

# **Integration of Grid Infrastructure in the Environment in Denmark**

Challenges for the TSOs within a sustainable energy supply  
Mini-symposium, Arnhem  
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## Agenda

- New guidelines on underground cables and overhead lines
- The development in the Danish transmission grid
- The DANPAC research project
  - Introduction to the DANPAC research project at Energinet.dk.
  - The planned and ongoing projects at Energinet.dk.
  - Project results so far.

# The trigger for new guidelines - April 2007!



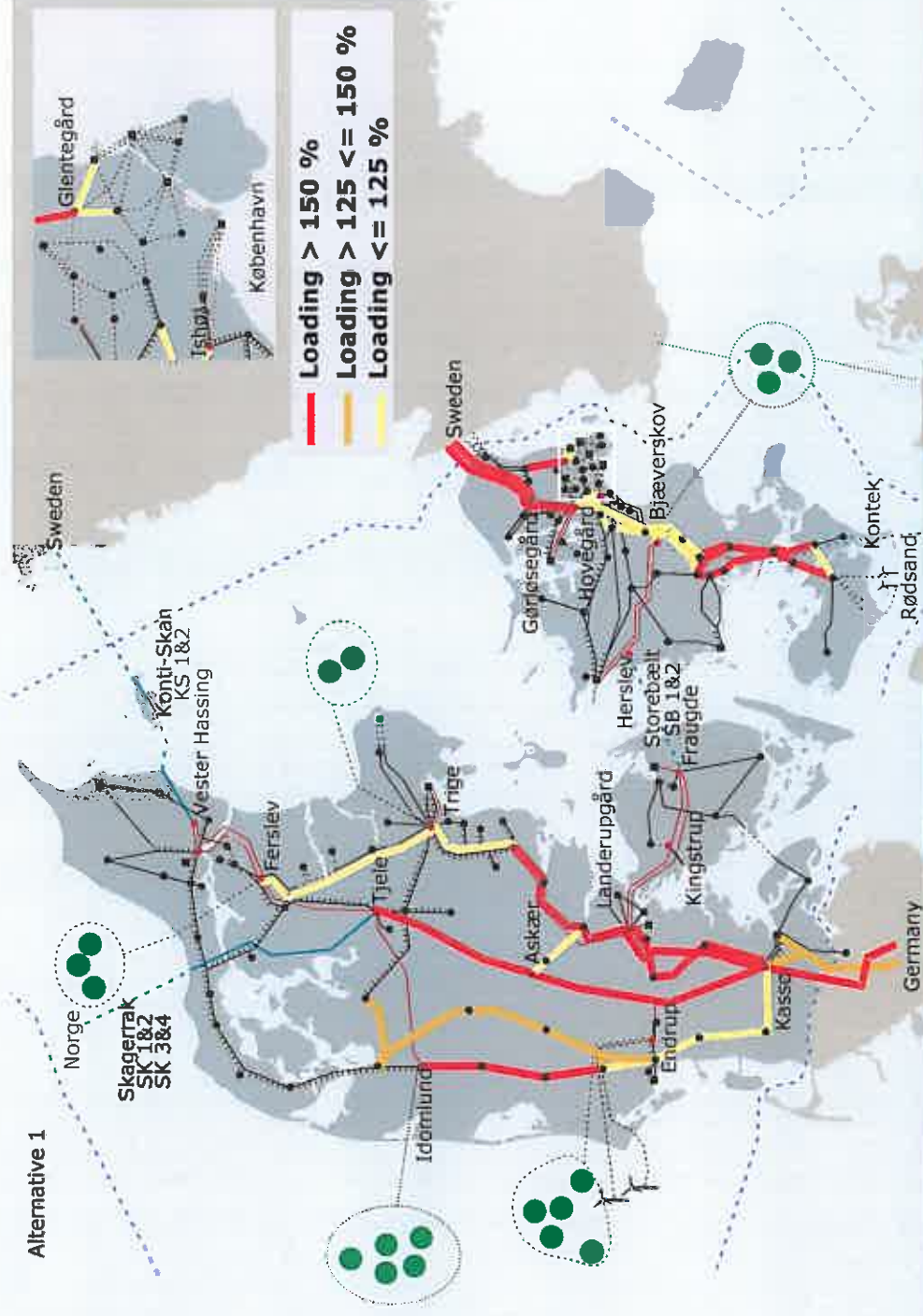
**9.000 km el-ledninger skal graves ned**  
Al LARS FROD  
Hovedparten af de godt 9.000 kilometer højspændingsledninger i Danmark skal graves ned i jorden, mener et bredt politisk flertal i Folketinget.



