



# The Scottish renewable resource assessment and implications for the grid

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# 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**

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# What's unique?

- **Temporal resolution: one-hour for wind and 3 hours for wave**
- **Spatial resolution: 1 km<sup>2</sup>**
- **Physical modelling using WAsP and WindFarmer: calculate wind at turbine height (80 m agl.) in each 1 km<sup>2</sup> 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>



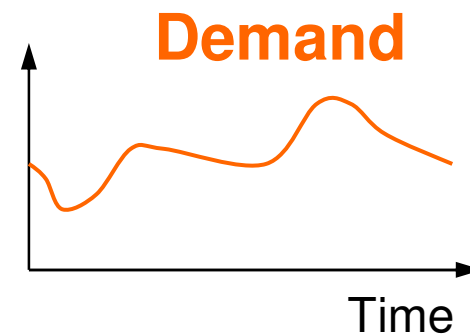
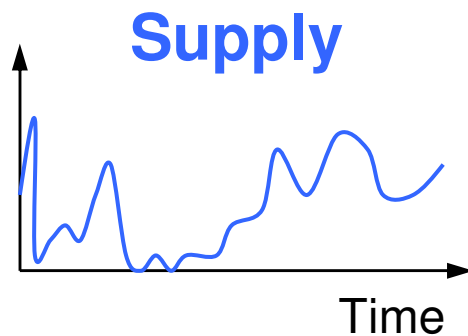
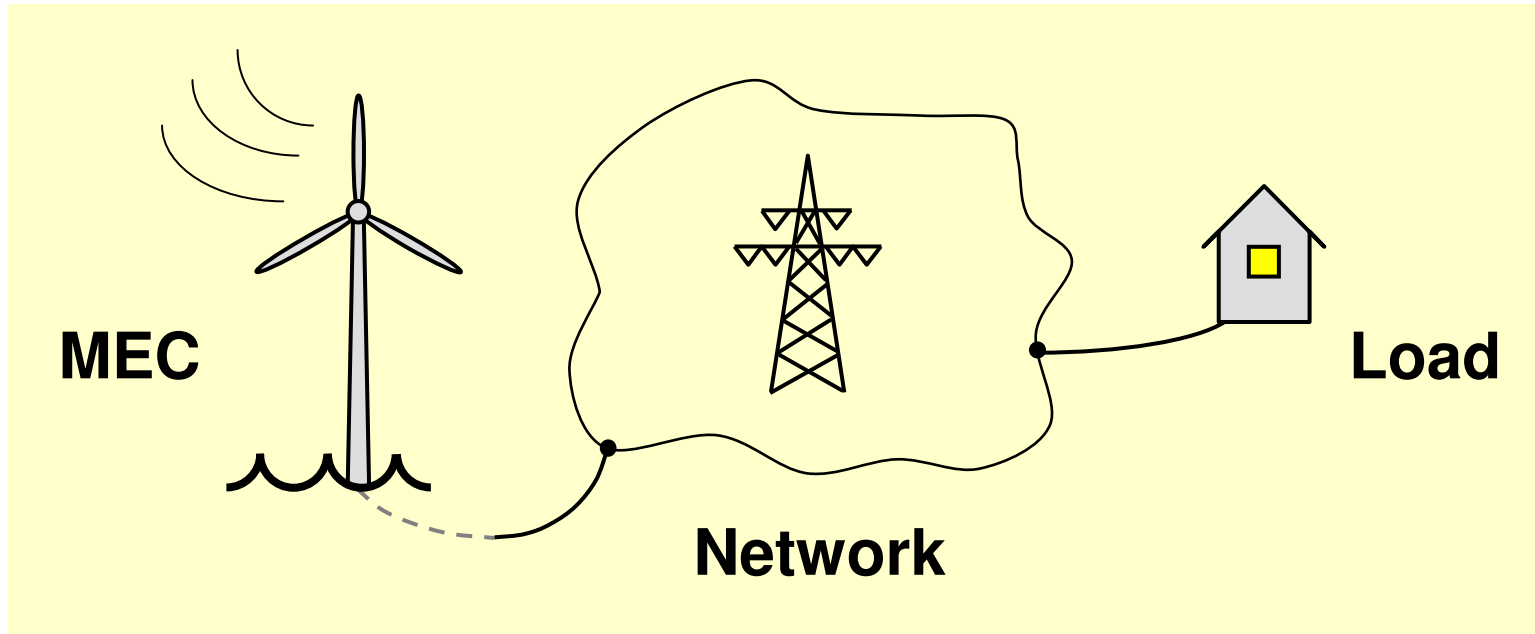
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# The Challenge



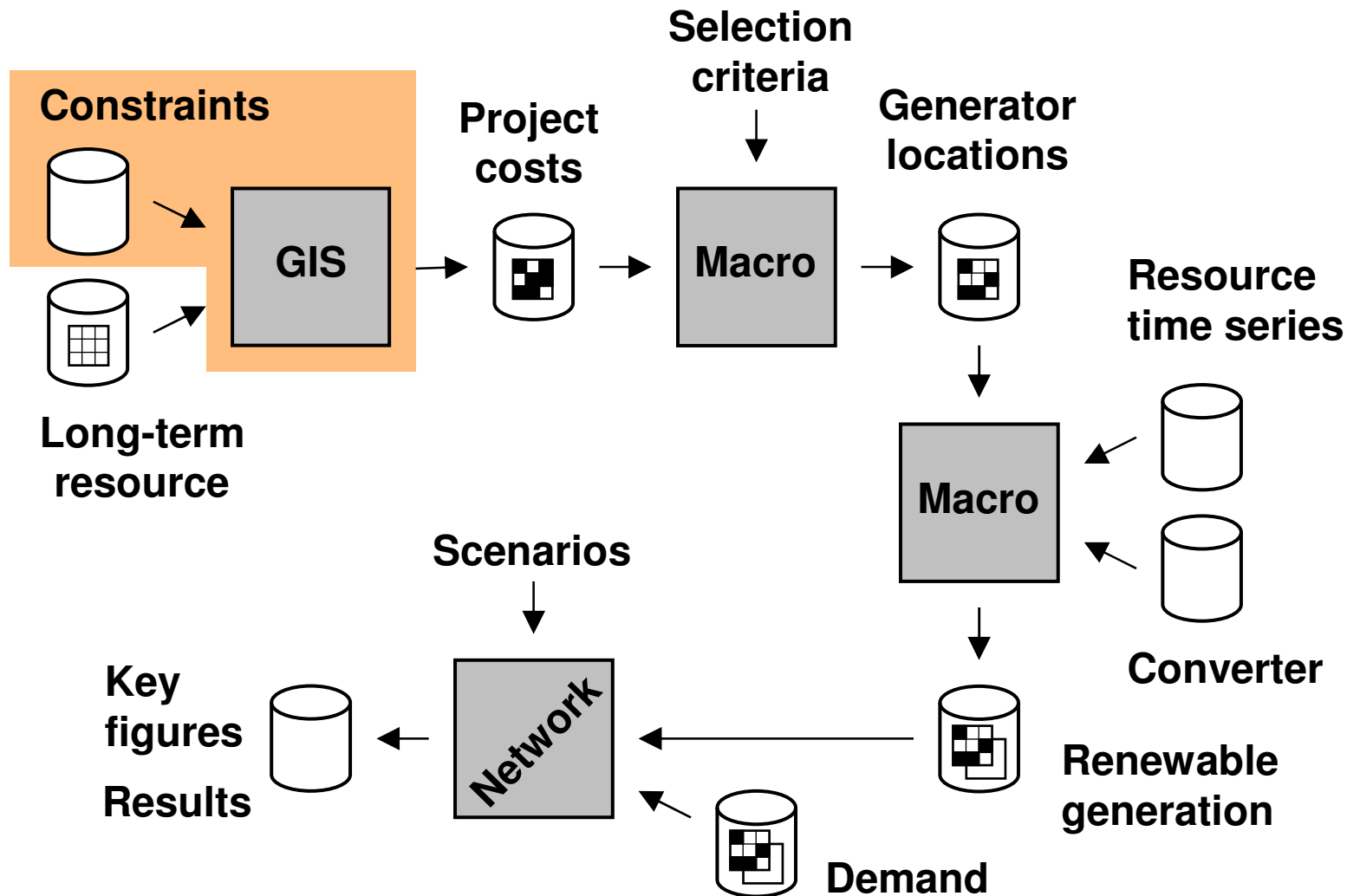
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# Constraints GIS Mapped



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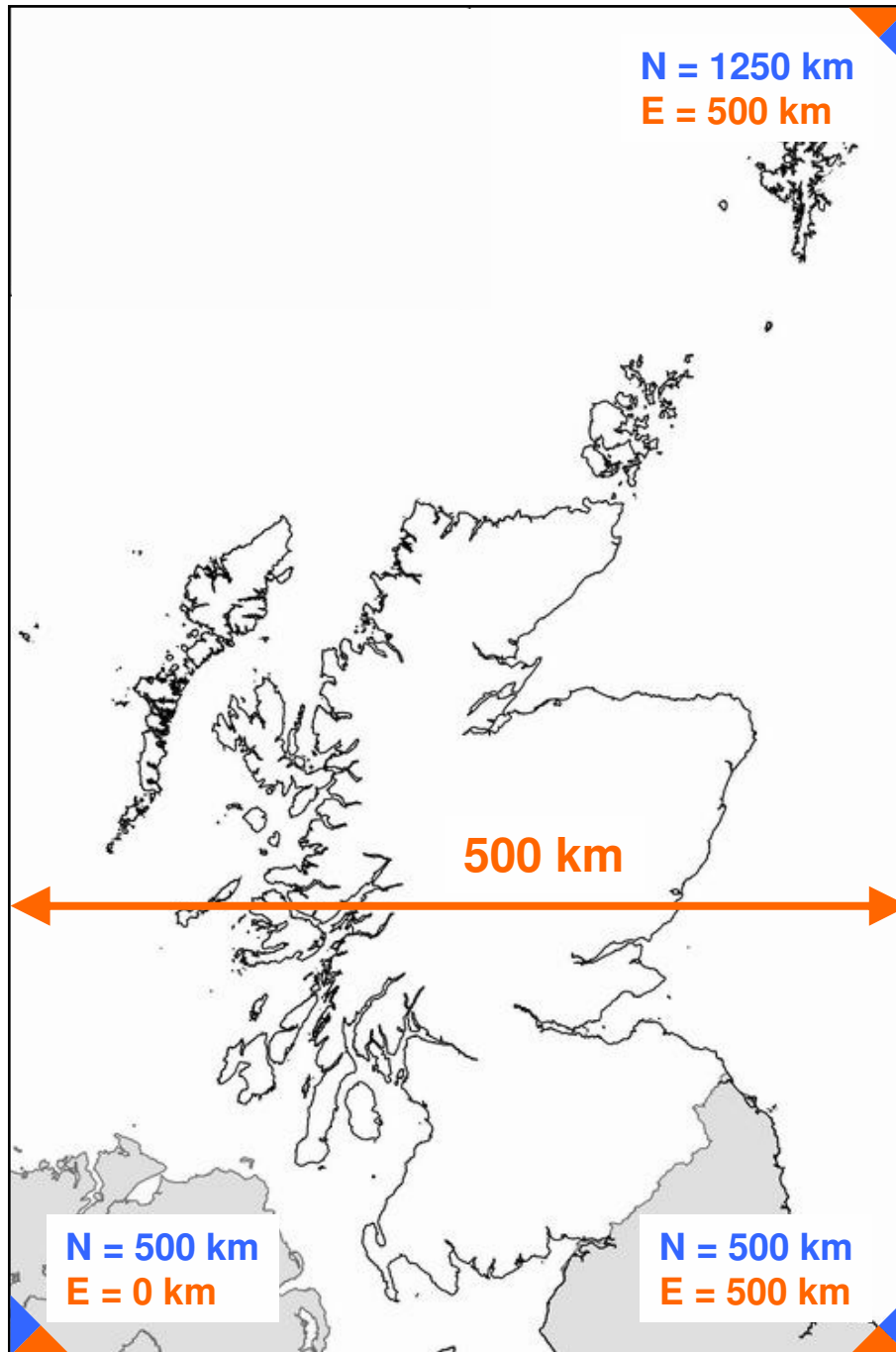
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# Study Area

