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Saving energy: reliability of national energy flows

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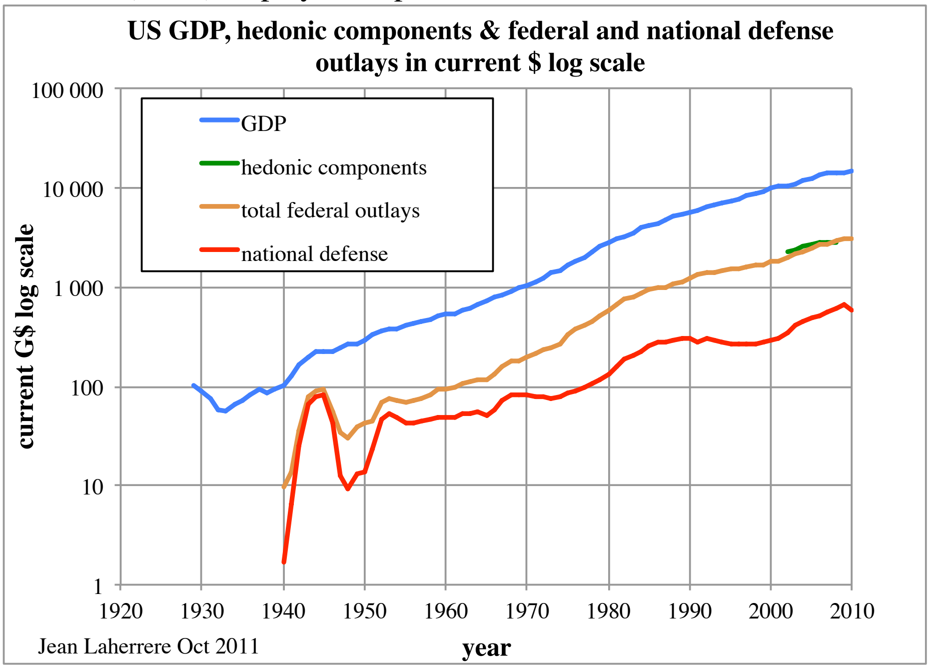
End of growth?

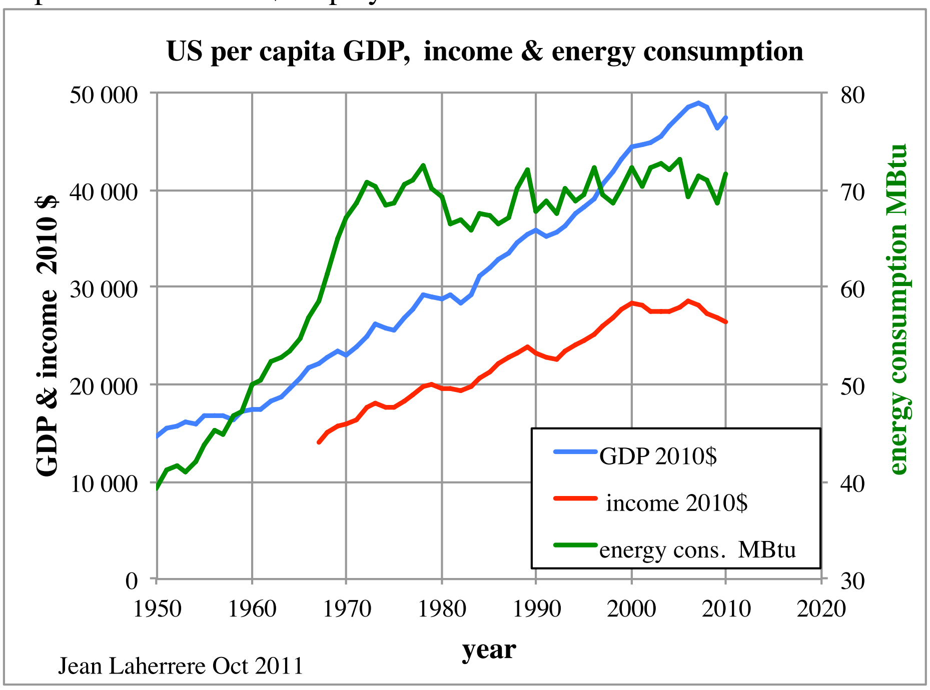
Which growth?

GDP = expenditures or Income or energy consumption: national or per capita?

US GDP in current G$ is compared in log scale to the total federal outlays, the national defense and the hedonic components (with questionable hedonic factor).
The national defense (DOD) displays a step in 1973 and 2000



The US per capita GPD in 2010 $ displays a linear increase from 1960 to 2007.



US per capita income = plateau since 2000, and energy consumption = plateau since 1972.

Let's concentrate on energy.

The world being finite, it is better to save energy than to try to find more very expensive oil & gas reserves. The best mine of savings being the waste, it is very important to know exactly how much energy we waste. A good chart being better than thousands of words, the best way is to look at the energy flow chart. But before looking, it is important to know exactly what every item of an energy flow means, because a lot of data is flawed, that is incomplete or wrong when actors are cheating.

-1-Lack of rules and referees or bad rules

In any sport there are rules and referees in order to force the players to follow the rules, if not they are thrown out when the referee shows a red card.
In the energy domain and in particular the national agencies, there are very few rules, which are contradictory and not respected, because there is no referee, and no fine if you do not follow the rule.
For the oil companies, the only rule is to make money fast, the only red card is the value of the stock market.

-Unit

In science, the International System of units (SI) is the rule, because it is easier to handle and also because it is the legal rule of every country except Bangladesh, Liberia and US not federal.
Since 1993 the US federal agencies have been forced to follow the SI, but it is barely done. And when they do it is contrary to the industry.
In 1998 the Mars Climate Orbiter probe was lost (150 M$): it crashed on Mars because NASA sent the instructions in newton (SI) when Lockheed built it in pounds (non SI).
In 1974 the first steel platform DP1 (105 m high, 6700 t) on the Frigg gas field in North Sea was lost (300 M$) by Elf, because the temporary buoyancy tanks used to put the platform on location were built with a wrong thickness because of a confusion in units.
Failures occur mainly because of bad designs, those of bad conversion are rare, but most are due to money saving, whereby security rules were not respected.
The Piper Alpha Platform blow out in 1988 (167 fatalities, cost 2.8 G£) was due to many failures because the Public Enquiry, which followed, made 106 recommendations. When Occidental asked Total to use the Frigg gas pipeline to send to shore their gas production, Total asked to see the platform. I went (as assistant to the E&P VP) on the only one packed platform (drilling, producing and sleeping) we were told that visitors were not welcome and I remember very well that the Total head of the gas pipeline was horrified by many equipment violating UK security rules. I was not surprised by the blow out! It was mainly costly for the insurance company and not for the guilty company.
After the 2010 Macondo blow out, where obviously the good practice was not followed, lacking good rules and good referees, MMS was split out into 3 branches of BOEMRE to separate regulations and enforcements.

The energy unit is the joule, which replaces the now illegal calorie (= to increase the temperature of 1 gram of water by 1°C with several definitions: IT, mean, thermochemical, 15°C, 20°C). A joule represents the work of a force of 1 newton for a move of 1 meter.
A joule is the work of lifting an apple (100 g) by one meter.
Energy reports in Australia and Canada are in PJ = petajoules = 10^{15} J or EJ= exajoule = 10^{18} J
The non SI energy unit used in the US is the British Thermal unit or Btu (illegal in the European union since the end of 1979), which is the energy to raise the temperature of one

pound of water by 1° Fahrenheit. The problem is that there are 8 definitions of Btu: IT, mean, therm, 39°F, 59°F, 60°F, UK gas industry, Gas Inspection act regulations 60.5°F.
Btu varies from 1.054 615 to 1.059 67 10^3 J (EIA = 1.05506, IEA = 1.0551).
US energy reports are in quad = quadrillion Btu = 10^{15} Btu = 1.055 056 EJ (EIA conversion factor).
In the European Union, any food should report its energy content in joule!
One hamburger has an energy content of about 1 MJ. One gasoline tank (45 L) represents 1.6 GJ.
The power unit is the watt, which is the energy of one joule during one second.
The use of kWh = kilowatt.hour seems to forget that it is in fact 1000 joule multiplied by 3600 seconds = 3.6 10^6 J = 3.6 MJ
The other non SI energy unit is the tonne oil equivalent (toe) or barrel oil equivalent (boe), but there are several definitions of the toe and boe.
1 toe can vary from 41. 85 GJ to 42 GJ (WEC)
For IEA & EIA 1 toe = 41.868 GJ = 10 Gcal= 39.69 MBtu = 11 630 kWh
There is also the tonne coal equivalent = tce with 1 toe = 1.5 tce (EIA 1 toe = 1.4287 tce and WEC 1 toe = 1.4334 tce)
The electronvolt is also an energy unit worth 1.6 10^{-19} J.
The energy industry reports in many different ways: volume or weight for oil, volume for gas, weight for coal, kWh for nuclear and hydropower.

