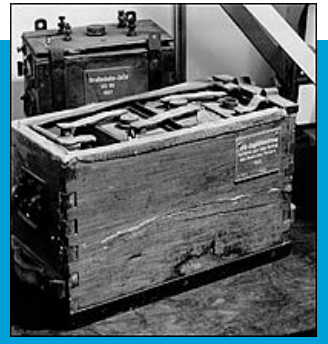
DNV·GL

ENERGY

Energy Storage

Keeping the lights on in a changing energy system

Or: ***The Role of Storage in Energy System Flexibility"***

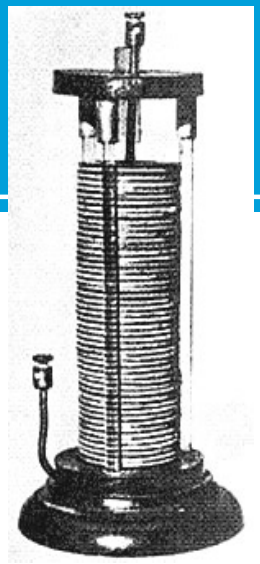


Varta Battery, 1907

Rob van Dijk

22-10-2014

Bagdad Battery, 227 to 126 v. Chr.



Rittersche Säule, 1802

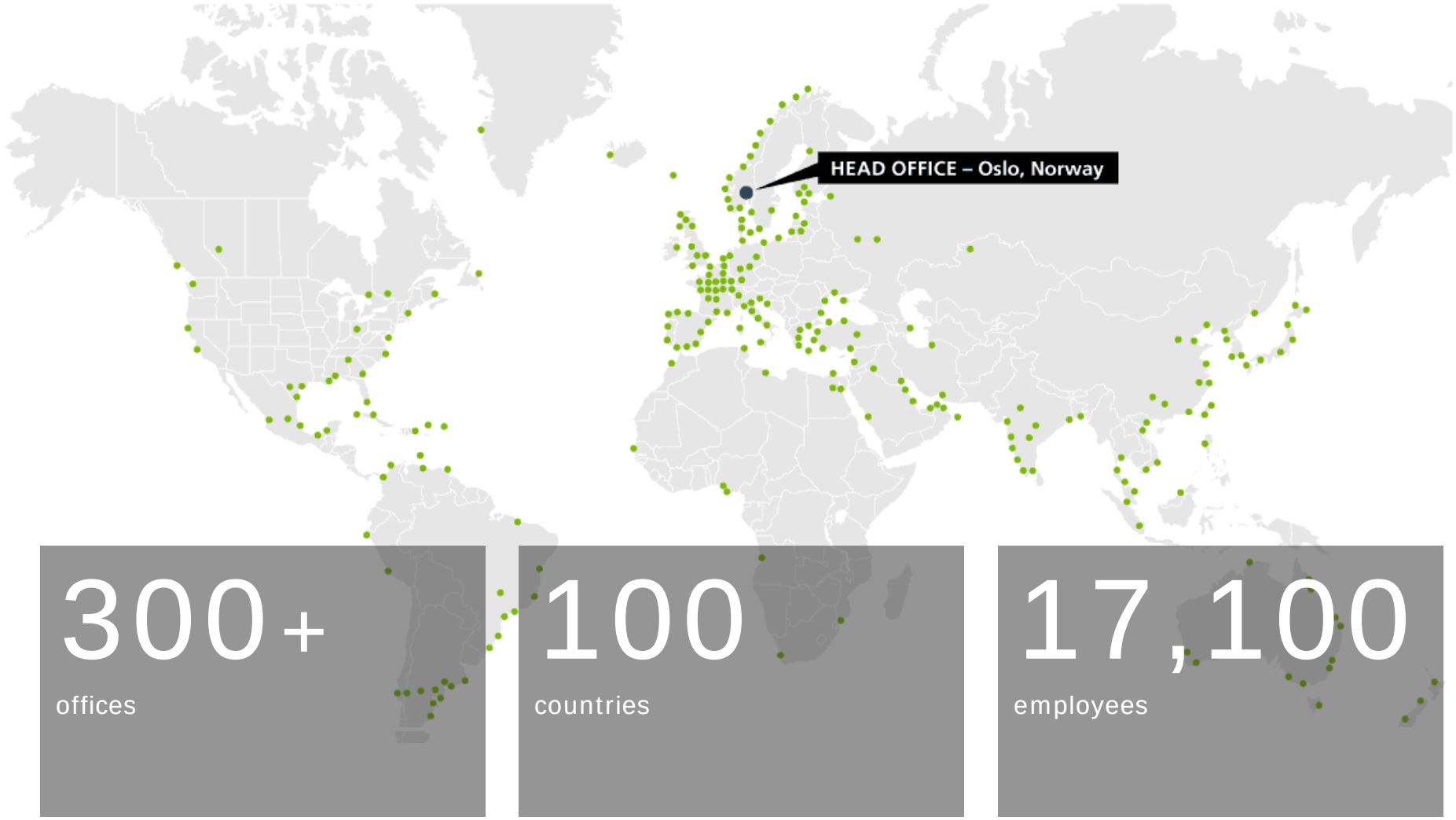
Leidsche fles, 1746

Content

- DNV GL introduction
- Energy system flexibility, security, standards
  - Flexibility
  - Security
  - Standards

