

Future perspectives on policy instruments and market coupling
for integration of RES-e in regional supergrids

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BIEE Conference, 22nd September 2016



OUTLINE

- ❑ Introduction
- ❑ Integrating RES and electricity markets in regional supergrids
- ❑ Regional profiles
- ❑ Methodology and results
- ❑ Conclusions



INTRODUCTION



Proposed DESERTEC EU-MENA Super-Grid, **SOURCE**(DESERTEC Foundation,2016)

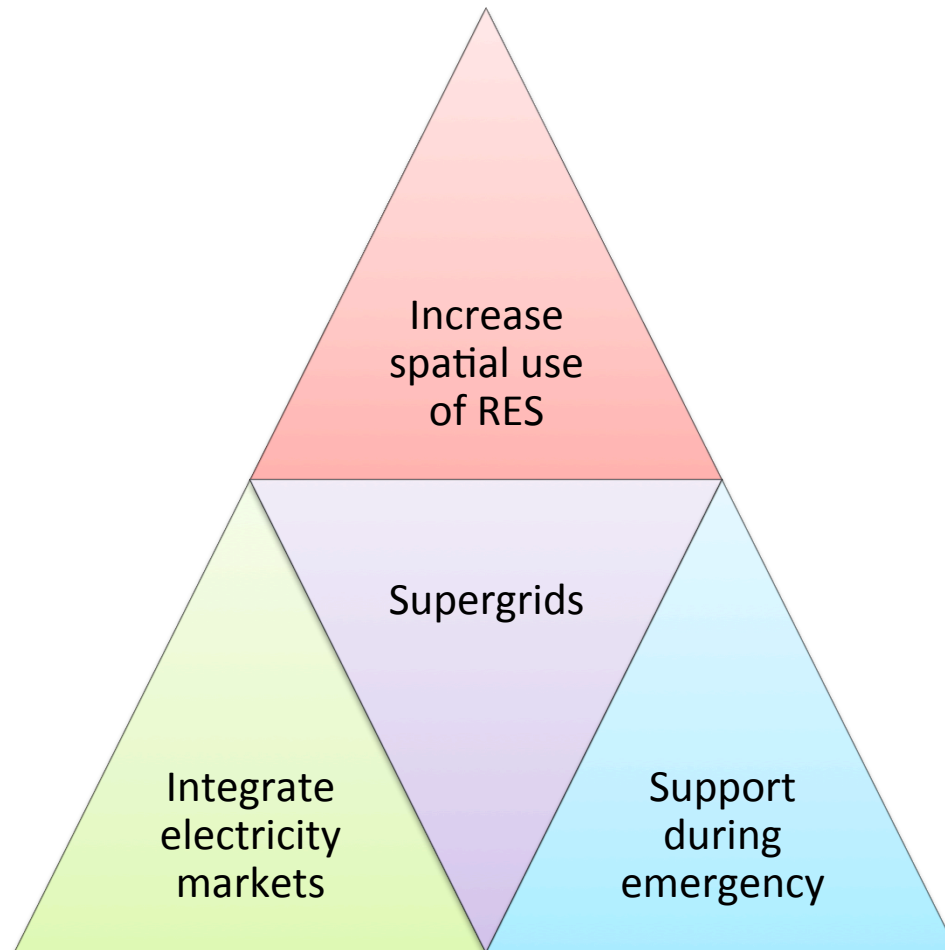
- Supergrid refers to interconnected electricity networks mostly using high voltage direct current cables
- DESERTEC Initiative: 17% of EU consumption imported from Middle East North Africa by 2050.

Why HVDC transmission in supergrids?

- Interconnect countries' transmission grids operating at different frequency - E.g. Proposed interconnections between Cote d' Ivoire (50Hz), Guinea (50Hz), Guinea (50Hz), Liberia (60Hz), and Sierra Leone (50Hz)
- 10% loss for transmission distance over 3000km compared to 40% for High Voltage Alternating Current (HVAC) lines (Trieb, Franz, et al., 2009)
- Lesser environmental impacts with the use of just two lines instead of four lines in HVAC for the same amount of electricity
- Over a distance of 800km on land and 50km in sea, HVDC has a lower investment cost (lines and converter stations) (ABB, 2016)



SUPERGRIDS TRILEMMA



SUPPORT MECHANISMS FOR DEPLOYMENT OF RES

Regulatory			
	Direct		Indirect
	Price-driven	Quantity-driven	
Investment focused	Investment incentives Fiscal incentives	Tendering	Environmental Taxes
Generation based	Feed-in-tariffs Rate-based incentives	Tendering Quota obligations (RPS) based on TGCs	
Voluntary			
	Direct (Price-driven)		Indirect
Investment focused	Contribution programmes Shareholder programmes		Voluntary Agreements
Generation based	Green tariffs		

Existing support mechanisms (Source: Fraunhofer Institute Systems and Innovation Research, 2005)

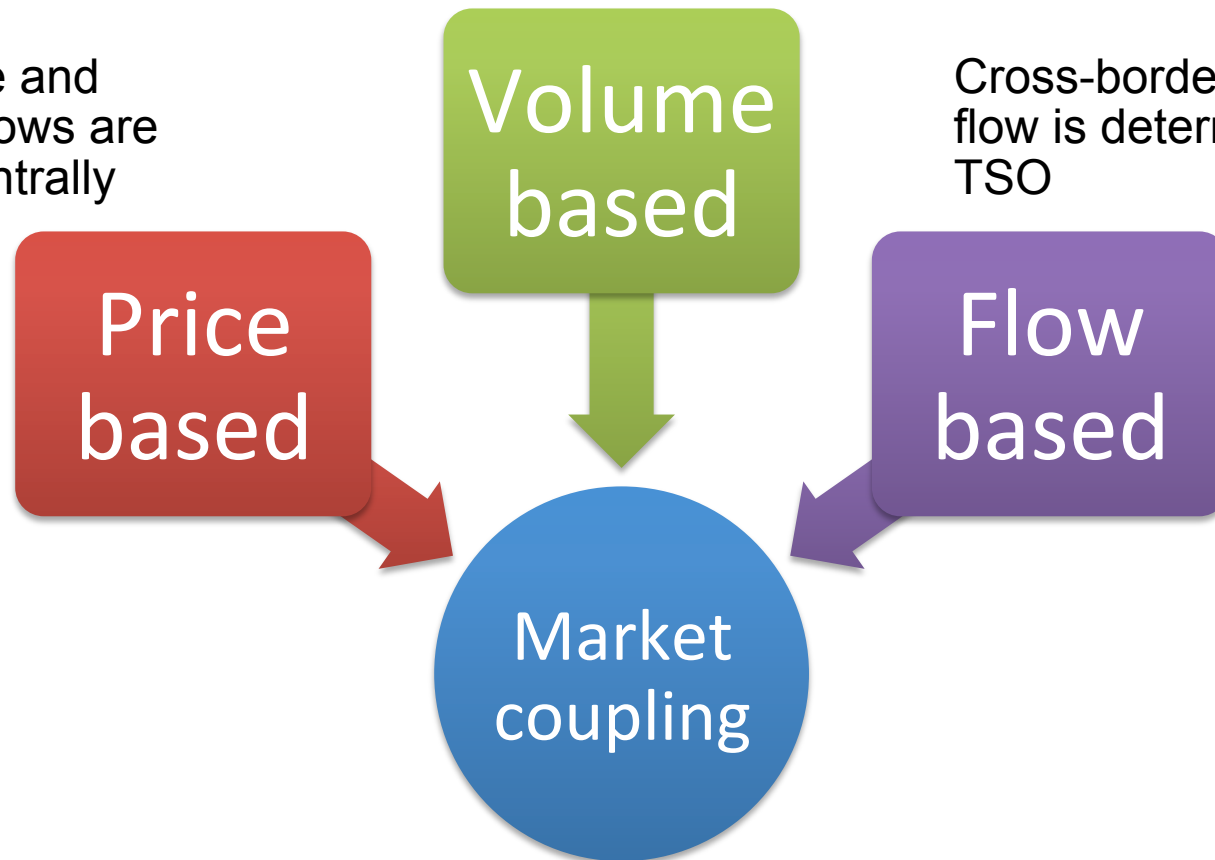


METHODS

Cross-border electricity flows
are determined centrally.
Electricity prices are determined
nationally

