EERA-DTOC: *Near future scenario*

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EERA DTOC
THE EUROPEAN ENERGY RESEARCH ALLIANCE
DESIGN TOOLS FOR OFFSHORE WIND FARM CLUSTER

Support by

SEVENTH FRAMEWORK PROGRAMME

STARTING POINTS

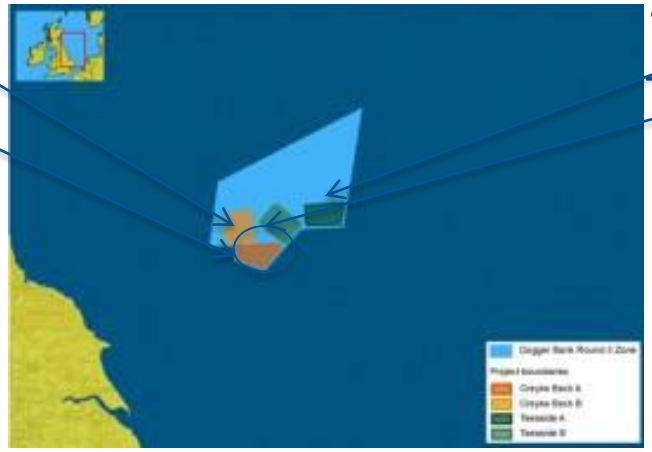
Starting points for near future scenario as agreed and establised by the consortium:

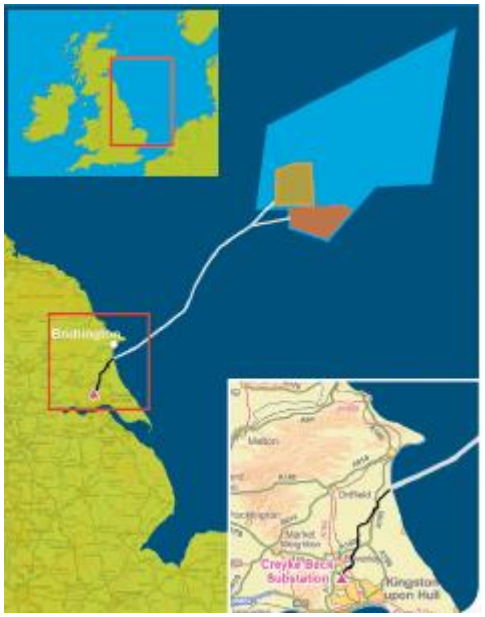
- Time line: Five years
- 1GW Wind farm consisting of 100 turbines of 10 MW
- Farm in ‘Dogger Bank’ cluster setting with neighbouring farms around

