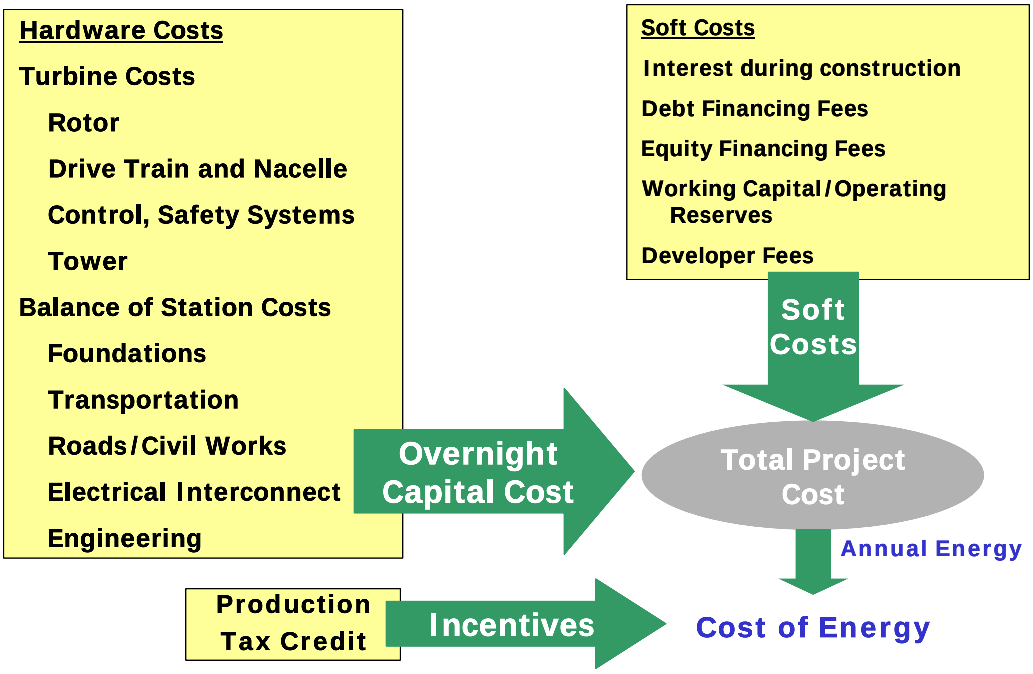
INTERNATIONAL ENERGY AGENCY

Implementing Agreement for Co-operation in the
Research and Development of Wind Turbine Systems
ANNEX XI

47th IEA Topical Expert Meeting

Methodologies for assessing the cost of (wind) electricity and the methodologies to estimate the impact of research on the cost

Paris, IEA Headquarters, November 2005



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For more information about IEA Wind see www.ieawind.org

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Methodologies for assessing the cost of (wind) electricity
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ANNEX XI
BASE TECHNOLOGY INFORMATION EXCHANGE

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The objective of this Task is to promote wind turbine technology through cooperative activities and information exchange on R&D topics of common interest. These cooperative activities have been part of the Agreement since 1978.

The task includes two subtasks. The objective of the first subtask is to develop recommended practices for wind turbine testing and evaluation by assembling an Experts Group for each topic needing recommended practices. For example, the Experts Group on wind speed measurements published the document titled "Wind Speed Measurement and Use of Cup Anemometry".

The objective of the second subtask is to conduct joint actions in research areas identified by the IEA R&D Wind Executive Committee. The Executive Committee designates Joint Actions in research areas of current interest, which requires an exchange of information. So far, Joint Actions have been initiated in *Aerodynamics of Wind Turbines, Wind Turbine Fatigue, Wind Characteristics, Offshore Wind Systems and Wind Forecasting Techniques.* Symposia and conferences have been held on designated topics in each of these areas.

In addition to Joint Action symposia, Topical Expert Meetings are arranged once or twice a year on topics decided by the IEA RD&D Wind Executive Committee. One such Expert Meeting gave background information for preparing the following strategy paper "Long-Term Research and Development Needs for Wind Energy for the Time Frame 2000 to 2020". This document can be downloaded from source 1 below.

Since these activities were initiated in 1978, more than 60 volumes of proceedings have been published. In the series of Recommended Practices 11 documents were published and five of these have revised editions.

All documents produced under Task XI and published by the Operating Agent are available to citizens of member countries from the Operating Agent, and from representatives of countries participating in Task XI.

More information can be obtained from:
1. www.ieawind.org
2. www.windenergy.foi.se/IEA_Annex_XI/ieaannex.html

INTRODUCTORY NOTE
IEA Topical Expert Meeting #47
on
Methodologies for estimation of cost of wind energy

Ian Baring-Gould, NREL, and Sven-Erik Thor, Vattenfall

"Wind power is often criticized as being economically 'uncompetitive'. Yet the real cost of wind power has decreased dramatically – by 50% over 15 years – and that trend is set to continue.", [1]

1. BACKGROUND

The cost of energy from wind turbines may be estimated in a variety of ways. Additionally, there are a number of different reasons for the development of cost data; to show technical advancements, to compare different technology options, or determine research focus areas. A macro economic approach will require methods that are different from those needed for a private financial analysis, and will possibly generate cost of energy figures not suitable for comparisons. Furthermore, even analyses intended for the same purpose may have different ways for estimating the cost of energy, and thus care should be taken whenever comparing energy cost figures to ensure that the analyses methods have been the same. This, slightly modified, text was taken from the introduction to the IEA Recommended Practice titled "Estimation of Cost of Energy from Wind Energy Systems", published 1994, second edition. This document can be obtained from [2].

As wind turbines become more cost effective and compete directly with conventional technologies, it will become more important to have an accepted method for calculating the expected costs of wind projects and to clearly state general cost of energy figures that can be used by other industries and governmental agencies.

Cost of wind generation depends on many parameters where the local wind situation and the lifetime of the turbine are strong drivers. Investment in capital equipment is the main cost driver, approximately. 1 €/W installed, 80% of which is for the turbine. The scaling factors of the turbine's size, mass production and cost improvement have reduced output-specific investment costs to less than a half over the last 15 years. The potential for further cost reduction becomes more difficult when the wind turbines are becoming more optimized and mature. Yet to be seen are the leap frog steps in technology which may take costs to even lower levels. Additionally, costs can vary quite widely from country to country or region to region based on governmental policy or incentives, land policy, environmental regulations and other parameters that are not directly related to the cost of the wind technology.

The main parameters governing wind power economics includes, for example:

- Investment cost, including auxiliary costs for foundation, grid-connection
- Operation and maintenance cost, including insurance
- Electricity production
- Feed in cost
- Turbine lifetime
- Project financing including structure, depreciation, and taxation.
- Externality costs
- Discount rate

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[1] Poul Erik Morthorst and Hugo Chandler, WIND - The cost of wind power, Renewable Energy World, July–August 2004, www.ewea.org/documents/Facts_fiction.pdf

[2] Copy of document can be obtained from sven-erik.thor@vattenfall.com

The competitiveness of wind power is dependent on the particular market conditions where wind developments are placed. It is generally accepted that wind energy and other renewable energy sources have environmental benefits when compared to conventional electricity generation. But are these benefits reflected in the market price of electricity? And, is conventional power generation charged for the environmental damage caused by polluting emissions? These are questions related to the external costs of energy. A thorough survey of these factors can be found in [3]. Additionally the variable nature of the wind resource requires some additional costs for backup power, variable transmission line loading and forecasting; all of which may place additional costs on the development of wind technologies.

Examples of external costs associated with wind energy are:

- Noise
- Visual impact
- Environmental emissions from production and erection, such as CO_2, NO_x and SO_2
- Environmental emissions from operation, such as oil, grease and debris
- Cost of power reserve margins
- Transmission line loading and capacity

Lastly, as wind technology moves from a primarily research oriented activity to a more mainstream energy source, governmental technology programs are requiring a better understanding of how current research programs are impacting the cost of a technology which is increasingly being driven by research conducted in private corporations. Ongoing research activities in some IEA member countries and new research programs such as the European Union Wind Energy Thematic Network targeting the Seventh Framework Program for R&D will require a more systematic method to assess the impacts of R&D on the COE from wind turbines. In order to defend coordination and further R&D funding, a method to assess these economic impacts may be required.

2. OBJECTIVES

This proposal aims to summon a meeting of experts the objective of which is to review and evaluate the status of research, experiences and activities concerning cost modelling in relation to wind energy development.

Participants in the meeting will present their experience in the field. Topics can be chosen from, but must not be limited to, the items below.

- Cost models
- Cost components and energy production
- Comments on the Recommended Practice on Cost Modelling
- Uncertainties, economy and wind
- Influence on location, on shore or off shore
- Externalities
- Comparisons with other electricity production types
- Use of COE calculations to assess programmatic technical improvements
- Differences between market and technical based COE calculations
- Non-economic methods for comparing different system efficiencies
- Methodologies to estimate the impact of research on the cost

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[3] Wind Energy the Facts, an analysis of wind energy in the EU-25, EU project 4.1030/T02-007/2002
http://www.ewea.org/06projects_events/proj_WEfacts.htm

3. INTENDED AUDIENCE

Participants will typically represent the following type of entities:

- Universities, research organizations
- Utilities, wind turbine owners
- Investors
- Government reporting agencies

4. TENTATIVE AGENDA

The tentative agenda covers the following items:

1. Introduction by host
2. Introduction by Operating Agent, Recognition of Participants
3. Collecting proposals for presentations
4. Presentation of Introductory Note
5. Individual presentations
    - Cost models, cost components and uncertainties
    - COE calculations to assess programmatic technical improvements
    - Externalities
    - Comments on Recommended Practice on Estimation of Cost of Energy from Wind Energy Systems
    - The role of R&D on cost
    - Miscellaneous
6. Discussion
7. Summary of meeting

5. OUTCOME OF MEETING

The outcome of the meeting is the proceedings and a plan for future information exchange and work within this area.

Potential outcomes of meeting include:

- An overview of existing methods
- Future research and development needs
- Understanding of methods to determine how new technologies and/or research programs will influence cost
- A decision on whether is necessary to update the Recommended practice on cost modelling is foreseen
- Discussion of other non-economic, technical based methodologies, to assess performance and or efficiencies of different wind power options.
- Determine the need to develop a common framework for the expressing of COE.
- Discussion on expanding the reporting for COE from different countries to counter clams from other energy sectors. Could be combined with a IEA Wind cost assessment document
- Determination of methods to assess cost curve trajectories

Supplement to the introductory note on Methodologies for estimation of cost of wind energy

Long title: Methodologies for assessing the cost of (wind) electricity and the methodologies to estimate the impact of research on the cost.

The second part of the long title above was not discussed to large intent in the original text. Hence the following text is supplied for your reference and consideration.

Researchers, national R&D program managers, wind interest groups, etc would like to:

- substantiate the claim that research does help reduce the cost of (wind) electricity
- come up with numbers that justify the investment in research
- convince (people / the taxpayer) to invest in research.
- quantify the effect of research on the cost of (wind) electricity

Some countries and the EU have RD&D programs that have a target for cost reductions, a method to evaluate research proposals for it’s claimed contribution to cost reductions and the expertise to assess those claims.

E.g. NREL in the US and ECN in the Netherlands have methodologies but they probably differ.

The meeting will try to make an inventory of:

- countries with a target for cost reductions in it’s RD&D programs
- country methodology to evaluate RD&D proposals for it’s claimed contribution to cost reductions

The meeting will try to

- formulate common elements, guiding principles and make recommendations for models to quantify the effect of research on cost reductions
- formulate an answer if it thinks it useful to develop (a) standard methodology(ies) to be able to recommend it for evaluating RD&D proposals.

Methodologies for Estimating the Cost of Wind Energy

An Irish Perspective

Eoin McLoughlin

IEA Topical Expert Meeting, Paris, 29/30th Nov 2005

Background and Outline

- SEI's mandate is to support Government in the formulation of sustainable energy policy
  - National Energy Agency

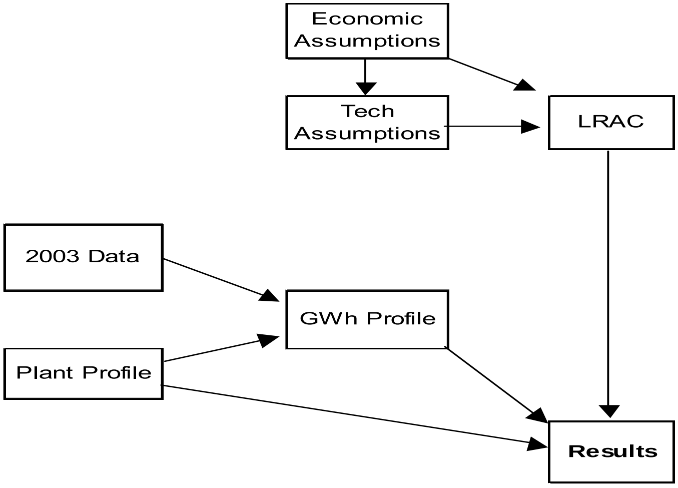
1. Renewable Energy Policy Support:
   - Current/Future RES-E support mechanism
   - Development of SEI's 'Energy Model for Electricity Generation'

2. RD&D:
   - RE RD&D programme

Financial Model

- To support RES-E policy mechanism design
- Evaluate appropriate levels of fiscal support for RES-E
  - Conventional financial DCF model
    - Uses W.A.C.C.
    - Varying risk adjusted discount rates by technology
  - Informed by technical experts, industry, bankers, etc.
  - Uses various financial metrics (RoI, etc.)

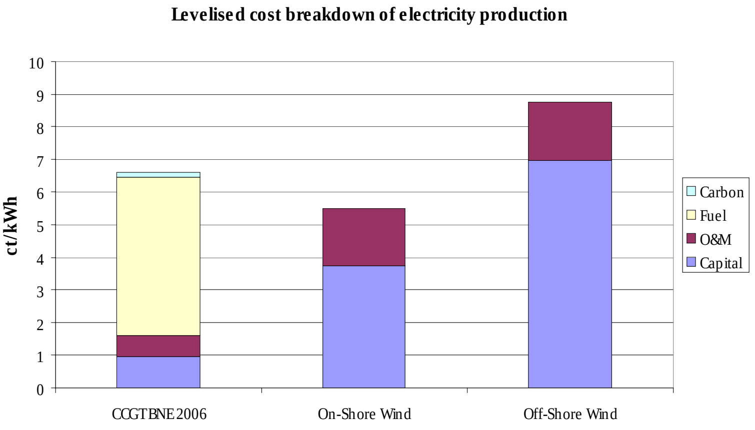
What is it?
-Diagram of the model

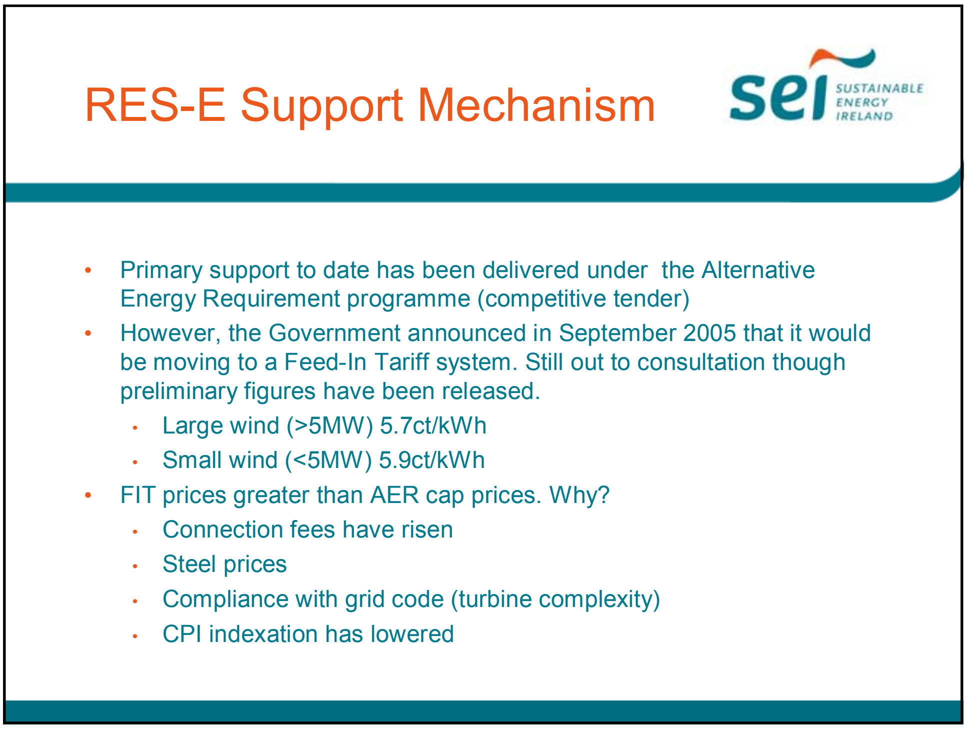


Methodology

- Uses typical levelised cost structure
  - Modelled after BNE calculation (as template)
    - Transparent
- The Commission for Energy Regulation determines the Best New Entrant cost (BNE) which is used as a proxy for the wholesale electricity price in Ireland.
- Derived as a 400MW (1+1) CCGT with the price for 2006 being set at a level of 6.61ct/kWh.
  - Rising gas prices and carbon costs means in recent years BNE has increased significantly

Levelised Cost
- Wind Example





RES-E Support Mechanism

- Primary support to date has been delivered under the Alternative Energy Requirement programme (competitive tender)
- However, the Government announced in September 2005 that it would be moving to a Feed-In Tariff system. Still out to consultation though preliminary figures have been released.
  - Large wind (>5MW) 5.7ct/kWh
  - Small wind (<5MW) 5.9ct/kWh
- FIT prices greater than AER cap prices. Why?
  - Connection fees have risen
  - Steel prices
  - Compliance with grid code (turbine complexity)
  - CPI indexation has lowered

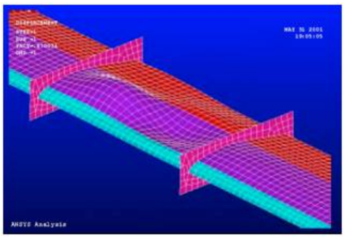
SEI RD&D Programme

- Ireland to a large extent is a technology taker
- However, a number of wind energy projects currently being supported under RD&D programme.
- This programme aims to support renewable sector:
  - Develop new markets/technologies
  - Identify/address market barriers
- Through:
  1. Commissioned work to support integration
  2. Funding for projects

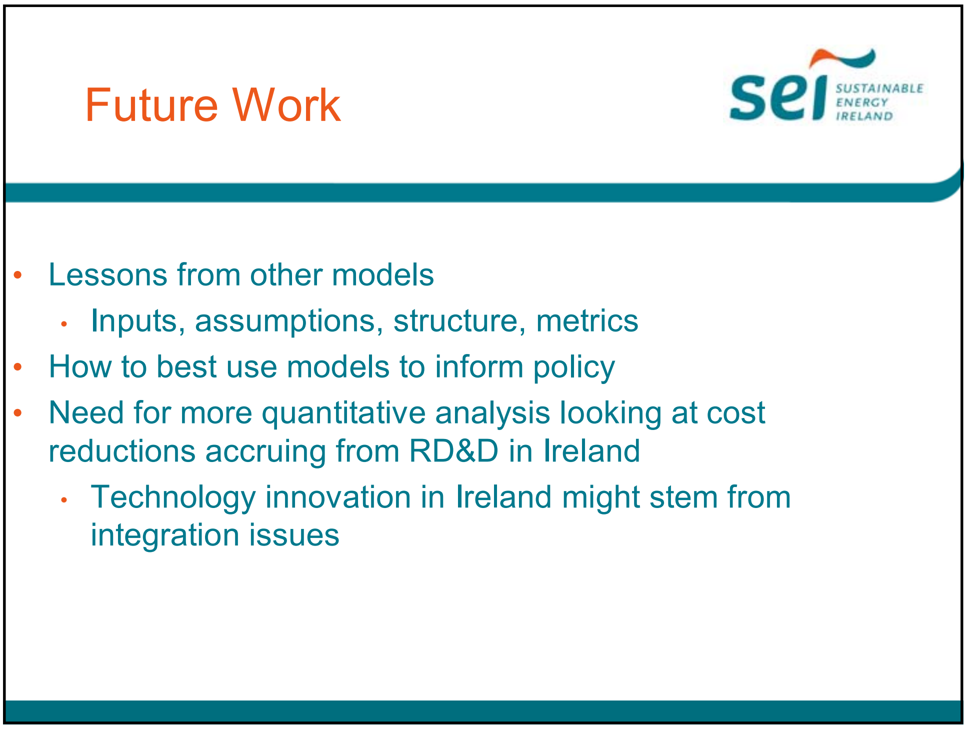
Commissioned Studies

- Current SEI Renewable Electricity Commissioned (Wind Related) Studies
  - Renewable Electricity and the MAE
  - Costs and Benefits of Embedded Generation in Ireland
  - Wind Energy and Operational Reserve Requirements
  - **New** “all-island” (N/S) work on wind integration will include costs and benefits.

Funded Projects – Greenblade



- 12.5m turbine blades from thermoplastic material with fast production time
- Cheaper to produce
- 10% lighter than existing blades
- 150% tougher
- 100% recyclable



Future Work

- Lessons from other models
  - Inputs, assumptions, structure, metrics
- How to best use models to inform policy
- Need for more quantitative analysis looking at cost reductions accruing from RD&D in Ireland
  - Technology innovation in Ireland might stem from integration issues

Thanks for listening

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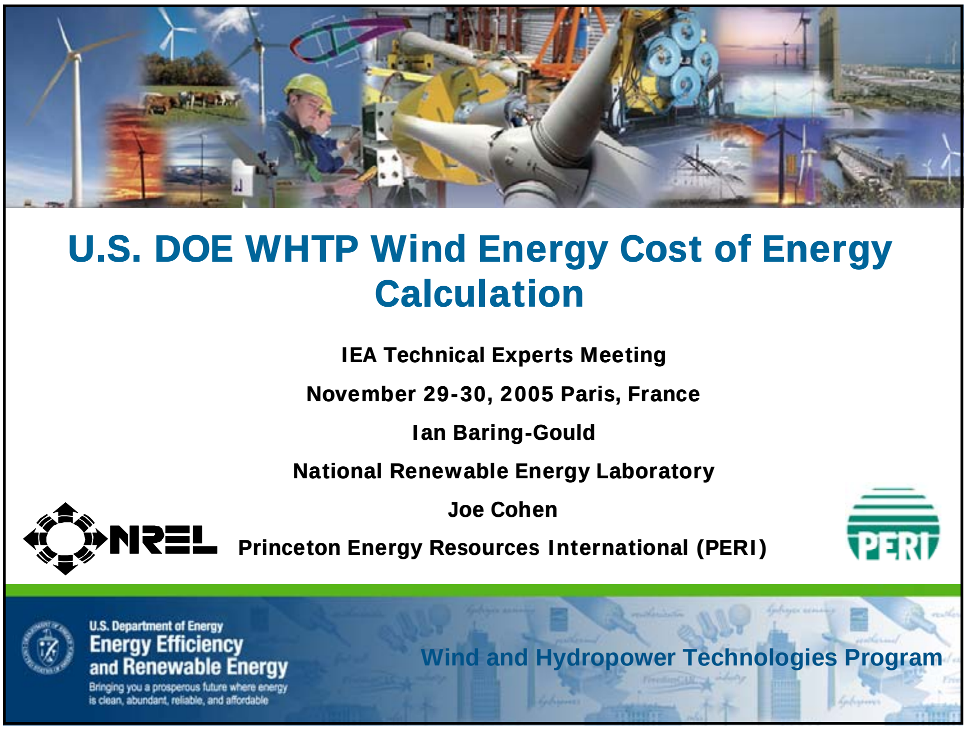


U.S. DOE WHTP Wind Energy Cost of Energy Calculation

IEA Technical Experts Meeting

November 29-30, 2005 Paris, France

Ian Baring-Gould

National Renewable Energy Laboratory

Joe Cohen

Princeton Energy Resources International (PERI)

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Wind and Hydropower Technologies Program

Outline

- What is COE used for?
- How can COE be calculated?
- What is the role of technology characterization?
- Why can calculating COE seem so difficult?

Who Asks “What Do Renewables Cost?”

- Prospective purchasers of renewable power
- Executive Branch of Government - Office of Management and Budget
- Hardware manufacturers
- Developers (we think they know, but aren’t telling!)
- Congress
- The “Press”
- Department of Energy management
- The general public
- Research community

There are plenty of subtle distinctions in answering this seemingly simple question.

What Do DOE Programs Do with COE?

Track technology improvement

- Annual performance targets
- Oversight and Auditing
- Technical review meetings

Perform benefits analyses

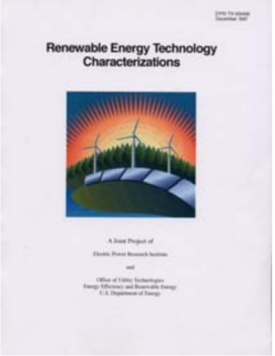
- Data inputs to benefits modeling exercises (Government Performance Reporting Act - GPRA)
- Analysis of program initiatives

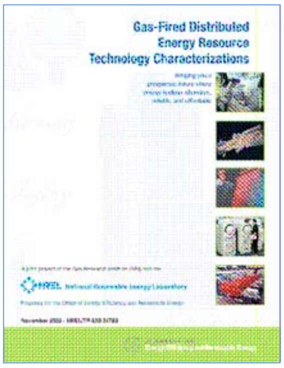
Communicate with outside audiences

- Program documents and talks before the general public
- Congress and the budget submission
- Discussions with the project development community

“Recent” Technology Characterizations

1997


Renewable Energy Technology Characterizations


Gas-Fired Distributed Energy Resource Technology Characterizations

2003

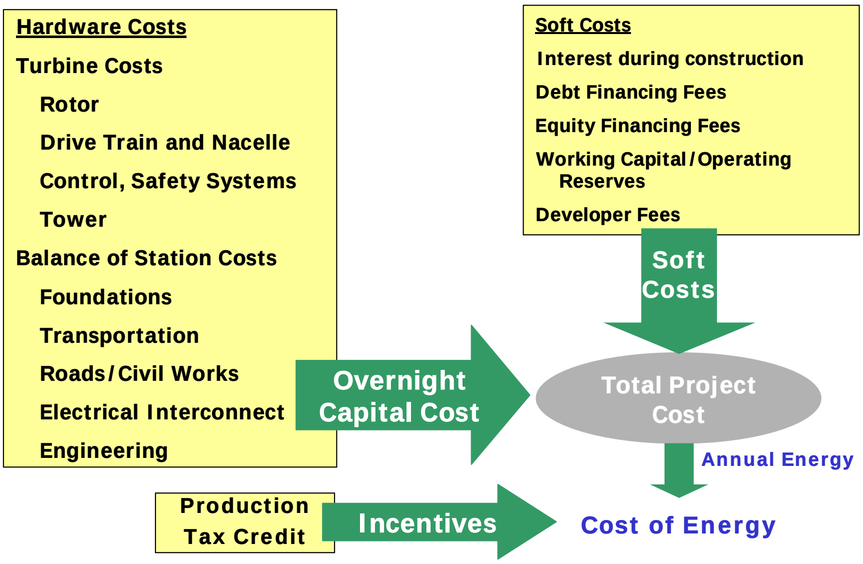
Others:

EPRI: Renewable Energy TAG - 2004

World Bank: Technical and Economic Assessment ….. (in preparation)

Individual DOE Programs: Solar CSP, Wind LWST, others?

What do Wind Turbines Cost?



Hardware Costs

Turbine Costs
- **Rotor**
- **Drive Train and Nacelle**
- **Control, Safety Systems**
- **Tower**

Balance of Station Costs
- **Foundations**
- **Transportation**
- **Roads/Civil Works**
- **Electrical Interconnect**
- **Engineering**

Soft Costs
- **Interest during construction**
- **Debt Financing Fees**
- **Equity Financing Fees**
- **Working Capital/Operating Reserves**
- **Developer Fees**

Soft Costs

Overnight Capital Cost

Total Project Cost

Annual Energy

Production Tax Credit

Incentives

Cost of Energy

What are the Issues Surrounding COE?

Technology Characterization Data

- Getting current proprietary data is difficult
- Industry partnerships are helping for projections, but the data is often proprietary
- We need to track at the subsystem level
- Non-hardware costs are even more difficult to generalize about – every project is different

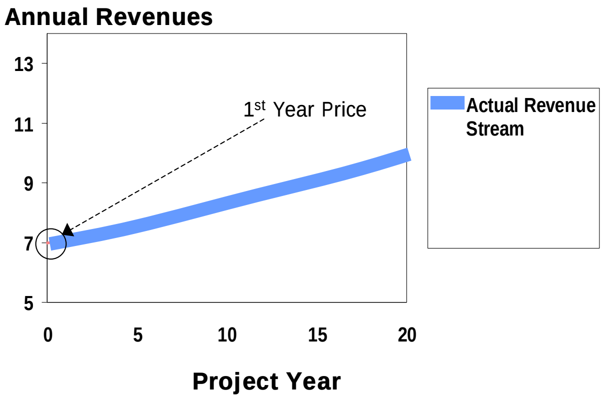
Programs COE

- COE can be calculated in many ways – and the wind program's way isn't used in the "real world"
- COE of advanced technology gets easily confused with "current COE"

How Can COE be Expressed?

In terms of its 1st Year Bid Price ...

1. Quotes PPA value for first year of the project (from Power Purchase Agreement)
2. Should also quote PPA escalation rate for completeness (but often does not)



What Are the Key Financing Parameters?

- Current or Constant
- Project Lifetime
- Amount of debt used
- Cost of debt
- Cost of equity (hurdle rate)

How Else Can COE be Expressed?

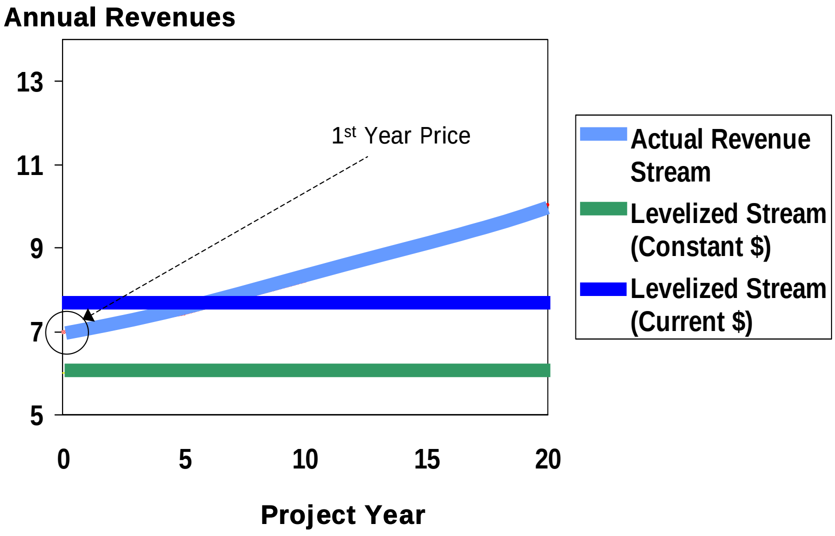
In Levelized Current Dollars

1. Take an escalating stream of revenues that includes inflation
2. Calculate the Net Present Value of the revenue stream (using a discount rate that includes inflation)
3. Multiply by a levelizing factor to get an equivalent non-escalating stream with the same Net Present Value
4. Divide (NPV * Levelizing Factor) by annual energy to get levelized COE

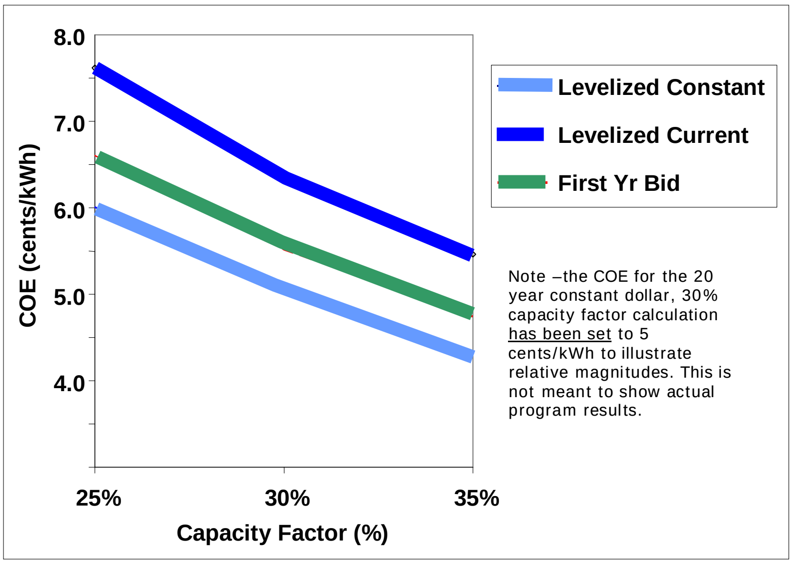
In Levelized Constant Dollars

1. Take an escalating stream of revenues in constant dollars
2. Calculate an equivalent non-escalating stream with the same Net Present Value (using a discount rate that does not include inflation)
3. Divide (NPV * Levelizing Factor) by annual energy to get levelized COE

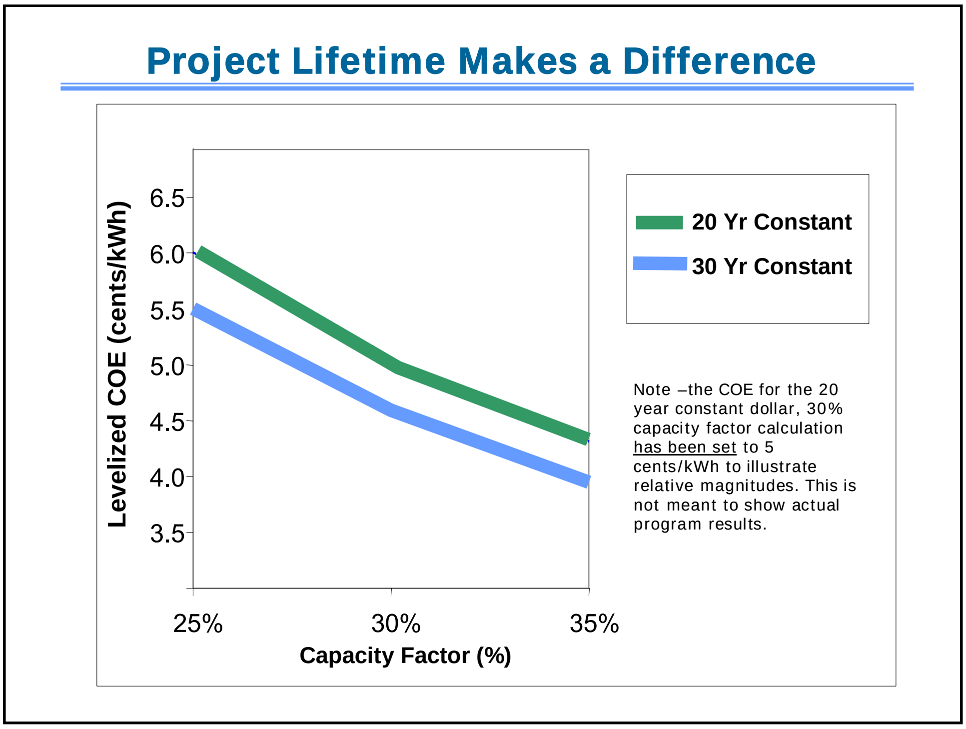
Comparison of Levelized Streams to Actual



What Difference Does How COE is Expressed Make?

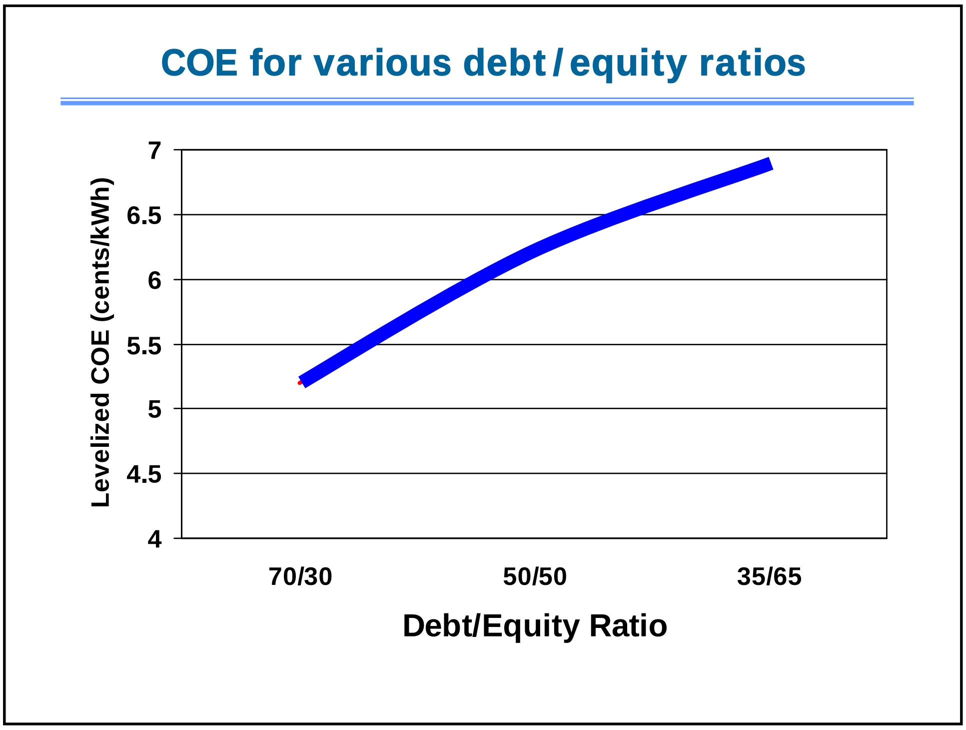


Note –the COE for the 20 year constant dollar, 30% capacity factor calculation has been set to 5 cents/kWh to illustrate relative magnitudes. This is not meant to show actual program results.



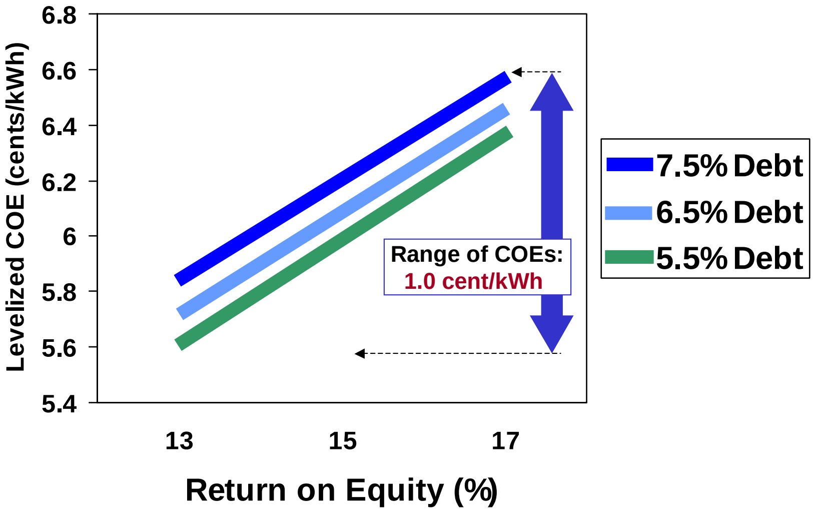
Project Lifetime Makes a Difference

Note –the COE for the 20 year constant dollar, 30% capacity factor calculation has been set to 5 cents/kWh to illustrate relative magnitudes. This is not meant to show actual program results.



COE for various debt/equity ratios

COE Can Vary Significantly Due to Assumptions



How Does The Wind Program Calculate COE?

