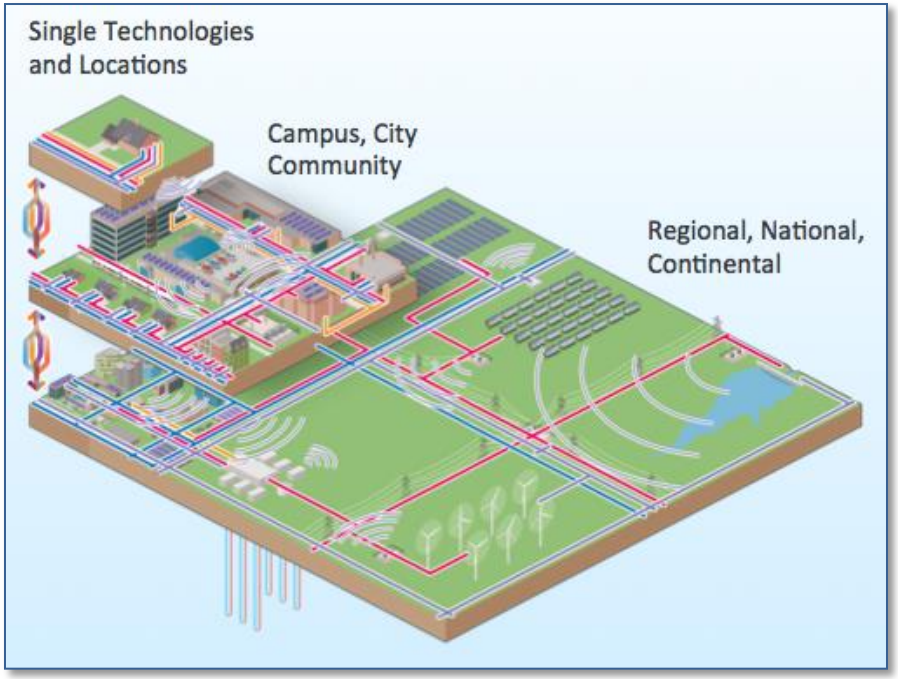
Energy Systems Integration (ESI) 101

Mark O'Malley

mark.omalley@ucd.ie

GCEP Research Symposium, Stanford, USA

8th October 2013



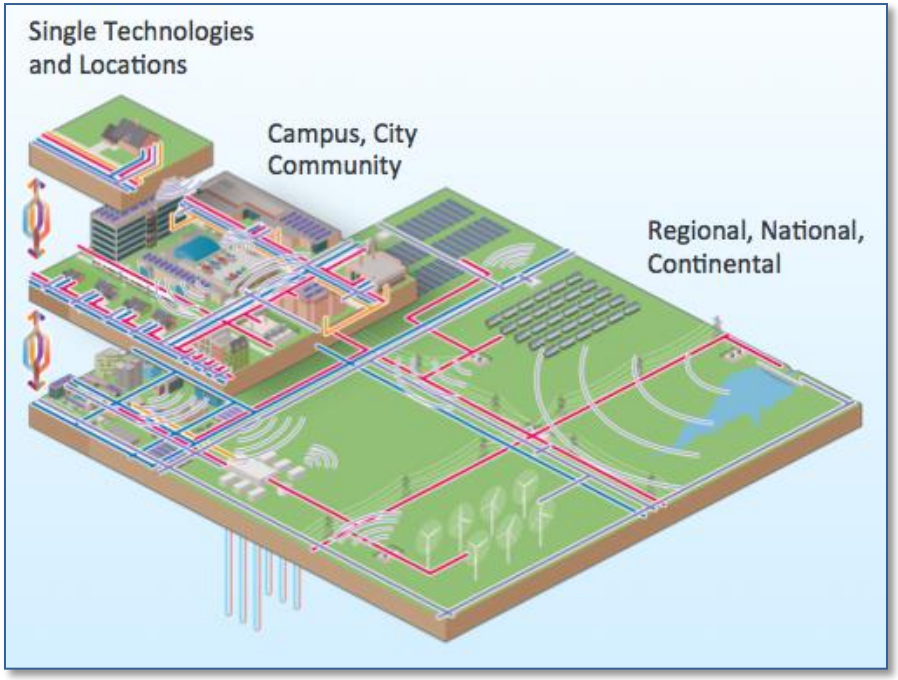
http://www.youtube.com/watch?v=w4LyN3Or60A

Introduction to Energy Systems Integration (ESI) and Overview of ESI 101

Mark O'Malley

mark.omalley@ucd.ie

21st July 2014



ESI International Institute™ for Energy Systems Integration

Energy Systems Integration 101 Course

Leuven, Belgium

May 18th 2015

What is Energy Systems Integration

Energy Systems Integration (ESI)

Optimizes the integrated suite of electrical, thermal, and fuels pathways at all scales

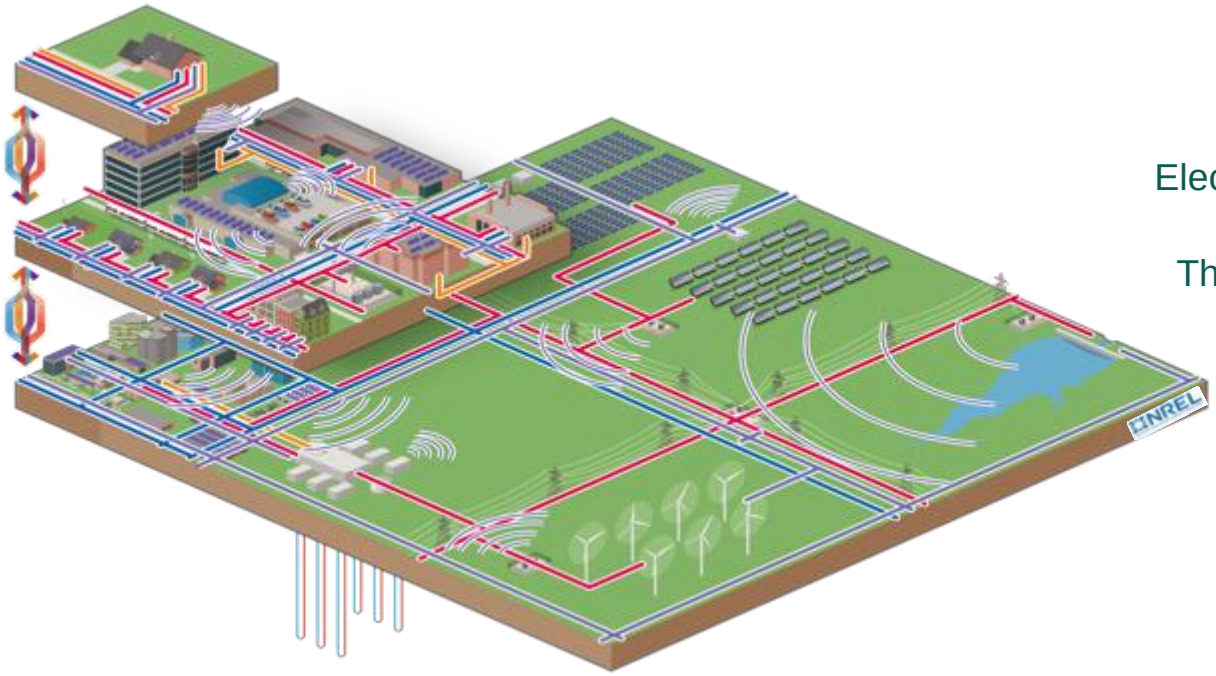
Energy Source

Fossil | Nuclear | Renewable

Single Technologies and Locations

Campus, City Community

Regional, National, Continental



Electricity

Thermal

Fuels

Data

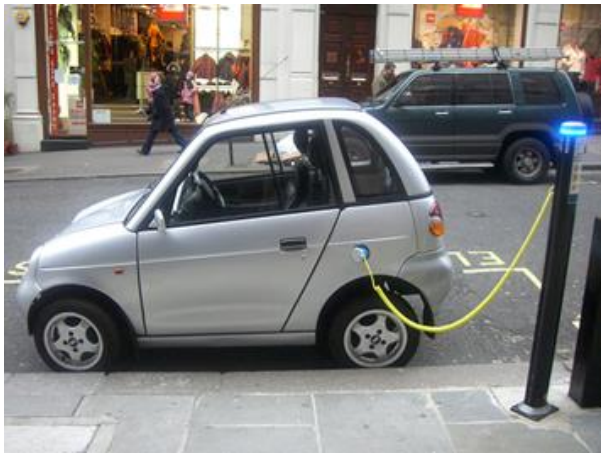
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Residential | Commercial | Industry | Mobility

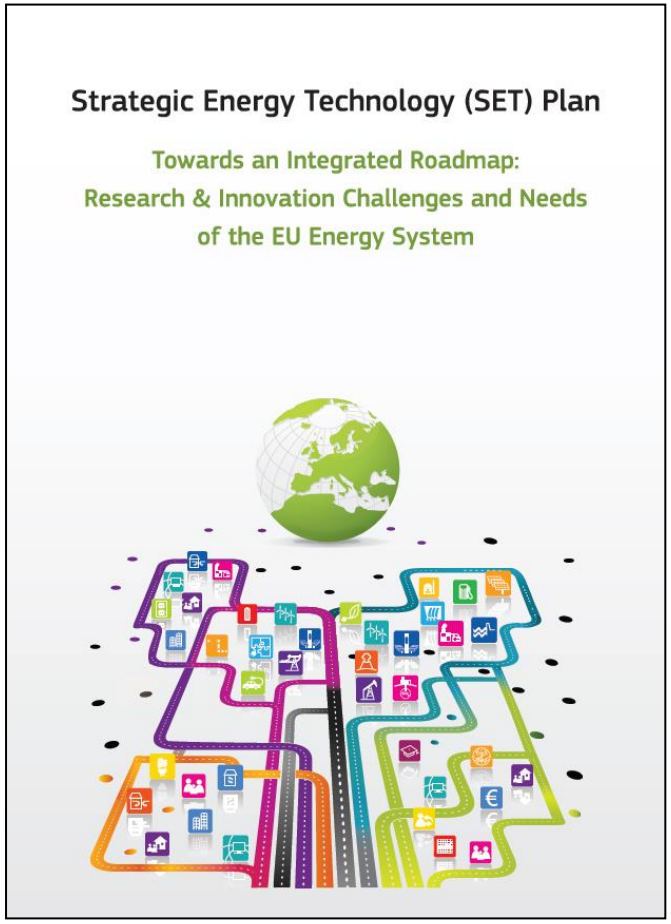
Energy Use Sector

focused on the interfaces where the coupling and interactions are strong and represent a challenge and/or an opportunity.

