IEA Wind Task 26: "Cost of Wind Energy" og IEA Wind Task 33: "Reliability Data". Hva kan dette gi for industrien?

Thomas Welte, Iver Bakken Sperstad

SINTEF Energy Research

Industry Meets Science
2015-06-04, Trondheim

Outline

- Overview: IEA Wind and IEA Wind Research Tasks
- IEA Wind Task 33: "Reliability Data"
- IEA Wind Task 26: "Cost of Wind Energy"
- Hva kan dette gi for industrien?

IEA Wind &
IEA Wind Research Tasks

Complete and updated presentation

"Benefits of the IEA Wind Co-Operation"

can be found at www.ieawind.org

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IEA Wind organisational details

- IEA Wind is one of the more than 40 Implementing Agreements under International Energy Agency (IEA) Organization for Economic Co-operation and Development (OECD). It is attached to the Renewable Energy Working Party (REWP).
- The full, legal name of the activity is the IEA Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems.
- Benefits include:
  - Guide national governmental programmes and policies through information exchange
  - Develop skills, knowledge and improve wind R&D cost effectiveness and minimise environmental effects
  - Provide information and technology to reduce costs and increase the value of wind energy
  - Identify and publicise societal, economical and governmental benefits

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Mission of IEA Wind

"…to stimulate co-operation on wind energy research and development and to provide **high quality information and analysis to member governments** and commercial **sector leaders** by addressing **technology development** and deployment and its **benefits, markets, and policy instruments**." – IEA Wind Strategic Plan

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IEA Wind operational details (1)

- The IEA Wind Executive Committee (ExCo) organises the overall information exchange and the R,D&D tasks
- The ExCo consists of a Member and an Alternate Member from each contracting party in the Implementing Agreement
- Most countries are represented by one contracting party such as a government department or agency
- The ExCo meets twice a year to discuss the R&D programs of the member countries, to report work progress on the various Tasks, and to plan future activities

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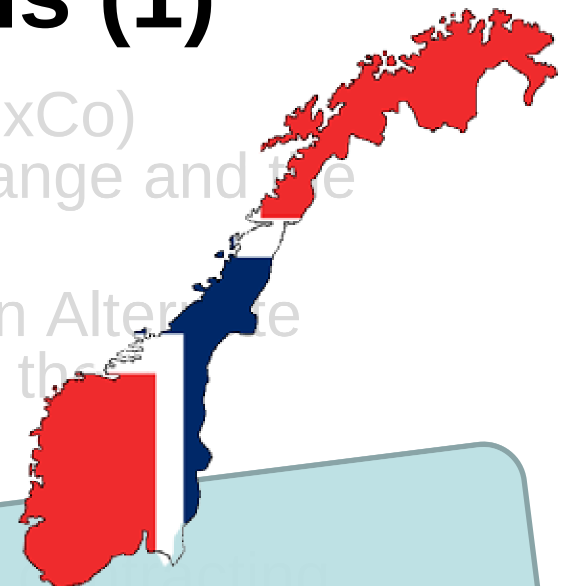

Norway

NVE (David Edward Weir, 22 95 93 52, dwe@nve.no)

Norges Forskningsråd (Harald Rikheim, 48 22 86 36, hri@forskningsradet.no)

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IEA Wind operational details (2)

- Most decisions are reached by majority vote with one vote per member country. Change to members rights and contractual obligations require unanimity
- Members share the cost of administration for the ExCo through annual contributions (based on the size of the nation's economy) to a Common Fund
- Each research task has its own budget and fees based on the work and number of participants
- Each member country must participate in at least one research task

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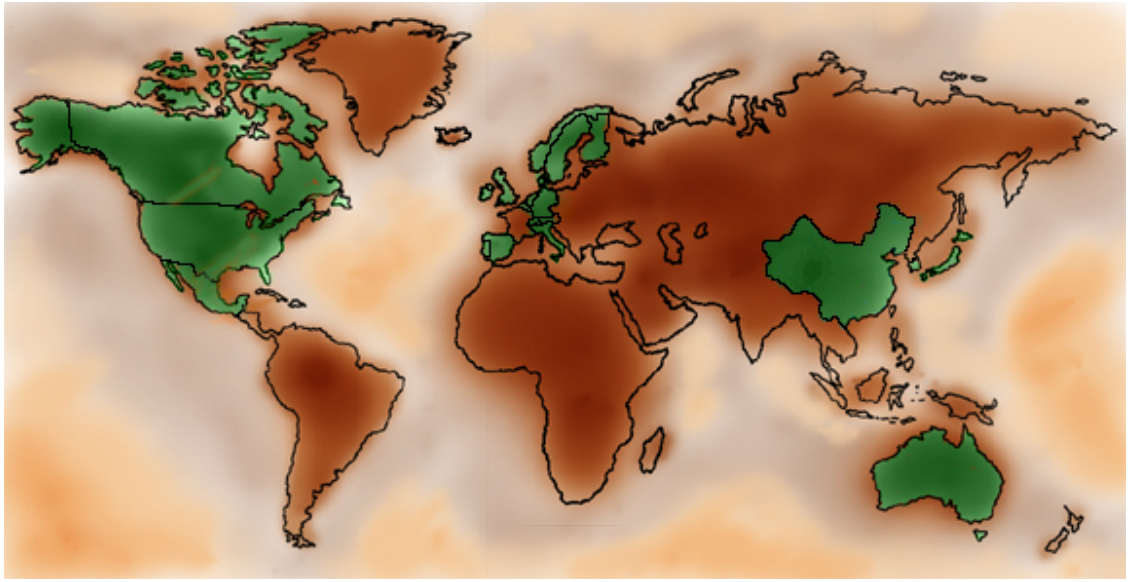
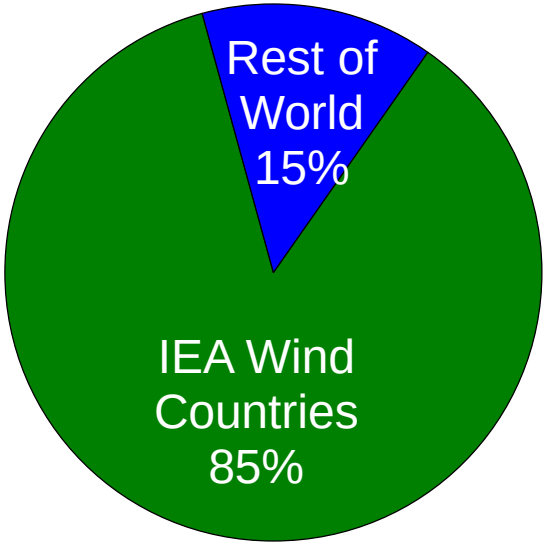
85% of the world wind capacity is in IEA Wind member countries