Uses Levelized Constant Dollar COE

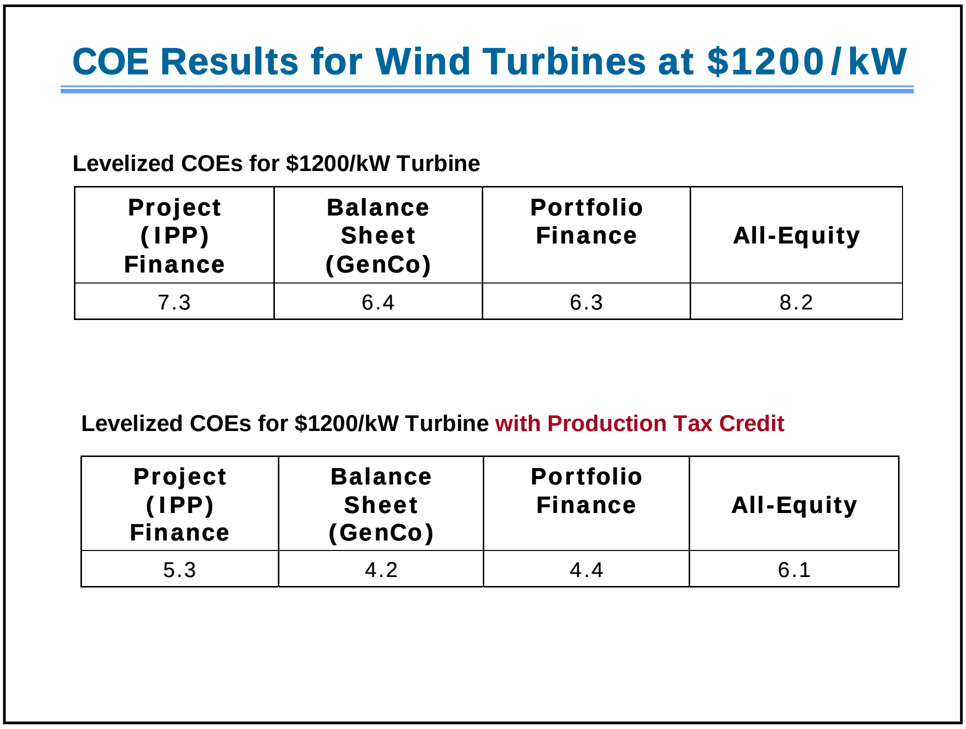
- Easier to set goals without (unknown) inflation
- Including inflation would tend to mask R&D progress
- Department models use constant dollars

Financial Structure

- Over the years, the program has transitioned from a required revenues (regulated utility) approach; to an IPP (highly leveraged) approach; to a GenCo Balance Sheet approach (lower required returns)
- These changes have attempted to mirror industry practice

Production Tax Credit is NOT included because it is not permanent

Can not account for other short term factors (exchange rate, commodity prices, market conditions, etc.)



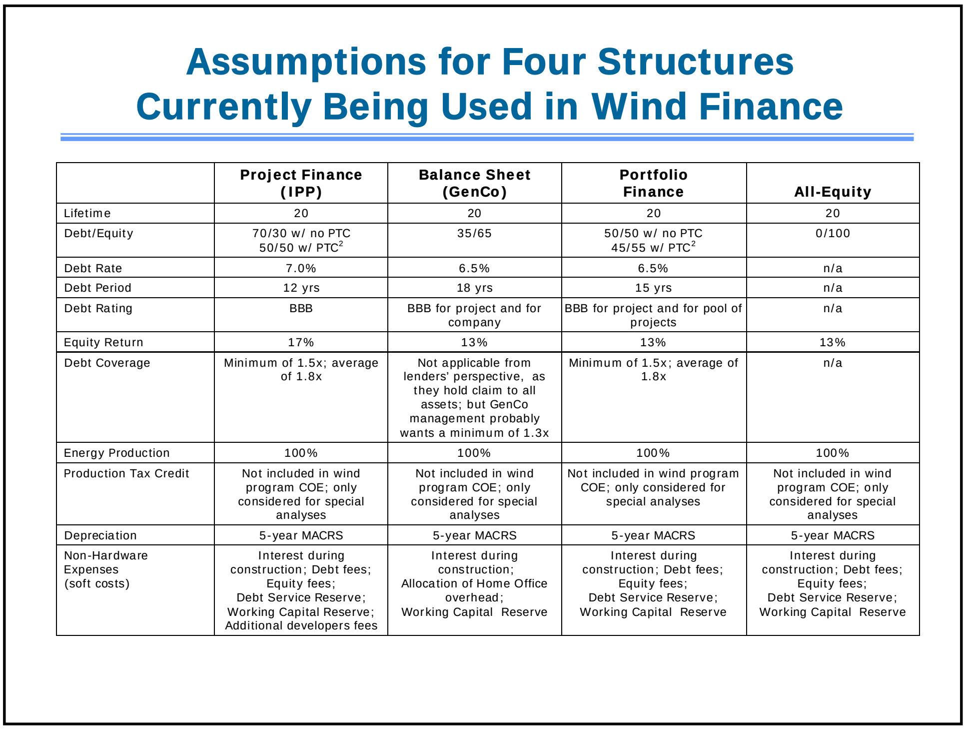
COE Results for Wind Turbines at $1200/kW

Levelized COEs for $1200/kW Turbine

Project (IPP) Finance	Balance Sheet (GenCo)	Portfolio Finance	All-Equity
7.3	6.4	6.3	8.2

Levelized COEs for $1200/kW Turbine with Production Tax Credit

Project (IPP) Finance	Balance Sheet (GenCo)	Portfolio Finance	All-Equity
5.3	4.2	4.4	6.1



Assumptions for Four Structures Currently Being Used in Wind Finance

	Project Finance (IPP)	Balance Sheet (GenCo)	Portfolio Finance	All-Equity
Lifetime	20	20	20	20
Debt/Equity	70/30 w/ no PTC 50/50 w/ PTC[2]	35/65	50/50 w/ no PTC 45/55 w/ PTC[2]	0/100
Debt Rate	7.0%	6.5%	6.5%	n/a
Debt Period	12 yrs	18 yrs	15 yrs	n/a
Debt Rating	BBB	BBB for project and for company	BBB for project and for pool of projects	n/a
Equity Return	17%	13%	13%	13%
Debt Coverage	Minimum of 1.5x; average of 1.8x	Not applicable from lenders' perspective, as they hold claim to all assets; but GenCo management probably wants a minimum of 1.3x	Minimum of 1.5x; average of 1.8x	n/a
Energy Production	100%	100%	100%	100%
Production Tax Credit	Not included in wind program COE; only considered for special analyses	Not included in wind program COE; only considered for special analyses	Not included in wind program COE; only considered for special analyses	Not included in wind program COE; only considered for special analyses
Depreciation	5-year MACRS	5-year MACRS	5-year MACRS	5-year MACRS
Non-Hardware Expenses (soft costs)	Interest during construction; Debt fees; Equity fees; Debt Service Reserve; Working Capital Reserve; Additional developers fees	Interest during construction; Allocation of Home Office overhead; Working Capital Reserve	Interest during construction; Debt fees; Equity fees; Debt Service Reserve; Working Capital Reserve	Interest during construction; Debt fees; Equity fees; Debt Service Reserve; Working Capital Reserve

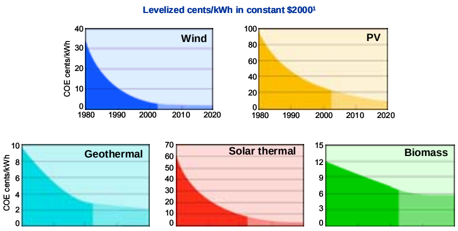
COE Assumptions Really Do Matter

	CSP Assumptions (Sargent & Lundy 2002)	Current Wind Assumptions	Adjust Wind Assumptions to Match CSP
COE	---	5.3	4.6
Key Assumptions			
Lifetime	30	20	30
Return on Equity	11.5	13	11.5
Debt Rate	6.0	6.5	6.0
Debt/Equity	60/40	60/40	60/40

CSP and current wind assumptions are different.
Wind's COE drops by about 15% if wind adopts the CSP assumptions.

Summary Thoughts

- Strawman
- The COE methodology used can really affect the answer



Until these are addressed, great caution is required in comparing COEs of different technologies

Renewable Electricity Technology Cost Trends

Chart Notes, Page 1

Background

- The Cost Curves are expressed in constant, 2000 year dollars and based on a uniform set of financial assumptions consistent with Generating Company Ownership (balance-sheet financing).
- Actual project costs can vary substantially – not only over time, but from project to project – based on variables such as siting and permitting costs, land costs, transmission access, labor costs, and financing terms.
- The Cost Curves are **not based on specific project data,** but are composite representations derived from a variety of sources outlined below.
- Historic costs from 1980 to 1995 generally reflect costs that were published in various DOE Renewable Energy Program plans such as five-year program plans, annual budgets, and other program publications.
- The Future Cost Curves generally reflect how the DOE Renewable Energy Programs expect the costs of renewable energy to decrease through lowered technology costs and improved performances, resulting from R&D efforts and other factors.
- Projections of cost to 2020 for biomass, geothermal, and photovoltaic energy technologies are based on the DOE/EPRI Renewable Energy Technology Characterizations published in 1997. Wind and solar thermal costs represent more recent DOE Renewable Energy Program projections.
- The Cost Curves generally assume the availability of high-quality resources. This is an important point because systems using lower quality resources are being built, in some cases with costs as much as double those shown.
- The Cost Curves do not include the effects of tax credits or production tax incentives.

Renewable Electricity Technology Cost Trends

Chart Notes, Page 2

General Observations

- The renewable technology cost trends typically show a steep decline from 1980 to the present. Projections show this decline to continue, but at a slower absolute pace as the technologies mature.
- Historic cost of energy trends reflected in this chart are in broad agreement with the trends published in “Winner, Loser, or Innocent Victim? Has Renewable Energy Performed as Expected?“ Renewable Energy Policy Project, Report No. 7, April 1999.

Technology Specific Notes

- Wind technology cost projections represent wind power systems in locations with Class 6 resources. Low wind-speed turbine technology is under development, which will make available large amounts of usable wind resources that are closer to transmission. Lower costs will result from design and technology improvements across the spectrum from foundations and towers, to turbine blades, hubs, generators, and electronics.
- Biomass cost projections are based on gasification technology. Lower costs will result from technology improvements indicated by current pilot plant operations and evaluation, including improvements in feedstock handling, gas processing/cleanup, and overall plant design optimization.
- Geothermal cost projections are for Flash technology. Cost reductions will result from more efficient and productive resource exploration and characterization as well as from continued improvements in heat exchangers, fluid-handling technologies, turbines, and generators.
- Solar thermal cost projections are for Parabolic Trough and Power Tower Technologies and are based on a detailed due-diligence study completed in 2002 at the request of DOE. Cost reductions will result from improved reflectors and lower-cost heliostat designs, improved solar thermal receivers, heat exchangers and fluid handling technologies, and turbines and generators, as well as from volume manufacturing.
- Photovoltaic cost projections are based on increasing penetration of thin-film technology into the building sector. Likely technology improvements include higher efficiencies, increased reliability (which can reduce module prices), improved manufacturing processes, and lower balance of system costs through technology improvements and volume sales.

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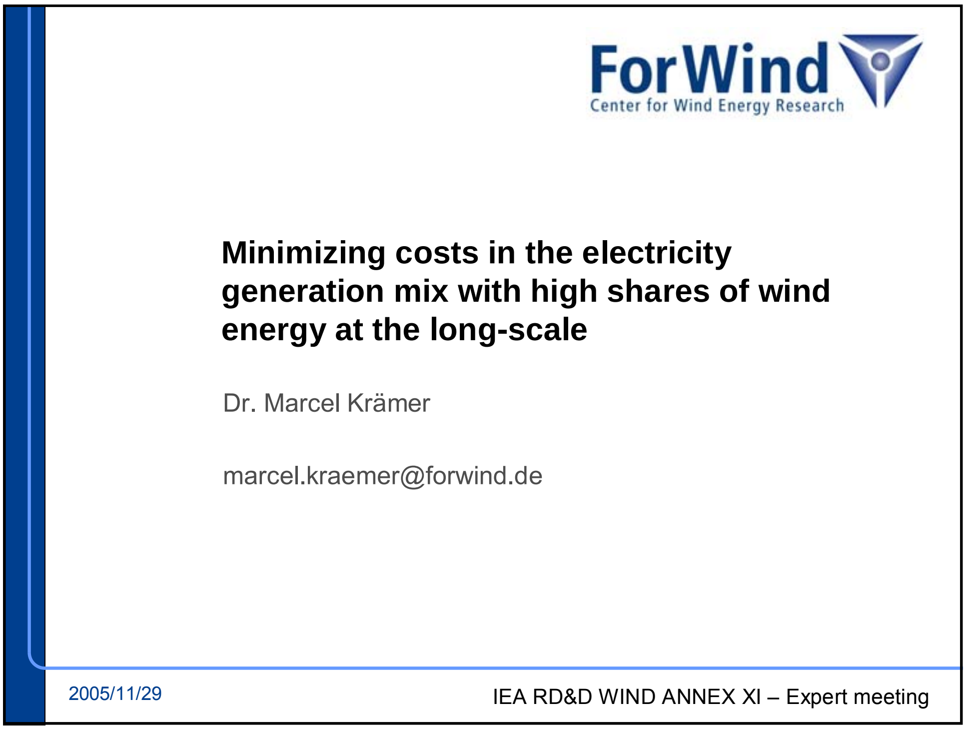


ForWind
Center for Wind Energy Research

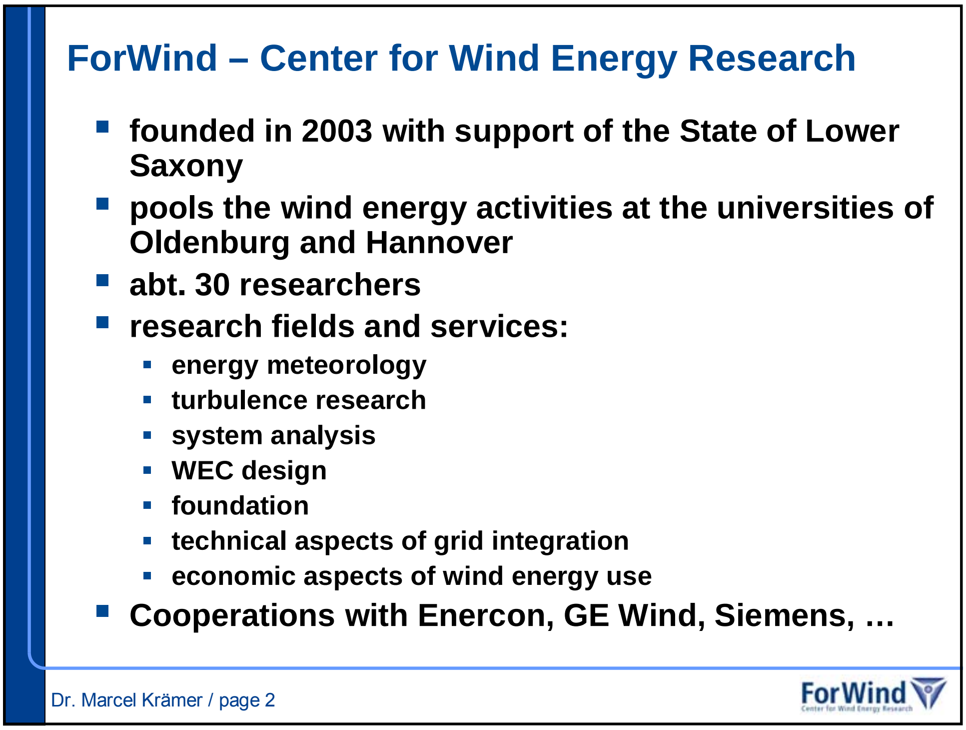
Minimizing costs in the electricity generation mix with high shares of wind energy at the long-scale

Dr. Marcel Krämer

marcel.kraemer@forwind.de

2005/11/29

IEA RD&D WIND ANNEX XI – Expert meeting



ForWind – Center for Wind Energy Research

- founded in 2003 with support of the State of Lower Saxony
- pools the wind energy activities at the universities of Oldenburg and Hannover
- abt. 30 researchers
- research fields and services:
  - energy meteorology
  - turbulence research
  - system analysis
  - WEC design
  - foundation
  - technical aspects of grid integration
  - economic aspects of wind energy use
- Cooperations with Enercon, GE Wind, Siemens, …

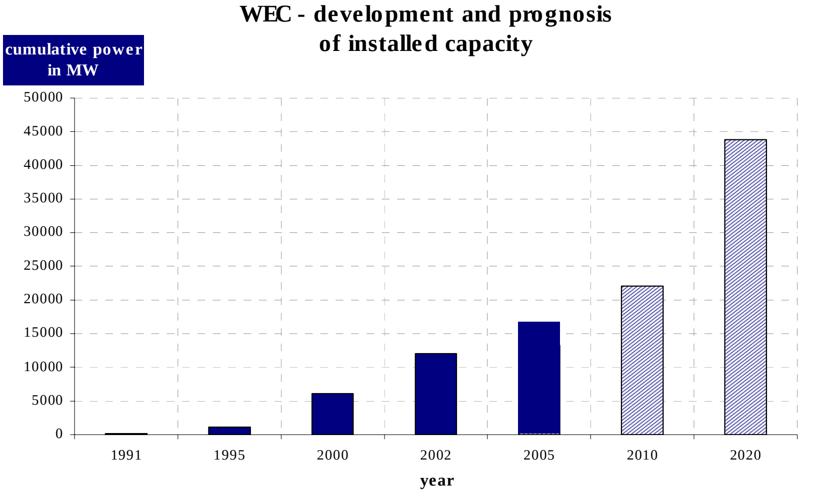
Dr. Marcel Krämer / page 2

ForWind

Overview

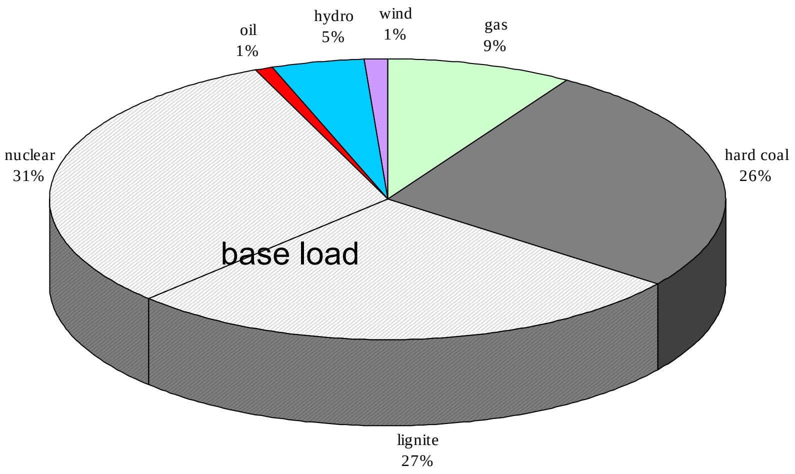
- „Roadmap“ wind energy use in Germany
- Today´s structure of conventional electricity generation (not only) in Germany
- The modelling approach WEsER
- Results of different scenarios
- Conclusions

Wind energy use in Germany



Source: BWE, DEWI

Shares of electricity generation in Germany in 2000

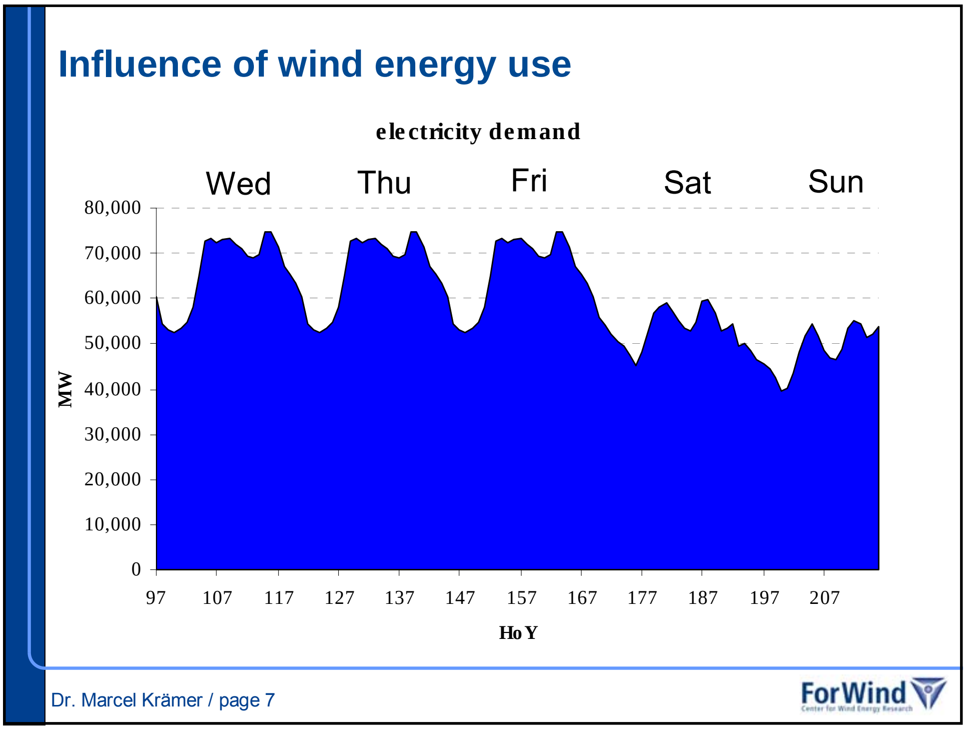


Source: VIK, VDN

Fade out of installed capacity

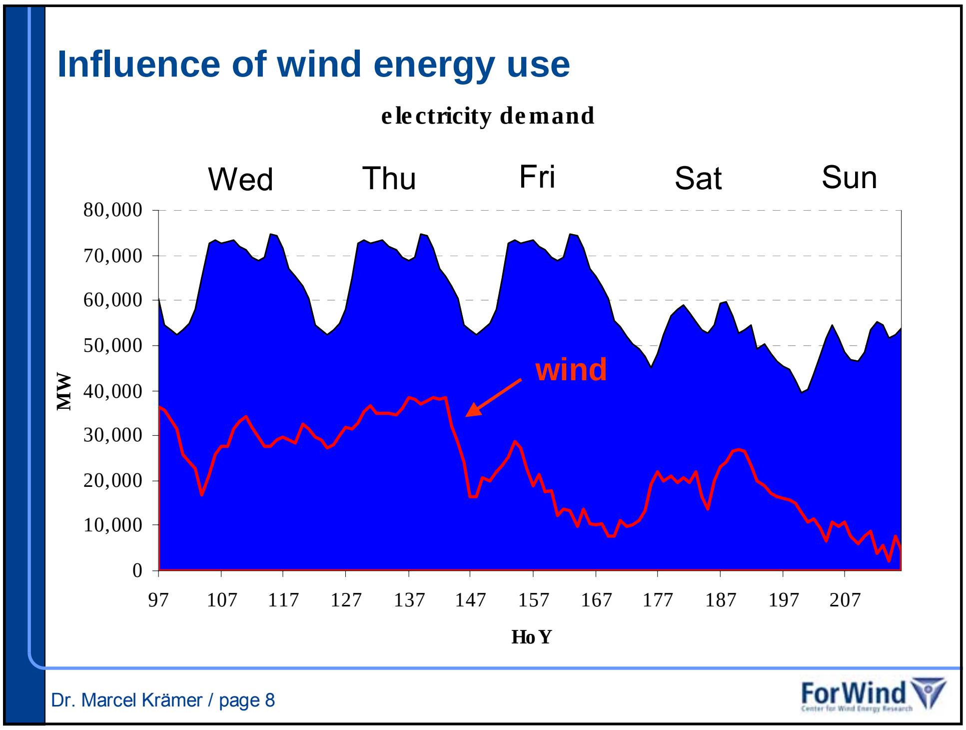
- 2010: 76 GW in operation
  → 14 GW missing
- 2020: 39 GW in operation
  → 51 GW missing!
- planning period: abt. 5..10 years
  → decisions for new capacity are made now!

→ chance to restructure electricity generation mix!



Influence of wind energy use

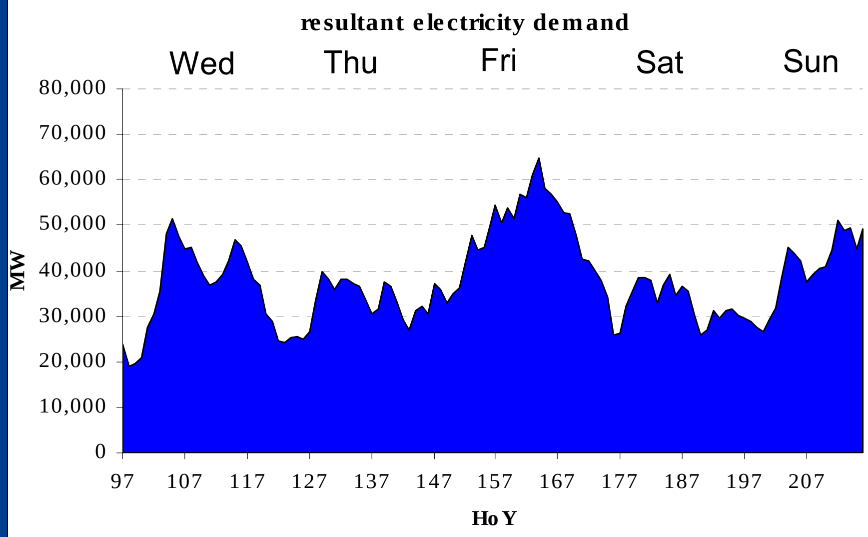
Dr. Marcel Krämer / page 7



Influence of wind energy use

Dr. Marcel Krämer / page 8

Influence of wind energy use



Key decision

- ☹ **Accept wind energy only as an additional electricity generator with an upper limit for installed capacity (which is reached recently)**

- ☺ **Find wind energy use as the first step to reorganize electricity generation towards sustainability and fit new conventional capacity on it.**

Basic hypothesis

Because of future wind energy use conventional power plant mix will change towards flexible systems

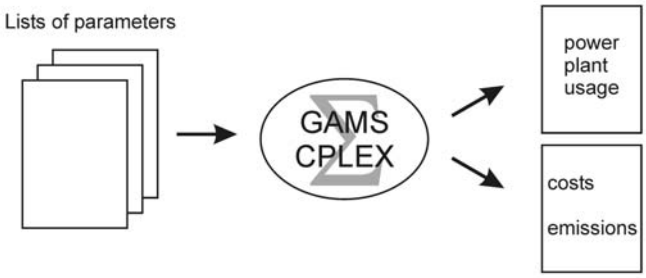
-

lignite and nuclear based power plants will loose cost advantages

---

Model approach WEsER

Wind Energy substitutes conventional Electricity Resources



objective: Σ (overall conventional costs) → min!

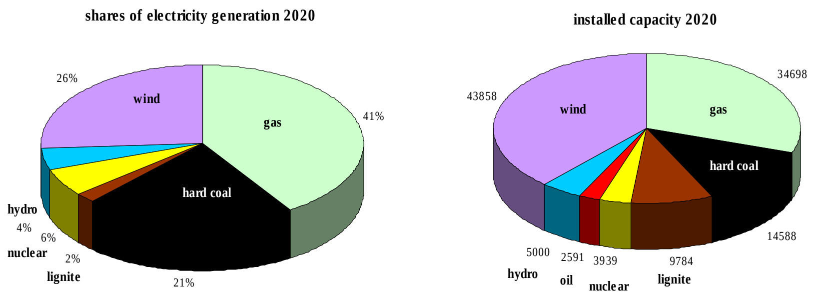
WEsER - characteristics

- linear optimization model
- observation period: 1 year; resolution: 1 hour
- one-node model of Germany
- outpointed example years: 2000, 2010 und 2020
- model input: tables of parameters, time series of demand and wind power input
- model output: costs, emissions, installed capacity, operation timetable of power plants

---

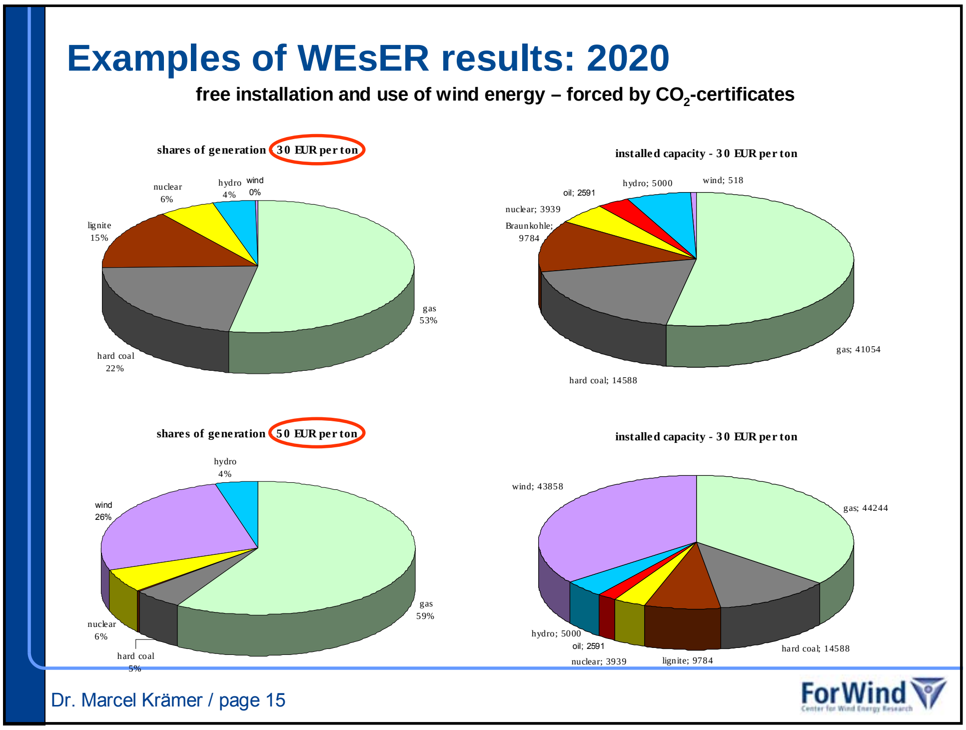
Examples of WEsER results: 2020

wind energy use in 2020 – forced by german renewable energy law (EEG)



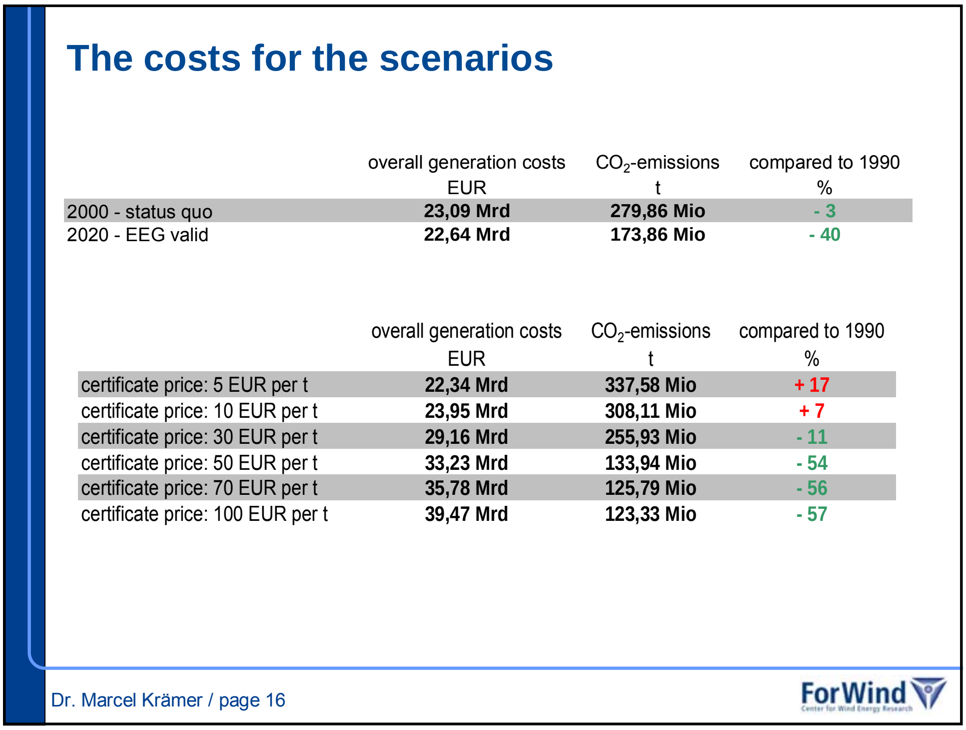
shares of electricity generation 2020

installed capacity 2020



Examples of WEsER results: 2020

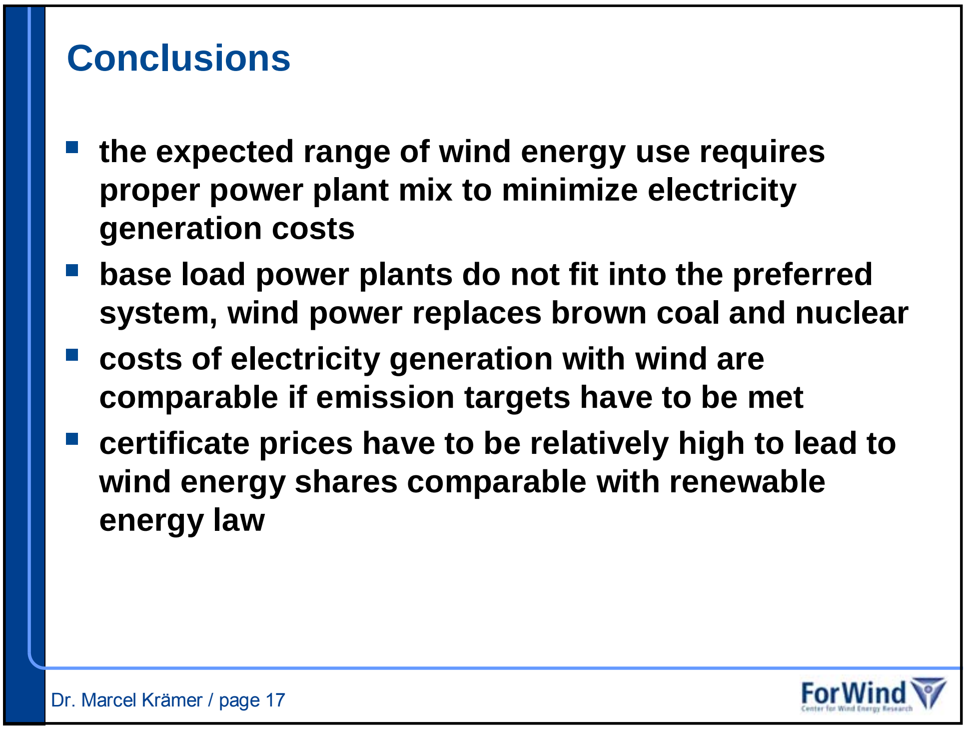
free installation and use of wind energy – forced by CO_2-certificates



The costs for the scenarios

	overall generation costs EUR	CO_2-emissions t	compared to 1990 %
2000 - status quo	**23,09 Mrd**	**279,86 Mio**	**- 3**
2020 - EEG valid	**22,64 Mrd**	**173,86 Mio**	**- 40**

	overall generation costs EUR	CO_2-emissions t	compared to 1990 %
certificate price: 5 EUR per t	**22,34 Mrd**	**337,58 Mio**	**+ 17**
certificate price: 10 EUR per t	**23,95 Mrd**	**308,11 Mio**	**+ 7**
certificate price: 30 EUR per t	**29,16 Mrd**	**255,93 Mio**	**- 11**
certificate price: 50 EUR per t	**33,23 Mrd**	**133,94 Mio**	**- 54**
certificate price: 70 EUR per t	**35,78 Mrd**	**125,79 Mio**	**- 56**
certificate price: 100 EUR per t	**39,47 Mrd**	**123,33 Mio**	**- 57**



Conclusions

- the expected range of wind energy use requires proper power plant mix to minimize electricity generation costs
- base load power plants do not fit into the preferred system, wind power replaces brown coal and nuclear
- costs of electricity generation with wind are comparable if emission targets have to be met
- certificate prices have to be relatively high to lead to wind energy shares comparable with renewable energy law

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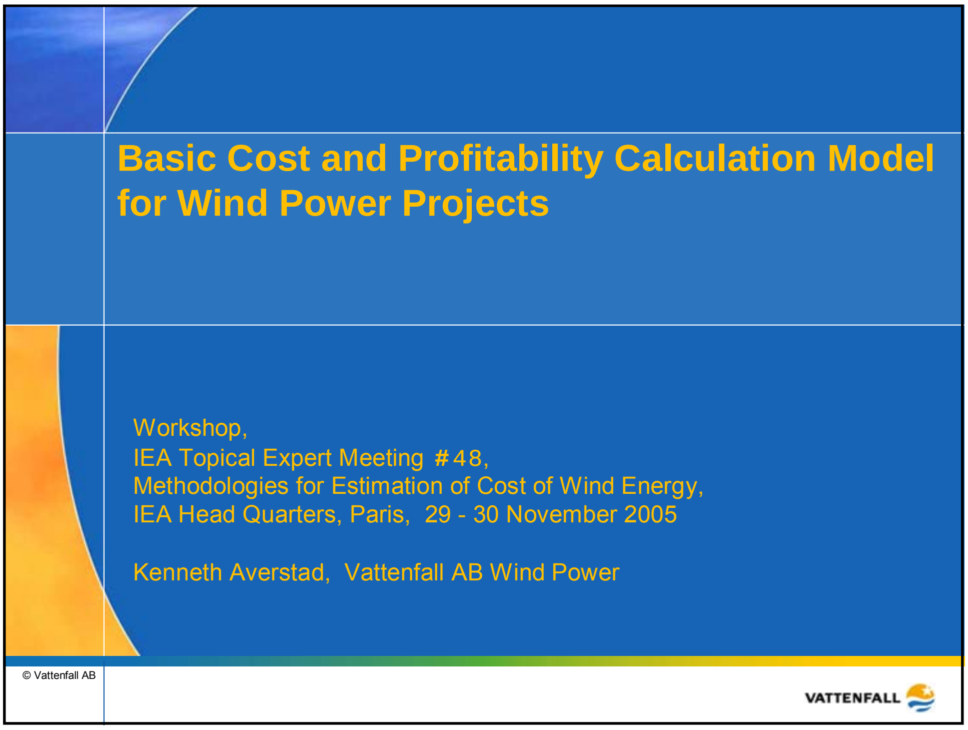
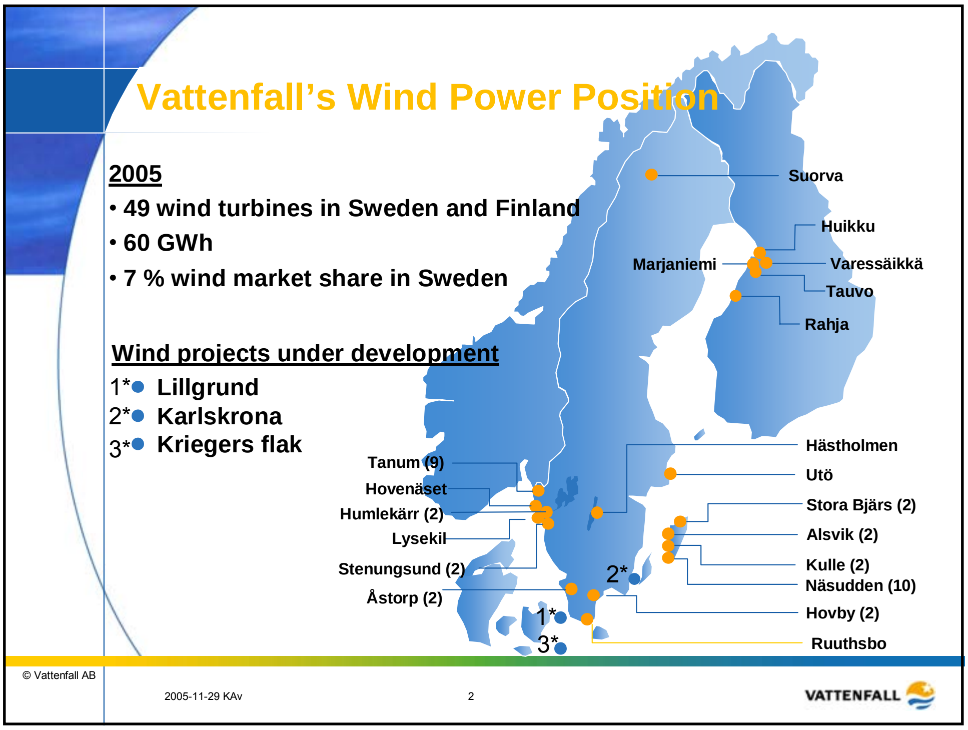


Basic Cost and Profitability Calculation Model for Wind Power Projects

Workshop,
IEA Topical Expert Meeting #48,
Methodologies for Estimation of Cost of Wind Energy,
IEA Head Quarters, Paris, 29 - 30 November 2005

Kenneth Averstad, Vattenfall AB Wind Power

VATTENFALL



Vattenfall’s Wind Power Position

2005

- **49 wind turbines in Sweden and Finland**
- **60 GWh**
- **7 % wind market share in Sweden**

Wind projects under development

1*● **Lillgrund**
2*● **Karlskrona**
3*● **Kriegers flak**

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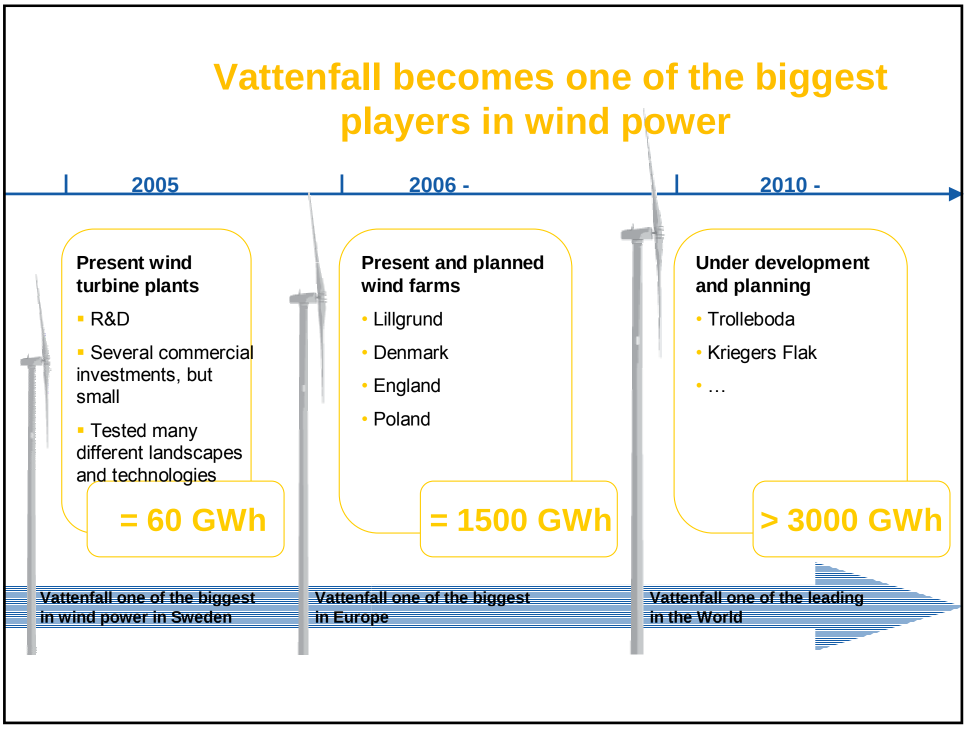


Vattenfall becomes one of the biggest players in wind power

Present wind turbine plants
- R&D
- Several commercial investments, but small
- Tested many different landscapes and technologies

= 60 GWh

Present and planned wind farms
- Lillgrund
- Denmark
- England
- Poland

= 1500 GWh

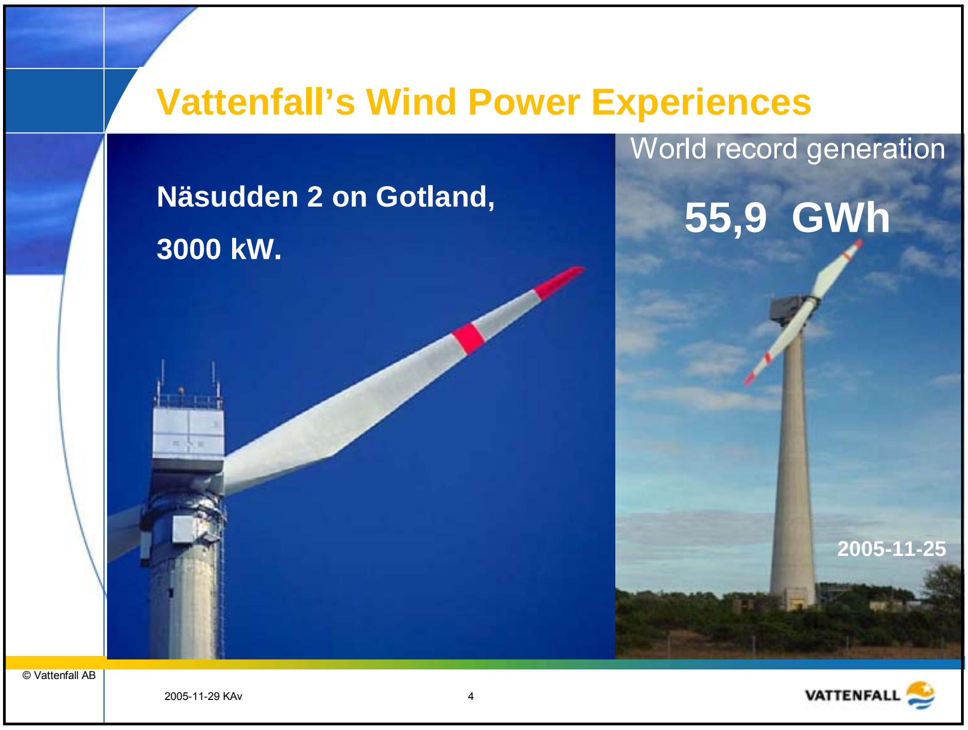
Under development and planning
- Trolleboda
- Kriegers Flak
- …

> 3000 GWh

Vattenfall one of the biggest in wind power in Sweden

Vattenfall one of the biggest in Europe

Vattenfall one of the leading in the World



Vattenfall's Wind Power Experiences

Näsudden 2 on Gotland,

3000 kW.

