Potential and realized economic impacts of NOWITECH innovations

Impello Management AS

Frode Iglebæk

23.08.2017

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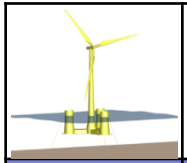
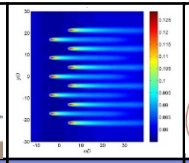
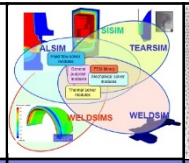
Realized economic impact from NOWITECH already exceeding the programme investment!

- **Research investment:** **35 MEUR** (NOWITECH budget 2009-2017)
- **Realized impact:** **35+ MEUR** (2 innovations + 3 companies)
- **Potential impact:** **>5 billion EUR** (7 innovations)

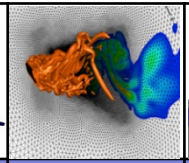
More than 40 innovations from NOWITECH 2009-2017

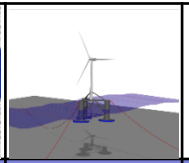

3Dfloat integrated model *TRL7*

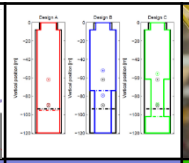

3DWind park wake model *TRL6*



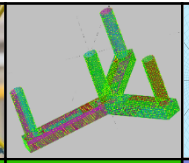
INVALS general purpose optimization *TRL8*

