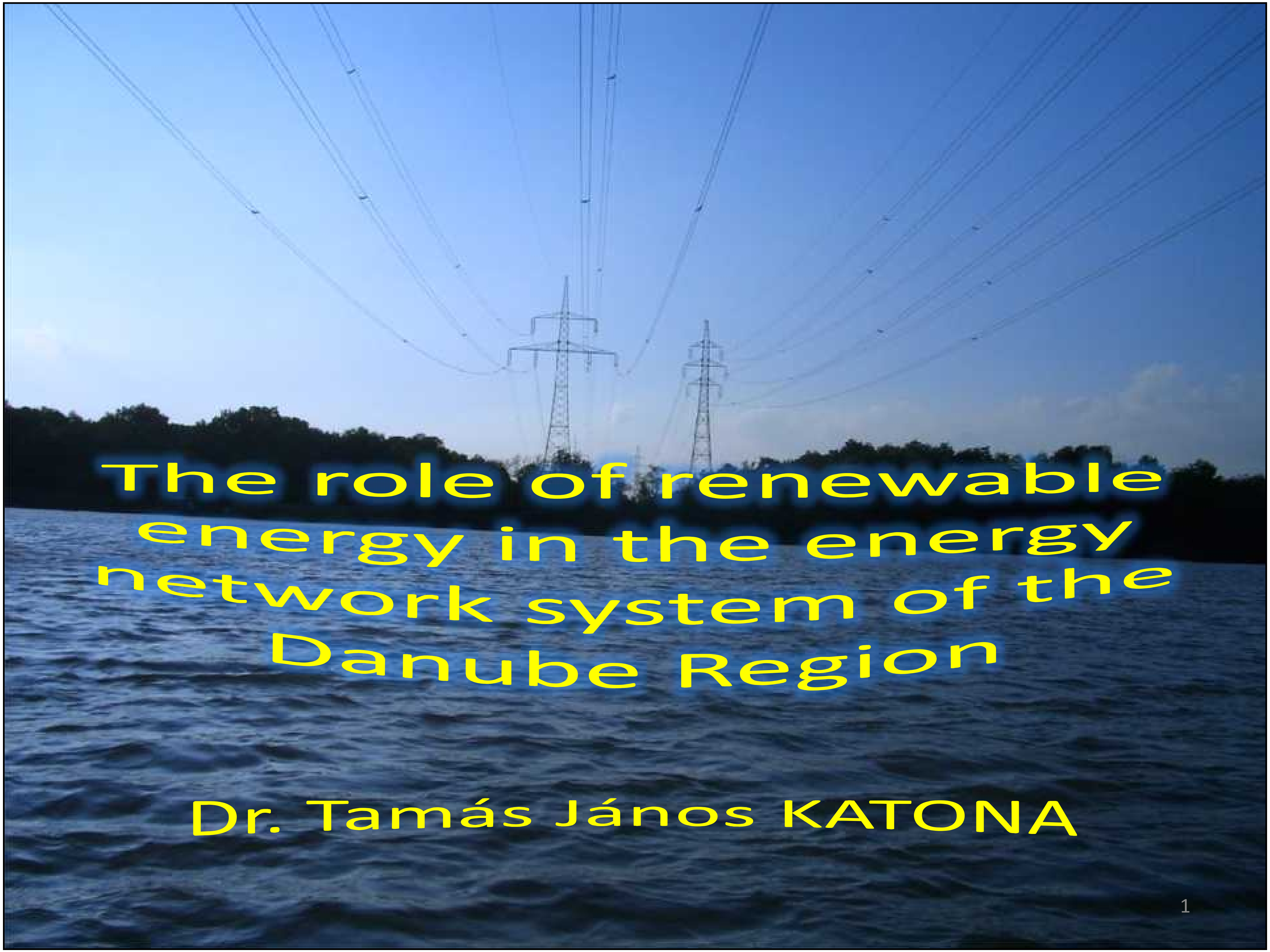
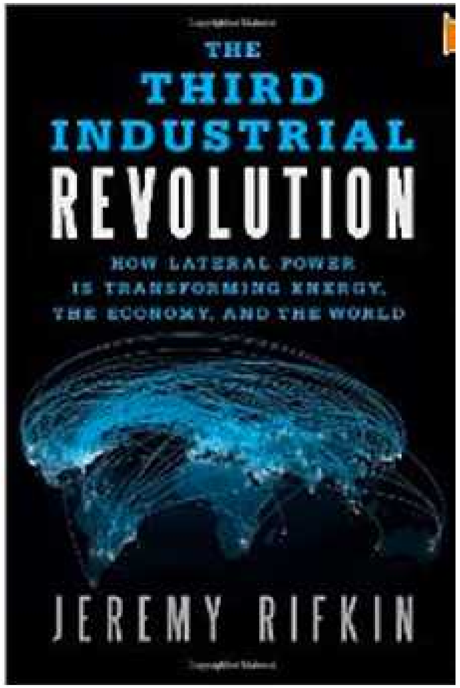


The role of renewable energy in the energy network system of the Danube Region

Dr. Tamás János KATONA

Vision or technological determinism

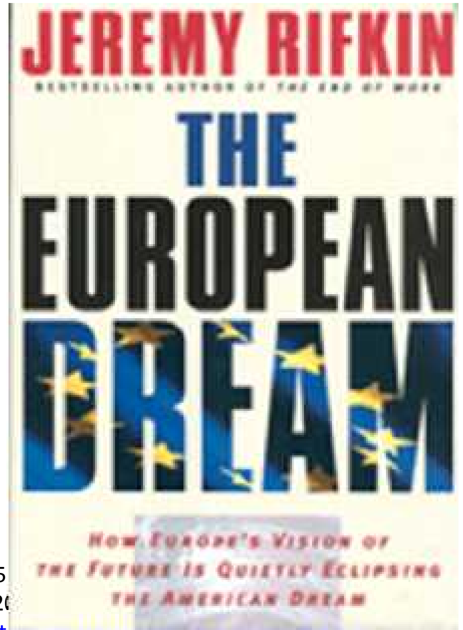


Rifkin's hypothesis : *The great economic revolutions in history occur when new communication technologies converge with new energy systems.*

Today, ***Internet technology*** and ***renewable energies*** are beginning to merge to create a new industrial infrastructure for a Third Industrial Revolution that will change the way power is distributed in the 21st century.

In the coming era, hundreds of millions of people will produce their own green energy in their homes, offices, and factories and share it with each other in an **"Energy Internet,"**- a distributed smart grid- just like we now generate and share information online. …

The democratization of energy will also bring with it a fundamental reordering of human relationships, impacting the very way we conduct business, govern society, educate our children, and engage in civic life.



Rifkin J. (2005): The European Dream: How Europe's Vision of the Future Is Quietly Eclipsing the American Dream, Tarcher, ISBN 978-158542435
Rifkin J. (2011): The Third Industrial Revolution: How Lateral Power Is Transforming Energy, the Economy, and the World, Palgrave Macmillan, 2(
Rifkin J. (2012): Industrial Policy Communication Update, A Contribution to Growth and Economic Recovery, http://ec.europa.eu/enterprise/initiatives/mission-growth/files/jeremy-rifkin-industrial-policy-communication-update-executive-summary_en.pdf

Vision

The five pillars of the Third Industrial Revolution are

(1) shifting to renewable energy;

(2) transforming the building stock of every continent into green energy efficient micro–power plants to collect renewable energies on-site;

(3) deploying hydrogen and other storage technologies in every building and throughout the infrastructure to store intermittent energies;

(4) using *Internet technology* to transform the power grid of every continent into an energy Internet - a distributed smart grid - that acts just like the Internet (when millions of buildings are generating a small amount of energy locally, on-site, they can sell surplus back to the grid and share electricity with their continental neighbors); and

(5) transitioning the transport fleet to electric plug-in and fuel cell vehicles that can buy and sell electricity on a smart, continental, interactive power grid.

"Europe is still lacking the infrastructure to enable renewable energy to develop and compete on an equal footing with traditional sources."

If one-third of electricity will be generated from green sources by 2020, the power grid must be digitalized and made intelligent to handle the intermittent renewable energies being fed to the grid from tens of thousands of local producers of energy.

The European Union would need significant allocation of funds between 2010 and 2020 to update its electricity grid in order to accommodate an influx of renewable energy.

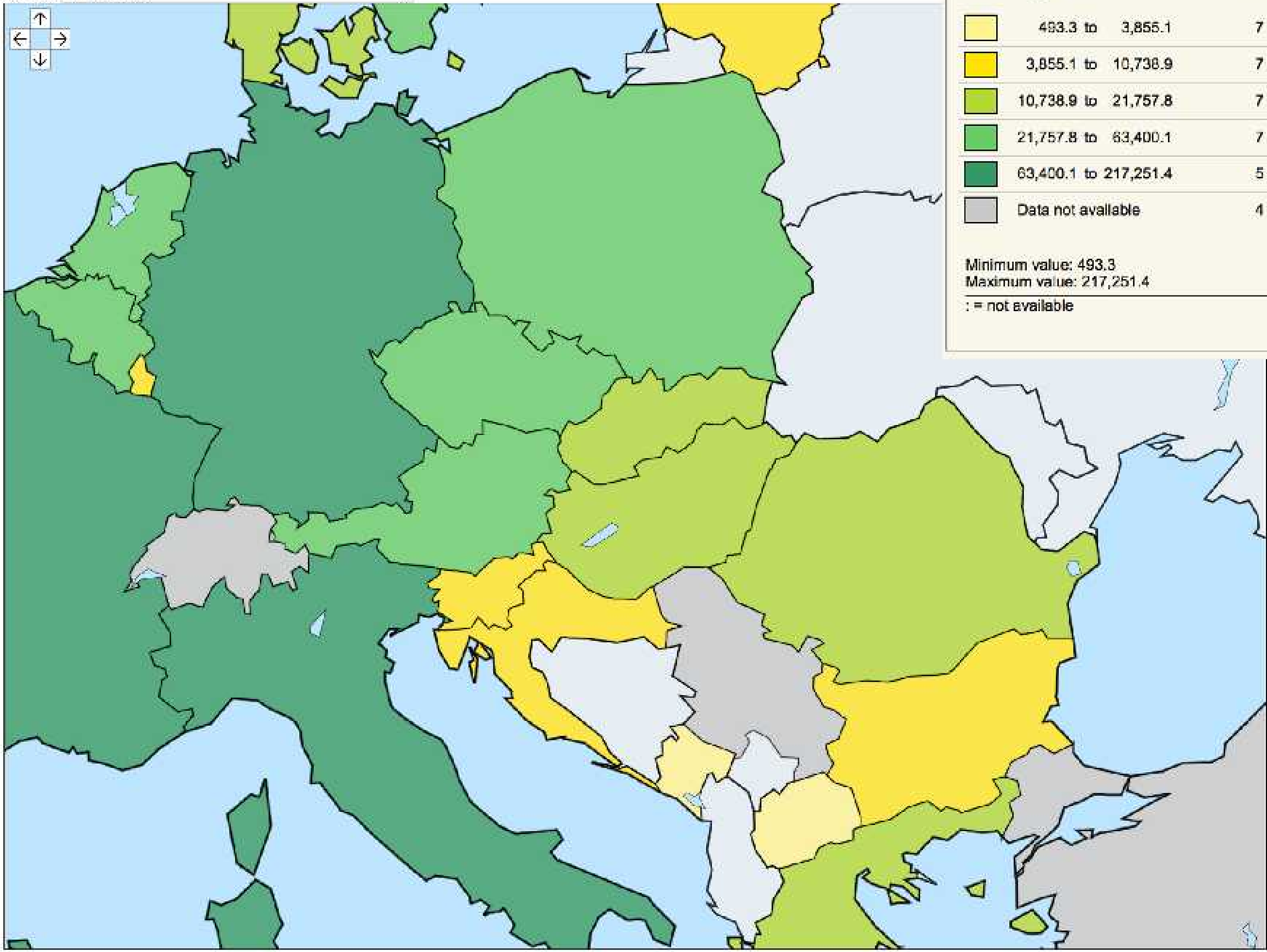
Rifkin J. (2012): Industrial Policy Communication Update, A Contribution to Growth and Economic Recovery

