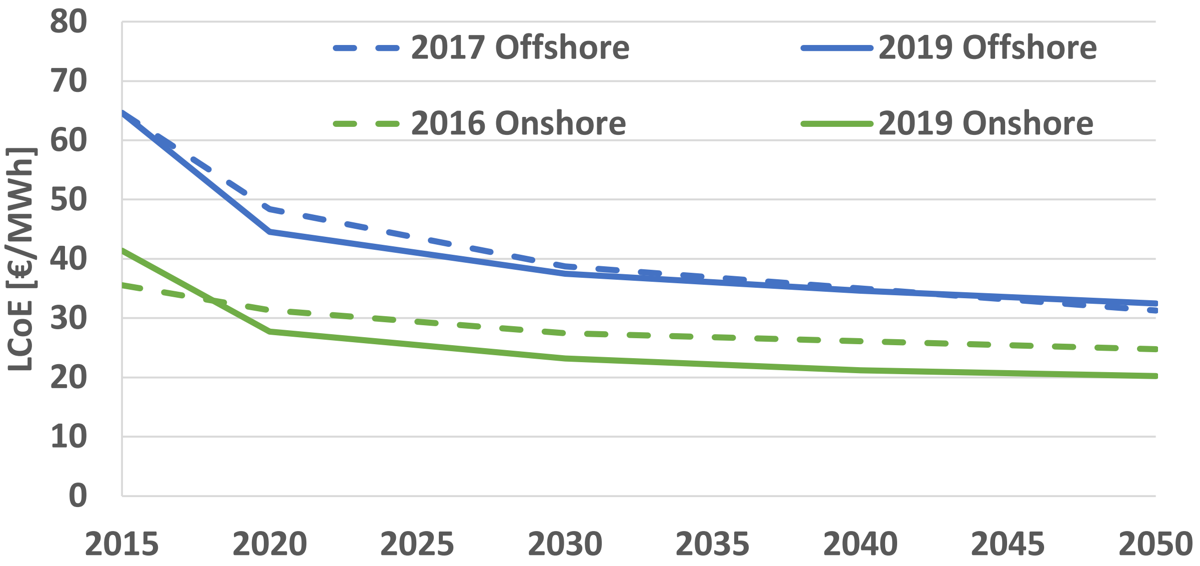
Offshore:

Cost reduction can materialize quicker than expected

Onshore:

Regulations and capacity expansion can affect technology costs

- Citizens living nearby wind farms are compensated economically
- Repowering of old turbines constitues a new cost



Data should always reflect the actual competitiveness of a certain technology, and not give wrong incentives!

Product

What is a Technology Catalogue?

Danish Energy Agency

<u>Currently six catalogues reflecting different energy sectors</u>

1. Generation of electricity and district heating
2. Individual heating installations
3. Renewable fuels (liquids and gaseous)
4. Energy storage
5. Distribution and transmission of electricity, gas and district heating
6. Industrial process heat

8 people at the DEA and Energinet are in the Technology Catalogue working group

https://ens.dk/en/our-services/projections-and-models/technology-data

What is a Technology Catalogue?

Danish Energy Agency

A. Data sheets

- Performance data (Efficiency, life time, availability, start up time)
- Financial data (Investment cost, O&M cost)
- Environmental data (emissions)
- Data sets for e.g. 2015, 2020, 2030, (2040) and 2050

B. Qualitative technology descriptions

- Understandable also for non-experts in the specific field
- Providing context to the quantitative assumptions

https://ens.dk/en/our-services/projections-and-models/technology-data

The Qualitative Description

Unified subsections across technologies, e.g.

- Brief technology description
- Input/Output energy
- Advantages/disadvantages
- Examples of market standard technologies
- Research and development perspectives
- Prediction of performance and cost
- …

20 Wind Turbines onshore

Contact information:
Danish Energy Agency: Rikke Næraa, rin@ens.dk
Author: Mads V. Sørensen / Per Nielsen (EMD)

Publication date
August 2016

Amendments after publication date

Date	Ref.	Description

Qualitative description

Brief technology description

The typical large onshore wind turbine being installed today is a horizontal-axis, three bladed, upwind, grid connected turbine using active pitch, variable speed and yaw control to optimize generation at varying wind speeds.

Wind turbines work by capturing the kinetic energy in the wind with the rotor blades and transferring it to the drive shaft. The drive shaft is connected either to a speed-increasing gearbox coupled with a medium- or high-speed generator, or to a low-speed, direct-drive generator. The generator converts the rotational energy of the shaft into electrical energy. In modern wind turbines, the pitch of the rotor blades is controlled to maximize power production at low wind speeds, and to maintain a constant power output and limit the mechanical stress and loads on the turbine at high wind speeds. A general description of the turbine technology and electrical system, using a geared turbine as an example, can be seen in figure 1.

