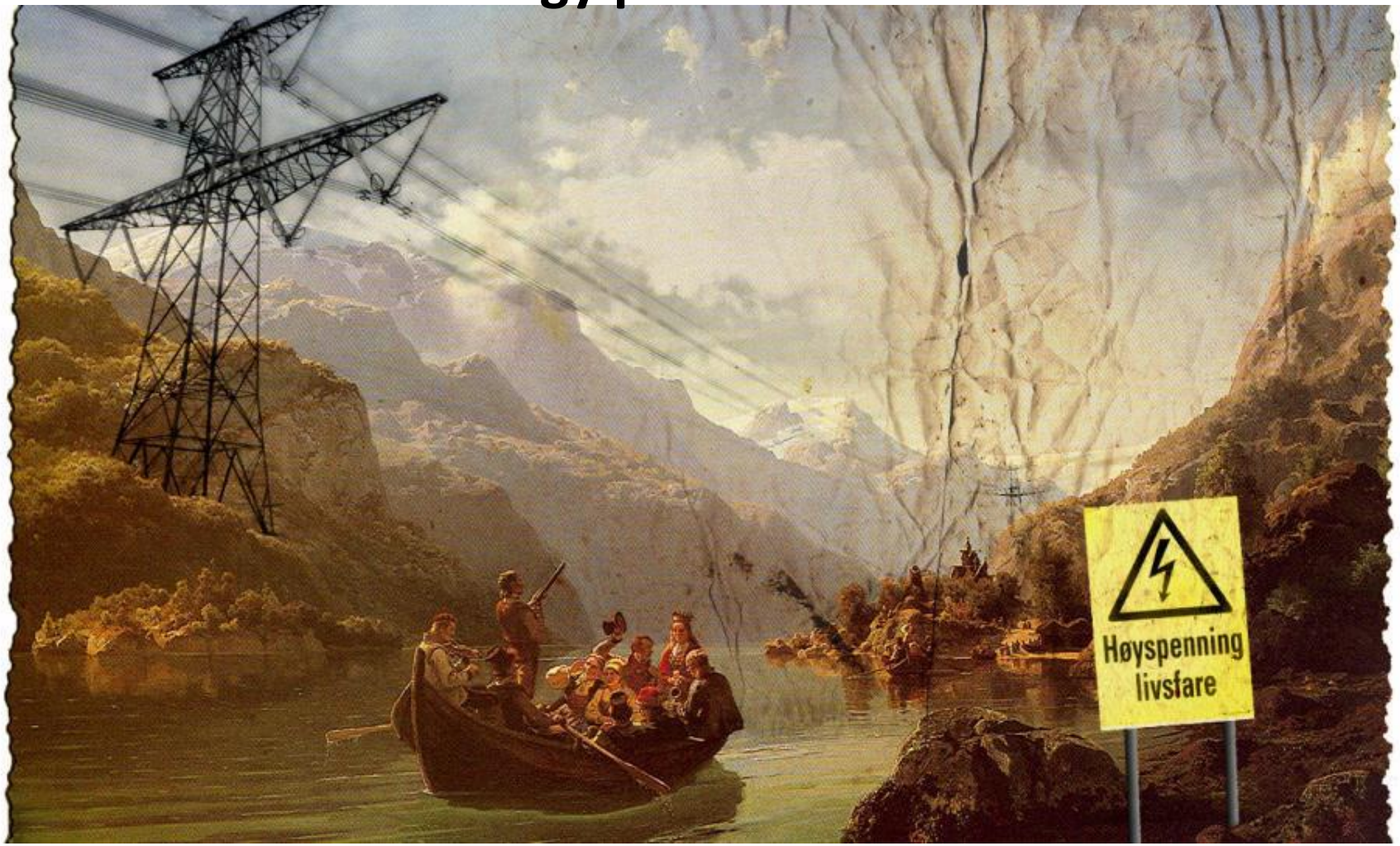
Accounting for environmental costs of renewable energy production and distribution



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Content

- Cost-Benefit Analysis (CBA) and environmental valuation
- Social costs of energy
- Damage Function Approach
- External Costs of Air Pollution from Fossil Energy
- Ecosystem Service Costs from Renewable Energy
    - Electric Transmission Lines
    - Hydro Power
    - Wind Power
- Conclusions and Recommendations

Norwegian Government Manuals for CBA

- **Norwegian Ministry of Finance (2018): Guidelines to CBA of public projects**)
- Veileder i samfunnsøkonomiske analyser
  https://dfo.no/fagomrader/utredning/samfunnsokonomiske-analyser

  Rundskriv R-109/21 – CBA principles and requirements

  https://www.regjeringen.no/globalassets/upload/fin/vedlegg/okstyring/rundskriv/faste/r_109_2021.pdf
- **Valuing Ecosystem Services** NOU (2013: 10: s18): Naturen Goder – Om verdien av Økosystemtjenester.: «Det bør beregnes økonomiske verdianslag for flere økosystemtjenester enn i dag, slik at verdien av disse tjenestene skal kunne inkluderes og tas med i vurderinger på lik linje med andre økonomiske verdier."

  http://www.regjeringen.no/nb/dep/kld/dok/nou-er/2013/nou-2013-10.html?id=734440
- **Sectoral guidelines to CBA in transport, energy and environment** (Environmental and public health valuation studies performed regularly to provide generalizable unit values for transport; ad-hoc for energy and environment; sectors but research projects

  - National Public Roads Administration (2018/ 2021):

  Konsekvensanalyser -Håndbok V712 (Combo CBA and EIA)

  https://www.vegvesen.no/Fag/Veg+og+gate/Planlegging/Grunnlagsdata/Konsekvensanalyser

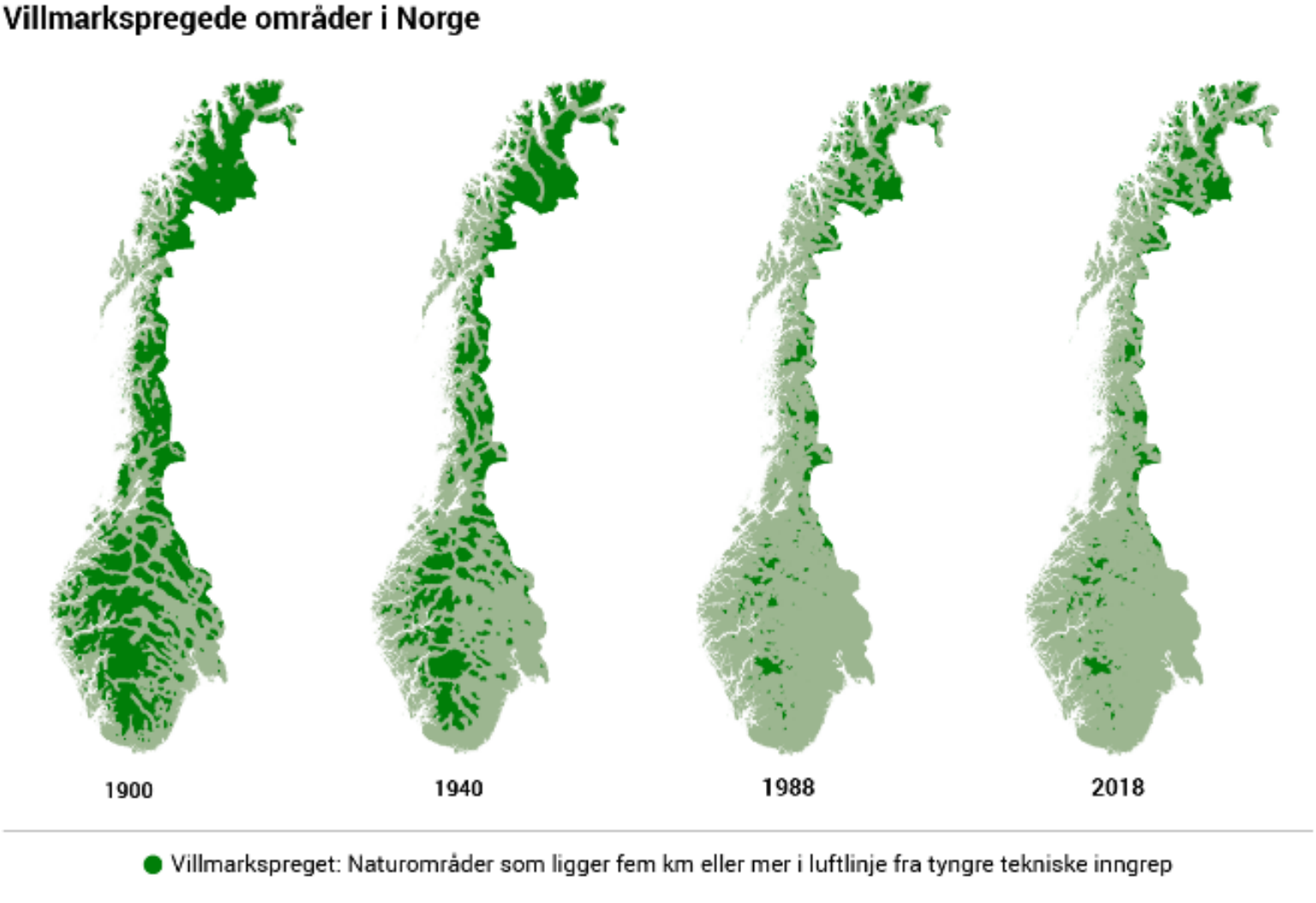
  - National Coastal Administration (Kystverket)

https://www.kystverket.no/contentassets/6453ebf35c4947f2a9dbe0a1843c84b8/veileder-i-samfunnsokonomisk-analyse.pdf/download