Electricity price and
cross-border flows are
determined centrally

Cross-border electricity
flow is determined by
TSO



MARKET COUPLING IN REGIONAL GRIDS

Benefits

- Utilize generation and reserve capacities more efficiently
- Improve market liquidity
- Price convergence
- Increase trade and competition



Market Coupling

Challenges

- Failed in some meshed grids
- Success is subject to national energy policies
- May lead to increase in electricity prices



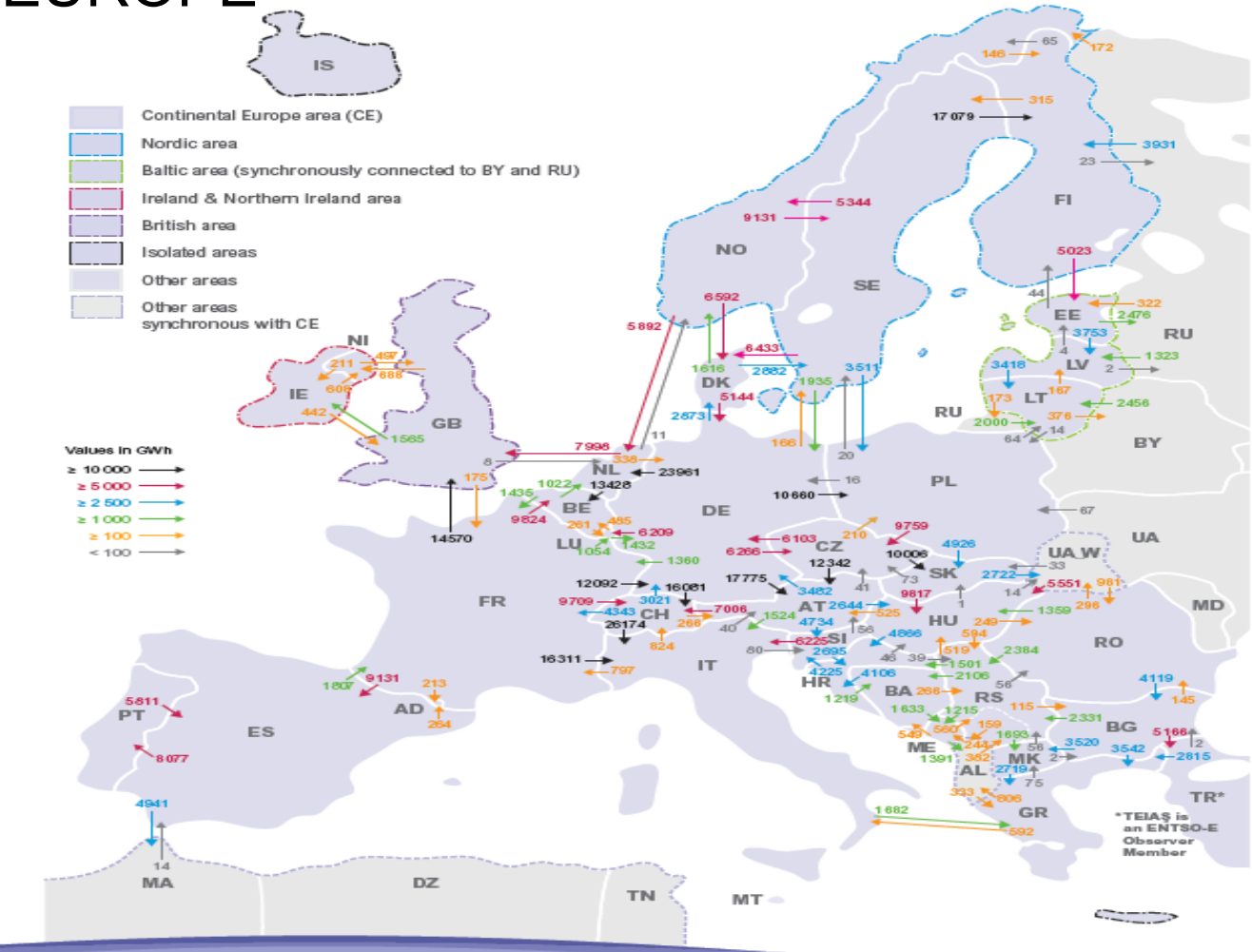
CASE STUDIES

Europe

West Africa



EUROPE



35 Countries

532 Million people

1030 GW generating capacity

3330 TWh electricity produced

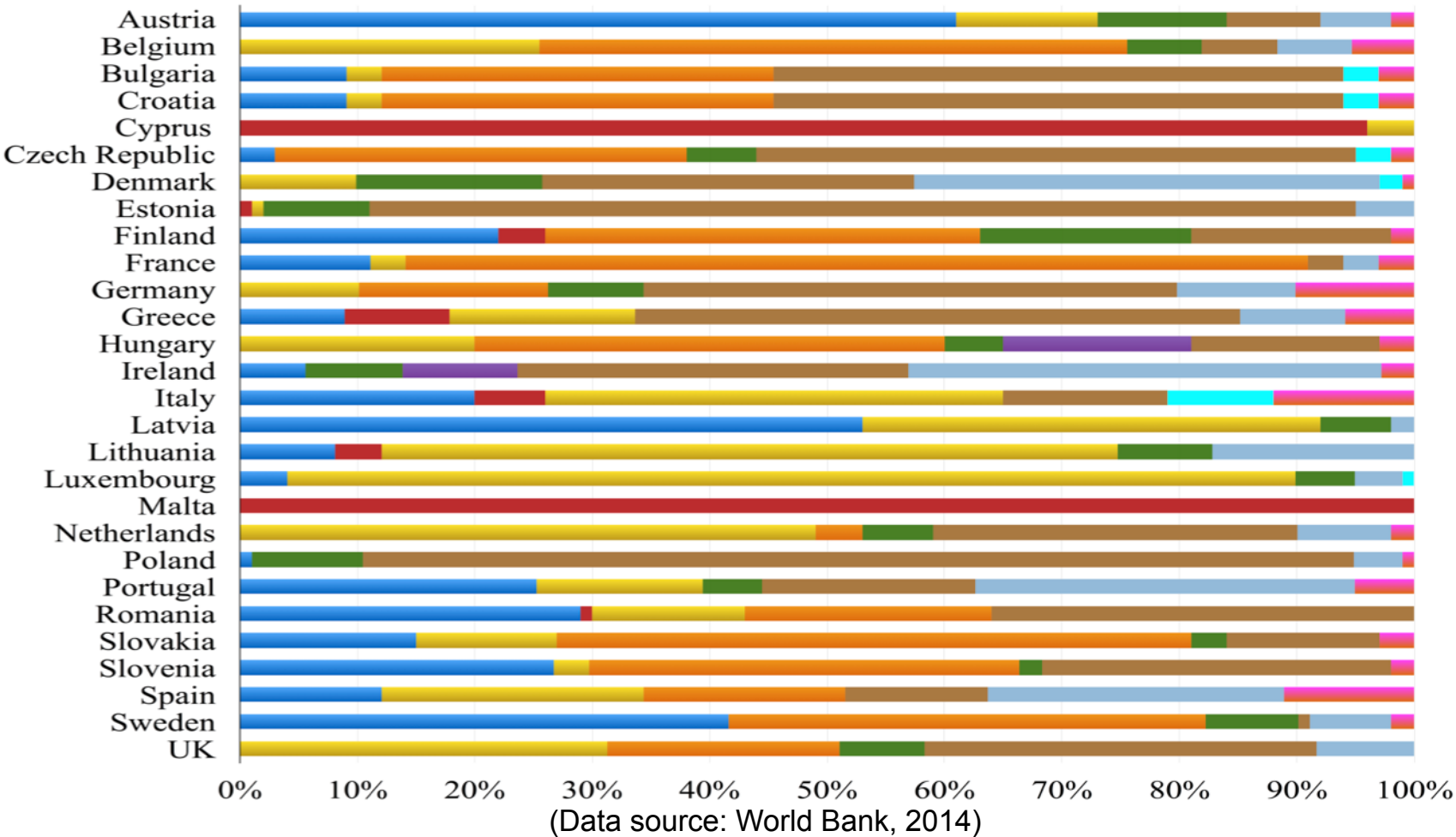
312, 693 km of transmission lines

449 TWh electricity exchanged

Physical Electricity Flows in Europe, SOURCE(ENTSOE-E,2016)



Electricity production by source in Europe (2014)



STEPS TOWARDS MARKET COUPLING IN EUROPE

Region	Time-frame	Countries
Scandinavia	1993	Scandinavian market
Northern Region (Nord Pool)	1996	Sweden-Norway
	1998	Denmark
	2000	Finland
	2010	Estonia
	2013	Poland, Latvia
Northwest Europe	2006	France-Belgium-Netherlands
Spain-Portugal	2007	Spain-Portugal
Central Western European (CWE)	2007	Denmark, Belgium, France, Germany, Luxembourg, the Netherlands, CWE TSOs
	2008	Germany-Denmark
Central East European (CEE)	2008	CEE countries
Poland-Sweden	2010	Both regions are linked between, Netherlands and Norway, Germany and Denmark, Germany and Sweden.
Slovenia-Italy	2011	Slovenia and Italy
CWE-Nordic - UK	2012	CWE-Nordic-UK
Central and Eastern Europe (CEE)	2012	Czech Republic, Slovakia, Hungary, Romania
South-Western Europe (SWE)	2014	France, Spain, Portugal
North-Western Europe (NWE)	2014	Nordic countries, Great Britain and CWE, Later SWE has joined
Italy-France-Austria-Slovenia	2015	Italy, France, Austria, Slovenia

(Source: Böckers and Heimeshoff, 2014; EC, 2014a; Tennet, n.d.)