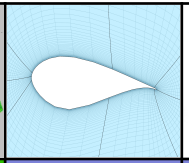

Commercial grade rotor CFD *TRL5*

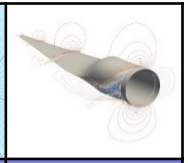

SIMO-RIFLEX *TRL7*


WindOpt *TRL4*

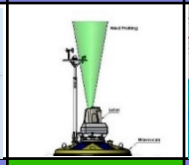

Real time hybrid model test in ocean basin *TRL5*

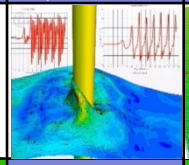

Novel floater *TRL5*

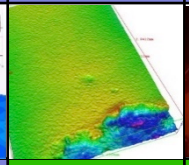

Variational Multiscale Error Estimator *TRL3*


www.IFEM.no *TRL3*


ASHES (SIMIS AS) www.ashes.no *TRL7*

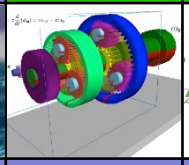

Seawatch Wind Lidar Buoy *TRL9*

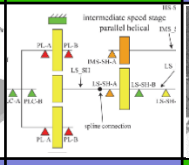

CFD simulation *TRL5*


Droplet erosion resistant blade coatings *TRL3*

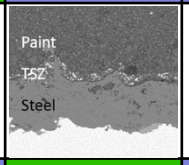

Droplet erosion testing *TRL5*


Fleet optimization *TRL5*

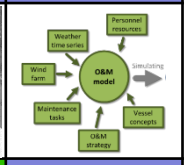

Gearbox fault detection *TRL3*



Gearbox vulnerability map *TRL3*

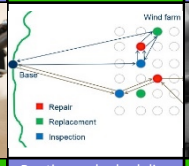


Dual layer corrosion protection coatings *TRL5*



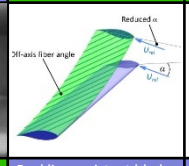
NOWIcob *TRL6*


REACT/Remote Presence (www.emip.no) *TRL5*

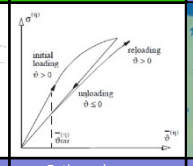


Routing and scheduling *TRL2*


Thermally sprayed SiC coatings *TRL5*

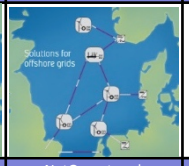


Buckling resistant blades *TRL3*

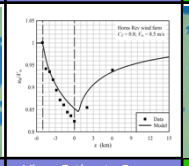


Fatigue damage simulation *TRL4*

PSST Power System Simulation *TRL5*



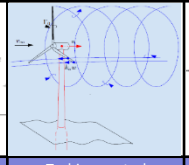
NetOp network optimization *TRL4*

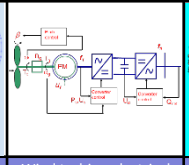

Viper Estimate Energy Output from OWF *TRL4*

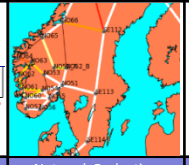
Smartgrid Lab HVDC grid *TRL4*

Control of multi-terminal HVDC grid *TRL4*


Wind Supply to Oil & Gas *TRL3*


Turbine control *TRL3*

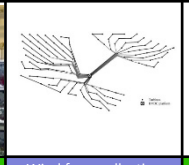

Wind turbine electrical interaction *TRL4*

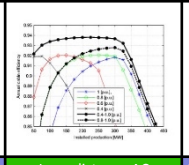

Network Reduction *TRL3*

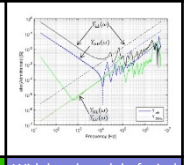

STAS Linear State-Space W.P. Plant Analysis *TRL4*


PM generator magnetic vibrations *TRL4*


PM generator integrated design *TRL3*


Wind farm collection grid optimization *TRL2*


Long distance AC transmission *TRL3*


Wideband model of wind farm collection grid *TRL2*

Numerical model

Technology / process

New business entity (spin-off)

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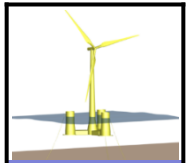
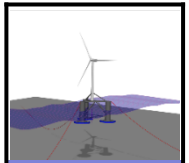
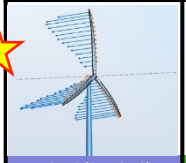
Review of 11 select innovations



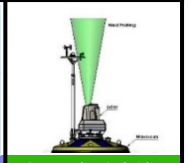
3Dfloat integrated model *TRL7*



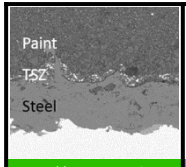
SIMO-RIFLEX *TRL7*



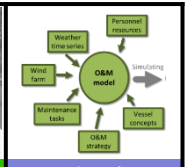
ASHES (SIMIS AS) www.ashes.no *TRL7*



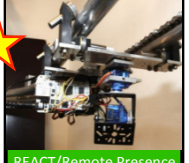
Seawatch Wind Lidar Buoy *TRL9*



Dual layer corrosion protection coatings *TRL5*

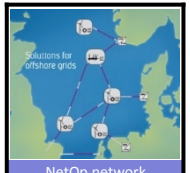


NOWIcob *TRL6*



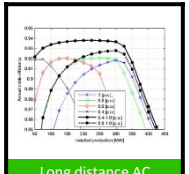
REACT/Remote Presence (www.emip.no) *TRL5*

Thermally sprayed SiC coatings *TRL5*



NetOp network optimization *TRL4*

STAS Linear State-Space W.P. Plant Analysis *TRL4*



Long distance AC transmission *TRL3*

Numerical model

Technology / process

New business entity (spin-off)

IMPELLO
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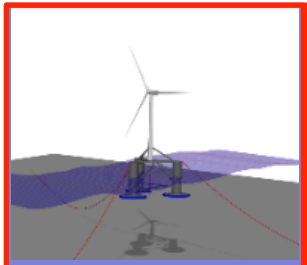
Numerical models



SIMO-RIFLEX
TRL 7

3Dfloat integrated model TRL 7

Software

- Integrated coupled analysis of
  - Complete structure
  - Wind loads
  - Sea loads
- Improved load prediction
- Reduced cost and risk

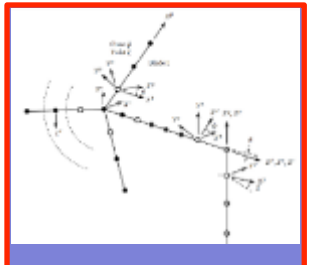
2500 MEUR

NetOp network optimization TRL 4

Methodology

- Optimization of offshore grid layout
  - Wind farm clusters
  - HVDC inter-connectors

