

Can we reduce the cost of energy by 40% in 2020?

Which innovations are needed and how/what will they contribute

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Introduction

- ✓ Now (2015) installed capacity of offshore wind energy is approx. 8 GW
- ✓ The target for 2020 is 47 GW in European offshore waters (EC 2013), medium growth scenario estimate EWEA (2014) 23,5 GW

To make growth possible a large cost reduction is required!

Netherlands

- ✓ Agreement between largest stake holders to reduce the cost of energy with 40%, from € 170/MWh to € 100/MWh, between 2010 – 2020 (FID)

UK

- ✓ Crown Estate, pathway study aims at a cost reduction from £ 140/MWh (2011 FID) to £ 100 / MWh (2020 FID)
- ✓ Carbon Trust 40% capital requirement reduction between 2008 – 2020

Cost Model Assumptions and Sensitivities

The simplified cost equation is :

$$LCoE = \frac{\left(\frac{CapEx}{a} + OpEx \right)}{AEP}$$

Where (Reference values 2010 FID)

CAPEX = Capital requirement

= 4600 €/kW

OpEx = Annual operational cost

= 125 €/kW/year

$a = \text{Annuity} = \frac{(1 - (1+r)^{-n})}{r}$

$r = \text{average discount rate}$

$n = \text{economic lifetime} = 15 \text{ years}$

AEP based on Load Factor of 47,5%

Parameter variations show that =>

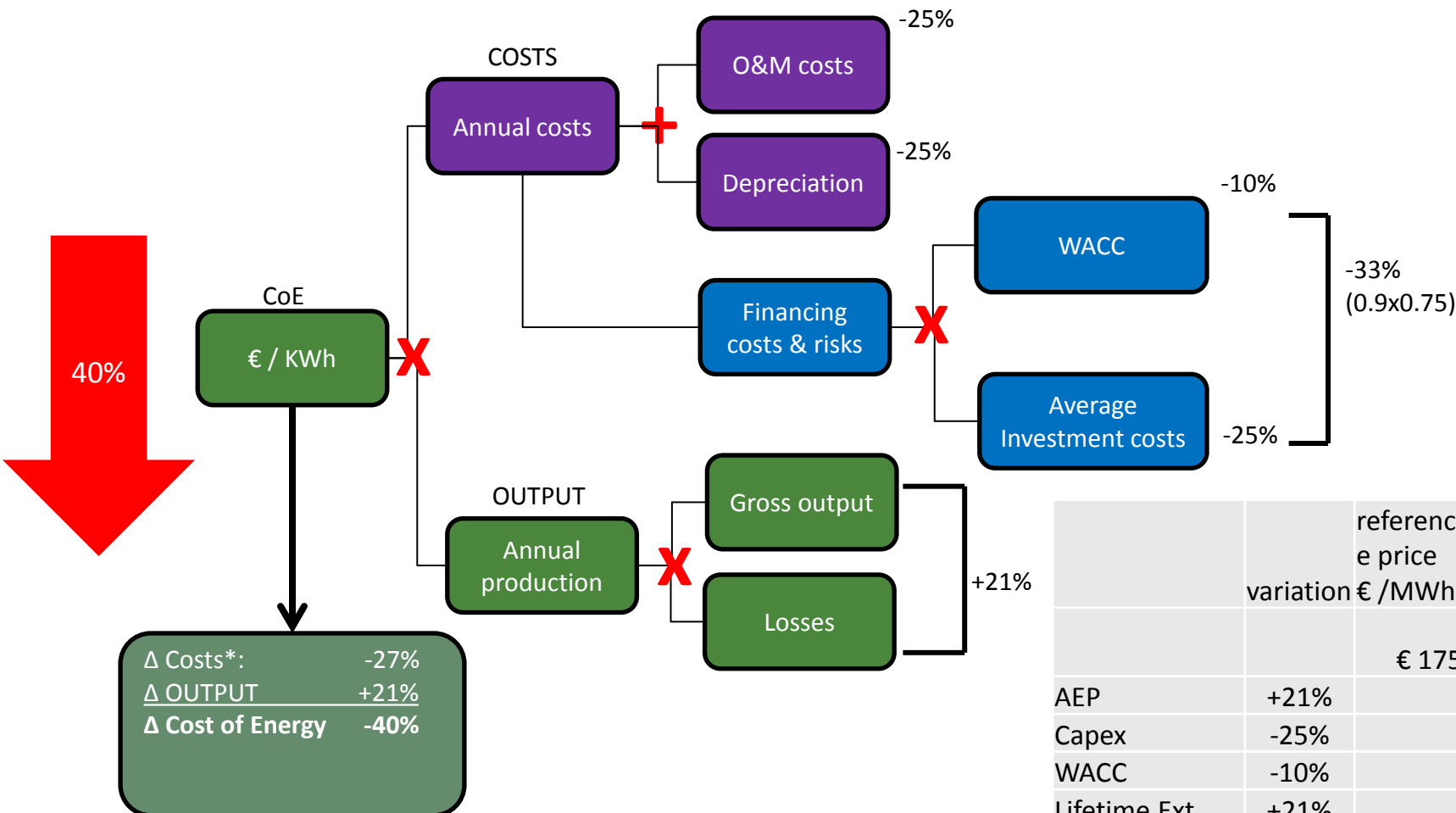
Capital Cost Assumptions

		interest /IRR
Equity	33,3%	15%
Debt	66,7%	7,5%
Average discount rate		10,0%

	variation	reference price €/MWh	LCoE variation
		€ 175	
AEP	10%	€ 159	-9,1%
CAPEX	-10%	€ 161	-8,3%
WACC	-10%	€ 167	-4,7%
Lifetime Extension	+10%	€ 169	-3,3%
OpEx	-10%	€ 172	-1,7%

So AEP and CAPEX have the highest influence!

Target LCoE reduction in the Netherlands*



	variation	reference price €/ MWh	LCoE variation
		€ 175	0,0%
AEP	+21%		
Capex	-25%		
WACC	-10%		
Lifetime Ext.	+21%		
Opex	-25%		
	total	€ 96	45%

*By TKI Wind @ Sea, based on typical costs offshore wind farm: 25-35% O&M, 40-50% CAPEX, 20-30% financing costs

ECN Cost Model

