The Scottish renewable resource assessment and implications for the grid

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EPRG seminar:

The Scottish renewable resource assessment and implications for the grid

16 May 2008

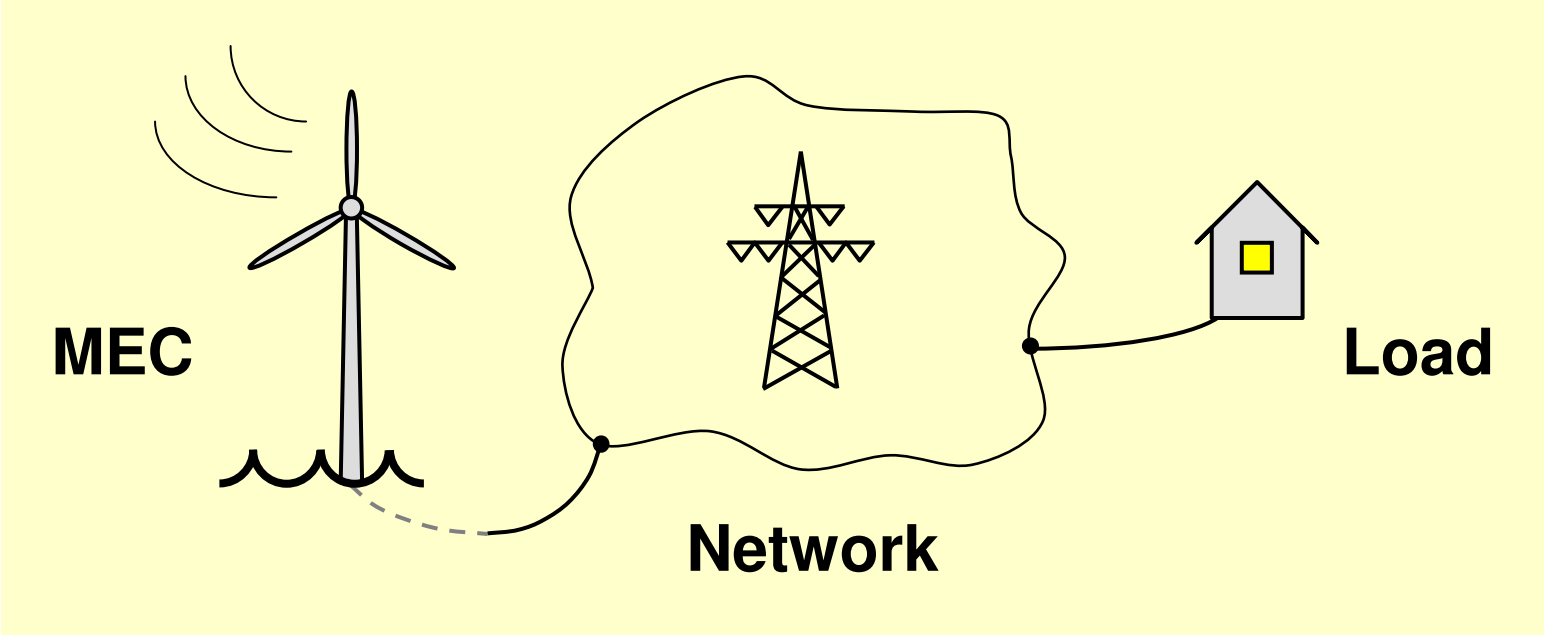
Background

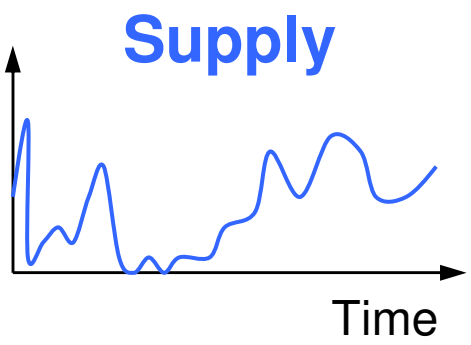
- Scottish renewable target: 40% by 2020, recently upgraded to 50%, interim milestone of 31% by 2011
- In 2004, the (then) Scottish Executive commissioned a report to appraise of the extent to which Scotland could meet the 40% target
- The aim: realistic assessment of Scotland's renewable potential (wind on- and off-shore, tidal and wave resource)
- The Scottish target is now 50% but the assessment of the resource still stands

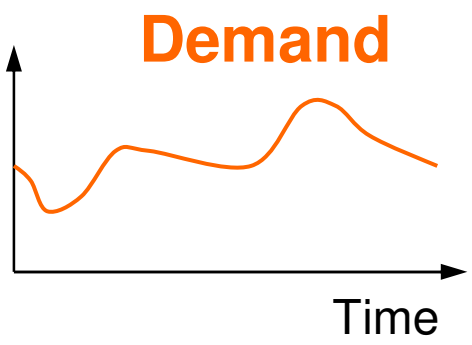
What's unique?

- Temporal resolution: one-hour for wind and 3 hours for wave
- Spatial resolution: 1 km^2
- Physical modelling using WAsP and WindFarmer: calculate wind at turbine height (80 m agl.) in each 1 km^2 cell from met station data, elevation data and surface roughness description
- Eliminate no-go areas and take limits into account
- Rank sites according to costs
- Full report available from: http://www.scotland.gov.uk/Publications/2006/04/24110728/0

