NOWITECH final event 22-23 August 2017

Offshore wind farm O&M and logistics optimization

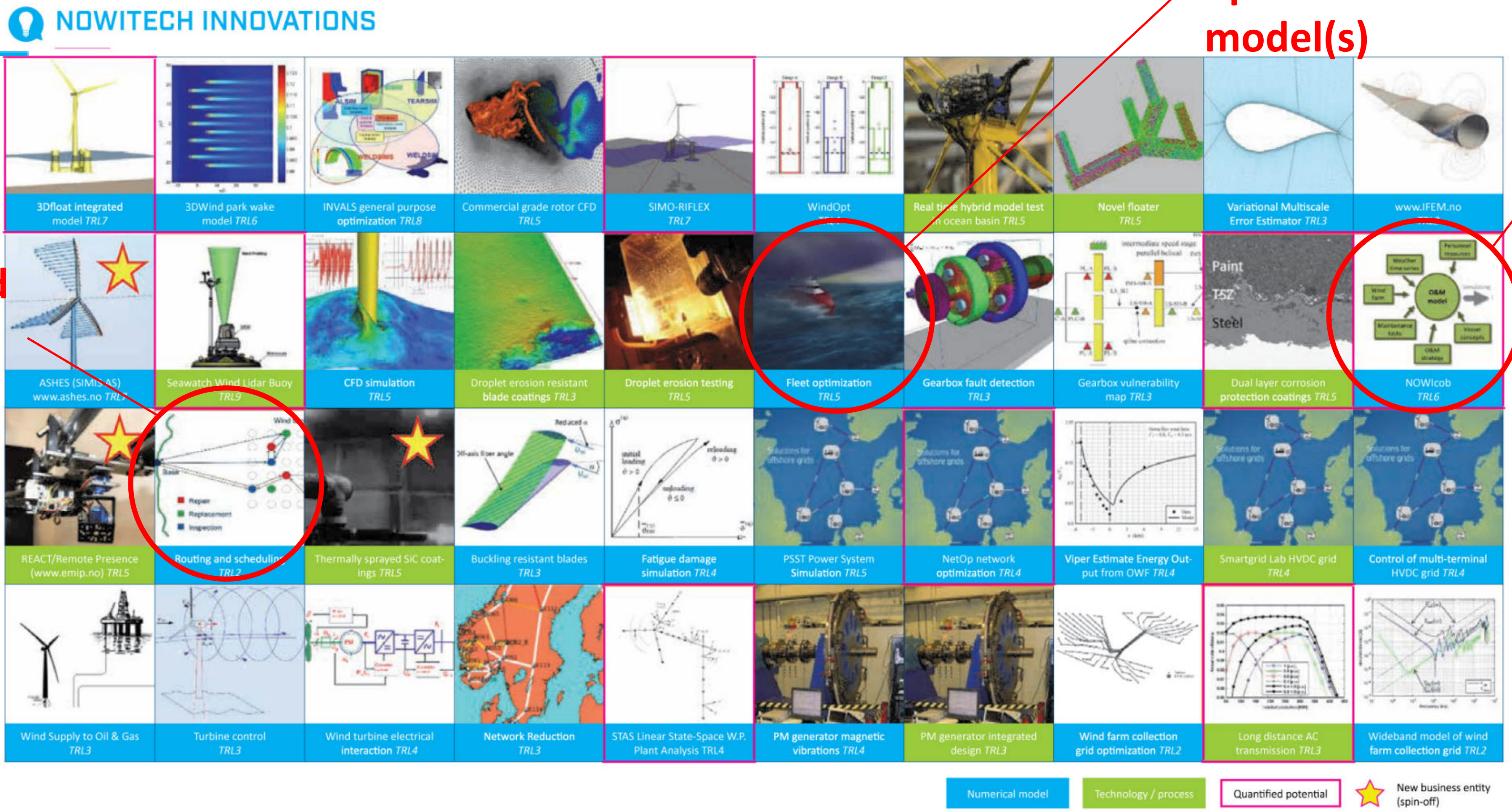
Elin Espeland Halvorsen-Weare
Research Scientist, SINTEF Ocean
Elin.Halvorsen-Weare@sintef.no

NOWITECH innovations

Vessel fleet optimization model(s)