IEA Wind Countries



World Wind Capacity

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IEA Wind has broad membership

OECD Participating Countries:

Europe:

Austria, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, the European Commission

North America:

Canada, Mexico, and the United States

Asia and Pacific:

Japan and South Korea

International Organizations:

Chinese Wind Energy Association (CWEA) and the European Wind Energy Association (EWEA)

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Wind contributes to national electrical demand

IEA Wind Country	National electricity demand (TWh/yr)	National electricity demand from wind* (%)
Denmark	34.9	29.9%
Portugal	49.1	20.0%
Spain	255.2	16.3%
Ireland	27.8	14.5%
Germany	594.5	7.7%
United Kingdom	365.3	6.0%
Greece	57.0	5.8%
Sweden	142.0	5.0%
Austria	60.5	5.0%
Netherlands	120.3	4.1%
Italy	325.3	4.0%
United States	4054.5	3.5%
Australia	226.0	3.4%
Canada	590.0	2.8%
China	4,940.0	2.0%
Mexico	272.0	1.2%
Norway	130.0	1.1%

* % of national electricity demand from wind = (wind generated electricity/ national electricity demand)
Source: IEA Wind 2012 Annual Report

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Wind contributes to national electrical demand

IEA Wind Member Country	National electricity demand	National electricity demand from wind
	TWh/yr	%
Denmark	34	32.7%
Spain	261	26.9%
Portugal	51	23.5%
Ireland	28	16.3%
Germany	600	8.9%
Sweden	139	7.0%
UK	376	6.0%
Austria	62	5.8%
Greece	57	5.8%
Italy	317	4.7%
Netherlands	120	4.7%
Australia	226	4.1%
United States	4,058	4.1%
Canada	560	3.1%
China	5,245	2.6%
México	249	1.5%
Norway	129	1.5%
Finland	84	0.9%
Japan	846	0.5%
Korea	532	0.2%
Switzerland	64	0.2%

* % of national electricity demand from wind = (wind generated electricity/ national electricity demand)
Source: IEA Wind 2013 Annual Report

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IEA Wind supports national efforts with information exchange and joint R&D

- Sharing information on:
  - Planning and execution of large-scale wind energy deployment
  - Experiences with tariffs, credits, certificates and other incentive and regulatory environments
  - Integration with electrical grids
  - Results of national technology research projects
- Cooperative research tasks performed with research and in some countries industry experts.

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IEA Wind Strategic Direction 2014-2019

- Reduce the cost of wind energy use, for both land-based and offshore wind
- Increase the flexibility of transmission and power systems
- Increase social acceptance and environmental compatibility of wind energy
- Increase the exchange of best practices

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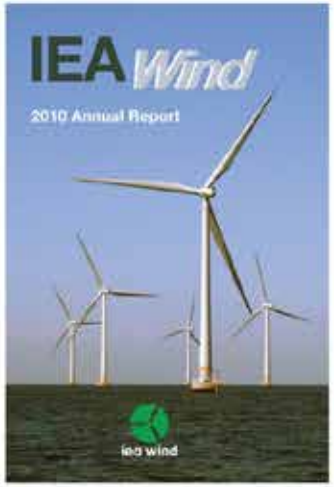
Information Dissemination



- Annual Reports (2,300 copies/yr)
- Website (www.ieawind.org)
- Technical reports, journal articles, conference presentations
- Outreach to new members
- Industry Encounters
- Recommended Practices
- E-newsletter

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IEA Wind R&D continues to reduce costs

- Grid integration tools
- Designs to increase performance/value
  - Forecasting
  - Aerodynamics
  - Structural dynamics
  - Electrical systems
- Designs for specific locations
  - Cold climate
  - Offshore
  - High wind/turbulence
- Impact assessment
  - Cost assessment tools
  - Social impacts
  - Environmental impacts

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IEA Wind Task and Priority Areas (2009-2019)

2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020

2009 — 2014 — 2019

Completed Term | Next Term

1) WIND CHARACTERISTICS

- 2010 Task 31 - WAKEBENCH 2014
- 2011 Task 32 - Lidar 2014

2) WIND POWER TECHNOLOGY

- 1987 Task 11 - Base Technology Information Exchange 2019
- 2001 Task 19 - Wind Energy in Cold Climates 2015
- 2008 Task 27 - Small Wind Turbines in Turbulent Sites 2016
- 2008 Task 29 - MexNext Aerodynamics 2014
- 2010 Task 30 - Computer Codes and Models for Offshore Wind Energy (OCS) 2017
- 2011 Task 33 - Reliability Data 2015
- 2013 Task 35 - Full-Size Ground Testing 2016

3) WIND INTEGRATION

- 2004 Task 24 - Integration of Wind and Hydro 2011
- 2005 Task 25 - Power Systems with Large Amounts of Wind Power 2014

4) SOCIAL, EDUCATIONAL and ENVIRONMENTAL ISSUES

- 2005 Task 23 - Offshore Wind Deployment 2010
- 2008 Task 26 - Cost of Wind Energy 2016
- 2007 Task 28 - Social Acceptence of Wind Energy Projects 2015
- 2013 Task 34 - Environmental 2016

5) COMMUNICATIONS

- 2011 Communication Strategy 2019

Active Research Tasks of IEA Wind

Full-Size Ground Testing of Wind Turbines and Components (Task 35)

Environmental Assessment and Monitoring for Wind Energy Systems (Task 34)

Reliability Data: Standardizing Data Collection for Wind Turbine Reliability, Operation and Maintenance Analyses (Task 33)

Lidar: Wind lidar systems for wind energy deployment (Task 32)

WAKEBENCH: Benchmarking wind farm flow models (Task 31)

Dynamic Codes and Models for Offshore Wind Energy (Task 30)

Aerodynamic Data Analysis of the EU MEXICO Project (Task 29)

Social Acceptance of Wind Energy Projects (Task 28)

Consumer Labeling of Small Wind Turbines (Task 27)

Cost of Wind Energy (Task 26)

Power Systems with Large Amounts of Wind Power (Task 25)

Wind Energy in Cold Climates (Task 19)

Base Technology Information Exchange (Task 11)

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Active Research Tasks of IEA Wind

- Each task is managed by an Operating Agent (OA) organization with a designated expert managing the work.
- Participants develop a work plan and agree to contribute to the work plan.
- Participants agree to pay the budgeted fees for the Operating Agent (if applicable).
- For detailed information about each task, including contact information and the work plan, visit www.ieawind.org and click on the Task website link at the left of the home page.