-prefix

In addition to confusion about the units, there is also the confusion about the symbols, in particular the prefix.
For SI
M = mega (large) = million,
G = giga (giant) = billion US = 10^9
T = tera (monster = tetra without t) = square million = billion SI = 10^{12}
P = peta (penta without n) = 10^{15}
E = exa (hexa without h) = 10^{18}
In the same article it is usual to find million with different symbols like M or MM or mm or m.
Billion cubic meter = bcm in US papers = 10^9 m^3 = km^3,
but for many 10^9 m^3 = Gm^3 when $Gm^3 = (Gm)^3 = 10^{27}$ m^3 ≈ million earth volume!
The IEA 2004 energy manual writes page 56 & 192 *million cubic meters (Mm^3)*
Mm^3 is $(Mm)^3 = 10^{18}$ m^3 and not 10^6 m^3 which is in fact hm^3 (cubic hectometer), but the best way is to write 10^6 m^3!

The IEA 2004 energy manual also writes page 57 & 58 *For example, country A is importing 3 000 Mm3 natural gas from the Netherlands and 5 000* **Mm3** *from Norway, with a respective calorific value of 33.3* **TJ/m3** *and 41.0* **TJ/m3**; *38.113 TJ/m^3, to be reported in the questionnaire as 38 113* ***KJ/m^3***
in fact it should be hm^3 and not Mm^3; MJ/m^3 and not TJ/m^3; kJ/m^3 and not KJ/m^3
The IEA manual (14 authors dated 2004 and still uncorrected in 2011) confuses T tera and M mega!
There is no referee and no fine, no “carton rouge” (red card), no one is expelled!

-decimal = dot or comma and thousand = no comma

Because the decimal is indicated by a dot in the US but by a comma in many countries like France, in order to avoid confusion the thousands should never be indicated by a comma or a dot but by a space

In the US 2008 edition of the National Institute of Standards and Technology: Guide for the use of the International System of Units (SI)
http://physics.nist.gov/cuu/pdf/sp811.pdf
2008 edition
10.5.3 Grouping digits
Because the comma is widely used as the decimal marker outside the United States, it should not be used to separate digits into groups of three. Instead, digits should be separated into groups of three, counting from the decimal marker towards the left and right, by the use of a thin, fixed space. However, this practice is not usually followed for numbers having only four digits on either side of the decimal marker except when uniformity in a table is desired.

Examples:	*76 483 522*	*but not: 76,483,522*
	43 279.168 29	*but not: 43,279.168 29*
	8012 or 8 012	*but not: 8,012*
	0.491 722 3	*is highly preferred to: 0.4917223*
	0.5947 or 0.594 7	*but not: 0.59 47*
	8012.5947 or 8 012.594 7	*but not: 8 012.5947 or 8012.594 7*

The violation of this rule "no comma for thousand but space" is the rule in the US and elsewhere!

-Significant digits and accuracy of the measure

World oil proved reserves end 2009 in Gb:
-BP Statistical Review 2011 = 1 376.561 882 567 12 = 15 significant digits (1/100th b)
-EIA/USDOE (EIA site Sept 2011) = 1 341.572 32 = 9 significant digits (10 000 b)
Only the first two digits are similar and only three significant digits should be used, the total should be rounded to 1380 Gb for BP and 1340 Gb for EIA. The large number of digits to 1/100th b for BP is ridiculous, showing that BP has a poor understanding on the accuracy of the data.
I remind that the arithmetic addition of field proved reserves is not the proved reserves of the country (largely underestimated) and that the arithmetic addition of country proved reserves is not the world proved reserves.
Rounding reflects the accuracy of the measure: for example 1000 means that the real value is between 900 and 1100 (or 800 and 1200) and 1 between 0.5 and 1.5

So 1000 +1 = 1000
and not 1001

-heat content

EIA oil 1 b = 5.08 MBtu Sudan, 6.35 MBtu Cuba median 5.88 Mbtu: range 1 to 1.25
EIA NGPL 1 b = 3.28 Mbtu Colombia, 5.08 Algeria median 4.29 Mbtu: range 1 to 1.55
EIA dry gas 1 cf = 0.78 kBtu Poland, 1.3 kBtu Greece, median 1.05 kBtu: range 1 to 1.67
IEA NG 1 m3 = 35.4 MJ Netherlands, 37.83 Russia, 39.17 Algeria, 42.51 Norway,

Calorific value can be measured as *gross* (including all the heat) or *net* (excluding the latent heat of the water formed during combustion). The difference is about 5 to 6% for solid and liquid and 10% for natural gas.

For natural gas the energy of one cubic meter with standard conditions = 15°C & 760 mm Hg is 1.055 higher than with normal conditions = 0°C & 760 mm Hg.
Again no consensus to use for the world the same rules!

-density = specific gravity

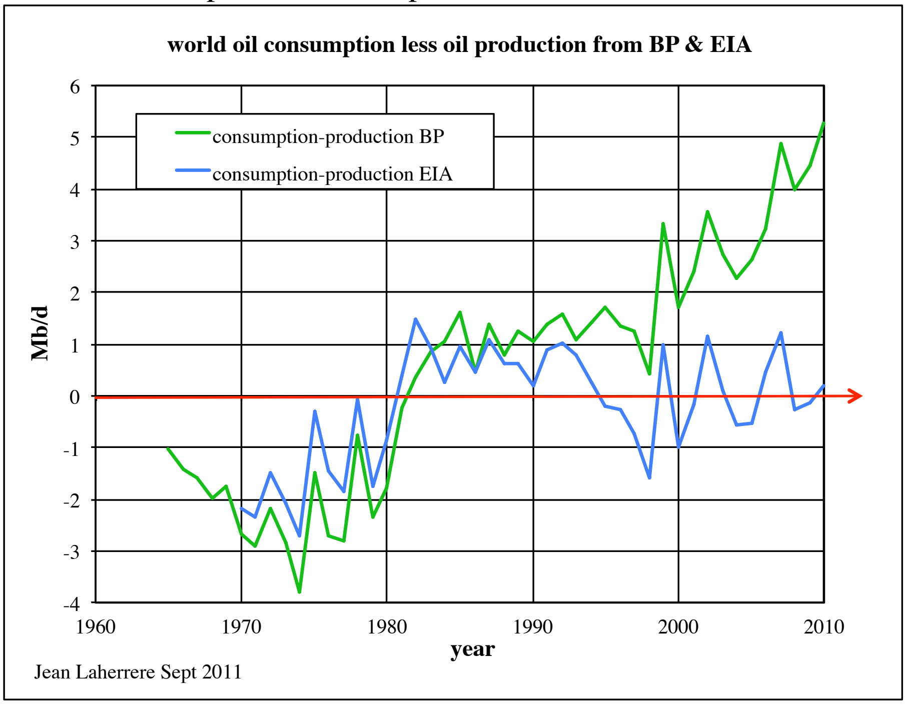
kg/m^3 or US gravity °API =145,5 / (sp gr -131.5) or b/t
IEA manual 2004
from 6.2 b/t in Surinam to 8.3 b/t in East Timor, median 7.3 b/t
page fuel oil is heavy when over 900 kg/m^3 = <25°API page 71
page 72 heavy <22°API = >922 kg/m^3
Colin Campbell, for his regular oil, excludes heavy oil at <17.5°API
There is no consensus on the definition of heavy oil, only for extra-heavy, that is heavier than water.

-definition of energy term

The same unit is used for work, energy and heat: it is confusing.
Energy does not die, it only changes and ends into heat.