NEAR FUTURE SCENARIO

Description: Connected to Doggersbank

- Creyke Beck B
- Creyke Beck A

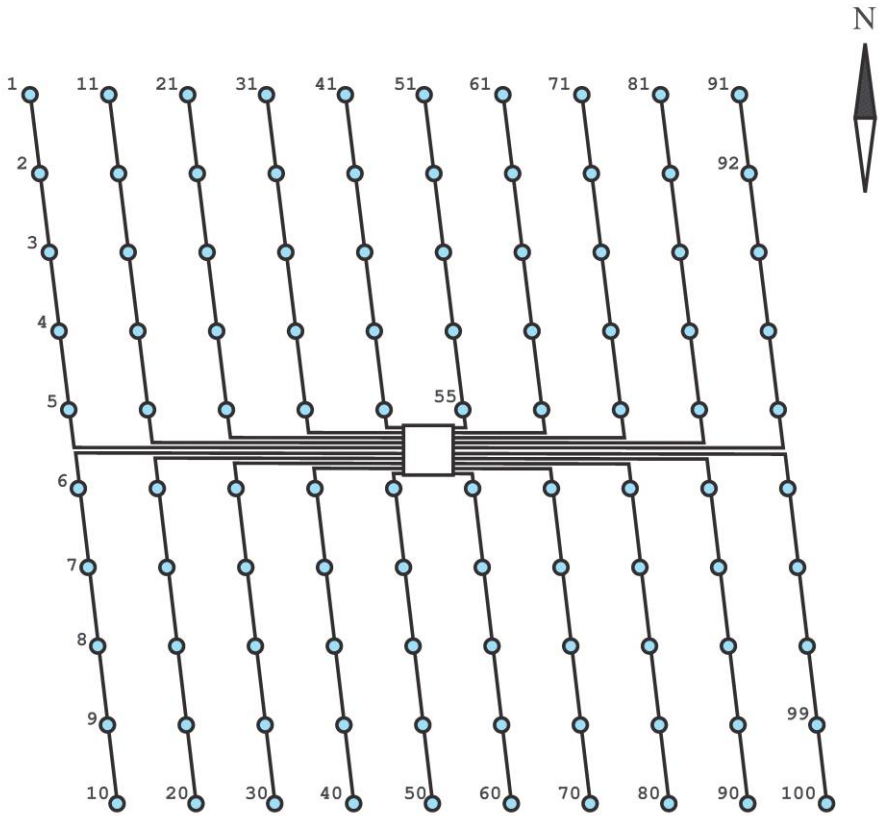




- Target wind farm: Creyke Beck A with Creyke Beck B Teesside A and Teesside B as surrounding farms, assuming them to be 1 GW

‘Target wind farm’ in near future scenario

- 1000 MW Wind farm
- 100*10 MW turbines
  - Innwind.EU 10 MW reference turbine
- 20 parallel grid lines (66 kV) connecting 5 turbines to a central sub station
- North Sea wind climate
- Distance to shore: ~125 km
- Water depth: ~40 m
- Distance between turbines variable between 3.6D and 10D



Status of near future scenario

- The wind climate has been calculated with WRF by DTU and CIEMAT (with and without wind farms)
- ECN, DTU, CarbonTrust, Statoil, CRES have recently started up calculating this scenario for user stories
  - "As a developer I can determine the wake effects of neighbouring wind farm clusters on a single wind farm (meso scale and micro scale modelling)"
  - "As a developer I can determine the optimum spacing, turbine model and hub height of turbines within off-shore farms"
  - "As a developer I want to use wind farm lay-out scenarios of my target wind farm with respect to nr of turbines, turbine types, thrust curves etc"

Status of near future scenario

- ECN has already calculated a ‘preliminary scenario’ based on the near future scenario with a combination of ECN’s aerodynamic (**FarmFlow**) and electrical tools (**EEFARM**)
- Investigate effect of distance between turbines
  - Large distance: Low aerodynamic losses, high electrical losses and high costs for the electrical infra structure
  - Small distance: High aerodynamic losses, low electrical losses and low costs for the electrical infra structure
  - Where do we find the optimum??

What is FARMFLOW?