400 MEUR

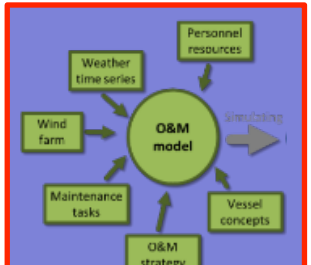


STAS Linear State-Space W.P. Plant Analysis TRL 4

Methodology

- Design of control algorithms for wind power plants
  - Optimize production
  - Reduce turbine fatigue

1100 MEUR



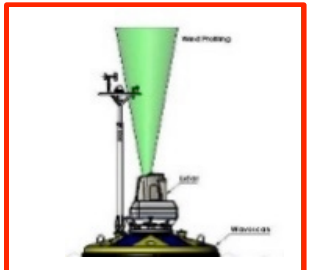
NOWIcob TRL6

Software

- Optimization of maintenance and logistics strategies
- Decision support tool

400 MEUR

Technology / process

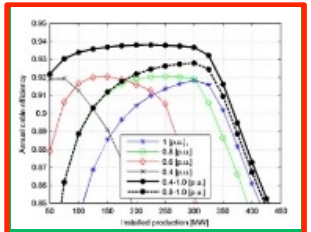


Seawatch Wind Lidar Buoy TRL 9

Commercial product

- Met-ocean buoy with LiDAR
- Measuring wind speed at different altitudes.
- Fugro OCEANOR

10 MEUR

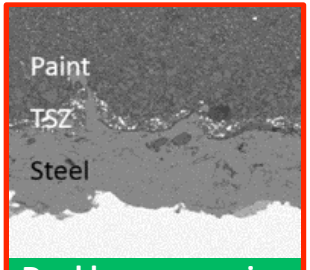


Long distance AC transmission TRL 3

Concept/method

- Control strategy
- Reduce electrical loss in long HVAC export cables
- Loss reduction: 1 %-point

200 MEUR



Dual layer corrosion protection coatings TRL5

Methodology

Optimize corrosion protection

- Low-cost coating / short maintenance intervals *vs.*
- Expensive dual layer coating / long maintenance intervals

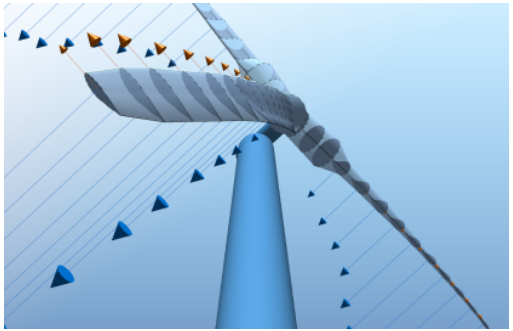
150 MEUR

Company spin-offs

Seram Coatings AS

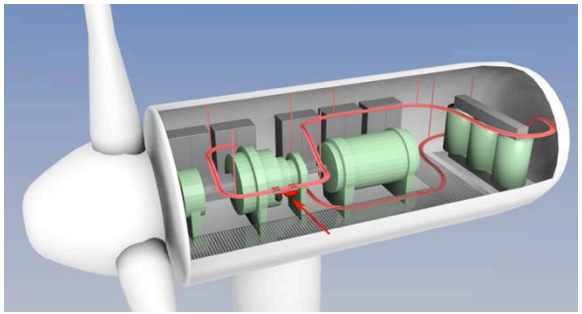
- **Thermasic** – an innovative method for thermal spraying of silicon carbide (SiC).
- Generic technology
- Large range of future application areas
- High commercial potential
- Based on PhD work in Nowitech.
- www.seramcoatings.com

SIMIS AS



- **Ashes** − wind turbine simulation software.
- Integrated simulation of e.g. wind loads, sea waves, gravity, buoyancy, and generator loads.
- Based on post.doc work in Nowitech
- www.simis.io

EMIP AS



- **REACT** – technology for remote inspection and maintenance of offshore turbines.
- IP owned by Norsk Automatisering.
- Funded by several RCN/EU projects.
- Based on PhD work in Nowitech.
- www.emip.no

SERAM COATINGS

20 MNOK investment in 2016

Thermal spraying of silicon carbide (SiC).