- Spatial resolution: 1 km<sup>2</sup>
- Use of British National Grid coordinates

750 km



Source: Ordnance Survey



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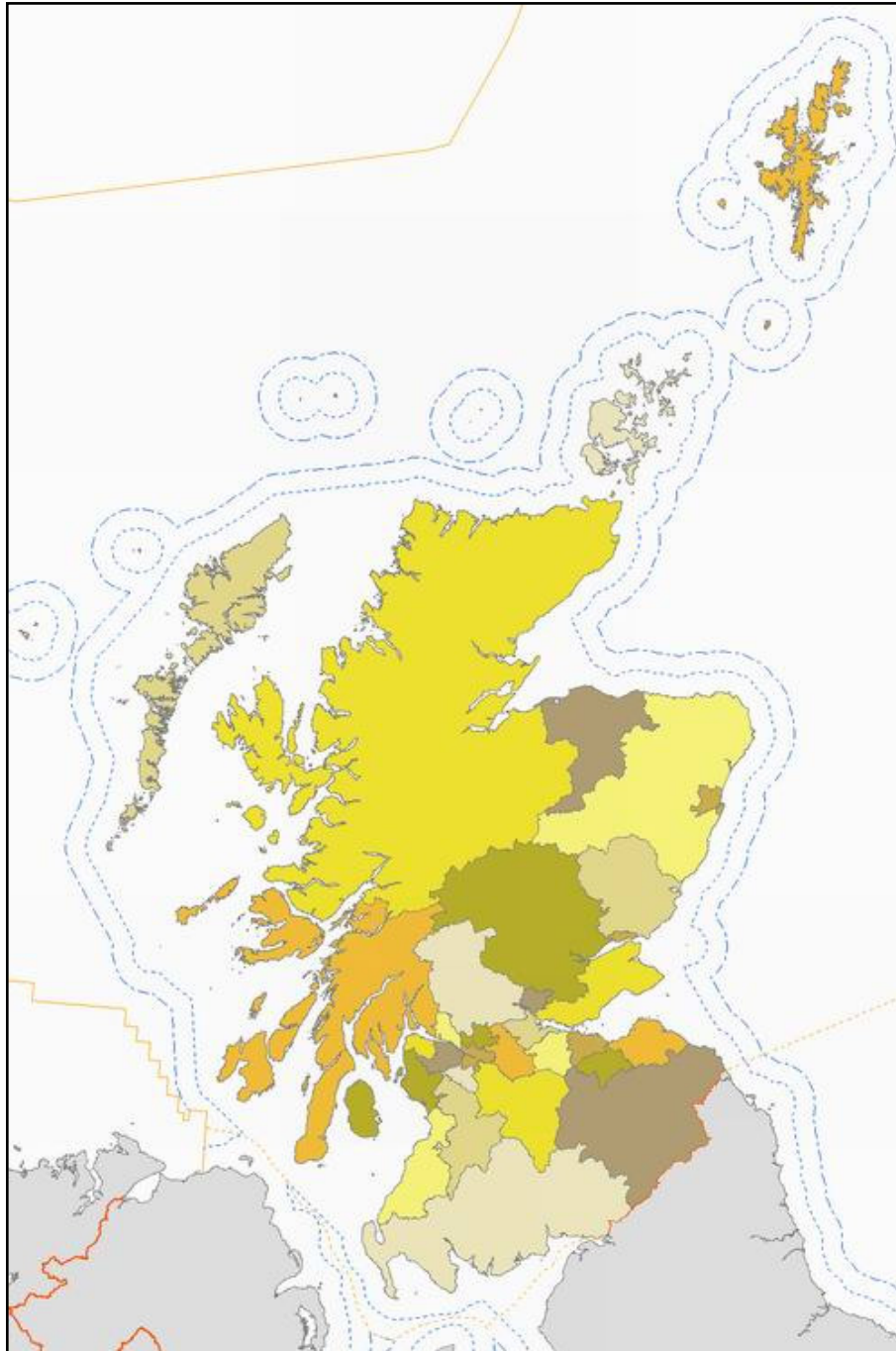
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# Political

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



Sources: OS, UKHO



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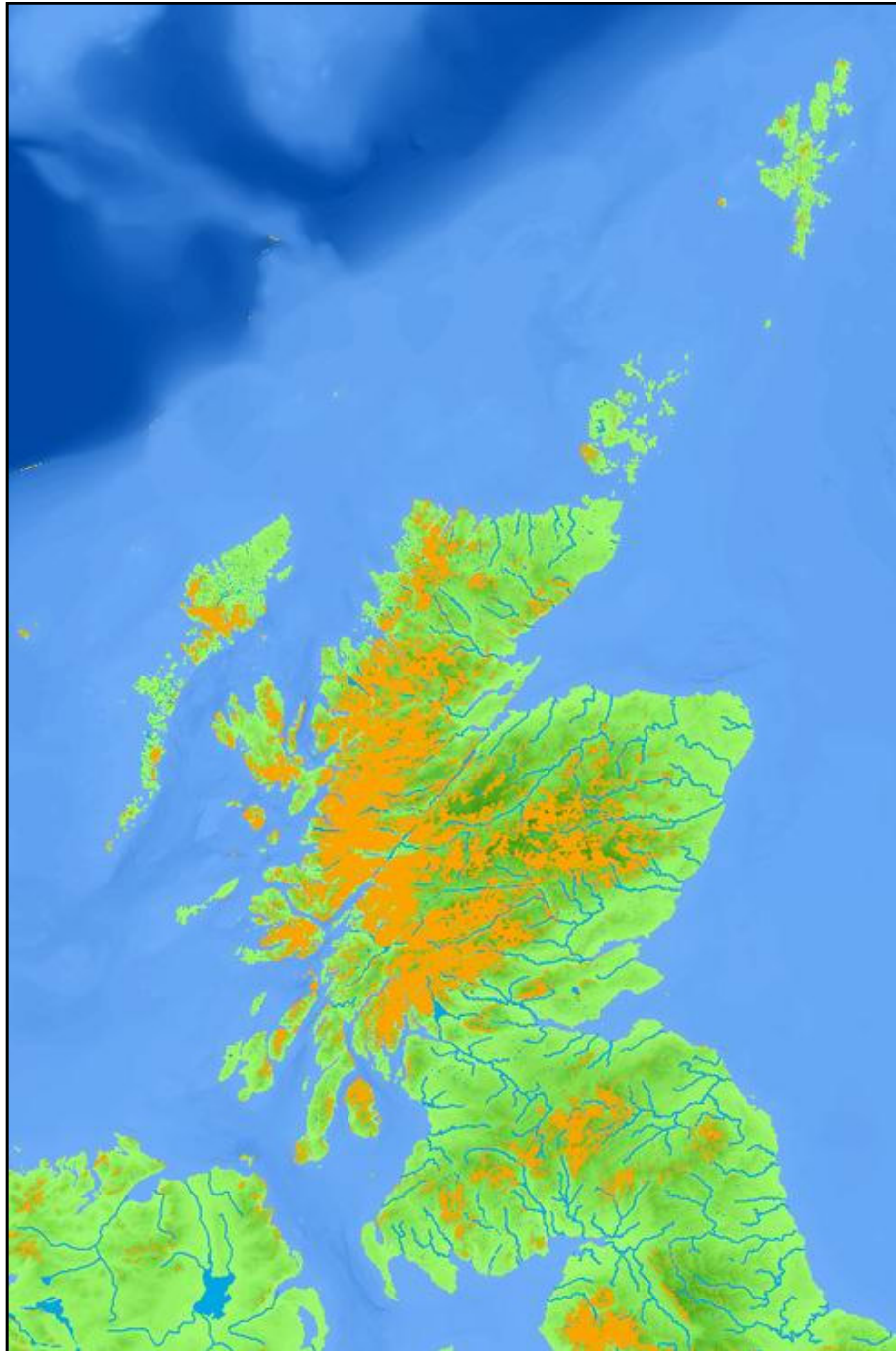
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# Physical

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

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



Sources: OS, BGS, BODC, SRTM



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# Environment

- **Recreation interests (high sensitivity)**

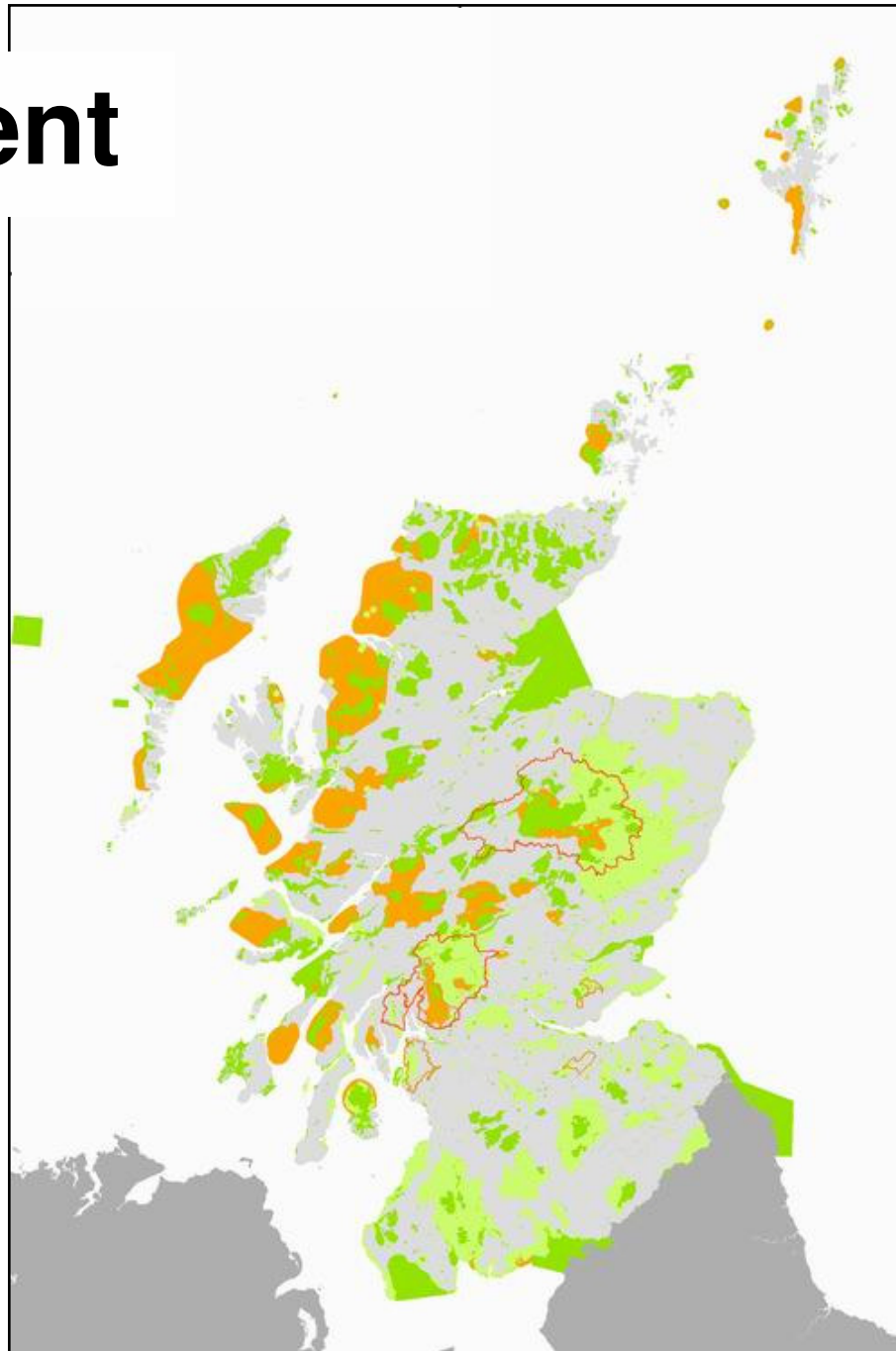
- National Scenic Area
- National Park
- Regional park

- **Biodiversity interests (high sensitivity)**

- Natura 2000, SSSI, ...