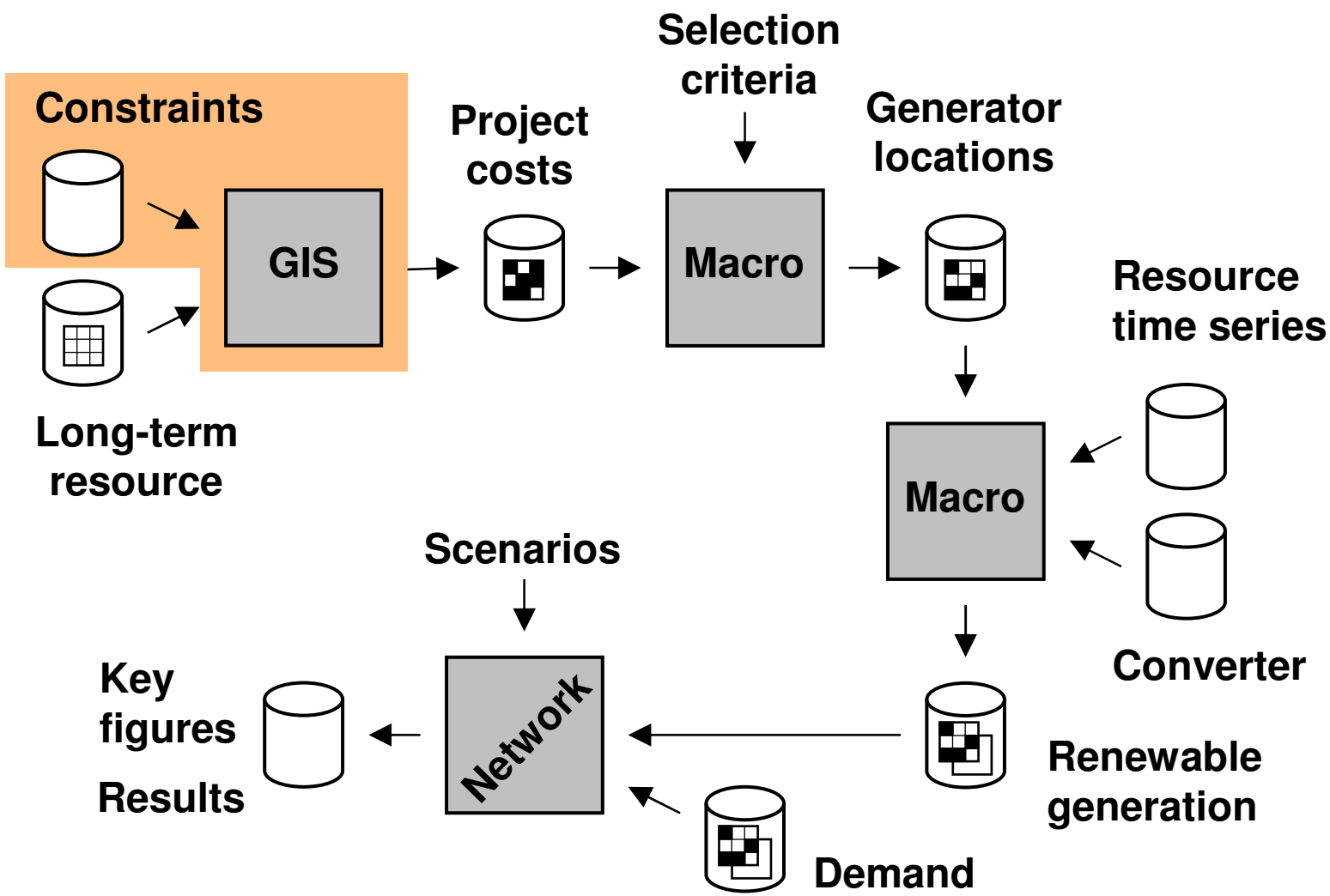
The Challenge







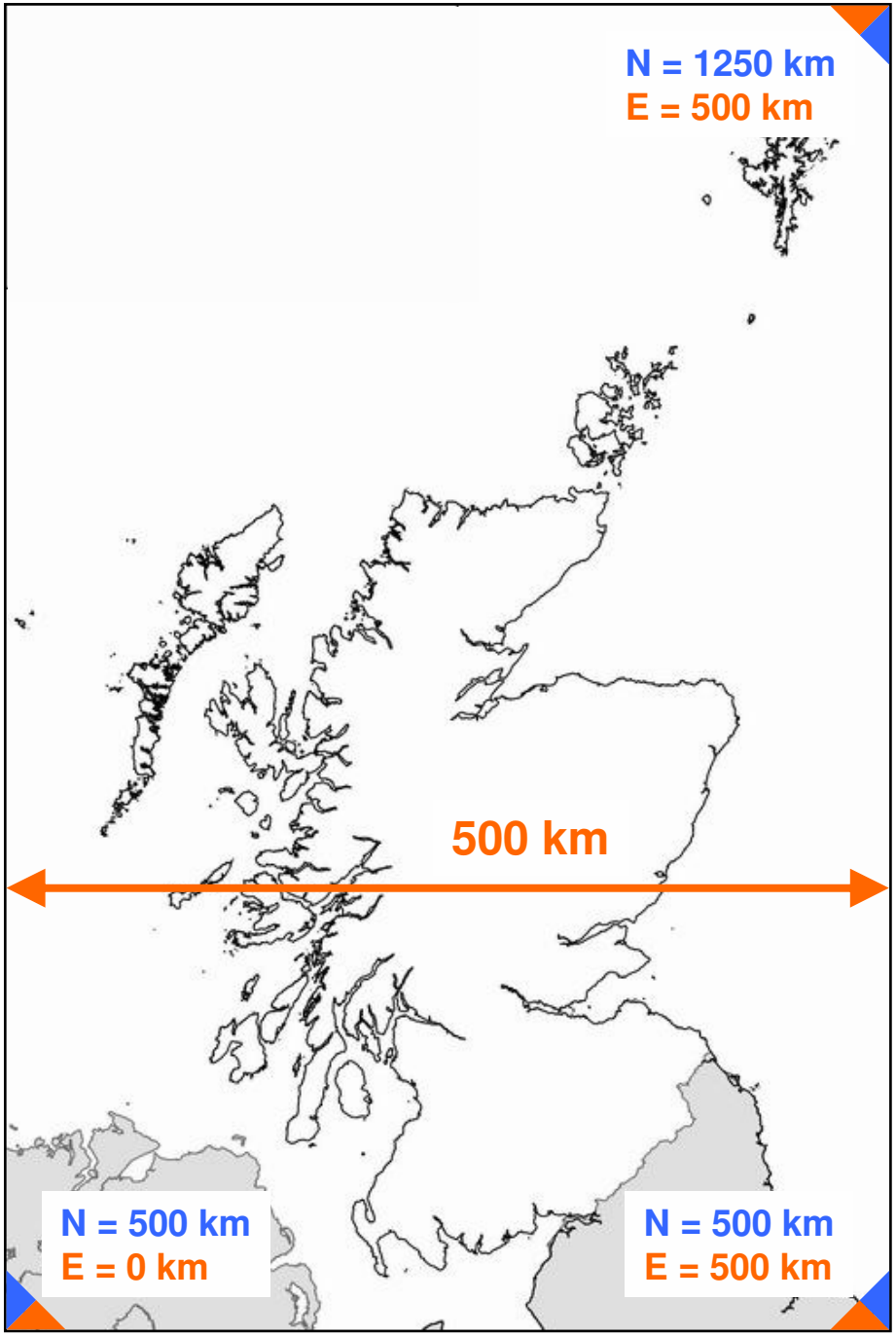
Constraints GIS Mapped



Study Area

- Spatial resolution: 1 km^2
- Use of British National Grid coordinates

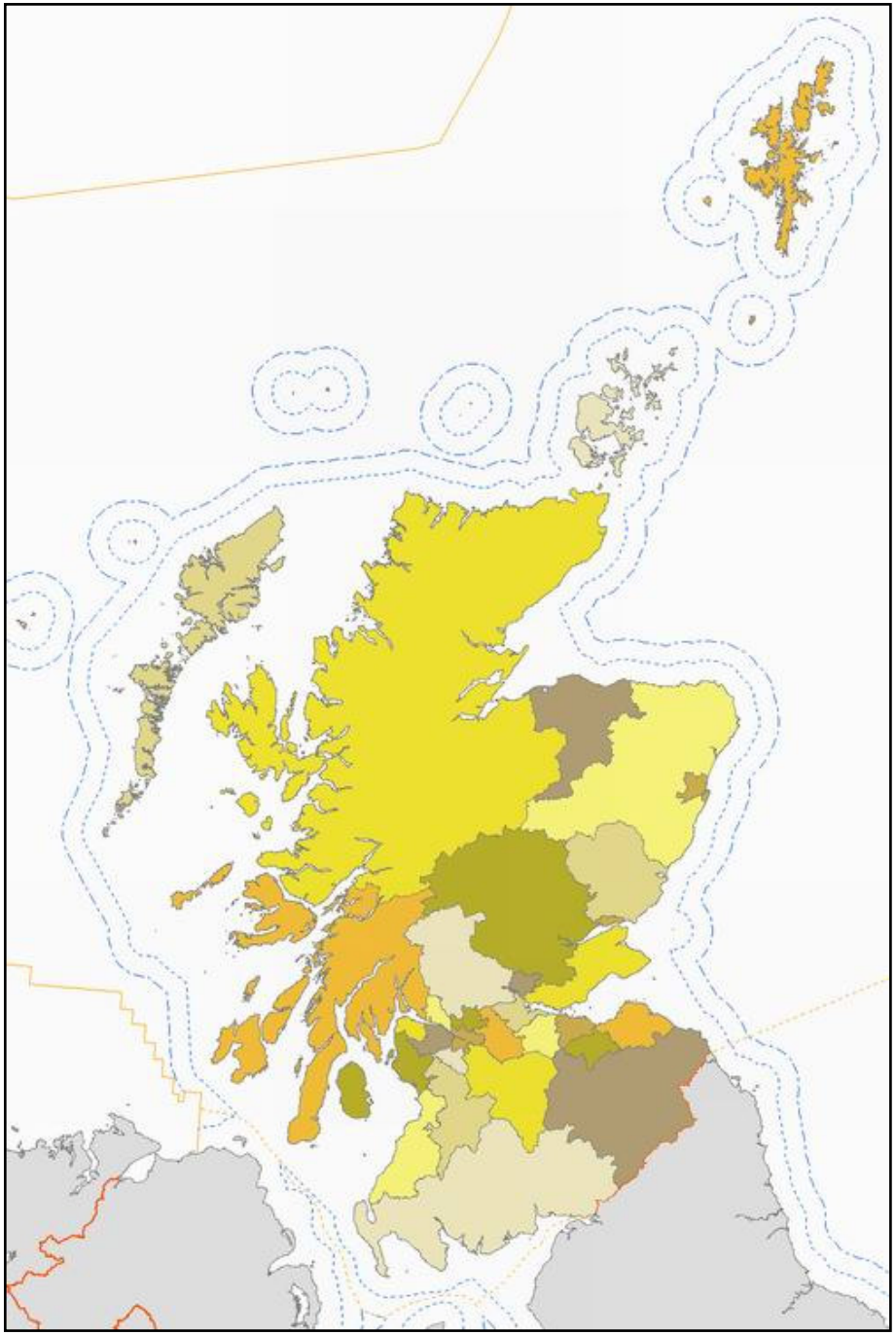
750 km



Source: Ordnance Survey

Political

- International limit (200 nmi, 12 nmi)
- National limit
- Fishing limit (6 nmi)
- Planning authorities
- Local regulations

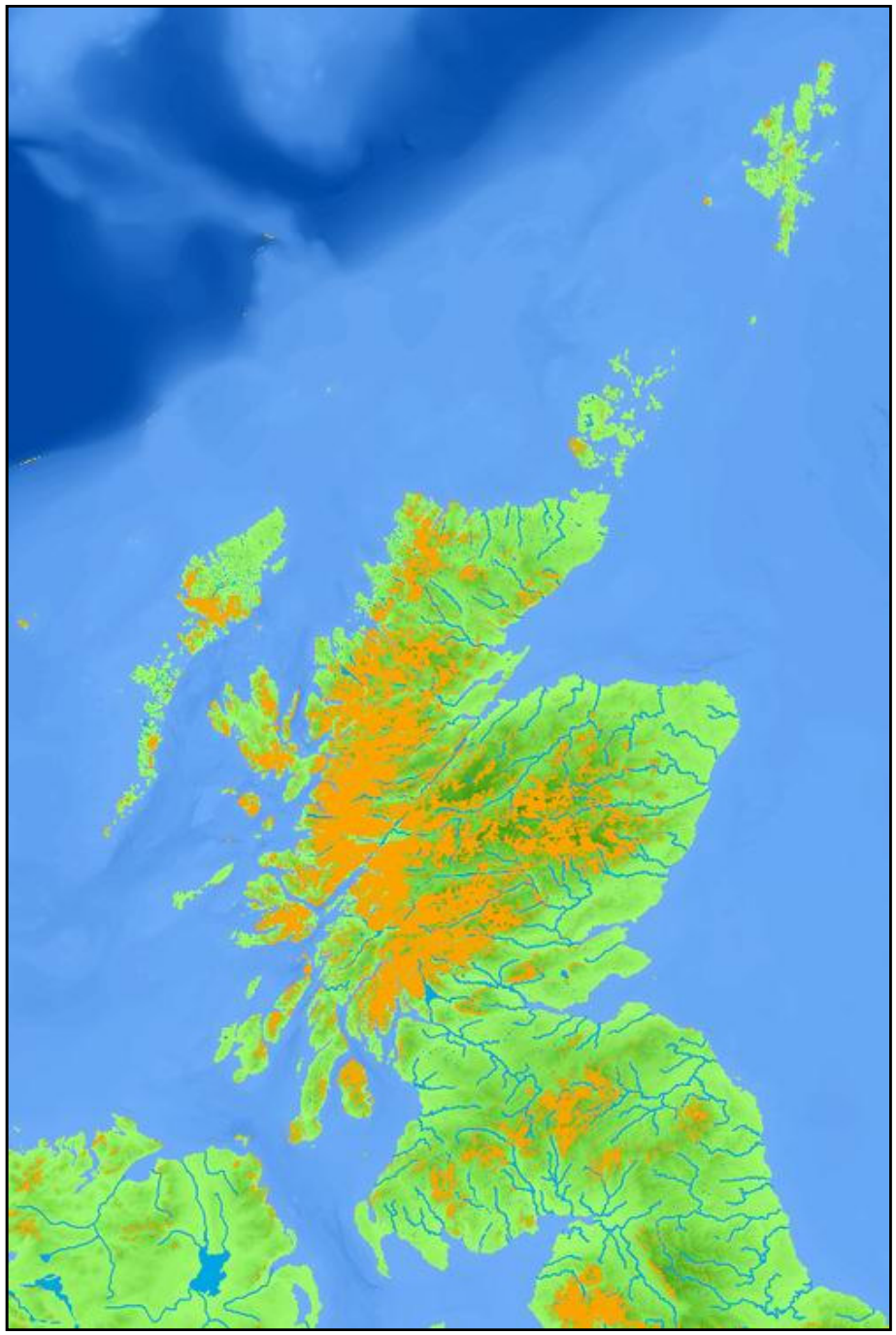


Sources: OS, UKHO

Physical

- **Water depth**
- **Slope**
- **Lakes**
- **Rivers**
- **etc.**

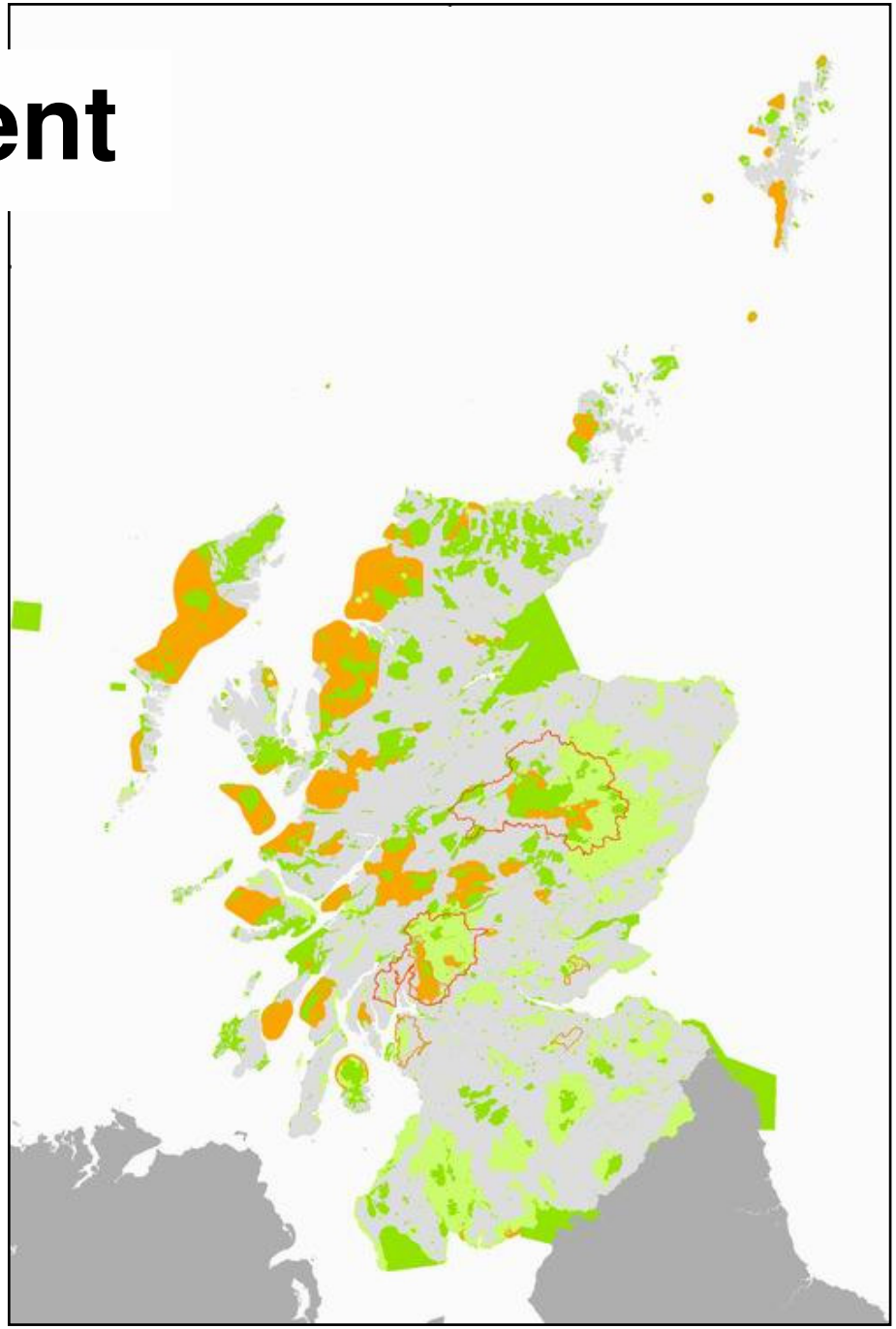
- Example:
  Average slope > 15% in a 1 km by 1 km square.