## Review of considerations taken in the expansions of the transmission grid

- The Minister of Transport- and Energy asked Energinet.dk to convene a committee to work out a technical report about the future expansions of the transmission grid
  - describe and quantify the total need for expansion
  - analyze different grid structures – including **extended cabling instead of overhead lines**
  - set up a number of models for the future expansion
  - evaluate environmental, scenic, technical and economical consequences of the different models
- TSO, Grid Companies, Ministries and Authorities,
- Report by 1. March 2008

# Power flow in Denmark 2025 assuming no grid reinforcements



**International power market and offshore parks lead to overloaded grid**

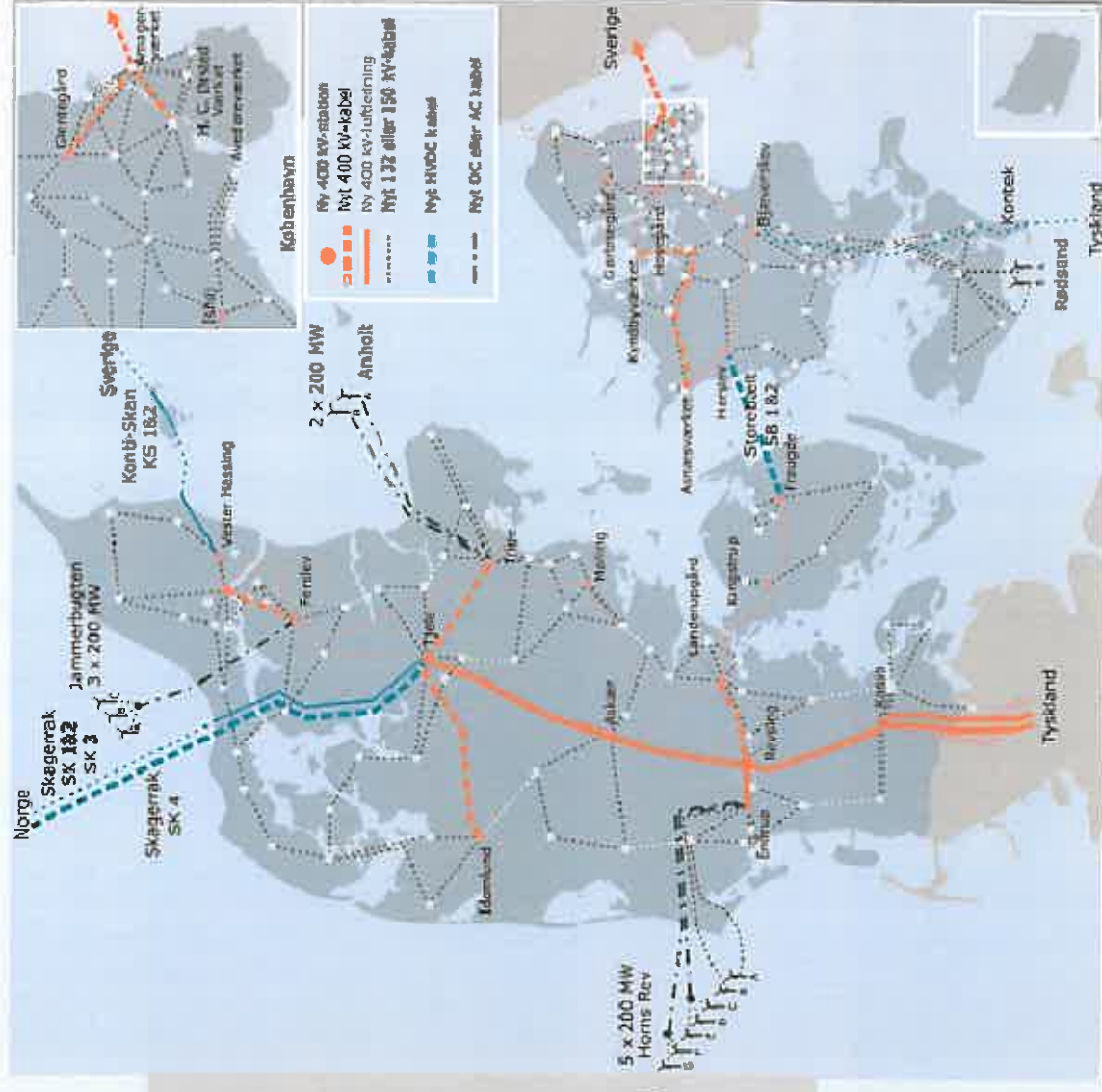
**There is a need for massive reinforcements in the transmission grid!**