ELECTRICITY MARKET INTEGRATION & LIBERALIZATION IN EUROPE

Time-Frame	Actions
By 1921	First network extensions for electricity transportation was initiated
1921-1922	Initiated project to liberalise and integrate EM
1925	Foundation of a first supervisory body for transmission lines
1939-1949	The electricity sector in most European countries became owned and controlled by Governments
1957	The Treaty of Rome had planned liberalisation for all commodity markets including the EM
1959	The exchange of electricity became liberalised
1987	Single European Act - a step to abolish state-owned national monopolies
1990	Initiated the liberalisation phase of European electricity wholesale markets
1992	Maastricht Treaty further strengthened European ambition to create free cross-border trades in electricity
1996	First Electricity Directive 1996/92/EC on electricity liberalisation
2000	Florence Forum - reach early agreements concerning market-based mechanisms for congestion management
2003	Second Electricity Directive 2003/54/EC, concerning common rules of the internal electricity market
2004	The EC set out its strategy on the electricity market integration
2005	Adopted Second internal market package for electricity
2006	Electricity Regional Initiatives (ERI) have been launched
2009	Third Internal market package for electricity has been adopted
2011	EU adopted new stringent rules on wholesale electricity trading (Regulation 1227/2011).
2014	Multiregional price coupling in North Western Europe
2015	New EU regulation (EC) 2015/1222 establishing a guideline on capacity allocation and congestion management



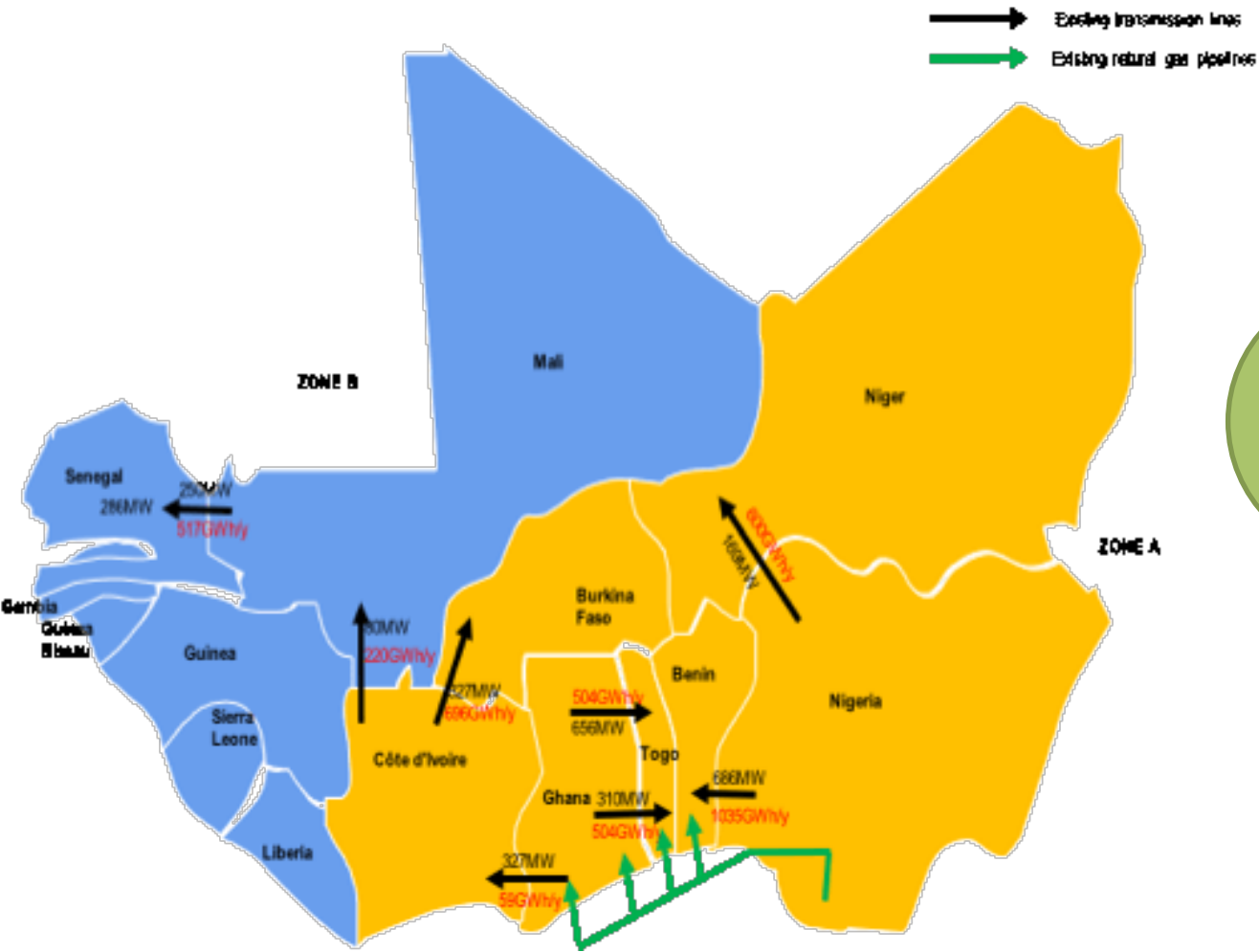
RES regulatory support schemes in Europe



(Data source: Ecofys et al. 2014)

- EU member state has its own set of support mechanisms
- Different instruments are combined depending on different technologies, and national goals and policies.