Wider Convergence



European/US context



http://www.nrel.gov/esi/esif.html

EERA
European Energy Research Alliance

New Joint Programme in Energy Systems Integration

IESI International Institute for Energy Systems Integration

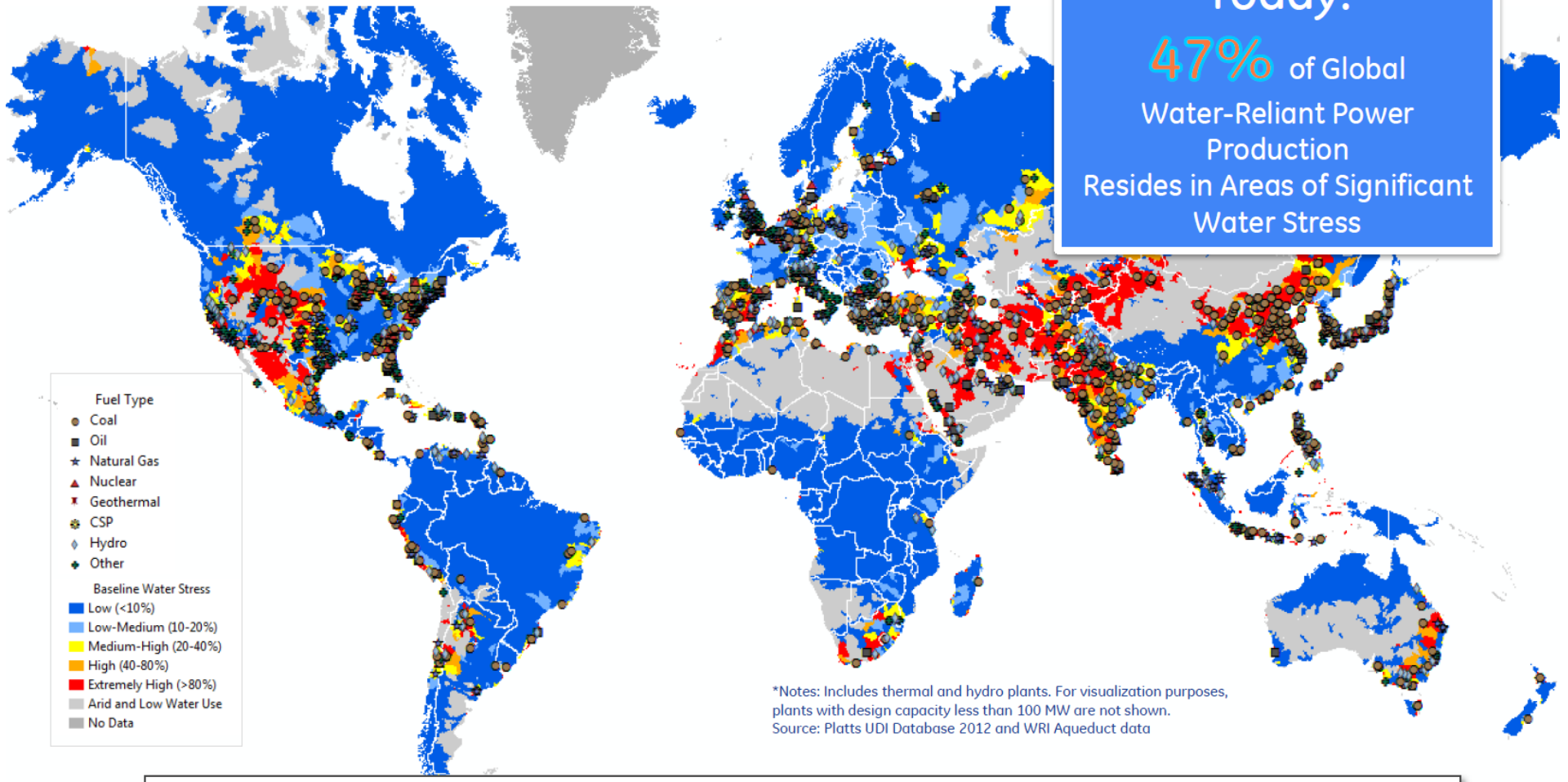
Some Examples

Global generation units with water stress*

Medium to extremely-high stress

Today:

47% of Global Water-Reliant Power Production Resides in Areas of Significant Water Stress



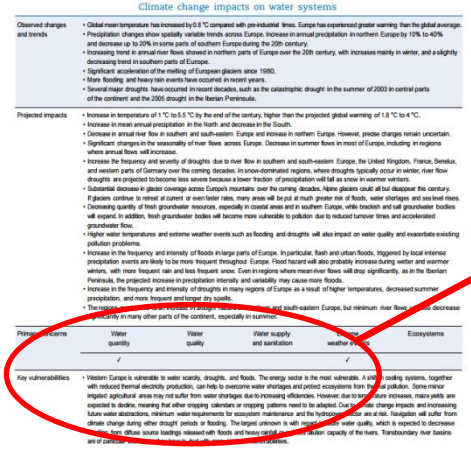
*Notes: Includes thermal and hydro plants. For visualization purposes, plants with design capacity less than 100 MW are not shown.
Source: Platts UDI Database 2012 and WRI Aqueduct data

Over 26,000 units are in areas of medium to extremely-high water stress

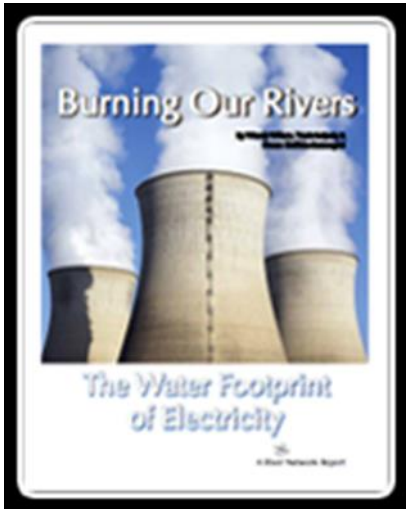
Water/Energy NEXUS

Energy poverty stifles sub-Saharan Africa's economic development

European Commission



"western Europe is vulnerable to water scarcity, droughts and floods. The energy sector is the most vulnerable". (OECD/EU 2013)



Carbon energy production is draining California water

By Carl Pope, Bloomberg News
Bloomberg

APRIL 29, 2015, 11:20 PM

Chapter 17

Water for energy

Is energy becoming a thirstier resource?

Highlights

- Energy depends on water – for power generation, the extraction, transport and processing of fossil fuels, and the irrigation of biofuels feedstock crops – and is vulnerable to physical constraints on its availability and regulations that might limit access to it. A more water-constrained future, as population and the global economy grow and climate change looms, will impact energy sector reliability and costs.
- Global water withdrawals for energy production in 2010 were estimated at 583 billion cubic metres (bcm), or some 15% of the world's total water withdrawals. Of that, water consumption – the volume withdrawn but not returned to its source – was 66 bcm. In the New Policies Scenario, withdrawals increase by about 20% between 2010 and 2035, but consumption rises by a more dramatic 85%. These trends are driven by a shift towards higher efficiency power plants with more advanced cooling

RESOURCES:

How China's thirst for clean drinking water may raise its CO2 emissions

Coco Liu, E&E Asia correspondent
ClimateWire: Monday, April 13, 2015

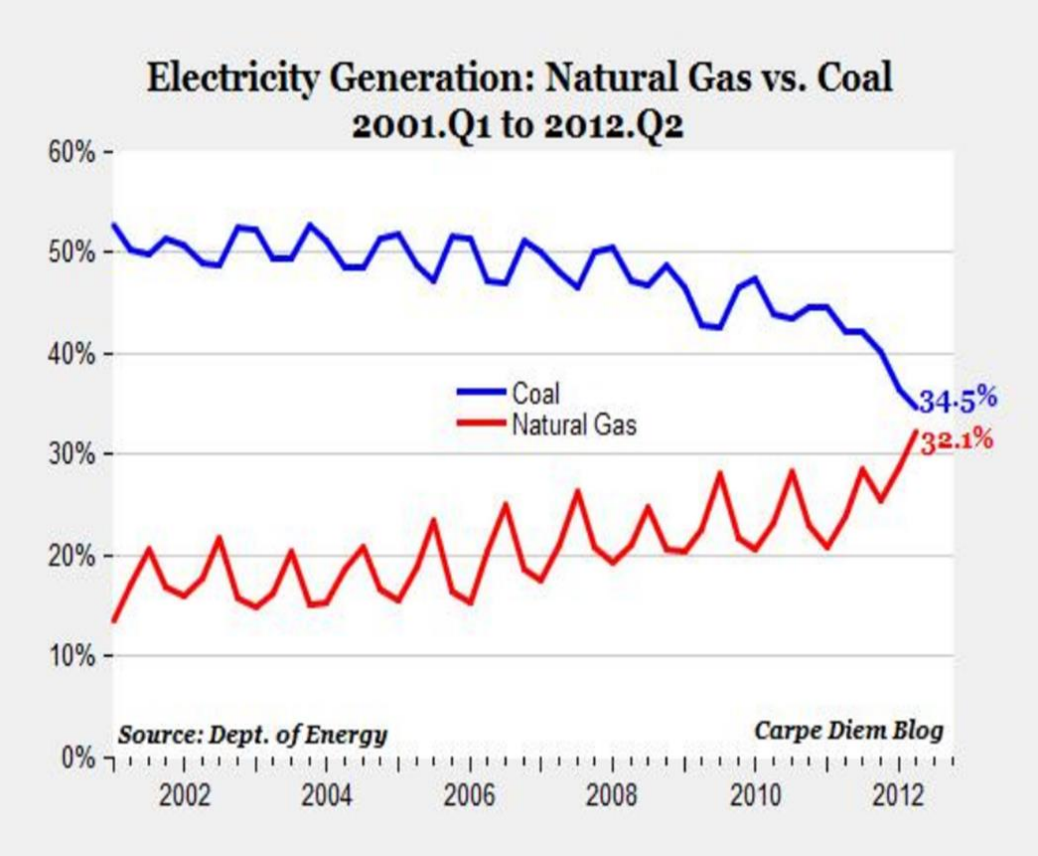
HONG KONG -- China has long been accused of using too much water to produce energy, but now some of its coastal cities are compounding this problem by planning for desalination, which will spike both their energy needs and their emissions.