- ✓ Model is based on engineering cost models, making it especially suitable to validate innovations.

 - ✓ ECN integrated Wind Energy cost model consist of sub-models for
 - *Energy output*, bases on ECN **FARMFLOW**
 - Wind turbine
 - Support structure
 - Electrical infrastructure – inter array & export cable, based on ECN **EeFARM**
 - Logistics & installation **ECN INSTALL**
 - Project development - Financial Close
 - Other cost

 - O&M, based on **ECN O&M TOOL**
- } Capital cost

Technical Innovations Validated

Wind Farm innovations / cost reduction

- ✓ Optimum spacing and layout of wind turbines
- ✓ Wind Farm control, like .e.g. Active Wake Control
- ✓ Integrated project approach
- ✓ Grid connection via TSO

Wind Turbine innovations

- ✓ Upscaling from 4MW to 8 MW Wind Turbines
- ✓ Reduction of rotor power density, from 375 W/m² to 300 Watts/m²
- ✓ Integral design of wind turbine & support structure

Innovations in logistics, Installation

- ✓ Optimum planning of logistics taking weather conditions / predictions into account

Innovations in O&M

- ✓ Asset sharing
- ✓ Optimum planning, less re-active (corrective) O&M more pre-active (preventive and condition based) O&M

Innovations reducing LCoE CAPEX and/or energy yield



Increasing the output of the wind farm while reducing CAPEX

- ✓ Reduction of the Rotor Power density from 375 W/m² to 300 W/m²
Increasing the Net Capacity Factor for offshore wind farms from 45% - $\geq$ 55%

Challenges: To keep the CAPEX of the WT $\div D^2$ (Rotor Area)

- ✓ Upscaling from 4 MW, @ 375 $\Rightarrow D=116,5$ m to
8 MW @ 300 $\Rightarrow D=188,4$ m

Challenges: CAPEX $\div D^2$

Load reduction by advanced controllers

Efficient support structures

- ✓ Grid connection via TSO

- Lower WACC due to high equity on balance sheet and longer depreciation term
- Due to uniformity lower capital requirements
- Higher availability due to redundancy

- ✓ Increasing the availability from $\sim 93\%$ to $> 96\%$, excluding higher availability due to grid redundancy.