World record generation

55,9 GWh

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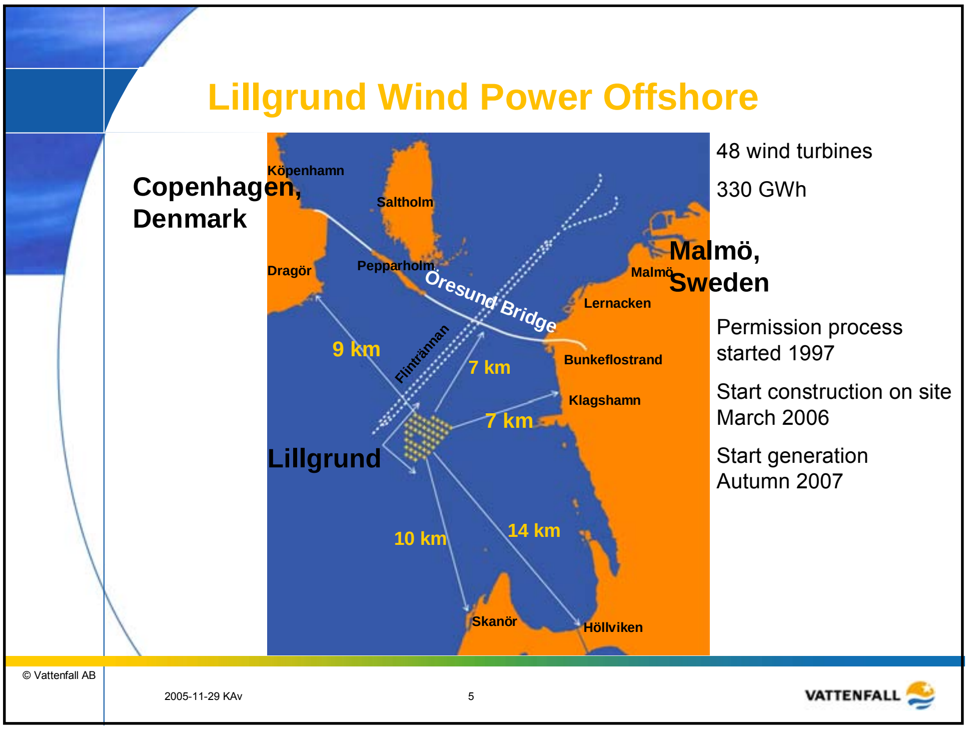

Lillgrund Wind Power Offshore

48 wind turbines

330 GWh

Permission process started 1997

Start construction on site March 2006

Start generation Autumn 2007

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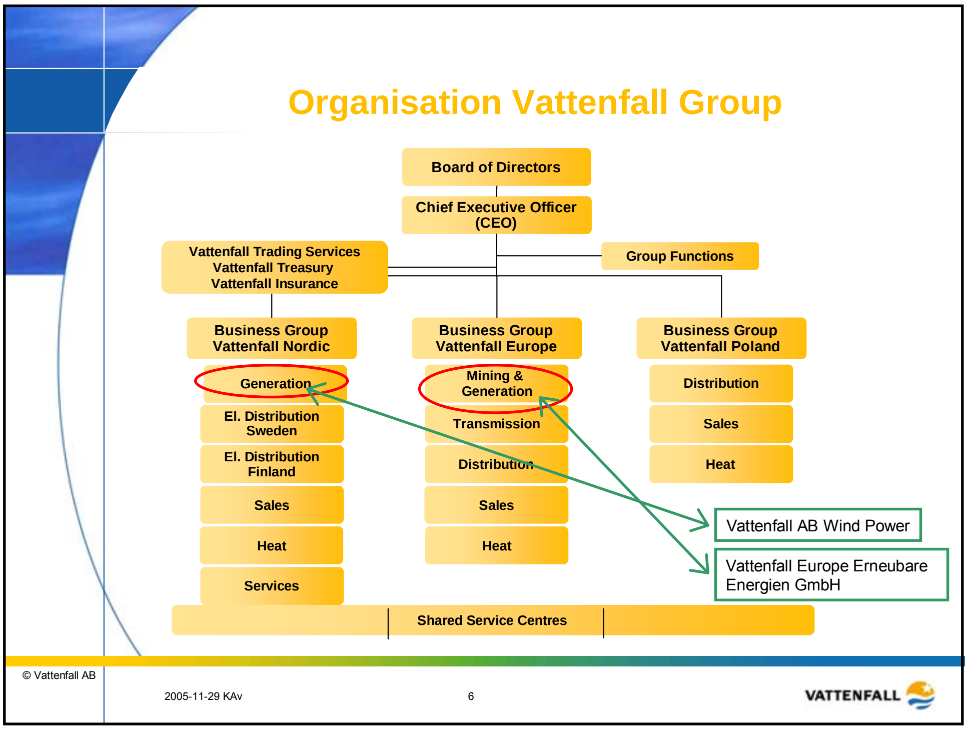

Organisation Vattenfall Group

Board of Directors

Chief Executive Officer (CEO)

Vattenfall Trading Services
Vattenfall Treasury
Vattenfall Insurance

Group Functions

Business Group Vattenfall Nordic	Business Group Vattenfall Europe	Business Group Vattenfall Poland
Generation	Mining & Generation	Distribution
El. Distribution Sweden	Transmission	Sales
El. Distribution Finland	Distribution	Heat
Sales	Sales	
Heat	Heat	
Services		

Shared Service Centres

Vattenfall AB Wind Power

Vattenfall Europe Erneubare Energien GmbH

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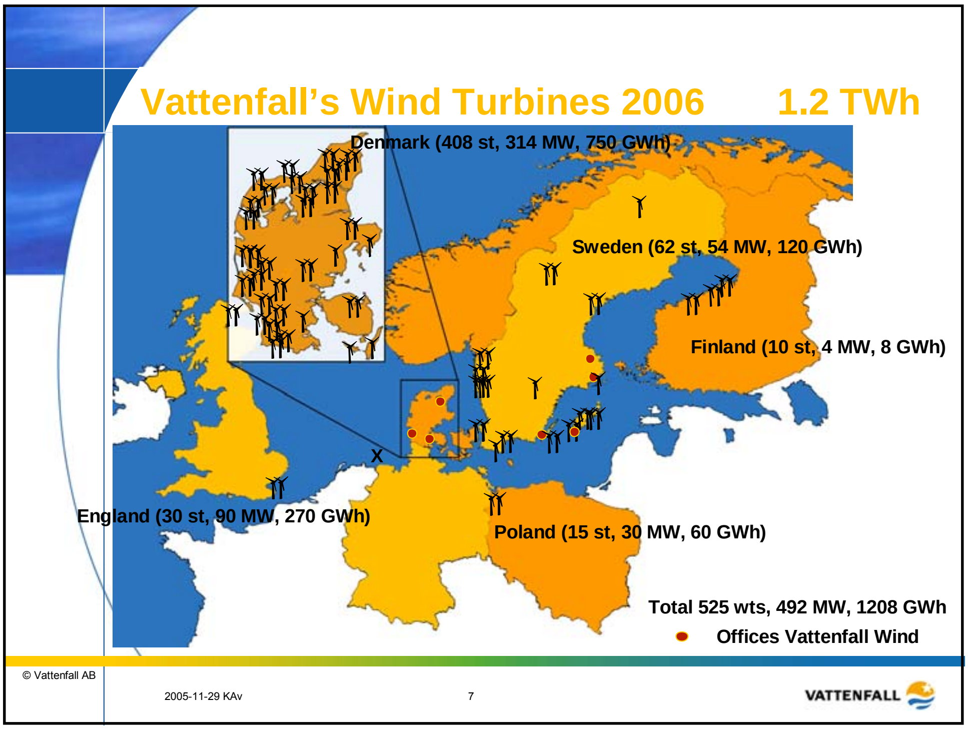


Vattenfall's Wind Turbines 2006 1.2 TWh

Denmark (408 st, 314 MW, 750 GWh)

Sweden (62 st, 54 MW, 120 GWh)

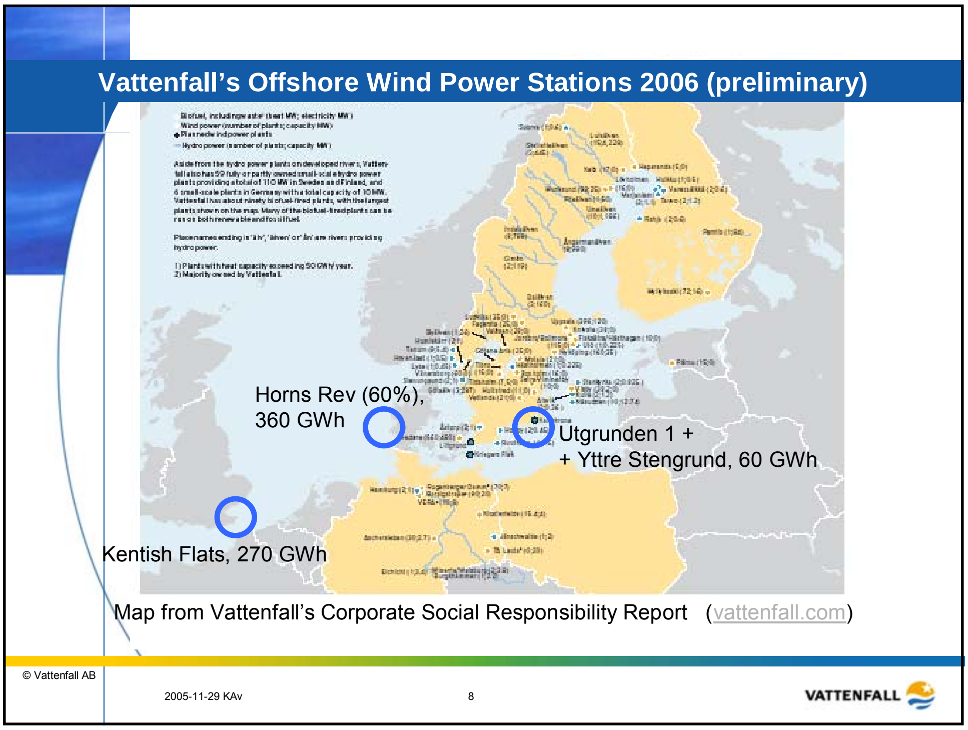
Finland (10 st, 4 MW, 8 GWh)

England (30 st, 90 MW, 270 GWh)

Poland (15 st, 30 MW, 60 GWh)

Total 525 wts, 492 MW, 1208 GWh

● Offices Vattenfall Wind



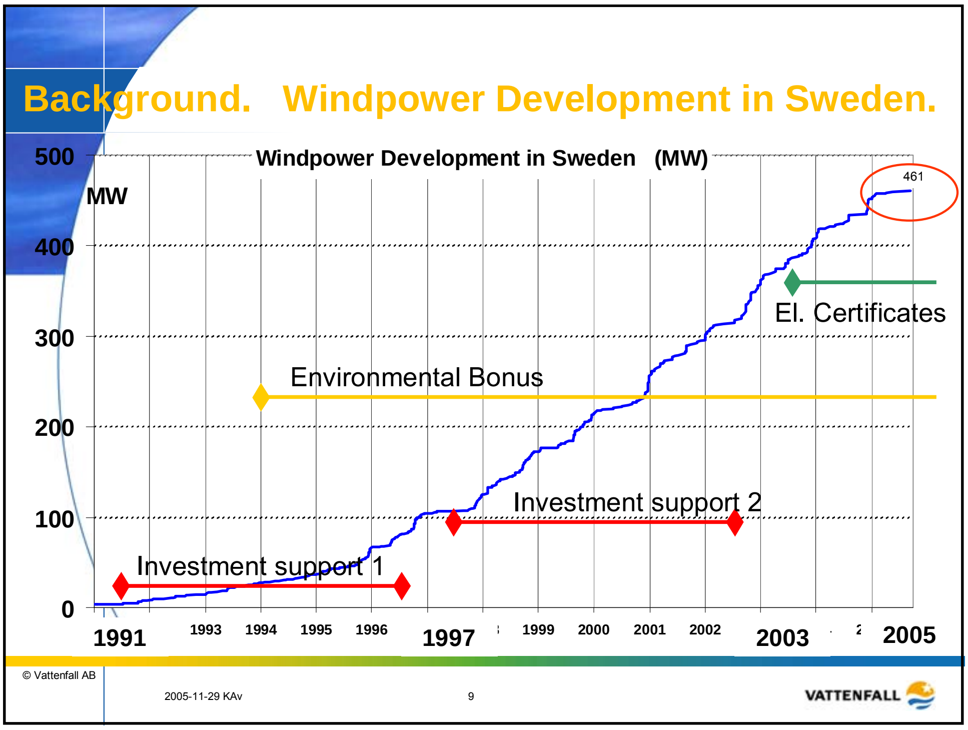
Vattenfall's Offshore Wind Power Stations 2006 (preliminary)

Horns Rev (60%), 360 GWh

Utgrunden 1 + + Yttre Stengrund, 60 GWh

Kentish Flats, 270 GWh

Map from Vattenfall's Corporate Social Responsibility Report (vattenfall.com)



Background.   Windpower Development in Sweden.

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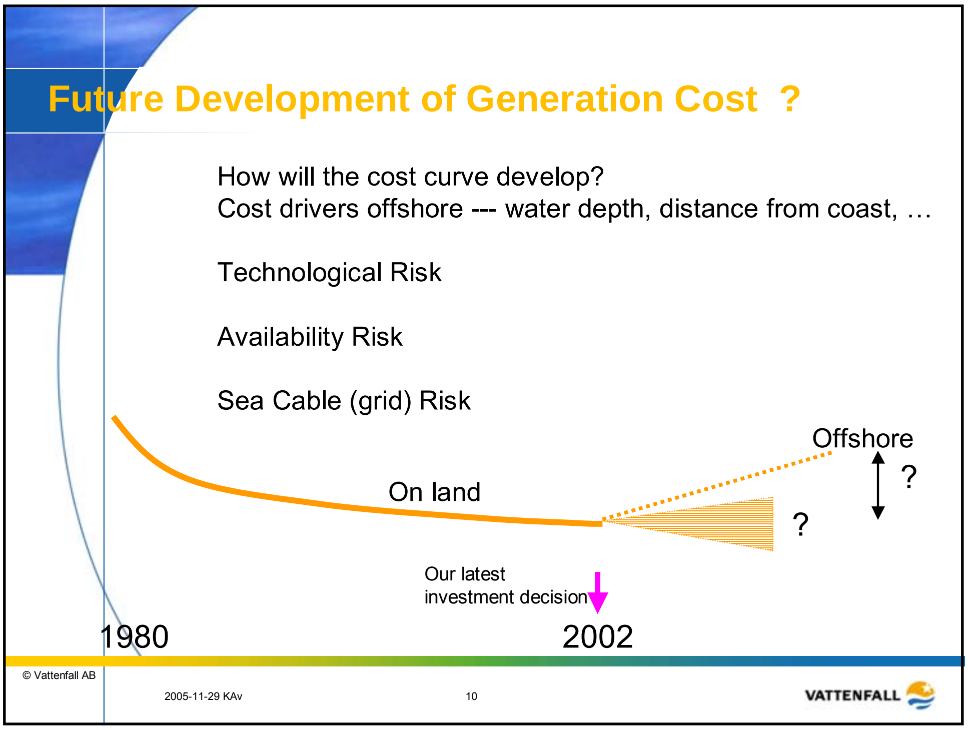

Future Development of Generation Cost ?

How will the cost curve develop?
Cost drivers offshore --- water depth, distance from coast, …

Technological Risk

Availability Risk

Sea Cable (grid) Risk

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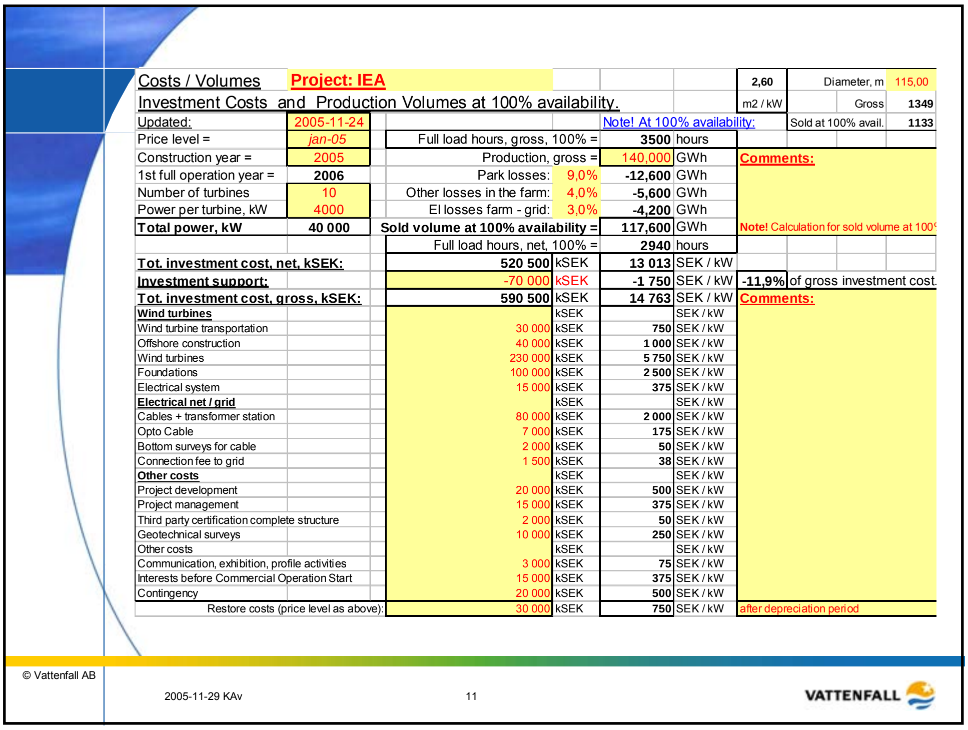
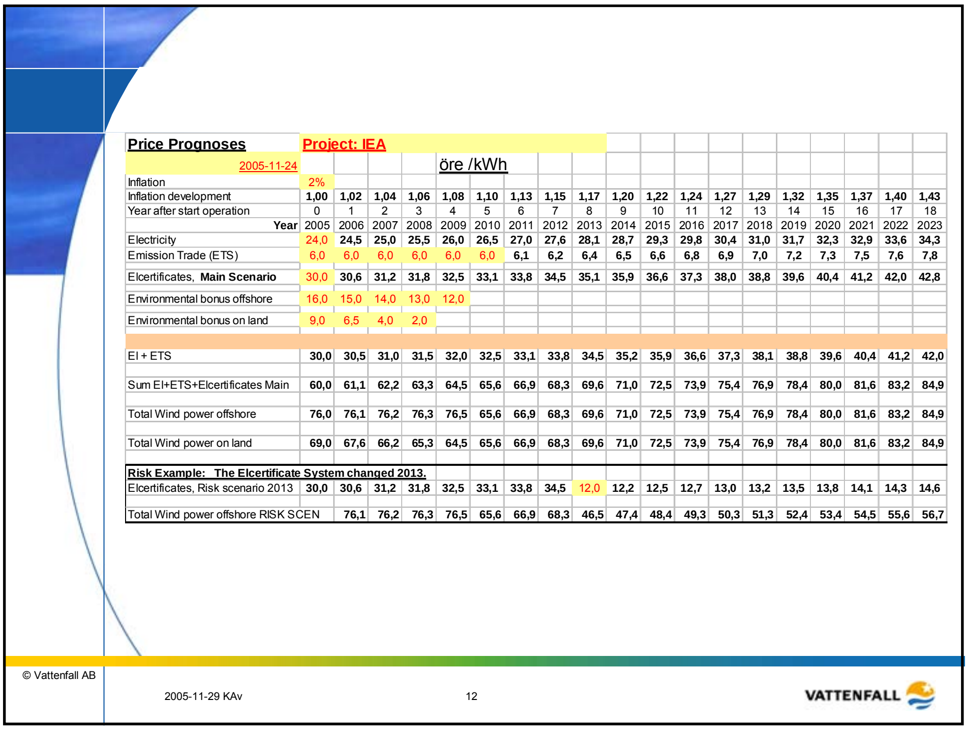
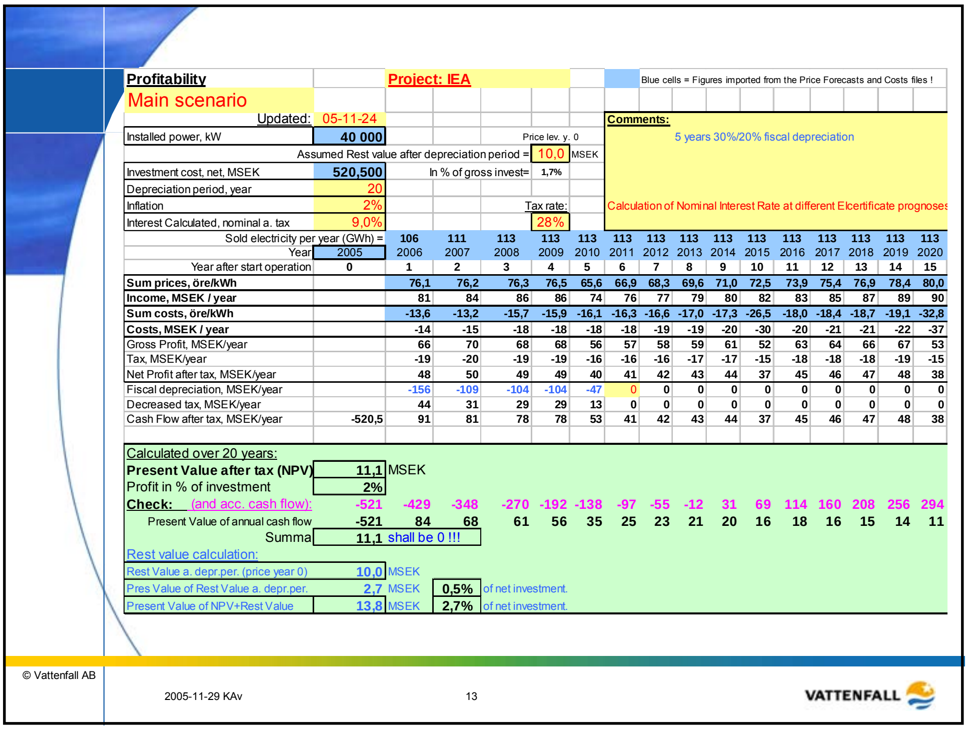


Costs / Volumes	**Project: IEA**					**2,60**	Diameter, m	115,00
Investment Costs and Production Volumes at 100% availability.						m2 / kW	Gross	**1349**
Updated:	2005-11-24			Note! At 100% availability:			Sold at 100% avail.	**1133**
Price level =	*jan-05*	Full load hours, gross, 100% =		**3500**	hours			
Construction year =	2005	Production, gross =		140,000	GWh	**Comments:**		
1st full operation year =	**2006**	Park losses:	9,0%	**-12,600**	GWh			
Number of turbines	10	Other losses in the farm:	4,0%	**-5,600**	GWh			
Power per turbine, kW	4000	El losses farm - grid:	3,0%	**-4,200**	GWh			
Total power, kW	**40 000**	**Sold volume at 100% availability =**		**117,600**	GWh	**Note!** Calculation for sold volume at 100		
		Full load hours, net, 100% =		**2940**	hours			
Tot. investment cost, net, kSEK:		**520 500**	kSEK	**13 013**	SEK / kW			
Investment support:		-70 000	kSEK	**-1 750**	SEK / kW	**-11,9%**	of gross investment cost.	
Tot. investment cost, gross, kSEK:		**590 500**	kSEK	**14 763**	SEK / kW	**Comments:**		
Wind turbines			kSEK		SEK / kW			
Wind turbine transportation		30 000	kSEK	**750**	SEK / kW			
Offshore construction		40 000	kSEK	**1 000**	SEK / kW			
Wind turbines		230 000	kSEK	**5 750**	SEK / kW			
Foundations		100 000	kSEK	**2 500**	SEK / kW			
Electrical system		15 000	kSEK	**375**	SEK / kW			
Electrical net / grid			kSEK		SEK / kW			
Cables + transformer station		80 000	kSEK	**2 000**	SEK / kW			
Opto Cable		7 000	kSEK	**175**	SEK / kW			
Bottom surveys for cable		2 000	kSEK	**50**	SEK / kW			
Connection fee to grid		1 500	kSEK	**38**	SEK / kW			
Other costs			kSEK		SEK / kW			
Project development		20 000	kSEK	**500**	SEK / kW			
Project management		15 000	kSEK	**375**	SEK / kW			
Third party certification complete structure		2 000	kSEK	**50**	SEK / kW			
Geotechnical surveys		10 000	kSEK	**250**	SEK / kW			
Other costs			kSEK		SEK / kW			
Communication, exhibition, profile activities		3 000	kSEK	**75**	SEK / kW			
Interests before Commercial Operation Start		15 000	kSEK	**375**	SEK / kW			
Contingency		20 000	kSEK	**500**	SEK / kW			
Restore costs (price level as above):		30 000	kSEK	**750**	SEK / kW	after depreciation period		



Price Prognoses	**Project: IEA**																		
2005-11-24					öre /kWh														
Inflation	2%																		
Inflation development	**1,00**	**1,02**	**1,04**	**1,06**	**1,08**	**1,10**	**1,13**	**1,15**	**1,17**	**1,20**	**1,22**	**1,24**	**1,27**	**1,29**	**1,32**	**1,35**	**1,37**	**1,40**	**1,43**
Year after start operation	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Electricity	24,0	**24,5**	**25,0**	**25,5**	**26,0**	**26,5**	**27,0**	**27,6**	**28,1**	**28,7**	**29,3**	**29,8**	**30,4**	**31,0**	**31,7**	**32,3**	**32,9**	**33,6**	**34,3**
Emission Trade (ETS)	6,0	6,0	6,0	6,0	6,0	6,0	**6,1**	**6,2**	**6,4**	**6,5**	**6,6**	**6,8**	**6,9**	**7,0**	**7,2**	**7,3**	**7,5**	**7,6**	**7,8**
Elcertificates, **Main Scenario**	30,0	**30,6**	**31,2**	**31,8**	**32,5**	**33,1**	**33,8**	**34,5**	**35,1**	**35,9**	**36,6**	**37,3**	**38,0**	**38,8**	**39,6**	**40,4**	**41,2**	**42,0**	**42,8**
Environmental bonus offshore	16,0	15,0	14,0	13,0	12,0														
Environmental bonus on land	9,0	6,5	4,0	2,0															
El + ETS	**30,0**	**30,5**	**31,0**	**31,5**	**32,0**	**32,5**	**33,1**	**33,8**	**34,5**	**35,2**	**35,9**	**36,6**	**37,3**	**38,1**	**38,8**	**39,6**	**40,4**	**41,2**	**42,0**
Sum El+ETS+Elcertificates Main	**60,0**	**61,1**	**62,2**	**63,3**	**64,5**	**65,6**	**66,9**	**68,3**	**69,6**	**71,0**	**72,5**	**73,9**	**75,4**	**76,9**	**78,4**	**80,0**	**81,6**	**83,2**	**84,9**
Total Wind power offshore	**76,0**	**76,1**	**76,2**	**76,3**	**76,5**	**65,6**	**66,9**	**68,3**	**69,6**	**71,0**	**72,5**	**73,9**	**75,4**	**76,9**	**78,4**	**80,0**	**81,6**	**83,2**	**84,9**
Total Wind power on land	**69,0**	**67,6**	**66,2**	**65,3**	**64,5**	**65,6**	**66,9**	**68,3**	**69,6**	**71,0**	**72,5**	**73,9**	**75,4**	**76,9**	**78,4**	**80,0**	**81,6**	**83,2**	**84,9**
Risk Example: The Elcertificate System changed 2013.																			
Elcertificates, Risk scenario 2013	**30,0**	**30,6**	**31,2**	**31,8**	**32,5**	**33,1**	**33,8**	**34,5**	12,0	**12,2**	**12,5**	**12,7**	**13,0**	**13,2**	**13,5**	**13,8**	**14,1**	**14,3**	**14,6**
Total Wind power offshore RISK SCEN		**76,1**	**76,2**	**76,3**	**76,5**	**65,6**	**66,9**	**68,3**	**46,5**	**47,4**	**48,4**	**49,3**	**50,3**	**51,3**	**52,4**	**53,4**	**54,5**	**55,6**	**56,7**



Profitability

Project: IEA

Blue cells = Figures imported from the Price Forecasts and Costs files !

Main scenario

Updated: 05-11-24

Comments:

5 years 30%/20% fiscal depreciation

Calculation of Nominal Interest Rate at different Elcertificate prognoses

Installed power, kW: 40 000

Price lev. y. 0

Assumed Rest value after depreciation period = 10,0 MSEK

Investment cost, net, MSEK: 520,500

In % of gross invest= 1,7%

Depreciation period, year: 20

Inflation: 2%

Tax rate: 28%

Interest Calculated, nominal a. tax: 9,0%

Sold electricity per year (GWh) =		106	111	113	113	113	113	113	113	113	113	113	113	113	113	113
Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Year after start operation	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sum prices, öre/kWh		76,1	76,2	76,3	76,5	65,6	66,9	68,3	69,6	71,0	72,5	73,9	75,4	76,9	78,4	80,0
Income, MSEK / year		81	84	86	86	74	76	77	79	80	82	83	85	87	89	90
Sum costs, öre/kWh		-13,6	-13,2	-15,7	-15,9	-16,1	-16,3	-16,6	-17,0	-17,3	-26,5	-18,0	-18,4	-18,7	-19,1	-32,8
Costs, MSEK / year		-14	-15	-18	-18	-18	-18	-19	-19	-20	-30	-20	-21	-21	-22	-37
Gross Profit, MSEK/year		66	70	68	68	56	57	58	59	61	52	63	64	66	67	53
Tax, MSEK/year		-19	-20	-19	-19	-16	-16	-16	-17	-17	-15	-18	-18	-18	-19	-15
Net Profit after tax, MSEK/year		48	50	49	49	40	41	42	43	44	37	45	46	47	48	38
Fiscal depreciation, MSEK/year		-156	-109	-104	-104	-47	0	0	0	0	0	0	0	0	0	0
Decreased tax, MSEK/year		44	31	29	29	13	0	0	0	0	0	0	0	0	0	0
Cash Flow after tax, MSEK/year	-520,5	91	81	78	78	53	41	42	43	44	37	45	46	47	48	38

Calculated over 20 years:

Present Value after tax (NPV) 11,1 MSEK

Profit in % of investment 2%

Check: (and acc. cash flow):	-521	-429	-348	-270	-192	-138	-97	-55	-12	31	69	114	160	208	256	294
Present Value of annual cash flow	-521	84	68	61	56	35	25	23	21	20	16	18	16	15	14	11

Summa 11,1 shall be 0 !!!

Rest value calculation:

Rest Value a. depr.per. (price year 0)	10,0	MSEK		
Pres Value of Rest Value a. depr.per.	2,7	MSEK	0,5%	of net investment.
Present Value of NPV+Rest Value	13,8	MSEK	2,7%	of net investment.

Thank You !