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re•li´•a•bil´•i•ty (ri, līə 'bilətē) *n.*

a person or thing with trustworthy qualities.

Task 33 · Reliability Data

Task 26

Cost of Wind Energy

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re•li´•a•bil´•i•ty (ri, līə 'bilətē) *n.*
a person or thing with trustworthy qualities. Task 33 · Reliability Data

IEA Wind Task 33: Reliability Data

Standardizing data collection for wind turbine reliability and O&M analyses

Thomas Welte

SINTEF Energy Research

Industry Meets Science
2015-06-04, Trondheim

Overall aims

- Addressing different developments of data collection and failure statistic to agree on standards and overall structures.
- Improving reliability and optimizing O&M of wind turbines (through the use of reliability data).

re•li´•a•bil´•i•ty (ri, līə 'bilətē) *n.*

a person or thing with trustworthy qualities.

Task 33 · Reliability Data

Objectives Task 33

1. Provide an international open forum for regular and continuous exchange of experience and progress from individual research activities and existing projects on failure statistics on wind turbines.
2. Development of “Recommended Practices for Reliability Data” during the course of the Task.
3. Identify areas for further research and development as well as standardization needs.

Participants

Nr	Country	Nr	Institution	Nr	First name	Familiy name
1	China	1	CWEA Chinese wind energy association	1	Wang	Siyong
		2	China General Certification Center(CGC)	2	Chen	Leijie
				3	Du	Guangping
		3	Goldwind	4	Yin	Lei
				5	Wang	Zhen
		4	China General Nuclear Power Group（CGN）	6	Cao	Jianlin
		5	Dongfang Turbine Co., Ltd.（DTC）	7	Wei	Guangyao
				8	Wei	Wanming
		6	Zhejiang Windey	9	Luo	Yongshui
				10	Chen	Qi
		7	China Classification Society	11	Jiang	Feng
				12	Zhang	Yanhong
2	Denmark	8	Uni Aalborg	13	John Dalsgaard	Sorensen
		9	DTU University Denmark	14	Peggy	Friis
3	Finland	10	VTT Technical Research Centre of Finland	15	Ville	Turkia
				16	Simo	Rissanen
				17	Hannele	Holttinen
		11	ABB	18	Raimo	Sakki
				19	Teijo	Karna
4	Germany	12	Fraunhofer IWES	20	Stefan	Faulstich
				21	Berthold	Hahn
				22	Paul	Kühn
5	Ireland	13	ServusNet	23	Frank	O'Connor
				24	Des	Farren
6	Netherlands	14	University Delft	25	Gerard	van Bussel
7	Norway	15	Sintef Foundation for Scientific and Industrial Research	26	Thomas	Welte
		16	NTNU University Trondheim	27	Jørn	Vatn
8	Sweden	17	Vattenfall	28	Lasse	Pettersson
		18	Chalmers University Gothenburg	29	Pramod	Bangalore
		19	KTH University Stockholm	30	Lina Bertling	Tjernberg
		20	Systecon	31	Fredrik	Bjarnegard
9	UK	21	ORE Catapult	32	Keith	Harrisson
				33	Conaill	Soraghan
				34	Jonathan	Hughes
10	USA	22	Sandia National Labs	35	Roger	Hill
				36	Benjamin	Karlson

Status

CMMS, SCADA, ...

Equipment

Decision support

Improvement and optimization of O&M, investment decision, construction/design, ..

Transfer for collection

Raw data (real equipment)

Analysis

Processed Data (generic equipment)

Transfer for application

Example raw data
1. # failures, service time
2. Observed lifetime (age/operating time at failure)
3. Observed condition
4. Observed failure cost

Examples analysis
1. total # failures / total service time
2./3. MLE (maximum likelihood estimation)
4. Calculation of mean value

Examples processed data
1. Estimate of failure rate
2. Parameter estimates Weibull distribution
3. Parameter estimates gamma process
4. Mean cost per failure

Status

Start October 2012

Survey of initiatives

O&M Tools | Statistical Methods | Data Collection

Recommended Practices 1st outline

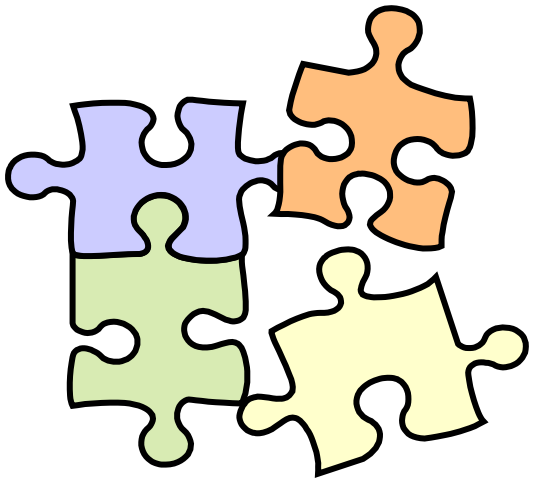
2015 April 15th

Complete, align contents

Regard industry demands

Finalize Wording, Publish

End September 2015 or September 2016 ?

