

Energy & Livability

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- I Energy flows
- II Energy systems
- III Consumption
- IV Livability

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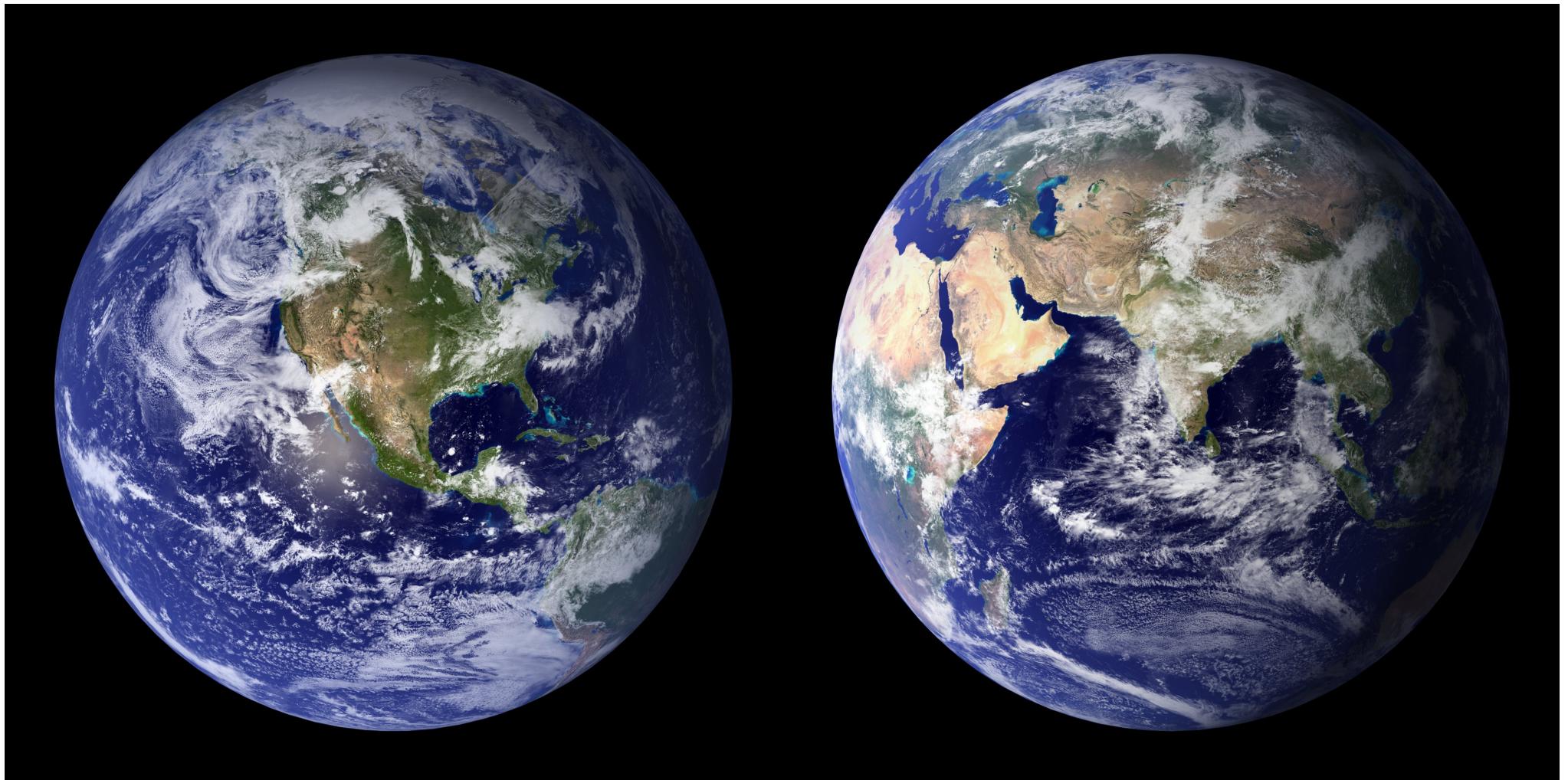
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How does energy related to life or livability?

«Energy is the basic ingredients for everything,
especially life;
everything or all systems are arranged
around energy gradients.»

$$\nabla f = \frac{\partial f}{\partial x_1} e_1 + \cdots + \frac{\partial f}{\partial x_n} e_n$$

Schneider, E.D. & Sagan, D. (2005). *Into the Cool – Energy Flow, Thermodynamics and Life* (p.xiv). The University of Chicago Press.



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The change in entropy (ΔS) of a system was originally defined for a thermodynamically reversible process as:

$$\Delta S = \int \frac{dQ_{rev}}{T}$$



Rudolf Clausius (1822-1888)

For an irreversible process in an isolated system, the thermodynamic state variable known as entropy is always increasing.



First law of thermodynamics

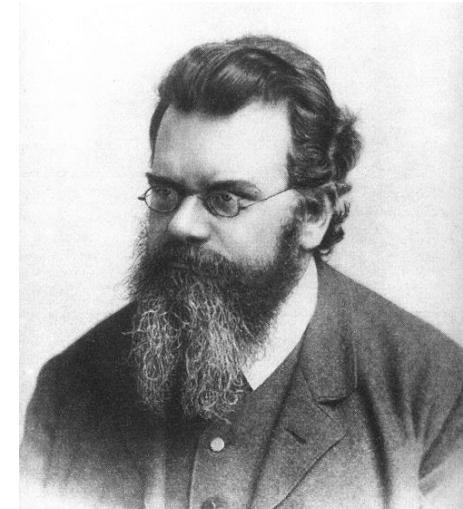
$$\Delta U_{\text{system}} = Q - W$$

Second law of thermodynamics

$$\partial Q = TdS$$

Third law of thermodynamics

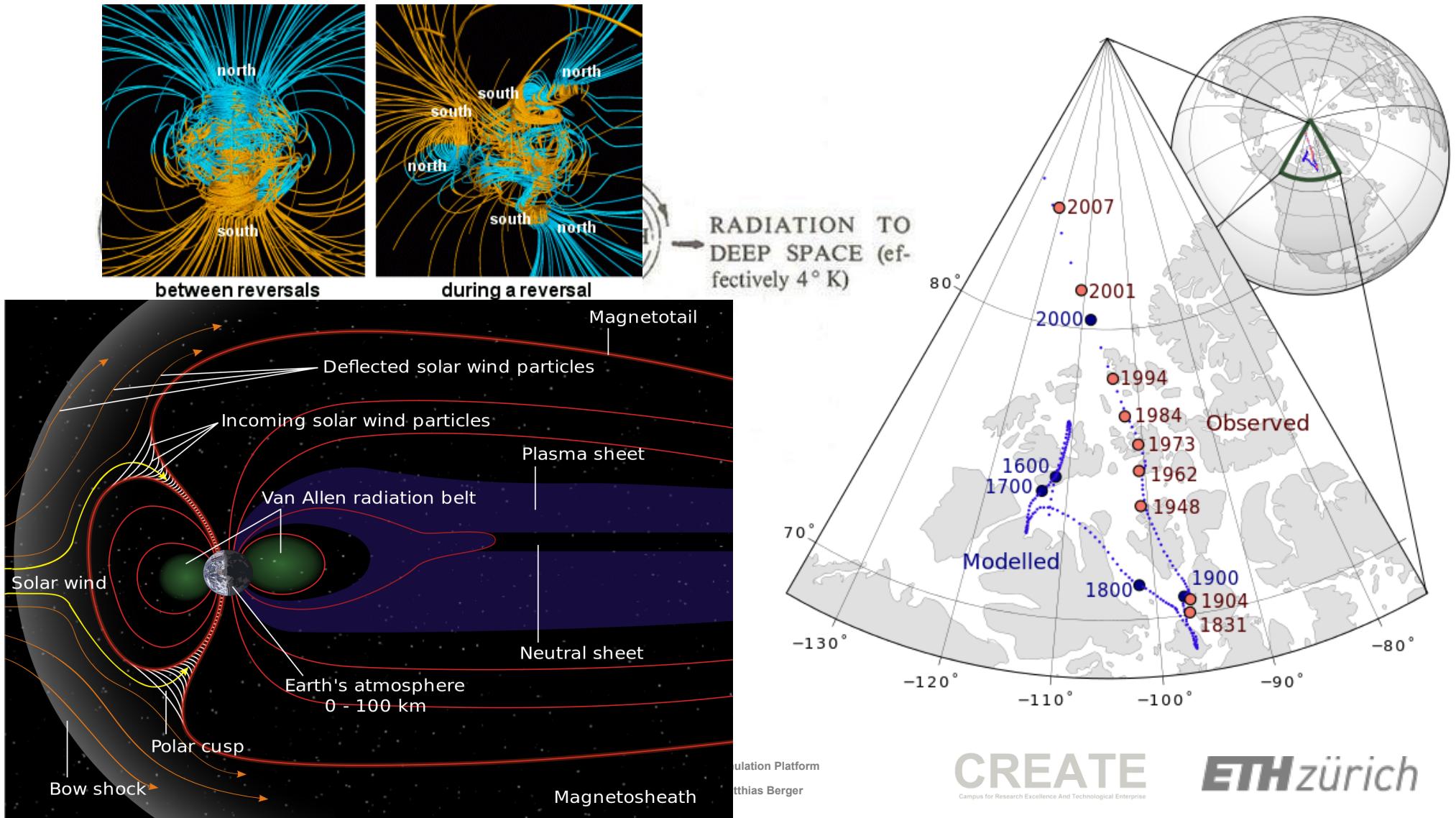
$$S = k_B \ln \Omega$$



Ludwig Boltzmann (1844-1906)

«If the gambler's version of the first law of thermodynamics is “you can't win” and of the second law is “you can't break even,” the gambler's version of the third law of thermodynamics is “you can't get out of the game.”»

