Global Electricity Network (pre-)Feasibility Study

David Radu

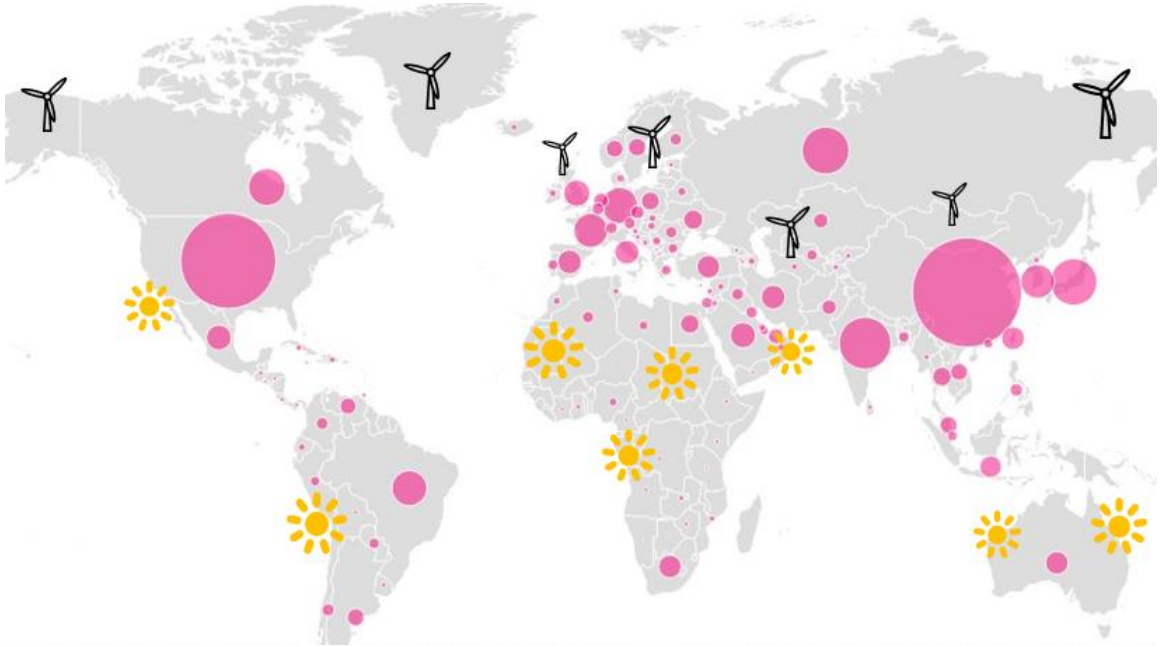
Montefiore Institute, University of Liège, Belgium

March 21, 2019

Motivation

(…beyond climate concerns, resource depletion, etc.)

- Sparse distribution of VRE sources and their location relative to demand centers
- Resource complementarity as solution to high power output intermittency
- Potential of integrating demand profiles over a range of longitudes (time zones)
- Other operational advantages

