Fizyka i Chemia Atmosfery

Wykład 14
Alternatywy

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Część I: Energia alternatywne

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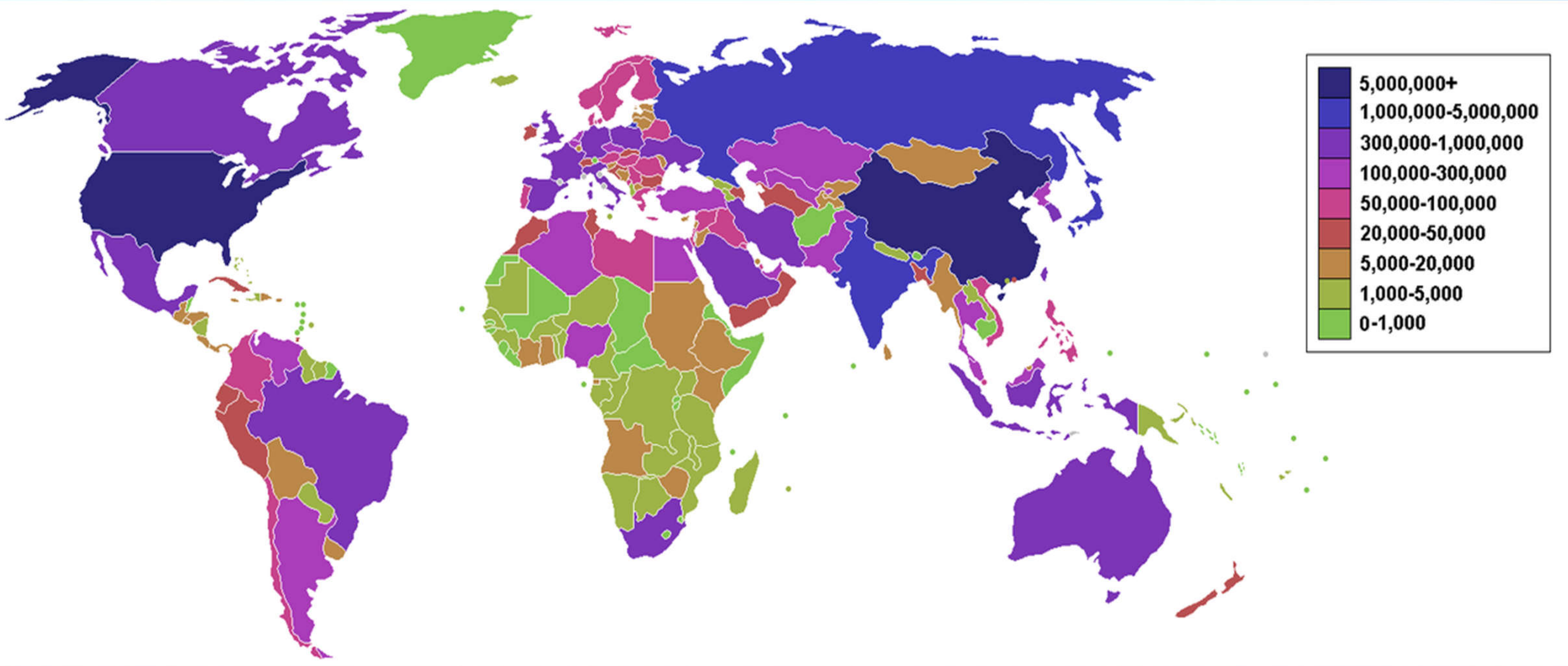
Uniwersytet Mikołaja Kopernika

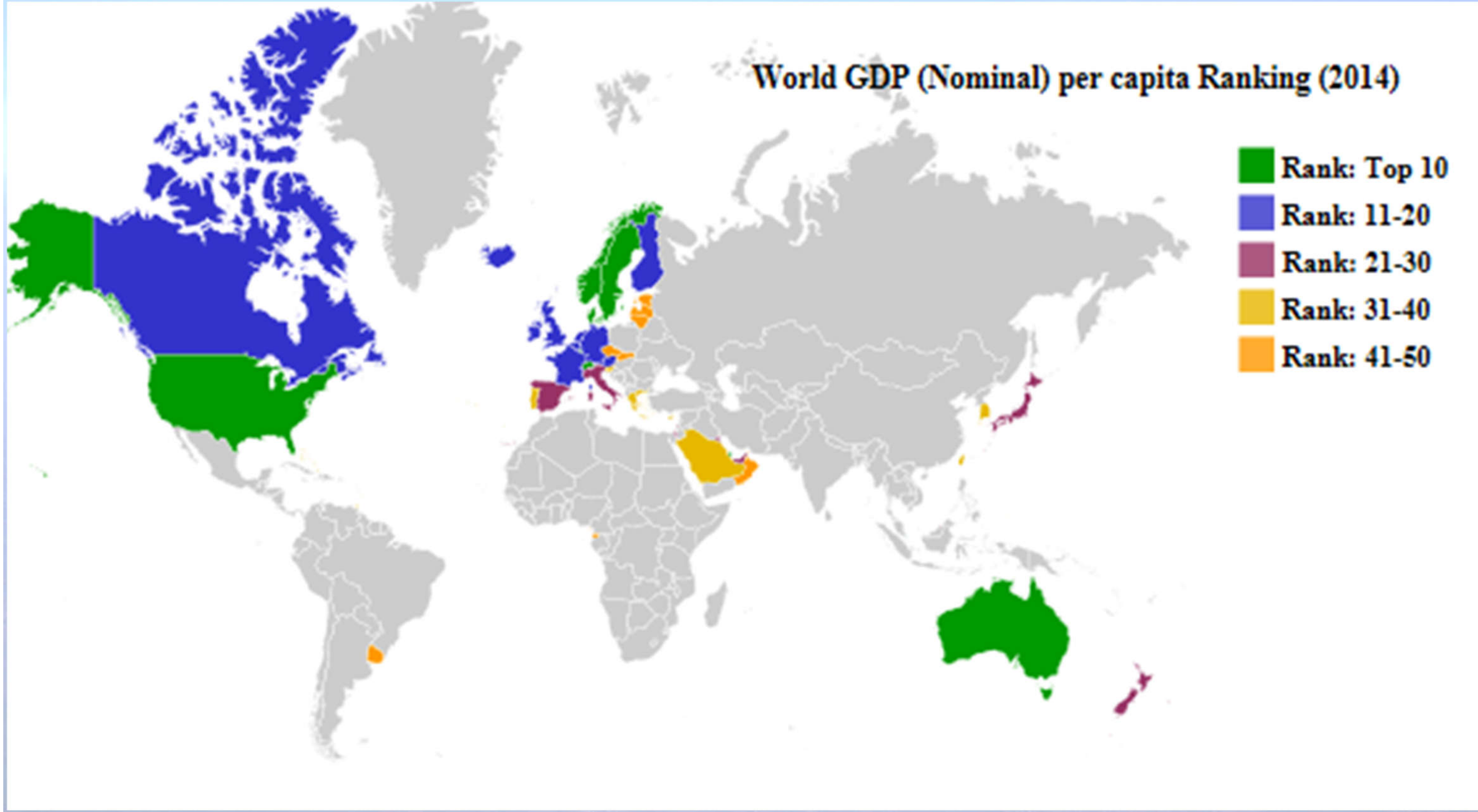
Toruń, 07.12.2014


CLIMA PAZZO
È colpa dell'Atlantico
OGGI
Alluvioni nel nord Europa e siccità al sud: l'oceano blocca i campi di pressione
FRA 10 ANNI
Il calo della salinità rallenterà la corrente del Golfo, portando il gelo in Europa
B
BASSA PRESSIONE
PIOGGE
SICCITÀ
ALTA PRESSIONE
A
Il ruolo dell'effetto serra, e la scoperta di un "El Niño" atlantico
RIMINI
LABORATORIO DEL COMPORTAMENTO
I PRIMI RISULTATI
www.focus.it

CO_2 emission (total)



GDP per capita (2014)



http://statisticstimes.com/economy/world-gdp-capita-ranking.php

Wind power

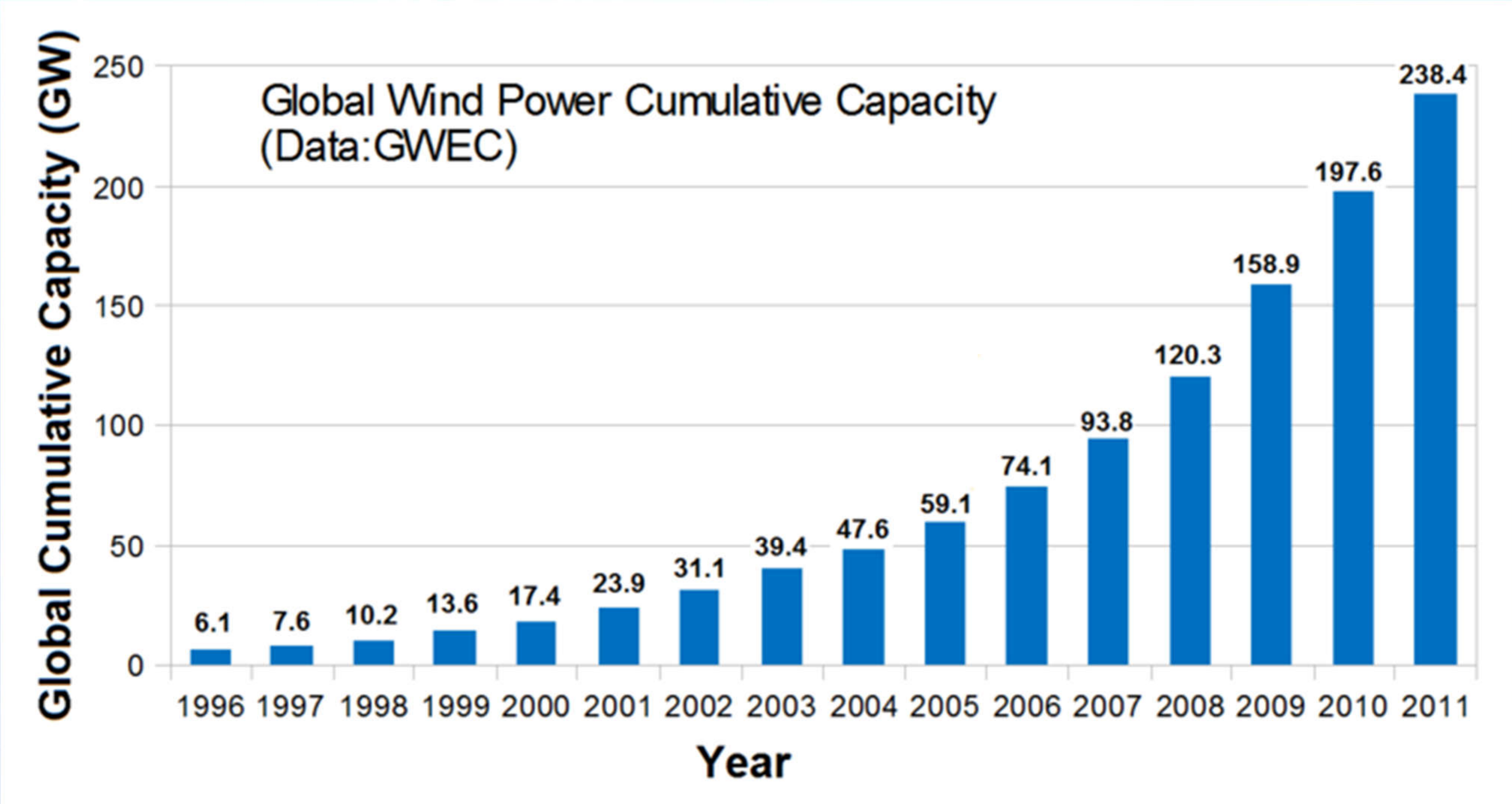
Ø 10m → 20-30 kW
Ø 90m → 3 MW (Vestas) = 1000 housholds

Wind power

London offshore 314 x 3.6 MW = 1 GW
Sund offshore: 48x2.3 MW = 110 MW (60 000 housholds

High costs!

Eolic - total



Global Wind Power Cumulative Capacity
(Data:GWEC)
Global Cumulative Capacity (GW)
250
200
150
100
50
0
6.1
7.6
10.2
13.6
17.4
23.9
31.1
39.4
47.6
59.1
74.1
93.8
120.3
158.9
197.6
238.4
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
Year

Wind power (2.5%)

Top 10 countries by nameplate windpower capacity (2011 year-end)[40]

Country	Windpower capacity (MW) ‡provisional	% world total
China	62,733‡	26.3
United States	46,919	19.7
Germany	29,060	12.2
Spain	21,674	9.1
India	16,084	6.7
France	6,800‡	2.8
Italy	6,747	2.8
United Kingdom	6,540	2.7
Canada	5,265	2.2
Portugal	4,083	1.7
(rest of world)	32,446	13.8
World total	**238,351 MW**	**100%**

Top 10 countries by windpower electricity production (2010 totals)[56]

Country	Windpower production (TWh)	% world total
United States	95.2	27.6
China	55.5	15.9
Spain	43.7	12.7
Germany	36.5	10.6
India	20.6	6.0
United Kingdom	10.2	3.0
France	9.7	2.8
Portugal	9.1	2.6
Italy	8.4	2.5
Canada	8.0	2.3
(rest of world)	48.5	14.1
World total	**344.8 TWh**	**100%**

Wind generator: 2.5MW

Technical data 2.5MW Gamma class[3] [edit]

Parameter	N80 IEC1	N90 IEC1	N90 IEC2	N100 IEC 2	N100 IEC3	N117/2400 IEC3
Rated Power (kW)	2,500	2,500	2,500	2,500	2,500	2,400
Cut-in wind speed (m/s)	3	3	3	3	3	3
Cut-out wind speed (m/s)	25	25	25	25	25	20
Rotor diameter (m)	80	90	90	100	100	117
Swept area (m^2)	5,026	6,362	6,362	7,823	7,823	10,751
m^2 per MW	2,010	2,548	2,548	3,129	3,129	4,480
Revolutions per minute	10.8-18.9	10.3-18.1	9.6-16.8	9.6-14.8	9.6-14.8	7.5-13.2
Overspeed control	Pitch	Pitch	Pitch	Pitch	Pitch	Pitch
Gearbox	yes	yes	yes	yes	yes	yes
Generator	double-fed asynchronous generator	double-fed asynchronous generator	double-fed asynchronous generator	double-fed asynchronous generator	double-fed asynchronous generator	double-fed asynchronous generator
Grid						

N100/2500 in the United States.

Nordex N117/2400 (Gamma) in Germany

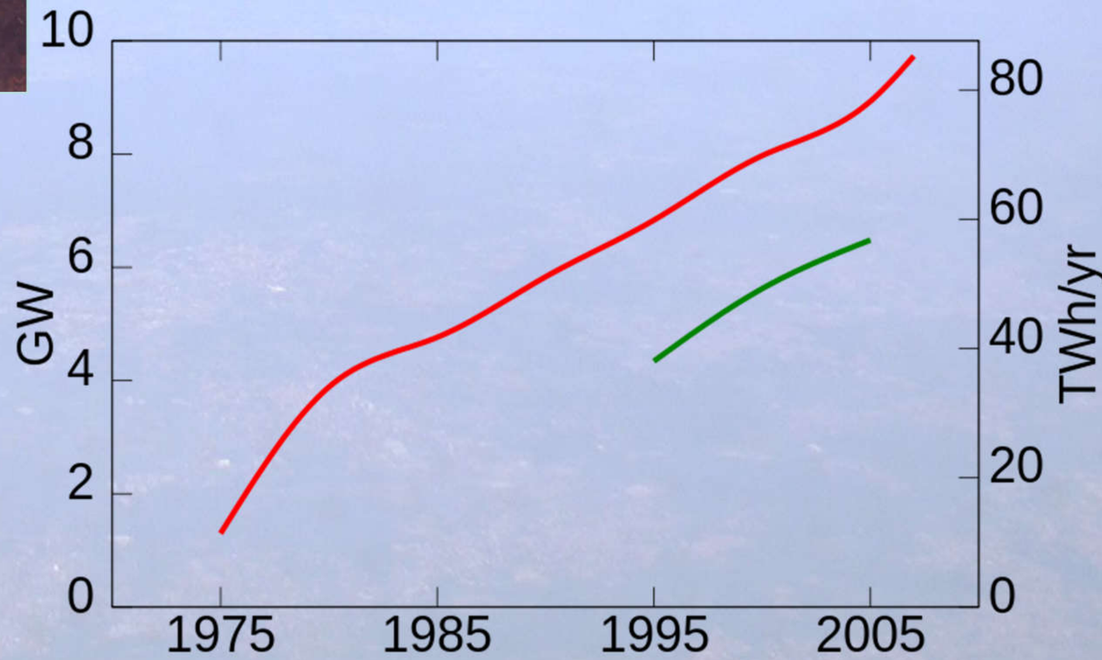
Sorce: Nordex

Eolic producers: np. Nordex

Statement of financial position							
Total assets as at 31 December	EUR million	1,066.1	1,191.4	1,239.9	1,460.1	2,994.2	>100%
Equity as at 31 December	EUR million	279.0	368.0	396.0	455.6	940.0	>100%
Equity ratio	%	26.2	30.9	31.9	31.2	31.4	0.2%-pp.
Employees							
Employees	Ø	2,536	2,543	2,800	3,148	4,645	47.6%
Staff costs[1]	EUR million	140.2	153.2	167.7	197.3	289.9	46.9%
Sales[1] per employee	EUR thousand	424	562	619	772	731	-5.3%
Staff cost ratio[1]	%	12.7	10.2	9.6	8.2	8.5	0.3%-pp.
Company performance indicators							
Order intake	EUR million	1,268.0	1,502.9	1,753.9	2,470.9	3,302.2	33.6%
Installed capacity	MW	919	1,254	1,489	1,697	2,622	54.5%