-definition of oil

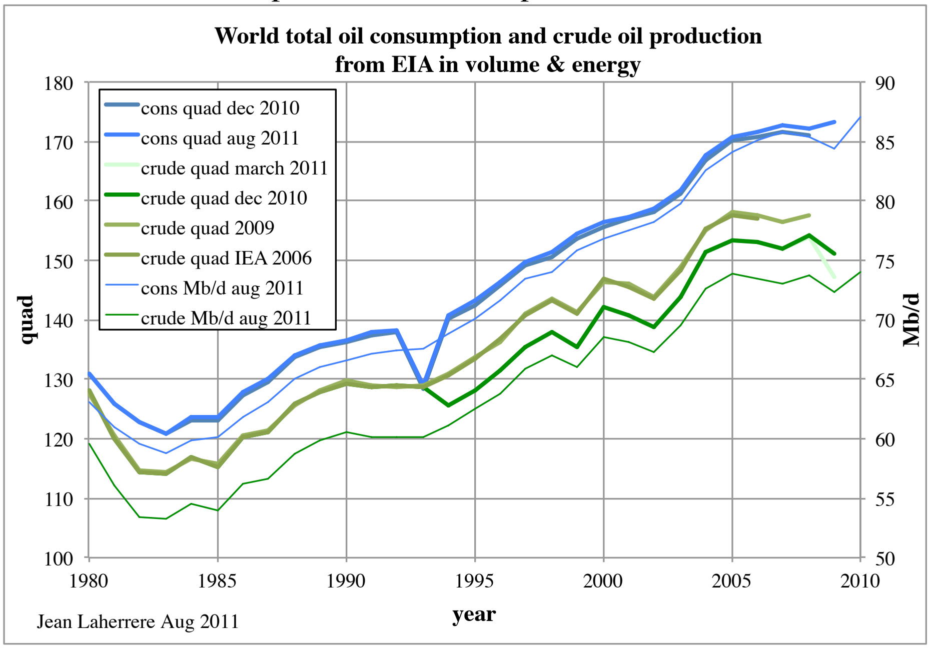
What is oil? Webster = unctuous combustible liquid, soluble in ether, but not in water, leaving a greasy stain on paper.
BP statistical review reports **oil supply** where biomass and coal derivatives are excluded, and **oil consumption** where biofuels are included. Why does BP use the same term?
The plots of the difference oil consumption less oil production from BP and EIA are close from 1970 to 1991 but started to diverge since 1995 because the omission of biofuels by BP in the production data.
Figure 1: World oil consumption minus oil production from BP & EIA



-energy equivalence

Each oil field, each coal mine has a different heat content which also varies with time.
Oil is measured either in volume or in weight, and the density should be also indicated in order to convert from one to the other. But it should be also reported in energy.
Each fuel should be reported in energy, but also in volume and weight: that is three values for every month, or for every year.
In the past EIA was reporting the world oil supply and crude oil production in volume (b) and in energy = quad (Btu), but there were mistakes and discrepancies, then the EIA has stopped reporting world oil production in energy, it is now only for oil consumption

Figure 2: World total oil consumption and crude oil production from EIA in volume & energy



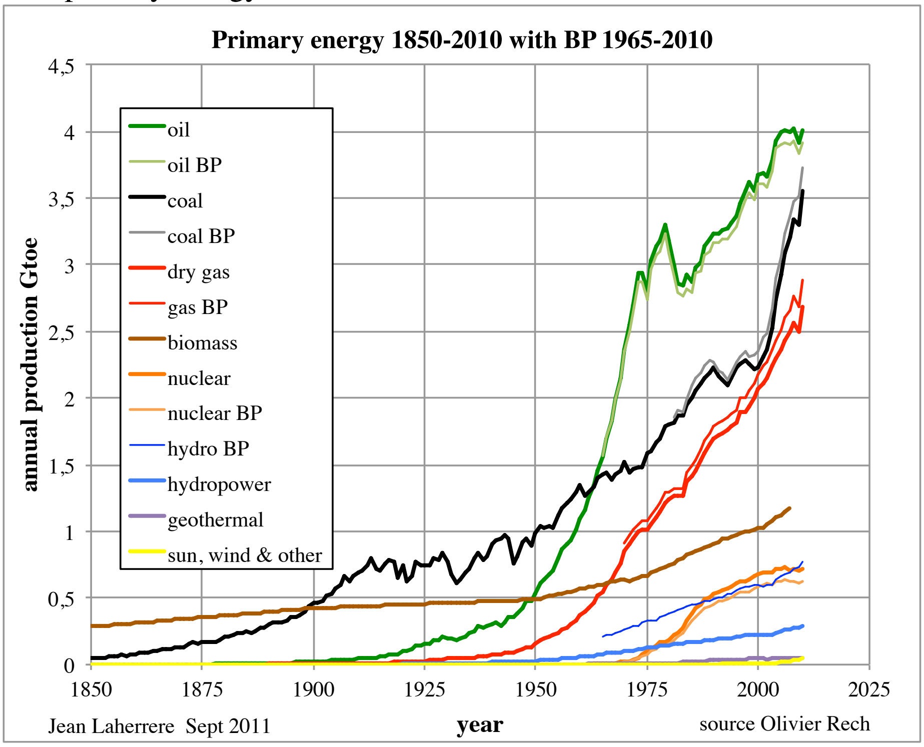
It is obvious that the plot in quad is wrong for the year 1993 consumption (that's been reported for years) and for 1994-2009 for crude production: if the IEA was plotting charts more often, this mistake should be easier to correct.

When comparing different energy sources (fossil fuels, nuclear, hydropower, geothermal, wind/sun) measured with different units it is necessary to make assumptions (energy equivalence) to compare them and to add them using a single unit.
These energy equivalences are arbitrary, needing consensus and evolution.
To convert the MWh measured for electricity into toe, there are two methods:
-*consumption equivalence* estimating the amount of oil which when burned will deliver the same amount of heat, where MWh = 0.086 toe, described by the IEA as the *physical energy content*.
-*production equivalence* estimating the amount of oil in a thermal plant which will deliver the same MWh, where MWh = 0.222 toe, described by the IEA manual as the *old partial substitution method*.
The difference is a ratio of 2.6!

-France as an example of change in energy equivalence

The best example to show the importance of these conversions factor is when France in 2001 decided to change its own national factors to use the IEA factors.
The electricity from nuclear went from 1 MWh = 0,222 toe (efficiency 38.7%) since 1974 (before it was 1 MWh = 0,27 toe corresponding to an efficiency of 31.9%) to 1 MWh = 0.260606 toe (theoretical efficiency of a thermal plant of 33%).
Electricity from geothermal sources is converted with 1 MWh = 0.86 toe (efficiency 10%), but electricity from conventional plants, wind, sun, tide is converted with 1 MWh = 0.086 toe
The percentage of nuclear in France's primary energy in 2001 moves from 79.1 Mtoe (30.8%) with the old method to 104.4 Mtoe (38.8%) with the new method: it is a large increase (26%) in percentage. The final energy consumption was reduced from 232.1 Mtoe with the old method to 175.1 Mtoe with the new method, a reduction of 25%, just by changing the methodology!
This example shows that these energy equivalences are not very reliable.

For nuclear electricity, now IEA is using the amount of the heat production. The European Union members report the steam generation on a monthly basis. For other countries where such information on the amount of steam supplied to the plant is not available, the IEA converts the gross electricity generation by a thermal ed fficiency of 33%. For geothermal energy, the IEA uses the primary heat, if not the thermal efficiency is taken at 10%. For hydropower the efficiency is 100%.
But comparing the primary energy from a 1865-2010 synthesis compiled by Olivier Rech (former IFP and IEA) and BP 1965-2010, the discrepancy is weak for most fuels except for hydropower (blue), **where BP is about three time the IEA**
Figure 3: World primary energy 1850-2010 with BP 1965-2010



Biomass is very difficult to estimate because of the large amount of non-commercial biomass (in particular dungs). BP does not report biomass.

Rules are necessary to present energy consumption of each source and how they vary.
The IEA energy Manual gives the difference between IEA and Eurostat for France 1999 natural gas in TJ page 36

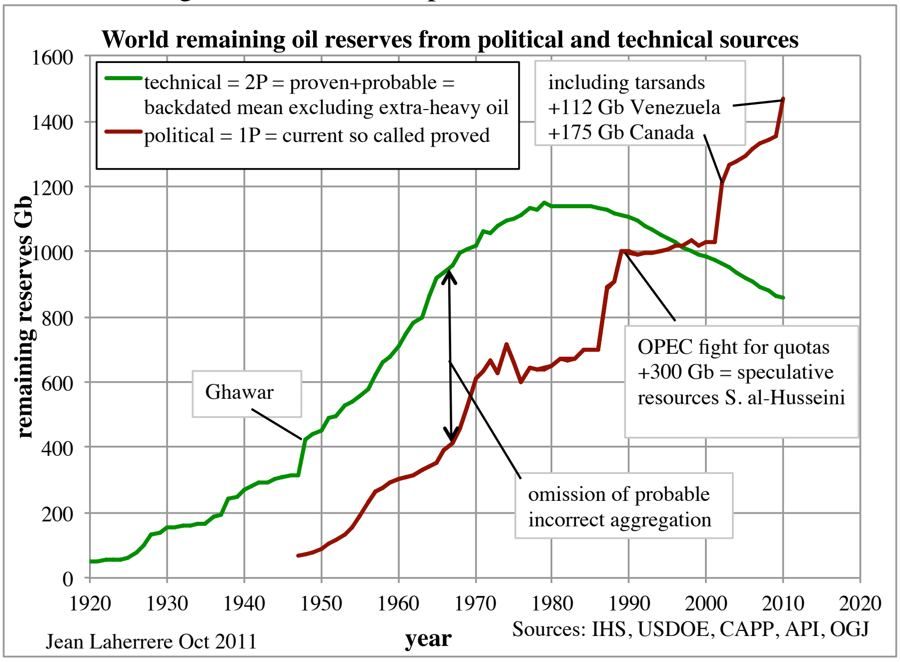
	Eurostat	IEA
Gross inland consumption	1 604 071	
Domestic supply		1 604 071
Final consumption		1 513 901
Available for final consumption	1 534 341	
Final energy consumption	1 410 755	

Only the two first digits are the same for final consumption and the data should be restricted to no more than 4 significant digits using PJ and not TJ! They ignore what is inaccuracy!