Final energy consumption by product

1 000 tonnes of oil equivalent

Final energy consumption includes all energy delivered to the final consumer's door (in ... more

product All products



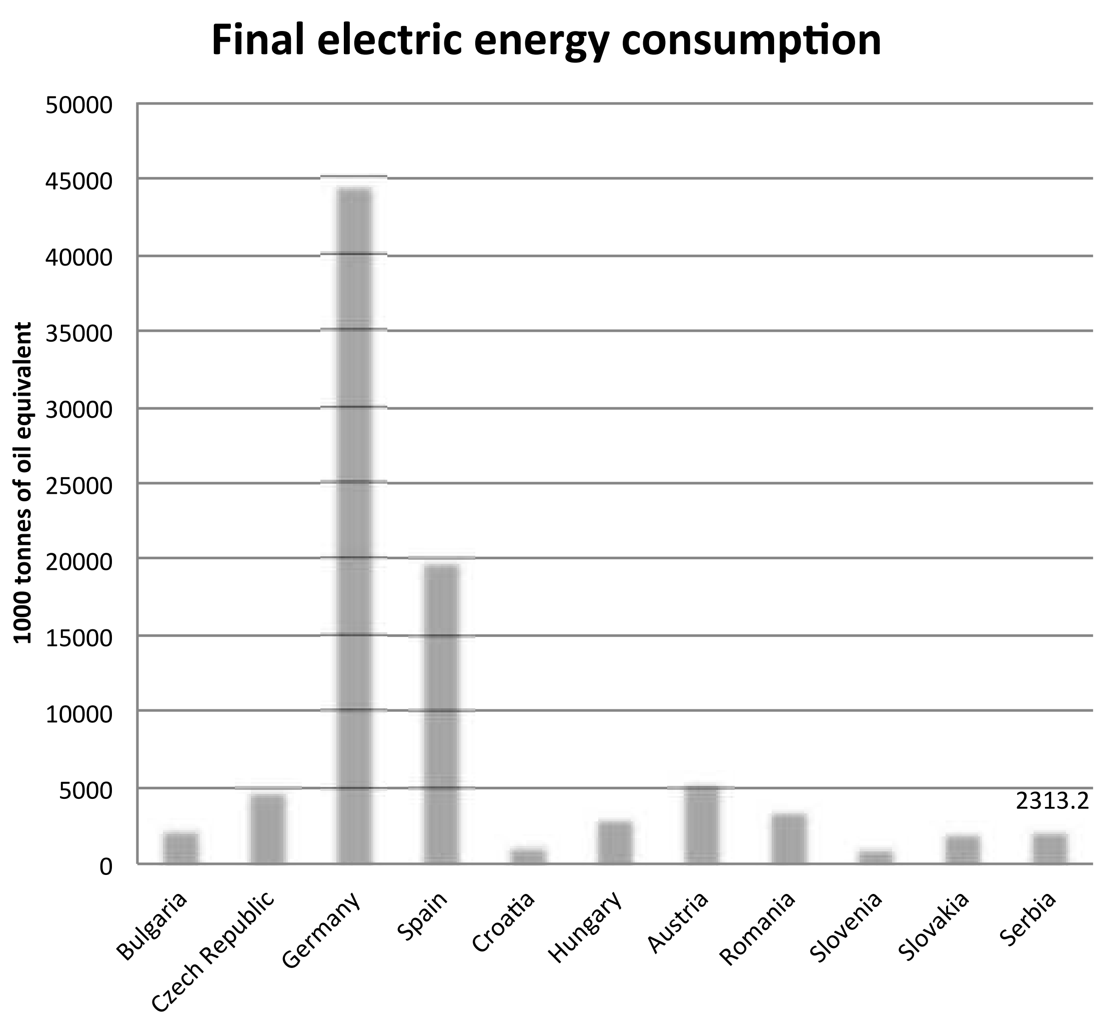
Data for 2013

Legend		Cases
	493.3 to 3,855.1	7
	3,855.1 to 10,738.9	7
	10,738.9 to 21,757.8	7
	21,757.8 to 63,400.1	7
	63,400.1 to 217,251.4	5
	Data not available	4

Minimum value: 493.3
Maximum value: 217,251.4

: = not available

Specific vision – Danube region



In spite of energy saving measures and decreasing of the energy intensity of the national economies **the desired development of the Danube region countries will result in increase of energy consumption and much more in the increase of the electric energy consumption.**

The energy system has to comply with certain critera.

The energy system

- reliable
- affordable
- sustainable

- reliable, when
  - secure
  - adequate

Reliability is an attribute of any system that consistently performs according to its specifications.

Reliability encompasses two concepts, *adequacy* and *security*.

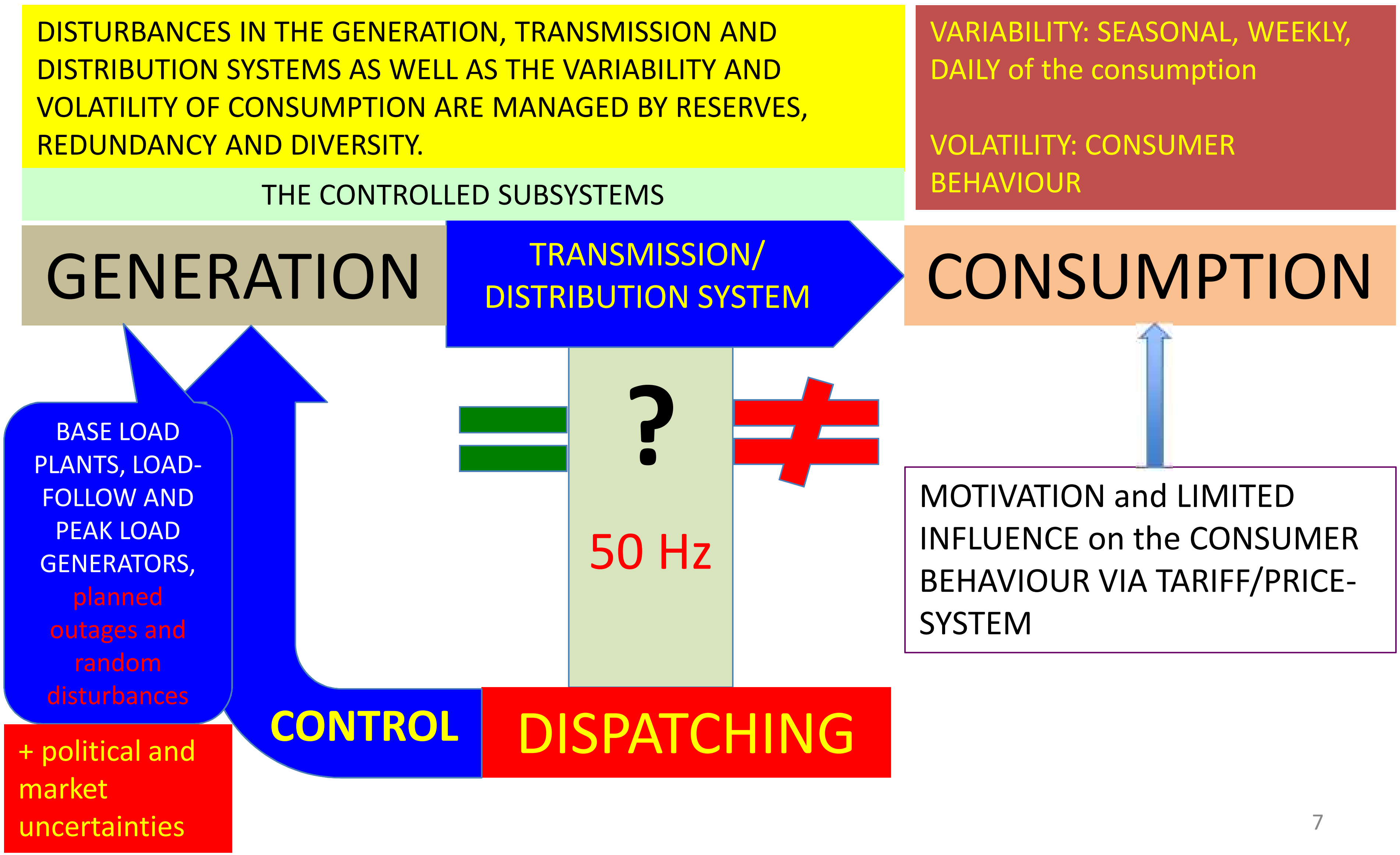
Adequacy implies that there are sufficient generation and transmission resources installed and available to meet projected electrical demand plus reserves for contingencies.

Security implies that the system will remain intact operationally (i.e., will have sufficient available operating capacity) even after outages or other equipment failure (or geopolitical crises).

The degree of reliability may be measured by the frequency, duration, and magnitude of adverse effects on consumer service.

Electric power system reliability: The degree to which the performance of the elements of the electrical system results in power being delivered to consumers within accepted standards and in the amount desired.

The classical system



The **Northeast blackout of 1965** was a significant disruption in the supply of electricity on Tuesday, November 9, 1965, affecting parts of Ontario in Canada and Connecticut, Massachusetts, New Hampshire, Rhode Island, Vermont, New York, and New Jersey in the United States. **Over 30 million people and 80,000 square miles (207,000 km^2) were left without electricity for up to 12 hours.**

The cause of the failure was human error that happened days before the blackout. **Maintena personnel incorrectly set a protective relay on one of the transmission lines between the Niagara generating station Sir Adam Beck Station No. 2 in Queenston, Ontario.**
The safety relay, which was to trip if the current exceeded the capacity of the transmission line, was set too low.
As was common on a cold November evening, power for heating, lighting and cooking was pushing the electrical system to near its peak capacity.
WIKIPEDIA

Northeast blackout repeated in 2003

European blackout (Saturday, November 4, 2006). More than 15 million clients of the European Network of Transmission System Operators for Electricity didn't have access to electricity during about two hours. The immediate action taken by the Transmission System Operators (TSO) prevented the disturbance to turn into a Europe-wide blackout.

Attributes of a „good" system

- Robust infrastructure
- Redundancy; several parallel solutions for one function
- Diversity:
  - markets/sources,
  - transmission lines, pipelines,
  - technologies ;
- Adaptive, developed internal connections
- Regional cooperation, interconnections
- Reliable and strong storage capacity

- More intense cooperation and solidarity steps among neighboring states
- Competitive energy markets(?)

STAKEHOLDER ENGAGEMENT

Stakeholder contributions play an essential part in the development of all main ENTSO-E deliverables, including network codes, network development plans, work programmes and R&D roadmaps. Consultation with stakeholders is far more than a mandatory requirement – stakeholder expertise is indispensable to draft sound, well critiqued and acceptable proposals. Stakeholder engagement is ensured through numerous informal meetings with individual stakeholders or stakeholder groups, and formal web-based consultations and consultation workshops.

