Introduzione al corso di Macchine

Energy and power

What is energy ?

Energy is a property that must be transferred to an object or a system in order to perform work on or transfer heat to the object or system. Energy can be converted or transferred but not created or destroyed.

We can have different forms of energy: mechanical work, heat, chemical energy, nuclear energy, electromagnetic, …

Different forms of energy have different values.

What is power ?

Power is energy divided by time, i.e. is the rate of the energy conversion or transfer.

What is the difference between energy and power ?

Time. Usefulness. Maximum rate of conversion. Ability to control. Ability to store.

Energy and power

What is the unit of energy ?

Work is the product of a force and movement: W=N*m

Joule: J= N*m

3,600 kJ = 3,412 BTU = 860 kcal = 1 kWh

What is the unit of power ?

Power is Energy divided by time: P=W/t=N*m/t=N*v

Watt: W=J/s

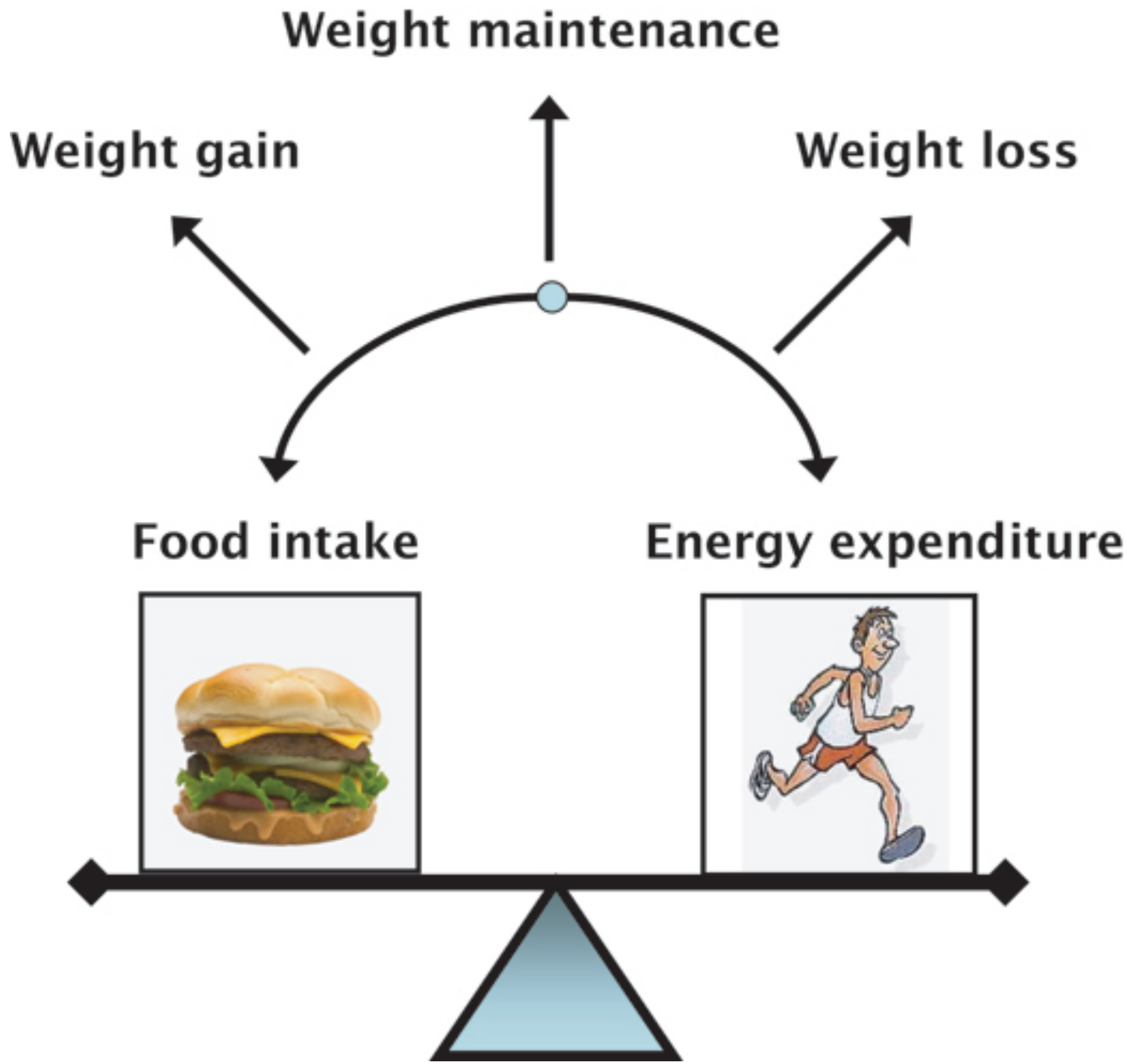
1 kW = 1.34 HP = 0,948 BTU/s = 860 kcal/h

Can we measure energy and power directly ?

No. We have to measure indirect properties and then calculate the result of some magnitude with some errors.

Do we need energy or power ?

- Natural systems limit power output
- Store and use energy at a limited rate
- Use energy continuously
- Only use stored energy



Do we need energy or power ?

- Machines have (almost) no limits
- They can use energy sources (we call them energy sources because we measure their potential and not the rate of utilization)
- Depending on their energy source they can generate huge amounts of power
- The Bagger 298 giant bucket wheel excavator stands 96 m tall and 225 m long, and weighs in at 14,200 tons. This multi-ton Tessie uses five operators to push her along, and can move 240,000 m3 of earth per day and is powered by 16 MW.

Do we need energy or power ?

- The Frecciarossa 1000 train is powered with 9.8 MW engines.
- Just a little more than the double of the Bagger 298.
- It weighs only 500 tons.
- Which is the difference ?

Do we need energy or power ?

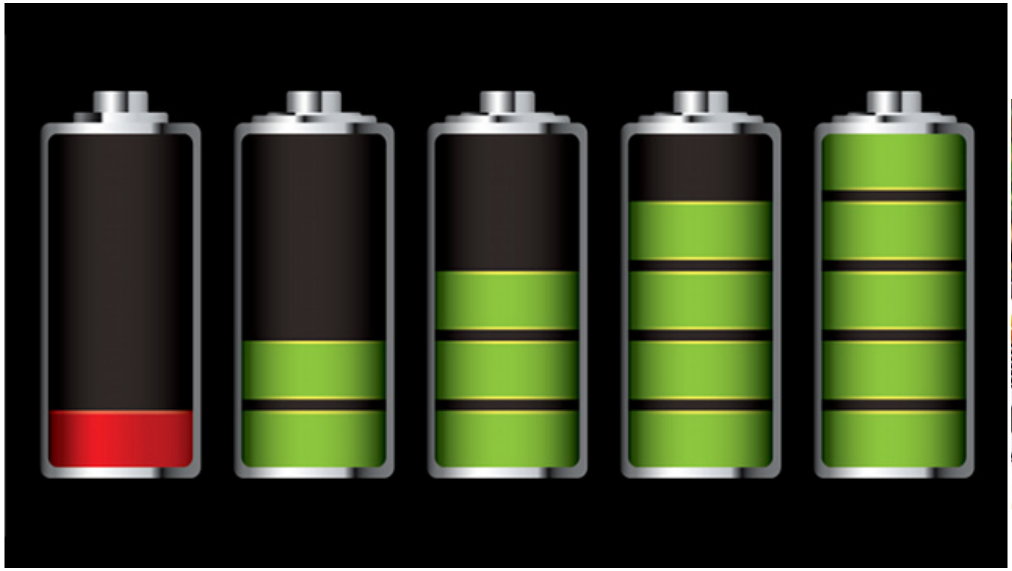
- Ferrari 812 superfast
- Displacement: 6500 cc
- Specific power: 90 kW/l
- Power: 588 kW
- Speed: 340 km/h
- 2.9 s to 100 km/h
- 7.9 s to 200 km/h
- Weight: 1525 kg

Do we need energy or power ?

- We can balance forces

Do we need energy or power ?