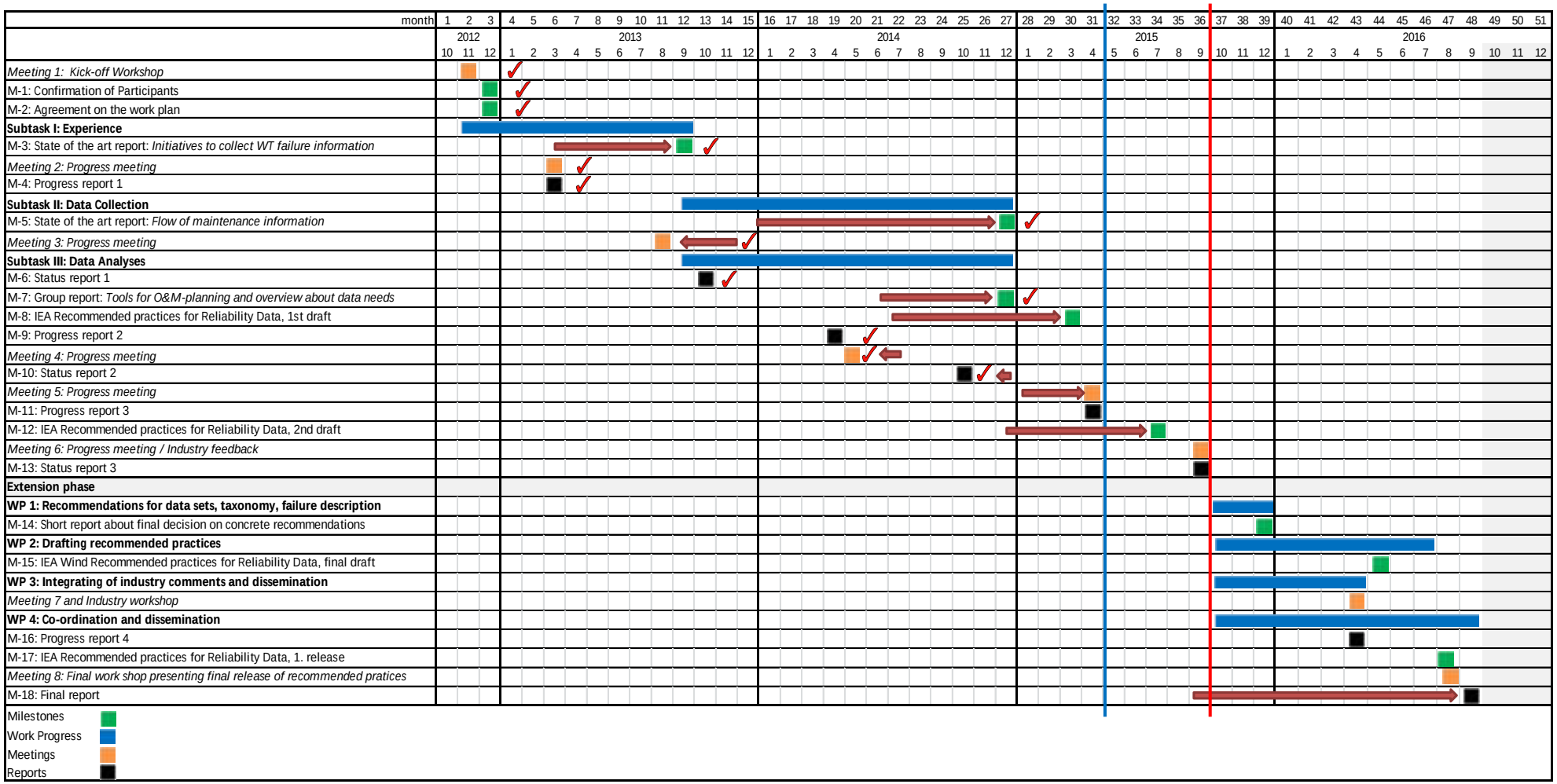


Joint Work

Group Work

Joint Work

Schedule current phase



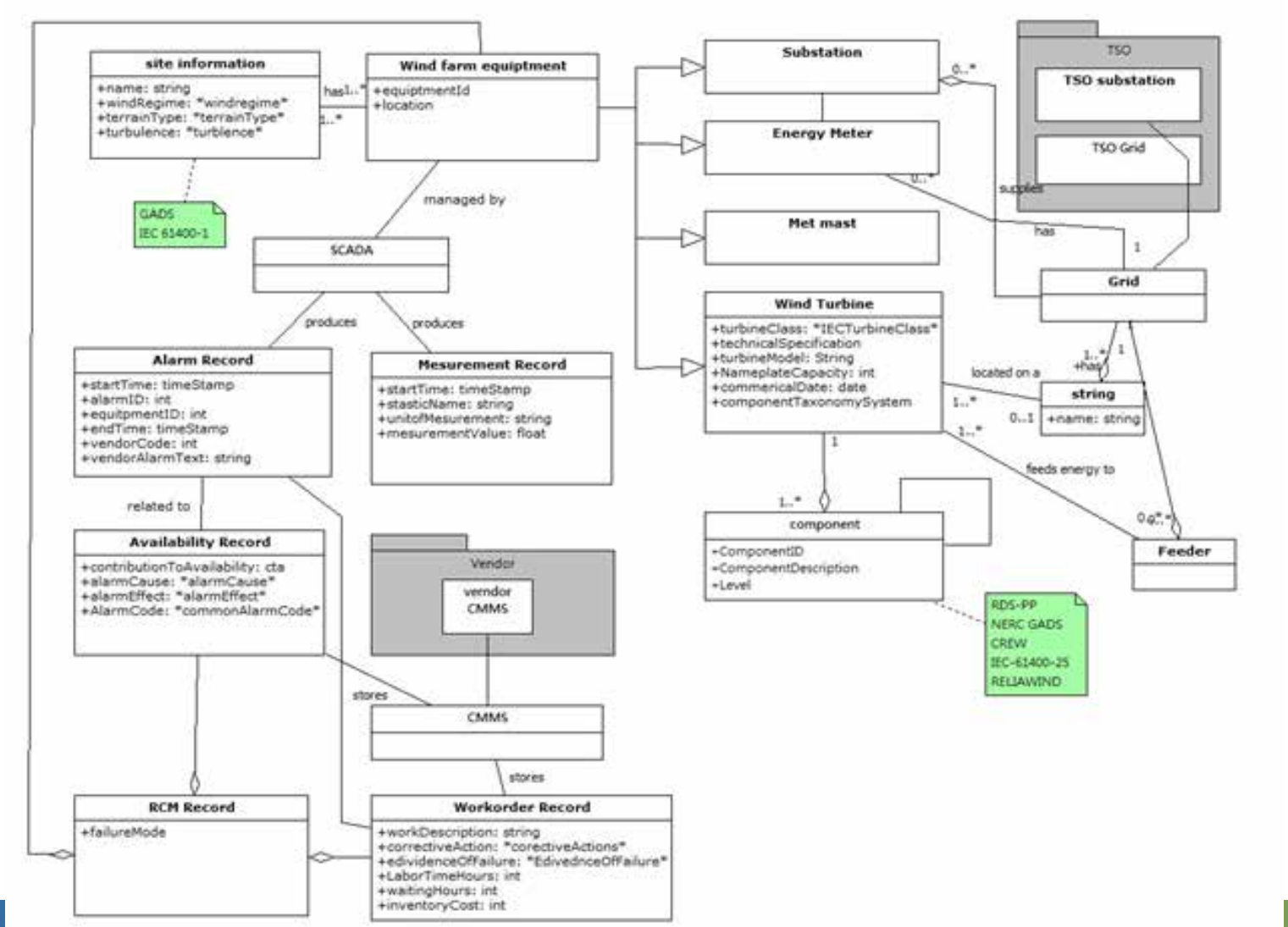
Outline Recommended Practices

- General / intro
  - Target Audience, Scope, Purpose, Terms & definitions, Standards,…
- Existing data collection initiatives
  - WMEP, Crew, Sparta, OREDA, ServusNet, ….
- Maintenance tasks and strategies
  - Stakeholders, Maintenance optimization, Maintenance models, RCM, …
- O&M methods and tools
  - LCC, Interval optimization, Maintenance grouping, Spare parts optimization, …
- (Statistical) Data analysis
  - Basic principles, Different types of models, Typical applications, …
- Data collection
  - Types of data, Data flow, Taxonomy, …

Example: Existing data collection initiatives

Countries		Germany				China		IRL	F	S	USA			
Databases		WMEP	LWK	Windstats (Ger.)	WInD-Pool	60-database	PI	ServusNet	VTT	RCM	BRC	CREW	GRC	NERC GADS
Initiatives		12	13	14	10 11	7	8	17	9	21	24	25	26	27
Information concerning	Scada / Operating Data													
	Current values	o	-	-	x	o	x	x	-	x	-	x	-	-
	Operating hours	x	x	x	x	x	x	x	x	x	-	x	o	x
	Operating state	-	-	-	x	o	o	x	-	x	-	x	-	o
	Functional state	-	-	-	x	-	o	o	-	-	-	x	-	o
	Event = Change of state	x	x	x	x	o	x	o	-	x	-	x	-	-
	CMS Data													
	...	-	-	-	-					-	-	-	o	o
	Event / Field Service Report													
	Start of event	x	-	-	x	x	x	x	o	x	o	-	o	-
	End of measure	x	-	-	x	x	x	x	o	x	o	-	o	-
	Parts affected	x	x	x	x	x	x	o	x	x	o	-	o	-
	Person in charge	-	-	-	o	o	x	-	-	x	o	-	o	-
Information concerning the affected element/component/subassembly of the wind turbine	Event / Field Service Report													
	Failure cause	x	-	-	x	o	x	o	o	o	o	-	o	-
	Failure mechanism	o	-	-	x	o	x	o	o	-	o	-	o	-
	Failure mode	-	-	-	x	o	x	x	o	o	o	-	o	-
	Need for measures	-	-	-	x	-	o	-	-	-	-	-	-	-
	Typ of measure	o	-	-	x	o	x	x	-	x	o	-	o	-
	Action taken	o	-	-	x	-	-	-	x	-	o	-	o	-

Example: Wind farm information model



Example: Wind turbine taxonomies qualities

	Comprehensive Hierarchy	*Industry Standard*	*Easy to use*	*Wind Turbine Specific*	*Publicly available*
Reliawind	yes	no	yes	yes	yes
NERC-GADS	yes	no	yes	yes	yes
RDS-PP	yes	yes	no	no	no

Cost of Wind Energy Task 26

IEA Wind Task 26: Cost of Wind Energy

