Leonardo as observer, scientist and inventor

How did *Leonardo da Vinci* succeed in foreseeing so much, and why did he sometimes fail?

increasing Ideality of technical systems

During their evolution the technical systems tend to improve the ratio between the SYSTEM PERFORMANCES and the EXPENSES required to perform these performances.

$$I = \frac{\sum P}{\sum E} \quad \begin{matrix}\text{(performance)} \\ \text{(expenses)}\end{matrix}$$

Useful for practice*:

Ideal machine – there is no machine, but the required action is performed.

Ideal process – there are no energy expenses and no time expenses,

but required action is performed (self-acting control).

Ideal substance – there is no substance, but function is performed.

*G.S.Altshuller: 1979. CREATIVITY AS AN EXACT SCIENCE. Sovietskoe radio, Moscow

From invention to innovation

Type of innovation (according to degree of radicalness)	Weighting (according to degree of radicalness)	Frequency (in the period 1953-1973)
1. Basic innovation	32 to 35	7
2. Radical innovation	28 to 31	29
3. Very important improvement innovations	24 to 27	62
4. Important improvement innovations	20 to 23	145
5. Mundane improvements	16 to 19	239
6. Minor product or process differentiation with new technology	0 to 15	760
Range of weights	0 to 35	
Total frequency		1242*

* The lower classes of innovation are increasingly underestimated in quantity

Source: Mensch, G. Stalemate in Technology: Innovations Overcome the Depression (Ballinger Pub Co, Cambridge, Massachusetts, 1978), 241. 088410611X.

From invention to innovation

Basic Innovations in the First Half of the Nineteen Century

NAME	INVENTION	INNOVATION	YEARS LEAD TIME
High voltage generator	1820	1849	29
Electro-medical stimulator	1831	1846	15
Deep sea cable	1847	1866	19
Electricity production	1708	1800	92
Insulated conductors	1744	1820	76
Arc lights	1810	1844	34
Pedal bicycle	1818	1839	21
Rolled rails	1773	1835	62
Rolled wires	1773	1820	47
Pudding furnace	1783	1824	41
Blast furnace with coke	1713	1796	83
Crucible steel	1740	1811	71
Locomotives	1769	1824	55
Telegraph	1793	1833	40
Lead chamber process	1740	1819	79
Pharmaceutical industries	1771	1827	56
Quinine industries	1790	1820	30
Hard rubber	1832	1852	20
Portland cement	1756	1824	68
Potassium chloride	1777	1831	54
Photography	1727	1838	**111**

Source: Mensch, G. Stalemate in Technology: Innovations Overcome the Depression (Ballinger Pub Co, Cambridge, Massachusetts, 1978), 241. 088410611X.

From invention to innovation

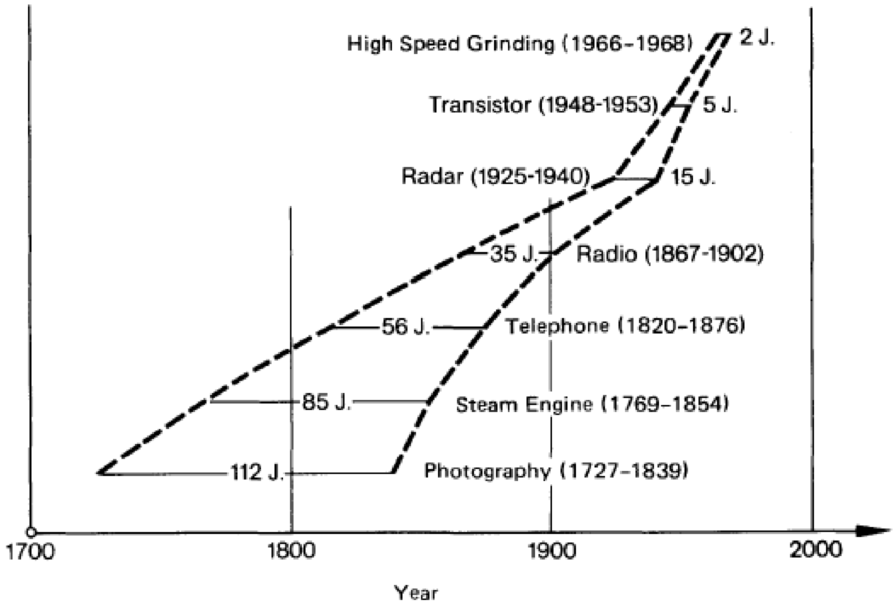
The case of Locomotive

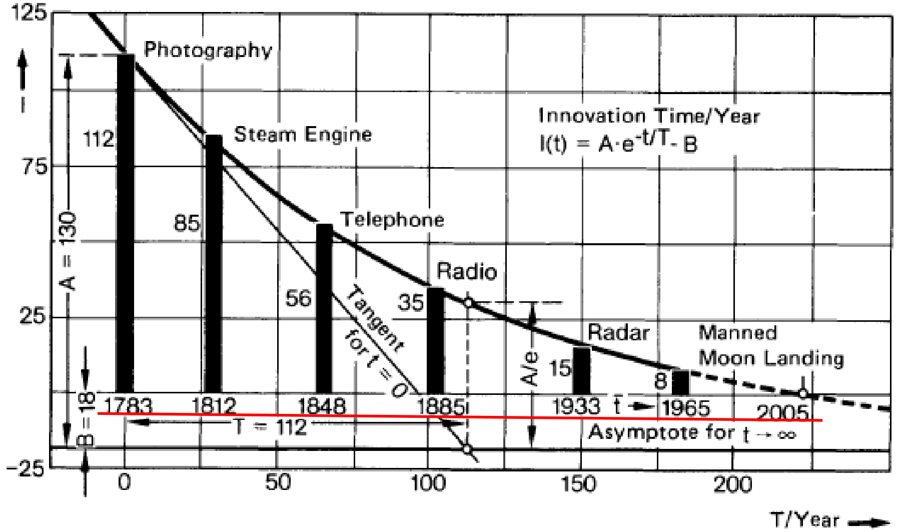
1769	Watt: Low pressure machine
1770	Cugnot: Steam gun vehicle
1790	Read: Steam road vehicle
1800	Watt's: Patent on steam engines expires
1801	Trevithick starts work on locomotives
1804	Evans: Road locomotive
1811	Blenkinskop: First toothed gear locomotive
1813	Hadley: Locomotive on rails
1814	Stephenson: starts work
1824	Stephenson: built first locomotive plant
1825	Stephenson: open Stockton-Darlington line

"…a technical event is a technological basic innovation when the newly discovered material or newly developed technique is being put into regular production for the first time*, or when an organized market for the new product is first created*."

Source: Mensch, G. Stalemate in Technology: Innovations Overcome the Depression (Ballinger Pub Co, Cambridge, Massachusetts, 1978), 241. ISBN 088410611X.

Acceleration in history





"..We observe long innovation periods for avant-garde innovations and shorter periods for innovation that follow familiar ground. Only pseudo-innovations occur with the wave in of a hand..."

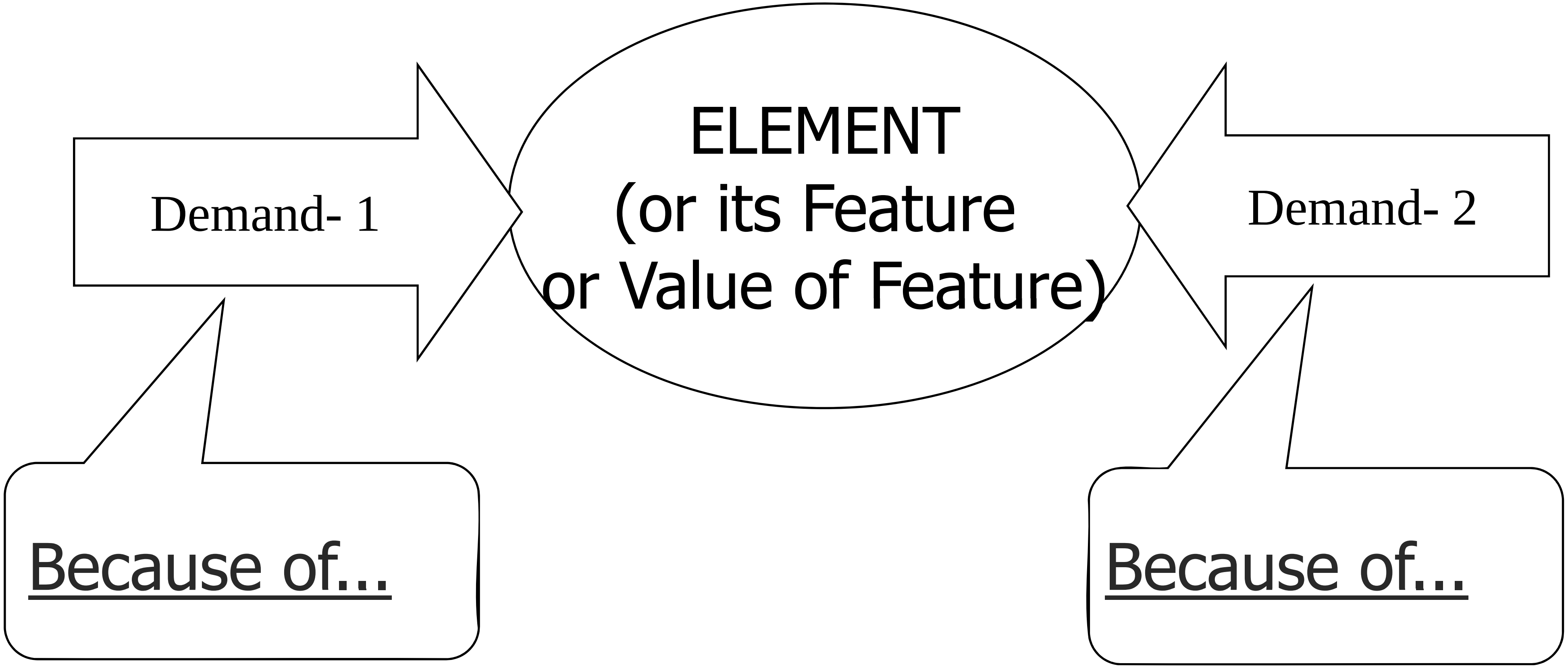
Source: Mensch, G. Stalemate in Technology: Innovations Overcome the Depression (Ballinger Pub Co, Cambridge, Massachusetts, 1978), pp. 160-161

"Gerard Mensch did classify innovations with the state of the first commercial sell and the inventions with the date of the first working prototype.“

"…the distance [between invention and innovation] decreases regularly inside a certain wave, but starts larger again in the next [wave]…”

Marchetti, C. Time Patterns of Technological Choice Options. p. 20 (International Institute for Applied Systems Analysis, Laxenburg, Austria, 1985).

what is contradiction meaning?