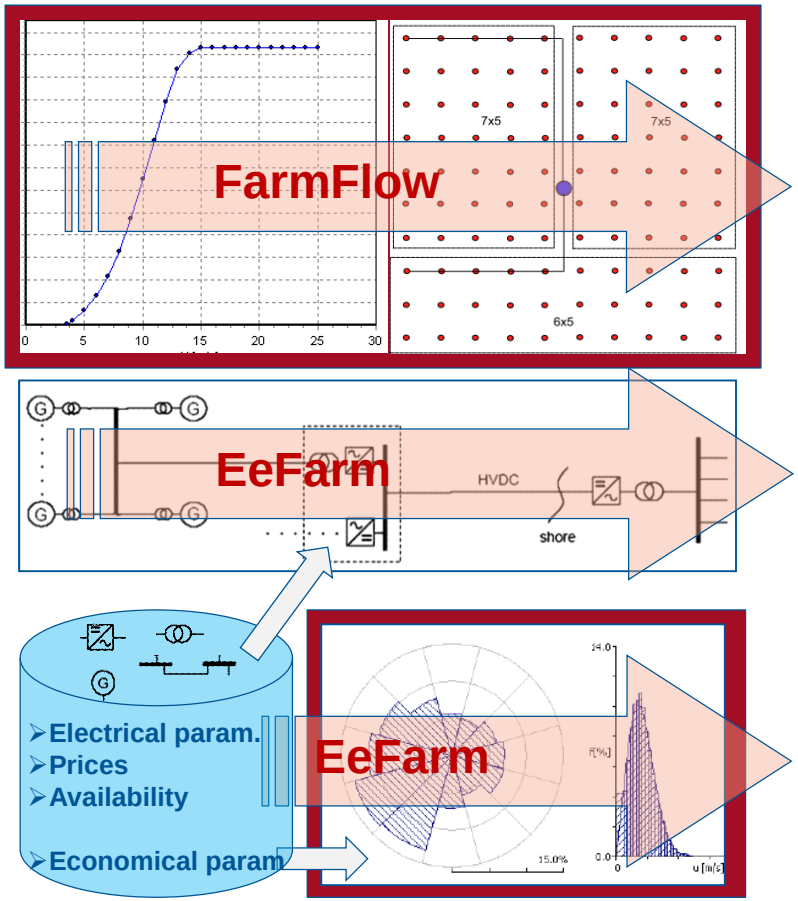
- Calculates:
  - Losses and added turbulence due to wakes
  - Annual energy production (AEP)
- The model is based on UPMWAKE [1])/WAKEFARM
  - Modified by ECN since 1993
  - Extensively validated with results from ECN's research farms and results from EU projects
- Solves the Parabolized Navier-Stokes equation
- Actuator disc for the turbines, prescribed by C_{Dax}
- Fast free wake model database approach for near wake and adjusted k-ε turbulence model to account for actuator disc assumption

[1]) Crespo et al. 1988

What is EEFARM?

- Program to study and optimise the electrical performance of wind farms.
- Program is used to determine the:
  - Energy production,
  - Electrical losses,
  - Component failure losses
  - Price of the produced electric power

EeFarm-II functional description linked to FarmFlow!



Aerodynamic power:

$P_{WT1} \ldots P_{WTN} = f(Vw, Vdir)$

Investments

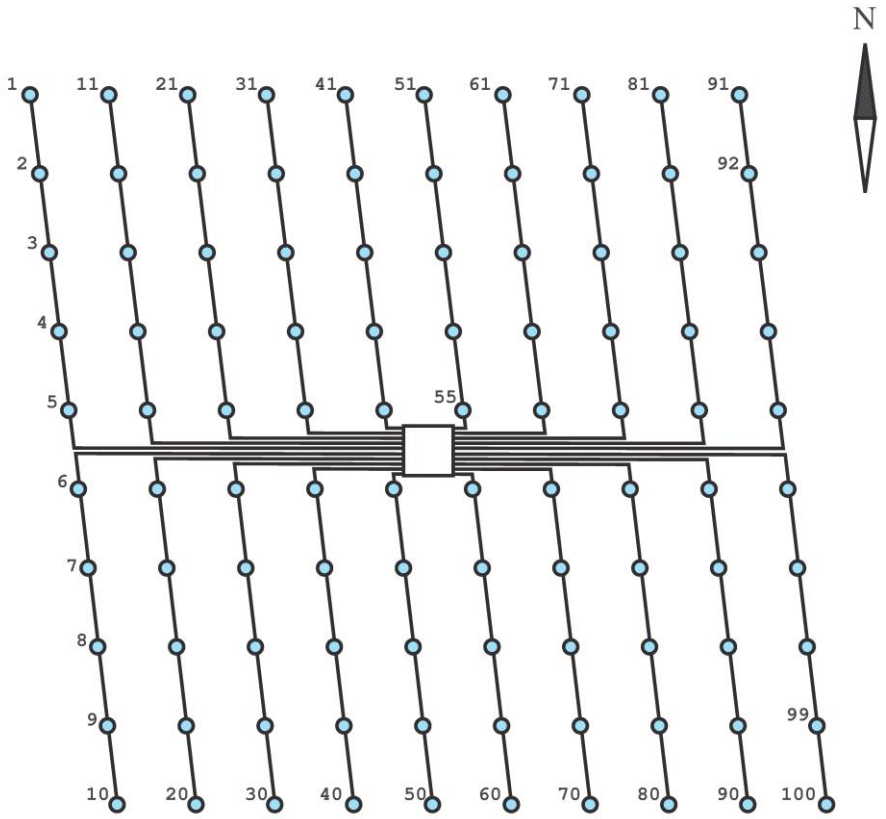
P_{loss}

P_{fail}

per component

Levelized Production Costs

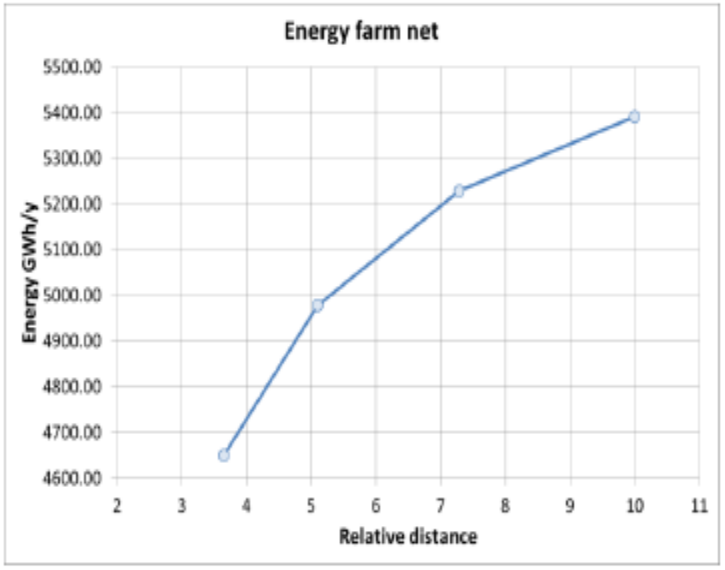
Recall: Lay-out of 1GW farm

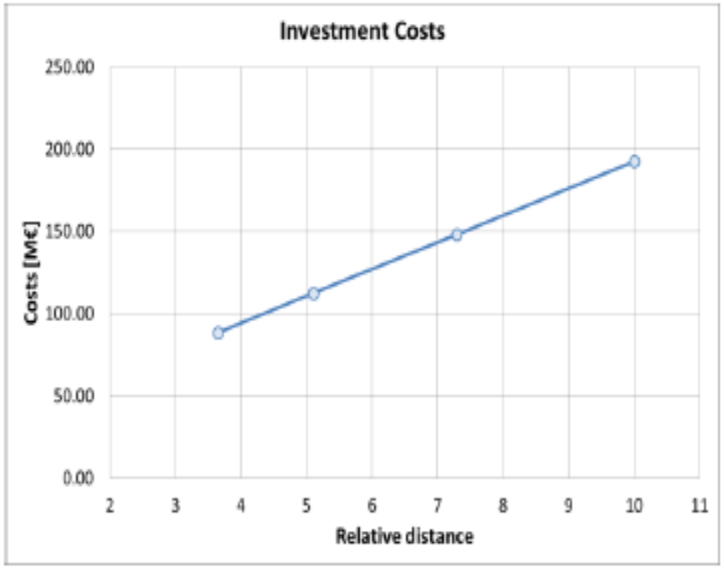


- 100 INNWIND.EU reference turbines of 10 MW
- Inter turbine distance is a variable between 3.6 and 10 D
- Grid lines connecting 5 turbines to central substation