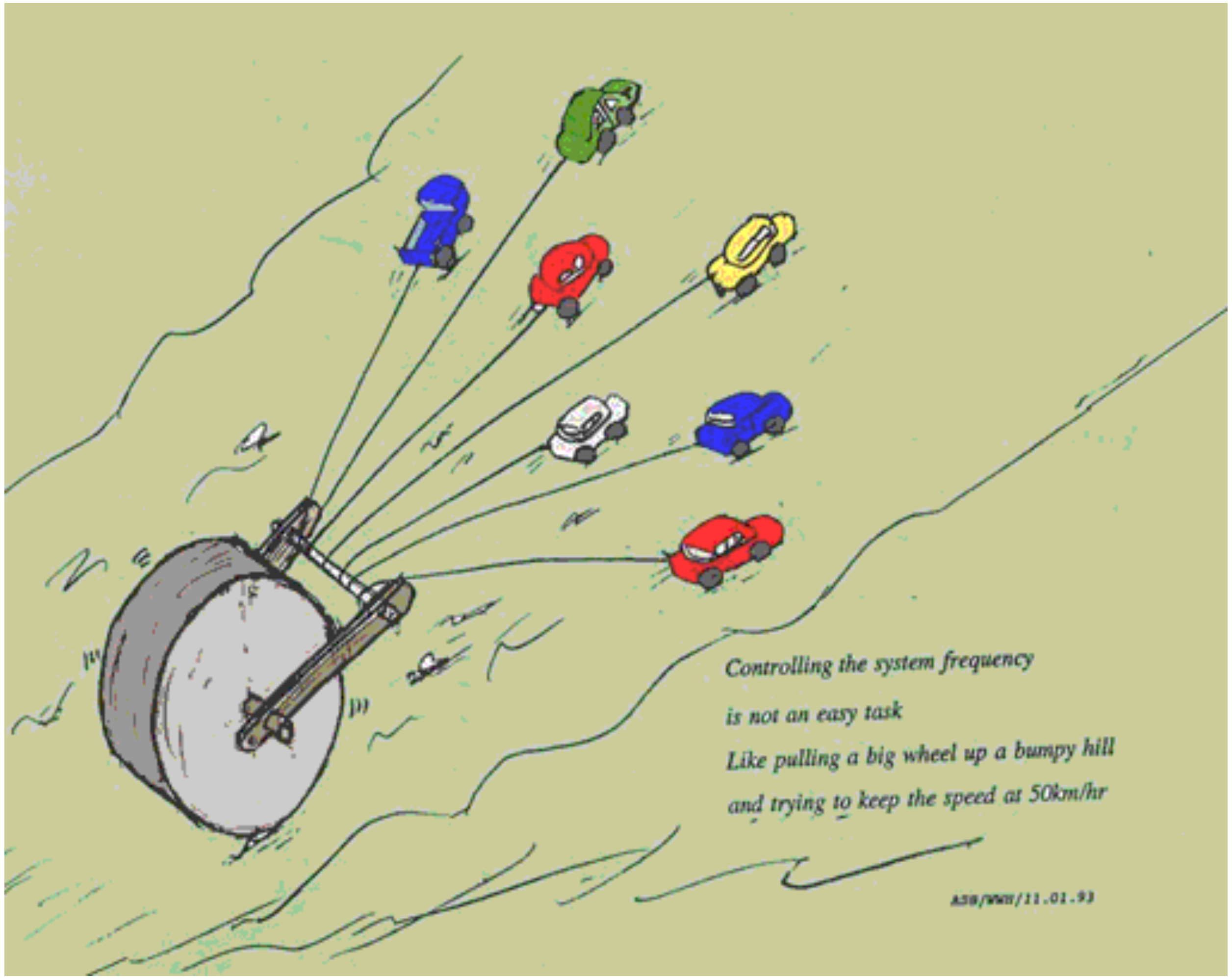
- We can convert work or energy



Do we need energy or power ?

Power needs to be balanced

- Time becomes an important variable
- The rate of energy conversion has to be balanced
- Otherwise...

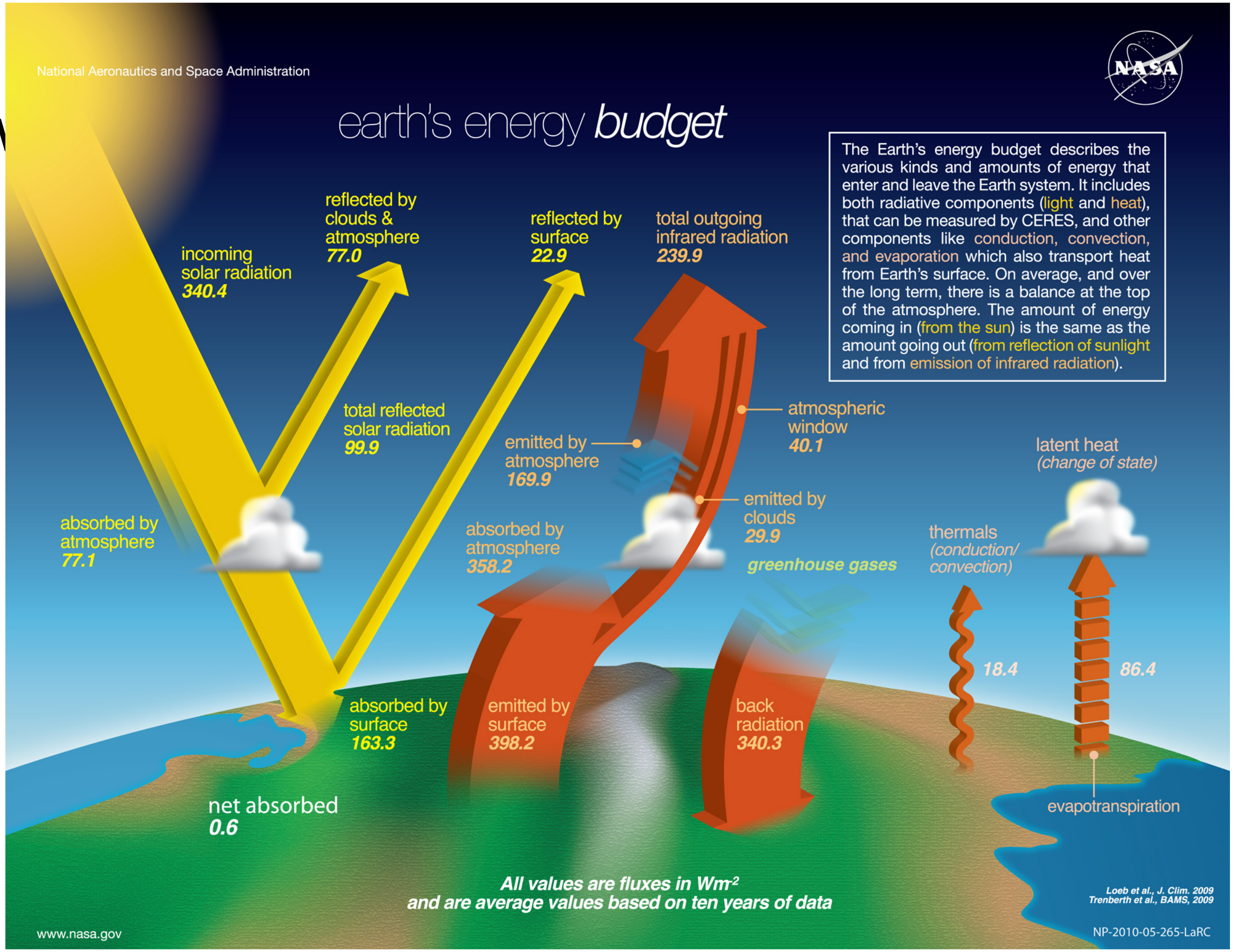


Do we need energy or power ?

- Unbalanced power

Do we need energy or power ?

• Pow



Do we need energy or power ?

- Some numbers about energy:
  - The annual potential of solar energy is 3,850,000 exajoules (EJ)
  - 1 EJ = 10^{18} J = 278 TWh
  - 3,600 kJ = 3,412 BTU = 860 kcal = 1 kWh
  - Total world energy consumption was 567 EJ in 2013
  - Total world electricity was 69 EJ in 2013
  - Photosynthesis captures approx. 3,000 EJ
  - 1 TOE=4.187e+7 kJ=39,685,102 BTU=11,630 kWh

Do we need energy or power ?

- Some numbers about power:
  - The solar radiation on the earth is 173,000 TW
  - The geothermal heat flux from the Earth's interior is approximately 47 TW
  - The solar constant is 1,366 W/m^2
  - Human production of energy is approximately 18 TW
  - Photosynthesis converts solar energy with an efficiency ranging from 0.1 to 2 %
  - Wind converts from 0.87 to 1.17 % of solar energy
  - 1 kW = 1.34 HP = 0.948 BTU/s = 860 kcal/h

The answer is…

Do we need energy or power ?

If we just want to move something or heat something we need energy.

If we want to move or heat something bigger, we may just need more energy (size of the energy system)

If we want to do it quicker, then I need power.

Sometimes the decision is ours, sometimes not.

The number of users increases the demand of power.

If time is not important. We may just need energy.

It is the difference between a fast and a slow elevator.

It is the difference between climbing a mountain on a car or on a horse or just walking.

A well sized power plant has to consider both the energy and the power.

You may need to calculate the energy when sizing the storage, but you will calculate the power to supply the demanded rate of energy.

Renewable and not

- What we mean with renewable energy ?

Renewable energy is a source of energy that is always available and whose consumption does not change the world energy resources

- Which renewable energy sources do you know ?

Sun, wind, hydro, biomass, geothermal, tidal, ocean streams, ocean thermal, wave.

Some convert thermal energy, some are fully mechanical, some are chemical.

Some derive from the sun, some from the moon, some from the earth.

Some can be easily stored, some require energy conversion thermodynamic cycles, some are available anywhere, some are available only in some places (This is very important!)

Man is always pushing to use standards and standard economic theories. We should change this when using renewables.

Renewable and not

- All energy sources are natural

Yes, even fossil fuels are derived by natural processes. They are renewable, but the time necessary to have them back from natural processes is millions of years. We cannot wait.

