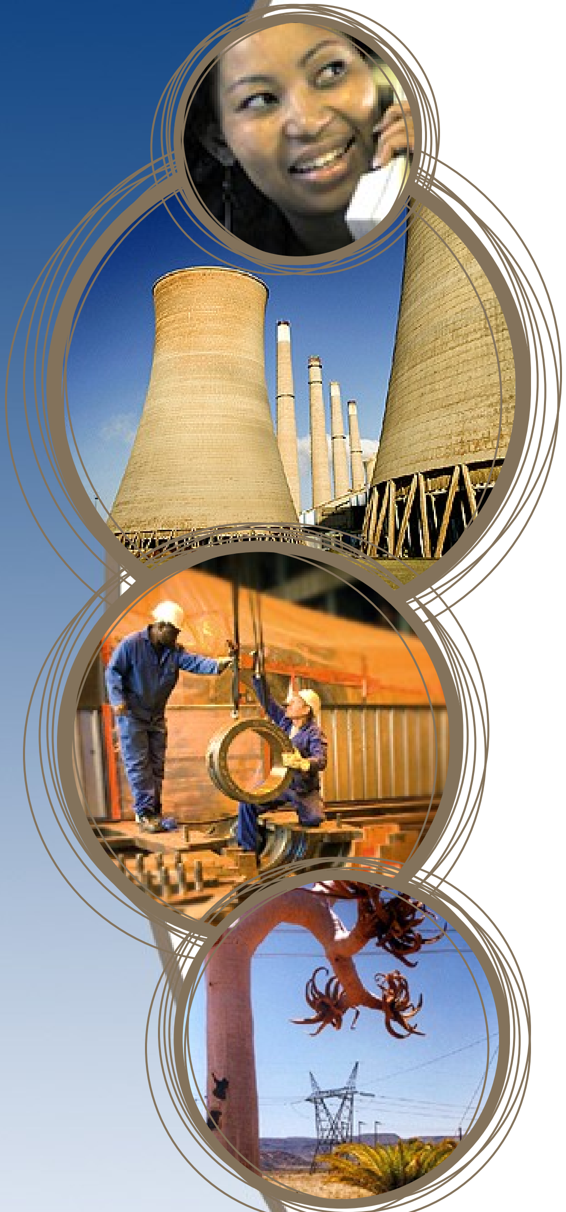

Denmark renewable generation grid integration skills development initiative

December, 2011

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(Input from Eskom team members, EA Energy Analyses, SEAS-NVE & Energinet.dk)

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- Overview of the training initiative
- Overview of Danish ESI
- Danish approach to wind farms
- Key learnings
  - Power System Analysis
  - General
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Introduction & background

- Eskom engineers have a technical understanding of the integration of conventional power plants to the grid
- Integrating Renewable Energy (RE) generation is a new concept within Eskom
- Intermittent renewable generation presents a range of new technical challenges not previously encountered in traditional large scale coal, nuclear and hydro generation
- More than 320 applications to connect various forms of renewable generation to the grid have been received. With REBID and other drivers, the demand for grid access is expected to increase
- Timelines associated with e.g. REBID place considerable pressure on the grid connection

Introduction & background

- Need to build adequate capacity and skills for the grid integration of renewable generation in Eskom Tx and Dx
- Within the last 4 years, Eskom has invited several overseas presenters to deliver courses/training locally. Largely theoretical. Specific questions remained unanswered. Require perspective of utility engineers and EG developers doing actual integration studies

Linkage with overseas utilities

- *EA Energy Analyses* is facilitating skills transfer between the South African National Treasury and Danish utilities in order to provide specialized advice via a bilateral relationship between South Africa and the Danish Governments

- Via *EA Energy Analyses,* the Danish system operator (*Energinet.dk)* and a Danish distribution company (*SEAS-NVE)* were approached

- Both have extensive experience and capacity in the grid integration of renewable generation, particularly wind

- A training and skills transfer initiative was developed between Eskom, EA Energy Analyses, Energinet.dk and SEAS-NVE

