DNV·GL

ENERGY

The Energy Transition

why renewables need more power engineers

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14 February 2019

PowerWeb Institute

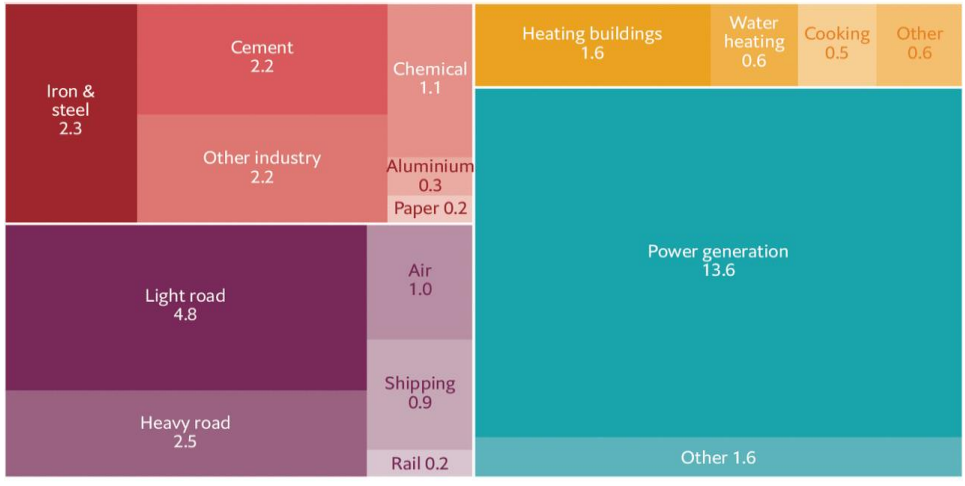
DCE&S
DC systems, Energy conversion & Storage

KEMA Laboratories

SAFER, SMARTER, GREENER

Dirty business

Global energy-related CO_2 emissions, by sector, 2014, tonnes bn
Total: 36.2bn



Source: International Energy Agency
The Economist

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From The Economist "Clean energy may not have yet reached a tipping point"

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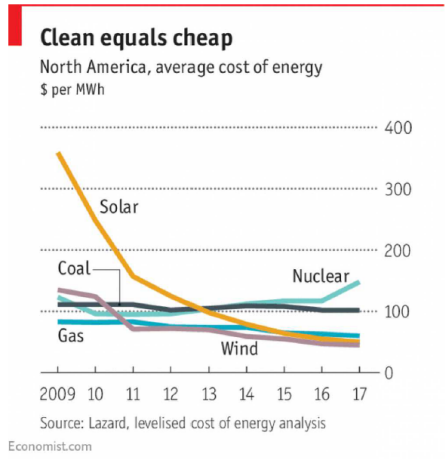
- Price drop solar due to economies of scale (not performance)
- Economics become less attractive the more they are deployed → market becomes flooded with cheap electricity
- Large interconnected systems and storage needed for variable renewables



Electricity: a key role in Energy Transition

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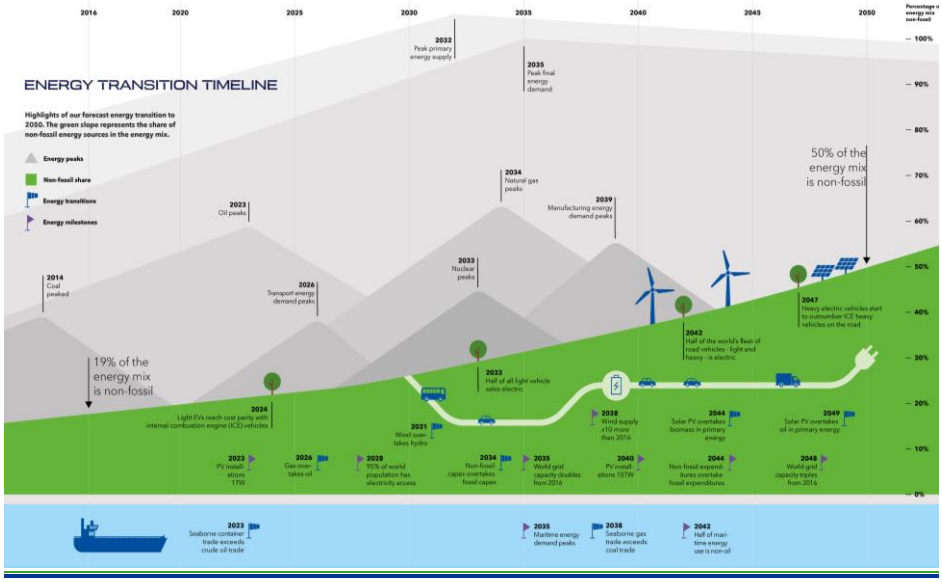
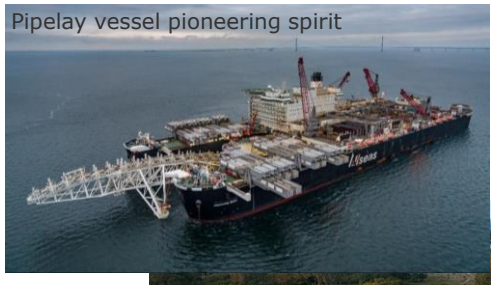
https://eto.dnvgl.com/2018/