Net energy farm production vs investment costs

10x10 wind farm with 10MW wind turbines
Different relative distance between the turbines are changed

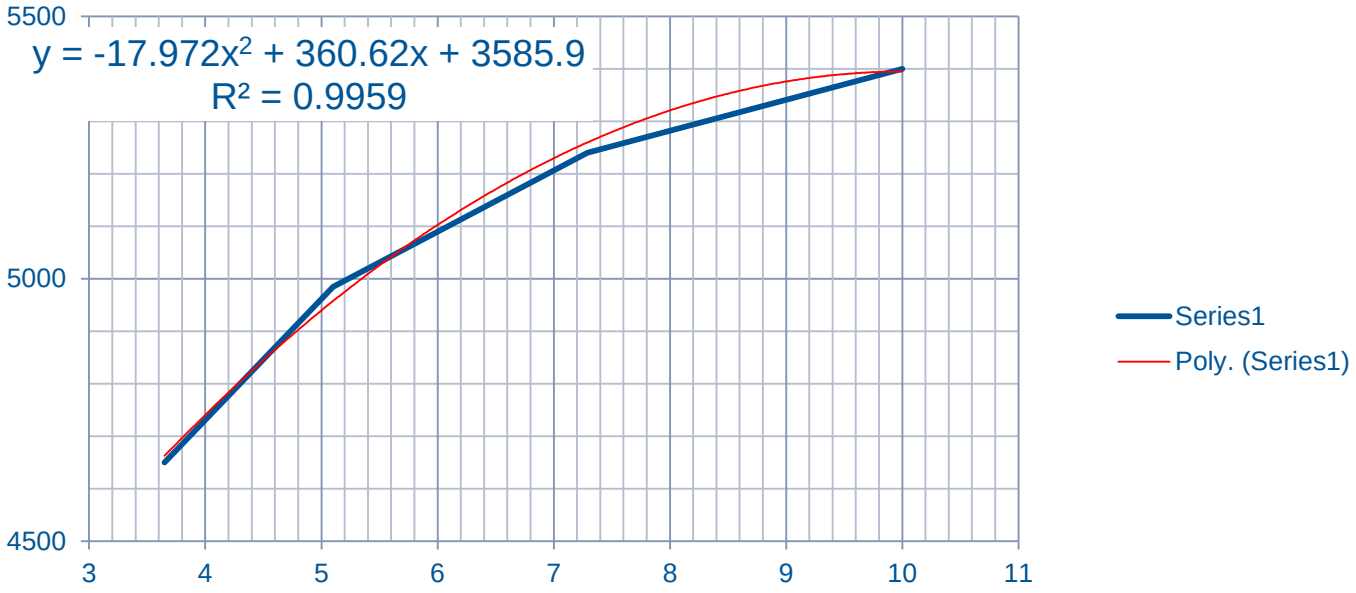




Net energy farm production (including aerodynamic **and** electrical losses)
Increase with distance

