How to upgrade the European power grid to enable high penetration of wind power

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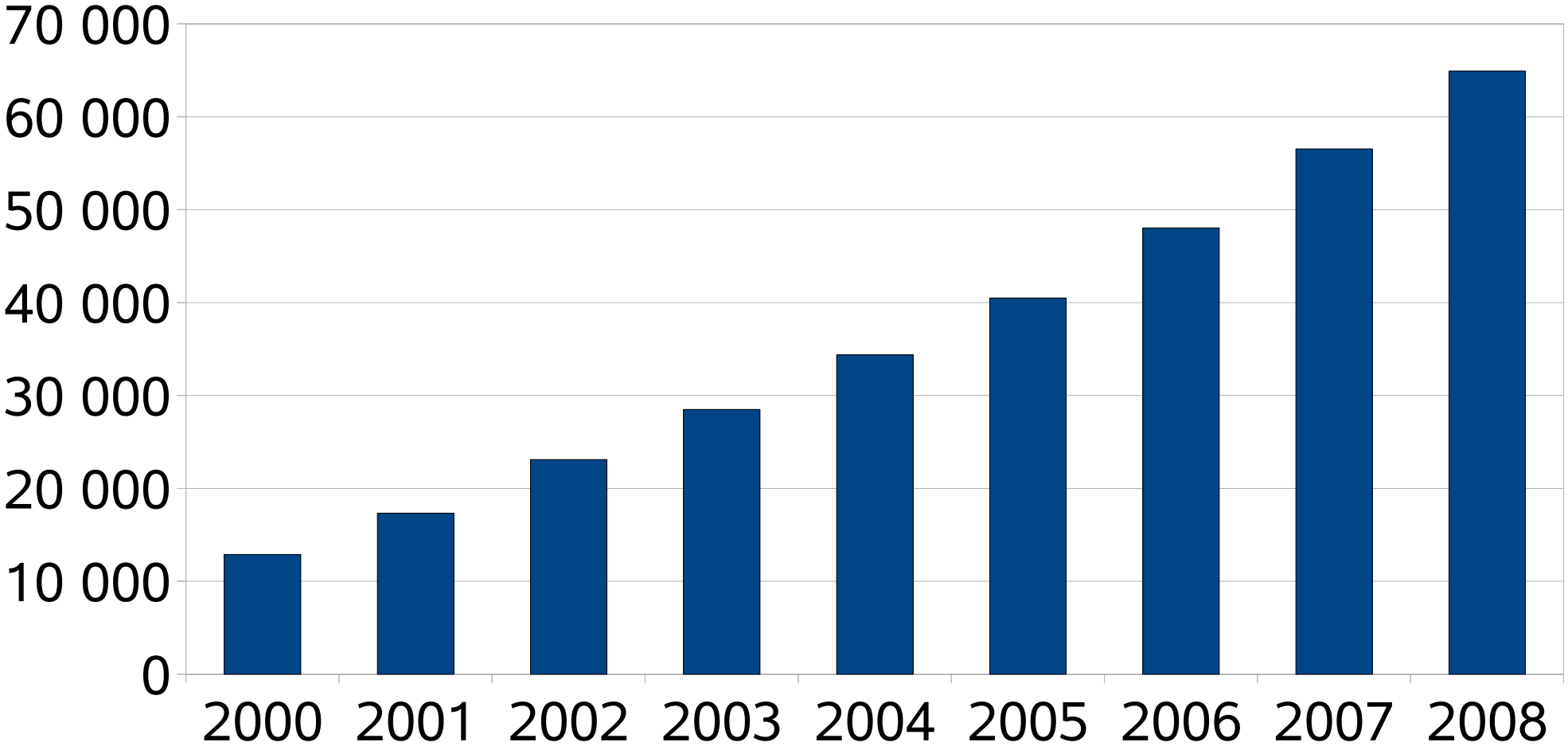
Outline

- Motivation: Growth of wind power capacity
- How much wind power can Europe produce?
- UCTE power flow scenarios
- Case study: Spain
- DC model, and why it failed
- Linear programming model
- Road to modelling the whole European network