Sources: OS, BGS, BODC, SRTM

Environment

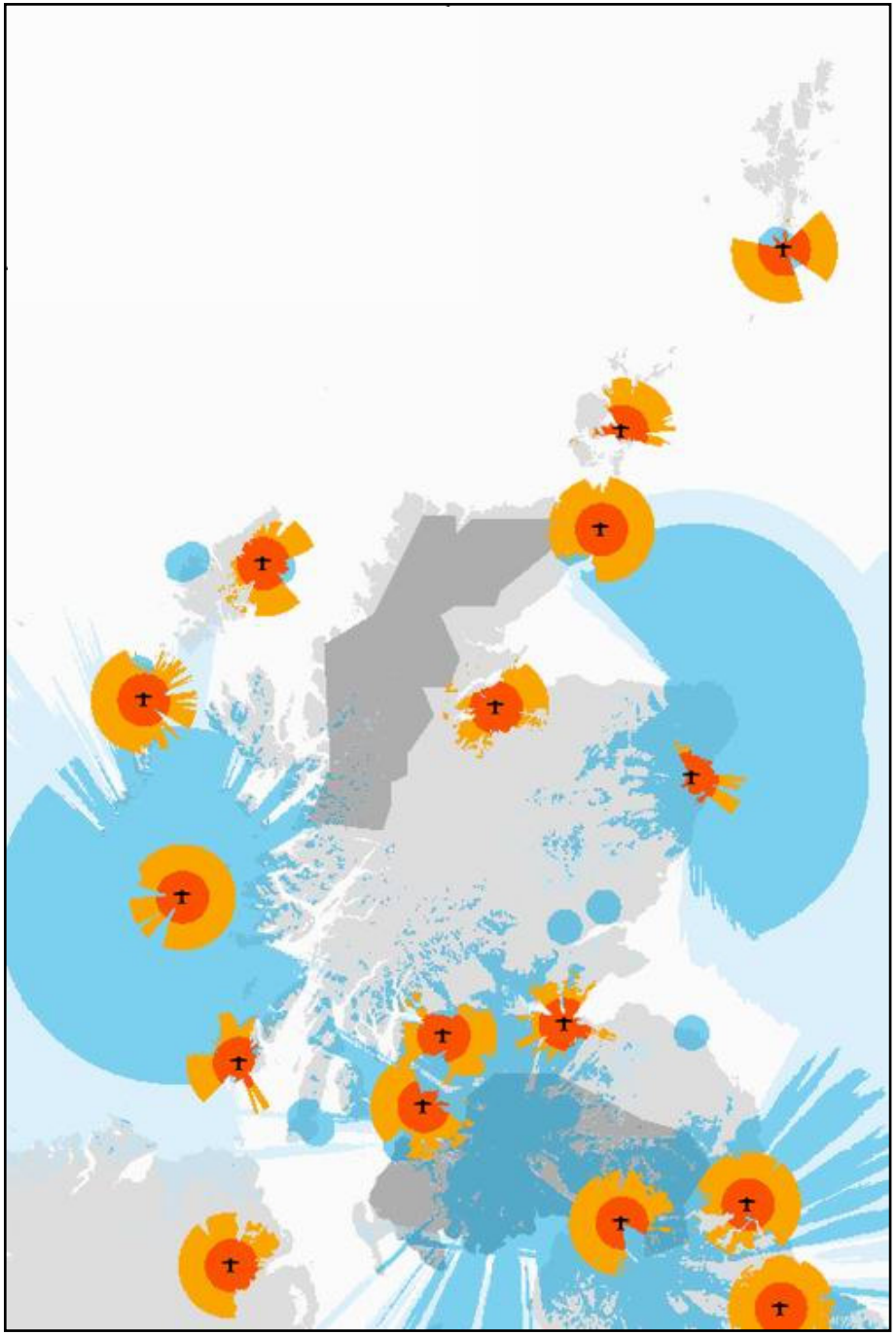
- **Recreation interests (high sensitivity)**
  - National Scenic Area
  - National Park
  - Regional park
- **Biodiversity interests (high sensitivity)**
  - Natura 2000, SSSI, ...
- **Medium sensitivity areas**
  - AGLV, LNR, ...



Sources: OS, SNH, SEGIS

Aviation Interests

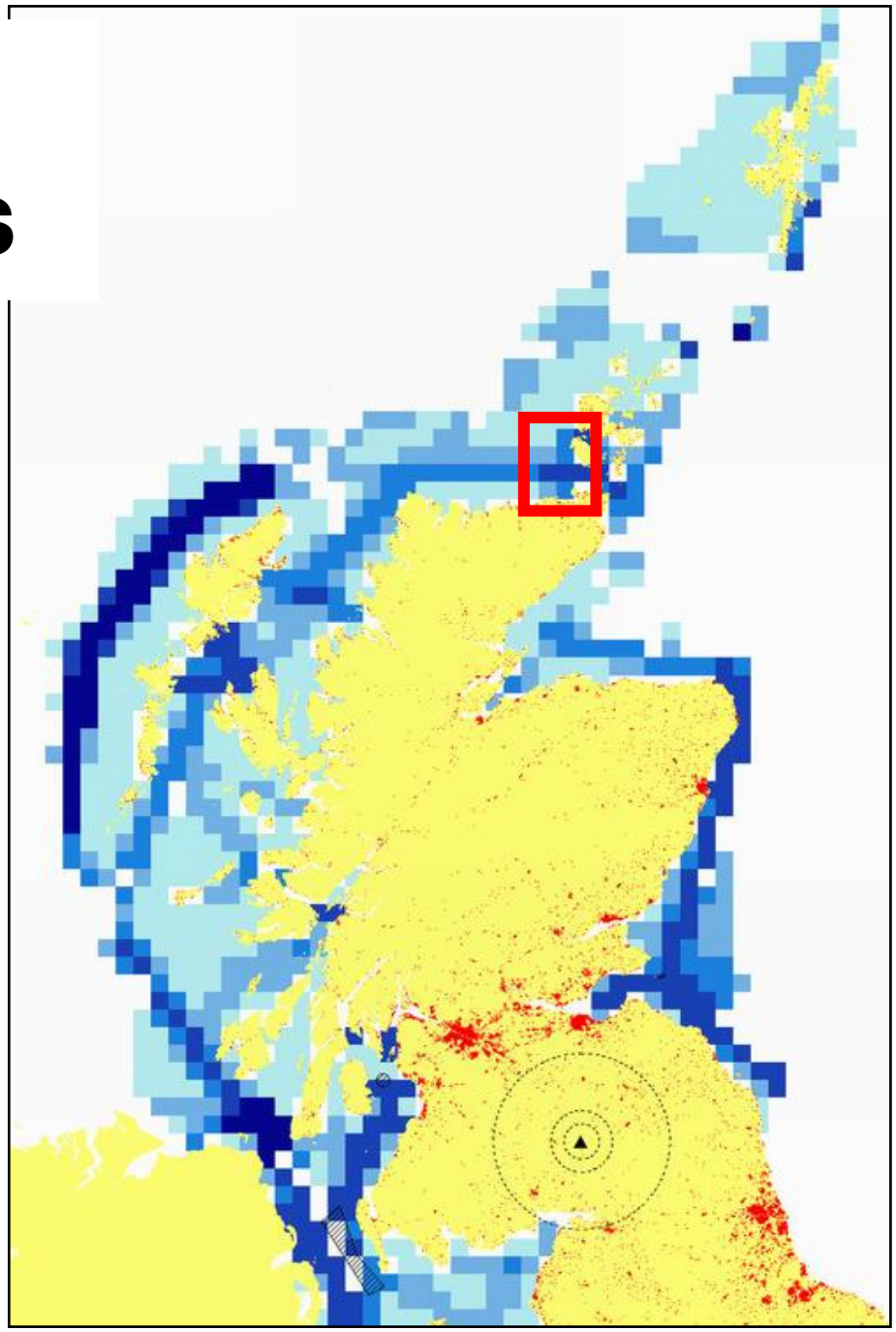
- **Civil radars**
  - 15 km exclusion zone
  - 30 km consultation zone
  - NATS high impact
  - NATS lower impact
- **Military radars**
- **Met Office radars**
- **Low Flying System**
  - Tactical Training Area



Sources: OS, DTI, CAA, BWEA

Further Constraints

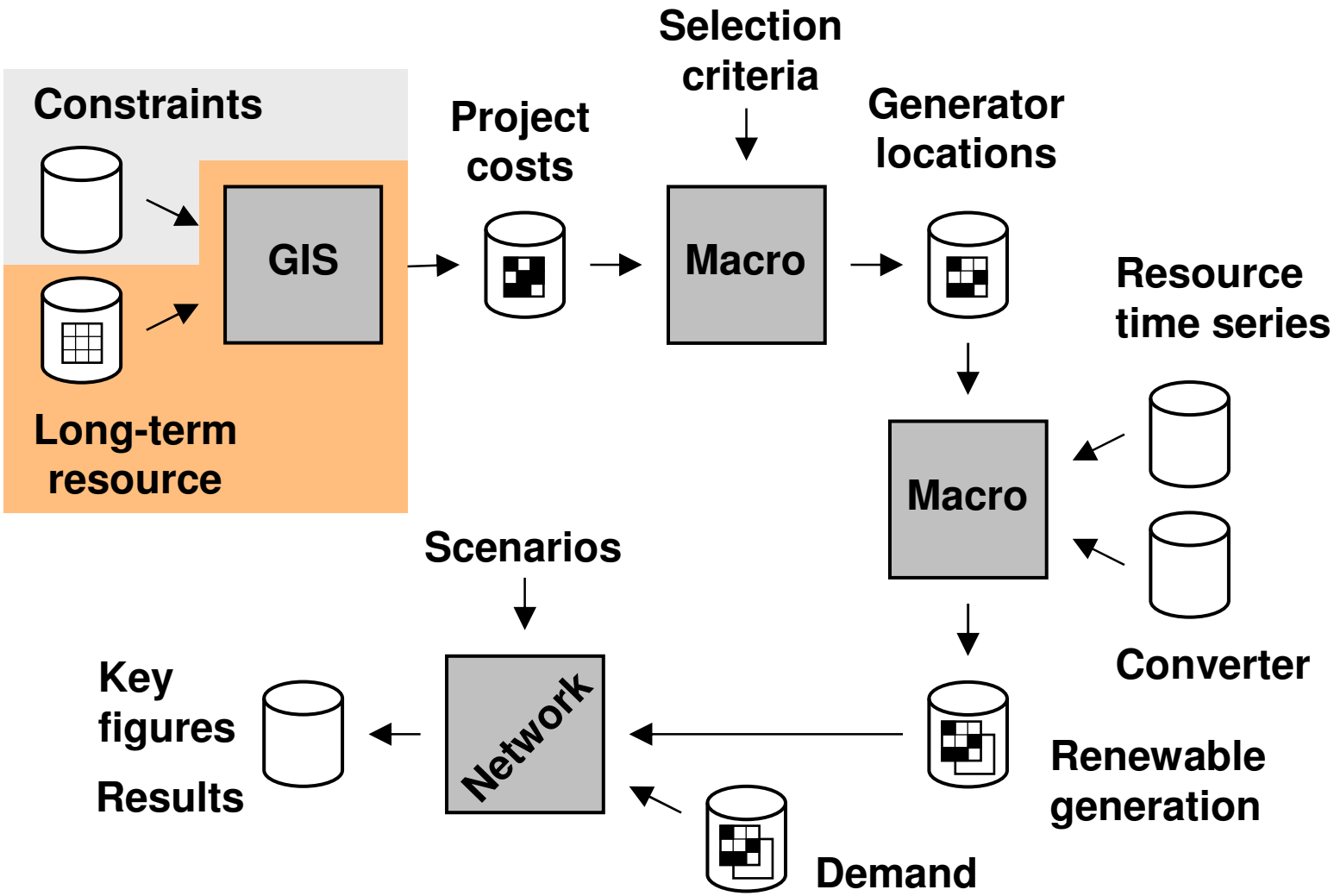
- **Urban areas**
  - Cities, towns, villages
- **Navigational risk**
  - very high
  - medium
  - very low
- **Seismological measurements**
  - Eskdalemuir
- **Ammunition dumping**
- **Distances, etc.**