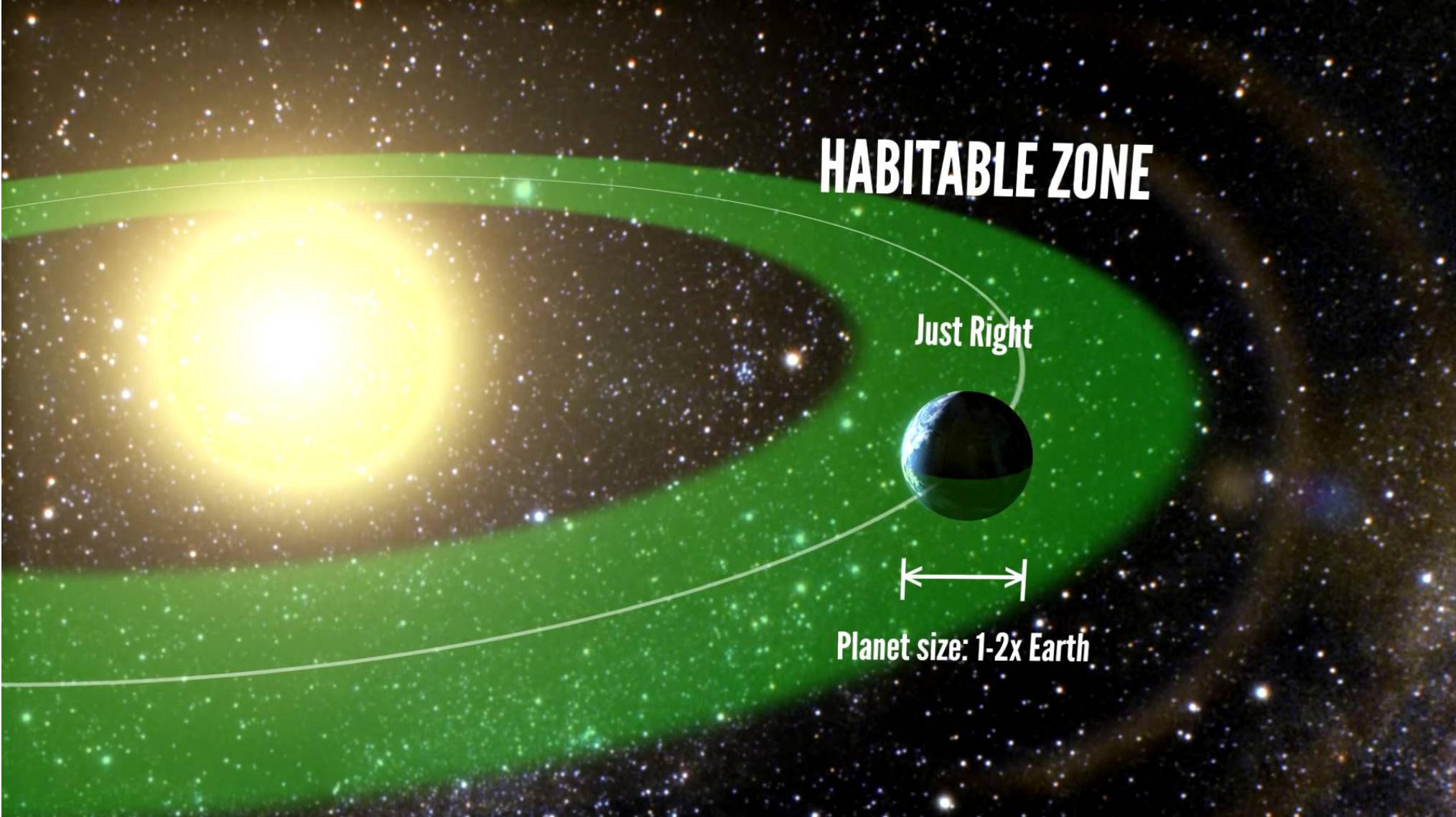
Schneider, E.D. & Sagan, D. (2005). *Into the Cool – Energy Flow, Thermodynamics and Life* (p.42). The University of Chicago Press.



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A diagram illustrating the habitable zone around a star. A central yellow star is surrounded by a green elliptical band representing the habitable zone. An Earth-like planet is shown at the center of the zone, with a horizontal double-headed arrow indicating its size relative to Earth. The text "Just Right" points to the planet.

HABITABLE ZONE

Just Right

Planet size: 1-2x Earth



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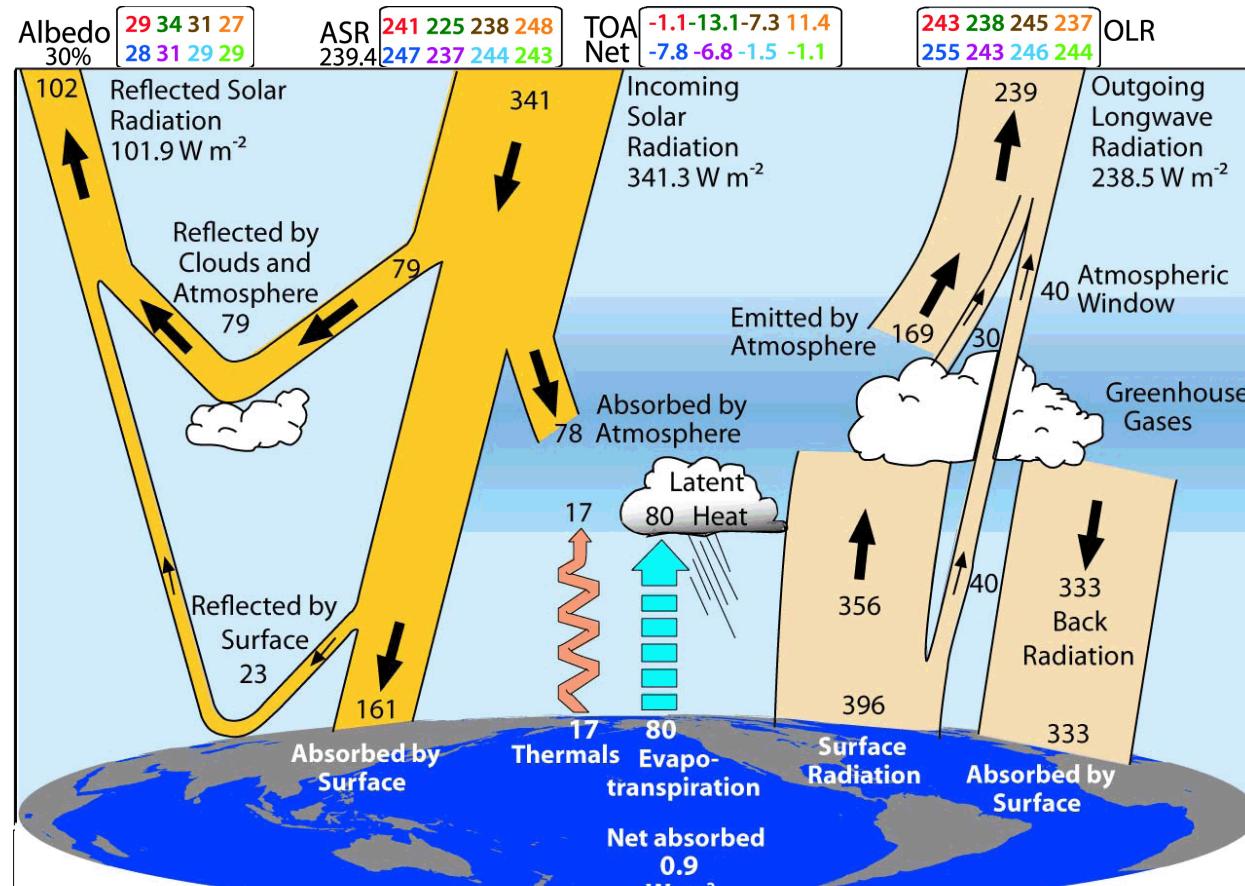
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Natural energy gradients: Global energy balance in [W/m²]



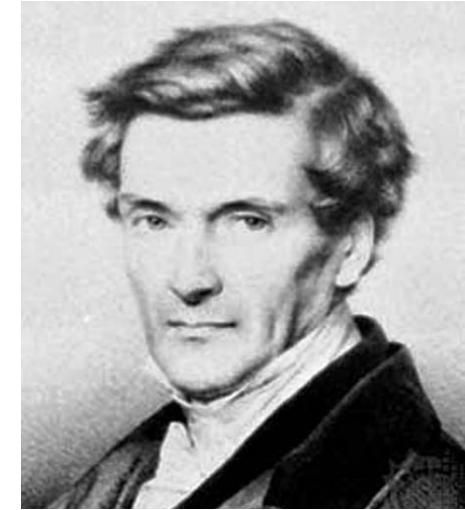
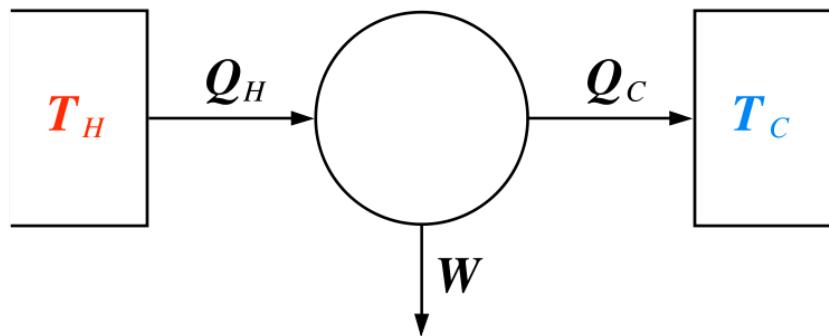
Step 3: global, with values (show lower left of the) energy fluxes from the various reanalyses for the 2002–08 period except for ERA40, for 2000–05 (Trenberth et al., 2009), (Trenberth et al., 2011).