Lillgrund Offshore

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Energy research Centre of the Netherlands

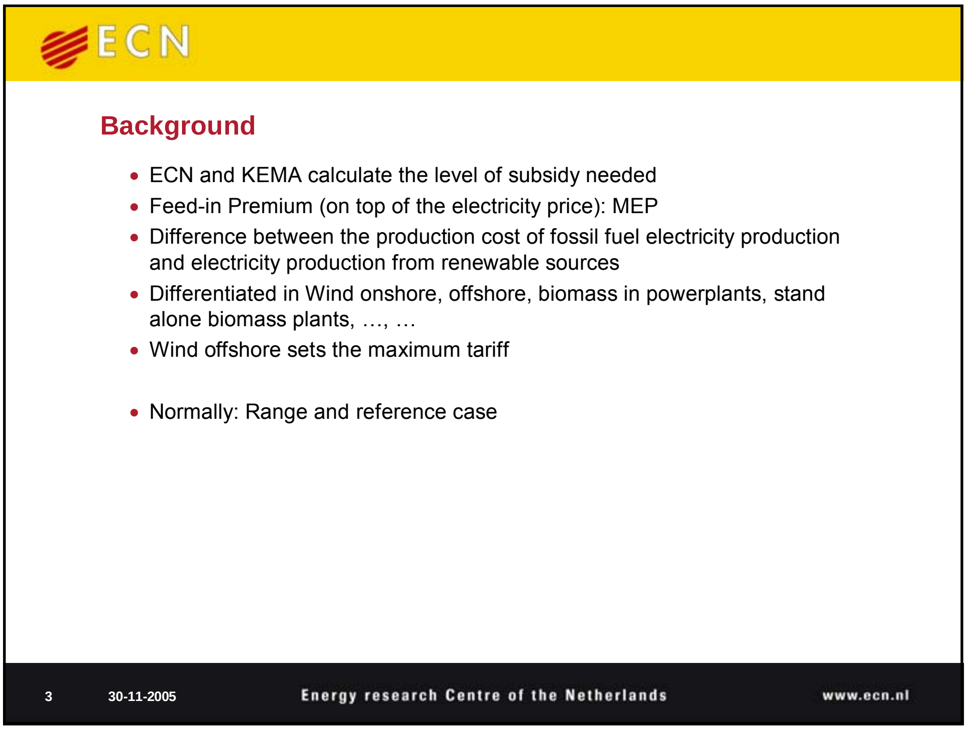
Calculating the financial gap of offshore wind

Hage de Vries, ECN Policy Studies

www.ecn.nl

Agenda

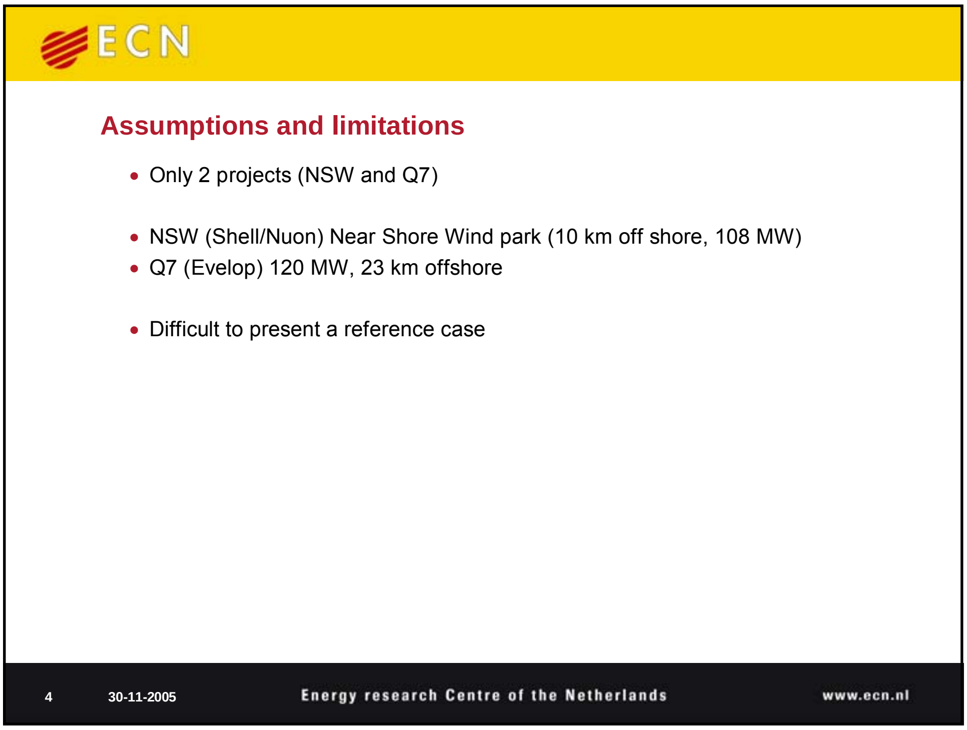
- Background
- Assumptions and limitations
- DCF-model (demonstration)



Background

- ECN and KEMA calculate the level of subsidy needed
- Feed-in Premium (on top of the electricity price): MEP
- Difference between the production cost of fossil fuel electricity production and electricity production from renewable sources
- Differentiated in Wind onshore, offshore, biomass in powerplants, stand alone biomass plants, …, …
- Wind offshore sets the maximum tariff

- Normally: Range and reference case

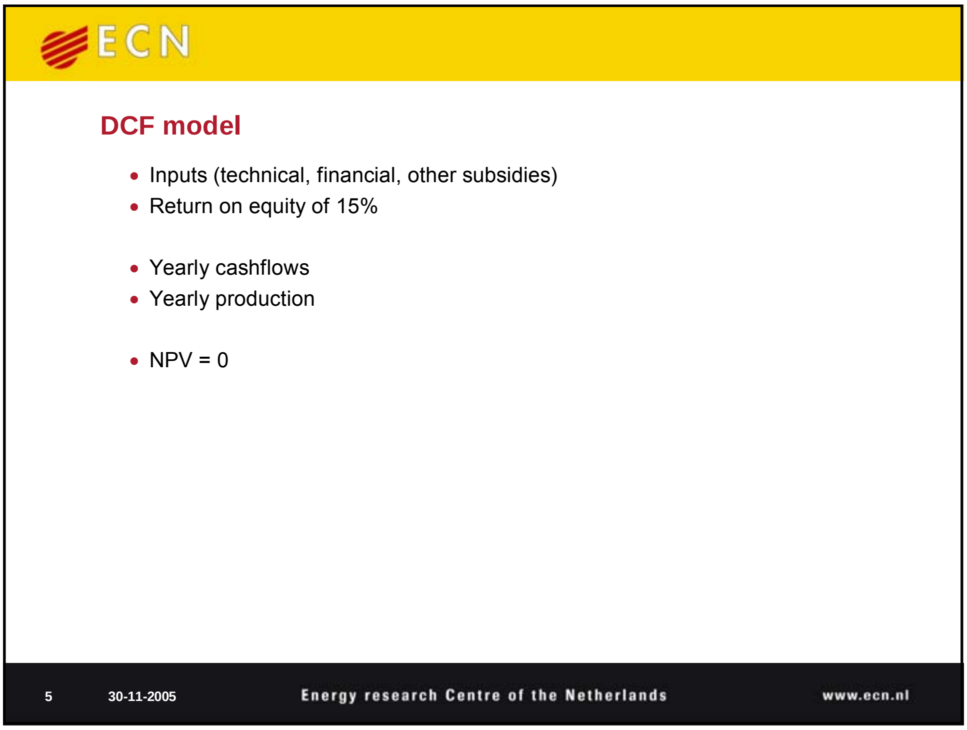


Assumptions and limitations

- Only 2 projects (NSW and Q7)

- NSW (Shell/Nuon) Near Shore Wind park (10 km off shore, 108 MW)
- Q7 (Evelop) 120 MW, 23 km offshore

- Difficult to present a reference case



DCF model

- Inputs (technical, financial, other subsidies)
- Return on equity of 15%

- Yearly cashflows
- Yearly production

- NPV = 0

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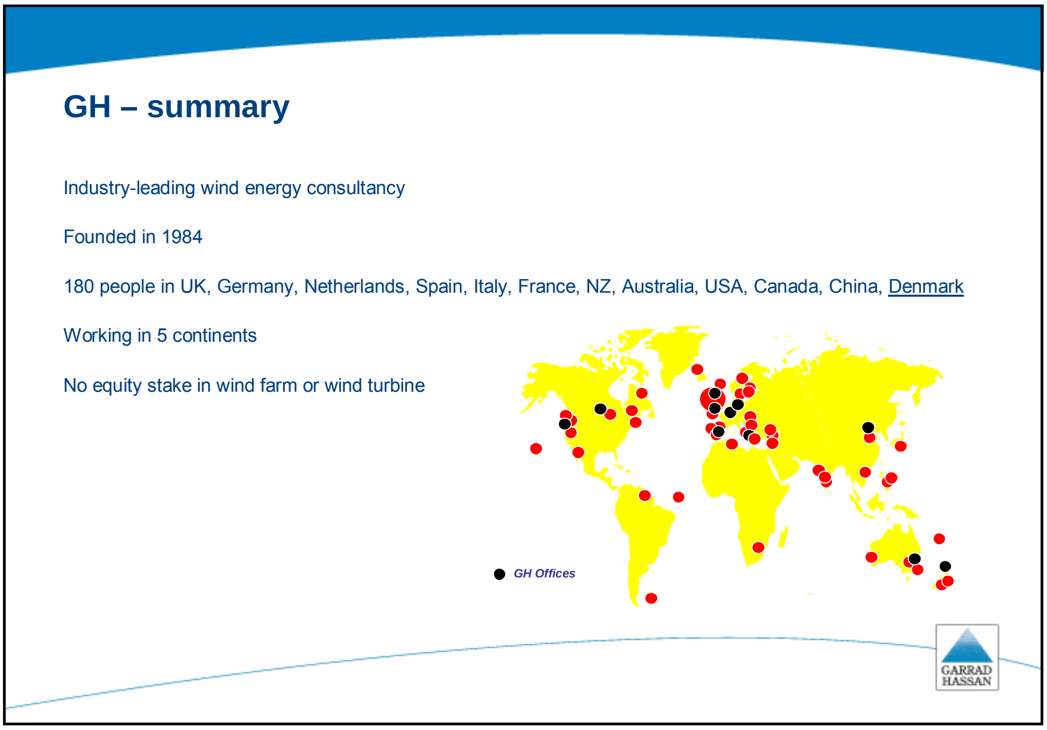
Garrad Hassan and Partners Ltd

Jerome Jacquemin, Offshore group, Bristol, UK

GARRAD HASSAN



GH – summary

Industry-leading wind energy consultancy

Founded in 1984

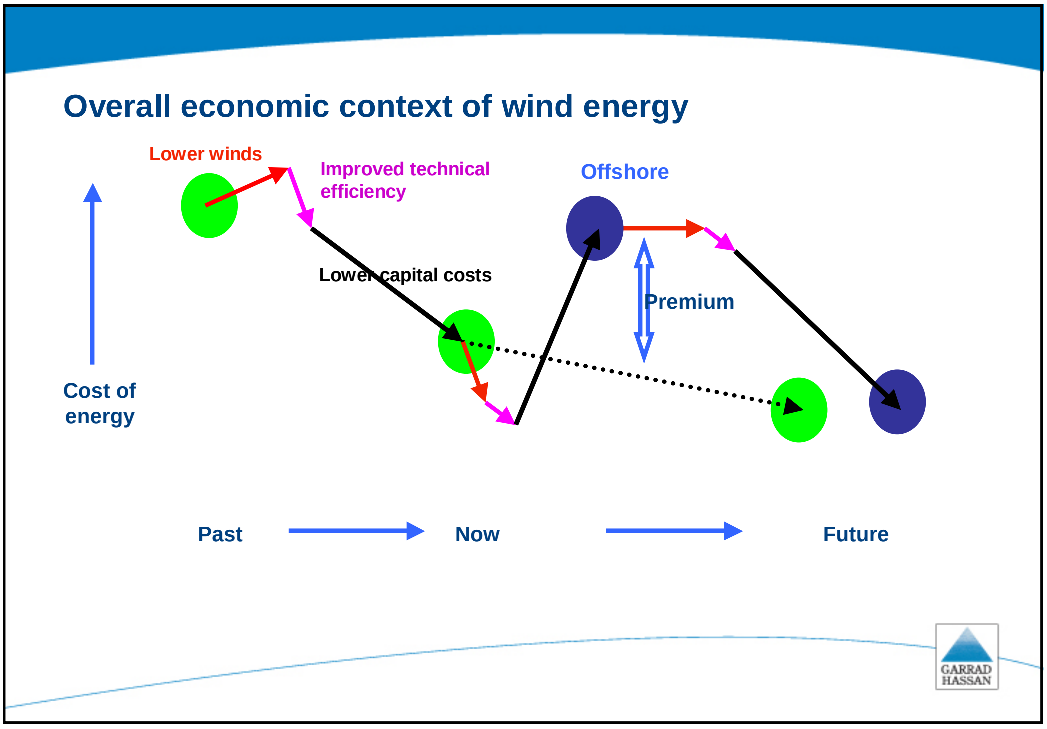
180 people in UK, Germany, Netherlands, Spain, Italy, France, NZ, Australia, USA, Canada, China, Denmark

Working in 5 continents

No equity stake in wind farm or wind turbine

● *GH Offices*

GARRAD HASSAN



Overall economic context of wind energy

Lower winds

Improved technical efficiency

Offshore

Lower capital costs

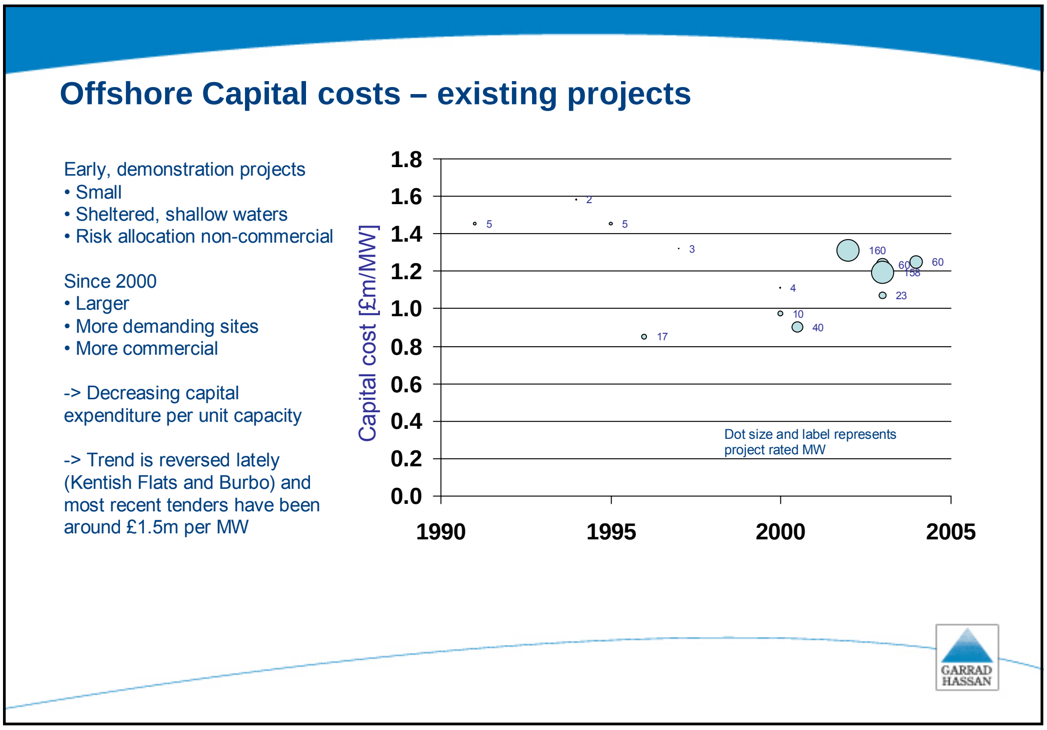
Premium

Cost of energy

Past

Now

Future



Offshore Capital costs – existing projects

Early, demonstration projects
- Small
- Sheltered, shallow waters
- Risk allocation non-commercial

Since 2000
- Larger
- More demanding sites
- More commercial

-> Decreasing capital expenditure per unit capacity

-> Trend is reversed lately (Kentish Flats and Burbo) and most recent tenders have been around £1.5m per MW

Dot size and label represents project rated MW

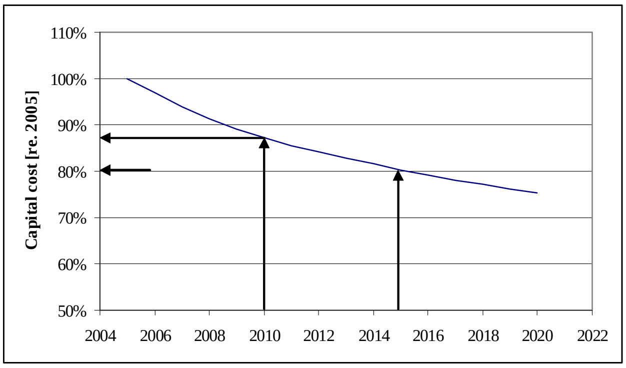
Offshore Capital costs – “progress ratio”

- Progress ratio of 92% (ISET study)
- Growth rate of 5% onshore

  10% offshore
- Capital cost reduction of turbines based on onshore + offshore growth
- Capital cost of BoP (60% of total) based on offshore growth only

➢ **13% by 2010**

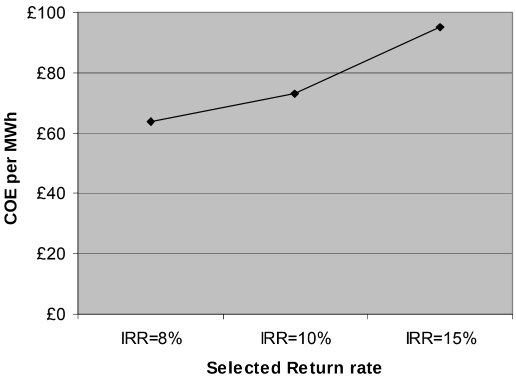
➢ **20% by 2015**

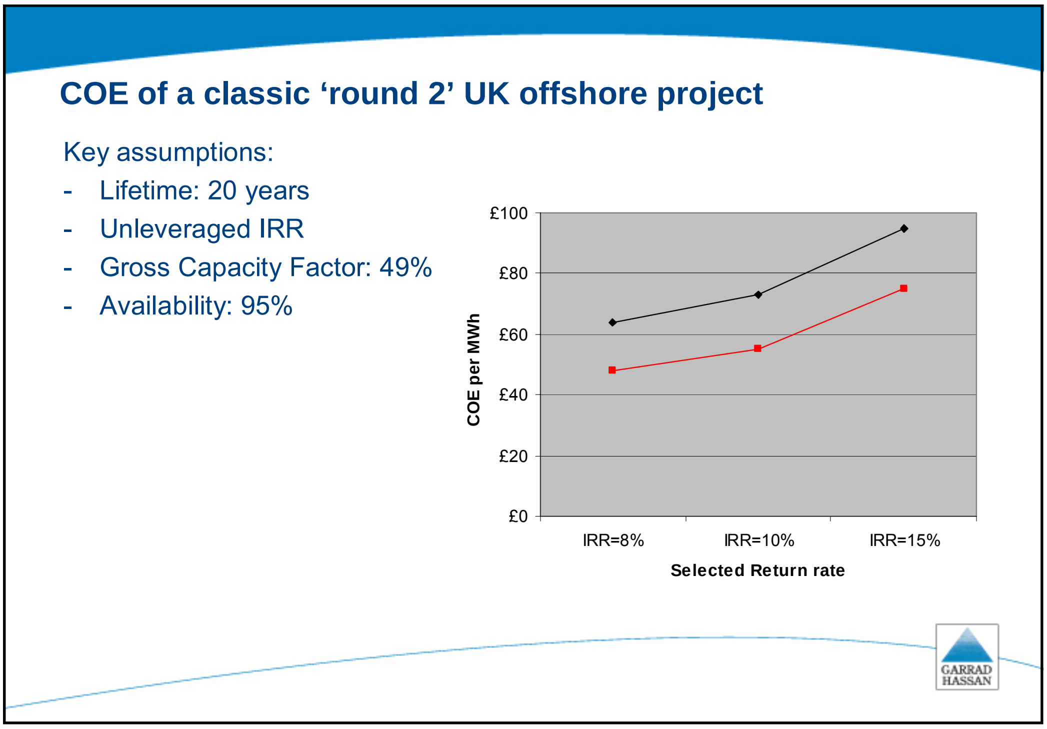


COE of a classic ‘round 2’ UK offshore project

Key assumptions:

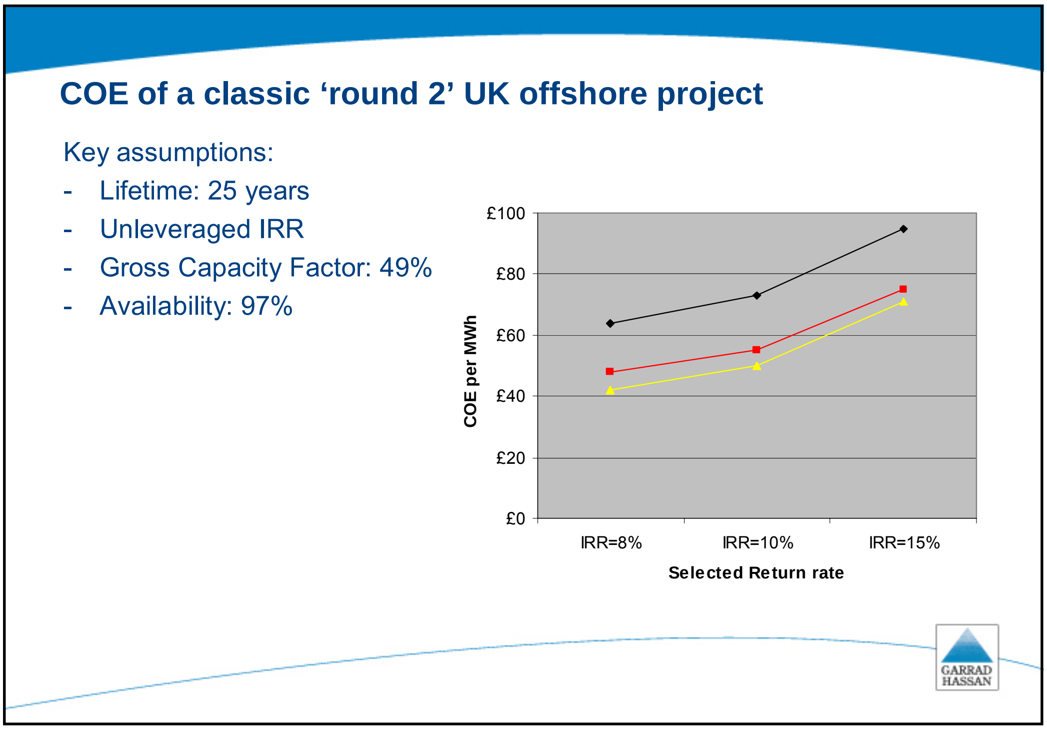
- Lifetime: 15 years
- Unleveraged IRR
- Gross Capacity Factor: 45%
- Availability: 90%





COE of a classic ‘round 2’ UK offshore project

Key assumptions:
- Lifetime: 20 years
- Unleveraged IRR
- Gross Capacity Factor: 49%
- Availability: 95%



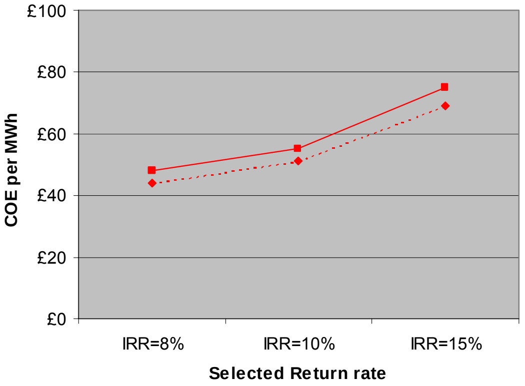
COE of a classic ‘round 2’ UK offshore project

Key assumptions:
- Lifetime: 25 years
- Unleveraged IRR
- Gross Capacity Factor: 49%
- Availability: 97%

COE with socialisation of grid connection costs

Key assumptions:

- Lifetime: 20 years
- Unleveraged IRR
- Gross Capacity Factor: 49%
- Availability: 95%
- Socialised transmission costs



Fundamental assumptions

Capacity factor?

- Single generic capacity factor to be used for COE comparison with other generation technologies
  - ➢ Present CF at low wind penetration (best sites still available)
  - ➢ Future lower CF at higher wind penetration (use of lower wind speed sites in Western europe)
  - ➢ Future higher CF (as the share of Germany reduces as a proportion of global wind capacity)
- Different wind climates and different CFs
  - ➢ Calculated COE for a range of CFs

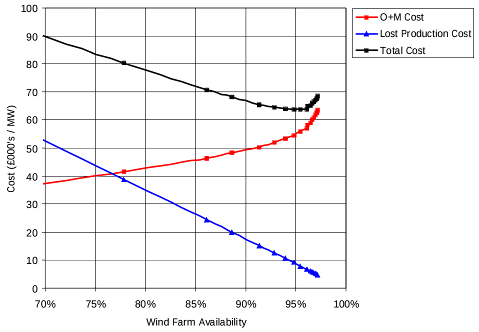
Return on investment?

- ➢ Modest IRR of traditional energy projects
- ➢ Superior IRR from current wind projects due to governmental incentive instruments

Fundamental assumptions

Availability and Opex?

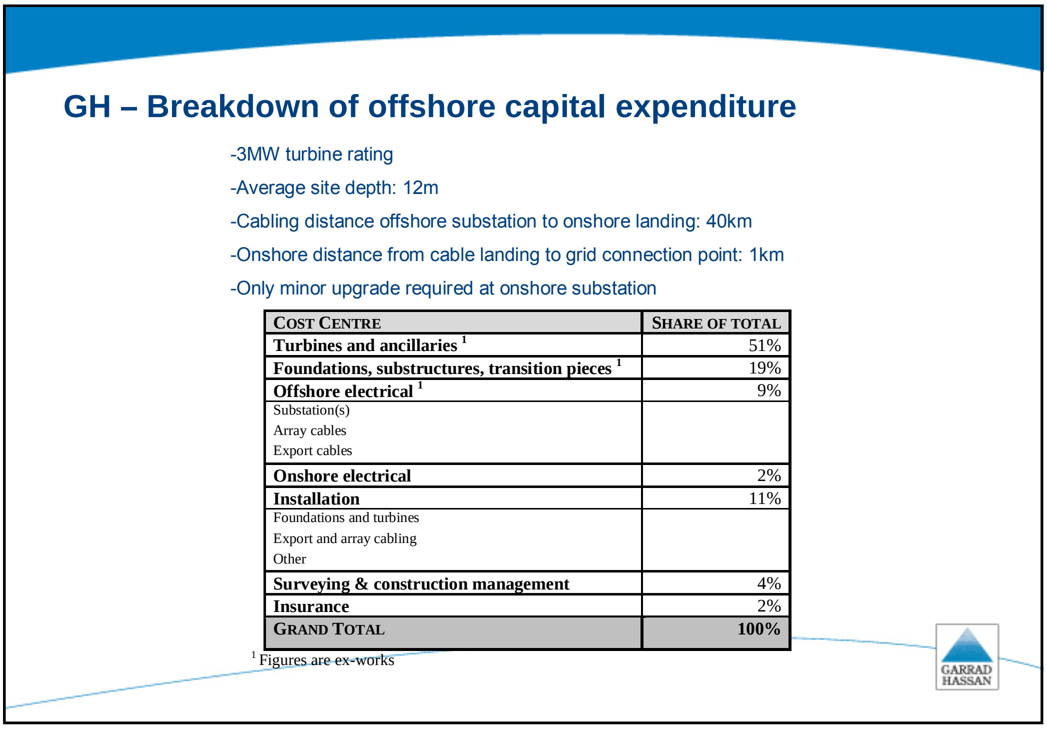
- High availability level -> not necessarily most economical
- More modest availability level (particularly offshore) and lower opex



GARRAD HASSAN

Questions?

GARRAD HASSAN



GH – Breakdown of offshore capital expenditure

-3MW turbine rating

-Average site depth: 12m

-Cabling distance offshore substation to onshore landing: 40km

-Onshore distance from cable landing to grid connection point: 1km

-Only minor upgrade required at onshore substation

COST CENTRE	SHARE OF TOTAL
Turbines and ancillaries [1]	51%
Foundations, substructures, transition pieces [1]	19%
Offshore electrical [1]	9%
Substation(s) Array cables Export cables	
Onshore electrical	2%
Installation	11%
Foundations and turbines Export and array cabling Other	
Surveying & construction management	4%
Insurance	2%
GRAND TOTAL	**100%**

[1] Figures are ex-works

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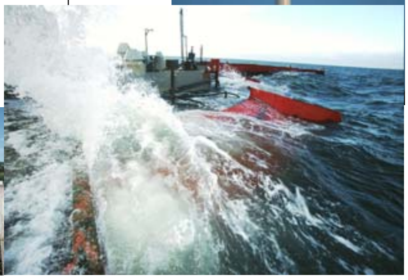
Important Considerations for Developing a Support Scheme

Poul Erik Morthorst
Niels-Erik Clausen
Risø National Laboratory

Important considerations for developing an efficient support scheme

Renewables have different characteristics

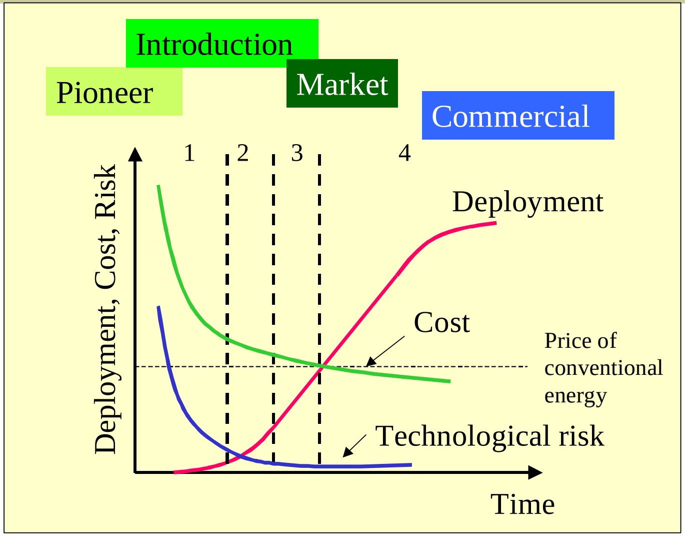
- Size
- Intermittence
- Investment
- Marginal cost
- Maturity

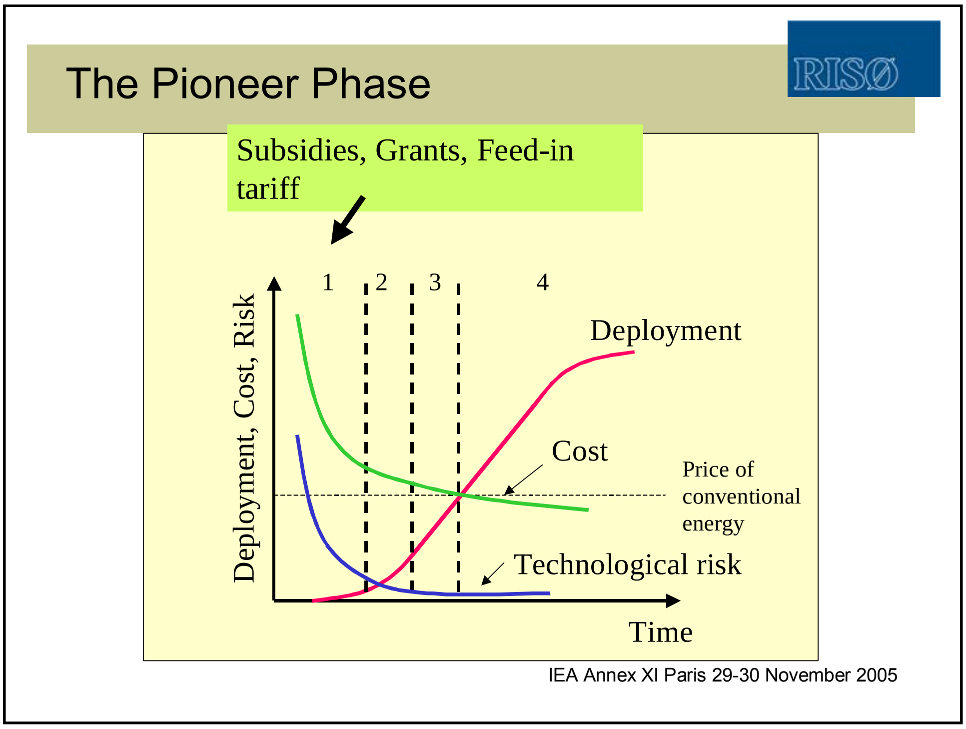


4 requirements to a support scheme

- Promote the development of renewables
  - Effective development of renewables
- Be attractive to entrepreneurs and developers
  - Implying a low risk and thus the lowest cost for society
- Be efficient in driving down the costs of new renewable technologies
  - Encourage competition among manufacturers
- Facilitate the transition to full commercialisation
  - Ease the introduction into liberalised energy markets

The 4 phases of market penetration

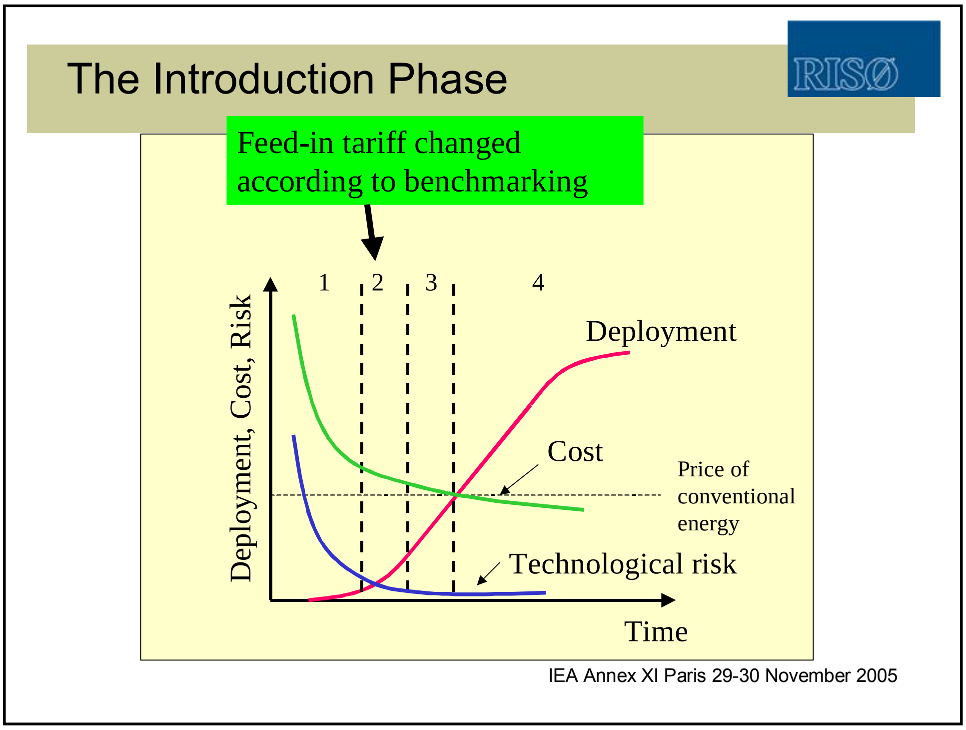




The Pioneer Phase

Subsidies, Grants, Feed-in tariff

IEA Annex XI Paris 29-30 November 2005

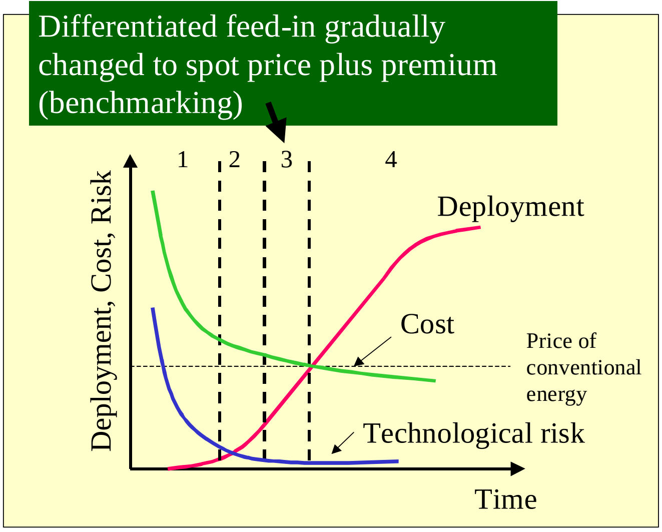


The Introduction Phase

Feed-in tariff changed according to benchmarking

IEA Annex XI Paris 29-30 November 2005

The Market Phase


Differentiated feed-in gradually changed to spot price plus premium (benchmarking)

IEA Annex XI Paris 29-30 November 2005

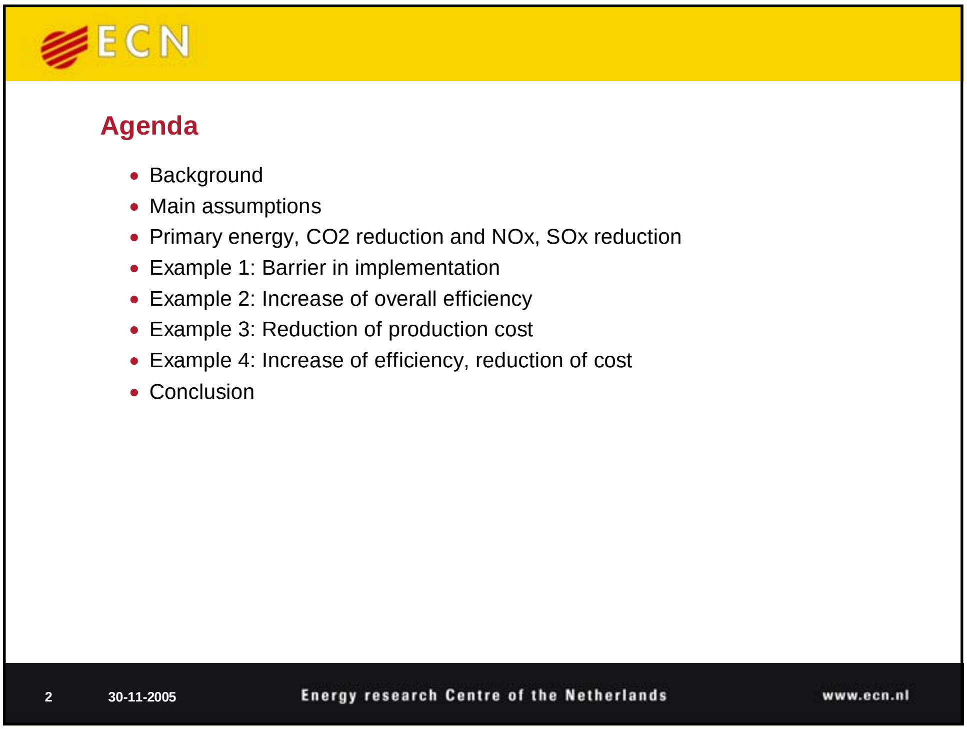
ECN

Energy research Centre of the Netherlands

How does R&D reduce the cost of wind energy?