NOWIcob

Routing and scheduling model

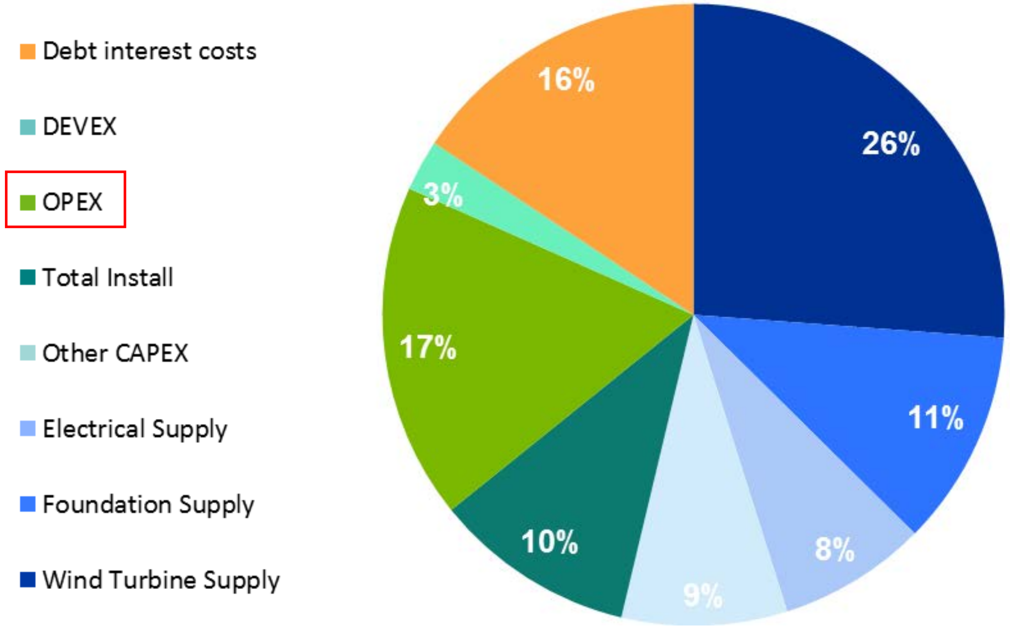


NOWITECH Norwegian Research Centre for Offshore Wind Technology

FME CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH
The Research Council of Norway

Models for O&M at offshore wind farms

- O&M models, also known as:
  - O&M cost models
  - O&M simulation models
  - Offshore wind farm decision support tools
  - Offshore wind life-cycle cost model
  - OPEX cost model
  - ………
- And there is more:
  - Vessel fleet optimization models
  - Optimization models for routing and scheduling
  - ………



LCOE distribution offshore wind farm (example)

Smart, G.; Smith, A.; Warner, E.; Sperstad, I.B.; Prinsen, B.; Lacal-Arántegui, R. (2016): "IEA Wind Task 26 – Offshore Wind Farm Baseline Documentation". IEA Wind.

O&M models – Types of models

Operational decisions

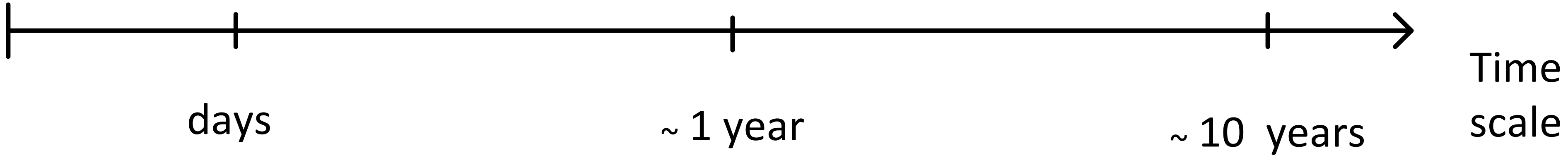
(e.g. "which turbines should we schedule to visit tomorrow?")

Tactical decisions

(e.g. "how and when should I charter this jack-up vessel?")

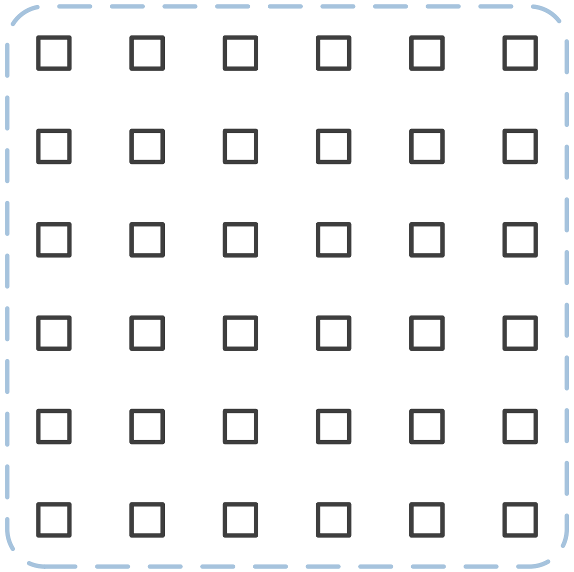
Strategic decisions

(e.g. "where should we locate our maintenance base?")