DNV GL
Introduction

Highly skilled people across the world



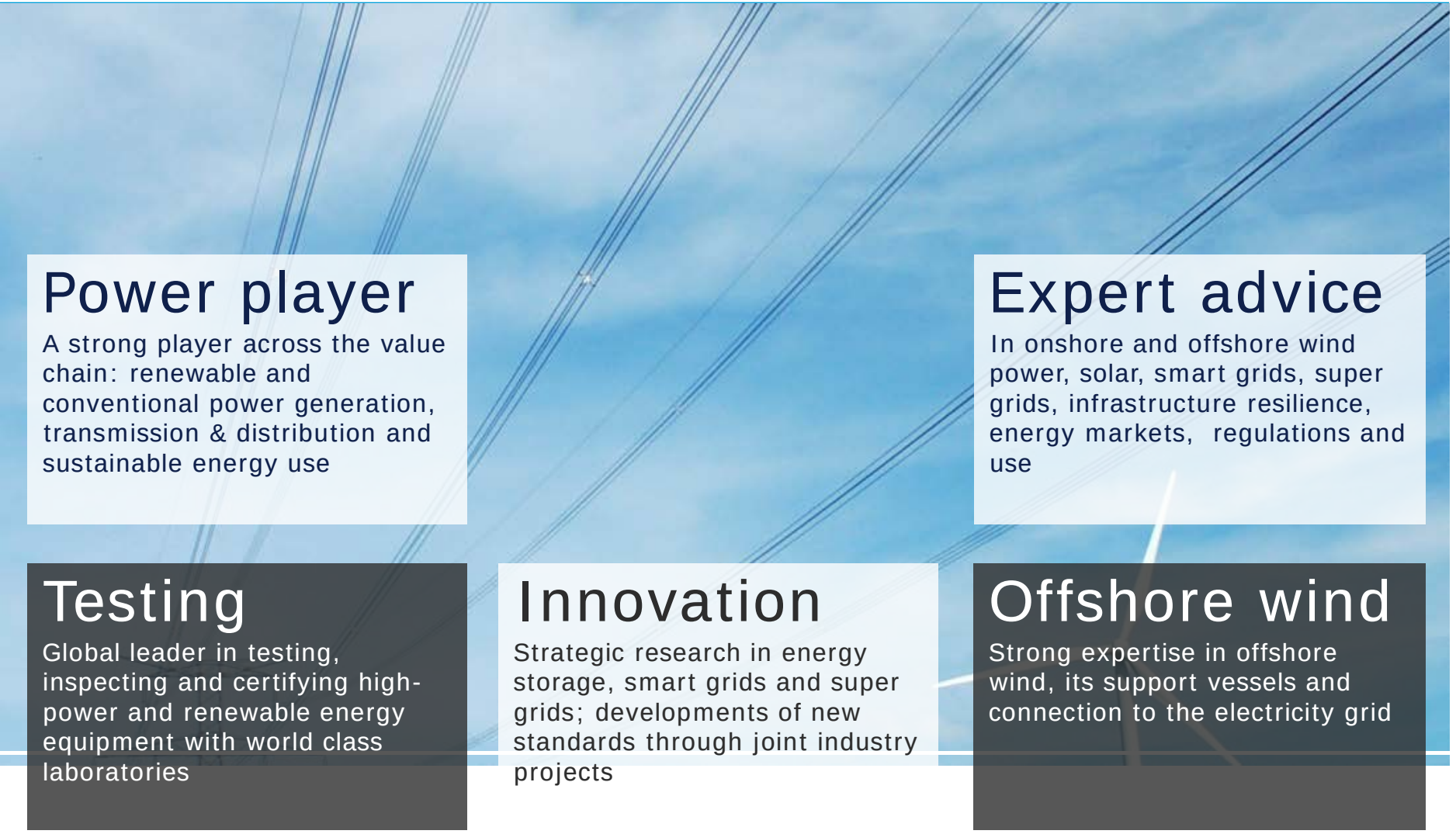
300+
offices

100
countries

17,100
employees

The DNV GL Group

An energy technology powerhouse



Power player

A strong player across the value chain: renewable and conventional power generation, transmission & distribution and sustainable energy use

Expert advice

In onshore and offshore wind power, solar, smart grids, super grids, infrastructure resilience, energy markets, regulations and use

Testing

Global leader in testing, inspecting and certifying high-power and renewable energy equipment with world class laboratories

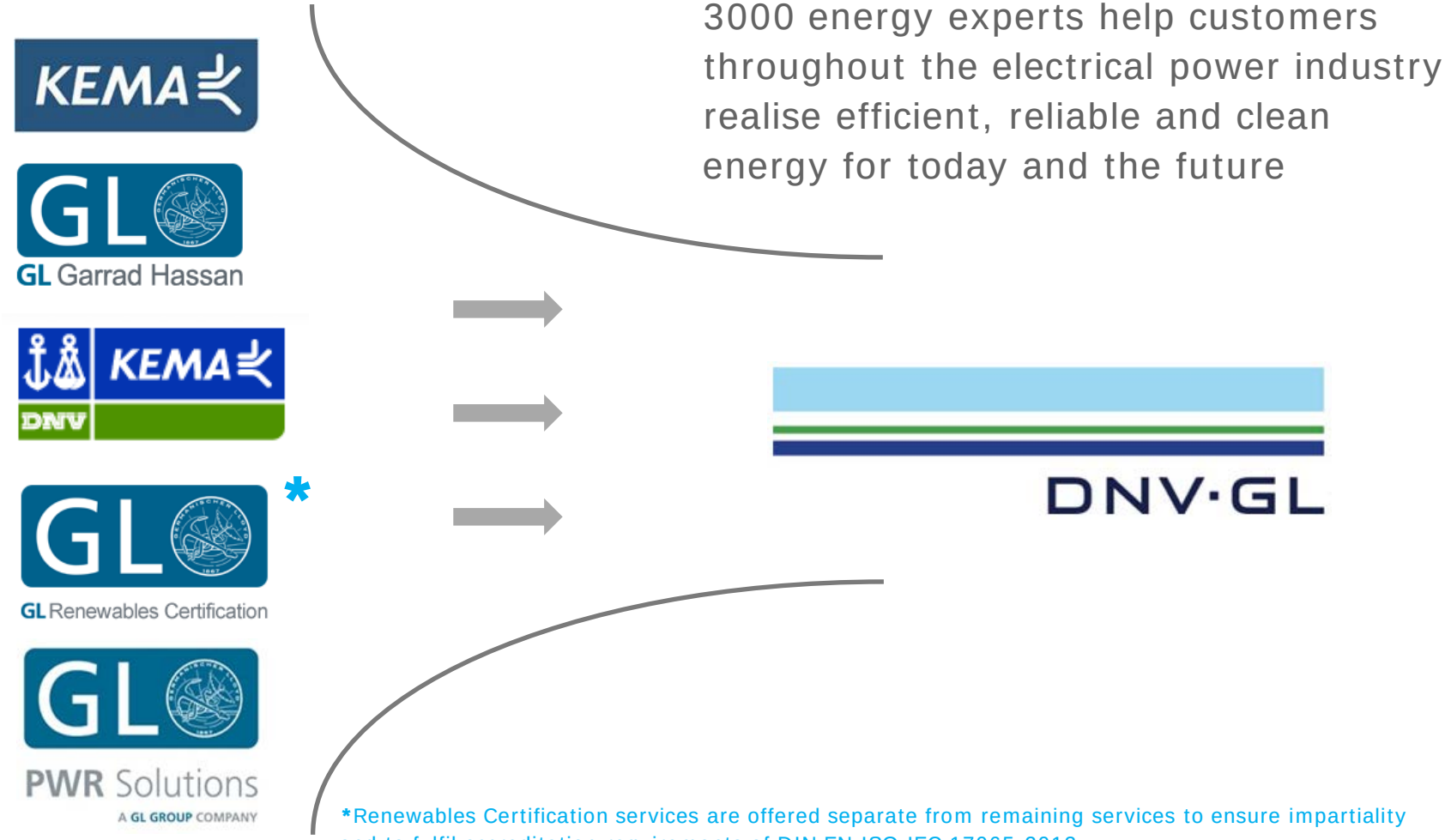
Innovation

Strategic research in energy storage, smart grids and super grids; developments of new standards through joint industry projects

Offshore wind

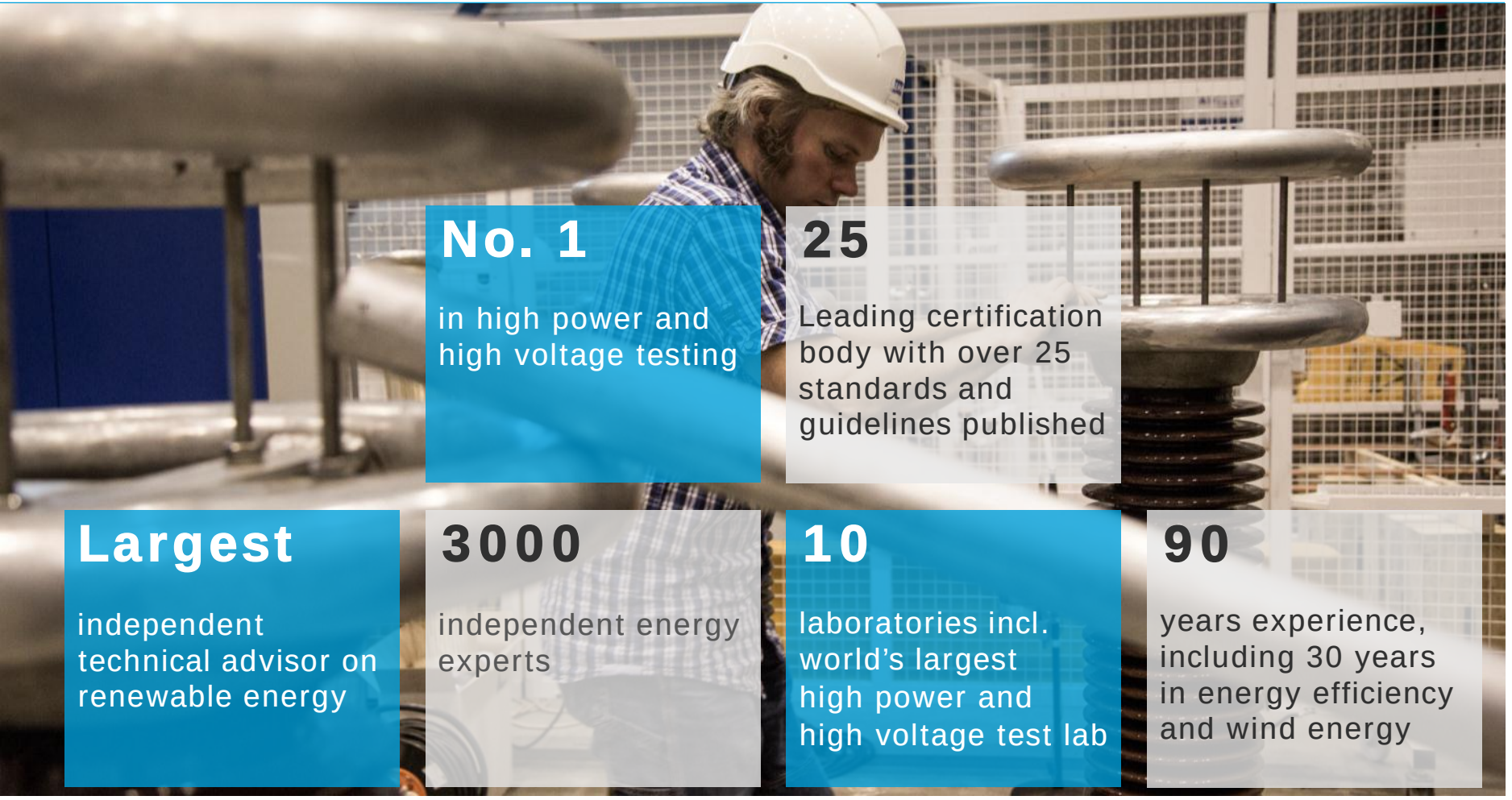
Strong expertise in offshore wind, its support vessels and connection to the electricity grid