SHARP DECLINE IN WILDERNESS AREAS IN NORWAY

Zero price of wilderness → Overdevelopment

Wilderness areas in Norway, defined as areas more than 5 km from heavy technical installations (like buildings, power lines and roads), have been reduced from 48 to 11.5 % of the total land area. (www.miljo.no)



Social Costs of Energy

Energy investment decision should be subjected to Cost-Benefit Analysis (CBA); considering both private costs and external costs (environmental costs)

$$C_s = C_p + C_e$$

Social Costs = Private Costs + External Costs

- External Costs of *production* and *distribution* of energy:
  - Local air pollution; impacts on **public health**, **ecosystem services, agricultural production, corrosion of buildings/ cultural heritage**
  - Greenhouse gas emissions
  - Impacts on biodiversity (e.g. Hydro→ fish, Wind →birds) Landscape aesthetic impacts (e.g., reduced flow in rivers and water falls, tall wind turbines, electric transmission lines)

Damage Function Approach to valuing impacts from air pollution

Source

EU project series: External effects of energy (ExternE)

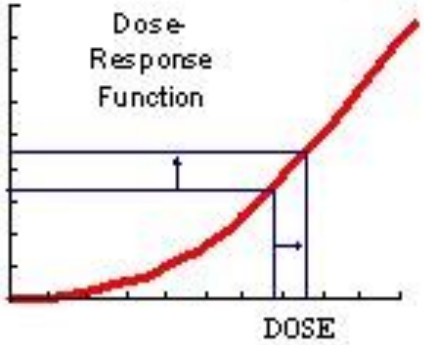
www.externe.info

SOURCE
(specification of site and technology)
⇒**emission**
(e.g., kg/yr of particulates)

DISPERSION
(e.g. atmospheric dispersion model)
⇒**increase in concentration at receptor sites**
(e.g., μg/m^3 of particulates in all affected regions)

DOSE-RESPONSE FUNCTION
(or concentration-response function)
⇒**impact**
(e.g., cases of asthma due to ambient concentration of particulates)

IMPACT



MONETARY VALUATION
⇒**cost**
(e.g., cost of asthma)

Classification of Environmental Valuation Techniques

Methods based on individual preferences

	Indirect	Direct
Revealed Preferences (RP)	Household Production Function (HPF) Approach: - Travel Cost (TC) - Averting Costs (AC) Hedonic Price (HP) analysis	Simulated markets Market prices Replacement Costs (RC)
Stated Preferences (SP)	Choice Experiments (CE)	Contingent Valuation (CV)

External costs of Energy (ExternE)

eurocents pr kwt www.externe.info

Country	Coal & lignite	Peat	Oil	Gas	Nuclear	Biomass	Hydro	PV	Wind
AUT				1-3		2-3	0.1		
BE	4-15			1-2	0.5				
DE	3-6		5-8	1-2	0.2	3		0.6	0.05
DK	4-7			2-3		1			0.1
ES	5-8			1-2		3-5*			0.2
FI	2-4	2-5				1			
FR	7-10		8-11	2-4	0.3	1	1		
GR	5-8		3-5	1		0-0.8	1		0.25
IE	6-8	3-4							
IT			3-6	2-3			0.3		
NL	3-4			1-2	0.7	0.5			
NO				1-2		0.2	0.2		0-0.25
PT	4-7			1-2		1-2	0.03		
SE	2-4					0.3	0-0.7		
UK	4-7		3-5	1-2	0.25	1			0.15

* : biomass co-fired with lignites

** : sub-total of quantifiable externalities
(such as global warming, public health, occupational health, material damage)

Mortality
Value of a Statistical Life (VSL)
i) Hedonic Wage

- **Hedonic Wage** analysis is used to calculate the Value of a Statistical Life (VSL)

- Workers demand a wage premium to take on riskier jobs
  $Wage_i = f(A_i, B_i, C_i, R_i)$

  where
  R_i = Risk of fatal accident (e.g x deaths in 100.000) for job *i*

- Extensive data needed on all factors affecting wage, assume that workers have full information about R and other factors when they choose jobs, perfectly functioning labour market etc. Not representative for the overall population (i.e. only workers' preferences (not students, retired people, unemployed etc).

Value of a Statistical Life (VSL)

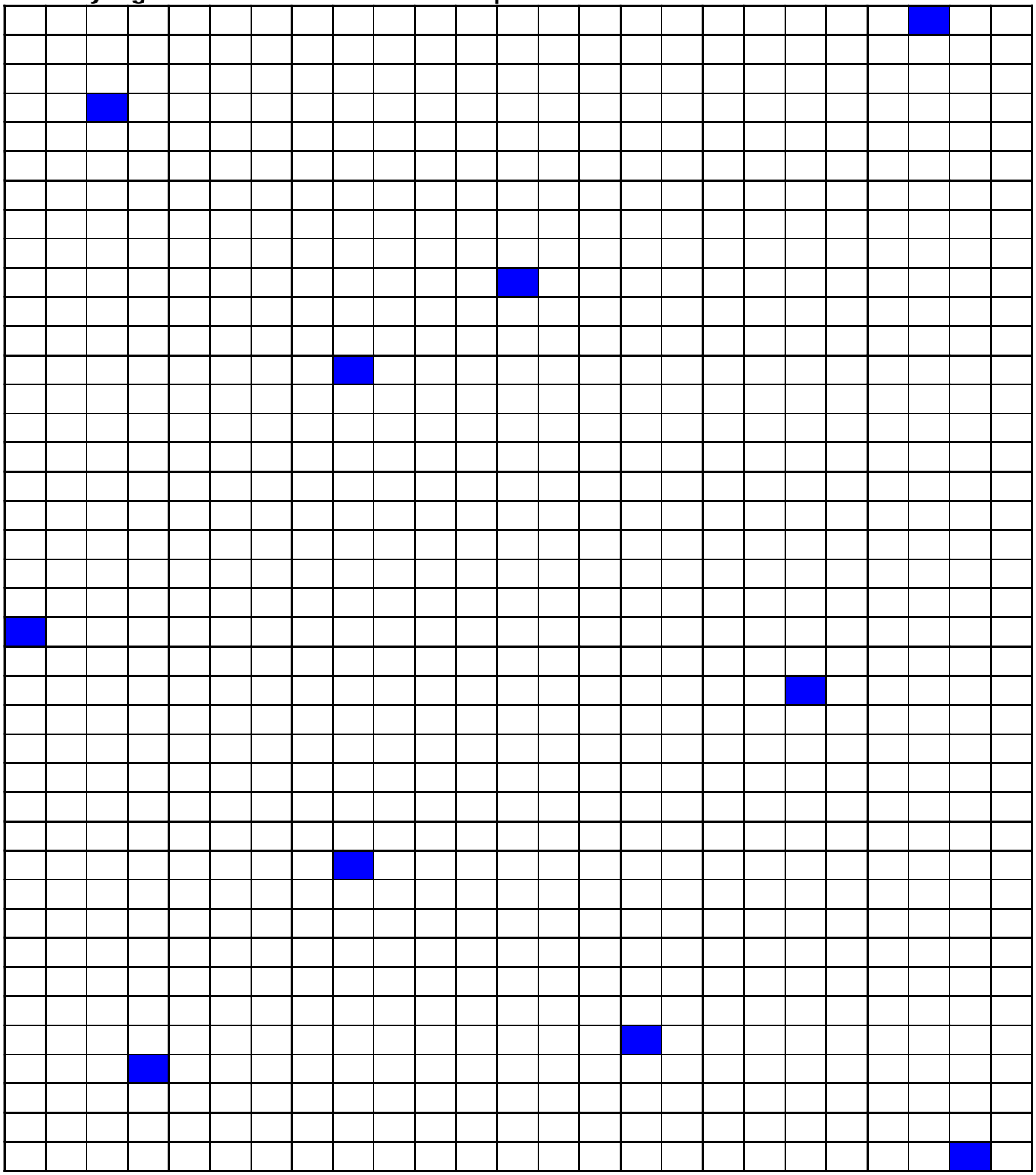
ii) Contingent Valuation

Contingent Valuation (CV):
Ask people´s Willingness-To-Pay (WTP) for a program/project that reduce the risk of dying prematurely from e.g.10:1.000 to 9:1.000 over a 10 year period