Northstream 2 pipeline 1250 km Russia – Europe
55 bcm gas per year



1bcm ≈ 1GW

Electricity in combination with molecules as fuel

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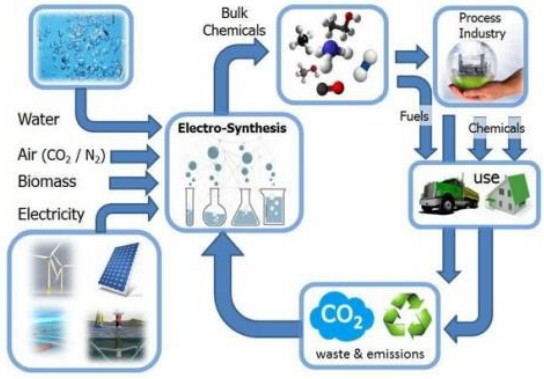
e:Refinery
Towards sustainable production of chemicals and fuels



Source TU Delft

Abundant variable renewables; in 2017 > 60GW wind and 100GW solar added

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Offshore wind farm

Wind farm

Large solar farm, Middle East

Distributed home solar systems

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Veltoor 100MW Solar Power Project India

DNVGL SE 0078 'project certification of photovoltaic power plants'

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Advanced Power Electronics

- **Software-controlled** compact configuration of **fast solid-state switches** capable of transforming electric energy with **high efficiency** in applications between power sources and loads. Advanced power electronics also enable **precise steering and protection**.

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High Power semiconductor switches

Thyristor
8kV, 5.5kA

IGBT
5kV, 3kA

Source: ABB

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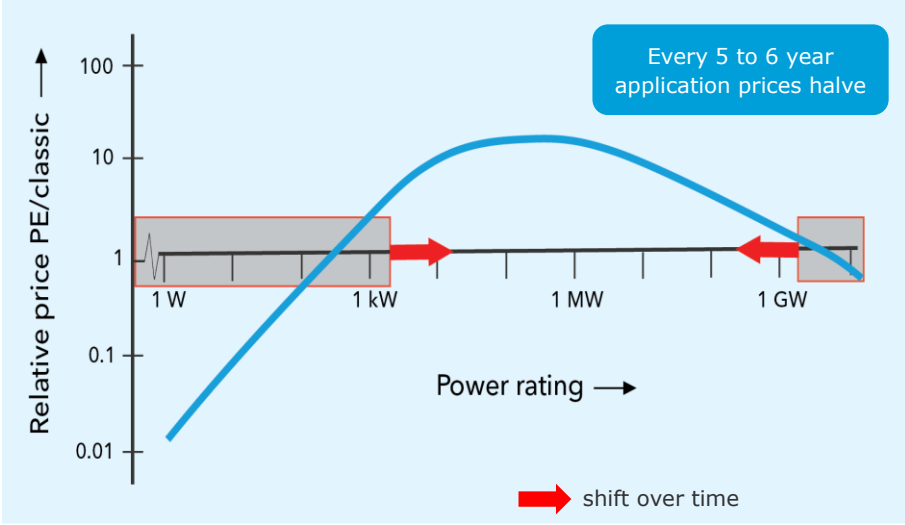
Price comparison "like-for-like" replacement



http://www.inmr.com/advanced-power-electronics-rule-future-power-systems-part/

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High Power Electronics - Skagerak VSC valve hall