} -15%

- 10%

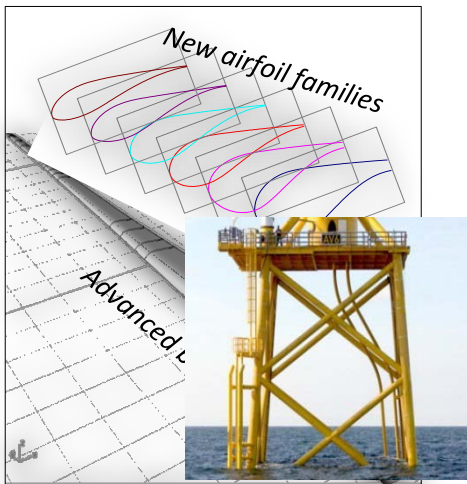
-3%

Fully Integrated wind farm design

A multi disciplinary approach



**Innovative Full Turbine design,
analysis and selection**



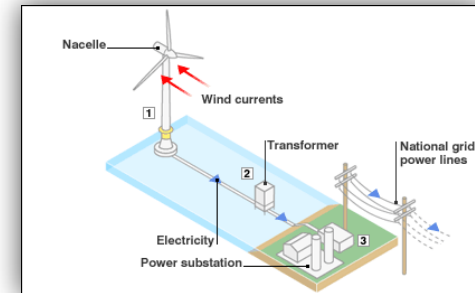
**Multi Disciplinary
Optimizer**

**ECN's Cost
Model**

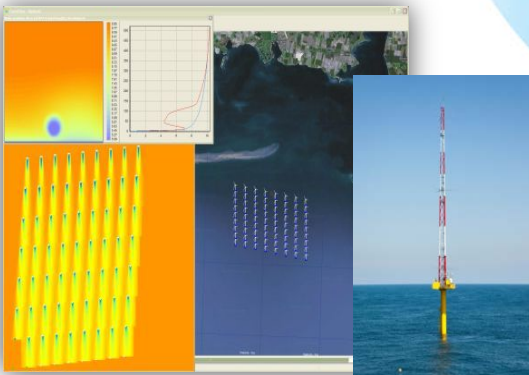


**Offshore wind
Power plant
LCoE reduction**

**Grid
connections
& electrical
systems**



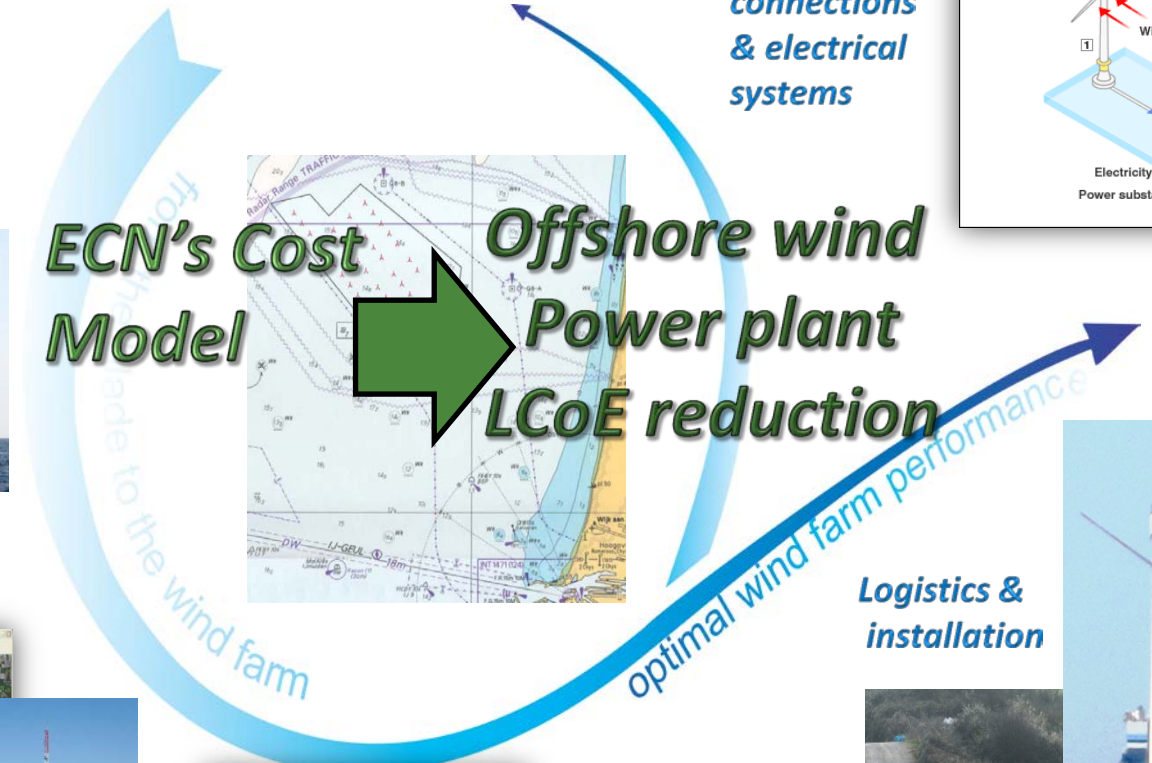
**Wind measurements &
Farm Power Forecasting**