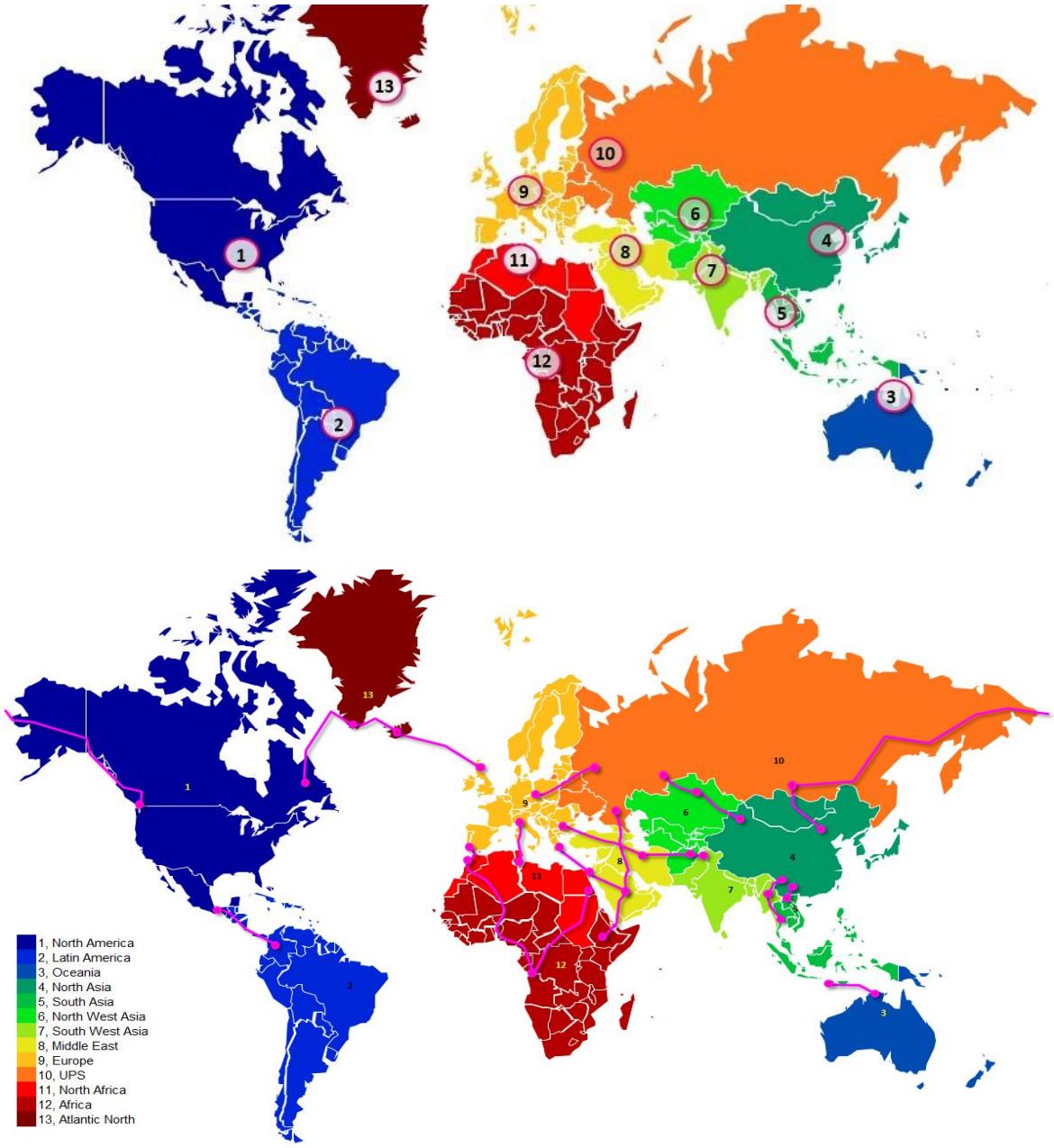


Scope

- Carrying out a first (pre-)feasibility study targeting macro-regional integration of power systems via large-scale HVDC/HVAC interconnectors
- Assessing costs and benefits, potential challenges in line with a set of assumptions