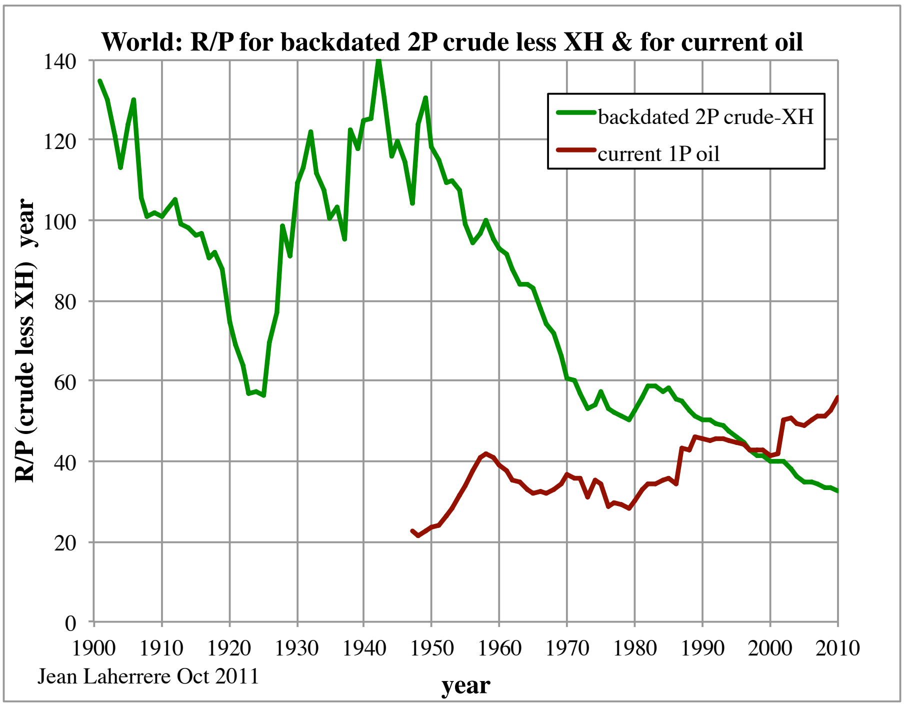
-reserves

The only rule for reporting reserves, which was followed by most majors because they are listed on the US stock market, was the SEC rule of reporting only proved reserves, based on very old 1977 SPE definitions, forbidding to report probable reserves when every operator decides the development of an expensive field on the *net present value* based on mean

reserves = proved + probable = 2P. This only SEC proved rule was mainly designed to protect the bankers and the shareholders in order to get the minimum value in case of bankruptcy. But it was disturbing the real estimate of the potential of a country, when the rest of the world was using the 2P estimate.
The US reserve growth is due partly to the omission of probable reserves, but mainly because the arithmetic addition of field proved reserves to measure the national total is scientifically incorrect (a probabilistic addition is necessary) and underestimating by half the real proved value of the country.
The 1977 SEC rule was obviously obsolete because meanwhile, the SPE/WPC has changed the reserve definition many times. So the SEC decided to change the rule in 2010, and they went too far. Before, proved reserves had to be the volume of the spacing of a producing well, now it can be estimated much larger with only a model, that can remain confidential. Many claim that the increase in shale gas reserves is due to the new technology of horizontal drilling and hydraulic fracturation (a technology that's been used for over 30 years), in fact it is due to the new change in SEC reserves definition.
Figure 4: World remaining oil reserves from political/financial and technical sources



The often used misleading R/P also shows a completely different trend, when using backdated (technical) or current (political) reserves.
Figure 5: World R/P from backdated 2P crude less XH oil and current 1P oil



-2- US energy flow charts

The Lawrence Livermore National Laboratory (LLNL, which is funded by USDOE) provides the energy flow charts for the US from 1976 to 2009 (with also 1950, 1960 and 1970) on the website https://flowcharts.llnl.gov/index.html

But the evolution of the annual LLNL reports with time shows that there is no rule and that each author does what he wants, despite the fact that the data always gives as reference the USDOE AER report, yet the data is interpreted and the revisions, which are numerous and significant, are not indicated.

Each author seems to have as a goal to do differently from his predecessor.

It is not a team effort!

Since 1993, the US federal agencies have been forced to follow the International system of units (SI) and energy should be reported in joule, like it is in Australia or Canada, but the USDOE/EIA publishes energy in quad (1 quad = 10^{15} Btu = 1,055 EJ). It is only for the period from 1995 to 2002, that the energy flows are reported (G.V.Kaiper) in PJ (petajoule with 1 PJ = 0,024 Mtoe, 1 Mtoe = 41.67 PJ), yet all the historical series are in quad.

The graph displays the energy use on the left and on the right two outputs: lost energy (called rejected energy from 1950 to 2009, but lost energy for 2001 and 2002) and useful energy (called useful energy from 1950 to 2002, but energy services since 2003).

For 2008, the LLNL publishes the following graph, almost identical to the graph from the USDOE (Office of Science), except that nuclear is at 8.15 instead of 8.45 and *rejected energy* = ***wasted*** and *energy services* = ***used.***

The title is *energy use,* against *energy production and usage*.

There is no consensus on the definition of energy terms among the scientists from the LLNL.

What is the meaning of ***energy services***?

For most it is a support to save energy and not the useful energy or used energy! There is a “energy services directive” (ESD) within the EU Directive 2006/32/EC, Art A5(5) with a savings target of 9% in 2016 (on the final inland energy consumption).

In US there is a National Association of Energy Service companies and the US energy services company (ESCO) industry had an activity amounting to about 3.5 G$ in 2006.

So “***energy services***” is a poor wording by the LLNL to represent the **used (or useful) energy**, which was the term used before and it is hard to understand the reasons for the change.