## Analysed principles

Technical report about the future expansions of the transmission grid

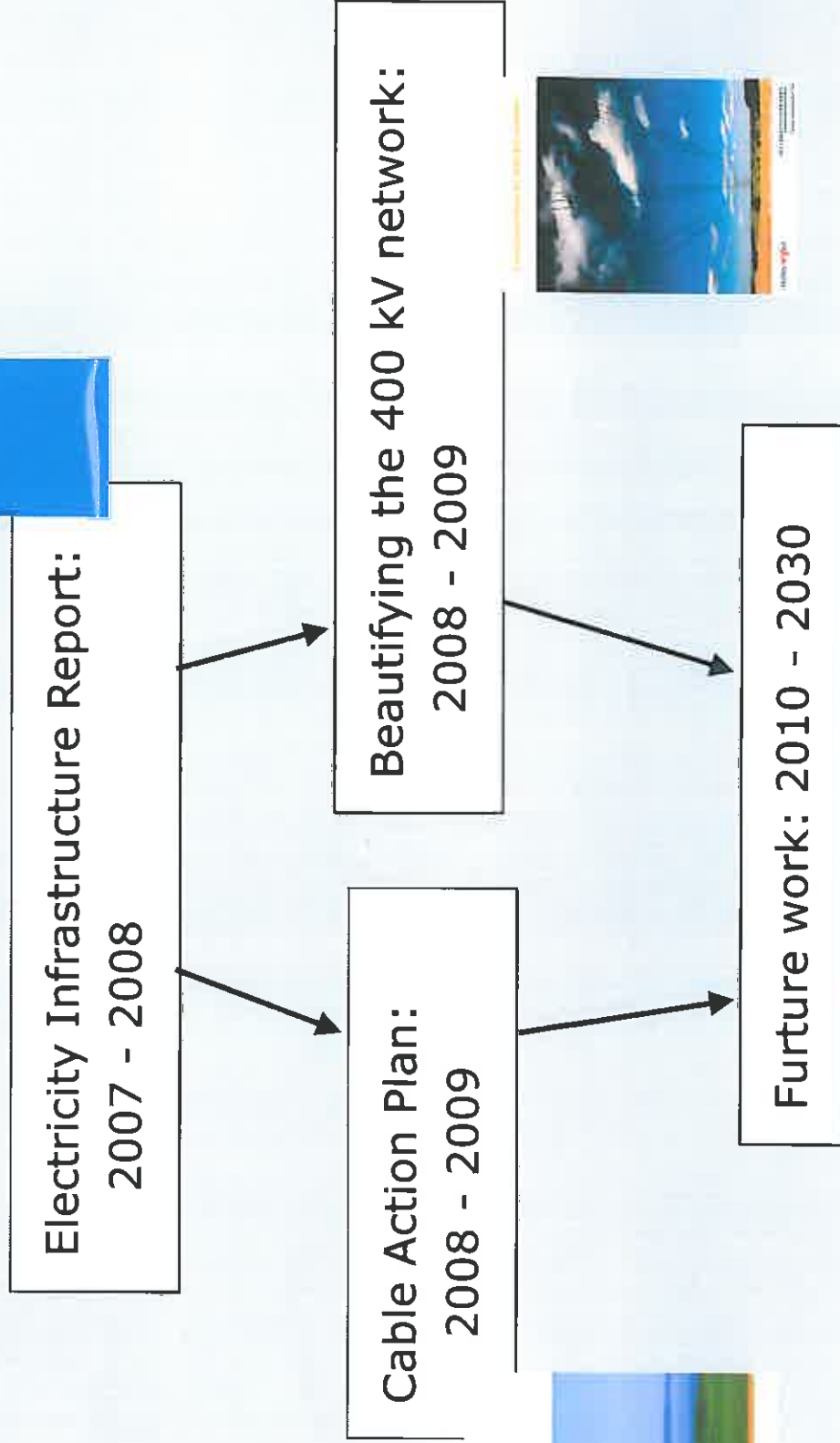
	A	B	C	D	E	F	
<b>400 kV</b>	Complete cabling	New lines in cables	New lines in cables and new towers in one existing track	New overhead lines in existing tracks	New overhead lines	No reinforcements	
<b>400 kV</b>			Embodishment of existing 400 kV overhead lines with lower towers in a new design + cabling in selected stretches				
<b>132/150 kV</b>		Cabling of existing 132/150 kV according to separate schedule		Cabling parts of existing 132/150 kV according to separate schedule			
<b>Billion Euro</b>	<b>6.46</b>	<b>2.63</b>	<b>2.30</b>	<b>0.537</b>	<b>0.362</b>	<b>0</b>	