Combined strength to support Energy customers



*Renewables Certification services are offered separate from remaining services to ensure impartiality and to fulfil accreditation requirements of DIN EN ISO IEC 17065:2013

DNV GL – Energy: An energy technology powerhouse



Energy system **flexibility**, security, standards

The World of Energy: Six major trends

1. Increased electricity demand
2. Environmental responsibility or stewardship
3. Declining fossil fuel supplies
4. Aging assets and workforce
5. Advancing technology, e.g. ICT
6. Maintaining reliability

The scale, and the priority of our business is shifting (1)

Supra-nationalisation

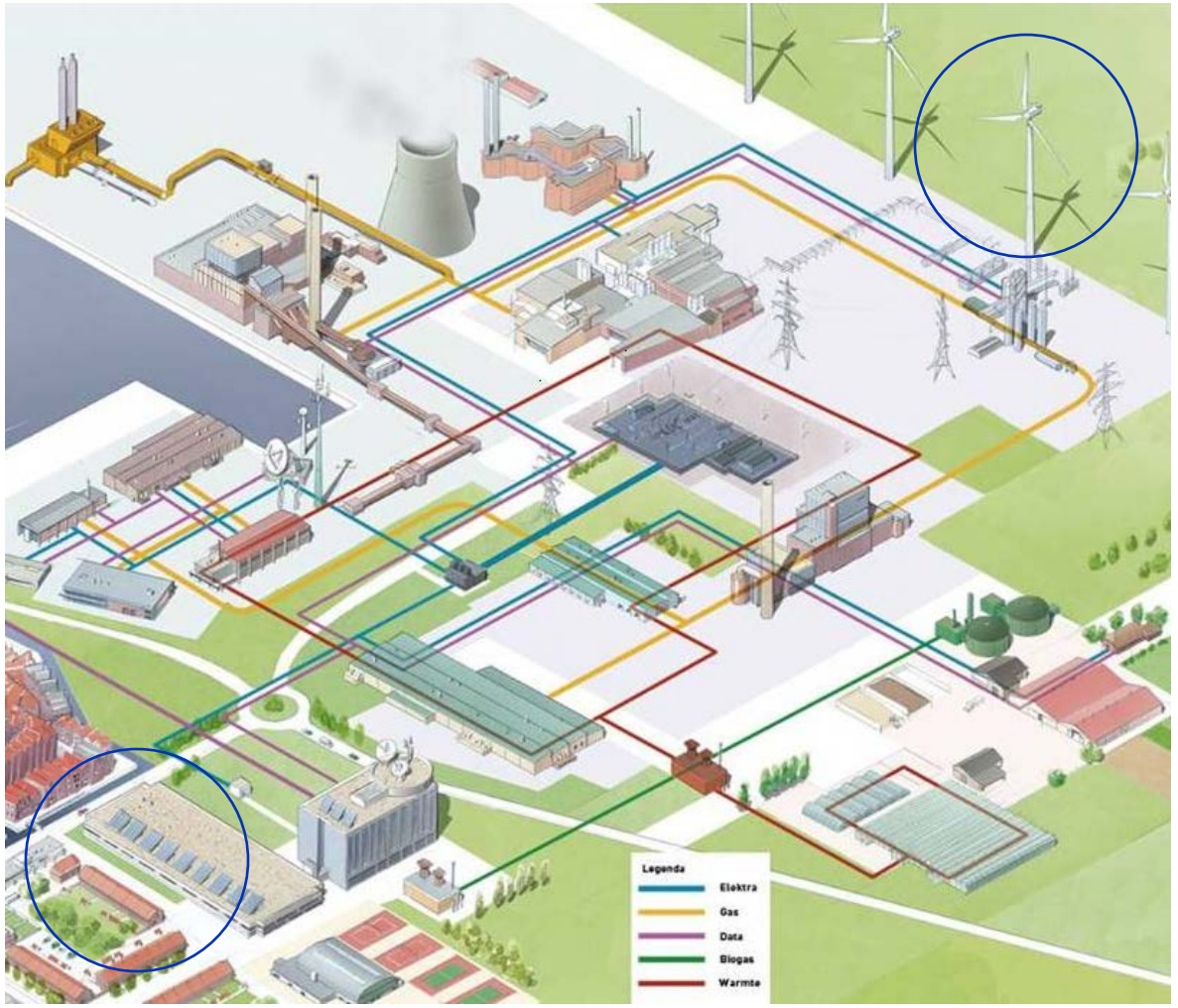
- cross-border energy exchange
- interconnection capacity
- in Europe: industries cooperate at transnational level