Erik Langaker (fra venstre), Knut Brundtland, Gisle Østereng, Sverre Skogen, Nuria Espallargas, Rune I. Fløgstad, Eivind Reiten, Erik Wold og Svein Aaser. Foto: Aleksander Nordahl

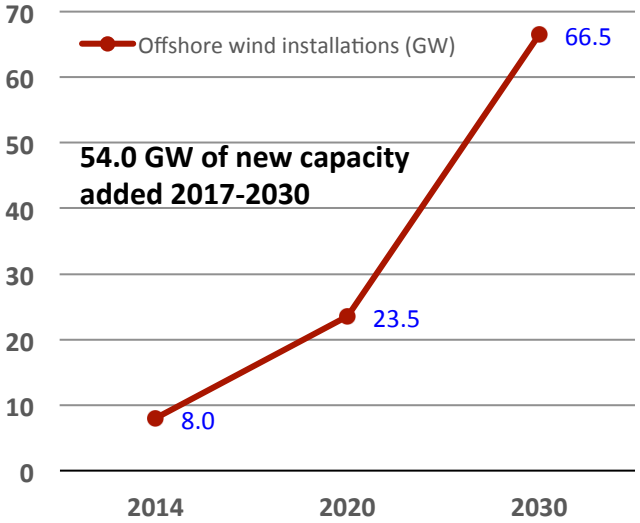
Ståltro på knallhard oppfinnelse

Syv av Norges fremste næringslivstopper satser 20 millioner kroner på en ny oppfinnelse som gjør at et verdens hardeste stoffer nå kan sprøytes rett på alt fra biler til raketter.

Methodology (1):

Market projections based on WindEurope's Central Scenario

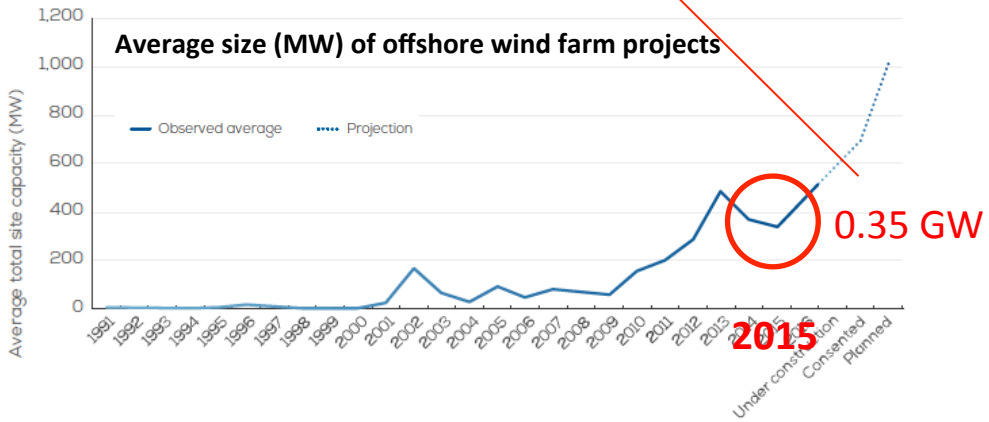
Accumulated capacity



Derived assumptions from the Central Scenario

	2014	2015	2016	2020	2025	2030
New installations (GW)		**3.0**	**1.5**	2.8	4.3	4.3
Accumulated installations (GW)	**8.0**	11.0	12.5	**23.5**	45.0	**66.5**
No. of new windfarms/yr		8.6	3.0	5.5	8.6	8.6
Accumulated no. of windfarms			**81**	103	146	189
Av. size of windfarm (GW)	**0.38**	**0.35**	**0.50**	0.50	0.50	0.50

Red figures = Central scenario
Black figures = Linear inter/extrapolation



Sources:
- WindEurope (2017): The European offshore wind industry. Key trends and statistics 2016
- EWEA (2015): Wind energy scenarios for 2030

Methodology (2):

Potential impact

Estimate cost saving (or profit)

- Per installed GW or produced GWh
- …multiplied with theoretical market size
  - installed GW, produced GWh
  - no. of parks, turbines, foundations, etc.
- …adjusted for relevance/applicability,
  - e.g. type of park, type of foundation, water depth, distance to shore, etc.