Iver Bakken Sperstad

SINTEF Energy Research

Industry Meets Science
2015-06-04, Trondheim

Focus on cost of energy and cost reduction

- Horizon 2020 Call for competitive low-carbon energy:
  "For 2015, the following technology-specific challenges have to be addressed: [...] Substantially reduce the costs of wind energy"
- European Strategic Energy Technology Plan:
  "To meet the [EU 20-20-20] targets, we need to lower the cost of clean energy ..."
- Energi21 strategy report:
  "Ambisjoner innen offshore vindkraft: [...]
  - § - økt energiproduksjon fra vindkraftanleggene.
  - § - reduksjon av kostnader langs hele verdikjeden [...]"
- ...

Estimates of the cost of wind energy

- NVE (2015). *Kostnadar i energisektoren.*
- Bloomberg New Energy Finance (2013): *World Energy Perspective – Cost of Energy Technologies*.
- Fichtner-prognos (2013). *Cost Reduction Potentials of Offshore Wind Power in Germany*.
- BVG associates *(2012). Offshore wind cost reduction pathways. Technology work stream.*
- ...

Levelised Cost of Energy (LCOE)

- Widely recognised metric for understanding how technology, capital investment, operations, and financing impact the life-cycle cost of building and operating a wind farm.
- Calculated from the perspective of a financial investor.
- Does not include subsidies or reflect revenue or policy incentives.

$$LCOE = \frac{\frac{Equity}{Share} \times \frac{Total}{Investment} + \sum_{t=1}^{T} \frac{(1 - Tax\ \ Rate) \times (Annual\ O\&M\ Outlays_t) - Tax\ Rate \times (Interest_t\ and\ Tax\ Depreciation_t)}{(1 + Return\ On\ Equity)^t}}{\sum_{t=1}^{T} \frac{Annual\ Electricity\ Produced_t \times (1 - Tax\ Rate)}{(1 + Return\ On\ Equity)^t}}$$

Schwabe, P., Lensink, S., and Hand, M. (2011). *IEA Wind Task 26: Multi-national Case Study of the Financial Cost of Wind Energy*. NREL/TP-6A2-48155. Golden, CO: National Renewable Energy Laboratory.

Levelised Cost of Energy (LCOE)

- Not one standardised LCOE formula; estimates will depend on
  - financing structure (debt/equity),
  - return rates,
  - project life time,
  - project construction time,
  - tax and tax depreciation,
  - decommissioning costs,
  - transmission costs
  - capacity factor,
  - inflation,
  - currency,
  - ...