- Focus on renewable generation grid integration studies (planning, operations, protection and power quality) for both Transmission and Distribution

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Phased approach

- Team of 12 Eskom engineers representing the key technical areas visit the two Danish utilities (*Energinet.dk & SEAS-NVE*) to get exposure to the simulation approaches, models, criteria etc
- Danish experts hold a follow-up session in South Africa to check implementation
- Training programme is in two phases:
  - Phase 1: Eskom team have hands-on exposure (Modules 1, 2 and 3) in Denmark for 3 weeks (31st October – 18th November, 2011)
  - Phase 2: Danish experts hold a follow-up session (Module 4) in South Africa for 2 weeks (6th February – 17th February, 2012)

Eskom team

Eskom Division	Business Unit	Area of expertise	Personnel
Distribution	Network Services	Network Planning	Maritza Rossouw
Distribution	Network Services	Network Planning	Thobeka Gcabashe
Distribution	Electricity Delivery	Network Optimization	Naniki Lukhele
Distribution	Electricity Delivery Network Services	Protection and coordination	Lize-Marie Kleyn
Technology	Power Delivery	Network Planning	Mobolaji Bello
Technology	Research, test and demonstration	Quality of Supply	Gerhard Botha
Technology	Power Delivery	Network Planning	Clinton Carter-Brown
Transmission	Grid Planning	Grid Planning	Pervelan Govender
Transmission	Grid Planning	Grid Planning	Dudu Hadebe
Transmission	System Operator	Operations Planning	Robby Palackal
Transmission	System Operator	Operations Planning	Bruce Siavhe
Transmission	Transmission	Southern African Energy	Prudence Matlou

Eskom team

Core deliverables

On their return the team are developing:

- Specifications, procedures and guidelines on the system studies required for the grid integration of renewables. These will cover Planning, Protection, QOS and Operations
- Development of case studies based on local South African conditions and networks
- Compilation of generator generic models to be used for these studies and to be suitably validated
- Review and advise on renewable grid code requirements
- Provide training and workshops for skills transfer within Eskom

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Danish system overview

Power balance Jan. 2011

Two synchronous areas

West:

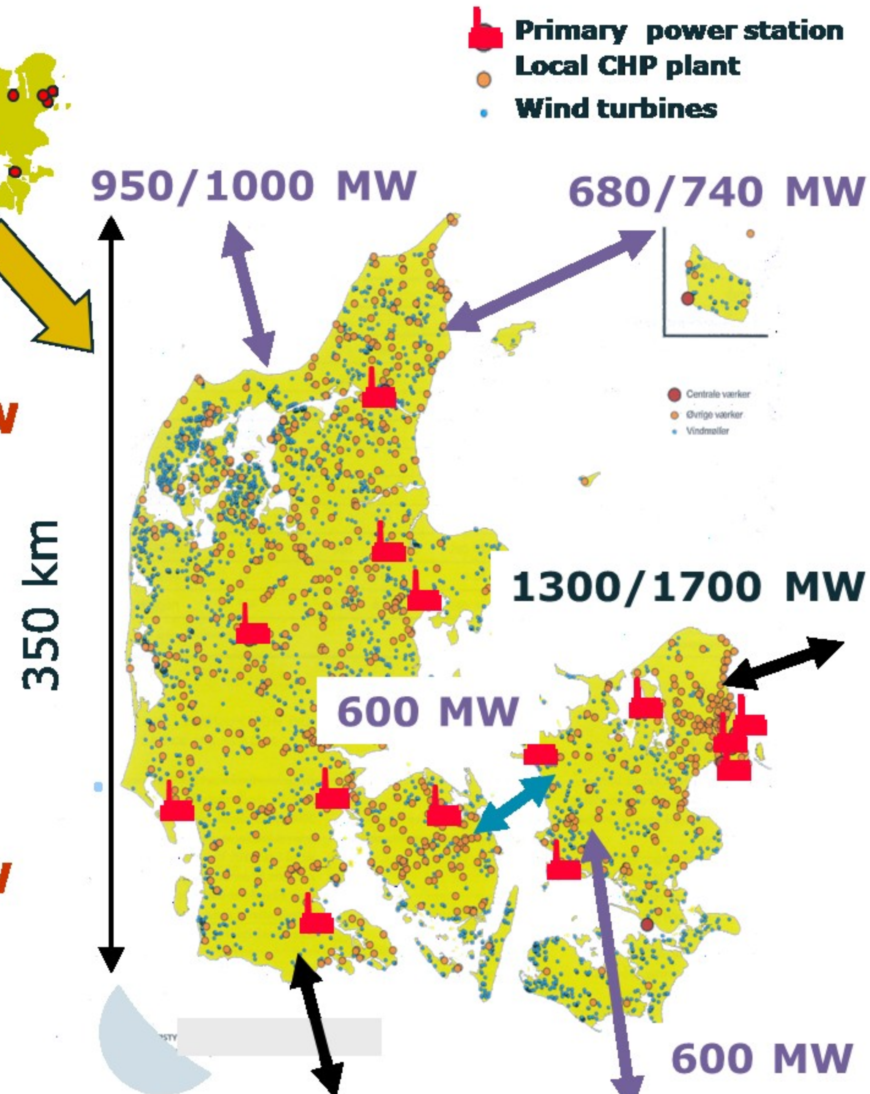
Consumption	1400 - 3700 MW
Primary power stations	3400 MW
Local CHP plants	1860 MW
Wind turbines	2840 MW