- All energy sources are renewable (almost…)

Nuclear fuel is not renewable. Emissions from fossil fuels could be recovered to convert them into new fuels.

- All energy sources can be stored (but...)

Yes, but storing a fuel is easy. Storing electricity is very difficult, storing mechanical energy is even more.

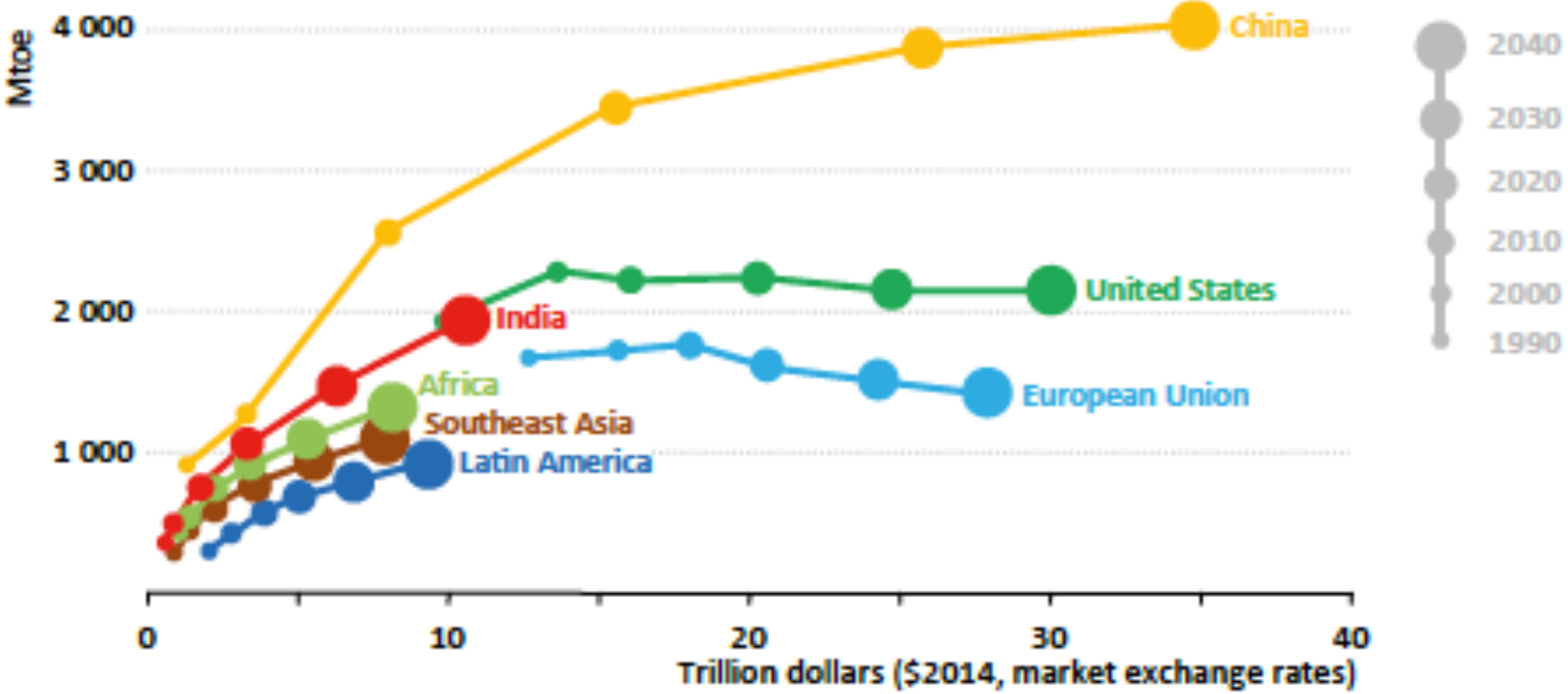
Renewable and not

- Why renewable energy ?

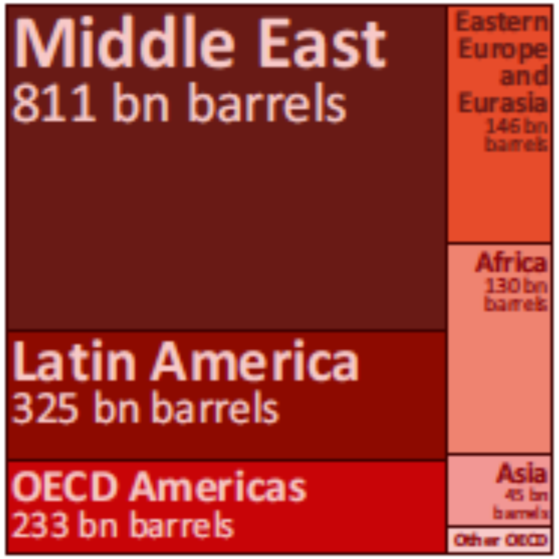
- Sustainable development
- End of fossil fuels resources
- Climate change
- Pollution
- Geopolitics
- ???

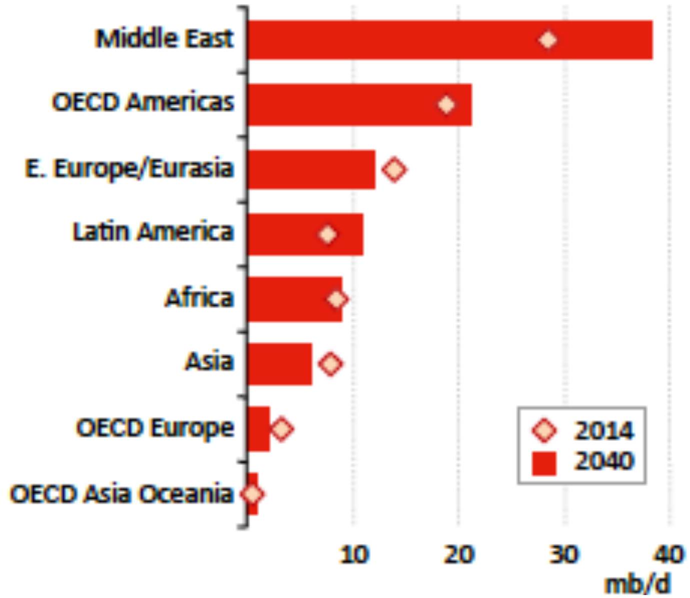
World energy in numbers

Figure 2.4 ▹ Primary energy demand and GDP by selected region in the New Policies Scenario, 1990-2040



World energy in numbers





47 Years

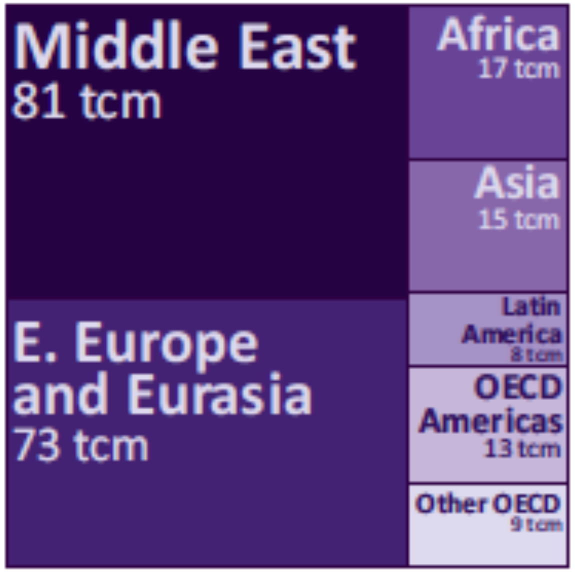
Table 3.1 ▷ Oil and total liquids demand by scenario (mb/d)

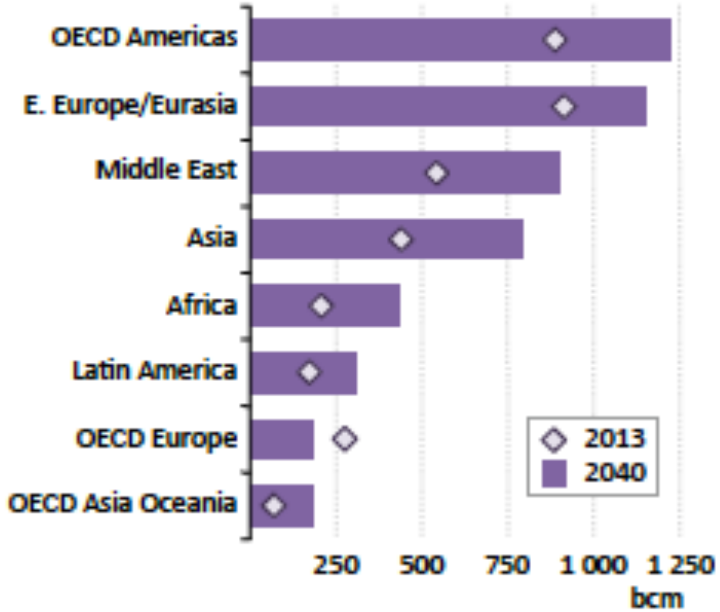
		New Policies		Low Oil Price		Current Policies		450 Scenario	
	2014	2020	2040	2020	2040	2020	2040	2020	2040
OECD	40.7	39.4	29.8	39.9	31.3	40.1	34.4	38.8	20.5
Non-OECD	42.9	48.9	63.6	49.4	65.4	49.7	71.4	47.7	46.7
Bunkers*	7.0	7.6	10.0	7.7	10.4	7.8	11.2	7.3	6.9
World oil	90.6	95.9	103.5	97.0	107.2	97.5	117.1	93.7	74.1
Share of non-OECD	*47%*	*51%*	*62%*	*51%*	*61%*	*51%*	*61%*	*51%*	*63%*
World biofuels**	1.5	2.1	4.2	1.9	3.3	1.9	3.6	2.1	9.4
World total liquids	92.1	98.0	107.7	98.9	110.4	99.5	120.7	95.8	83.4

* Includes international marine and aviation fuels. ** Expressed in energy-equivalent volumes of gasoline and diesel.