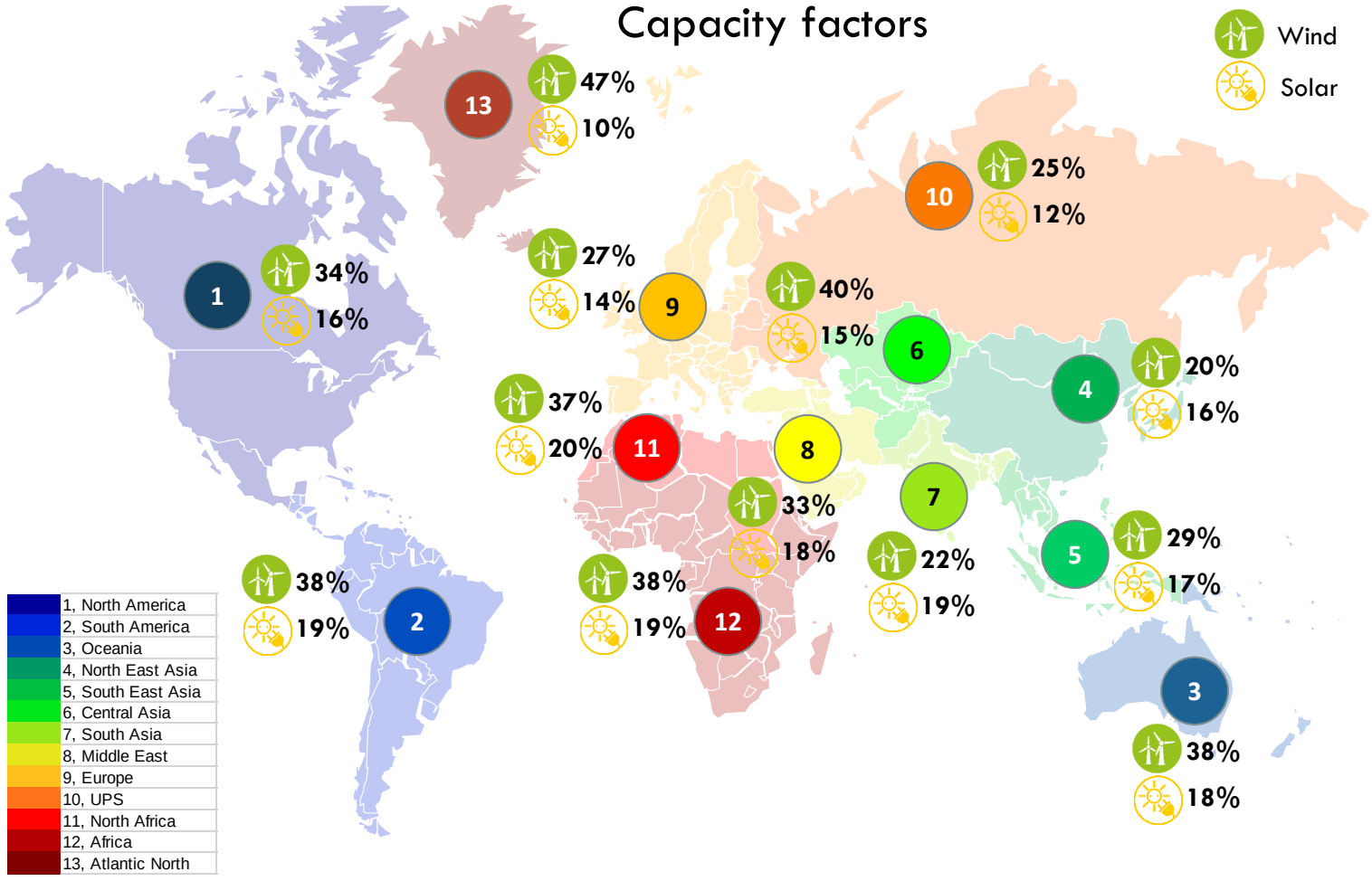
Region and Corridor Mapping

- Splitting into 13 macro-regions (nodes) based on geographical boundaries, basic economic indicators and existing political ties
- Transmission corridor selection (20 links) done via a-priori assessment of terrain (OHL following “easy access” routes and already existing infrastructure elements) and bathymetry (2000m max for USCs)
- Connection points coincide with existing, large-scale transmission assets (sub-stations and lines)