According to a recent study by the World Resources Institute, northern China's Qingdao city may risk using too much energy to produce water. Since the country's power supplies mainly come from coal, increased energy use means higher carbon dioxide emissions and worsening air pollution.

The environmental organization made the conclusion after looking at different energy needs for producing drinking water from various sources in Qingdao.

Its finding shows that desalination plants -- which are expected to meet a significant share of Qingdao's future water demand -- use 10 times more energy than extracting water from local rivers.

Gas/Electricity the Global Situation



" This issue of gas-electric interdependence is not a reason to panic, but it's absolutely a reason to plan, and to do so now"

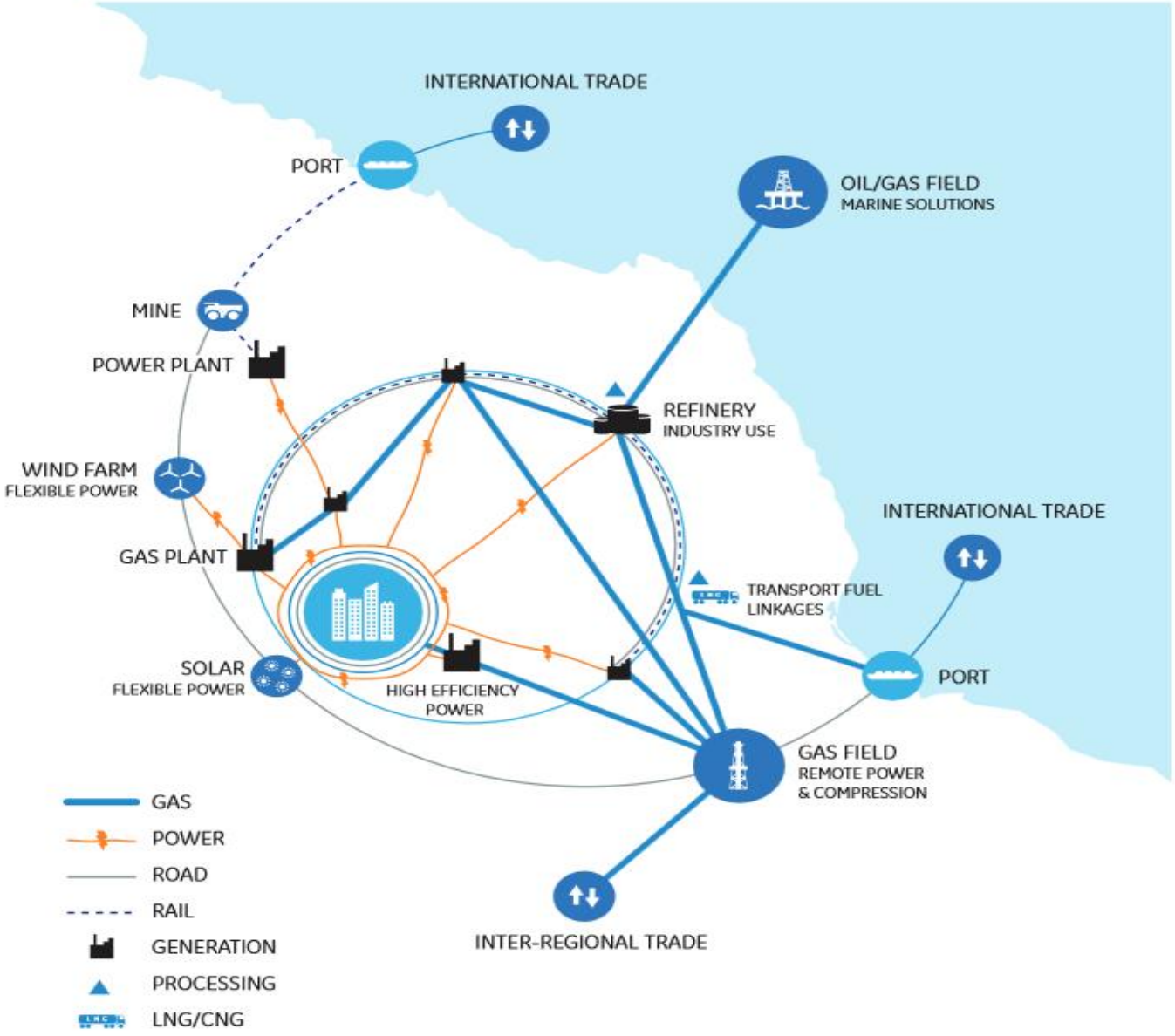
Cheryl A. LaFleur the acting chairman of the Federal Energy Regulatory Commission

July 15, 2013, 11:49 a.m. ET

E.ON to Mothball Slovak Gas Power Plant Malzenice from October

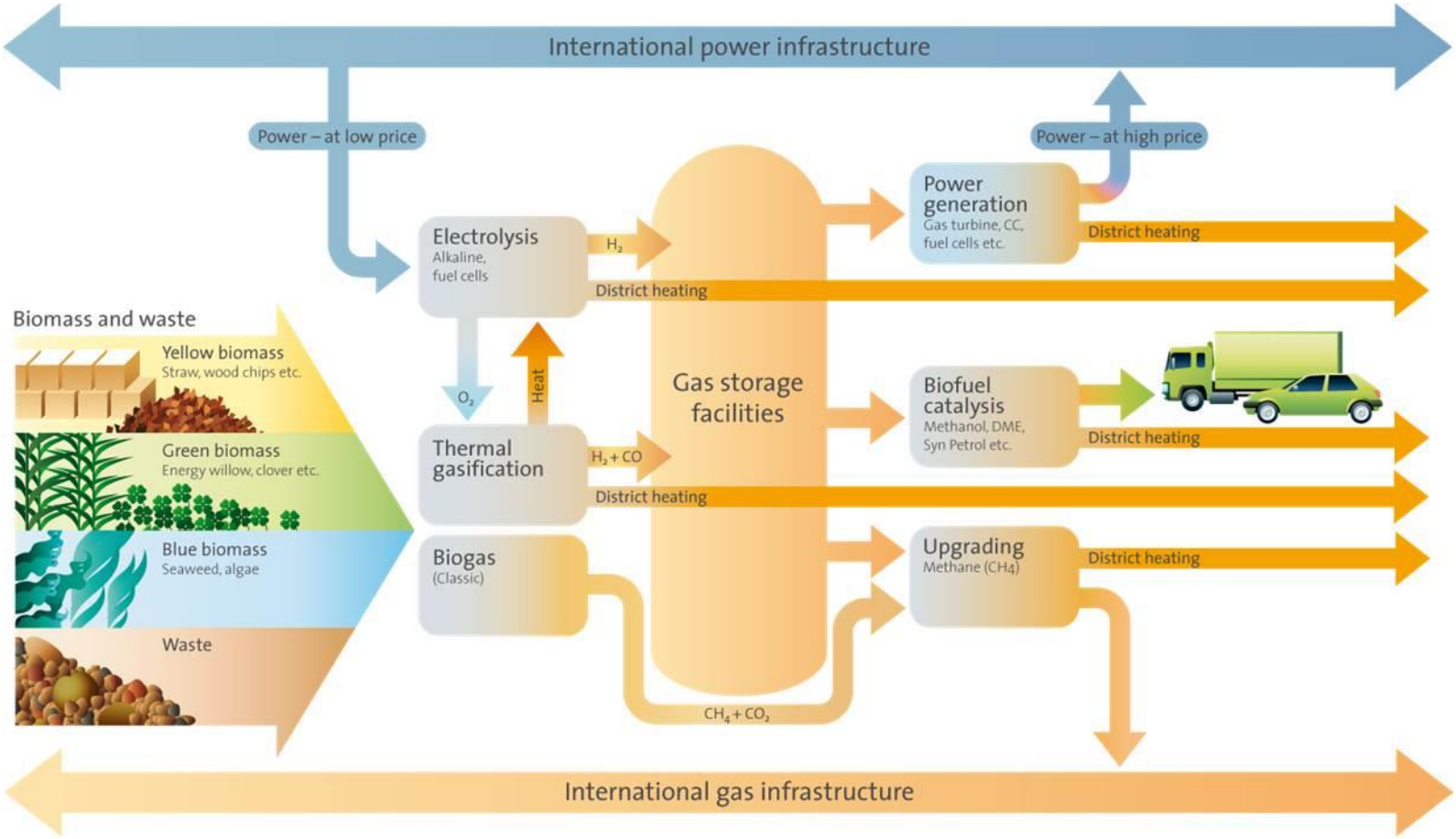
Figure 12. Multi-Network Integration: Gas, Power, Road and Rail