Note: Further information on methodology and data issues may be found at *www.worldenergyoutlook.org/weomodel/*.

World energy in numbers





54 Years

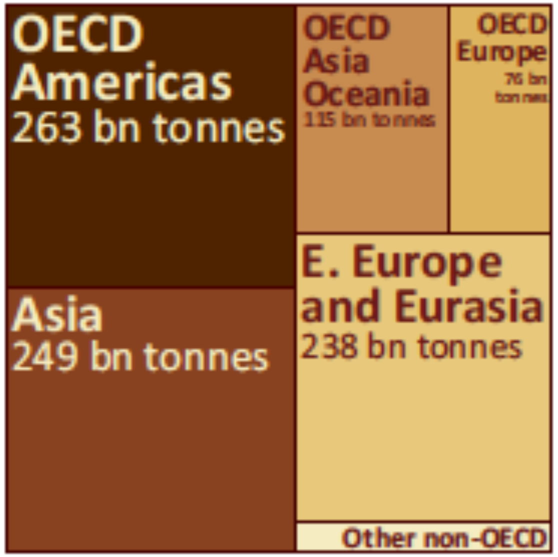
Table 5.1 ▷ Natural gas demand by major region and scenario (bcm)

			New Policies		Current Policies		450 Scenario	
	2000	2013	2020	2040	2020	2040	2020	2040
OECD	1 413	1 657	1 704	1 870	1 744	2 125	1 684	1 354
Non-OECD	1 102	1 850	2 139	3 258	2 170	3 491	2 080	2 662
World*	2 515	3 507	3 849	5 160	3 914	5 617	3 770	4 073

* The world numbers include the use of LNG as a marine bunker fuel.

World energy in numbers

World proven coal reserves: 968 billion tonnes



Coal production by region

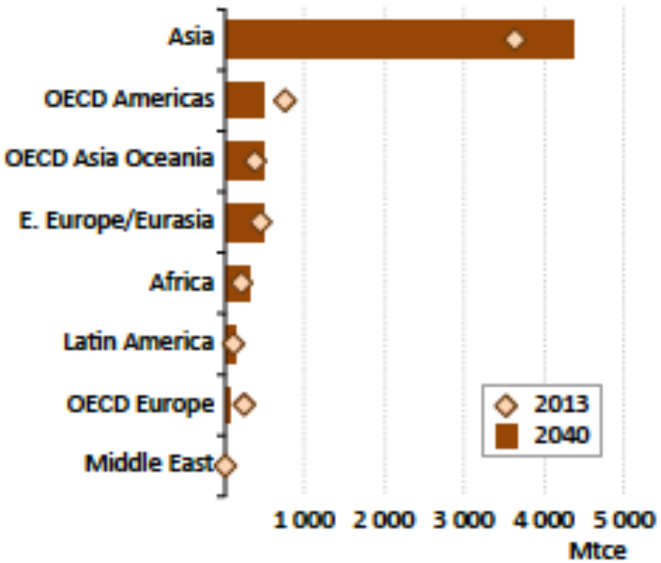


Table 7.1 ▷ Coal demand, production and trade by scenario (Mtce)

				New Policies		Current Policies		450 Scenario	
		2000	2013	2020	2040	2020	2040	2020	2040
Demand	OECD	1 573	1 470	1 307	878	1 413	1 289	1 152	523
	Non-OECD	1 774	4 143	4 454	5 428	4 627	6 737	4 208	3 041
	World	3 347	5 613	5 762	6 306	6 040	8 026	5 360	3 565
	Steam coal	2 590	4 379	4 523	5 266	4 784	6 835	4 175	2 813
	Coking coal	452	940	929	785	941	851	903	601
	Lignite*	304	295	309	254	315	341	282	151
Production	OECD	1 380	1 361	1 255	1 042	1 391	1 505	1 134	627
	Non-OECD	1 875	4 362	4 507	5 263	4 648	6 521	4 226	2 938
Trade**	World	471	1 084	1 143	1 291	1 221	1 780	1 038	594
	Steam coal	310	814	847	984	913	1 447	759	373
	Coking coal	175	272	299	311	310	337	284	229
Share of world demand	*Non-OECD*	*53%*	*74%*	*77%*	*86%*	*77%*	*84%*	*79%*	*85%*
	Steam coal	*77%*	*78%*	*79%*	*84%*	*79%*	*85%*	*78%*	*79%*
	Trade	*14%*	*19%*	*20%*	*20%*	*20%*	*22%*	*19%*	*17%*

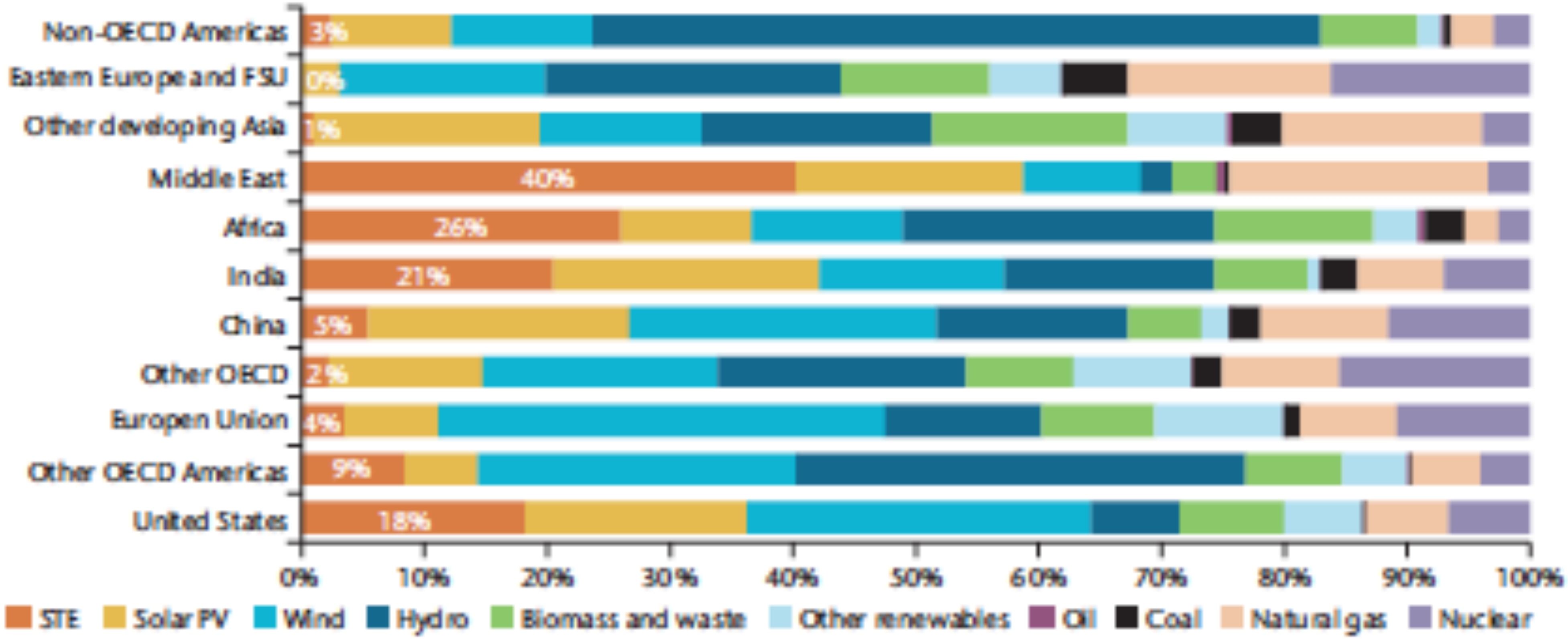
* Includes peat. ** Total net exports for all *WEO* regions, not including intra-regional trade.

Note: Historical data for world demand differ from world production due to stock changes.

113 Years

World energy in numbers

One or several energy mixes ?



KEY POINT: In the hi-Ren Scenario, STE is the largest source of electricity in Africa and the Middle East by 2050.