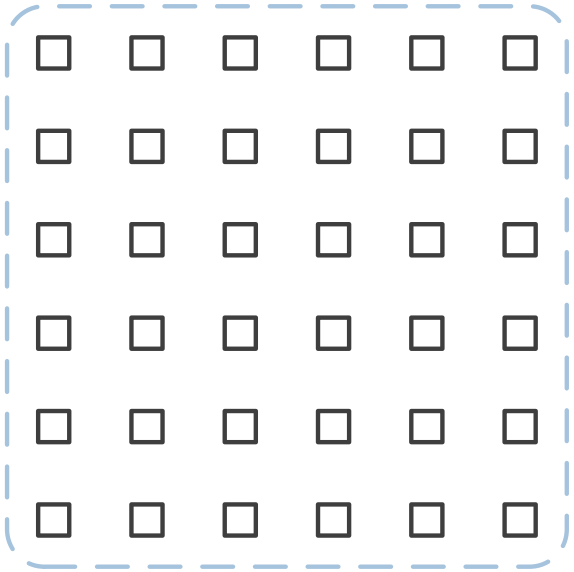


O&M models – Types of models

☐ Possible solution

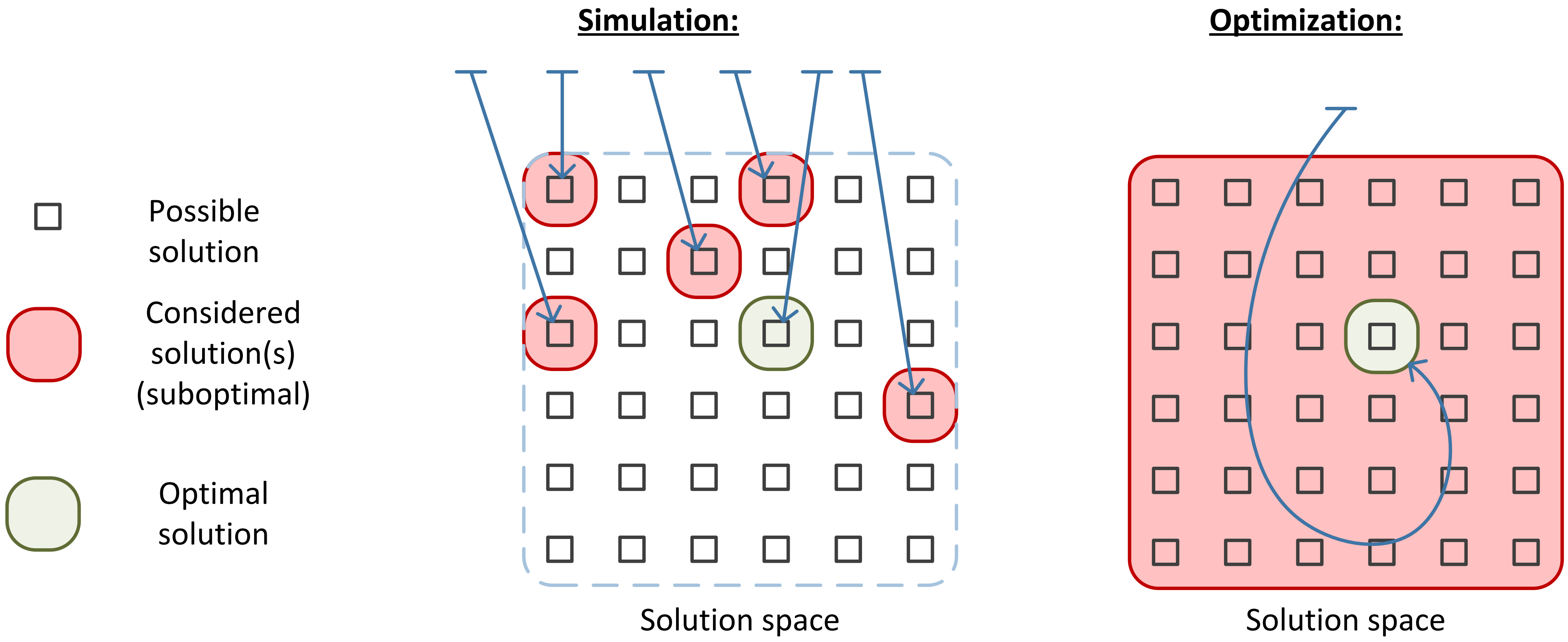


Solution space



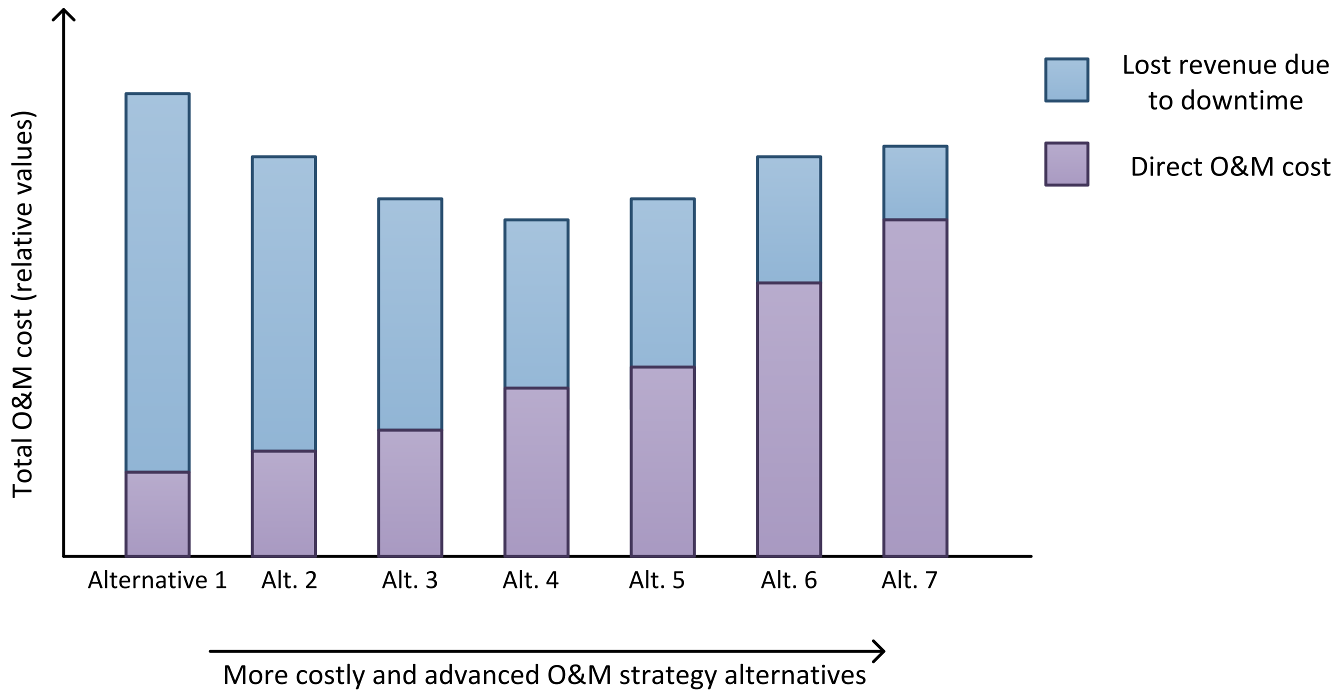
Solution space

O&M models – Types of models

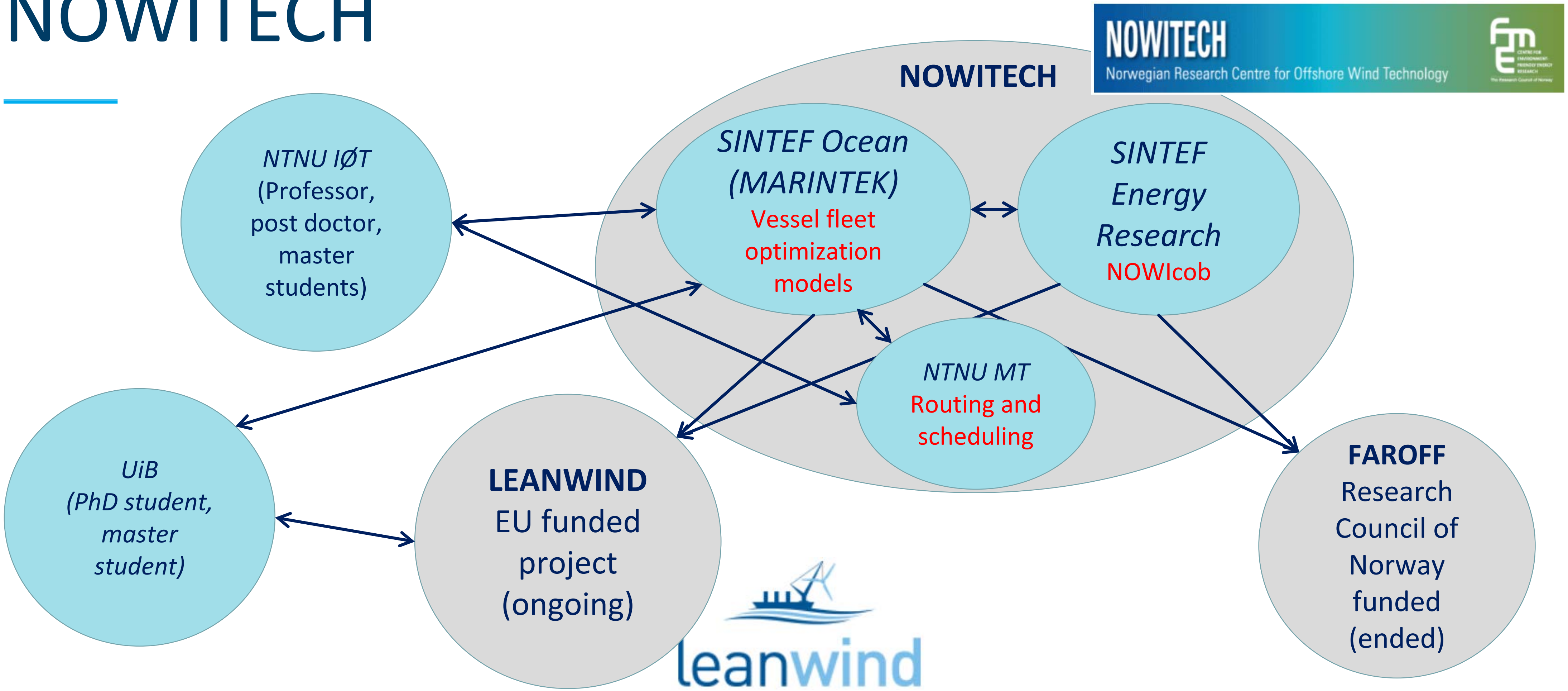


Objective function for O&M optimization

Total O&M cost = Direct O&M cost + Lost revenue due to downtime