WEST AFRICA

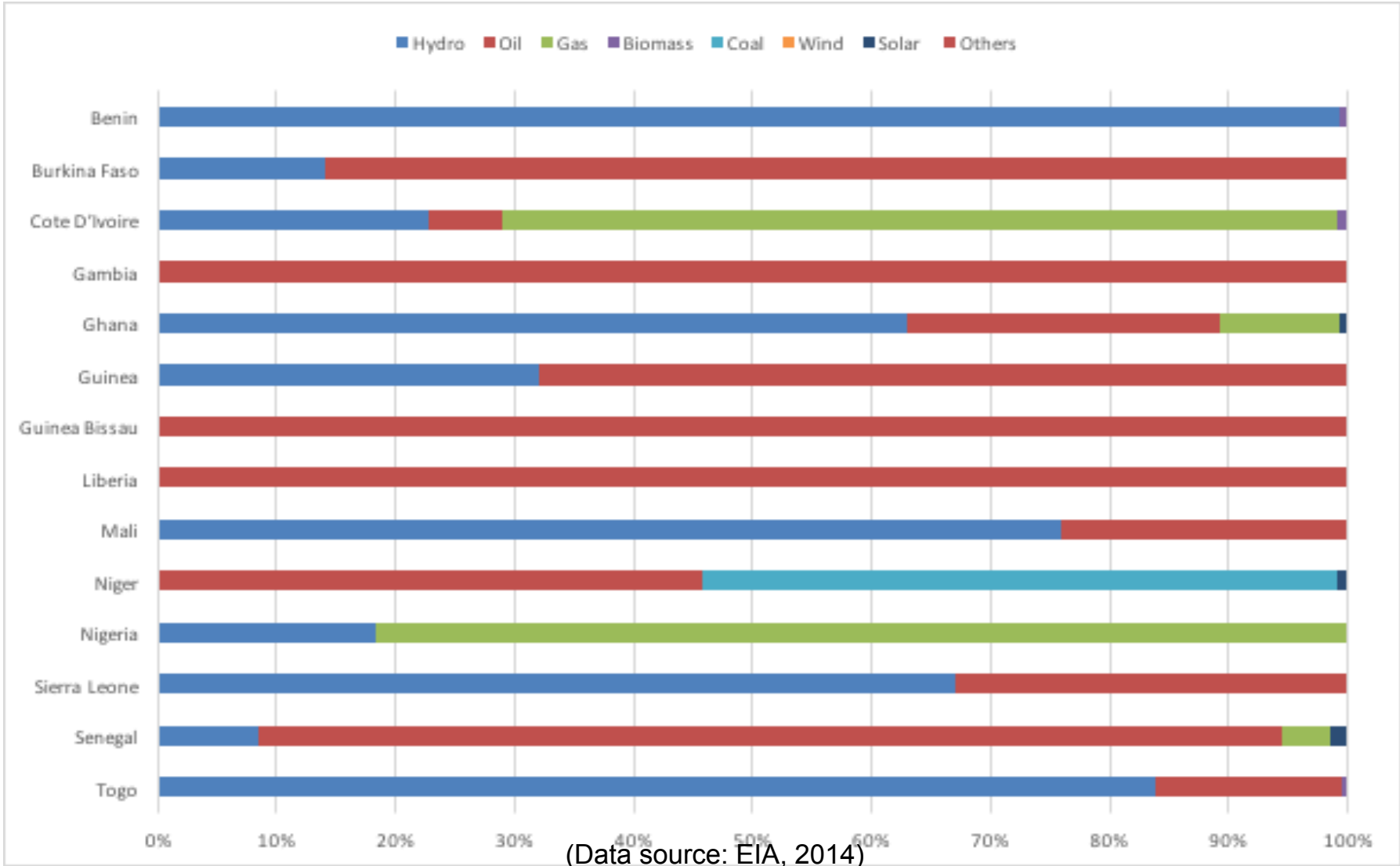


- 14 Countries
- 327 Million people
- 9.9GW generating capacity
- 176 Million without access to electricity
- 56 TWh electricity produced
- 5.3 TWh electricity exchanged



Interconnected electricity grid in West Africa.

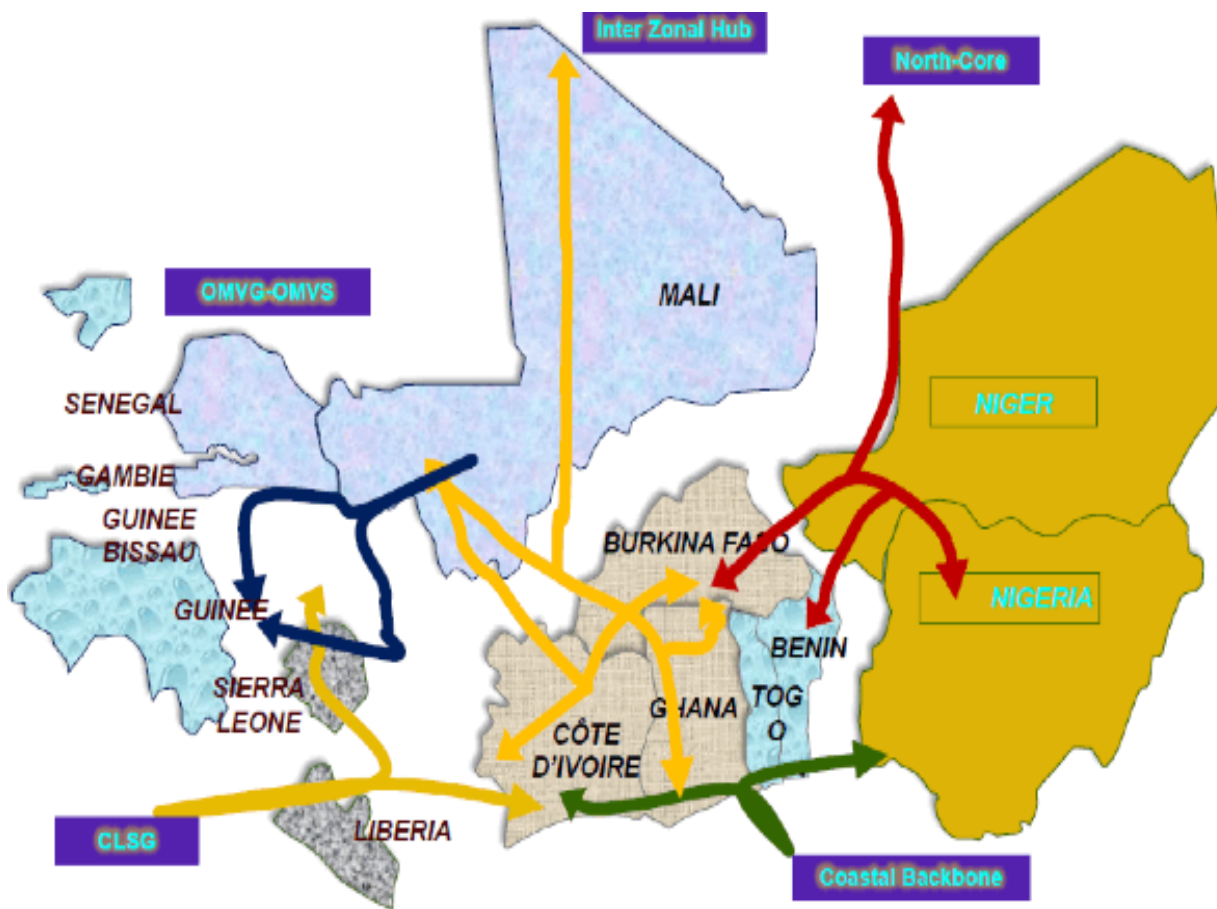
ELECTRICITY PRODUCTION BY SOURCE IN WEST AFRICA (2014)



ELECTRICITY TRADING IN WEST AFRICA

Time-Frame	Actions
1992	Bilateral contract between Nigeria and Niger for the supply of electricity to Niger
1997	Bilateral contract between Cote D'Ivoire and Burkina Faso for the supply of electricity to Burkina Faso
1997	Bilateral contract between Nigeria and Benin for the supply of electricity to Benin
1999	Bilateral contract between Cote D'Ivoire and Benin for the supply of electricity to Benin
2000	The West Africa Power Pool (WAPP) was to established to develop power plants and interconnected transmission infrastructures for the region and also create a unified regional electricity market.
2003	The ECOWAS Energy Protocol was adopted to promote regional cooperation, development and integration in the West Africa energy sector
2007	Memorandum of understanding for the trade of electricity between Ghana and Cote D'Ivoire
2008	The ECOWAS Regional Electricity Regulatory Authority was established to coordinate with national electricity regulatory authorities in regulating cross border electricity trade.
2011	Electricity trade agreement between Ghana and Benin.
2011	The WAPP's first business plan was published and it identified priority generation and transmission projects that will provide affordable electricity to 2 or more countries.
2013	Memorandum of understanding to supply electricity from Ghana to Benin.
2015	The WAPP's business plan was revised to reevaluate ongoing and cancelled projects and included new projects.

PROPOSED ELECTRICITY MARKET INTEGRATION IN WEST AFRICA



SOURCE(WAPP,2015)

- **Phase 1:** countries trade based on bilateral contracts between the national market operators
- **Phase 2:** Increased trading in each of the 5 sub-zones, with some countries just acting as transit for the exchange
- **Phase 3:** A single regional market operator with spot market operations occurring on a daily basis.



RES REGULATORY SUPPORT SCHEMES IN WEST AFRICA

	RES-E Support Schemes				
	Regulatory Policies			Incentives	
	FIT/ FIP	Quota Obligation	Tenders	Capital Subsidy	Fiscal Incentives
Benin					
Burkina Faso					x
Cote D'Ivoire					
Gambia					x
Ghana	x	x		x	x
Guinea					
Guinea Bissau					
Liberia					
Mali		x		x	x
Niger					
Nigeria	x	x			x
Senegal	x			x	x
Sierra Leone					
Togo					

- Unlike EU countries, only a few West African countries have RES-E support mechanisms
- Fiscal incentives that exempt renewable energy equipment from tax is the main support that government provides.