World energy in numbers

Table 8.2 ▷ World electricity generation by source and scenario (TWh)

			New Policies		Current Policies		450 Scenario	
	2000	2013	2020	2040	2020	2040	2020	2040
Total	15 431	23 318	27 222	39 444	27 988	43 120	26 206	33 910
Fossil fuels	9 966	15 735	16 805	21 409	17 772	27 659	15 604	9 851
Coal	6 001	9 612	10 171	11 868	10 918	16 534	9 185	4 107
Gas	2 752	5 079	5 798	9 008	6 006	10 534	5 658	5 465
Oil	1 212	1 044	836	533	849	590	760	279
Nuclear	2 591	2 478	3 186	4 606	3 174	3 974	3 218	6 243
Hydro	2 620	3 789	4 456	6 180	4 423	5 902	4 464	6 836
Other renewables	255	1 316	2 774	7 249	2 619	5 586	2 921	10 980
Fossil fuels	65%	67%	62%	54%	63%	64%	60%	29%
Coal	39%	41%	37%	30%	39%	38%	35%	12%
Gas	18%	22%	21%	23%	21%	24%	22%	16%
Oil	8%	4%	3%	1%	3%	1%	3%	1%
Nuclear	17%	11%	12%	12%	11%	9%	12%	18%
Hydro	17%	16%	16%	16%	16%	14%	17%	20%
Other renewables	2%	6%	10%	18%	9%	13%	11%	32%

World energy in numbers

Figure 8.9 ▻ Total power generation costs in the New Policies Scenario, 2020

a) World

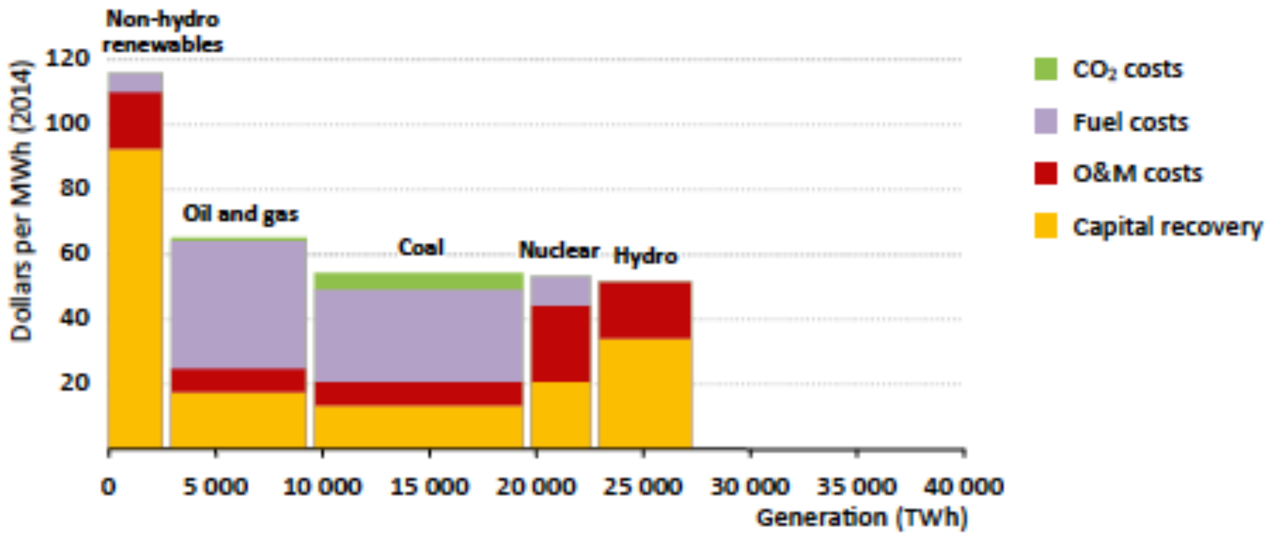
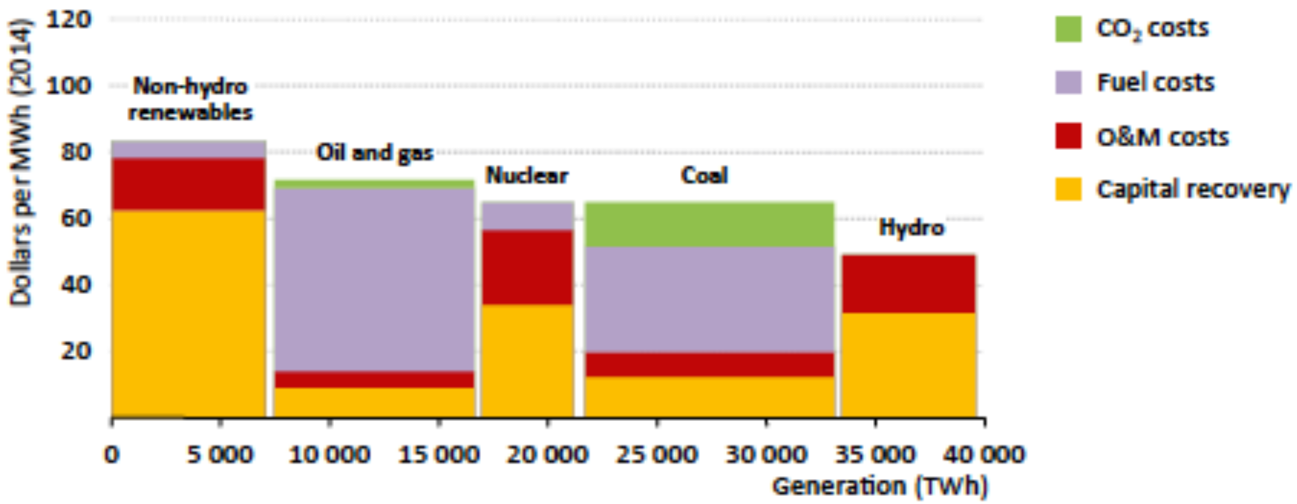


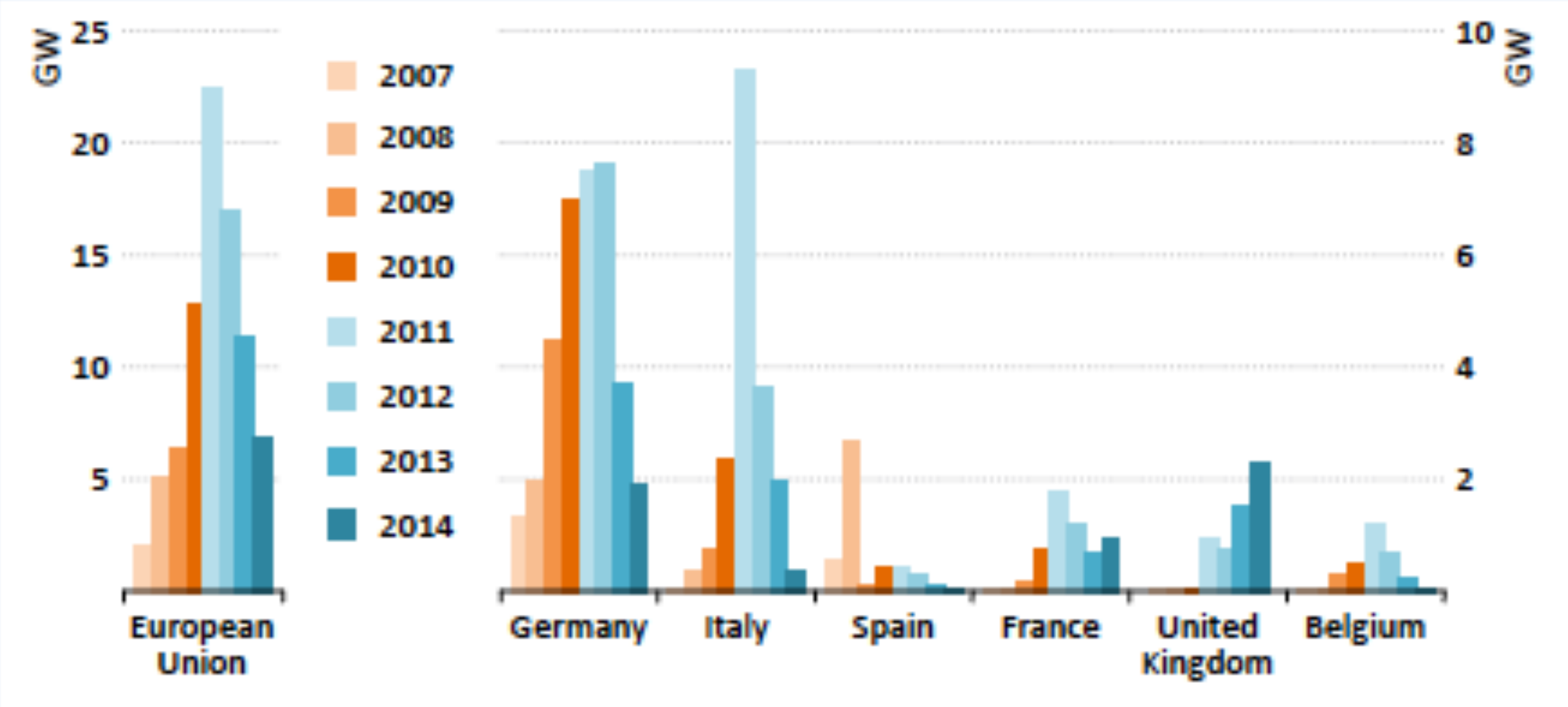
Figure 8.10 ▻ Total power generation costs in the New Policies Scenario, 2040

a) World



World energy in numbers

Figure 9.9 ▷ Solar PV capacity additions in European Union and selected countries, 2007-2014