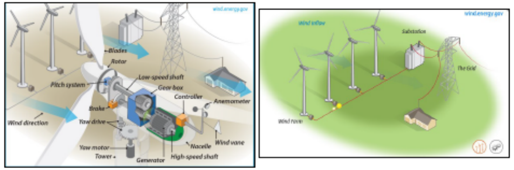


Figure 1: General turbine technology and electrical system.

Wind turbines are designed to operate within a wind speed range which is bounded by a low "cut-in" wind speed and a high "cut-out" wind speed. When the wind speed is below the cut-in speed the energy in the wind is too low to be utilized. When the wind reaches the cut-in speed, the turbine begins to operate and produce electricity. As the wind speed increases, the power output of the turbine increases, and at a certain wind speed the turbine reaches its rated power. At higher wind speeds, the blade pitch is controlled to maintain the rated power output. When the wind speed reaches the cut-out speed, the turbine is shut down or operated in a reduced power mode to prevent mechanical damage.

Onshore wind turbines can be installed as single turbines, clusters or in larger wind farms.

Commercial wind turbines are operated unattended, and are monitored and controlled by a supervisory control and data acquisition (SCADA) system.

Input

Input is wind.

Cut-in wind speed: 3 – 4 m/s.

Rated power generation wind speed: 10-12 m/s, depending on the specific power (defined as the ratio of the rated power to the swept rotor area).

Cut-out or transition to reduced power operation at wind speed: 25 m/s.

In the future, it is expected that manufacturers will apply a soft cut-out for high wind speeds (indicated with dashed red curve in figure 2) resulting in a final cut-out wind speed around 30 m/s.

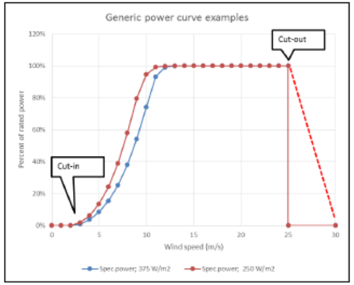


Figure 2: Turbine power curves (Information's from expert workshop held by DEA 27-4-2015)Specific power values refer to e.g. 3 MW with 124m rotor diameter (250 W/m^2) and 3 MW with 101 m rotor diameter (375 W/m^2)

The Quantitative Description

Explanatory notes & references

Data up to 2050

Uncertainty range

Technical data

Regulation ability

Financial data

Technology-specific data

Technology	20 Large wind turbines on land										
Year of final investment decision	2015	2020	2030	2040	2050	Uncertainty (2020)		Uncertainty (2050)		Note	Ref
Energy/technical data						Lower	Upper	Lower	Upper		
Generating capacity for one unit (MW)	3.1	4.2	5	5.5	6	2.0	6.0	1.5	8.0	A1	3
Average annual full-load hours	3100	3400	3600	3700	3800	2000	4000	2000	4500	A, L	3
Forced outage (%)	3.0%	2.5%	2.0%	1.8%	1.5%	1.0%	5.0%	1.0%	5.0%	B	4
Planned outage (%)	0.3%	0.3%	0.3%	0.3%	0.3%	0.1%	0.5%	0.1%	0.5%	C	4
Technical lifetime (years)	25	27	30	30	30	25	35	25	40	D	14
Construction time (years)	1.5	1.5	1.5	1.5	1.5	1	3	1	3	E	4
Space requirement (1000m2/MW)	---	---	---	---	---	---	---	---	---	F	
Regulation ability											
Primary regulation (% per 30 seconds)										G	
Secondary regulation (% per minute)										G	
Financial data (in 2015€)											
Nominal investment (M€/MW)	1.33	1.12	1.04	0.98	0.96	0.77	1.16	0.80	1.19		16, 2, 4
- of which equipment	0.89	0.71	0.64	0.59	0.58	0.57	0.86	0.46	0.69		25
- of which installation/development	0.12	0.09	0.08	0.08	0.07	0.07	0.11	0.06	0.09		25
- of which is related to grid connection	0.06	0.05	0.05	0.05	0.05	0.04	0.06	0.04	0.06		25
- of which is related to rent of land	0.09	0.09	0.09	0.09	0.09	0.07	0.10	0.07	0.10		25
- of which is related to decommissioning of existing turbines	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.03	0.04		25
- of which is related to other costs (i.e. compensation of neighbours, etc.)	0.13	0.14	0.14	0.14	0.14	0.11	0.17	0.11	0.17	I	25.26
Fixed O&M (€/MW/year)	25,600	14,000	12,600	11,592	11,340	11,200	16,800	9,072	13,608	I	25.26
Variable O&M (€/MWh)	2.80	1.50	1.35	1.24	1.22	1.20	1.80	0.97	1.46		
Technology specific data											
Rotor diameter	106	130	145	155	165	90	130	100	150	K	4, 26
Hub height	85	85	100	105	110	85	120	85	150		4, 26
Specific power (W/m2)	351	316	303	291	281	314	452	191	453		
Average capacity factor	35%	39%	41%	42%	43%	23%	46%	23%	51%		4, 26
Average availability (%)	97%	97%	98%	98%	98%	99%	95%	99%	95%		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Process
(and methodology)