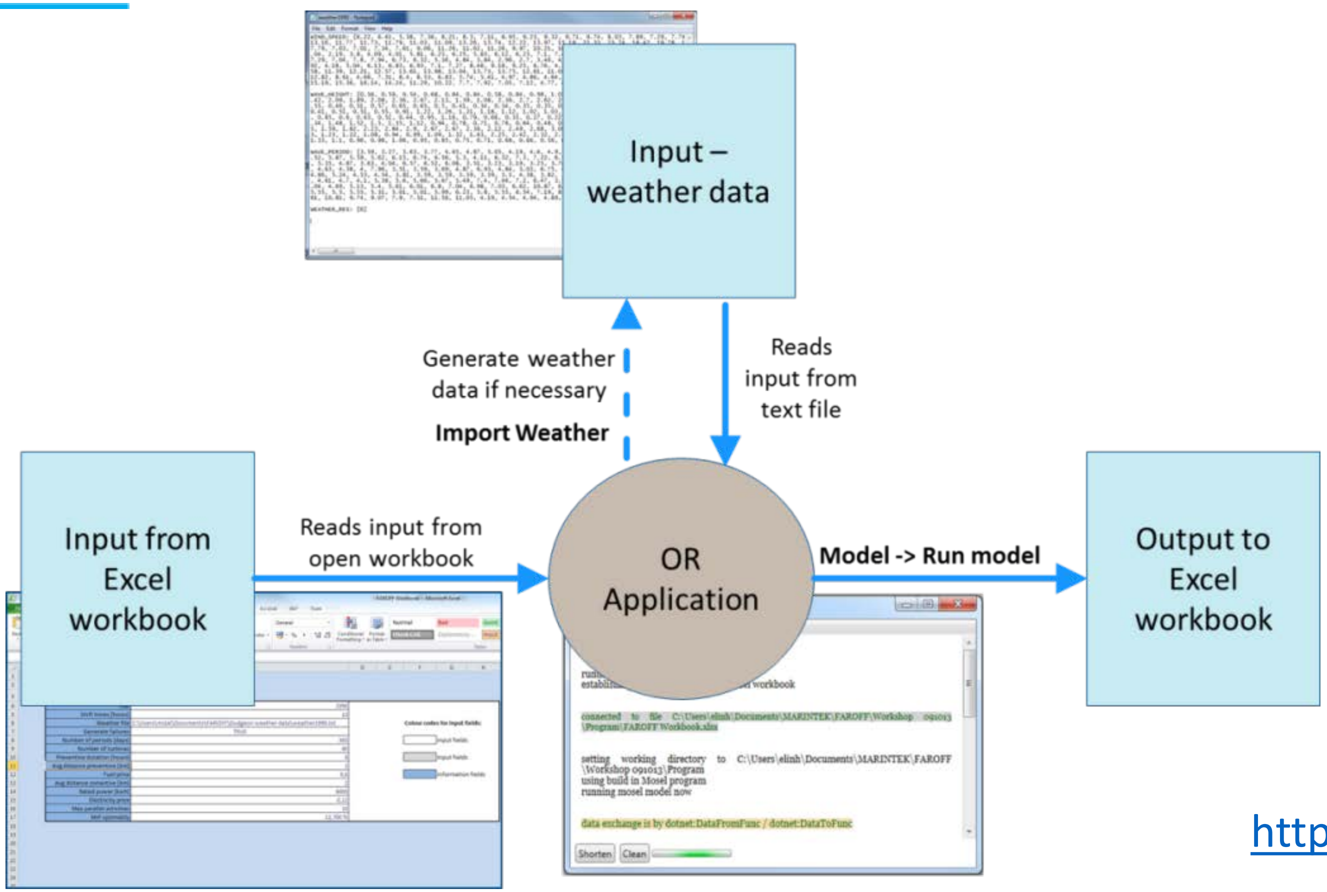
Models and cooperation within NOWITECH



Vessel fleet optimization – why?

- Many options for vessels and access solutions make it impractical to evaluate all options
- 10 vessel types, 0-3 vessels each → $2^{20} \approx 1$ million combinations
- Use techniques from operations research to efficiently evaluate the solution space