Local CHP plants + Wind turbines: **4700 MW**

East:

Consumption	900 - 2700 MW
Primary power stations	3800 MW
Local CHP plants	640 MW
Wind turbines	960 MW

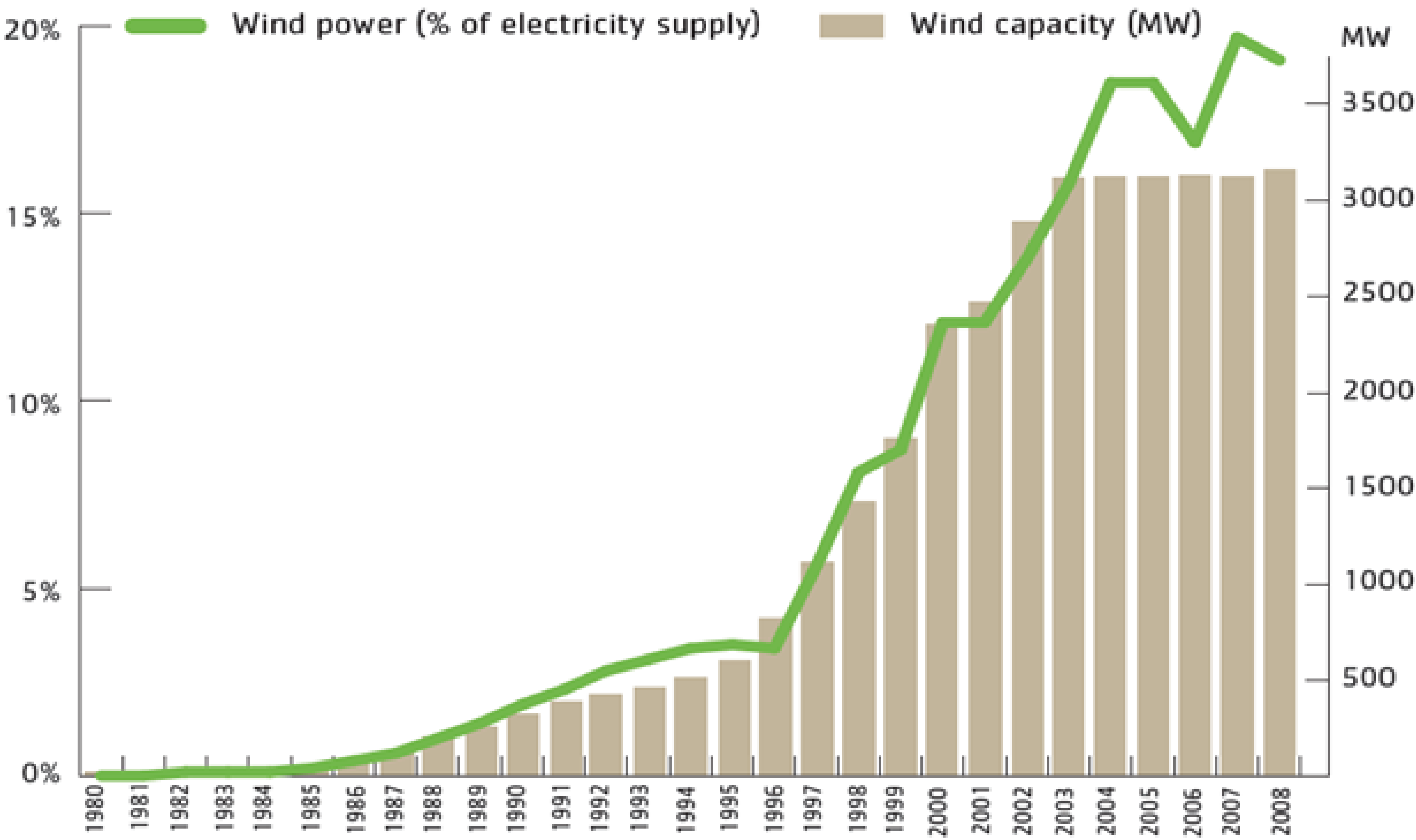
Local CHP plants + Wind turbines: **1600 MW**



