EU GCC CLEAN ENERGY TECHNOLOGY NETWORK

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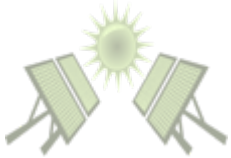

Tackling Climate Change How Hydrogen Enables the Energy Transition: a European Perspective.

Frank Wouters

Director

DUBAI SOLAR SHOW SEMINAR WEEK 2017

23 - 25 OCTOBER, DUBAI INTERNATIONAL EXHIBITION AND CONVENTION CENTRE

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Content

1. Changing energy paradigm
2. Growth of renewables
3. Our electricity system
4. Flexibility
5. Energy pathways
6. The hydrogen case for the Northern Netherlands
7. UAE: the car as power plant

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CHANGING PARADIGM

1

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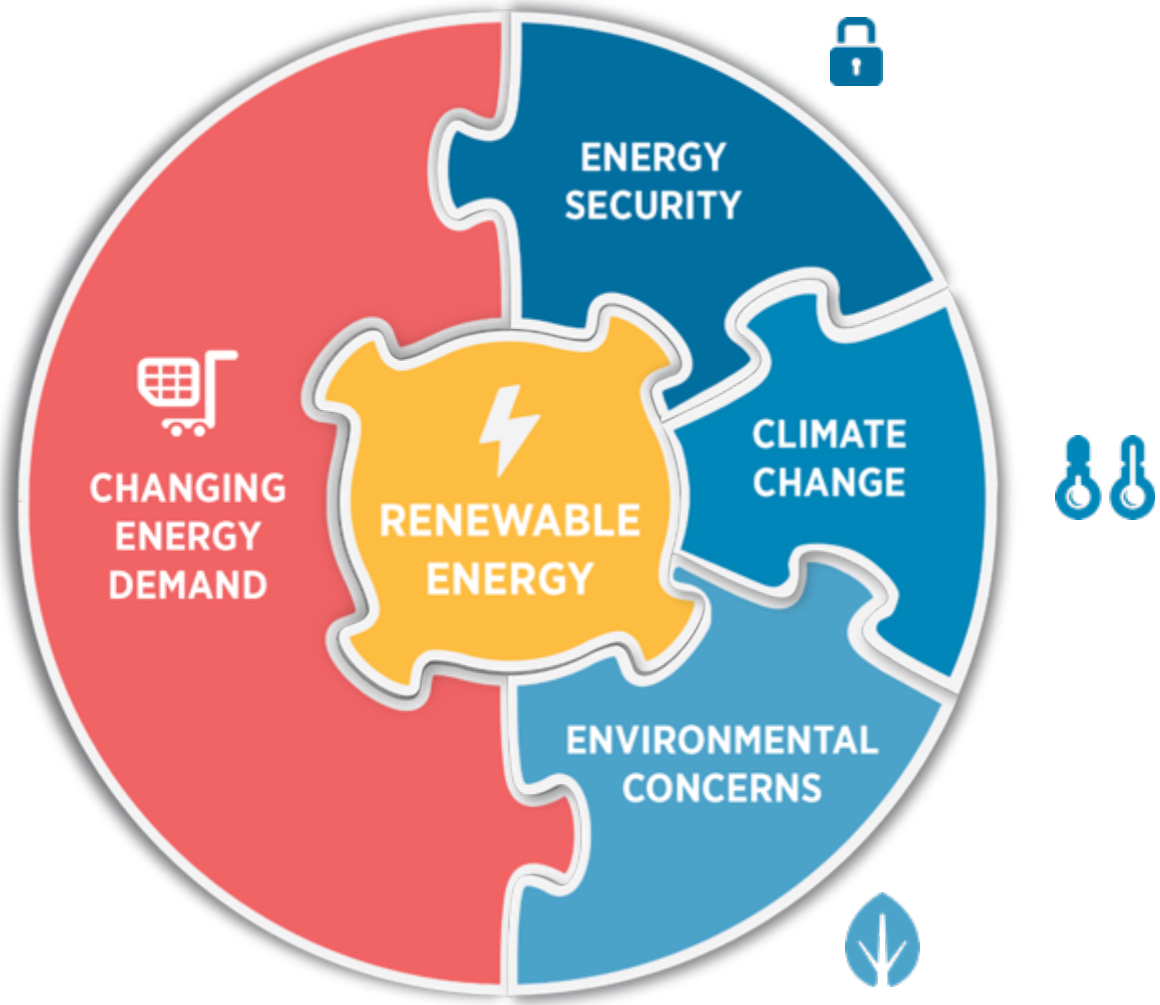
The world of energy is transforming



Source: IRENA

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Our 4D world

Transformation of the Energy System: Electrification

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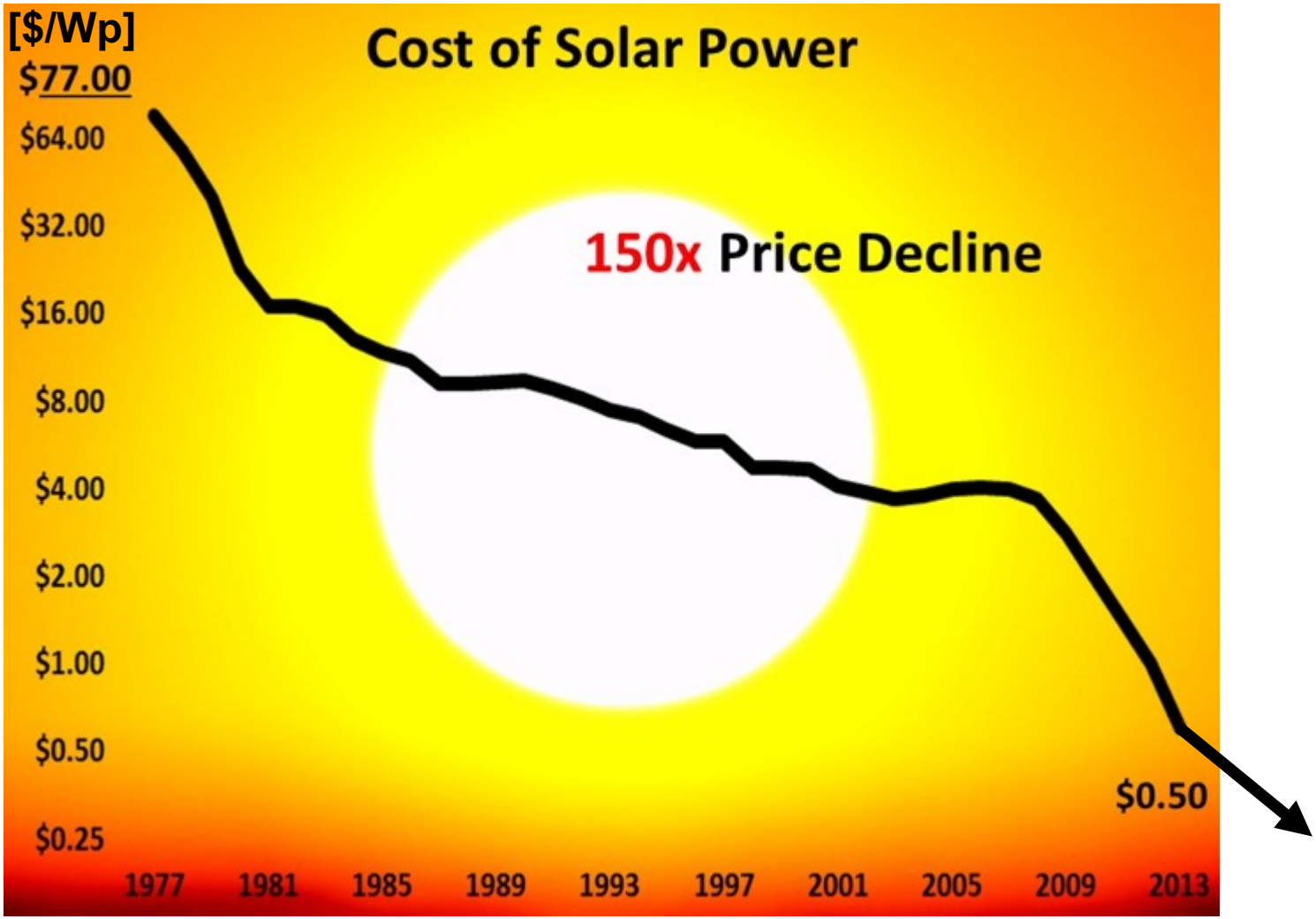
Cost of solar



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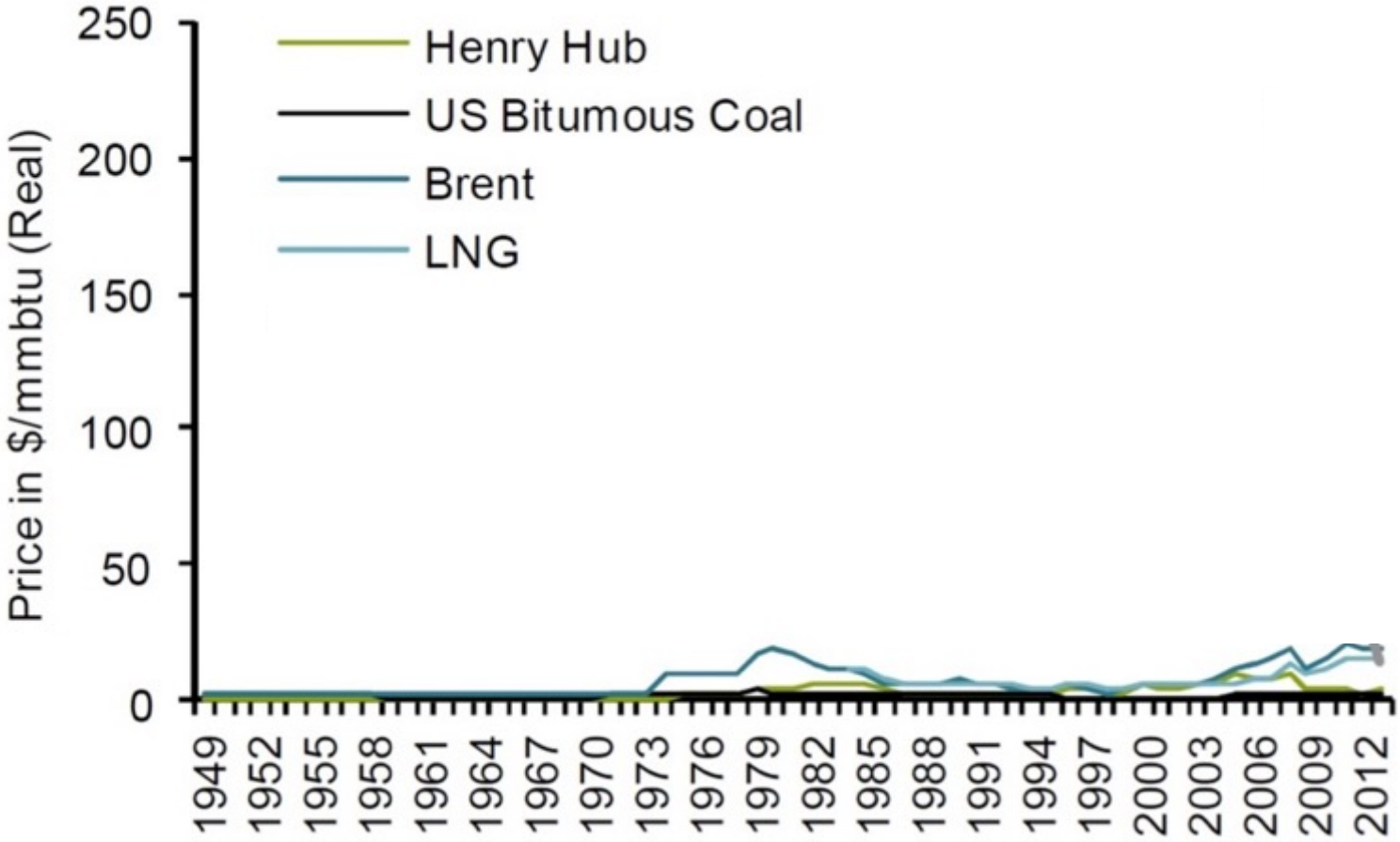
Cost of energy