- **Medium sensitivity areas**

- AGLV, LNR, ...



Sources: OS, SNH, SEGIS



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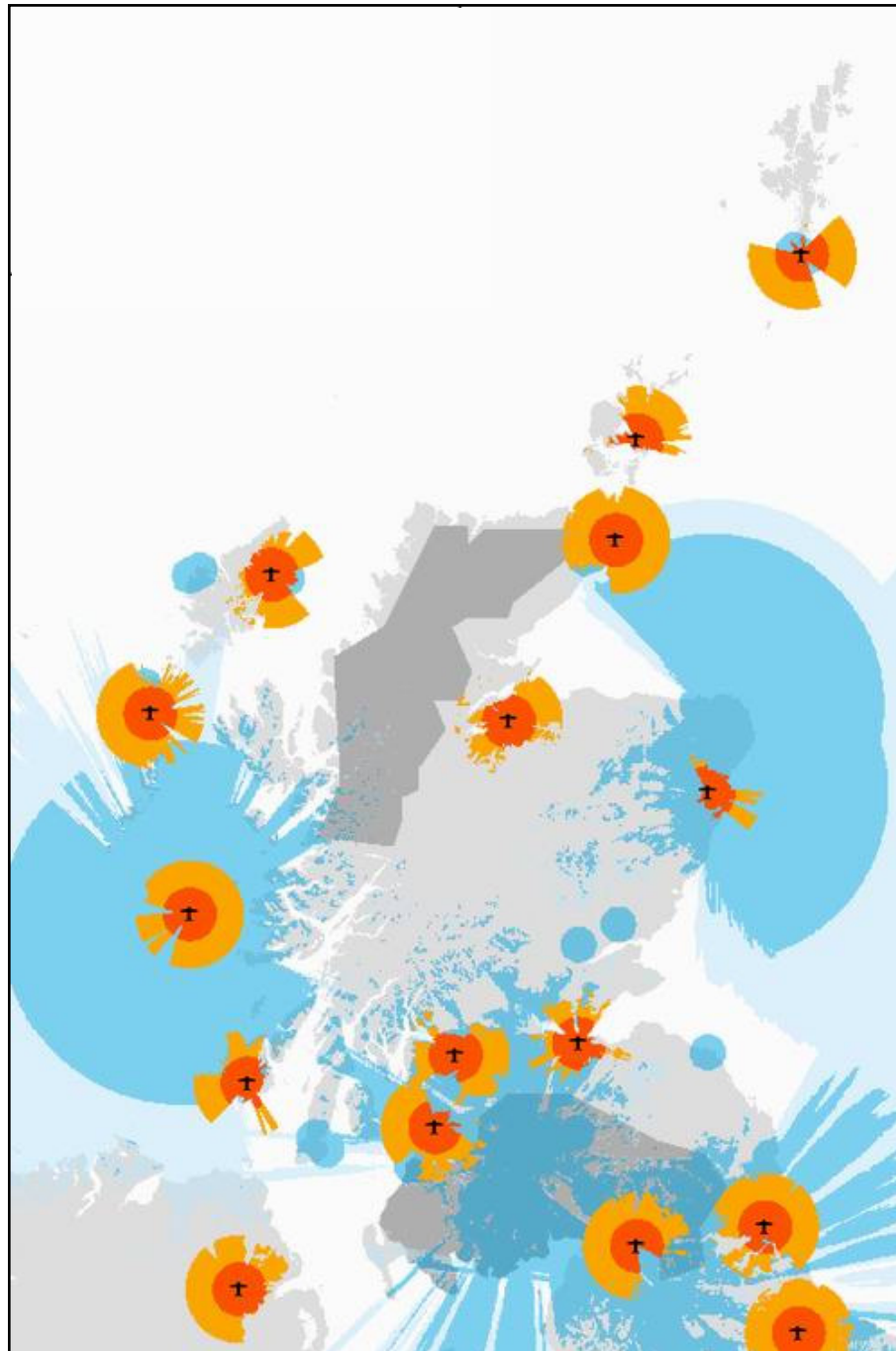
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# Aviation Interests

- **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



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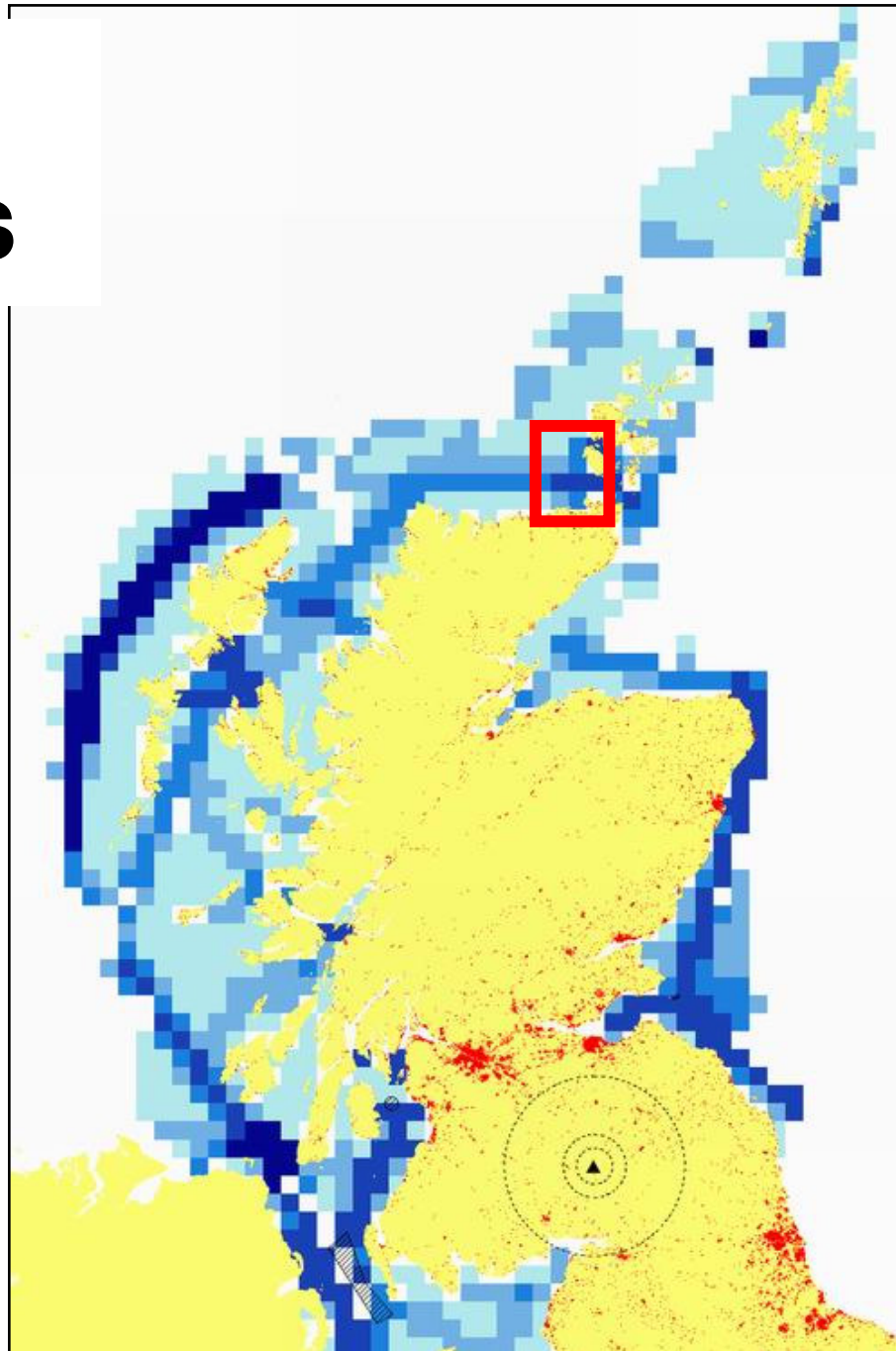
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# Further Constraints

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



Sources: OS, DTI, GAA, BWEA



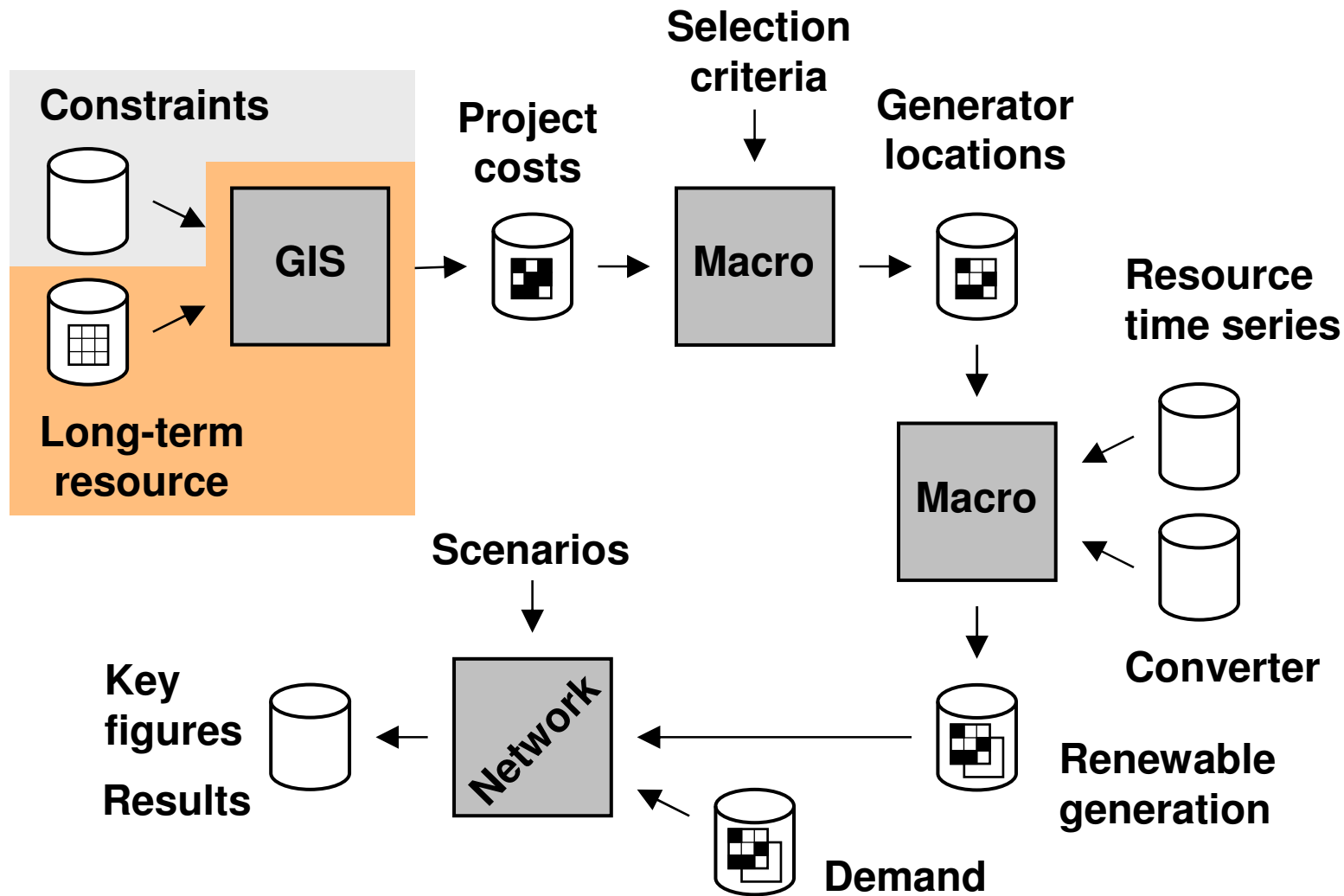
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# Long-Term Resource