IEA Wind Task 26: Cost of Wind Energy

- IEA Wind Task 26 is an international collaboration dedicated to exploring past, present and future cost of wind energy.

- Objective: Provide information on cost of wind energy in order to understand past, present, and anticipate future trends using consistent transparent methodologies as well as understand how wind technology compares to other generation options within the broader electric sector.

IEA Wind Task 26 activities

- Common, transparent, traceable methodology for calculating and comparing LCOE values (incl. cash flow models).
- Updated data, analysis and understanding of land-based wind energy cost trends and comparison among countries.
- Identification of the primary offshore wind energy cost drivers and the variation of these costs among participating countries.
- Experts meeting on methods to value wind energy and methods to evaluate historical and future technology cost trends.
- Expert survey on future costs of wind energy.

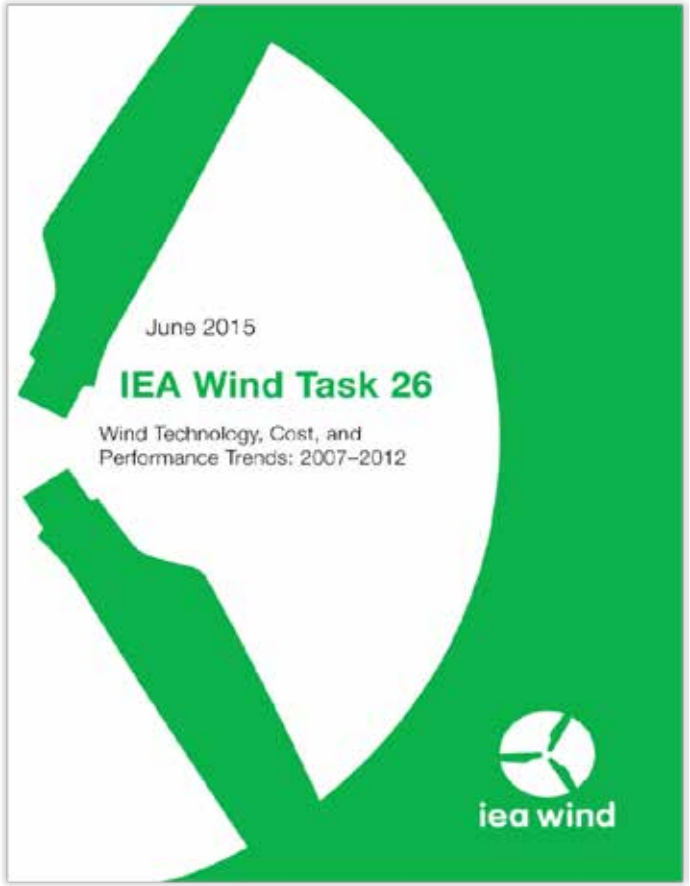
Task participants

Country	Organisation
USA	National Renewable Energy Laboratory (NREL; OA) Lawrence Berkeley National Laboratory (LBNL)
Denmark	Ea Energy Analyses DTU
Germany	Deutsche WindGuard GmbH Fraunhofer IWES
Norway	Norwegian Water Resources and Energy Directorate (NVE) SINTEF Energy Research
Ireland	Dublin Institute of Technology
Netherlands	TKI Wind-op-zee EcoFys
European Commission	Joint Research Centre (JRC)
UK	Offshore Renewable Energy Catapult

Plans for next phase of Task 26

- Phase 2 has been running from October 2012 and is ending September 2015
- Plans for proposed Task extension (3 years):
  - Continue updating land-based wind energy cost trends (annualy)
  - Continue identifying major cost drivers for offshore wind in different countries
  - Understanding trends through expert elicitation
  - Learning curves
  - Repowering
  - Market design

Updated report on cost of land-based wind energy



NB: Not yet published
Launch date: June 15 2015
Will be made available at
http://www.ieawind.org/task_26.html

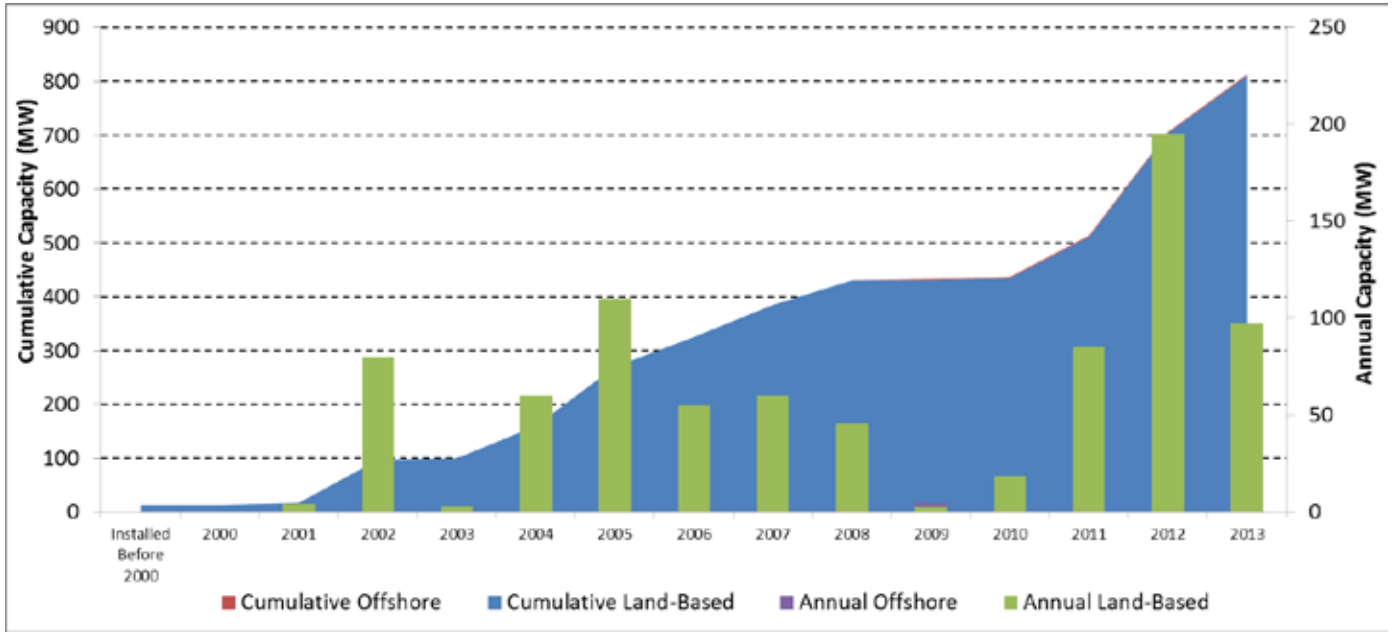
Hand, M.M., ed. (2015). *IEA Wind Task 26 - Wind Technology, Cost, and Performance Trends: 2007–2012*. NREL/TP-6A20-64332. Golden, CO: National Renewable Energy Laboratory.