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2016 unsubsidised clean energy world records

Solar PV

Location:	Peru
Bidder:	Enel Green Power
Signed:	February 2016
Construction:	2017
Price:	US$ 4.8 c/kWh

Onshore wind

Location:	Morocco
Bidder:	Enel Green Power
Signed:	January 2016
Construction:	2018
Price:	US$ 3.0 c/kWh

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Source: Bloomberg New Energy Finance;
Images: Siemens; Wikimedia Commons

2016 unsubsidised clean energy world records

Solar PV

Location:	Coahuila, Mexico
Bidder:	Enel Green Power
Signed:	March 2016
Construction:	2018
Price:	US$ 3.6 c/kWh

Onshore wind

Location:	Morocco
Bidder:	Enel Green Power
Signed:	January 2016
Construction:	2018
Price:	US$ 3.0 c/kWh

Funded by European Commission

Source: Bloomberg New Energy Finance;
Images: Siemens; Wikimedia Commons

2016 unsubsidised clean energy world records

Solar PV

Location:	Dubai
Bidder:	Masdar Consortium
Signed:	May 2016
Construction:	2019
Price:	US$ 2.99 c/kWh

Onshore wind

Location:	Morocco
Bidder:	Enel Green Power
Signed:	January 2016
Construction:	2018
Price:	US$ 3.0 c/kWh

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Source: Bloomberg New Energy Finance;
Images: Siemens; Wikimedia Commons

2016 unsubsidised clean energy world records

Solar PV

Location:	Chile
Bidder:	Solarpack Corporation
Signed:	August 2016
Construction:	2019
Price:	US$ 2.91 c/kWh

Onshore wind

Location:	Morocco
Bidder:	Enel Green Power
Signed:	January 2016
Construction:	2018
Price:	US$ 3.0 c/kWh

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Source: Bloomberg New Energy Finance;
Images: Siemens; Wikimedia Commons

2017 unsubsidised clean energy world records

CSP

Location:	Dubai
Bidder:	Acwa Power
Signed:	September 2017
Construction:	2020
Price:	US$ 7.3 c/kWh

Offshore wind

Location:	German North Sea
Bidder:	Dong
Signed:	April 2017
Construction:	2021-2025
Price:	US$ 5.2 c/kWh

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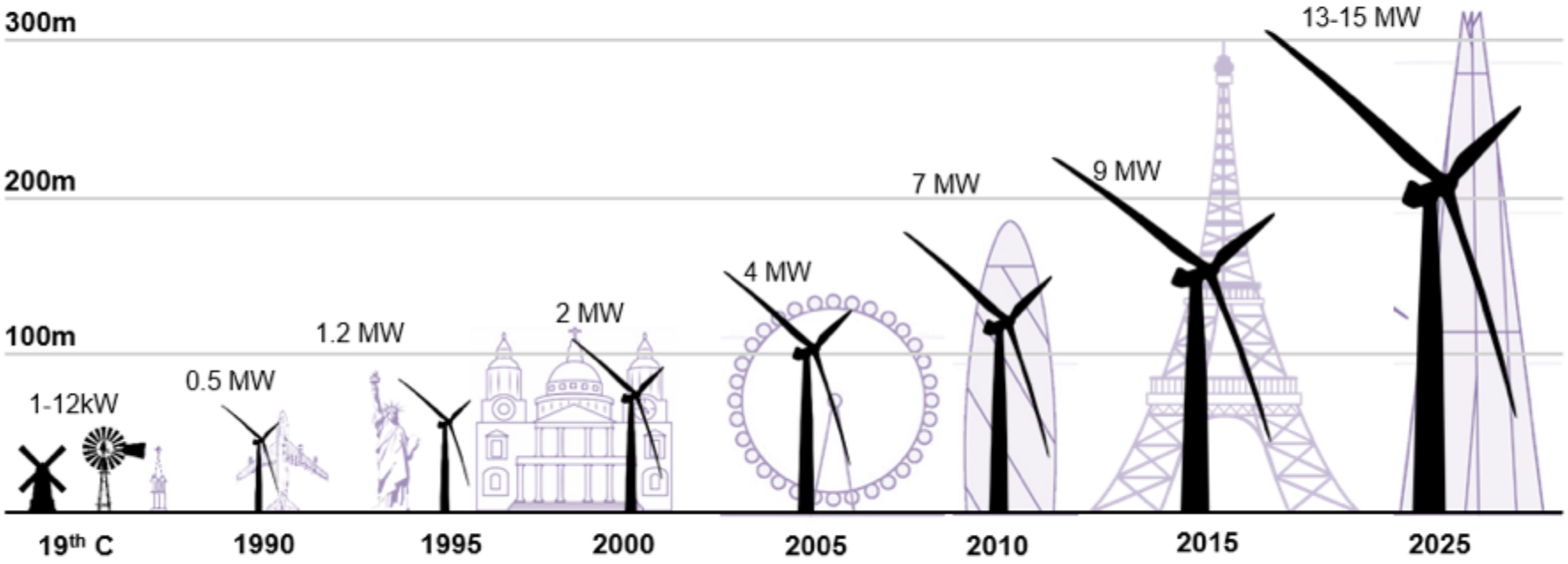
Source: Bloomberg New Energy Finance;
Images: Siemens; Wikimedia Commons

Reducing cost

Evolution of wind turbine heights and output



Sources: Various; Bloomberg New Energy Finance

Bloomberg New Energy Finance

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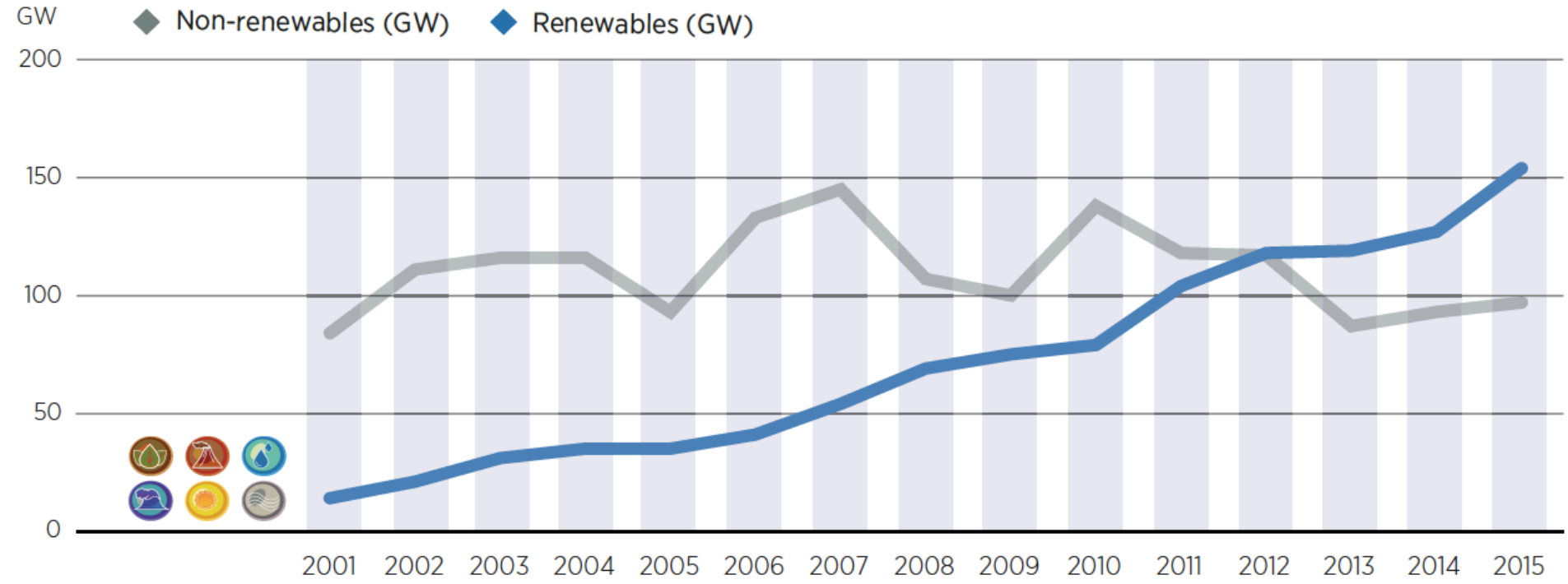
Moving to the majority in new capacity additions



Source: IRENA

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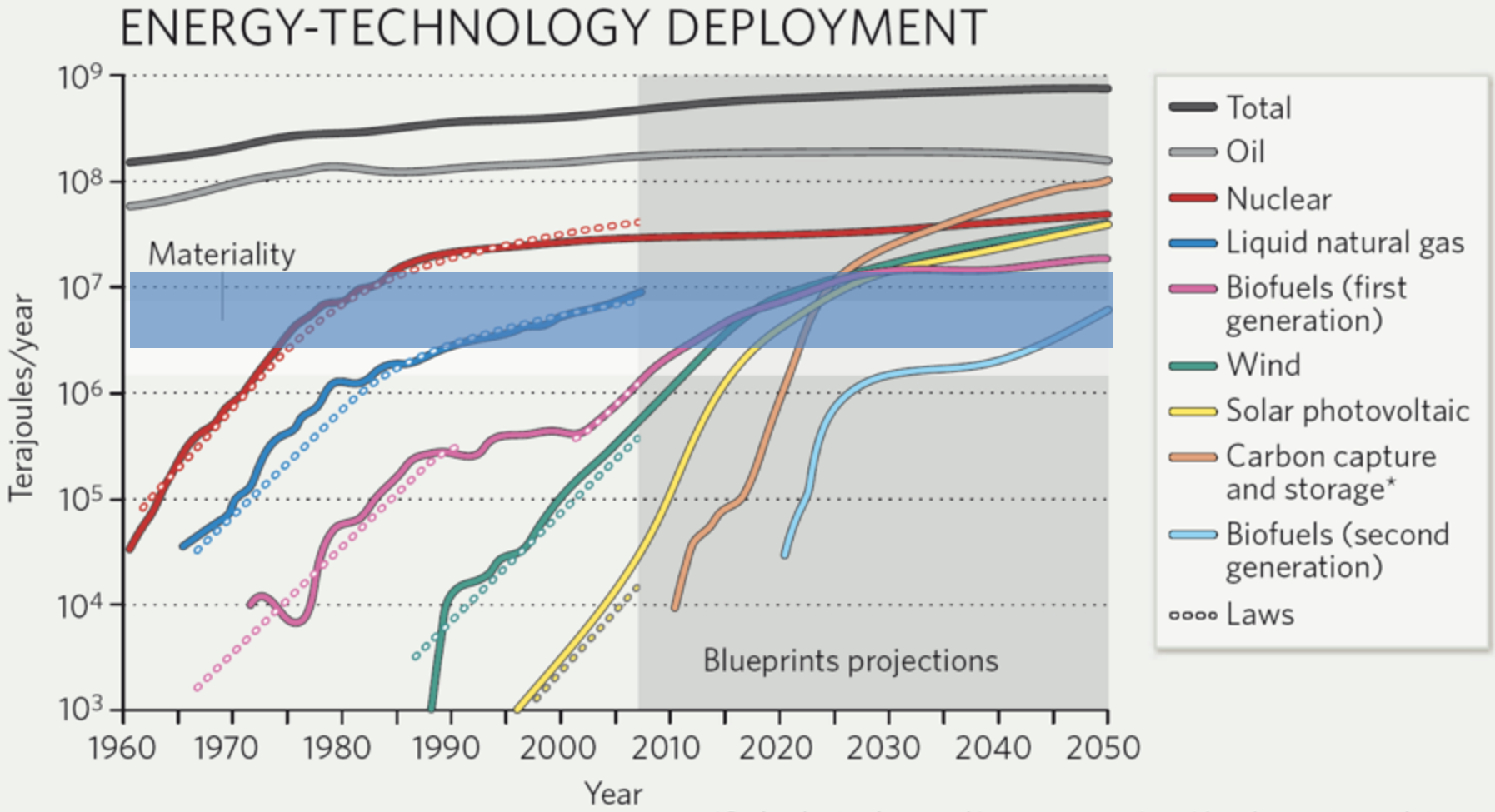
GROWTH OF RENEWABLES