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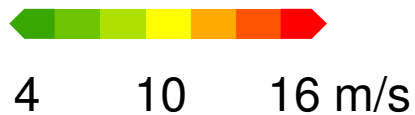
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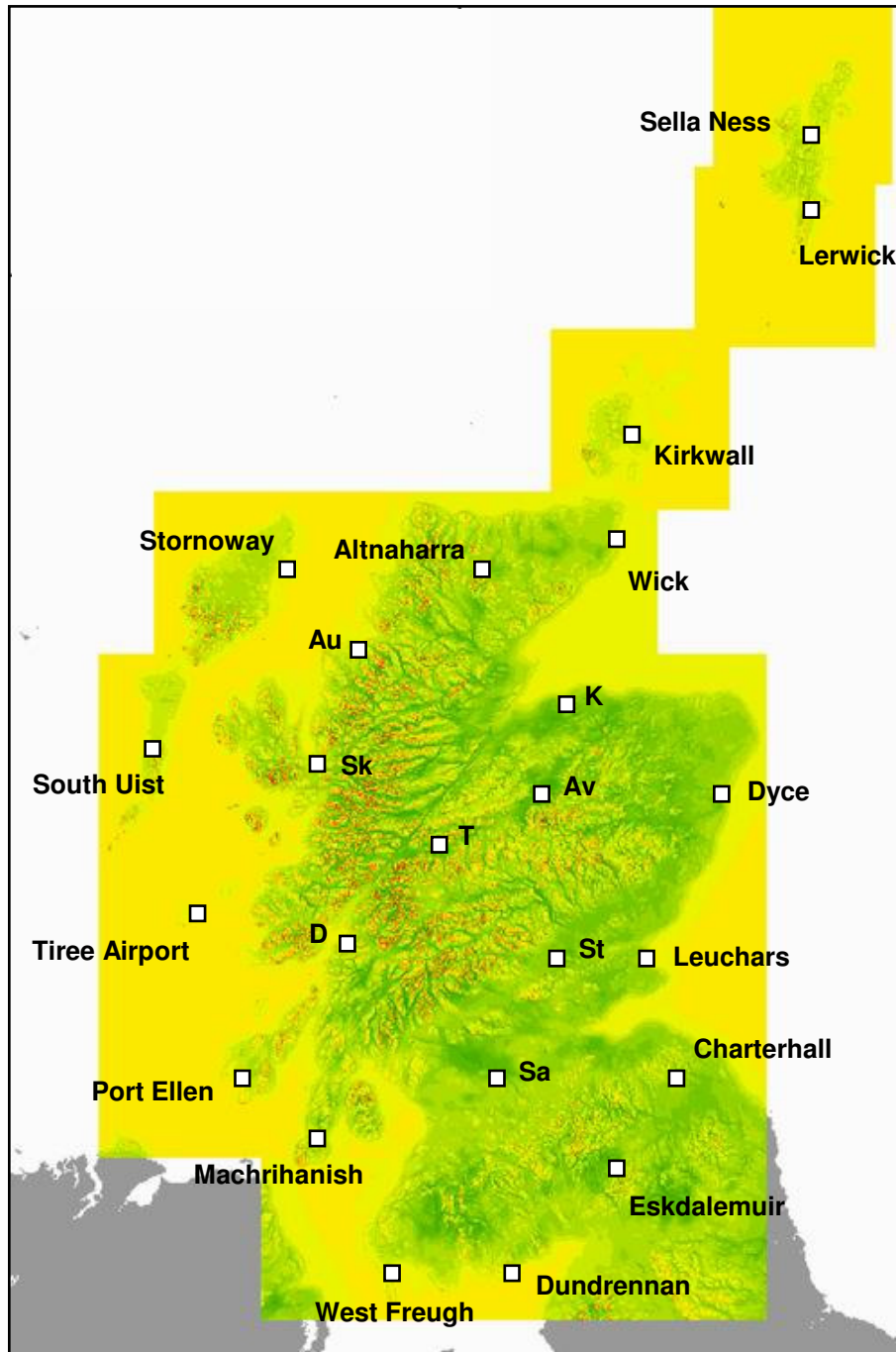
# Onshore Wind Resource

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

10 years data (1994-2003)



□ Meteorological station (21 + 3)



Sources: OS, Met Office



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# Offshore Wind Resource

Average wind speed  
at 80 m height asl.

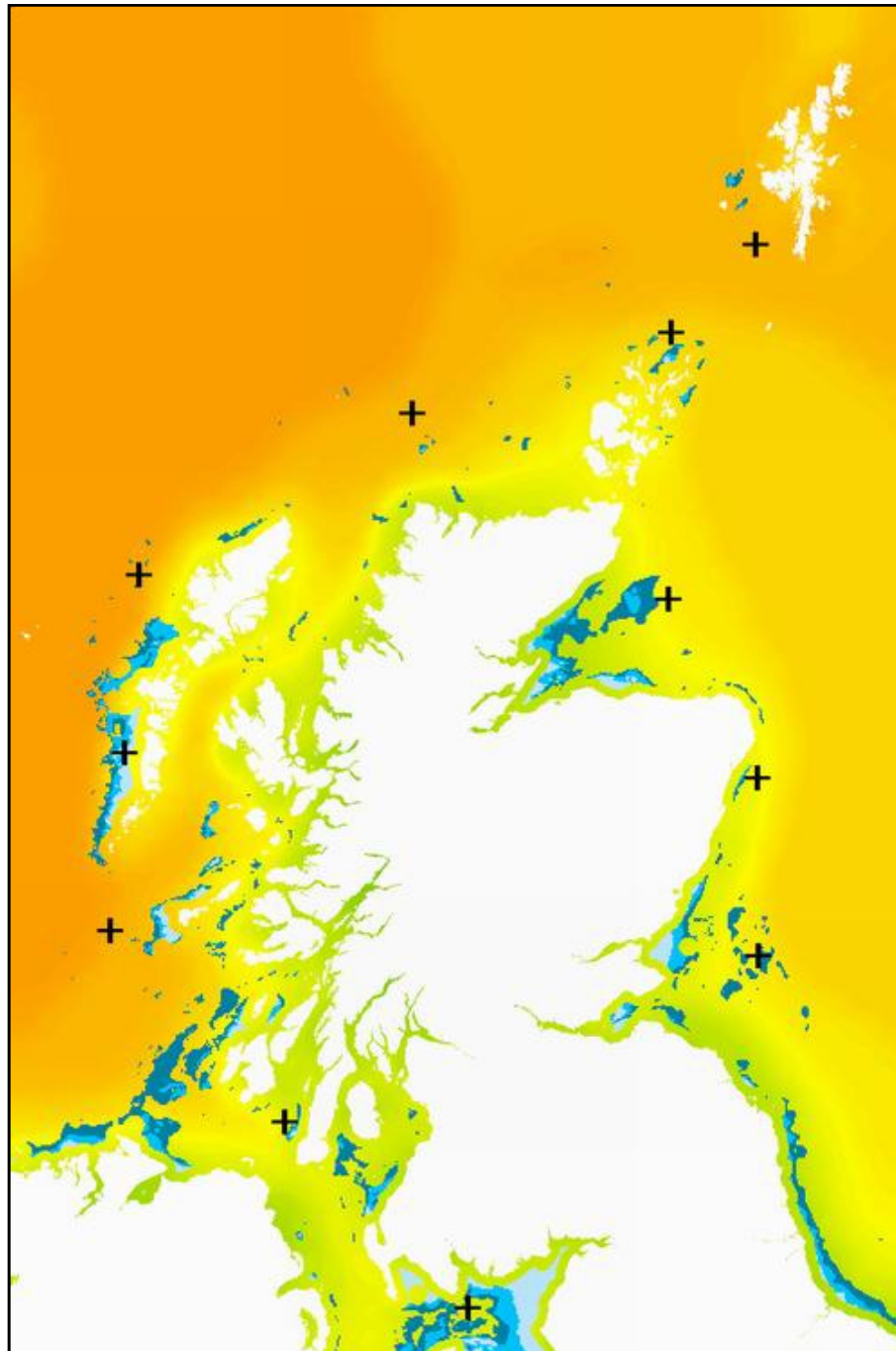


4 10 16 m/s

Water depth, 5 km  
offshore

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

Met Office  
Simulation Point  
(11)



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# Wave Resource

3 hour data: March 2000 – Nov 2004

Wave power per metre crest length

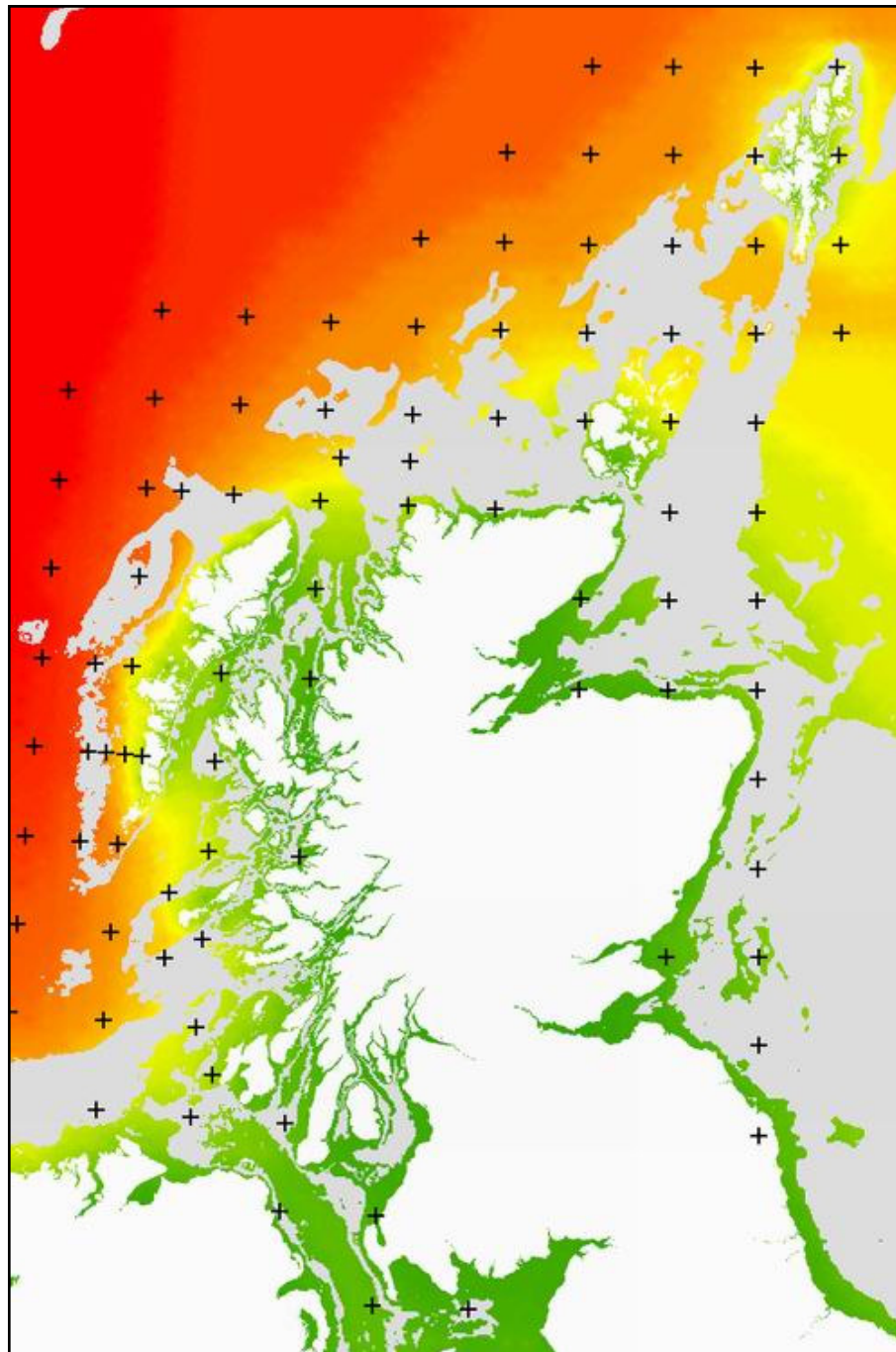


5 30 55 kW/m

Water depth, 5 km offshore

□ 50 ... 100 m

+ Met Office Simulation Point (84 + 11)