METHODOLOGY & RESULTS



ENERGY SYSTEMS MODELS IDENTIFIED IN THE LITERATURE

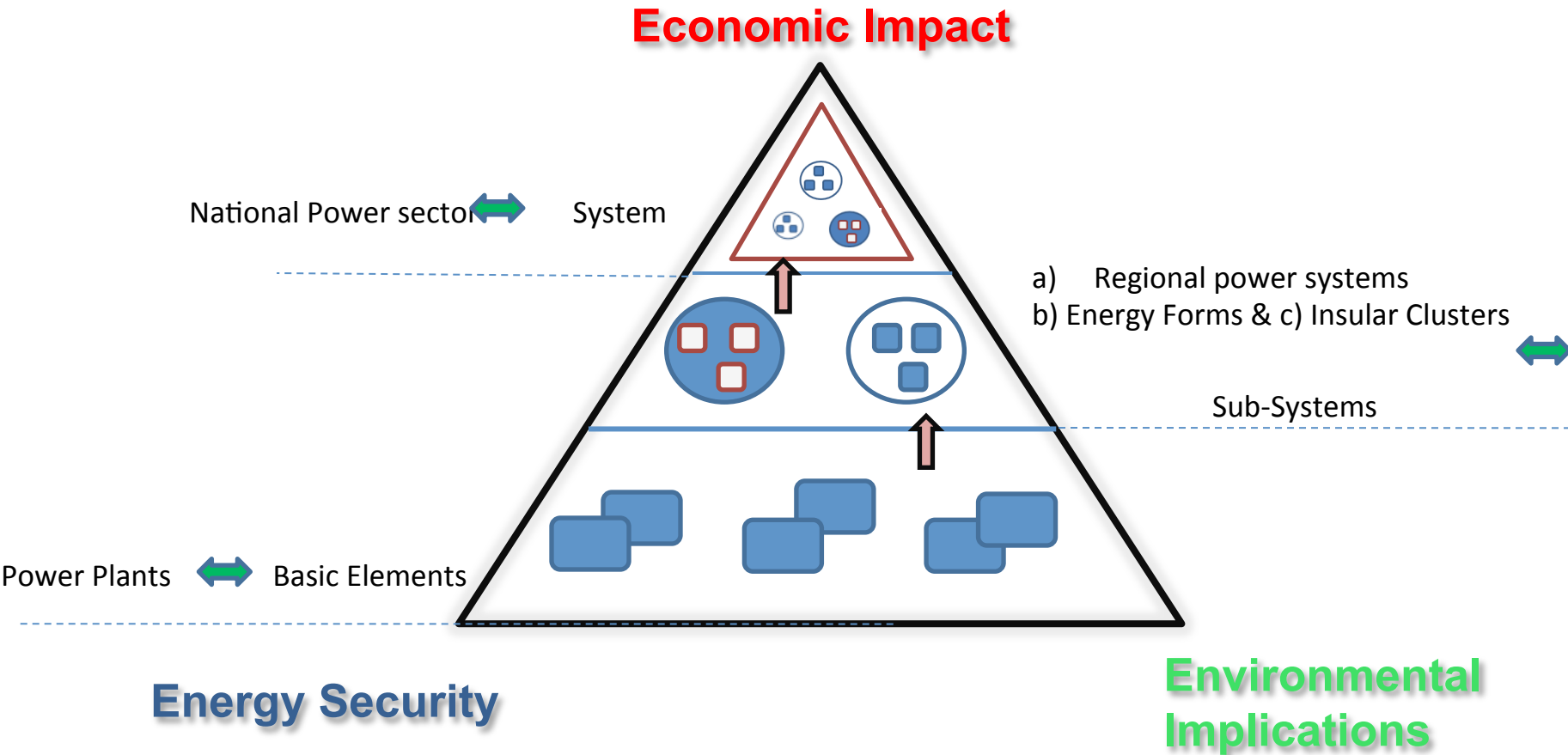
MODELS	
LEAP	BALMOREL
GTMMax	Mesap Planet
WASP	AEOLIUS
Wilmar	IKARUS
MODEST	PERSEUS
EMPS	UPLAN
RAMSES	4see
MARKAL/TIMES	SIVAEL
RAMSES	EnergyPLAN
AURORAx	PLEXOS
EMCAS	EuroDYS



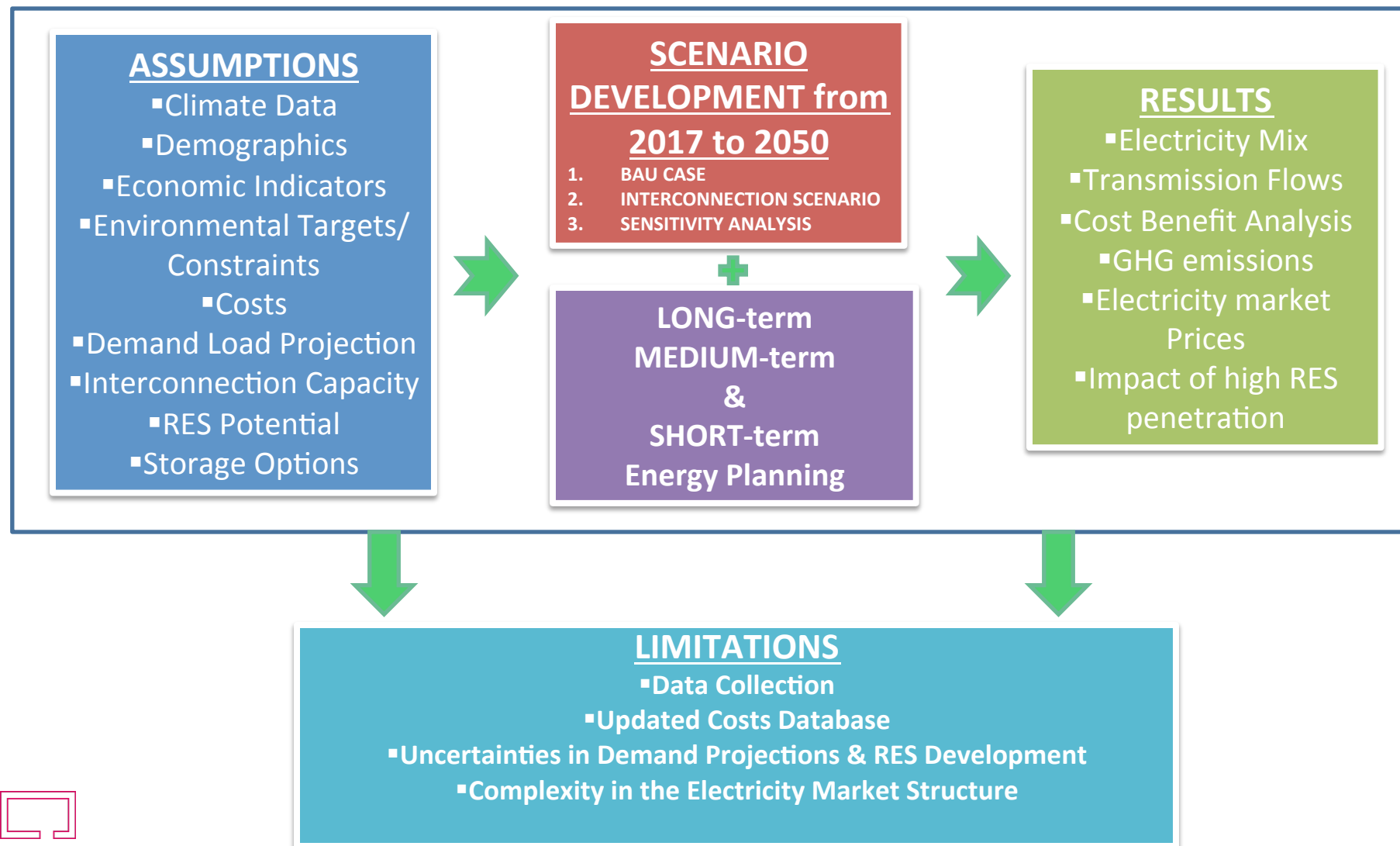
Source: E. Zafeiratou (2016)