- p.6: nature abhors a gradient
- p.77: gradient destruction rather than entropy production is a better explanation for the 2nd law
- p.79: equilibrium is one extreme, in some distance to equilibrium there is another metastable point, with minimum entropy production
- p.85: so called self-organized systems are not really self-organizing, but better described as gradient-organized systems with self-referential attributes



Ilya Prigogine (1917-2003)

Schneider, E.D. & Sagan, D. (2005). *Into the Cool – Energy Flow, Thermodynamics and Life*. The University of Chicago Press.



Sadi Carnot (1796-1832)

$$\eta_{\max} = 1 - \frac{T_{H,sink}}{T_{C,source}}$$



Image: KKW Gösgen [NZZ]

Man-made energy gradients:
Energy systems
using a thermal gradient

→ difference in temperature

If Carnot is right, what is now the function of the cooling tower at a power plant?



Bahrain WTC



Windmill in Kuremaa, Estonia

Man-made energy gradients:
Energy systems
using a kinetic gradient

→ difference in (wind) speed



Grande Dixence dam

Man-made energy gradients:
Energy systems
using a gravity gradient

→ difference in potential



Tesla model S

Man-made energy gradients:
Energy systems
using a chemical gradient

→ difference in potential

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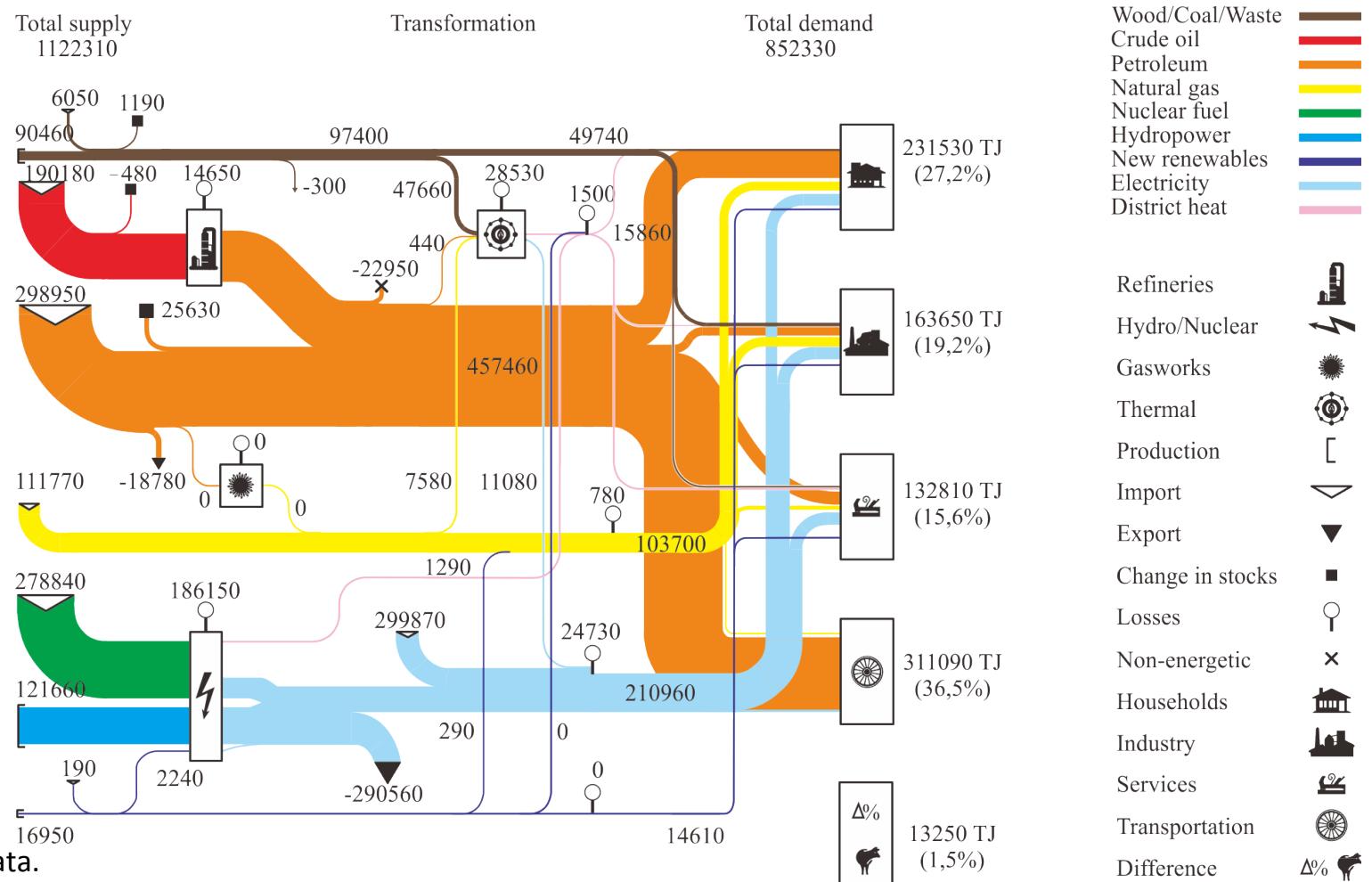
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Sankey diagram of energy flow in Switzerland

Population 8'014'000
 Energy dem. 852'330 TJ
 Area 41'285 km²
 Density 194/ km²
 GDP(PPP) 340 bil. US\$

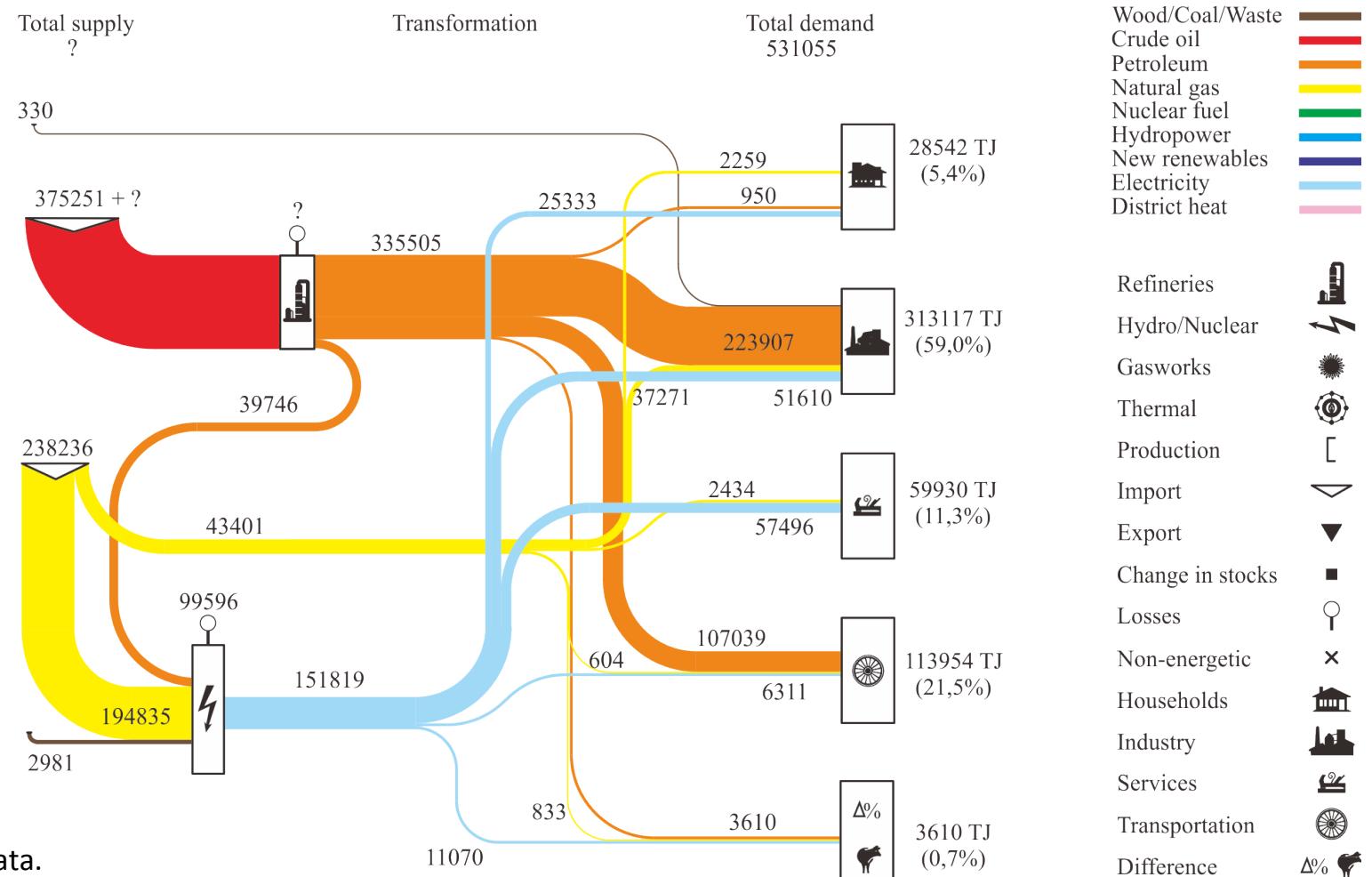


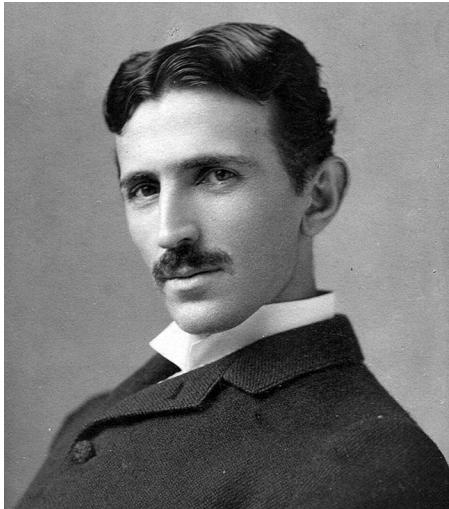
Annual values based on 2012 data.