Vessel fleet optimization models



- Optimization models, 3 versions:
  - Deterministic, stochastic, heuristic
- Support for strategic decisions regarding optimal vessel fleet for wind farm O&M and maintenance logistics
- Model developer: SINTEF Ocean (MARINTEK)

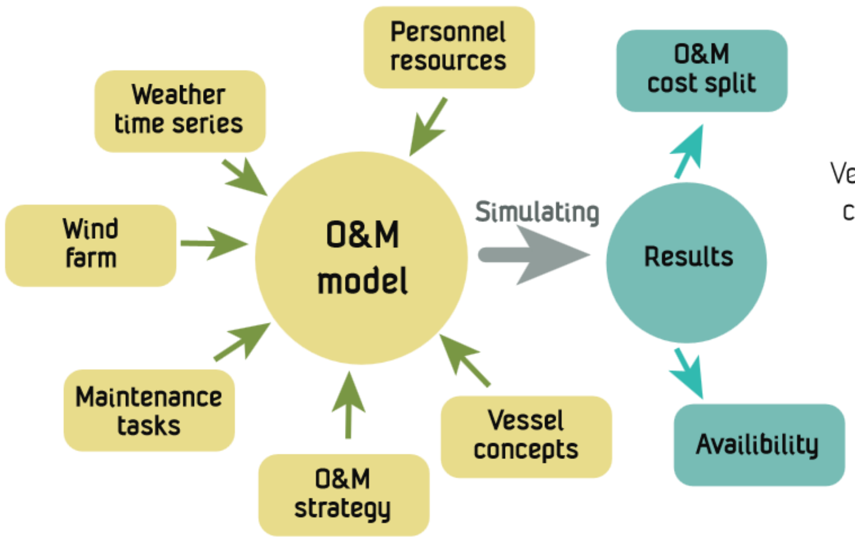
http://www.sintef.no/projectweb/marwind/