ABB

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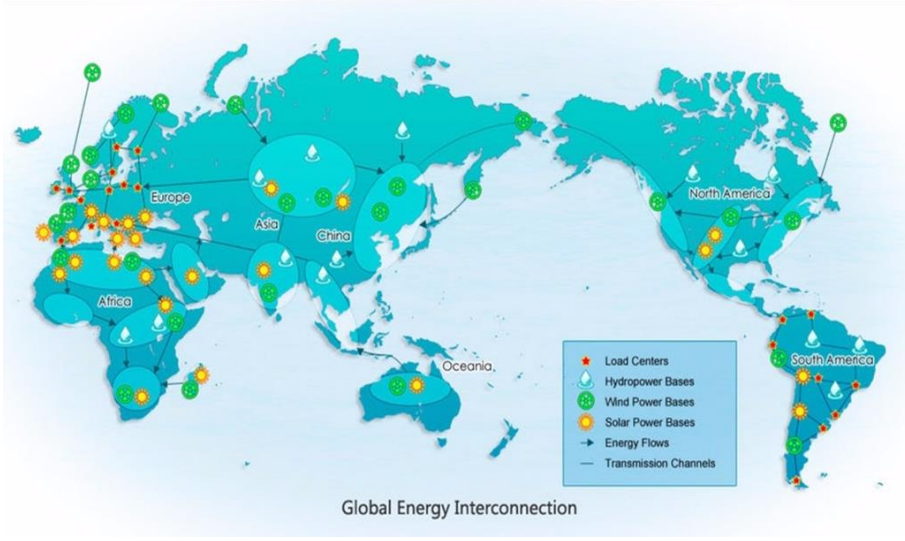
Belt and Road initiative



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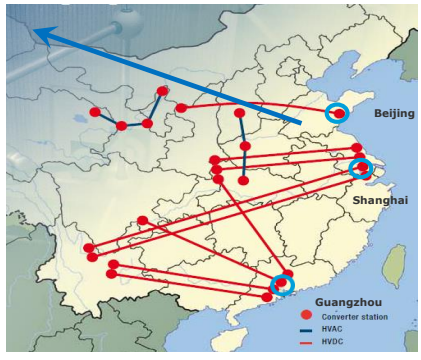
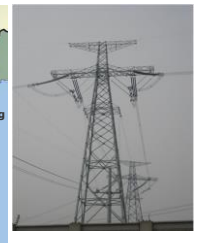
Electric Power Highways in China → grid





- Ultra high voltages ±800kV → ±1100kV
- Huge distances > 2000km → 3300km
- Large Capacity > 8000MW → 12000MW
- Losses (typical) 2x0.5% + 2-3%/1000km

"Electric Silk Route" transformers for 12GW link

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Source ABB Ludvika LV unit and HV unit

600MVA/unit
750kV AC
1100kV DC

"Electric Silk Route" transformer for 12GW link

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Source Siemens 1100kV HVDC converter transformer

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"Undergrounding" is a trend

TenneT, 380kV Transmission line and cable

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HVDDC cable prequalification and type testing

KEMA "Kleefse Waard" DC test laboratory

High Power Laboratory #1 in the world; 15000MVA

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HVDC circuit breaker principle concept

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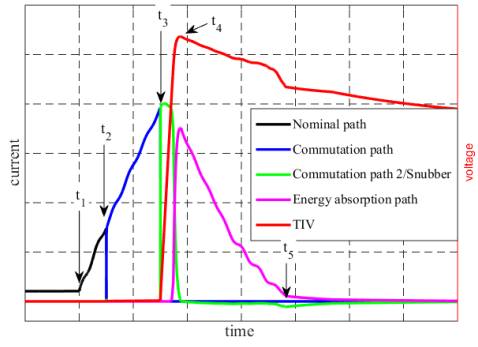
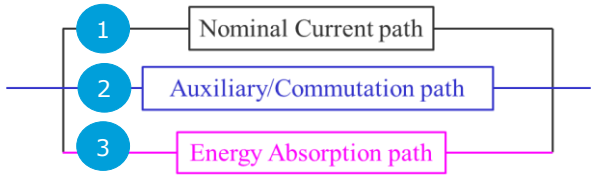
1. Based on artificial current zero creation
   - Commutation to separate path
   - Counter current injection
2. Absorbing magnetic energy in the system