Figure 6: US 2008 energy flow from the LLNL

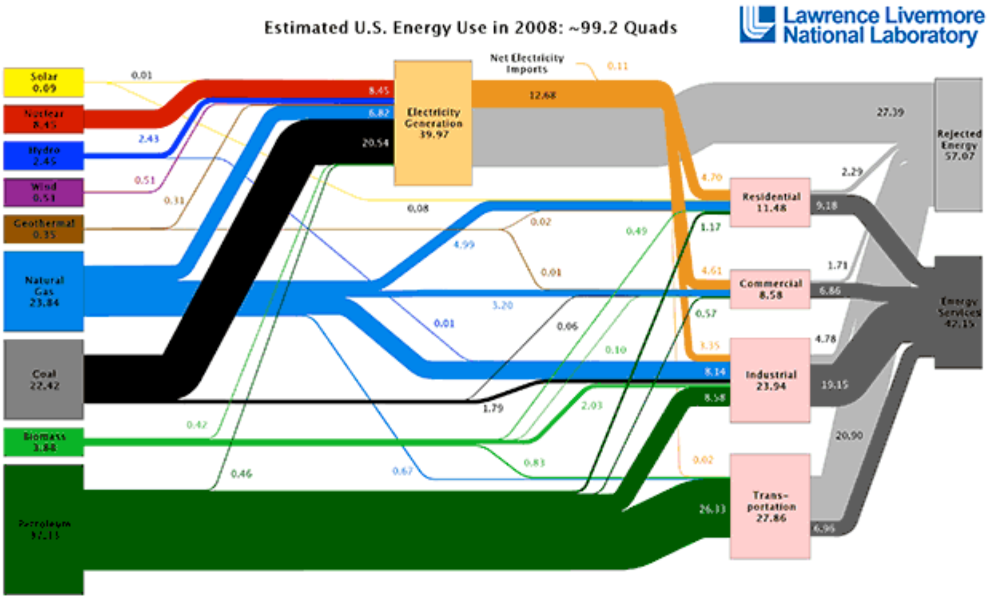
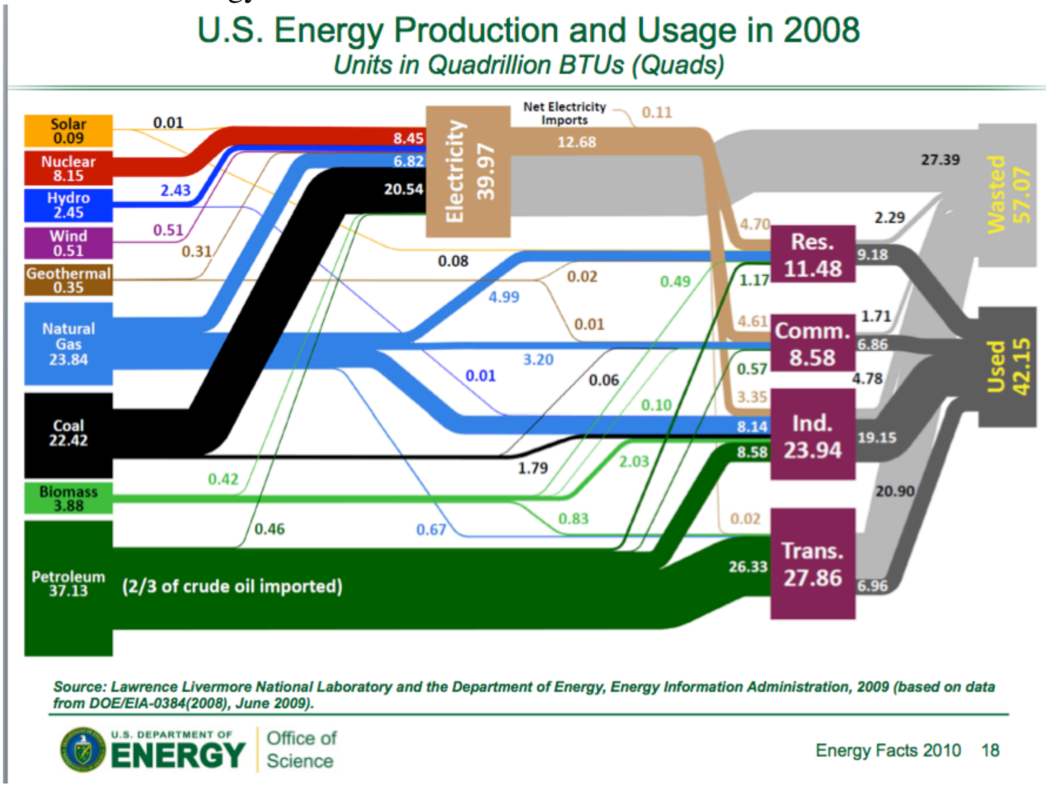


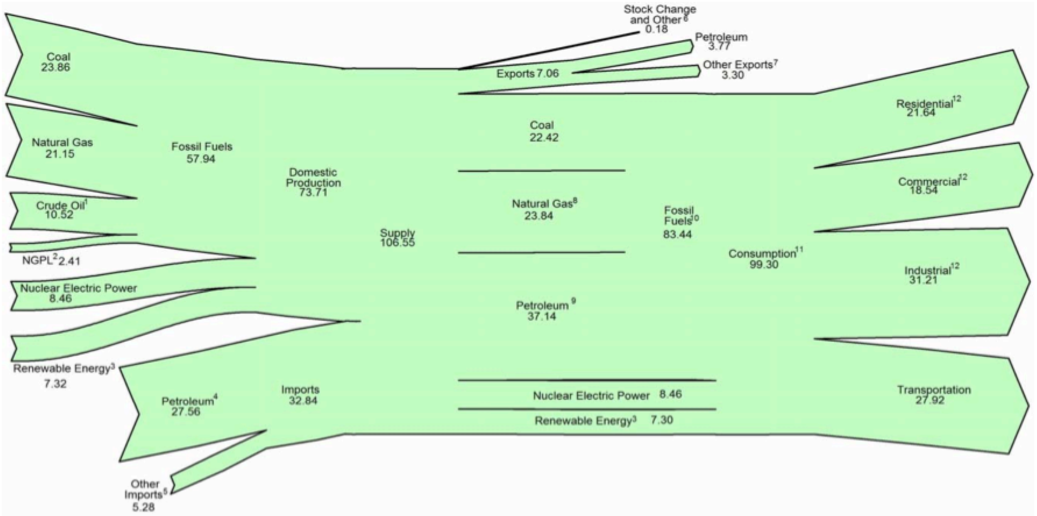
Figure 7: US 2008 energy flow from the USDOE Office of Science



All the data comes from the USDOE/EIA AER reports, but the AER presentation of the flow is quite different, because you cannot see what is useful and what is lost: it was guessed by the LLNL authors, using simple assumptions of efficiency (80% for residential, commercial and industrial, but 25% for transportation)!

Figure 8: US 2008 energy flow from the EIA AER

Figure 1.0 Energy Flow, 2008
(Quadrillion Btu)



It is a pity to see that all the 2008 data is given with 4 significant digits when the accuracy of such data is such that the second digit is questionable and the others are surely wrong.
For 1988, the edition of the previous year was corrected and the correction was important, going from 78 quads to 80 quads. The rejected energy was increased from 41.8 to 43.6 quads and the useful energy from 30.3 to 30.6 quads.