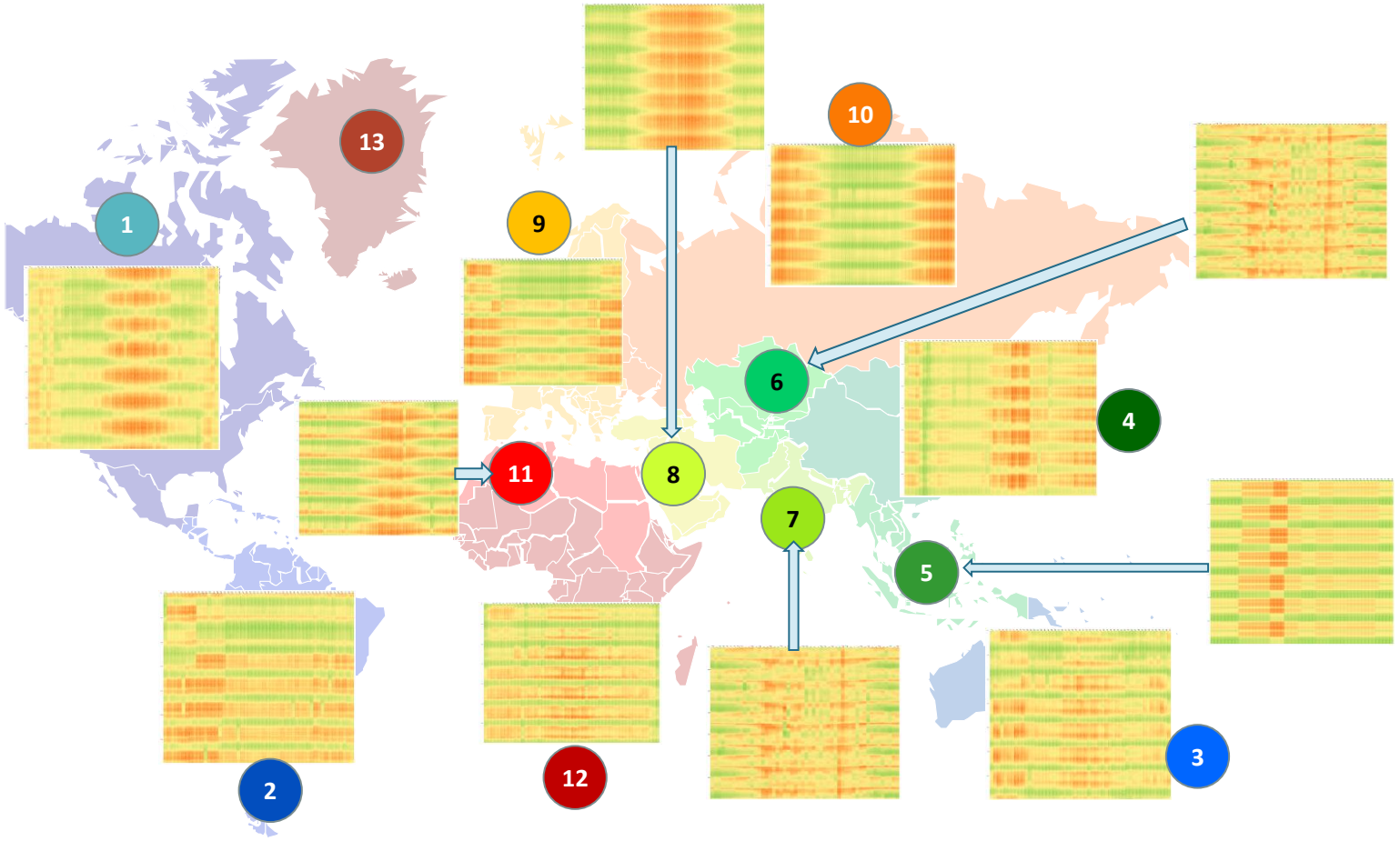
Data collection & Analysis

- Conventional generation: WEC data on installed capacity, utilization factors
- VRE generation: unconstrained technical potential, potential modelled via reanalysis data
- Demand data: WEC data on total volumes, internal data on yearly profiles
- Costs: IEA data for generation, European/Asian project data for transmission ($/km*GW)



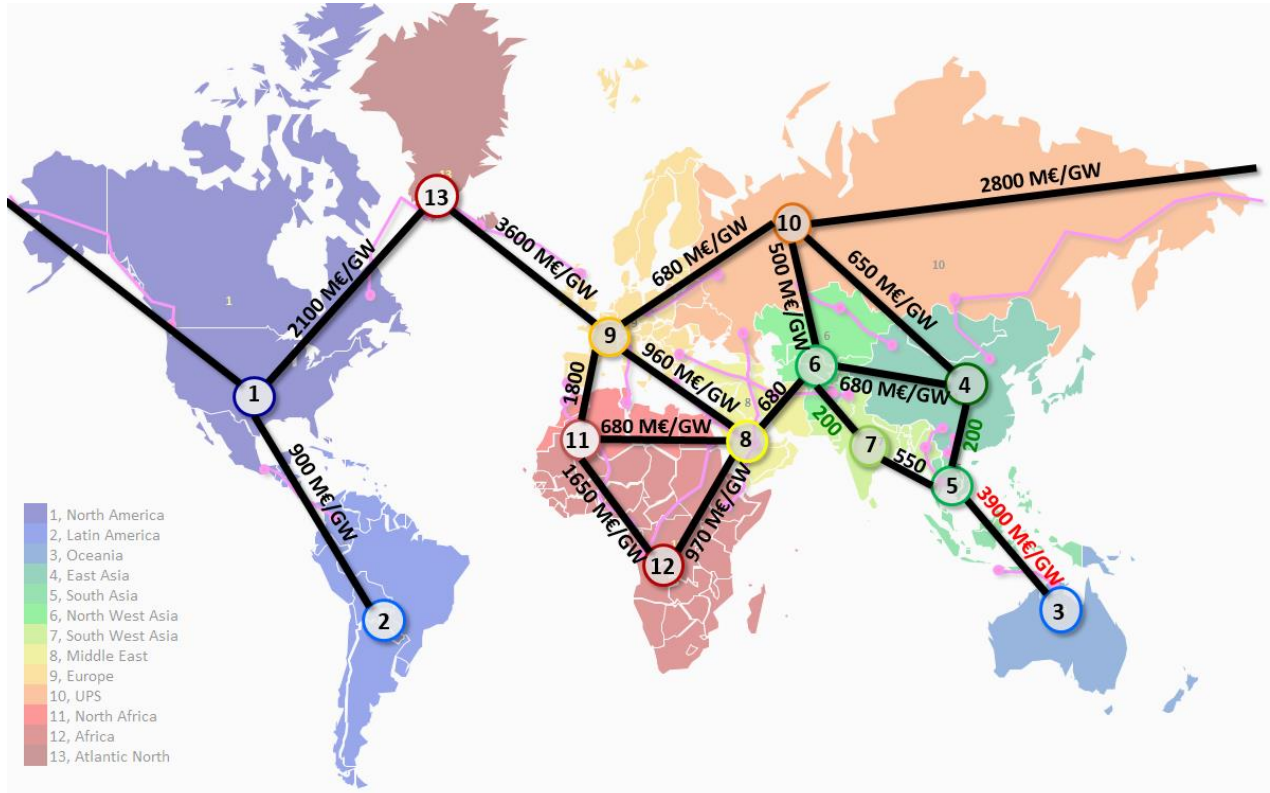
Data collection & Analysis

- Conventional generation: WEC data on installed capacity, utilization factors
- VRE generation: unconstrained technical potential, potential modelled via reanalysis data
- Demand data: WEC data on total volumes, internal data on yearly profiles
- Costs: IEA data for generation, European/Asian project data for transmission ($/km*GW)