Growth of wind power

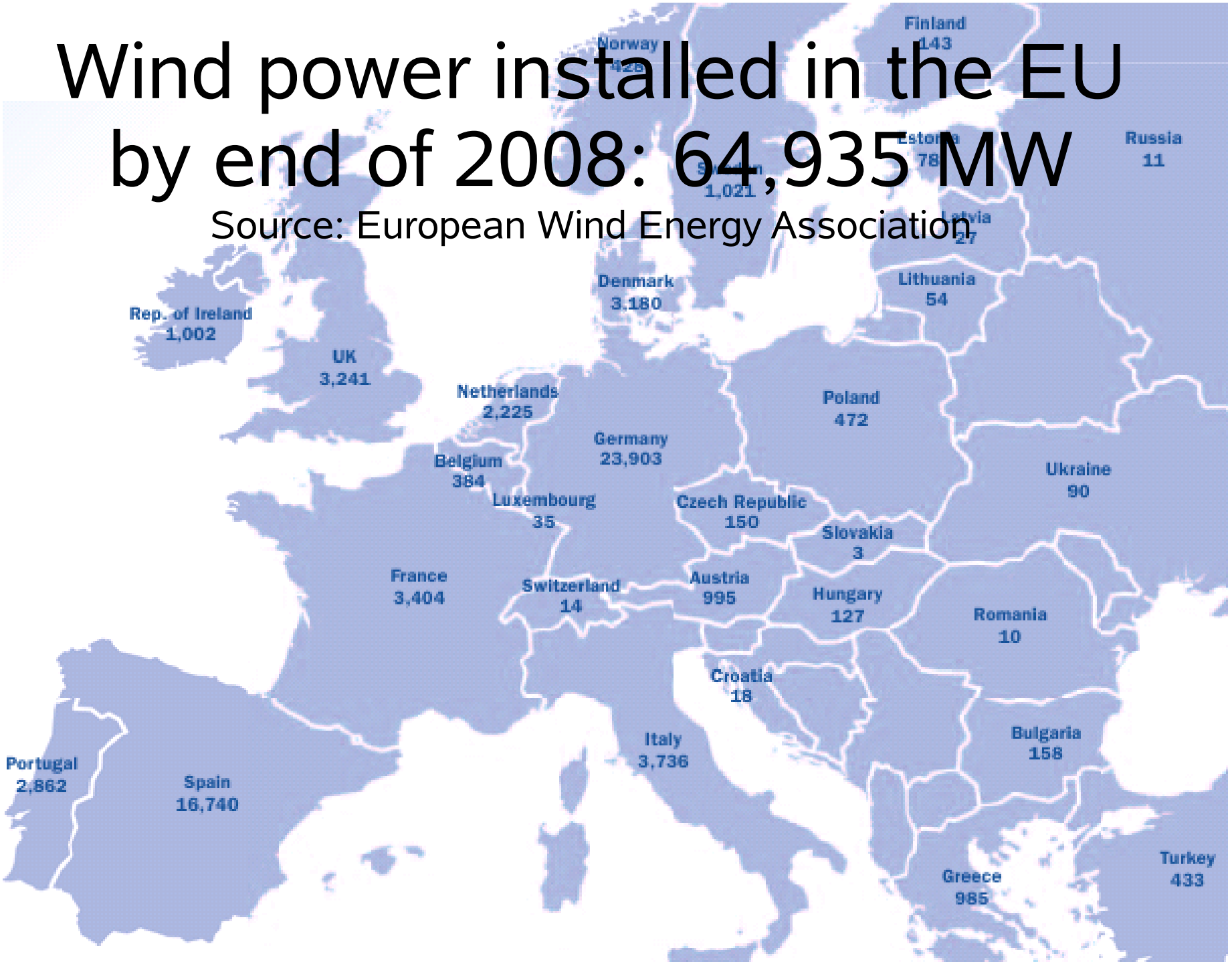
Cumalative wind power capacity in the EU [MW]

Source: European Wind Energy Association



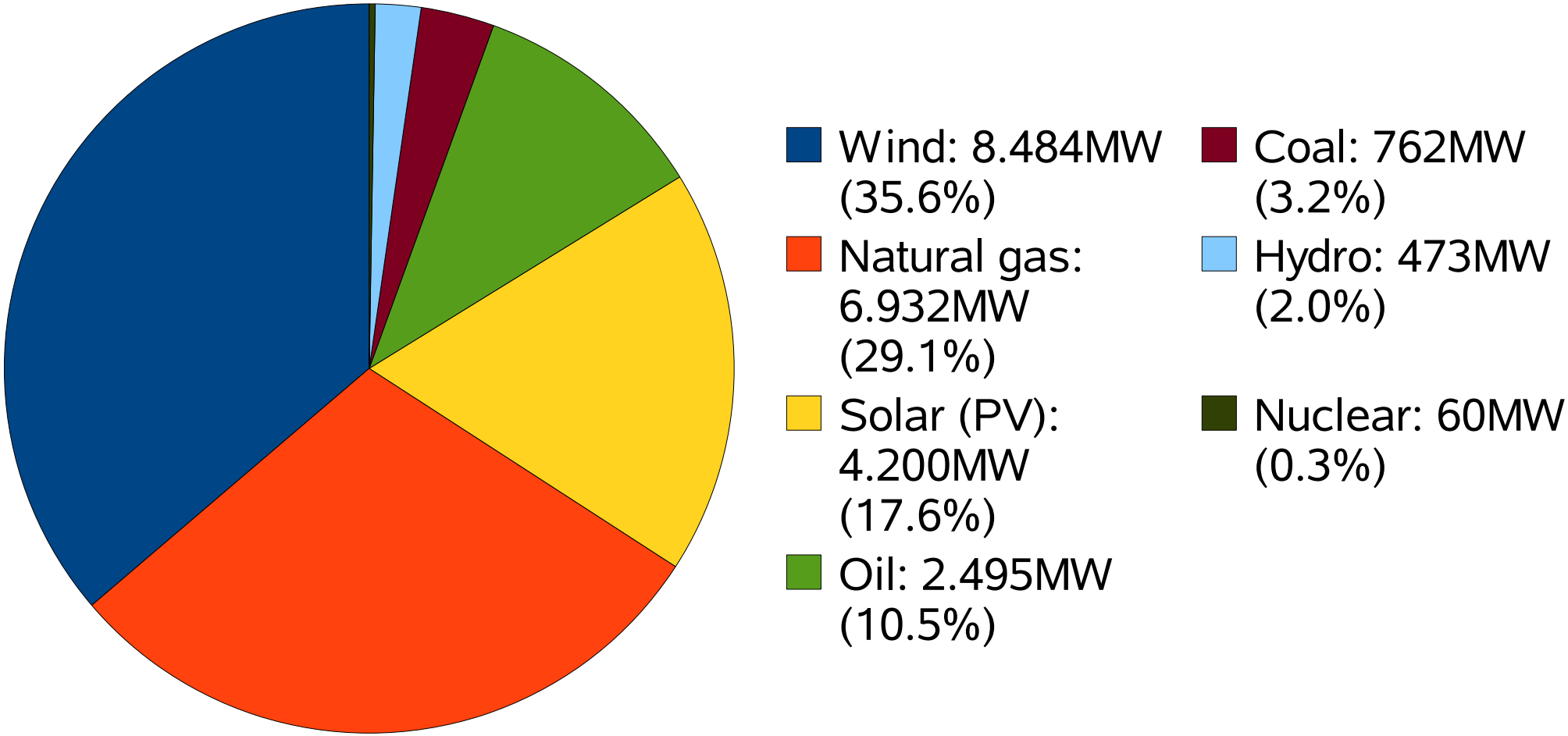
Wind power installed in the EU by end of 2008: 64,935 MW