Sources: OS, DTI, CAA, BWEA

Contents

Long-Term Resource



Onshore Wind Resource

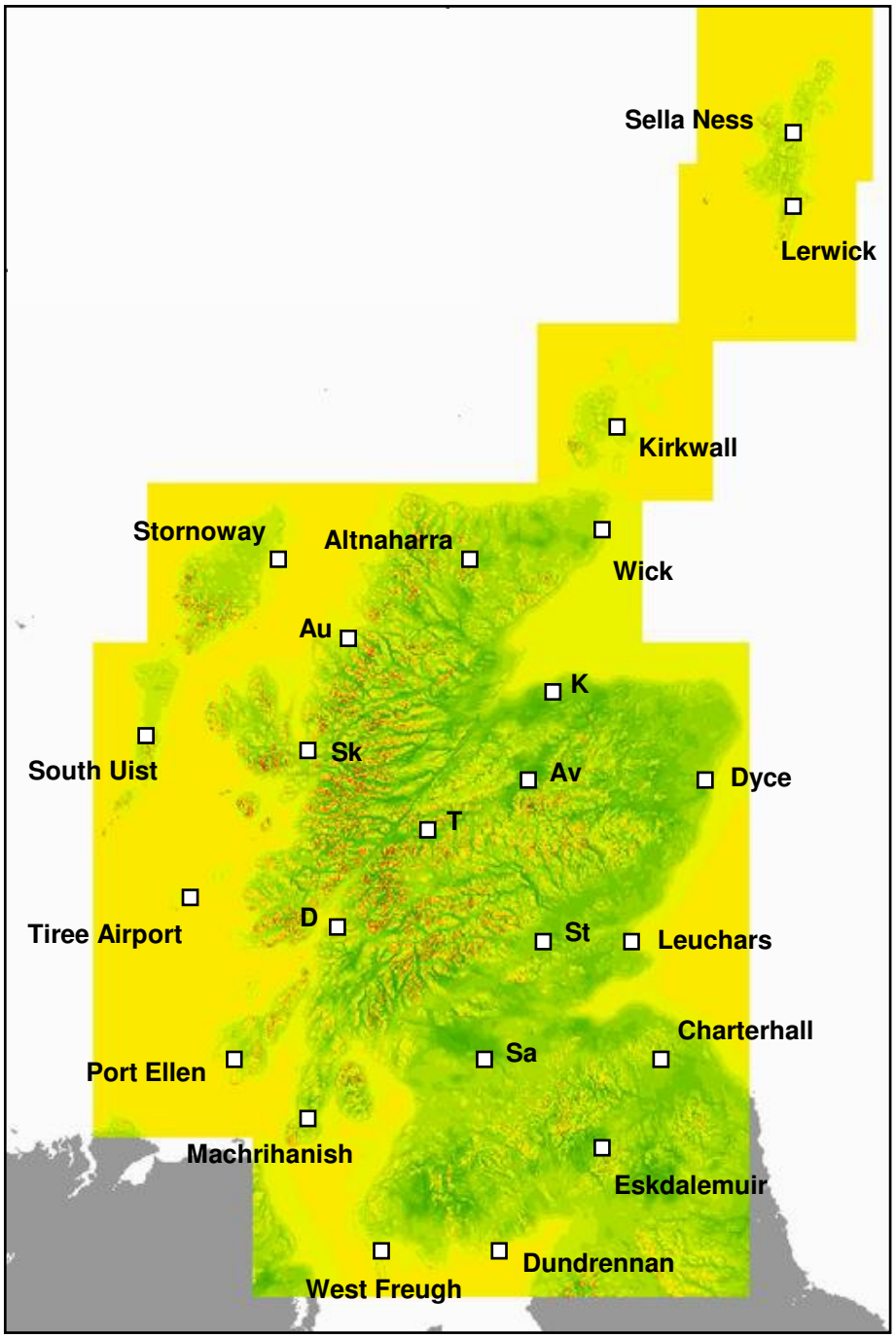
Average wind speed in each 1 km^2 cell at 80 m height agl. calculated from met station data using WAsP and WindFarmer

10 years data (1994-2003)

4 10 16 m/s

Meteorological station (21 + 3)

Sources: OS, Met Office



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Offshore Wind Resource

Average wind speed at 80 m height asl.

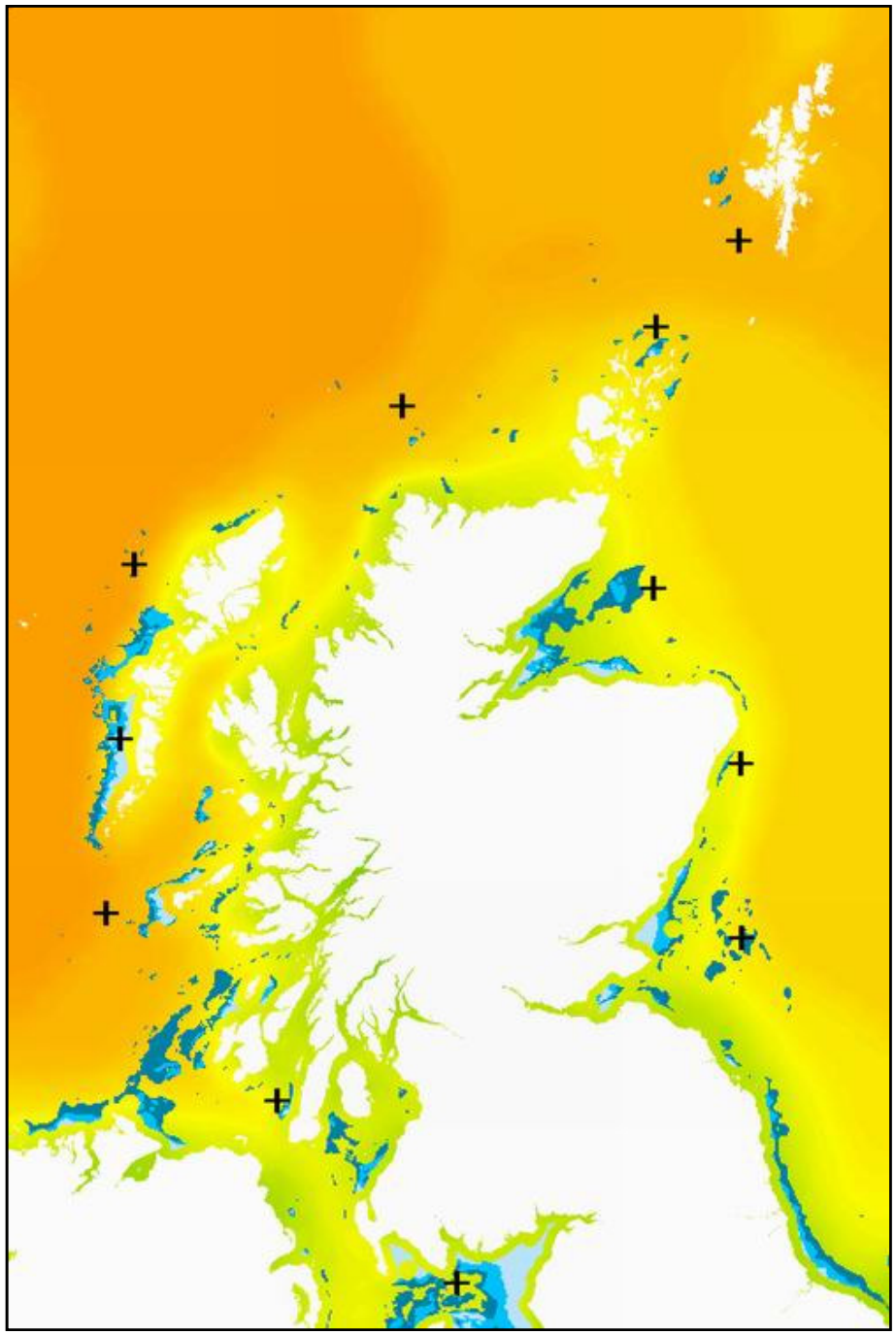
4 10 16 m/s

Water depth, 5 km offshore

- 0 ... 30 m
- 30 ... 40 m
- 40 ... 50 m

+ Met Office Simulation Point (11)

Sources: OS, DTI, Met Office



Wave Resource

3 hour data: March 2000 – Nov 2004

Wave power per metre crest length

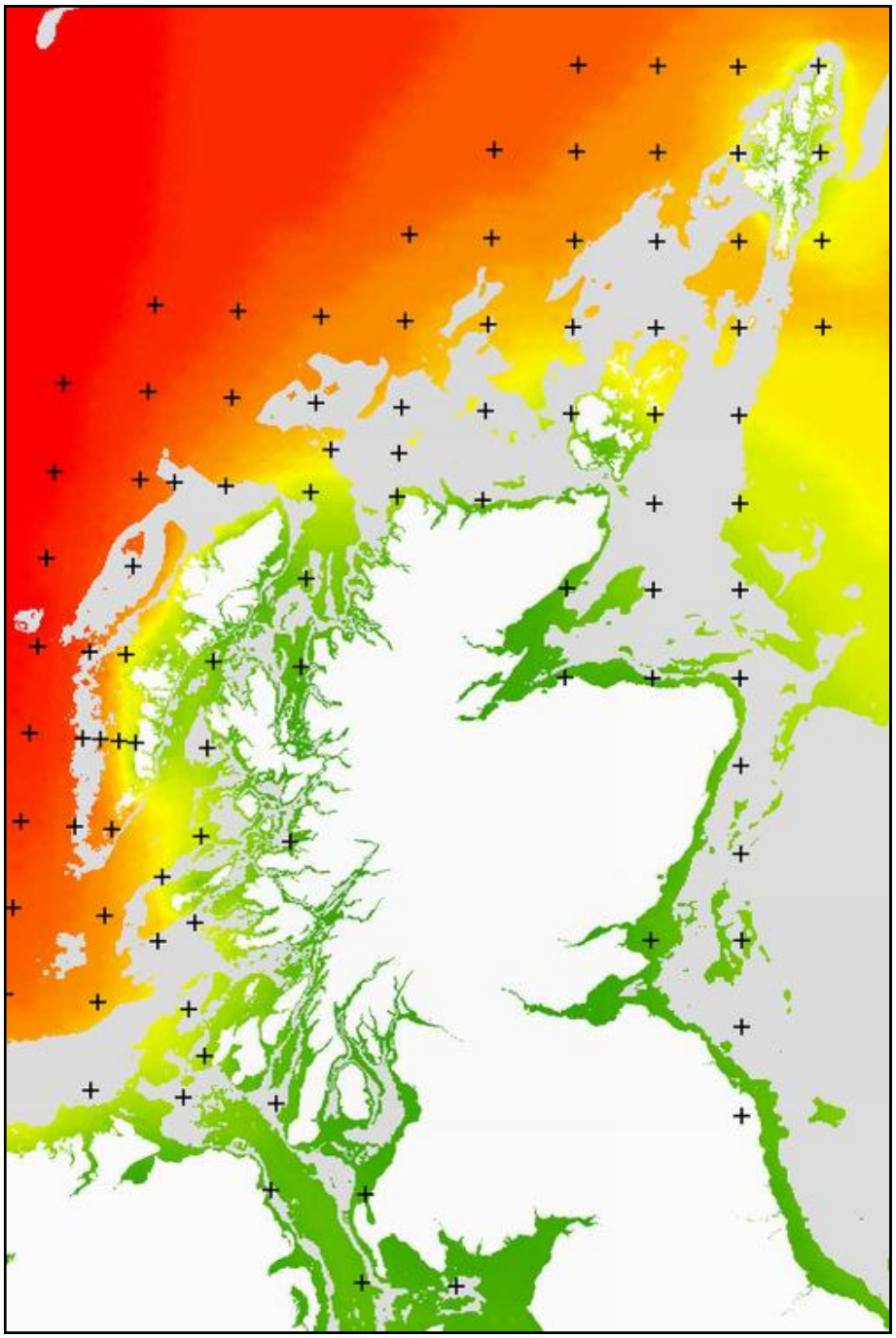
5 30 55 kW/m

Water depth, 5 km offshore

50 ... 100 m

+ Met Office Simulation Point (84 + 11)