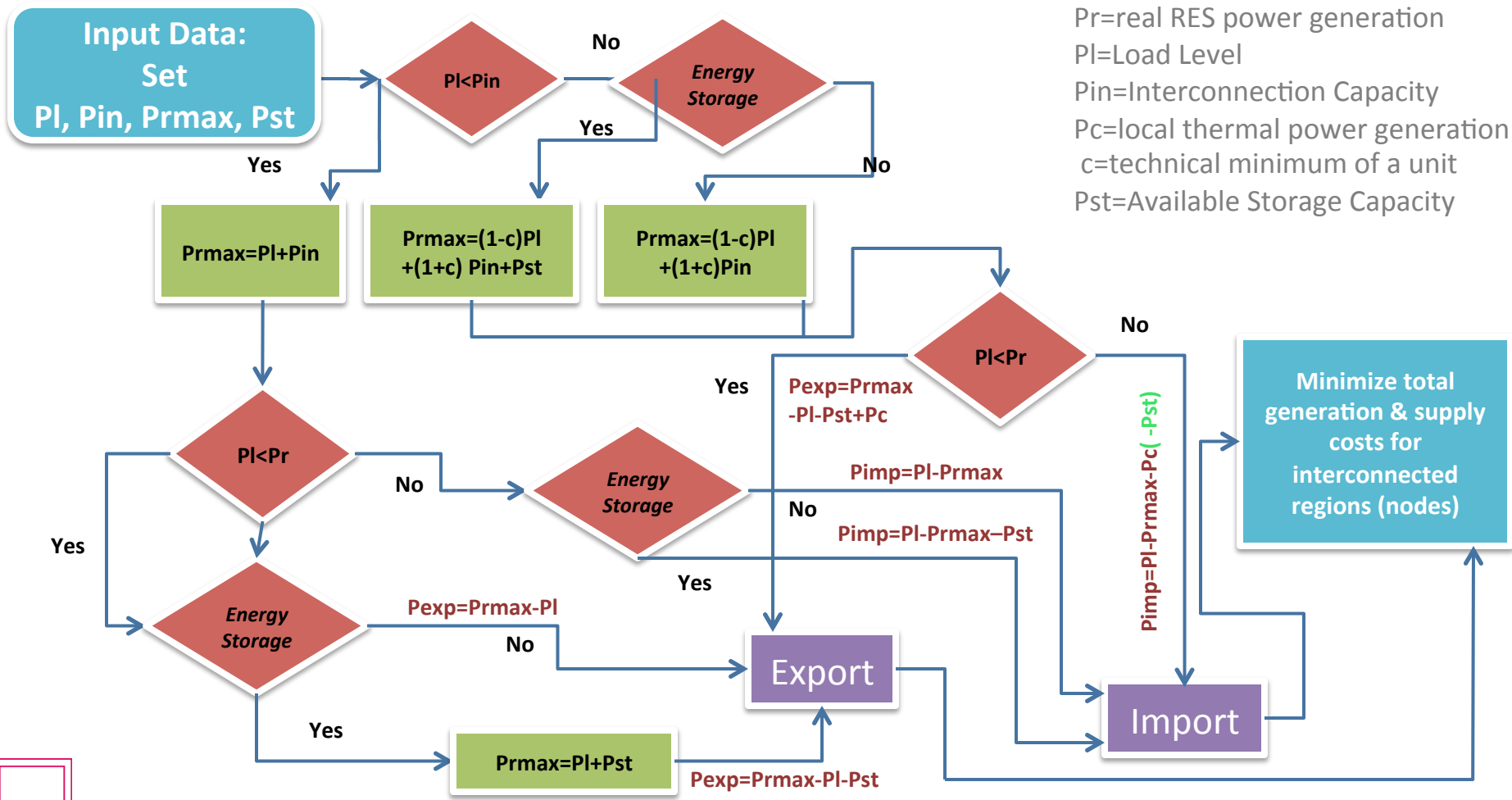
SYSTEM ANALYSIS & ENERGY TRILEMMA



INTEGRATED MODELING TOOL STRUCTURE



INTEGRATED MODELING TOOL SHORT TERM OPERATION PLANNING

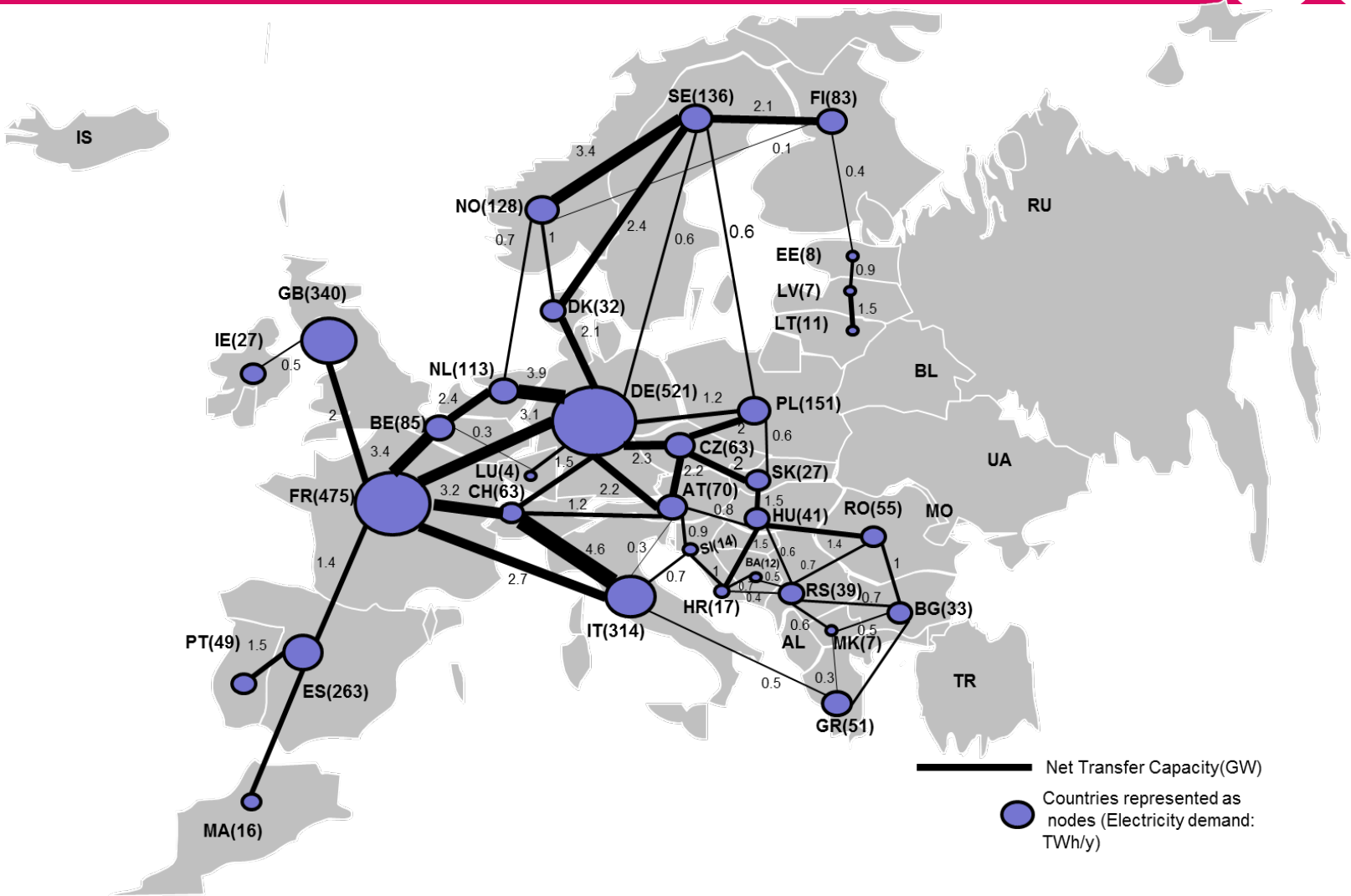


Where:
 $Prmax$ =RES Power Integration Limit
 Pr =real RES power generation
 PI =Load Level
 Pin =Interconnection Capacity
 Pc =local thermal power generation
 c =technical minimum of a unit
 Pst =Available Storage Capacity