Source: European Wind Energy Association



New installed power capacities in the EU in 2008

Source: European Wind Energy Association



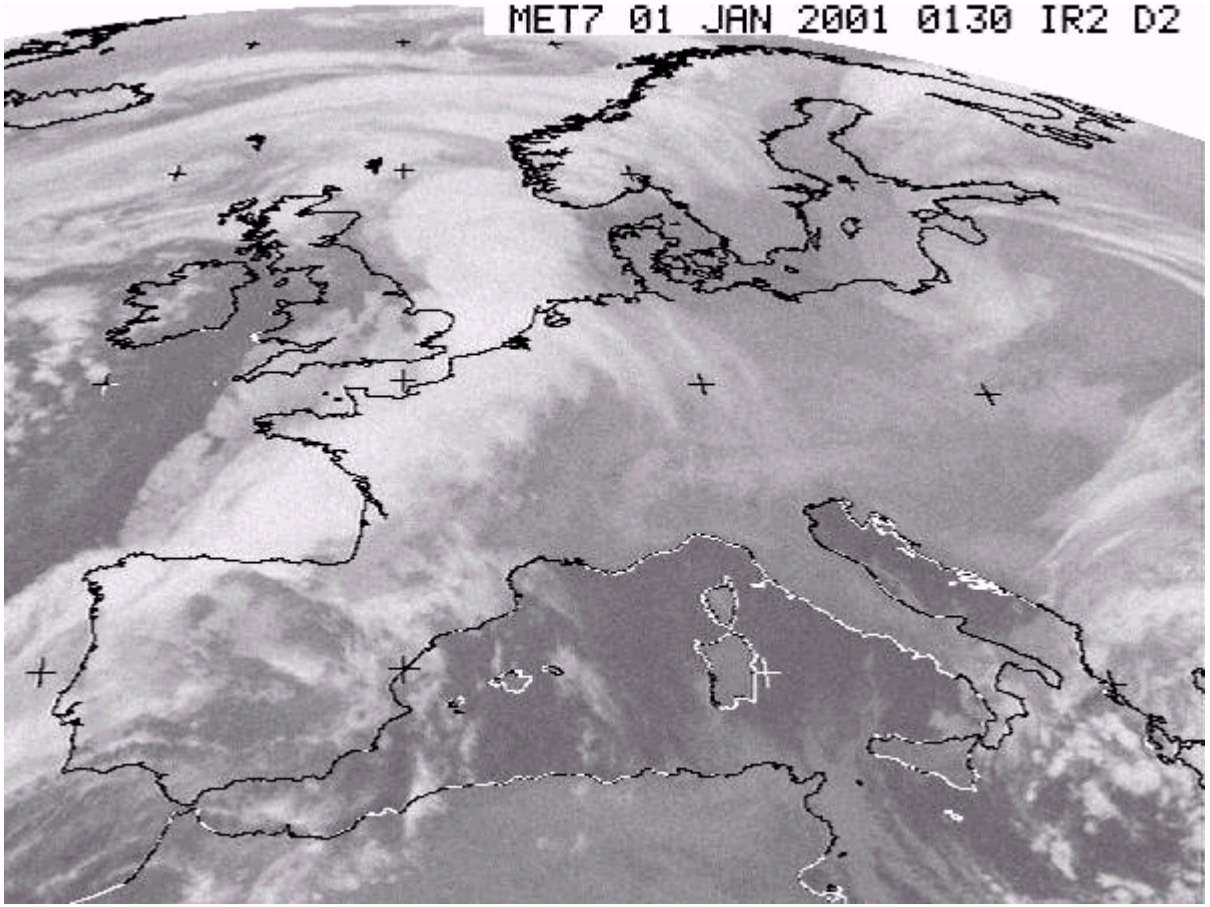
How much wind power can Europe produce?

European Environmental Agency: “Europe's onshore and offshore wind energy potential” (technical report, June 2009). Its main conclusion is that considering

- technological development in turbine design,
- environmental constraints and
- economical competitiveness,

potentially approx. 12 200 TWh/year wind energy can be produced in 2020, which is 3 times larger than the EU's projected total energy demand.