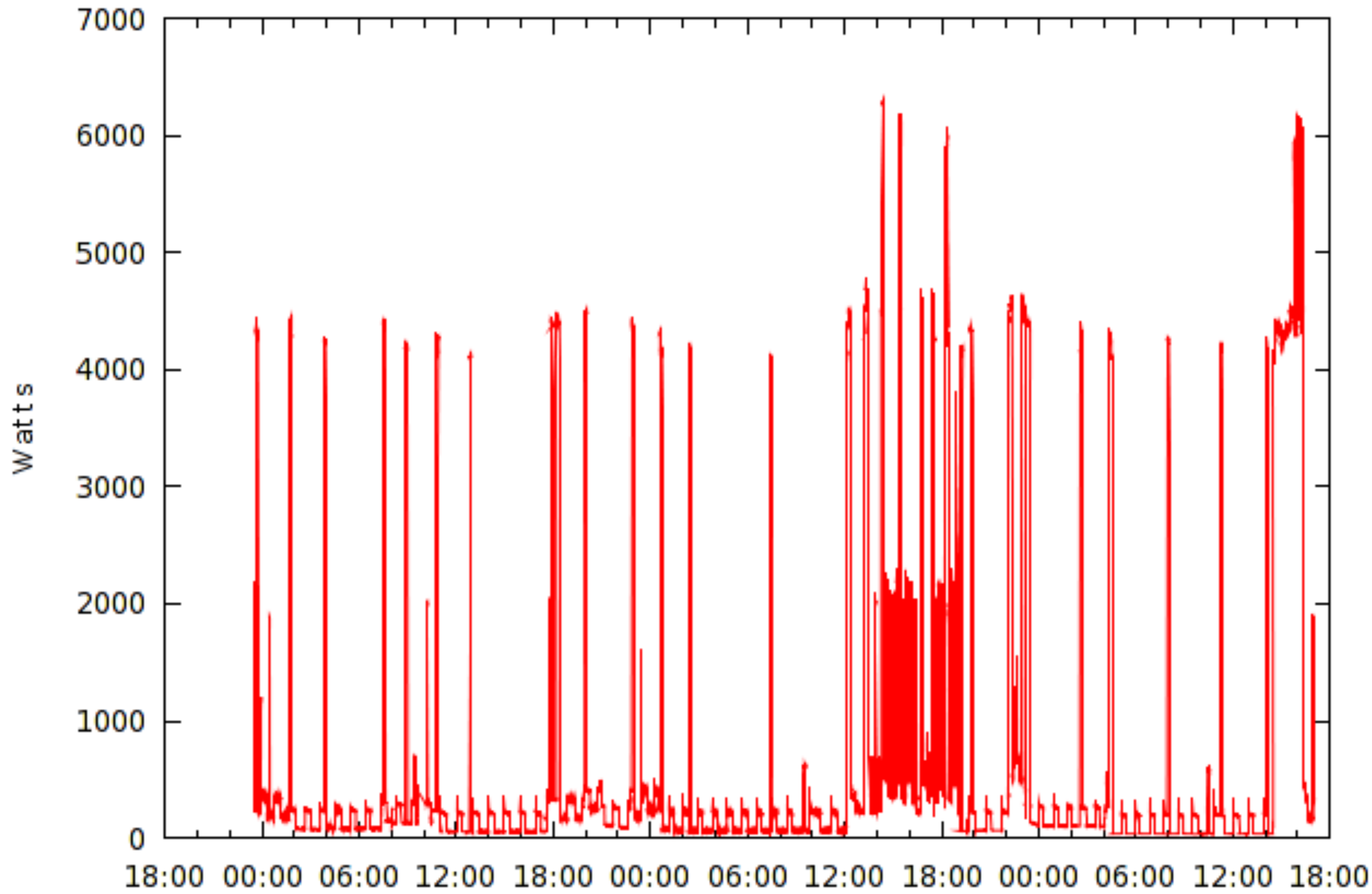
Why renewable now ?

- Technical issues
  - Programmability
  - Supply/demand match
  - Close to users ?
  - Efficiency
  - Storage
  - Intensity
  - Lack of standards
  - Lack of unique solutions
  - Power to heat
  - Power to gas
  - New concepts

- Non-technical issues
  - Cost
  - Monopoly of technologies
  - Availability of materials
  - Recycling/LCA
  - NIMBY
  - Impact on the environment
  - Change of infrastructure and world trade

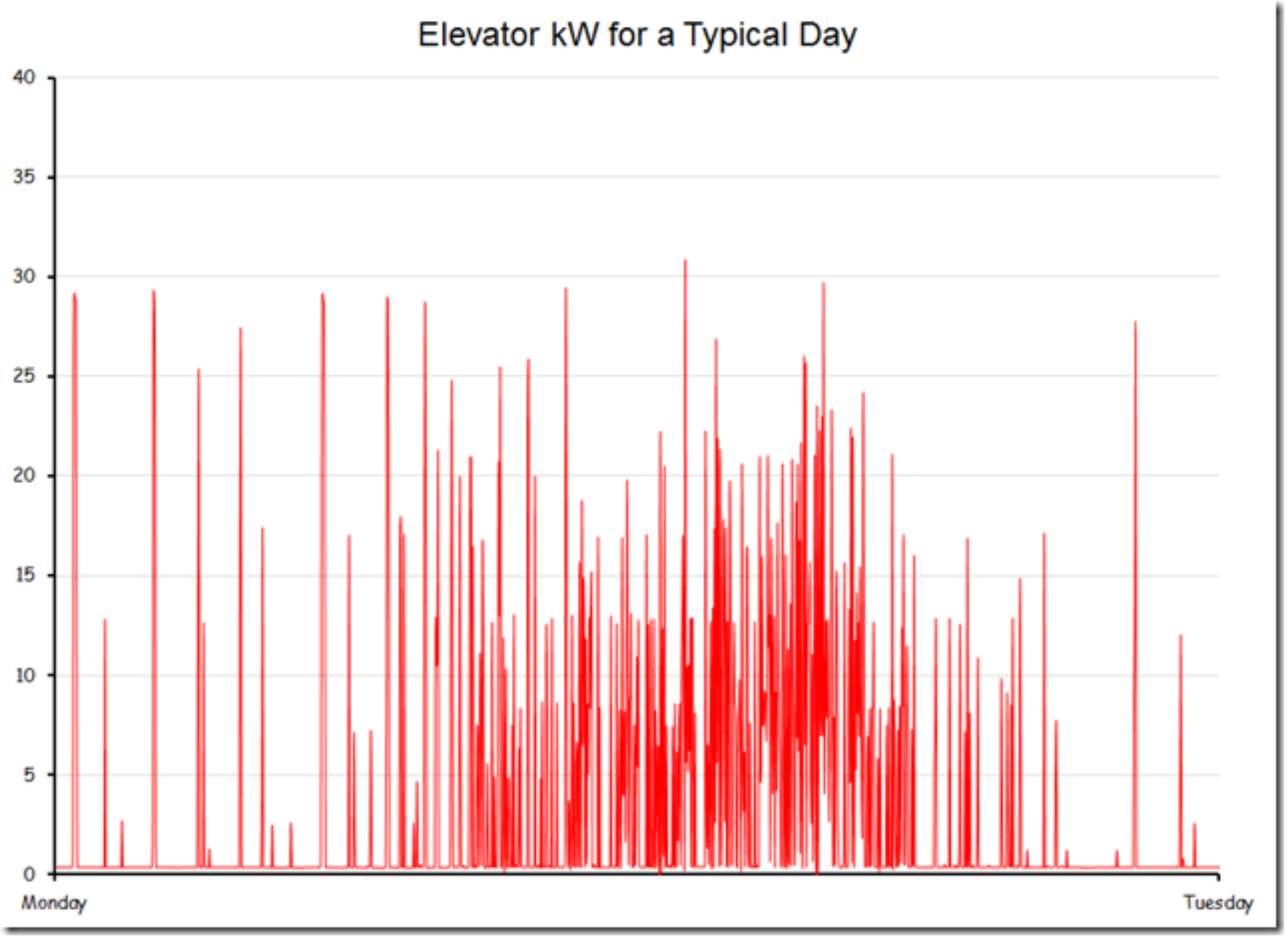
Challenges

- Power in households



Challenges

- … with elevators



Challenges

- Smaller grids mean a more unpredictable demand
- We may have greatly differing mixes of demand (industrial, residential, services, agricultural, …)
- Supply has to be more flexible
- Supply depends on the site
- Costs depend on the site and the availability of energy during the day