Hage de Vries, ECN Policy Studies

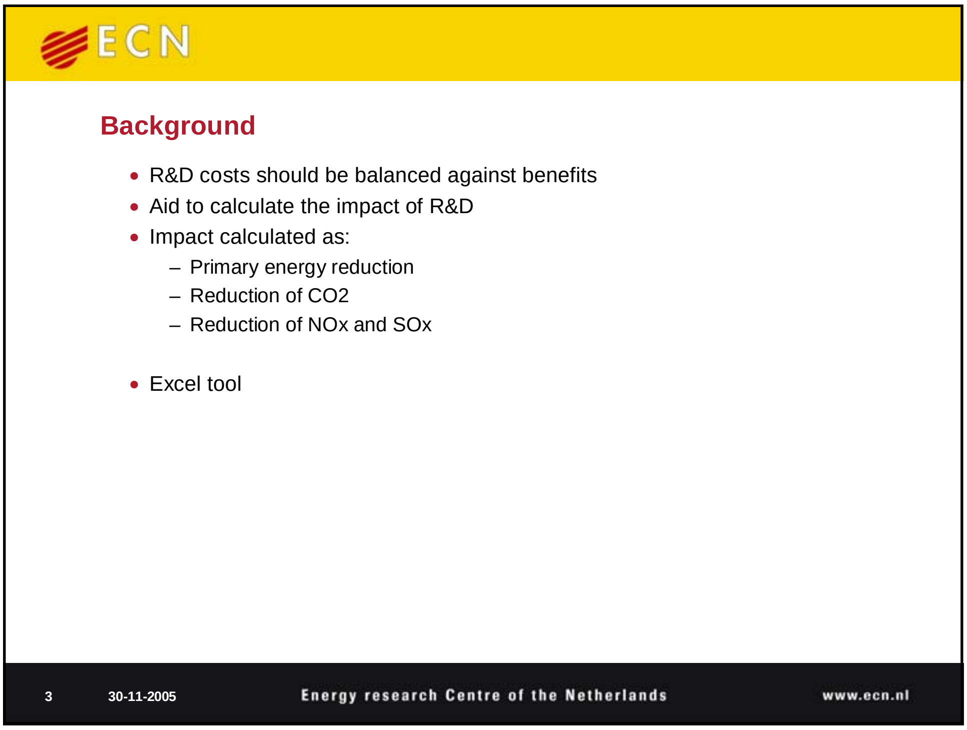
www.ecn.nl



ECN

Agenda

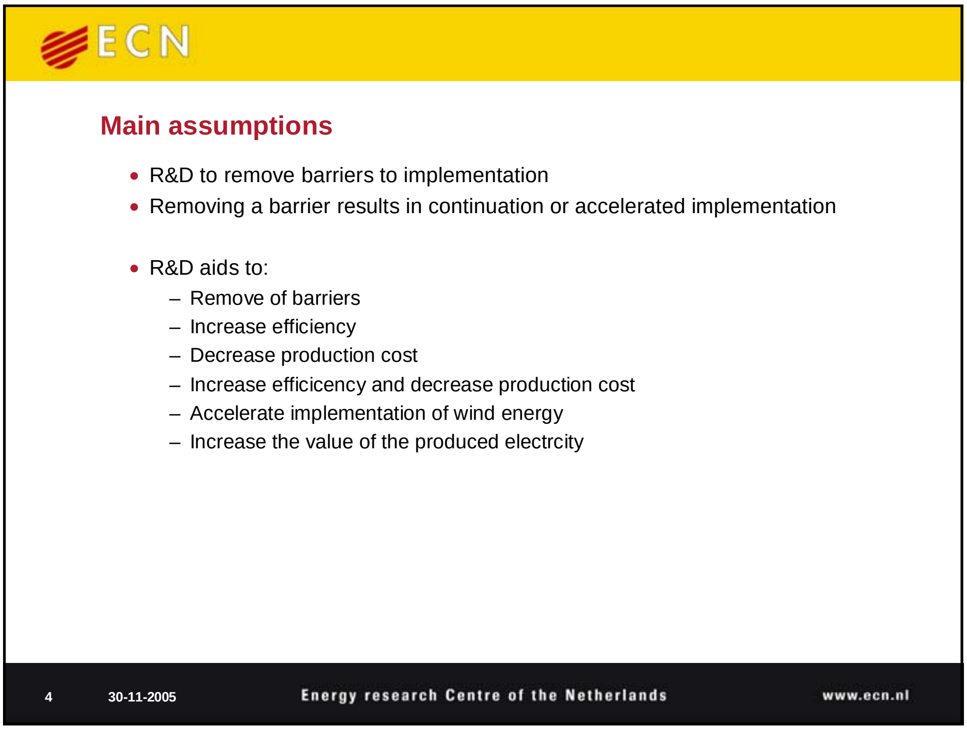
- Background
- Main assumptions
- Primary energy, CO2 reduction and NOx, SOx reduction
- Example 1: Barrier in implementation
- Example 2: Increase of overall efficiency
- Example 3: Reduction of production cost
- Example 4: Increase of efficiency, reduction of cost
- Conclusion



Background

- R&D costs should be balanced against benefits
- Aid to calculate the impact of R&D
- Impact calculated as:
  - Primary energy reduction
  - Reduction of CO2
  - Reduction of NOx and SOx

- Excel tool



Main assumptions

- R&D to remove barriers to implementation
- Removing a barrier results in continuation or accelerated implementation

- R&D aids to:
  - Remove of barriers
  - Increase efficiency
  - Decrease production cost
  - Increase efficicency and decrease production cost
  - Accelerate implementation of wind energy
  - Increase the value of the produced electrcity

Primary Energy, CO2 reduction, NOx and SOx reduction

- Reference case: Dutch 2010 and 2020 targets for wind onshore and wind offshore (1500 MW onshore in 2010, 6000 MW offshore in 2020)
- Assumptions on park efficiencies and availabilities
- Assumptions on development installed capacity

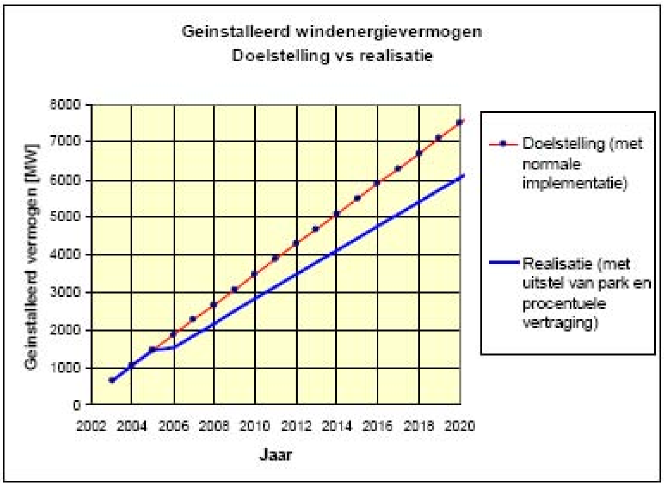
- Calculation of kWh produced

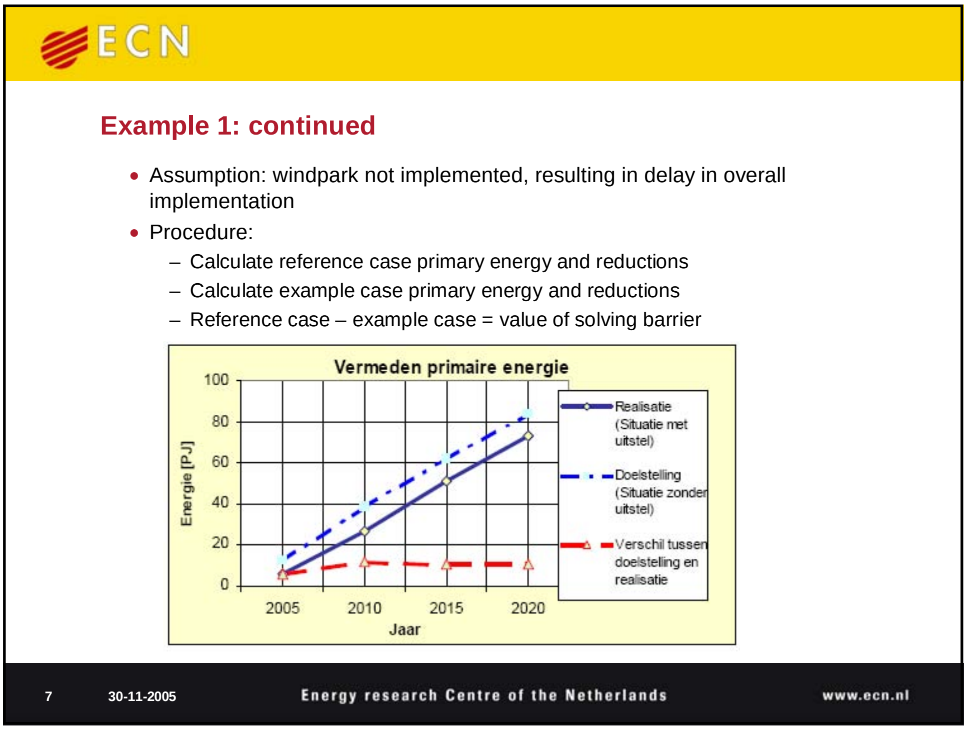
- Primary energy reduction = elektricity produced / (efficiency total fuel mix)

- CO2 reduction depends on emission factor total fuel mix

- NO_x and SO_2 reduction calculated as acid equivalents
  (AE: 1 AE = gram NO_x / 46 + gram SO_2 / 32)

Example 1: Barrier in implementation

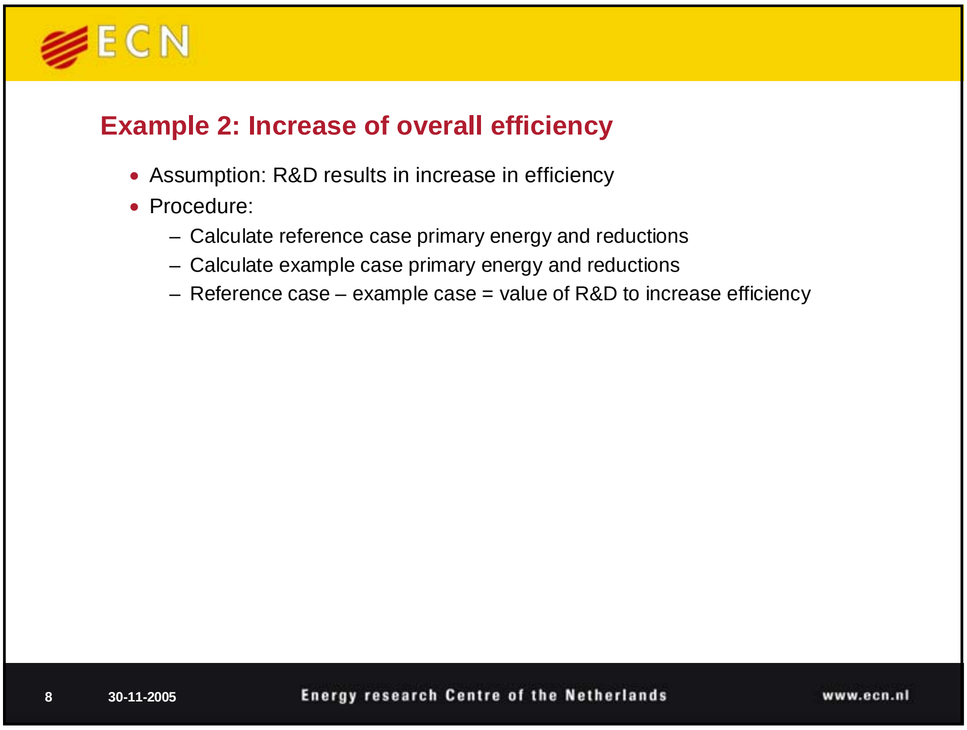




ECN

Example 1: continued

- Assumption: windpark not implemented, resulting in delay in overall implementation
- Procedure:
  - Calculate reference case primary energy and reductions
  - Calculate example case primary energy and reductions
  - Reference case – example case = value of solving barrier



ECN

Example 2: Increase of overall efficiency

- Assumption: R&D results in increase in efficiency
- Procedure:
  - Calculate reference case primary energy and reductions
  - Calculate example case primary energy and reductions
  - Reference case – example case = value of R&D to increase efficiency

Example 3: Reduction of production cost

- 4 main cost groups:
  - Design
  - Technology
  - Transport and installation
  - Operations and Maintenance

  - Levelised Production Cost (LPC)

  - Assumption: cost reduction leads to more available capital leads to more capacity installed

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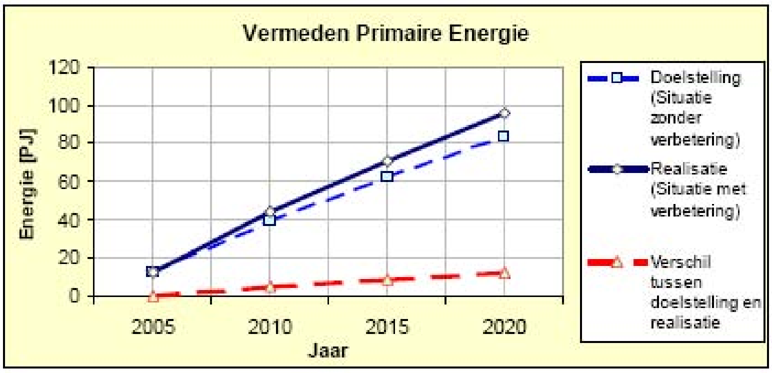
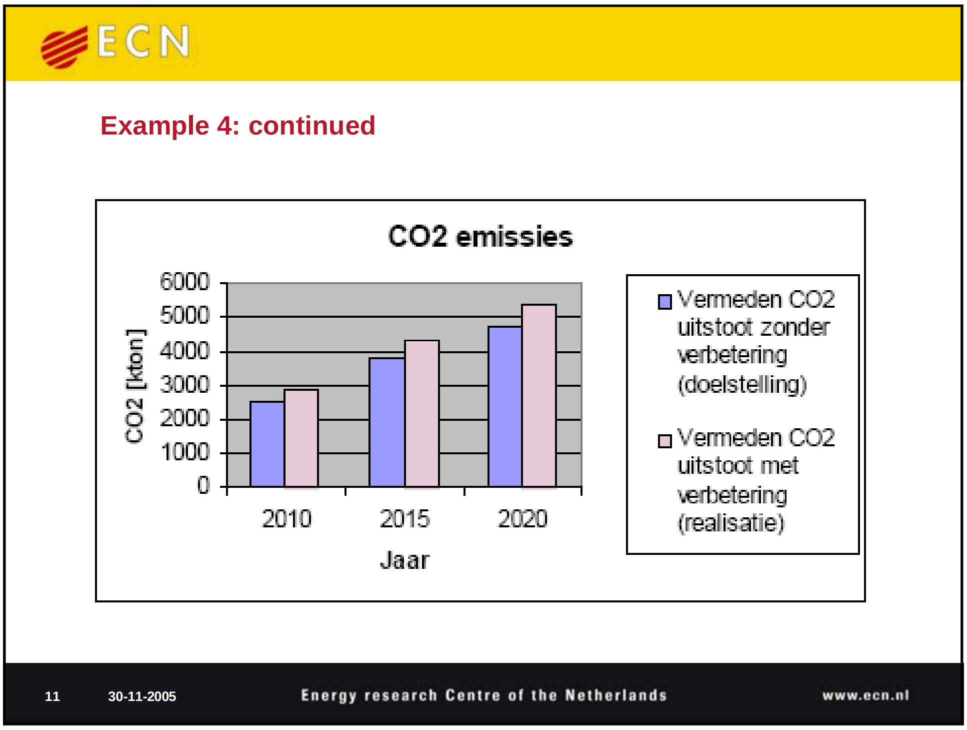
Example 4: Increase of efficiency, reduction of cost





ECN

Example 4: continued

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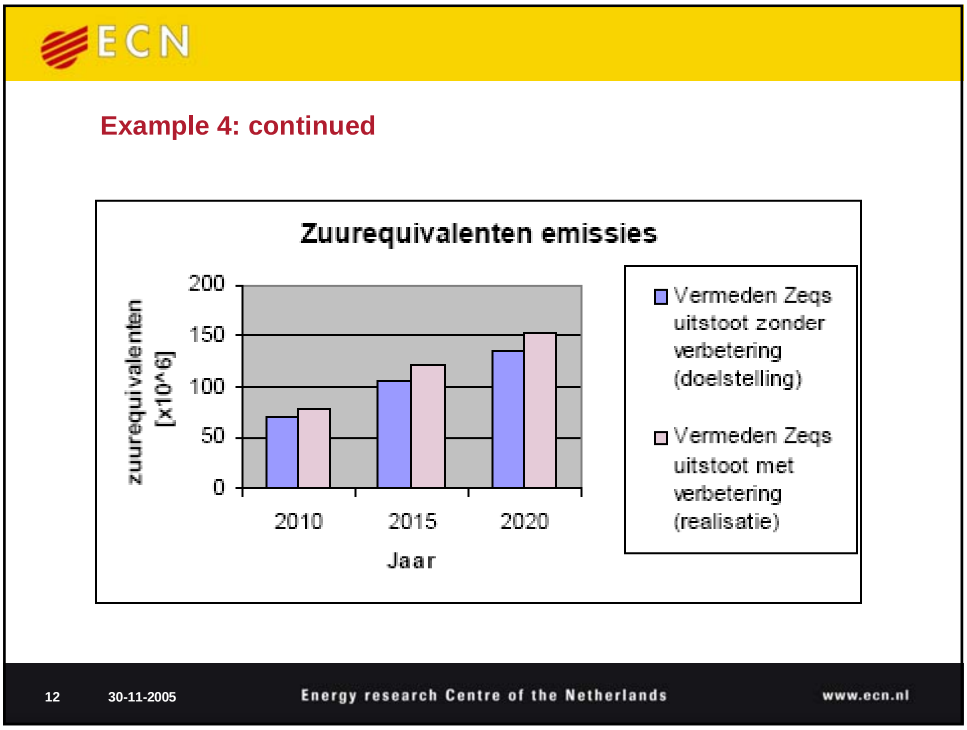

ECN

Example 4: continued

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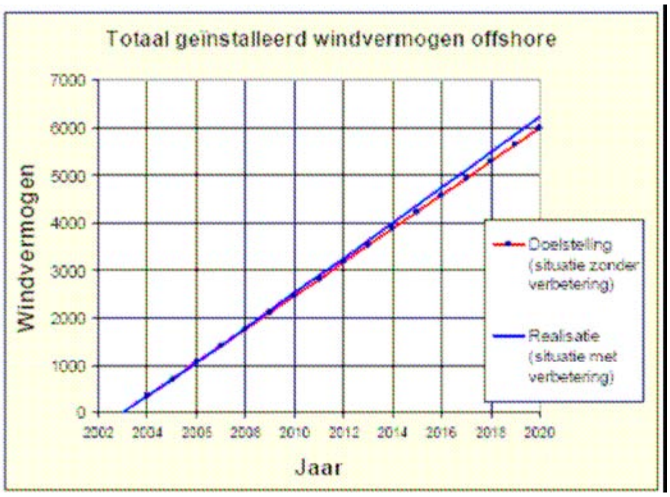
Example 4: continued



Conclusion

- Method to estimate impact of R&D
- Reference case determines total impact
- Expert judgement to which extent R&D projects contributes to the removal of barriers

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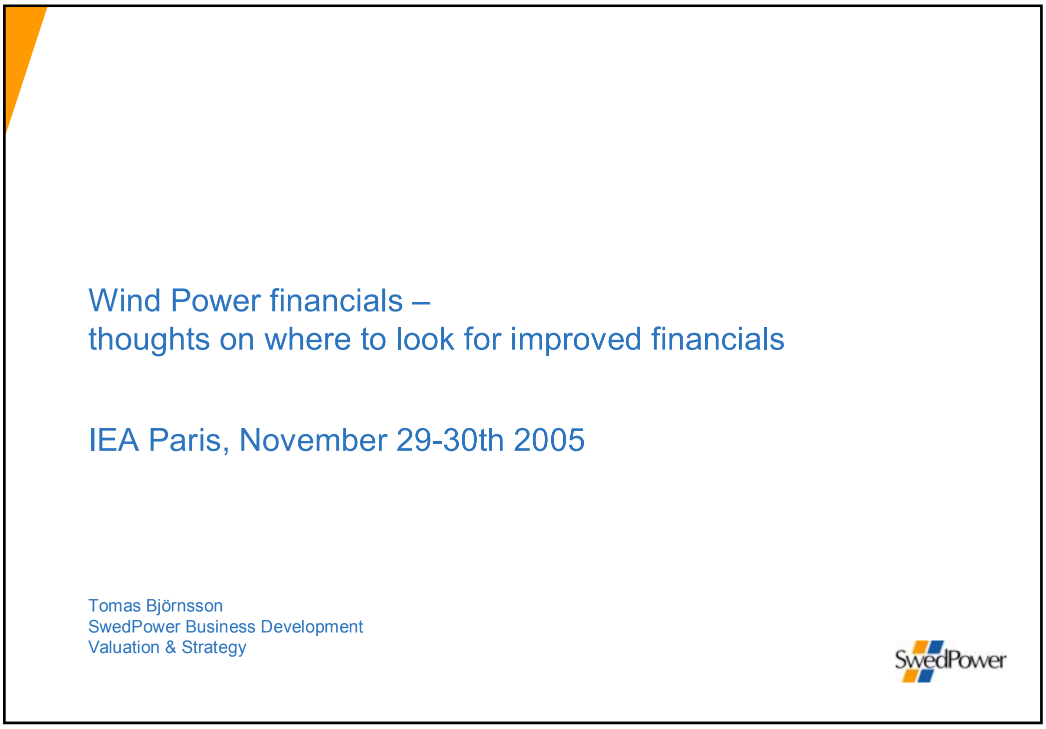
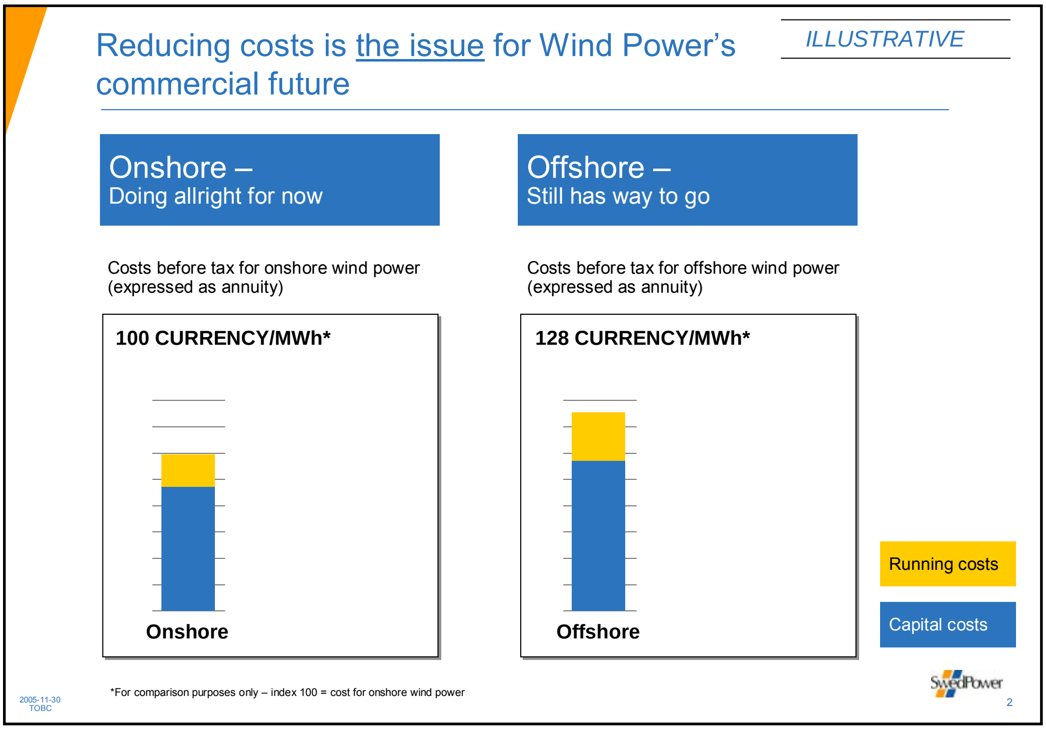


Wind Power financials –
thoughts on where to look for improved financials

IEA Paris, November 29-30th 2005

Tomas Björnsson
SwedPower Business Development
Valuation & Strategy



Reducing costs is <u>the issue</u> for Wind Power's commercial future

ILLUSTRATIVE

Onshore –
Doing allright for now

Offshore –
Still has way to go

Costs before tax for onshore wind power (expressed as annuity)

Costs before tax for offshore wind power (expressed as annuity)

*For comparison purposes only – index 100 = cost for onshore wind power

Three potential sources for cost improvements

Experience curve	Supplier performance	Economies of Scale
Technology development	Industry consolidation	Larger turbines
Young commercial scale technology – larger volumes may bring cost savings in more efficient manufacturing	WTG industry's been growing at 28% annually since 1999 – gross inefficiency likely as delivery rather than cost is bottleneck Industry's been focusing on WTG technology rather than system performance	Larger turbines the general industry trend – larger turbines may decrease per unit produced costs through investment and operating costs

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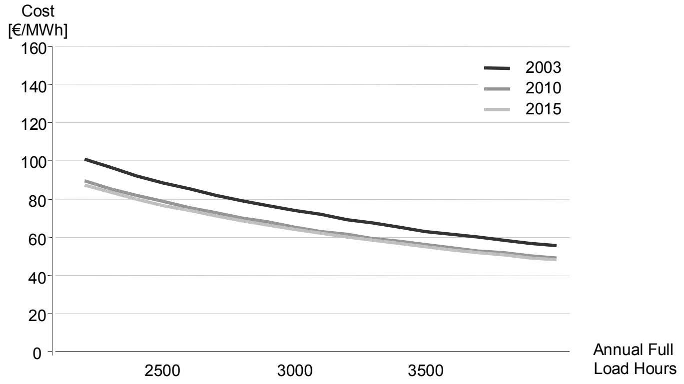
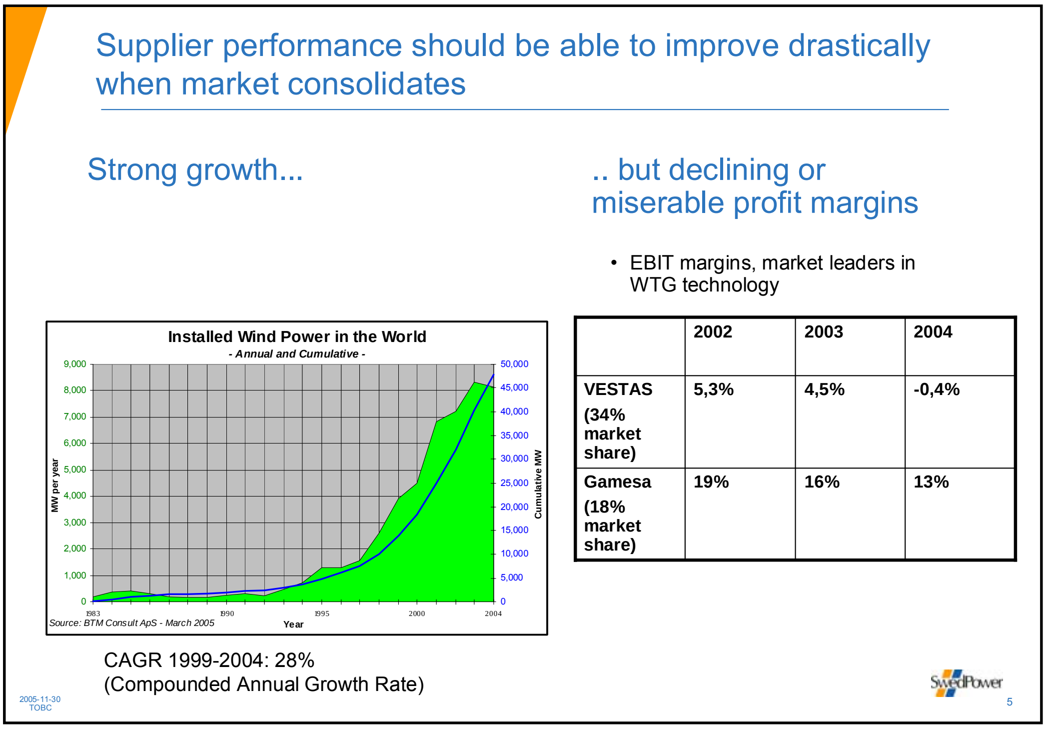
Learning curves indicate possibility of approximately 5 €/MWh reduced production cost offshore by 2015



ExTool Study indicates possibility of around 10 % (+/- 5%) cost decrease from learning curve, assuming 88 000 MW installed European capacity 2015



Supplier performance should be able to improve drastically when market consolidates

Strong growth...

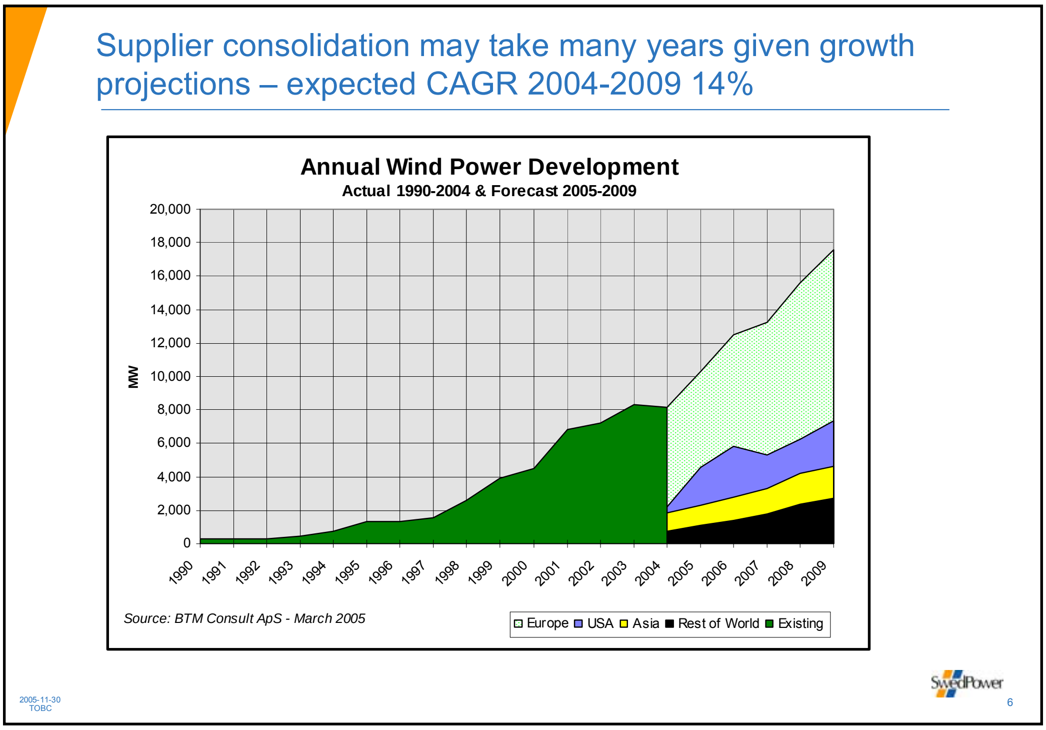
.. but declining or miserable profit margins

- EBIT margins, market leaders in WTG technology

	2002	2003	2004
VESTAS **(34% market share)**	**5,3%**	**4,5%**	**-0,4%**
Gamesa **(18% market share)**	**19%**	**16%**	**13%**

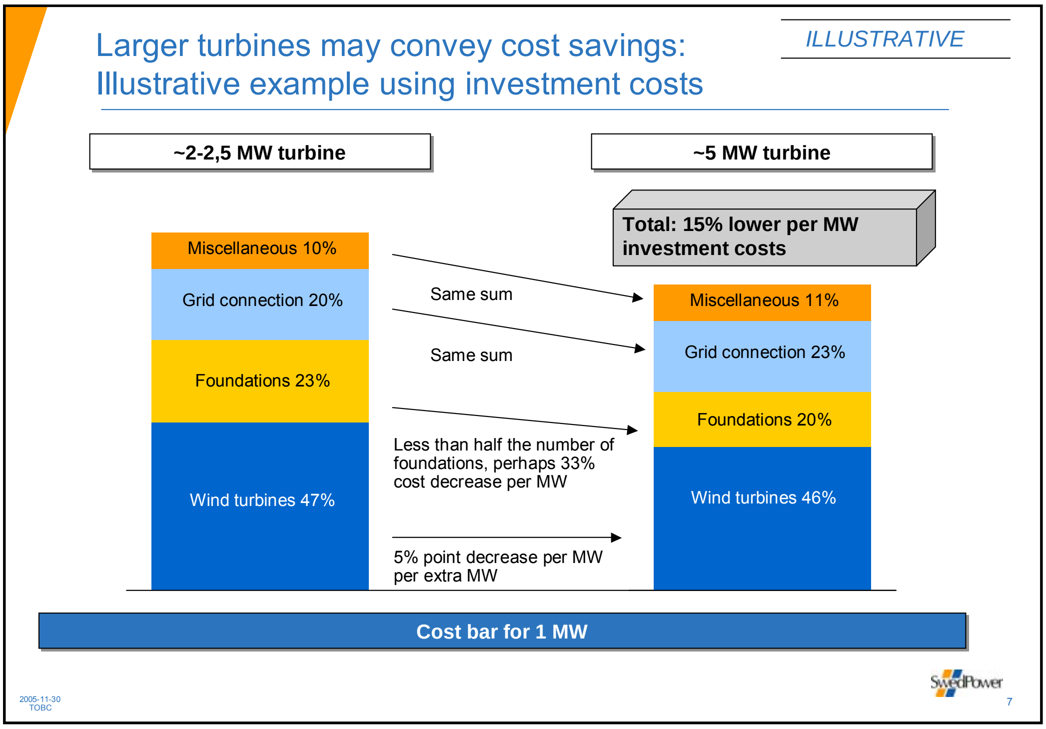
Source: BTM Consult ApS - March 2005

CAGR 1999-2004: 28%
(Compounded Annual Growth Rate)



Supplier consolidation may take many years given growth projections – expected CAGR 2004-2009 14%

Source: BTM Consult ApS - March 2005



ILLUSTRATIVE

Larger turbines may convey cost savings: Illustrative example using investment costs

~2-2,5 MW turbine

~5 MW turbine

Total: 15% lower per MW investment costs

Miscellaneous 10%

Grid connection 20%

Foundations 23%

Wind turbines 47%

Same sum

Same sum

Less than half the number of foundations, perhaps 33% cost decrease per MW

5% point decrease per MW per extra MW

Miscellaneous 11%

Grid connection 23%

Foundations 20%

Wind turbines 46%

Cost bar for 1 MW

2005-11-30
TOBC

SwedPower

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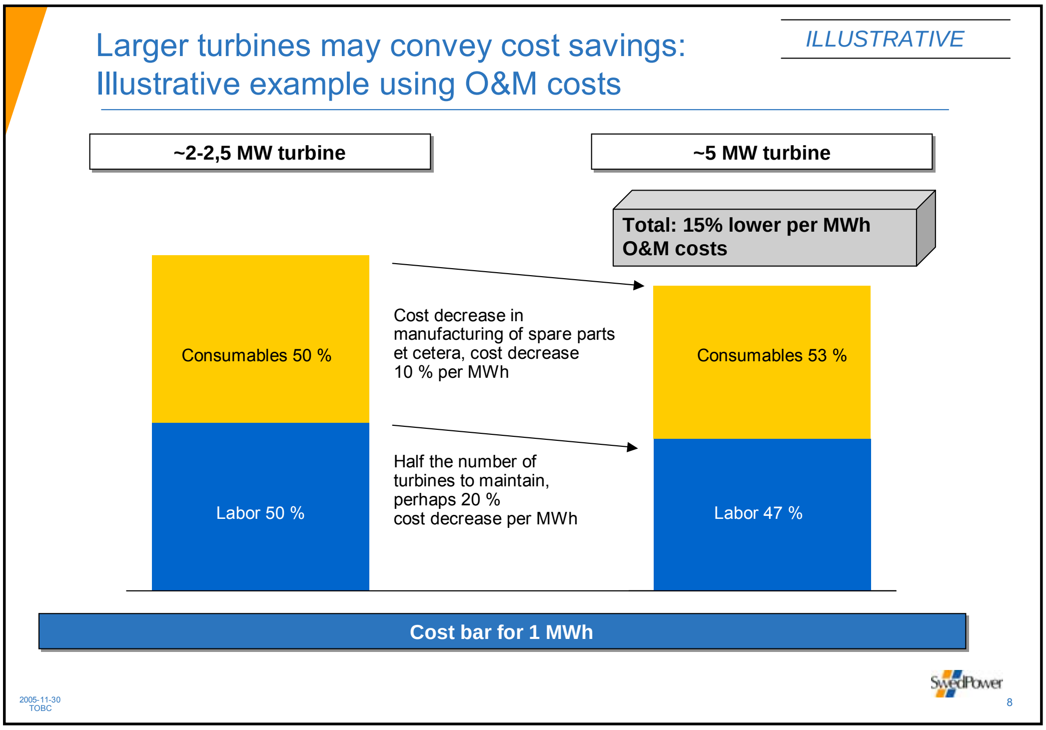

ILLUSTRATIVE

Larger turbines may convey cost savings: Illustrative example using O&M costs

~2-2,5 MW turbine

~5 MW turbine

Total: 15% lower per MWh O&M costs

Consumables 50 %

Labor 50 %

Cost decrease in manufacturing of spare parts et cetera, cost decrease 10 % per MWh

Half the number of turbines to maintain, perhaps 20 % cost decrease per MWh

Consumables 53 %

Labor 47 %

Cost bar for 1 MWh

2005-11-30
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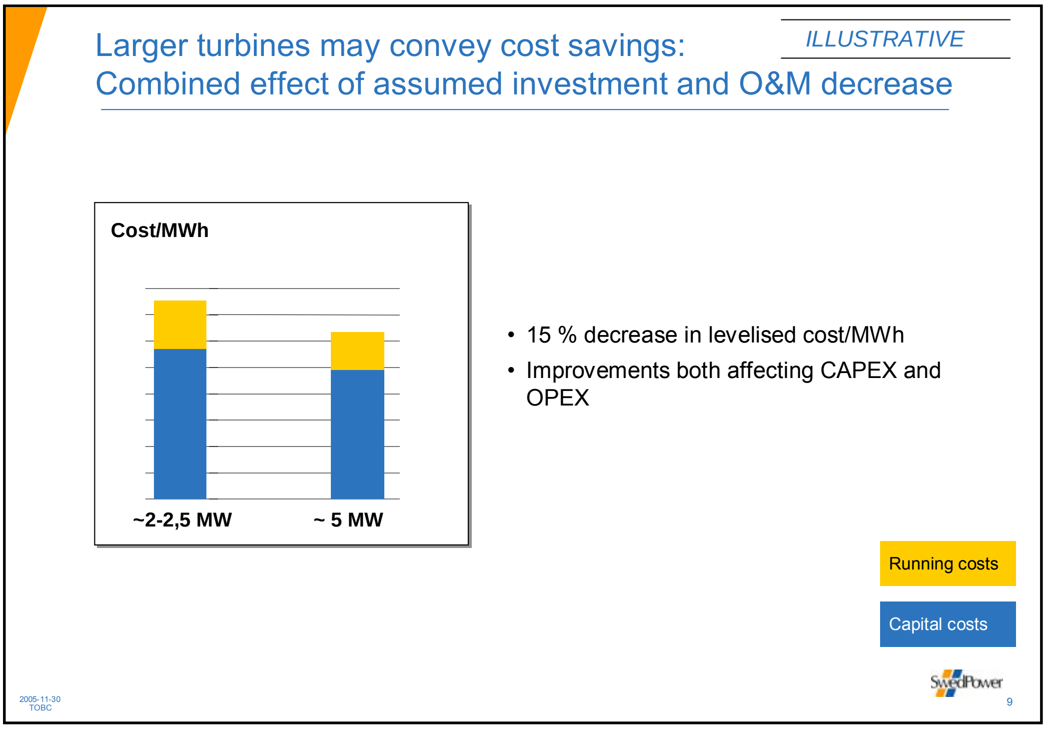
8



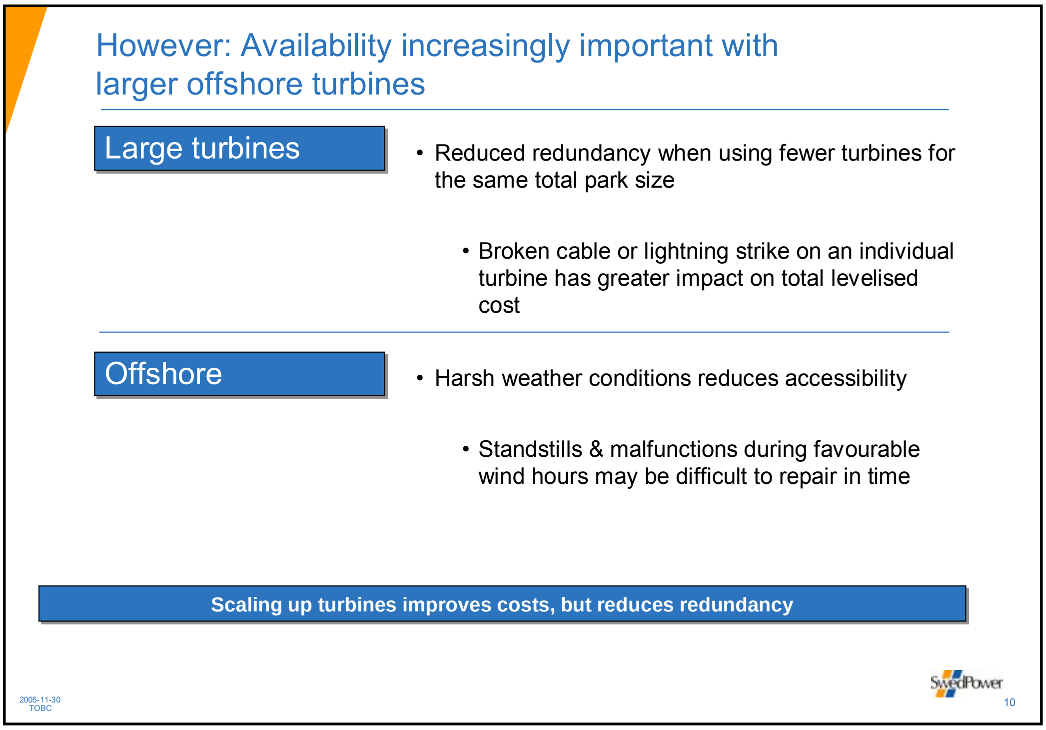
ILLUSTRATIVE

Larger turbines may convey cost savings: Combined effect of assumed investment and O&M decrease

- 15 % decrease in levelised cost/MWh
- Improvements both affecting CAPEX and OPEX

🟨 Running costs

🟦 Capital costs



However: Availability increasingly important with larger offshore turbines

Large turbines

- Reduced redundancy when using fewer turbines for the same total park size
  - Broken cable or lightning strike on an individual turbine has greater impact on total levelised cost

Offshore

- Harsh weather conditions reduces accessibility
  - Standstills & malfunctions during favourable wind hours may be difficult to repair in time

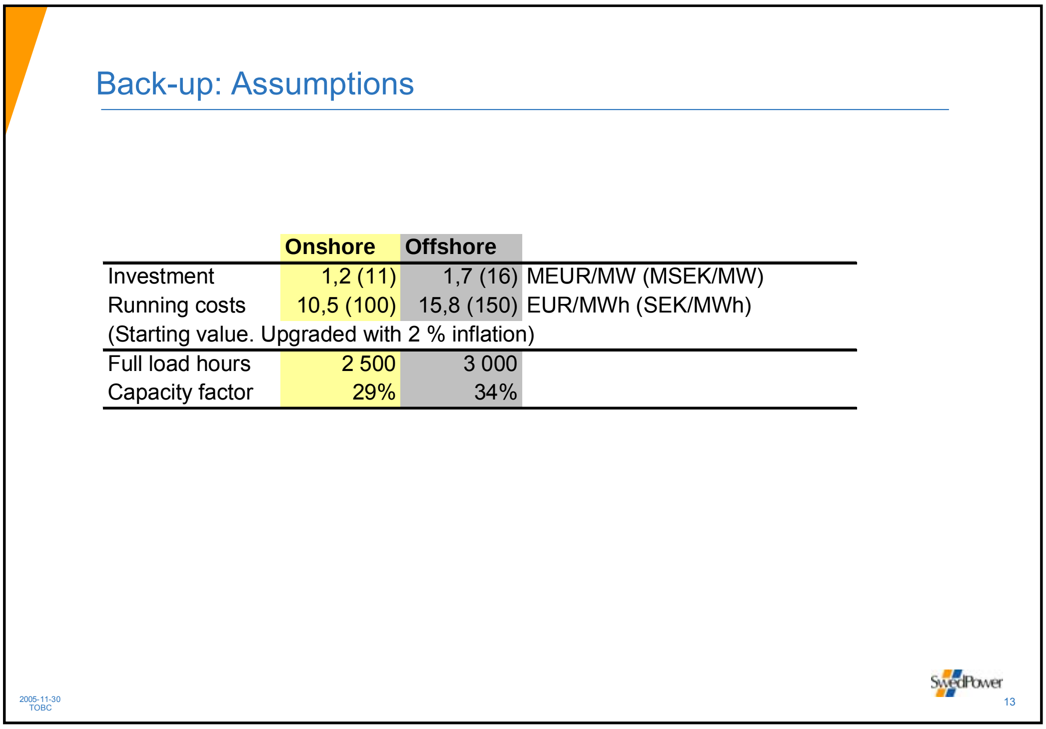
Scaling up turbines improves costs, but reduces redundancy

Summary

Large turbines as source for cost reductions

- Larger turbines on paper provides the basis for short to medium term cost decreases
- High effort should be aimed at understanding the potential and mechanisms of scale advantages
  - Foundation technology status and cost improvement potential
  - Turbine technology and savings potential
  - Operating cost savings potential
  - Limiting factors for scale advantages
- High effort should be aimed at ensuring availability for large offshore turbines

Back-up



Back-up: Assumptions

	Onshore	Offshore	
Investment	1,2 (11)	1,7 (16)	MEUR/MW (MSEK/MW)
Running costs	10,5 (100)	15,8 (150)	EUR/MWh (SEK/MWh)
(Starting value. Upgraded with 2 % inflation)			
Full load hours	2 500	3 000	
Capacity factor	29%	34%	

2005-11-30
TOBC

SwedPower

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Defining Technology Goals and Tracking Wind R&D Progress

IEA Technical Experts Meeting

November 29-30, 2005 - Paris, France

Ian Baring-Gould

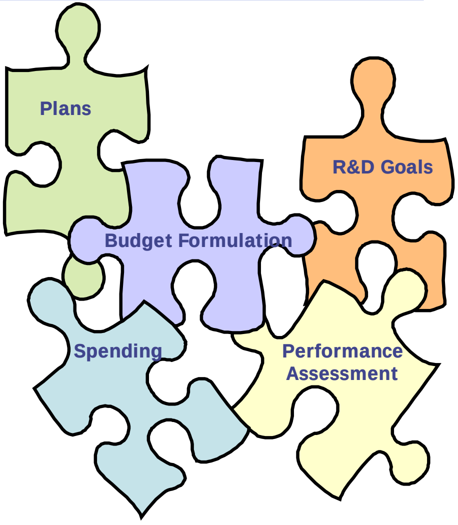
National Renewable Energy Laboratory

Tom Schweizer and Joe Cohen

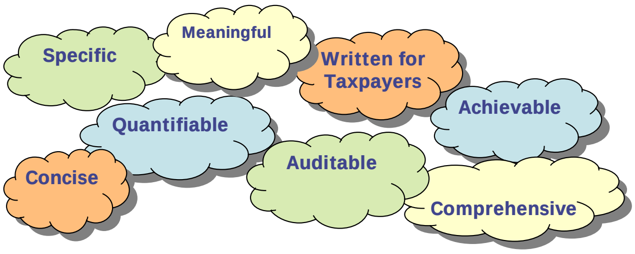
Princeton Energy Resources International (PERI)

The Context for Multi Year Planning and Performance Assessment

- President’s Management Agenda requires that all the pieces of program planning and execution fit together
- DOE management systems contain explicit linkages among Planning, Budget and Performance documents
- The Office of Management and Budget (OMB) is focused on these tools and processes
- It’s just good business practice!