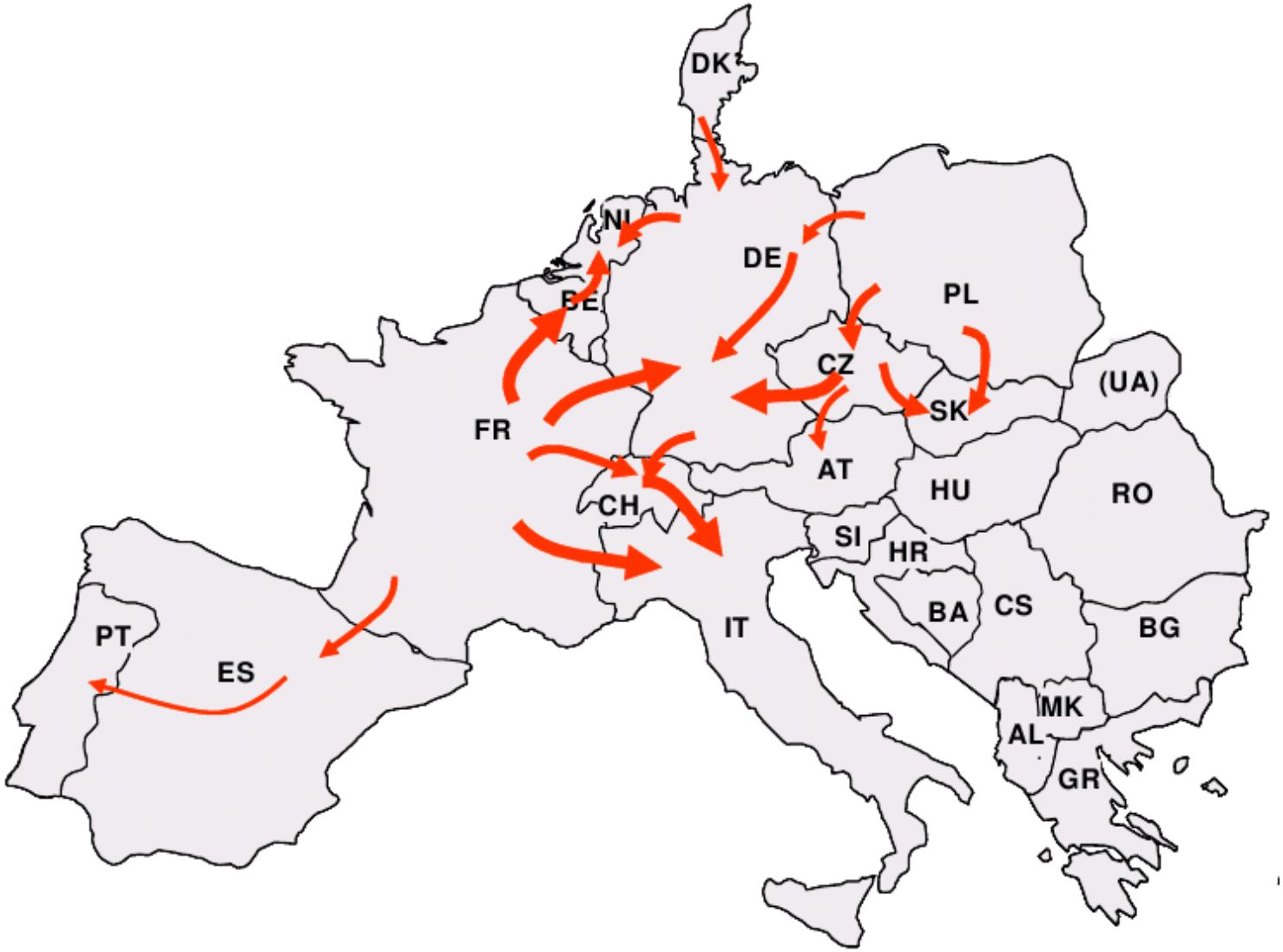
Wind power is always changing, like weather,



Source: EUMETSAT, Meteosat Images of Europe, [Internet]. British Atmospheric Data Centre, 2000-2009. Available from http://badc.nerc.ac.uk/data/meteosat/

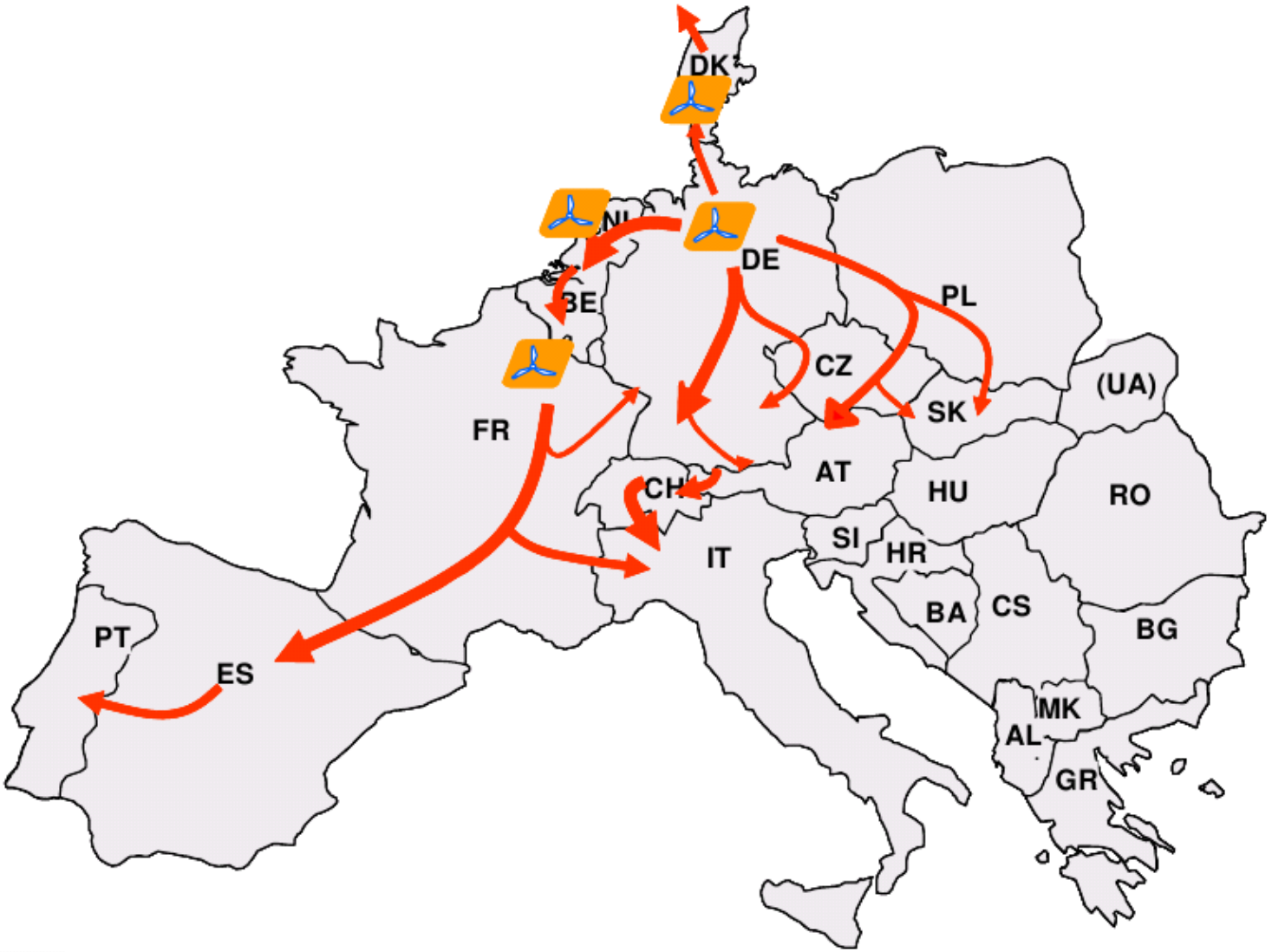
Power flow in the UCTE grid: Business as usual scenario