© N.Khomenko. 1997-2002. Materials for seminars: OTSM-TRIZ: Main technologies of problem solving, "Jonathan Livingston" Project.

types of contradiction models

Administrative contradiction

we know what is required, but we do not know how to achieve that.

Technical contradiction

we know how to achieve required result, but it will make system worse.

TC-1: If there is <V>, then <R1->, but <R2+>.

TC-2: If there is <Λ>, then <R1+>, but <R2->.

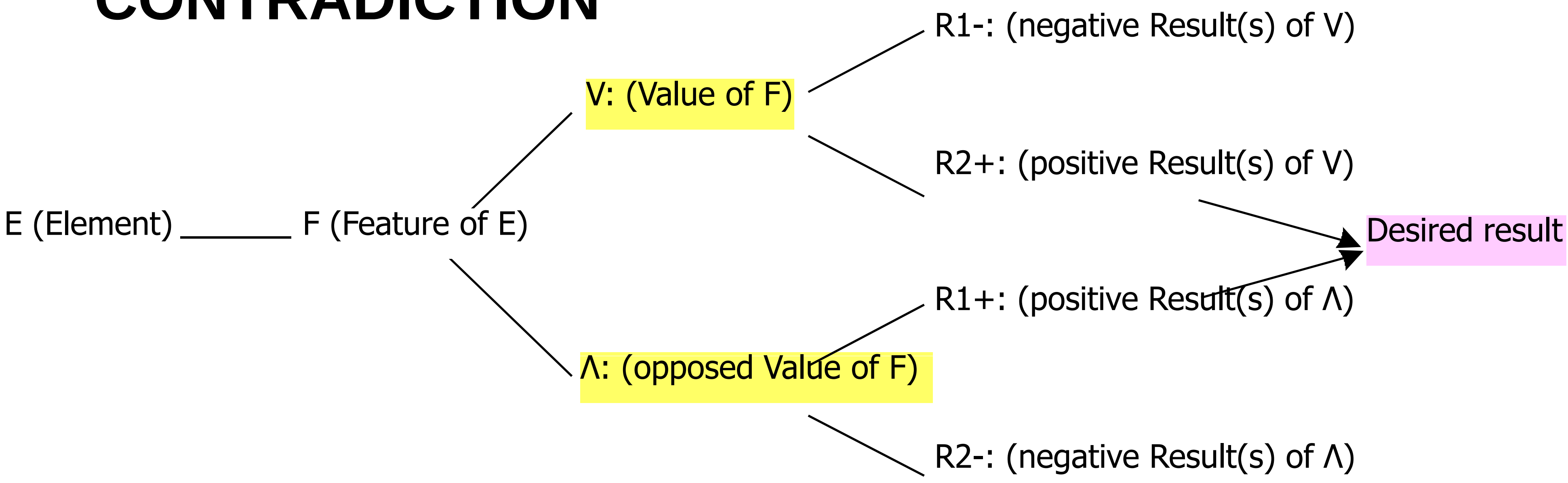
Physical contradiction

we know what is required and how it has to work but we do not know working principle.

<Feature> has to be <Value>, to <R2+>

< Feature> has to be <opposed Value>, to <R1+>

CONTRADICTION



- It is recommended to start construction of such a description from Right side (from Desired result) and to continue what are the positive and negative Results take place when known (typical) ways are in use.
- Result(s) 1 and 2 for opposed Values of Feature should be inverse. *If R1 is negative for V it should become positive for Λ*.
- Values of Feature should be opposed. Feature and Element are disclosed to complete model. Model should be logically harmonized in accordance with initial situation.

Forecasting contexts

[excerpt]

Sociological context:

- Public acceptance of new technology (e.g. safety issue, public comfort)
- Political context (e.g. security and energy supply, energy independence, fiscal & regulatory policies, local and global environmental policies)
- Educational context (e.g. manpower capacity, existing skills)
- Employment context…

Economic context:

- Economic growth
- Energy production context (e.g. distributed power, centralized one)
- Energy cost & profitability …

Technological context

- Industrial structure (e.g. local environmental policies)
- Compatibility with existing infrastructure (super-systems)
- Technological challenges, safety issue…

Environmental context

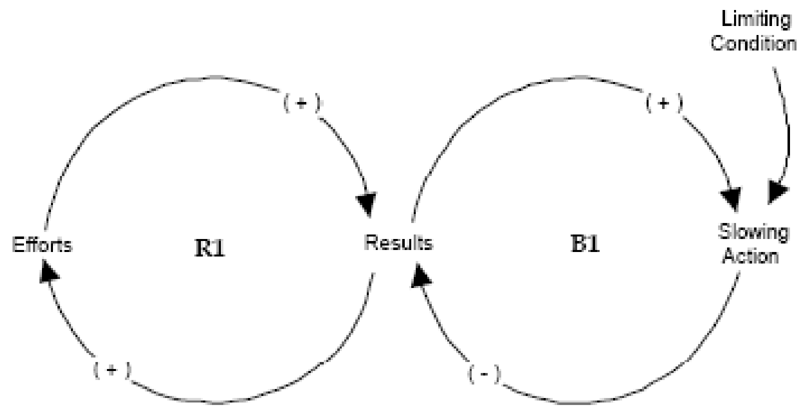
- Occupied space use, natural resources use (e.g. materials, energy, water…)
- Environmental awareness (e.g. noises issue, air quality, global warming…)
- Safety and long-run reproducibility issues…

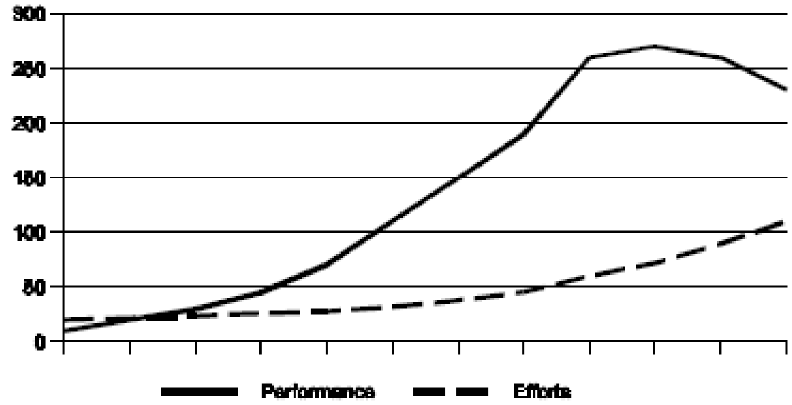
Source: GAUTIER, L., et al. (2005): "Technological Forecasting of Fuel Cells for Small Stationary Applications," Karlsruhe: European Institute for Energy Research - EIfER, 38.

system dynamics -> system archetypes

Systems Archetypes describe common patterns of system's behavior (e.g. organizations)

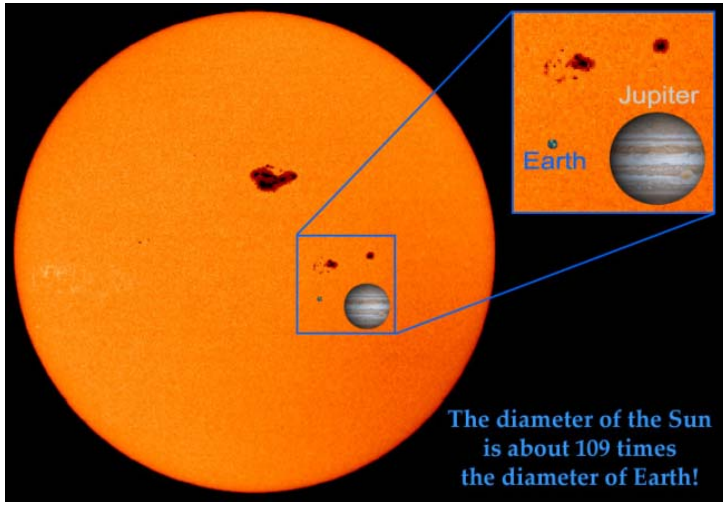
1. **Limits to Growth**
   (aka Limits of Growth)
2. Shifting the Burden
3. Eroding Goals
4. Escalation
5. Success to the Successful
6. Tragedy of the Commons
7. Fixes that Fail
8. Growth and Underinvestment
9. Accidental Adversaries
10. Attractiveness Principle