2050
Total Transmission Requirements Assuming 80% RES & 20% DR

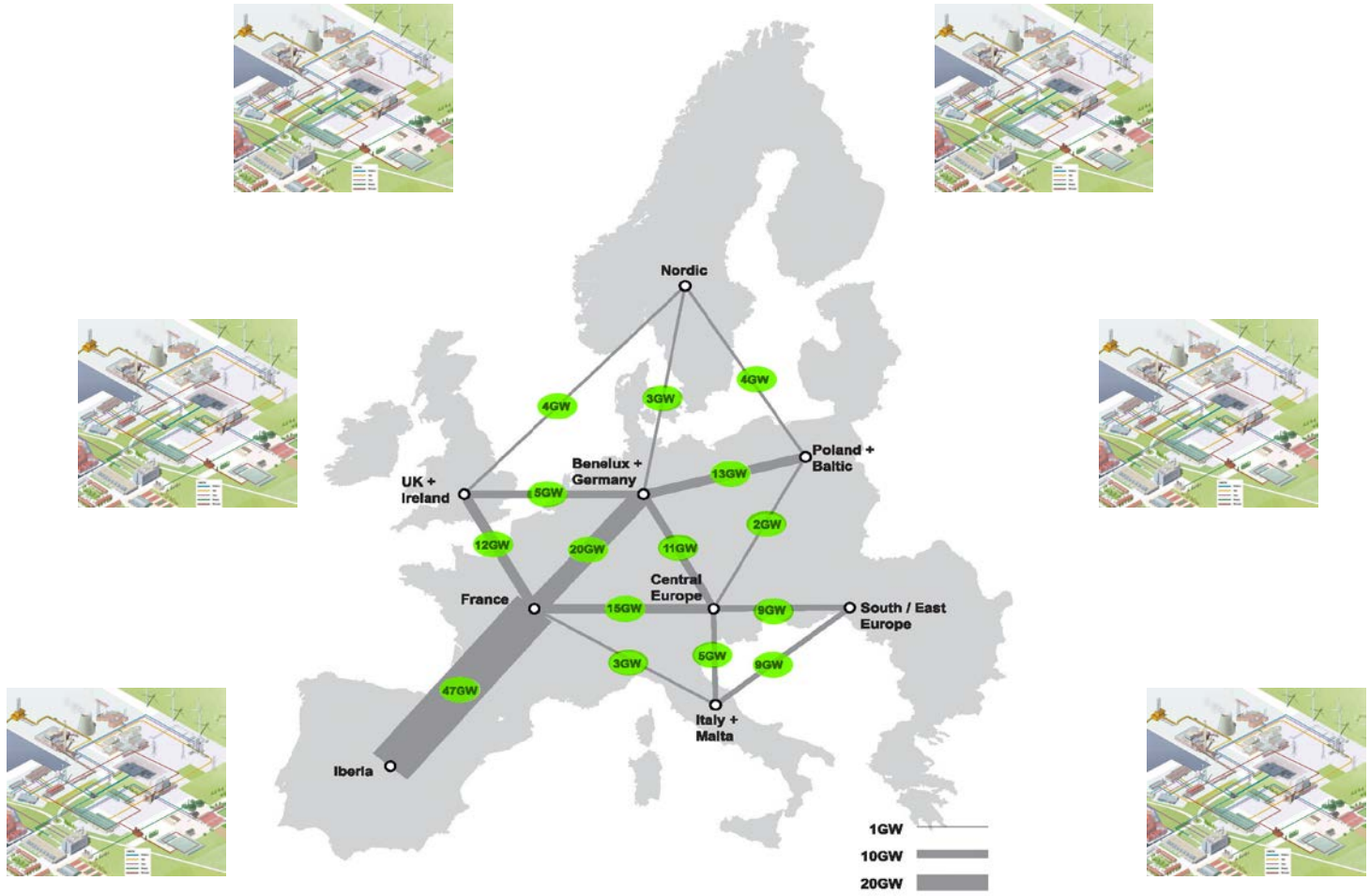
The scale, and the priority of our business is shifting (2)

Decentralisation

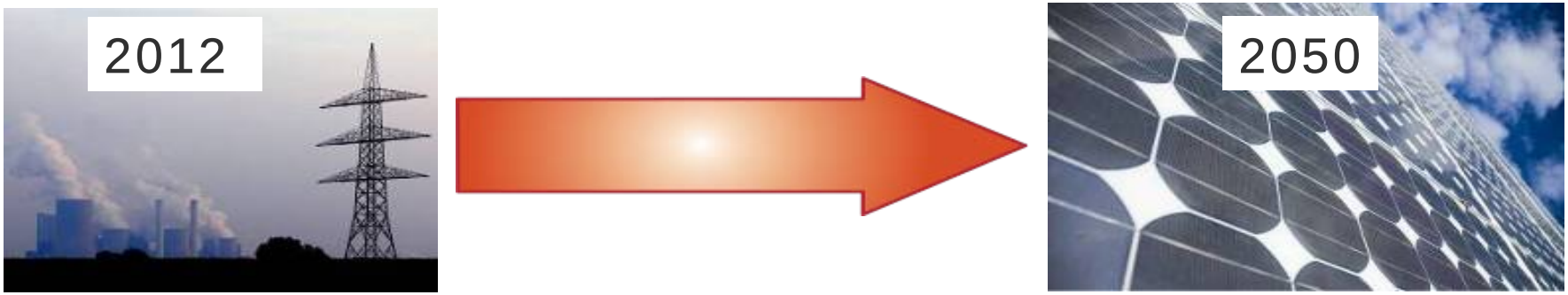
- local energy (DG)
- new initiatives from small companies, citizens, and municipalities
- innovative business models



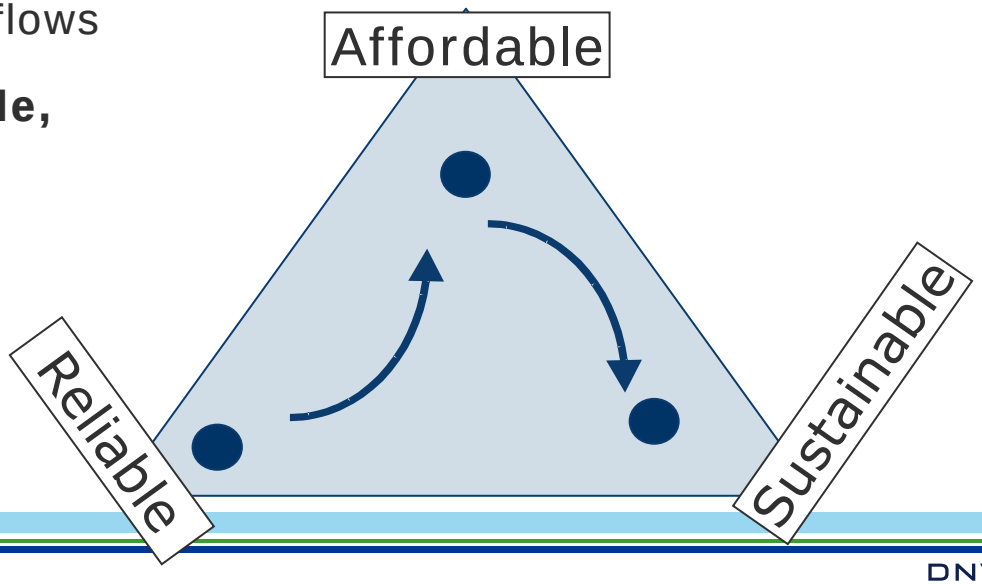
Supra-nationalisation and decentralisation develop in parallel



Three parallel trends in European power sector



- **Decentralization**: large amounts of distributed generation (DG), new entrants in the energy market (often SMEs); new ways of cooperation; participating end-users
- **Europeanization**: mergers and acquisitions; power plants at remote distance from load centers; cross-border power flows
- Requirement to have an **affordable, reliable and sustainable** grid



The Electricity challenges of 21st century can be countered by various solutions,....

Keeping up with a changing energy world:

Conventional:
Less income due to decrease in production

Solar & Wind:
Intermittent production

T&D Grid:
Balancing supply & demand without outage

Electricity demand:
Increased share in energy mix
- Heating (HP, CHP)
- Mobility (EV, PHEV)

CHALLENGE:

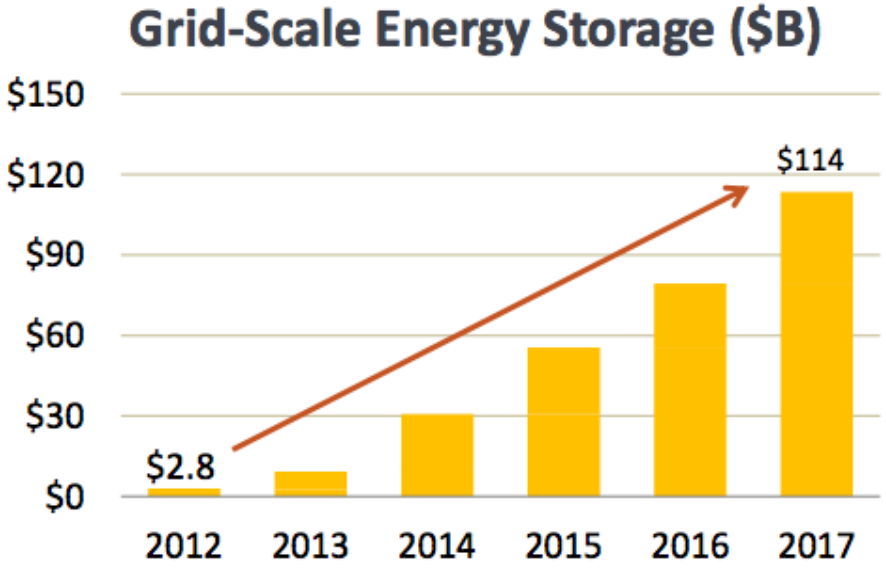
FLEXIBILITY!

regulation capacity for mismatch between production and demand

- ***Increase plant regulation***
- ***Strengthening grid***
- ***Demand side response***
- ***Storage***

Is there a market for Energy Storage?