2

How energy technologies grow



Nature, 2009

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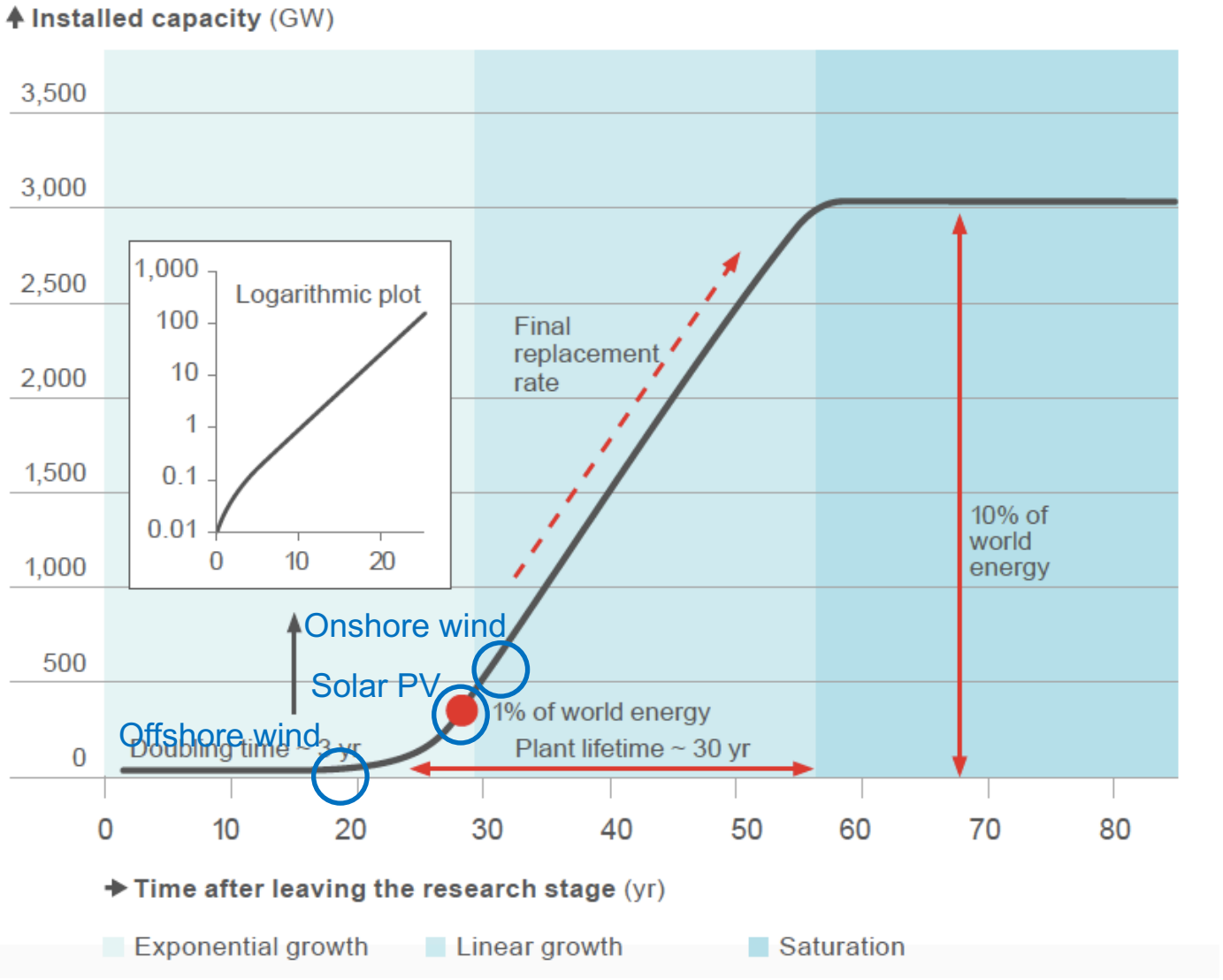
Growth into materiality



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Exponential growth

- Imagine I give you a large piece of paper and ask you to fold it,
- then please fold it again,
- and again.
- A total of fifty times.
- How tall is the paper stack?

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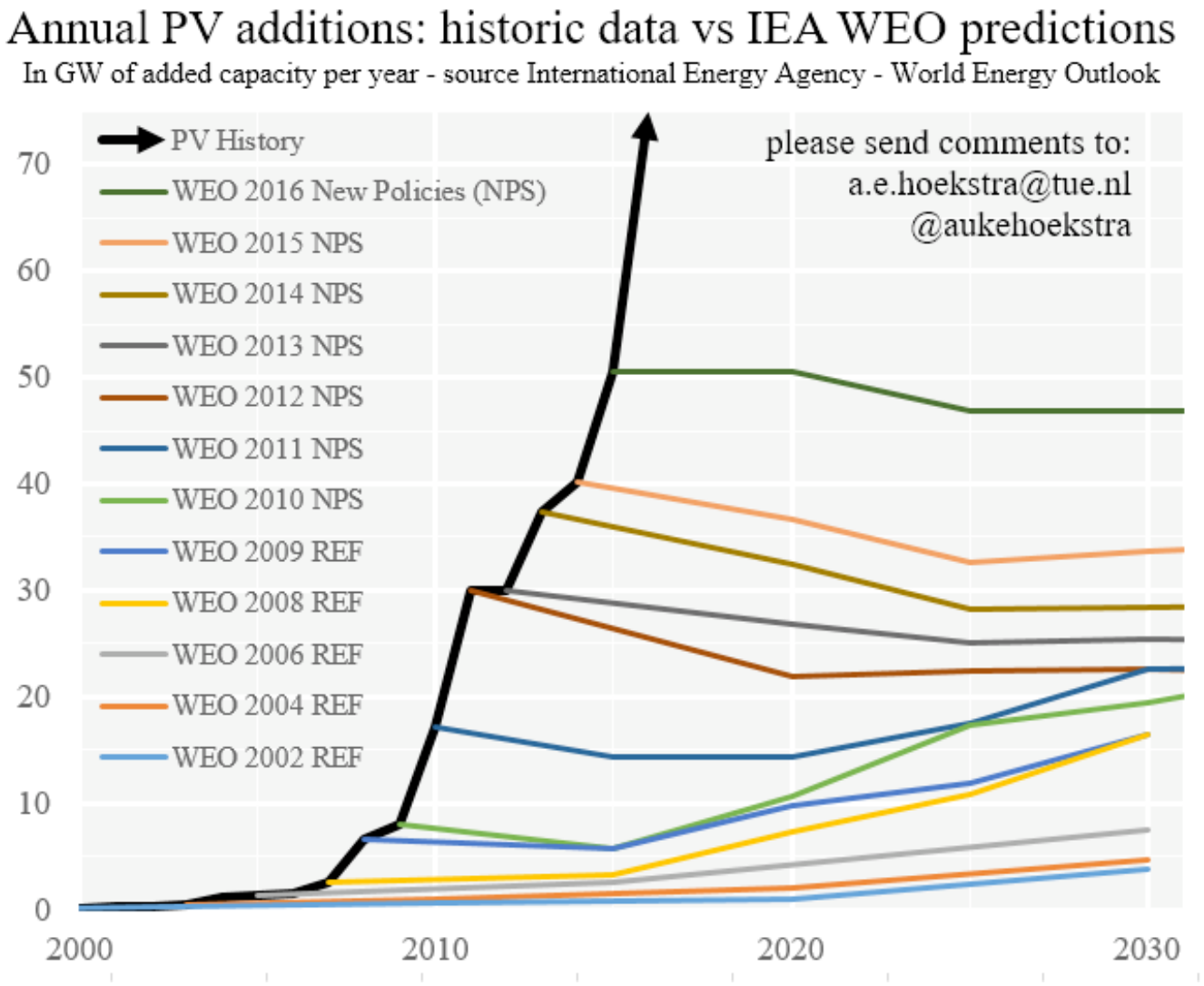
Predictions by the establishment……



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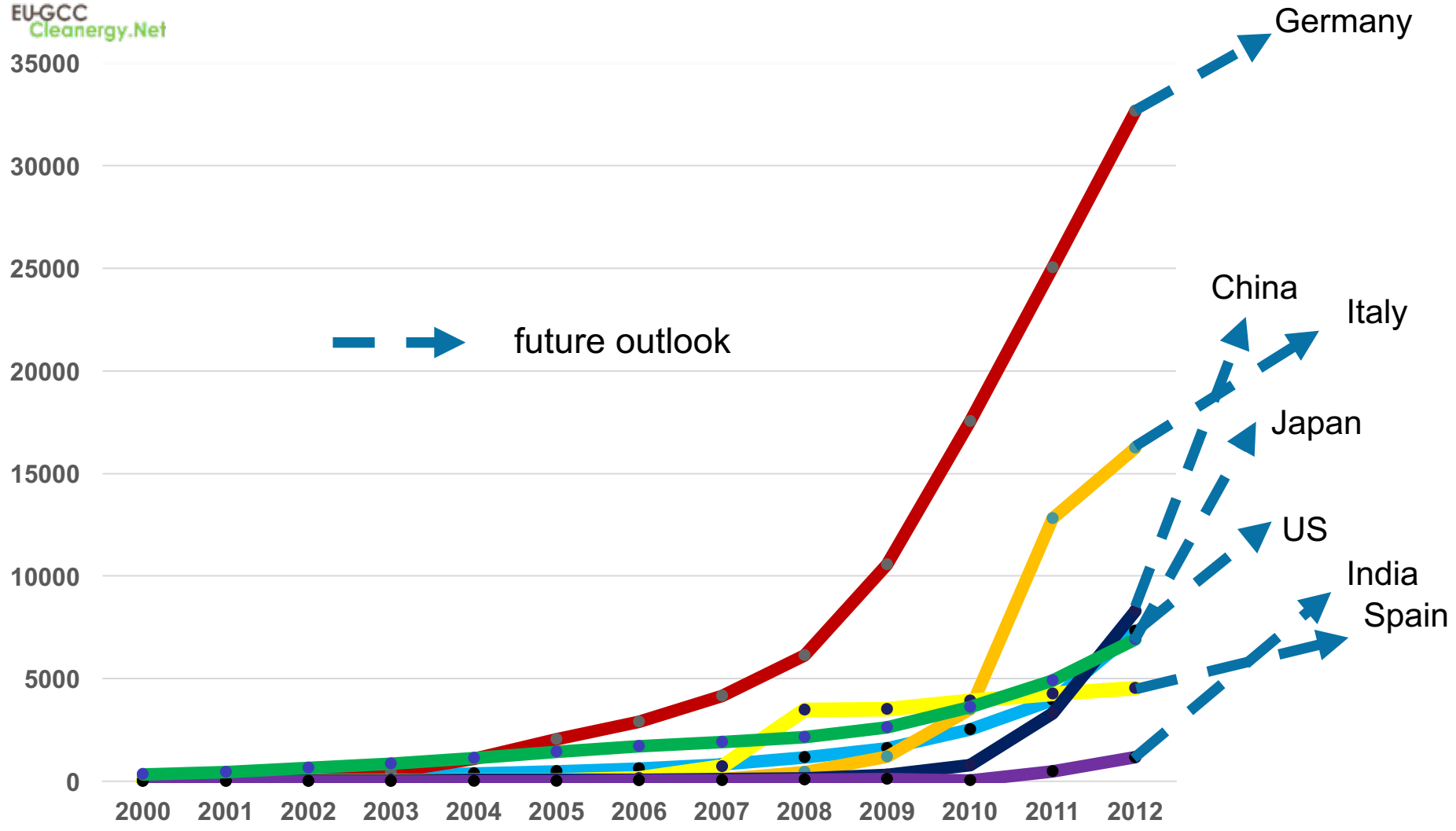
How markets develop (MW)