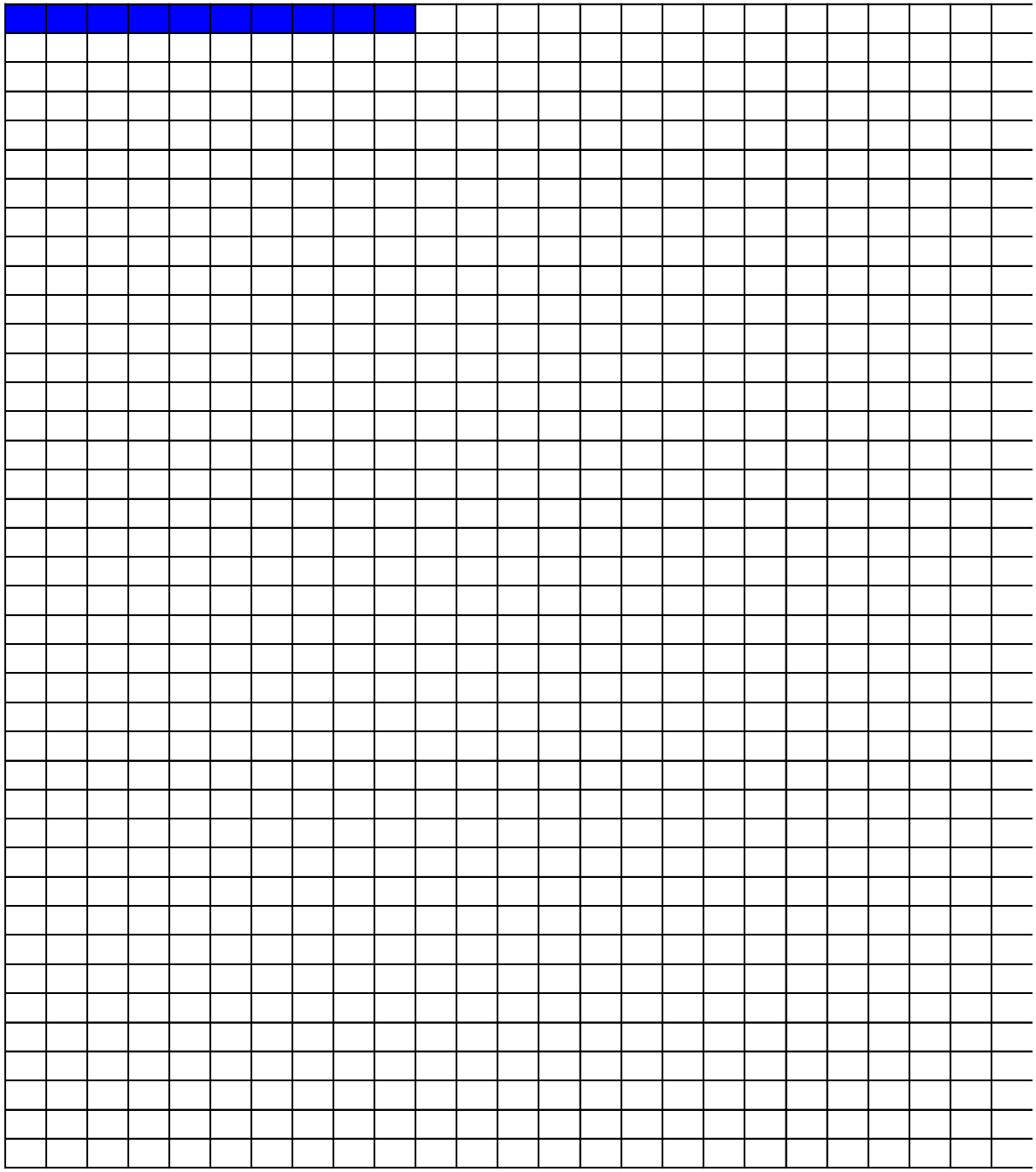
→ Annual risk reduction = 1:10.000

Illustrate by saying: In a town of 10.000 1 pe less will die prematurely; and show risk diagram (see next slide)

Sannsynligheten for å dø = 10 til 1000 i løpet av de neste 10 årene

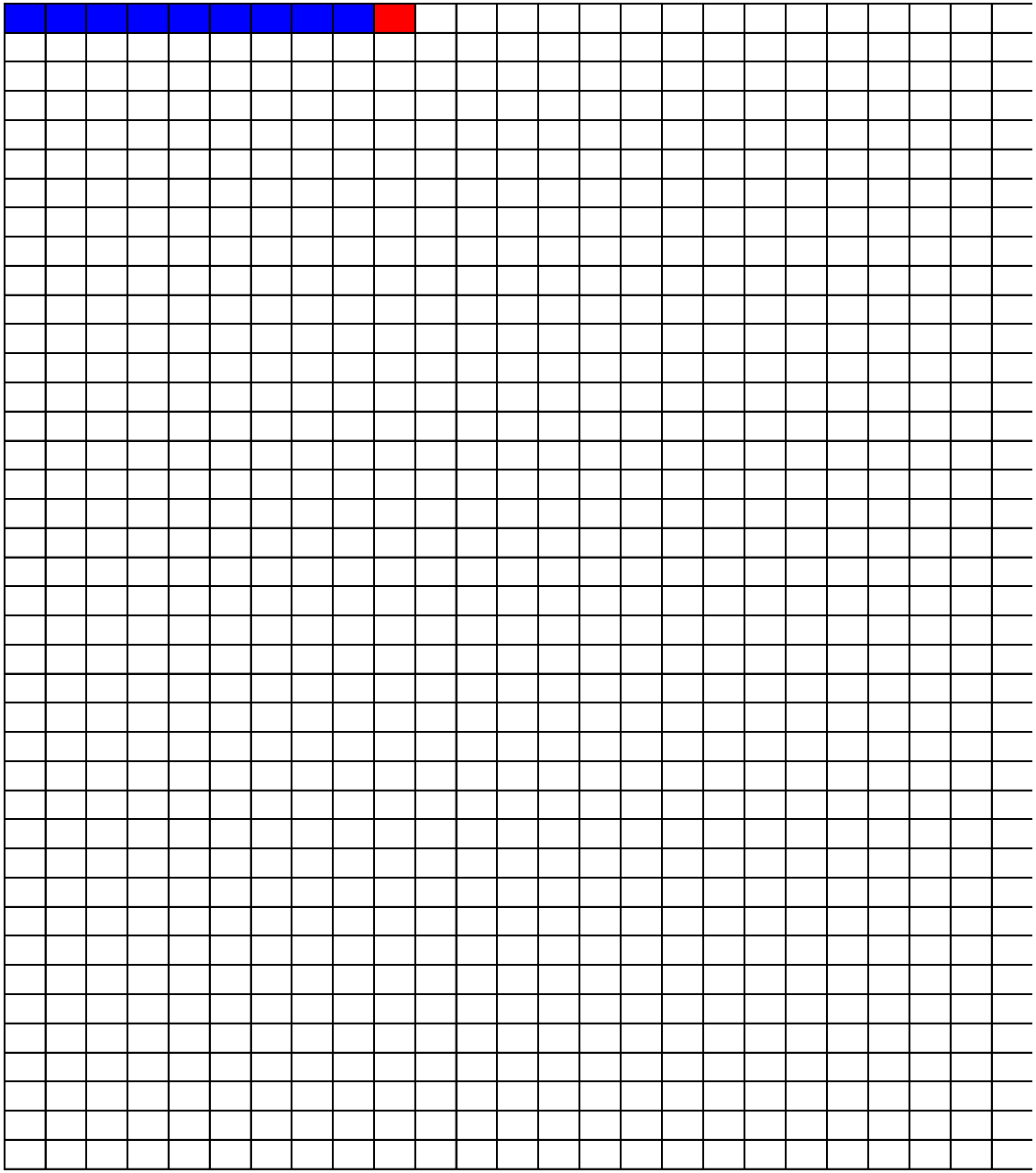


Sannsynlighet for å dø – Utgangspunkt: 10 av 1000



Sannsynlighet for å dø på grunn av trafikkulykker– Utgangspunkt: 10 av 1000

Redusert sannsynlighet for å dø på grunn av tiltak mot trafikkulykker



How to calculate VSL from WTP results in Contingent Valuation

WTP = 300 $/person/year for annual *risk reduction* 1: 10,000

For every 10,000 people, one death would be prevented with this risk reduction. Summing the individual WTP values of $300 over 10,000 people gives the number referred to as Value of Statistical Life (VSL) = US $ 3 million

VSL Norway based on national CV and CE Survey:

Adults = 35 mill. 2022-NOK / Children (2 x)= 70 mill

OECD Meta analysis of existing CV studies of VSL:

VSL = US $ 2,4 million global median

Global Meta analysis of Stated Preference Studies of VSL

Lindhjem, Navrud, Braathen and Biausque (2011) Valuing lives saved from environment, transport and health policies. A meta analysis. *Risk Analysis* 31 (9); 1381-1407.

OECD (2012): Mortality Risk Valuation in Environment, Health and Transport Policies. OECD Publishing, Paris.