Data collection & Analysis

- Conventional generation: WEC data on installed capacity, utilization factors
- VRE generation: unconstrained technical potential, potential modelled via reanalysis data
- Demand data: WEC data on total volumes, internal data on yearly profiles
- Costs: IEA data for generation, European/Asian project data for transmission ($/km*GW)



Cost (M€)	DC OHL (M€/km/GW)	DC USC (M€/km/GW)	AC OHL (M€/km/GW)	AC/DC Converter (M€/GW/SS)	AC/AC B2B (M€/GW/SS)
Max	0,33	1,90	0,25	158	158
Min	0,18	1,27	0,13	90	90

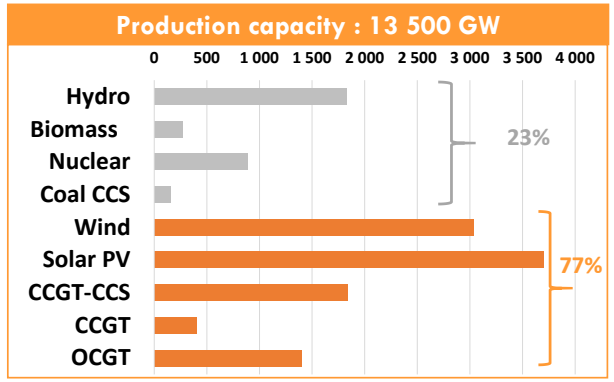
Methodology and Test Cases

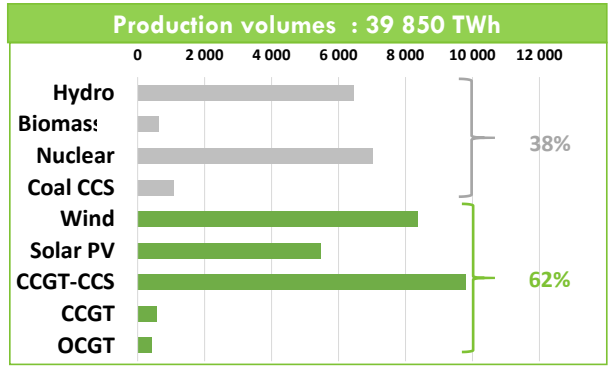
- ANTARES used as optimization tool
  - no limits on sizing variables
  - copper plate within regions
  - flat costs across regions
  - conservative demand profiles
  - no actual PSO/PSS investigation

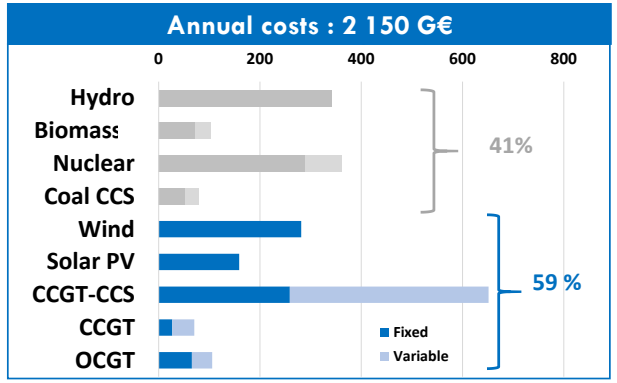
- Inputs: load & VRE gen. potential hourly time series, conventional gen. capacities, annualized tech. costs, CO2 cost
- Objective function: minimize system cost to serve given electricity demand
- Outputs: VRE/NG installed capacities, interconnector capacities/hourly flows, electricity generation mix, etc.