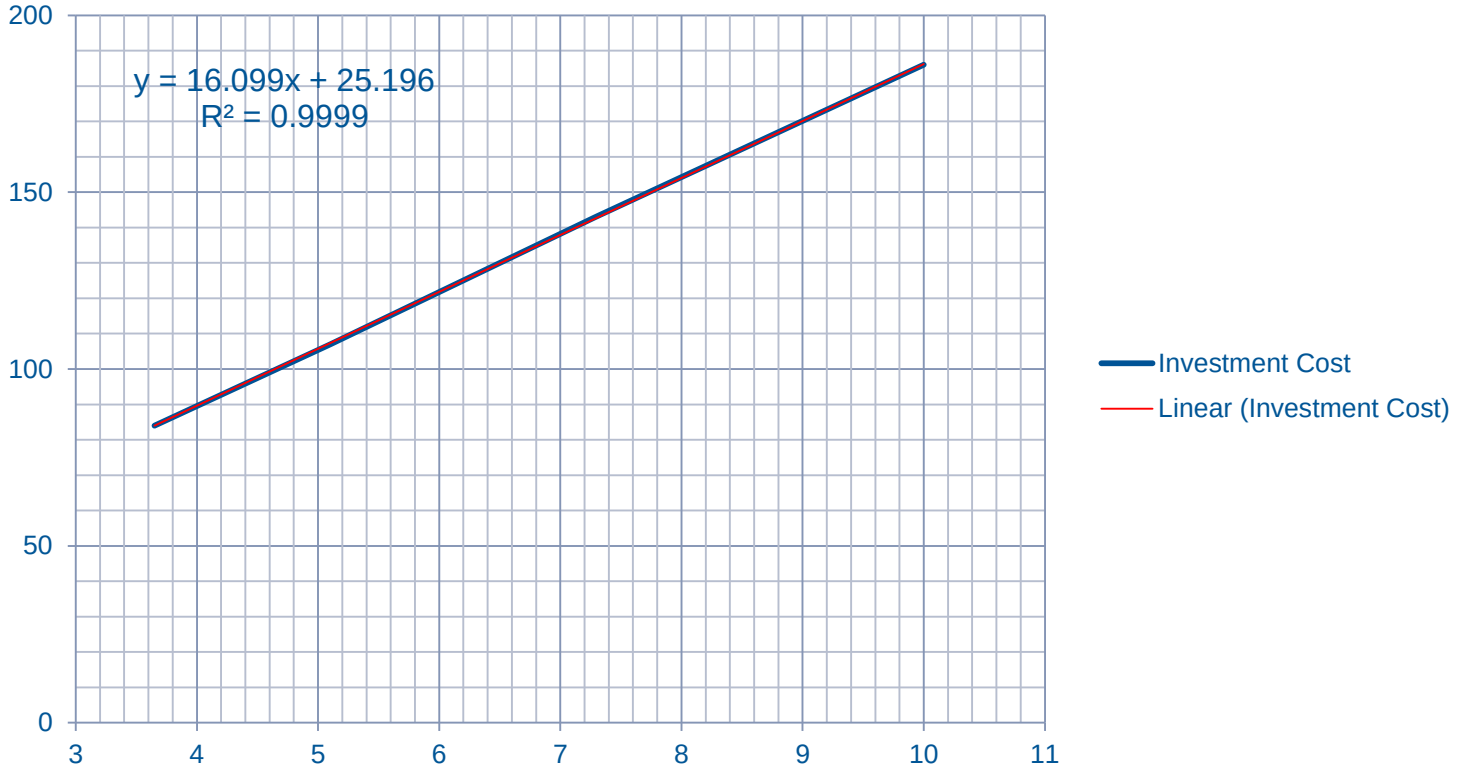
Investment costs of electrical infrastructure
Increase ~ linearly with distance