ENTSO-E IN FIGURES

41 transmission system operators across **34** European countries

The geographical area covered by ENTSO-E member TSOs is going beyond the EU

532 million customers served by the represented TSOs

This corresponds to the world's biggest economic area, roughly on par with the USA

307,503 km of transmission lines managed by TSOs required to keep the lights on in Europe

which, if laid out would circle the earth's circumference more than 7 times

3,307.9 TWh electricity consumption in 2013

This accounts for almost 15% of the world's total electricity consumption in 2013 [1)]

387,251 GWh of electricity exchange between member TSOs in 2013

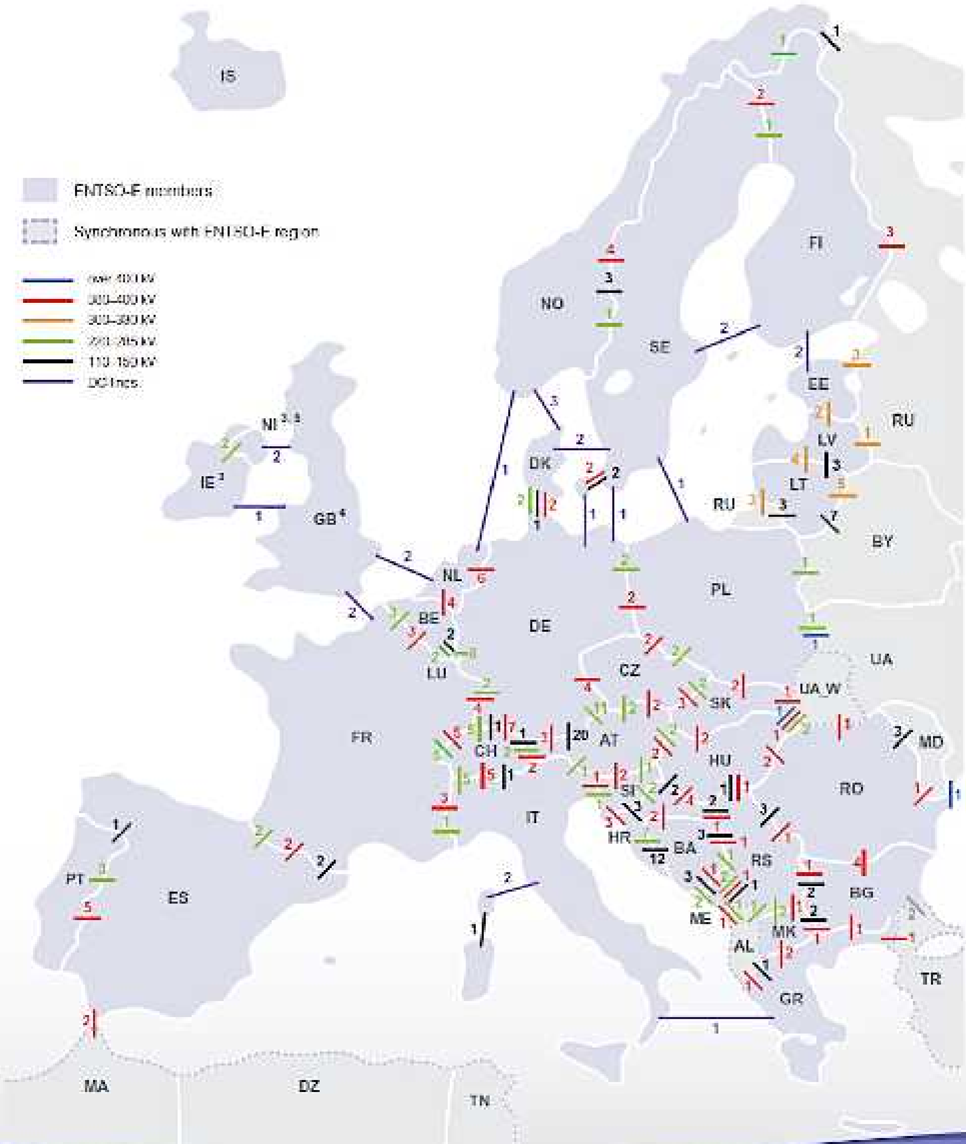
This is over 4 times the yearly production capacity of the largest power plant in the world – the Three Gorges Dam in China [2)]

1,004,062 MW net generation capacity

This is roughly as much as in the US or China and one fifth of the world's installed generation capacity [3)]

1) Based on figures from the World Energy Council, World Energy Resources Survey 2013
2) Based on figures from www.cleanenergyactionproject.com
3) Based on figures from http://www.sp-data-portal.org/10-120-CapacityMapOvChart

Grid information



Number of circuits on cross-frontier transmission lines as of 31 December 2013 in the ENTSO-E area[1,2]

ENTSO-E Overview circuit length in km

	Length of AC circuits	of which AC cable	Sum of DC cable
220–285 kV	111350	3230	
330 kV	9141	14	
380/400 kV	151272	1512	
750 kV	471	0	
Sum	302243	4756	5200

Number of cross frontier lines in the ENTSO-E area

	AC	DC
Over 400 kV	7	7
380–400 kV	116	4
300–330 kV	18	
200–285 kV	89	10
110–150 kV	88	1
Under 110 kV	1	
Sum	319	22

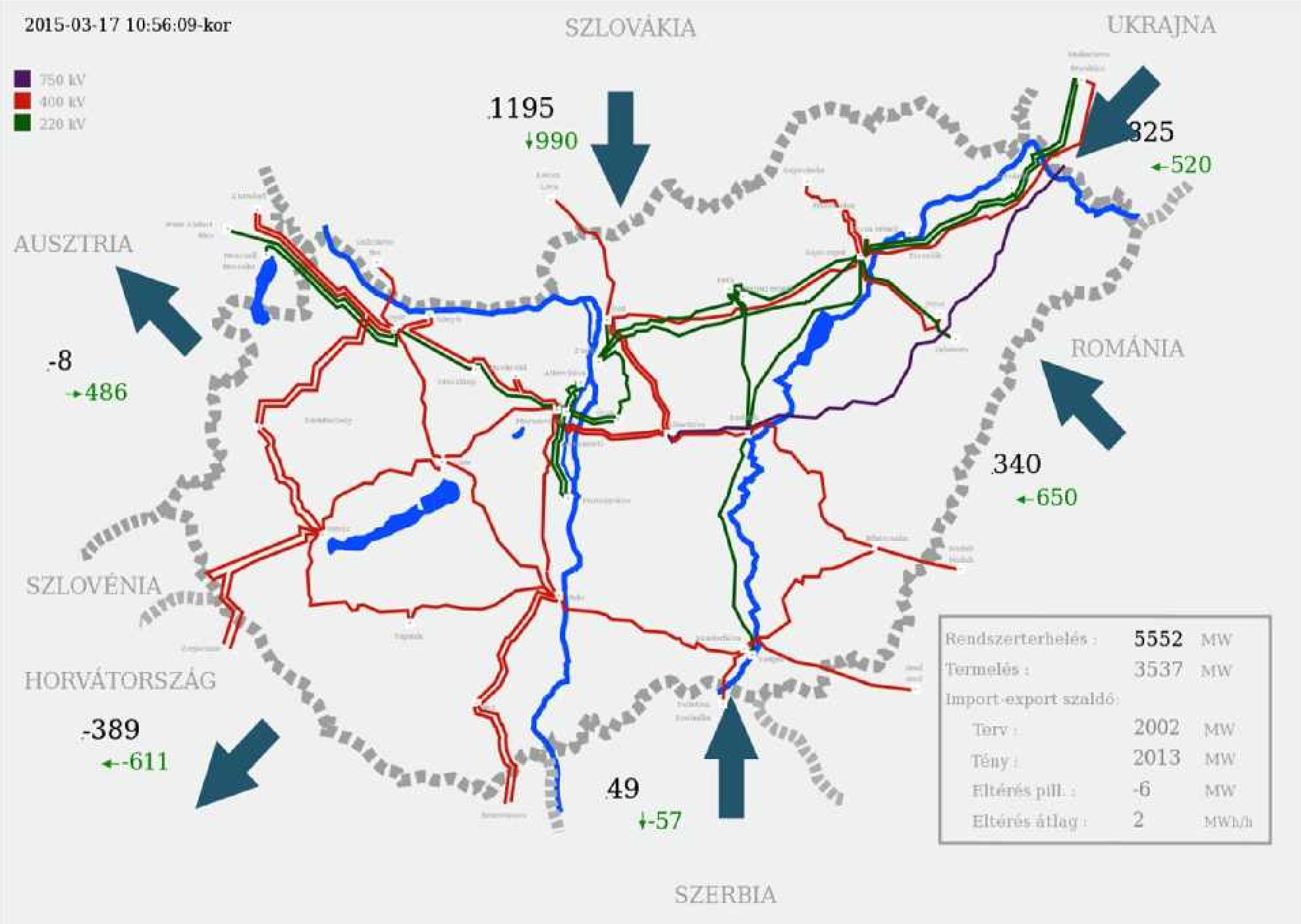
[1] Non geographic location of lines.

[2] Between IE and NI 275kV instead 220kV.

[3] Only lines operated by TSOs are taken into account.

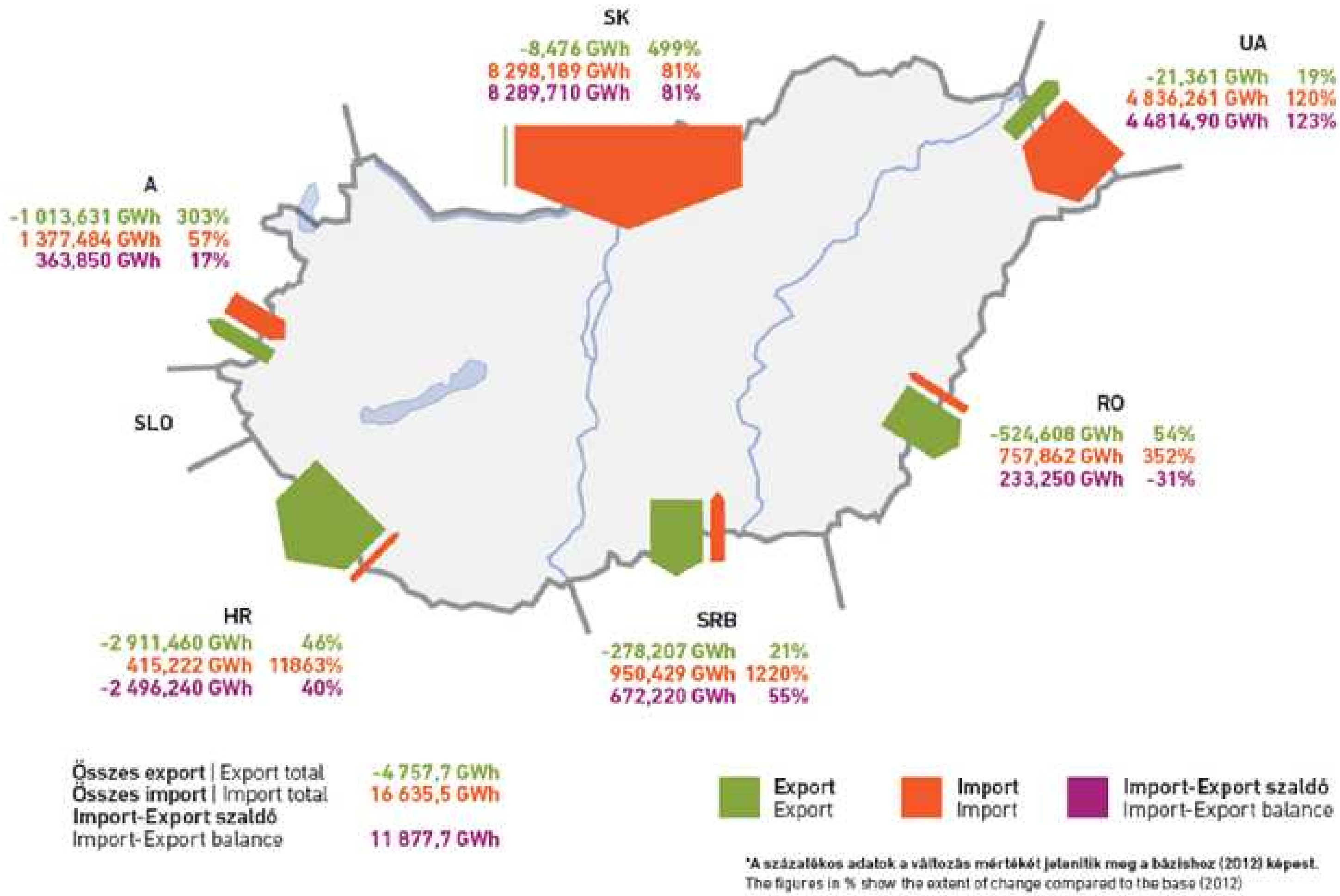
[4] All data with the country code GB represents monthly statistical data as sum of England, Scotland and Wales.