Danish renewable energy targets

- Long-term vision is to be fossil-fuel independent
- Plan for the period 2008-2011 is the installation of 1300MW of new wind capacity which represented a 40% increase in installed wind capacity
- Danish contribution for the European Union 2020 targets is a target of 30 renewable energy generation, which implies that the power system may have to handle 50% wind power

Danish wind energy and installed capacity



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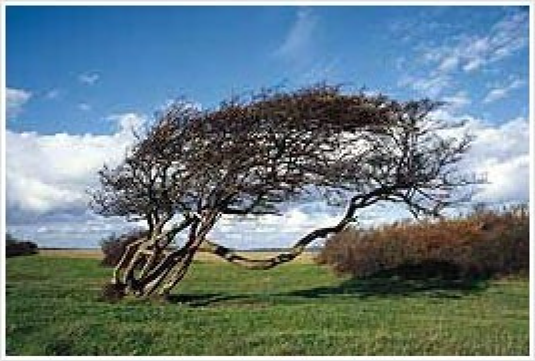
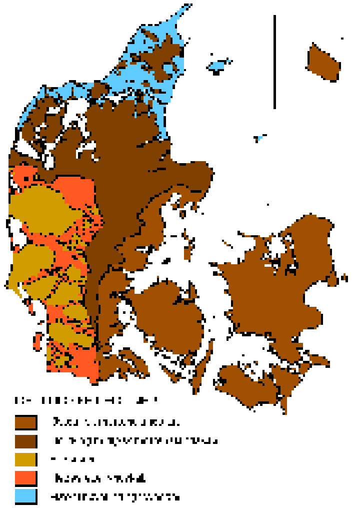
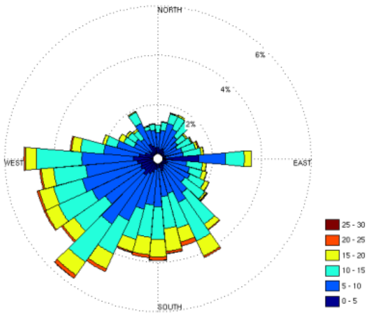
What to look for before planning wind farms?