Figure 9: US 1988 energy flow = 80 quads after revision in 1990

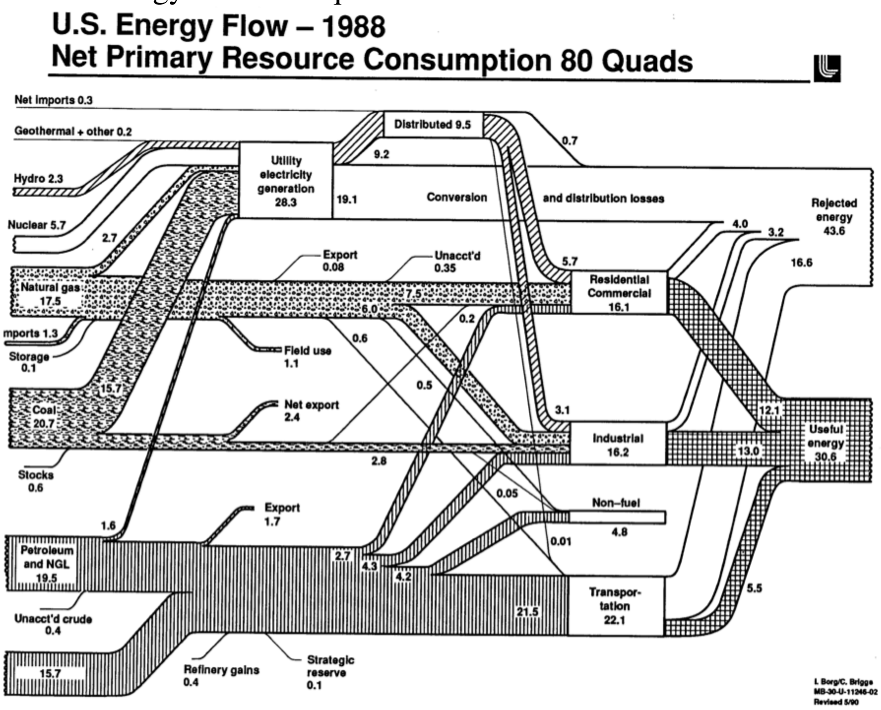


Figure 10: US 1988 energy flow = 78 quads in 1989

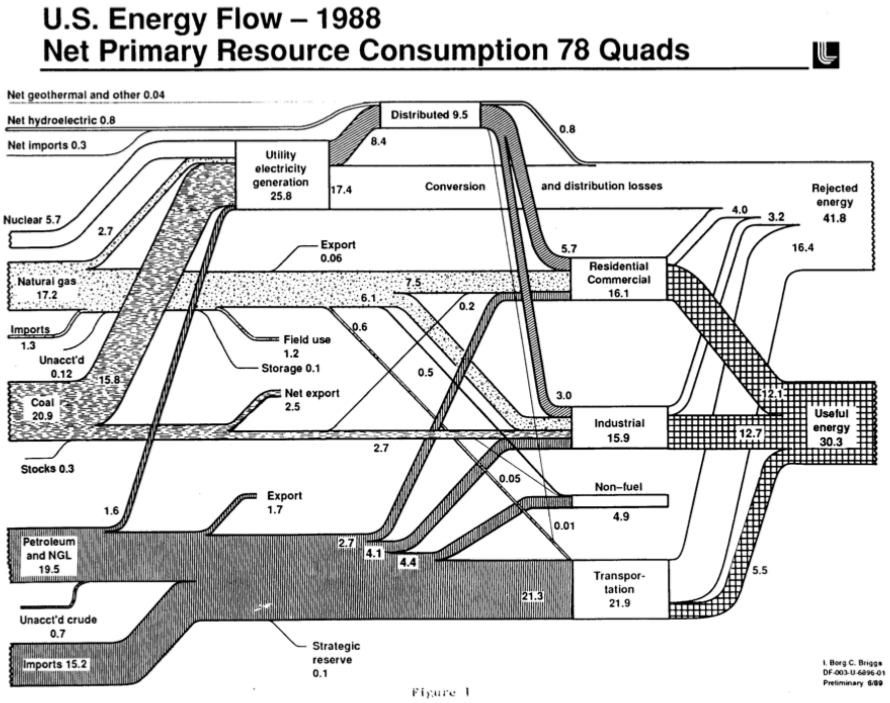


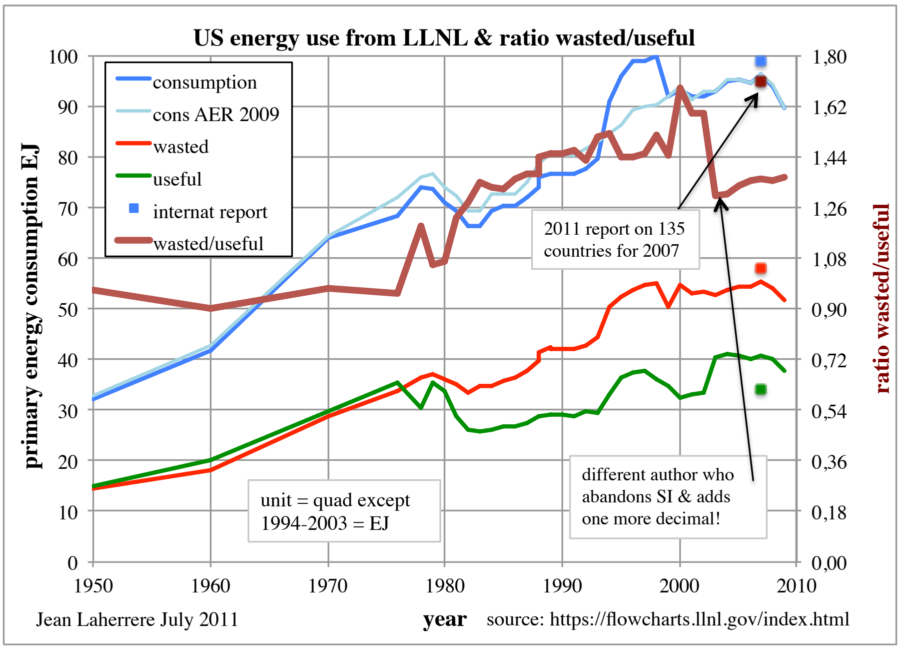
Figure 1

However some years, new authors more conscious about the accuracy of the data gave only 3 or even 2 significant digits, but not in the recent years.

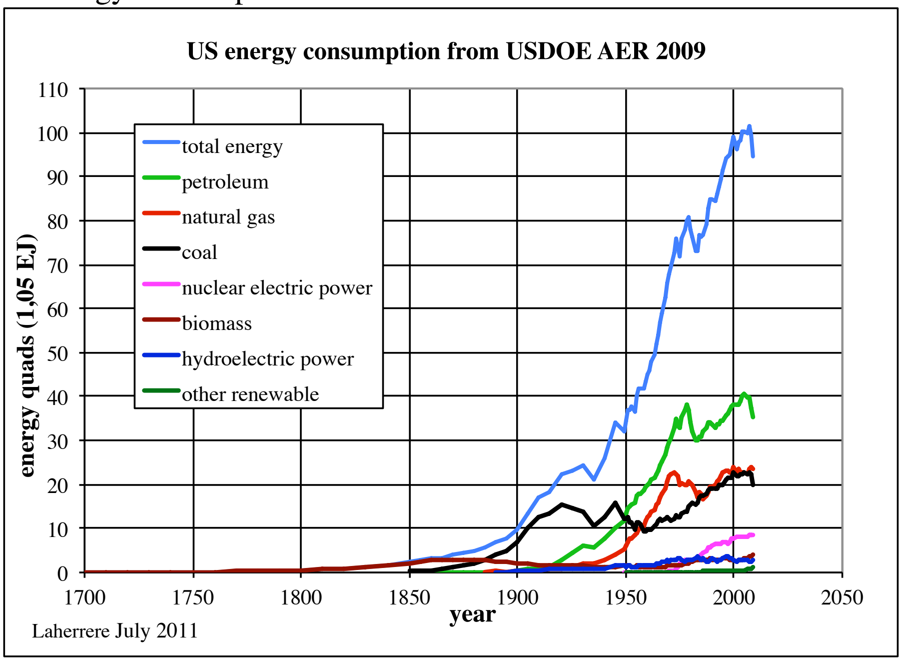
An interesting ratio is the ratio between lost energy and useful energy: from 1950 to 1976 it was lower than 1, then increased up to 1.6 in 2000, then a questionable drop in 2003 where the author also gave up the SI units, increased the decimal from one to two, and came back to the ambiguous terms of *energy services* and *rejected energy,* instead of *used* and *wasted*.

The LLNL chart data is plotted on the following graph with
-consumption of primary energy (energy use) with also the recent EIA corrected data (there is a significant difference from 1970 to 1999)
-wasted energy
-useful energy
-ratio of wasted/useful (brown curve) with doubtful drop in 2003

The 2007 value of consumption differs on the March 2011 international report (blue dot)
The ratio wasted/useful is 1.7 in 2007 from the 2011 international report in PJ and not 1.4 (see below) showing that energy waste is on the increase.
Figure 10: US energy use from current LLNL & wasted/useful ratio, with AER 2009



The US wasted/useful ratio was below 1 before 1976!
The current LLNL data is obviously wrong, but no correction is posted in archives.
USDOE/EIA AER 2009 gives details about the energy consumption since 1640.
Figure 11: US energy consumption from USDOE AER 2009



The AER 2010 announced last year for July 2011 is not yet published!

In the 2011 report on the energy flows of 136 countries for 2007 given in PJ, the US wasted/useful ratio is 1.7 (58 000/34 000); when the ratio from archives in quads and not revised is 1.4 (58.47/43.04). The large discrepancy is on the US useful energy, being 43.04 = 40.8 EJ, when it is 34 EJ in the 2011 international report, that is 17% lower.
The inaccuracy about useful energy is quite large!
Figure 12: US 2007 energy flow from the LLNL 2011 international report in PJ

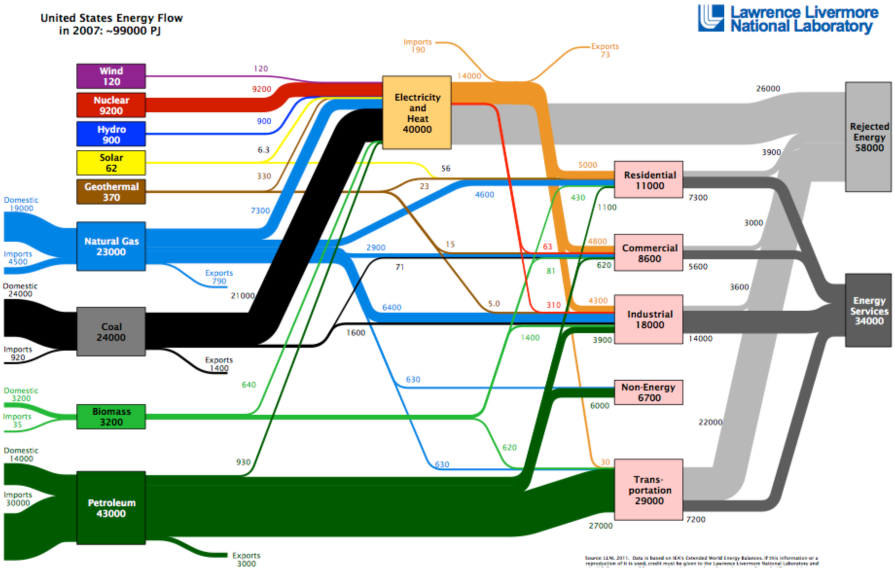
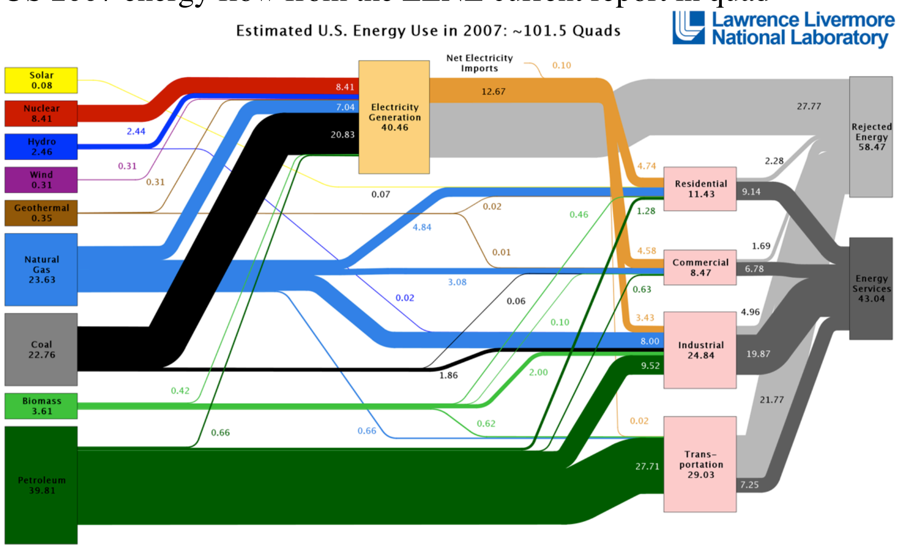