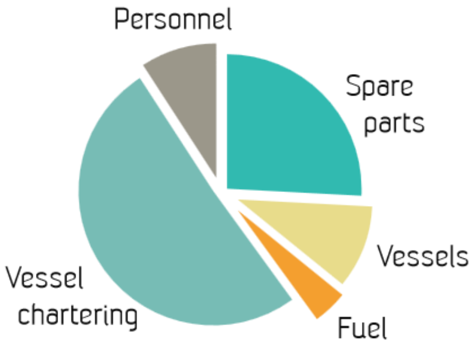
NOWIcob

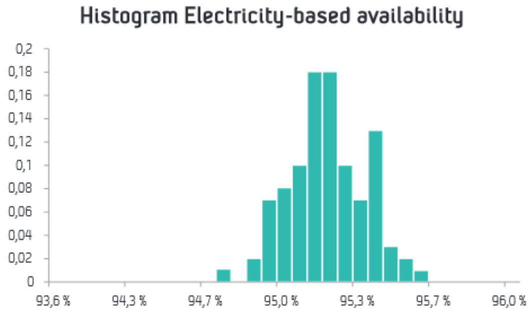
Norwegian offshore wind power life cycle cost and benefit

- Offshore wind farm O&M simulation model
- Strategic decision support
- Model developer: SINTEF Energy Research
- NOWIcob = LEANWIND O&M Strategy model

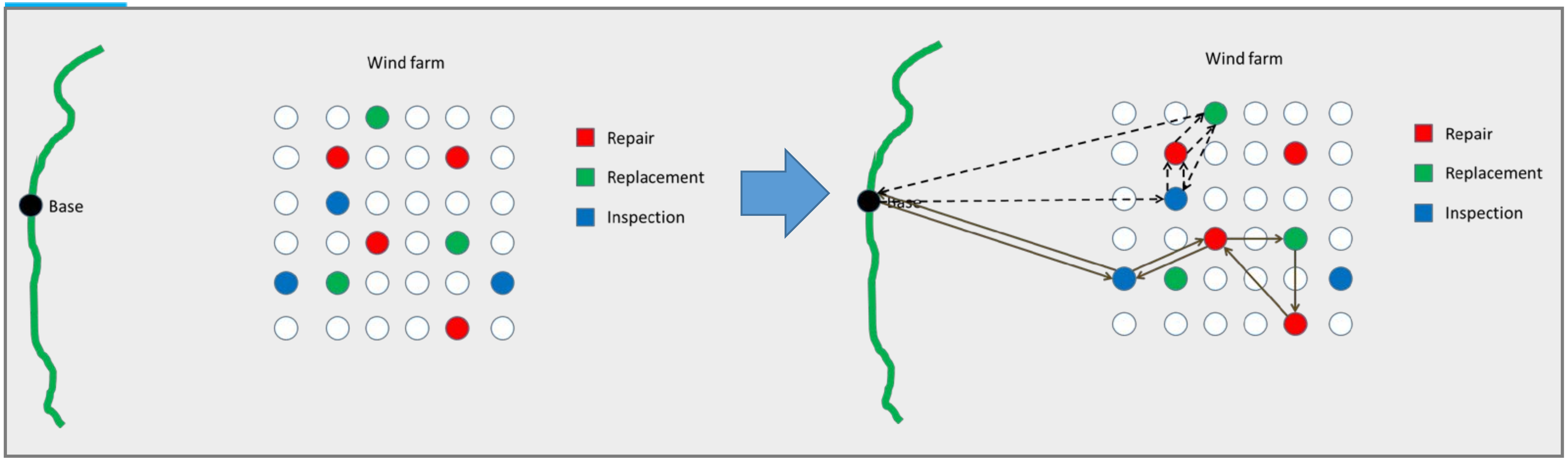
http://www.sintef.no/nowicob







Routing and scheduling model



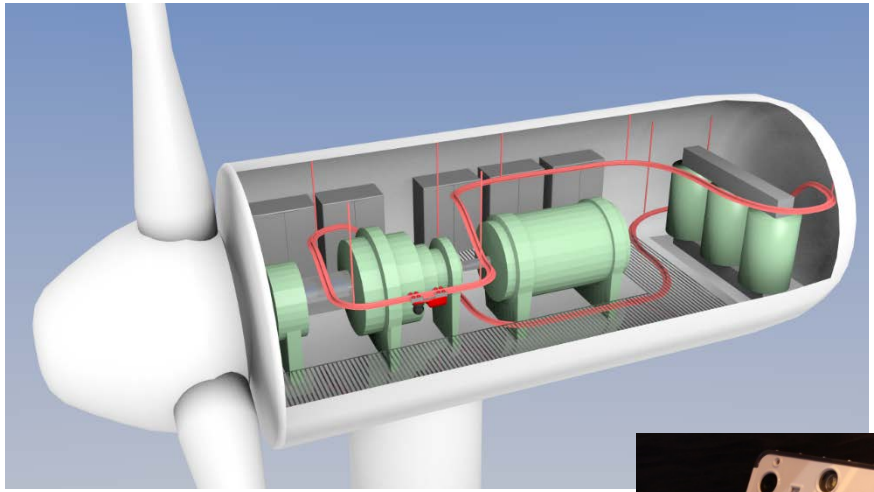
- Mathematical optimization model(s)
- Find optimal routes and schedules: One for each vessel for each day – which maintenance tasks to execute, when to deliver and pick-up technicians at turbines
- Developers: NTNU MT/NTNU IØT/SINTEF Ocean