Source: GE Global Strategy and Analytics, 2013

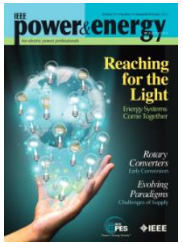


http://www.ge.com/sites/default/files/GE_Age_of_Gas_Whitepaper_20131014v2.pdf

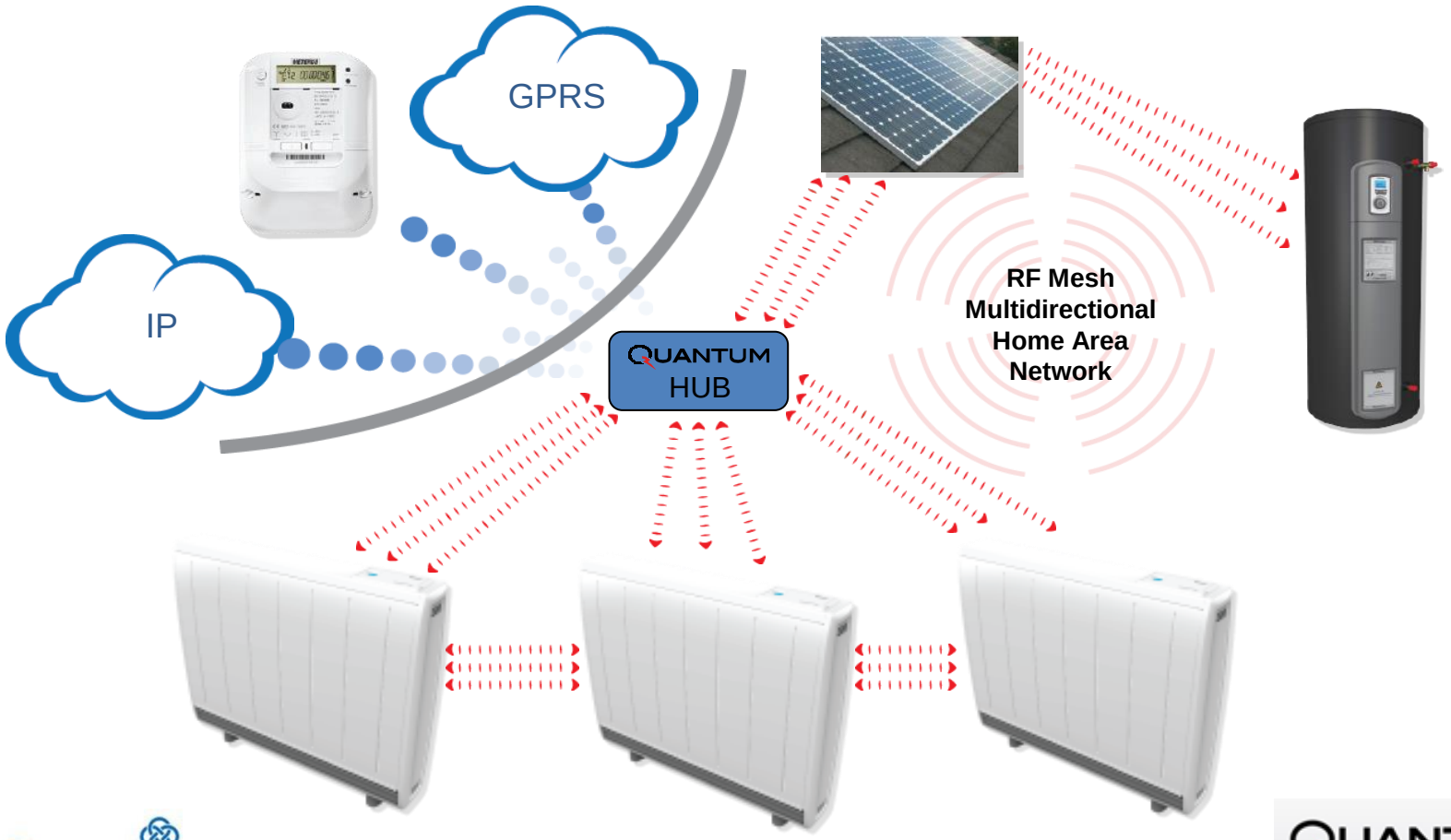
ESI in Denmark



Meibom, P.; Hilger, K.B.; Madsen, H.; Vinther, D., "Energy Comes Together in Denmark: The Key to a Future Fossil-Free Danish Power System," *Power and Energy Magazine, IEEE* , vol.11, no.5, pp.46,55, Sept. 2013. doi: 10.1109/MPE.2013.2268751



Electric Heat Demand is Very Flexible



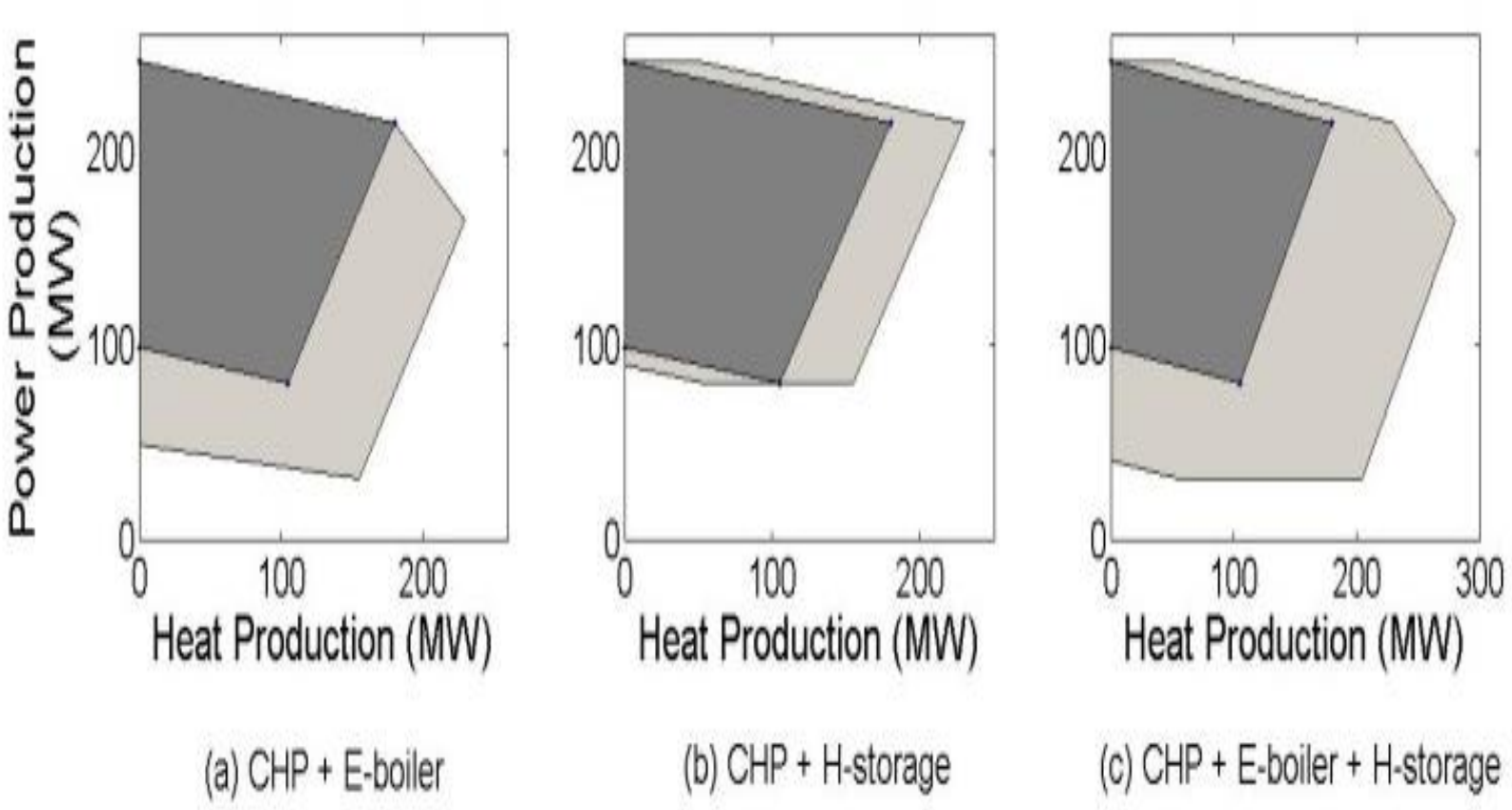
- Kiviluoma, J., Meibom, P.; “Influence of wind power, plug-in electric vehicles, and heat storages on power system investments” Energy, Volume 35, Issue 3, March 2010, Pages 1244-1255
- Papaefthymiou, G.; Hasche, B.; Nabe, C.; , "Potential of Heat Pumps for Demand Side Management and Wind Power Integration in the German Electricity Market," Sustainable Energy, IEEE Transactions on , vol.3, no.4, pp.636-642, Oct. 2012