[5] All data with the country code NI represents the monthly statistical data GB Northern Ireland.



2015-03-17 10:56:09-kor
750 kV
400 kV
220 kV
SZLOVÁKIA
UKRAJNA
AUSZTRIA
ROMÁNIA
SZLOVÉNIA
HORVÁTORSZÁG
SZERBIA
1195
990
325
520
-8
486
340
650
-389
-611
49
-57
Rendszerterhelés : 5552 MW
Termelés : 3537 MW
Import-export szaldó:
Terv : 2002 MW
Tény : 2013 MW
Eltérés pill. : -6 MW
Eltérés átlag : 2 MWh/h

Cross-border electric energy transfer 2013



courtesy of Dr. ASZÓDI Attila

Source: Mavir (2014): Data of the Hungarian Power System 2013

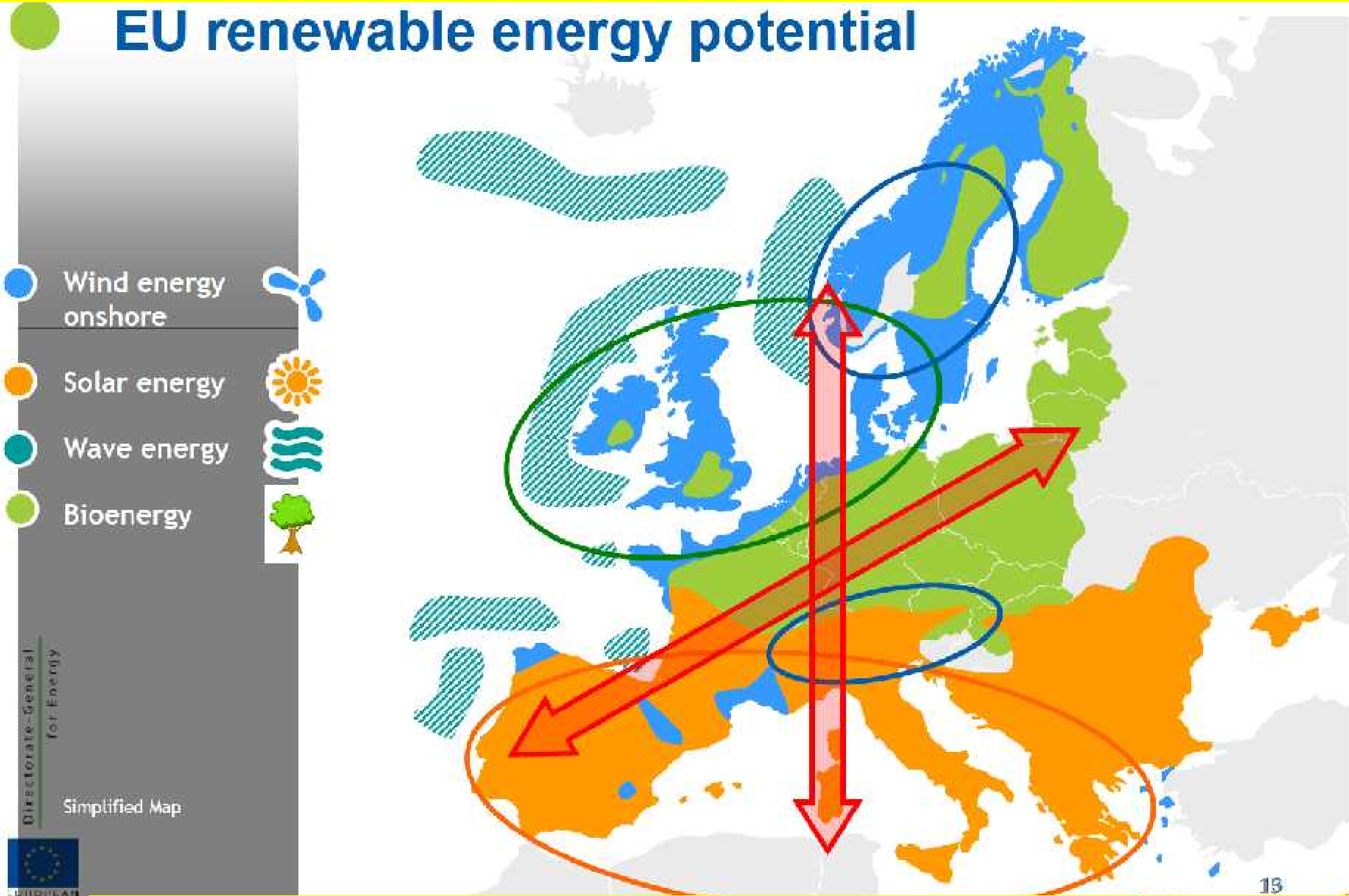
Effect of the increasing utilization of renewable energy sources on the reliability

Increased share of renewables in the energy mix - positive effects:

- decrease import dependency
- increase emission-free consumption

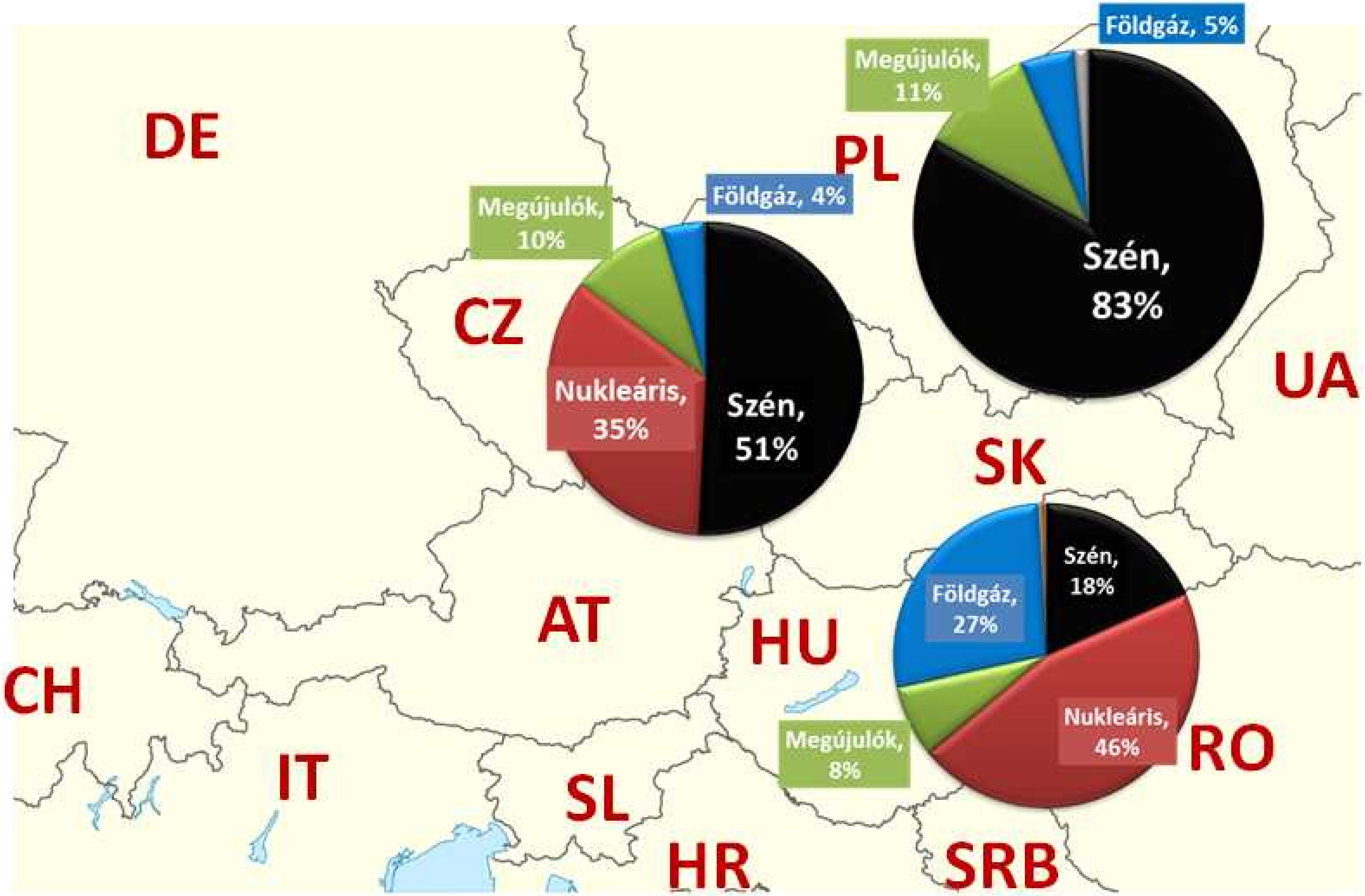
Robustness of the system improves with increasing RES since the RES are some kind of internal resources

RES does not run out, does not depend on the volatility of market and geopolitics (?), it depend mainly on God will



EU Energy Roadmap 2050, Institute of International and European Affairs, Dublin, Philip Lowe, Director General for Energy 10 November 2011