Updated report on cost of land-based wind energy

- General trends over the period from 2008 to 2012:
  - Initial indications since 2012 suggest a trend toward lower cost of energy through 2014.
  - Capital investment costs reached a peak and have declined in most countries despite the increased wind turbine size.
  - Operation and maintenance costs anticipated over the life of a wind plant are not well understood, and project cost data are lacking.

- Credits for Norway chapter on land-based wind energy:
  - Leif I. Husabø and David E. Weir, Norwegian Water Resources and Energy Directorate (NVE)

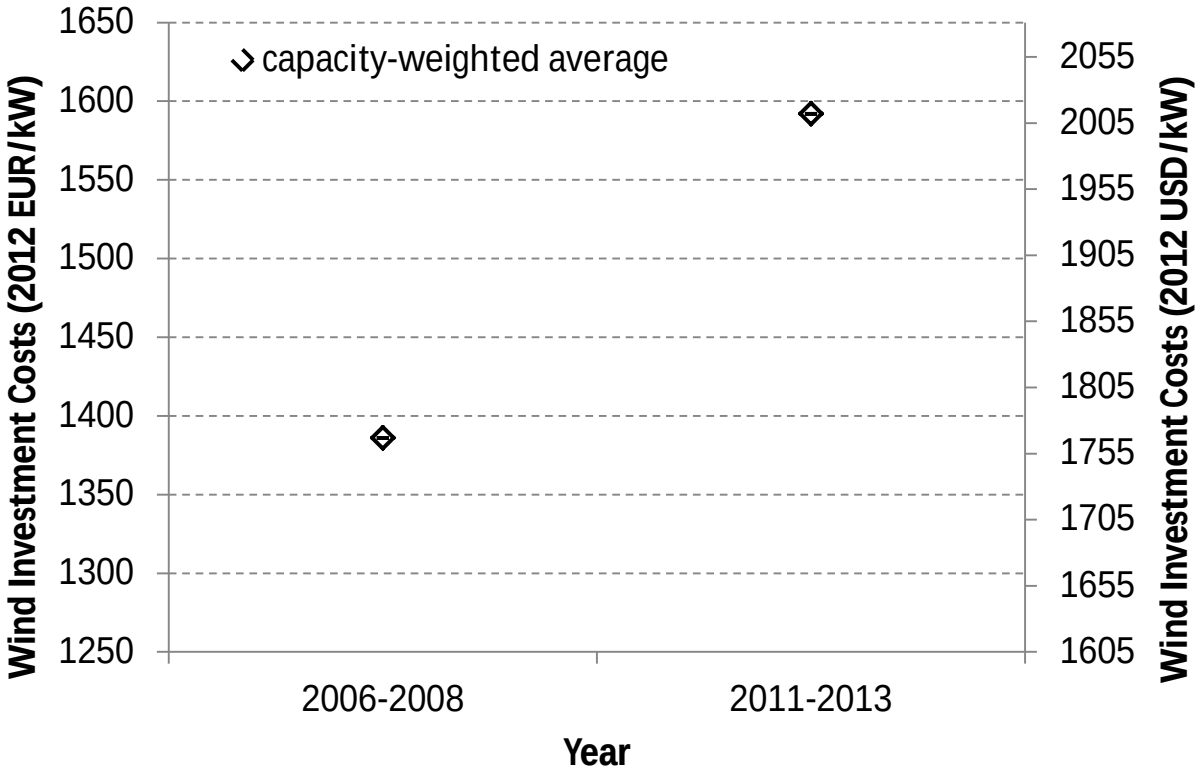
Results on cost of land-based wind energy in Norway



Cumulative and annual wind installations in Norway

(Husabø, L. and Weir, D. (2015). "Wind Energy Development in Norway," Chapter 4. Hand, M. M., ed., *IEA Wind Task 26 - Wind Technology, Cost, and Performance Trends: 2007–2012*. NREL/TP-6A20-64332. Golden, CO: National Renewable Energy Laboratory)

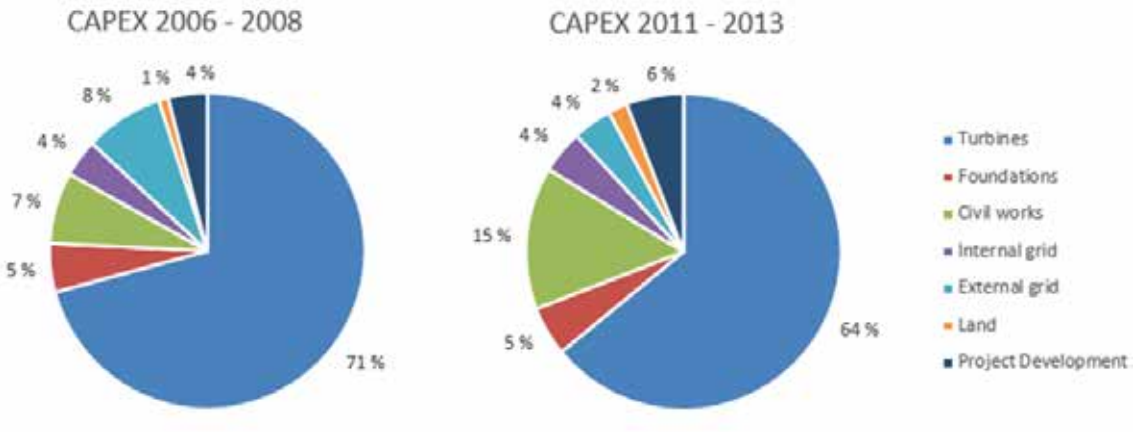
Results on cost of land-based wind energy in Norway