Geothermal - trends

Pozzuoli (Volterra)



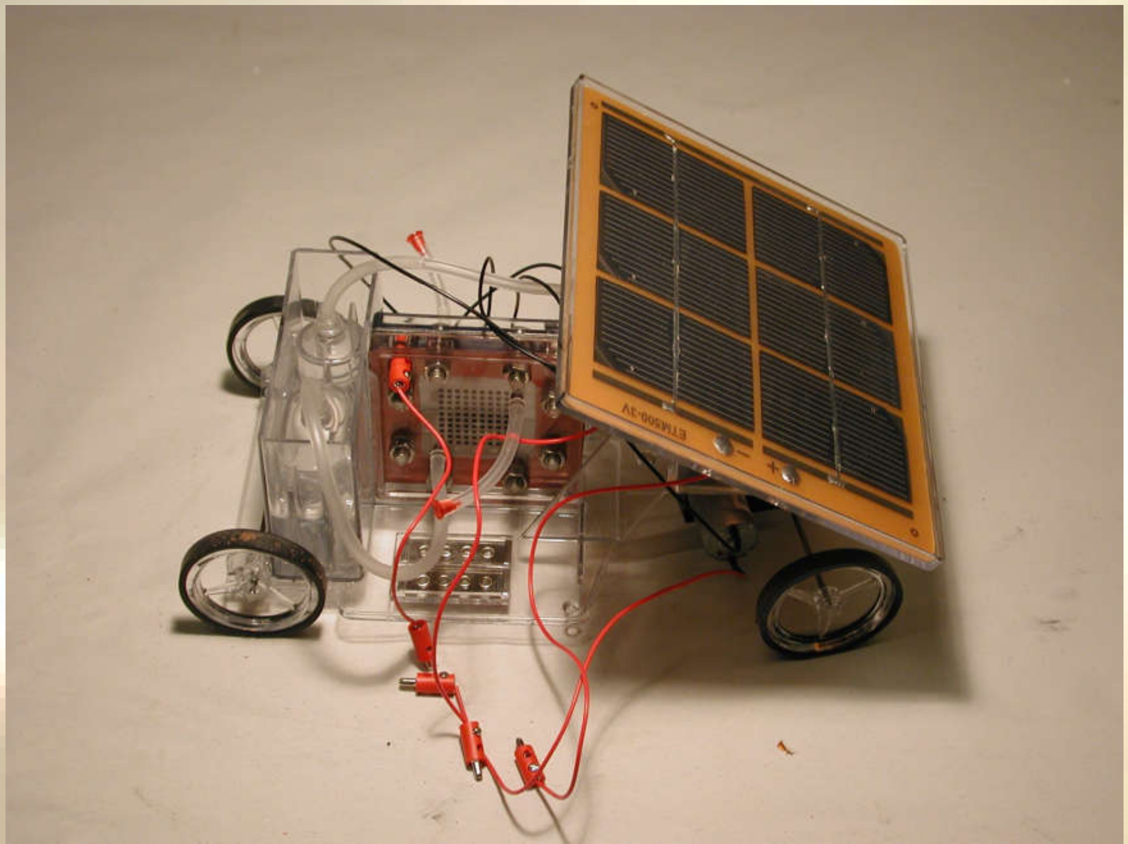
Energy flux: 65mW/m^2

Geothermal - total

Installed geothermal electric capacity

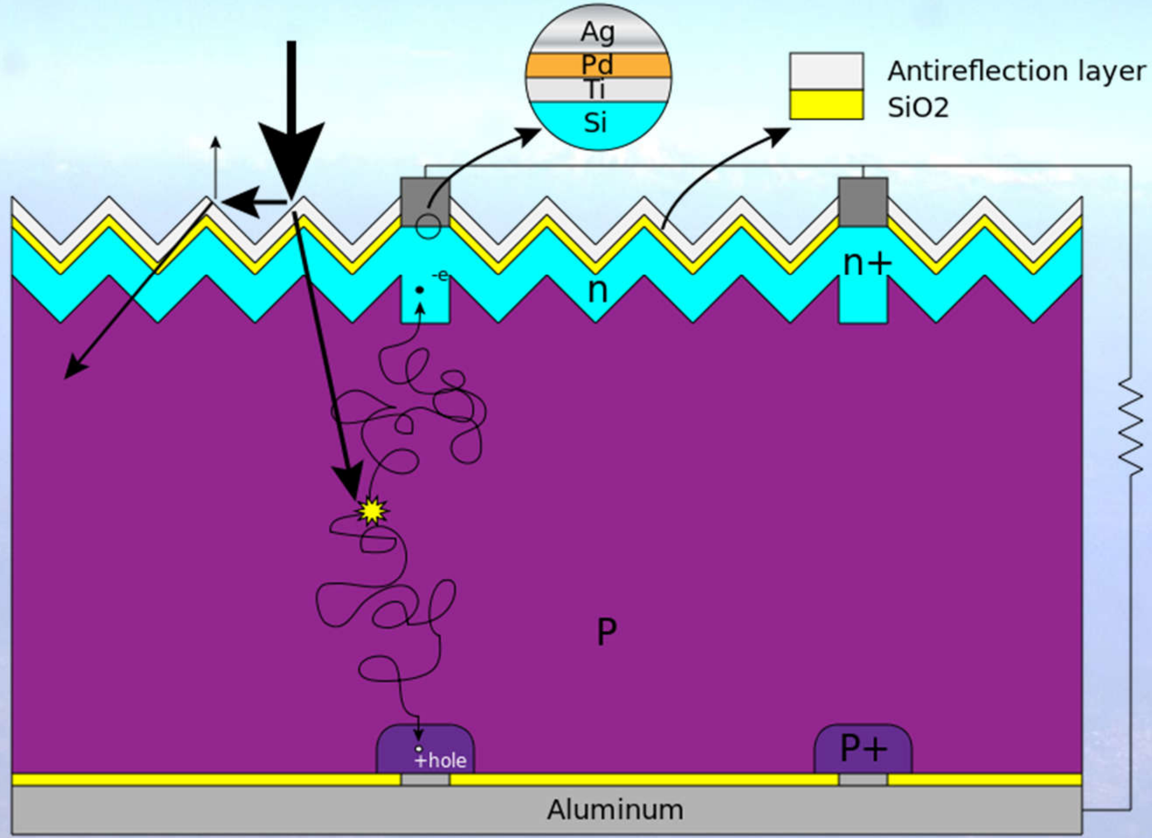
Country	Capacity (MW) 2007[11]	Capacity (MW) 2010[23]	Percentage of national production
United States	2687	3086	0.3%
Philippines	1969.7	1904	27%
Indonesia	992	1197	3.7%
Mexico	953	958	3%
Italy	810.5	843	1.5%
New Zealand	471.6	628	10%
Iceland	421.2	575	30%
Japan	535.2	536	0.1%

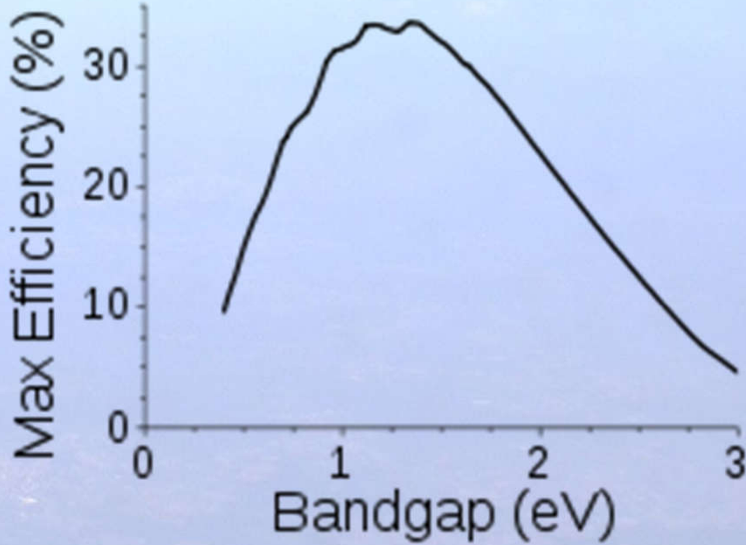
Solar constans: 1364 W/m^2



“Foto-Voltaico” = “luce → corrente”

Solar – principle





Energia fotovoltaica – rendimento tecnico

16% nei moduli in eterogiunzione;
14% nei moduli in silicio monocristallino;
13% nei moduli in silicio policristallino;
10% nei moduli in silicio microsferico;
6% nei moduli in silicio amorfo.

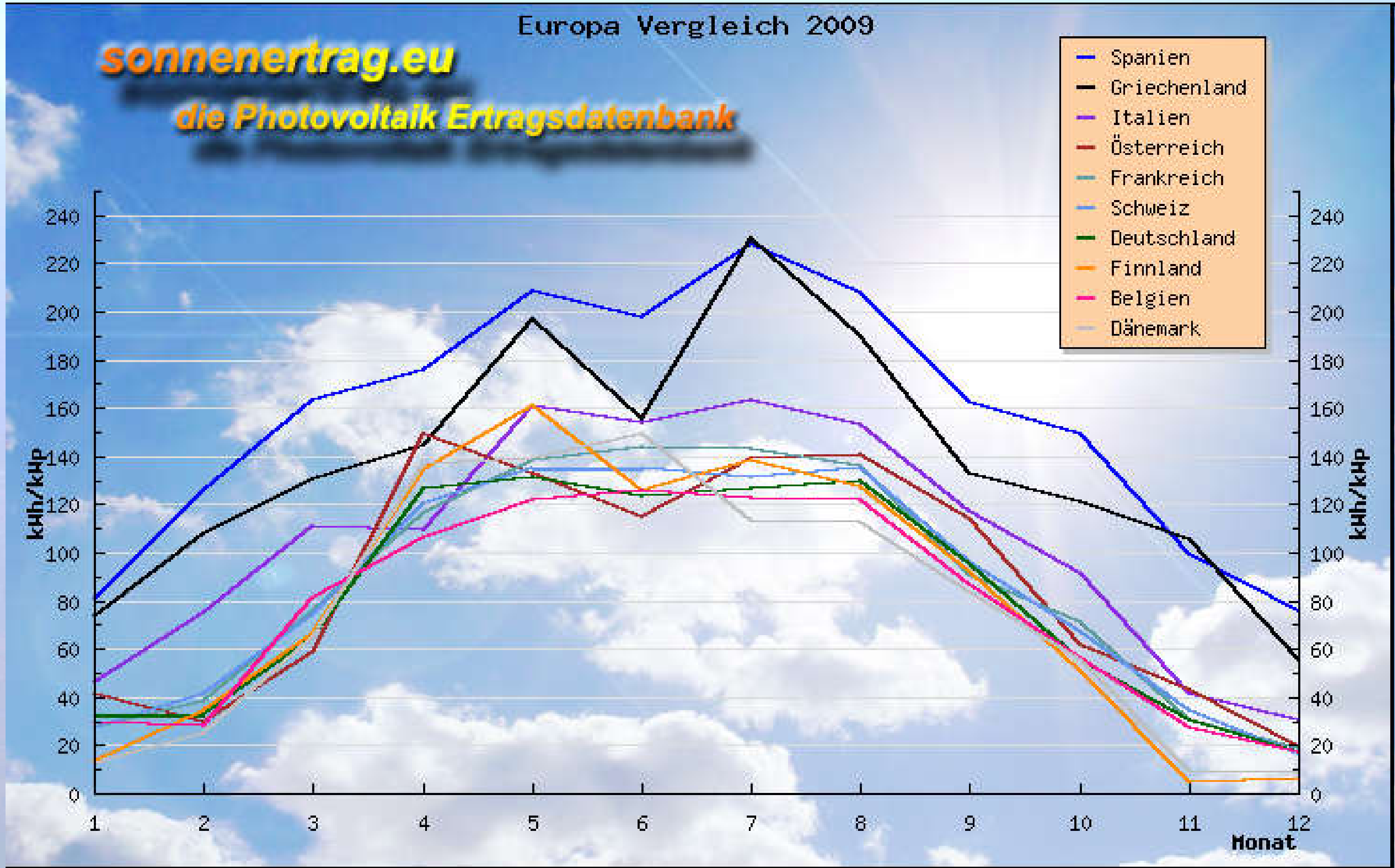
Nazione:	Deutschland	Regione:	Sachsen-Anhalt
Quartiere:	Halle	Targa automob.:	SK
Cap:	06237	Località:	Spergau
Inizio attività:	2009	Pagina web:	
Inclinazione:	40,00 °	Potenza:	**10,500 kWp**
Produttore del modulo:	Sunpower	Orientamento:	200,00 °
Tipo del modulo:	300-WHT		
Tipologia modulo:	mono		
Inseguimento:	stationario		
Prodotture dell'inverter:	Fronius		
costo dell'impianto:	**39500**		
Altro:			
Esperienza:			

http://www.sonnenertrag.eu/it/derstromer/spergau/11126/11406.html

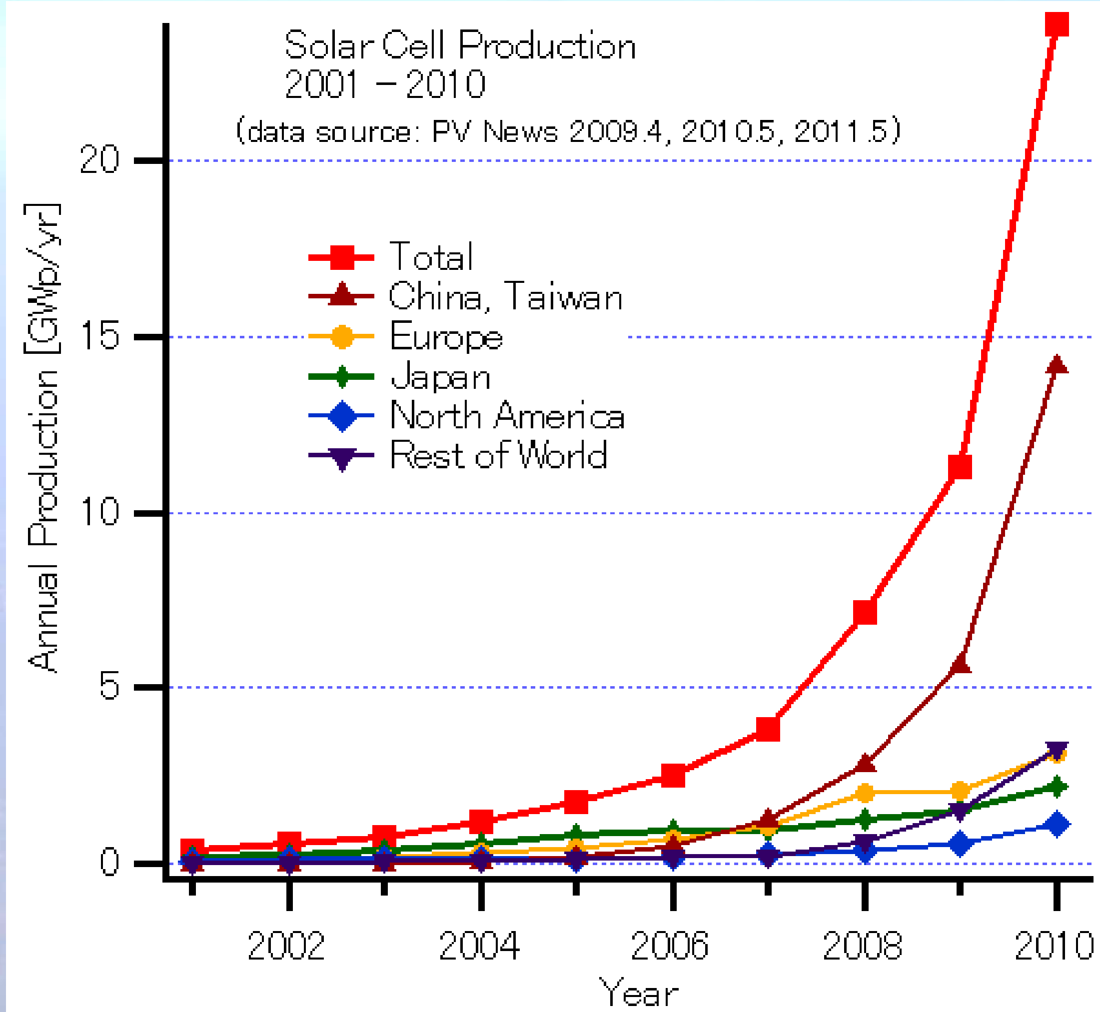
Energia fotovoltaica - Europa

Posto	Rendimento kWh	Potenza kWp	Efficienza kWh/kWp (month)	Ort	Impianto
1	269,70	3,45	**78,17**	2425 Monte real	NunoVentura
2	247,36	3,45	**71,70**	2420 Leiria	crasto
3	8177,00	115,20	**70,98**	30520 Murcia	panapa
4	750,00	11,20	**66,96**	52511 geilenkirchen	ökobäuerin
5	1726,90	27,84	**62,03**	72477 Schwenningen	schwenningen (Solarpark S
6	6018,05	99,90	**60,24**	54625 Thessaloniki	Engaia (Engaia Ltd - Edes
7	1536,42	25,80	**59,55**	72379 Hechingen	TECHMASTER
8	191,94	3,24	**59,24**	8600 Diksmuide	Danny Plaisier
9	173,97	2,96	**58,77**	32100 BELLUNO	kebrox