INITIAL RESULTS

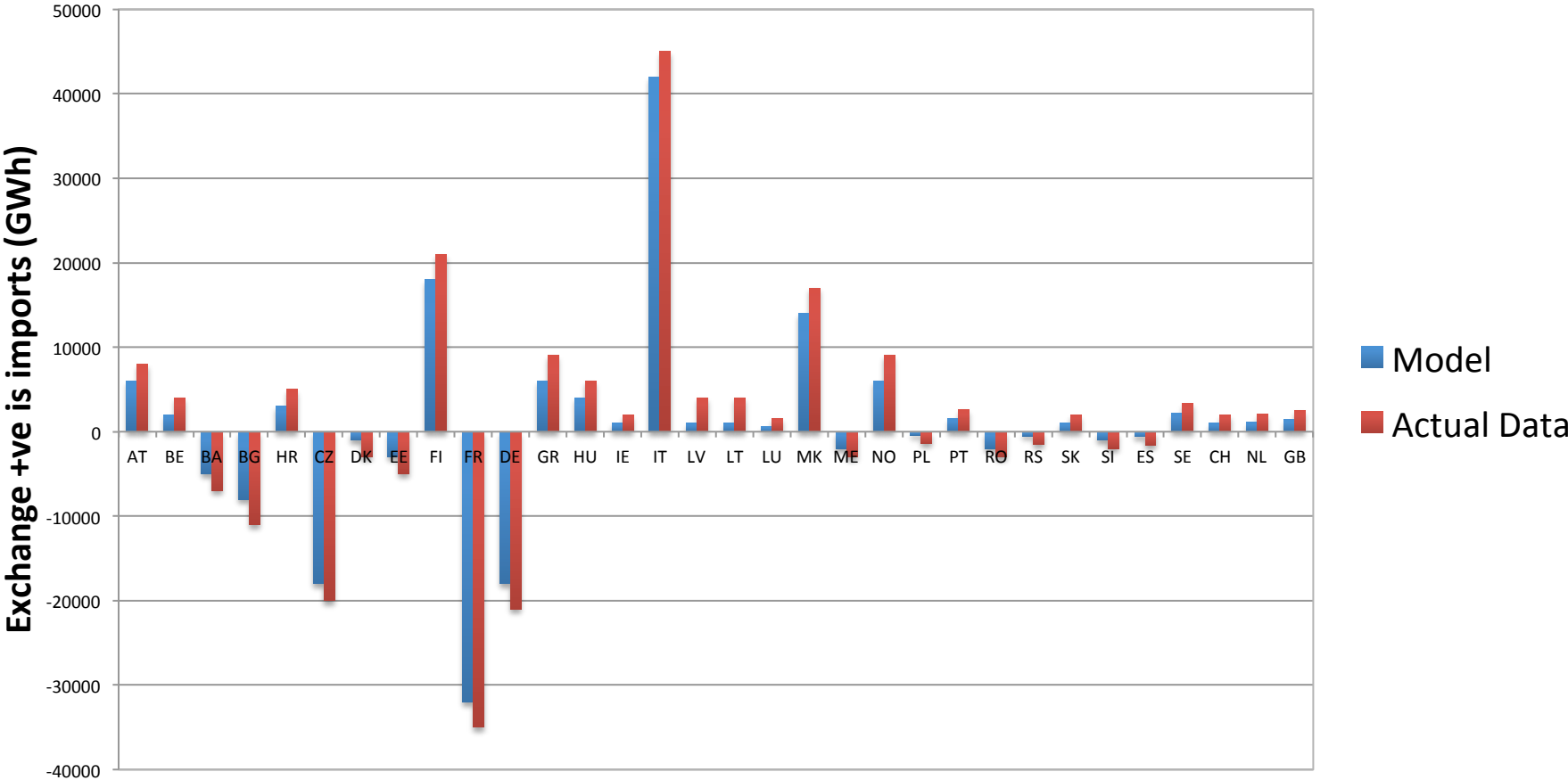


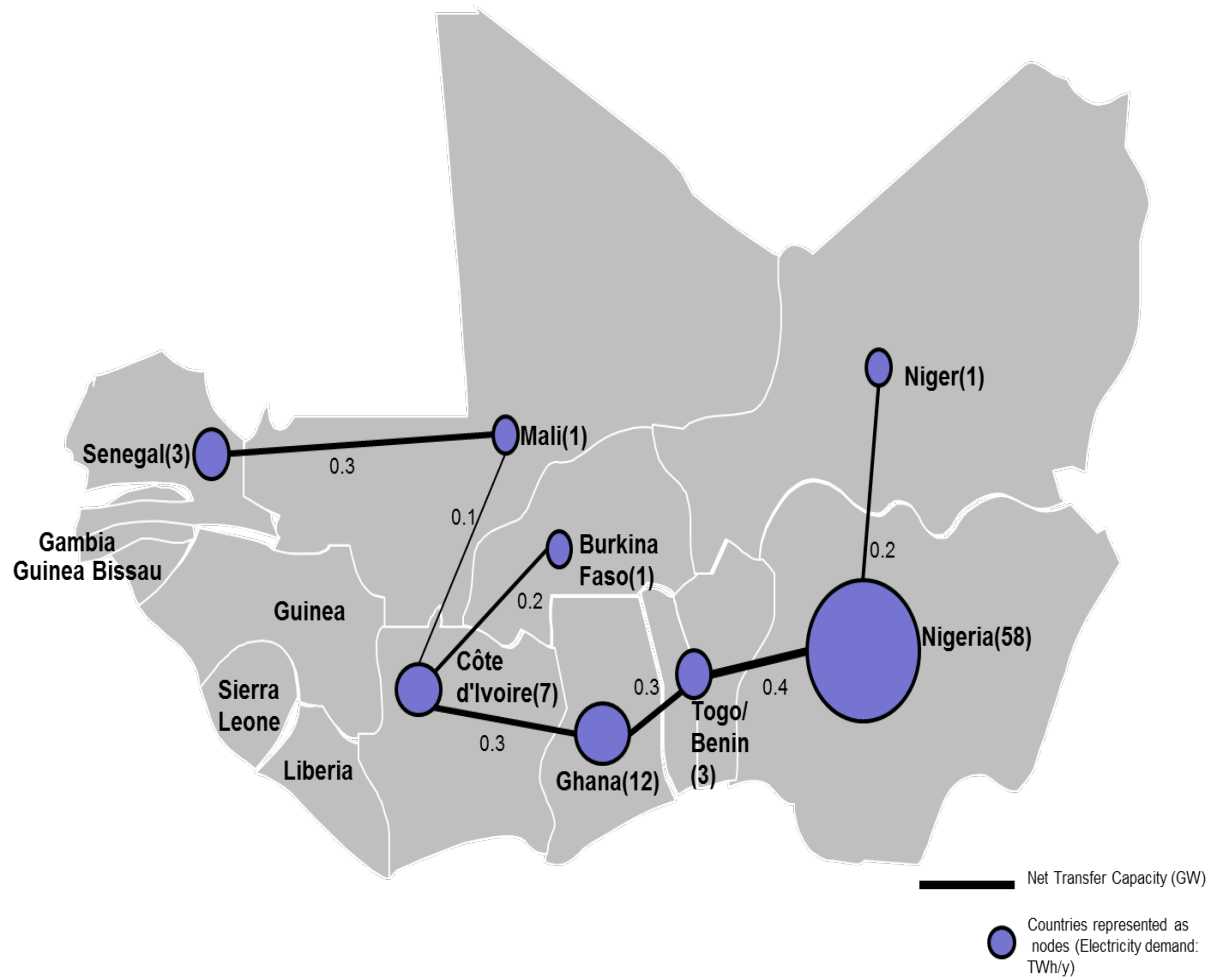


Net transfer capacity for EU



Results - Annual Net electricity exchange per country in Europe (Model Results and ENTSOE-E Statistics data)