Source: BP Statistical Review of World Energy 2013

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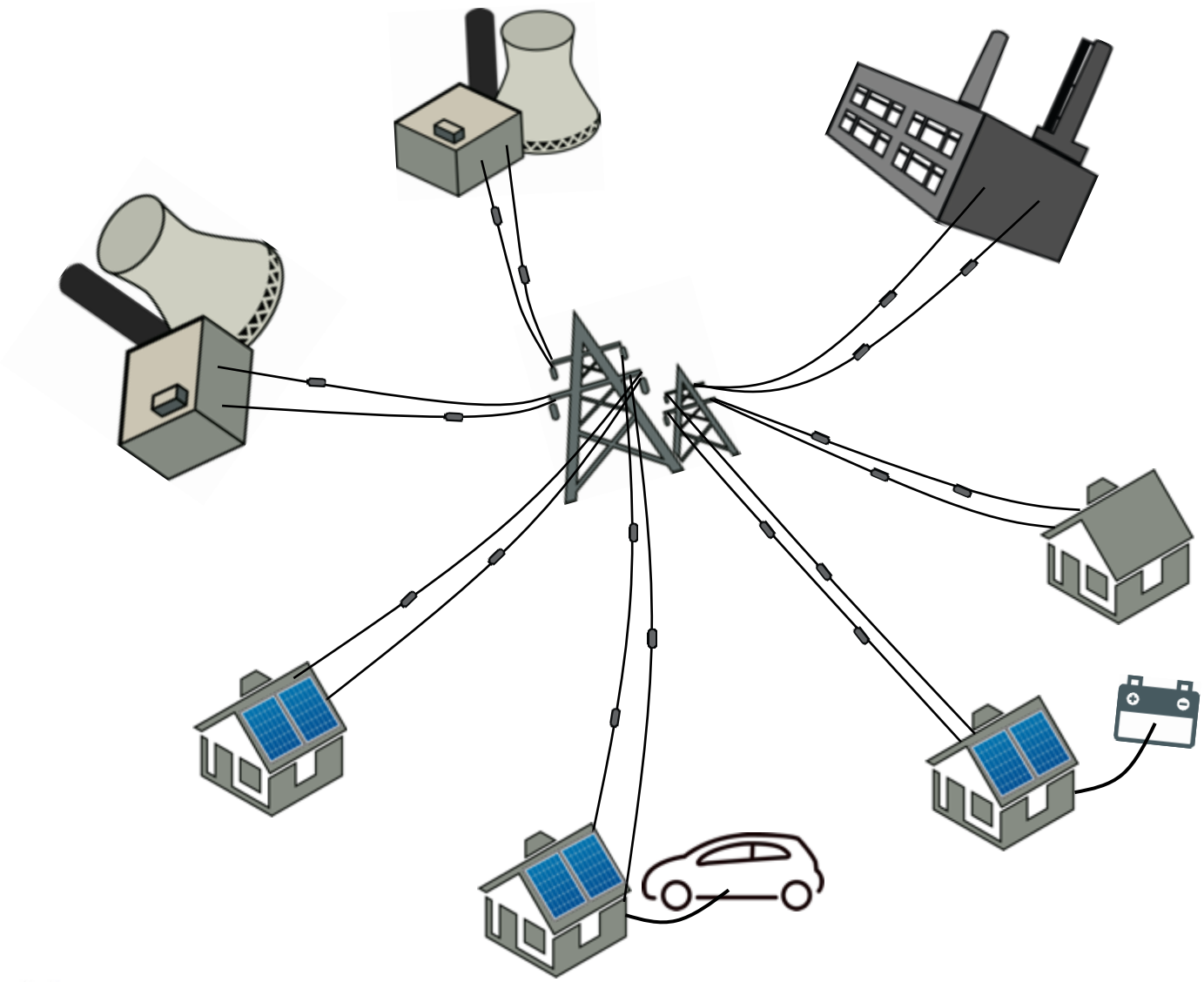
Our electricity system



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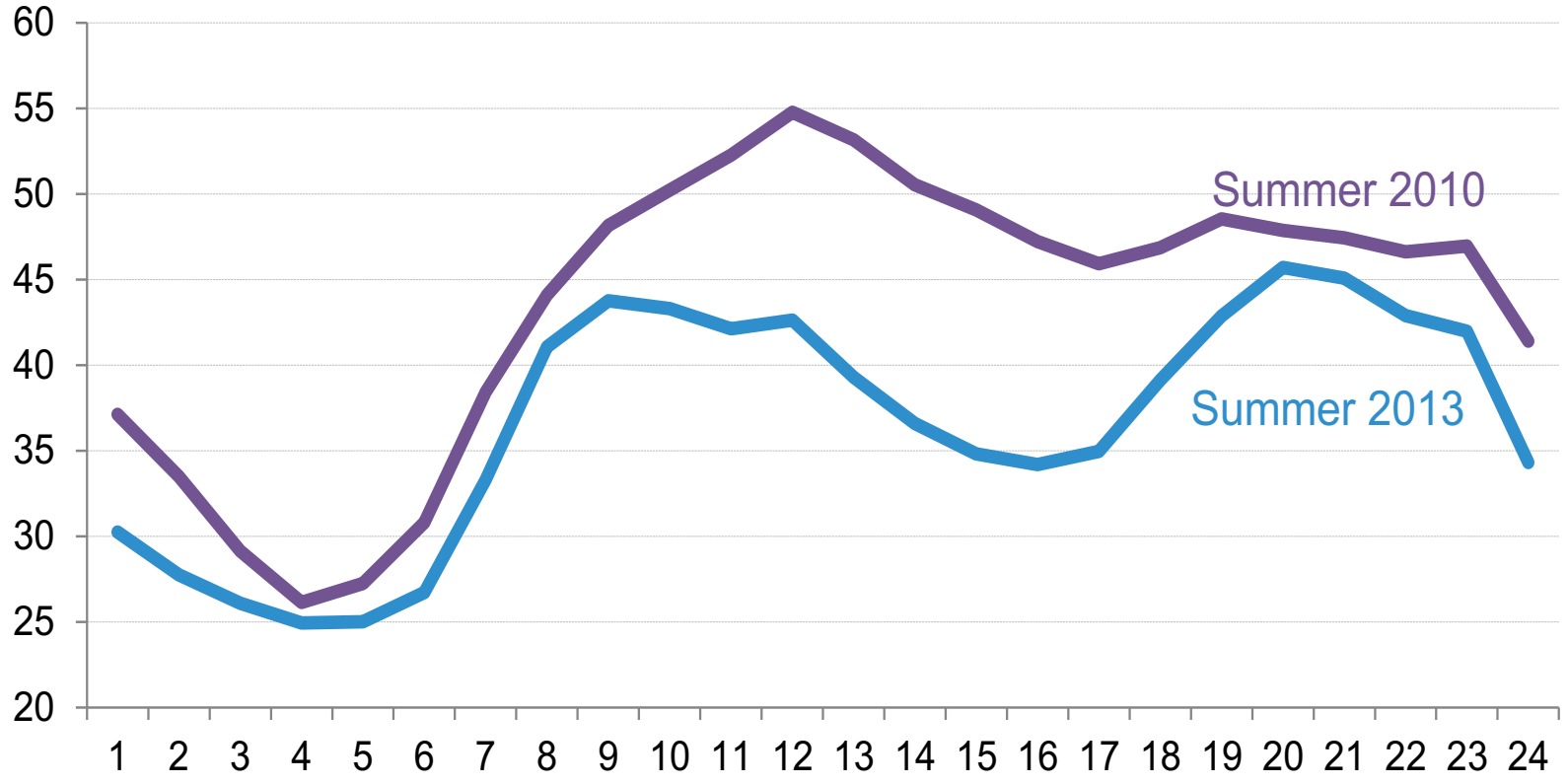
Average daily summer spot price profile in Germany, 2010 and 2013 (EUR/MWh)



Source: EEX; BNEF

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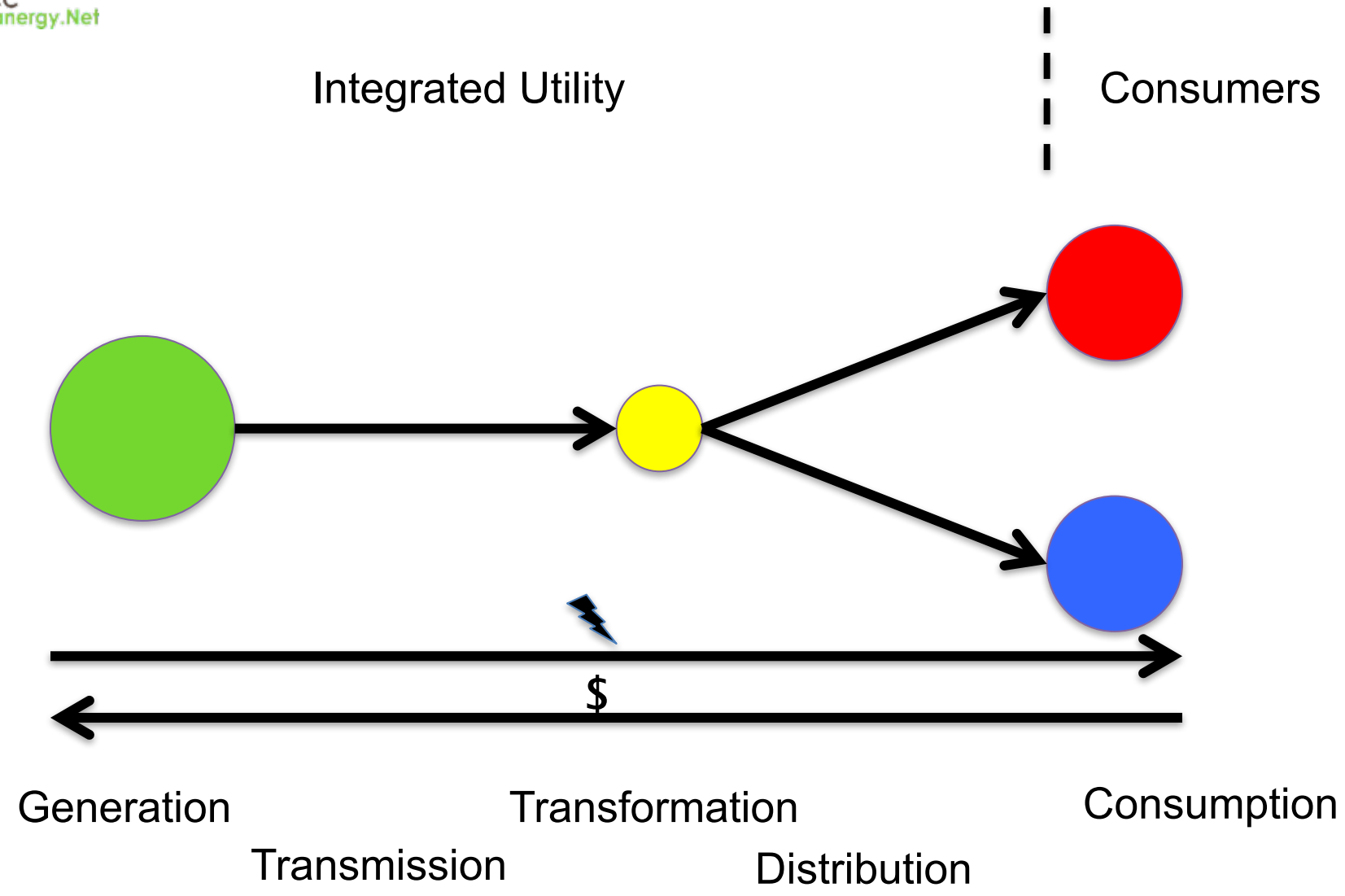
Conventional Set-up