Sankey diagram of energy flow in Singapore

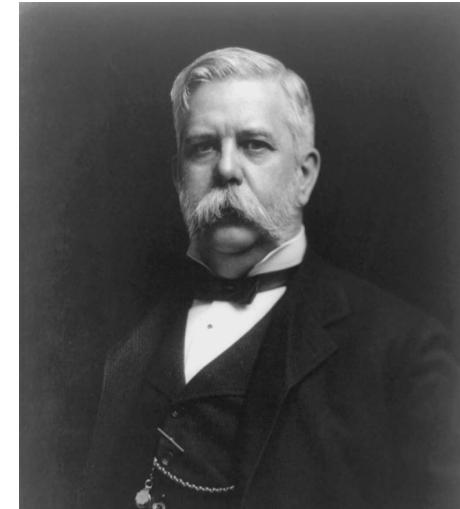
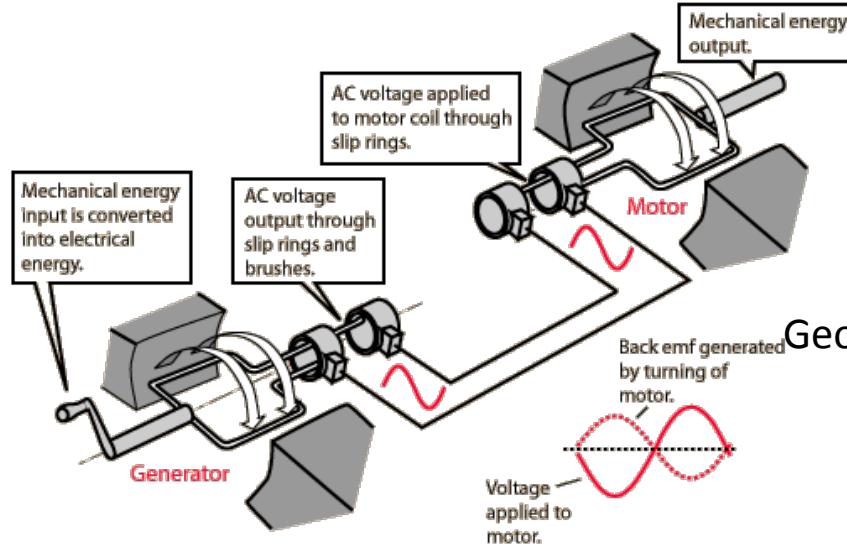
Population 5'312'400
 Energy dem. 531'055 TJ
 Area 712.4 km²
 Density 7126 / km²
 GDP(PPP) 315 bil. US\$

Annual values based on 2012 data.

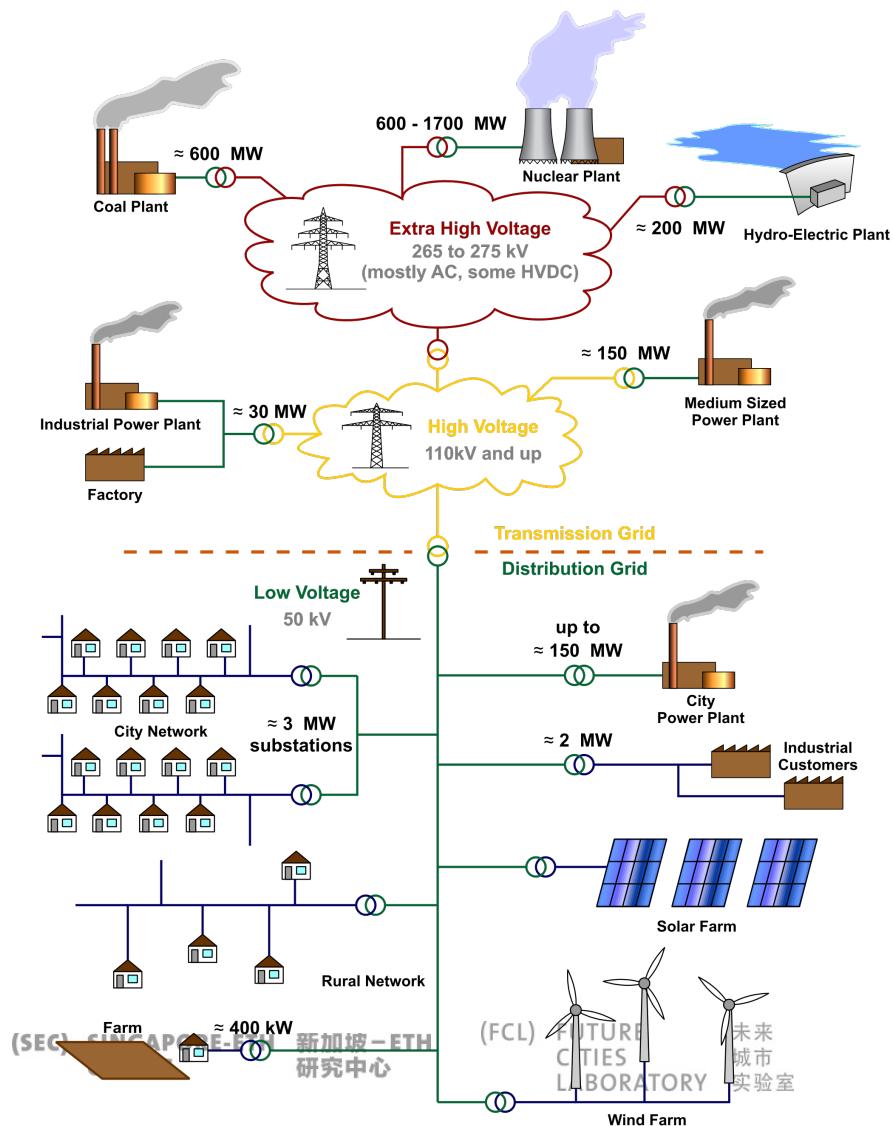




Nikola Tesla (1856-1943)



George Westinghouse (1846-1914)



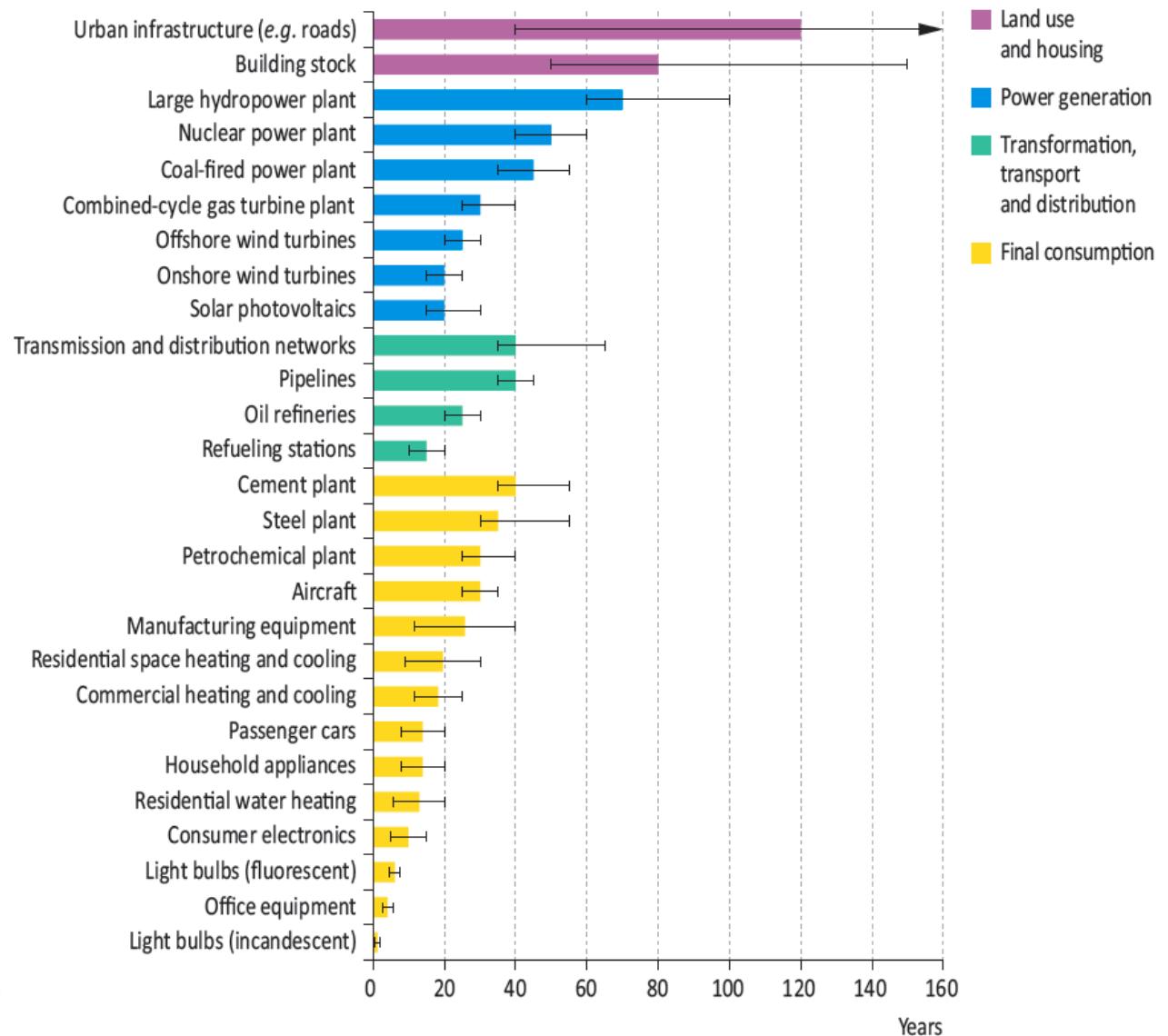
Electricity grid for transmission and distribution, including production and consumption.