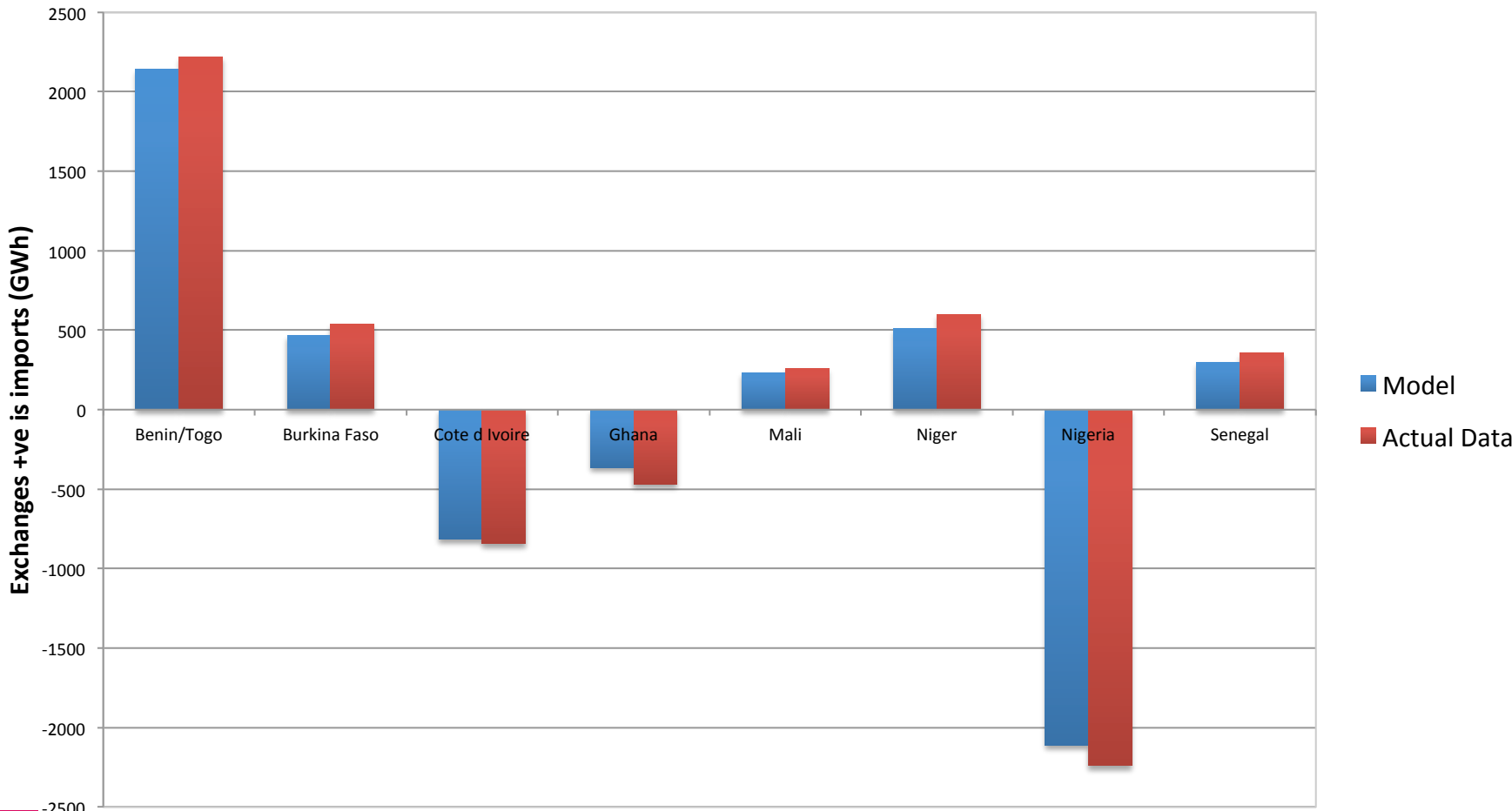


- 8 Nodes
- 7 Interconnectors
- Aggregated generating and transmission capacity
- Time Step: Hourly (8760hr/year)
- Time Horizon :2015

Net transfer capacity in West Africa

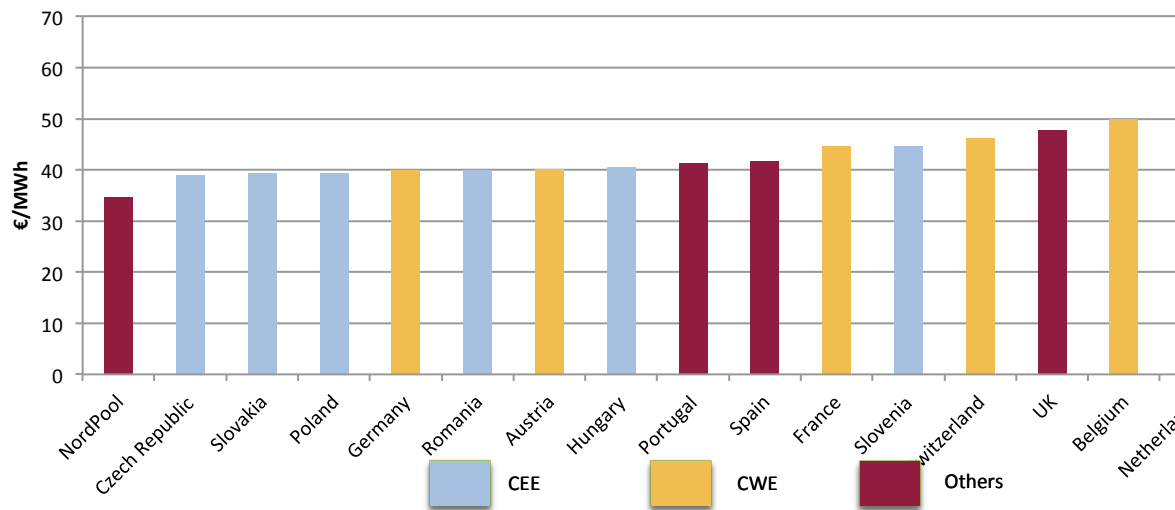


Results - Annual Net electricity exchange per country in West Africa



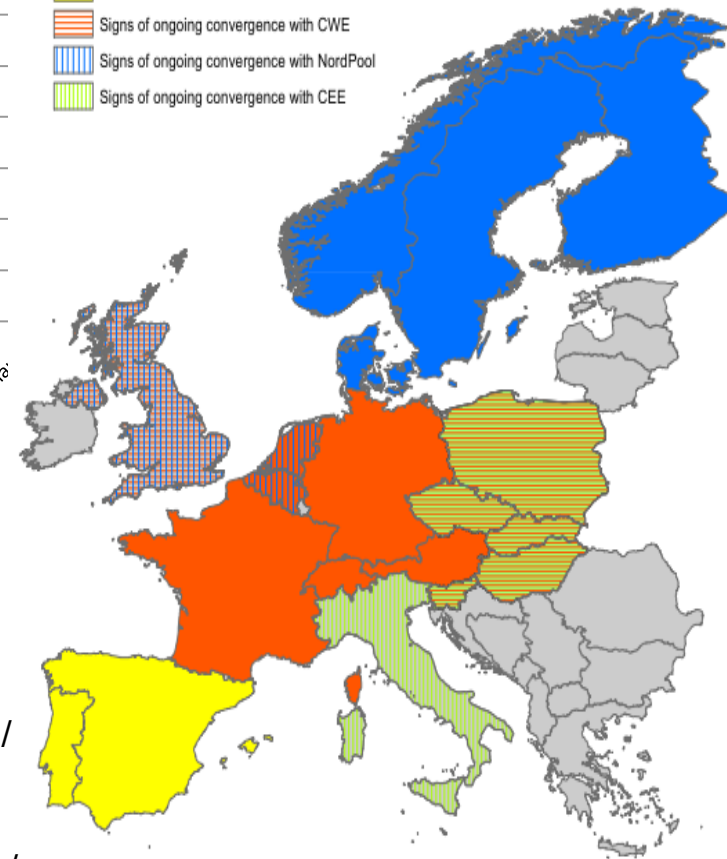
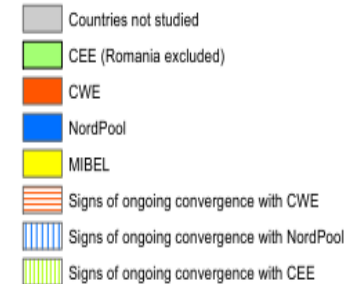
MARKET COUPLING EUROPE

Average of electricity prices in European countries between July 2012 and June 2014



- Low price in NordPool thanks to its hydro reserves
- High price in Italy because of high share of fossil fuels in its electricity mix and isolation
- 4 regional markets well integrated: CWE, CEU, Nordic Countries, Spain/Portugal
- Sign of convergence between CWE and CEE (13 pairs CWE/CEE with a correlation coefficient higher than 0.77)
- Italy is still in isolation
- The UK shows sign of correlation with NordPool and Belgium/Netherlands

Regions of price convergence in 2013



Ouriachi, A., Spataru, C. 2015

CONCLUSIONS

- The European Union has done significant work for the deployment of RES. However, there is no single best support mechanism that will work in all member states, because of the different resources and internal markets.
- Support mechanisms are evolving and as a result renewable energy will be more competitive and this will result in phasing out the support instruments once RES will be introduced to the real market.
- There is an obvious but expensive need to reinforce the interconnected grid in Europe
- One of the challenges currently facing market coupling in Europe is congestion management due to increasing electricity supply especially from RES ,this challenge holds an opportunity for West Africa region to account for sufficient capacities as extensions to national and cross-border transmission infrastructures are been planned
- The methodology can be applied to other regional case studies, such as South America, MENA countries