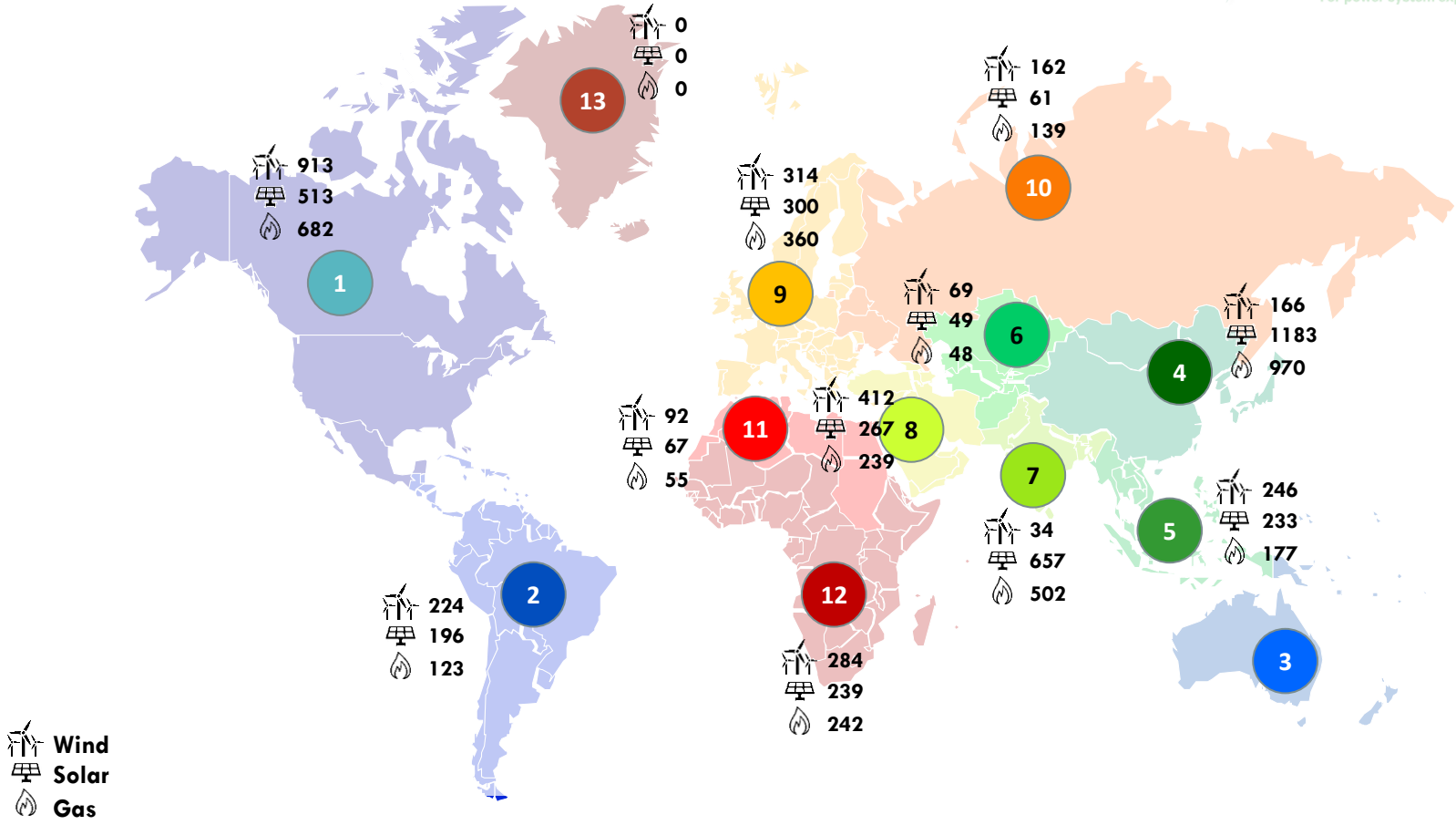
	What are we testing?
0	Base case, all regions are decoupled.
1	Regions can be interconnected.
2	Influence of VRE potential in selected regions.
3	Influence of transmission losses.
4	Sensitivity on transmission cost.
5	Addition of daily regulated (low power) storage.
6	Addition of daily regulated (high power) storage.
7	Consideration of seasonal storage.
8	Influence of CO2 price.
9	Solar PV deployments only.
10	VRE deployments only.
11	US-Russia geopolitical impact.
12	Sensitivity on EUMENA transmission costs.

Results – Case 0 (Isolated regions)





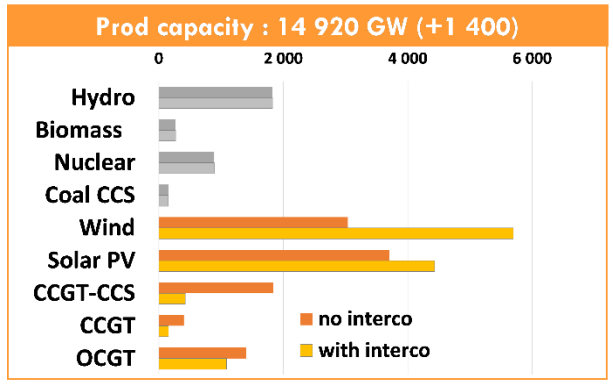


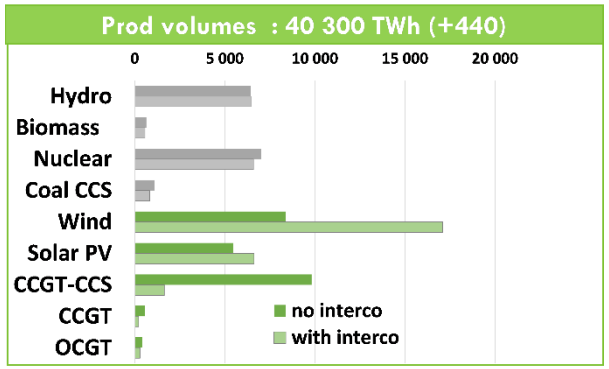


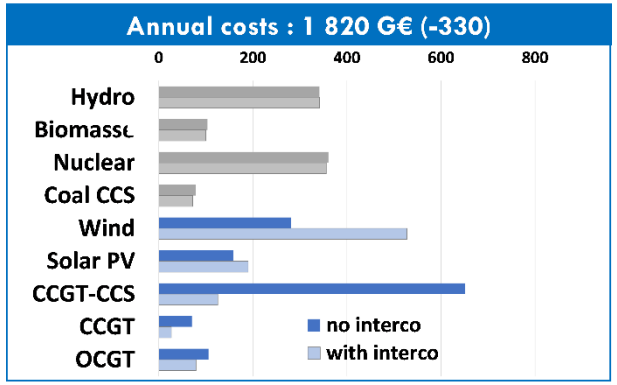
Interconnection cap. : 0 GW
Interconnection cost : 0 B€/year