Examples of some industrial applications

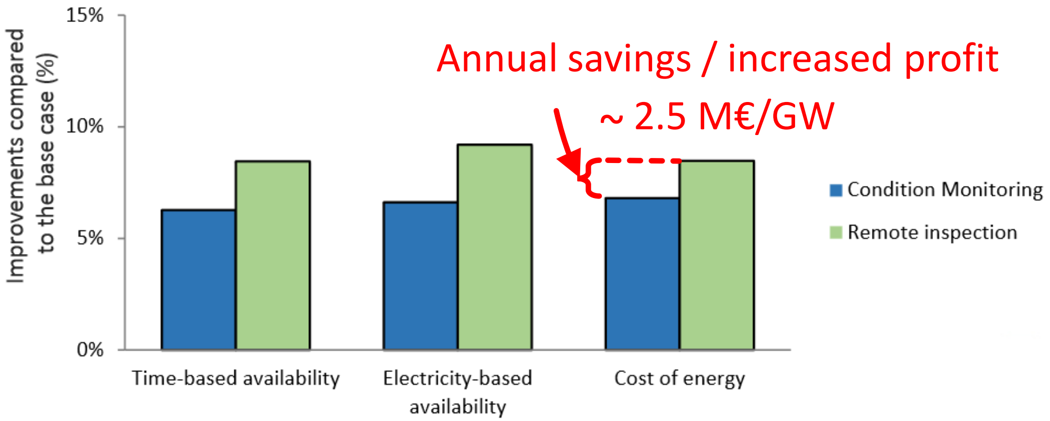
- Investment decision / due diligence for offshore wind farm projects
  - E.g. Dudgeon offshore wind farm investment decision – energy-based availability for different vessel concepts
- Support agreement with Statkraft
  - Model customization, user support, analysis of wind farm scenarios
- Evaluation of O&M modelling tools, e.g.
  - model comparison and validation activity with ScottishPower and Iberdrola
  - testing and validation together with an European offshore wind farm owner


WPB
OPERATION & MAINTENANCE A
Summary of results 2014
32
NOWITECH
33

Cost-benefit - Remote presence (REACT)

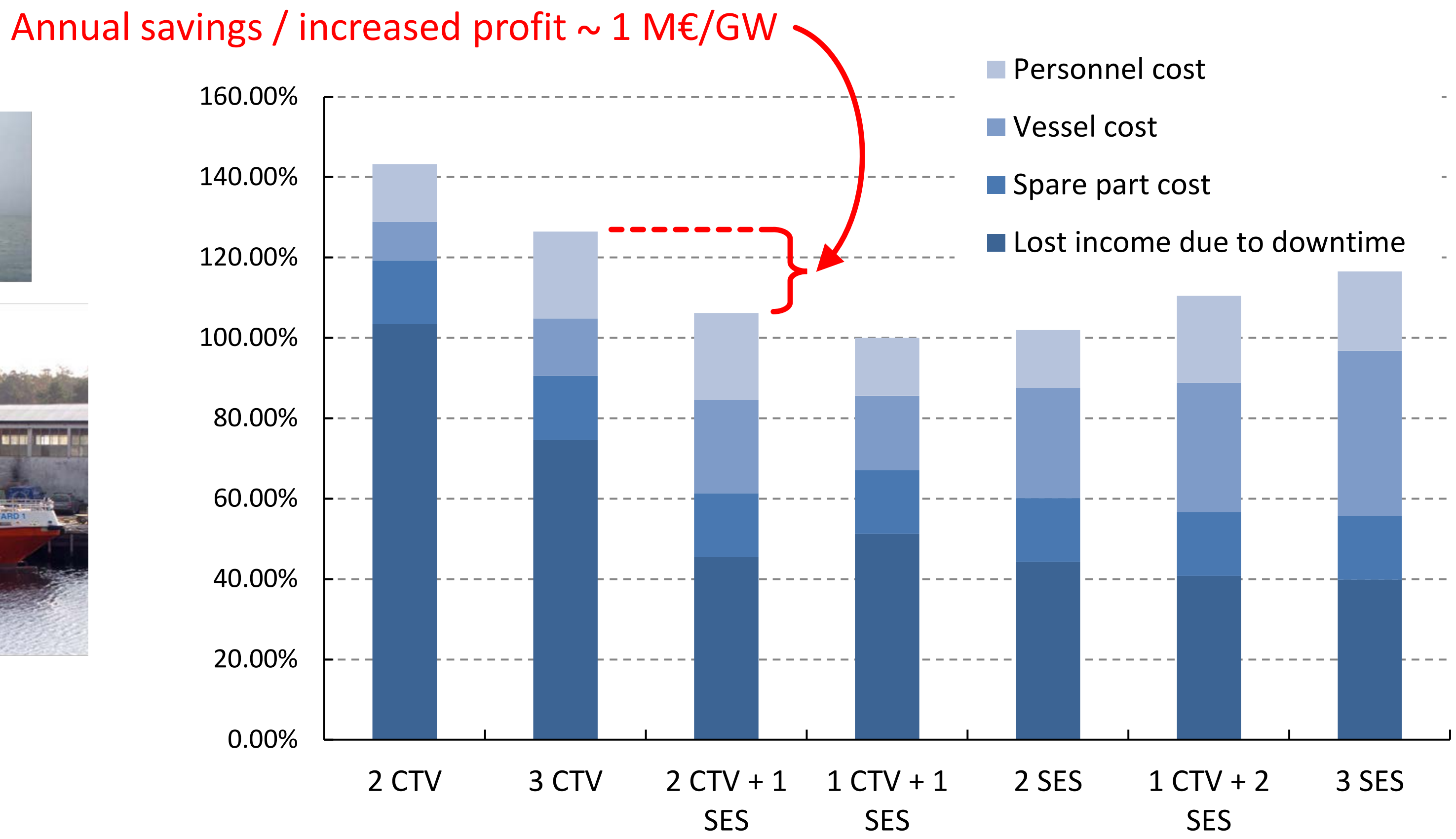


- Remotely controlled robot for inspection of components in wind turbine nacelle
- Developer:
  Norsk Automatisering AS / EMIP AS



