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Spatial allocation of wind power in Norway: Modelling trade-offs between energy, biodiversity, and local disamenities

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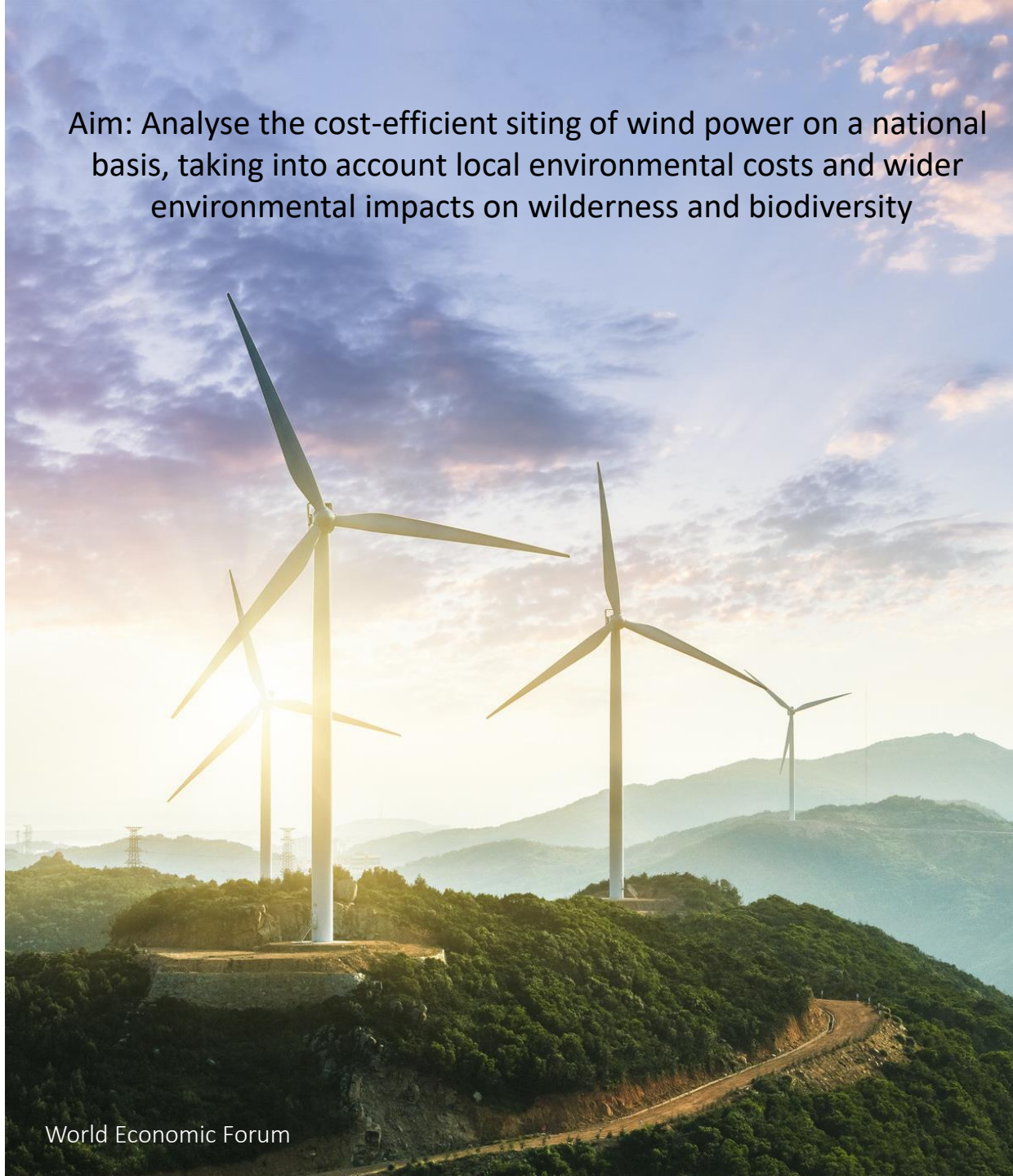
Introduction

- The energy transition push for more renewable power
- Local resistance related to
  - Noise pollution
  - Landscape aesthetics
  - Loss of wilderness
  - Loss of biodiversity
- + carbon emissions from land use change (mires and forest)
- Profitability of WPPs depend on location
- Profitability must be balanced with environmental costs