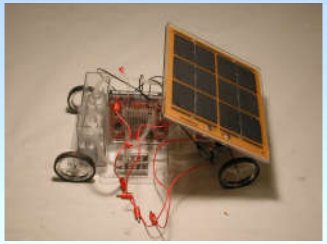
Energia fotovoltaica – rendimento per mese



Solar – total 67GW, 85TWh/y

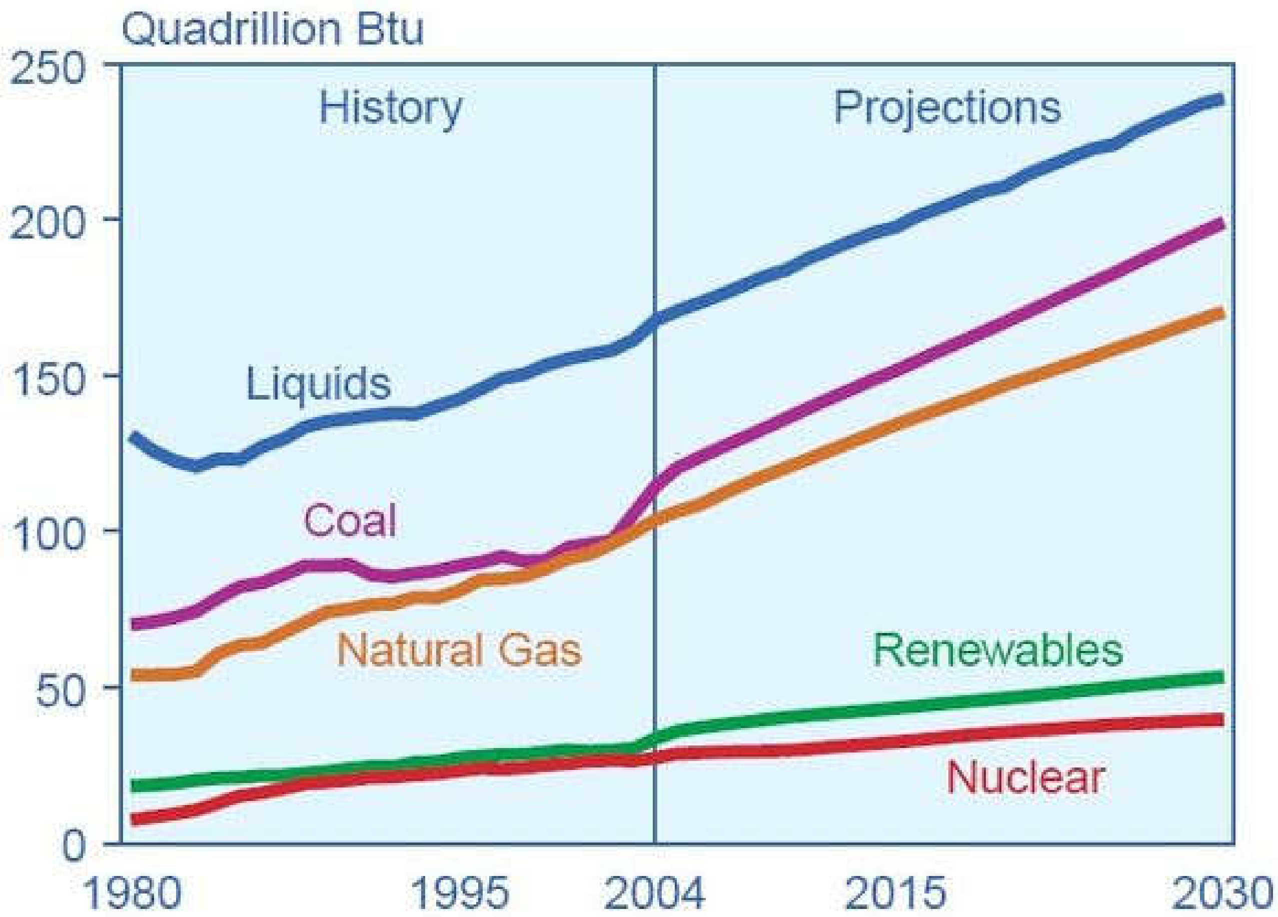


Renewable energy - costs

	2006	2014
	15 $/barile	12 $/barile
	25 $/barile	25 $/barile
	15 $/barile	18 $/barile
	20 $/barile	15 $/barile
Petrol:	30 $/barile	40-45 $/barile
Nuclear:	60 $/barile	100-120 $/barile

Tradional energy ↔ renewable

Figure 4. World Marketed Energy Use by Fuel Type, 1980-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2004* (May-July 2006), web site www.eia.doe.gov/iea. **Projections:** EIA, System for the Analysis of Global Energy Markets (2007).

Burning biomass

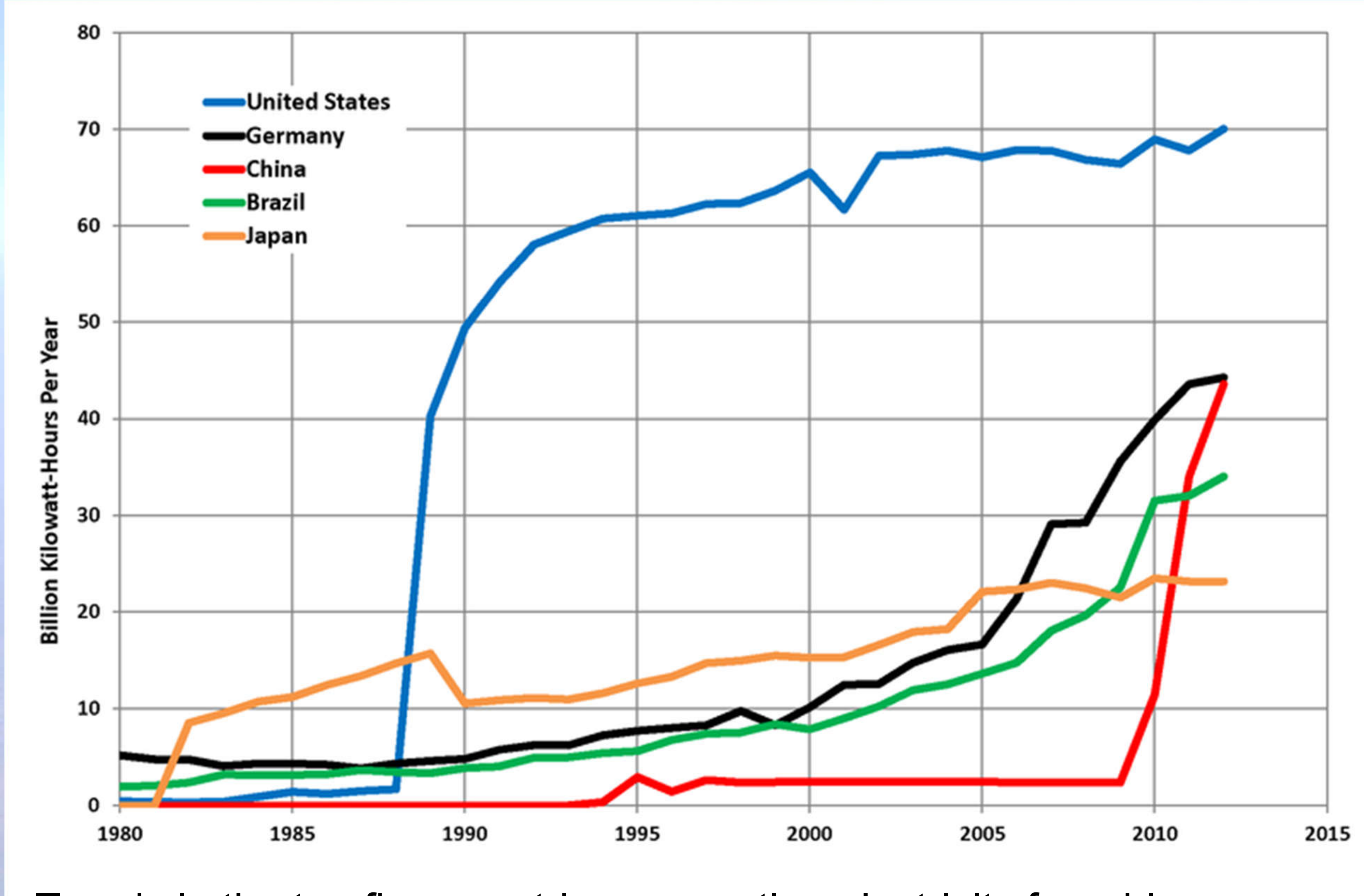
Burning biomass releases carbon emissions, around a quarter **higher than burning coal**, but has been classed as a "renewable" energy source in the EU and UN legal frameworks, because plants can be regrown.

Using biomass as a fuel produces air polution in the form of carbon monoxide, carbon dioxide, N_2O, NO, NO_2 (nitrogen oxides), VOCs (volatile organic compounds), particulates and other pollutants at levels above those from traditional fuel sources such as coal or natural gas

A cogeneration plant in Metz, France. The station uses waste wood biomass as an energy source, and provides electricity and heat for 30,000 dwellings.

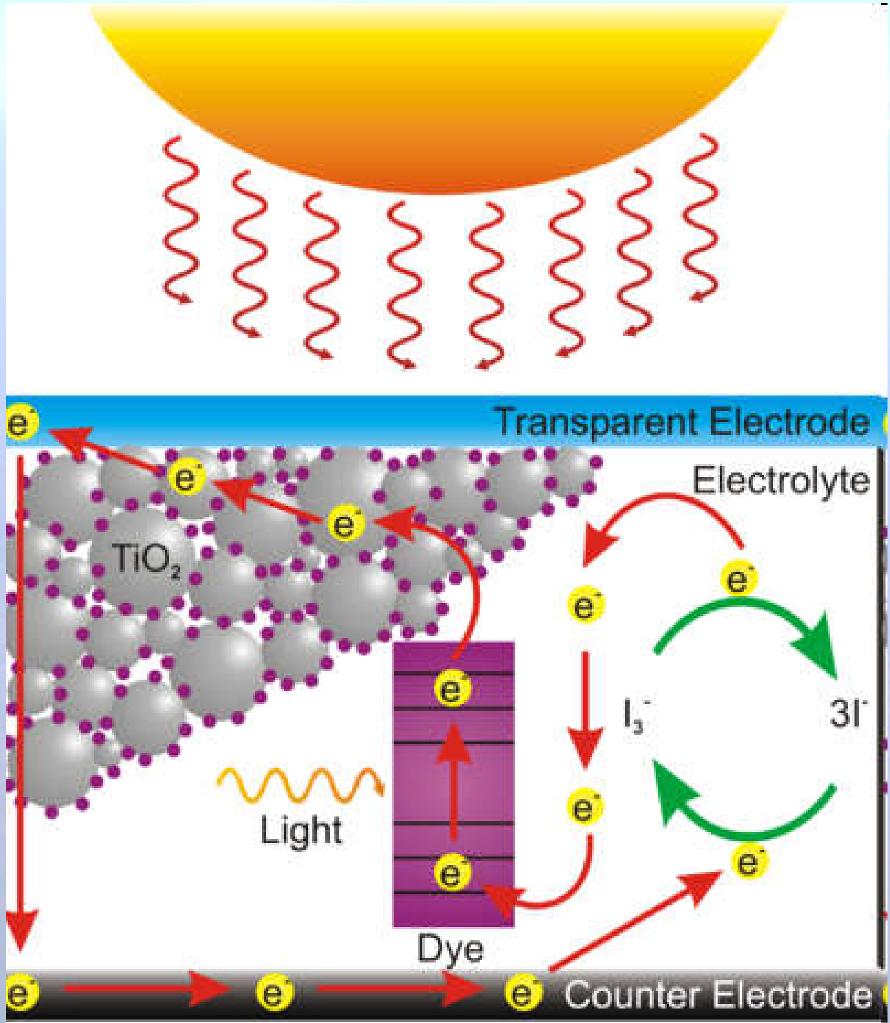
https://en.wikipedia.org/wiki/Biomass

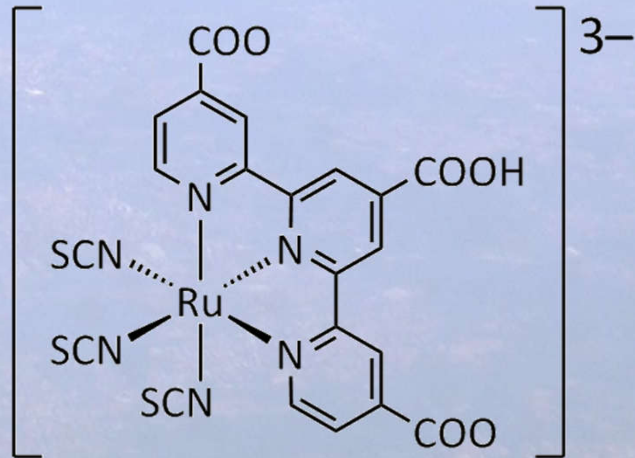
Electricity from biomass



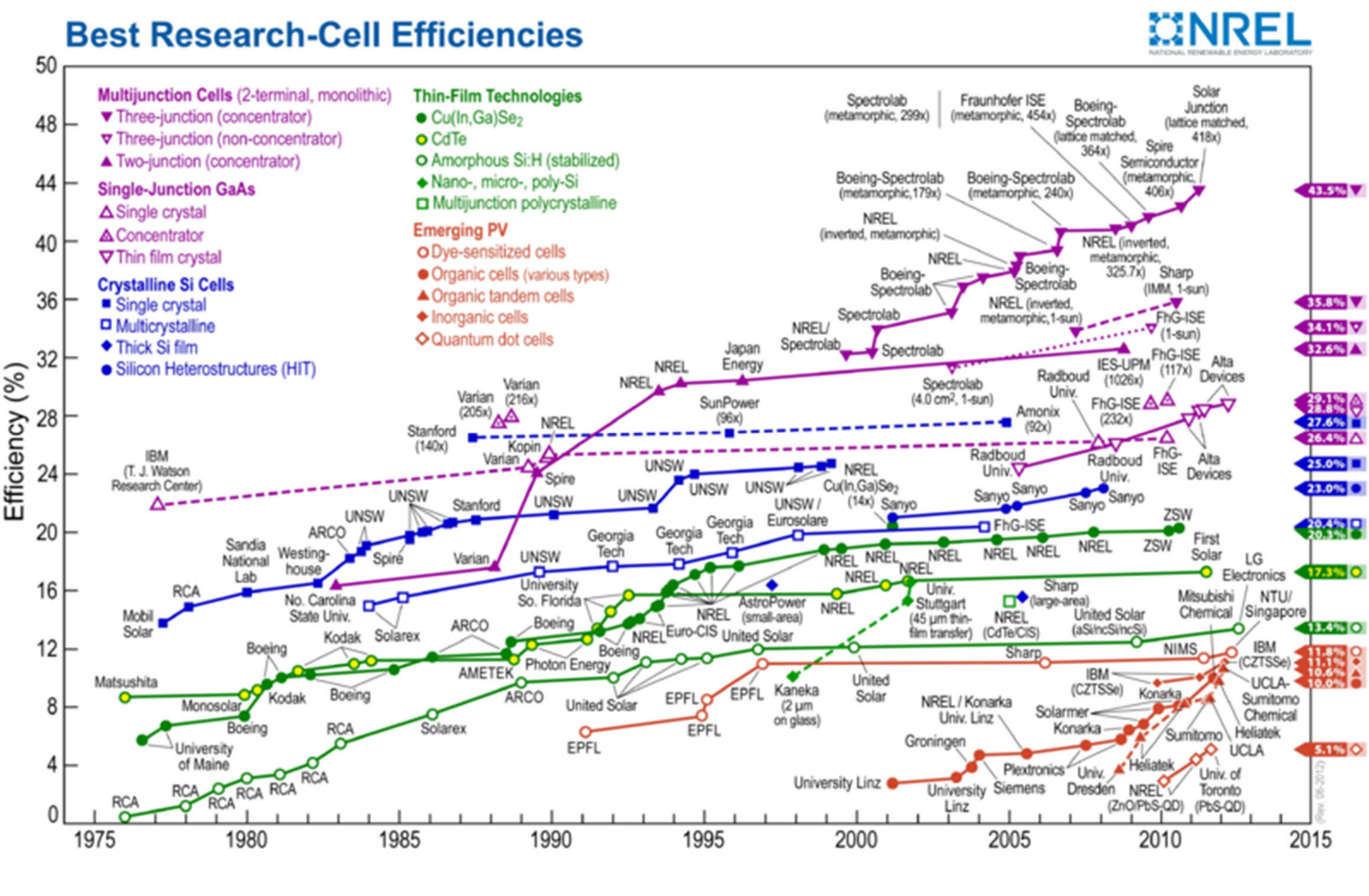
Trends in the top five countries generating electricity from biomass
USA: 11 GW (1.4%) electricity production