Estimate annual cashflow for each innovation:

+ Annual net cost savings (profit) per GW

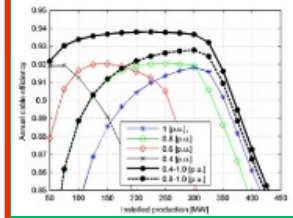
– Required additional investments per GW

= Net cashflow per year

Calculate net present value (NPV):

- Net cashflow discounted over 10 or 25 years
- 5 % discount rate (cost of capital)

Long distance AC transmission



Long distance AC transmission
TRL 3

- Control strategy for minimizing electrical losses in long HVAC export cables
- Continuous adjustment of cable operating voltage
- **Loss reduction**: 1 %-point of produced electricity.

Quantified potential:

NPV ≈ 200 MEUR

ASSUMPTIONS		
Wind farm size	1.2	GW
Investment period	10	yrs
Operation period	25	yrs
Capacity factor	46	%
Full load hours	4030	hrs
Annual electricity production per 1.2 GW farm	4836	GWh
Loss reduction (percent points)	**1.0**	**%**
Loss reduction (GWh) per 1.2 GW farm	48.4	GWh
Market relevance (applicable new installations)	20	%
Inflation rate	2.0	%
Discount rate (cost of capital)	5.0	%
Electricity price	50	EUR/MWh
Annual savings/yr per GW installed	**2.0**	**MEUR**
Additional required investment per GW	**10.0**	**MEUR**

Long distance AC transmission − NPV estimate

CASHFLOW AND NPV [MEUR]	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	…	2054	NPV MEUR
Investment (3 years prior to operation)	5.5	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	-	-	-		–	
Annual saving (nominal values)	-	-	-	1.1	2.8	4.6	6.3	8.0	9.8	11.5	13.2	15.0	16.7	18.4		1.7	
Net profit/yr (nominal values)	-5.5	-8.6	-8.6	-7.5	-5.8	-4.0	-2.3	-0.6	1.2	2.9	4.6	15.0	16.7	18.4		1.7	113
Net profit/yr (real values)	**-5.5**	**-8.8**	**-8.9**	**-8.0**	**-6.2**	**-4.4**	**-2.6**	**-0.6**	**1.4**	**3.5**	**5.7**	**18.6**	**21.2**	**23.8**		**3.6**	**184**

Total new installations (GW) – **Central scenario**				**2.8**	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	**≈ 200 MEUR**
Applicable new installations (GW)	**20 %**			0.6	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	
Accumulated new applicable installations							0.6	1.4	2.3	3.1	4.0	4.9	5.7	6.6	

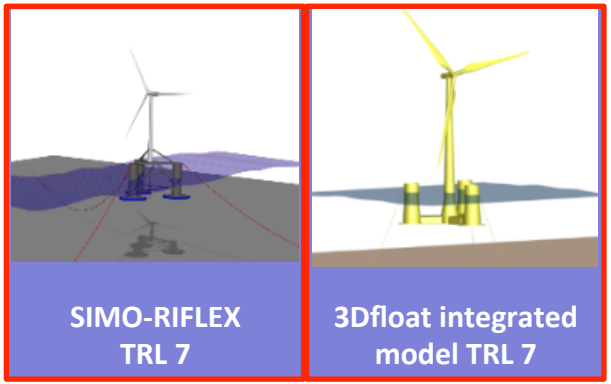
Investment 2017: 10 MEUR/GW * 2.8 GW * 20 % = **5.5 MEUR**