## Principle C – New lines in cables and reinforcement of the backbone in Jutland with new towers in the existing track



- Price:
  - 0,7 B€ for 400 kV
  - 1,5 B€ for 132/150 kV (excl. stations, transformers and dismantling)
- Detailed plan for cabling of 132/150 kV
- Embellishment of existing 400 kV overhead lines
- R&D on long ac-cable

# The process





## **The Cable Action Plan**

- A detailed implementation plan for the next 5 years has been finished on the 31. August 2010.  
And the prioritised cable projects are being started.
- The Cable Action Plan will be updated in 2011 and every second year until 2030.
- A detailed implementation plan for the next 5 years will be updated in 2012 and every second year until 2030.

# Embellishment of the 400 kV grid

- 22 critical locations were identified
- Of these 6 locations are suggested for embellishment
- For these 11 different solutions are suggested
  - altered track
  - cabling
  - new towers
- Costs between 7 M€ and 80 M€ /project



# Suggested locations for embellishment of 400 kV



Aggersundbroen



Årslev Engsø



Vejle Ådal



Kongernes Nordsjælland



Roskilde Fjord



Lillebælt

Total costs: 100 – 160 M€

# **DANPAC – DANish Power system with Ac Cables**

## **Research and development project in HVAC cables**

## **Introduction to the DANPAC project at Energinet.dk**

- Energinet.dk realised that the necessary design concepts for a transmission network with all cables on 132 kV and 150 kV level and long 400 kV cables was not available in-house at Energinet.dk.
- And very limited experience was available in the world regarding a transmission network with all cables and long 400 kV cables.
- The concern is that:
  - Critical technical considerations may be overlooked due to lack of experience.
  - Solutions become too expensive.

## Introduction to the DANPAC project at Energinet.dk

- Energinet.dk therefore decided to start a research and development project with the aim to setup design guide lines to be used in the design of a transmission network with all cables that insures a technical and economical optimal transmission network.
  - This means:
    - Finding the studies to be carried out.
    - Carry out the studies needed to be able to document the design guidelines for a transmission network with all 132-150 kV cables and long 400 kV cables.
- Project period is 5 years.
- Manpower:
  - 4 full time positions spread over 8 project members.
  - 4 PhD projects.

## DANPAC - The planned system related projects

- Optimisation of the 132 kV and 150 kV network structure.
- Optimise the reactive compensation in the transmission network.
- Transient studies – Finding the dimensioning transient phenomena in a transmission network with all cables and for a network with both overhead lines and cables.
- Analyse the mechanical stability and the voltage stability for the network and find the necessary solutions to reach a stability equal to or better than for the present network.
- Black-Start study for the network according to the Cable Action Plan.
- ...

## DANPAC - The planned component related projects

- Maximal cable lengths
- Controlled backfill
- Need of an ECC for HVAC cable lines
- Sharing experience and information on long 132-400 kV cable lines in the world
- Installation of underground and submarine cables
- Quality assurance for cable laying
- Repair techniques
- Test procedures, 1,7pu in 30min instead of 1pu in 24 hours
- On site parameter estimation for long cable lines
- Reviewing Energinet.dk cable handbook
- Manual for HVAC cable maintenance
- on-line state estimation for link boxes
- Description of environmental conditions during and after cable laying
- ...

## Results so far, system related projects

- Optimisation of the 132 kV transmission network from the Cable Action Plan.
  - An optimisation algorithm has been developed.
    - Optimisation variables:
      - Network structure.
      - Cable standard sizes.
      - 400/132 kV transformer standard sizes.
    - Optimization parameter is the sum of the establishment costs for the cables and the transmission losses capitalised over the expected lifetime of the cables.
  - Optimisation results for Zealand.
    - Savings of 132 million Euro from an original budget for the Cable Action Plan of 732 million Euro.
  - Next step in the project is to do the same optimisation for the 150 kV transmission grid in Vest Denmark.