Energia fotovoltaica – Graetzel cell

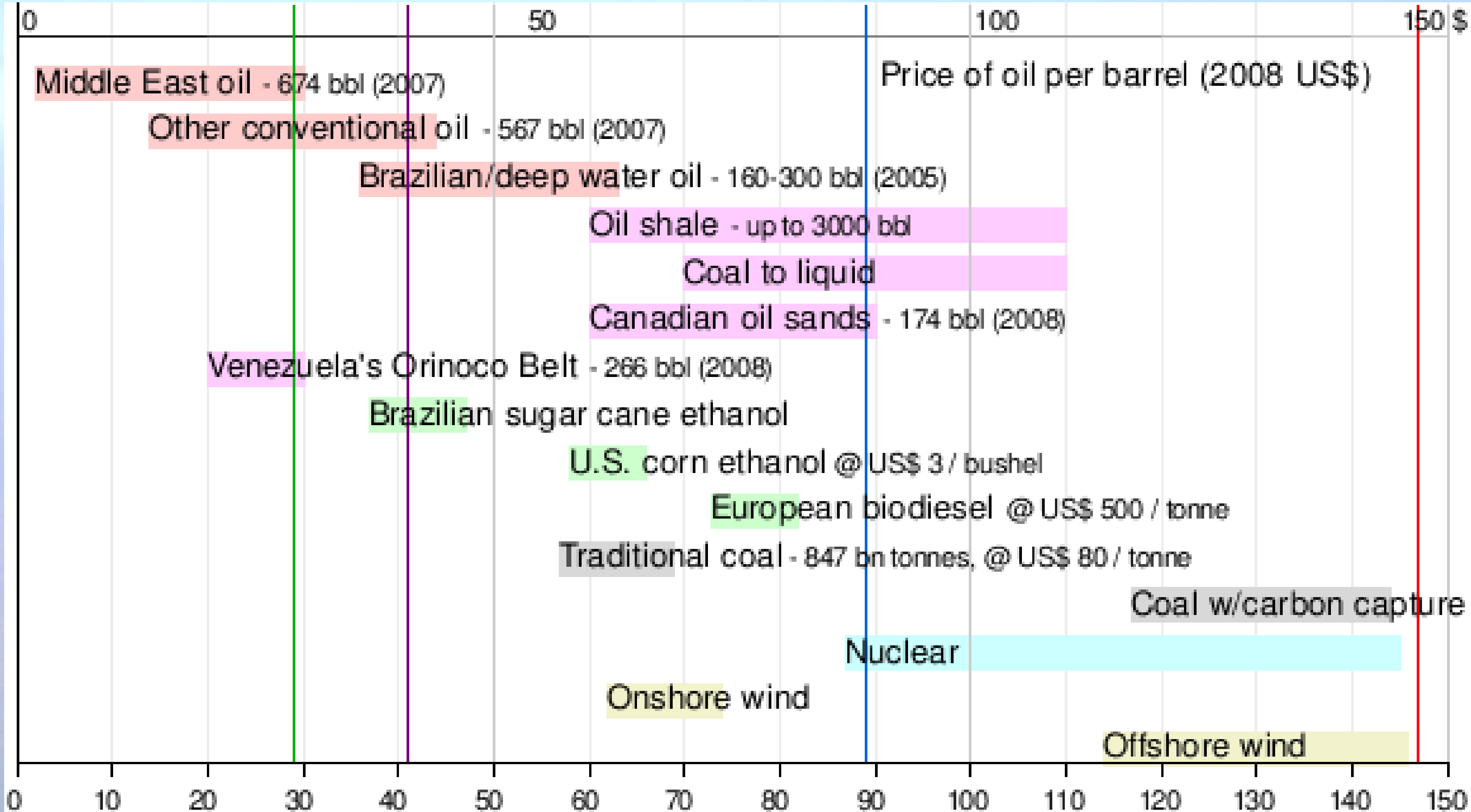




Solar - efficiency



Koszty energii (USA 2010)



Settling the fracking question

Energy firms have not convinced sceptics that shale-gas extraction, or "fracking", is safe for the environment. Jon Cartwright examines whether physics could help

Hydraulic fracturing, or "fracking", is by any measure controversial. The process – which involves pumping sand and liquid into deep shale deposits to liberate natural gas – has been touted by its proponents as an energy saviour. For them, fracking allows energy companies to tap into reserves that are otherwise difficult, if not impossible, to get gas from. Yet the process has been slammed by opponents as being hugely damaging to the environment.

While fracking has taken off rapidly in the US, it has been banned in France and Bulgaria. Unfortunately, this polarized debate about fracking is not helped by a shortage of facts. No-one is sure to what extent fracking can contaminate groundwater, either with methane or with toxic chemicals. There is also a concern that fracking can trigger moderate earthquakes. While there may be no hard-and-fast answers, it seems that geophysics may be able to prod the debate in a constructive direction.

Without geophysics, of course, fracking would not be possible at all. Shale is a fine, clay-based sedimentary rock that has low permeability, so it will not release its gas into a well easily. To get at the gas, therefore, energy companies have to display their engineering prowess by drilling wells 1500–3000 m deep into a shale deposit and then running a perforated steel pipe horizontally. Millions of litres of water are pumped into the pipe, together with sand and chemicals, at

Heading underground The International Energy Agency suggests the world might be en route to "a golden age of gas" thanks to the emergence of hydraulic fracturing, or "fracking" – a rig for which is pictured here in Colorado.

2.4 trillion m^3, according to the US Geological Survey, which is one of the more modest estimates. Colorado-based business-information company HIS, for example, puts the figure at about 42 trillion m^3.

The US is not, though, the only nation with large deposits. UK energy firm Cuadrilla Resources estimates around 5.6 trillion m^3 of shale-gas reserves in the UK. Hardly surprising, then, that a report last year from the International Energy Agency suggested the world might be en route to "a golden age of gas".

Gaz łupkowy?

Znaczne zniszczenia środowiska!

Physics World, 12.03.2012

Część II: Smog, czy atom? Trudny wybór!

Grzegorz Karwasz

Zakład Dydaktyki Fizyki

Uniwersytet Mikołaja Kopernika

Toruń, 07.12.2017

Plan

- Co to jest efekt cieplarniany ?
- Kto za niego odpowiada?
- Jak działa elektrownia jądrowa?
- Co się wydarzyło w Fukoshimie?
- Czym oddychamy ?
- Kiedy będzie gotowy reaktor termojądrowy?

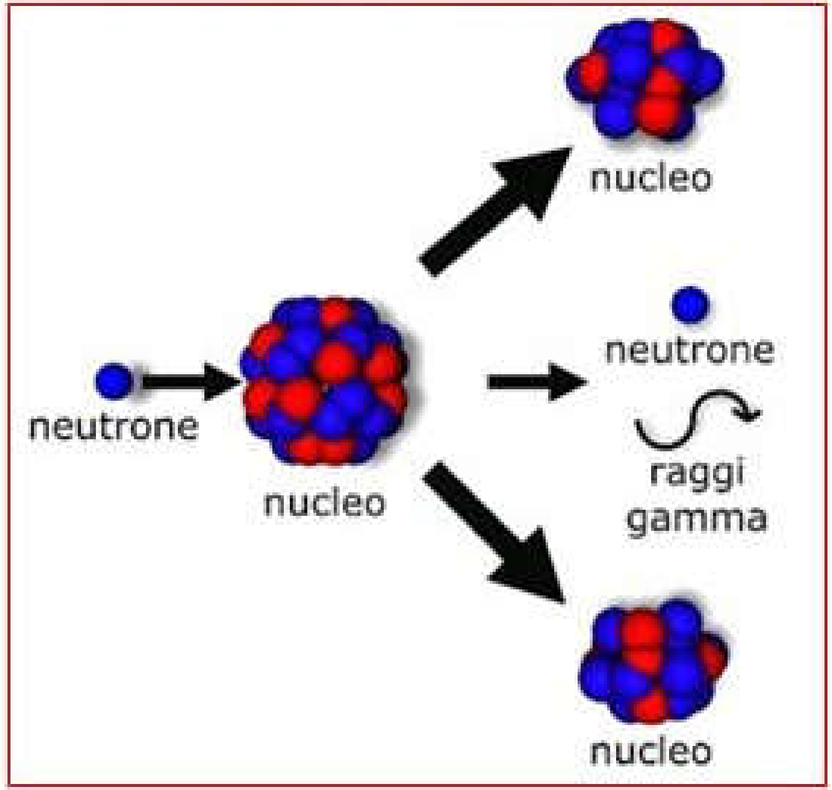
Rozszczepienie uranu ^{235}U

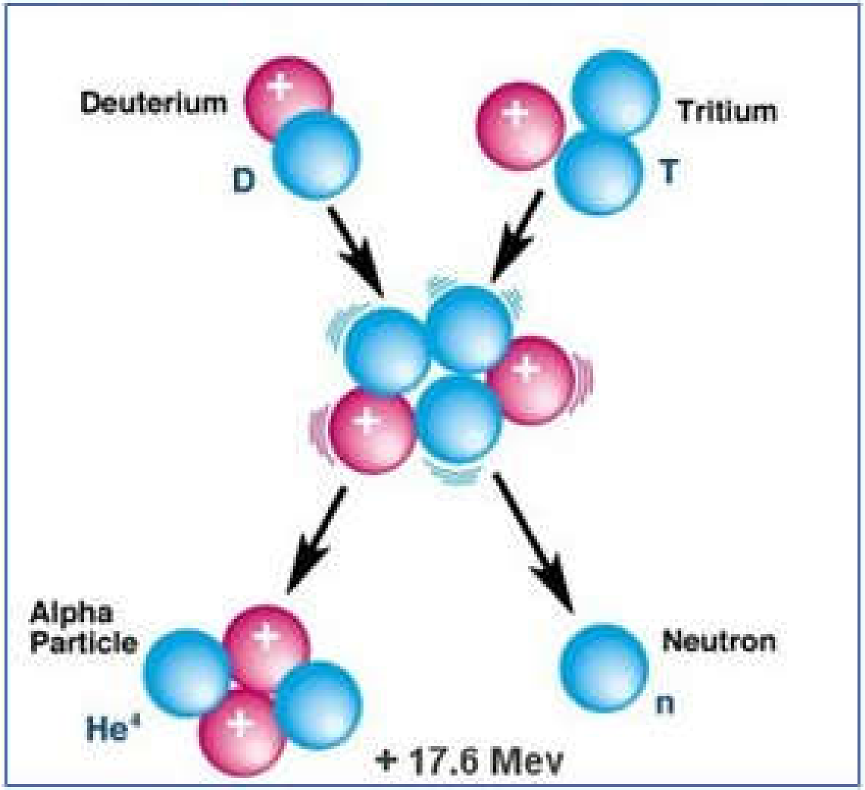
3.8 Reakcje jądrowe

Krótko przed II wojną światową dwójka niemieckich uczonych, Lisa Meitner i Otto Hahn zauważyli, że rzadziej występujący izotop uranu ^{235}U po pochłonięciu neutronu nie podlega żadnej ze znanych wówczas przemian jądrowych, ale, żartobliwie mówiąc „rozpada się na dwie nierówne połowy".

Reakcja, nazywana reakcją *rozszczepienia*, może mieć przebieg, np.

$$ {}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{90}_{36}Kr + {}^{144}_{56}Ba + {}^{1}_{0}n + {}^{1}_{0}n \qquad (3.12) $$



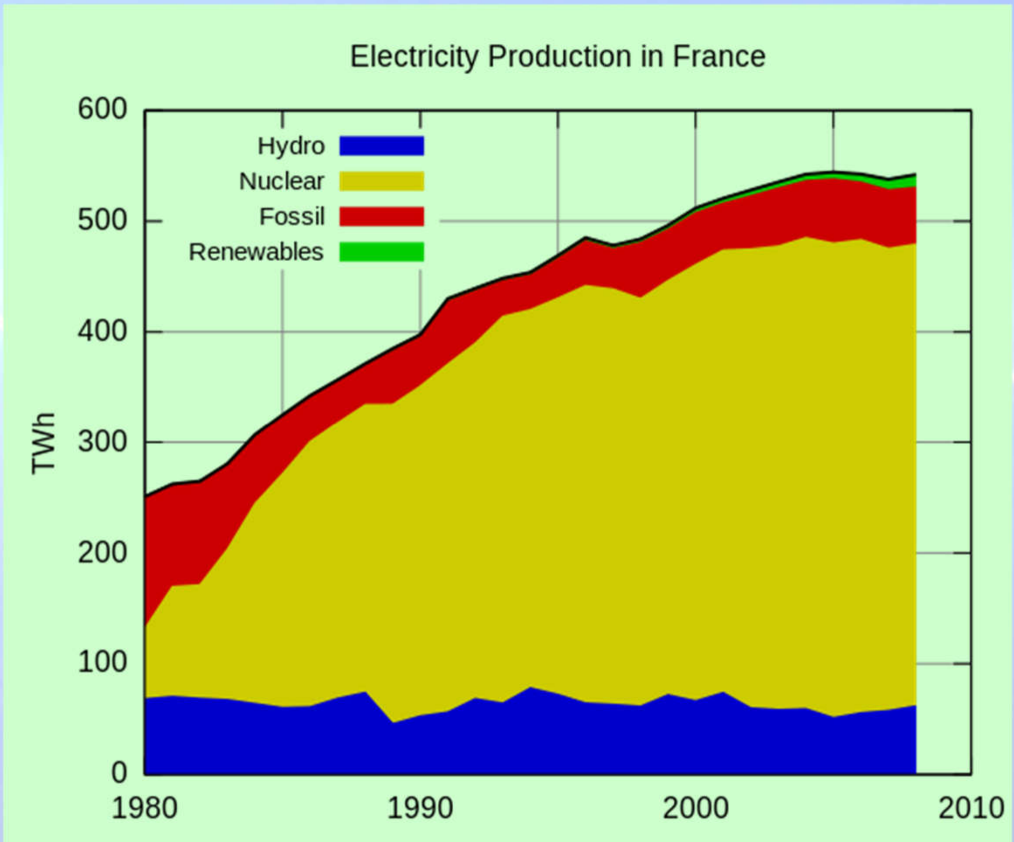


Energia jądrowa

$^{235}U + n \rightarrow A + B + 2(\text{ lub } 3)\ n$

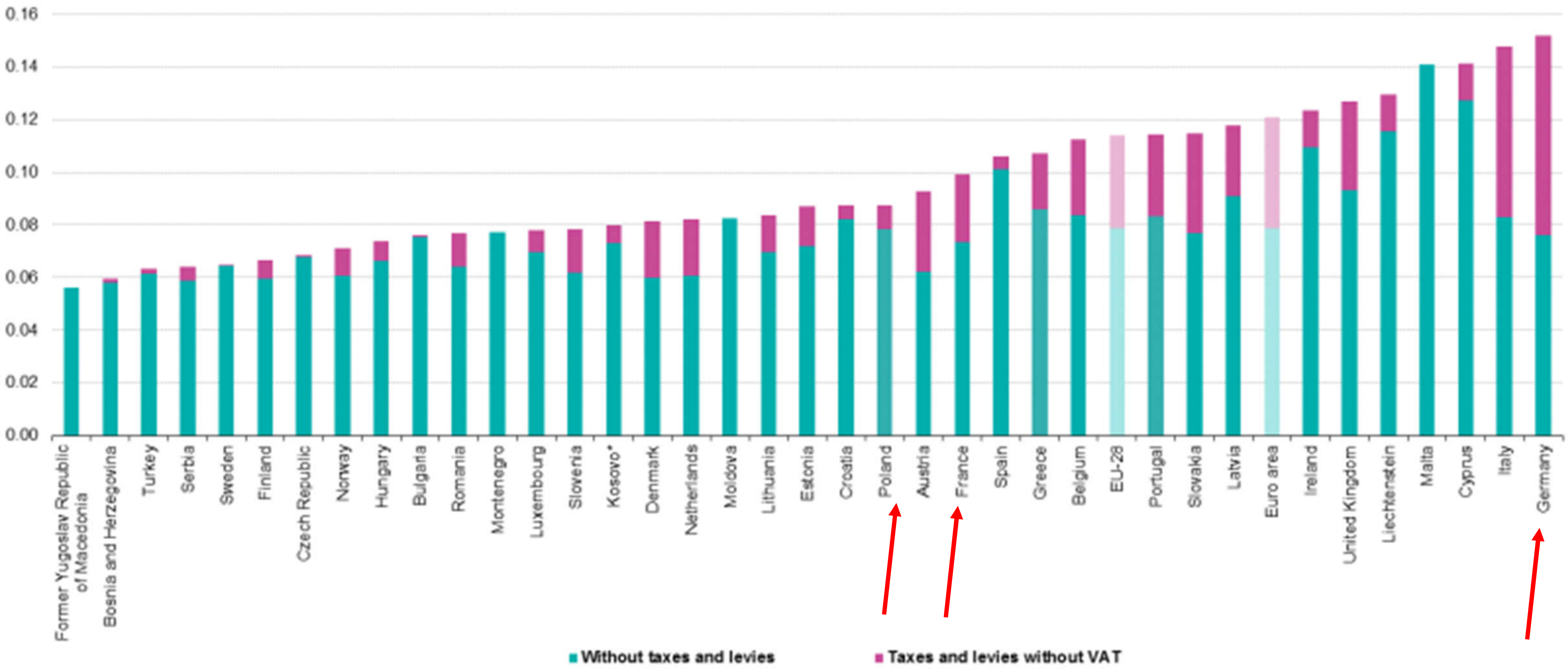
^{235}U = 0.7% w naturalnej rudzie
Bomba U> 20% ^{235}U
Reaktor jądrowy> 2-4%