Sources: OS, DTI, Met Office



Tidal Current Resource

Variable but deterministic

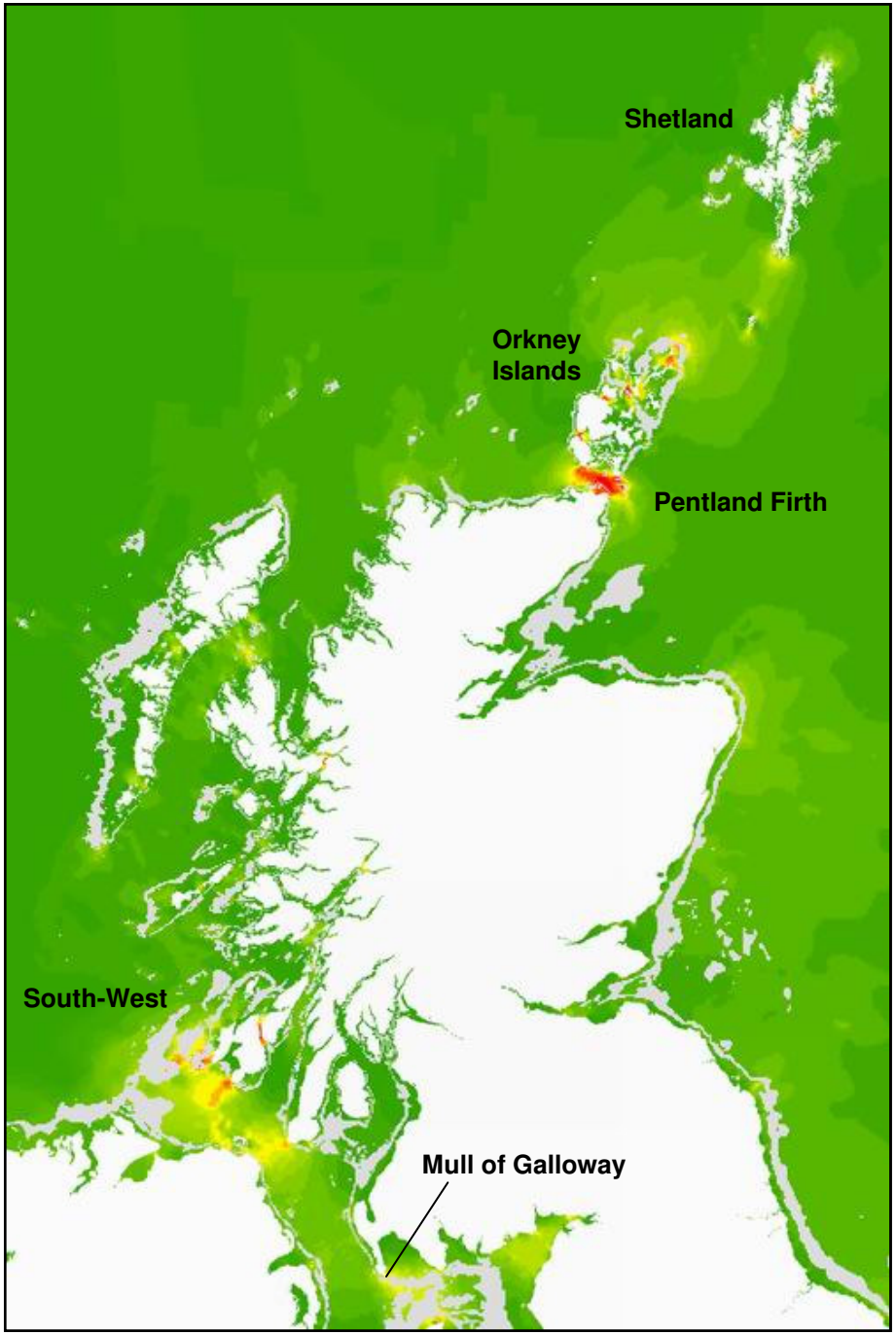
Average spring tide velocity (surface)

0.5 1.5 2.5 m/s

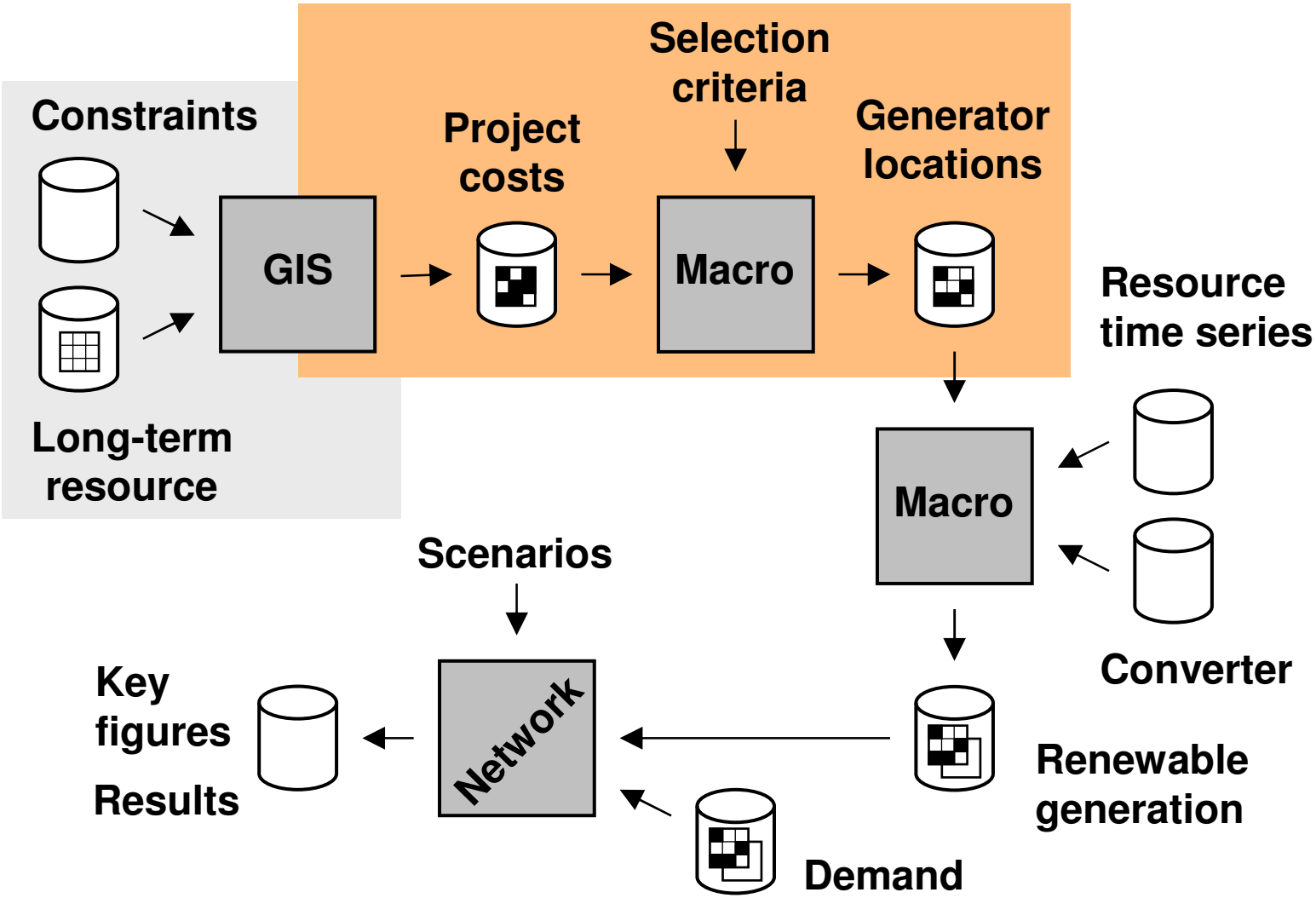
Water depth

30 ... 50 m

Sources: OS, DTI, Robert Gordon Univ.



Future Generator Locations



Cost Calculation

Step	Remark
Remove "no go" cells	e.g. cities, NSAs
Calculate annual energy output	
Calculate (initial) levelised project cost (LPC) per cell	Excluding grid connection costs
Remove "expensive" cells	e.g. > 10 p/kWh
Check capacity limit in consultation areas	e.g. by 100 km^2 area, remove more cells
Cluster to projects (for cost sharing)	neighbouring cells, total capacity limit
Calculate (final) LPC per cell	Including grid connection costs
Select cells	per area; capacity or cost limit

Project Costs

Example:

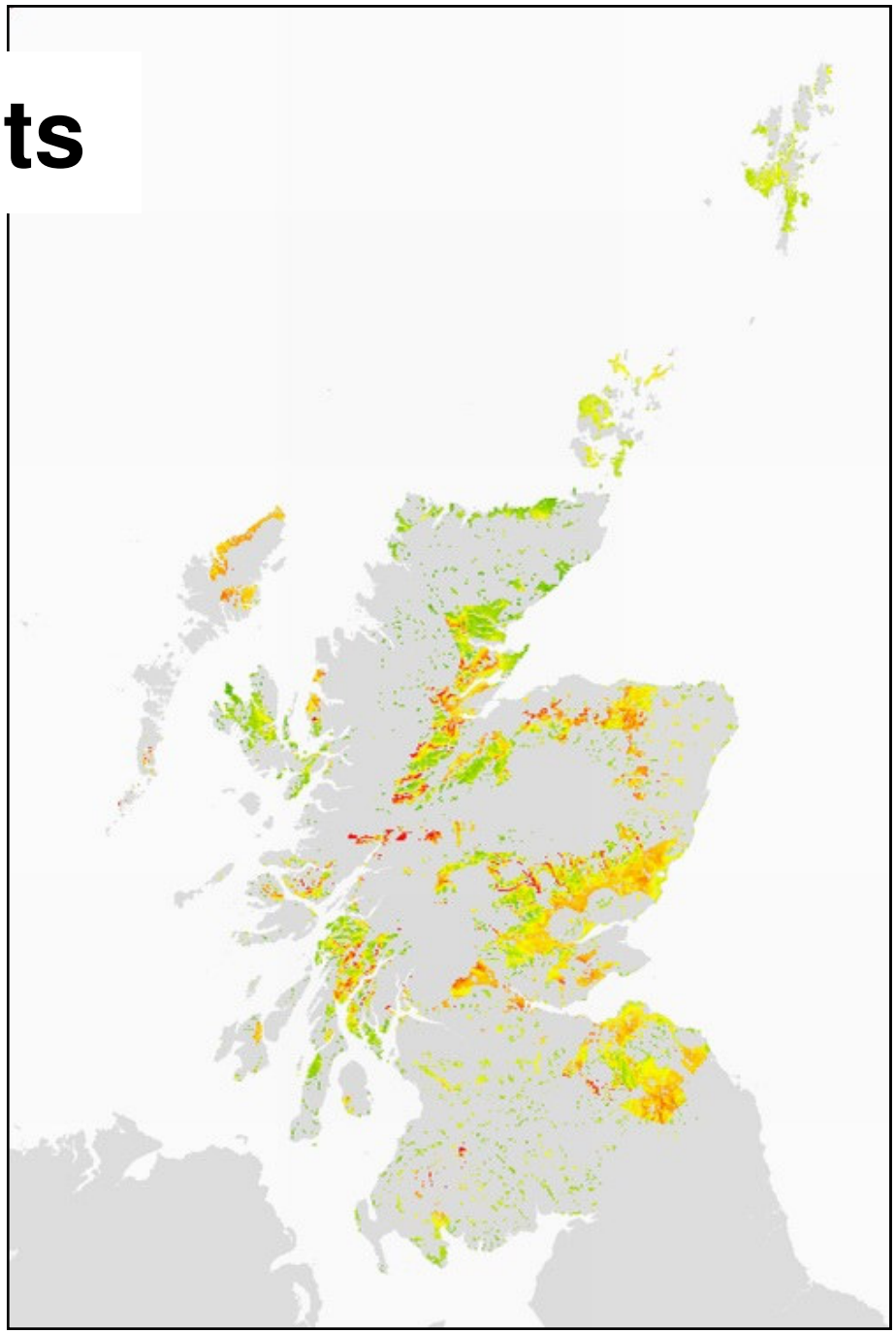
Estimated onshore wind project costs ***including*** connection to existing network