Image: European Wind Energy Integration Study Interim Report 2008



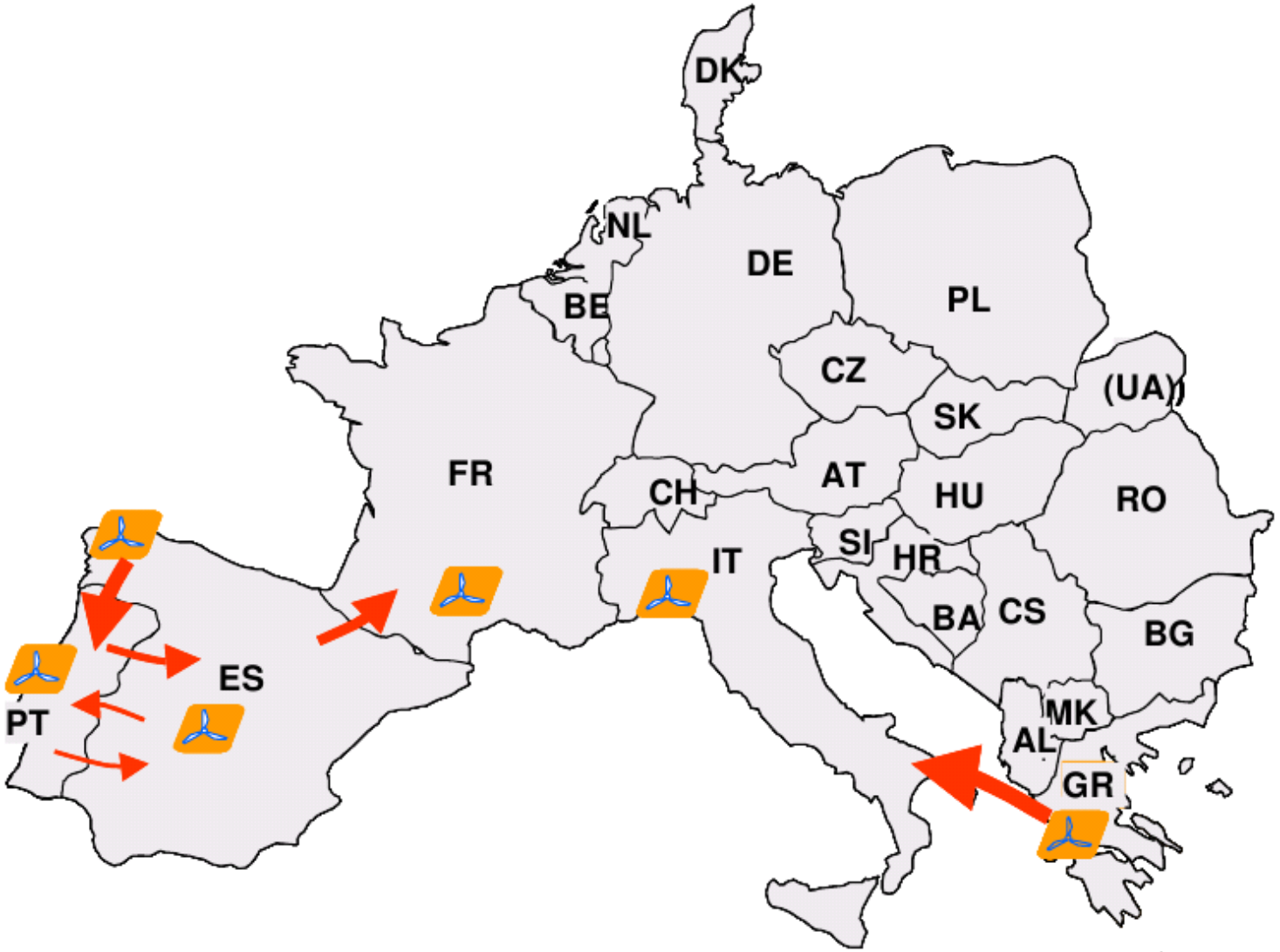
Power flow in the UCTE grid: Northern wind scenario