Challenges

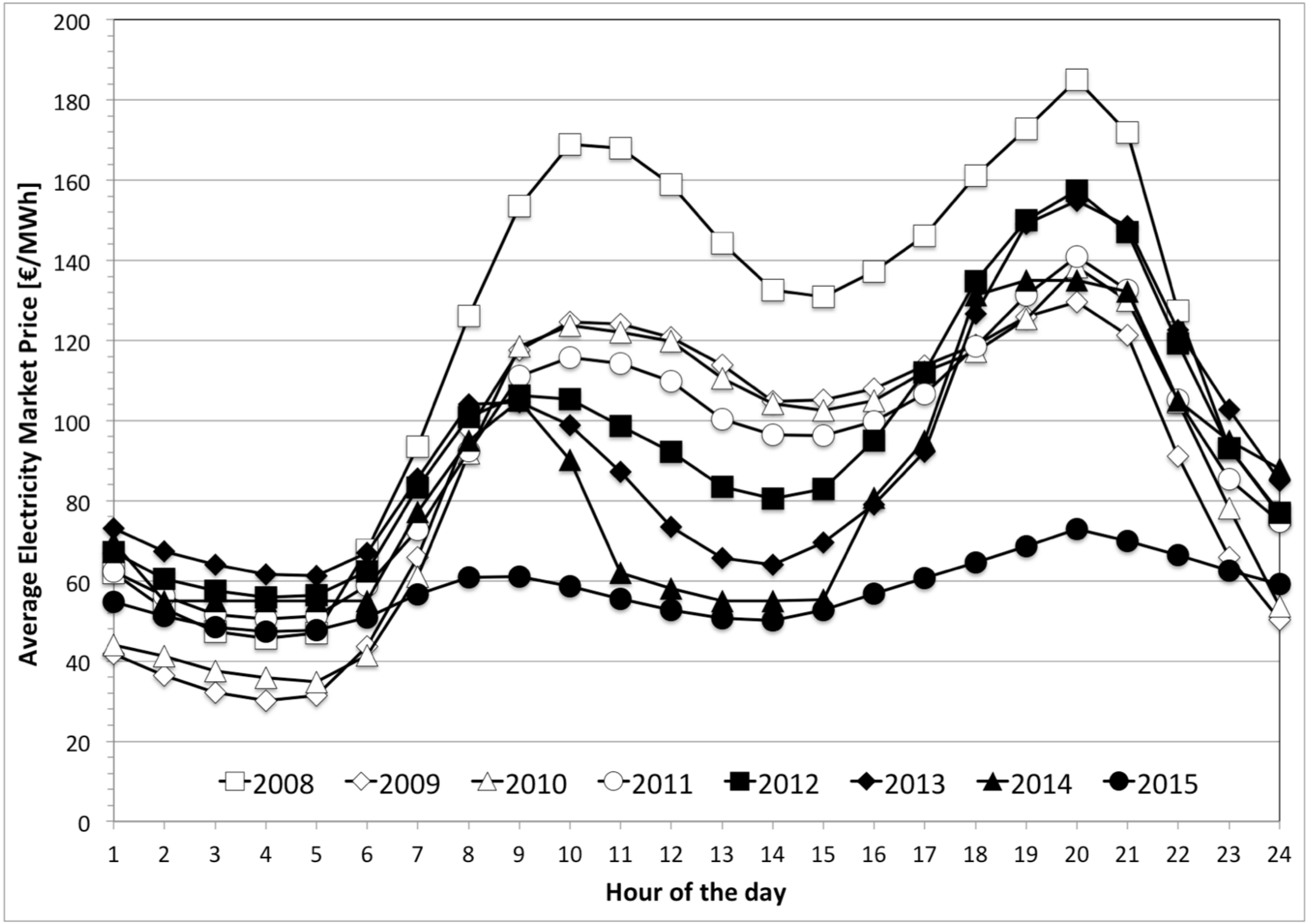
- In the end it is all a matter of matching…

Challenges

- Smart grids are a management tool not a solution.
- A better management cannot make everything work properly if the systems cannot be managed as the tool can be programmed.
- What is lacking ? (before, let us look at the following slides)