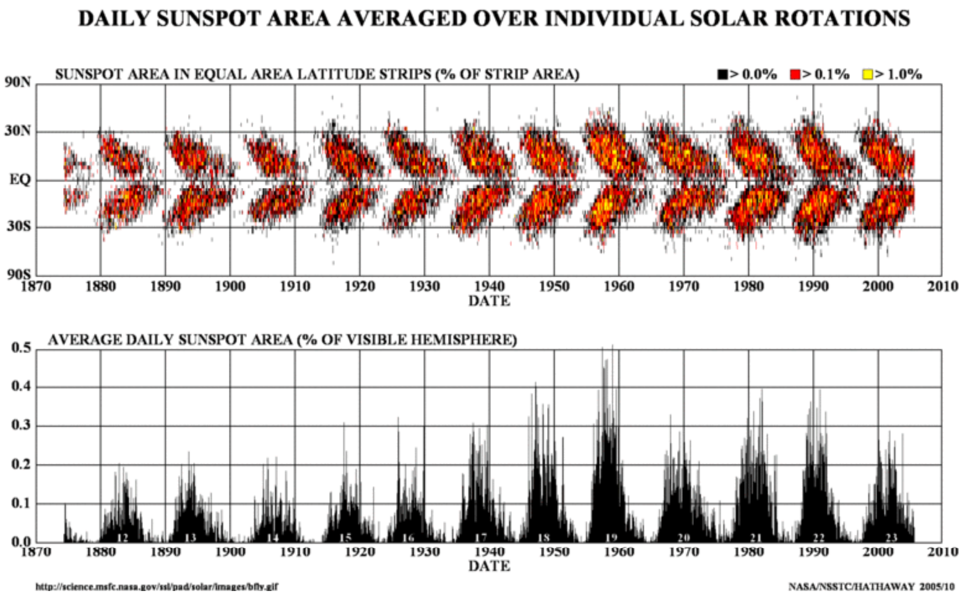


* Source: Braun, W. *The System Archetypes*. (The Systems Modeling Workbook2002).

Sunspots



Sunspot
is a region on the Sun's surface (photosphere) that is marked by a lower (4000-4500K) temperature than its surroundings (5800K) and has *intense magnetic activity*.



The **Wolf number** (International sunspot number, relative sunspot number, or Zürich number)
It is computed using the formula (collected as a daily index of sunspot activity):

$$R = k(10g + s)$$

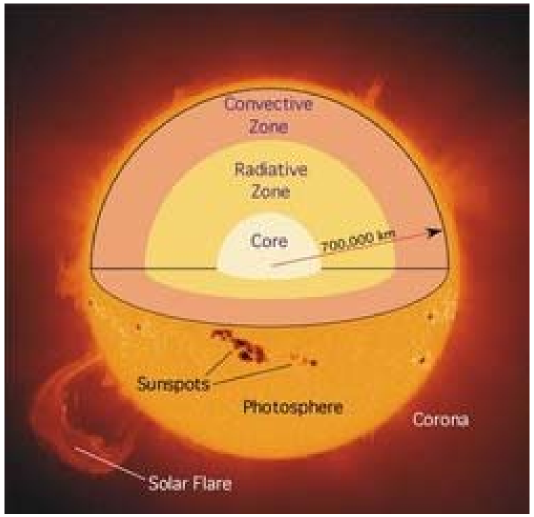
where R is the relative sunspot number, s is the number of individual spots, g is the number of sunspot groups, and k is a factor that varies with location and instrumentation (also know as the observatory factor).

Source: http://en.wikipedia.org

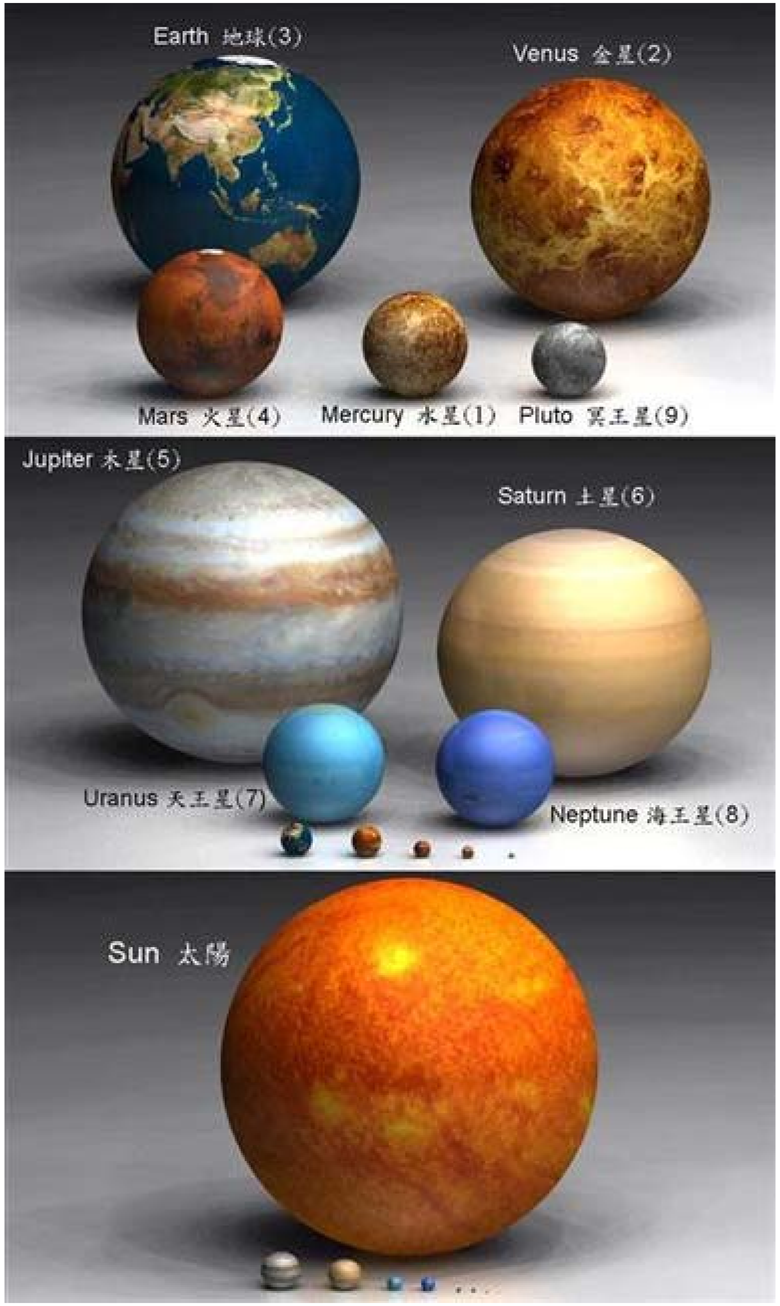
The Sun

- The Sun's mass is roughly 1.99 x 10^{30} kg. This is about 333 000 times the mass of the Earth.
- The Sun contains 99.8% of all of the mass of the Solar System.
- The Sun is 149 680 000 km (or 1 Astronomical Unit) from the Earth; this is **107.5** diameters of Sun.
- Light from the Sun takes about 8 minutes to reach the Earth.

http://www.eoearth.org/article/Solar_radiation



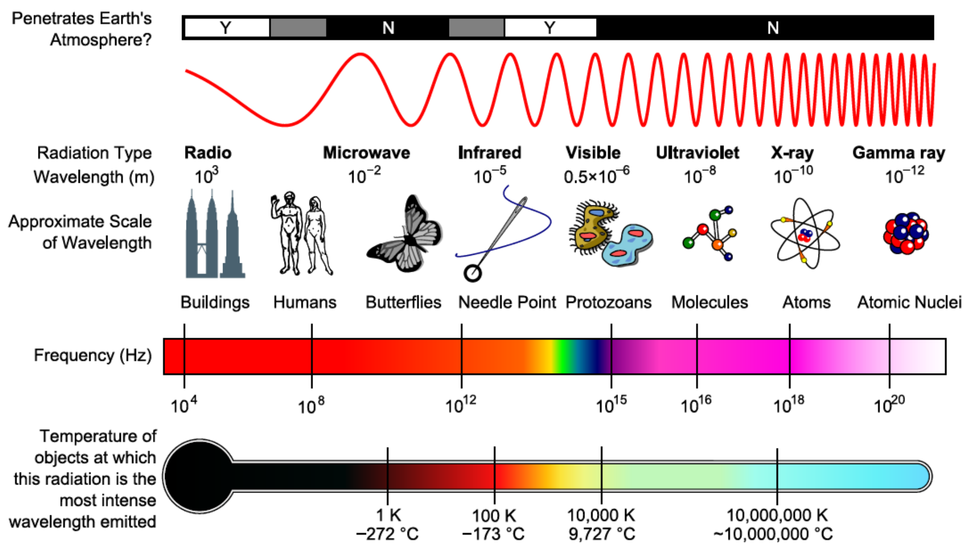
- Sunspots, Solar Flares, Prominences, the Solar Wind, and Coronal Mass Ejections.