Figure 13= US 2007 energy flow from the LLNL current report in quad



It seems that most of inaccuracy comes from the electric conversion, because the comparison for 2006 between LLNL and USDOE Office of Science shows that the gap is principally on the estimate of unused electricity

	Elect.	elect. unused	unused/ used	unused energy	useful energy	unused/ used
USDOE	38.96	25.89	2.14	54.59	42.51	1.28
LLNL	39.66	27.21	2.19	56.99	42.8	1.33

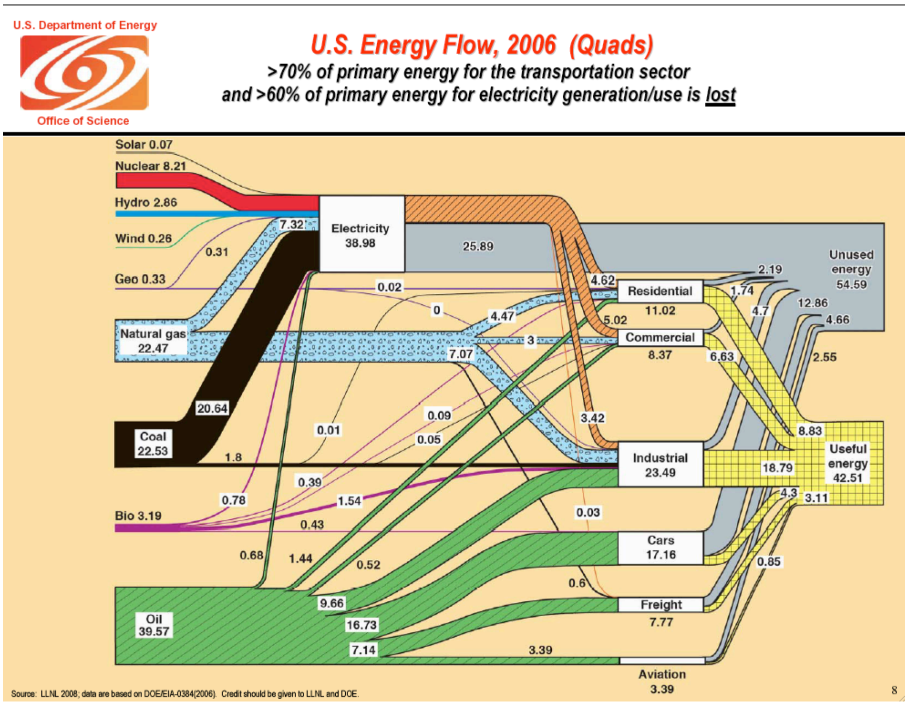
Giving 4 significant digits is ridiculous when the second digit is different with the agency, coming from the same source!

Another arbitrary (guess) assumption is the efficiency taken as 25% for transports (cars and aviation), 40% for trucks and 80% for residential, commercial & industrial.

In 2008 USDOE changed useful energy into used, and unused energy into wasted.

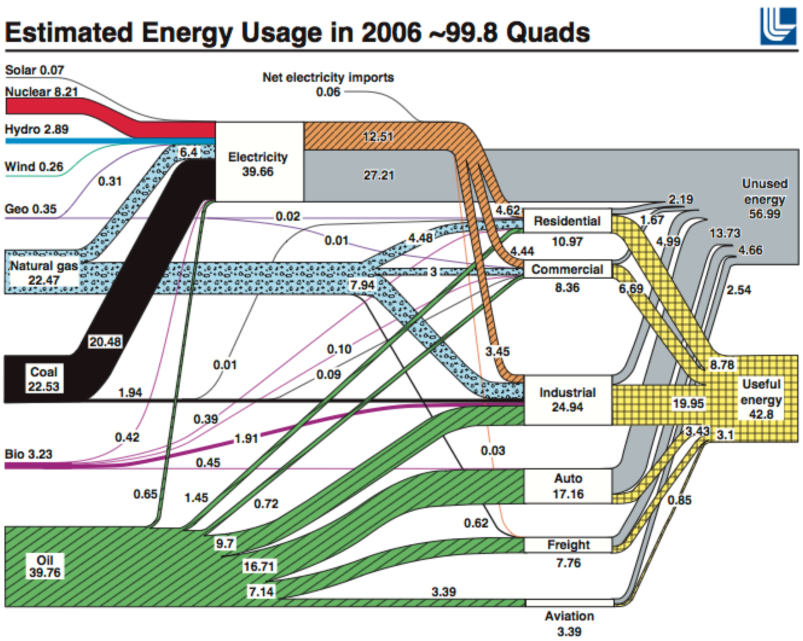
Figure 14: USDOE 2006 energy flow with in the title

>70% of primary energy for transportation and > 60% for electricity generation/use ***is lost***



For the years 2000 to 2002 G.Kaiper used different wording and unit (only charts in EJ) and said that a generous 20% was assumed for transport, which corresponds to the approximate average of internal combustion engines as measured on Federal Driving Schedules. Since 1950 to 2009, except 2000 to 2002, transport efficiency was taken as 25% for US (and for every country in 2007 international report).

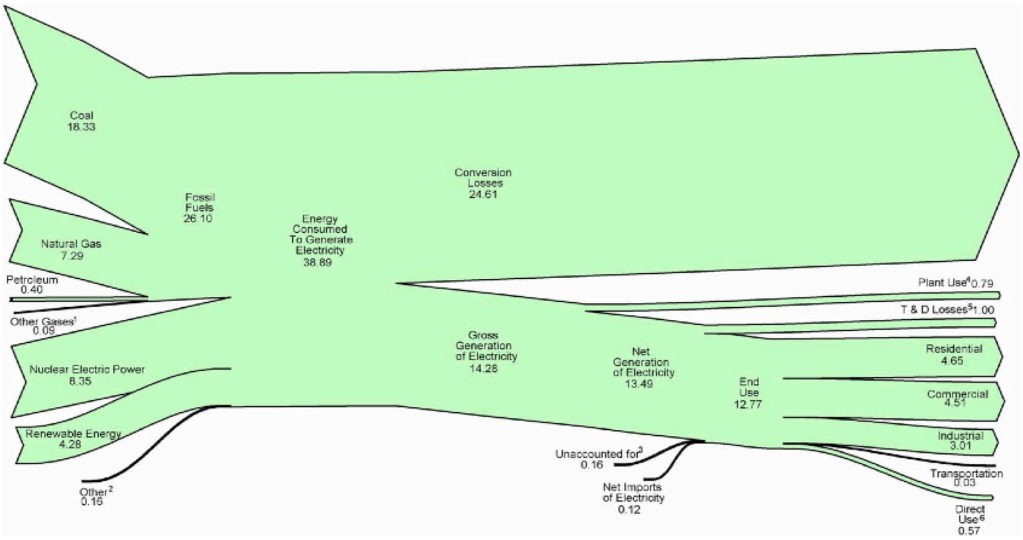
Figure 15: LLNL 2006 energy flow



In the 2009 US electricity flow the lost/generated ratio is 24.61/14.28 =1.72, much less than above.