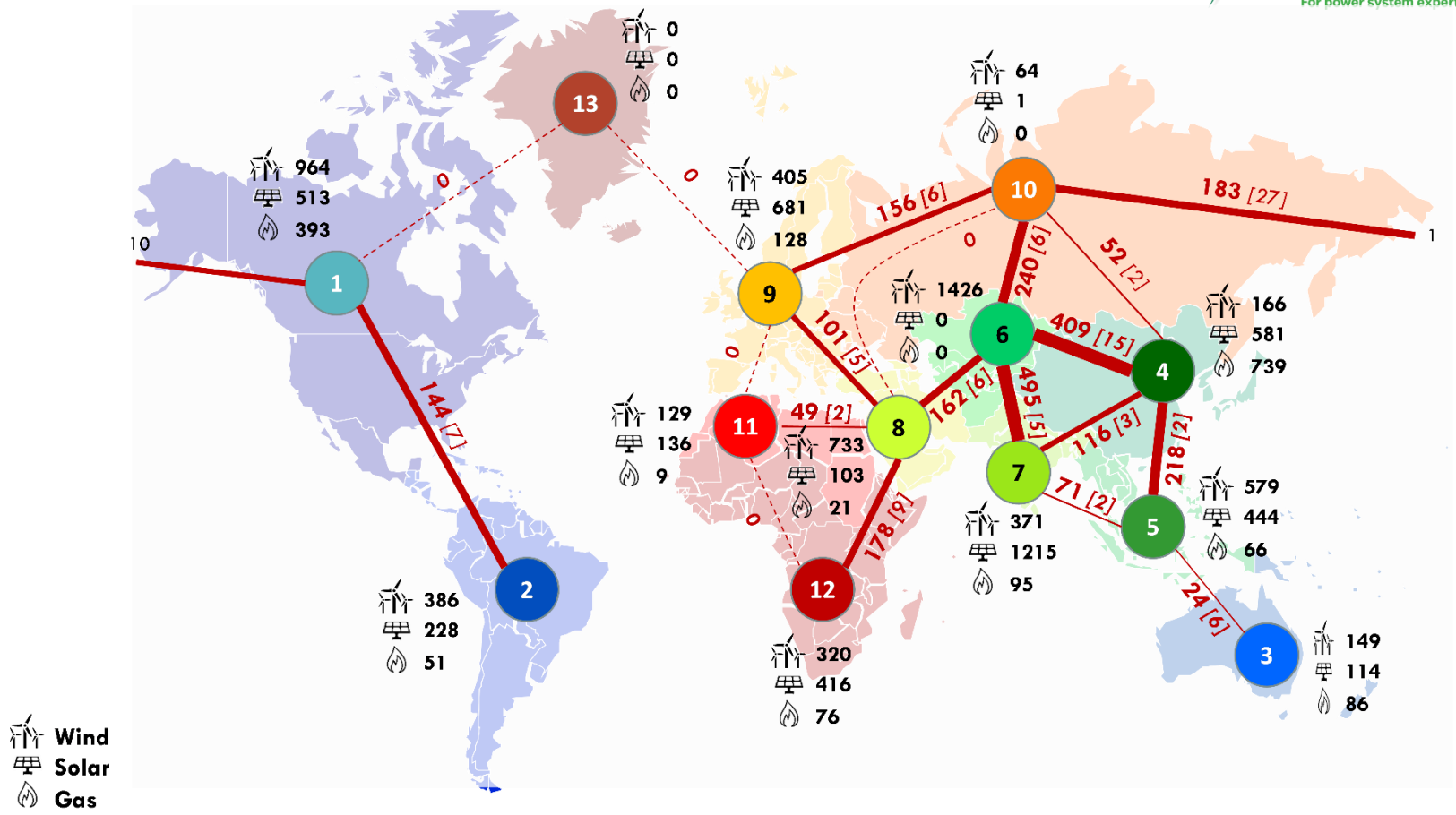
System cost : 54 €/MWh
RES share : 53 %
CO2 emissions: 850 Mt/year

Results – Case 1 (The value of interconnections)









Interconnection cap. : 2600 GW
Interconnection cost : 104 B€/year

System cost : 48 €/MWh (-6 €/MWh)
RES share : 76% (+23%)
CO2 emissions: 343 Mt/y. (-510 Mt/y.)