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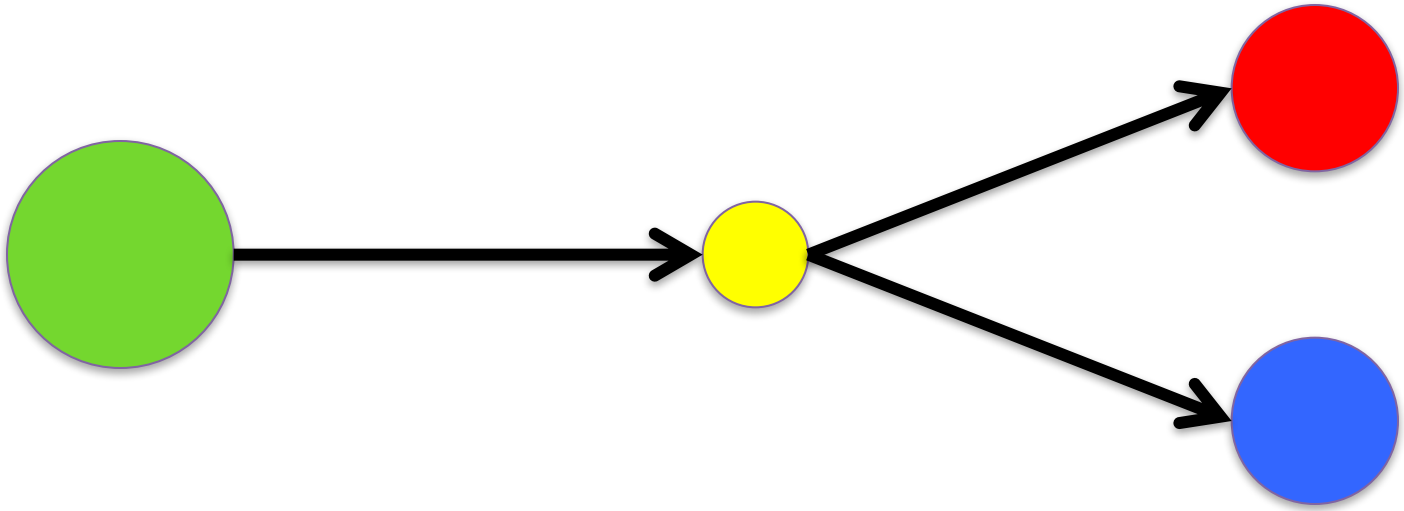
Unbundling

Utility | Utility | Consumers



Generation | Transmission | Transformation | Distribution | Consumption

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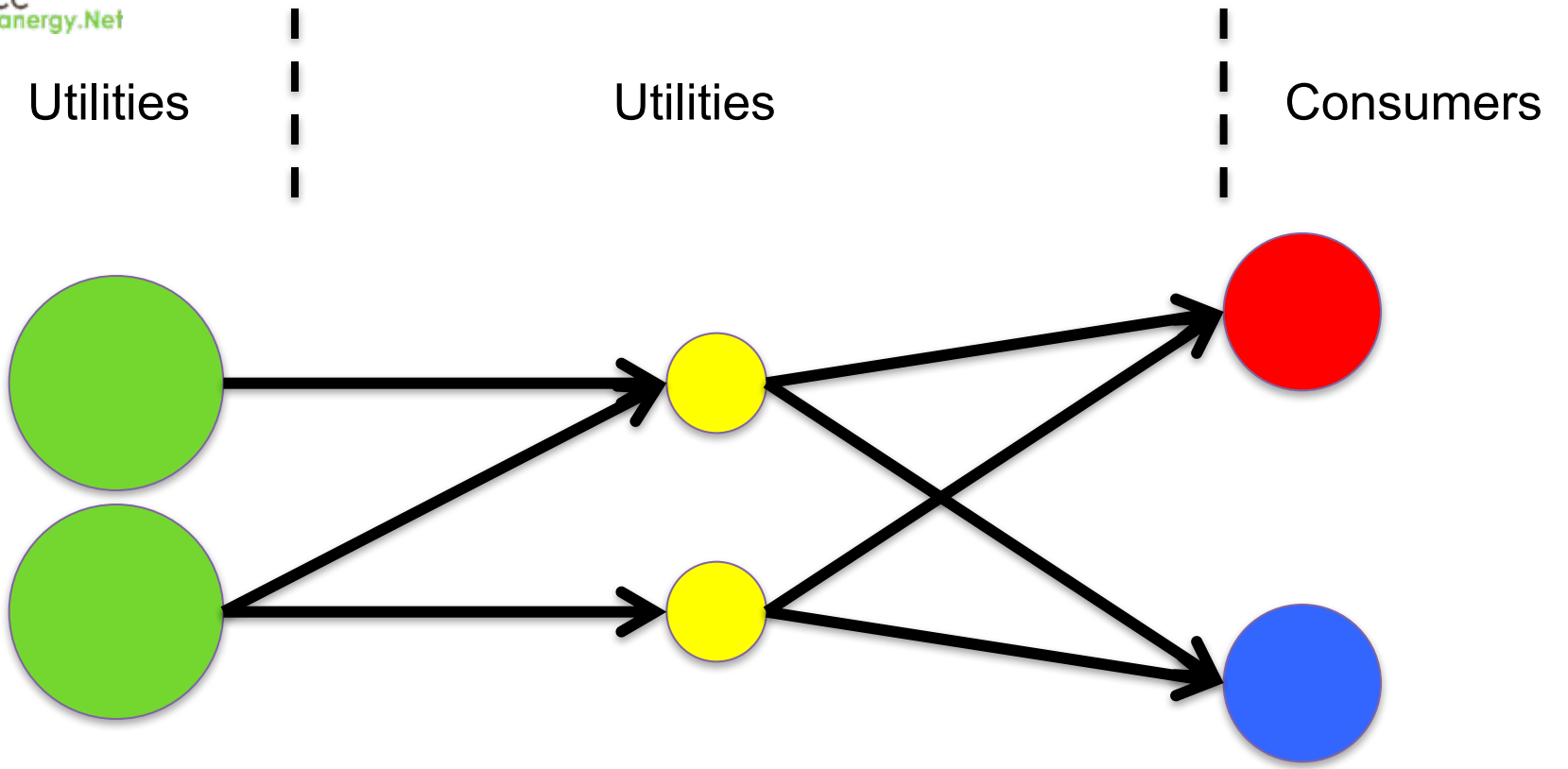
Privatization



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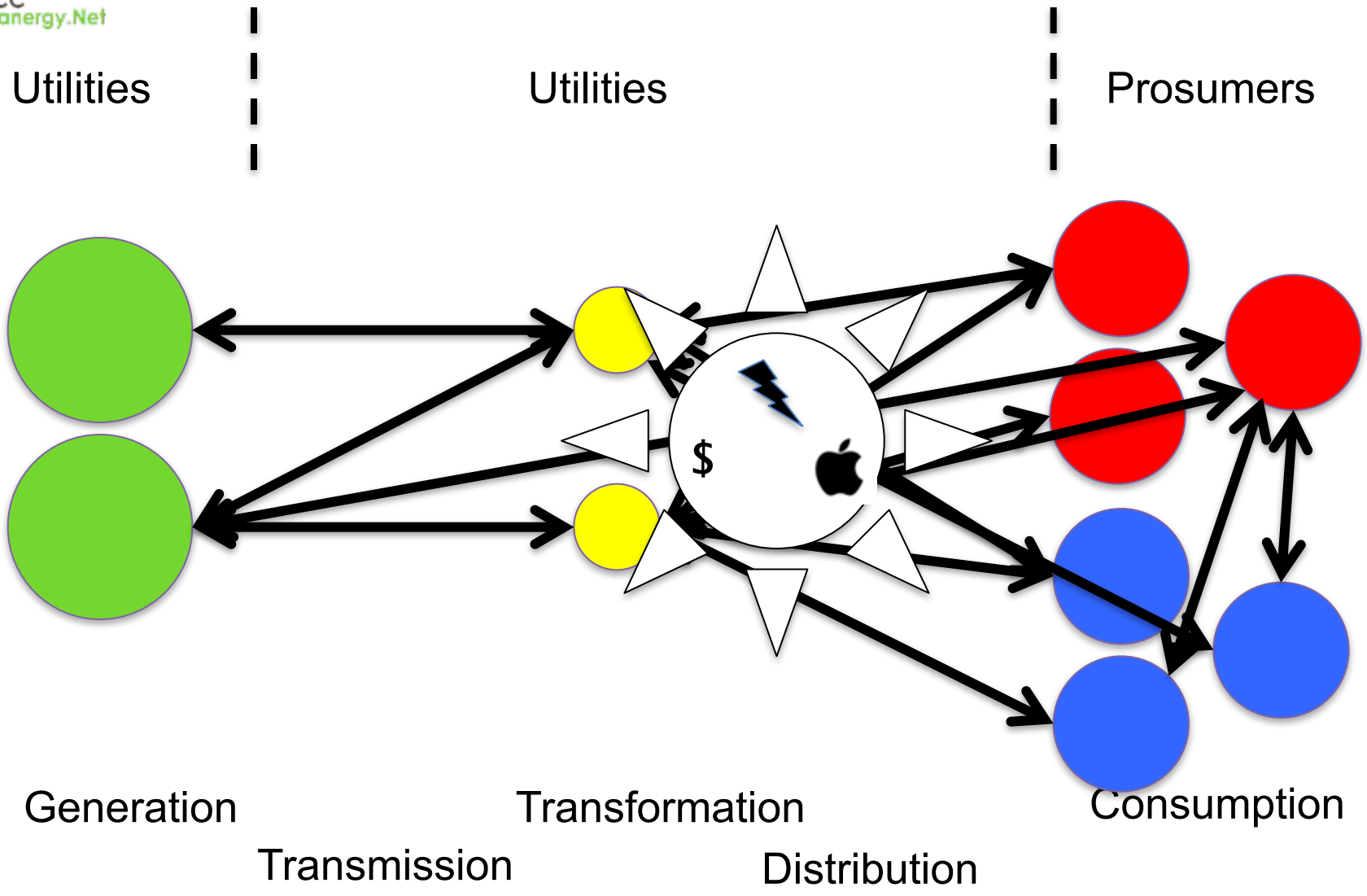
Democratization



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Not only winners

Last updated: September 20, 2013 3:46 pm

RWE to halve dividend amid renewables boom

By Chris Bryant in Frankfurt

RWE plans to cut its dividend by half and lower future investor payouts in response to a slide in profits in conventional power generation caused in part by the boom in renewable energy.

The German utility is set to propose a dividend of €1 a share at its next annual meeting, down from the €2 it paid shareholders last year.