1 block = 1 GW



USA: 100 GW (100 reactors)
20% of USA electricity
33% of world nuclear energy

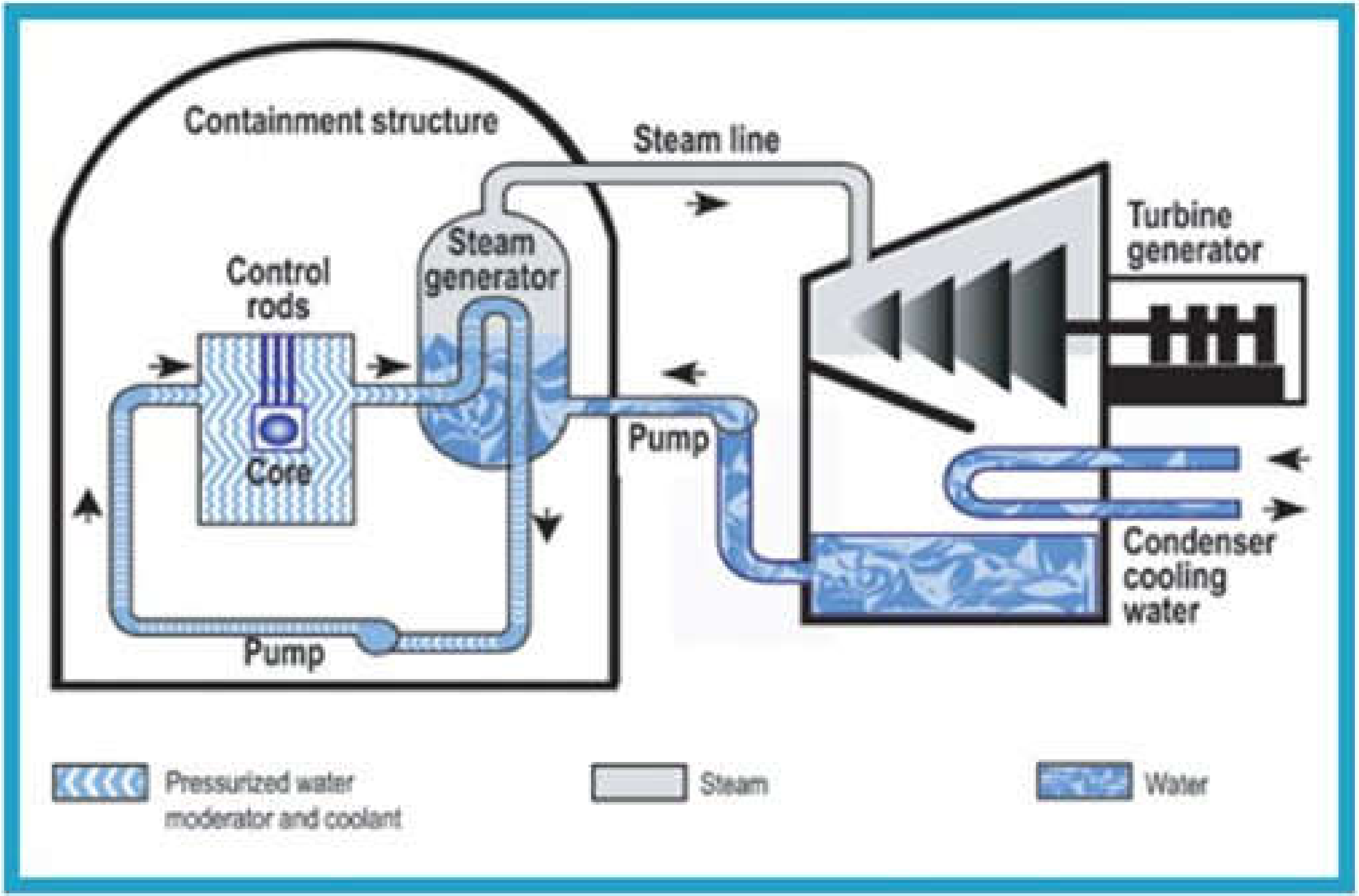
Ceny prądu dla przemysłu + VAT



*This designation is without prejudice to positions on status, and is in line with UNSCR 1244 and the ICJ Opinion on the Kosovo Declaration of Independence.

Source: Eurostat (online data code: nrg_pc_205)

Elektrownia jądrowa



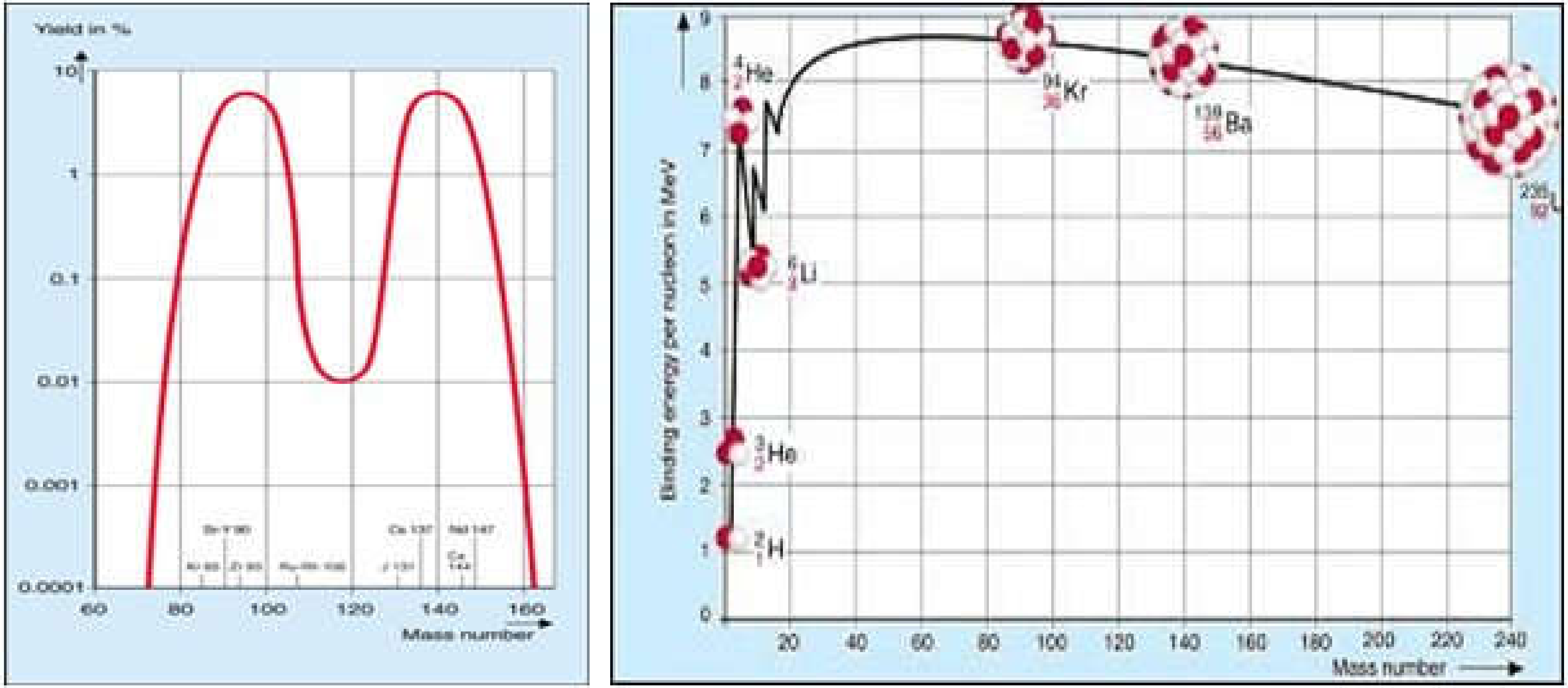
Ryc. 6.4. Schemat działania elektrowni jądrowej; paliwo jądrowe znajduje się w rdzeniu (*core*); pręty kontrolne (*control rods*) regulują prędkość reakcji, gorące chłodziwo (woda pod ciśnieniem) wytwarza parę wodną (*steam generator*) w wymienniku ciepła, gorąca para (*steam line*) napędza turbinę generatora (*turbine generator*), dodatkowa linia wody (*cooling water*) chłodzi parę po przejściu przez turbinę. (źródło: World Nuclear Association)

G. Karwasz, M. Więcek, *Toruński poręcznik do fizyki*. *Fizyka współczesna*, ZDF 2011

Np. reaktor kanadyjski na ubogi uran

CanDU at Quinsham

Produkty rozpadu ^{235}U



Ryc. 3.10. a) Produkty rozszczepienia uranu ^{235}U (na dwa fragmenty) obejmują szeroki rozkład izotopów od A = 70 do A = 170; zwróć uwagę, że skala pionowa jest względna (0.1, 1, 10); **b)** energia wiązania na jeden nukleon w zależności od liczby masowej A; cząstka alfa, czyli ^{4}He ma dużą energię wiązania; maksimum krzywa osiąga około żelaza ^{56}Fe; dla jąder poniżej masy żelaza korzystna energetycznie jest synteza, powyżej żelaza – rozszczepienie (Źródło: European Nuclear Society)

G. Karwasz, M. Więcek, *Toruński poręcznik do fizyki*. *Fizyka współczesna*, ZDF 2011

Energia jądrowa – koszty ukryte

Reactor Radioactive Waste Production

3 GW Thermal PWR Yearly Discharge ≈ 50 t

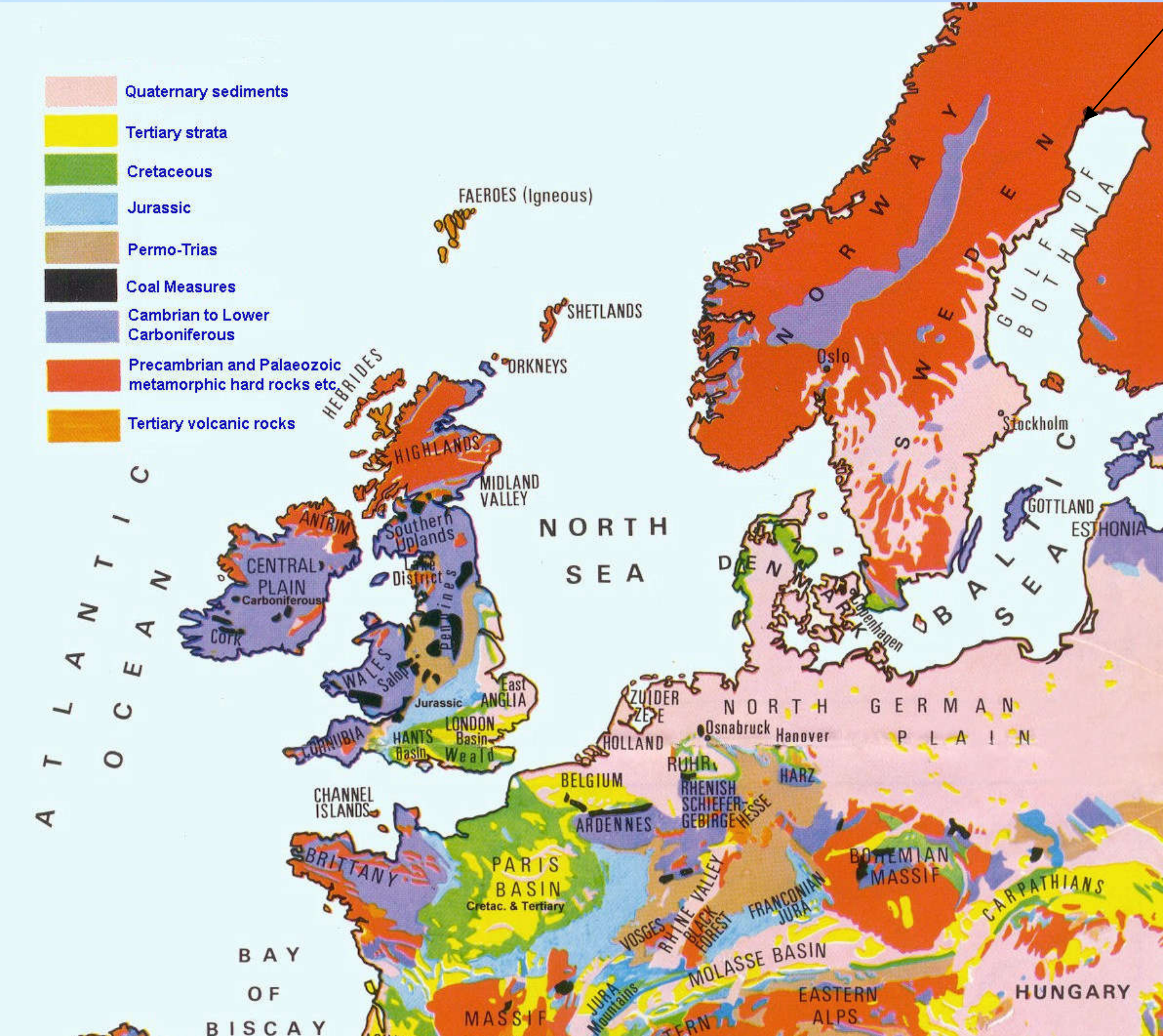
Nuclide	Half-Life (yrs)	kg
238Pu	88	4.5
239Pu	24000	166
240Pu	6600	77
241Pu	14	25
242Pu	380,000	16
237Np	2,000,000	15
241Am	432	17
243Am	7400	3
99Tc	200,000	25
129I	16,000,000	6
135Cs	3,000,000	10
93Zr	1,500,000	23
107Pd	6,500,000	7
90Sr	30	13
137Cs	30	31

Fig. 2. Long-lived Radionuclides in High-level Nuclear Waste.

Nuclear: 60 $/barile 100-120 $/barile

Gdzie ukryć odpady?

granity
> 2 mld lat

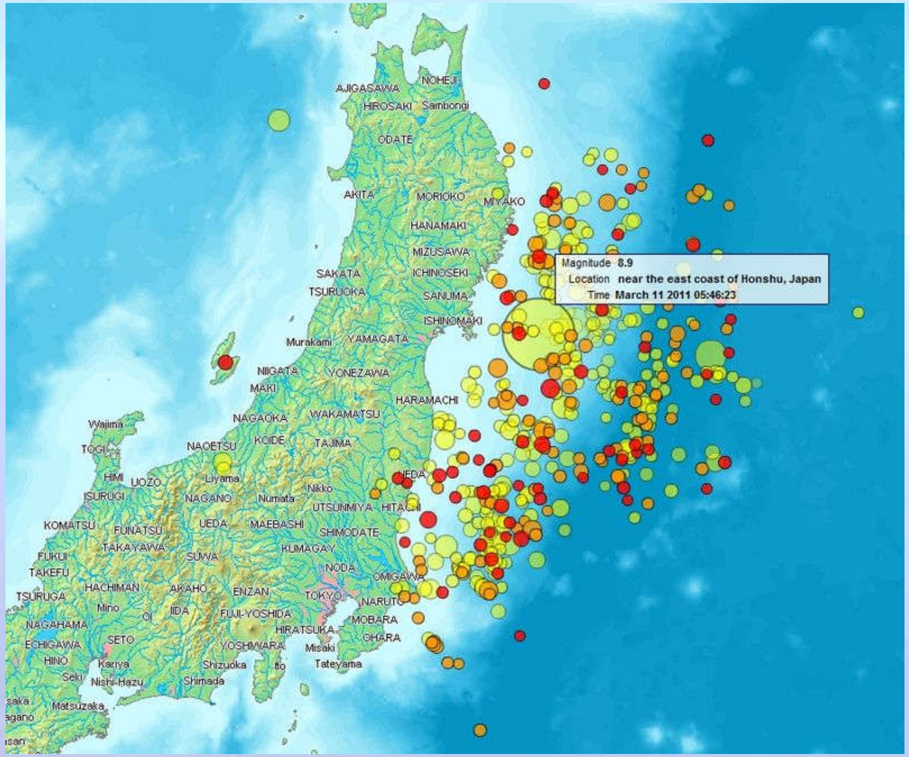


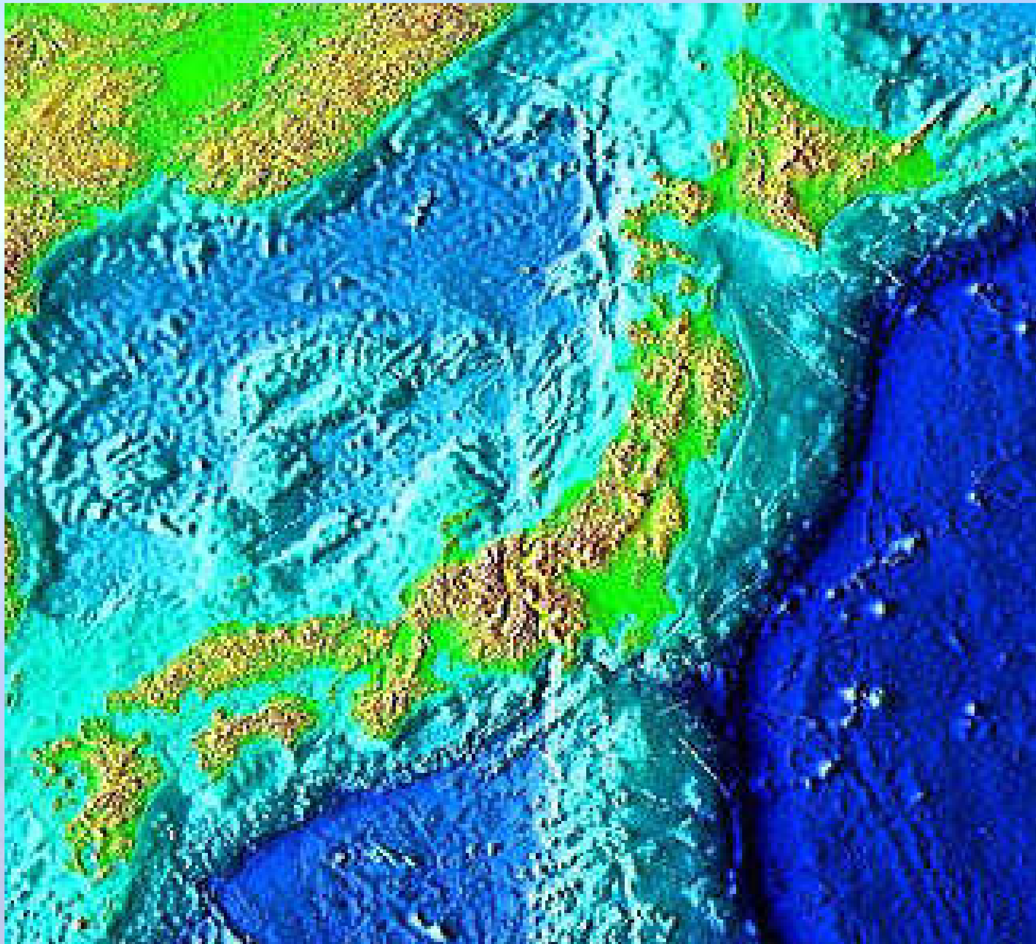
http://ww

Co się stało w Fukoshimie?