OECD Website for data and reports:
www.oecd.org/env/policies/vsl

Fjord landscape with overhead transmission line

JORDLANDSKAP -Med luftledning

ECOSYSTEM SERVICES:

Classification

- **SUPPORTIVE ECOSYSTEM SERVICES are those that are necessary for the production of all other ecosystem services, such as photosynthesis and nutrient cycling**

- **REGULATING ECOSYSTEM SERVICES are the benefits people obtain from the regulation of ecosystem processes, including, carbon sequestration, regulation of floods, water purification**

- **PROVISIONING ECOSYSTEM SERVICES are the products people obtain from ecosystems such as timber, fish, wildlife, genetic resources etc.**

- **CULTURAL ECOSYSTEM SERVICES are the nonmaterial benefits people obtain from ecosystems such as recreational and aesthetic services; non-use values (existence and bequest values)**

Willingness-to-pay (WTP) for a public good

How much of their income (Y) are people willing to give up/willing to pay (WTP) (and thus reduce their consumption of private goods at prices ***p***) in order to acheive a marginal improvement in the quality/quantity of a public good (e.g. ecosystem services like landscape aesthetics) from Q^0 to Q^1 and stay at the same, initial utility level U^0

$$U(\mathbf{p}, Q^0, Y) = U(\mathbf{p}, Q^1, Y - WTP) = U^0$$

- **Households' WTP is termed Total Economic Value (TEV)**

  TEV can be divided into two main parts depending on what motivates their WTP:

  1) Use Value

  - Direct Use Value- Consumptive use (e.g. recreational and commercial fishing, hunting) and non-consumptive (whale wathcing, nature photography, aesthetic beauty of landscapes)

  - Indirect Use Value (Regulating services);

  e.g. carbon sequestration, pollination

  - Option value (i.e. pay to have an option to use it in the future)

  2) Non-Use Value

  - Existence and Bequest values (i.e. preserving the existence of the resource for the current and future generations)

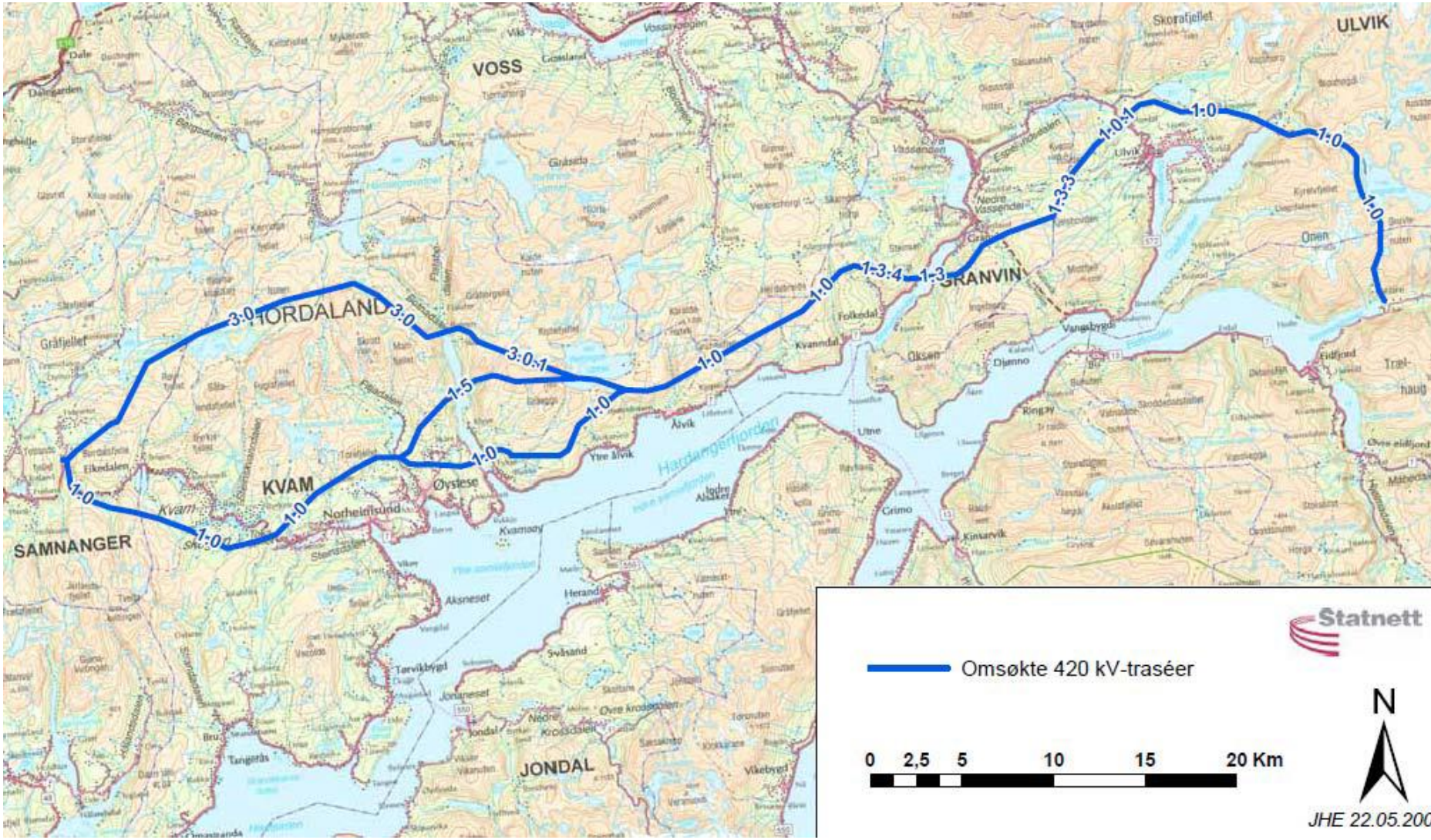
Transferring and Aggregating Environmental Costs and Benefits

- Number of ”affected” households (N) important for non-use values of landscape like the Hardanger Fjord
- Total WTP = Mean WTP/household x **N**
- How to determine N ?
- Local, regional, national or global good
  - Local/regional recreational area vs. National Park vs. World Heritage Sites
- Distance decay in WTP ?
- Value transfer techniques (in space and over time)

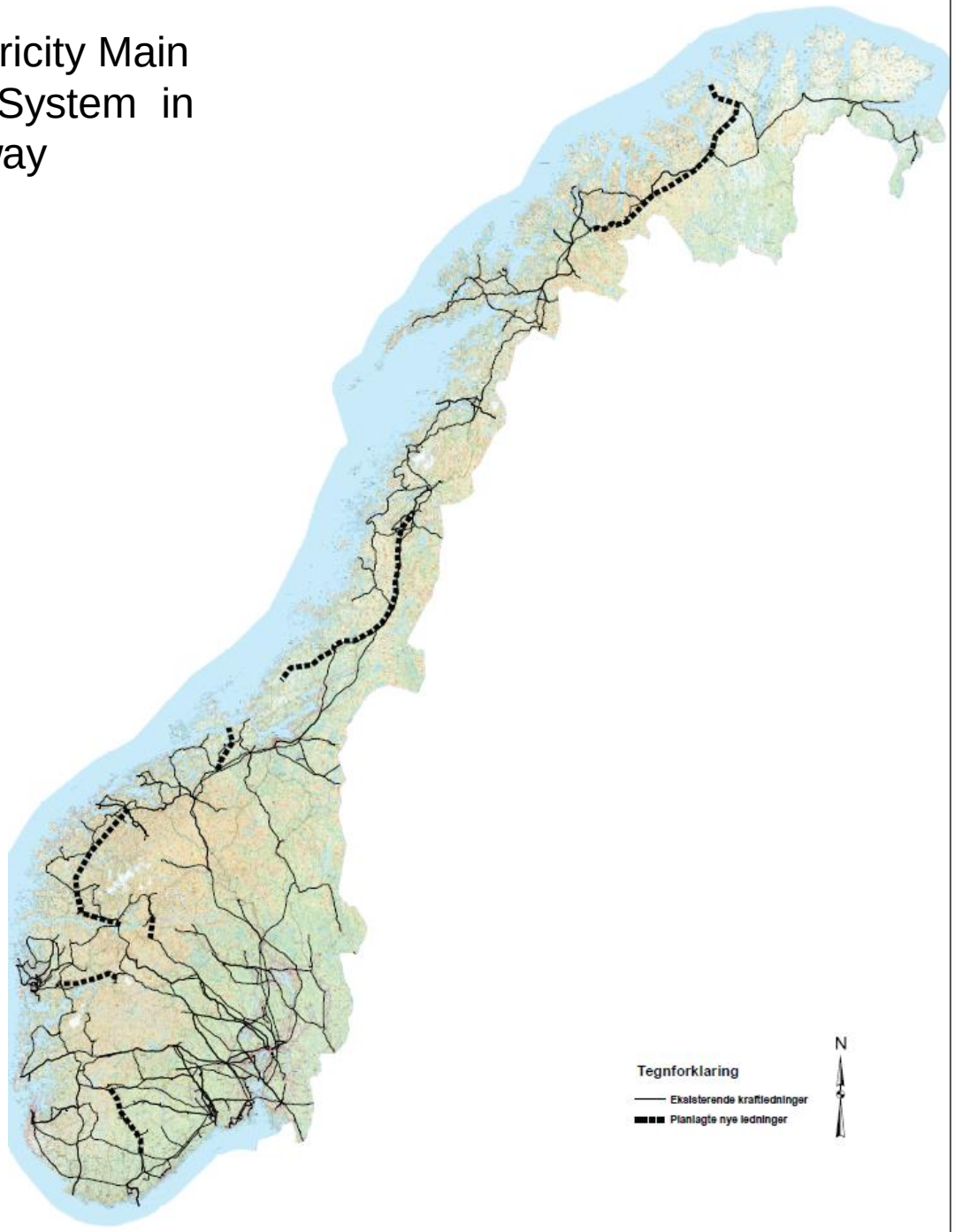
  Unit values vs. Benefit Functions vs. Meta Analysis

Landscape aesthetic impacts of electric transmission lines

Case: Sima-Samnanger / Hardanger fjord



Electricity Main Grid System in Norway



What is the value of avoiding landscape aestethic impacts from high voltage transmission lines (HVTL)?