Flexibility

4

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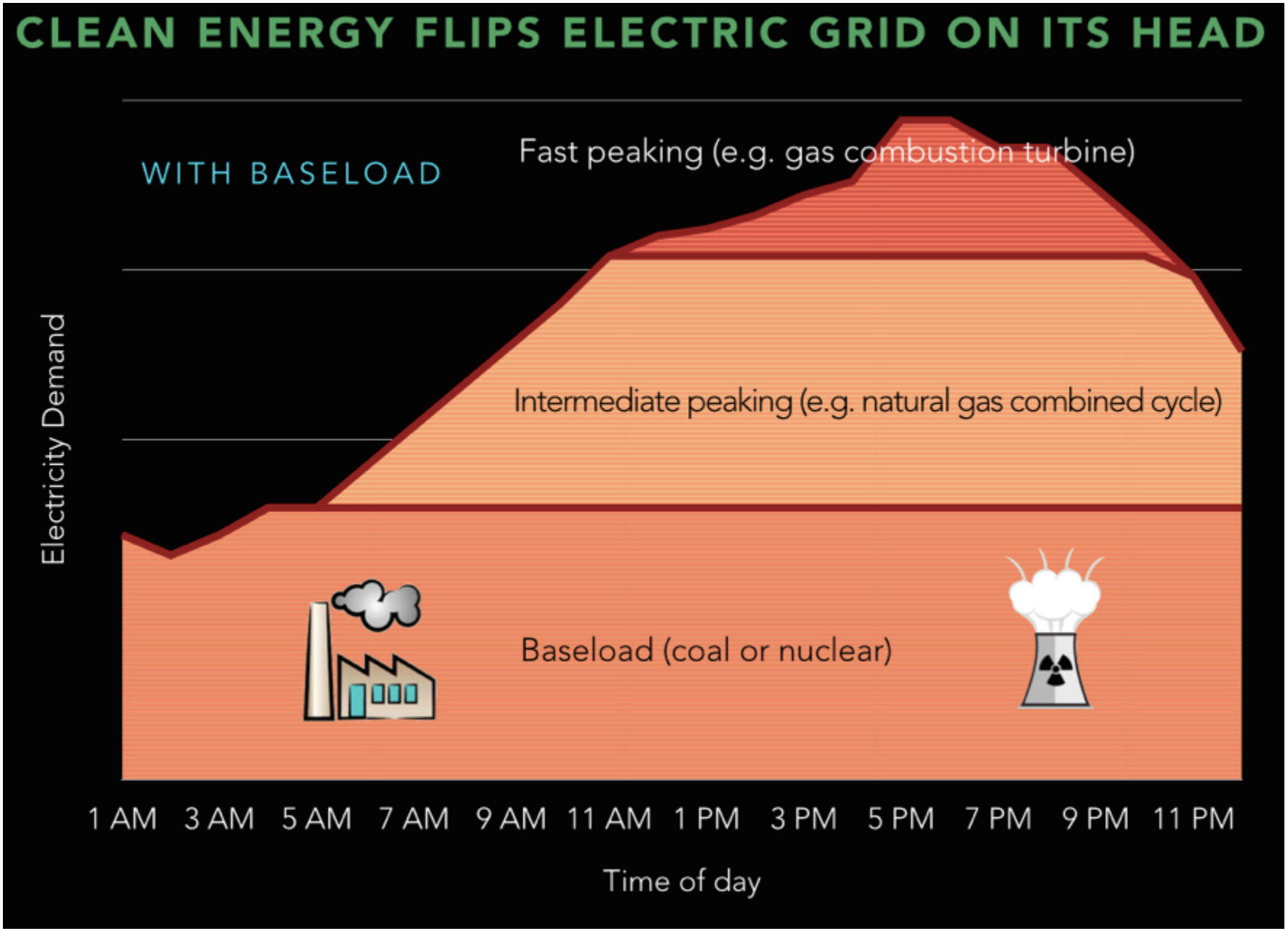

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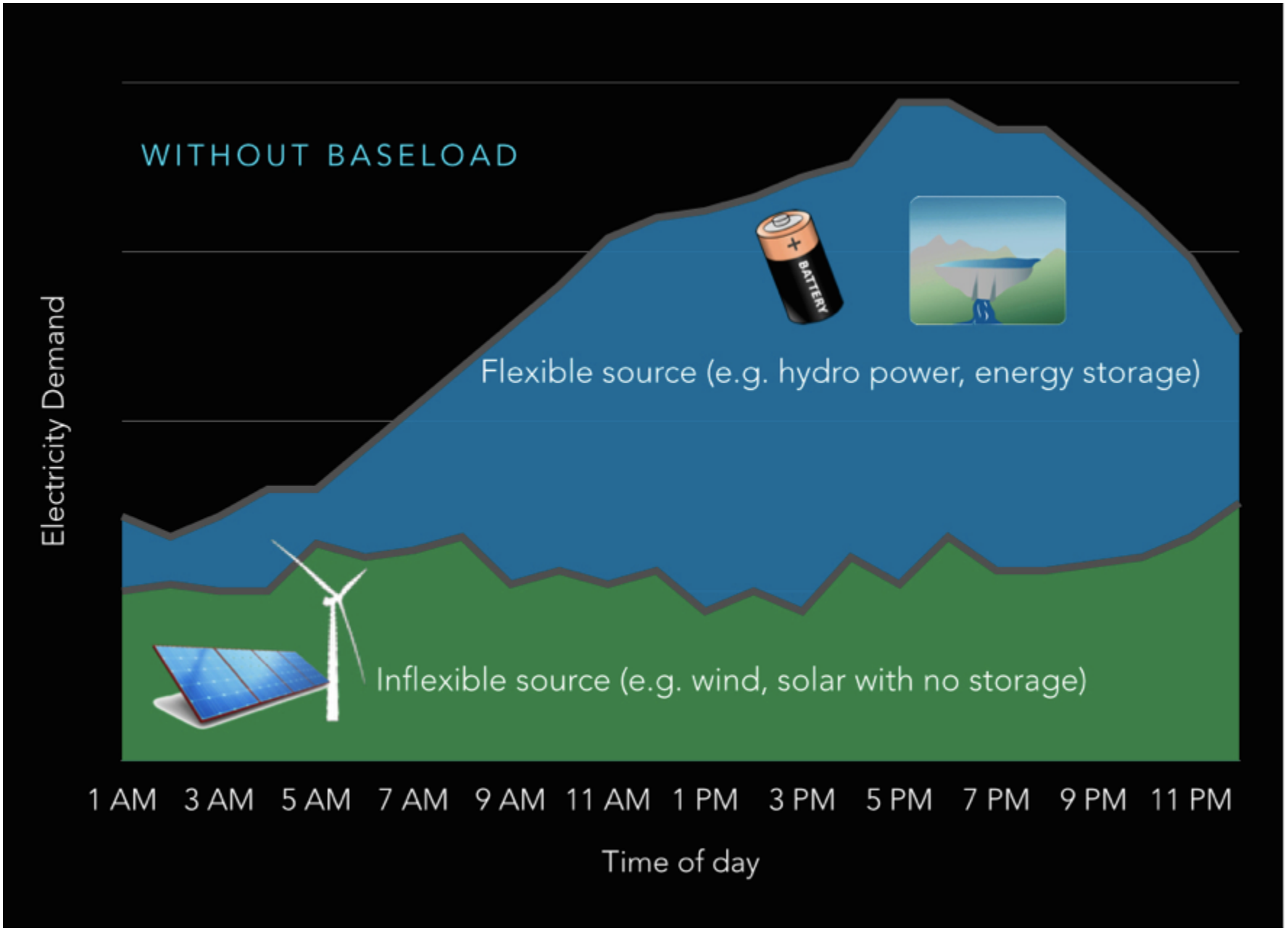

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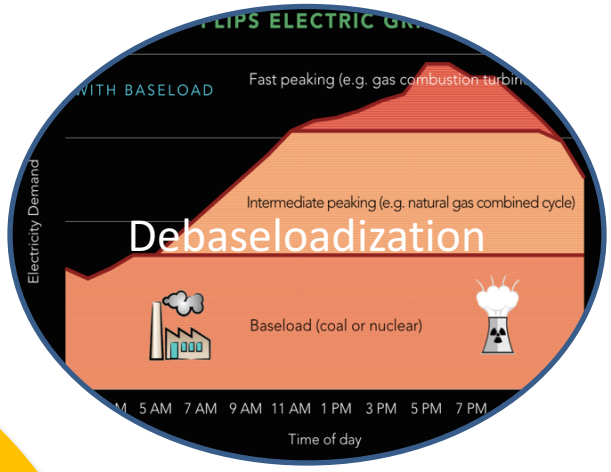
5D world

EU-GCC Cleanenergy.Net



Transformation of the Energy System: Electrification

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Flexibility tools

1. Dispatchable power
2. Demand response
3. Storage
4. Interconnectivity

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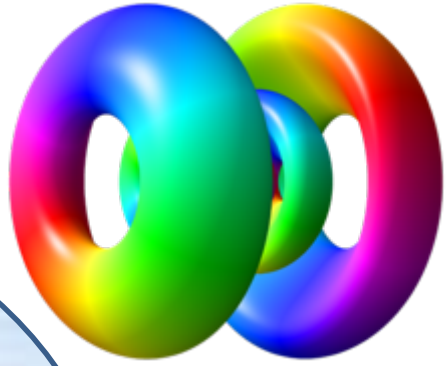
Energy Pathways: Hydrogen

Future 4D energy pathways

Electricity



Hydrogen

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Main 4D pathways

Electricity and **Hydrogen** are the two main energy carrier pathways in a 4D world.

Considerations:

- Ability to replace fossil fuels in transport
- Ease of transporting over longer distances
- Versatility of role in the economy: transport, buildings, chemistry
- Ability to use as storage medium
- Cost
- Infrastructure

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The hydrogen case for the Northern Netherlands

6

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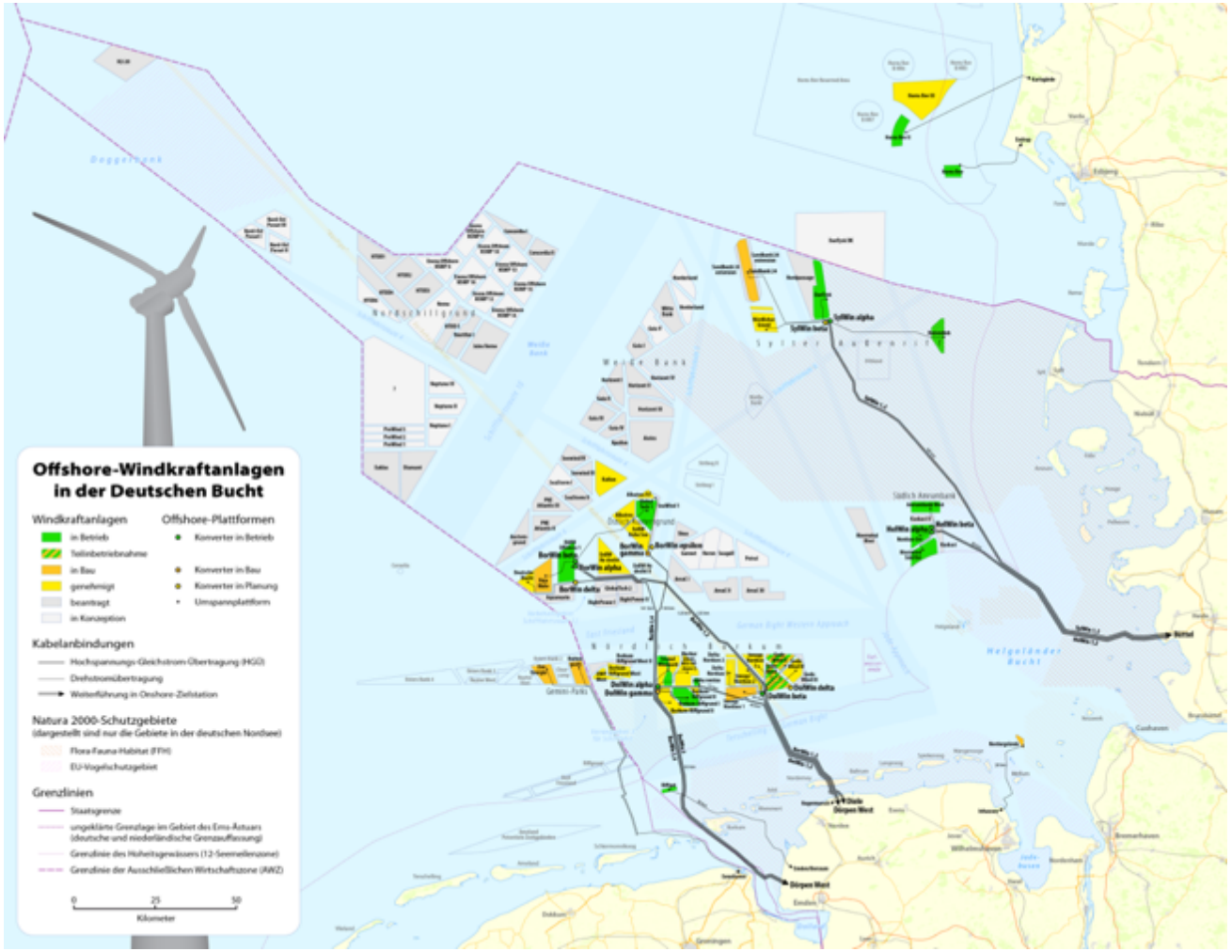
Offshore Wind Development Germany



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Electricity and Gas Transport Grid