How - Examples of how quantitative data from the start year is provided

- **Specific projects recently build / contracted**
- **Bids for tenders**
- **National register / statistics**
- **Expert assessments, e.g.**

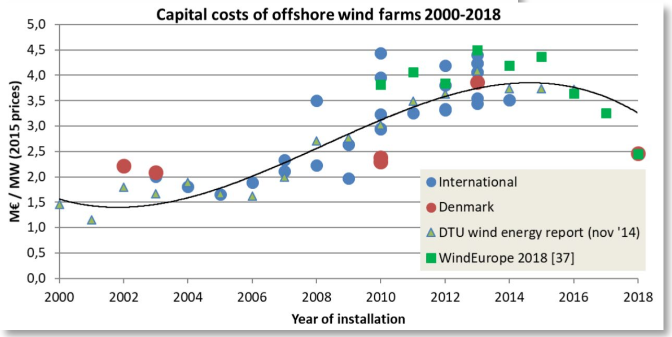
  National studies / surveys

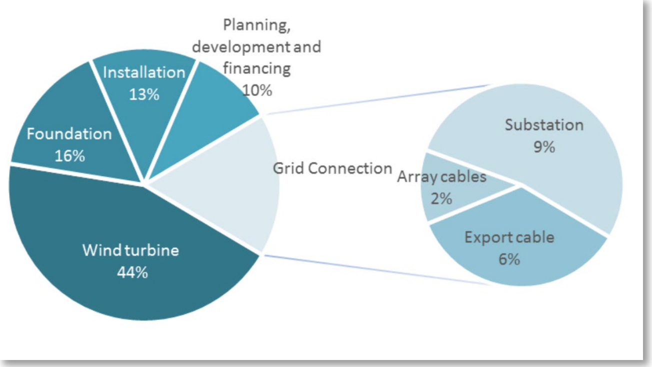
  Engineering bottom-up approaches

  International studies / surveys

The trend seen in the 2017 amendment were seen to continue. The reasons are as described in 2017 amendment. The costs have decreased further illustrated by the bid winning prices:

	øre/kWh	MW	MW/WTG
HR3 - installed 2018	77	406,7	8,3
VH (Vesterhav)	47,5	344,4	8,4
KF (Krigers Flak)	37,2	604,8	8,4