**Logistics &
installation**



**O&M strategies
& infrastructure**

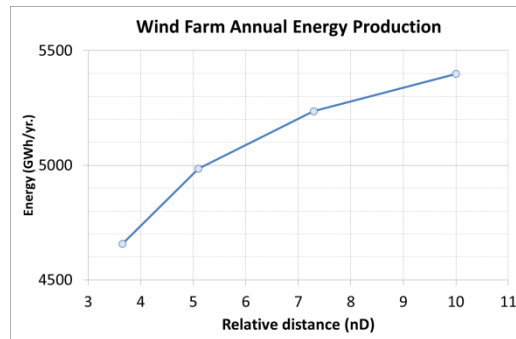


Example of the System Engineering approach

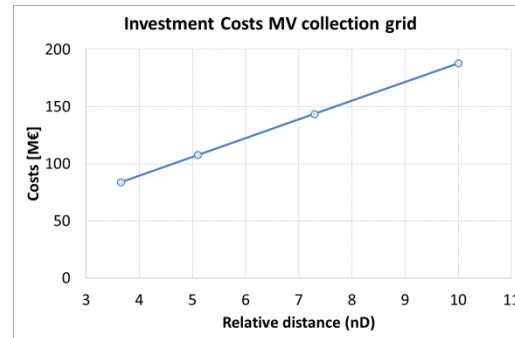
Optimisation of the Lay-Out (EERA DTOC project)

- ✓ 1 GW Wind farm, 100 WT's of 10 MW, in high wind speed regime.
- ✓ Virtual wind turbine used in EU project InnWind

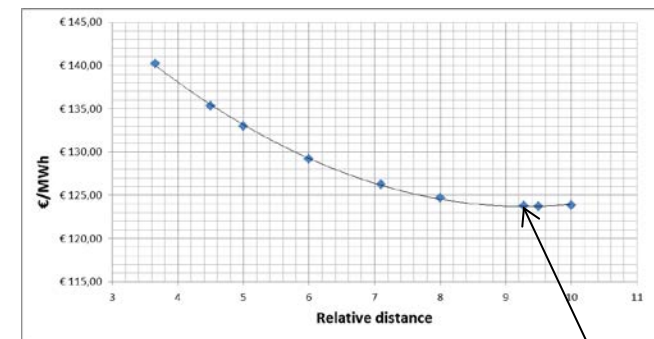
Net yield as function of the spacing



Cost of E-infra inside the WF



LCoE dependency on WF Spacing



Using simple cost model, assuming CapEx = k€ 3,5/kW @ 5 D spacing and
O&M = € 125 / MWh

~9,25 D

Cost reduction from 5 - 6 D spacing to optimal spacing - 6%

Reduction of WACC

- ✓ Main factor influencing the WACC, Risk perception:
 - ☐ Successful projects
 - ☐ Increase the transparency of offshore projects, see e.g. SPARTA programme in the UK (obligation via tender conditions?)
- ✓ Managing Risk instead of pricing risk
 - ☐ Sharing risk instead of stacking risk
 - ☐ Innovations separately financed / risks shared with public authorities
- ✓ Accelerator is to reduce the ratio Equity – Debt capital.

		interest /IRR
equity	25%	12,5%
loan	75%	6%
Average discount rate		7,6%

LCoE => - 10%

Risks that endanger the cost reductions

As all of Europe has challenging targets with respect to building up Offshore Wind Energy capacity till 2020 and beyond.

		2014/15	2020/23*	2030	
Belgium		712	1900	3000	
Denmark		1271	2236		
Germany		1049	6500	15000	
Netherlands		247	4500	6000+	
United Kingdom		4495	10000+	30000+	

* International Wind Energy Development offshore report 2013 BTM Consult

Due to these ambitious targets there is a chance that prices go up due to:

- ✓ Sensitivity to commodity prices, e.g. steel (support structures), or rare earth (permanent magnet generators).
- ✓ Shortage in installation ships which will drive up the price
- ✓ Higher capital cost (how unlikely it looks at the moment)

Conclusions, can the targets be achieved?

YES!

The options are available that the LCoE reduction targets can be achieved, however special attention should be given to :

- ✓ Implementing the innovations,
- ✓ technology advances, due to upscaling and capacity factor increase are in the pipeline, but need to show reliability
- ✓ NO focus on MW and more focus on GWh and LCoE

¿Questions?