Energy Storage Market Potential

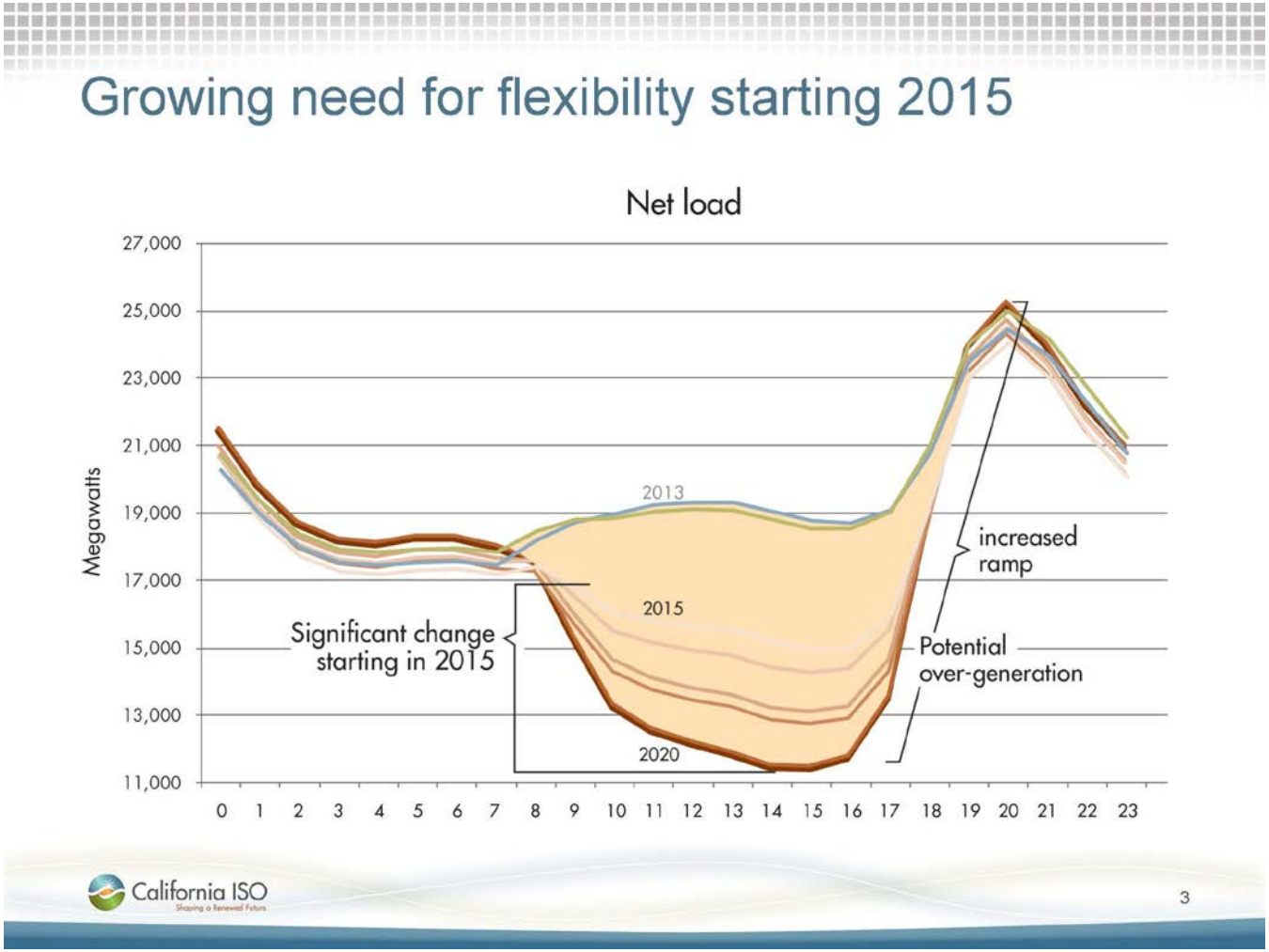


- Lux Research – $114 B by 2017
- Piper Jaffrey – $600 B market over 10-12 years
- Boston Consulting Group – $400 B market by 2020
- EPRI/DOE – annual savings of $50 billion/year via energy storage

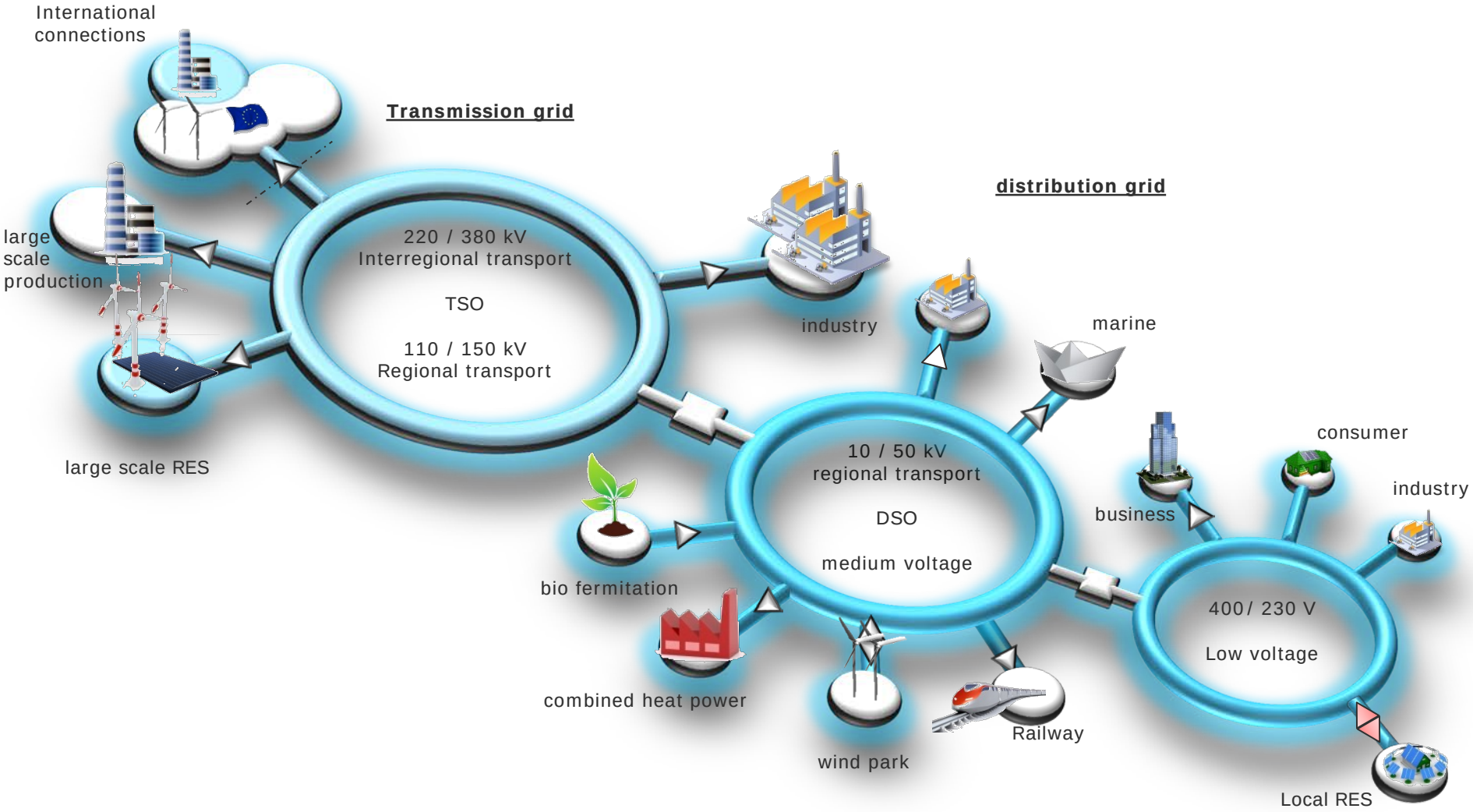
Plenty of market potential... for the right product at the right price