Image:European Wind Energy Integration Study Interim Report 2008

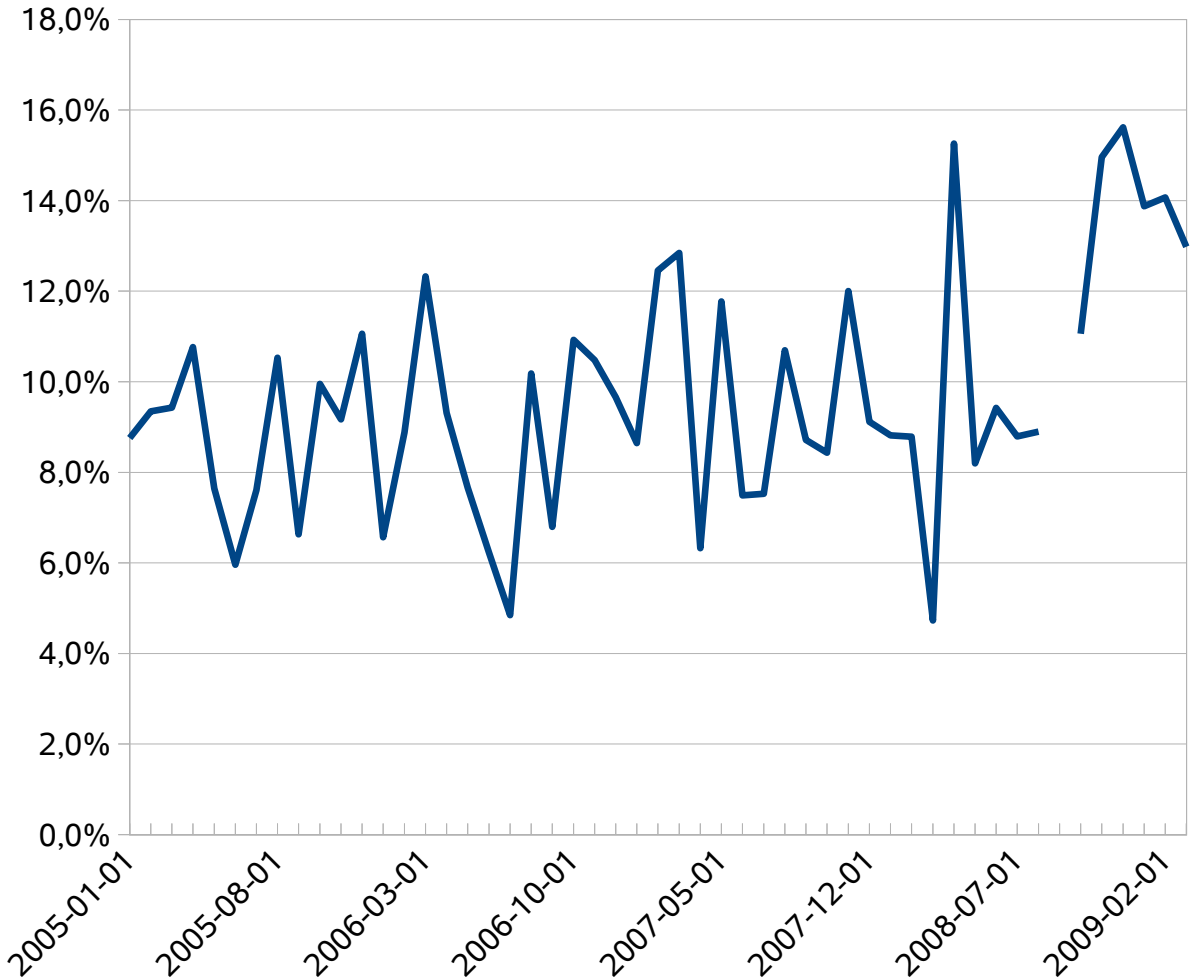


Power flow in the UCTE grid: Southern wind scenario

Image:European Wind Energy Integration Study Interim Report 2008



Case study: Spain



Share of wind power in consumption (monthly average)

Installed capacity (end of 2008): 16740 MW

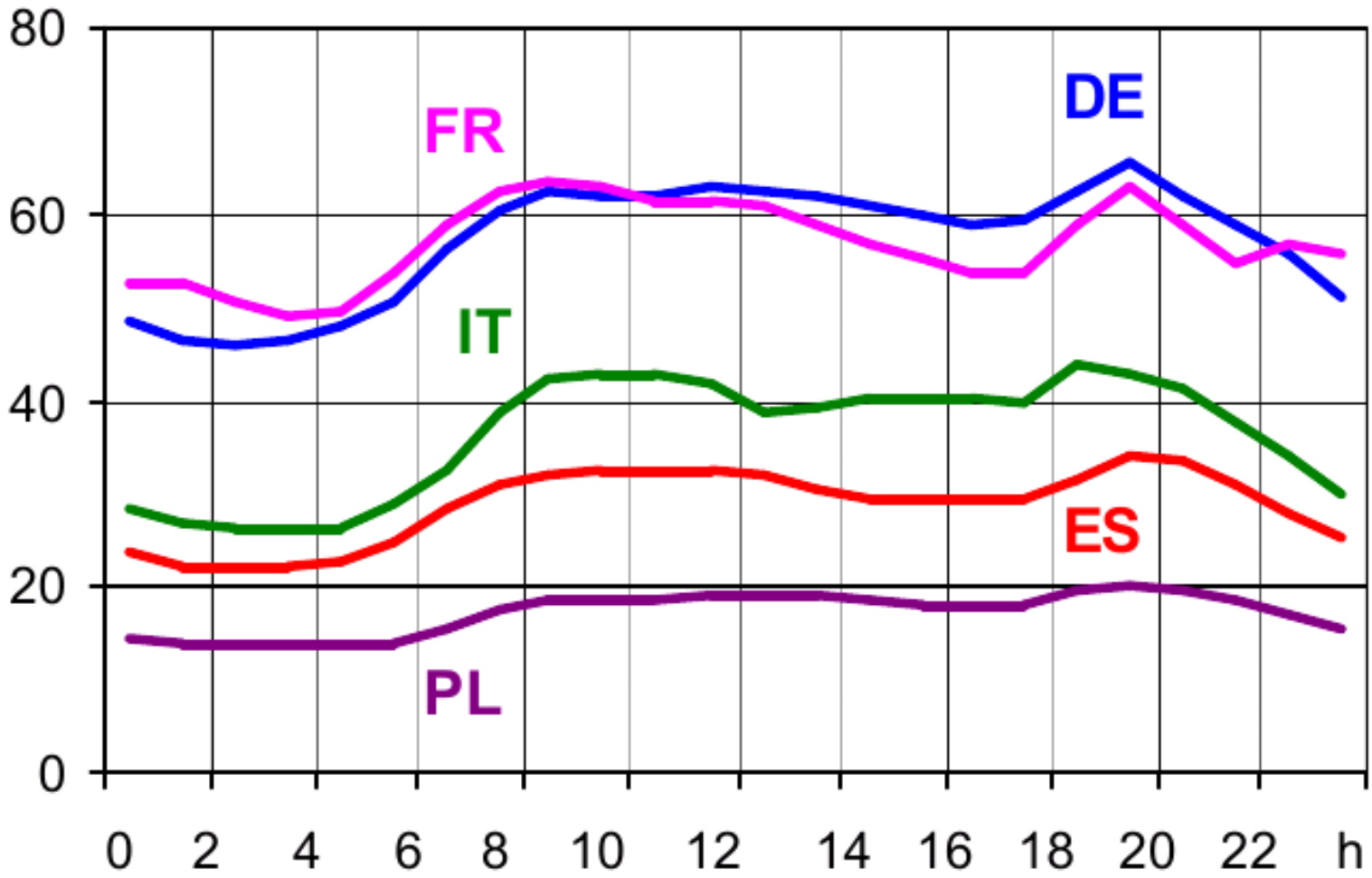
Wind power record in Spain!
5 March 2009

The share of wind power exceeded 40% for several hours. The peak wind power was 11180 MW, corresponding to 69% capacity facotr (the long time average capacity factor is 21-23%).