Large Loads

Large-scale Wastewater Treatment

Data centres

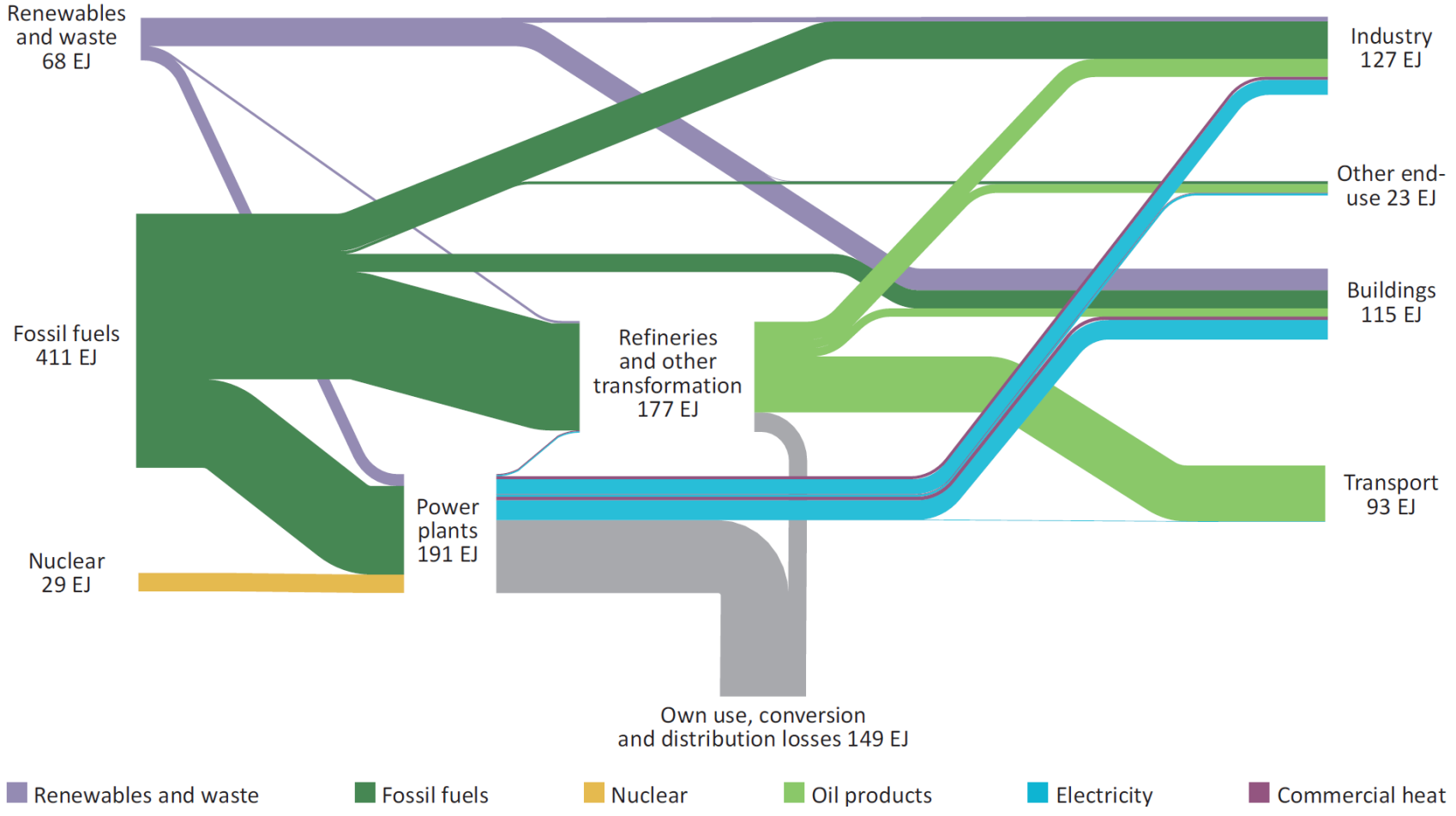
Combined heat and power (CHP) can be made flexible



X. Chen, C. Kang, Q. Xia, B. Jianhua, L.Chun, L. Ji, R. Sun, L. Hui and M.J. O'Malley, *"*Increasing the Flexibility of CHP with Heat Storage and Electrical Boilers for Wind Power Integration in China: Modeling and Implications*"*, *IEEE Transactions on Power Systems*, in press, 2015.

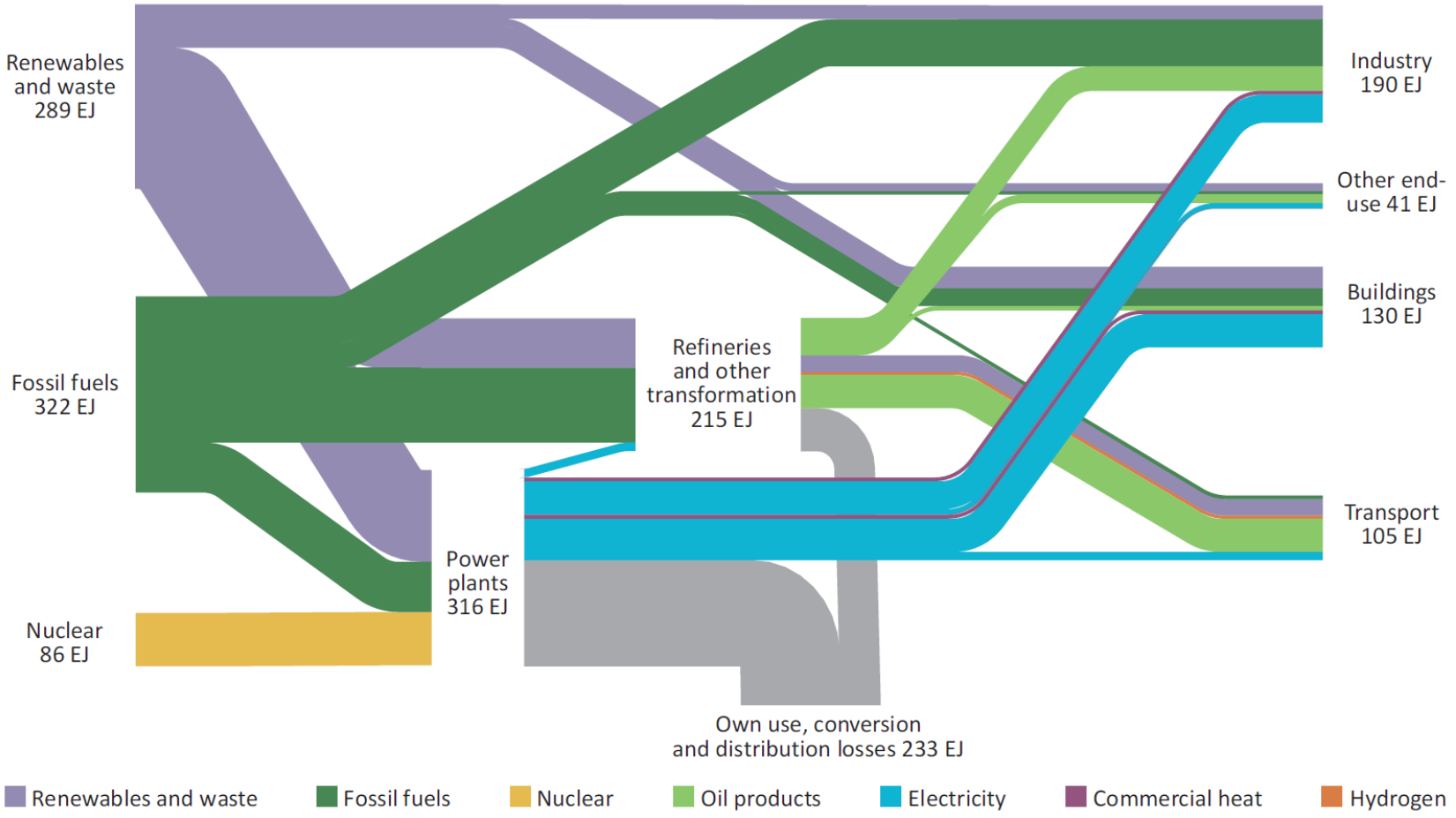
The Importance of Electricity in ESI

The global energy system today

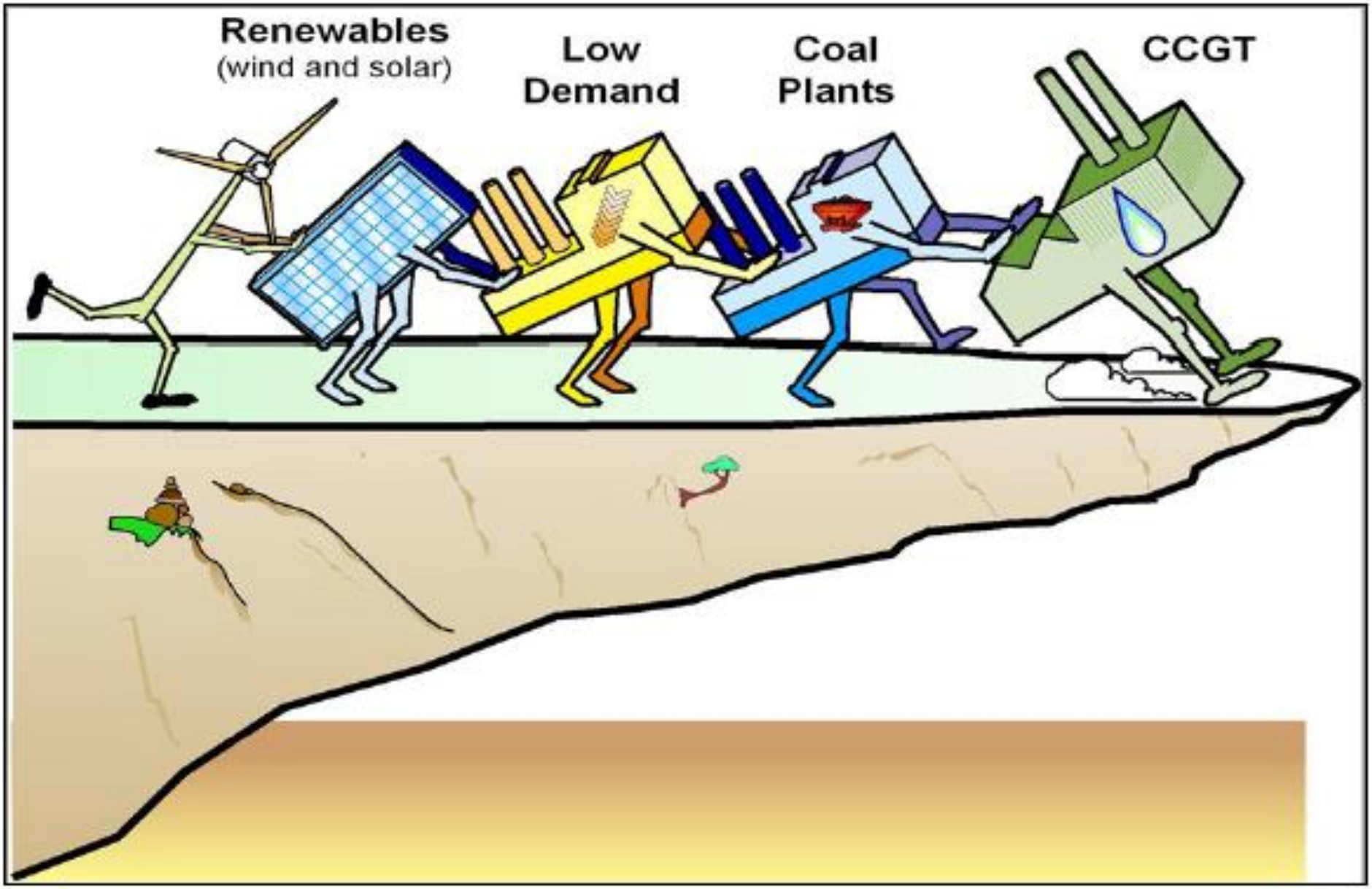


Dominated by fossil fuels in all sectors: (Source IEA)