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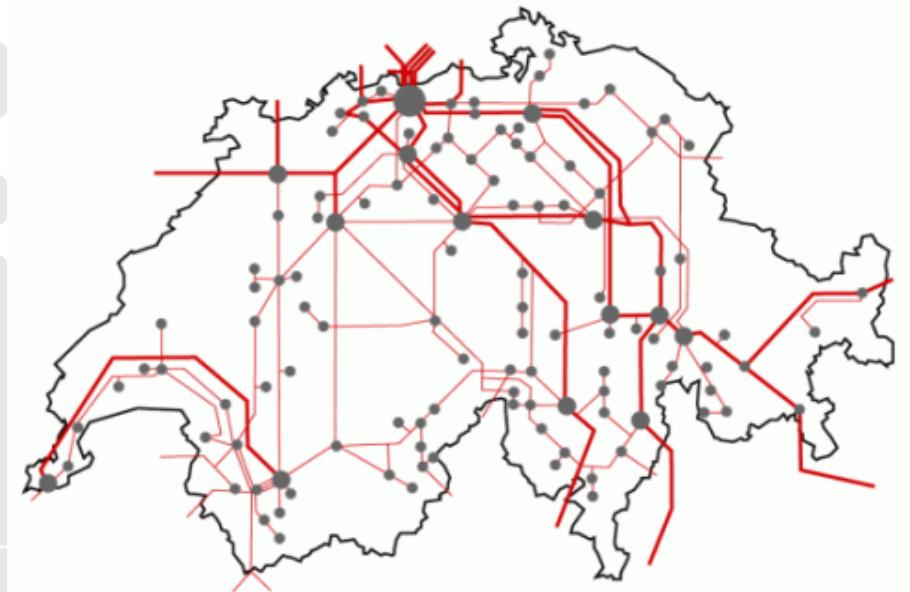
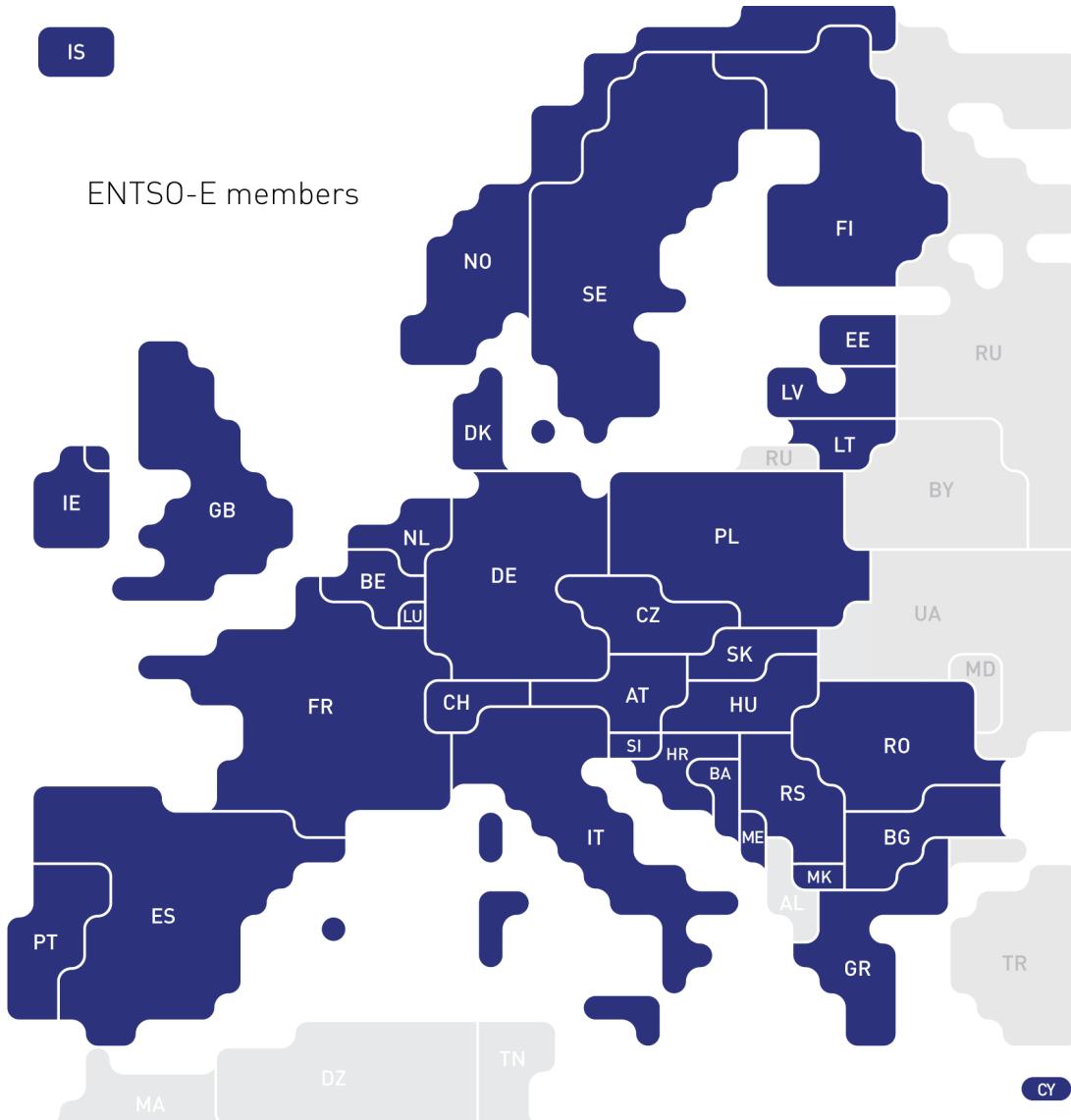


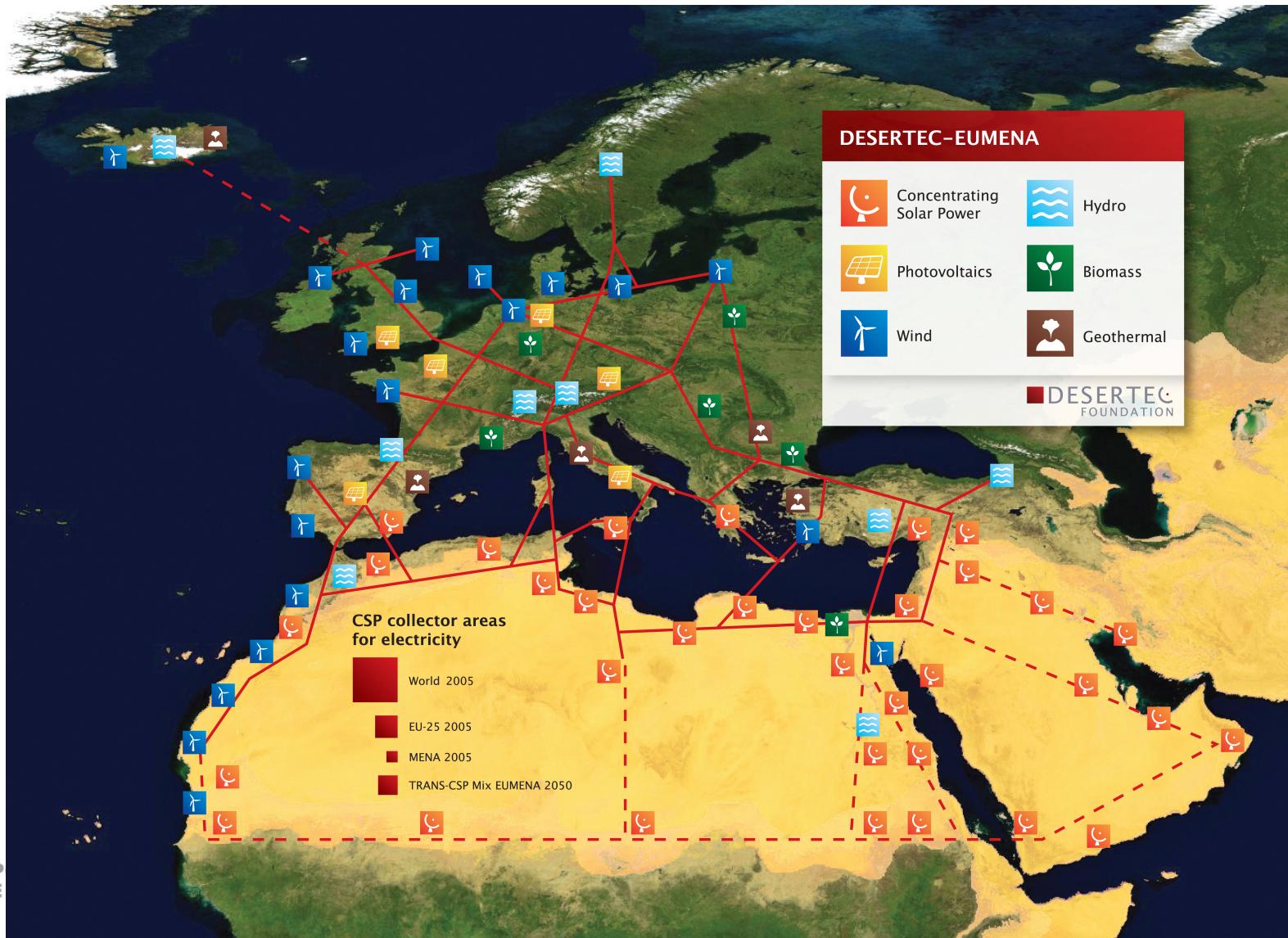
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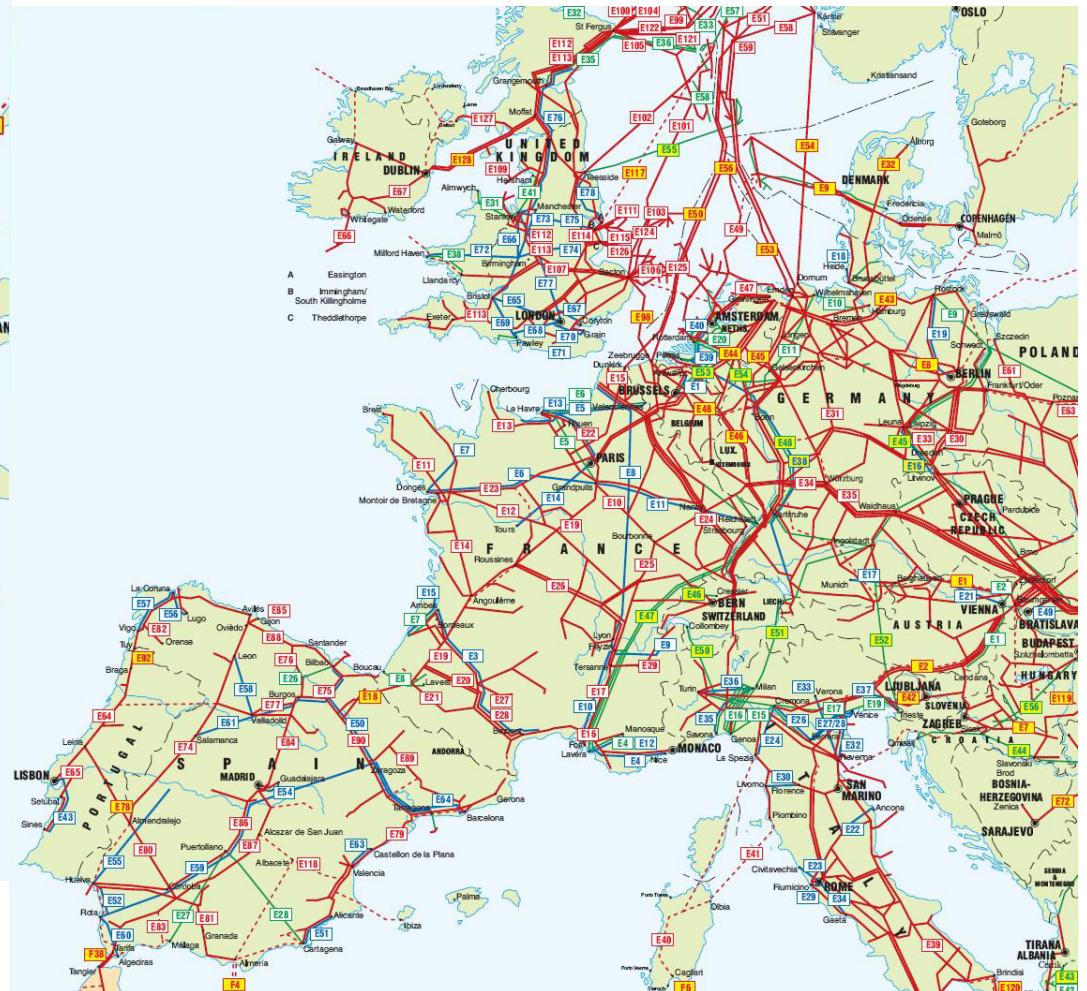
ENTSO-E members