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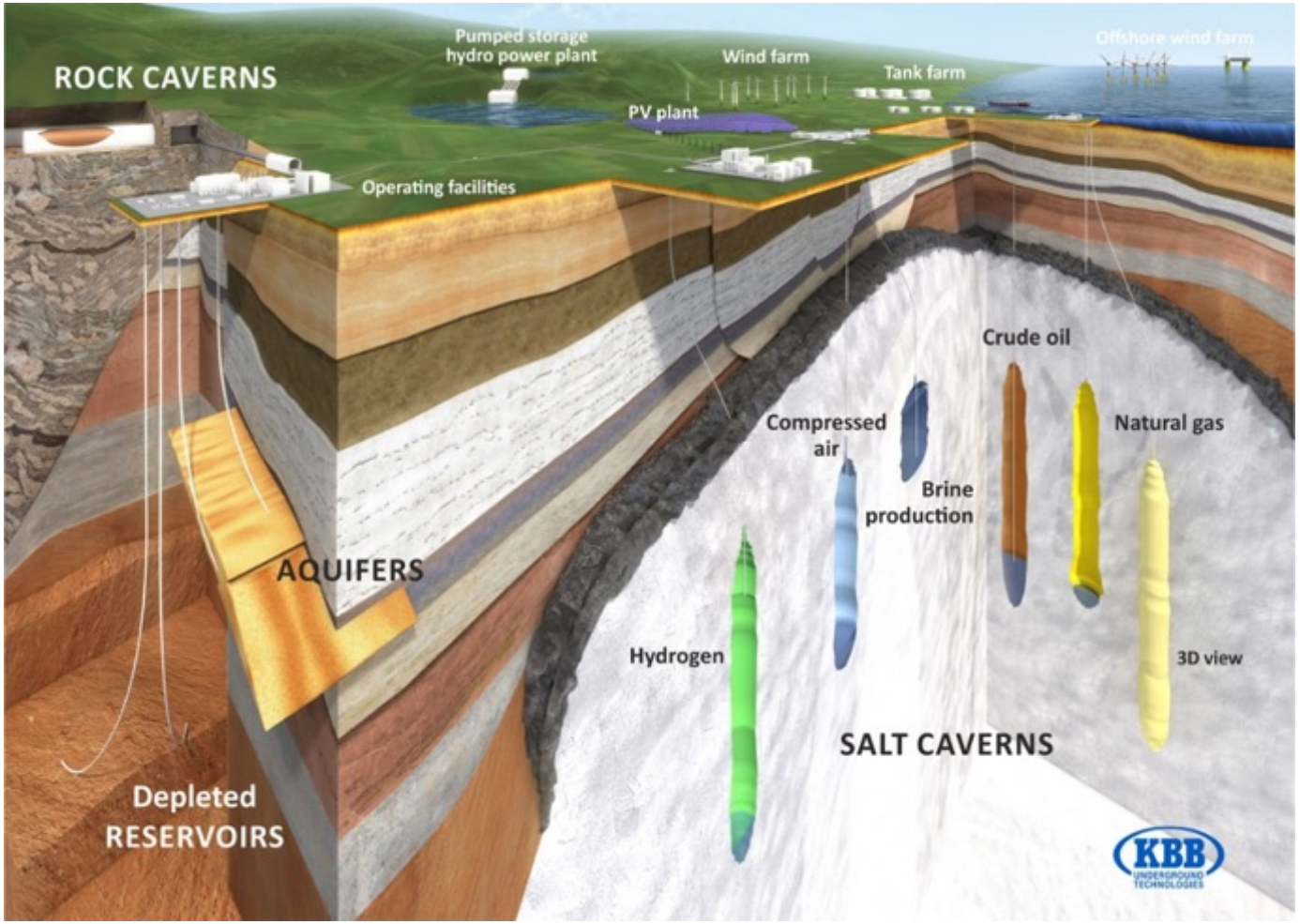
Hydrogen storage in salt caverns



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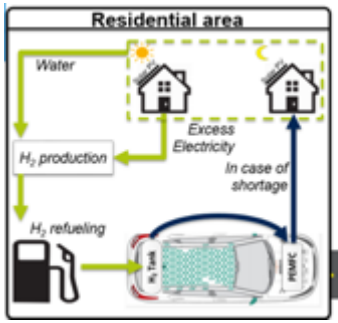
Green hydrogen markets

EU-GCC Cleanergy.Net

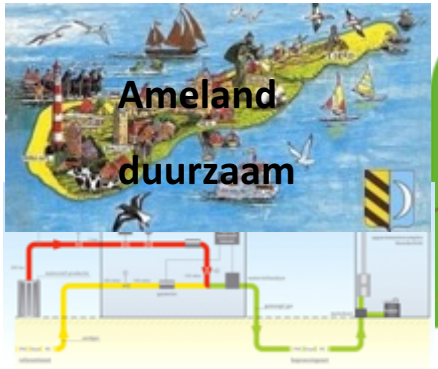
Chemical Feedstock

Electricity Balancing



Transport

Heating



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Delfzijl chemical site

Ammonia, Methanol, Hydrogen-Peroxide production

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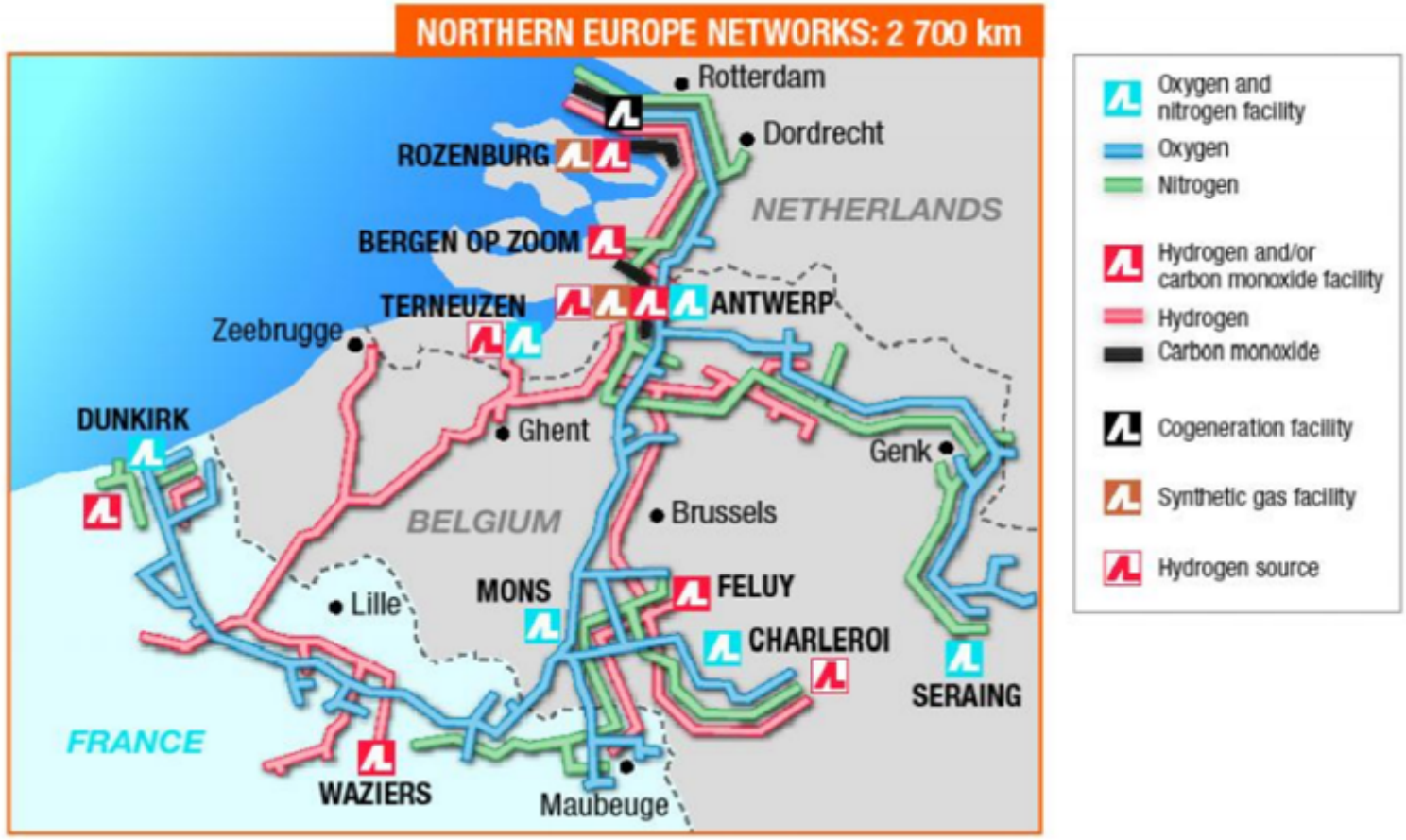
Hydrogen Pipelines Netherlands-Belgium-France



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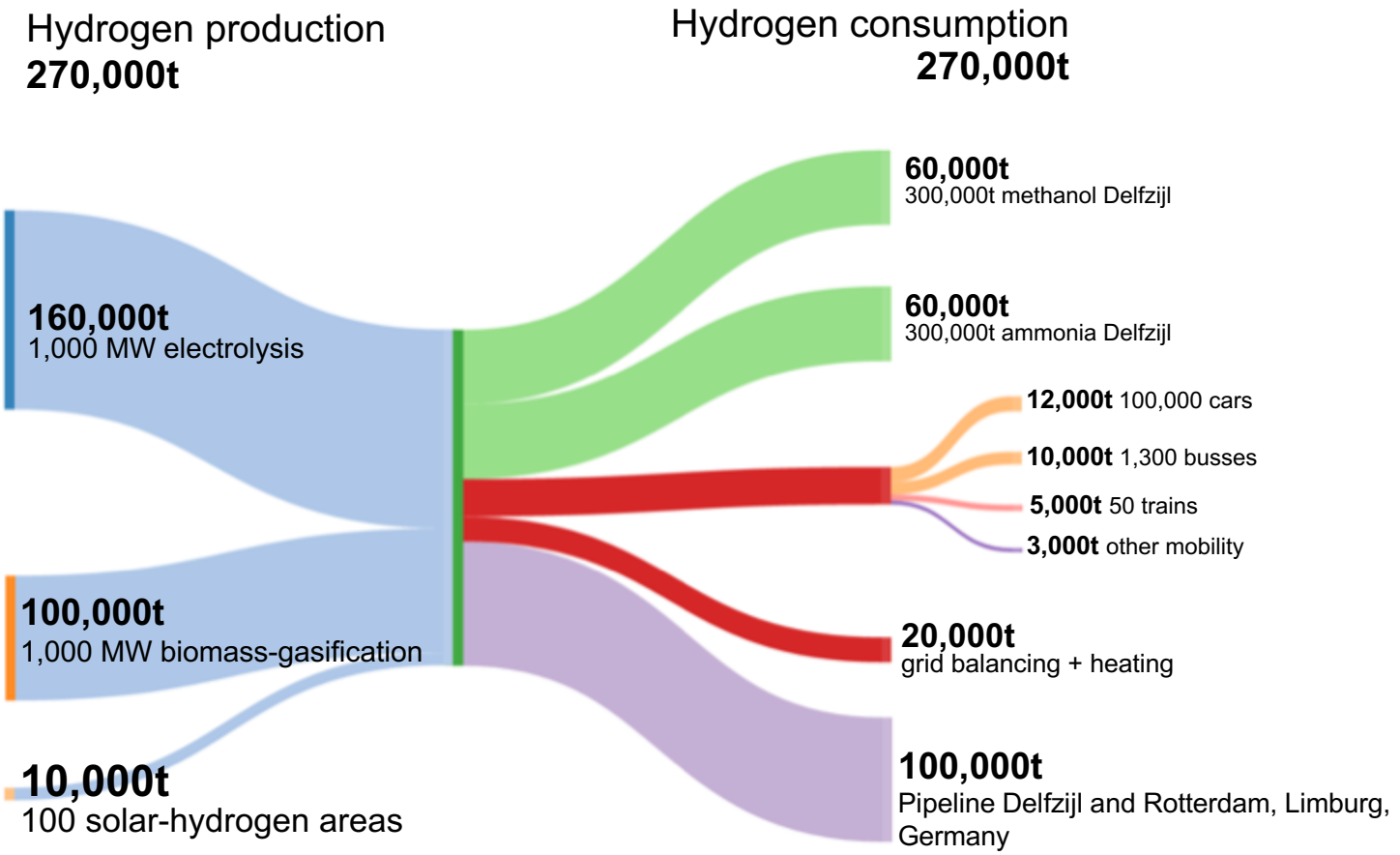
Green Hydrogen Economy Northern Netherlands 2030