The future low-carbon energy system



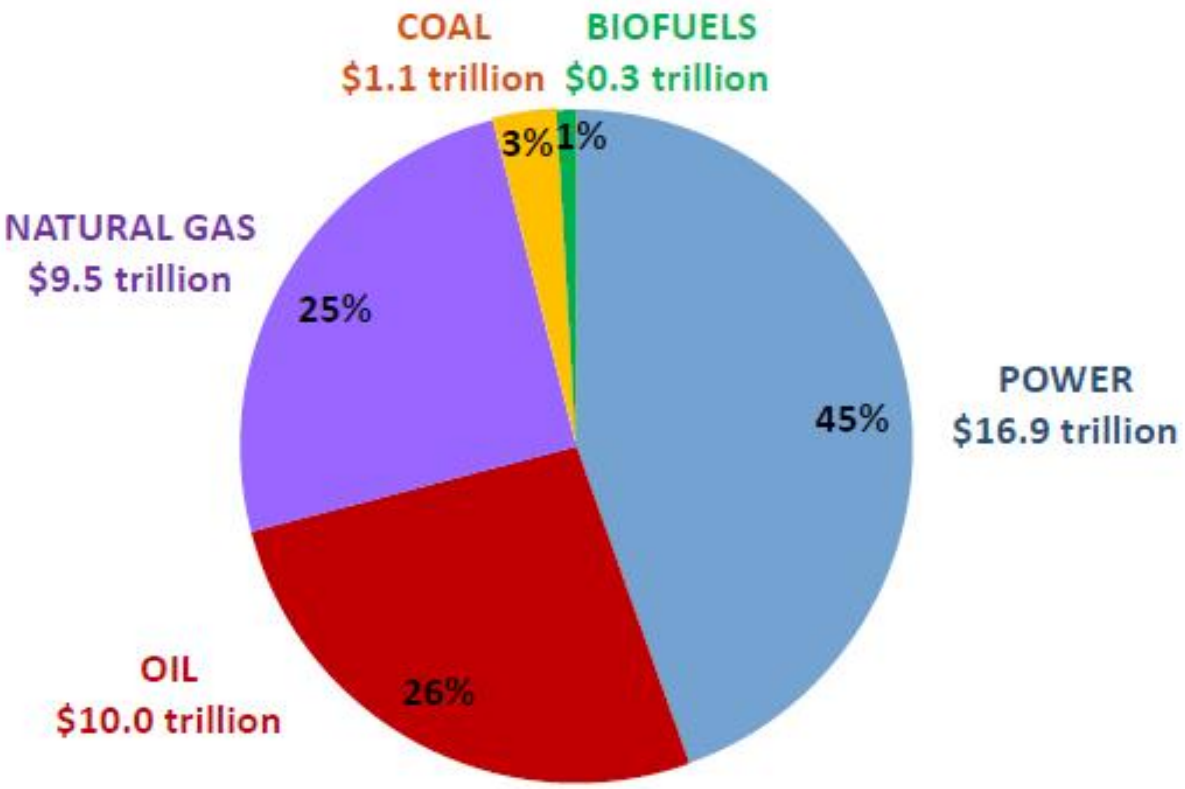
The 2DS in 2050 shows a dramatic shift in energy sources and demands: (Source IEA)