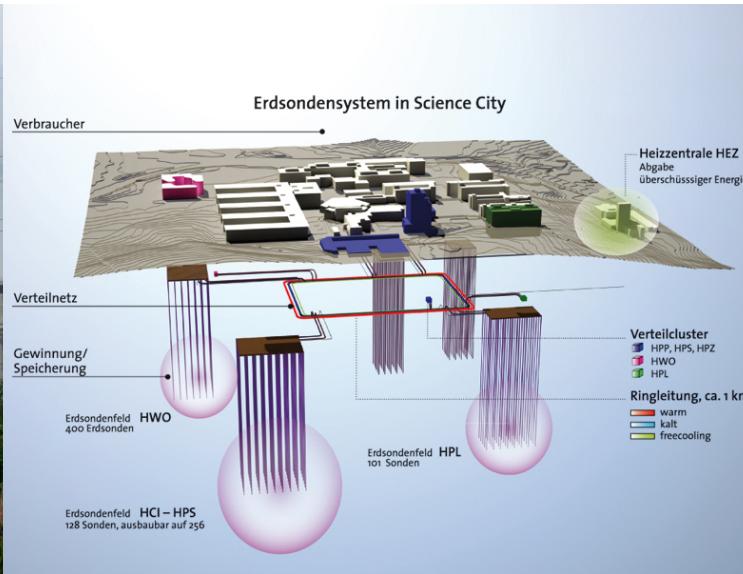


Natural gas and oil grid for transmission .





Three Gorges dam



Thermal storage @ ETH Hönggerberg

Energy storage

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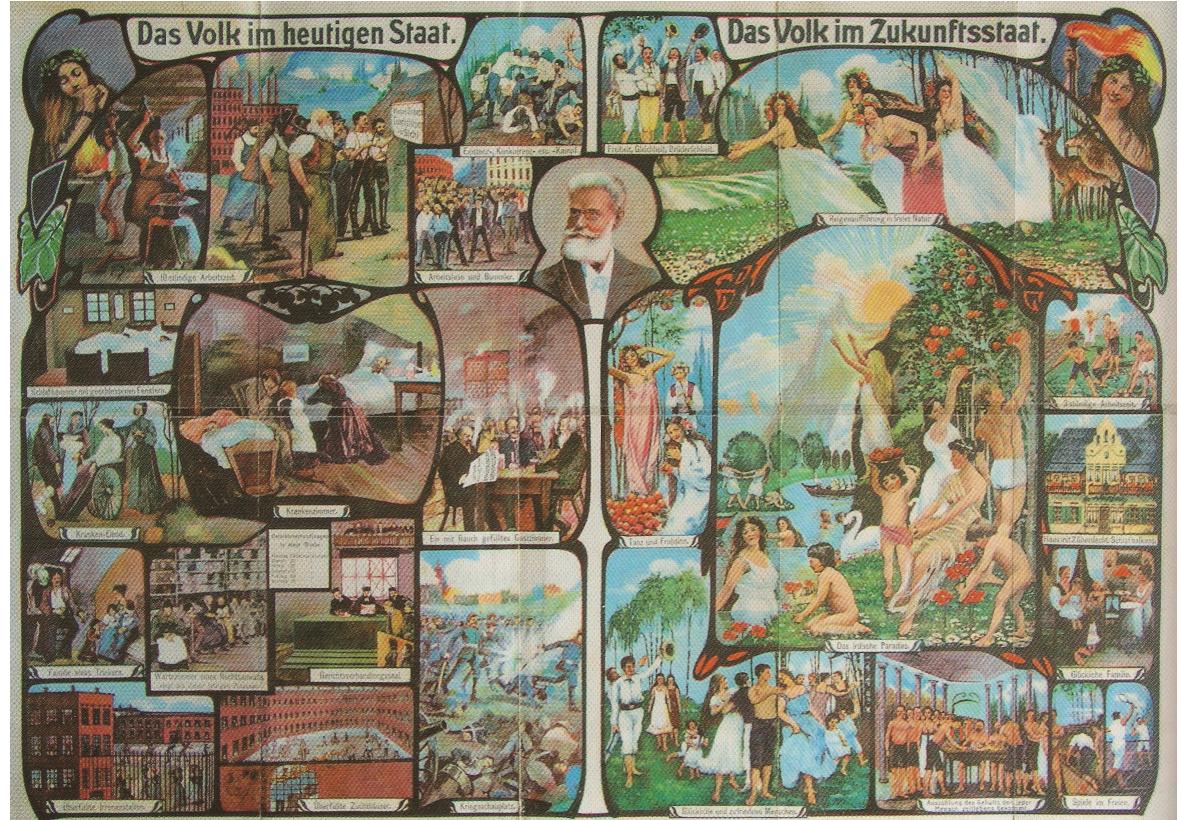
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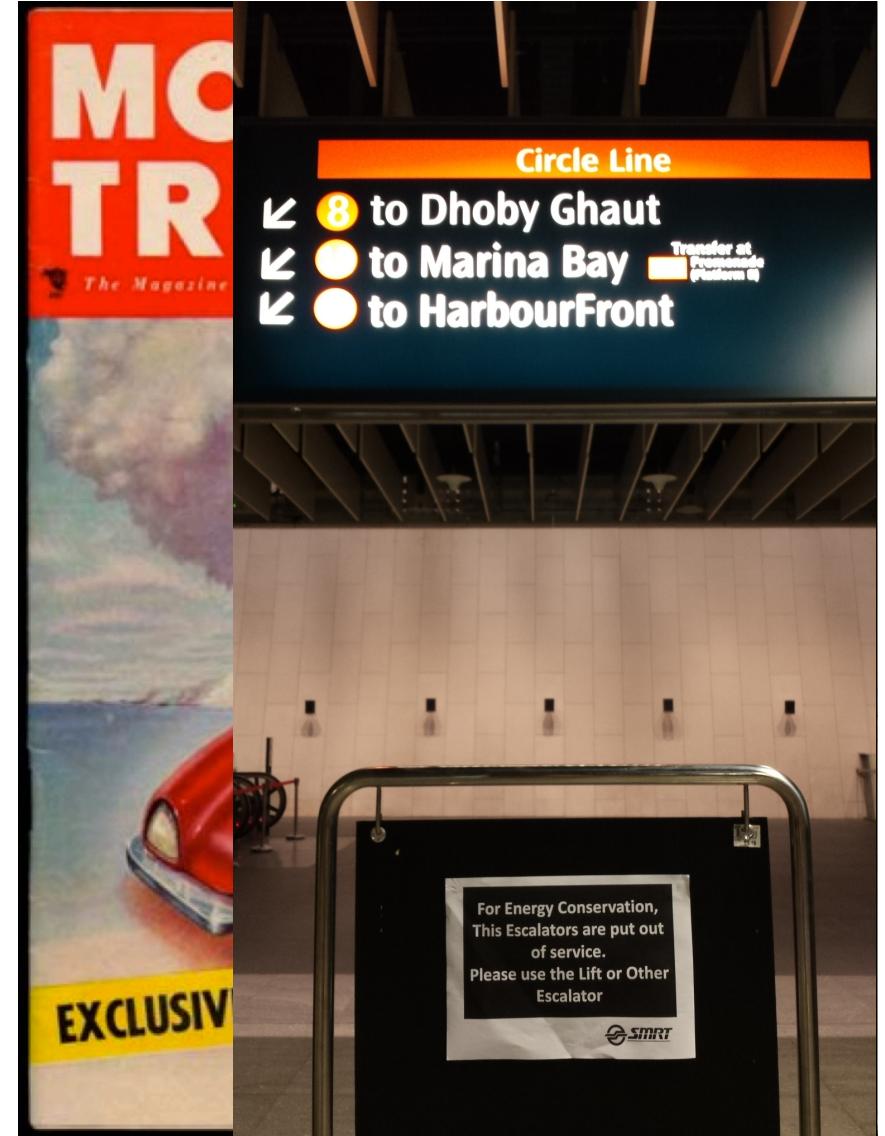
Energy vs. Society?