https://upload.wikimedia.org/wikipedia/commons/7/7d/Fukushima_I_by_Digital_Globe.jp

Tōhuku Earthquake





Magnitude=9.1

4º najsilniejsze w dziejach zapisów

Przesunięcie wyspy Honsiu o 2.4 m na wschód

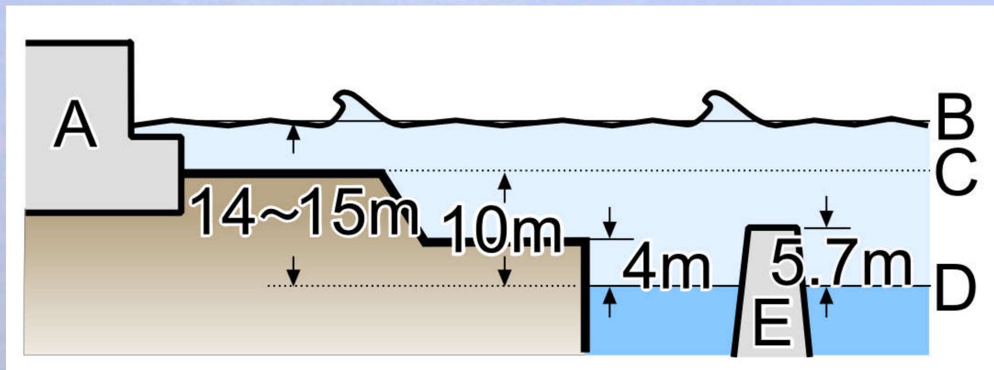
Naprężenie zakumulowane od 800 lat

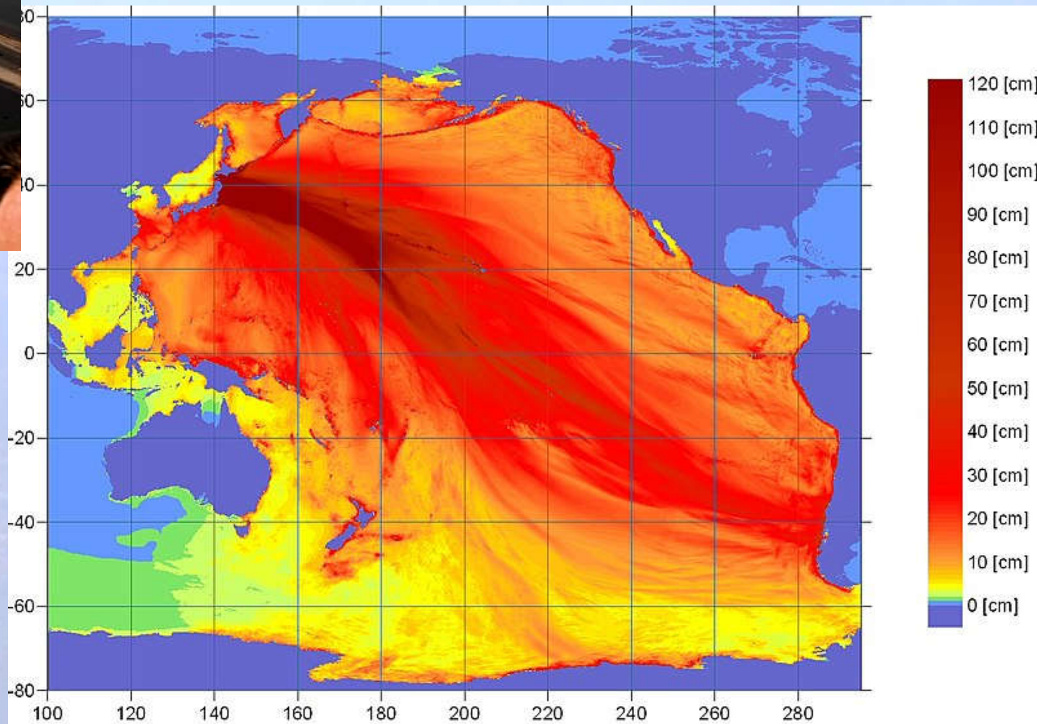
By www2.demis.nl, Uploader User:Heinz-Josef Lücking - http://www2.demis.nl/quakes/, Public Domain, https://commons.wikimedia.org/w/index.php?curid=14546462

https://en.wikipedia.org/wiki/Japan_Trench

Tōhuku tsunami

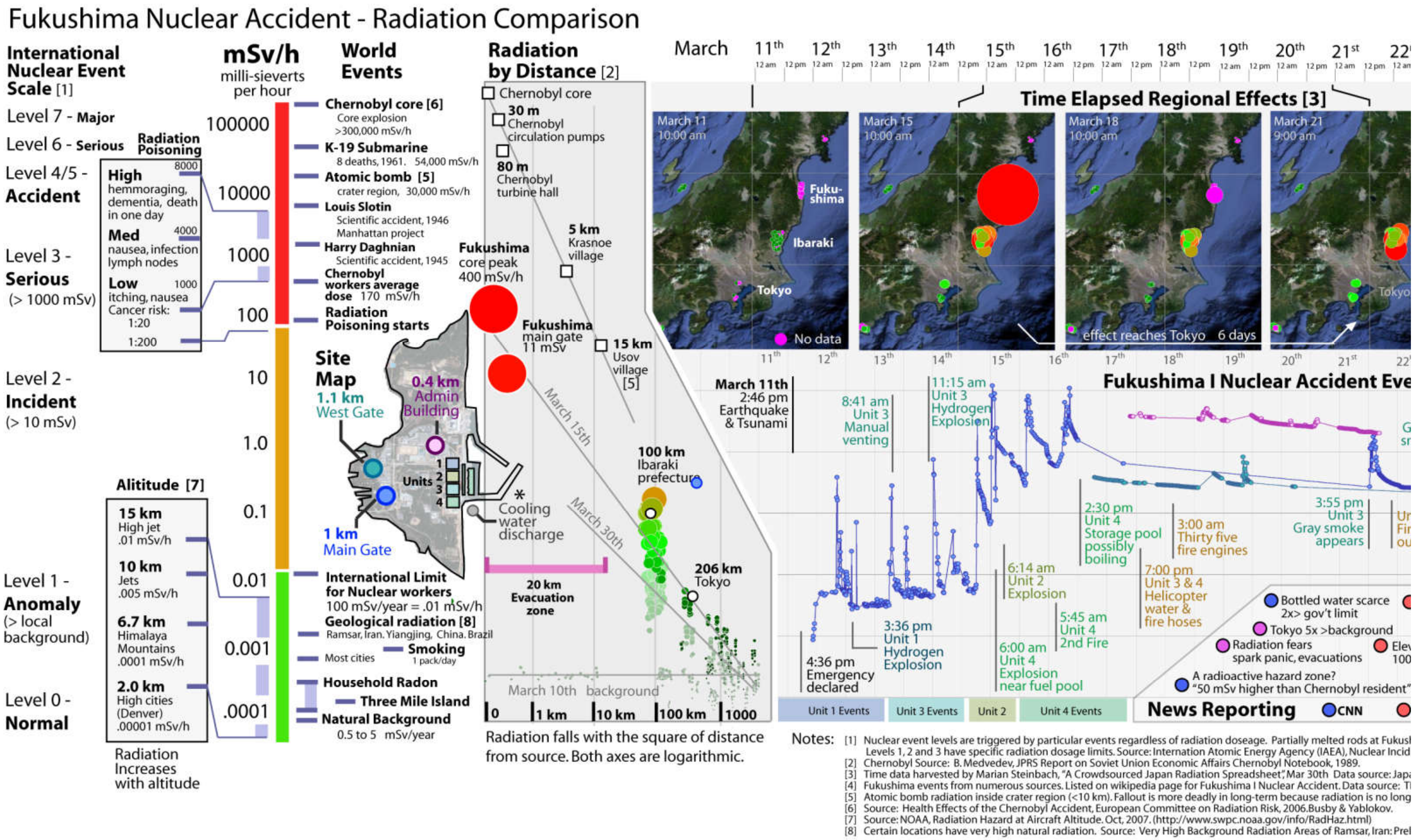
Sendai airport





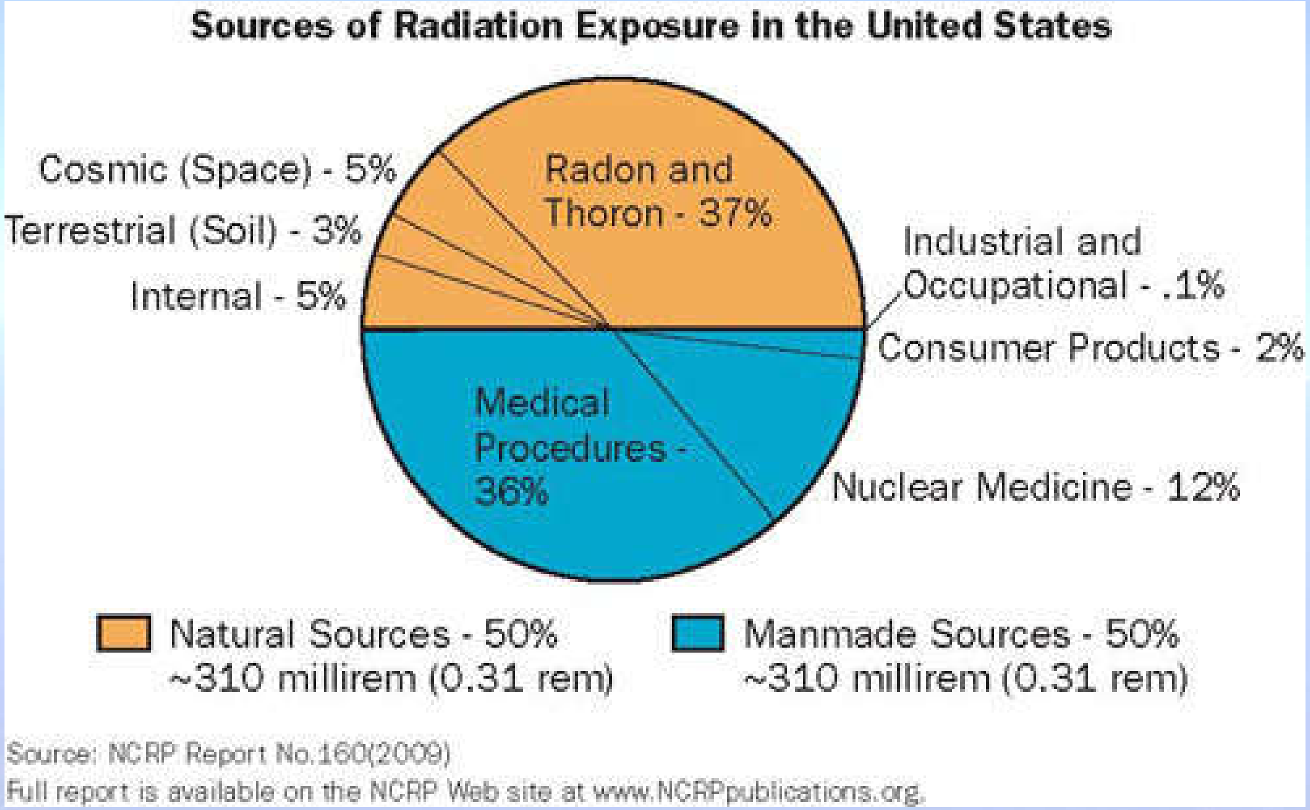
By West Coast & Alaska Tsunami Warning Center, National Oceanic and Atmospheric Administration - wcatwc.arh.noaa.gov (direct image URL [1])
There is a similar image here with a caption; "contours of forecasted maximum wave amplitudes [cm], detailing tsunami energy propagation".
Presumably the scale simply stops at 120cm; but at the coasts the wave rises much higher., Public Domain,
https://commons.wikimedia.org/w/index.php?curid=14546656

Skażenie radioaktywne?



https://upload.wikimedia.org/wikipedia/commons/2/2f/Fukushima7.png

Promieniowanie: dawka (sievert)



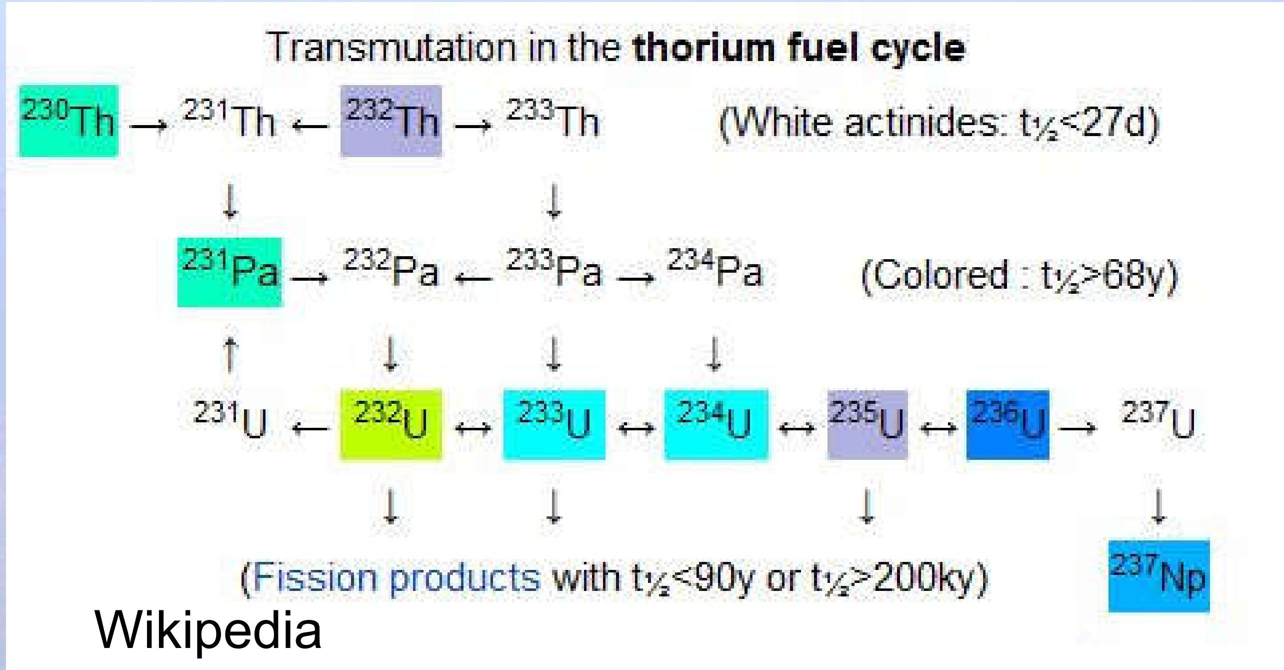
Siewert (Sv) = jednostka dawki równoważnej promieniowania jonizującego
Limit USA: 1 mSv/rok
Tomografia komputerowa (full scan): 10-30 mSv
Podróż na Marsa: 250 mSv
Fukoshima inhabitants: 68 mSv

https://www.nrc.gov/about-nrc/radiation/around-us/sources.html
https://en.wikipedia.org/wiki/Sievert

Reaktor torowy (Carlo Rubbia)

- ${}_{90}Th^{232}$ ($T_{1/2}$=1.405×10^{10} y) + $n \rightarrow {}^{233}Th \rightarrow {}_{91}Pa^{233} + e^{-}$

- ${}^{233}Pa \rightarrow {}_{92}U^{233}$
- ${}_{92}U^{233} + n \rightarrow$ fission