Annual saving 2020: 2 MEUR/GW * 2.8 GW * 20 % = **1.1 MEUR**

REFERENCES

- **Gustavsen, Bjørn and Olve Mo (2016)** *Variable Transmission Voltage for Loss Minimization in Long Offshore Wind Farm AC Export Cables*, DOI 10.1109/TPWRD.2016.2581879, IEEE Transactions on Power Delivery
- **O. Mo, B. Gustavsen**, EERA Deepwind 2016 presentation, Feb 2016, http://www.sintef.no/globalassets/project/eera-deepwind2016/presentations/b2_olve-mo.pdf

SIMO-RIFLEX and 3Dfloat



- Software simulation tools – coupled analysis
- **Cost reduction**: Reduced materials use
- Relevant for both floaters and bottom fixed

Quantified potential:

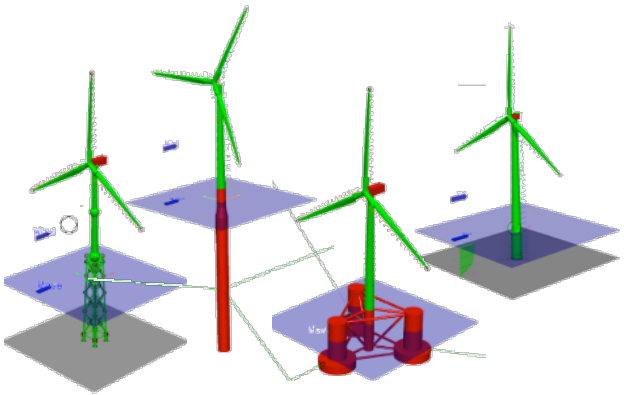
NPV ≈ 2500 MEUR

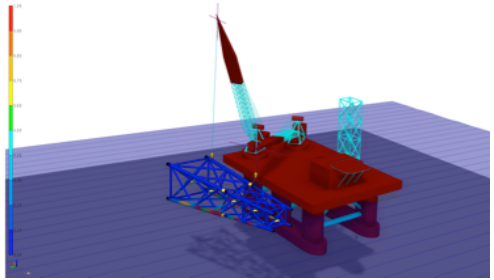
ASSUMPTIONS		
Wind farm size	1,0	GW
Project duration (technology obsolete after this)	10	yrs
Market relevance (applicable new installations)	**100**	**%**
Materials weight - floater	3 670	tons
Materials weight - monopile	1 370	tons
Reduced materials use (tower, substructure, mooring)	5	%
Unit costs (materials)	5.0	EUR/kg
Materials savings per turbine - floater	918	kEUR
Materials savings per turbine - monopile	343	kEUR
Turbine size	6.0	MW
No. of turbines per wind park (1 GW)	167	turbines
Materials savings per 1 GW - floater park	**153**	**MEUR**
Materials savings per 1 GW - monopile park	**57**	**MEUR**
Floater park share	15	%
Monopile park share	85	%
Total additional investments per 1 GW park	**1.0**	**MEUR**
Discount rate (cost of capital)	5	%

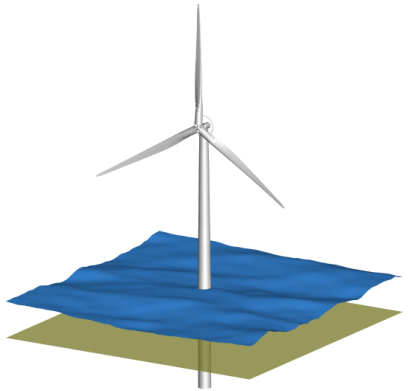
SIMA (SIMO/RIFLEX) and 3Dfloat – NPV estimate

CASHFLOW AND NPV [MEUR]	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	...	NPV MEUR
Investments - 3 years prior to operation	2,8	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	-	-	-		
Annual saving - floater parks (nominal values)	-	-	-	63.1	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.6	98.6		
Annual saving - monopile parks (nom. values)	-	-	-	133.4	208.6	208.6	208.6	208.6	208.6	208.6	208.6	208.6	208.6	208.6		
Net profit/yr (nominal values)	-2.8	-4.3	-4.3	192.2	303.0	303.0	303.0	303.0	303.0	303.0	303.0	307.3	307.3	307.3		2 183
Net profit (real values)	**-2.8**	**-4.4**	**-4.5**	**204.0**	**327.9**	**334.5**	**341.2**	**348.0**	**355.0**	**362.1**	**369.3**	**382.1**	**389.7**	**397.5**		**2 551**