Renewables
(wind and solar)
Low
Demand
Coal
Plants
CCGT

Investment: the essence of energy

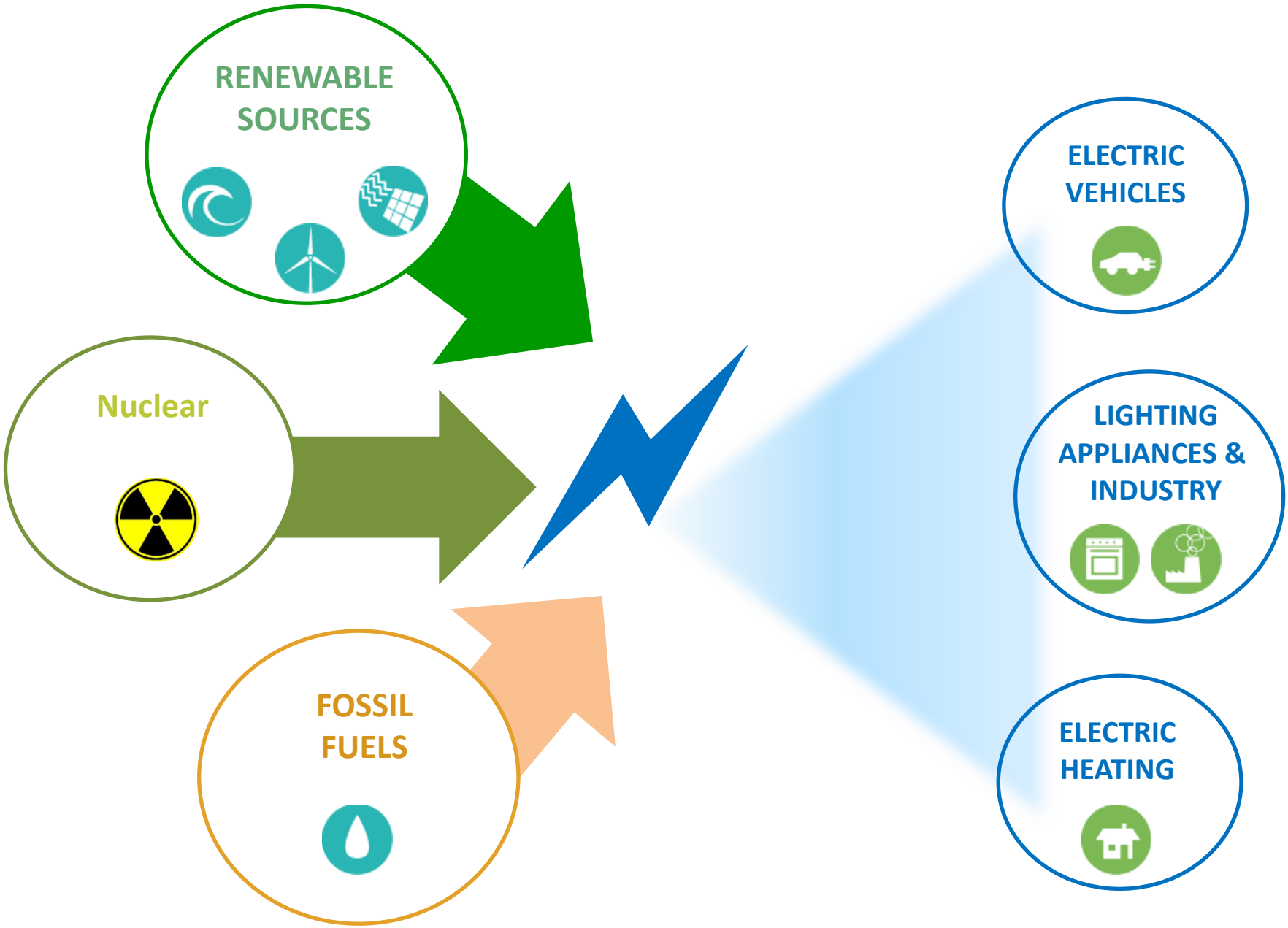
WORLD ENERGY OUTLOOK 2011

Cumulative investment in energy infrastructure, *2011-2035*

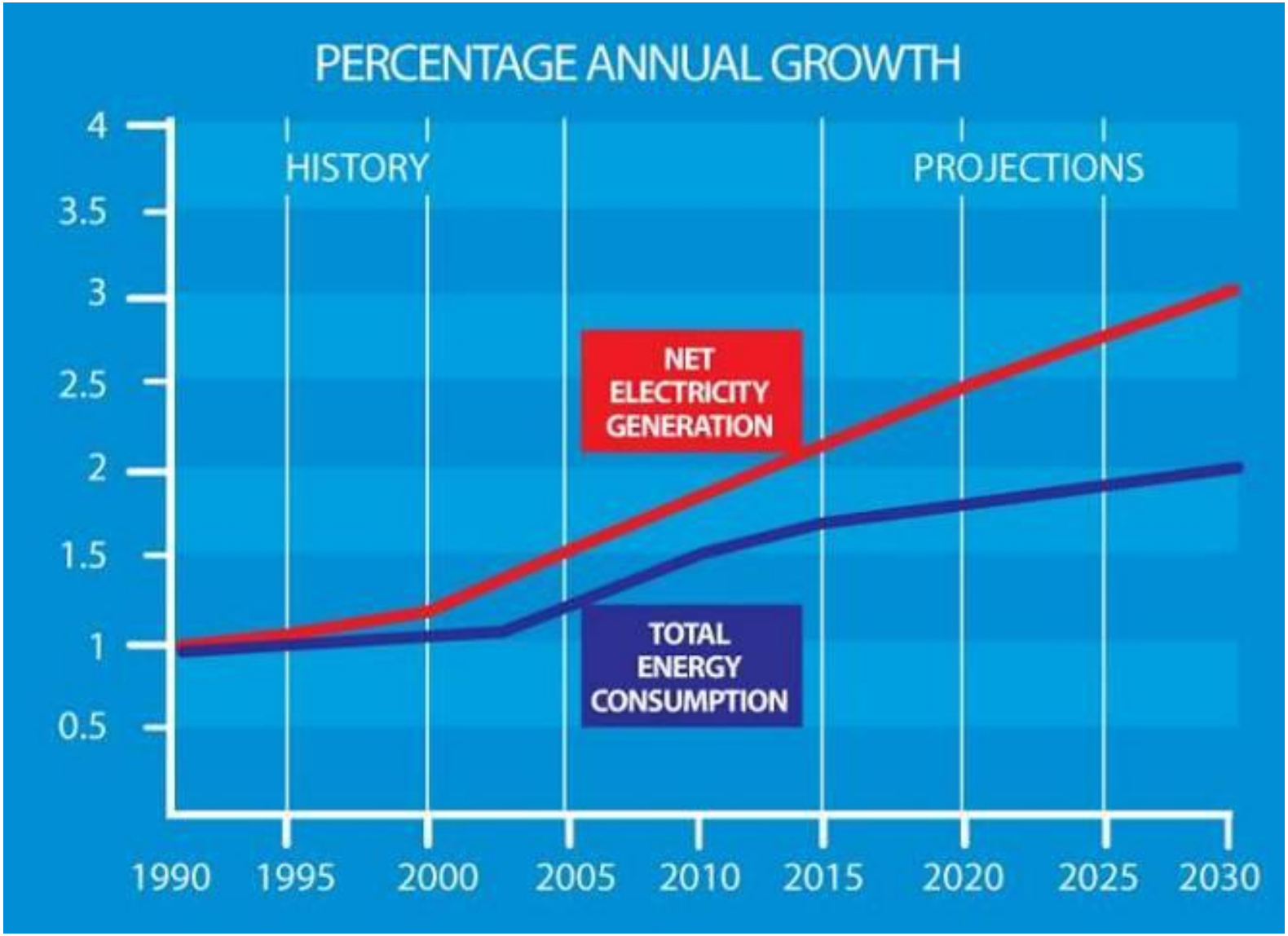


WEO-2011 will show that $38 trillion of investment is required to meet projected energy demand through to 2035 and that investors in energy projects are facing a multitude of risks

The Electric Future



The Future is Electric



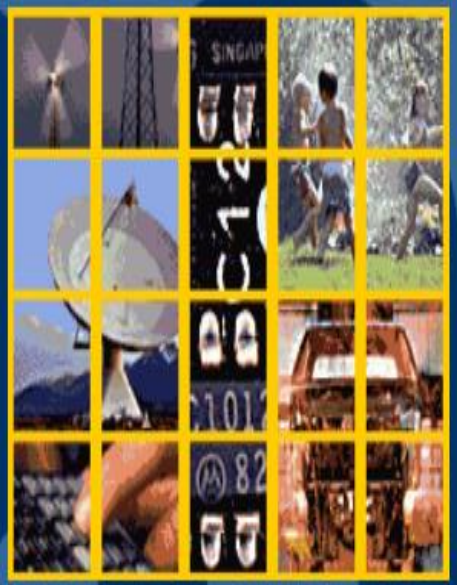
Source: Energy Information Administration (EIA), 2008.

Greatest Engineering Achievements of the 20th Century

Welcome!

How many of the 20th century's greatest engineering achievements will you use today? A car? Computer? Telephone? Explore our list of the top 20 achievements and learn how engineering shaped a century and changed the world.

1. Electrification
2. Automobile
3. Airplane
4. Water Supply and Distribution
5. Electronics
6. Radio and Television
7. Agricultural Mechanization
8. Computers
9. Telephone
10. Air Conditioning and Refrigeration
11. Highways
12. Spacecraft
13. Internet
14. Imaging
15. Household Appliances
16. Health Technologies
17. Petroleum and Petrochemical Technologies
18. Laser and Fiber Optics
19. Nuclear Technologies
20. High-performance Materials



Greatest Achievements

21st Century Innovation Topics

1. Energy conservation
2. Resource protection
3. Food and water production and distribution
4. Waste management
5. Education and learning
6. Medicine and prolonging life
7. Security and counter-terrorism
8. New technology
9. Genetics and cloning
10. Global communication
11. Traffic and population logistics
12. Knowledge sharing
13. Integrated electronic environment
14. Globalization
15. AI, interfaces and robotics
16. Weather prediction and control
17. Sustainable development
18. Entertainment
19. Space exploration
20. "Virtualization" and VR
21. Preservation of history
22. Preservation of species

Policy Failures because they are not holistic

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Windmills Overload East Europe's Grid Risking Blackout: Energy

By Ladka Bauerova and Tino Andresen - Oct 26, 2012 12:01 AM GMT

15 COMMENTS QUEUE

Sean Gallup/Getty Images

Germany is dumping electricity on its unwilling neighbors and by wintertime the feud should come to a head.

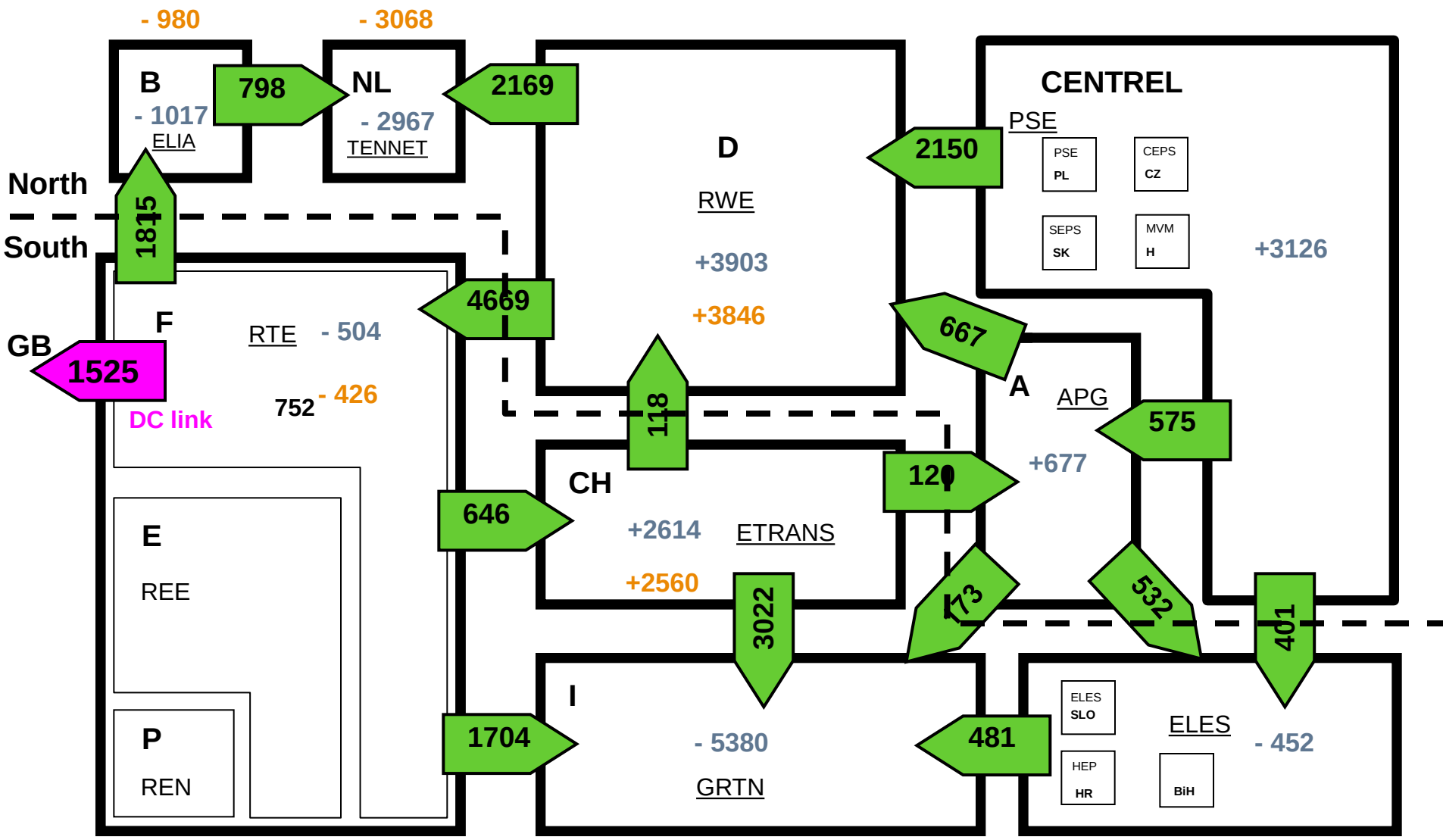
Germany is dumping electricity on its unwilling neighbors and by wintertime the feud should come to a head.

- http://ec.europa.eu/energy/gas_electricity/studies/doc/electricity/20131 0_loop-flows_study.pdf