Approximation of Net energy yield



2nd order approximation of net energy farm production

Approximation of Investment costs of electrical infrastructure

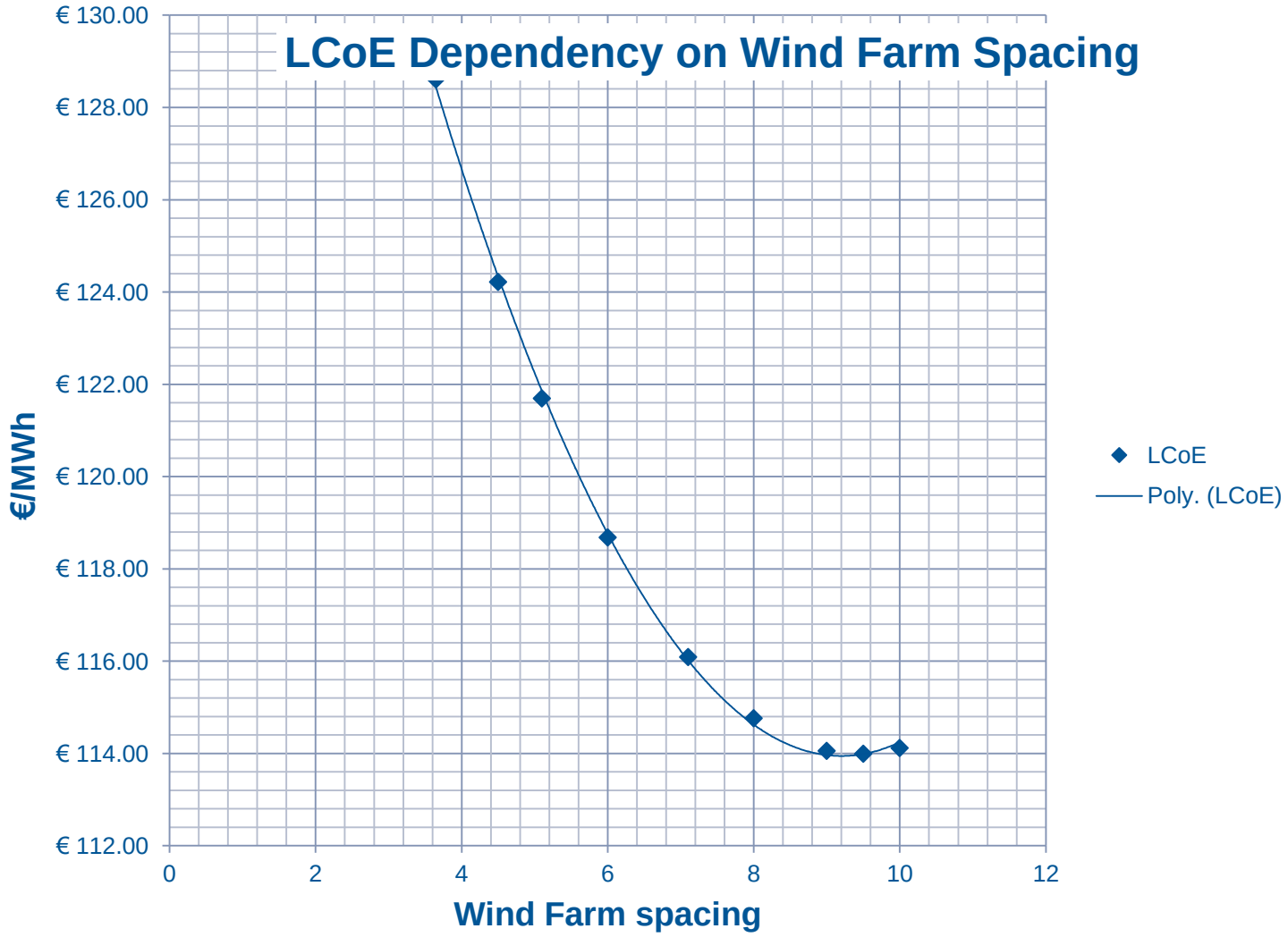


Linear approximation of investment costs

Cost modelling assumption

- Average discount rate: 7.8%
- Economic lifetime: 12 years
- Availability: 95%
- Opex:0.107 MEUro/MW/year
- Capex: 3,876 MEuro/MW for **5.1D** distance
  - Variation of electrical investment costs as function of distance take into account
  - Based on the variation of EEFARM investment costs as function of distance