Power load

18 March 2009

source: UCTE



France-Spain border

Cross border lines maximum total capacity: 2930 MW

Source: UCTE

Power grid simulation: DC model (linearized)

Assumptions:

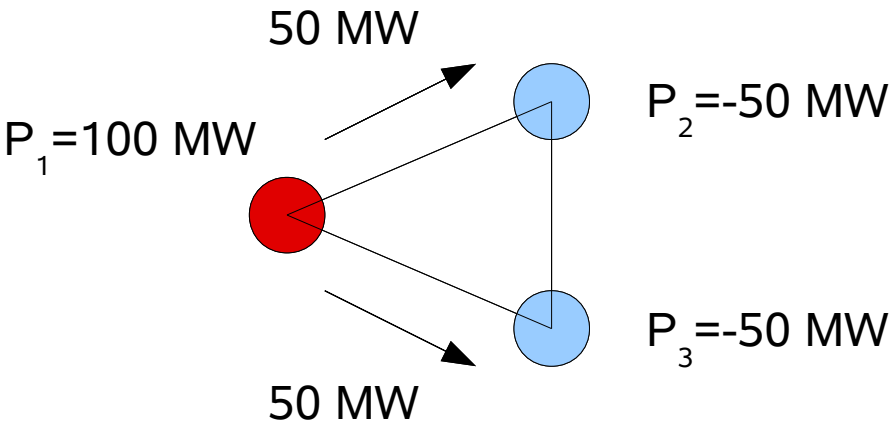
- Connecting lines at a node have the same voltage (U) and phase (θ)
- Along a line, phase shift $\Delta\theta << 1$
- $x << r$ for the complex resistance $r+i*x$

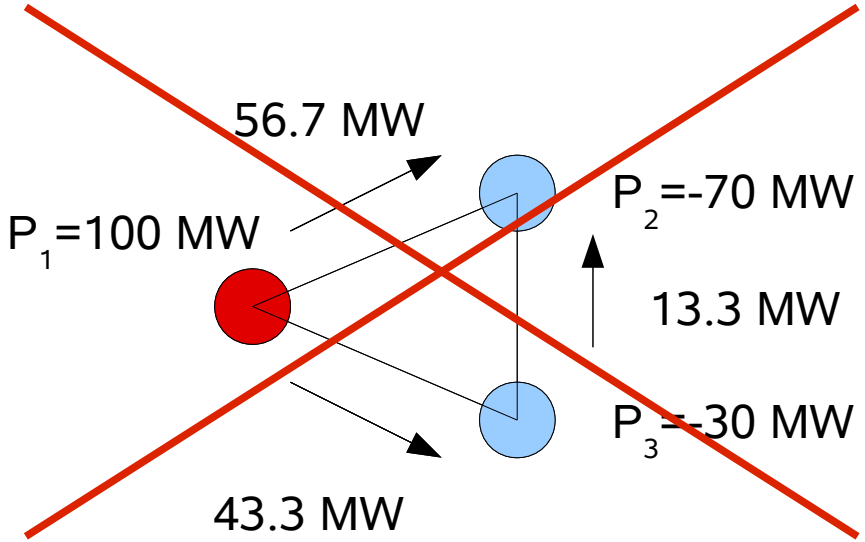
Power flow: $P = U^2 \Delta\theta / x$

Constraints: sums of power flows at nodes are zero → sparse set of linear equations for the phases.

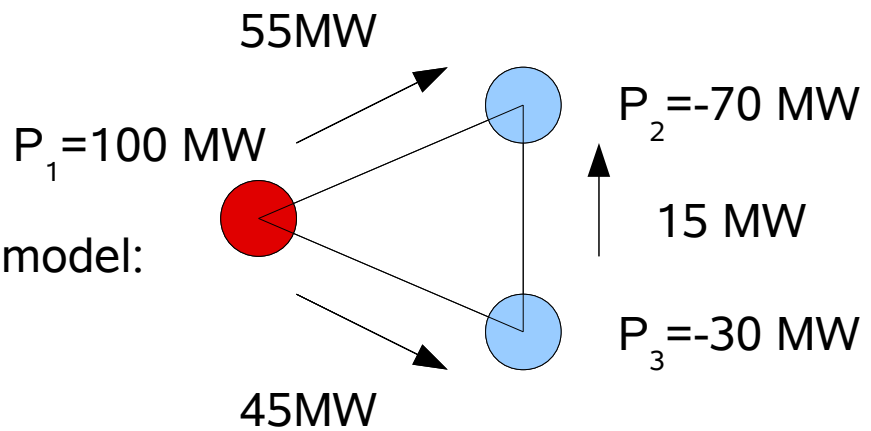
DC model is not suitable for power line overload testing