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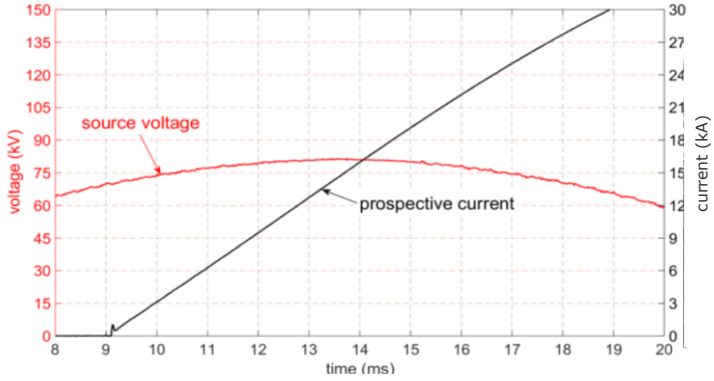
AC generators for HVDC CB testing



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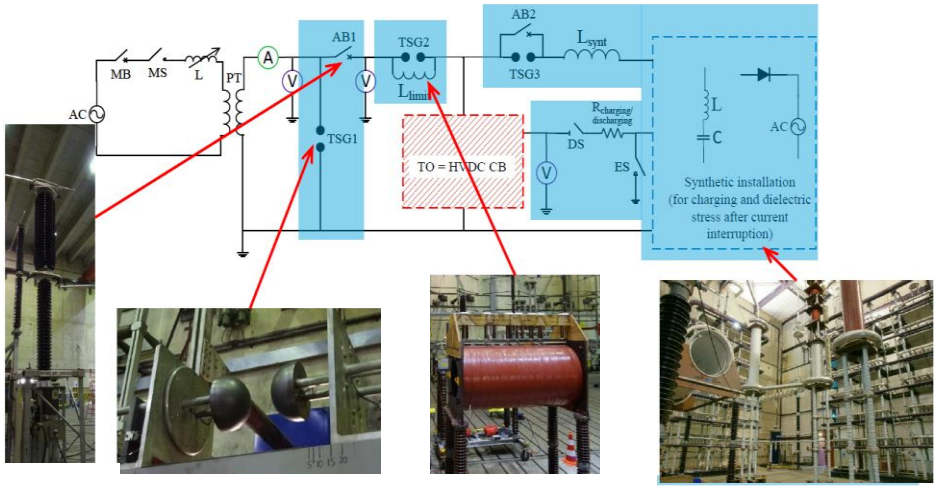
Complete HVDC DC breaker test setup



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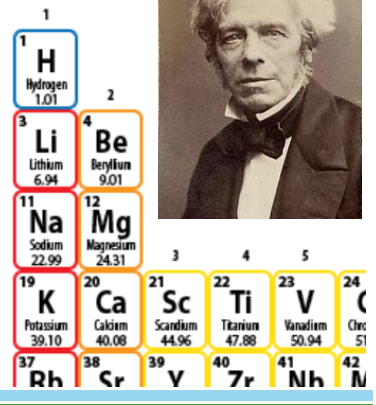
Battery storage basics: Faraday constant

F ≈ 100,000 J/mol electrons = 0.027 kWh/V/mol

How much Energy can fit in a kg/dm^3 ?