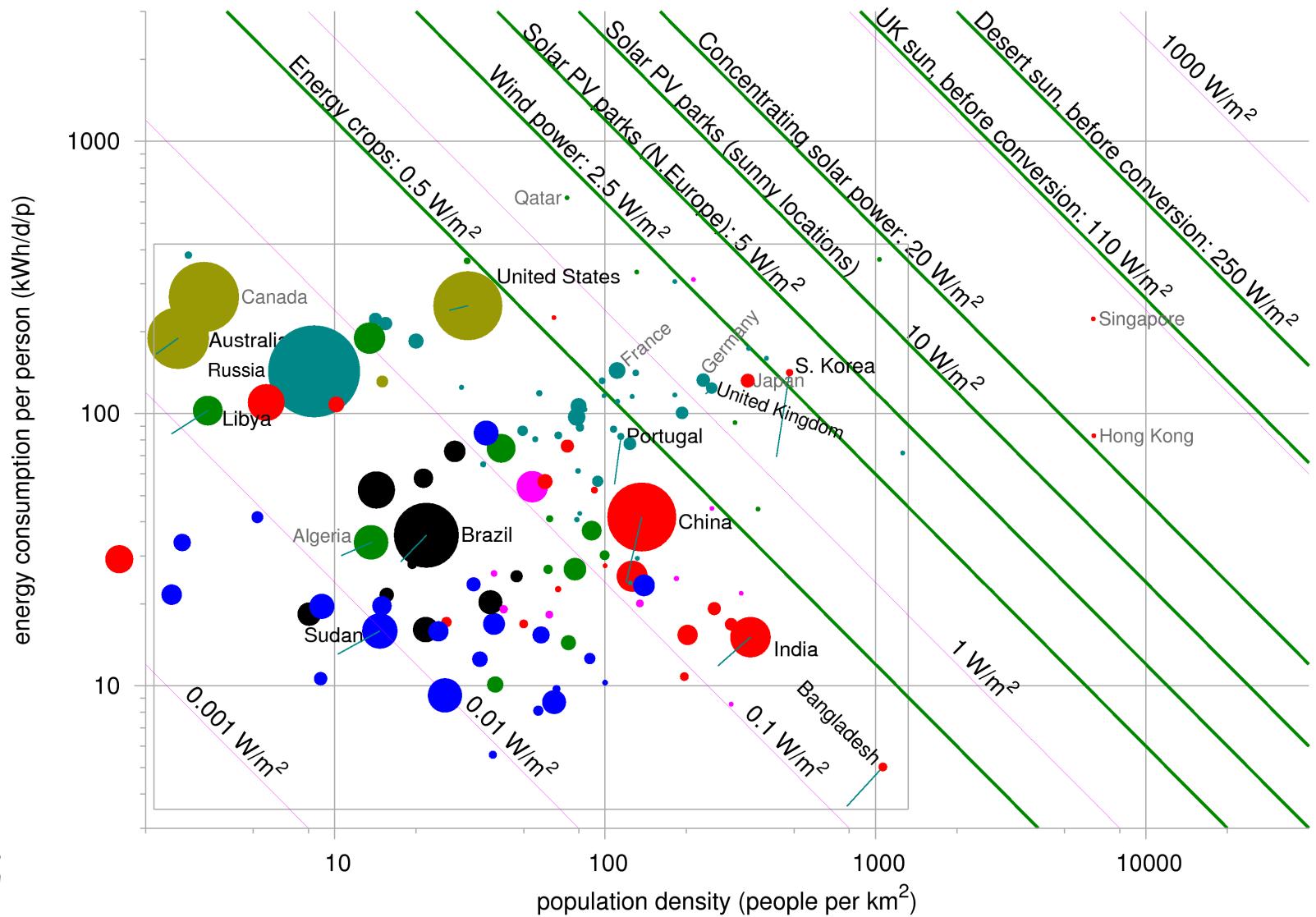


Bilz, Friedrich Eduard (1904). *Das Volk im Zukunftsstaat*.

«Our children will enjoy in their homes electrical energy **too cheap to meter**...

It is not too much to expect that our children will know of great periodic regional famines in the world only as matters of history, will travel effortlessly over the seas and under them and through the air with a minimum of danger and at great speeds, and will experience a lifespan far longer than ours, as disease yields and man comes to understand what causes him to age.»