- low cost
- medium cost
- high cost

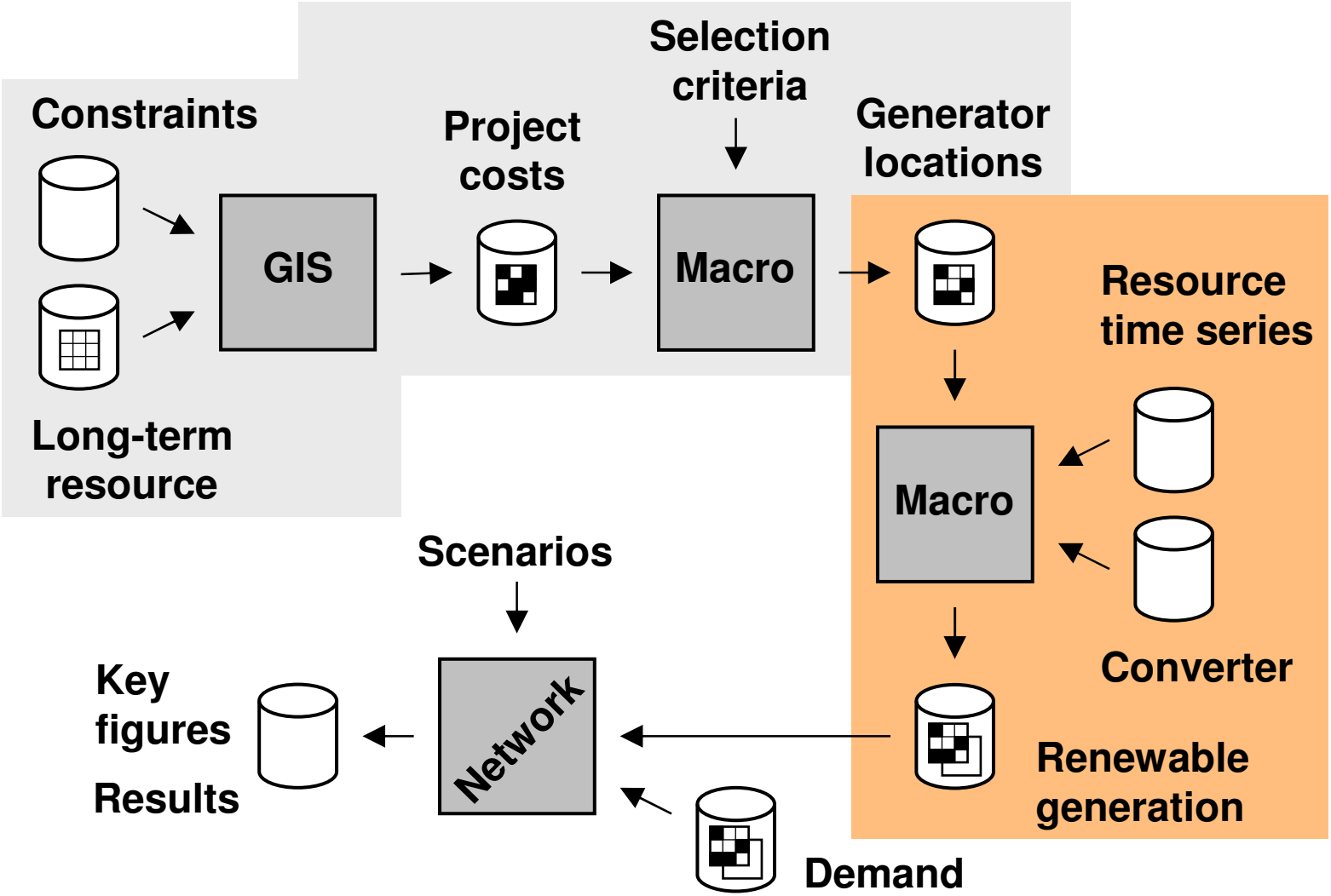
- "no go" zone

Assumptions:

- 3 x 2.5 MW per km^2
- 80 m hub height
- 20 years, 8 % discount rate



Creating Power Time Series



Energy Converters

On/Offshore Wind

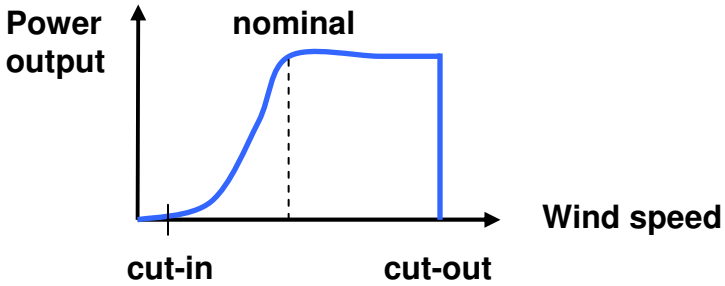
- 3-bladed horizontal axis turbine with pitchable blades
- 80 / 120 m diameter
- 2.5 / 5 MW
- 80 m hub height
- Offshore: < 40 m water depth

Waves

- Semi-submerged articulated structure
- 180 m long
- 1.5 MW
- 50 ... 150 m water depth

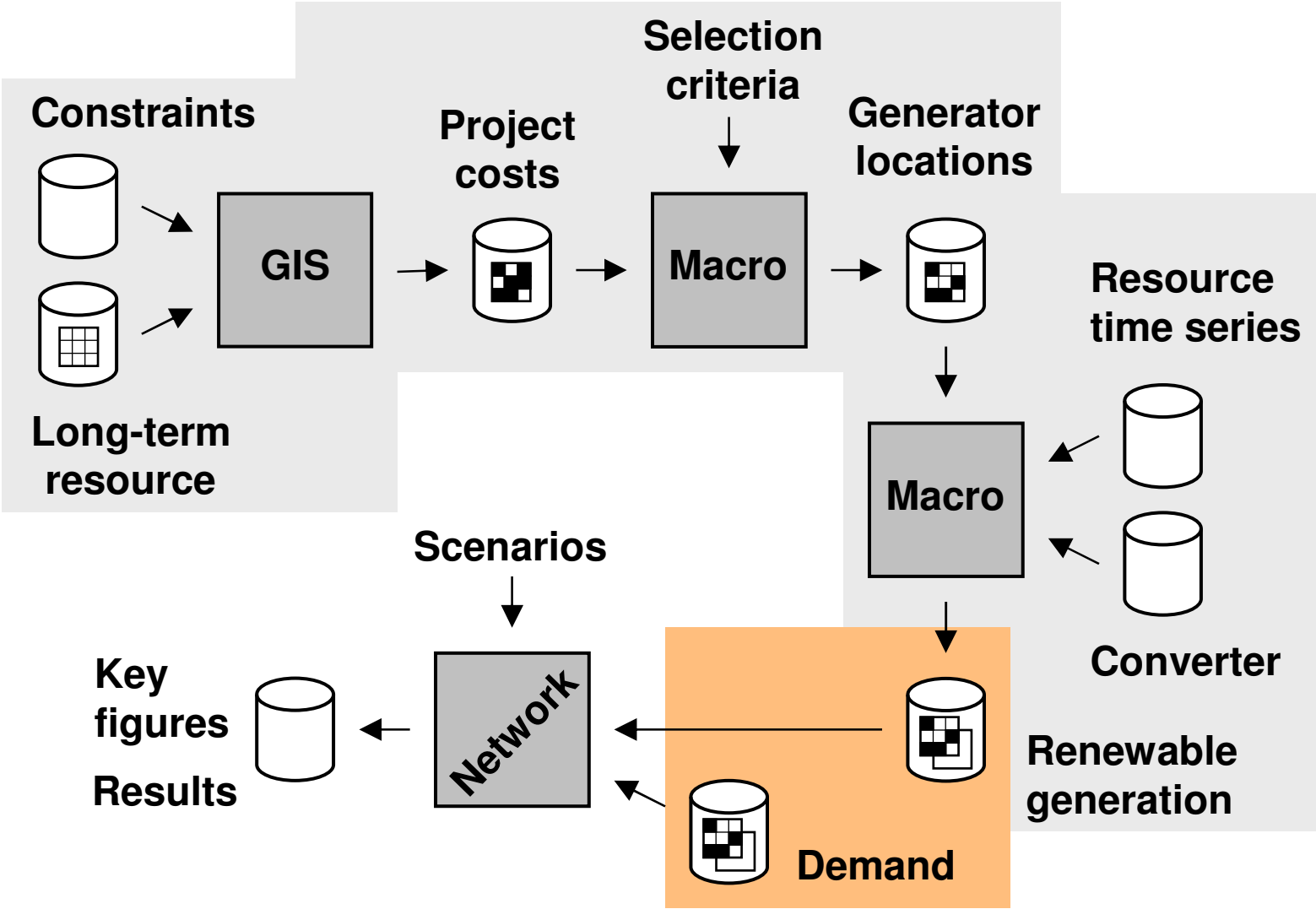
Tidal Currents

- Twin-rotor horizontal axis turbine with pitchable blades
- 20 m rotor diameter
- 2 x 500 kW
- 30 ... 50 m water depth