Energy system flexibility, **security**, standards

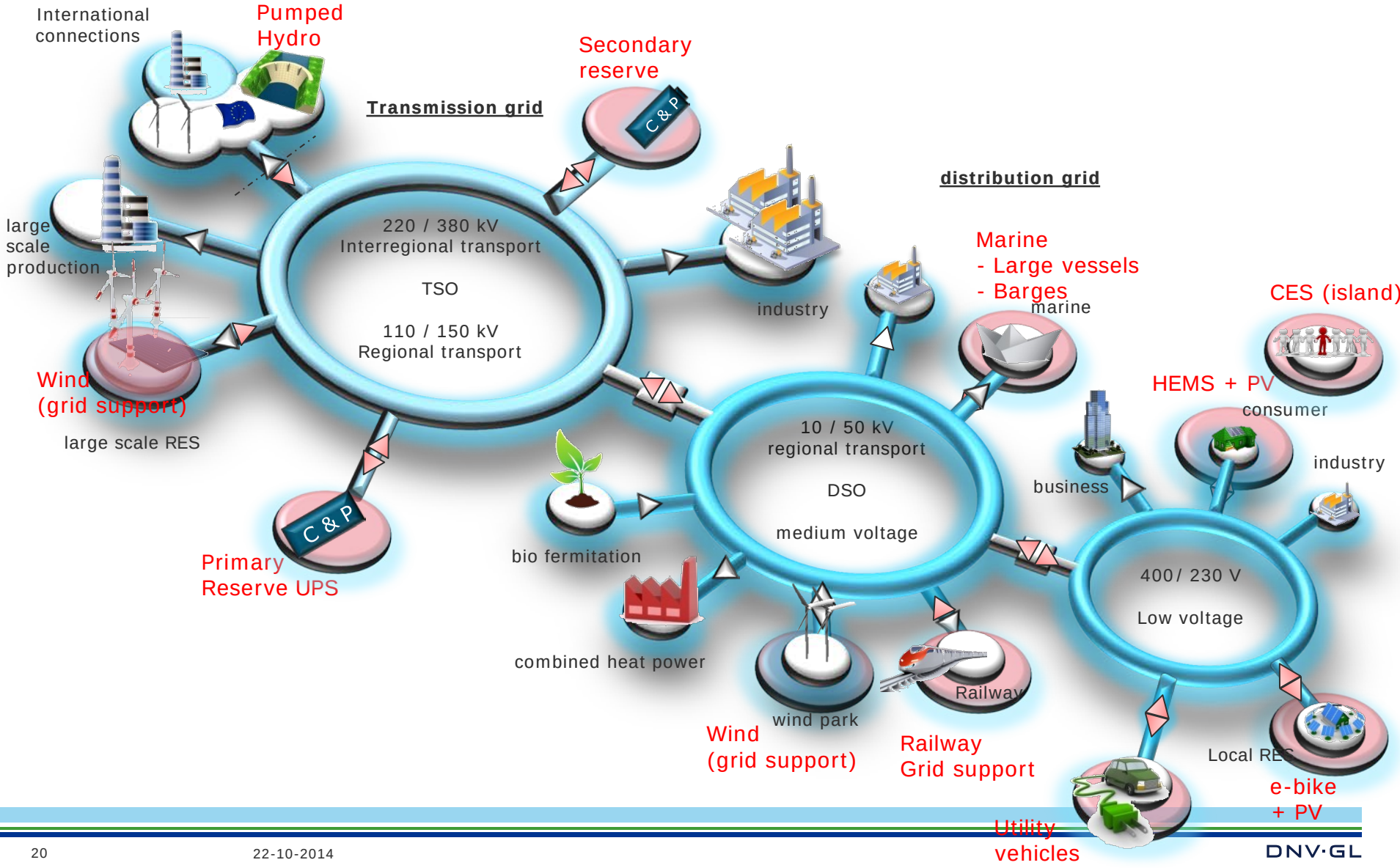
What happens to the light when the suns starts shining?



Electricity grid and storage: potential applications



Electricity grid and storage: potential applications



...systems are being deployed at small sizes.

RWE Power

ADELE – ADIABATIC COMPRESSED-AIR ENERGY STORAGE FOR ELECTRICITY SUPPLY

RWE

McPhy Energy INGRID Project

Comments

- 39 MWh Grid Connected Renewable Energy Storage
- Solid-state high-density hydrogen storage system
- 1.2 MW hydrogen generator
- provides balancing support for the local grid managed by Enel Distribuzione

Siemens lithium-ion rechargeable battery

Comments

- 500 KWh storage system
- For the use of ENEL
- Modular power storage system called as 'Siestorage'
- Based on lithium-ion rechargeable battery technology

AES Energy Storage

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AES Reaches More Than 100 MW of Grid-Scale Storage in the U.S. with 40 MW Resource in Ohio

Largest Advanced Energy Storage Resource in Ohio Now Online Within PJM Interconnection

January 2014
AES Storage Fleet Surpasses 1.5 Million MW -h of Service
September 2013

SAFT lithium-ion battery storage plant

Comments

- Lithium-ion batteries
- Capacity of 1.1 MW and 560 kWh of power
- supplied by SAFT
- Acciona incorporates energy storage into a grid-connected PV solar plant

One of Europe's largest electricity storage plants using lithium batteries was built in Spain. Also,the Isernia project is still ongoing and Enel's Research is testing the main cutting-edge technologies used to improve storage systems

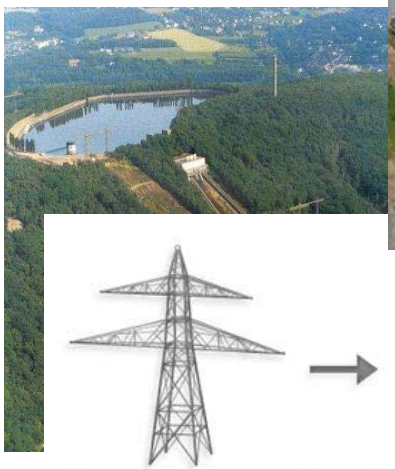
In the Canary Islands, in Spain, one of Europe's largest plants using lithium batteries was built. Once it's connected to the grid, the plant will supply a capacity of **1 MW for 3 consecutive** (3 MWh), so that it can meet demand peaks and enhance the frequency and the current of the local distribution network.

ABB DynaPeaQ® energy storage installation

Comments

- Static var compensator (SVC) Light® technology with a highly scalable lithium-ion battery
- Eight stacks of 13 Saft lithium-ion battery modules
- Stores up to 200 kWh
- Rated power and storage capacity is typically about 20 MW for approximately 15–45 minutes
- Connected to UK Power Networks

..., and also at a large scale.