Max. power line capacity: 55 MW





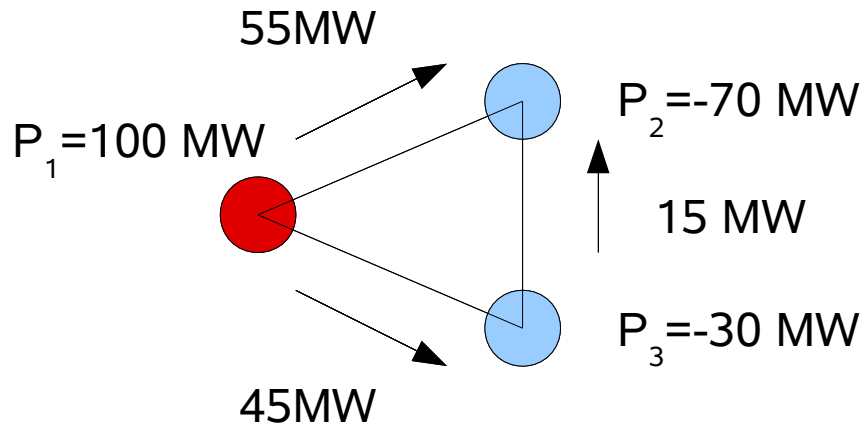
Linear programming model:



Linear programming model

Variables:

$I_{21} = P_2 - P_1$
$I_{31} = P_3 - P_1$
$I_{32} = P_3 - P_2$



Model inequalities:

minimize: $|i_{21}| + |i_{31}| + |i_{32}|$
$|i_{21}| \leq 55$ MW
$|i_{31}| \leq 55$ MW
$|i_{32}| \leq 55$ MW
$i_{21} + i_{31} = 100$ MW
$-i_{21} + i_{32} = -70$ MW
$-i_{31} - i_{32} = -30$ MW

Linear programming solver

lp_solve

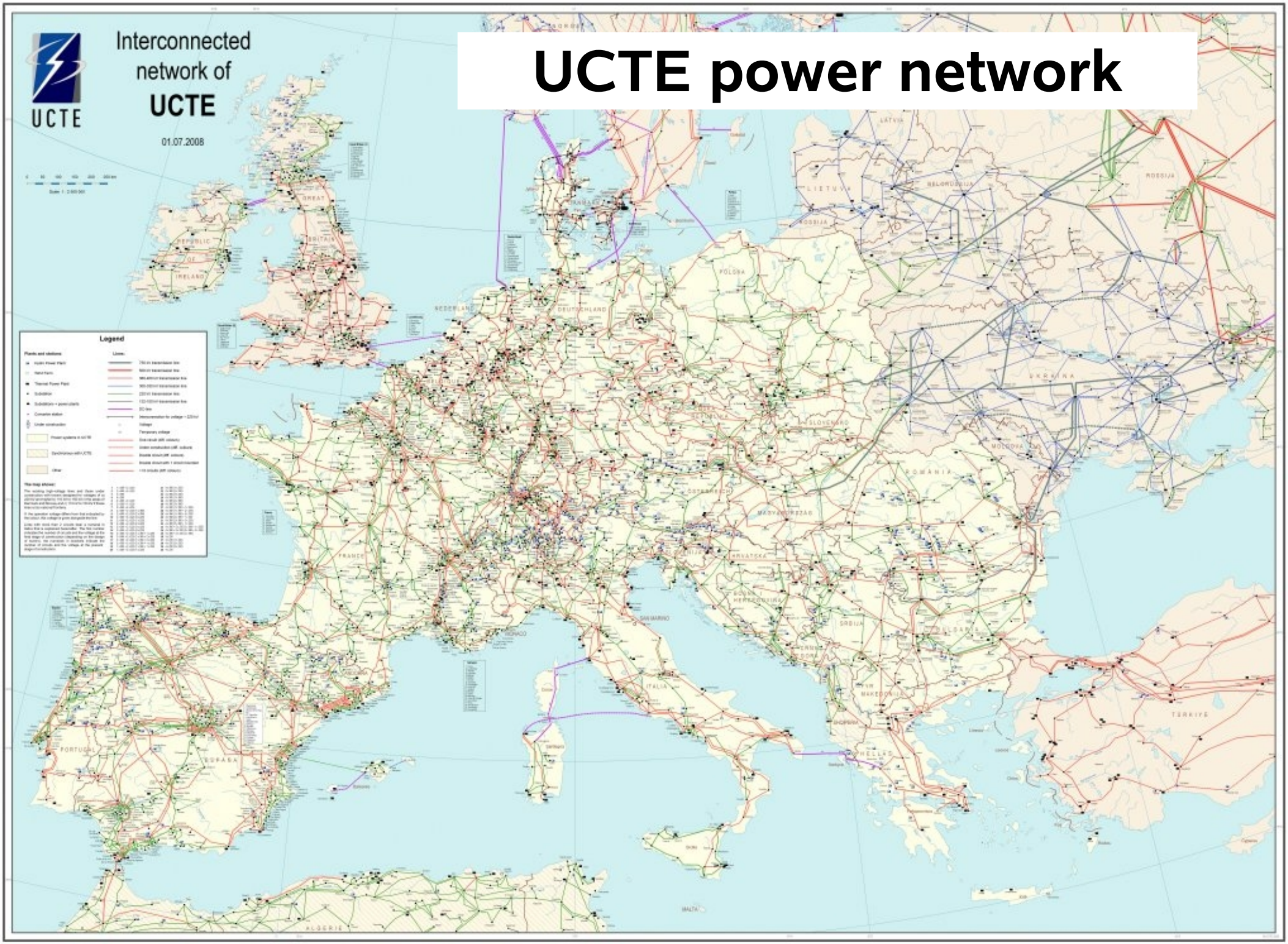
- Easy to formulate the problem
- Good performance compared to commercial software
- Open source, free to use
- More information: http://lpsolve.sourceforge.net

“It is much easier than Matlab, I don't have to write the many zeros into the matrix.”(Aleksandra Kanevce, Skopje)

European network modelling

- Linear programming model instead of DC model
- Goal: determine safe maximum of wind power
- Power plant types: base load plants (e.g. nuclear), conventional plants (e.g. natural gas fuelled), wind power plants
- Wind modelling: ERA-40, ERA-Interim, airport measurement data
- The system softly fails if wind power plants has to be stopped
- Hard failure: the network collapses if one line fails (N-1 criterion)
- Still work in progress

UCTE power network



A closer look at the UCTE map