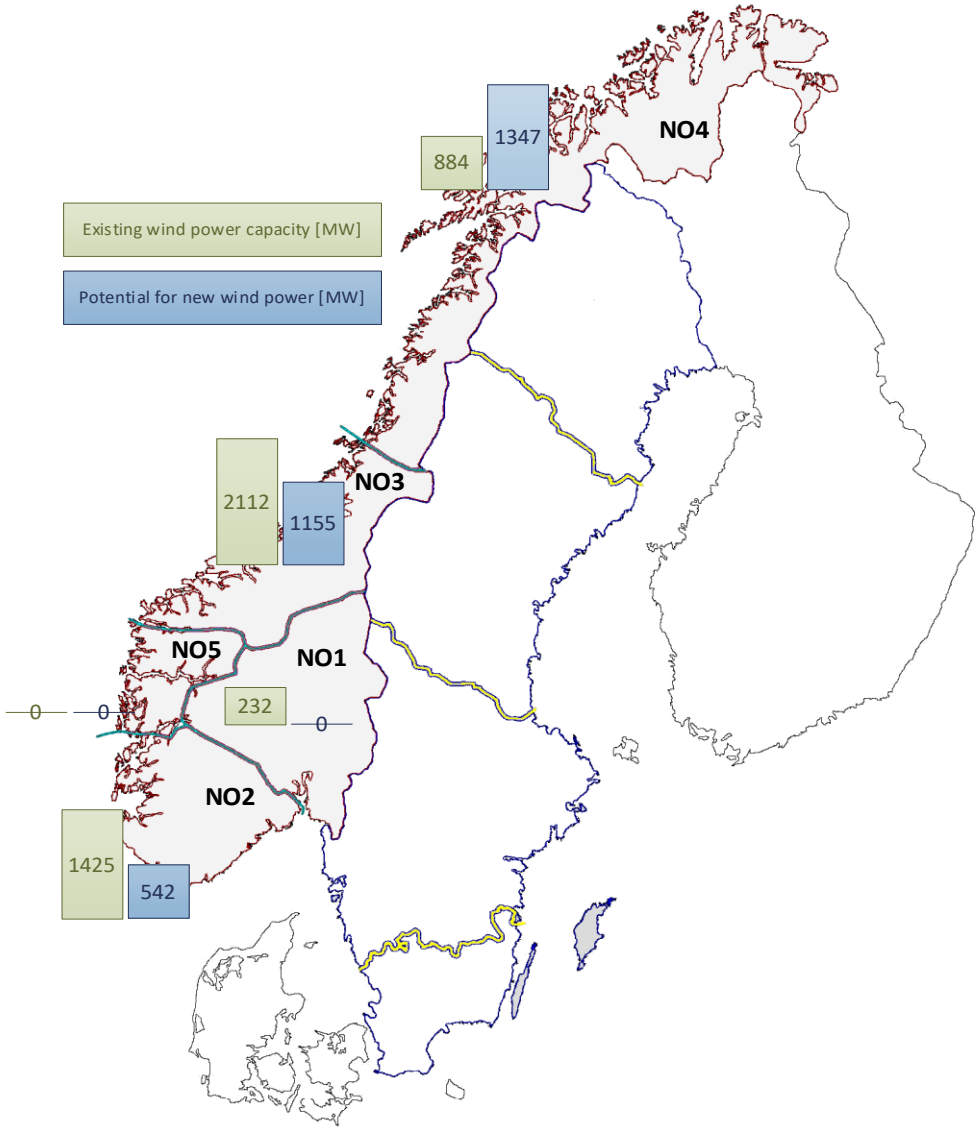
Aim: Analyse the cost-efficient siting of wind power on a national basis, taking into account local environmental costs and wider environmental impacts on wilderness and biodiversity



World Economic Forum

IFE-TIMES-Norway

- TIMES is a modelling tool developed by ETSAP, implementing agreement of IEA
- Long-term optimization model of the Norwegian energy system
- Captures the interplay between sectors, technologies, energy carriers and emissions
- Model specifications
  - 5 spot price regions
  - Time horizon: 2018-2050
  - Temporal resolution: 4 seasons x 24h
- Wind power
  - 15.5 TWh existing wind power
  - 11 TWh new wind power (potential)
    - Approved license applications
    - Applications under consideration
  - New production target of 4 TWh



Environmental concerns

Cost for local households:

- Number of residential and recreational homes within 0-30 km (GIS data)
- Number of turbines calculated based on WPP capacity
- Constant cost per household per turbine per year
  - Based on two local choice experiment studies

Carbon costs:

- 4% of area directly affected by infrastructure
- GIS data on biomass stored in forests and area of mires
- Loss of stored carbon in forests and mires during construction + future CO_2 uptake potential

Loss of wilderness and biodiversity:

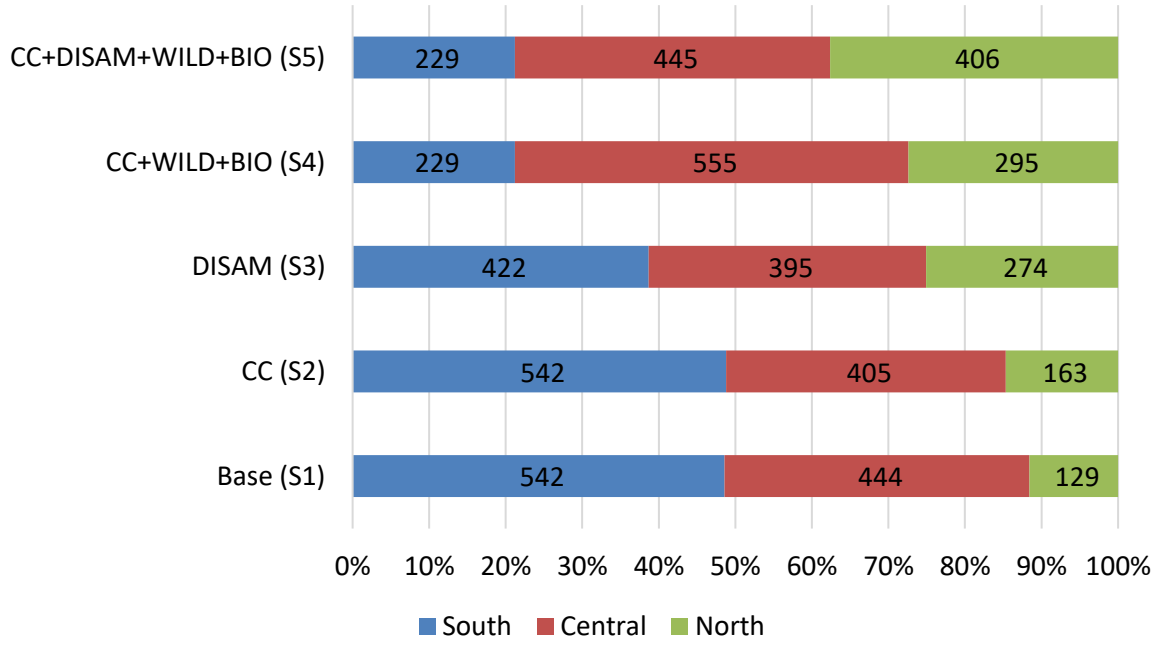
- Wilderness: Infrastructure index (< 1.8 = wilderness area)

- Biodiversity: Overlap > 1% of WPP area for one of the criteria (important nature types, protected areas, threatened species, wild reindeer areas etc.)

Scenario definition

Nummerering	Beskrivelse
S1	Cost efficient siting (Base)
S2	“Carbon costs” (CC)
S3	“Cost of local households” (DISAM)
S4	Carbon costs and sustainability constraints (CC+WILD+BIO)
S5	All local environmental costs and sustainability constraints (CC+DISAM+WILD+BIO)

Spatial distribution of WPPs



	CC (S2)	DISAM (S3)	CC+WILD+BIO (S4)	CC+DISAM+WILD+BIO (S5)
Number of WPP's included compared to S1	0	0	2	1
Number of WPP's excluded compared to S1	0	3	10	10
Total number of WPP's	16	13	8	7

Energy system surplus (ESS) and monetised welfare

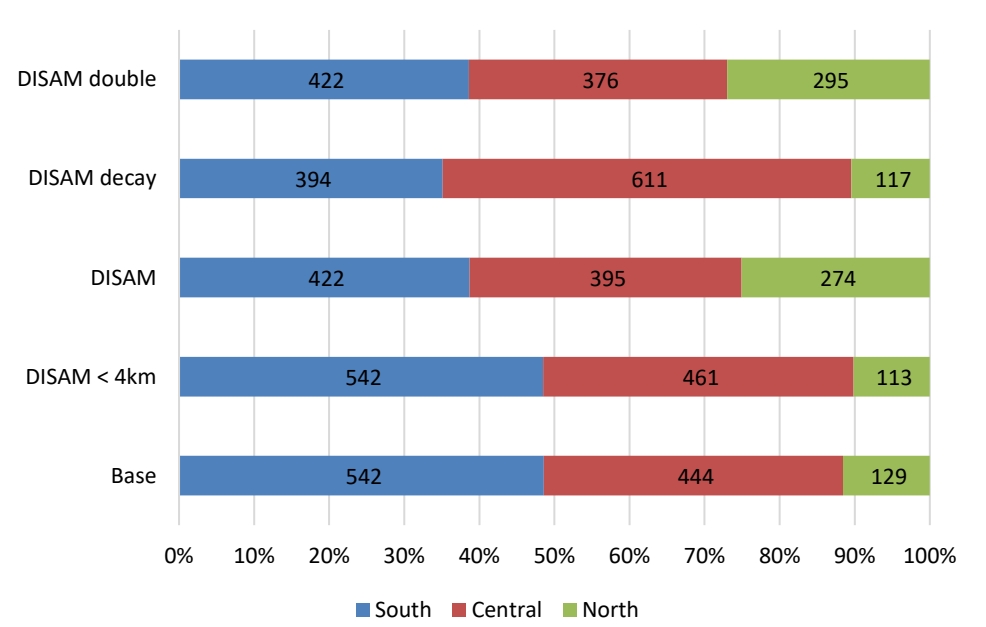
€/MWh	Base (S1)	CC (S2)	DISAM (S3)	CC+WILD+ BIO (S4)	CC+DISAM+ WILD+BIO (S5)
Energy system surplus(ESS)	33.9	33.9	33.3	32.3	32.0
Local cost of households	1.9	1.9	0.8	4.0	1.2
Carbon costs	0.1	0.1	0.1	0.1	0.1
Monetised welfare	**32.0**	**32.0**	**32.4**	**28.2**	**30.8**