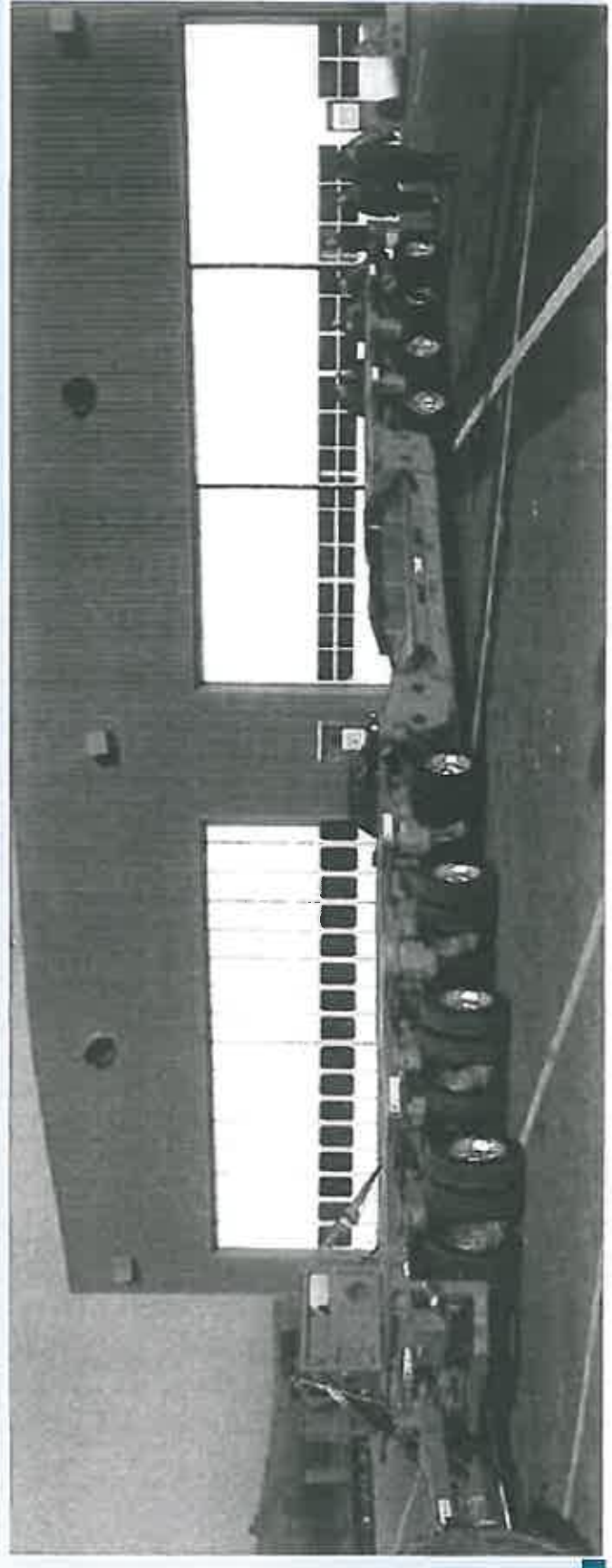
## Results so far, component related projects

- Maximal cable lengths
  - DANPAC has together with different cable manufactures analyzed the possibilities of maximizing the cable sections that safely can be transported and laid in Denmark and thereby increased the maximum 400 kV cable lengths to be transported and laid from  $\approx 900$  m to 1400 m.
  - Energinet.dk has bought a special cable trailer to transport the cable drums from the drop off zone of the cable manufacture to the cable site.
  - Savings so far:
    - SK4 (400 kV DC connection to Norway)
      - $\rightarrow$  **saves 24 junctions**
    - Kassø-Tjele
      - 400 kV hybrid AC line
      - 3 cable sections, each possibly saving 1 junction
      - $\rightarrow$  **total saving of  $3 \cdot 12 = 36$ , 400 kV cable junctions**

**It is possible to maximize the cable drum length when transporting the cable drums this way**



**The cable trailer**



## Results so far, component related projects

- Controlled backfill
  - The controlled backfill project has resulted in:
    - Better quality assurance of the backfill material.
    - Our future cable projects will be design for a thermal resistivity of 0,8 °C·m/W instead of the standard 1 °C·m/W for the controlled backfill material.
  - Savings of ≈5% are expected for our planned 400 kV project due to cable cross section reductions.