Sjøkabelutvalg IV «Economic impacts of submarine cables» (2010):
***Additional cost of submarine cable* = ca. 3.400 mill NOK**

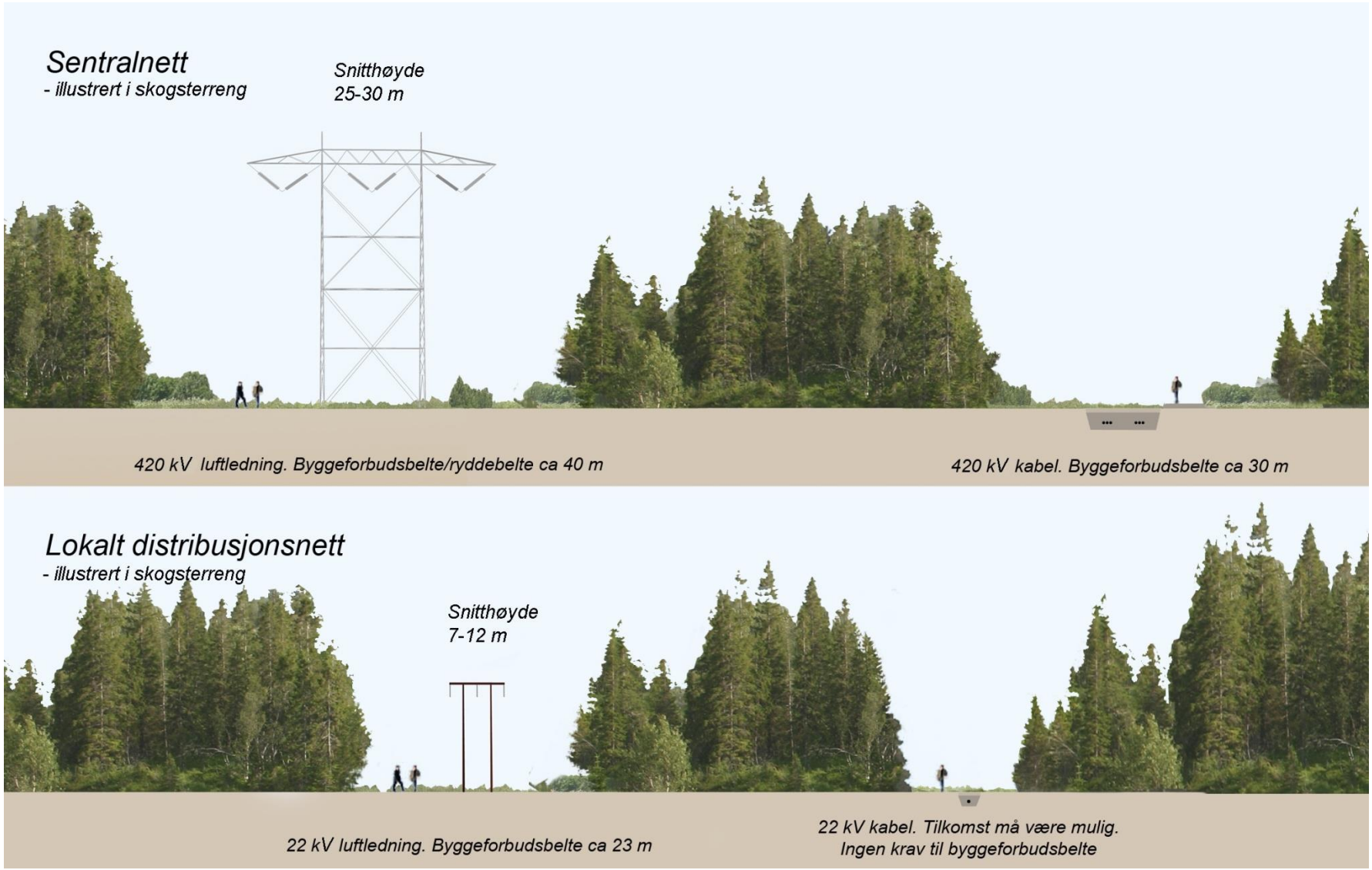
If the affected landscape is a ***national* public good**:
90 NOK/household/year in 35 years

If the affected landscape is a ***regional* public good** (i.e. only households in the county Hordaland are «affected», i.e., they gain utiliity from avoiding negative landscape impacts):
1000 NOK/household/year in 35 years

Are the social benefits of avoiding the landscape aestethic impacts of HVTL larger than these additional costs of the submarine cable?

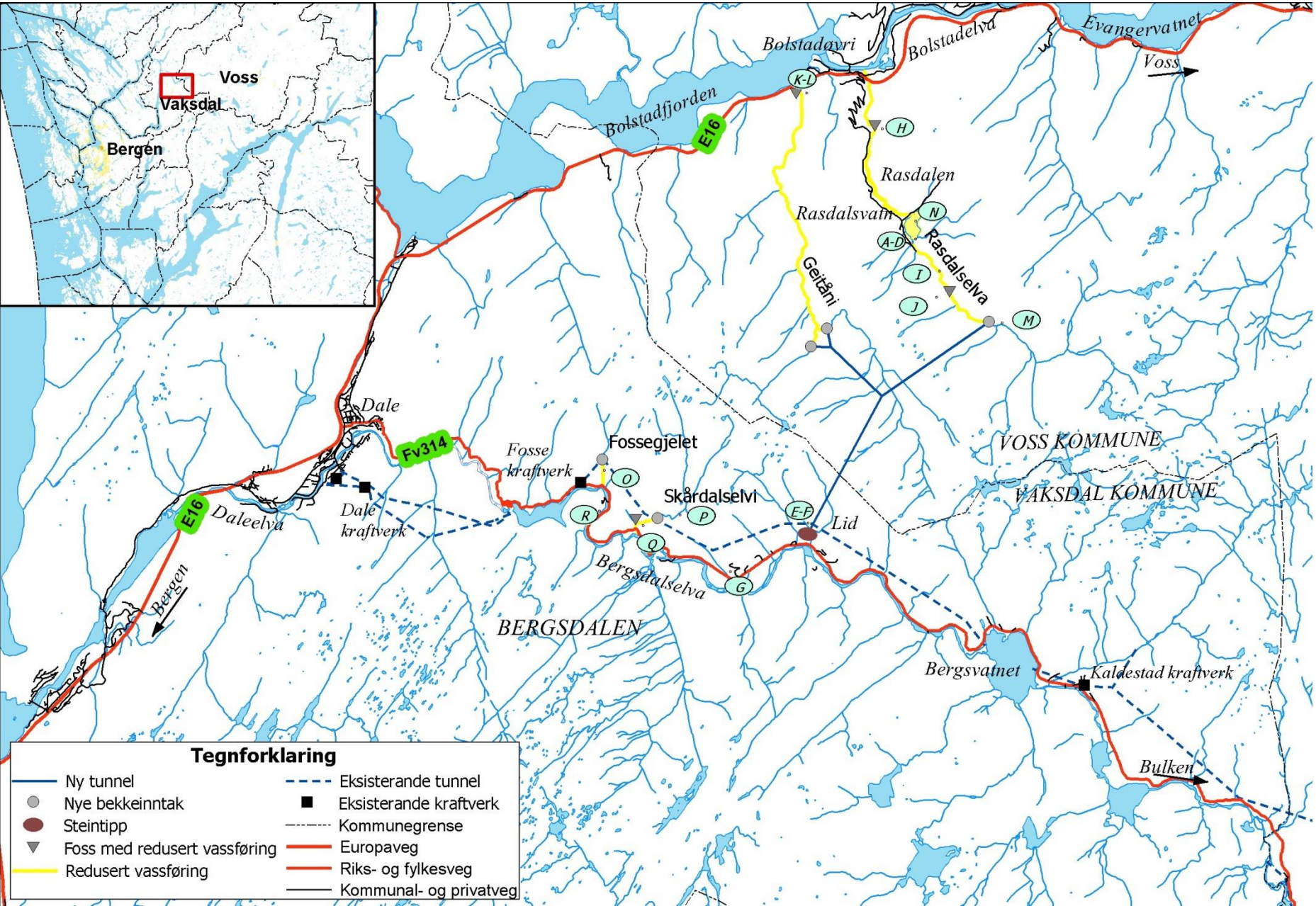
National Contingent Valuation survey (Magnussen, Navrud & San Martin 2009) of a representative sample (1000 households) of the national population of a new hypothetical transmission line between Eastern and Western Norway indicates clearly «Yes» if all Norwegian households are affected, and «break even» if only households in the county are assumed to be «affected».