~25g

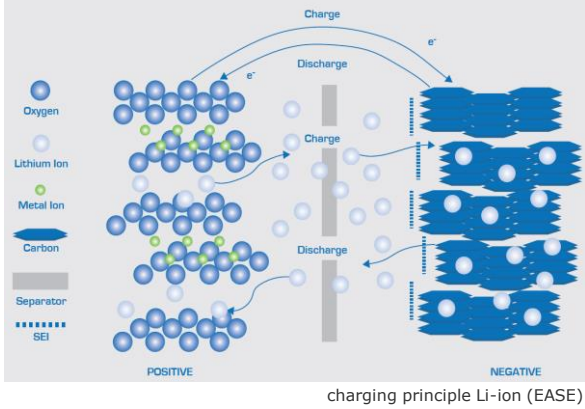


Michael Faraday

Batteries get cheaper … not "better"

F = 0.027 kWh/V/mol
Cell voltage = 3.6V
Molar mass 0.08 - 0.2 kg/mol
#Electrons/molecule = 1
Fill factor = 0.8

Theoretical energy density:
0.4 - 1.0 kWh/kg



charging principle Li-ion (EASE)

Present state of the art (a.o. Tesla battery) 0.12 – 0.18 kWh/kg

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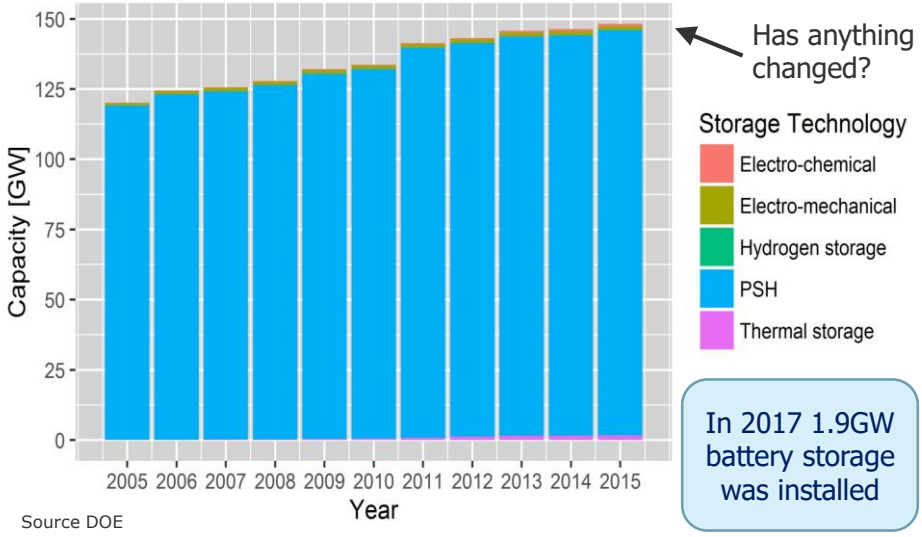
Storage capacities (different technologies)



Source DOE

In 2017 1.9GW battery storage was installed

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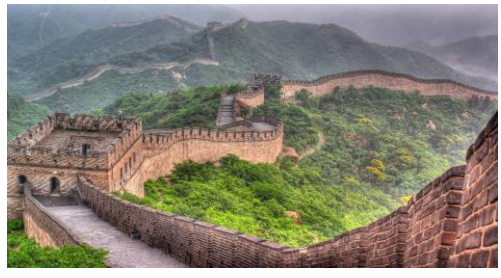
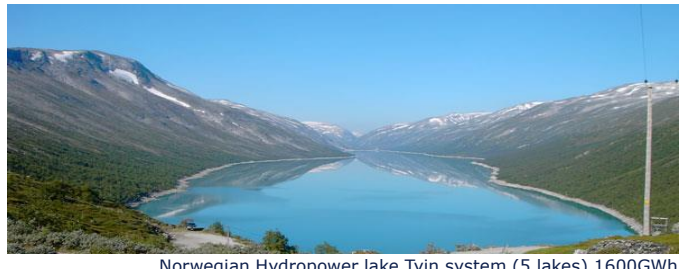
Battery storage; another perspective

The 6000km long Chinese wall fitted with 10 Powerwalls every meter, on both sides, computes to 1700GWh



Powerwall 14kWh



Norwegian Hydropower lake Tyin system (5 lakes) 1600GWh

A bright and challenging future for power engineers

1. Electricity as "Fuel of Choice"
2. Abundant Renewables (wind and solar)
3. key-role for Power Electronics

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Thank you for your attention

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