# Results so far, component related projects

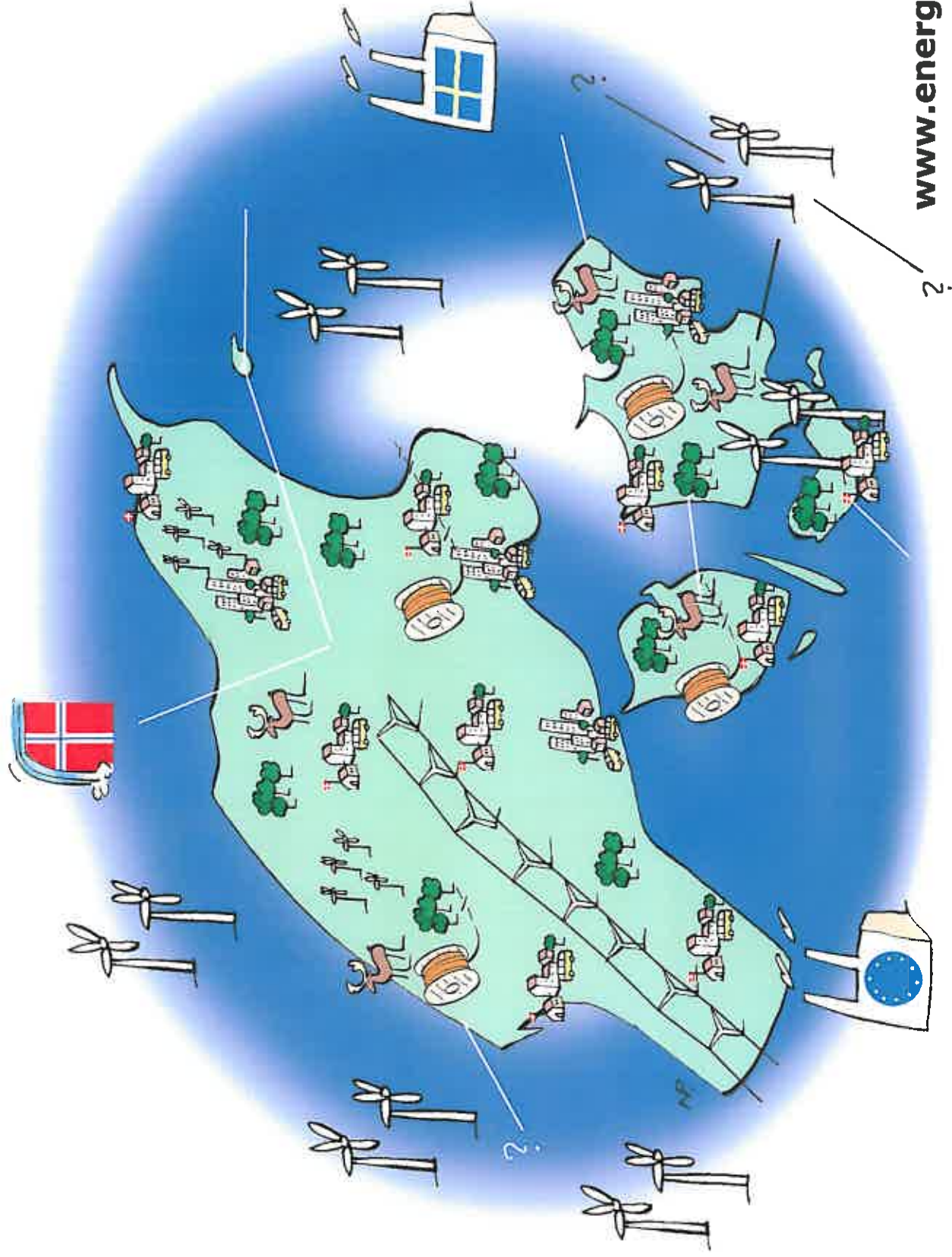
- Controlled backfill
  - 23 sand samples from 12 different gravel pits in Denmark with grain sizes from 0-2 mm to 0-8 mm have been analyzed for their thermal resistivity during normal humidity and in a dried out state.
  - Full scale measurements have been carried out for 4 of the best and 2 of the worst of the 23 samples.

Regulated warm water is circulated in pipes through the sand samples and temperature and humidity measurements have been recorded.



**Thank you for your attention!**

**ENERGINET** DK



[www.energinet.dk](http://www.energinet.dk)

**Would you build an overhead line here?**