THEMA CONSULTING GROUP

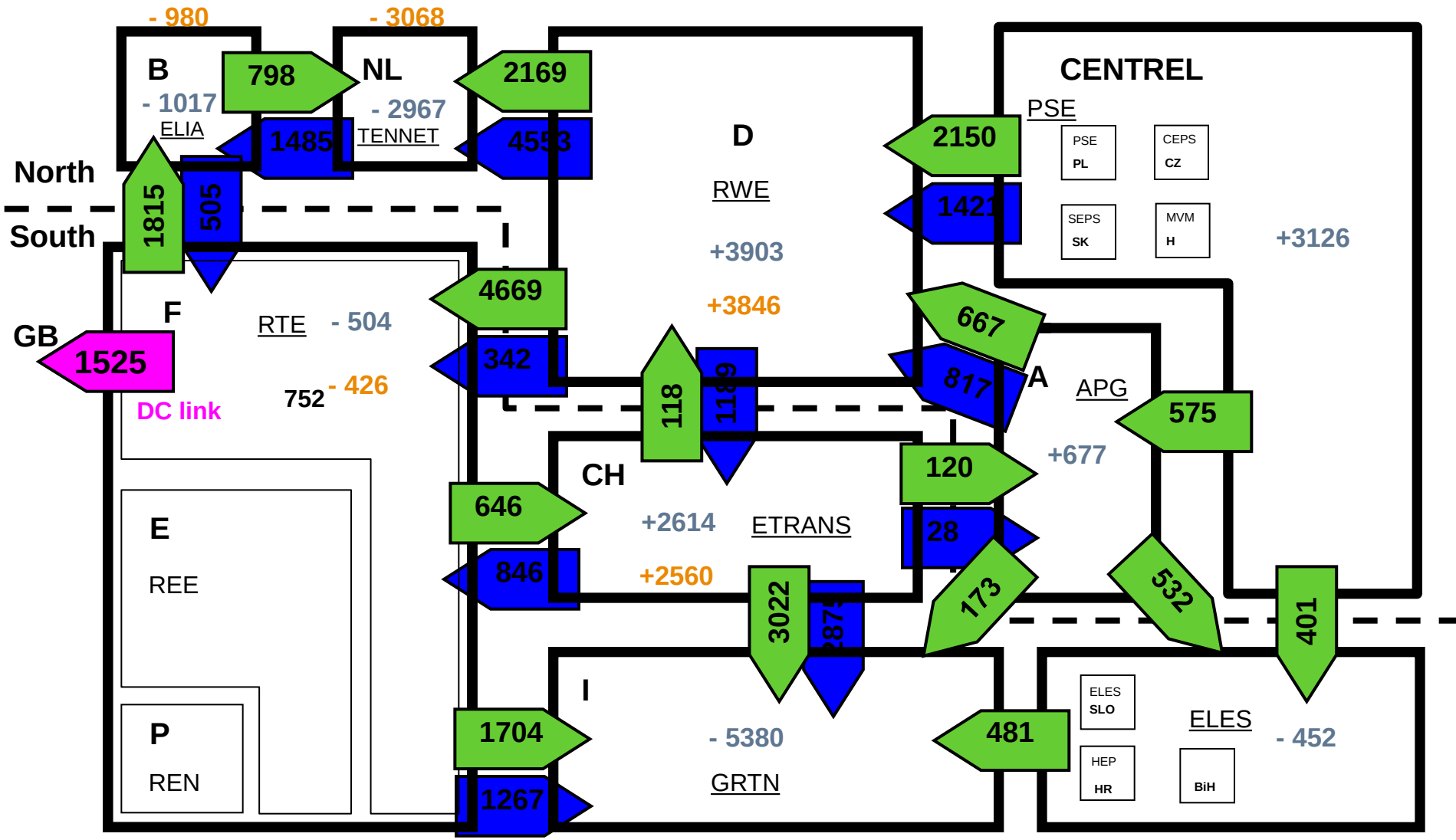
Prepared for The European Commission
October 2013

THEMA Report 2013-36



Source: Ronnie Belmans, ELIA

Scheduled Power Exchanges vs Physical Power Flows



Source: Ronnie Belmans, ELIA

Reading Material

IEEE Power & Energy Magazine, Sept./Oct. 2013

M. O'Malley and B. Kroposki Guest Editors

- Planning ESI – Jim McCalley *et al.*, Iowa St.
- Hawaii ESI – Dave Corbus, *et al.*, NREL
- EU ESI – John Holms, EASAC & Oxford University
- Danish ESI – Peter Meibom *et al.*, Dansk Energi, DTU
- Tools and modeling for ESI – Juan Van Roy *et al.* KU Leuven
- China ESI – Chongqing Kang *et al.*, Tsinghua University

O'Malley, M.J. and Kroposki B. "Energy comes together the integration of all systems", Editorial, Special issue in Energy Systems Integration, *IEEE Power & Energy Magazine*, Vol. 11, Sept/October, pp. 18 – 23, 2013.

Reading Material # 1

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Introduction to Energy Systems Integration & iiESI

Leuven, Belgium

May 18th 2015

iiESI International Institute for Energy Systems Integration

Addressing energy challenges through global collaboration

The International Institute for Energy Systems Integration (iiESI) is a community of scholars and practitioners from around the world engaged in developing an efficient global energy system.

Countries, international organizations, industry, policymakers, and regulators all have distinct and somewhat different views of the energy system. The International Institute for Energy Systems Integration seeks to leverage the expertise of scholars and practitioners from these diverse views to understand the full energy system and the challenges to realizing highly integrated, flexible, clean, and efficient energy systems.

By fostering the exchange of ideas, results, lessons learned, and best practices from energy systems integration-related activities throughout the world, the International Institute for Energy Systems Integration seeks to determine and prioritize the challenges that must be addressed and ensure investments in energy systems are coordinated and optimized to yield the greatest value to the global community.

Learn more about energy systems integration.

Download the whitepaper

International Institute for Energy Systems Integration (iiESI)

- **Vision:** A global community of scholars and practitioners from leading institutes engaged in efforts to enable highly integrated, flexible, clean, and efficient energy systems

- **Objectives:** Share ESI knowledge and Experience: Coordination of R&D activities: Education and Training Resources

Enabling world class research in ESI

iiESI International Institute for Energy Systems Integration

Evolution of Activities iiESI 2014/15

Feb 18-19th 2014
Workshop, Washington DC
46 attendees, 15 EU, 1 Asia, 30 US, very positive reaction to the concept, but mainly technical need more on policy

Feb 27th 2014
European Union,
Energy Research Alliance initiates a process to form a
Joint Programme (JP) in ESI

May 27-28th 2014
Workshop, Copenhagen
100 attendees, 10 US, 90 Europe, emphasis on policy & water

Jul 21-25th 2014
ESI 101 at NREL US
Course for PhD students in ESI
40 PhD students from US
Instructors from Europe & US

Jul 27-31st 2014
iEEE PES General Meeting
Panel Session on Energy Systems Integration, Research Challenges and Opportunities.

Sept 16th 2014
Workshop jointly with IEA Renewable Energy Working Party
70 people from all parts of the world

Nov 17th 2014
Asian Workshop
Kyoto
25 attendees from US, Europe, Japan, Korea, China

March 30/31st 2015
Workshop on ESI Research Challenges, Imperial College London
35 research active attendees from all over the world

May 18 – 22, 2015
ESI 101 at KU Leuven

July 28th at IEEE PES Denver
ESI Panel Session
Aug 3 – 8th, NREL, Denver
ESI 101, NREL

October 21st, Korea
Workshop, ESI, ICT, Virtual
Nov, 2015, Stanford
Workshop, Consumer

Recently

iiESI International Institute for Energy Systems Integration

Summary of iiESI Workshop on ESI Research Challenges in London

March 30th and 31st

Imperial College London

The workshop brought together an experienced group of international research active people with a diverse range of expertise (see list of attendees below). The workshop was open and vibrant, (see agenda and briefing documents below) and while **the focus of the workshop was on identifying the research challenges in Energy Systems Integration (ESI),**

http://iiesi.org/assets/pdfs/iiesi_london_summary.pdf

Trilemma

"Difficult task for investors to navigate policy and market uncertainties", (IEA WEO, 2014)

Competiveness

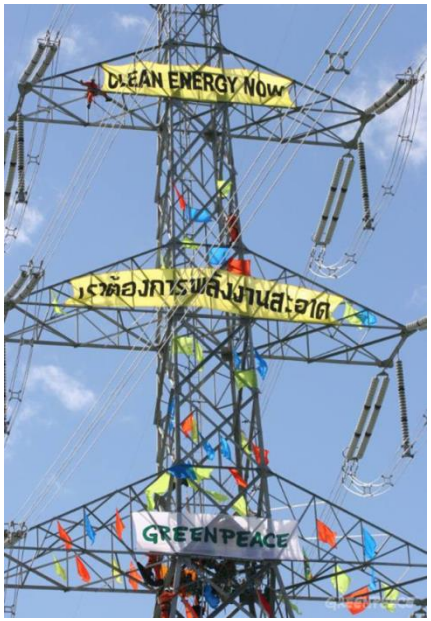
Sustainability

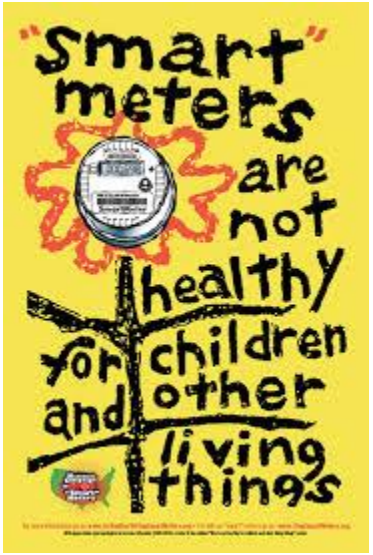
Security of supply

The consumer

"Engineers (and economists) tend to be ignorant and arrogant about customers"

Source: Lancaster University





The “consumer”

The human dimensions of sustainable energy transitions
Research agenda

Platform for Energy Research in the Socio-economic Nexus (PERSON)
November 2014

Consumer Behaviour in an Integrated Energy System

DIETER TELEMANS/PANOS

Masai women from Kenya take a course on solar energy in India.

Energy studies need social science

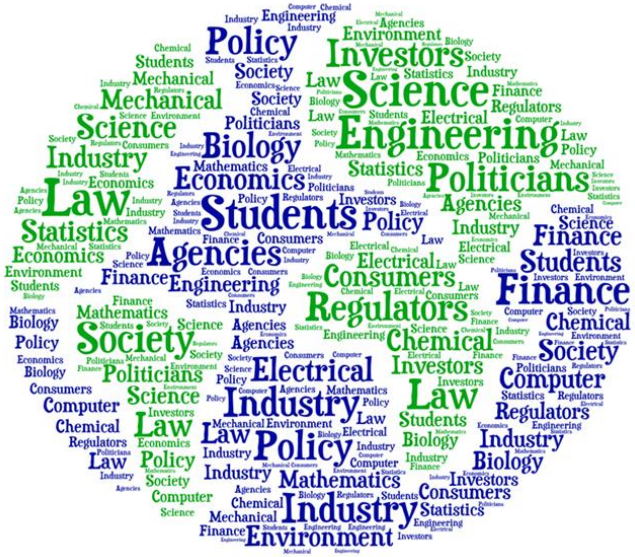
'Engineers and economists are ignoring people and miscasting decision making and action'

Sovacool, B.K. (2014) Nature 511, 529-530

Trilemma plus the “consumer”

Key Take Away

- It is more about the whole integrated energy system than ever before
  - Energy Systems Integration can reduce cost and uncertainty etc.
  - It is multidisciplinary and the consumer is central to it all



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