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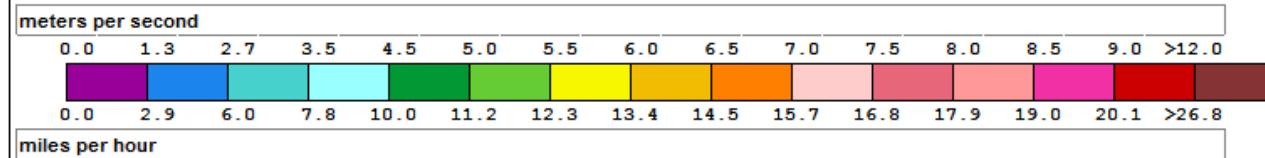
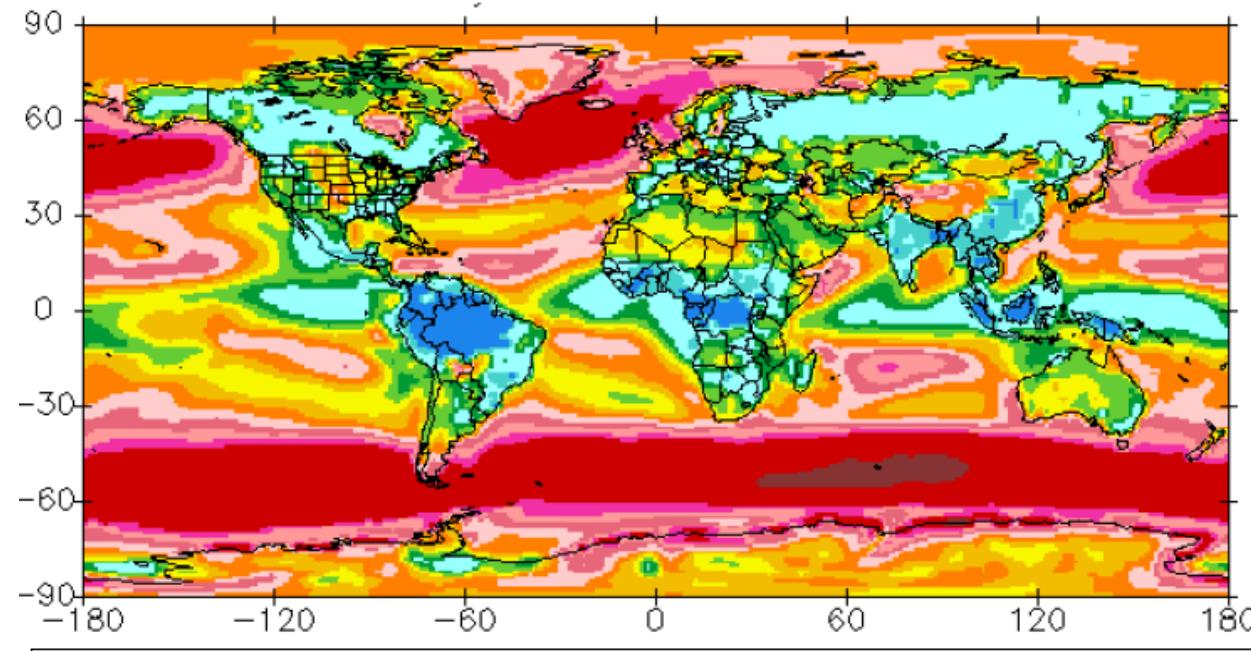
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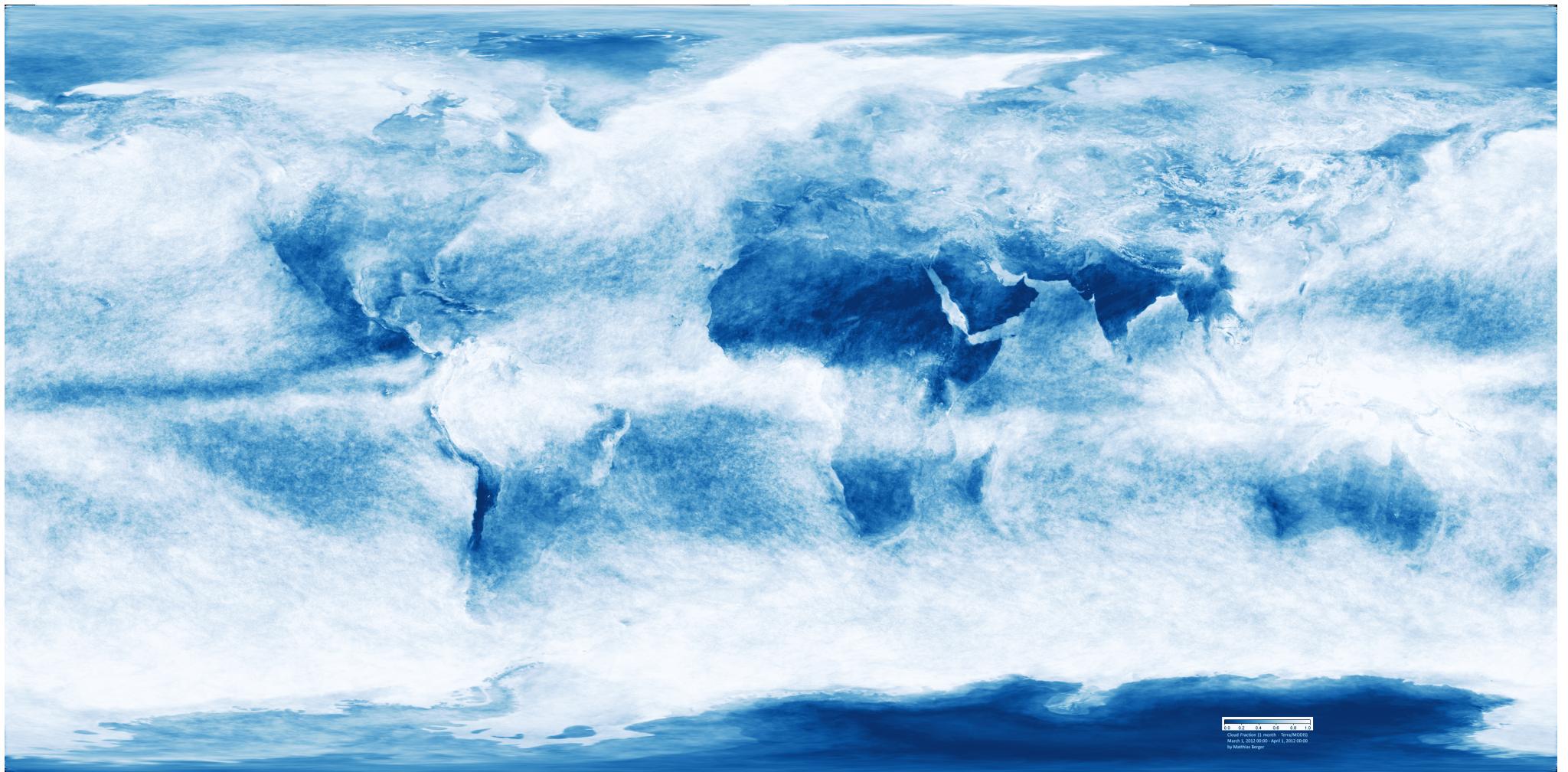
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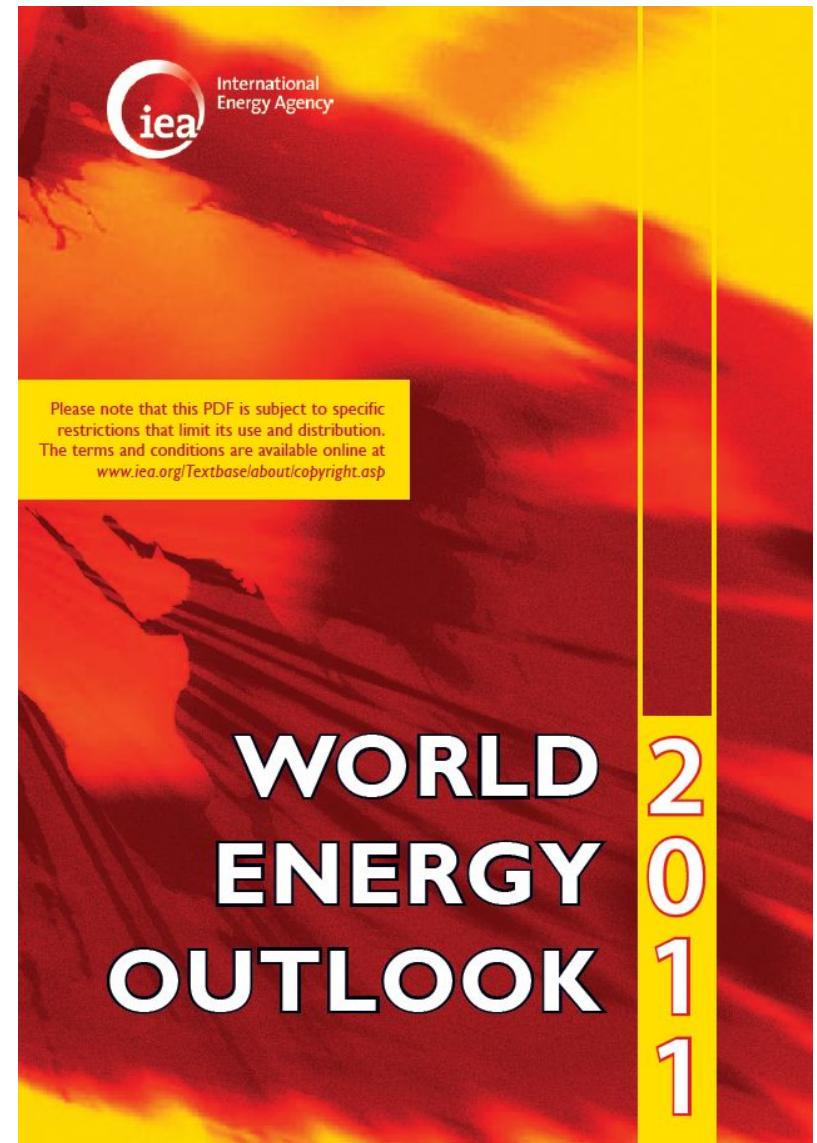
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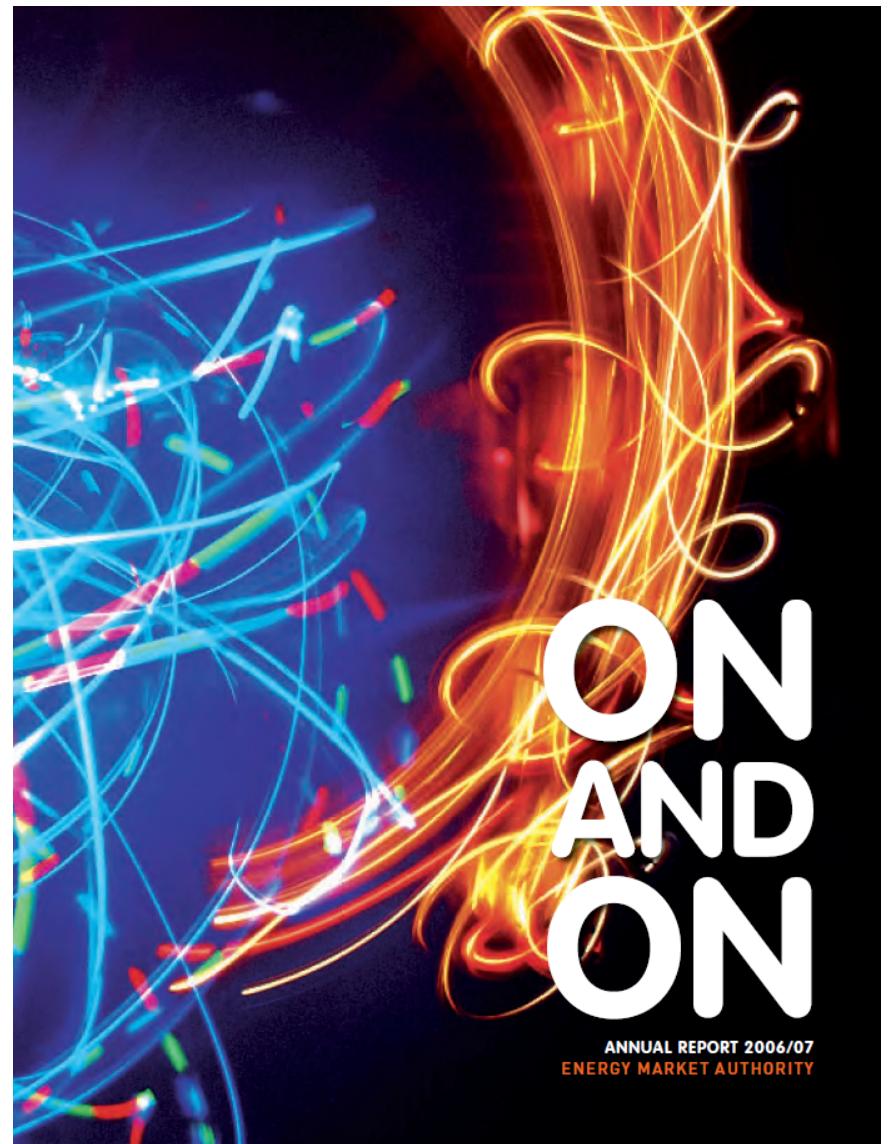
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2012 The Outlook for Energy: A View to 2040





The New Monte Rosa Hut SAC by ETH Zürich