Primary sources of the power generation (2012)



courtesy of Dr. ASZÓDI Attila

source: EU energy in figures 2014

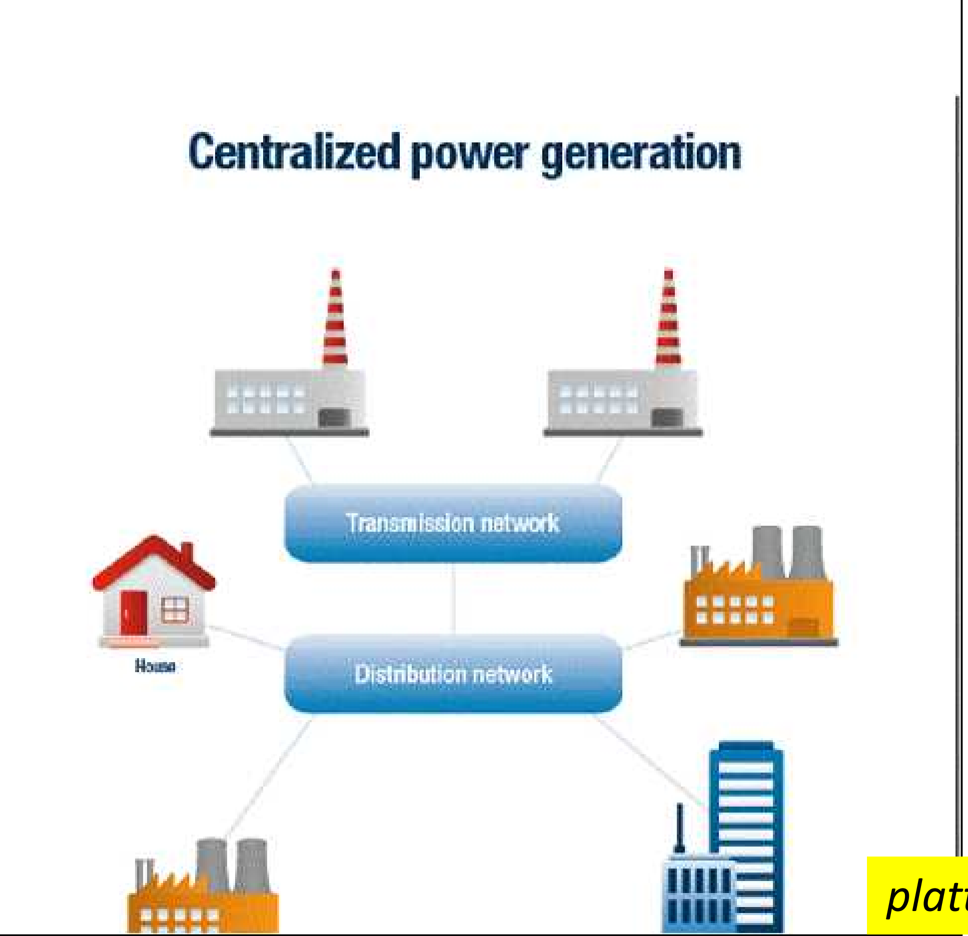
Conclusion 1

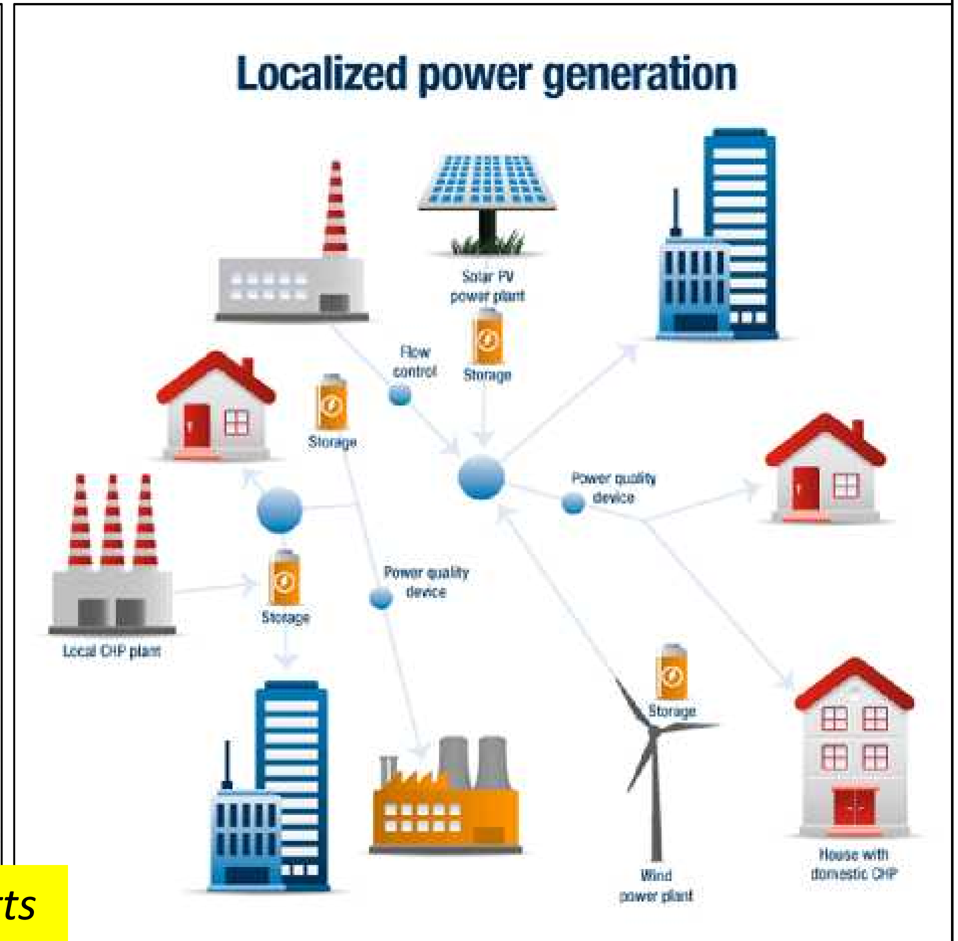
In the Danube region

Although the interconnections between national grids improve the reliability of supply, the interconnections of the power systems transmit electricity generated by burning coal

New era

500 million generators, 500 million consumers





platts

not only the consumption and market are variable and volatile, but the generators as well

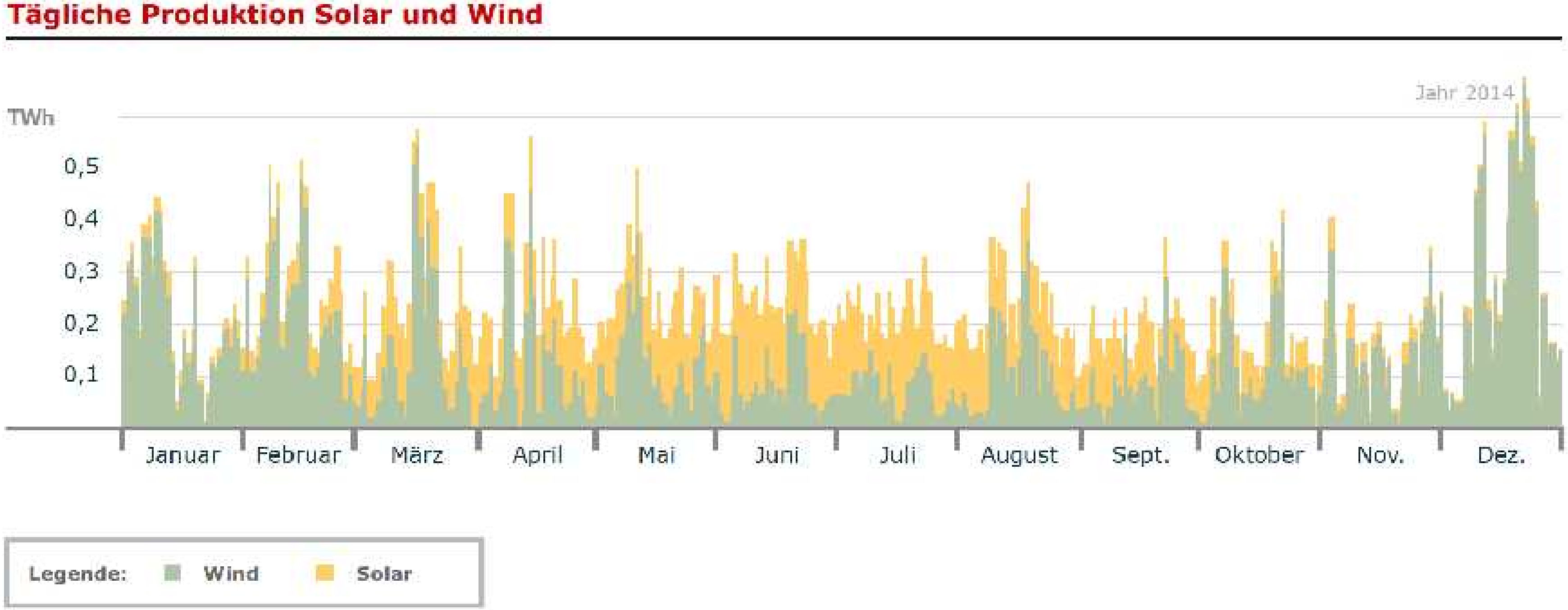
Challenges of the increasing utilization of renewable energy sources

Increased share of renewables in the energy energy mix:

- positive effects:
  - decrease import dependency
  - increase emission-free consumption
- issues to be solved
  - problems related to the intermittent generation
  - need of reliable base-load generation
  - need of storage
  - need of developed regional cooperation regarding reserves and storage

Conclusion 2 (trivial)
Integration of generation using renewables requires enormous effort in grid development.

Tägliche Produktion Solar und Wind



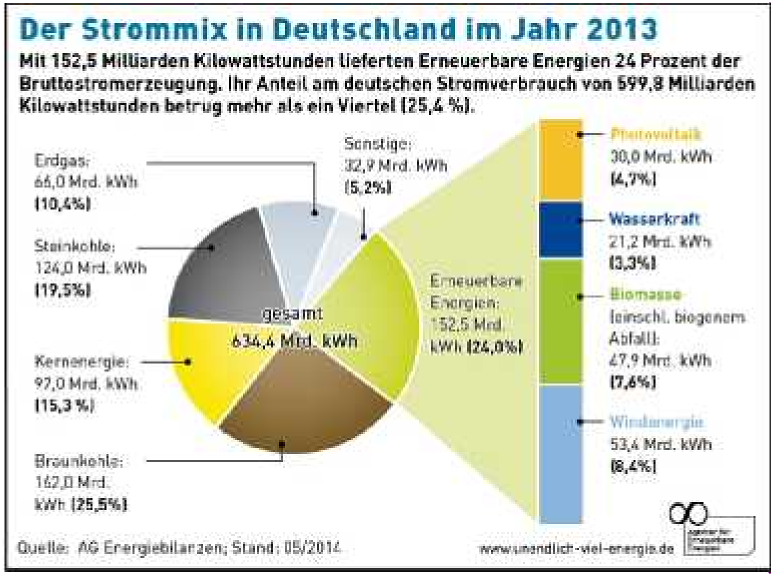
- Die maximale tägliche Summe der Stromproduktion aus Solar und Wind betrug 0,676 TWh am 22.12.2014
- Die minimale tägliche Summe der Produktion betrug 0,022 TWh am 21.01.2014

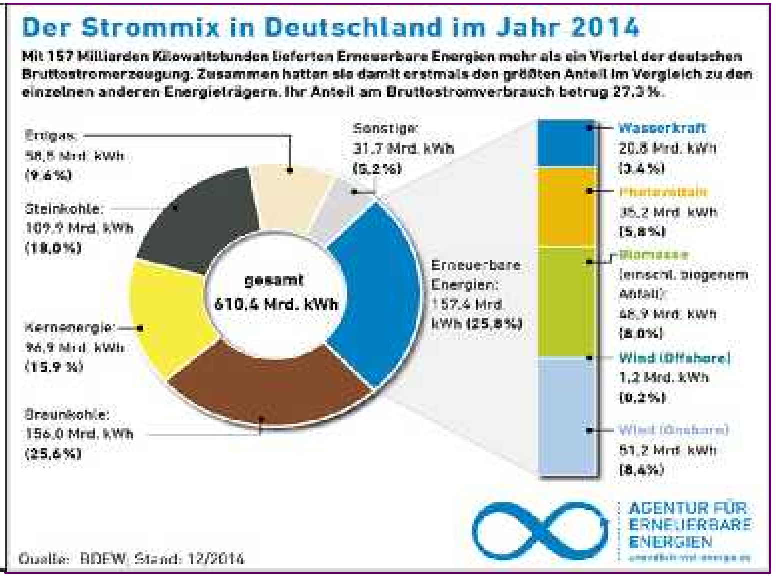
Grafik: B. Burger, Fraunhofer ISE; Daten: Leipziger Strombörse EEX