Example Wind Farm aerodynamics vs cabling costs vs efficiency



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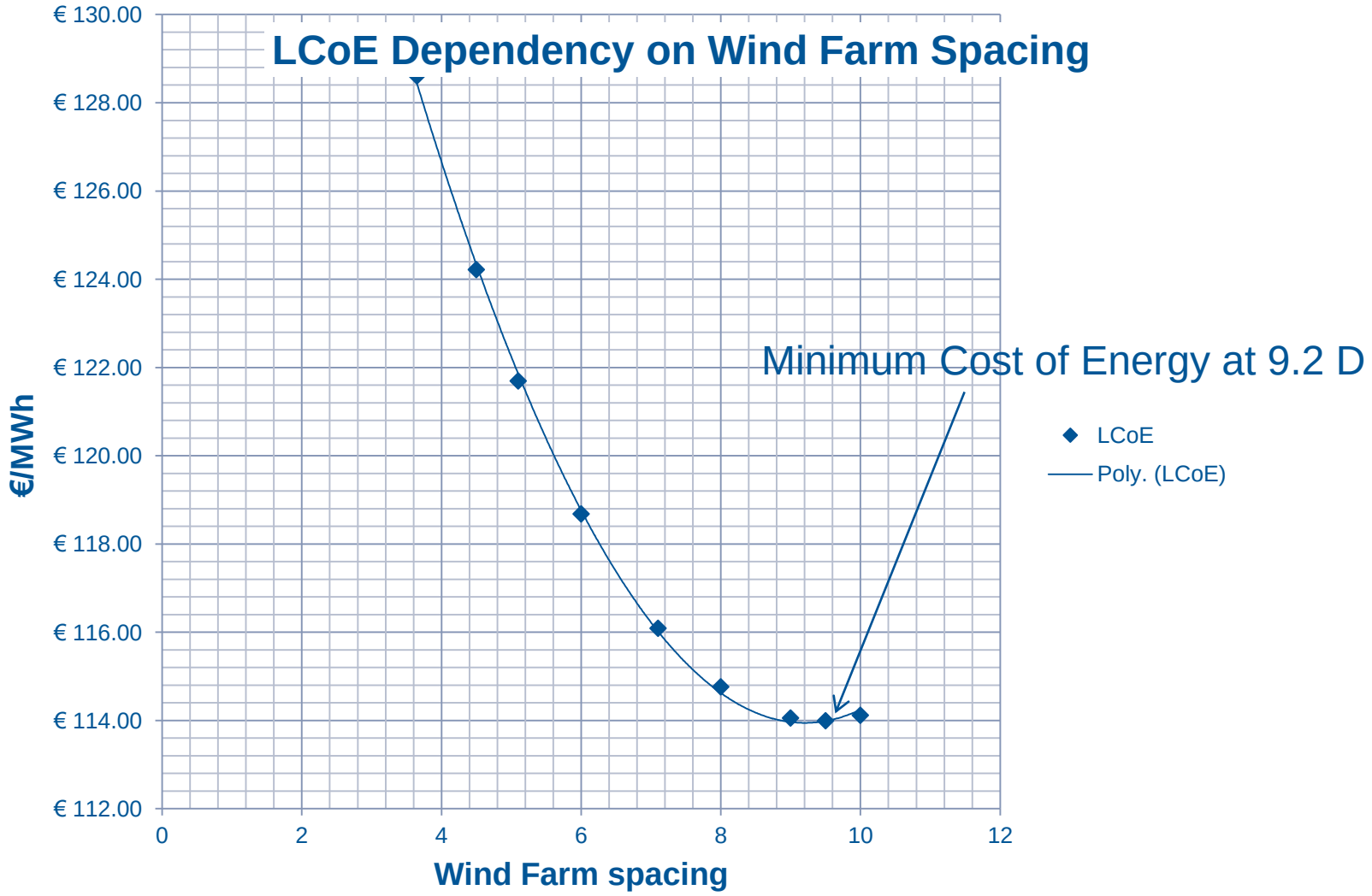

Conclusions

- The near future scenario has been defined consisting of 1 GW wind farm with 100 INNWIND.EU turbines
- The calculations on this scenario have recently started up for several user stories
- A preliminary scenario has been calculated with ECN tools showing the minimum LCOE for an inter turbine distance of 9.2D

Thank you very much for your attention