Investment costs for projects installed from 2007 – 2012

(Husabø, L. and Weir, D. (2015). "Wind Energy Development in Norway," Chapter 4. Hand, M. M., ed., *IEA Wind Task 26 - Wind Technology, Cost, and Performance Trends: 2007–2012*. NREL/TP-6A20-64332. Golden, CO: National Renewable Energy Laboratory)

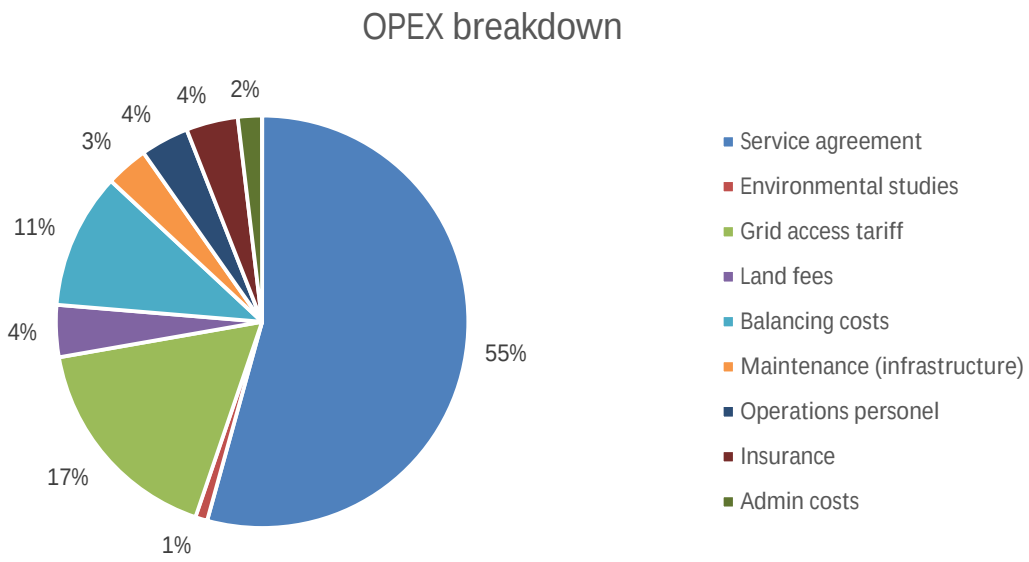
Results on cost of land-based wind energy in Norway



CAPEX breakdown 2007 – 2012

(Husabø, L. and Weir, D. (2015). "Wind Energy Development in Norway," Chapter 4. Hand, M. M., ed., *IEA Wind Task 26 - Wind Technology, Cost, and Performance Trends: 2007–2012*. NREL/TP-6A20-64332. Golden, CO: National Renewable Energy Laboratory)

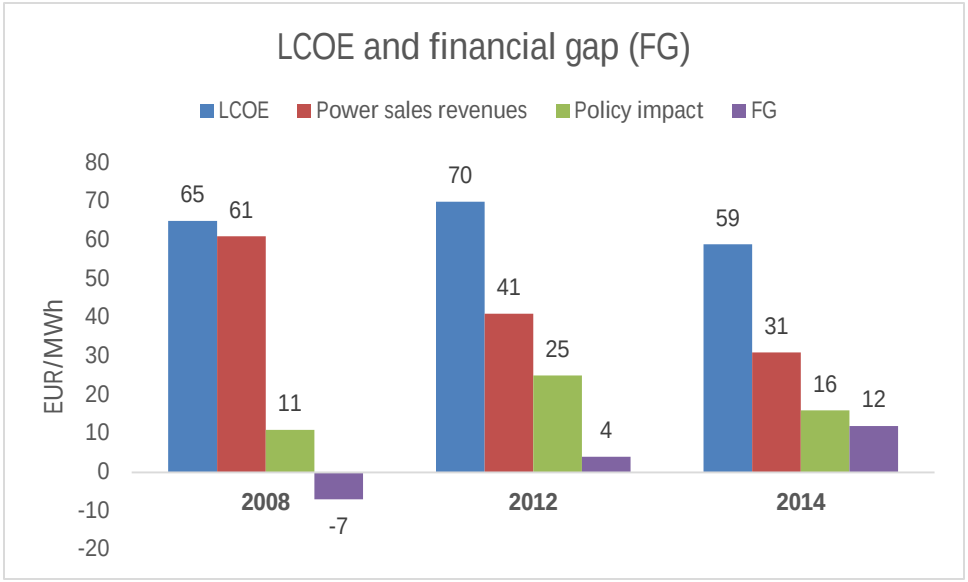
Results on cost of land-based wind energy in Norway



Estimated average breakdown of operations and maintenance costs for projects installed from 2007 – 2012

(Husabø, L. and Weir, D. (2015). "Wind Energy Development in Norway," Chapter 4. Hand, M. M., ed., *IEA Wind Task 26 - Wind Technology, Cost, and Performance Trends: 2007–2012*. NREL/TP-6A20-64332. Golden, CO: National Renewable Energy Laboratory)

Results on cost of land-based wind energy in Norway



Wind energy revenue and policy incentives in Norway in 2008, 2012 and 2014

(Husabø, L. and Weir, D. (2015). "Wind Energy Development in Norway," Chapter 4. Hand, M. M., ed., *IEA Wind Task 26 - Wind Technology, Cost, and Performance Trends: 2007–2012*. NREL/TP-6A20-64332. Golden, CO: National Renewable Energy Laboratory)

Hva kan dette gi for industrien?

- Deltakelse i taskene gir:
  - Ny kunnskap på temaområdene som tasken(e) jobber med.
  - Innsikt i status og praksiser (state-of-the-art) hos ulike aktører i de forskjellige IEA Wind medlemslandene.
  - Større nettverk og internasjonale kontakter.
  - Innflytelse og påvirkning av viktige internasjonale utviklings- og standardiseringsprosesser, samt politiske prosesser.

Veien videre for Task 26 og Task 33

- Deltakende Task-partnere må dekke selv kostnadene for direkteutgifter (Operating Agent, reiser, …) og timer (taskarbeid, deltakelse i møter, …).
- Finansiering for videre deltakelse av Norge i Task 26 og Task 33 ikke avklart ennå.