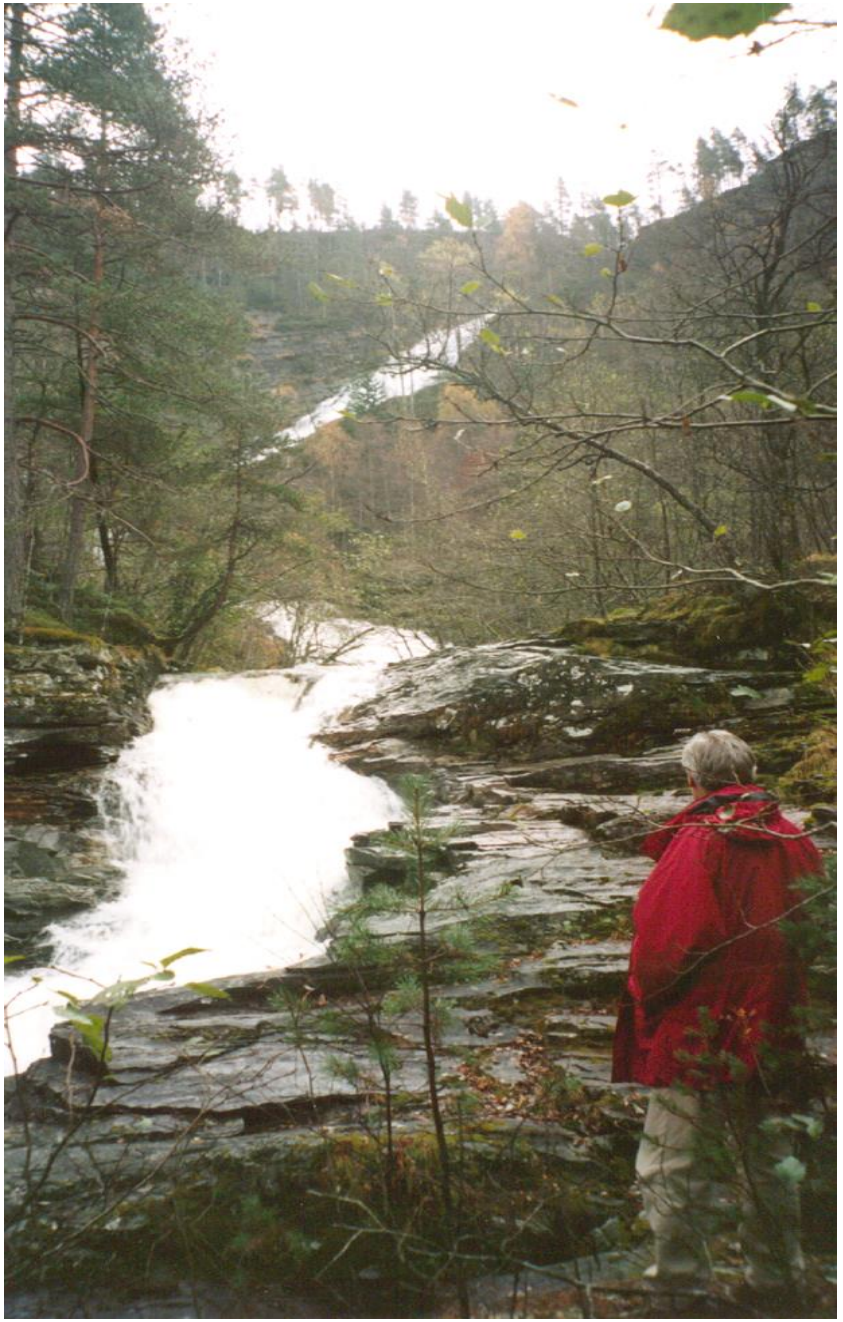
Overhead and underground transmission lines



Contingent Valuation – External costs of hydropower development in Voss/Vaksdal

Navrud (2003)





Without Hydropower project

With Hydropower Project

Environmental Costs (NOK/kWh) of hydropower development in four rivers in Voss/Vaksdal, Western Norway

Contingent Valuation study in 2003 repeated in Master thesis in 2004 shows **stable environmental costs over time** for all four rivers combined, but somewhat lower for Rasdalselva which has cabins and is used for recreation – could be due to the fact that respondents throught development of the river was less likely in 2004 as the energy producer had put the plans on hold)

	Totalt ***(0.04 TWh)***	**Rasdals-elva** **(0.02TWh)**	**Geit-åni** **(0.02TWh)**	**Skårdals-elva** **(0.0018 Twh)**	**Fosse-gjelet** **(0.0007Twh)**
2003	*0.09*	0.17	0.05	0.29	0.65
2004	*0.08*	0.08	0.05	0.29	0.70

Choice Experiment (CE)

Local plan for wind power development (2019)

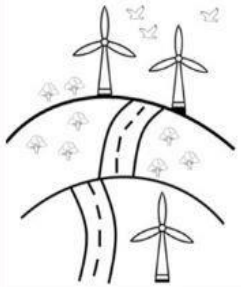
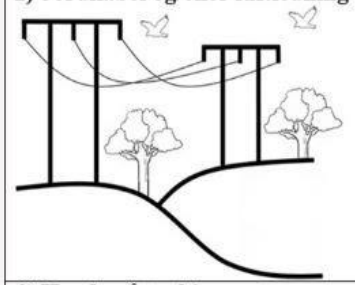
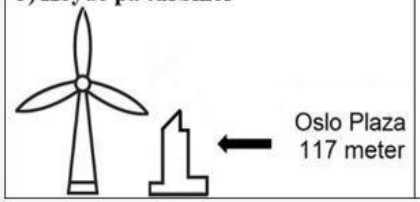
Setten Wind Power Development, Aurskog-Høland

250 meters turbiner

Description of main impacts (attributes in CE)

1) number of wind turbines (and road built), 2) underground cable or overhead power line, and 3) Height of turbines (visibility)

Oppsummering av hoved-virkningene av de tre første egenskapene.

Egenskap	Effekter
1) Antall turbiner 	- Negativ påvirkning på natur og dyreliv - Arealbeslag - Støy, lysblink, iskast og skyggekast
2) Jordkabel og/eller luftledning 	- Luftledninger har mer negativ påvirkning på natur og dyreliv - Luftledninger er mer synlige for folk
3) Høyde på turbiner 	- Synlighet - Blinkende rødt lys som kan være forstyrrende

Attribute : Number of wind turbines (and roads built)

Number of wind turbines (0 -12)

150 meters turbiner

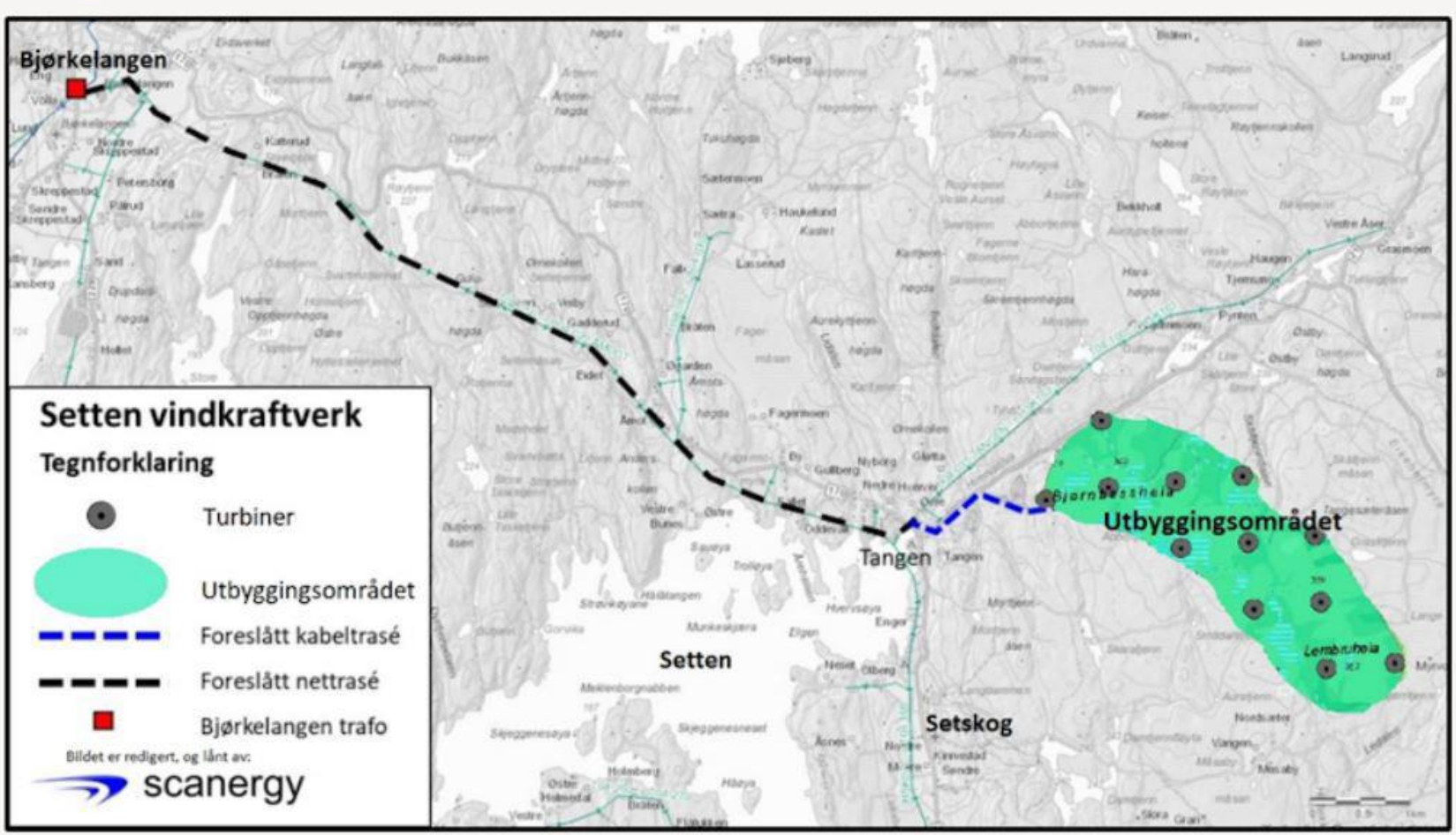
250 meters turbiner

Road: Before and after wind power development – without and with new road to wind park

Før:

Etter:

2) Power line (overhead or underground) in different types of landscape (urban forest,mountain)



Bildet illustrerer hvor de planlagte nye kraftledningene vil gå.