Wikipedia

Reakcje rozszczepienia toru wymaga zewnętrznego „zapłonu” - źródła protonów

Reaktor torowy

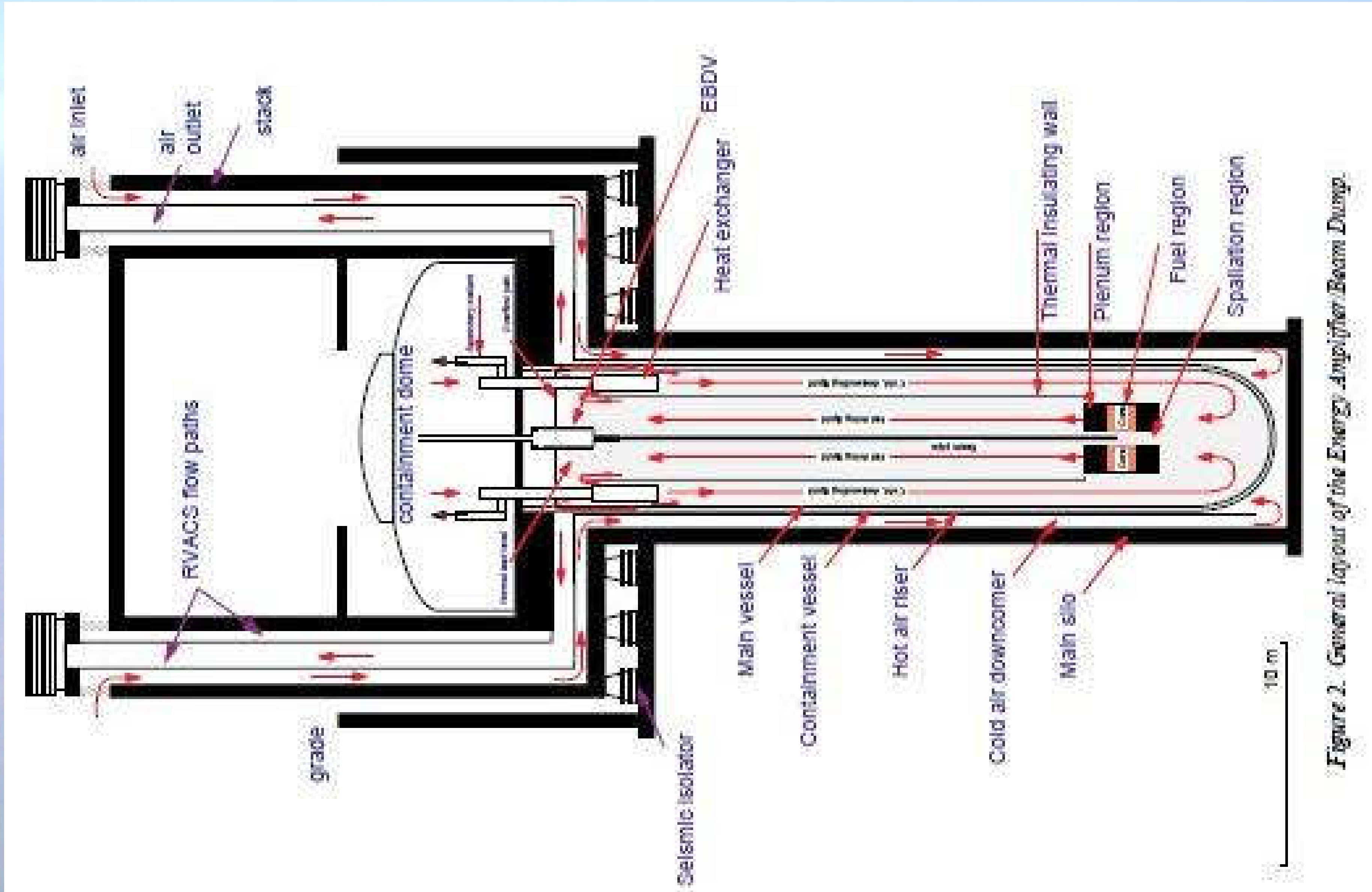


Figure 2. General layout of the Energy Amplifier Beam Dump.

Energy amplifier, C. Rubbia 1996

Table 9. Total Direct investment costs.

Item	Best Estimate Million US$	Lower limit Million US$	Upper limit Million US$
EGU	58.98	45.61	67.51
Secondary Loop	59.55	45.69	72.21
Auxiliary Systems	7.69	6.15	9.23
Accelerator System	184.45	165.45	217.10
Mech. & Electrical Classical Eq.	233.50	210.15	256.85
General Assembly	37.88	30.30	45.45
Instrumentation & Control	35.00	28.00	42.00
Structures & Civil Work	175.00	140.00	210.00
Total	792.05	671.35	920.35

Kraje UE nie wykazują szczególnego zainteresowania…
W tor szczególnie bogate są piaski bałtyckie…

GK: „Tor, alternatywa dla uranu”, Dziennik Bałtycki, dawno temu…

Thorium based nuclear reactor (C. Rubbia)

WORLD NUCLEAR ASSOCIATION

Thorium as a nuclear fuel

Today uranium is the only fuel supplied for nuclear reactors. However, thorium can also be utilised as a fuel for CANDU reactors or in reactors specially designed for this purpose. Neutron efficient reactors, such as CANDU, are capable of operating on a thorium fuel cycle, once they are started using a fissile material such as U-235 or Pu-239. Then the thorium (Th-232) atom captures a neutron in the reactor to become fissile uranium (U-233), which continues the reaction. Some advanced reactor designs are likely to be able to make use of thorium on a substantial scale.

The thorium fuel cycle has some attractive features, though it is not yet in commercial use. Thorium is reported to be about three times as abundant in the earth's crust as uranium. The 2009 IAEA-NEA *Red Book* lists 3.6 million tonnes of known and estimated resources as reported, but points out that this excludes data from much of the world, and estimates about 6 million tonnes overall. See also companion paper on Thorium.

http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/uranium-resources/supply-of-uranium.aspx

International Atomic Energy Agency
Atomic Molecular Data Services
Provided by the Nuclear Data Section

Narodowe Laboratorium Technologii Kwantowych

플라즈마물성데이터센터
Data Center for Plasma Properties

Atomic Physics at ITER

Grzegorz Karwasz

Uniwersytet Mikołaja Kopernika w Toruniu

Progress Report from IAEA Decennial Meeting,
Daejeon, Korea, 15-19.12. 2014

Sun: thermonuclear synthesis

Zadanie (na sprawdzian): znajdź w internecie wartości masy protonu i neutronu wyrażone w kg i powtórz to obliczenie korzystając z równania Einsteina. Wynik wyraź z dżulach.

Z powyższego przykładu wynika jasno, że w reakcji

$$ {}^{1}_{0}n + {}^{1}_{0}n + {}^{1}_{1}p + {}^{1}_{1}p \rightarrow {}^{4}_{2}\mathrm{He} \quad (3.13)$$

uzyskać można aż 28 MeV energii. Taki typ syntezy, z udziałem aż czterech cząstek nie jest możliwy do realizacji w warunkach ziemskich (jest on zapewne możliwy wewnątrz bardzo ciężkich gwiazd *neutronowych*). Tak w gwiazdach „zwykłych" w rodzaju Słońca jak do zastosowań energetycznych na Ziemi wykorzystywaną reakcją *syntezy termonuklearnej* jest synteza helu z dwóch ciężkich izotopów wodoru – deuteru ^{2}H i trytu ^{3}T według wzoru

$$ {}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}n \quad (3.14)$$

W reakcji tej wydziela się 17,6 MeV. Wydaje się to mniej niż w reakcji rozszczepienia uranu, ale w odniesieniu do masy paliwa w reakcji **termojądrowej** wydziela się około 4 razy więcej energii niż w reakcji „jądrowej". Eksplozja bomby termojądrowej o „sile" równoważnej 15

„Słońce w (magnetycznym) koszyku"

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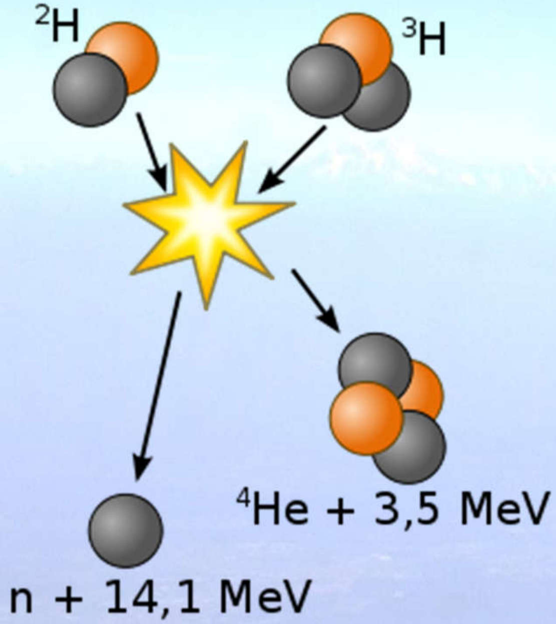
GK, *Słońce w magnetycznym koszyku* (Głos Uczelni, marzec 2017)

Fuzja termojądrowa

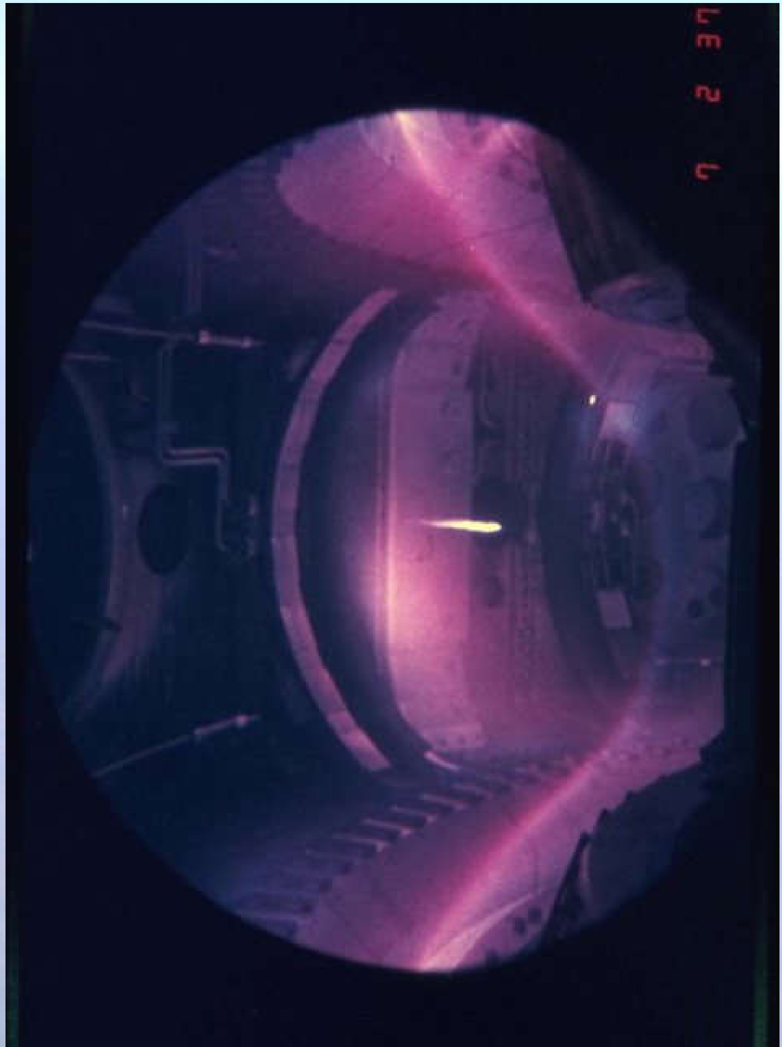


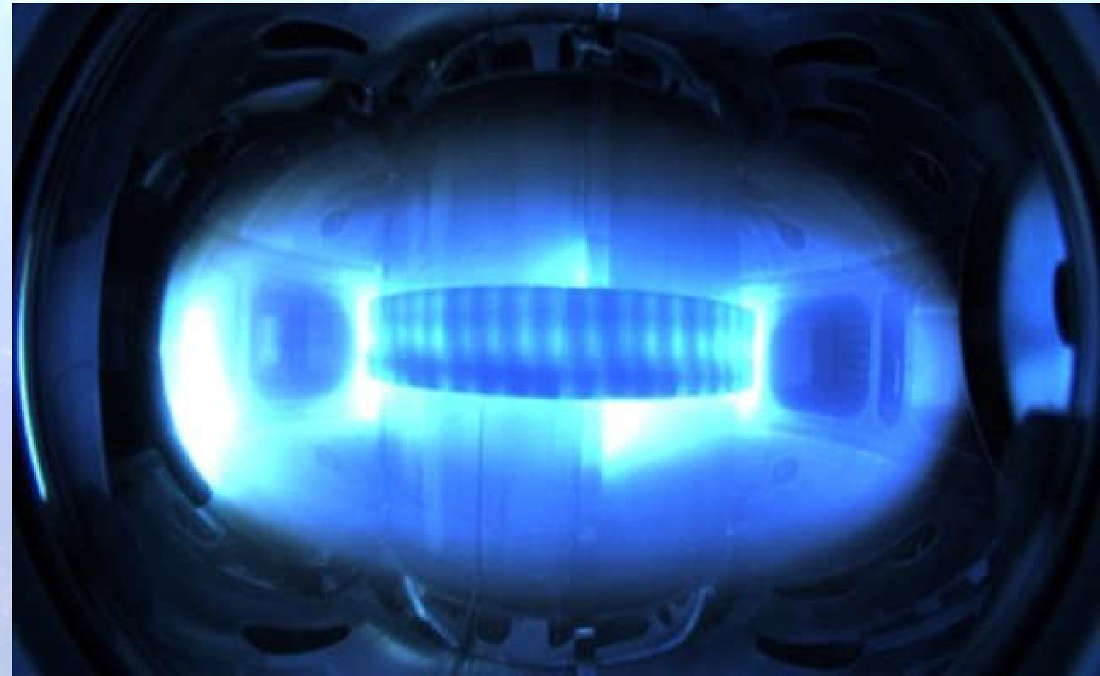
Li + *n* → ^{3}H + ^{4}He

1GWy: 2,7 bln t coal
or 250 kg ^{2}H + ^{3}H

The projected design for the next-step demonstration fusion power plant, or DEMO, designed to produce 2000-4000MW of power.