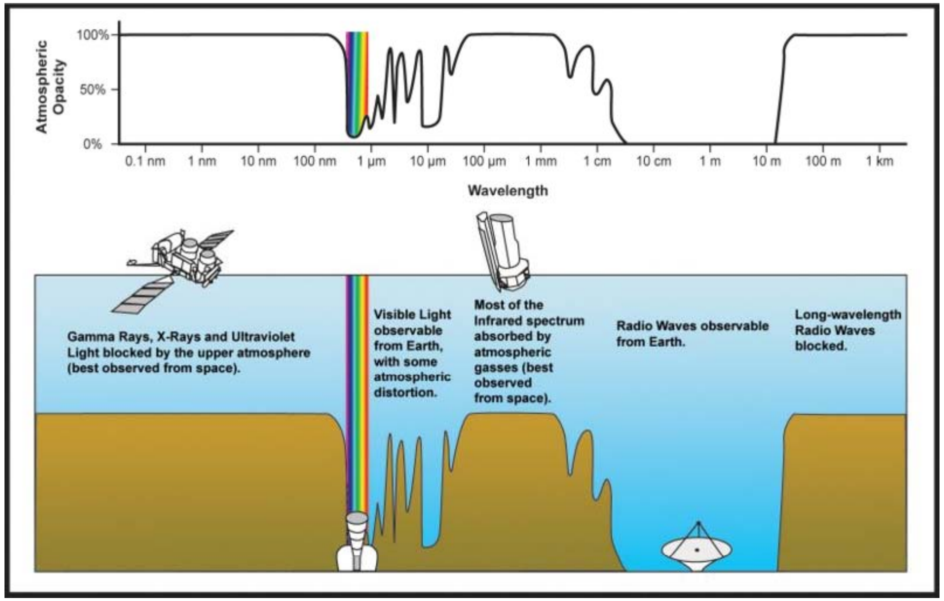


Source: http://en.wikipedia.org

The Sun: electromagnetic radiation

- Sun emits 63,000,000 Watts/m^2 of electromagnetic radiation.
- Electromagnetic Radiation (Waves):
  emission of energy in the form of electromagnetic waves.





Source: http://en.wikipedia.org

Solar energy

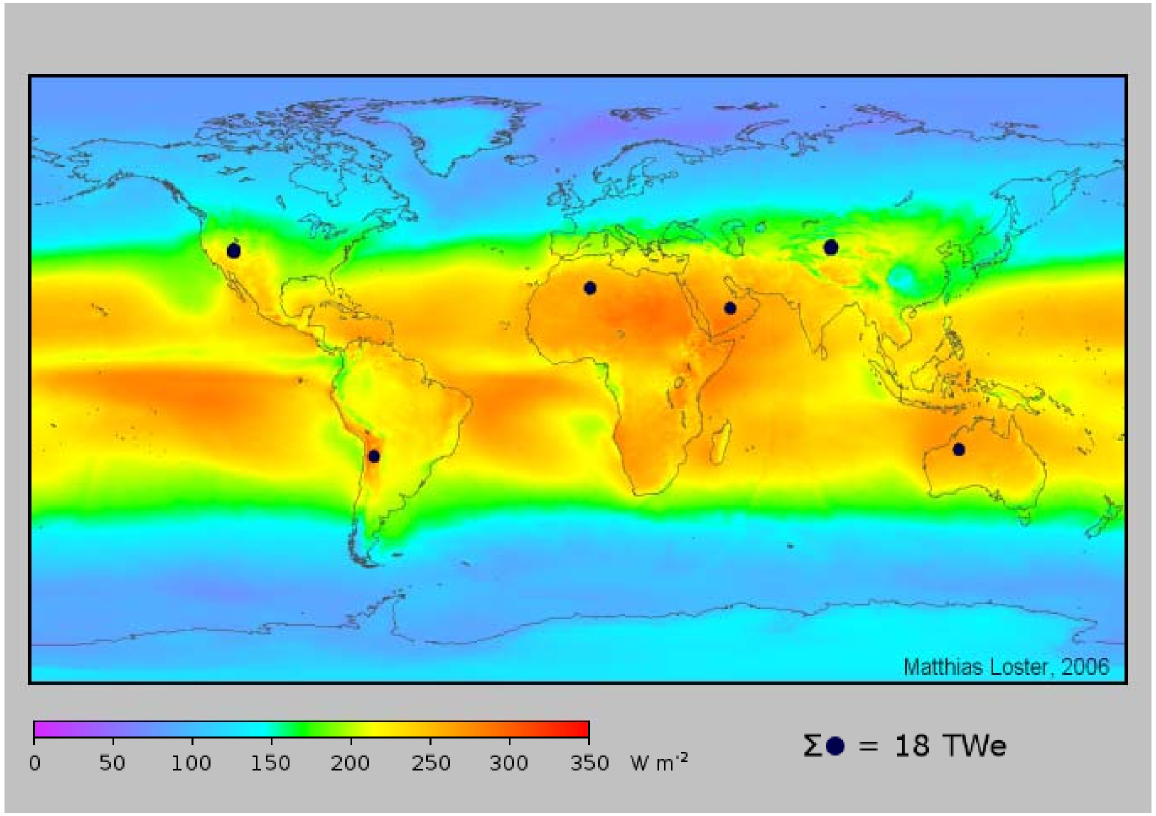
Solar energy is energy from the Sun in the form of radiated heat and light.

SOLAR ENERGY TECHNOLOGIES

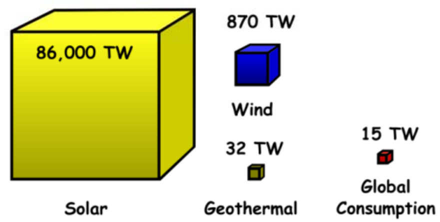
Solar buildings and urban heat island
Agriculture and horticulture
Solar lighting
Solar thermal
- Water heating
- Heating, cooling and ventilation
- Process heat
- Cooking
- Desalination and disinfection

Solar electricity
- Photovoltaics
- Concentrating solar energy
- Experimental solar power

Solar chemical
Solar mechanical
Solar vehicles



Annual average insolation at Earth's surface. The black dots represent the land area required to replace the total world energy supply with electricity from solar cells.



Solar energy reaching the Earth's surface

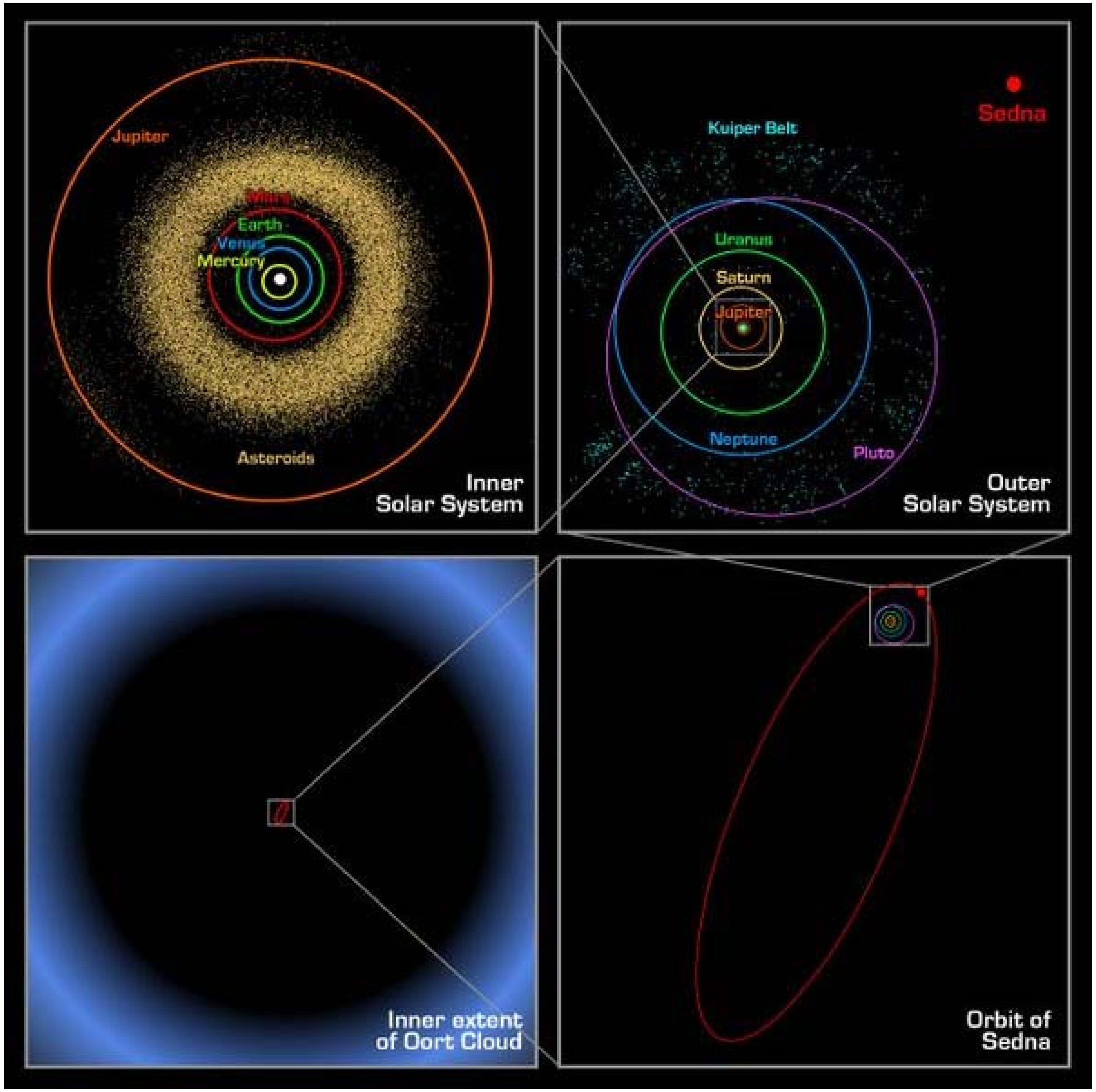
* http://en.wikipedia.org

Solar system

Along with light, the Sun radiates a continuous stream of charged particles (a plasma) known as the **solar wind**. This stream of particles spreads outwards at roughly 1.5 million km/h creating the *heliosphere*.