Three major elements must be in place

- Wind
- Good ground conditions
- Access to electricity net

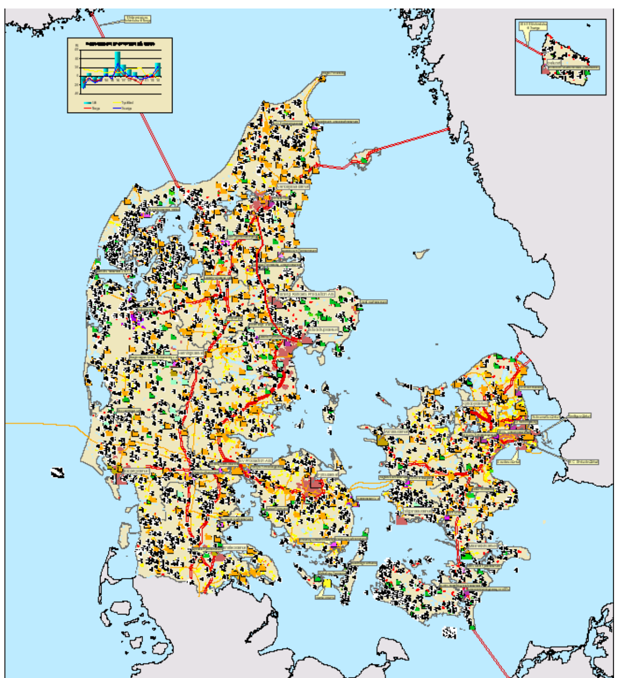






Planning of onshore wind turbines in Denmark

- As a general rule, the municipalities are responsible for the planning for the erection of onshore wind turbines.
- The erector of a wind turbine must apply to the municipality
- Premium (25 øre/kWh ~ 0,37 ZAR/kWh) on top of market price in 22.000 Peak-load hours



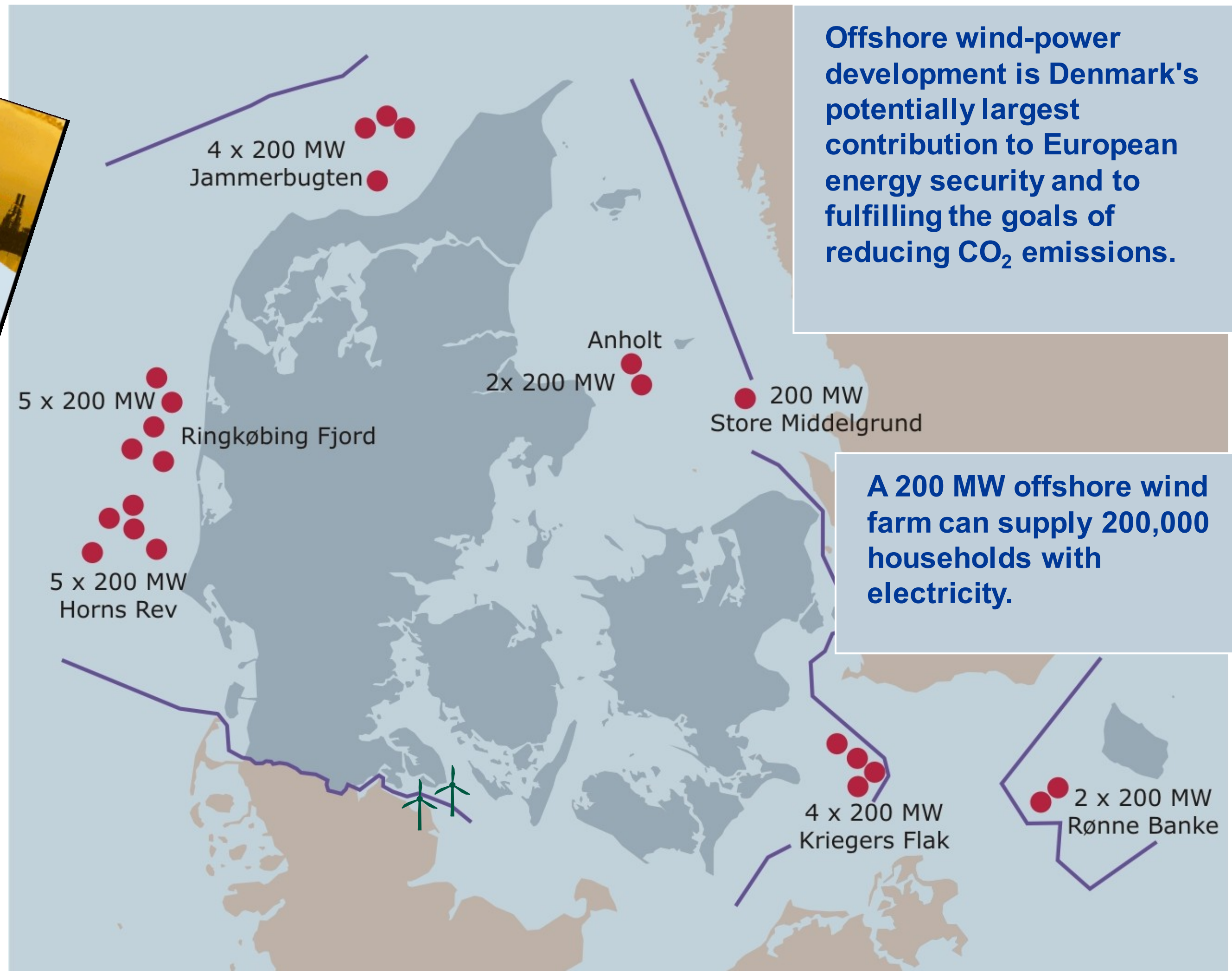
Denmark – 20 years of experience in offshore wind