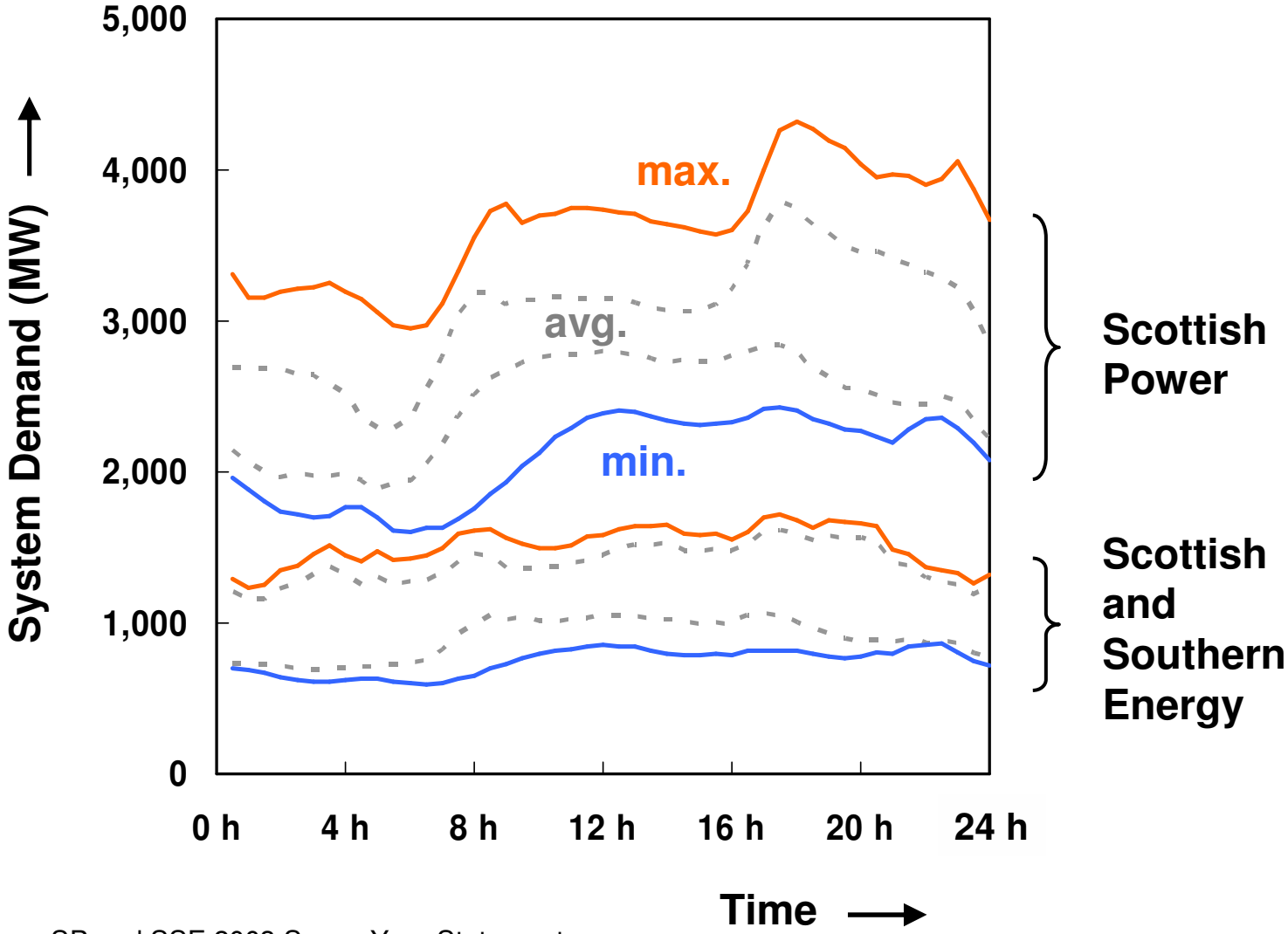
Source: Nordex, OPD, MCT

Generation vs. Demand



Demand - Daily

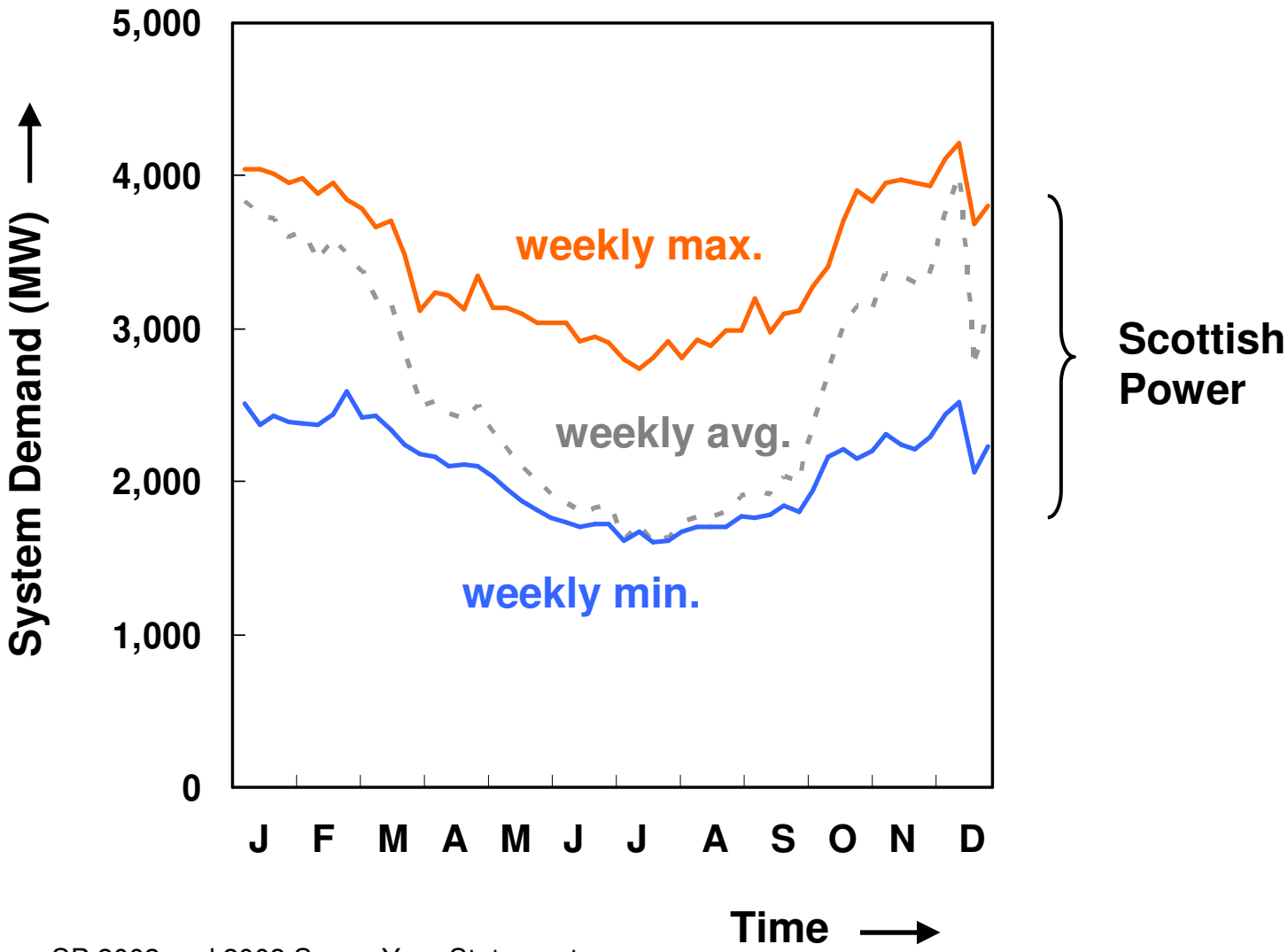
Example:
2002/03



Source: SP and SSE 2003 Seven Year Statements

Demand - Annual

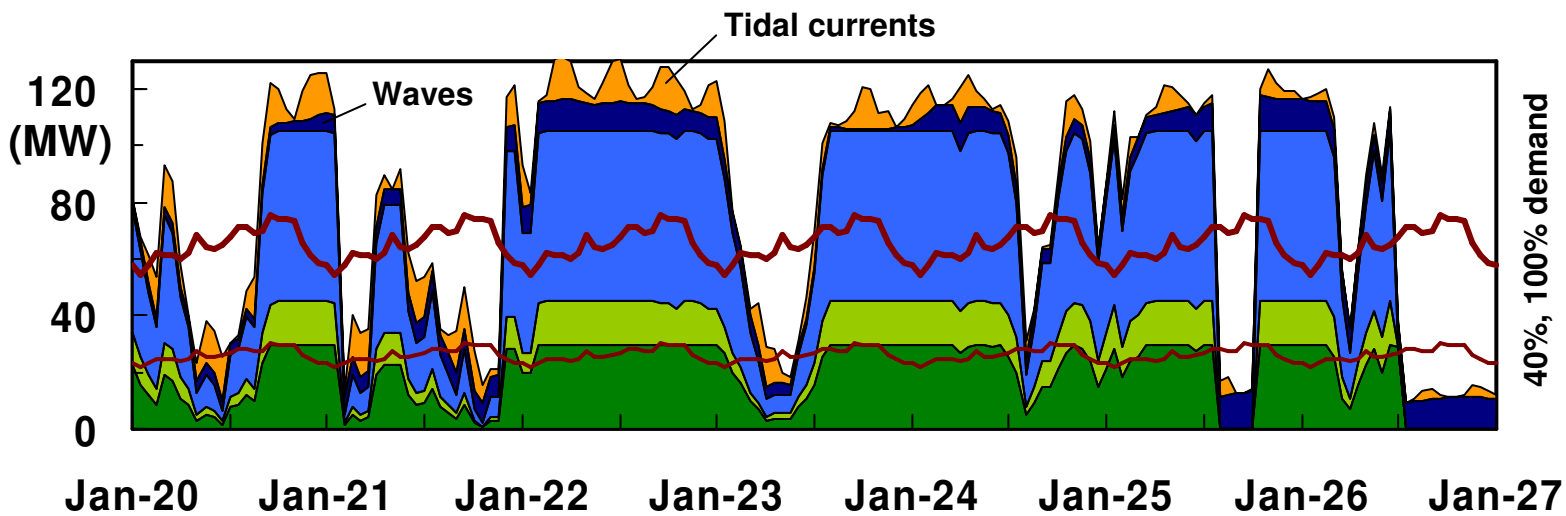
Example: 2002

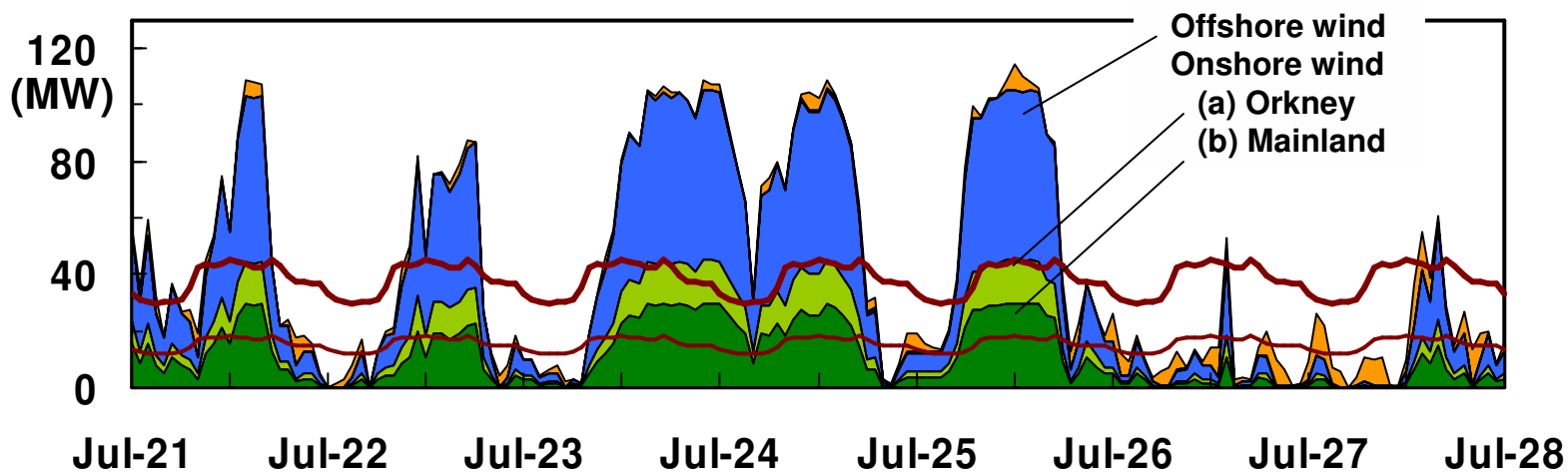


Source: SP 2002 and 2003 Seven Year Statements

Sample Area

Demand Matching January, July 2003





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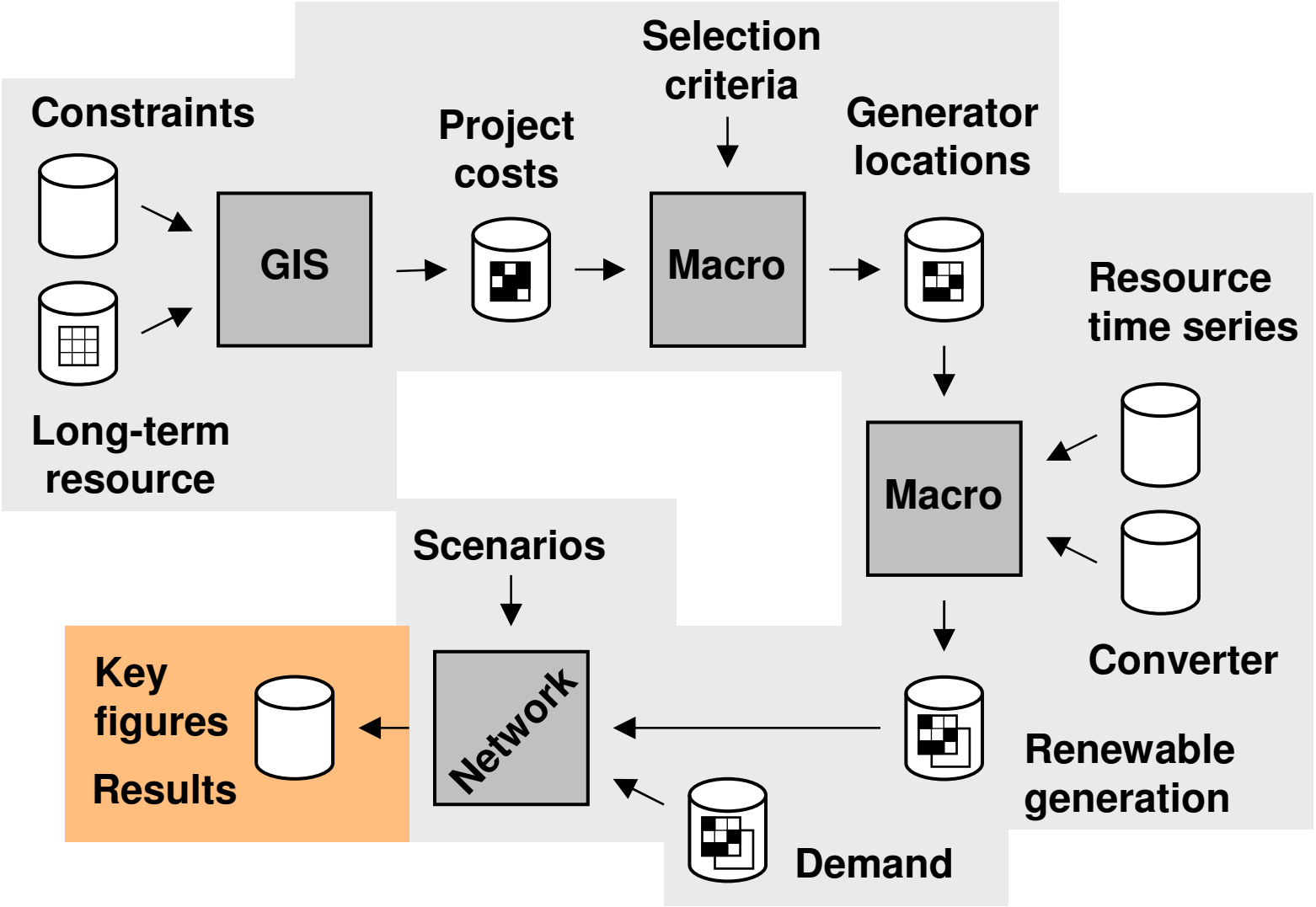
Key Figures and Results



Results

After application of geographical constraints it could be possible to develop <u>at least</u>

- 6 GW of onshore wind
- 3 GW of offshore wind
- 3 GW of wave and
- 1 GW for tidal current

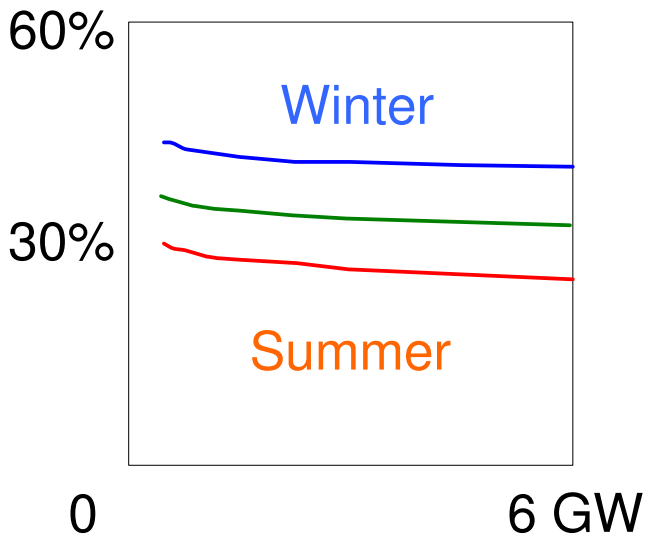
or any combination of these technologies.

Results

Annual plant capacity factors derived from production time-series all exceed 30%

- They reduce as the capacity increases by adding less energetic higher cost sites.
- Seasonal values for wind and wave power are significantly higher in winter than in summer.

Plant capacity factor (%)		
	3 GW	6 GW
Onshore-wind	33.9	32.7
Offshore-wind	35.8	-
Wave	31.7	-
Tidal-current (750 MW)	(30.0)	-
75-10-10-5% mix	34.7	33.5

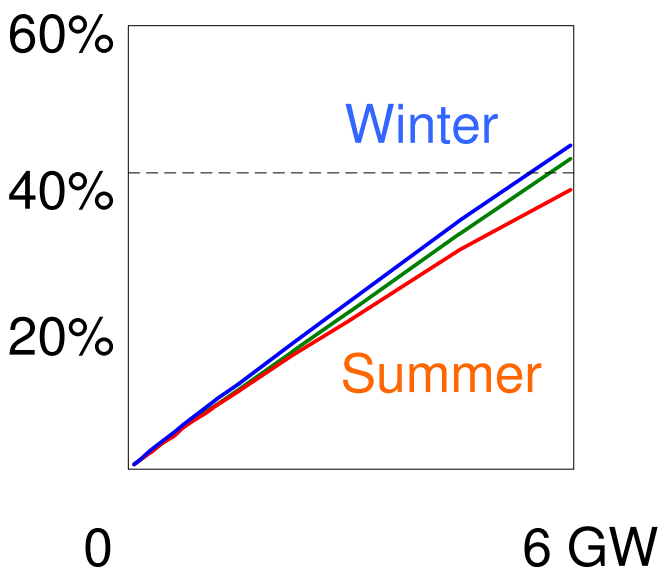


Results

Onshore wind or the mixed technology portfolio of 6 GW would on average meet at least 40% of the electricity demand in 2020

Potential to increase the penetration to 50% or more

Long-term local matching (%)		
	3 GW	6 GW
Onshore-wind	21.8	41.5
Offshore-wind	23.0	-
Wave	20.4	-
Tidal-current (750 MW)	(4.8)	-
75-10-10-5% mix	22.3	42.7



Results