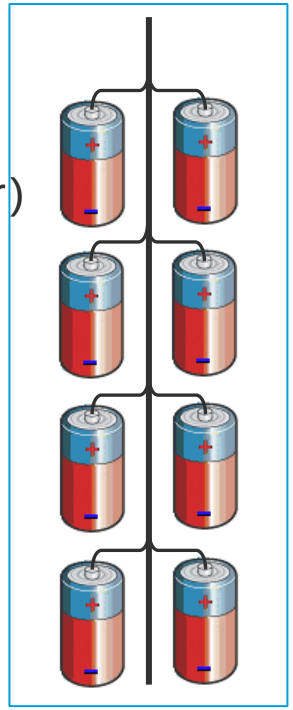


Illustrations from www.powertogas.info

Central vs. Distributed Bulk Storage

BOTH central and distributed resources will play a role in future grids but aggregated fleets of distributed storage units will dominate the market:

1. **Startup cost** is lower (gradual investment)
2. **Shorter waiting** (construction) time
3. **Higher reliability** of electric service (backup power)
4. **Redundancy** (unit outage less critical to grid operations)
5. **Higher flexibility** (responsive to local needs)
6. **Higher resiliency** (hard to totally shut it down and quick to recover)
7. **Higher synergy** with transportation batteries



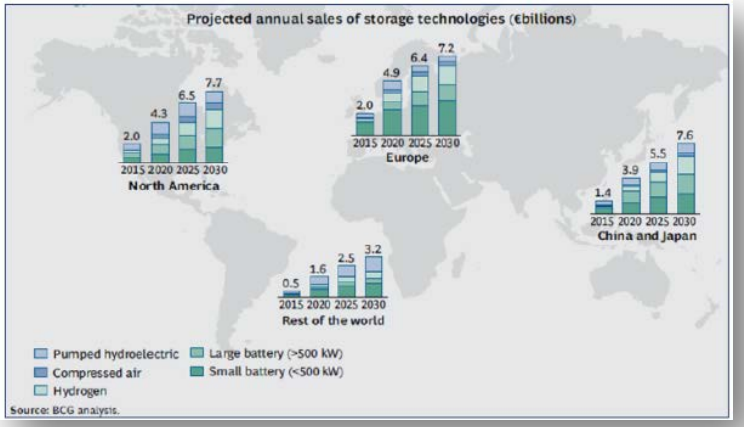
EXCEPTION: Certain countries are geologically ideal for large central pumped hydro or Compressed Air Energy Storage (CAES)

Energy system flexibility, security, **standards**

Energy Storage Market Situation

- **Present situation:**
  - Increasing demand for Grid-Connected Energy Storage Systems
  - Increasing attention to safety, operation and performance

- **Survey** in 2014 amongst electric utilities, storage vendors and other stakeholders. Outcome survey: "Lack of clarity on applicable standards for grid-connected energy storage systems"
  - Difficulty proving the validity of a system
  - Risk for sector as a whole



- **Global activities: e.g.**
  - IEC TC 120
  - NEN
  - DOE / Sandia
  - ...

Linking developments in ES recomm. practices / standards (1)

IEC

120/44/DC

For IEC use only

2014-06-06

INTERNATIONAL ELECTROTECHNICAL COMMISSION

TECHNICAL COMMITTEE NO.120: ELECTRICAL ENERGY STORAGE (EES) SYSTEMS

ESC | ENERGY STORAGE COUNCIL

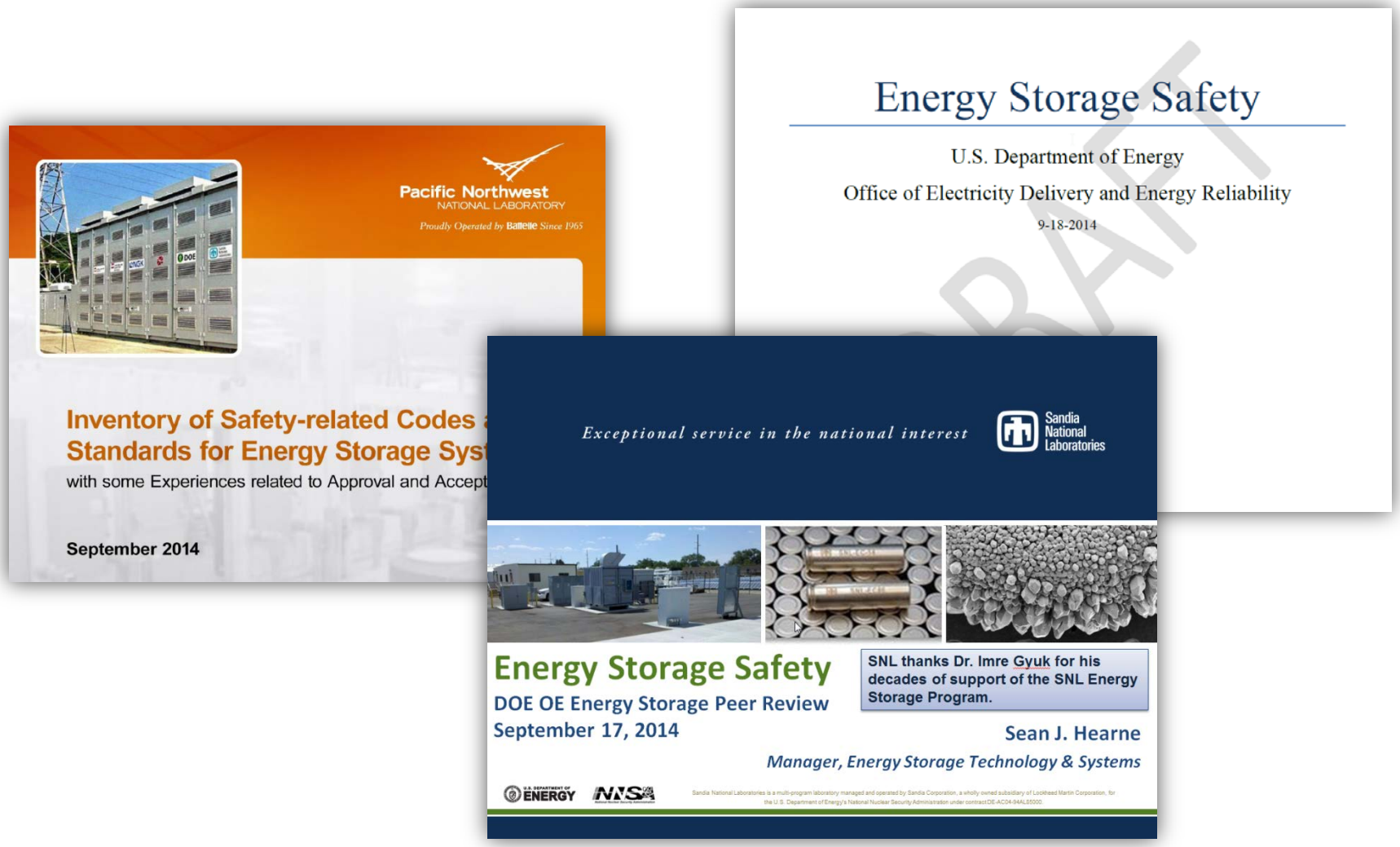
12 September 2014

Media Contact: John Grimes on 0400 102 396

Energy Storage Peak Body Launched

Today the Australian Energy Storage Council – the new peak body for the energy storage industry – has been formally launched, opening up exciting new opportunities for the sector in Australia.