- 1991 First Danish offshore wind farm
- 2007/08 Strategic assessment for future location of 5200 MW wind power. Revised in 2011.
- 2011 868 MW installed offshore
- 2012 Anholt 400 MW new offshore wind farm
- 2013 app. 1300 MW offshore

Visit to off-shore wind farm (Nysted)

Preparing for the future – Denmark strategic assessment

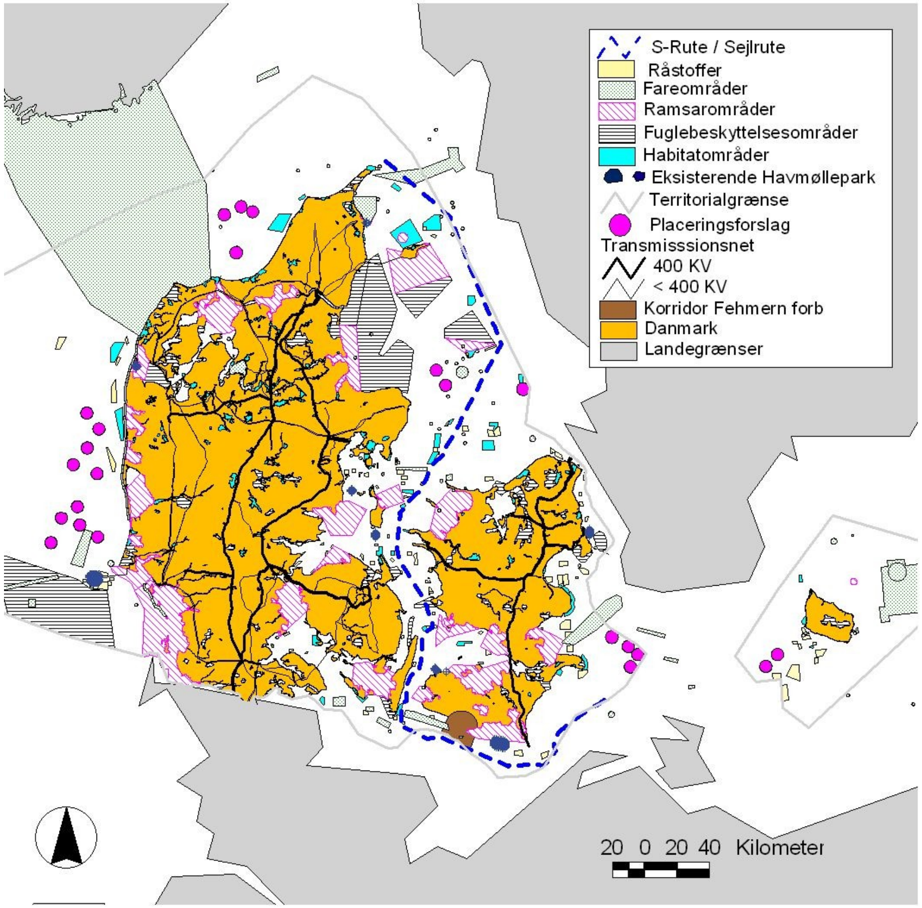
Potential offshore wind farm sites (total of 4.6 GW)