Netland, Ø.; Sperstad, I. B.; Hofmann, M.; Skavhaug, A. (2014). Cost-benefit evaluation of remote inspection of offshore wind farms by simulating the operation and maintenance phase. Energy Procedia, vol. 53, pp. 239-247.

Cost reduction potential



Crew transfer vessel fleet optimization

References

- Dai L., Stålhane M, Utne IB (2015). Routing and scheduling of maintenance fleet for offshore wind farms. Wind Engineering 39(1). 15-30.
- Dinwoodie I, Endrerud O-EV, Hofmann M, Martin R, Sperstad IB (2015). Reference Cases for Verification of Operation and Maintenance Simulation Models for Offshore Wind Farms. Wind Engineering 39. 1-14.
- Gundegjerde C, Halvorsen IB, Halvorsen-Weare EE, Hvattum LM, Nonås LM (2015). A stochastic fleet size and mix model for maintenance operations at offshore wind farms. Transportation Research Part C 52. 74-92.
- Gutierrez-Alcoba A, Ortega G, Hendrix, EMT, Halvorsen-Weare EE, Haugland D (2017). A model for optimal fleet composition of vessels for offshore wind farm maintenance. Procedia Computer Science 108. 1512-1521.
- Irawan CA, Ouelhadj D, Jones D, Stålhane M, Sperstad IB (2016). Optimisation of maintenance routing and scheduling for offshore wind farms. European Journal of Operational Research 256(1). 76-89.
- Halvorsen-Weare EE, Gundegjerde C, Halvorsen IB, Hvattum LM, Nonås LM (2013). Vessel fleet analysis for maintenance operations at offshore wind farms. Energy Procedia 35. 167-176.
- Halvorsen-Weare EE, Norstad I, Stålhane M, Nonås LM (2017). A metaheuristic solution method for optimizing vessel fleet size and mix for maintenance operations at offshore wind farms under uncertainty. Accepted for publication in Energy Procedia. 8p.
- Hofmann M (2013). A review of decision support models for offshore wind farms with an emphasis on operation and maintenance strategies. Wind Engineering 35. 1–16.
- Hofmann M, Sperstad IB (2013). NOWIcob – A tool for reducing the maintenance costs of offshore wind farms. Energy Procedia 35. 177–186.
- Hofmann M, Sperstad IB (2014). Will 10 MW wind turbines bring down the operation and maintenance cost of offshore wind farms? Energy Procedia 53. 231-238.
- Netland Ø, Sperstad IB, Hofmann M, Skavhaug A (2014). Cost-benefit evaluation of remote inspection of offshore wind farms by simulating the operation and maintenance phase. Energy Procedia 53. 239-247.
- Sperstad IB, Halvorsen-Weare EE, Hofmann M, Nonås LM, Stålhane M, Wu M (2014). The effects of using multi-parameter wave criteria for accessing wind turbines in strategic maintenance and logistics models for offshore wind farms. Energy Procedia 53. 221-230.
- Sperstad IB, McAuliffe FD, Kolstad M, Sjømark S (2016). Investigating key decision problems to optimise the operation and maintenance strategy of offshore wind farms. Energy Procedia 94. 261–268.
- Sperstad IB, Stålhane M, Dinwoodie I, Endrerud OEV, Martin R, Warner E (2016). Testing the robustness of optimal vessel fleet selection for operation and maintenance of offshore wind farms. 13p. http://www.sintef.no/globalassets/project/nowicob/sperstad_et_al_vessel_fleet_optimisation_paper_2016-02-18_draft.pdf
- Stålhane M, Halvorsen-Weare EE, Nonås LM (2016). A decision support system for vessel fleet analysis for maintenance operations at offshore wind farms. 32p. http://www.sintef.no/globalassets/project/maritime-logistics-optimization-for-offshore-wind/staalhaneetal_wp_2016.pdf
- Stålhane M, Hvattum LM, Skaar V (2015). Optimization of routing and scheduling of vessels to perform maintenance at offshore wind farms. Energy Procedia 80. 92-99.
- Stålhane M, Vefsnmo H, Halvorsen-Weare EE, Hvattum LM, Nonås LM (2016).Vessel fleet optimization for maintenance operations at offshore wind farms under uncertainty. Energy Procedia 94. 357-366.
- Welte TM, Sperstad IB, Sørum EH, Kolstad ML (2017). Integration of Degradation Processes in a Strategic Offshore Wind Farm O&M Simulation Model. Energies 10(7), 925. 18p.

NOWITECH final event 22-23 August 2017

Offshore wind farm O&M and logistics optimization

Elin Espeland Halvorsen-Weare
Research Scientist, SINTEF Ocean
Elin.Halvorsen-Weare@sintef.no