Results – Case 10 (100% VRE system)

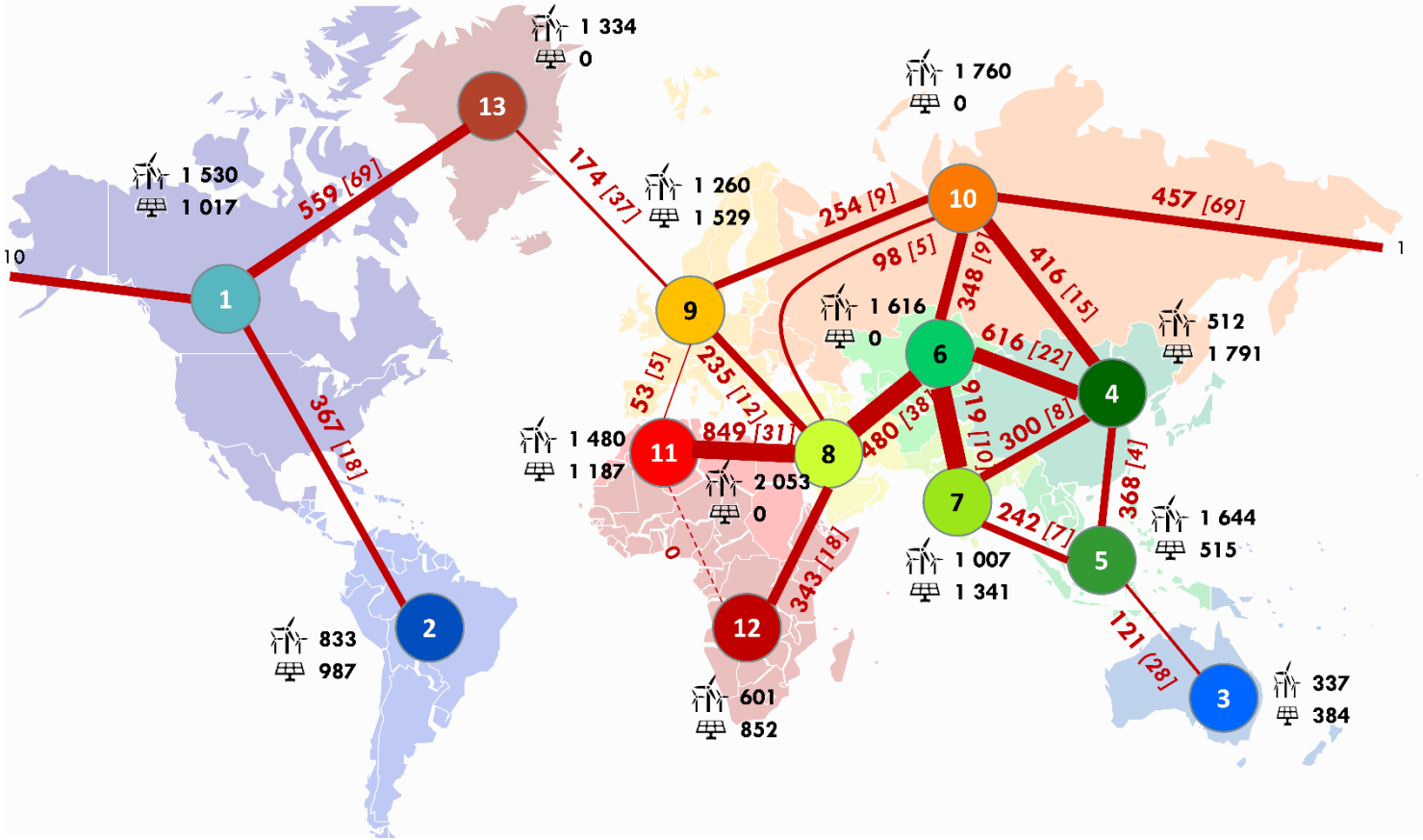
For a given demand level & value of lost load:

Interconnection cap. : 7800 GW
Interconnection cost : 415 B€/year

VRE capacity: 25800 GW
VRE generation: 62000 TWh
VRE curtailment: 22000 TWh

Interconnection-to-VRE: 30%

System cost: 58 €/MWh



Challenges & Follow-up…

- C1.35 technical brochure coming out
- Follow-up WG (end of 2019) to assess:
  - Interconnection vs. storage trade-off
  - Sequence of interconnector deployment
  - More accurate estimation of VRE potential / demand profiles

On the ULiège side:

- Scientific material already out
- Ongoing (and exciting) work on renewable resource complementarity
- Development of planning tools focusing on VRE deployment schemes & interconnector vs. storage trade-offs

Critical Time Windows for Renewable Resource Complementarity Assessment

Complementarity Assessment of South Greenland Katabatic Flows and West Europe Wind Regimes