Required Attributes of Program Goals



Meaningful

Specific

Written for Taxpayers

Quantifiable

Achievable

Concise

Auditable

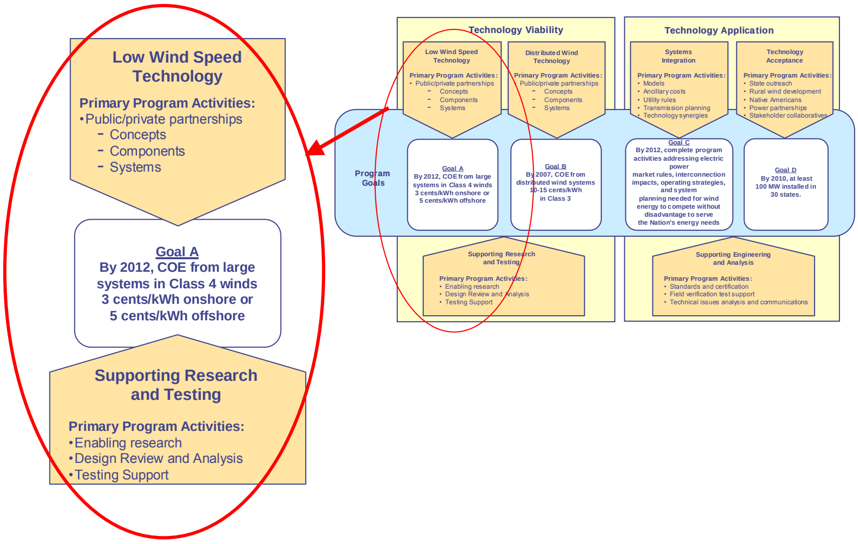
Comprehensive

- Results-oriented – focusing on what the program can control
- Have a baseline – against which to measure progress
- Trackable on an annual basis – progress made, for dollars spent
- Should cover 80-90% of all program efforts
- Must be linked to program activities

Program Structure and Goals

Focus of this talk

Overall Program Structure



Low Wind Speed Technology

Primary Program Activities:
- Public/private partnerships
  - Concepts
  - Components
  - Systems

Goal A
By 2012, COE from large systems in Class 4 winds 3 cents/kWh onshore or 5 cents/kWh offshore

Supporting Research and Testing

Primary Program Activities:
- Enabling research
- Design Review and Analysis
- Testing Support

Technology Viability

Low Wind Speed Technology

Primary Program Activities:
- Public/private partnerships
  - Concepts
  - Components
  - Systems

Distributed Wind Technology

Primary Program Activities:
- Public/private partnerships
  - Concepts
  - Components
  - Systems

Technology Application

Systems Integration

Primary Program Activities:
- Models
- Ancillary costs
- Utility rules
- Transmission planning
- Technology synergies

Technology Acceptance

Primary Program Activities:
- State outreach
- Rural wind development
- Native Americans
- Power partnerships
- Stakeholder collaboratives

Program Goals

Goal A
By 2012, COE from large systems in Class 4 winds 3 cents/kWh onshore or 5 cents/kWh offshore

Goal B
By 2007, COE from distributed wind systems 10-15 cents/kWh in Class 3

Goal C
By 2012, complete program activities addressing electric power market rules, interconnection impacts, operating strategies, and system planning needed for wind energy to compete without disadvantage to serve the Nation's energy needs

Goal D
By 2010, at least 100 MW installed in 30 states.

Supporting Research and Testing

Primary Program Activities:
- Enabling research
- Design Review and Analysis
- Testing Support

Supporting Engineering and Analysis

Primary Program Activities:
- Standards and certification
- Field verification test support
- Technical issues analysis and communications

Two Elements of LWST Program Planning

Pathways Analysis

- Reference Turbine
- LWST Goals
- Technology Improvement Opportunities (TIOs)
- Wind Pathways (Monte Carlo) Model

Portfolio Assessment

- Annual Turbine Technology Update
- Yearly LWST Subcontract (S/C) Portfolio Assessment
- Yearly SR&T Portfolio Assessment

LWST Goals and Performance Tracking

Performance Measurement is a Four Step Process:

Step 1: Determine Reference
(COE in 2002)
Step 2: Develop Goal
(COE in 2012)
Step 3: Identify Pathway
Step 4: Measure and Report Annual Progress
(COE Annually)

Step 1: Determine Reference – 2002 Turbine

Nominal Description of Reference Turbine:

- 1.5 MW
- 70 m rotor diameter
- 65 m tower
- Upwind, 3-blade; variable pitch
- Variable speed

Is a composite of available technologies – based primarily on (2002) WindPACT studies and market data

Step 1: Determine Reference – 2002 Turbine

Levelized Cost of Energy of Reference (2002) Turbine: 4.8 cents/kWh

- In constant end-of-2002 dollars
- Class 4 winds (13 mph average at 10 m)
- Assumes financing structures typical of GenCos (i.e., balance sheet financing)
- Detailed cash flow model used to calculate COE using assumptions for taxes, insurance, depreciation, cost of capital, financing fees, and construction financing
- Caveat – uses a relatively high required rate of return compared to current market rates and a 30 year project life

Step 2: Develop Goal (2012)

Within the DOE program, defining a program goal is a critical aspect of program development.

Politically:

- The goal must be believable and achievable
- Provide enough “pizzazz” to convinced senior management and congress that it is worth funding
- Provide near term benefit

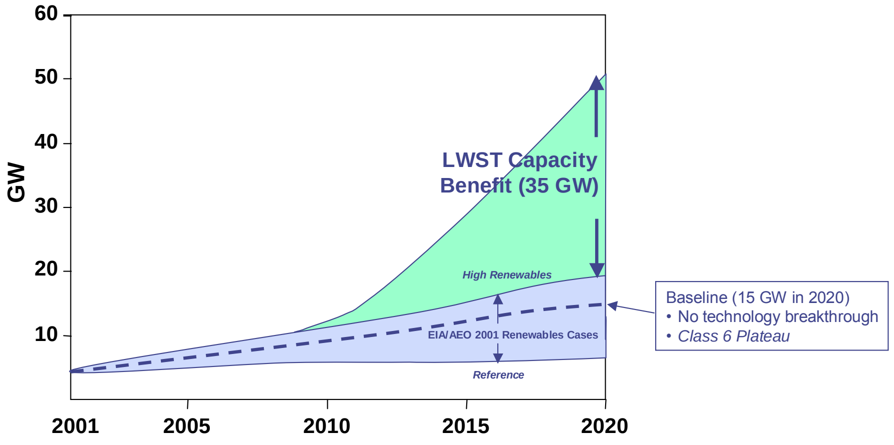
Technically:

- Balance between identifying what is needed for success in the marketplace and what is technically possible

Wind Program LWST goal -

- An LWST goal of 3 cents/kWh was attractive – it would result in an additional 35 GW of wind by 2020
- However, the question remained – is 3 cents/kWh possible?

National Benefits – Projected by NEMS

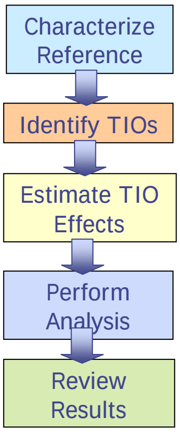


Program Goal:
3 cents/kWh COE in class 4

- Expands resource base **20-fold**
- Reduces average distance to load **5-fold**

Step 3: Is 3 cents/kWh achievable in Class 4 winds?

Analysis Process



Characterize a set of cost and performance parameters for a composite, reference turbine

Identify a "menu" of Technology Improvement Opportunities (TIOs) that could lead to this improvement

Estimate the range of potential change in cost, performance, reliability, and O&M for each TIO category

Run these through a turbine systems model (the "Pathways Model") to assess impact on cost of energy

Produce a curve of COE versus likelihood of achieving it.

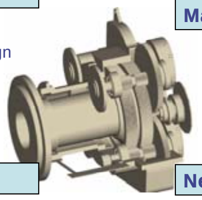
Data Sources

NREL/Sandia staff, WindPACT studies, Next Generation Turbine project, LWST proposals, in-house knowledge, etc.

Technology Improvement Opportunities (TIOs)

Advanced (Enlarged) Rotor TIOs

- Advanced materials
- Changed/improved structural/aero design
- Active controls
- Passive controls
- Higher tip speed ratios/lower acoustics



Site-Specific Design/Reduced Design Margin TIOs

- Improved definition of site characteristics
- Design load tailoring
- Micrositing
- Favorable wind speed distributions and shear

Manufacturing TIOs

- Manufacturing methods
- Lower margins
- Manufacturing markups

New Drive Train Concept TIOs

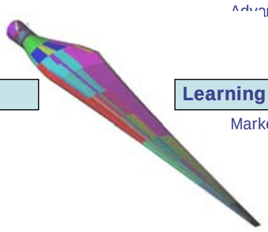
- Permanent magnet generator
- Innovative mechanical drives

Reduced Energy Losses and Increased Availability TIOs

- Health monitoring (SCADA, etc.)
- Blade soiling mitigation
- Extended scheduled maintenance

Advanced Power Electronics TIOs

- Incorporation of improved PE components
- Advanced circuit topology

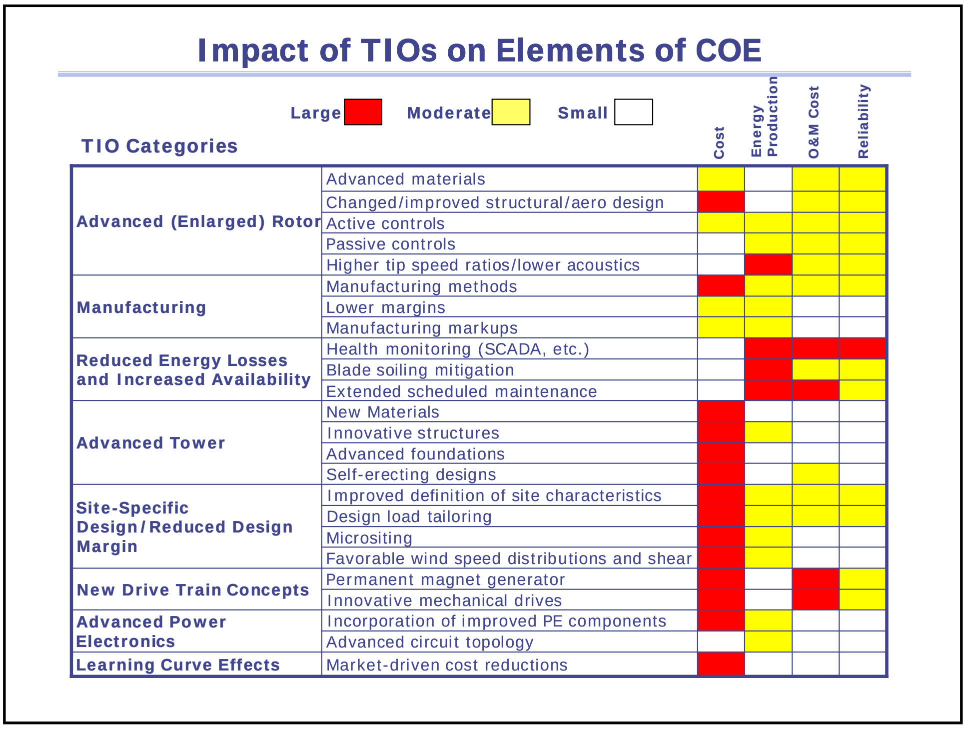


Advanced Tower TIOs

- New Materials
- Innovative structures
- Advanced foundations
- Self-erecting designs

Learning Curve Effects

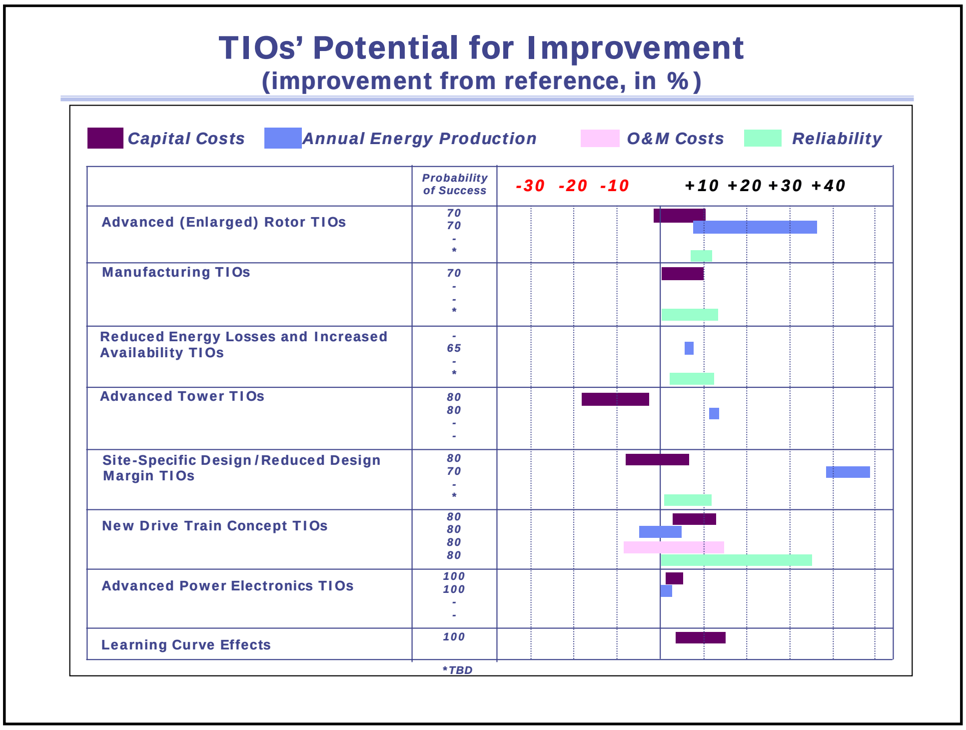
- Market–driven cost reductions



Impact of TIOs on Elements of COE

Large 🟥 Moderate 🟨 Small ⬜

TIO Categories		Cost	Energy Production	O&M Cost	Reliability
Advanced (Enlarged) Rotor	Advanced materials	🟨	⬜	🟨	🟨
	Changed/improved structural/aero design	🟥	⬜	🟨	🟨
	Active controls	🟨	🟨	🟨	🟨
	Passive controls	⬜	🟨	🟨	🟨
	Higher tip speed ratios/lower acoustics	⬜	🟥	🟨	🟨
Manufacturing	Manufacturing methods	🟥	🟨	🟨	🟨
	Lower margins	🟨	🟨	⬜	⬜
	Manufacturing markups	🟨	🟨	⬜	⬜
Reduced Energy Losses and Increased Availability	Health monitoring (SCADA, etc.)	⬜	🟥	🟥	🟥
	Blade soiling mitigation	⬜	🟥	🟨	🟨
	Extended scheduled maintenance	⬜	🟥	🟥	🟨
Advanced Tower	New Materials	🟥	⬜	⬜	⬜
	Innovative structures	🟥	🟨	⬜	⬜
	Advanced foundations	🟥	⬜	⬜	⬜
	Self-erecting designs	🟥	⬜	🟨	⬜
Site-Specific Design/Reduced Design Margin	Improved definition of site characteristics	🟥	🟨	🟨	🟨
	Design load tailoring	🟥	🟨	🟨	🟨
	Micrositing	🟥	🟨	⬜	⬜
	Favorable wind speed distributions and shear	🟥	🟨	⬜	⬜
New Drive Train Concepts	Permanent magnet generator	🟥	⬜	🟥	🟨
	Innovative mechanical drives	🟥	⬜	🟥	🟨
Advanced Power Electronics	Incorporation of improved PE components	🟥	🟨	⬜	⬜
	Advanced circuit topology	⬜	🟨	⬜	⬜
Learning Curve Effects	Market-driven cost reductions	🟥	⬜	⬜	⬜



TIOs' Potential for Improvement

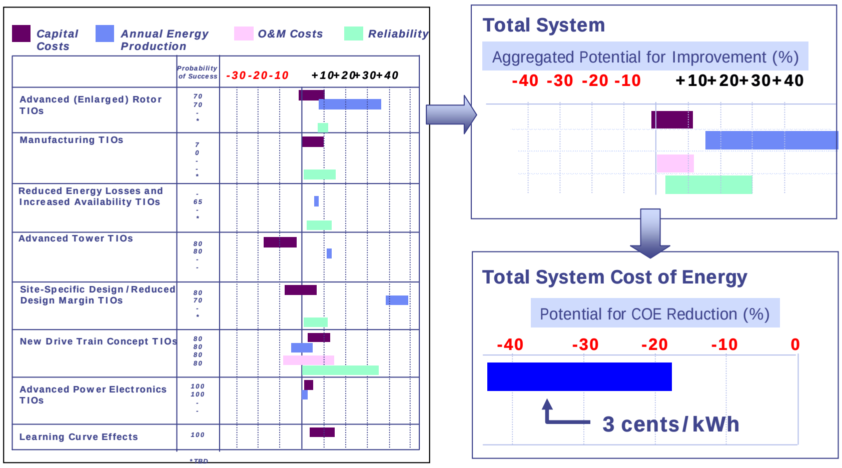
(improvement from reference, in %)

	Probability of Success
Advanced (Enlarged) Rotor TIOs	70 70 - *
Manufacturing TIOs	70 - - *
Reduced Energy Losses and Increased Availability TIOs	- 65 - *
Advanced Tower TIOs	80 80 - -
Site-Specific Design/Reduced Design Margin TIOs	80 70 - *
New Drive Train Concept TIOs	80 80 80 80
Advanced Power Electronics TIOs	100 100 - -
Learning Curve Effects	100

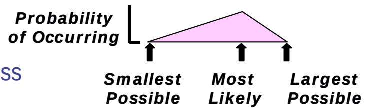
*TBD

Wind Technology Pathways Model

(A Monte-Carlo Wind Turbine Analysis Tool)

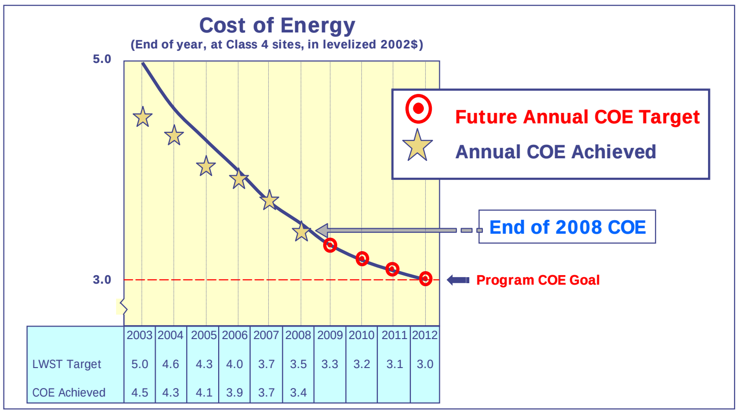


Note: Each bar represents a probability distribution representing the likelihood of success



Step 4: Reporting Annual Progress:

Hypothetical Example for 2008 Annual Report

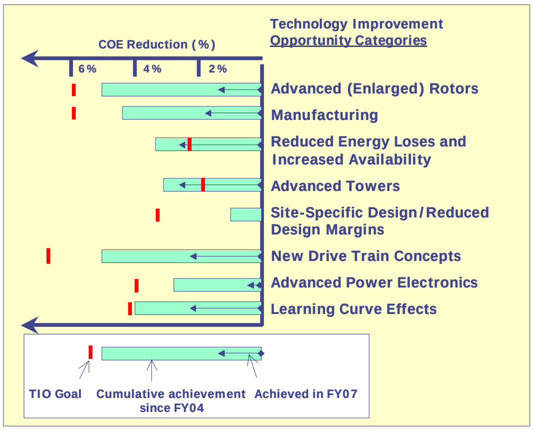


	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
LWST Target	5.0	4.6	4.3	4.0	3.7	3.5	3.3	3.2	3.1	3.0
COE Achieved	4.5	4.3	4.1	3.9	3.7	3.4				

- **When the LWST program began, the Wind Program developed a trajectory of COEs, leading to the goal**
  - **At the time, technology was available at 5.5 cents/kWh (the program's 2002 baseline)**
  - **Must track and report annual progress against that trajectory**

Approaches to the
"Annual Turbine Technology Update"

- In some years, the Program may actually have a new turbine to point to for the Annual Turbine Technology Update process
- In other years, may have to build a "paper turbine" based on component progress, interim prototype progress, SR&T progress, etc.
- Expert judgment required; program will draw on an expert panel for evaluation



Progress in achieving the potential of the TIOs can be used as inputs to the virtual process and the Pathways Model can be run again

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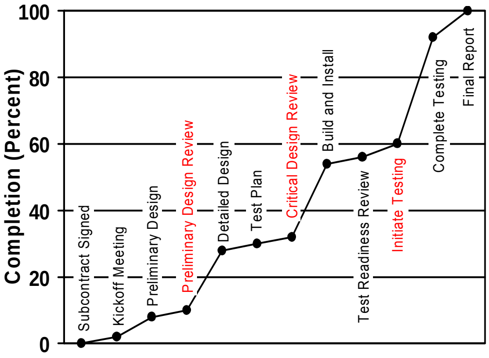
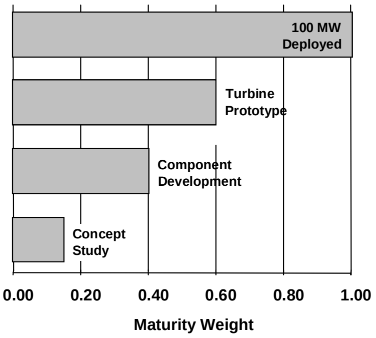
Contract Weighting Factor

Due to multi-year nature of development projects, a weighting factor was applied to account for progress towards deployment



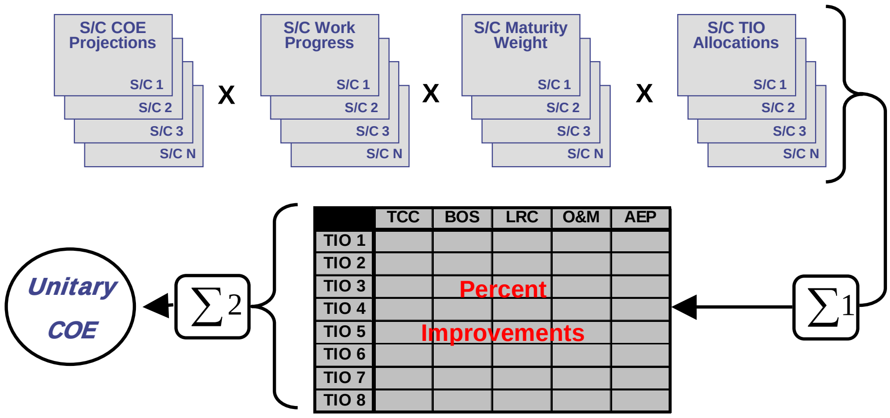
Stage Gates used to assess importance of each project



Greatest value is only achieved with substantial ommercialization (100 MW deployed)

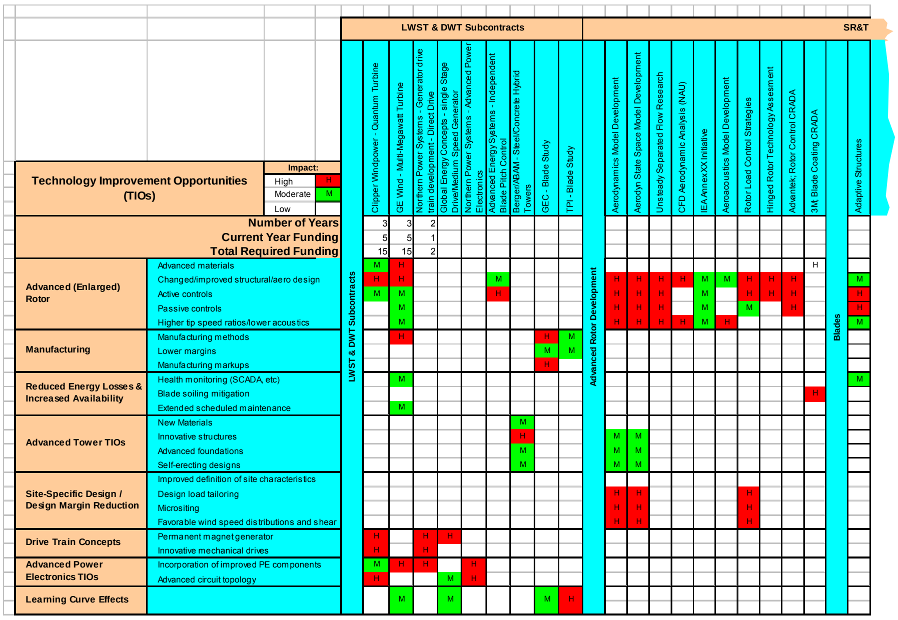
Yearly Progress Rollup

Yearly assessment of each project is conducted by the contractors and progress of all contracts rolled into the calculation for the annual turbine



	TCC	BOS	LRC	O&M	AEP
TIO 1					
TIO 2					
TIO 3					
TIO 4					
TIO 5					
TIO 6					
TIO 7					
TIO 8					

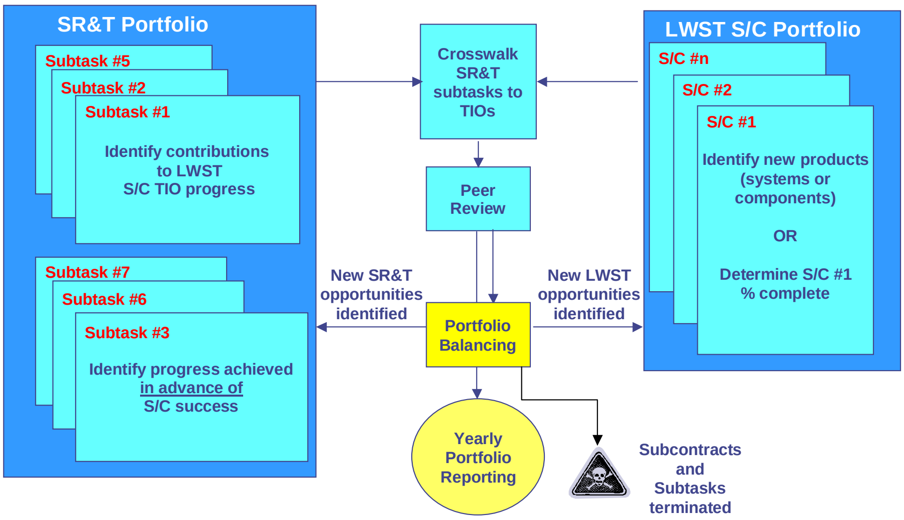
Portfolio Assessment



Impact:
High H
Moderate M
Low

Technology Improvement Opportunities (TIOs)		LWST & DWT Subcontracts									SR&T													
		LWST & DWT Subcontracts	Clipper Windpower - Quantum Turbine	GE Wind - Multi-Megawatt Turbine	Northern Power Systems - Generator drive train development - Direct Drive	Global Energy Concepts - single Stage Drive/Medium Speed Generator	Northern Power Systems - Advanced Power Electronics	Advanced Energy Systems - Independent Blade Pitch Control	Berger/ABAM - Steel/Concrete Hybrid Towers	GEC - Blade Study	TPI - Blade Study	Advanced Rotor Development	Aerodynamics Model Development	Aerodyn State Space Model Development	Unsteady Separated Flow Research	CFD Aerodynamic Analysis (NAU)	IEA Annex XX Initiative	Aeroacoustics Model Development	Rotor Load Control Strategies	Hinged Rotor Technology Assesment	Advantek; Rotor Control CRADA	3M; Blade Coating CRADA	Blades	Adaptive Structures
Number of Years			3	3	2																			
Current Year Funding			5	5	1																			
Total Required Funding			15	15	2																			
Advanced (Enlarged) Rotor	Advanced materials		M	H																		H		
	Changed/improved structural/aero design		H	H				M					H	H	H	H	M	M	H	H	H			M
	Active controls		M	M				H					H	H	H		M		H	H	H			H
	Passive controls			M									H	H	H		M		M		H			H
	Higher tip speed ratios/lower acoustics			M									H	H	H	H	M	H						M
Manufacturing	Manufacturing methods			H						H	M													
	Lower margins									M	M													
	Manufacturing markups									H														
Reduced Energy Losses & Increased Availability	Health monitoring (SCADA, etc)			M																				M
	Blade soiling mitigation																					H		
	Extended scheduled maintenance			M																				
Advanced Tower TIOs	New Materials								M															
	Innovative structures								H				M	M										
	Advanced foundations								M				M	M										
	Self-erecting designs								M				M	M										
Site-Specific Design / Design Margin Reduction	Improved definition of site characteristics																							
	Design load tailoring												H	H					H					
	Micrositing												H	H					H					
	Favorable wind speed distributions and shear												H	H					H					
Drive Train Concepts	Permanent magnet generator		H		H	H																		
	Innovative mechanical drives		H		H																			
Advanced Power Electronics TIOs	Incorporation of improved PE components		M	H	H		H																	
	Advanced circuit topology		H			M	H																	
Learning Curve Effects				M		M				M	H													

Yearly Portfolio Assessment



SR&T Portfolio

Subtask #5

Subtask #2

Subtask #1

Identify contributions to LWST S/C TIO progress

Subtask #7

Subtask #6

Subtask #3

Identify progress achieved <u>in advance of</u> S/C success

Crosswalk SR&T subtasks to TIOs

Peer Review

New SR&T opportunities identified

Portfolio Balancing

New LWST opportunities identified

Yearly Portfolio Reporting

Subcontracts and Subtasks terminated

LWST S/C Portfolio

S/C #n

S/C #2

S/C #1

Identify new products (systems or components)

OR

Determine S/C #1 % complete

Conclusion

- Process allows the program to assign specific long range goals that can be easily understood and who’s impact can be quantified
- Progress to the goals can be assessed on a regular basis
- All research and development activities can be tracked and evaluated to insure that projects are helping to achieve program goals

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Wind Farm O&M costs

Niels-Erik Clausen
Poul Erik Morthorst
Risø National Laboratory

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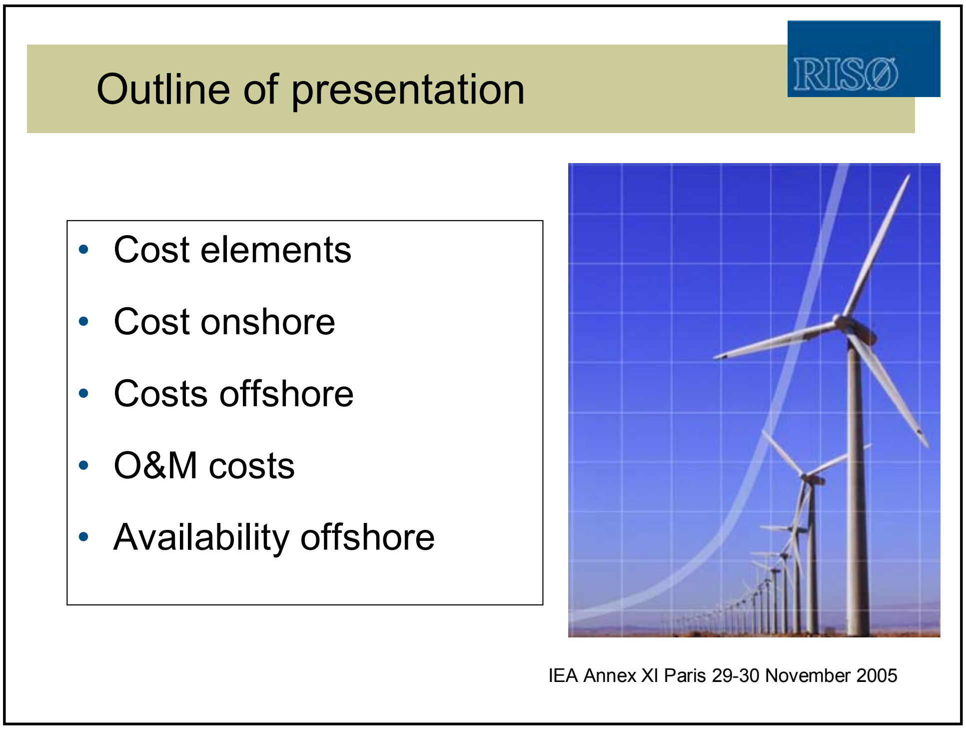

Outline of presentation

RISØ

- Cost elements
- Cost onshore
- Costs offshore
- O&M costs
- Availability offshore

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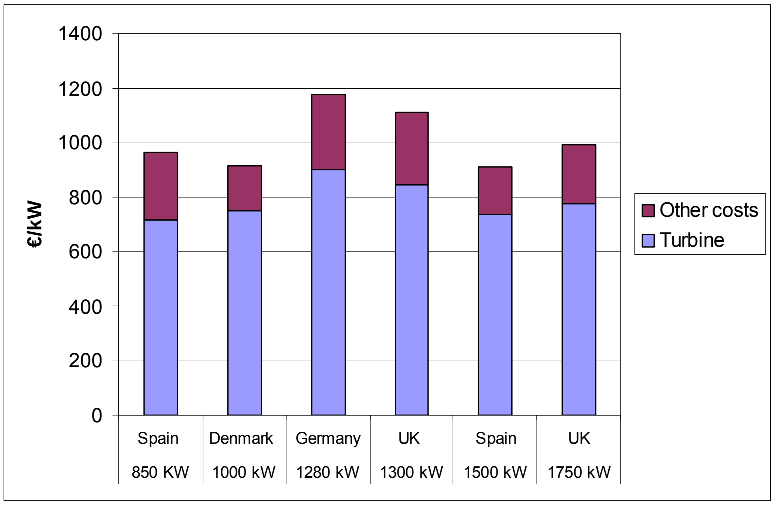
The main economic parameters

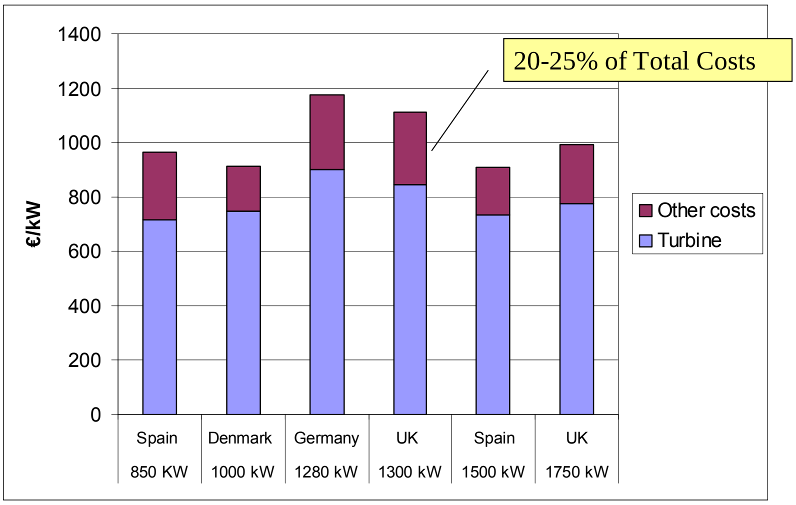
The main parameters governing wind power economics include the following:

- Investment costs, including balance-of-plant costs for foundation, grid-connection, etc.
- Operation and maintenance costs
- Electricity production (availability & av. wind speed)
- Turbine lifetime
- Discount rate

Investment costs per kW



Investment costs per kW



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Investment costs offshore

Component	**Investment 1000€ / MW**	**Share %**
Turbines ex works incl. transport & erection	815	49
Trafo-station and main cable to land	270	16
Internal grid in wind farm	85	5
Foundations	350	21
Design, project management	100	6
Environmental analysis	50	3
Miscellaneous	10	<1
Total	1680	≈100%

Average investment costs per MW based on the offshore wind farms at Horns Rev and Nysted. Exchange rate 1 € = 7.45 DKK.