Overhead power line in forest

Egenskap 2) Eksempel på luftledning i skogområde

Bildet viser hvordan luftledningene i skogområdene vil se ut. Skog må fjernes for å sette opp ledningene.

Underground cable in forest

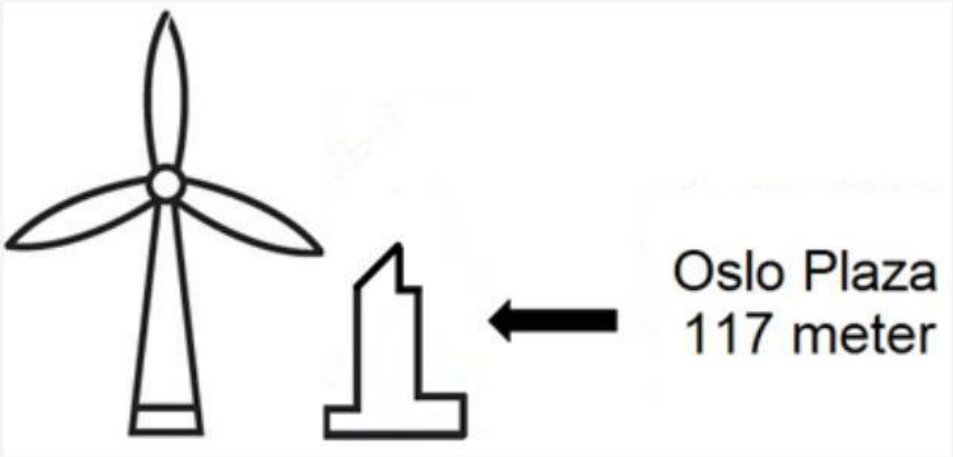
Egenskap 2) Eksempel på jordkabel i skogområde

Bildet viser hvordan jordkabel i skogområdene vil se ut. Ved bruk av jordkabel må også skog fjernes så lenge kablene er der, men her vil ikke kablene være synlige. I tillegg vil man få en anleggsvei ved siden av kabelgrøften (ikke vist på bildet).

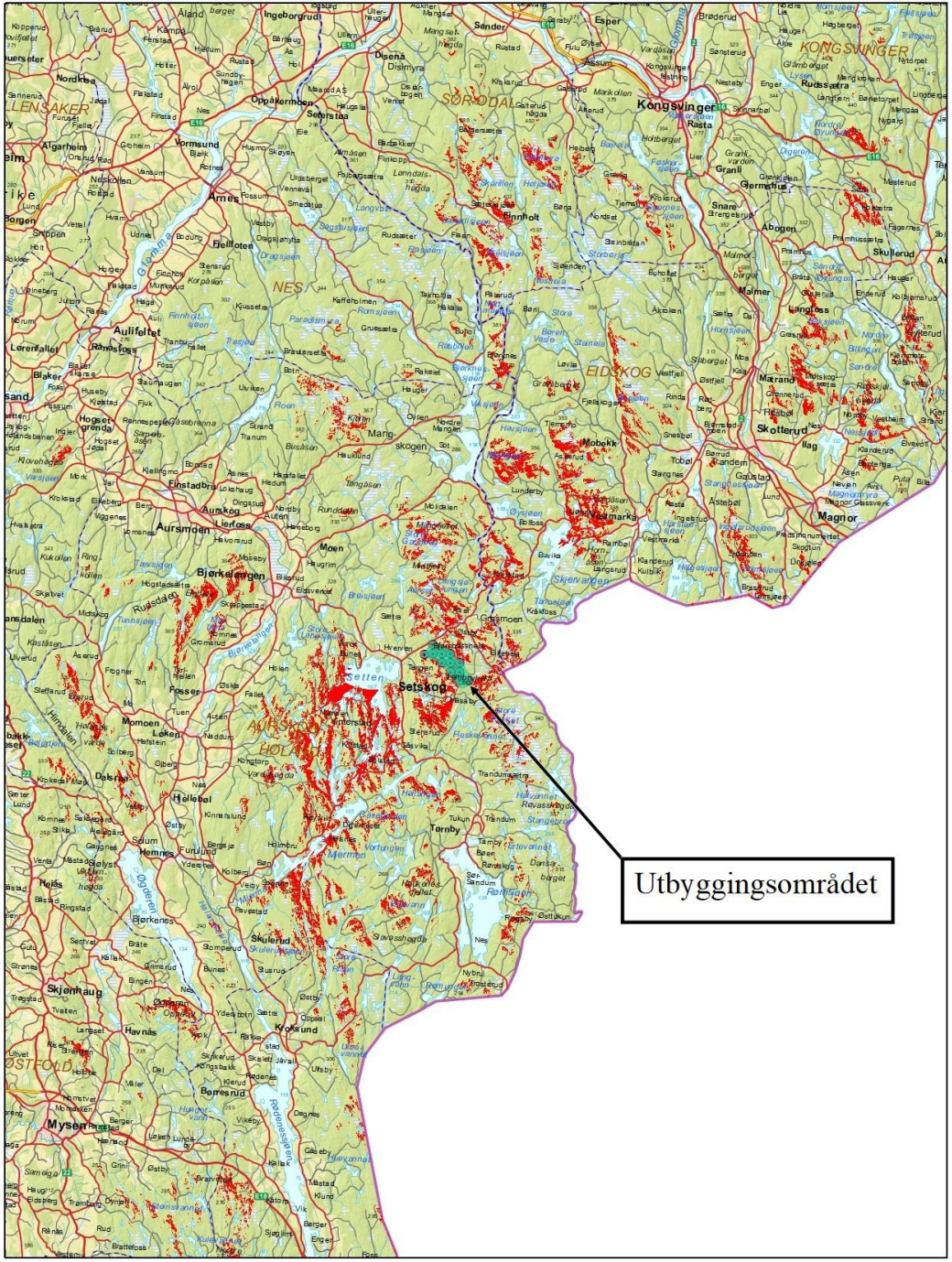
3) Height of Wind turbines (150, 200 and 250 m)

Egenskap 3) Høyde på vindturbinene

Fra bakken til toppen av vingespissen kan en vindturbin være mellom 150 til 250 meter høy. Høyden er avgjørende for hvor mye strøm en vindturbin kan produsere. Høyere vindturbiner produserer mer strøm og er mer synlige. Vindturbiner kan være synlige over avstander på 40 til 50 kilometer, om det er fri sikt.



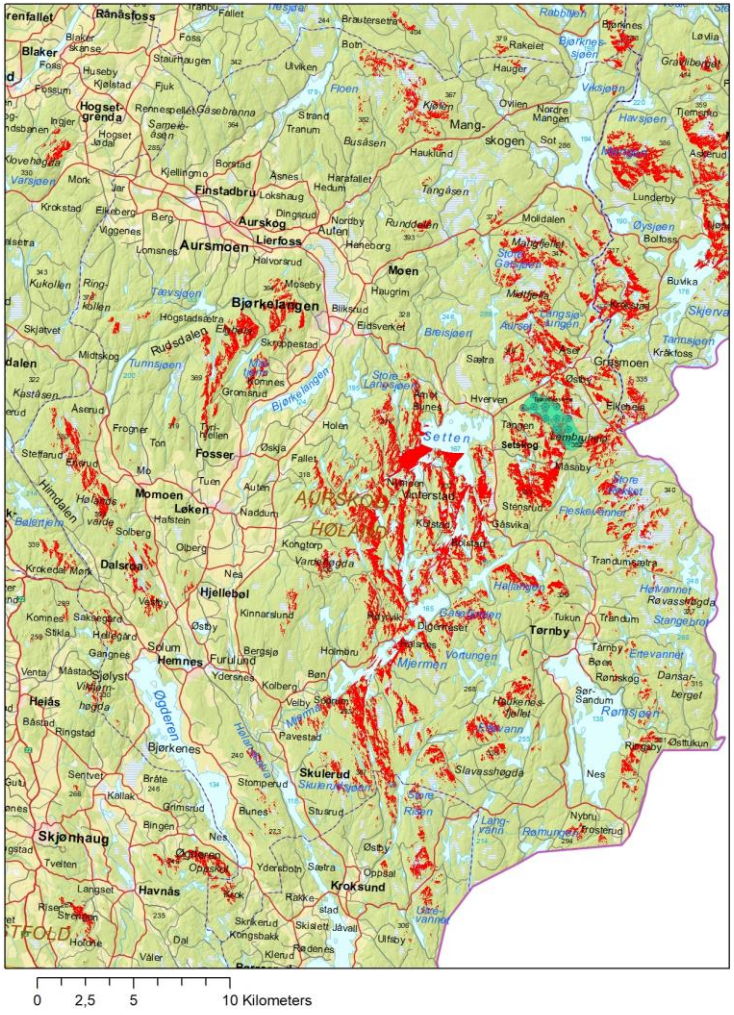
I utbyggingsplanene vil høyden på vindturbinene, målt fra bakken til tuppen av vingespissen, variere fra 150 til 250 meter.