Sources: OS, DTI, Met Office



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# Tidal Current Resource

Variable but deterministic

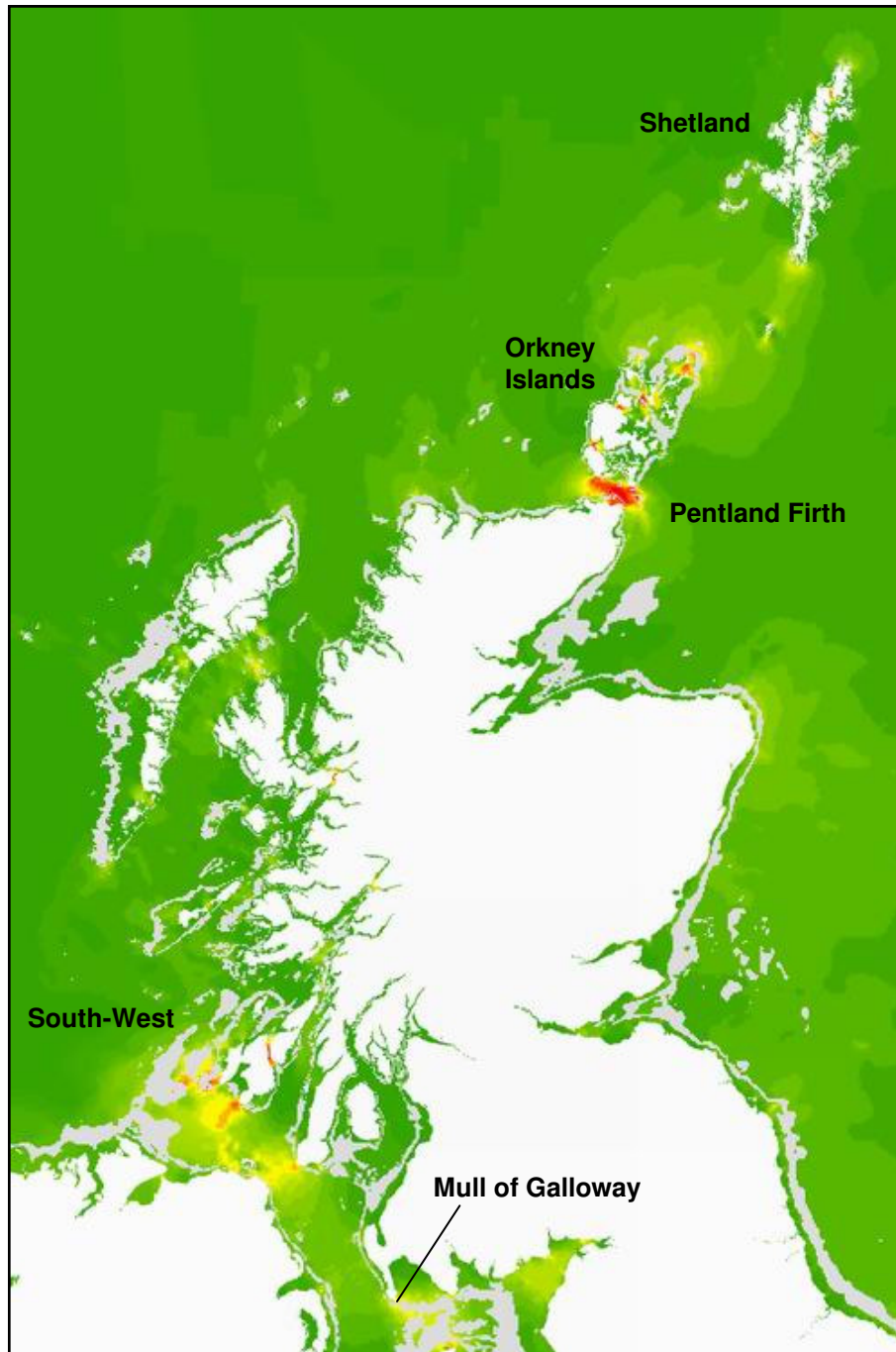
Average spring tide velocity (surface)



0.5 1.5 2.5 m/s

Water depth

□ 30 ... 50 m



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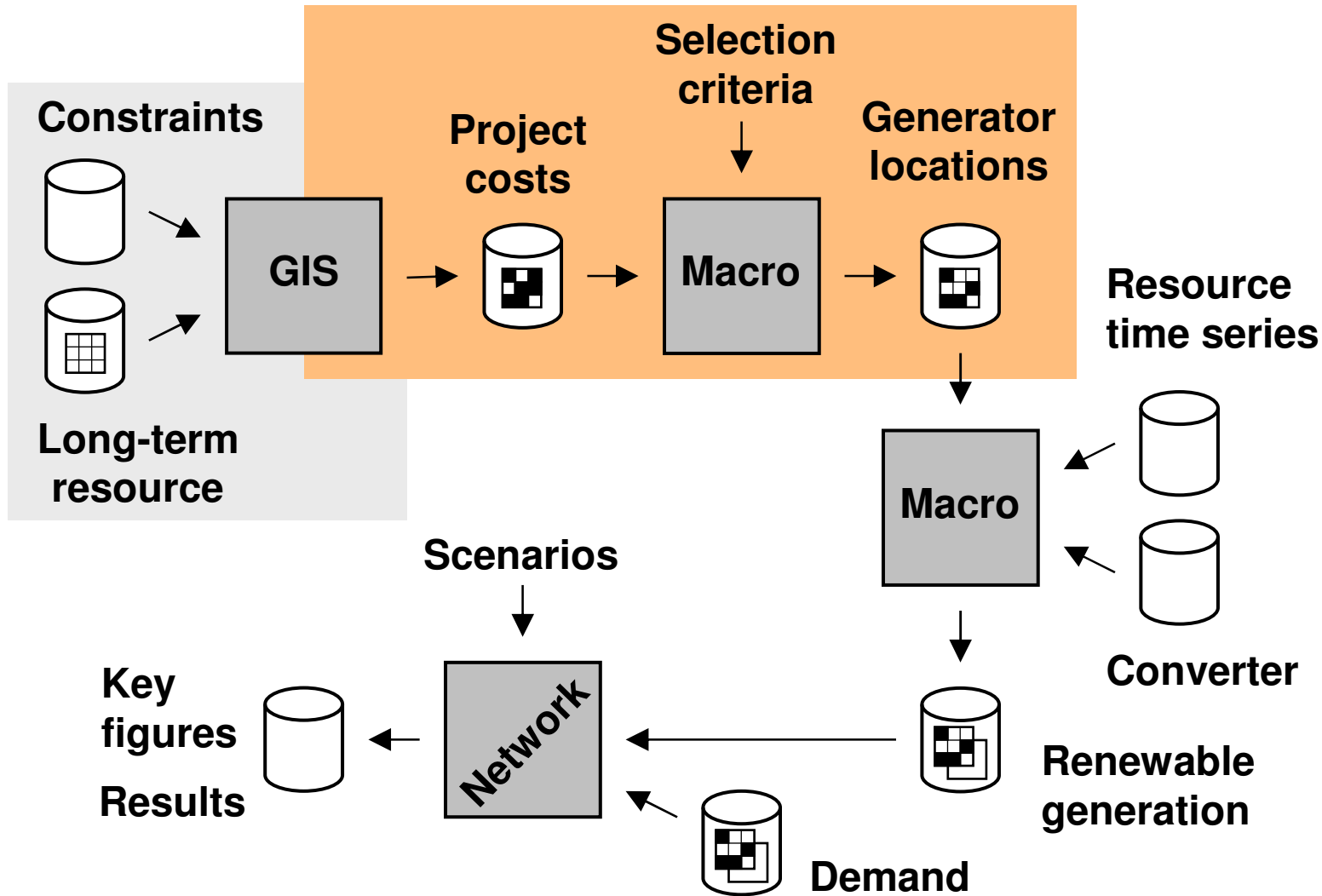
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# Future Generator Locations



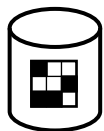
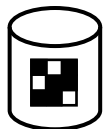
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# Cost Calculation



## Step

**Remove “no go” cells**

**Calculate annual energy output**

**Calculate (initial) levelised project cost (LPC) per cell**

**Remove “expensive” cells**

**Check capacity limit in consultation areas**

**Cluster to projects (for cost sharing)**

**Calculate (final) LPC per cell**

**Select cells**

## Remark

e.g. cities, NSAs

Excluding grid connection costs

e.g. > 10 p/kWh

e.g. by 100 km<sup>2</sup> area, remove more cells

neighbouring cells, total capacity limit

Including grid connection costs

per area; capacity or cost limit

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# Project Costs

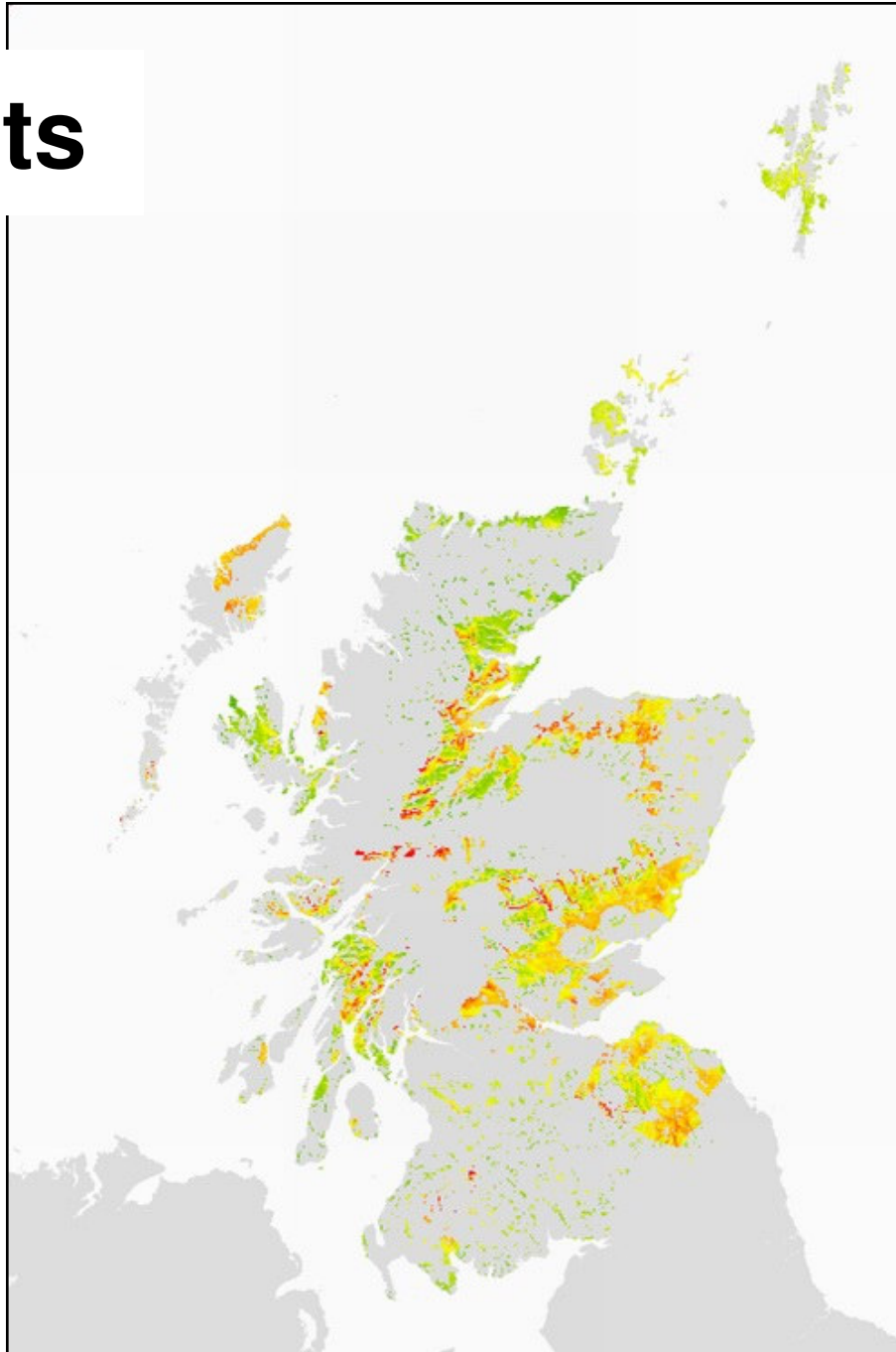
## Example:

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<sup>2</sup>
- 80 m hub height
- 20 years, 8 % discount rate



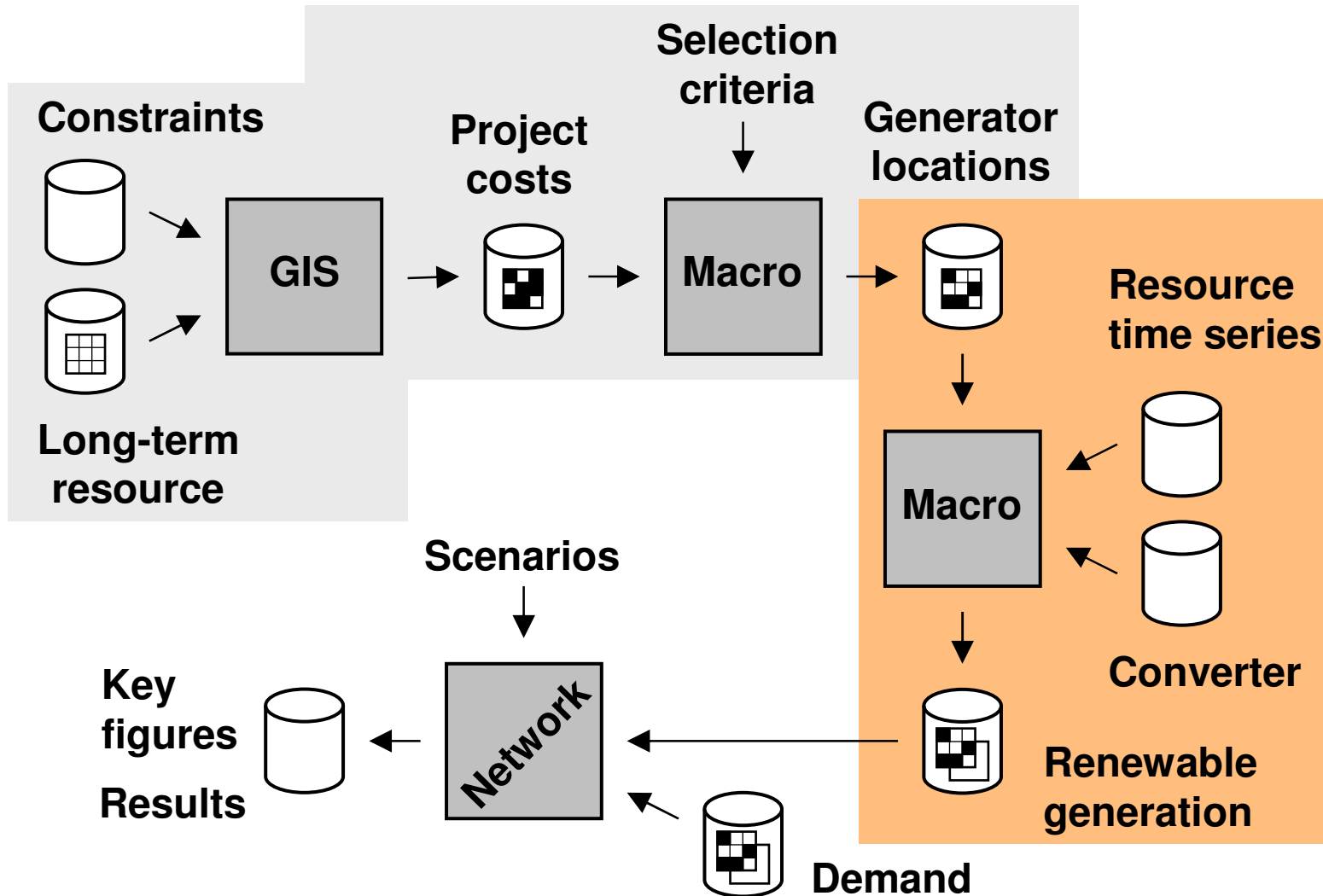
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# Creating Power Time Series



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# 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

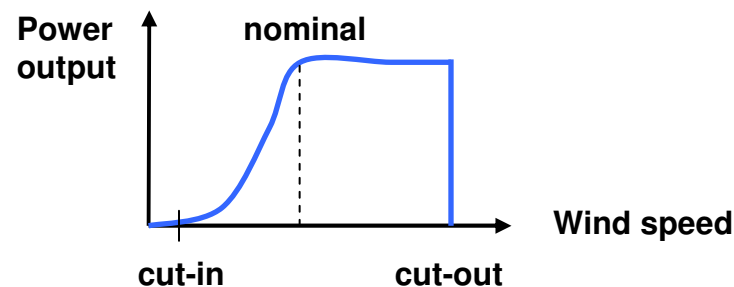
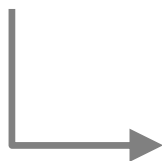


- Semi-submerged articulated structure
- 180 m long
- 1.5 MW
- 50 ... 150 m water depth

## 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

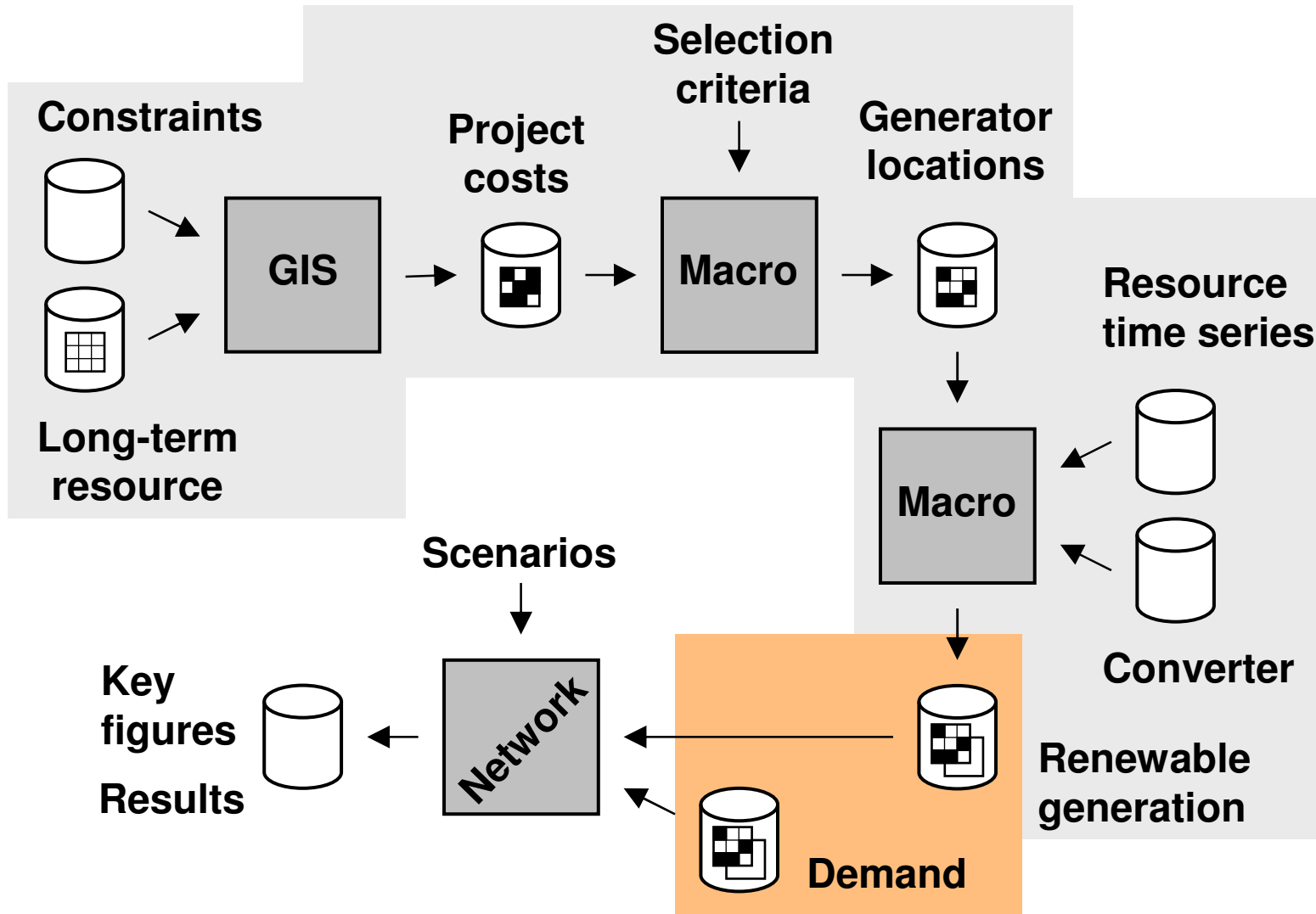
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# Generation vs. Demand