This is known as the **interplanetary medium**. Geomagnetic storms on the Sun's surface, such as *solar flares* and *coronal mass ejections*, disturb the *heliosphere*, creating space weather.

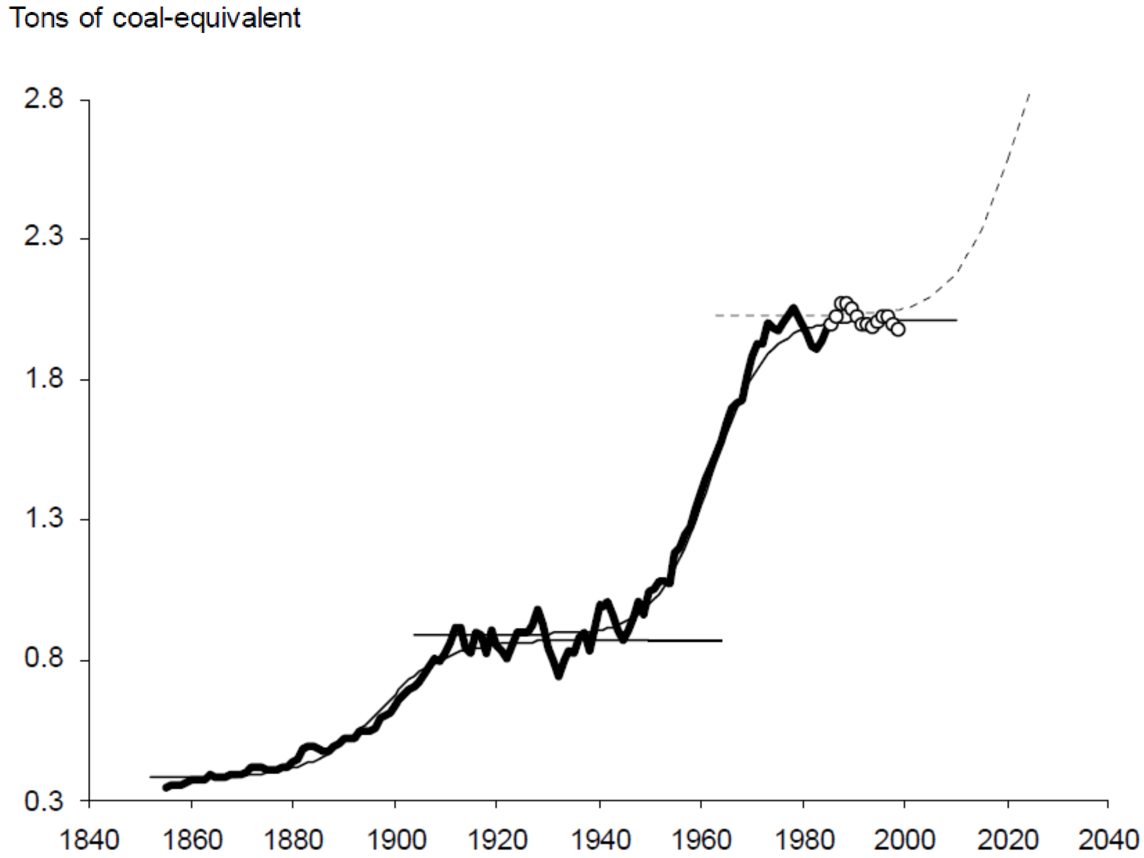
Earth's magnetic field protects its atmosphere from interacting with the *solar wind*.



The orbits of the bodies in the Solar System to scale (clockwise from top left)

* http://en.wikipedia.org/wiki/Solar_system

Fractal structure of Natural Growth



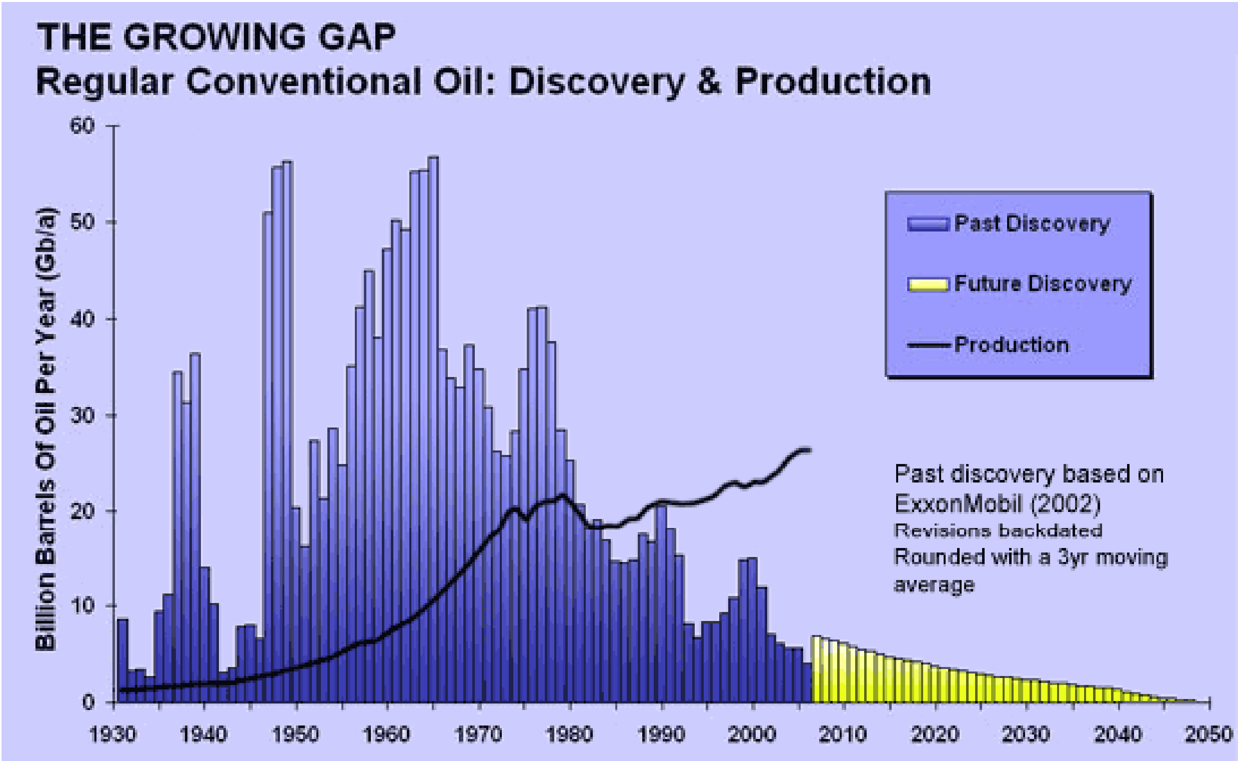
The per capita annual energy consumption worldwide: data, fits, and a scenario for the future.
The small circles show what happened in the last fourteen years.
The prediction is largely confirmed.

This figure reproduces in part a drawing from J. Ausubel, A. Grubler, N. Nakicenovic, "Carbon Dioxide Emissions in a Methane Economy," Climatic Change, vol. 12 (1988): 245-63.
Recent data come from the Statistical Abstract of the United States, U.S. Department of Commerce, Bureau of the Census.

* Source: Source: Modis, T. Predictions - 10 Years Later. (Growth Dynamics, Geneva, Switzerland, 2002)

Oil: the growing gap

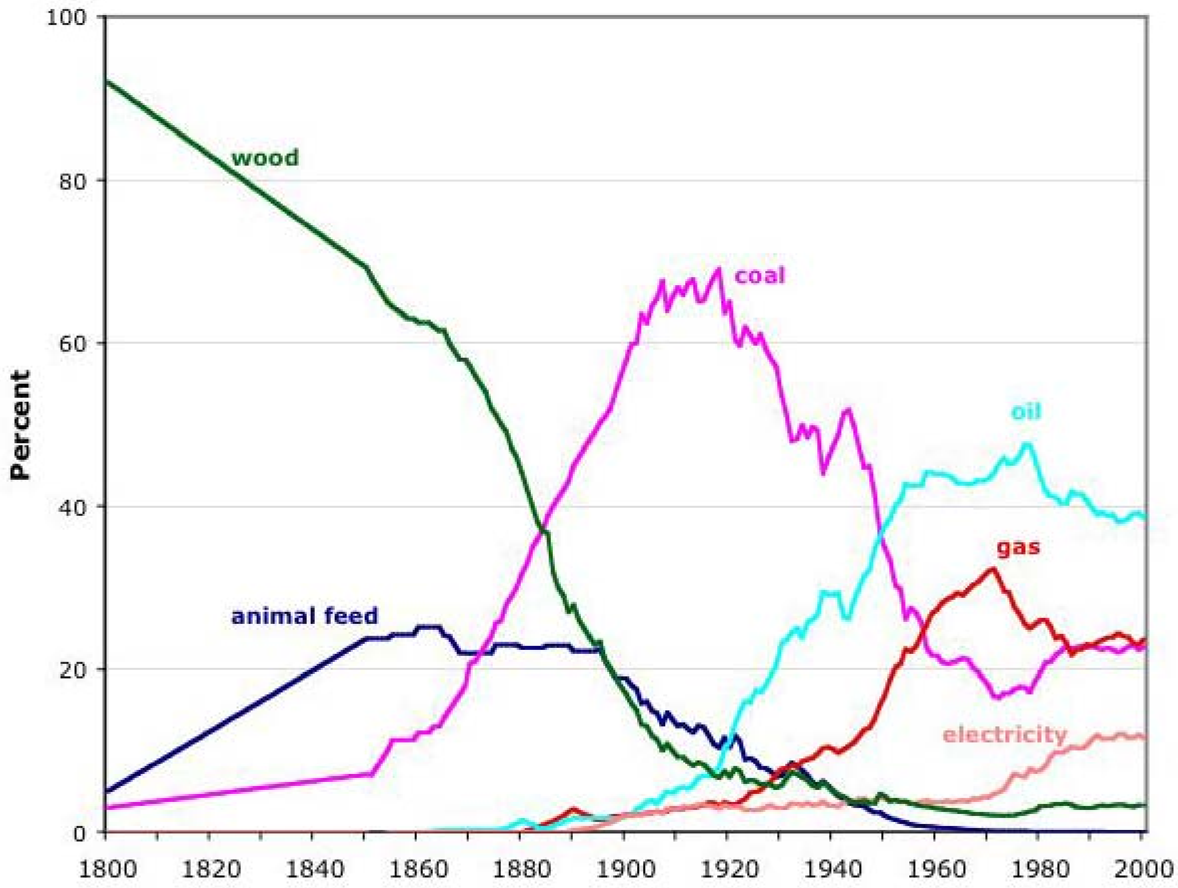
The rate of global oil production compared to the rate at which oil is added to global proved reserves.