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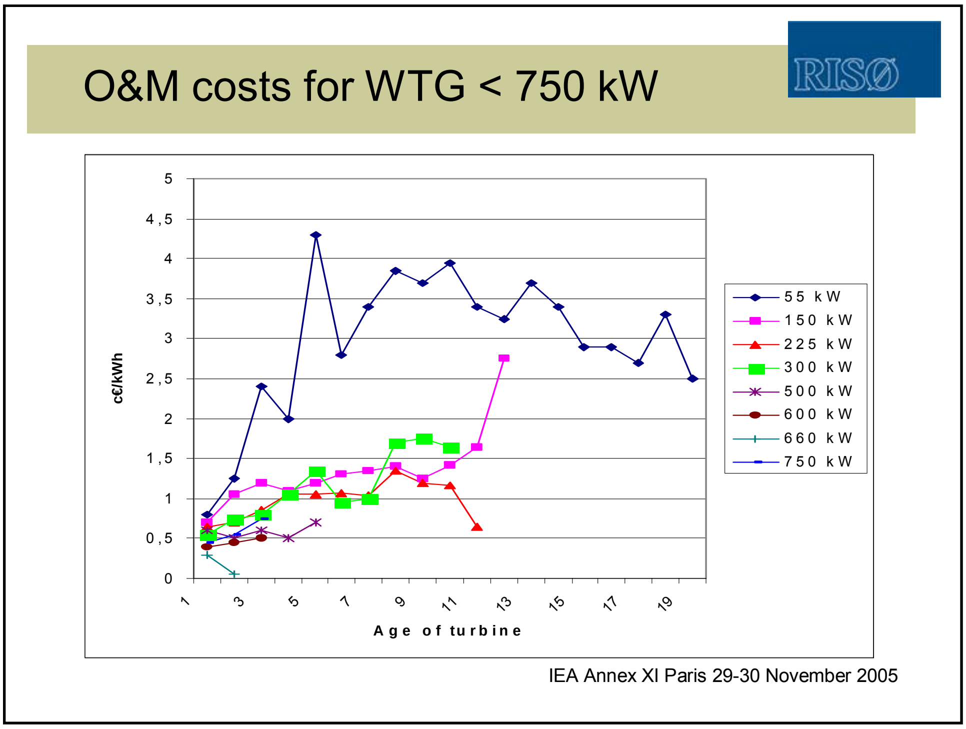

O&M costs for WTG < 750 kW

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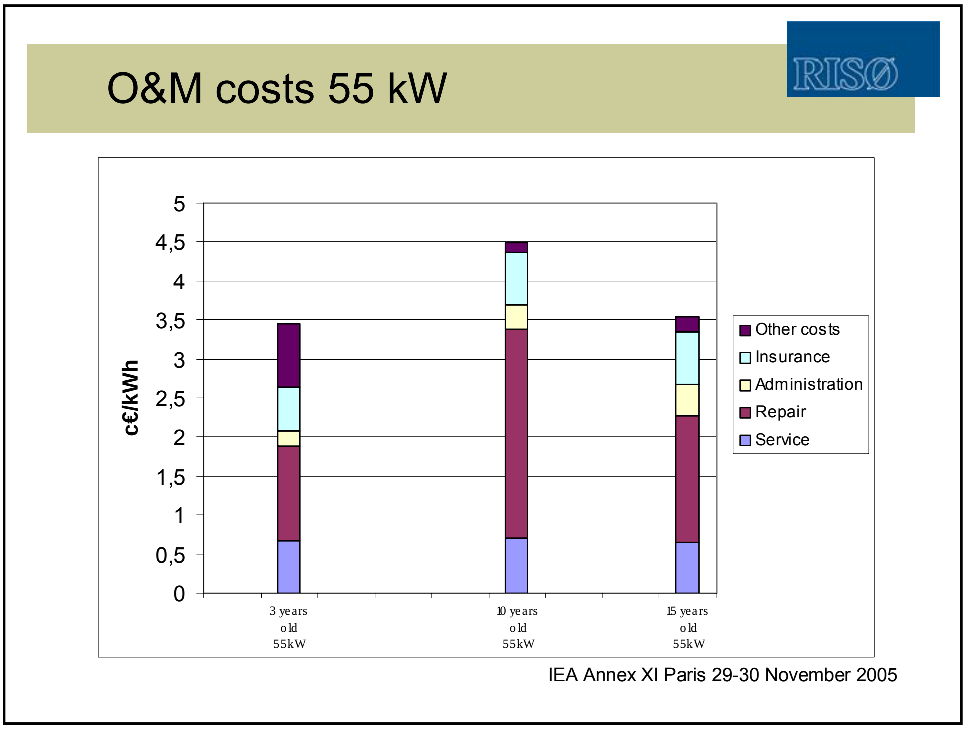

O&M costs 55 kW

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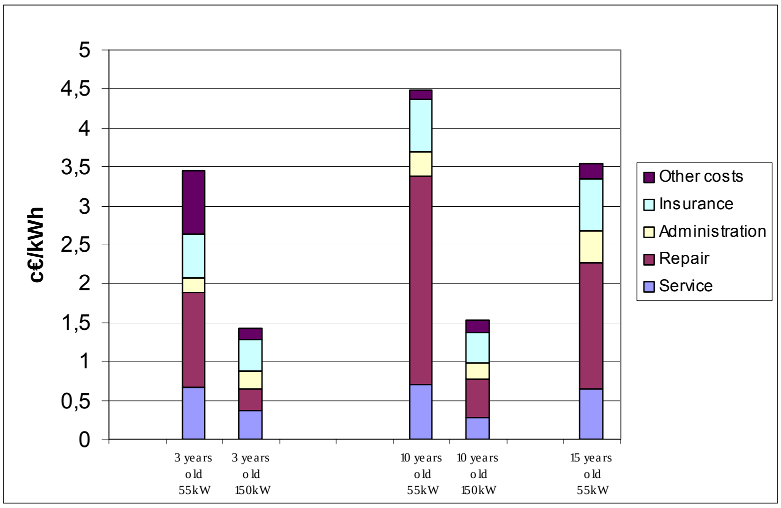
O&M costs 55 kW and 150 kW



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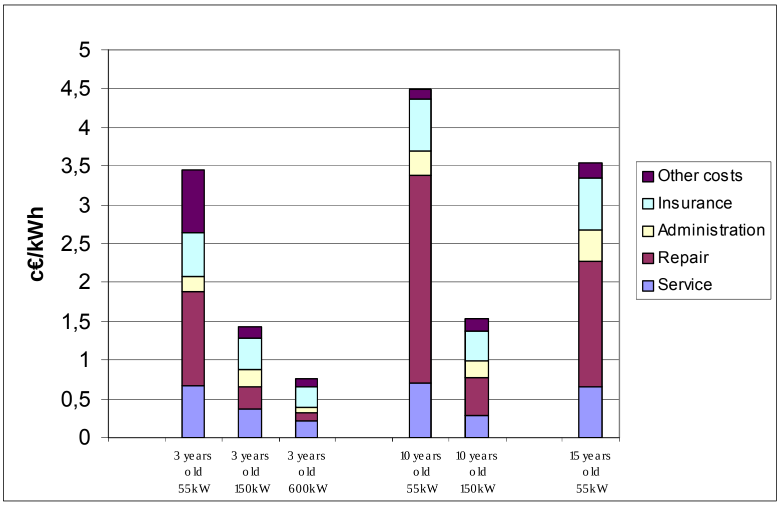
Comparison of O&M costs



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O&M costs offshore

RISØ

1. Vindeby
2. Tunø Knob
3. Middelgrunden
4. Horns Rev
5. Rønland
6. Nysted
7. Samsø
8. Frederikshavn

Key figures for O&M costs for Middelgrunden offshore wind farm for the years 2003 and 2004

COST item	EUR/MWh
Service on wind turbines	4.1
Service control, daily maintenance **Service of 30 kV system**	1.2
Insurance	2.6
Electricity consumption	0.3
TOTAL	8.2

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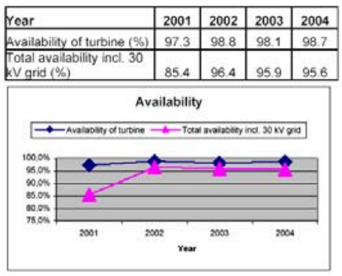
Wind farm availability offshore

RISØ

Availability of the ten 2.3 MW wind turbines owned by the Middelgrunden Cooperative



Year	2001	2002	2003	2004
Availability of turbine (%)	97.3	98.8	98.1	98.7
Total availability incl. 30 kV grid (%)	85.4	96.4	95.9	95.6

Availability figures for Samsø, Horns rev and Nysted offshore wind farms

Wind farm	First year	Second year	1-3 quater 2005
Samsø	**97.3**	**94***	
Horn rev			**96.5**
Nysted	**97**	**97.6**	

*94 days of production lost due to transformer failures and faulty installation of HV cables

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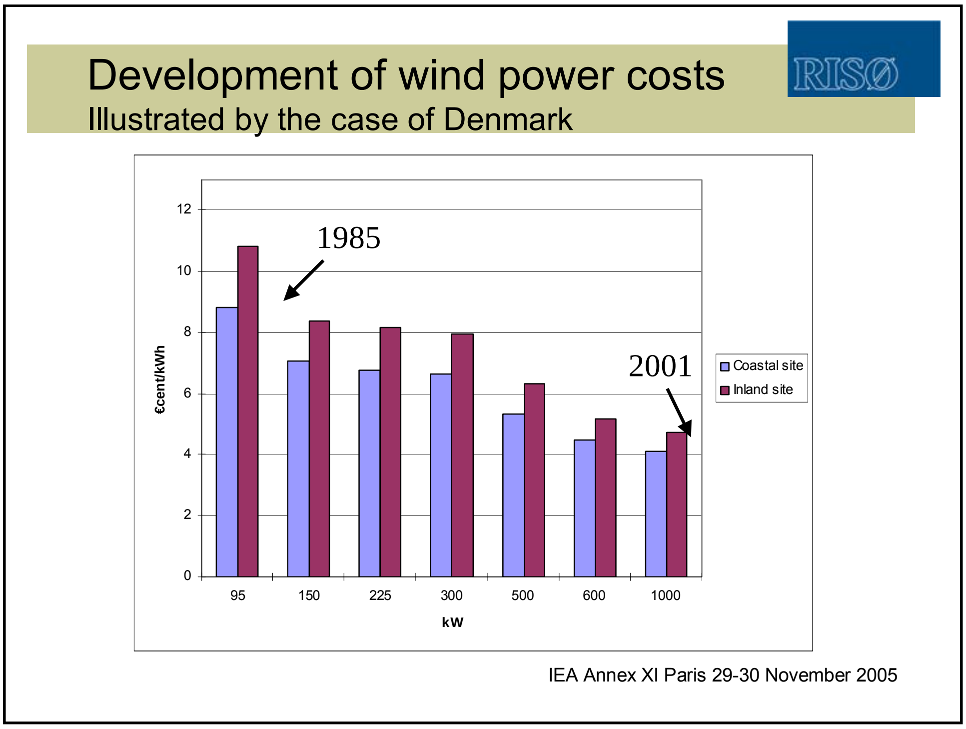

Development of wind power costs

Illustrated by the case of Denmark

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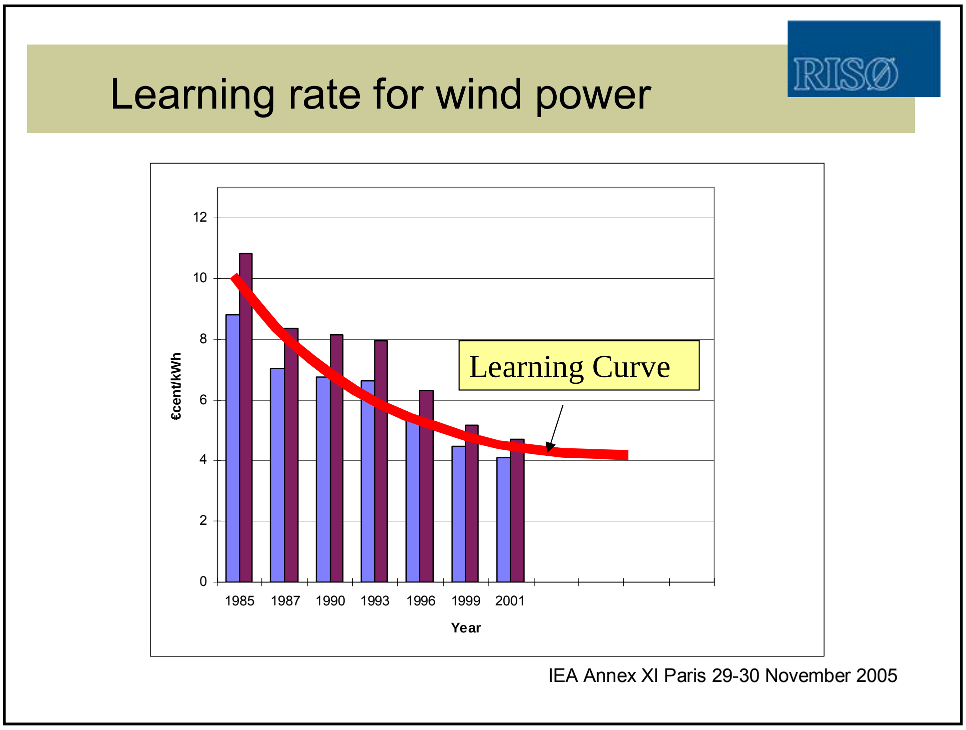

Learning rate for wind power

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Learning curve approach

- Cost reduction in relation to acc. installed capacity
  - Simple way of looking at the cost-consequences of mass production

EXTOOL* project

- Excellent data for wind power
- Learning rates between 9% and 17%

Thus when the global capacity of wind power is doubled costs are reduced by 9 to 17% per kWh

*Experience curves: A tool for energy policy assessment, EU5 ENG1-CT2000-00116

Conclusion

- The cost of wind power is reduced by 9 to 17% when the global installed capacity is doubled
- O&M for wind turbines does not scale with size but with number
- Few data on O&M experience

Thank you for your attention

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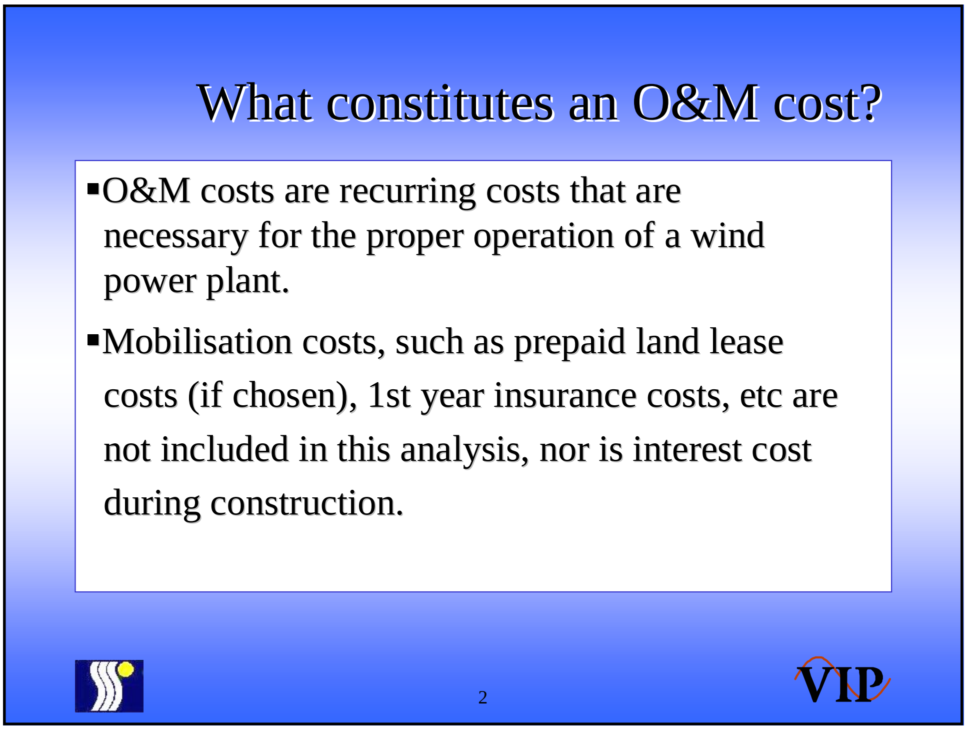
Methodologies for Estimation of Cost of Wind Energy

Estimation of O & M
costs in financial models

IEA R&D Wind Annex
Paris, 29 – 30 November 2005



What constitutes an O&M cost?

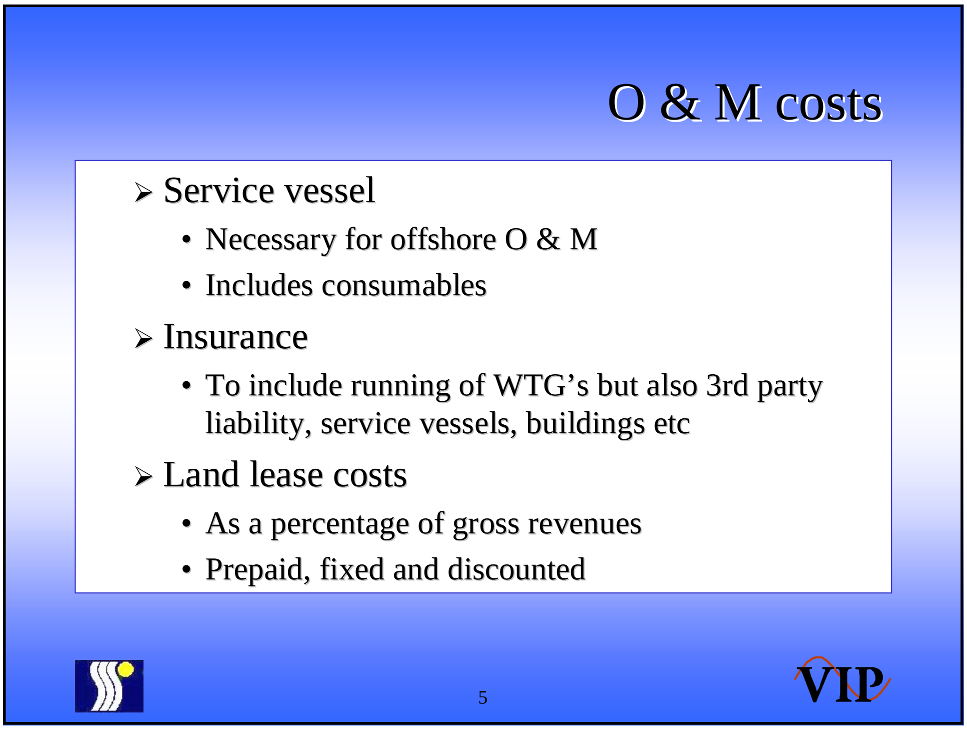
- O&M costs are recurring costs that are necessary for the proper operation of a wind power plant.
- Mobilisation costs, such as prepaid land lease costs (if chosen), 1st year insurance costs, etc are not included in this analysis, nor is interest cost during construction.

O & M costs

- Costs that are included in this analysis: -
  - Administration costs
    - Accountancy
    - Office rent
    - Communication (NB not with WTG's)
    - Cars etc
  - Personnel
    - Service personnel if not contracted out
    - Boat personnel for offshore WTG's

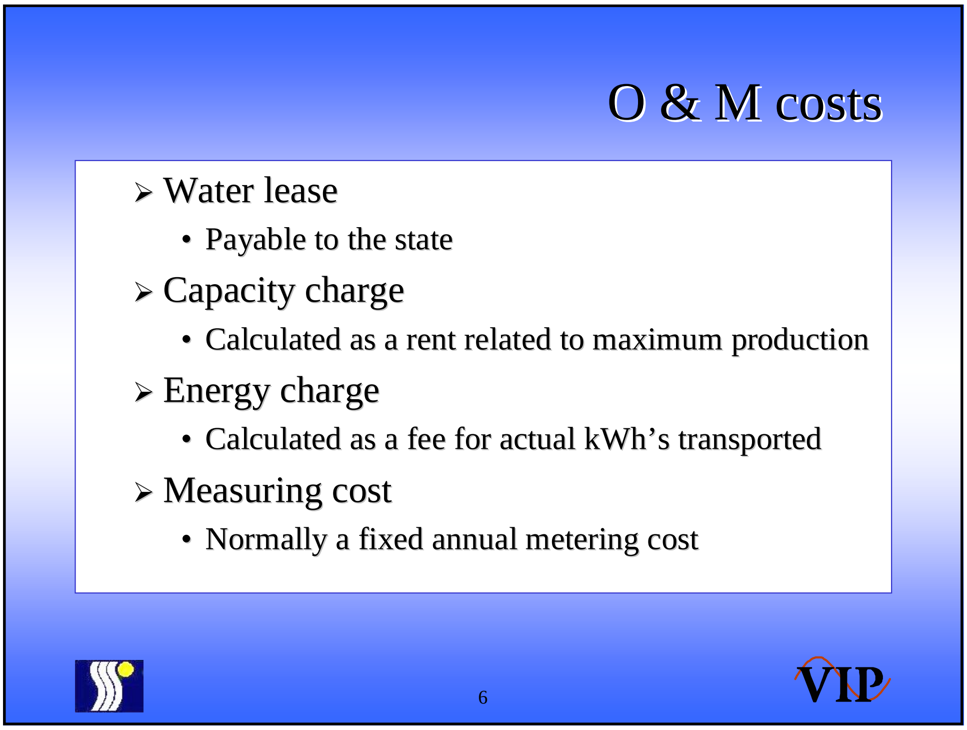
O & M costs

- Communication costs
  - Mobile phone & broadband connection with WTG's
- Service Agreement
  - Initially with WTG supplier
  - Different price levels depending on warranty period
- Spareparts
- Maintenance fund
  - To cover larger maintenance work such as change of gearbox, generator or blade(s)



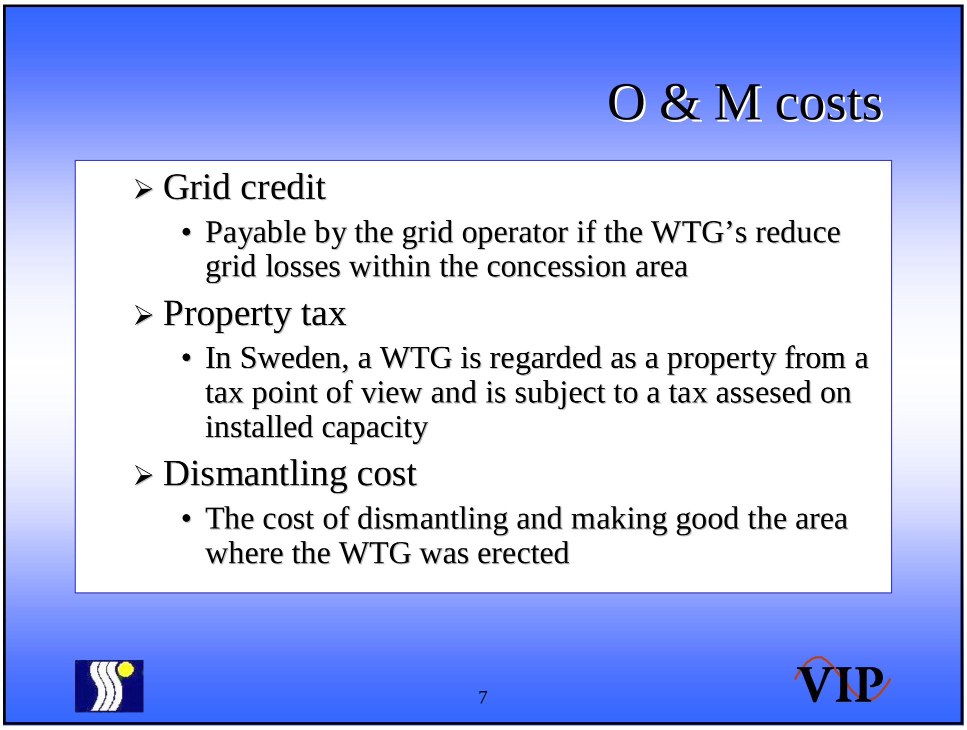
O & M costs

- Service vessel
  - Necessary for offshore O & M
  - Includes consumables
- Insurance
  - To include running of WTG’s but also 3rd party liability, service vessels, buildings etc
- Land lease costs
  - As a percentage of gross revenues
  - Prepaid, fixed and discounted



O & M costs

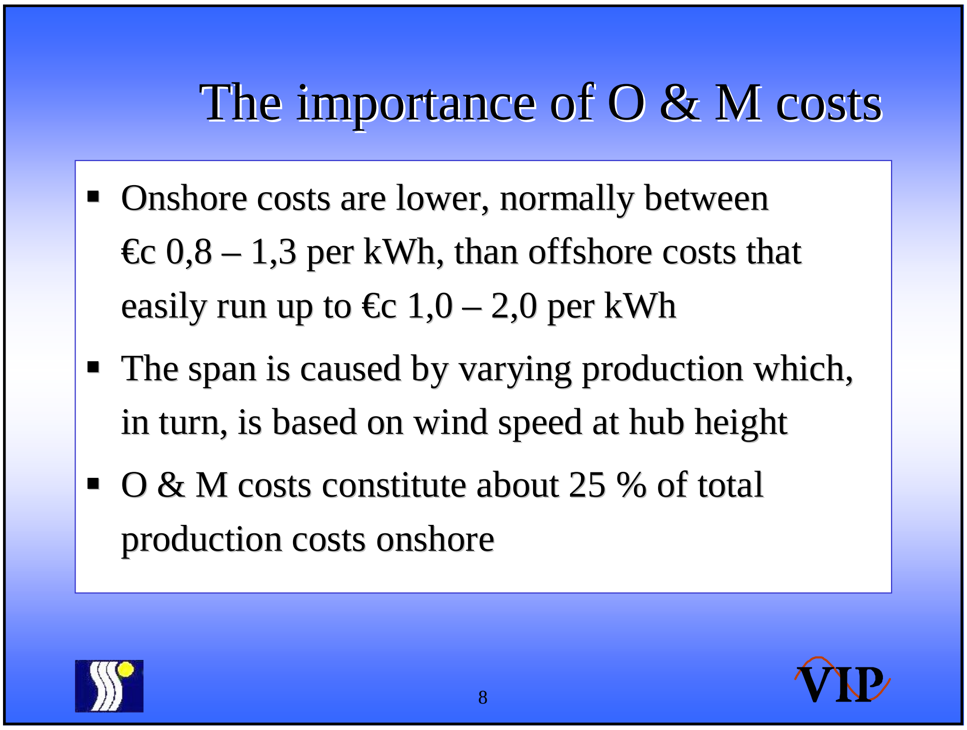
- Water lease
  - Payable to the state
- Capacity charge
  - Calculated as a rent related to maximum production
- Energy charge
  - Calculated as a fee for actual kWh’s transported
- Measuring cost
  - Normally a fixed annual metering cost



O & M costs

- Grid credit
  - Payable by the grid operator if the WTG's reduce grid losses within the concession area
- Property tax
  - In Sweden, a WTG is regarded as a property from a tax point of view and is subject to a tax assesed on installed capacity
- Dismantling cost
  - The cost of dismantling and making good the area where the WTG was erected

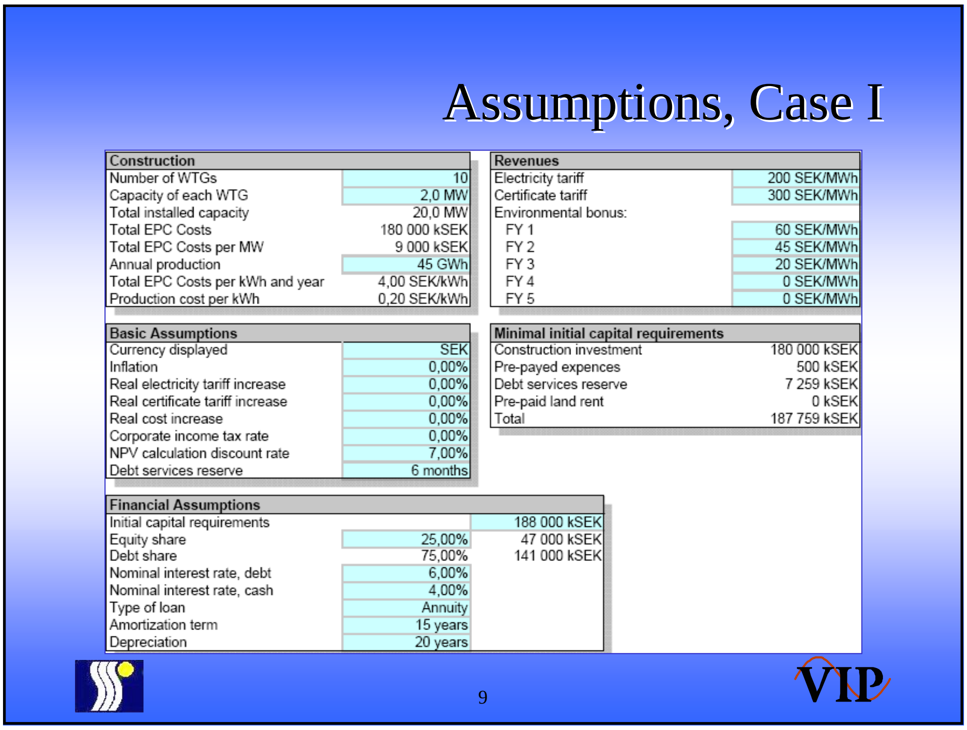
VIP



The importance of O & M costs

- Onshore costs are lower, normally between €c 0,8 – 1,3 per kWh, than offshore costs that easily run up to €c 1,0 – 2,0 per kWh
- The span is caused by varying production which, in turn, is based on wind speed at hub height
- O & M costs constitute about 25 % of total production costs onshore

VIP



Assumptions, Case I

Construction	
Number of WTGs	10
Capacity of each WTG	2,0 MW
Total installed capacity	20,0 MW
Total EPC Costs	180 000 kSEK
Total EPC Costs per MW	9 000 kSEK
Annual production	45 GWh
Total EPC Costs per kWh and year	4,00 SEK/kWh
Production cost per kWh	0,20 SEK/kWh

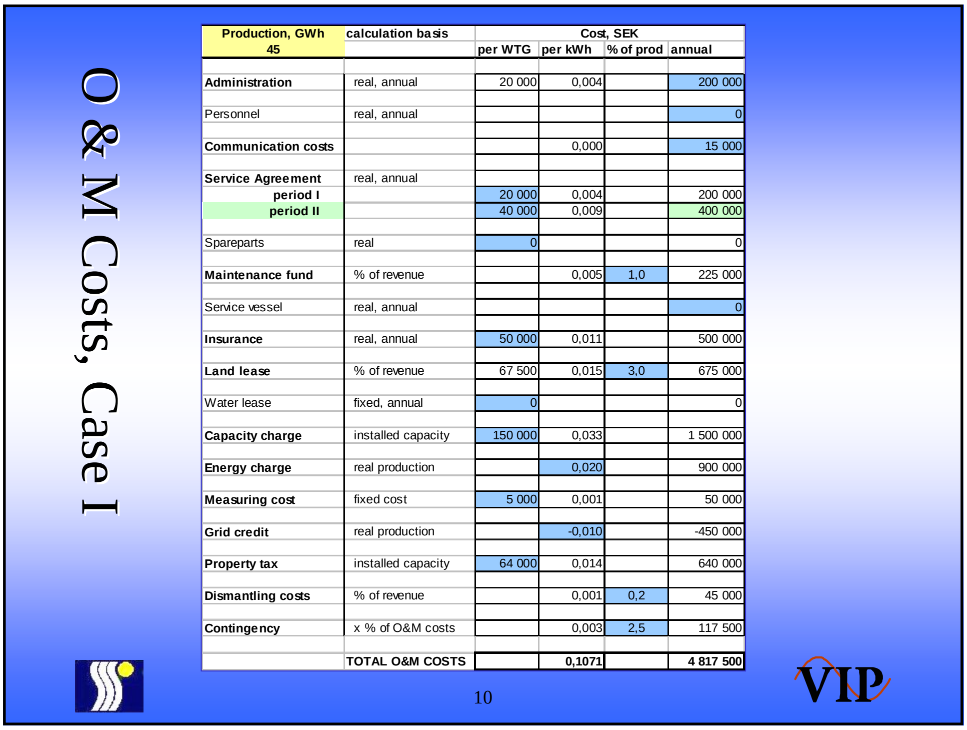
Revenues	
Electricity tariff	200 SEK/MWh
Certificate tariff	300 SEK/MWh
Environmental bonus:	
FY 1	60 SEK/MWh
FY 2	45 SEK/MWh
FY 3	20 SEK/MWh
FY 4	0 SEK/MWh
FY 5	0 SEK/MWh

Basic Assumptions	
Currency displayed	SEK
Inflation	0,00%
Real electricity tariff increase	0,00%
Real certificate tariff increase	0,00%
Real cost increase	0,00%
Corporate income tax rate	0,00%
NPV calculation discount rate	7,00%
Debt services reserve	6 months

Minimal initial capital requirements	
Construction investment	180 000 kSEK
Pre-payed expences	500 kSEK
Debt services reserve	7 259 kSEK
Pre-paid land rent	0 kSEK
Total	187 759 kSEK

Financial Assumptions		
Initial capital requirements		188 000 kSEK
Equity share	25,00%	47 000 kSEK
Debt share	75,00%	141 000 kSEK
Nominal interest rate, debt	6,00%	
Nominal interest rate, cash	4,00%	
Type of loan	Annuity	
Amortization term	15 years	
Depreciation	20 years	

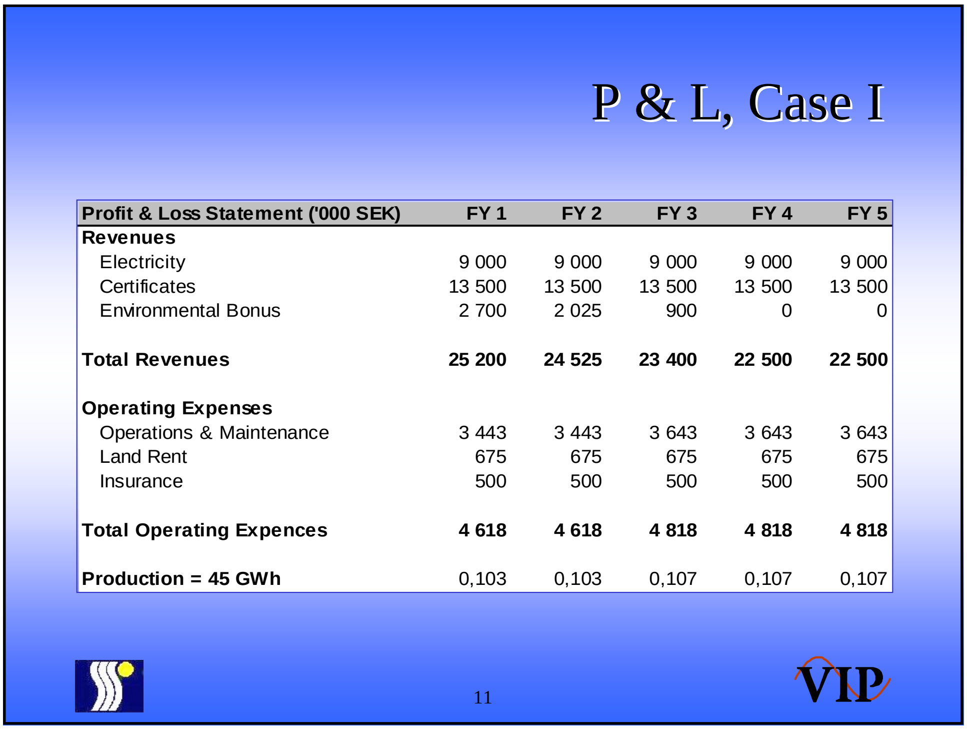
VIP



O & M Costs, Case I

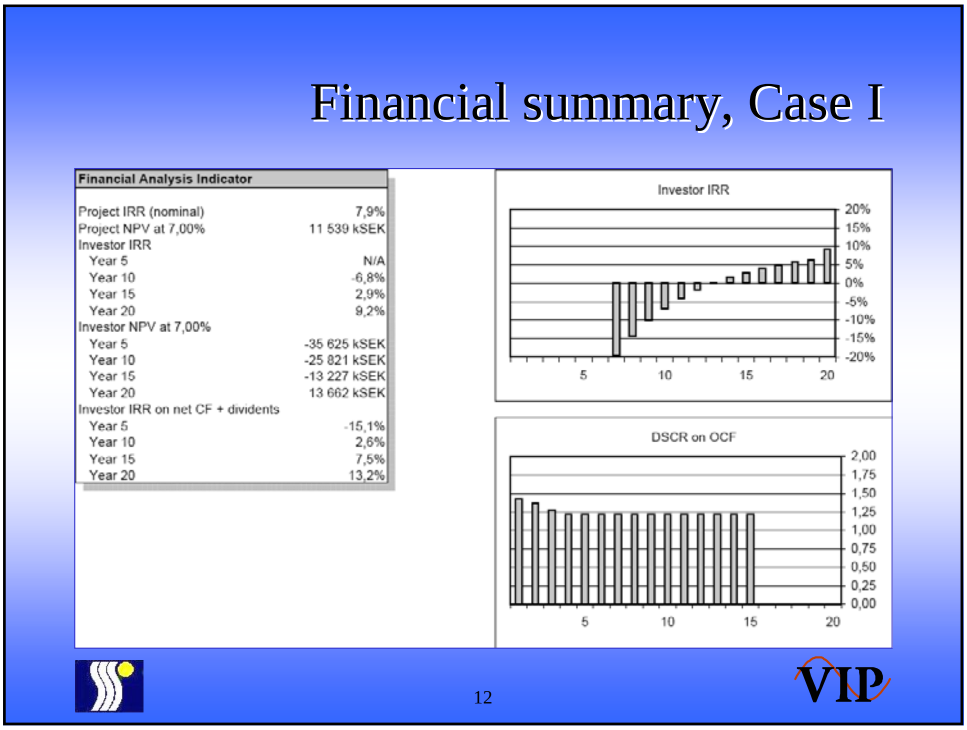
Production, GWh 45	calculation basis	Cost, SEK			
		per WTG	per kWh	% of prod	annual
Administration	real, annual	20 000	0,004		200 000
Personnel	real, annual				0
Communication costs			0,000		15 000
Service Agreement	real, annual				
period I		20 000	0,004		200 000
period II		40 000	0,009		400 000
Spareparts	real	0			0
Maintenance fund	% of revenue		0,005	1,0	225 000
Service vessel	real, annual				0
Insurance	real, annual	50 000	0,011		500 000
Land lease	% of revenue	67 500	0,015	3,0	675 000
Water lease	fixed, annual	0			0
Capacity charge	installed capacity	150 000	0,033		1 500 000
Energy charge	real production		0,020		900 000
Measuring cost	fixed cost	5 000	0,001		50 000
Grid credit	real production		-0,010		-450 000
Property tax	installed capacity	64 000	0,014		640 000
Dismantling costs	% of revenue		0,001	0,2	45 000
Contingency	x % of O&M costs		0,003	2,5	117 500
	TOTAL O&M COSTS		**0,1071**		**4 817 500**

VIP



P & L, Case I

Profit & Loss Statement ('000 SEK)	FY 1	FY 2	FY 3	FY 4	FY 5
Revenues					
Electricity	9 000	9 000	9 000	9 000	9 000
Certificates	13 500	13 500	13 500	13 500	13 500
Environmental Bonus	2 700	2 025	900	0	0
Total Revenues	**25 200**	**24 525**	**23 400**	**22 500**	**22 500**
Operating Expenses					
Operations & Maintenance	3 443	3 443	3 643	3 643	3 643
Land Rent	675	675	675	675	675
Insurance	500	500	500	500	500
Total Operating Expences	**4 618**	**4 618**	**4 818**	**4 818**	**4 818**
Production = 45 GWh	0,103	0,103	0,107	0,107	0,107



Financial summary, Case I

Financial Analysis Indicator	
Project IRR (nominal)	7,9%
Project NPV at 7,00%	11 539 kSEK
Investor IRR	
Year 5	N/A
Year 10	-6,8%
Year 15	2,9%
Year 20	9,2%
Investor NPV at 7,00%	
Year 5	-35 625 kSEK
Year 10	-25 821 kSEK
Year 15	-13 227 kSEK
Year 20	13 662 kSEK
Investor IRR on net CF + dividents	
Year 5	-15,1%
Year 10	2,6%
Year 15	7,5%
Year 20	13,2%

Assumptions, Case II

[redacted]

[redacted]

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O & M Costs, Case II

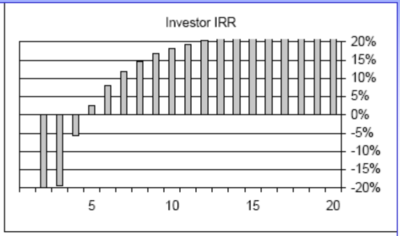
Production, GWh 60	calculation basis	Cost, SEK			
		per WTG	per kWh	% of prod	annual
Administration	real, annual	20 000	0,003		200 000
Personnel	real, annual				0
Communication costs			0,000		15 000
Service Agreement	real, annual				
period I		20 000	0,003		200 000
period II		40 000	0,007		400 000
Spareparts	real	0			0
Maintenance fund	% of revenue		0,005	1,0	300 000
Service vessel	real, annual				0
Insurance	real, annual	50 000	0,008		500 000
Land lease	% of revenue	90 000	0,015	3,0	900 000
Water lease	fixed, annual	0			0
Capacity charge	installed capacity	150 000	0,025		1 500 000
Energy charge	real production		0,020		1 200 000
Measuring cost	fixed cost	5 000	0,001		50 000
Grid credit	real production		-0,010		-600 000
Property tax	installed capacity	64 000	0,011		640 000
Dismantling costs	% of revenue		0,001	0,2	60 000
Contingency	x % of O&M costs		0,002	2,5	129 125
	TOTAL O&M COSTS		**0,0916**		**5 494 125**