Offshore wind-power development is Denmark's potentially largest contribution to European energy security and to fulfilling the goals of reducing CO_2 emissions.

A 200 MW offshore wind farm can supply 200,000 households with electricity.

Preparing for the future – Denmark strategic assessment



4600 MW - 23 sites of 200 MW identified

Equivalent to 8 % of total demand or 50% of electricity demand

7 areas prioritised

Kriegers Flak 1'th priority

EIA required for each site

The priority are not binding

Politicians decide

Denmark models for installing offshore capacity

Eskom

Open door

- Typically smaller scale and test farms
- Application
- Cable to shore paid by investor
- Variable time schedule
- EIA carried out by the operator

Tender

- Large scale farms
- Political agreement
- Cable to shore paid by electricity consumers
- Strict time schedule
- EIA carried out by the TSO (paid by the winner afterwards)

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Key learnings: Power System Analysis

- Network Planning:
  - High dependency on suitable Grid Codes and Generic Models. Wind turbines must be type tested
  - Only relatively basic studies (load-flow, short circuit) performed for assessment of individual wind farms
  - More advanced system studies (dynamic stability, LVRT etc) required as part of strategic planning considering all embedded generation. Not for individual applications
  - Developer to design for compliance with Grid Code
  - Developer requires basic fault level and impedance information for the Point of Connection (POC)

Key learnings: Power System Analysis

- Power System Analysis Models:
  - Generic (typical) models used during Planning phase
  - Full simulation models have to be provided by the Developer within 3 months of connection
  - Standardisation of the models is required. Presently a focus of IEC
  - Need to capture and maintain the model input data (discussed further)
  - Need to develop a local library of models representing typical and "worst case" wind farms that will be connected in RSA
  - Need to expand models to include all sizes and other forms of generation e.g. solar thermal, solar PV etc

Key learnings: Power System Analysis

- Network Operations:
  - Wind farms operated in unity power factor but as per Grid Code can perform voltage control and voltage droop control
  - SCADA visibility at the POC. No need for information beyond POC i.e. within the wind farm
  - Have ability to constrain generation – if critical

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Key learnings: General

- Role of Electrical network in the move towards renewable energy sources:
  - Oil heaters move to heat pumps, vehicles move to Plug in Electrical Vehicles (PEVs)
  - Increased electrical demand
  - A strong network, flexible demand and Smart Grids will be required
  - New demands such as heat pumps and PEVs will need to be controllable
  - High renewable generation penetration will be more cost effective via cross-border trading to balance supply and demand (the scope for this in RSA is however more limited than in Europe)
  - End user tariffs will need to be more reflective of the time varying cost of generation

Key learnings: General

- Embedded generation data:
  - It is essential that the TSO and DSOs have a suitable understanding of all embedded generators connected in their networks, ranging from large multi MW wind farms to small few kW LV connected solar PV installations
  - Appropriate models of embedded generators are required for power system studies. These models require certain data
  - This data needs to be housed in a central database such that the TSO and DSOs can develop appropriate models for the embedded generators supplied by their networks
  - Stakeholders (IPPs, Eskom, AMEU, NERSA, DOE) need to establish the appropriate custodianship for this data
  - In Denmark the TSO is responsible for this database, which is populated by the DSOs. Not on database = don’t get paid