Linking developments in ES recomm. practices / standards (2)



Desk study: existing standards

Standard	Application Type				Category			Technology Type				Level				Application Area						Require-ments			Testing Procedures			Other Procedures			
Name / code	Mobile	Stationary	UPS	Island	Safety	Operation	Performance	Pb-A	Li-ion	NiCd	Non-batt.	BOS	System	Cells	Modules	Residential PV	Maritime	Automotive	Industrial	Telecom	RES	Controls	Safety	General	Safety	Performance	Functionality	Personnel	Maintenance	Installation	Inspection
GL RP-A203	X	X			X	X	X	X	X	X	X	X	X						X				X		X	X	X	X	X	X	X
EA S9310-AO-S	X	X			X	X	X		X					X	X			X				X	X	X	X	X	X	X	X	X	X
/IATA DGR	X	X			X			X	X	X	X			X	X	X	X	X	X	X	X		X		X						
(IMO)	X	X			X						X		X					X					X		X			X			
ubject 2580	X				X						X		X		X	X	X	X	X	X	X		X		X						
50092-504	X	X			X							X			X			X				X	X							X	X
50529	X	X			X							X			X	X	X	X	X	X	X	X		X		X						
50812	X	X			X							X	X			X	X	X	X	X	X		X					X				
51025	X	X			X							X	X			X	X	X	X	X	X		X					X				
51508 (all parts)	X	X			X							X			X	X	X	X	X	X	X		X							X		
51511-1	X	X			X							X			X				X				X							X		
52061	X	X			X							X			X				X				X							X		
1772 / IEC 6219	X	X			X							X			X			X					X					X		X		
63	X	X			X							X			X	X	X	X	X	X	X		X		X							
52281 (2011)	X	X			X				X					X	X	X	X	X	X	X	X		X		X							
642	X	X			X				X				X			X	X	X	X	X	X		X					X				
8.3 (United Nati	X	X			X				X				X			X	X	X	X	X	X		X					X				
TS 62257-5				X	X							X			X						X		X					X				
2464	X				X			X	X	X			X					X					X		X							
50092-351	X				X							X			X		X						X		X				X	X	X	
2660-03 (under	X				X				X				X					X					X									
12405-3 (under	X				X				X				X					X					X									
2929	X				X				X				X					X					X									
1 / IEC62660-01	X				X				X				X					X					X	X								
1 / IEC62660-02	X				X				X				X					X					X	X					X			X
0510-11	X				X				X				X						X			X	X		X							
1495		X			X						X		X					X					X									
ubject 9540		X			X						X		X						X				X							X		
52133 (2012)		X			X			X	X	X				X	X	X	X	X	X	X	X		X									
52485-2 (2010)		X			X			X	X	X				X	X				X			X	X		X				X	X	X	
52485-3 (2010)		X			X			X	X	X				X	X				X				X						X			X
1375		X			X			X	X	X			X						X				X									
547		X			X							X			X	X	X	X	X	X	X		X			X	X			X		
741		X			X							X			X		X						X				X			X		
52485-1 (under		X			X				X					X	X				X				X					X				
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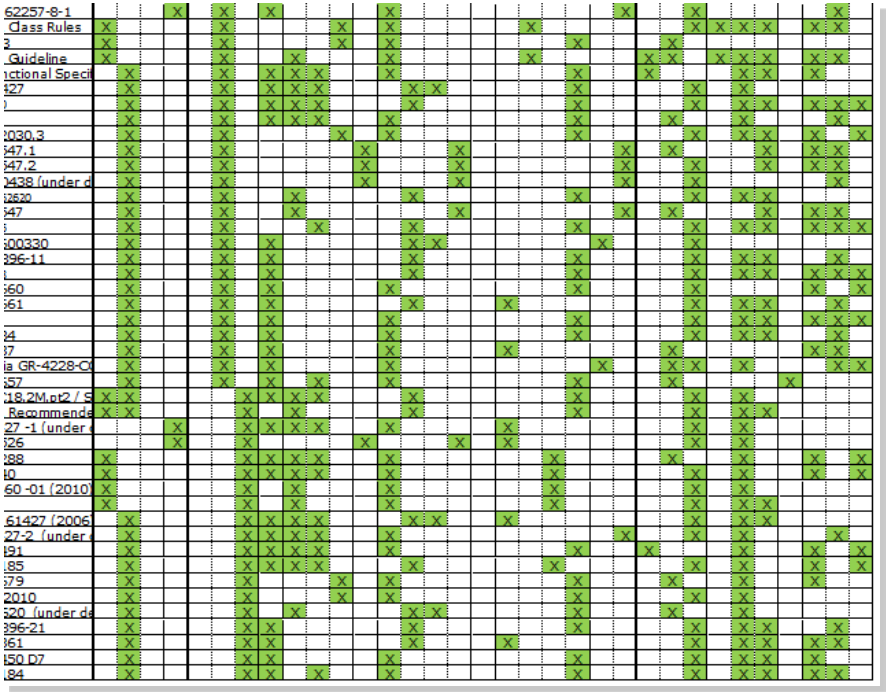
896		X			X				X				X						X				X					X				
52897 (under de		X			X				X					X	X				X				X							X		
ion Project		X			X				X				X						X			X	X		X			X				
rdia GR-3150-C		X			X				X				X							X			X	X						X		
rdia GR-3020-C		X			X					X			X							X			X	X	X	X						
0272-2		X			X			X		X			X						X				X		X					X		
52040-1		X	X		X			X	X	X			X						X				X					X				
52040-1-2		X	X		X			X	X	X			X						X				X					X				
50730-1 (2013)	X	X				X					X	X			X	X	X	X	X	X	X		X									
70	X	X				X					X	X			X	X	X	X	X	X	X		X					X		X	X	
10A	X	X				X				X					X				X					X	X		X					
1679	X	X				X			X		X		X						X					X							X	
50622	X	X				X				X				X					X					X		X	X					
50623	X	X				X				X				X					X					X		X	X					
1375	X	X				X		X		X			X						X					X							X	
TS 62257-9-1				X		X						X			X						X			X							X	
TS 62257-9-2				X		X						X			X						X			X							X	



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Desk study: existing standards (2)

"There are already many standards, and together they cover all relevant aspects of grid-connected energy storage."

Well…No:

- *No single standard* that comprehensively covers and links all aspects relevant for grid-connected energy storage (fragmentation)
- Unclear or *impossible to combine* ~100 standards into 1 comprehensive standard
  - Wildly differing scopes
  - Difficult to read/understand
  - Difficult to get overview, know and choose from all standards
- A standard may *address* an aspect ("X"), but may not *cover it completely*
- A standard may *address* an aspect ("X"), but may have a *low quality* for it
- *Gaps* exist: some aspects are not or insufficiently covered

What is needed to move standardization forward?

- A guidebook that allows new adopters to easily understand the steps that need to be taken in order to install storage systems
- One framework standard for grid-connected energy storage
- Gaps filled: addition/expansion with newly written guidelines where needed
- Comprehensive and complete
  - *System-level approach*, but including components
  - Addressing issues from an international perspective
  - Created *specifically for grid-connected energy storage*
  - Created by international *industry-wide consortium* (independent, unbiased)
- Recommended Practice: freely accessible, well maintained, updated and delivered to the market quickly

Joint Industry Project on Grid-Connected Energy Storage

- **DNV GL** setting up & coordinating an open source **Joint Industry Project (JIP)** to facilitate / stimulate optimal and safe implementation of Energy Storage

- JIP consortium of approx. 10 to 15 participants
  - End-users (DSO, TSO, utilities etc)
  - Energy Storage system integrators, suppliers
  - Regulators

- Deliverables: *Recommended Practice(s) on grid-connected energy storage*
  - guidelines and methods to evaluate, assess and test safety, operation and performance of grid-connected ES
  - taking into account worldwide accepted regulations and best practices like ISO, IEC and IEEE standards

- Global approach: US, EU, APAC and ME

GRIDSTOR

Take Home Messages

- The future energy system will have an increased requirement for **flexibility**
- Storage can improve system **security**, both on (inter)national and decentralized level
- **Standardization** is required to enable the safe and sustainable implementation of energy storage systems

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SAFER, SMARTER, GREENER