Source: http://www.eoearth.org/article/Fundamental_principles_of_energy
Primary source: ASPO-Ireland http://www.peakoil.ie/

Transitions in energy systems

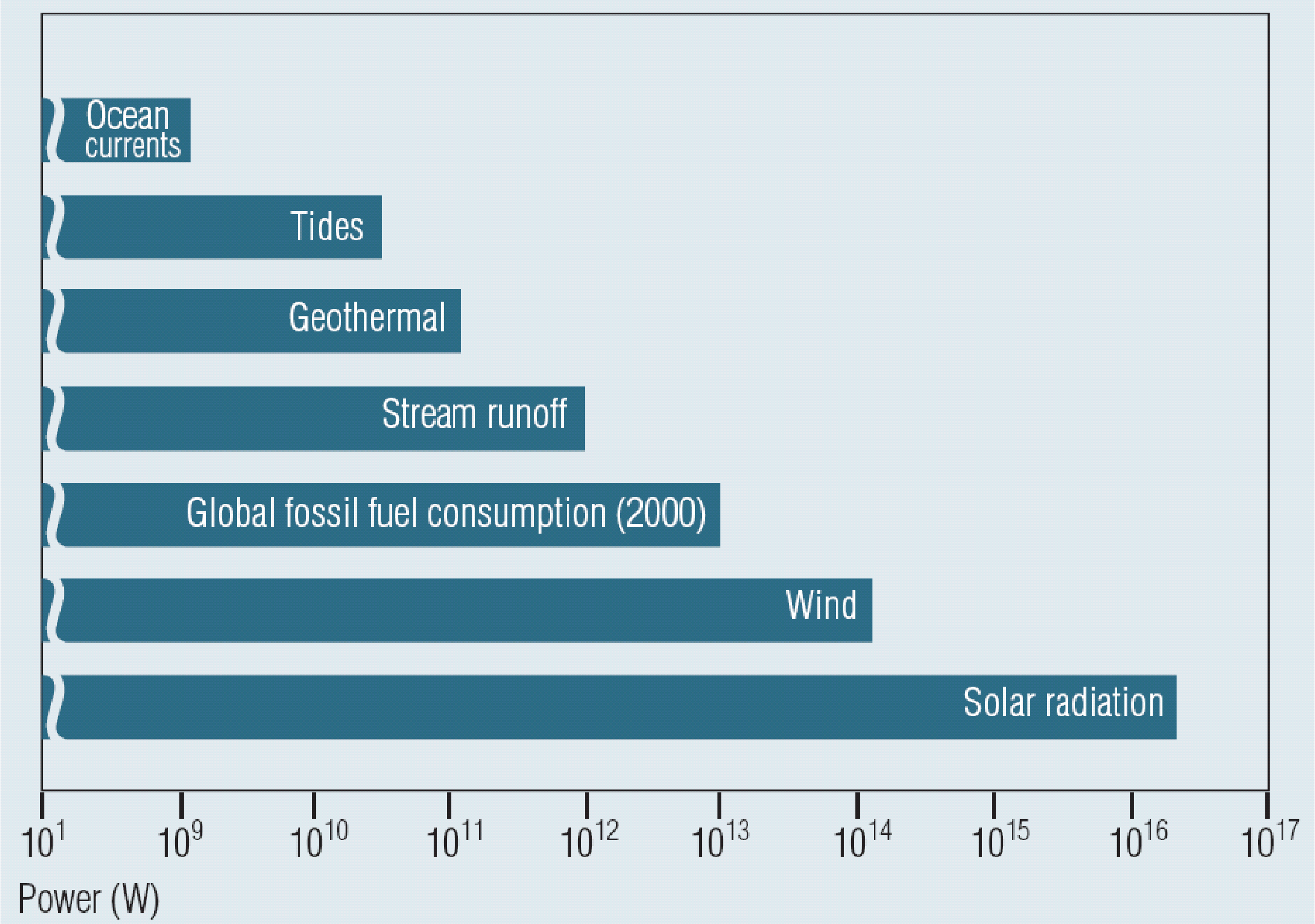
Composition of U.S. energy use. Electricity refers to power from primary sources only: nuclear, hydropower, solar, wind, and geothermal.



* Source: http://www.eoearth.org/article/Fundamental_principles_of_energy

Transitions to new energy source

The global flux of fossil and renewable fuels.



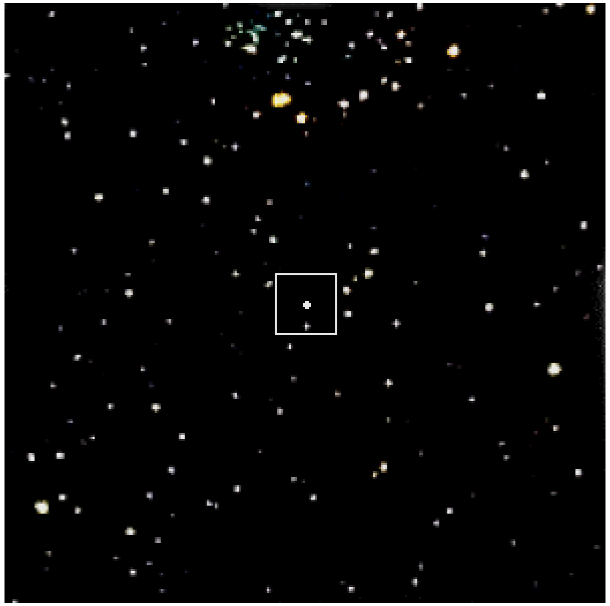
Source: http://www.eoearth.org/article/Energy_transitions_past_and_future
Primary source: Smil, V. 2006. ''21st century energy: Some sobering thoughts.'' OECD Observer 258/59: 22-23.).

Is it big difference 10^{13} and 10^{16} ?

The Solar System

Scale: 10^{13} meters = 10 Tm = 10 terameters: Light takes ~8 hours to cross this picture.

The Oort Cloud



Scale: 10^{16} meters = 10 Pm = 10 petameters ~1 light year

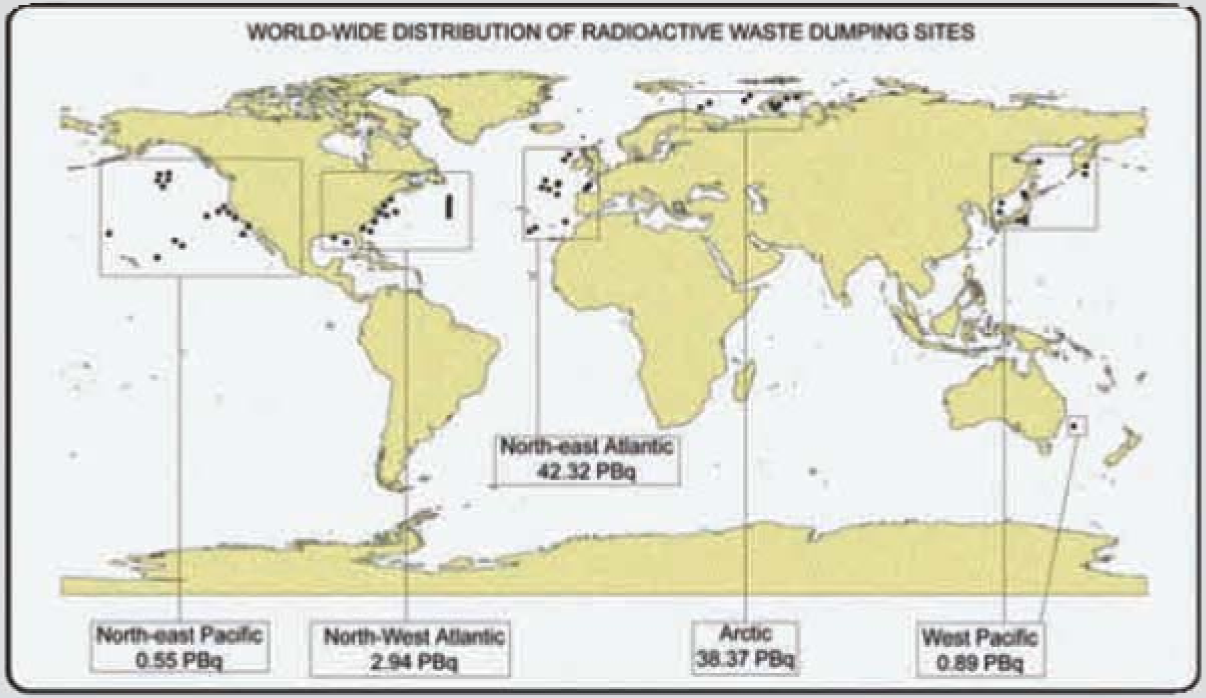
Source: http://www.wordwizz.com/pwrsof10.htm

World-Wide distribution of radioactive waste…

Case Study: Dumping of Radioactive Waste at Sea

The Report of the United Nations Conference on Human Environment held in Stockholm in 1972 defined the principles for environmental protection, specifically for the assessment and control of marine pollution. These were forwarded to an Inter-Governmental Conference held in London later that year, where the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (also known as the London Convention of 1972) was adopted and which entered into force on 30 August 1975.