Key learnings: General

- Customer front office:
  - Danish TSO has a customer “front office” for embedded generators that is similar to Eskom’s Grid Access Unit
  - The “front office” handles all queries regarding grid codes, PPAs, connection procedures etc using standardised processes and systems
  - Engineering analysis, scope and costing is done by DSOs and TSO. The “front office” has a network of internal and external experts that issues can be referred to
  - The “front office” is based in the TSO and services the whole of Denmark. The “front office” will put developers in contact with the relevant DSOs
  - Should we have a “front office” based in the TSO servicing the entire South African ESI i.e. TSO, Eskom and Municipalities?

Key learnings: General

- Sharing of power system analysis data:
  - The Danish TSO and DSOs do not provide wind farm developers with models of the utility network.
  - Developers only require information on the point of connection fault levels and impedances in order to do the internal design of their plant and ensure compliance with the grid code
  - In unusual cases combined studies may be required
    e.g. very large off-shore wind farms

Key learnings: General

- Planning for large scale wind farms:
  - The Danish approach to the planning off-shore wind farms requires good data and cooperation between role payers.
  - Has significant benefits as wind farms can be located in optimal locations considering a range of requirements
  - Developers do not spend considerable effort and funding developing business cases for locations that are potentially sub-optimal
  - South Africa should consider transitioning to this model for large scale on-shore wind developments
  - This must not be done at the expense of constraining access to the grid

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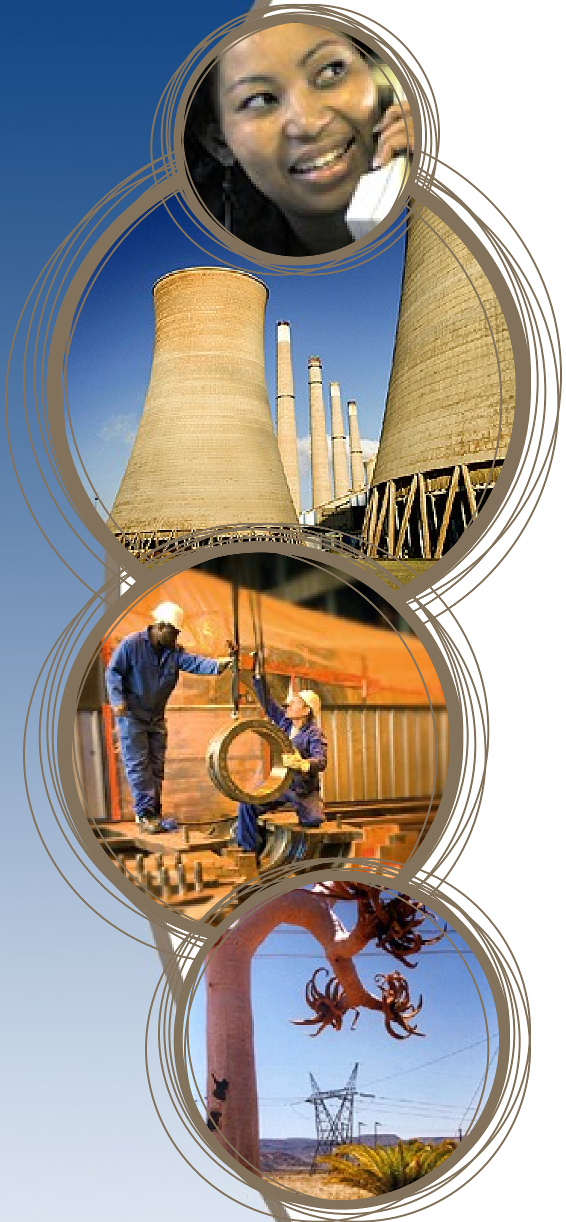
Next steps

- Finalise Eskom trip report
- Implement deliverables project plan:
  - Standards and guidelines
  - Training material
  - Training delivery
  - Power system simulation models
  - Systems and processes as relating to network analysis
- Interface with key stakeholders as per project plan



Thank you

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