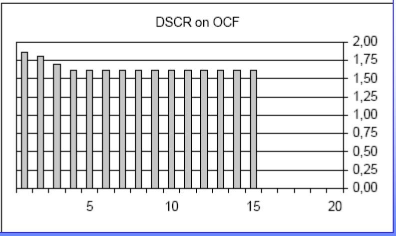
P & L, Case II

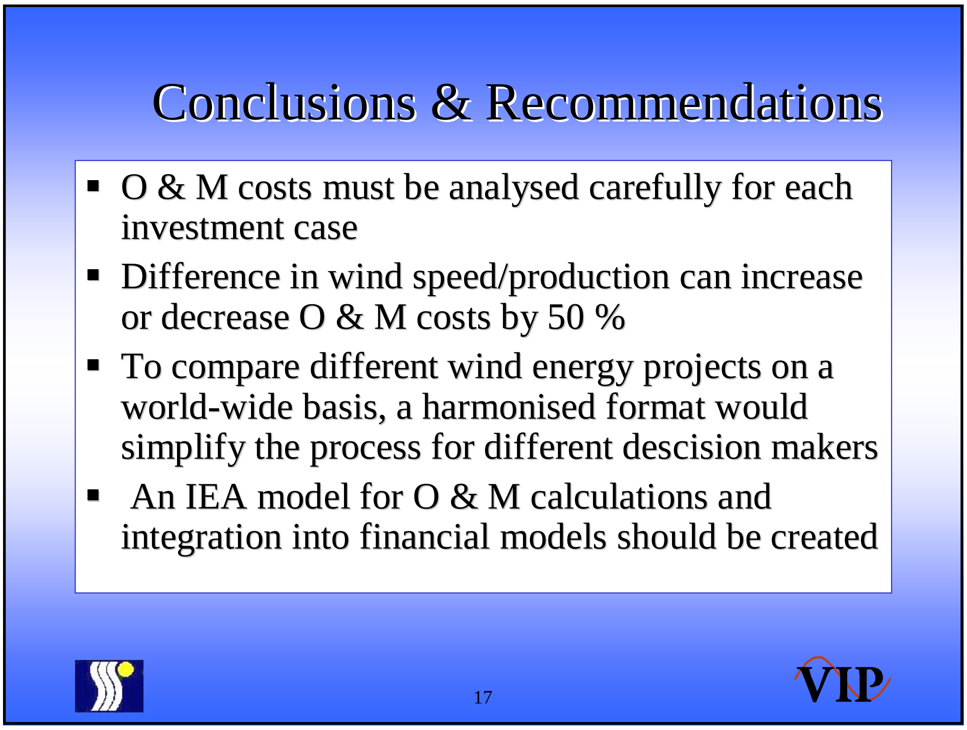
Profit & Loss Statement ('000 SEK)	FY 1	FY 2	FY 3	FY 4	FY 5
Revenues					
Electricity	12 000	12 000	12 000	12 000	12 000
Certificates	18 000	18 000	18 000	18 000	18 000
Environmental Bonus	3 600	2 700	1 200	0	0
Total Revenues	**33 600**	**32 700**	**31 200**	**30 000**	**30 000**
Operating Expenses					
Operations & Maintenance	3 894	3 894	4 094	4 094	4 094
Land Rent	900	900	900	900	900
Insurance	500	500	500	500	500
Total Operating Expences	**5 294**	**5 294**	**5 494**	**5 494**	**5 494**
Production = 60GWh	0,088	0,088	0,092	0,092	0,092

Financial summary, Case II

Financial Analysis Indicator	
Project IRR (nominal)	13,1%
Project NPV at 7,00%	85 134 kSEK
Investor IRR	
Year 5	2,4%
Year 10	18,2%
Year 15	21,9%
Year 20	23,5%
Investor NPV at 7,00%	
Year 5	-4 839 kSEK
Year 10	24 221 kSEK
Year 15	49 899 kSEK
Year 20	86 908 kSEK
Investor IRR on net CF + dividents	
Year 5	29,4%
Year 10	38,4%
Year 15	39,6%
Year 20	40,1%







Conclusions & Recommendations

- O & M costs must be analysed carefully for each investment case
- Difference in wind speed/production can increase or decrease O & M costs by 50 %
- To compare different wind energy projects on a world-wide basis, a harmonised format would simplify the process for different descision makers
- An IEA model for O & M calculations and integration into financial models should be created

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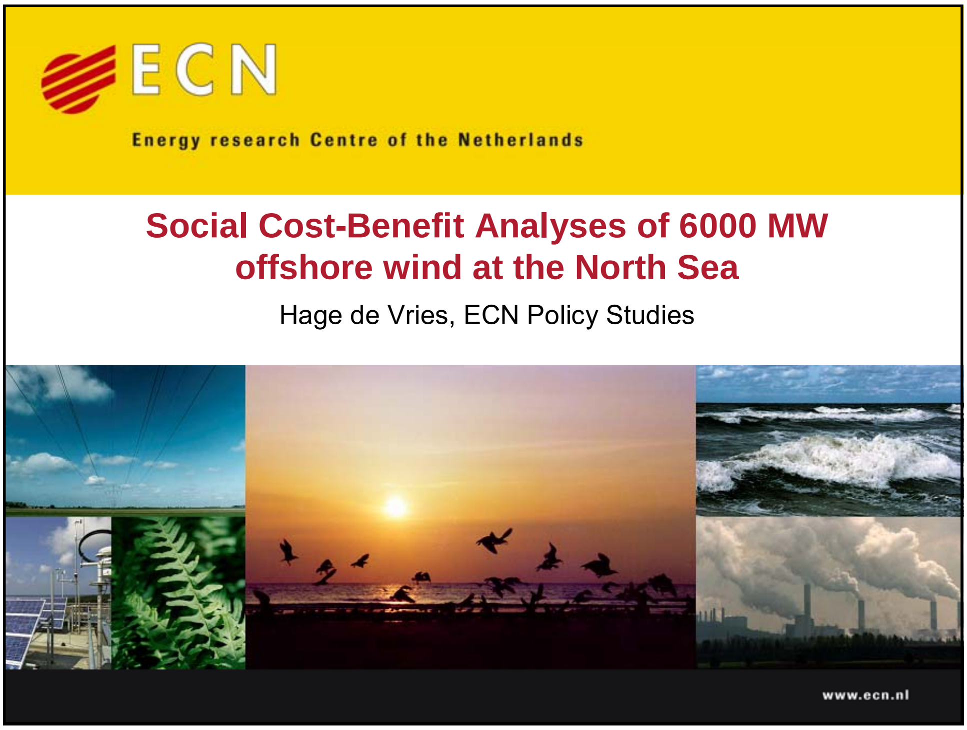
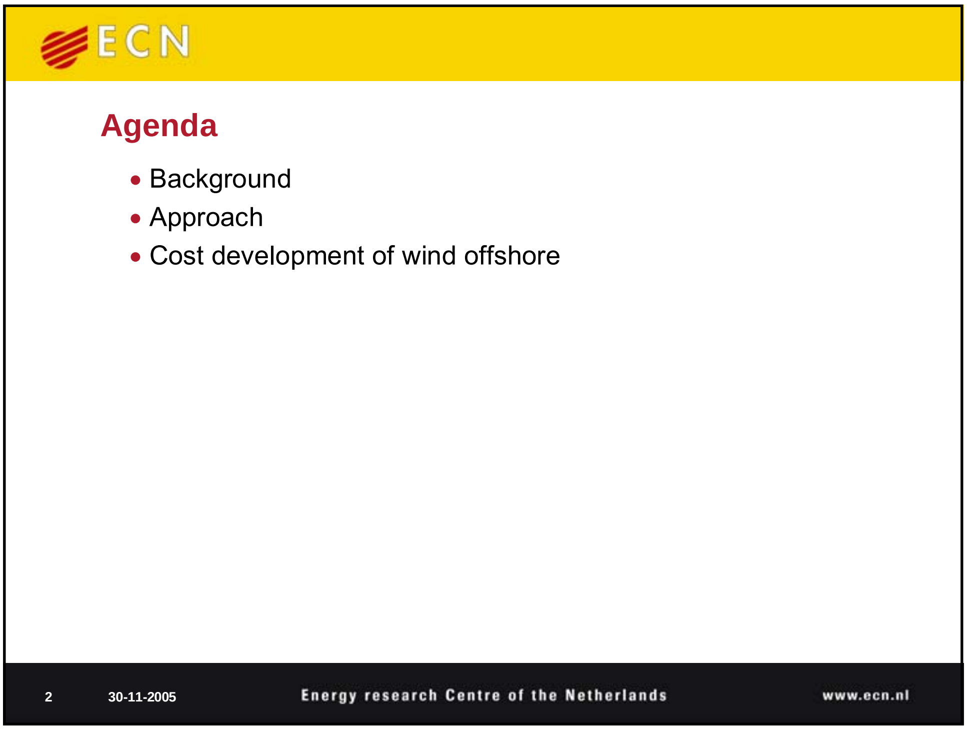


Energy research Centre of the Netherlands

Social Cost-Benefit Analyses of 6000 MW offshore wind at the North Sea

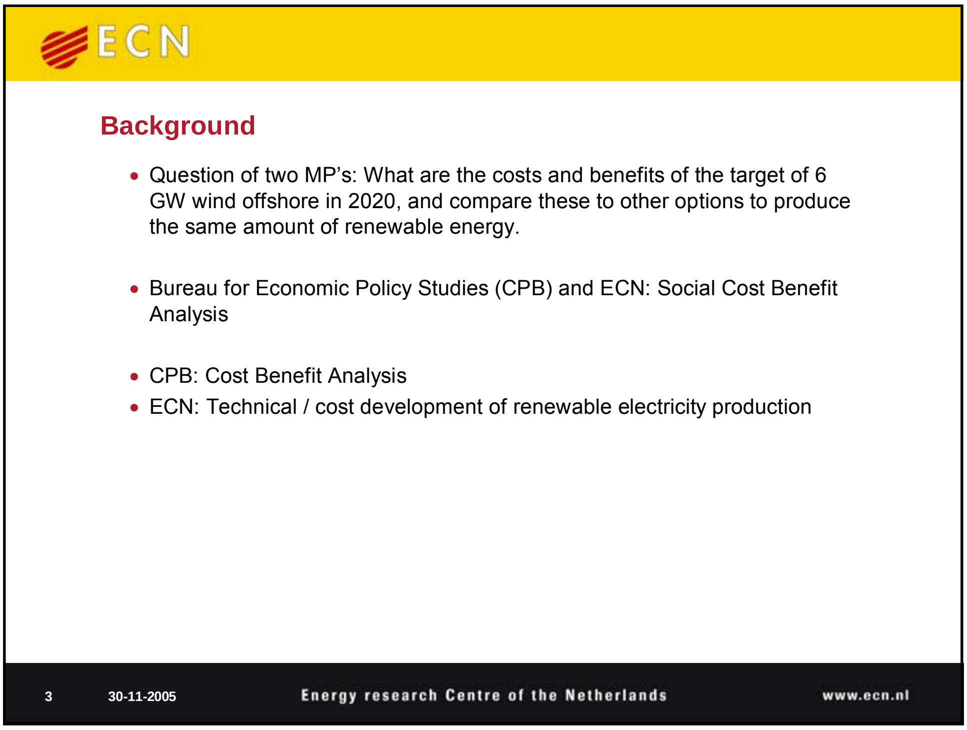
Hage de Vries, ECN Policy Studies

www.ecn.nl



Agenda

- Background
- Approach
- Cost development of wind offshore

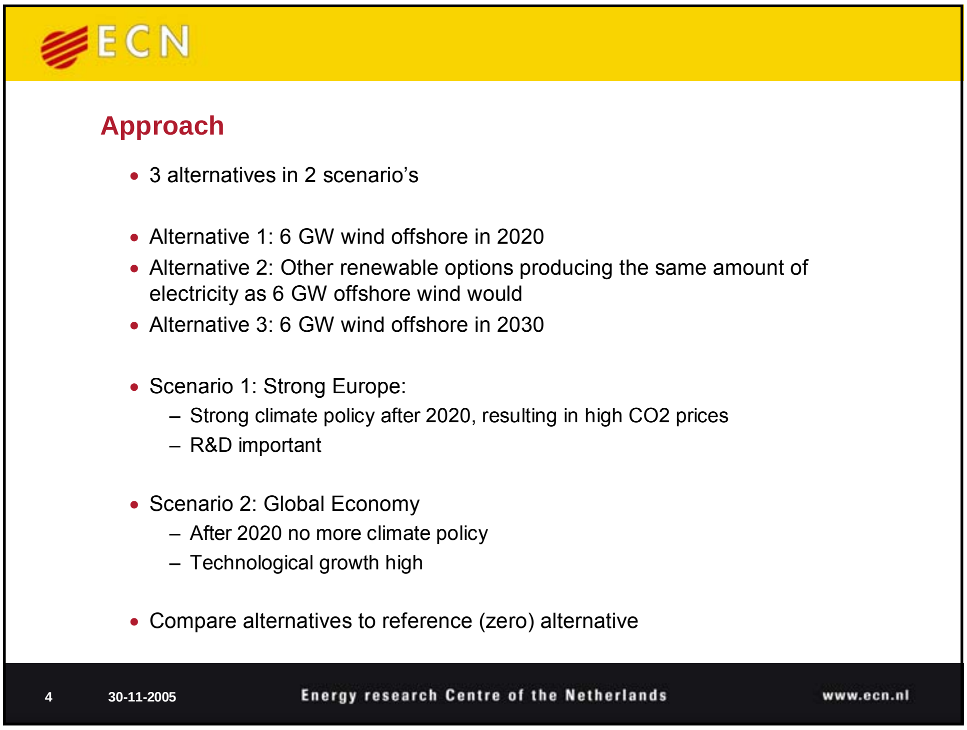


Background

- Question of two MP's: What are the costs and benefits of the target of 6 GW wind offshore in 2020, and compare these to other options to produce the same amount of renewable energy.

- Bureau for Economic Policy Studies (CPB) and ECN: Social Cost Benefit Analysis

- CPB: Cost Benefit Analysis
- ECN: Technical / cost development of renewable electricity production



Approach

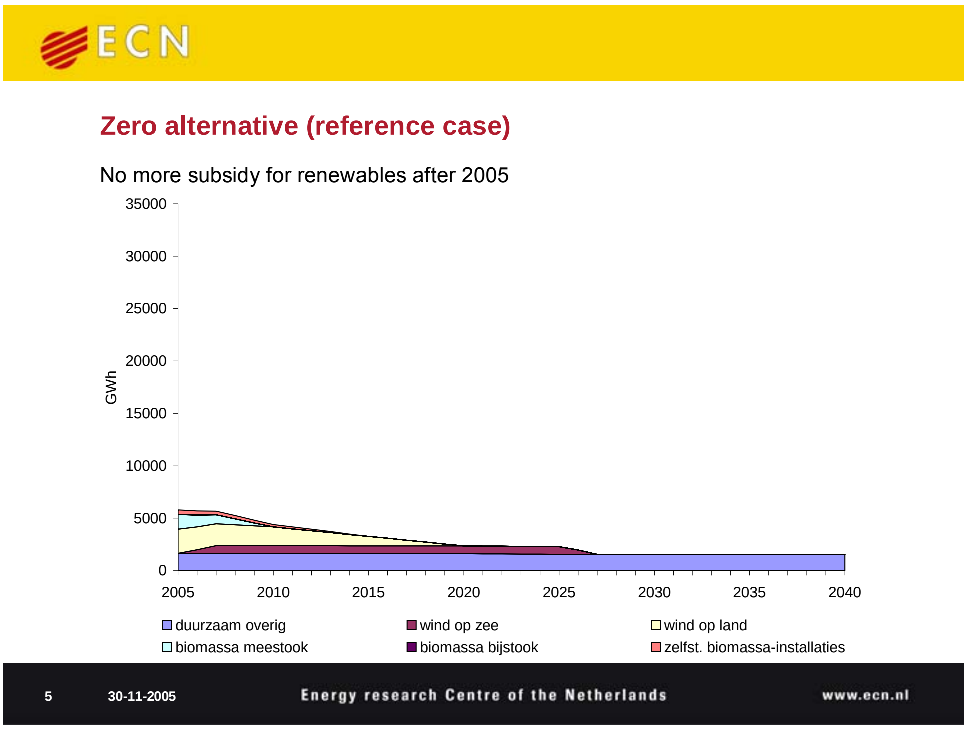
- 3 alternatives in 2 scenario's

- Alternative 1: 6 GW wind offshore in 2020
- Alternative 2: Other renewable options producing the same amount of electricity as 6 GW offshore wind would
- Alternative 3: 6 GW wind offshore in 2030

- Scenario 1: Strong Europe:
  - Strong climate policy after 2020, resulting in high CO2 prices
  - R&D important

- Scenario 2: Global Economy
  - After 2020 no more climate policy
  - Technological growth high

- Compare alternatives to reference (zero) alternative



ECN

Zero alternative (reference case)

No more subsidy for renewables after 2005

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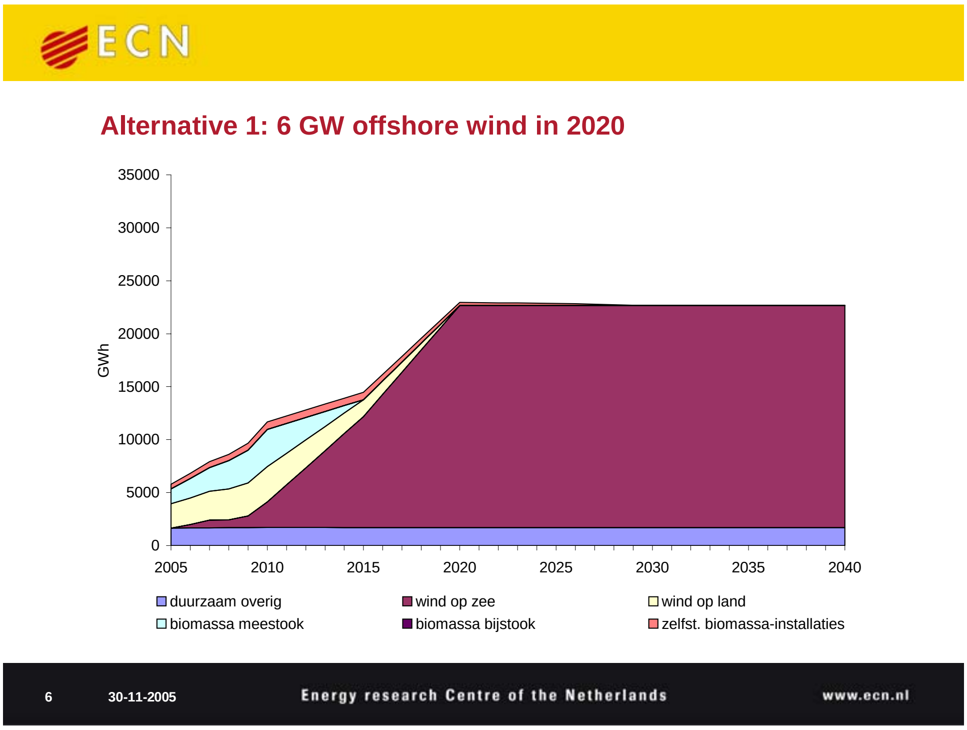

ECN

Alternative 1: 6 GW offshore wind in 2020

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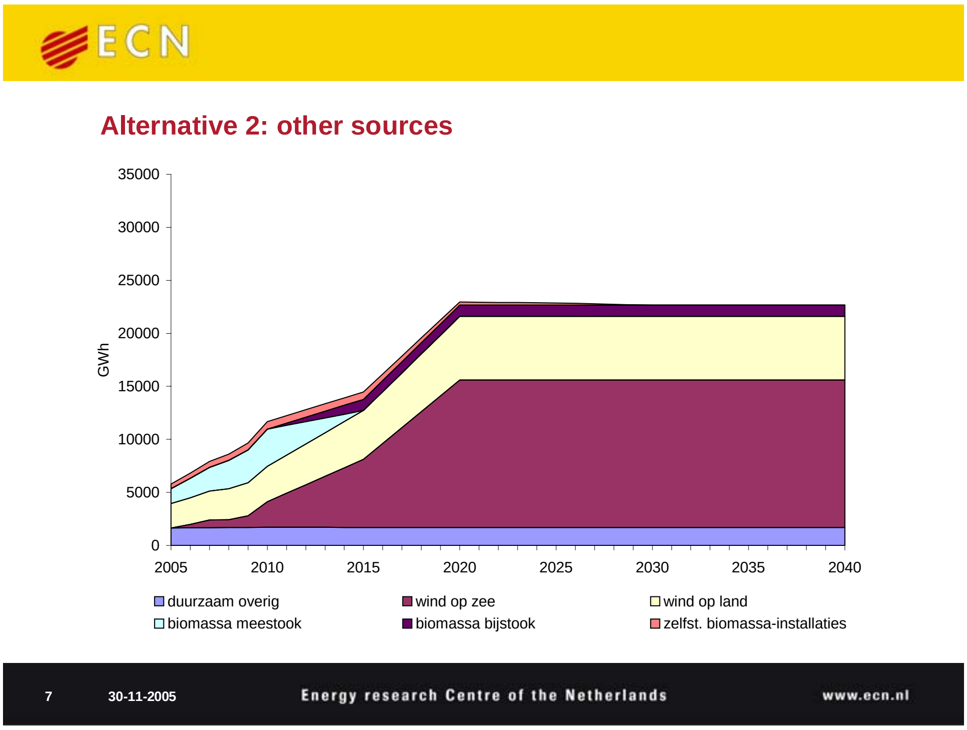

Alternative 2: other sources

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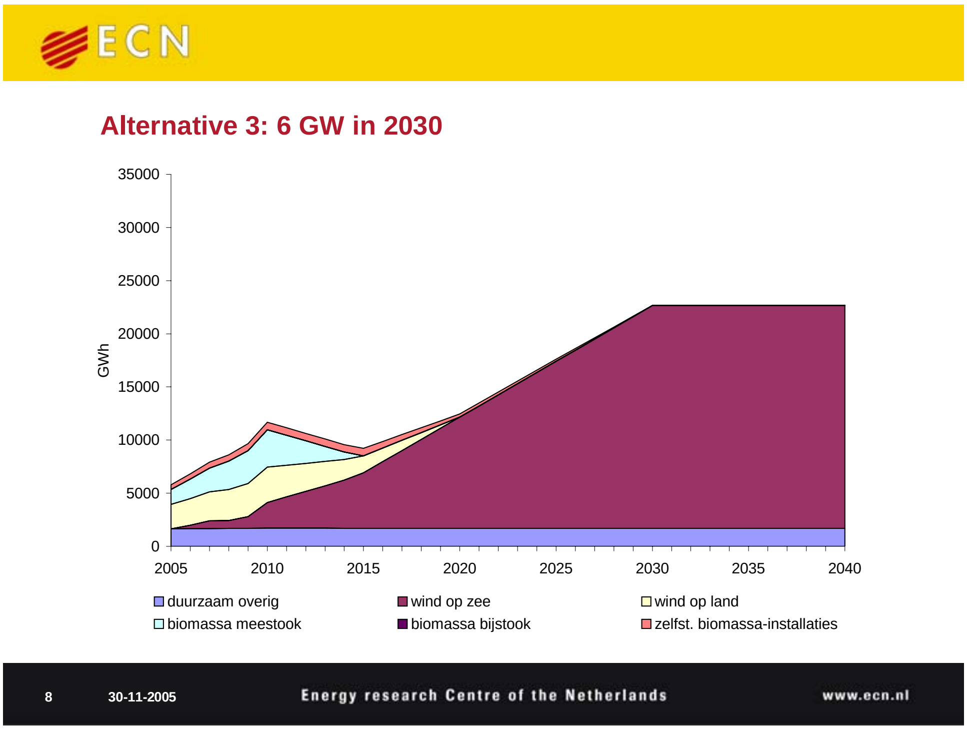

Alternative 3: 6 GW in 2030

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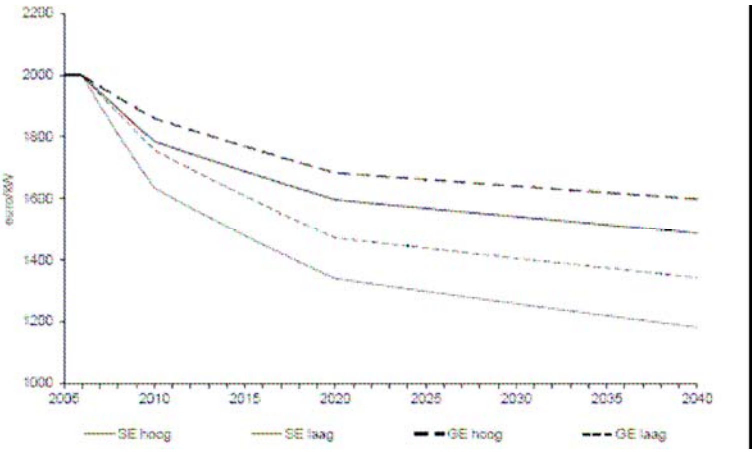
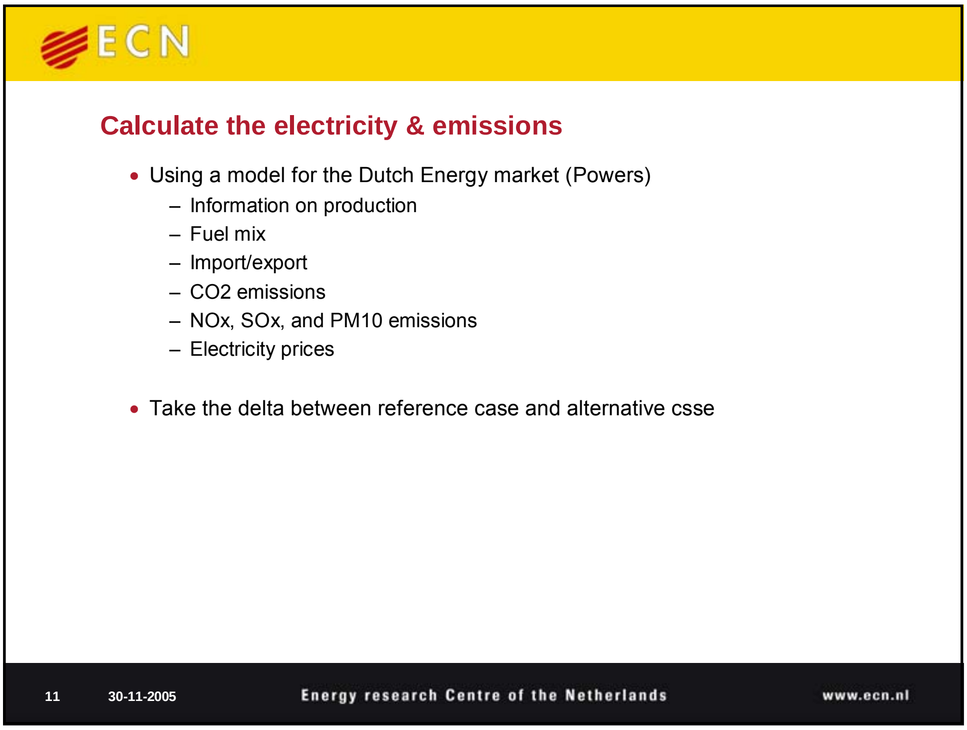
Cost development of wind offshore

- Learning curve approach
- Assumptions on development of global capacity
- Assumptions on progress ratio’s:
  - Fast learning components
  - Slow learning components
  - Non learning components

- Also learning curve on O&M costs

Investment cost development

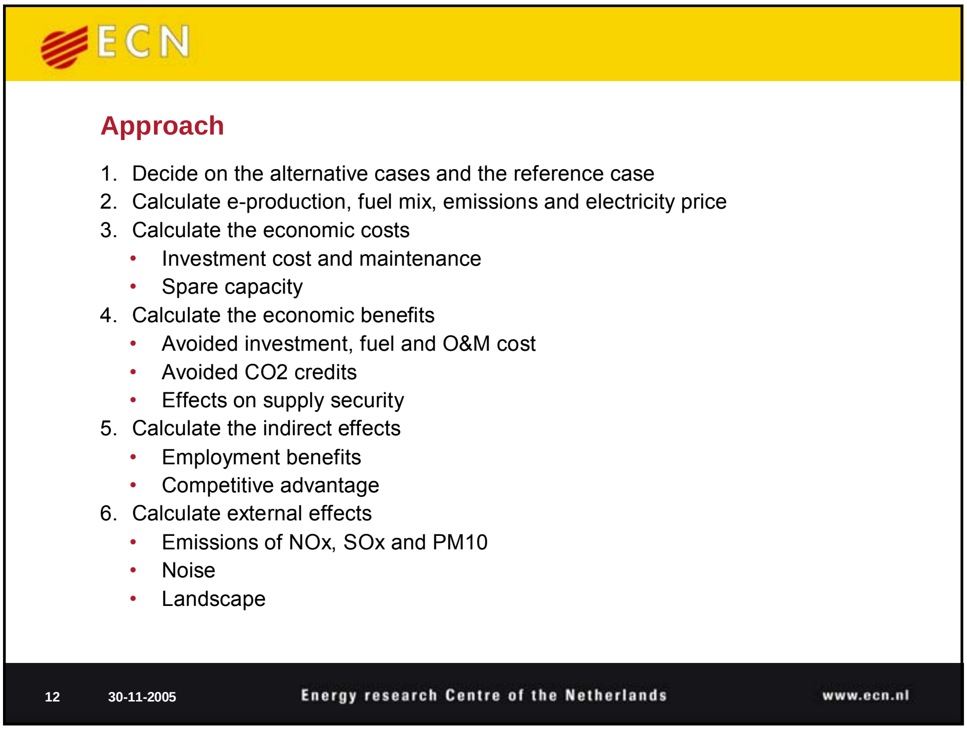




Calculate the electricity & emissions

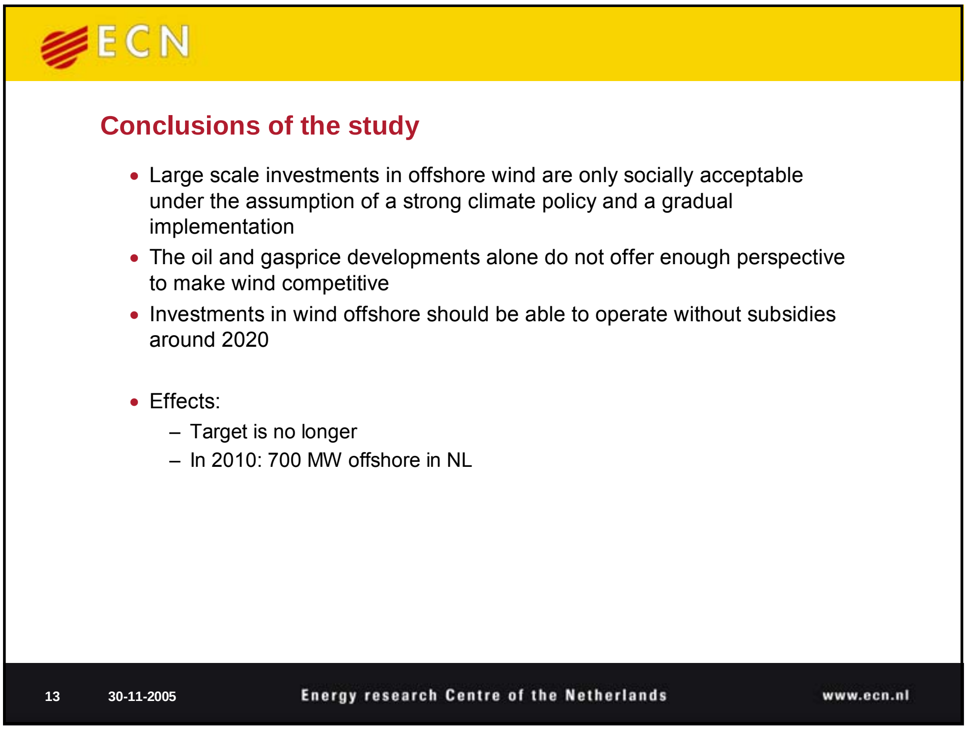
- Using a model for the Dutch Energy market (Powers)
  - Information on production
  - Fuel mix
  - Import/export
  - CO2 emissions
  - NOx, SOx, and PM10 emissions
  - Electricity prices

- Take the delta between reference case and alternative csse



Approach

1. Decide on the alternative cases and the reference case
2. Calculate e-production, fuel mix, emissions and electricity price
3. Calculate the economic costs
   - Investment cost and maintenance
   - Spare capacity
4. Calculate the economic benefits
   - Avoided investment, fuel and O&M cost
   - Avoided CO2 credits
   - Effects on supply security
5. Calculate the indirect effects
   - Employment benefits
   - Competitive advantage
6. Calculate external effects
   - Emissions of NOx, SOx and PM10
   - Noise
   - Landscape



ECN

Conclusions of the study

- Large scale investments in offshore wind are only socially acceptable under the assumption of a strong climate policy and a gradual implementation
- The oil and gasprice developments alone do not offer enough perspective to make wind competitive
- Investments in wind offshore should be able to operate without subsidies around 2020

- Effects:
  - Target is no longer
  - In 2010: 700 MW offshore in NL

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Summary of IEA RD&D Wind – 47th Topical Expert Meeting on

METHODOLOGIES FOR ESTIMATION OF COST OF WIND ENERGY AND THE METHODOLOGIES TO ESTIMATE THE IMPACT OF RESEARCH ON THE COST

November 2005, Paris, IEA Headquarters
Tomas Björnsson and Sven-Erik Thor

Background

The cost of wind-generated electricity may be estimated in a variety of ways. Additionally, there are a number of different reasons for the development of cost data, for example:

- Showing technical advancements
- Comparing different technology options
- Determining research focus areas

A macro economic approach requires methods that are different from those needed for a private financial analyst and would possibly generate cost of energy figures not suitable for comparison.

Also, including the effects of noise, visual impact or environmental influence would yield results not comparable with other estimations that do not include such external factors.

Furthermore, even analyses intended for the same purpose may have different ways of estimating the cost of energy, and thus care should be taken whenever comparing energy cost figures to ensure that the same analysis methods have been used.

Objective

The objective of the 47th Topical Expert Meeting was to review and evaluate the status of research, experiences and activities concerning cost modelling in relation to wind energy development.

Furthermore, the meeting aims were to review and discuss the different methodologies used to evaluate and quantify the effect of research on the cost of (wind) electricity.

Questions relevant to the meeting:

- Is it useful to update the Recommended Practice for cost modelling?
- Should common elements, guiding principles and recommendations be formulated for models to quantify the effect of research on cost reductions?
- Is it useful to develop a standard methodology for evaluating RD&D proposals?

Participants/Presentations

A total of 11 participants attended this meeting with representatives from Denmark, Germany, Ireland, Italy, the Netherlands, the UK, the US and Sweden. The participants represented National Research Centres, Investor & Developer Organisations, Consultancy companies and Utilities.

A total of 13 presentations were given on the following topics:

1. Methodologies for Estimating the Cost of Wind Energy – An Irish Perspective
2. U.S. DOE WHTP Wind Energy Cost of Energy Calculation
3. Minimizing Costs in the Electricity Generation Mix With High Shares of Wind Energy at the Long-scale
4. Basic Cost and Profitability Calculation Model for Wind Power Projects
5. Calculating the Financial Gap of Offshore Wind
6. The Cost of Offshore Wind Energy
7. Important Considerations for Developing a Support Scheme
8. How Does R&D Reduce the Cost of Wind Energy?
9. Thoughts on Where to Look for Improved Financials
10. Defining Technology Goals and Tracking Wind R&D Progress
11. Wind Farm O&M Costs
12. Methodologies for Estimation of Cost of Wind Energy
13. Social Cost-Benefit Analysis of 6000 MW Offshore Wind at the North Sea

Discussion

A discussion was held on two topics:

- Should IEA update the recommended practice on Estimation of Cost?
- How should the cost benefit of R&D proposals/projects be estimated?

Should IEA update their recommended practice on Estimation of Cost?

Cost analyses intended for the same purpose may have different ways of estimating the cost of energy. Including or excluding external factors would yield different results, as would parameter variations of life length, discount rate, including/excluding the cost of the export cable, etc.

With this background, the IEA Recommended Practice entitled “Estimation of Cost of Energy from Wind Energy Systems” was put together, the second edition being published in 1994.

There still exists great difficulty in answering the question of what the cost of wind power really is. Going offshore has added a new dimension of uncertainty in how to answer this question. By updating the recommended practice, it is certain that the meeting results are distributed to all IEA member countries and do not stay within the walls of this meeting.

However, the vast amount of effort required for an update should be taken into consideration, and the Recommended Practice should not be updated unless enough benefits from doing so are seen.

The most significant benefits from updating the Recommended Practice are found to be:

- Using an update as a way of sharing the results of this expert meeting with others
- Being able to determine what the cost of wind power really is

The issue of modelling the cost of wind energy can be split into two separate issues:

- Modelling of the COE in general
- Wind power specific issues

An idea would be to raise the modelling of COE to a higher level than the Wind RD&D working group, allowing input from other energy sources as well. This would enable the IEA RD&D Wind group to focus on the wind specific issues, and the result of this workshop and the aftermath would not be an update of the Recommended Practice but an entirely new document.

As few significant benefits are found as a consequence of updating the recommended practice, the recommendations to the Executive Committee are:

- Not to update the recommended practice on cost modelling
    - Instead allow the writing of a new document about the cost of wind power in a broader sense
        - Input on what such a paper would include is to be gathered afterwards by circulating a document among the attendants of this meeting
    - Instead prioritise a new annex for evaluating the cost benefits from RD&D programs/projects

Cost Benefits of R&D proposals

Wind power generation has come to a “historical” point where investment cost per MW, and hence the cost per generated kWh, is increasing for new wind turbines. Some reasons for this increase are believed to be:

- The increasing price of raw material, especially for steel
- Turbine manufacturers’ focus on meeting order stocks rather than on cost performance (lack of competition)

Current signals on the US market indicate possibilities of future onshore investment levels around 1800 $/kW.

National support systems with a fixed high tariff or increasing quotas for RES are driving higher cost for the end consumer since the quotas are currently not being met. The high revenue levels for producers of renewable energy are believed not to encourage focus on cost performance for the manufacturers of wind turbines, and as a consequence, the production costs are unlikely to drop in the near future.

Since cost reductions in the immediate to near future may be discouraged by the current support systems in combination with the lack of competition among turbine manufacturers, there is an increased need to focus on:

- RD&D programs for the cost reduction possibilities of components other than turbines
    - Foundations, grid connection, export cable, etc.
    - These cost components make up half the investment cost and are potentially a source of future cost reduction.
- Evaluating the cost benefits of RD&D programs
    - Despite the imminent need for cost reduction, not all countries seem to take this parameter into consideration when evaluating RD&D proposals.
    - A well developed methodology to evaluate RD&D proposals on their ability to contribute to overall wind power cost reduction should yield much more effective RD&D in terms of reducing cost.
    - Inviting turbine manufacturers to take part in the working group may yield insights on where the greatest potential can be found.

As the value of evaluating RD&D proposals is significant, the question may be better dealt with within the framework of a new annex. An annex is a good way of investigating the issue further, due to its simplicity, speed and its way of operating around a specific theme. The annex members will have to find funding themselves - joining the annex is a commitment to supporting and financing the Operating Agent of the Annex.

A list of bullet points will be circulated and a working group will type up a proposal for an annex. The working group will consist of:

- Ian Baring-Gould, National Wind Technology Center, U.S.A.
- Tomas Björnsson, SwedPower AB, Sweden
- Niels Erik Clausen, RISØ National Laboratory Wind Energy Department, Denmark
- Hage deVries, ECN Policy Studies, the Netherlands

The result of the working group will be a 3 – 5 page proposal submitted to the Executive Committee. The future of the Wind RD&D cost benefit annex will be discussed at the next Executive Committee meeting.

- The process may be accelerated if the proposal is sent out ahead of the Executive Committee meeting in March.
    - All present at this workshop will get a circulating document and will be able to make comments. Everyone is encouraged to contact their country representative to discuss the matter beforehand.
    - Mid-February – document ready

The recommendations for the Executive Committee are to:

- Take into consideration the starting of an annex with focus on how to evaluate the cost benefits of RD&D programs.
- Include representatives from WTG manufacturers and industry organisations, such as EWEA, in the working group.

Continuation

A paper will be circulated among the group participants in order to ensure that everyone gets a chance to comment on the recommendations for the Executive Committee and the content of the proposal.

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IEA R&D Wind Annex XI, Topical Expert Meeting
METHODOLOGIES FOR ESTIMATION OF COST OF WIND ENERGY
IEA HQ, Paris
29-30 November 2005

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