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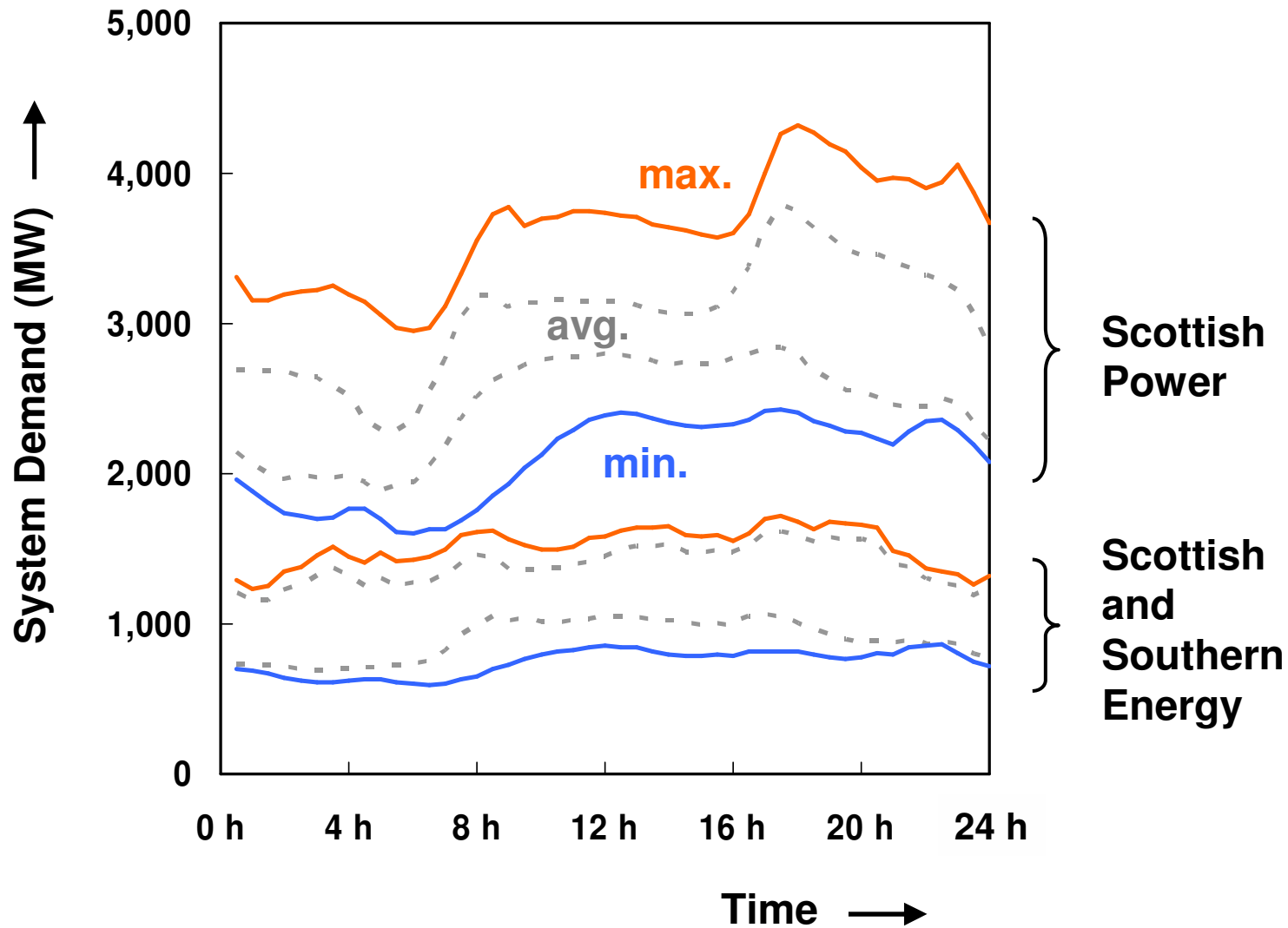
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# Demand - Daily

Example:  
2002/03



Source: SP and SSE 2003 Seven Year Statements

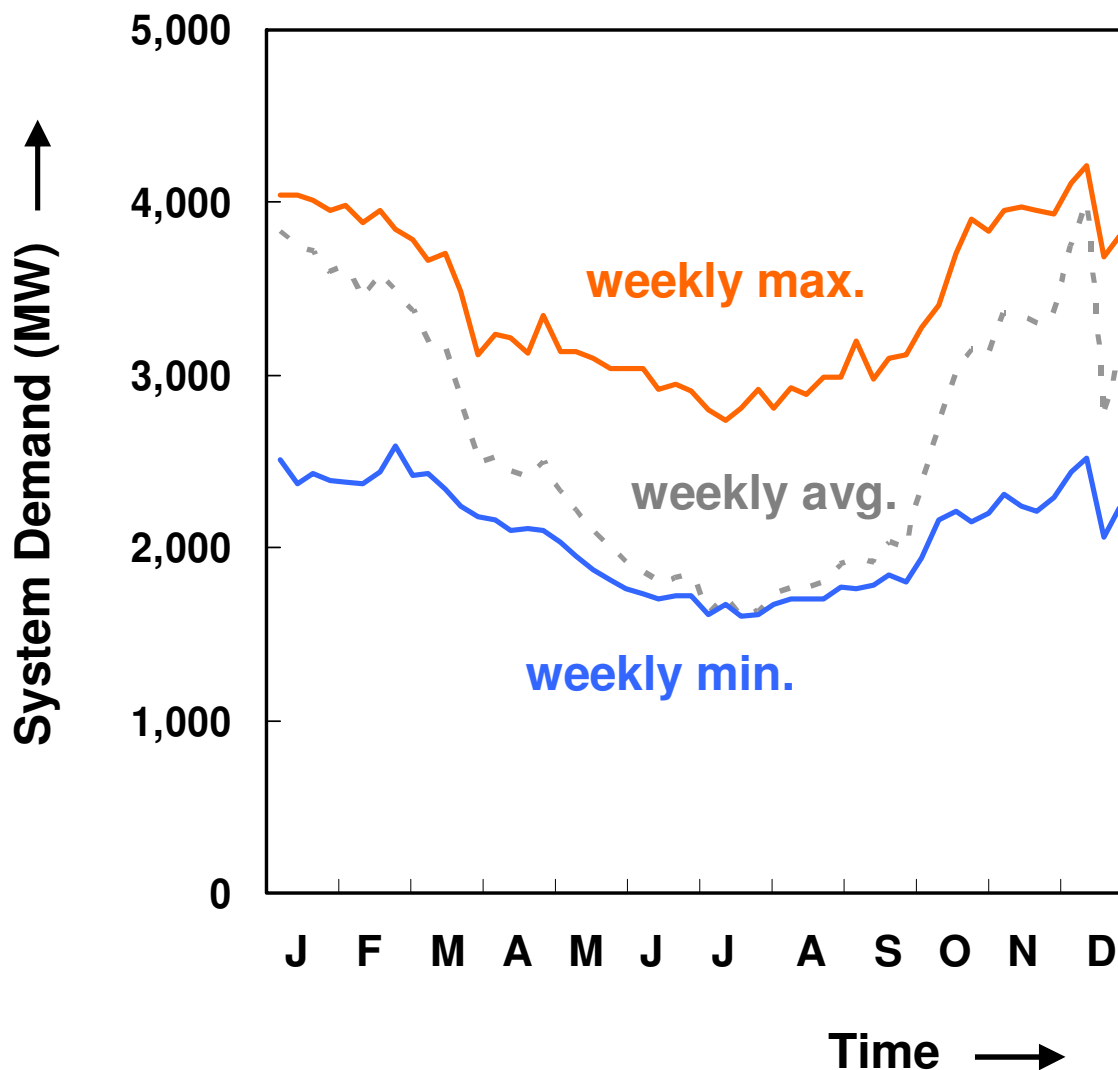
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# Demand - Annual

Example:  
2002



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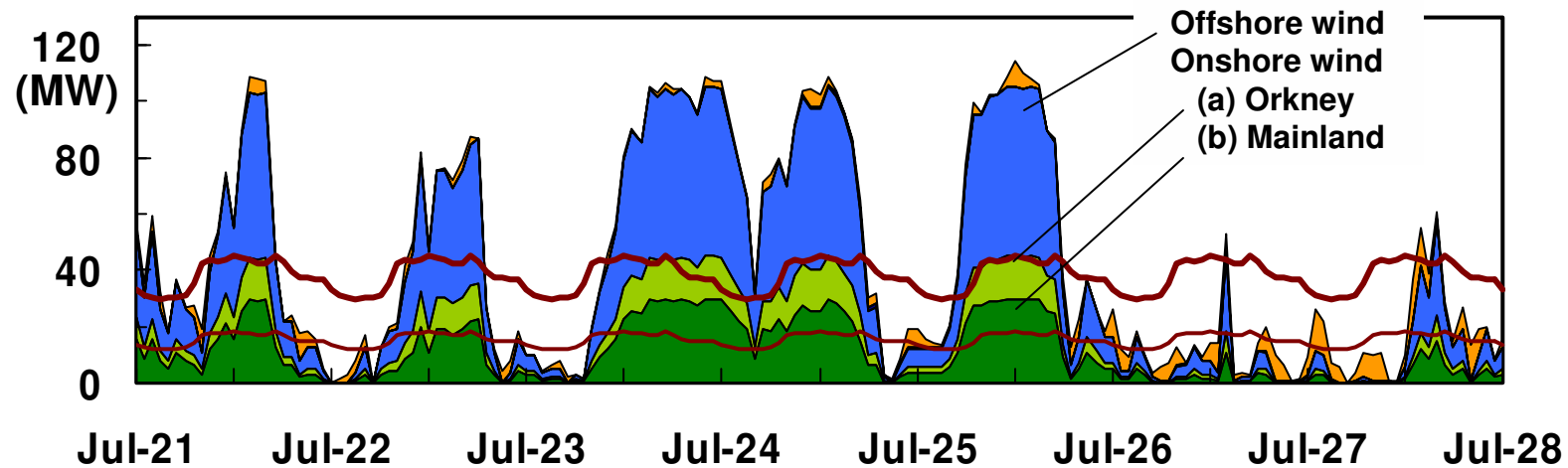
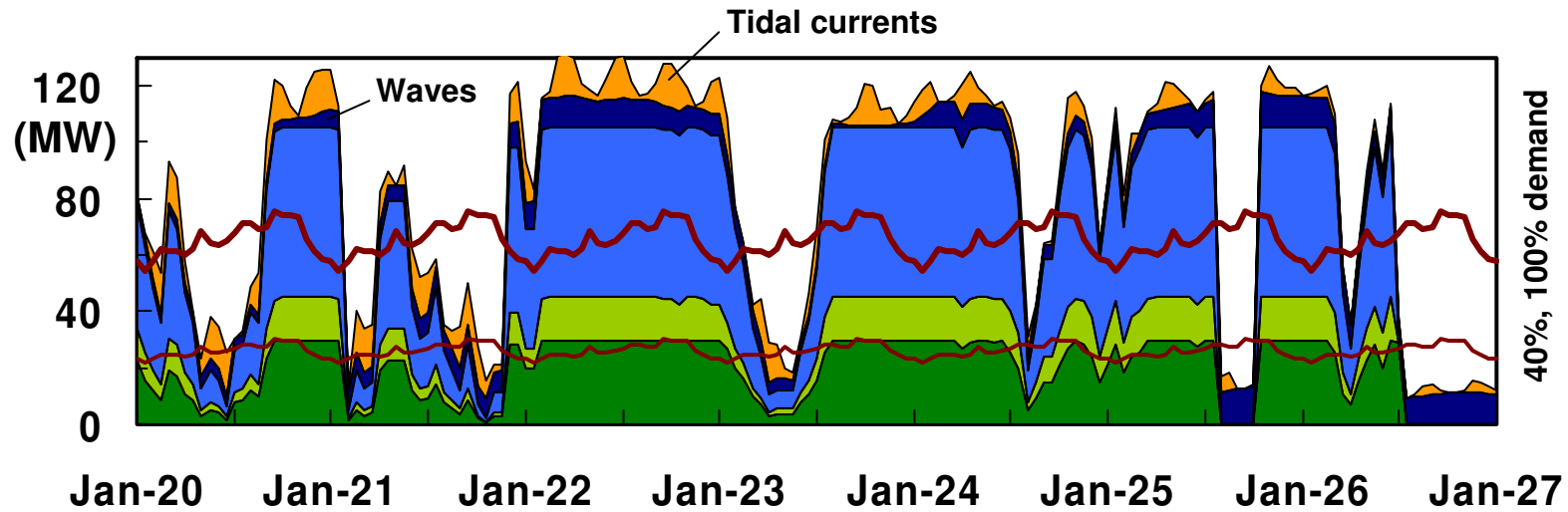
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# Sample Area