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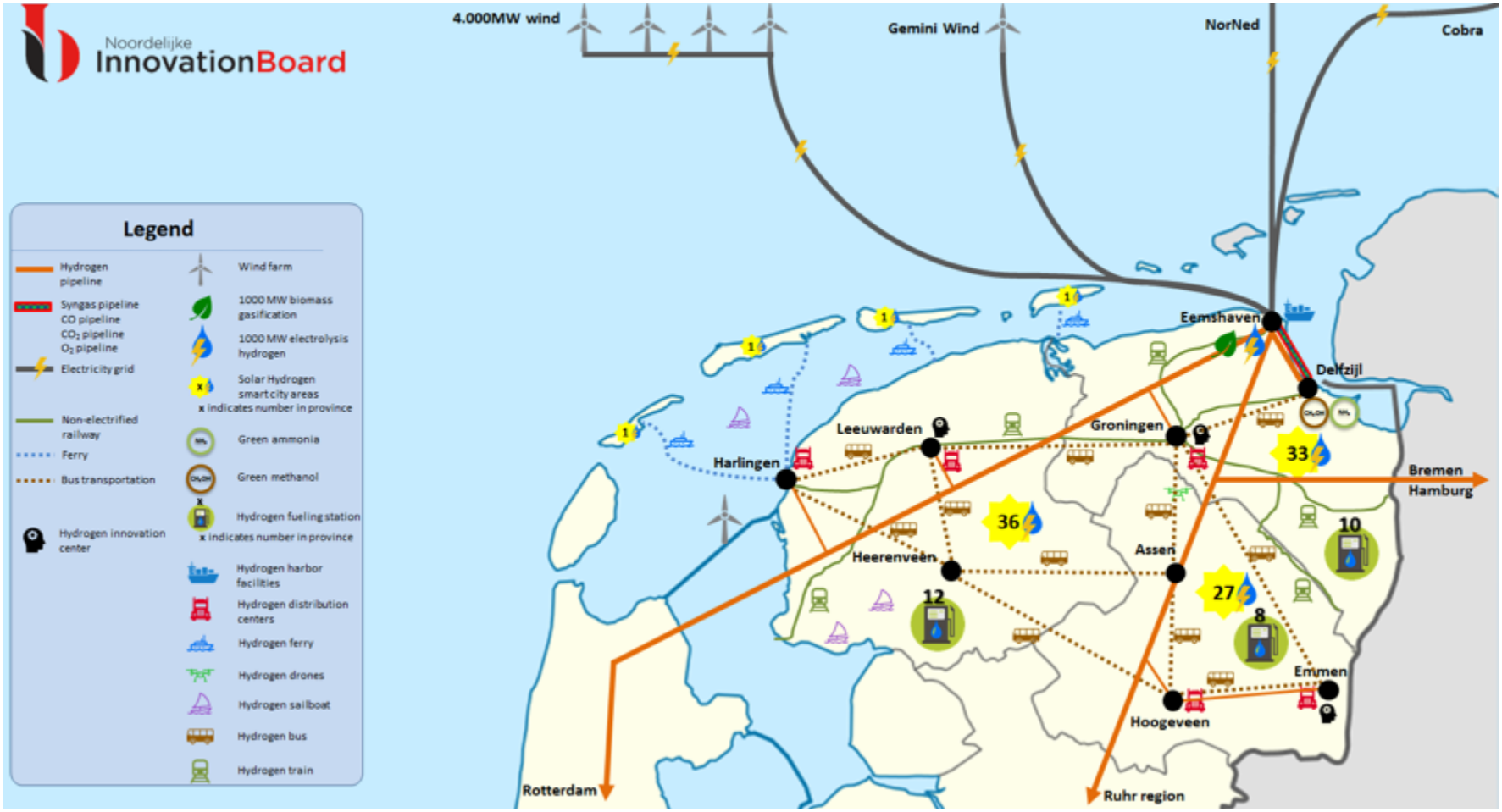
Green Hydrogen Economy Northern Netherlands 2030



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UAE: the car as power plant

7

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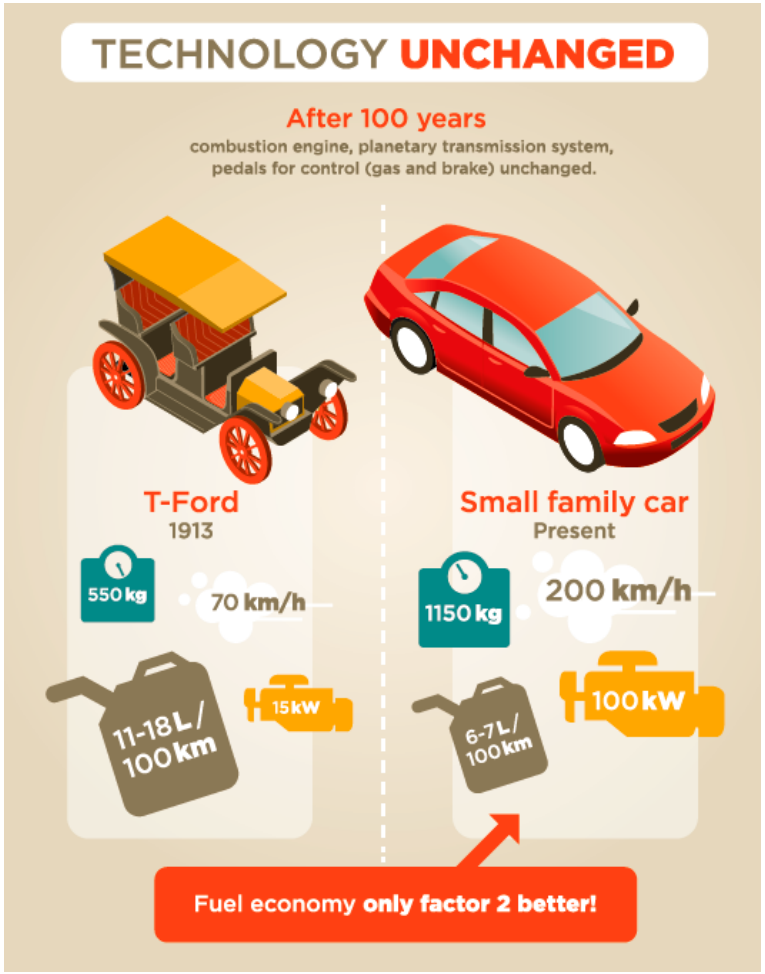
Our car: 100 year unchanged



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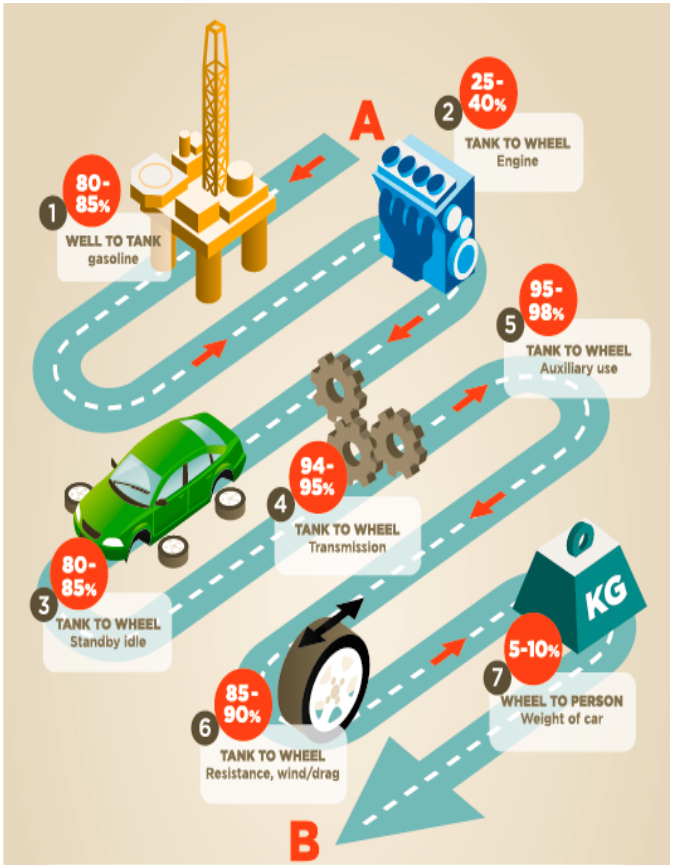
Our car: efficiency



Energy efficiency low 0.80*0.25*0.80*0.94*0.95*0.85*0.05 = 0.006

Energy efficiency high 0.85*0.40*0.85*0.95*0.98*0.90*0.10 = 0.024

FROM A TO B TOTAL **0.6-2.4%**

What this means:
Our traditional car is a moving stove! From A to B more then 97% of the energy gets lost.

And, we only use our car on average 1 hour per day, which is only 4% of the time!

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Our cars take over power plants

Power plants

Total installed capacity (2010)

5.000 GW

Cars

1 car = **50 kW**

1.000 million cars (2010)

1.000 million x 50 kW =

50.000 GW

(5% of time in operation)

New cars

1 new car = **100 kW**

80 million new cars per year

80 million x 100 kW =

8.000 GW

per year

1.000 MW = 10.000 new cars

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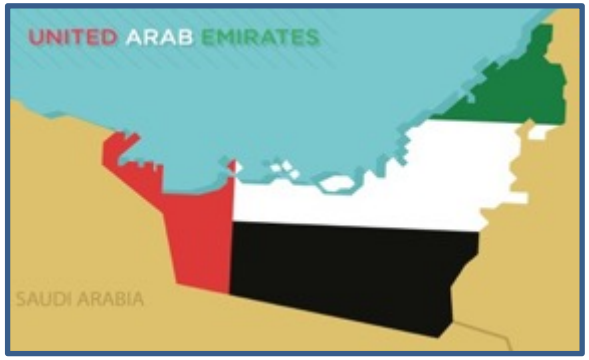
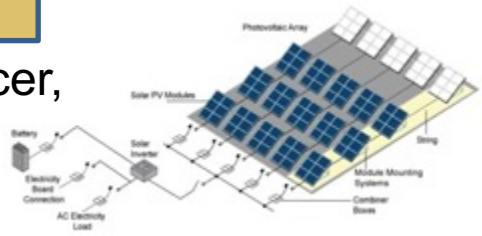
EU-GCC Cleanergy.Net

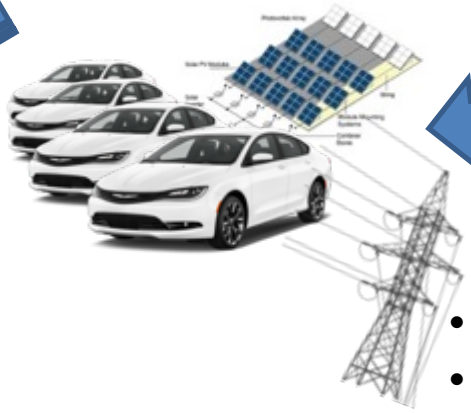
- Driving is 50% cheaper
- Cost of electricity is 7ct/kWh, which is the same as now

- 5 million cars
- 100 billion km/year
- Requires 1 billion kg H_2



A low cost energy producer, both fossil and solar





- 141 GW of solar PV
- Electrolysers
- Land use less than 4%
- Costs $2/kg

- 100 TWh/year
- 5% of the residential drinking water

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Thank You

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