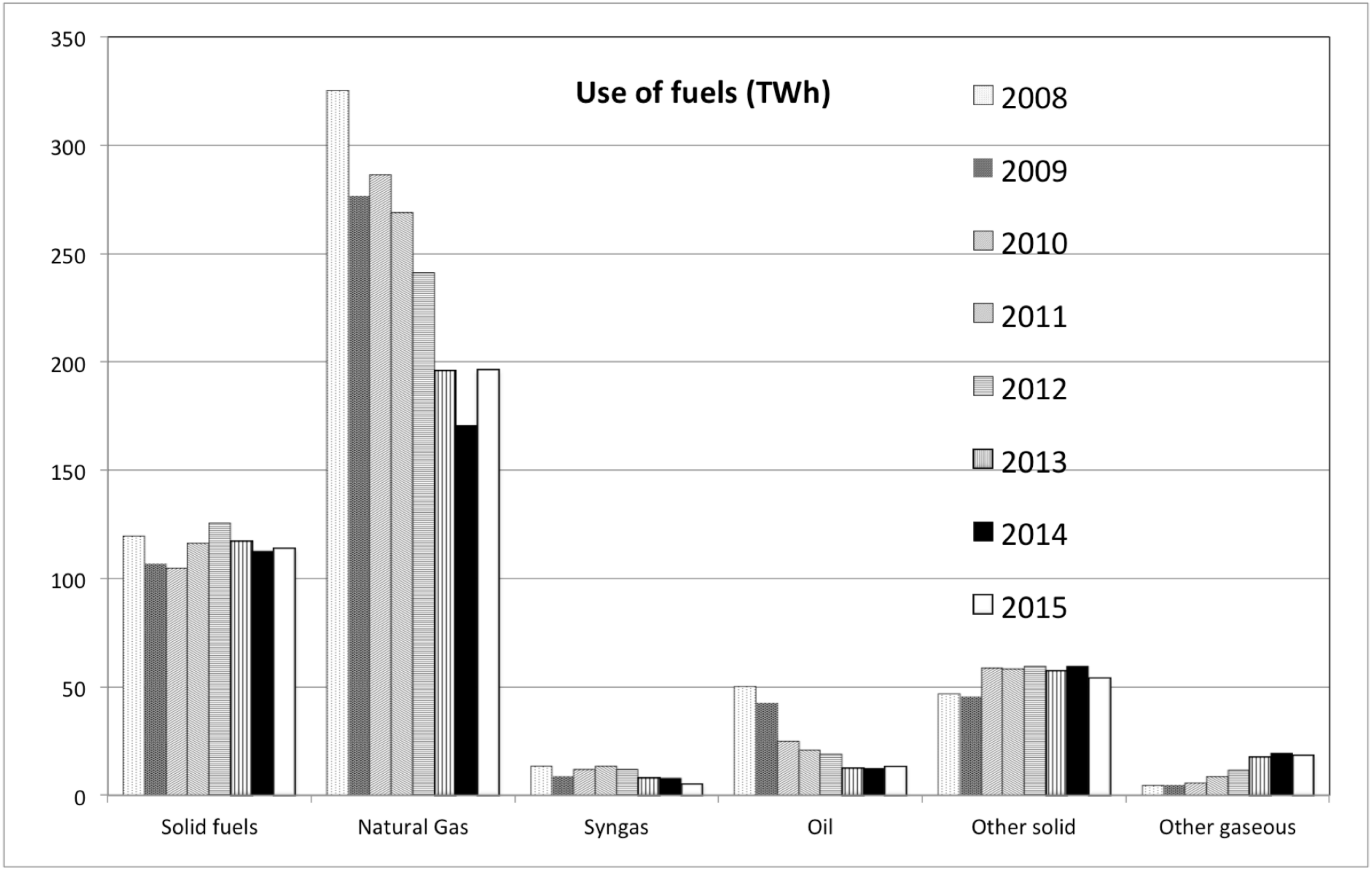
Challenges

- After 9 years of renewable development in Italy



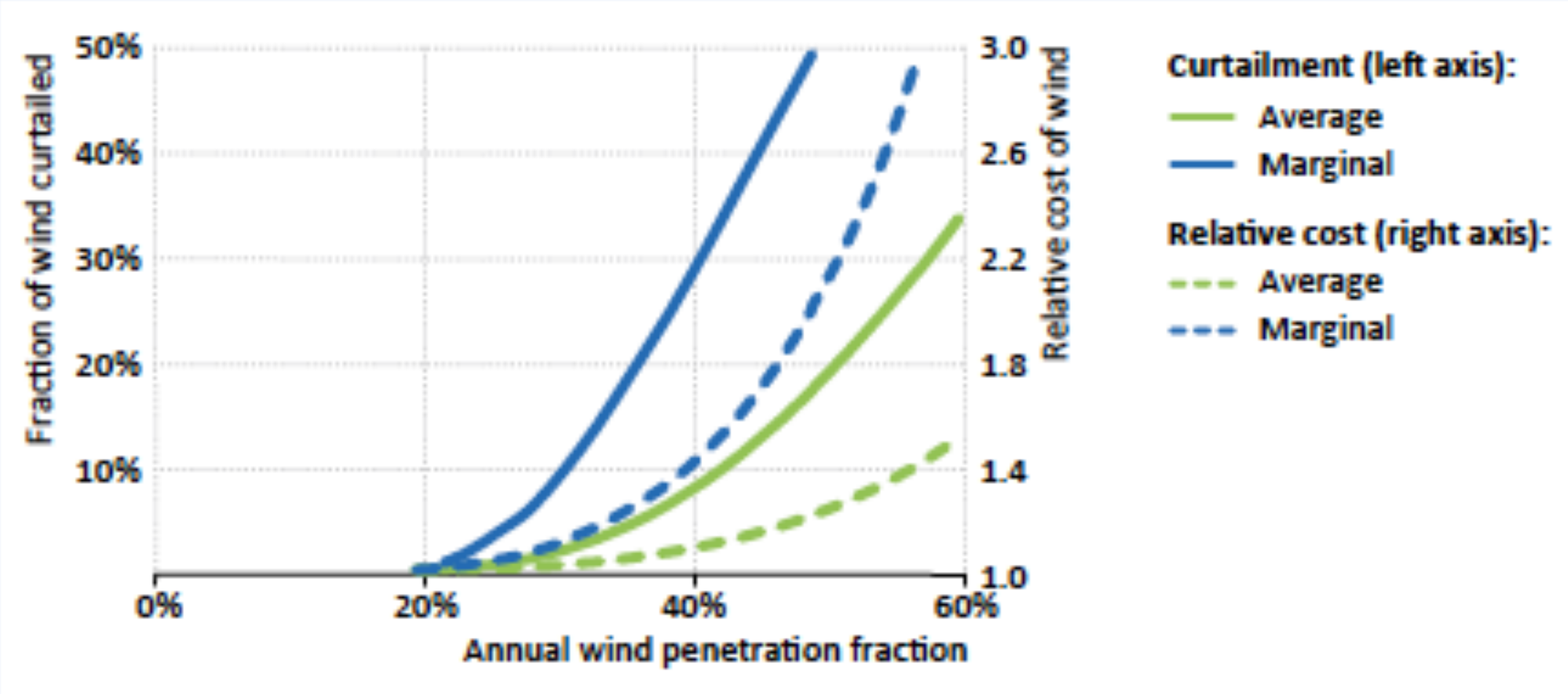
Challenges

- Use of fuels in Italy



World energy in numbers

Figure 9.16 ▷ Curtailment of wind power output and corresponding impact on levelised costs as a function of wind penetration



Source: Denholm and Hand (2011).

The future

- What do we need for the future ?
  - Education
  - Technologies
  - Integration with other networks
  - Infrastructures and costs
  - Thinking with our own mind

The future

- Education
  - We are used to think that energy is always available and many basic services are based on a safe and secure supply of electric and thermal energy: water, cooling, heating, light, safety equipment, mobility…
  - Nobody is willing to change his habits
  - What is my personal benefit ? The grass is always greener on the other side
  - Technology has to be easy and understandable
  - Utilities should adapt their costs to renewable power generation

The future

- Technologies
  - Energy saving
  - Improved flexibility of control of power plants
  - Lowering capital costs
  - Developing more programmable renewable systems (there is not only wind and solar PV)
  - Developing storage systems (we practically have none)
  - Developing new appliances and equipment that can be more easily programmed

The future

- Underdeveloped renewable energy sources:
  - Ocean energy
    - Wave, tidal, OTEC
  - Biomass
    - Heat and power, heat pumps, efficient thermal energy and load balancing
  - Geothermal
    - Heat pumps, thermal energy storage
  - High altitude wind
  - Small and mini-hydro

The future

- Energy Storage Systems
  - Electrical storage
    - Peak
    - Daily/Weekly
    - Seasonal
  - Thermal storage
    - Centralized
    - Distributed
    - Power to heat
  - Chemical storage
    - Power to fuels

The future

- Electric energy storage technologies
  - Pumped hydroelectric storage
  - Chemical energy storage
    - Hydrogen
    - LAES
    - Flow batteries
  - Electrochemical energy storage
  - Compressed air energy storage
  - Flywheels
  - ???

The future

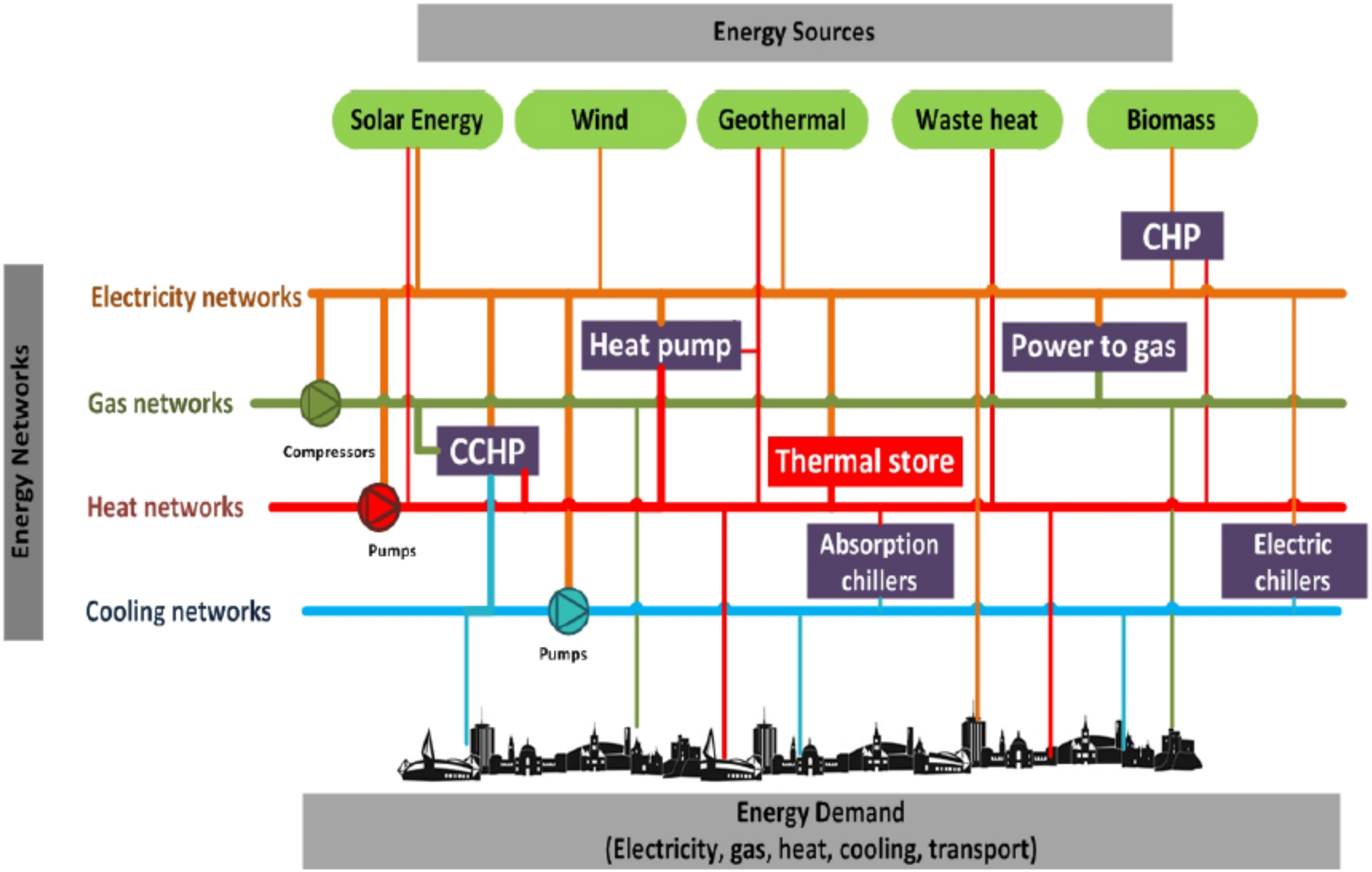
- Thermal Energy Storage
  - Hot water tanks
    - District storage
    - Distributed storage
  - PCM
  - Heat recovery from hot water
  - MicroCHP with heat recovery
  - ???

The future

- Mobility
  - Many car manufacturers are looking for solutions to replace internal combustion engines:
    - Electric motors with batteries
    - Other electric systems
    - Fuel cells
  - Or they are looking for different fuels
    - Biofuels such as ethanol and biodiesel
    - Natural gas
  - But we should probably… redefine the mobility for the next decades

The future

- Integration with other networks



The future

- Costs !
  - Infrastructures and costs
  - Who pays for the infrastructures ?
  - We need a different approach to/from utilities
  - We need a strong planning capacity
  - We need a strong political consciousness
  - We need to know the new technologies and the challenges

Conclusions

- You are living a revolution (maybe you did not realize…)
- You are changing the world (more than you think)
- But do not forget that we should perfectly mix technology, economy and environment protection to make a better world