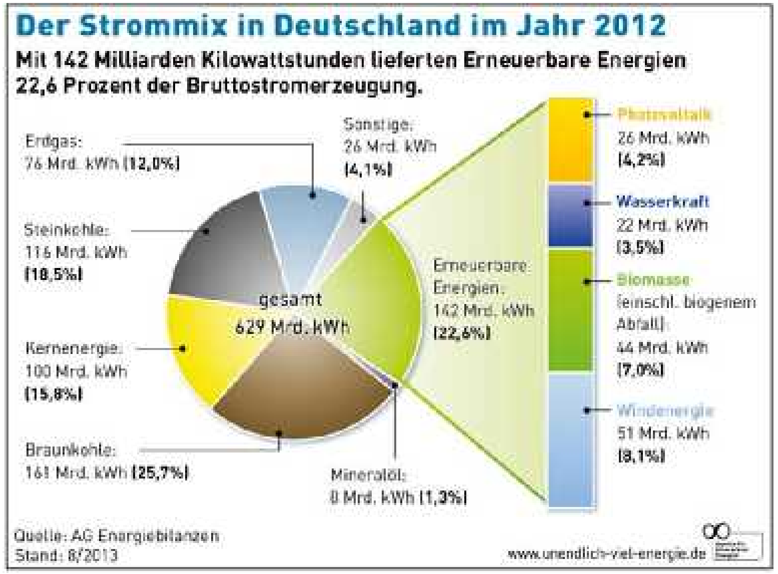
© Fraunhofer ISE

Fraunhofer ISE

"Unendlich viel Energie" case - Germany







2014: fossil 324400 GWh + nuclear 96900 GWh= 421300 GWh, i.e. 69% nonRES

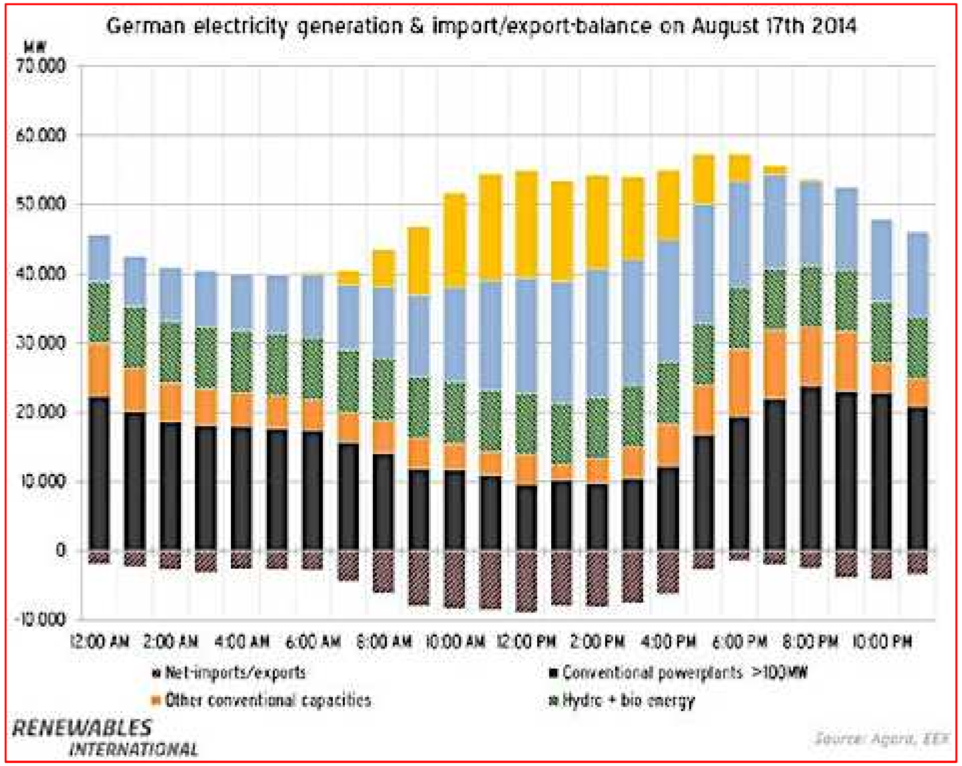
2013: fossil 352000 GWh + nuclear 97000 GWh= 449 000 GWh, i.e. 70,8% nonRES

2012: fossil 353000 GWh + nuclear 100000 GWh = 453 000 GWh, i.e. 73,3 % nonRES

Between 2012-2014 production of the base load plants in the system is nearly constant 59,3÷60,3% (±1%) while the production by RES increased by 3,2%.

WHY?

The best day of RES generation

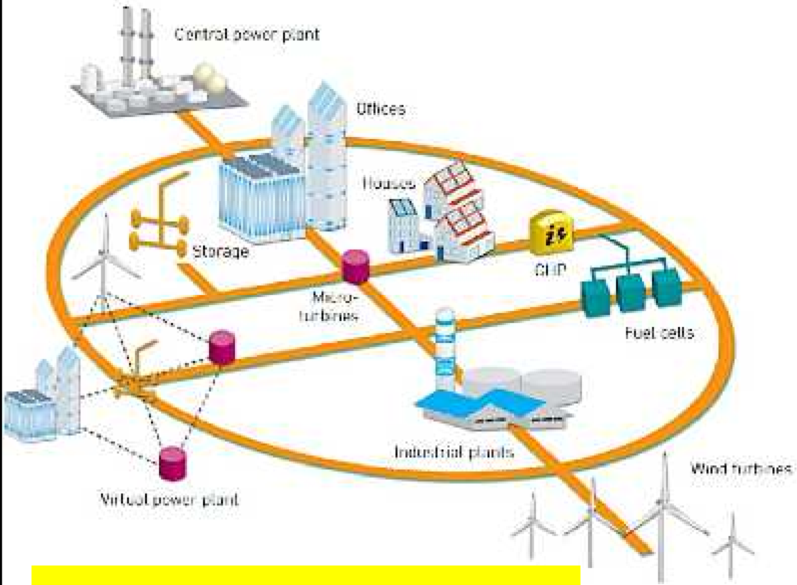


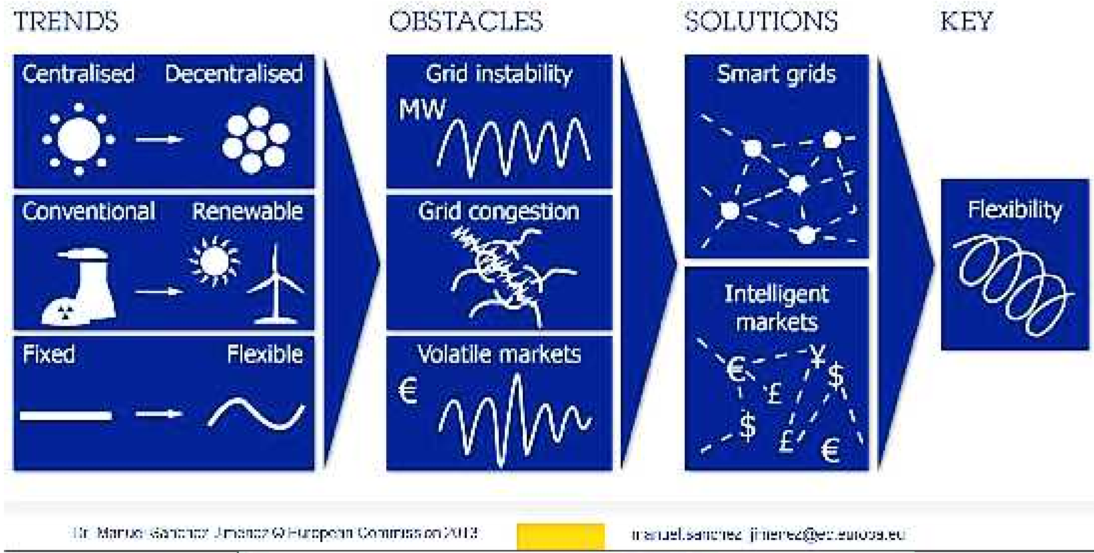
Aug 18 was a Sunday like any other in Germany. At 2 pm, the country's renewable generation capacity peaked at 41 GW while demand was around 53.5 GW – meaning that renewables accounted for roughly 75% of generation capacity, a new record for Europe's biggest economy. At the time of the peak, wind capacity stood at 18.6 GW, solar at 13.5, hydro at 4 with approx. 4.9 from biomass.

This meant that theoretically only 13.4 GW of conventional thermal generation was needed to serve the load. In reality, however, thermal plants were throttled back to 21.4 GW, either because they could not ramp down any further or for grid reliability reasons.

When the wind is blowing and the sun is shining, Germany is selling the excess electric power generated by the base-load coal fired plants, which could not be stopped because of the system stability.

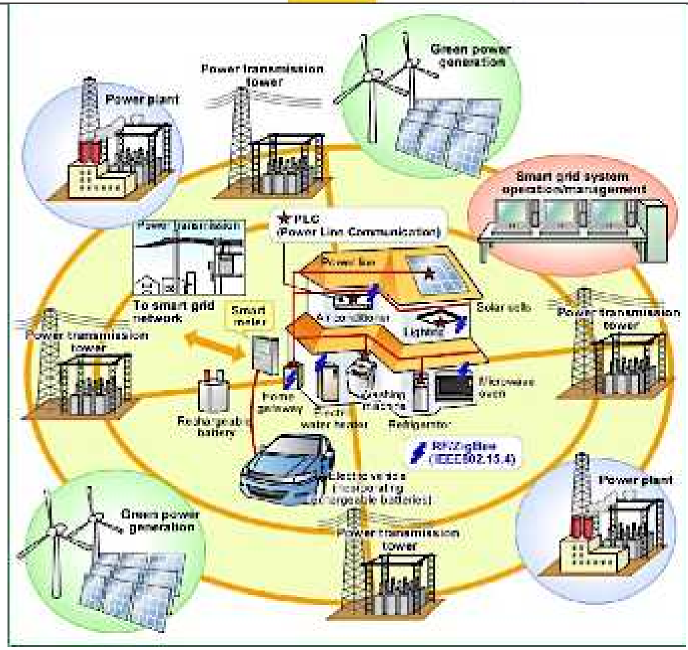
Renewable Energy Integration





Smart appliances
Smart households
Smart communities
Smart cities
Smart metering
Smart grid
Smart market

A new smarter mankind



Smart Grid

Principal smart grid functional characteristics

- Self-healing from power disturbance events
- Enabling active participation by consumers in demand response
- Operating resiliently against physical and cyber attack
- Providing power quality for 21st century needs
- Accommodating all generation and storage options
- Enabling new products, services, and markets
- Optimizing assets and operating efficiently

Smart grid that uses digital technology to improve reliability, resiliency, flexibility, and efficiency (both economic and energy) of the electric delivery system.

Storage options

Table 3: Existing and planned US energy storage technologies, split by capacity.

Storage technology	MW	%
Open-loop Pumped Hydro Storage	22545	78.9
Closed-loop Pumped Hydro Storage	4100	14.4
Molten Salt Thermal Storage	541	1.9
Compressed Air Storage	423	1.5
Lithium ion Battery	209	0.7
Lead-acid Battery	133	0.5
Chilled Water Thermal Storage	130	0.5
Electro-chemical	104	0.4
Flywheel	98	0.3
Thermal Storage	72	0.3
Ice Thermal Storage	64	0.2
Gravitational Storage	50	0.2
Flow Battery	39	0.1
Nickel based Battery	27	0.1
Sodium based Battery	23	0.1
Others/unspecified	13	0.1

Table 9: US energy storage applications, by capacity[12].