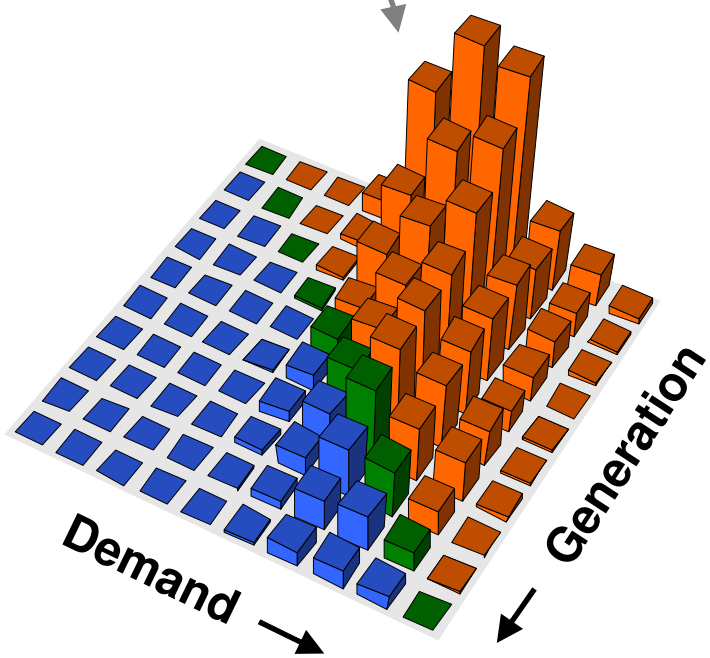
Coincident hours best describe ongoing hourly match as a histogram

There is about 29 hours/year when the demand > 90% of the peak while on-shore wind provides less than 10% of its capacity

Diversification by using a portfolio of renewable generation reduces that number to 20 hours/year

Coincident hours for demand > 90% and production < 10% (h/year)

	3 GW	6 GW
Onshore-wind	29	29
Offshore-wind	14	-
Wave	19	-
Tidal-current (750 MW)	(22)	-
75-10-10-5% mix	18	20

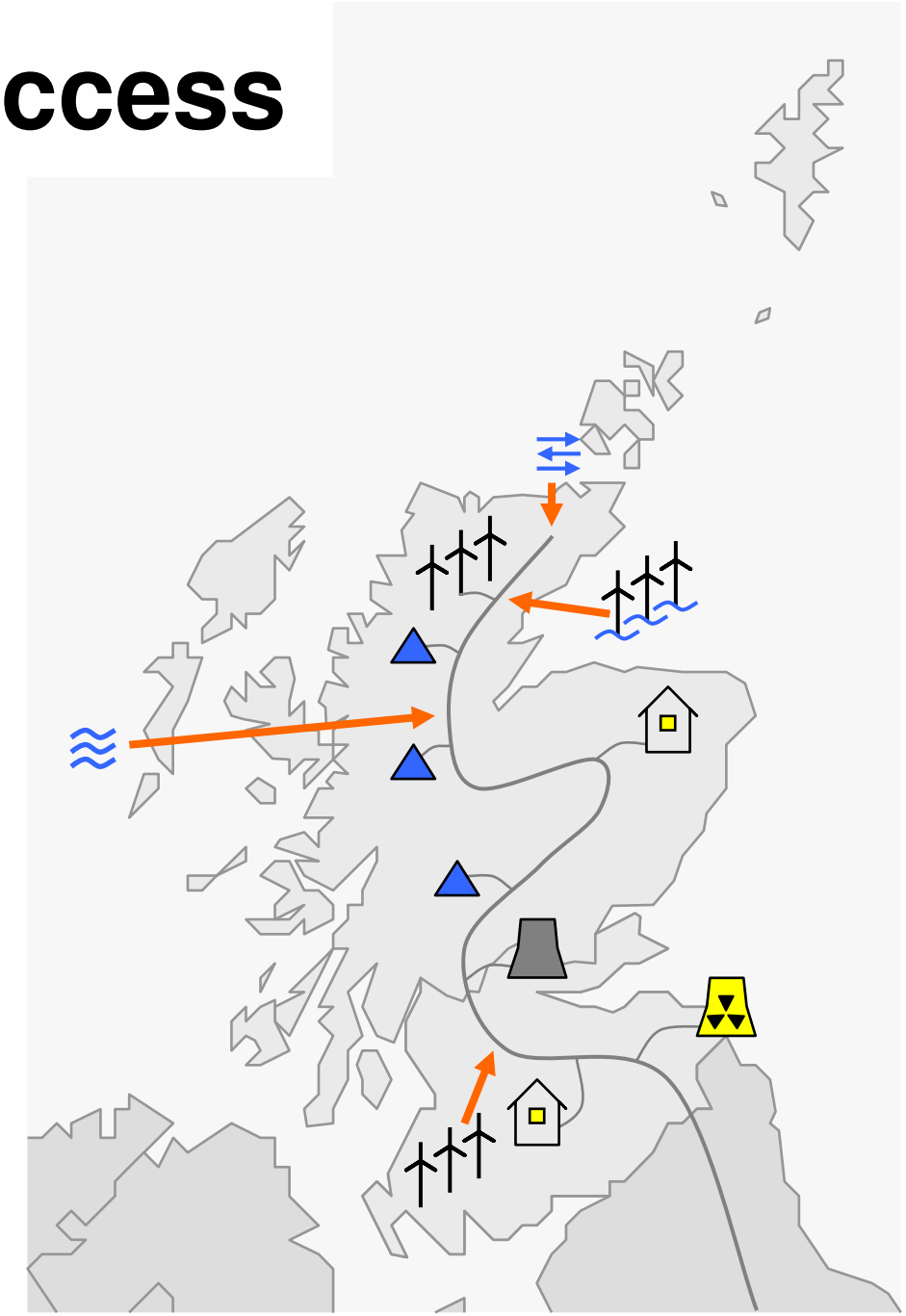


Network Access

Generally weak network in Scotland

Competition for network access

Full development of the more remote onshore and most of the offshore resource would require completion of planned network upgrades in northern and western Scotland.



Need for network upgrades

Current developments: review of GB Security and Quality of Supply Standard (SQSS) and Transmission Access Review (TAR)

Controversy regarding scaling factor for wind for network planning purposes (currently 60%)

Need for upgrades could be reduced if control schemes were more widely used (quad boosters, intertrips)

Summary

The study has refined understanding of characteristics and availability of renewable resource in Scotland through detailed physical modelling using geographical and surface roughness data

Realistic assessment by eliminating no-go areas and including limits tp renewable generation

Diversification of renewable energy sources helps to manage variability of renewable input but a strong interconnected transmission system is required

SuperGen FlexNet projects will extend the study to the whole GB although in less detail