The contracting parties to the London Convention agreed to promote the effective control of all sources of pollution of the marine environment and to take all practicable steps to prevent the pollution of the ocean by dumping of waste and other matter that is liable to create hazards to human health and to harm living resources and marine life. The International Atomic Energy Agency (IAEA) was designated as the international body that should oversee matters related to the disposal of radioactive wastes in the ocean.



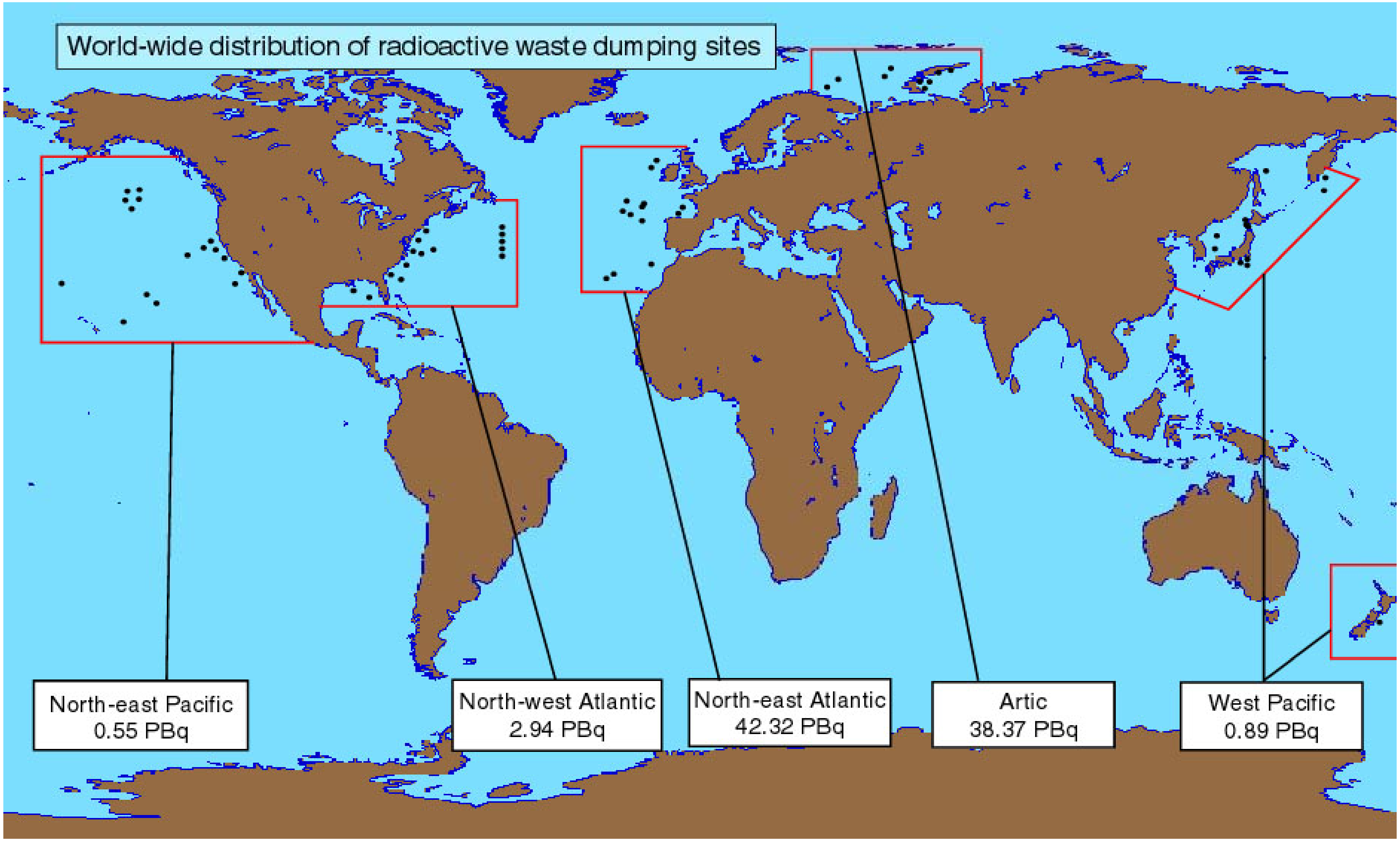
The first reported ocean disposal operation of radioactive waste was carried out by the USA in 1946 in the North-East Pacific Ocean and the latest was carried out by the Russian Federation in 1993 in the Japan Sea/East Sea. During the 48 year history of sea disposal, 14 countries have used more than 80 sites to dispose of approximately 85 PBq (1 PBq = 1015 Bq) of radioactive waste.

The figure shows the geographical distribution of disposal operations.

Source: Modified from http://www.oceansatlas.org/servlet/CDSServlet?status=ND0xNDExMyY3PWVuJjYxPSomNjU9a29z. Figure has been modified from http://www.oceansatlas.com/unatlas/about/physicalandchemicalproperties/radiosp/index.htm.

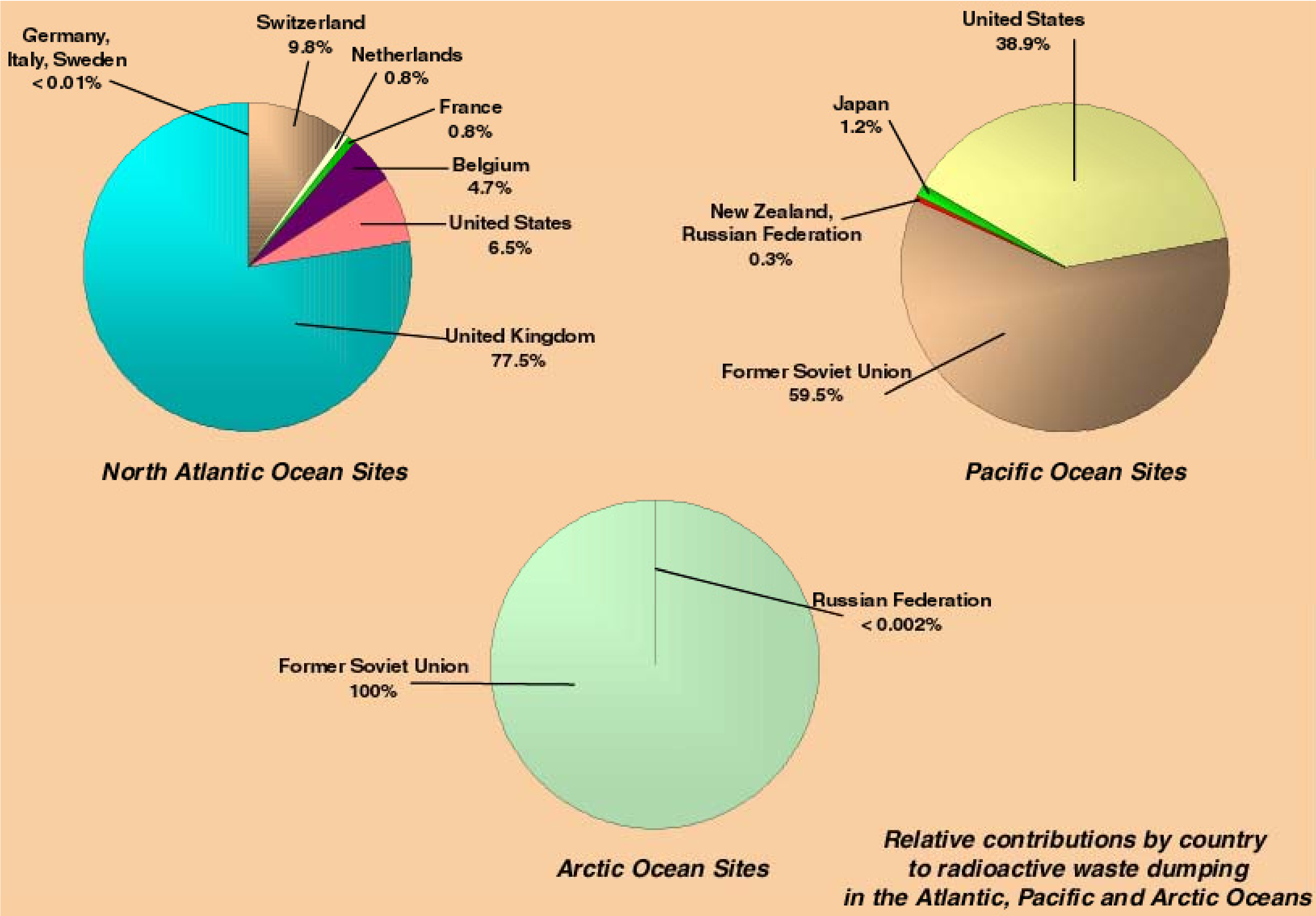
Source: (2005). "One Planet Many People: Atlas of Our Changing Environment." from http://na.unep.net/OnePlanetManyPeople/chapters.html.