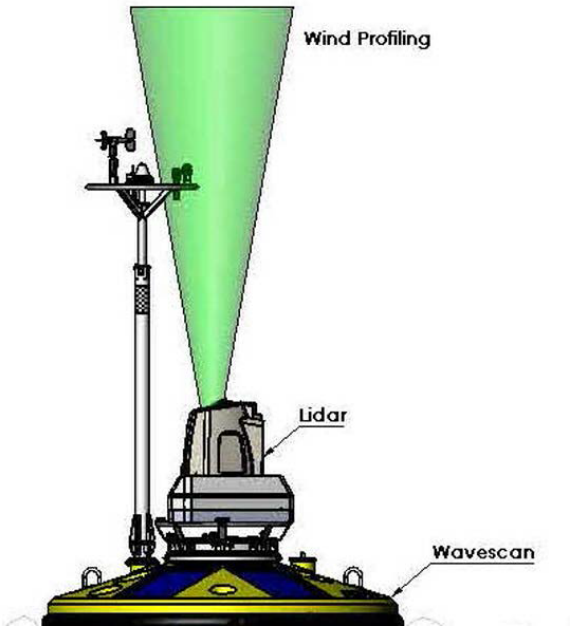
Total new installations (GW) – **Central scen.**				2.8	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	**≈ 2500 MEUR**
Applicable new installations (GW) **(100 %)**				2.8	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	
Accumulated new applicable installations				**2.8**	**7.1**	**11.4**	**15.7**	**20.0**	**24.3**	**28.6**	**32.9**	**37.2**	**41.5**	**45.8**	







Fugro OCEANOR – Seawatch wind lidar buoy



Floating met-ocean buoy

- Reduced cost of collecting data
  - Wind speed at different altitudes
  - Waves, current
- NOWITECH contributed to the start-up of the development.

Commercial product

- 80-100 MNOK (≈ 10 MEUR) of totals sales since 2012

Realized revenues > 10 MEUR

Dudgeon (Statoil/Statkraft)

The Dudgeon wind farm is expected to produce 1.7 terawatt-hours (TWh) of electricity per year.

Realized impact > 25 MEUR

Selection of monopile rather than jacket foundation

- ...for relatively deep water and large turbines
- Importance of non-linear hydrodynamics viewed against the structural responses in an integrated design tool

Realized impact

- Risk and cost reduction through reducing uncertainty
- Improved modeling of both fatigue and extreme loads

- Consensus estimate by SINTEF, Statoil and Statkraft

Summing up: > 5 billion EUR economic impact from NOWITECH

- **Research investment:** 35 MEUR
- **Realized impact**: 35+ MEUR
- ***Exceeds the programme investment!***
- **Potential impact**: >5 billion EUR
  - Quantified potential for 7 innovations
  - Potential of the other innovations not estimated

Disclaimer: Using other assumptions will give other NPV figures and thus a higher/lower total potential economic impact of NOWITECH.

Initial NOWITECH project investment	MEUR
320 MNOK (2009-2017)	**35**

Realized impact	MEUR
Dudgeon foundations (Statoil/Statkraft)	25
Seawatch buoy (Fugro OCEANOR)	10
Seram Coatings AS	New company
SIMIS AS	New company
EMIP AS (Remote Inspection)	New company
Total (MEUR)	**35**

Potential impact	NPV
Long Distance AC Transmission	200
NOWIcob	400
Remote Inspection	250
STAS	1100
Dual Layer Corrosion Protection Coating	150
SIMA (SIMO/RIFLEX) and 3Dfloat	2,500
NetOp/PowerGIM	400
Total (MEUR)	**5,000**

IMPELLO

(lat.); stimulere, drive fremover, utvikle.