Application	Capacity (MW)	%	Technology categories
Electric Energy Time Shift	15,683	54.9	Pumped Hydro Storage, Electro-chemical, Thermal Storage
Electric Supply Capacity	5,505	19.5	Thermal Storage, Electro-chemical, Pumped Hydro Storage
Electric Supply Reserve Capacity - Spinning	3,585	12.5	Electro-chemical, Electro-mechanical, Pumped Hydro Storage
Load Following (Tertiary Balancing)	1,266	4.4	Electro-chemical, Pumped Hydro Storage
Renewables Energy Time Shift	694	2.4	Electro-mechanical, Electro-chemical, Thermal Storage, Pumped Hydro Storage
Grid-Connected Commercial (Reliability & Quality)	530	1.9	Electro-chemical, Pumped Hydro Storage
Ramping	330	1.2	Electro-chemical, Pumped Hydro Storage
Renewables Capacity Firming	322	1.1	Thermal Storage, Electro-chemical, Electro-mechanical
Voltage Support	211	0.7	Electro-chemical, Pumped Hydro Storage
Frequency Regulation	199	0.7	Electro-mechanical, Electro-chemical, Thermal Storage
Electric Bill Management	77	0.3	Electro-chemical, Thermal Storage
Resiliency	45	0.2	Electro-mechanical
Electric Bill Management with Renewables	7	0.0	Electro-chemical
Transportable Transmission/Distribution Upgrade Deferral	7	0.0	Electro-chemical
Onsite Renewable Generation Shifting	5	0.0	Thermal Storage, Electro-chemical
Transportation Services	5	0.0	Electro-mechanical, Electro-chemical
Stationary Transmission/Distribution Upgrade Deferral	3	0.0	Electro-chemical
Electric Supply Reserve Capacity - Non-Spinning	2	0.0	Electro-chemical
Microgrid Capability	2	0.0	Electro-chemical
On-Site Power	2	0.0	Electro-chemical
Distribution upgrade due to solar	1	0.0	Electro-chemical
Grid Connected Residential (Reliability)	1	0.0	Electro-chemical
Black Start	0.4	0.0	Electro-chemical

12 From DOE Energy Storage Database data. All capacities rounded up to the nearest megawatt except for sub-megawatt amounts.

EU framework for Smart Grids

- ✓ Electricity Directive 2009/72/EC
- ✓ Energy Efficiency Directive 2012/27/EC
- ✓ Energy Infrastructure Regulation (EC) 347/2013
- ✓ Electro-mobility Draft Directive AFI COM(2013)18
- ✓ COM(2011)202 on Smart Grids
- ✓ COM(2012)663 Recommendation OJ L/73 13/03/2012
- ✓ COM (2013)7243 on IEM and public intervention
- ✓ SWD(2013)442 on Demand Side Flexibility

Key questions

Questions about the reliability, affordability and sustainability of our energy future often boil down to questions about investment.

Investment

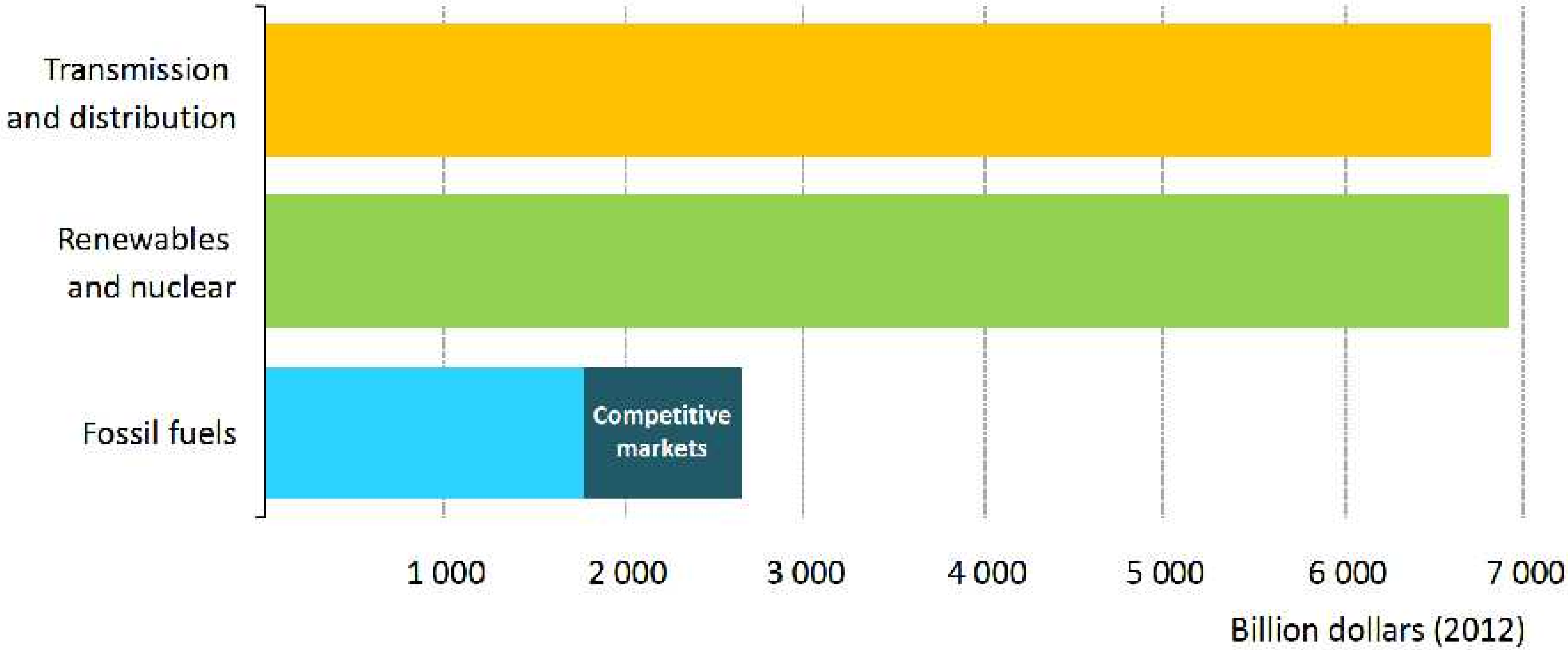
- in research and development
- deployment
- implementation

International cooperation has an important role.

Governments, not market signals, are driving power sector investment

WORLD ENERGY INVESTMENT OUTLOOK
Special Report

Power sector investment, 2014-2035



With current market designs, competitive parts of markets require less than $1 trillion of cumulative investment to 2035 out of total power sector needs of $16.4 trillion

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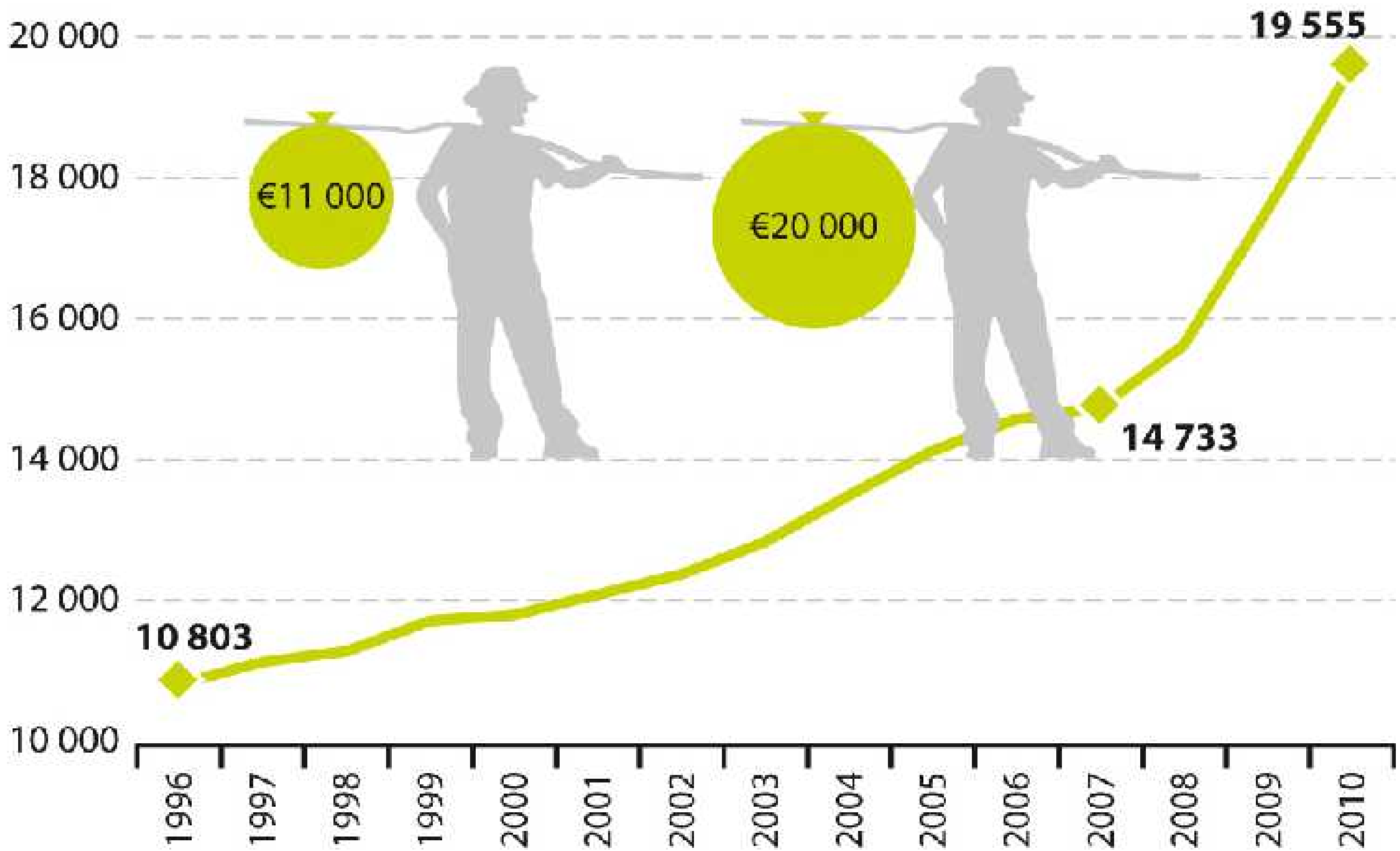
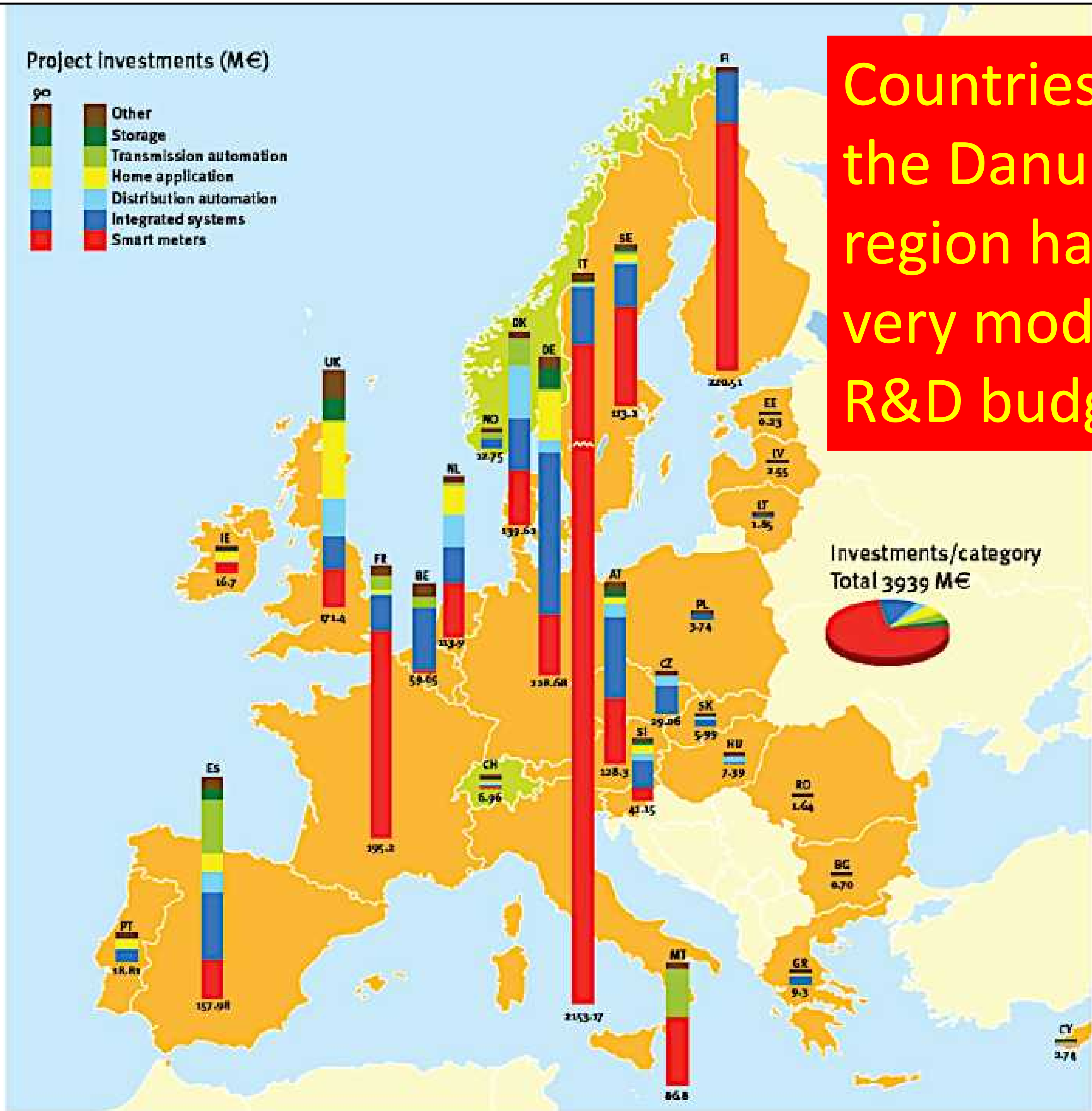
Gross state depths