150 mln K plasma

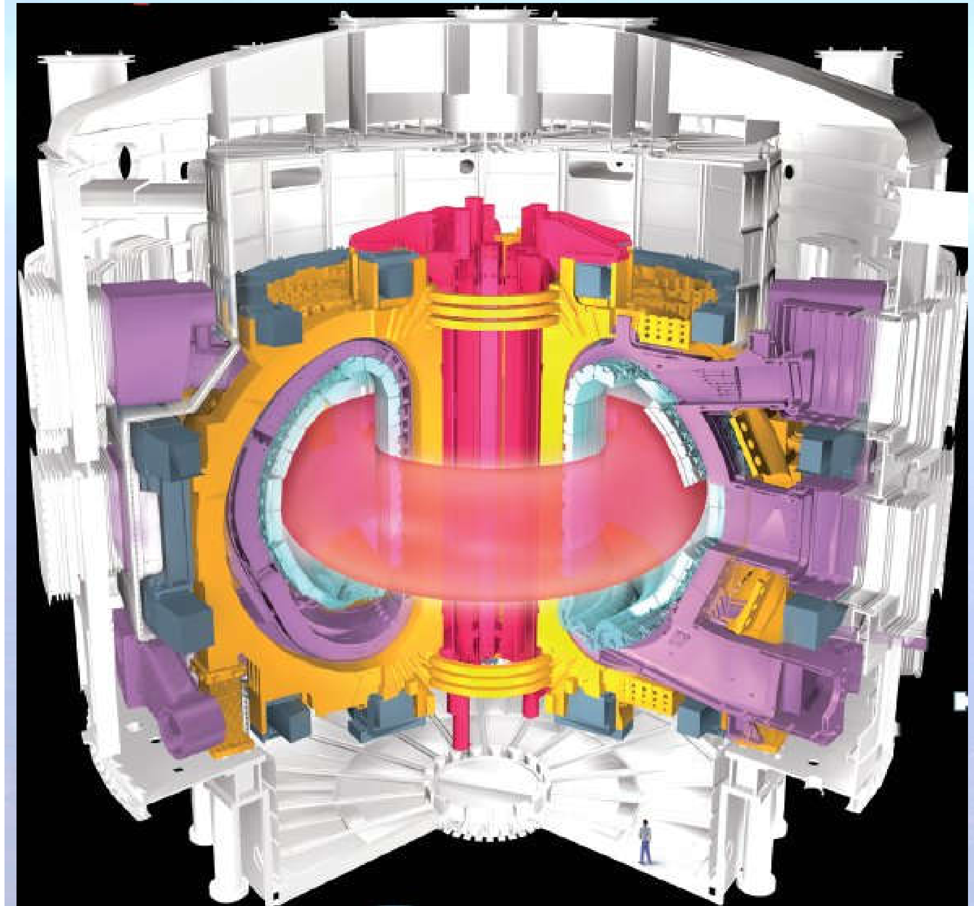


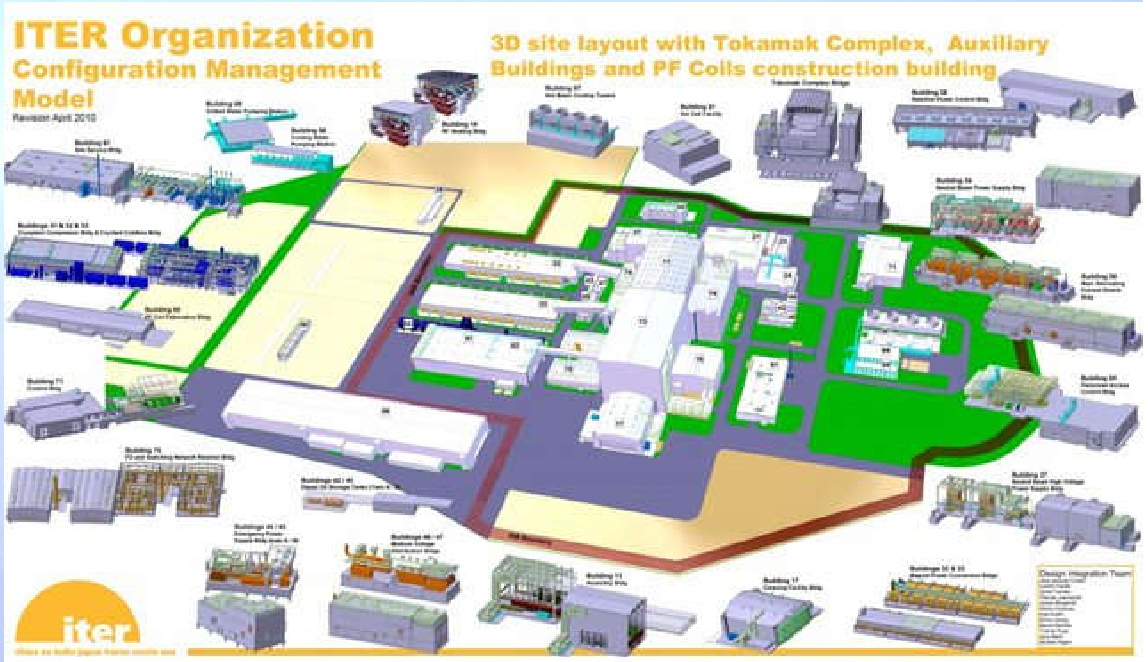


Progress towards Fusion Energy at ITER

The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

ITER, France, Cadarache





50 MW input → 500 MW output

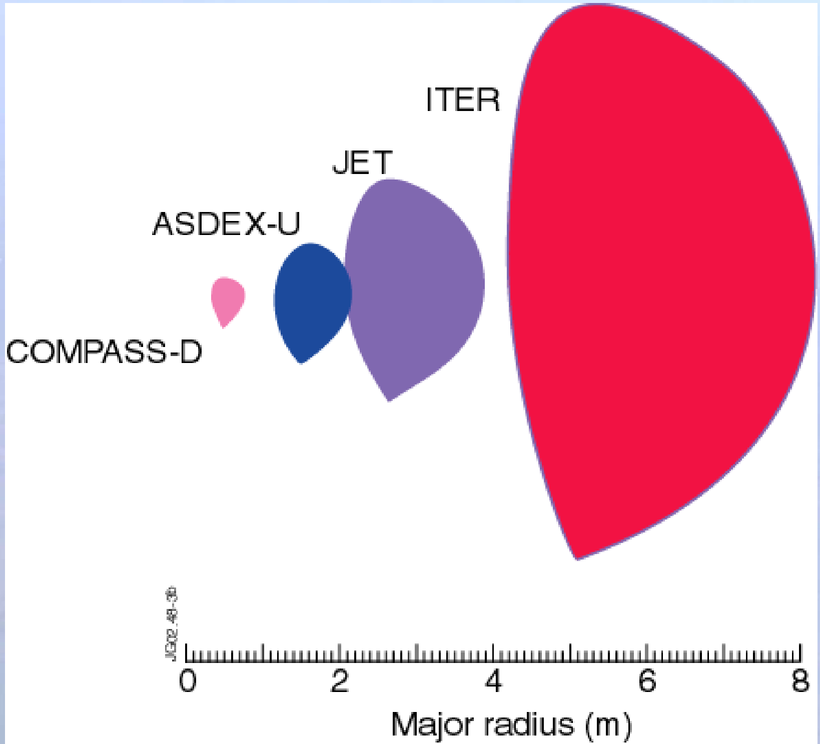
13 mld €: największy (oprócz lotów kosmicznych) projekt badawczy ludzkości

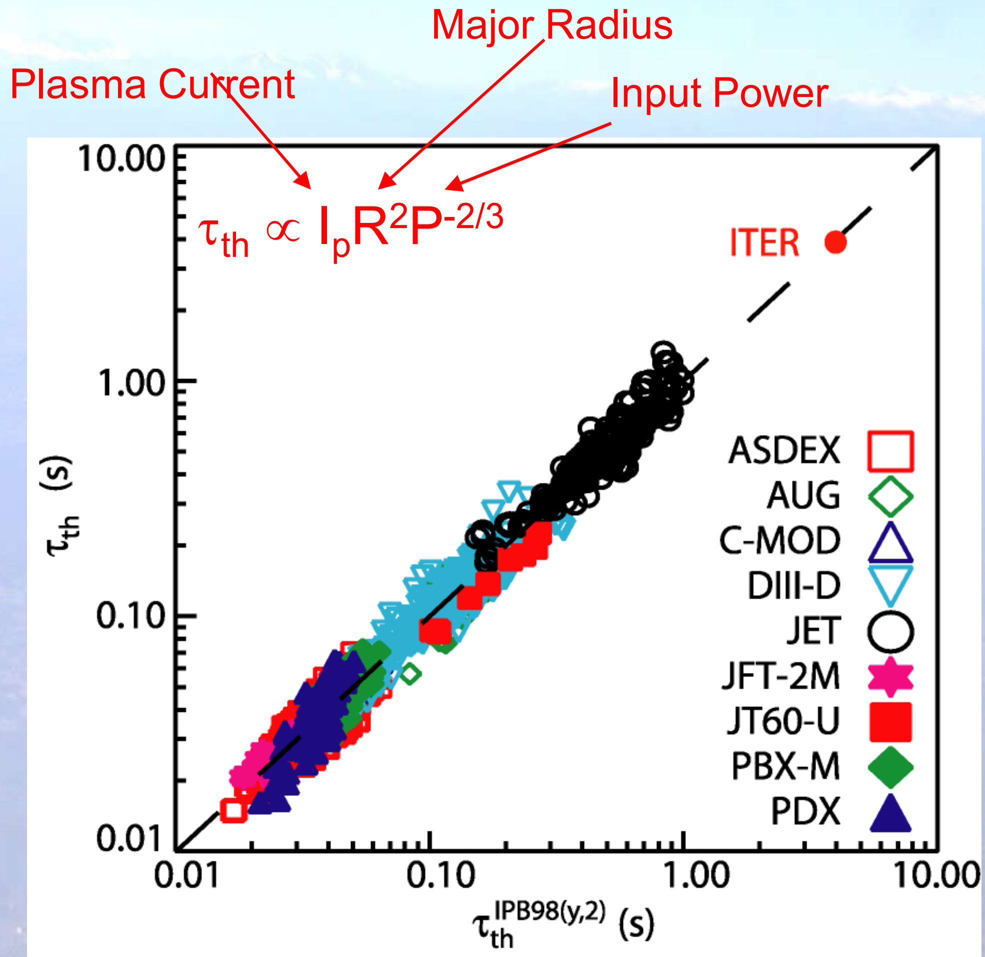
It will be operative in 2020

DEMO (Korea) – first commercial reactor: **2050**

Plasma Confinement: τ_E Scaling

- **Turbulent transport in fusion plasmas difficult to predict quantitatively:**
  - so, we use scaling experiments to predict the level of energy confinement in ITER
  - H-mode turns out to be robust enough to provide the basis for the ITER design $\Rightarrow$ significant reduction in size of device

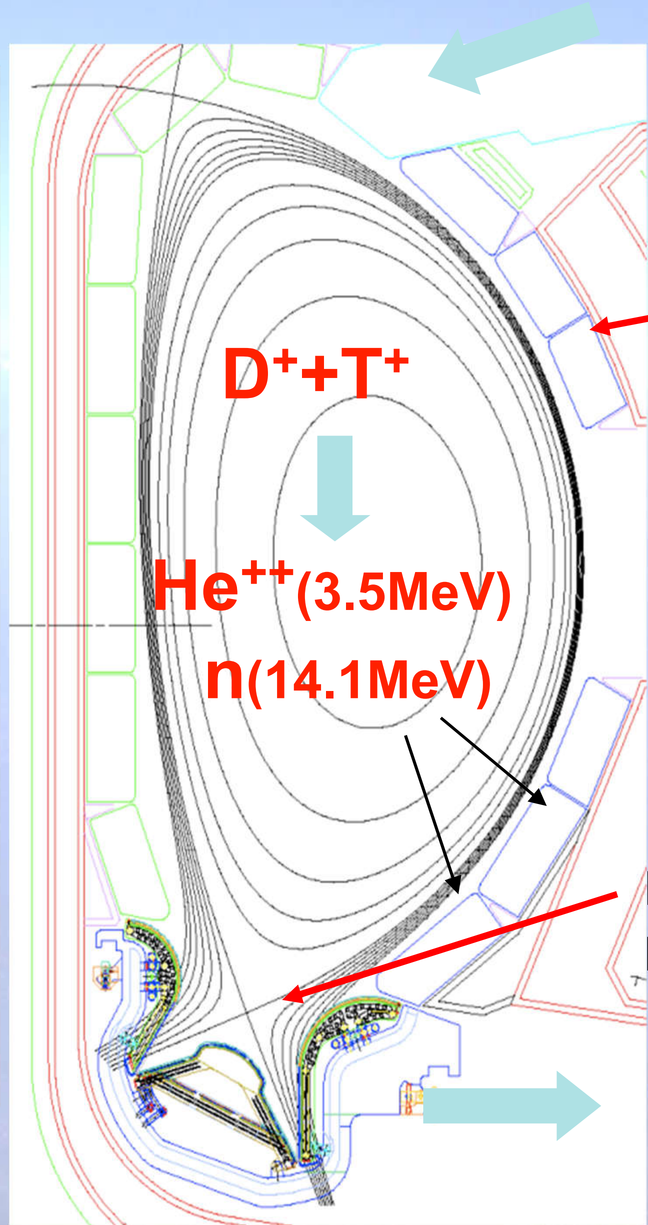




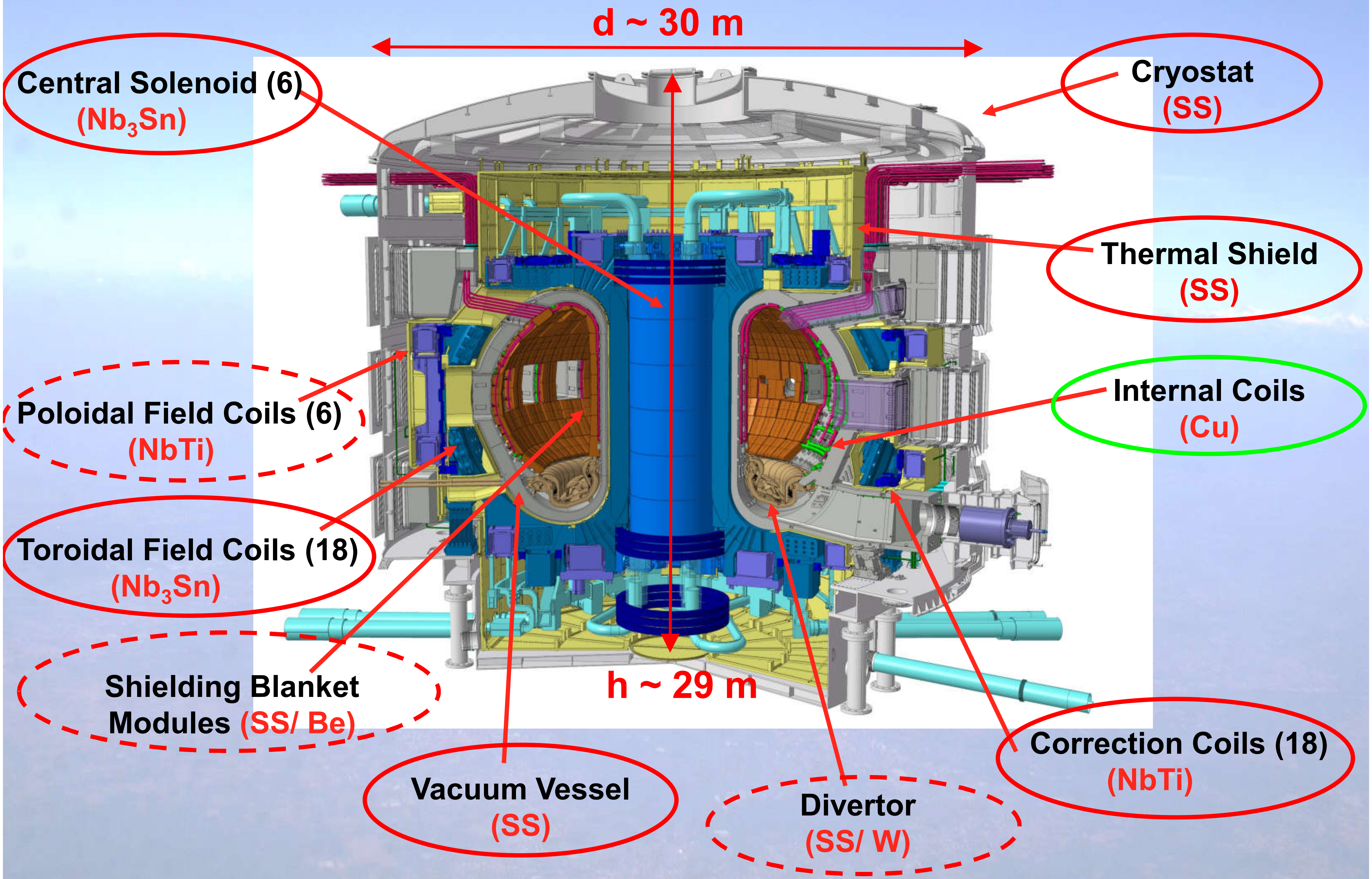
ITER: controlled reactions objectives

ITER Plasma:

R/a:	**6.2 m /2 m**
Volume:	**830 m^3**
Plasma Current:	**15 MA**
Toroidal field:	**5.3 T**
Density:	**10^{20} m^{-3}**
Peak Temperature:	**2×10^8 K**
Fusion Power:	**500 MW**
Plasma Burn	**300 - 500 s**
("Steady-state"	**~3000 s)**



ITER – Tokamak Core Components



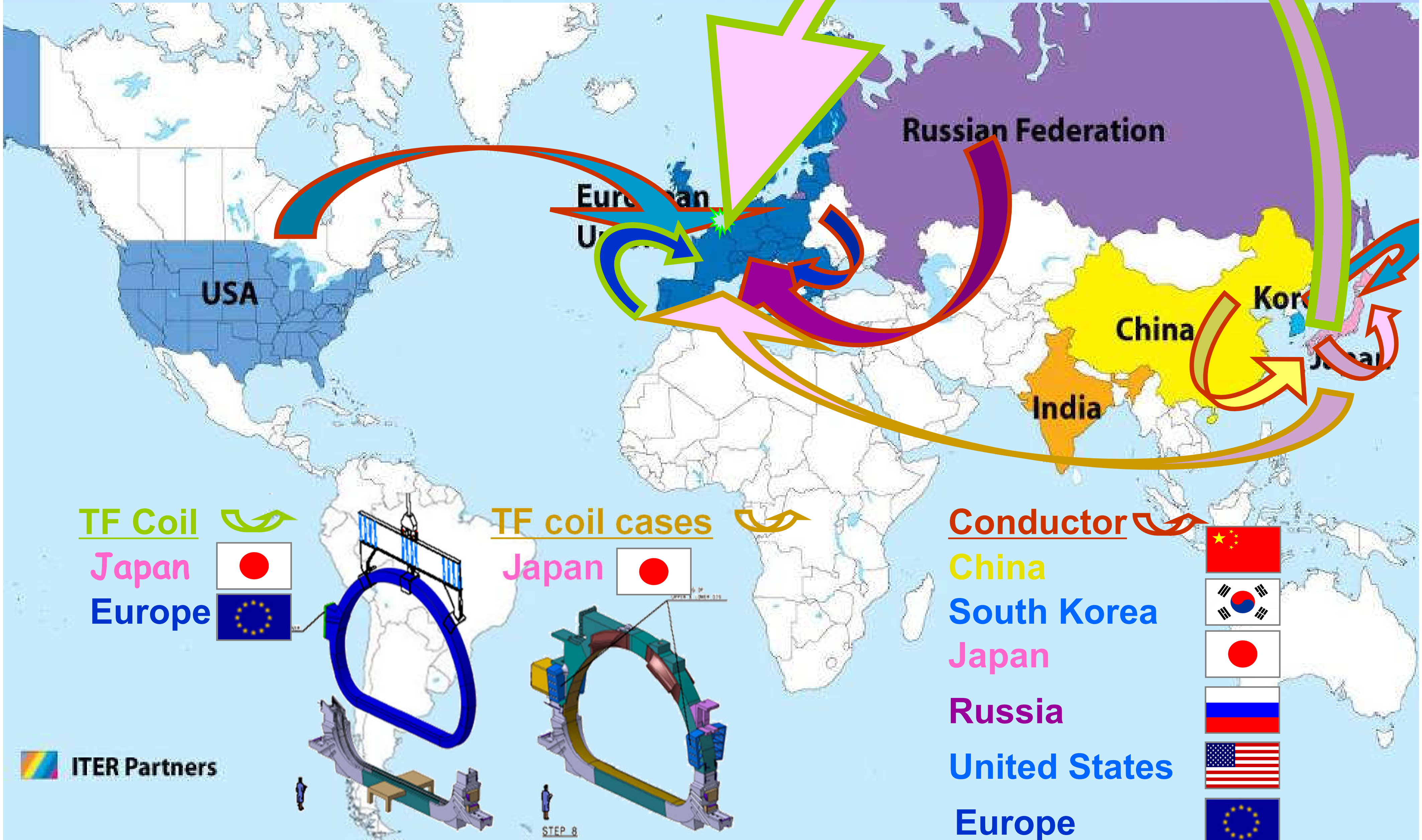
(C) D.J. Campbell, ITER

ITER – A Major International Collaboration

- **90% of ITER components will be supplied "in-kind" by the Members through their Domestic Agencies**

- **This approach necessitates the integration of ITER management, design and procurement activities across the globe**

TF Coils – A Global Collaboration



We work for you...!

Podsumowanie?