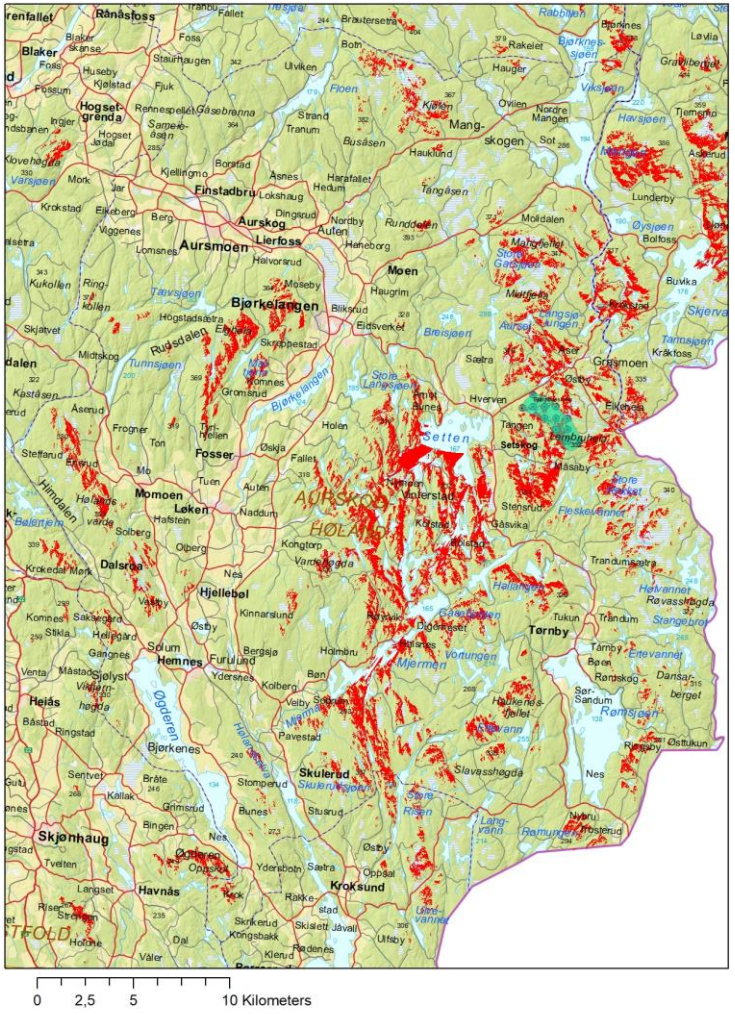
Visibility maps

Setten Wind power Development (see green oval) with150-250m high turbines will be visible from the areas shown in red

Synlighets-kart 150 meters turbiner over Aurskog-Høland



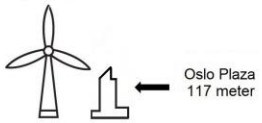
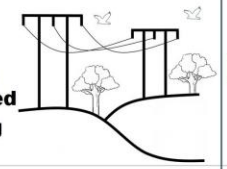
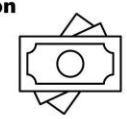
Synlighets-kart 250 meters turbiner over Aurskog-Høland



Choice Card (example – 6 different choice cards per respondent)

Example: Willingness to accept (WTA) compensation.

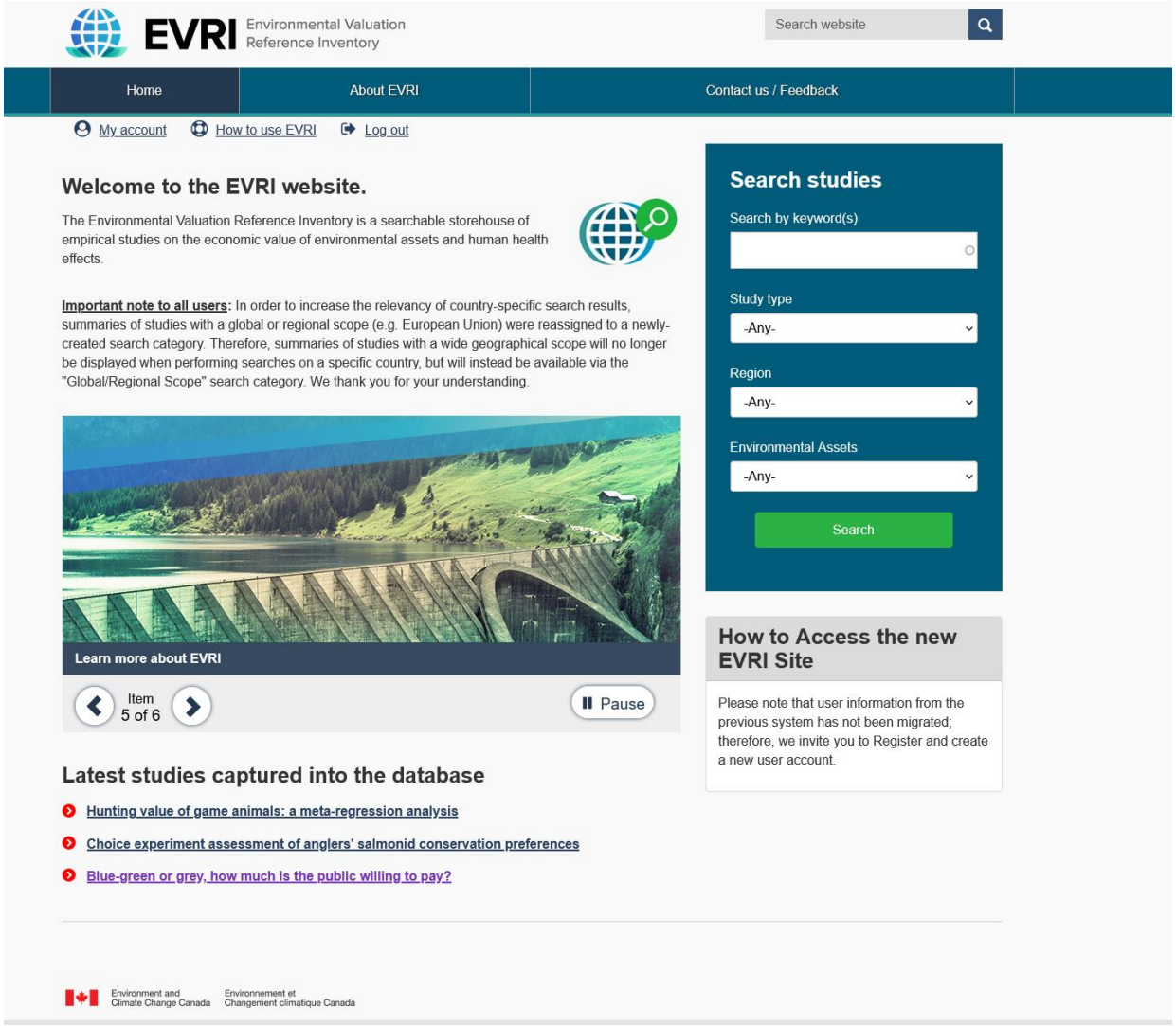
Which alternative do you prefer ?
No development (blue), Development plan 1, or 2 (orange).

Attributes	Dagens situasjon Ingen utbygging	Utbyggingsplan 1	Utbyggingsplan 2
No. of wind turbines (and roads built)	Antall vindturbiner  Ingen utbygging	10 vindturbiner	8 vindturbiner
Height of wind tuirbines	Høyde på vindturbinene  Ingen utbygging	250 meter	150 meter
Power line (overhead or underground in urban area, forests, and/or mountains)	Type kraft-ledning i tettsted og skog  Ingen utbygging	Luftledning i både tettsted og skog	Jordkabel i både tettsted og skog
Annual reduction in municipal charges (NOK)	Årlig reduksjon i kommunale avgifter  0 kr	4000 kr	500 kr
MY CHOICE IS:	MITT VALG ER: ●	●	●

International database for environmental valuation studies

More than 5200 studies (Norway:110)

Need for new, original state-of-the-art valuation studies constructed to provide generalizable unit values /value transfer for use in CBA and design of policy measures



Conclusions and Recommendations

- **Produce electricity with minimum *social* costs**
- **Adding private production costs and external costs per kWh to get total social costs of each energy source**

  - inclusive all ecosystem service impacts of energy production and *external costs* of distribution (transmission lines) and other infrastructure needed (e.g., roads). Also include *external benefits (*e.g., energy system providing high security of supply)
- **Renewable energy sources could have potentially high external costs**

  --> New context-specific environmental valuation studies neeed
- **Consider averting measures/environmental designs;** e.g., re-stocking rivers with trout and salmon, avoiding locating the wind park near densly populated areas and areas with populations of white-tailed sea eagles etc
- **Increased value of environmental goods over time** due to scarcity of wilderness areas/biodiversity, increased income and stronger preferences for environmental protection

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