World-Wide distribution of radioactive waste…



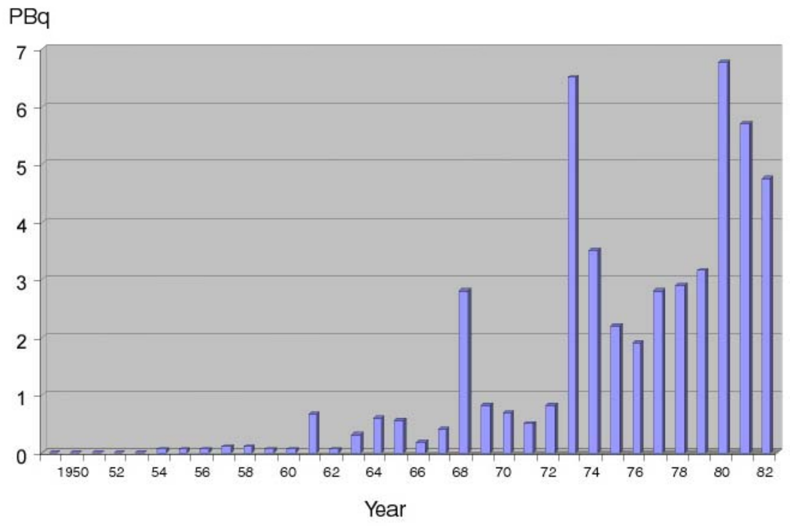
Source: http://www.oceansatlas.org/unatlas/about/physicalandchemicalproperties/radiosp/htm/Geographical.html

World-Wide distribution of radioactive waste…

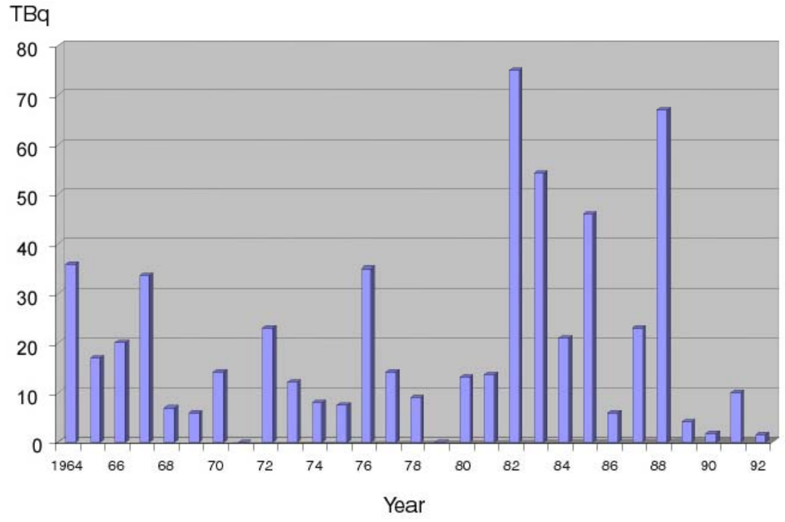


Source: http://www.oceansatlas.org/unatlas/about/physicalandchemicalproperties/radiosp/htm/Geographical.html

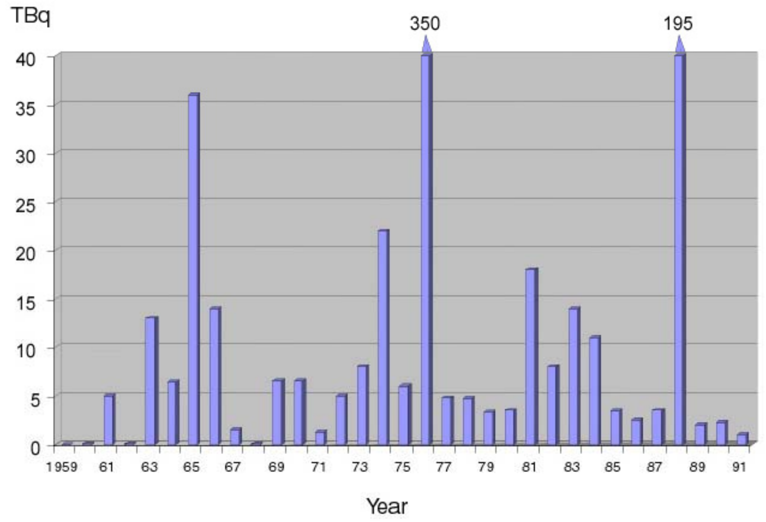
World-Wide distribution of radioactive waste…



Dumping operations in the North-East Atlantic



Dumping operations in the Arctic (solid wastes)

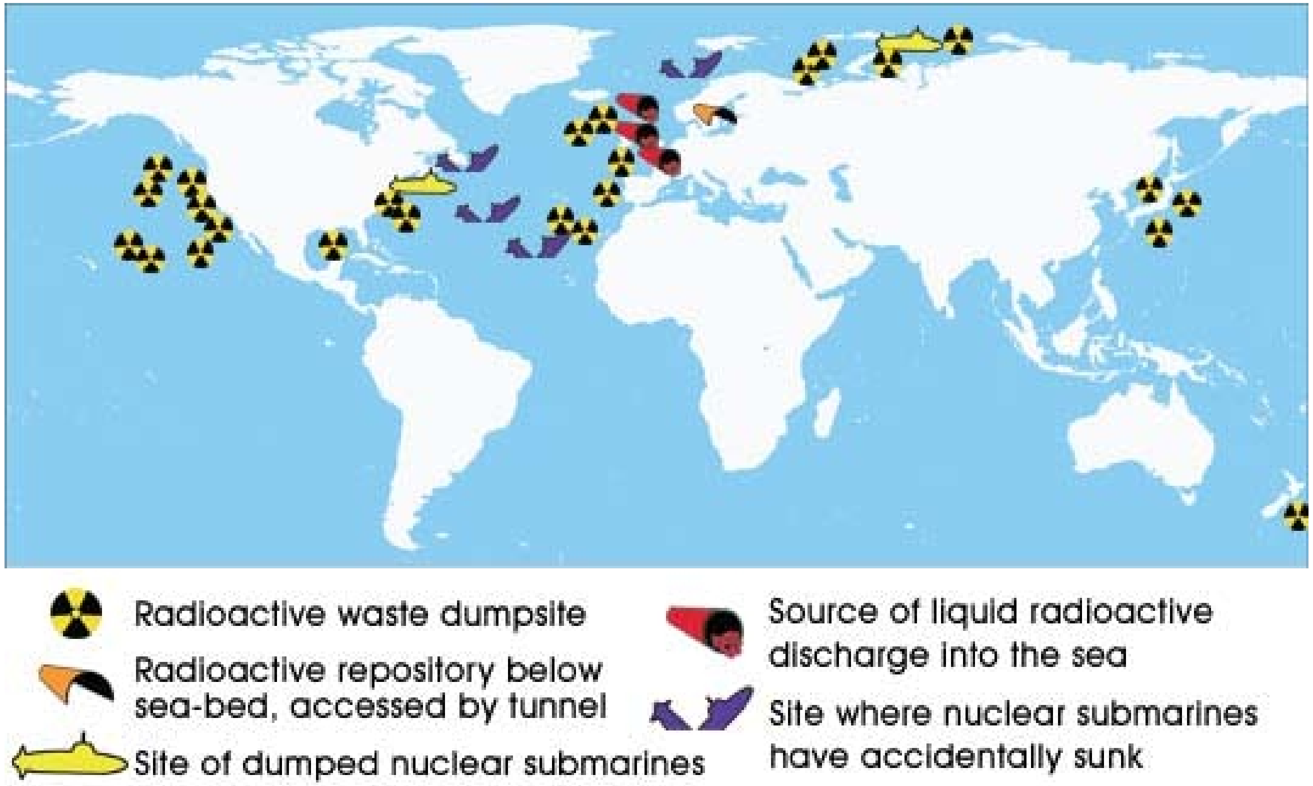


Dumping operations in the Arctic (liquid wastes)

Source: http://www.oceansatlas.org/unatlas/about/physicalandchemicalproperties/radiosp/htm/Geographical.html

Technological forecasting

World-Wide distribution of radioactive waste…



Source: http://www.informaction.org/cgi-bin/gPage.pl?menu=menua.txt&main=weapons_effects.txt&s=Weapons

Functions of Science & Technology roadmaps*

1. To portray the structural relationships among science, technology, and applications.
2. To enhance communications among stakeholders (researches, managers, suppliers, users etc.)
3. S&T marketing.
4. S&T management (Strategy, Planning, Executing, Reviewing, Transitioning etc.)
5. Identify gaps and opportunities in S&T programs.
6. Identify obstacles to rapid and low-cost product development.
7. Provide a consensus view or vision of the future S&T landscape available to decision makers.
8. Help develop consensus among decision makers about a set of S&T needs.
9. Provide a way to identify, evaluate, and select strategic alternatives to achieve desired S&T objectives.
10. Helps narrow the field of requirements and possible solutions to those most likely to be pursued.
11. Provide a mechanism to help experts forecast S&T developments in target areas.
12. Present a framework to help plan and coordinate S&T developments at different levels: organization-company; discipline-industry; cross-industry – national/international.
13. To assess future technological development within an environment of constant change.
14. Facilitate in enhancing efficiency of the technology transfer process.
15. Assist in filtering out the less promising technologies from the more promising ones.
16. To elicit champions for supporting S&T.
17. To identifying S&T gaps and opportunities.
18. To enhance communications among all the interested parties in S&T program development.
19. To promote a common understanding of the global context of S&T development.
20. To identify potential impacts…

*Adopted from: Kostoff, R.N. and R.R. Schaller, Science and Technology Roadmaps. IEEE Transactions On Engineering Management, 2001. 48(2): p. 132-143