# Demand Matching January, July 2003



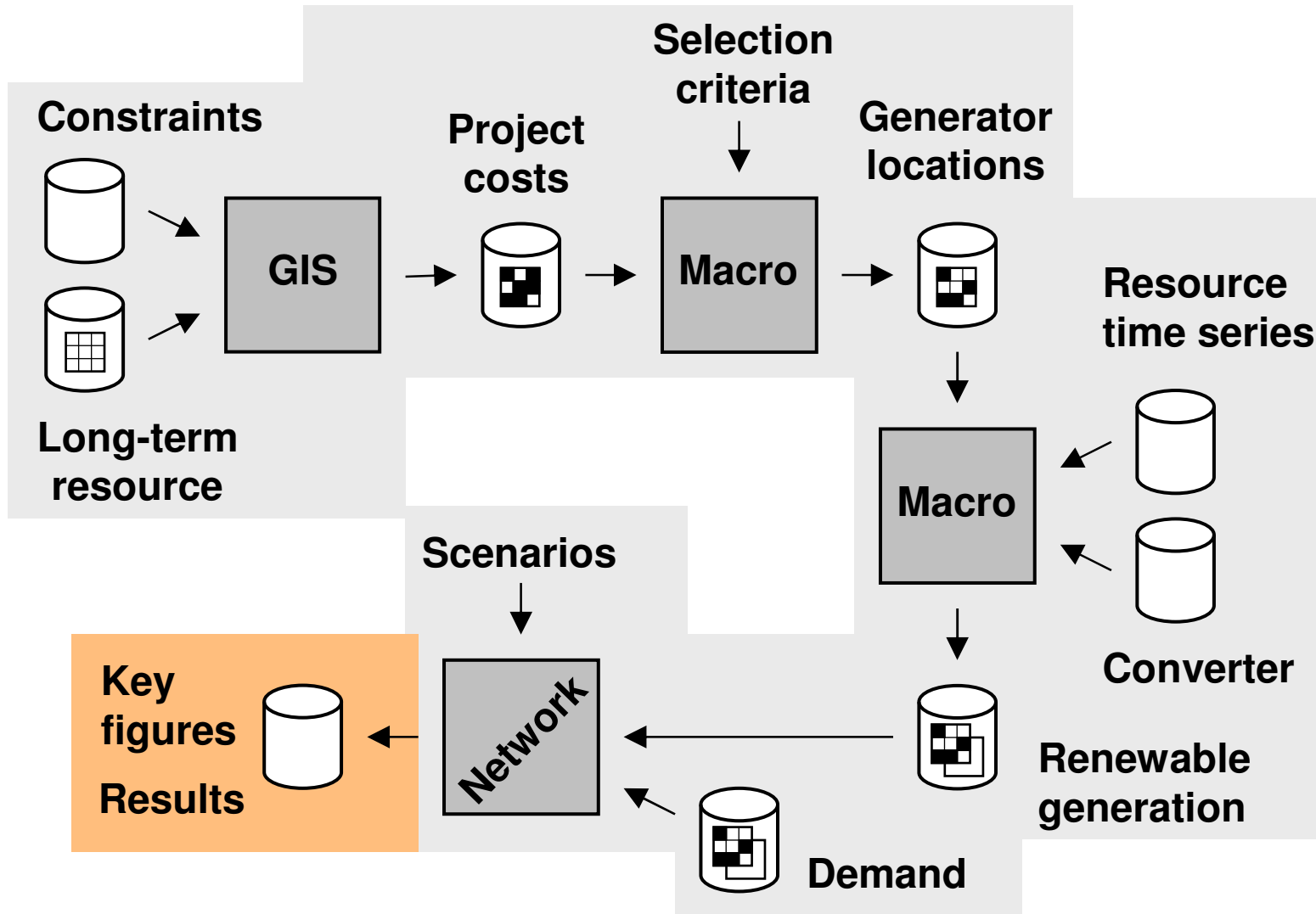
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# Key Figures and Results



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# Results



After application of geographical constraints  
it could be possible to develop at least

- 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.*

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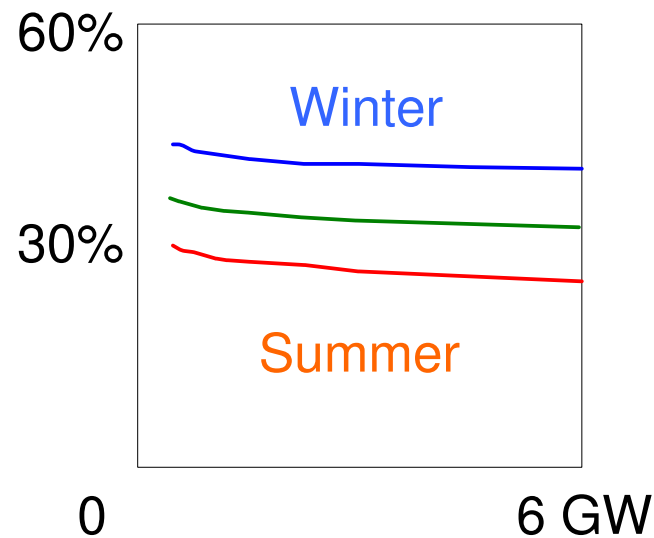
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# Results

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	



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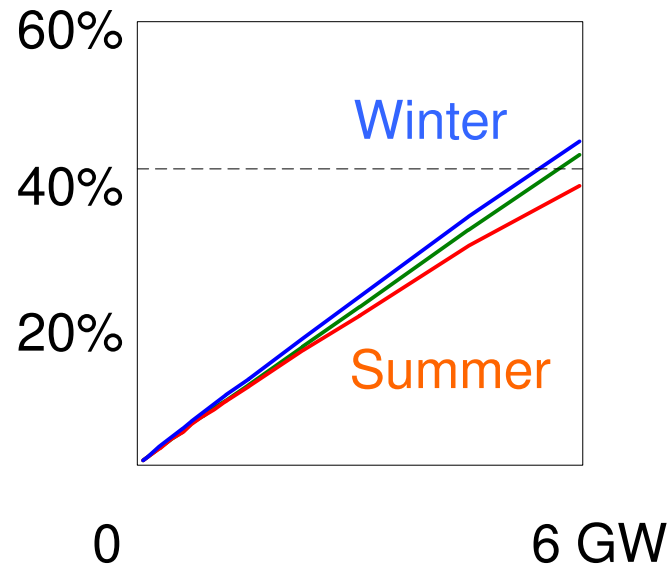
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# Results

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



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# Results

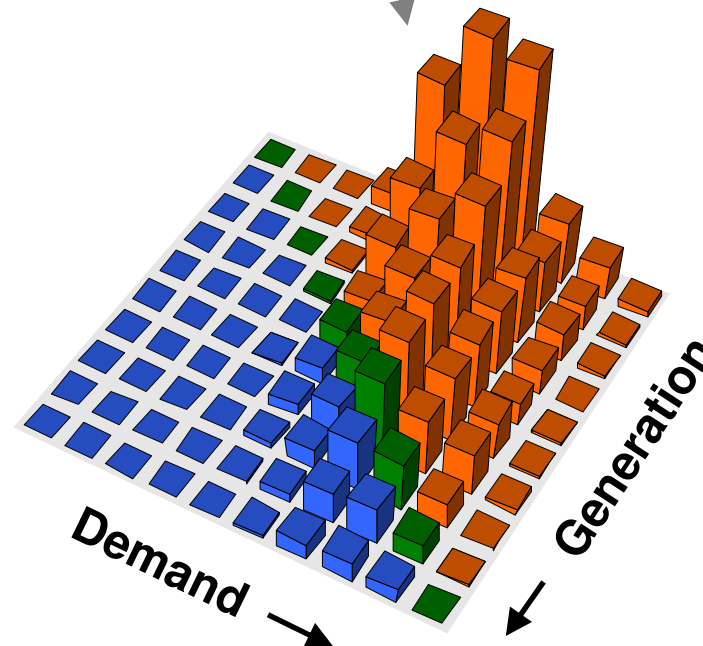
Coincident hours best describe ongoing hourly match as a histogram

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



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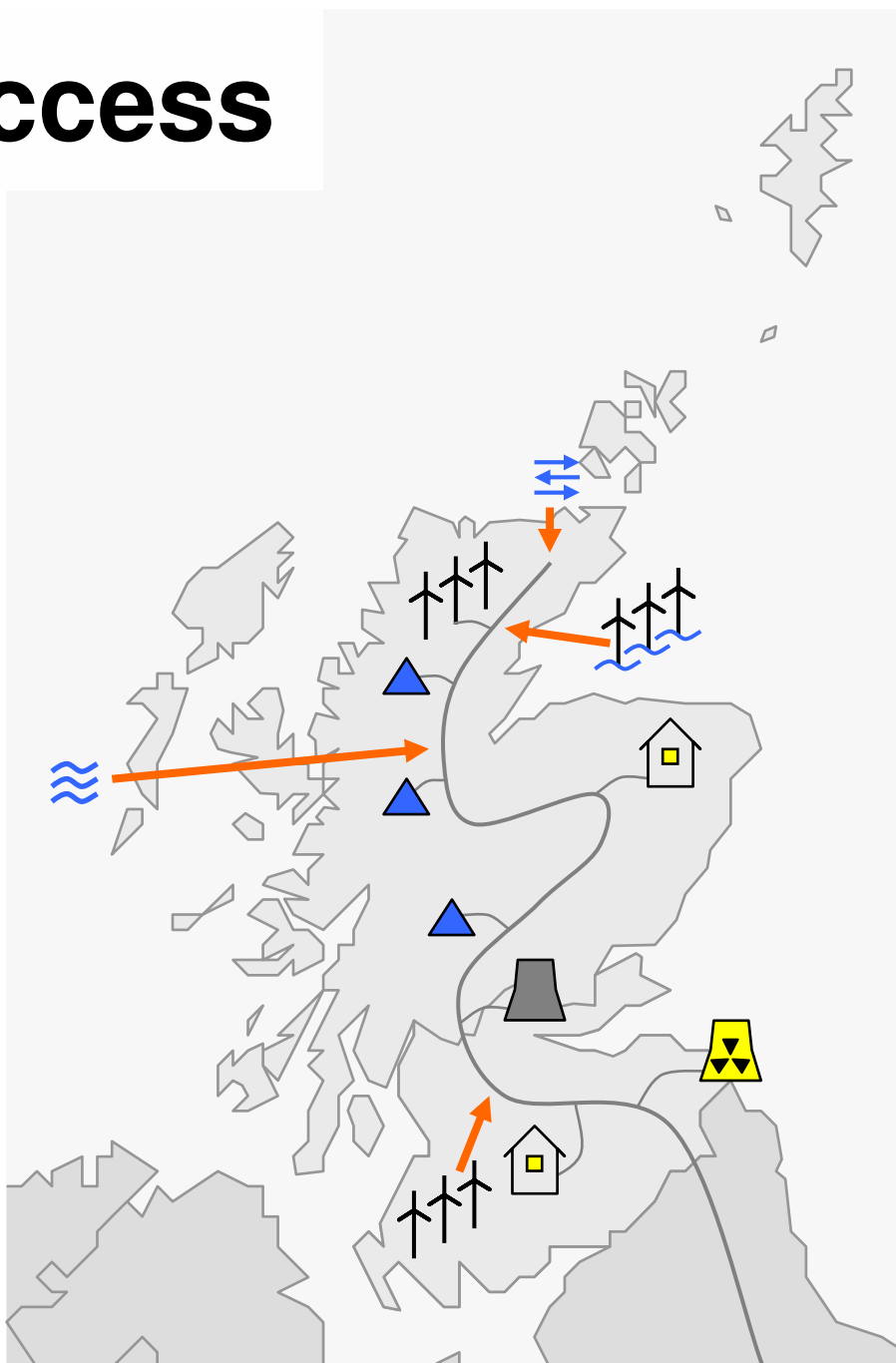
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# Network Access

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.



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# 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)

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# 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 to 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



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