How - Examples of methodology for the projection

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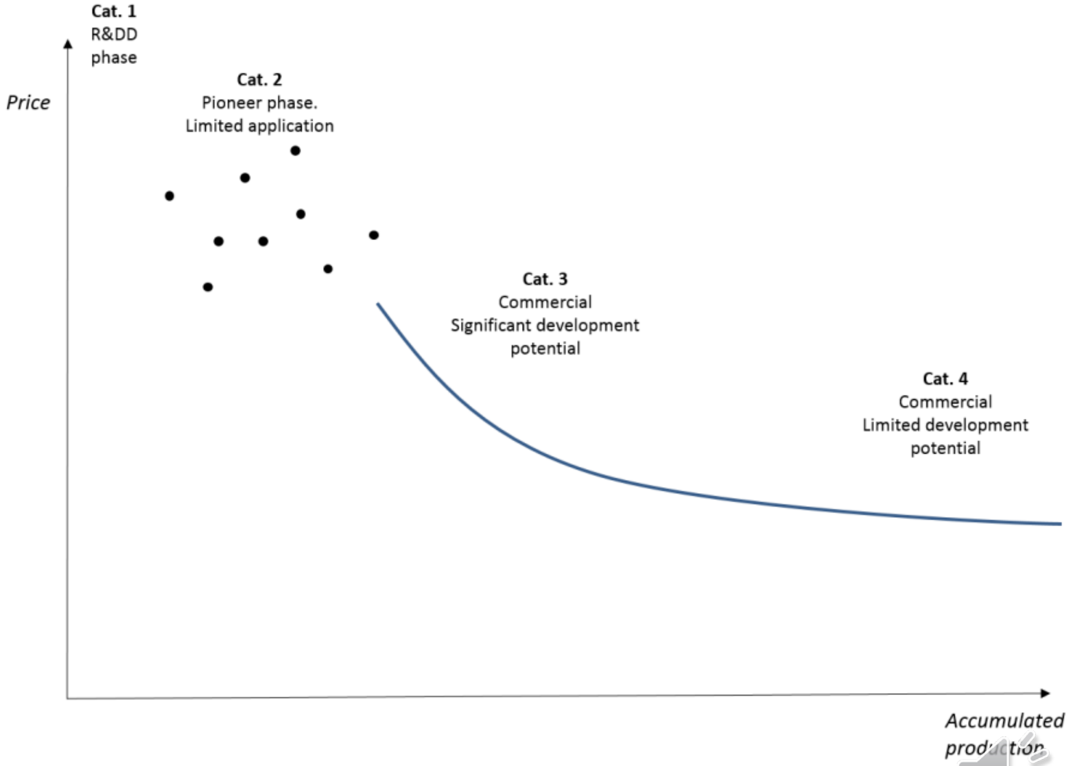
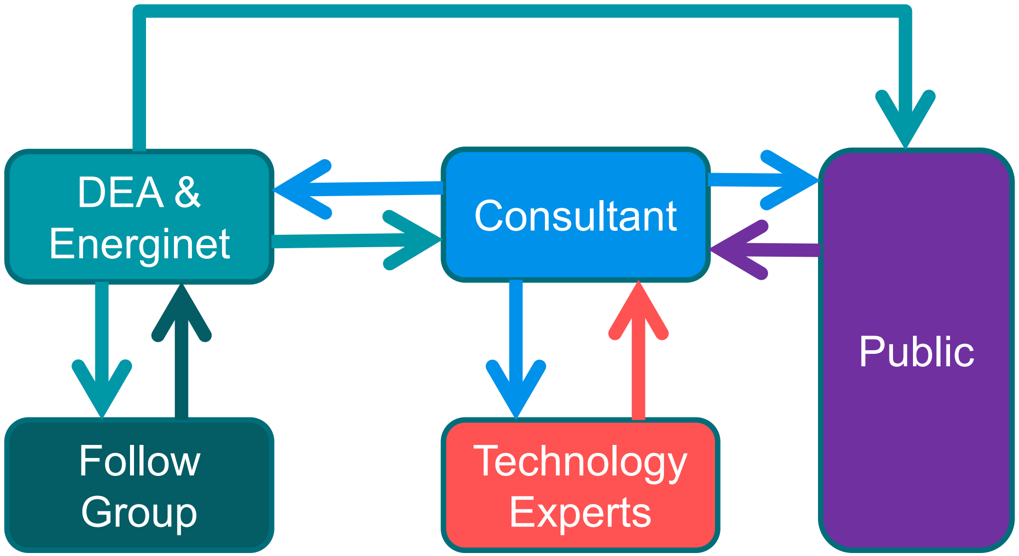
- **Experience curves / learning curves**
  Cost reduced X% every time the installed capacity doubles
- **Fixed yearly improvement**
  for mature technologies or components
- **Bottom-up approaches**
  what is the cost development for each component
- **Expert judgements**



Who - Stakeholder setup & process

1. Follow Group suggests updates of the catalogue in discussion with DEA/Energinet
2. DEA/Energinet decide on updates and hire a consultant for the task
3. Consultant writes a draft update and presents it to the technology experts at a deep dive workshop
4. Consultant writes an updated draft and receives written feedback from the technology experts and all other interested stakeholders
5. Consultant writes final version
6. DEA/Energinet publish final version

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Lessons learned

Lessons learned from Denmark, as well as Vietnam and Mexico

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Engagement of potential users and data providers has shown to be the most difficult part to start with

Data collection can be difficult e.g. because of lack of interest from the data owner or because data is not available

The people who know the most about the technology can be **biased**

Simplification of the technology description is necessary but unpopular

Disseminate, publish, spread the word, put it to use!

Lessons learned for offshore wind

Danish Energy Agency

Offshore wind is of **key interest** for many stakeholders as developers, manufacturers, public sector, lobby organisations…

Some players have more **market power** than others and will have different opinions about costs than smaller players

Offshore wind is a very **site-specific technology** that makes generalisation of data difficult and hard to defend

Official governmental data is more trustworthy than secondary references and can help showing technology maturity and development perspectives
→ a commitment which also gives security for investors

Next session

Upcoming in session 2:

Data collection and data management

- *Details about managing the technology catalogue process*
- *Possible methods and tools*
- *Reflections on moving the Danish experiences to an Indian context*

Q&A session on Monday, June 8

Live online Q&A session discussing:

- Possible questions from presentations and the project
- The exercises
- Brief evaluation

If you have any questions or points that are worth discussing, please send the questions in advance to KEHA@ens.dk.

They will be aggregated and answered by the DEA!

Exercise

Question 1:

Why is a national set of technology data important for energy systems planning? Provide 3 examples.

Question 2:

What do you think is more decisive for the description of emerging technologies – perfectly accurate data or regular revision of data? Why?

Question 3:

How can the Indian authorities learn from the Danish approach and stakeholder management, and what could be adapted for India? What could be done in a different way?

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Thank you for listening!