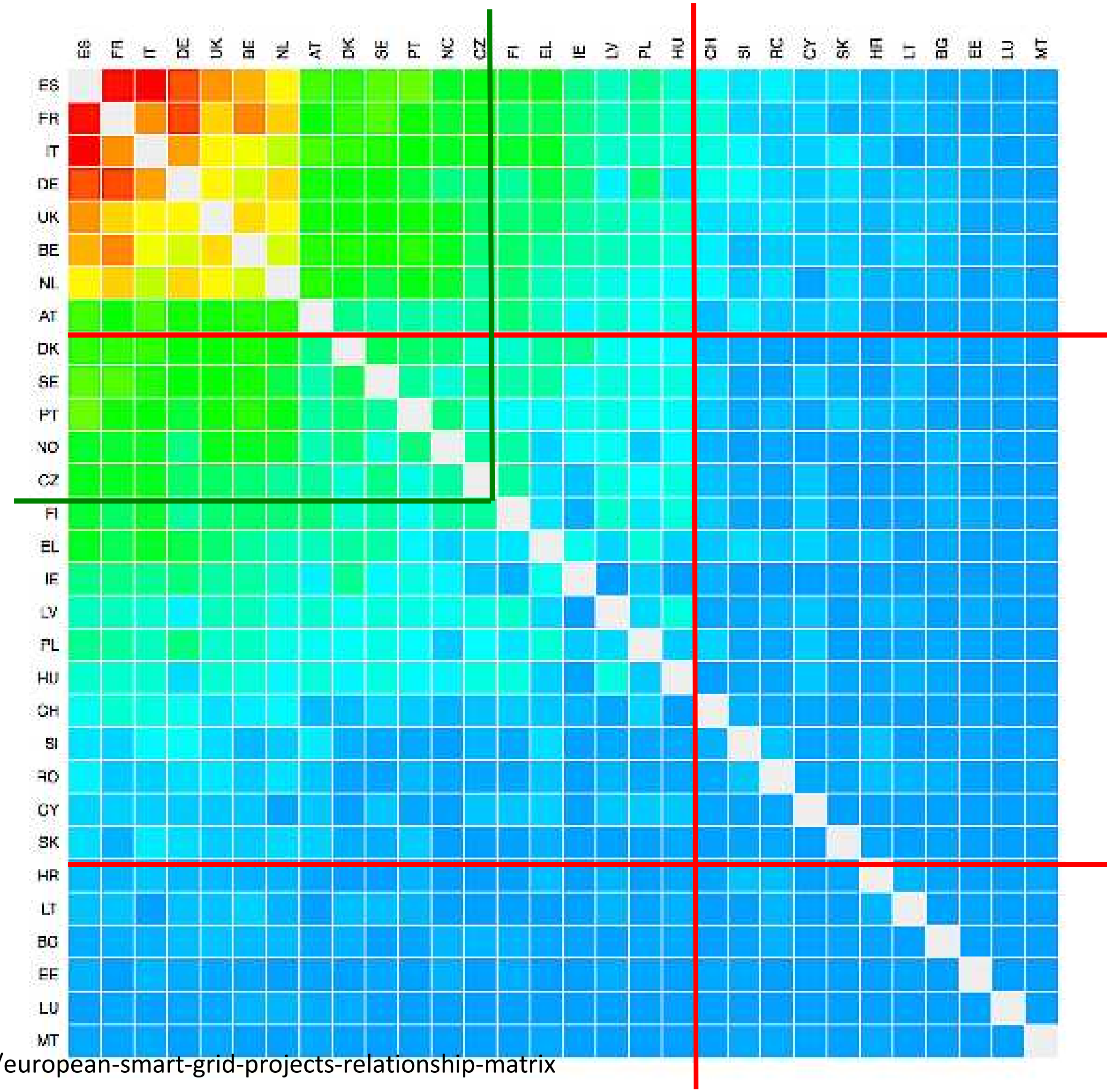




Countries in the Danube region have very moderate R&D budget

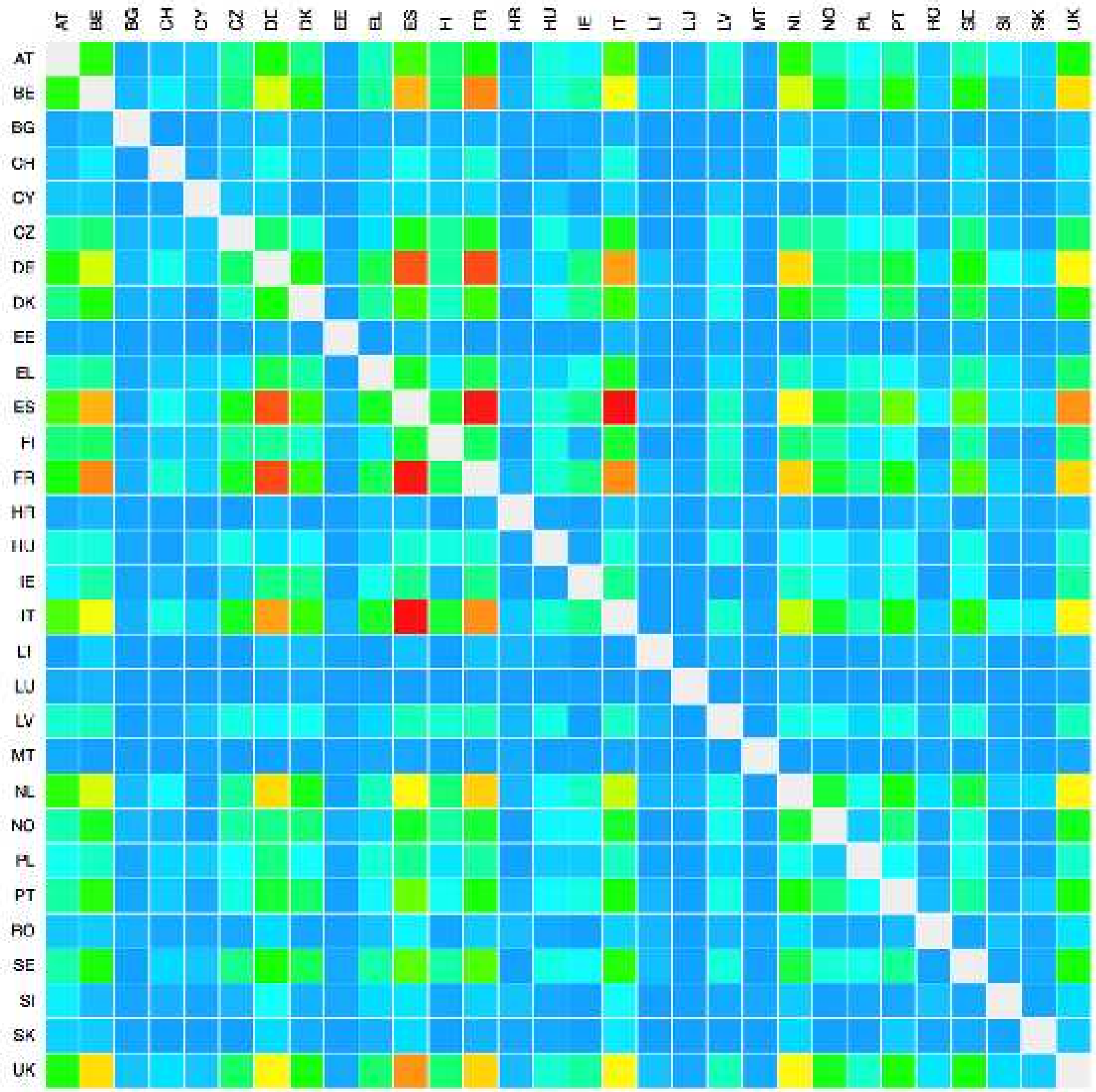
Renewable energy in EU

European smart grid projects: relationship matrix by value



http://ses.jrc.ec.europa.eu/european-smart-grid-projects-relationship-matrix

European smart grid projects: relationship matrix by name



http://ses.jrc.ec.europa.eu/european-smart-grid-projects-relationship-matrix

Conclusion

The cooperation between the Danube region countries in smart grid projects needs further improvements

Will Europe keep the lights on?

- Over the past decade, four-fifths of investment in European power generation went to renewables, 60% just to wind and solar PV
- Europe needs to invest $2.2 trillion (2nd largest after China) to 2035 to replace ageing infrastructure & meet decarbonisation goals
- Current overcapacity offers some breathing space, but 100 GW of new thermal plants is needed before 2025 to safeguard reliability
- This investment won't happen with current market rules: wholesale power prices are 20% (or 20$/MWh) below cost-recovery levels
- Higher wholesale prices could increase end-user bills, adding to the strain on households & on competitiveness of EU industry

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LET’S DREAM TOGETHER!