- Highest energy system surplus when no environmental concerns are included in optimization (S1)
- Incorporating environmental costs and sustainability constraints shifts investments towards North
  - Less cost effective WPPs + lower electricity price results in lower revenues
- Trade-off between loss of welfare for local households and loss of wilderness and biodiversity
  - Local environmental cost more than doubled in S4 compared to S1
- Local environmental costs S5 < S1 -> monetised welfare reduced by only 4% (1.2 €/MWh)
  - 10 WPPs excluded when moving from S1 -> S5
- Implicit welfare cost of sustainability constraints = 1.6 €/MWh (S5-S3)

Sensitivity

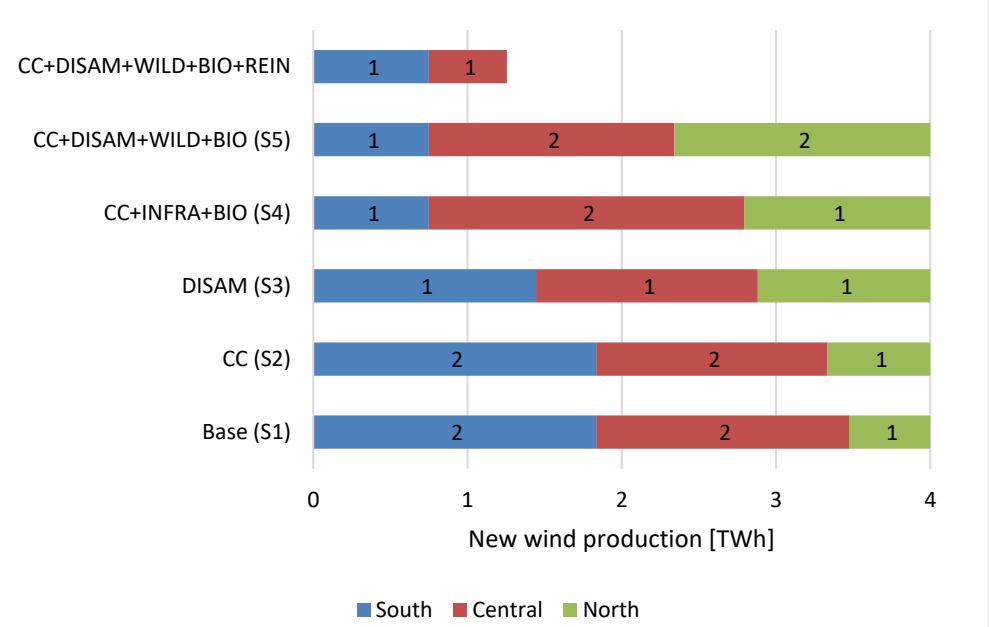
Local cost of households

Distance decay: cost differentiated based on distance intervals 0-2 km, 2-4 km, 4+ km



Impact of reindeer husbandry

> 1% overlap with reeindeer indicators (breeding, grazing, migration etc.)



Conclusion

- Developed framework for optimal siting of wind power plants under local environmental concerns and sustainability constraints in an energy system model
- Southern Norway is the most cost-optimal region due to higher electricity prices and proximity to export cables
- Investments are shifted to northern Norway when local environmental costs are considered
- Focusing only on wilderness and biodiversity leads to increased deployment of wind turbines in more populated areas
- Welfare is reduced by only 4% in social optimal scenario -> cost of including environmental concerns in the selection process is rather low

Thank you!

Spatial Trade-Offs in National Land-Based Wind Power Production in Times of Biodiversity and Climate Crises | Environmental and Resource Economics

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Thank you for your attention!

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