Figure 16: USDOE 2009 electricity flow

Figure 8.0 Electricity Flow, 2009
(Quadrillion Btu)



The *wasted/useful ratio* for the US states in 2008 shows that Florida and California waste more than the average, when Texas and Louisiana waste less!
Energy is given in quad with many decimals for the States (useless and misleading)

State	E use	rejected E	E services	wasted/used	loss %
Florida	4.1527	2.8728	1.2799	2.24	69
California	7.7086	4.5576	3.1514	1.45	59
US	99.2	57.07	42.19	1.35	57
Texas	11.4854	6.028	5.4574	1.10	52
Louisiana	3.3877	1.4508	1.9369	0.75	43

-3-LLNL flowcharts on 136 countries for 2007

The LLNL has published on March 2011 (Smith, Belles & Simon) the energy flows of 136 countries (in fact 135 countries + world) in 2007.
Data are given in PJ with only two significant digits: it is the way that all energy flows should be reported.
For the world the flow is 490 000 PJ (11.7 Gtoe) and it is compared to BP Stat Review 2011 in Mtoe (1 toe = 41.868 GJ): they are close except for hydropower where BP is almost three times as high

	LLNL PJ	BP Mtoe	BP PJ
-petroleum	170 000	4007	167 800
-coal	130 000	3306	138 400
-natural gas	110 000	2661	111 400
-nuclear	30 000	622	26 000
-hydro	11 000	696	29 200
-geothermal	2 100		
-biomass	48 000		
-wind	630		
-solar	200		

For hydro consumption BP reports 696.5 Mtoe and 3078 TWh
or 1 Mtoe = 42 PJ & 1 TWh = 3,6 PJ (1 Wh = 3,6 kJ)
696.5 Mtoe = 29 200 PJ

3078 TWh = 11 000 PJ
BP uses a different conversion than the EIA for hydropower
The conventions for energy equivalence adopted by France (DGEMP) in 2001, in order to be in line with the IEA rules have considerably changed the percentage of the French energy mix in 2001, as shown below comparing with the BP editions 2002 & 2011(significant changes in the second digit, showing that the third one is useless)

France 2001 primary energy in Mtoe

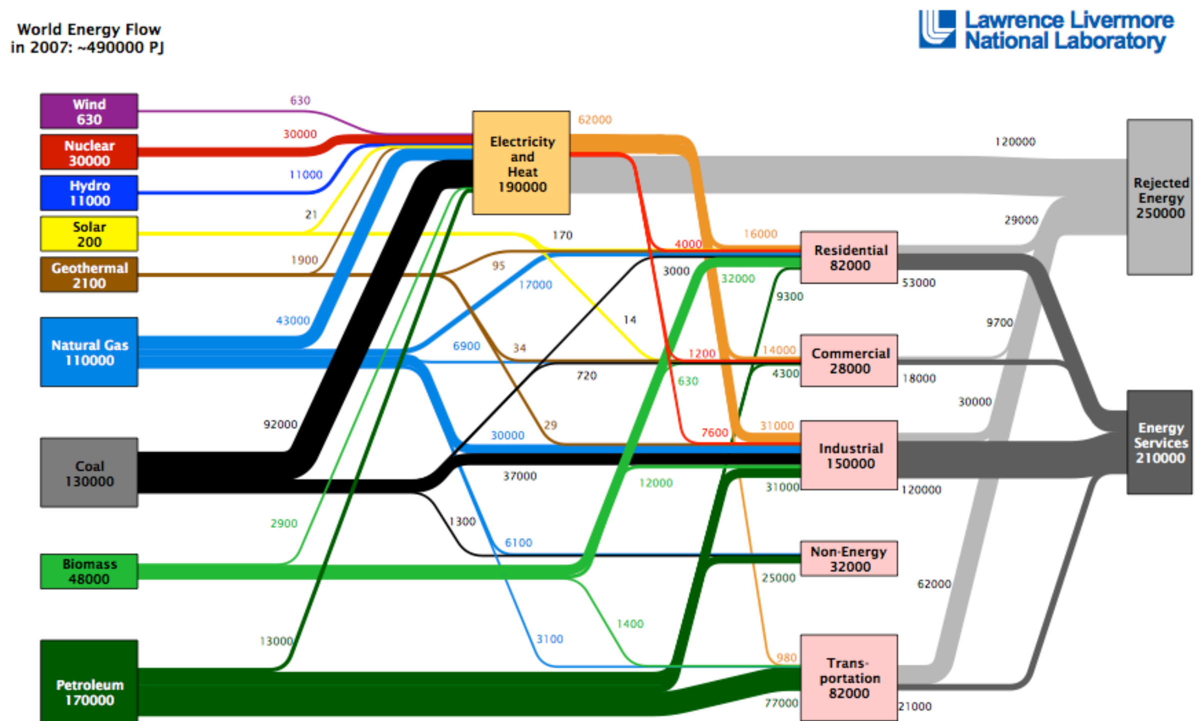
	DGEMP		BP 2002	BP 2011
	New method	Old method		
Coal	11.9	11.9	10.9	12.1
Oil	96.5	99	95.8	95.5
Gas	37.2	37.2	36.6	37.5
Nuclear	104.4	79.1	94.9	95.3
Hydro, wind, sun	6.8	17.7	18.1	17
Other renewables	12.2	12.1		
Total	269	257.1	256.4	257.4

BP is then close to the old DGEMP estimate for hydropower.!

-world

The world LNNL 2007 energy flow, the *used energy* (also called *useful energy* and now *energy services*) is only 210 000 PJ when the *wasted energy* (now called *rejected energy*) is 250 000 PJ, giving a wasted/used ratio of 1.2

Figure 17: LLNL 2007 world energy flow in PJ



For the transport, of the 82 000 PJ, 62 000 PJ are lost = 76%!
For the electricity, of the190 000 PJ, 120 000 PJ are lost = 63%!

The ranking of the 136 countries for the *wasted/used ratio* by increasing ratio from 0.3 to 3.5 is as follows:

rank	Country	PJ energy flow	PJ wasted energy	PJ used energy	Ratio wasted/ used	Ratio used/ flow
1	Ethiopia	970	230	740	0,3	0,8
2	Korea N	770	240	530	0,5	0,7
3	Congo Dem Rep	770	240	520	0,5	0,7
4	Zambia	320	100	210	0,5	0,7
5	Mozambique	380	130	250	0,5	0,7
6	Tanzania	770	270	510	0,5	0,7
7	Togo	100	36	68	0,5	0,7
8	Cote d'Ivoire	420	150	270	0,6	0,6
9	Nepal	400	150	260	0,6	0,7
10	Sudan	620	230	380	0,6	0,6
11	Angola	460	170	280	0,6	0,6
12	Nigeria	4500	1700	2800	0,6	0,6
13	Eritrea	30	11	18	0,6	0,6
14	Haiti	120	46	71	0,6	0,6
15	Myanmar	660	260	390	0,7	0,6
16	Norway	1200	430	640	0,7	0,5
17	Kazakhstan	2700	1100	1600	0,7	0,6
18	Kenya	780	320	460	0,7	0,6
19	Zimbabwe	400	160	230	0,7	0,6
20	Cambodia	220	92	130	0,7	0,6
21	Ghana	400	170	240	0,7	0,6
22	Qatar	960	330	450	0,7	0,5
23	Benin	120	52	70	0,7	0,6
24	Cameroon	300	130	170	0,8	0,6
25	Turkmenistan	760	330	430	0,8	0,6
26	Brazil	10 000	4200	5400	0,8	0,5
27	Paraguay	180	80	98	0,8	0,5
28	Gabon	94	42	51	0,8	0,5
29	Indonesia	8100	3500	4200	0,8	0,5
30	Kyrgyzstan	120	55	66	0,8	0,6
31	Vietnam	2400	1100	1300	0,8	0,5
32	Colombia	1200	560	650	0,9	0,5
33	Congo	54	25	29	0,9	0,5
34	Trinidad & Tobago	670	150	170	0,9	0,3
35	Pakistan	3500	1600	1800	0,9	0,5
36	Sri Lanka	400	190	210	0,9	0,5
37	Peru	630	300	330	0,9	0,5
38	Uzbekistan	2000	920	1000	0,9	0,5
39	Austria	1400	650	700	0,9	0,5
40	Venezuela	2800	1300	1400	0,9	0,5
41	Yemen	310	150	160	0,9	0,5
42	Finland	1600	730	760	1	0,5
43	Namibia	65	32	33	1	0,5
44	Belarus	1200	510	520	1	0,4
45	Armenia	120	59	60	1	0,5
46	China	85 000	40 000	40 000	1	0,5
47	Croatia	390	180	180	1	0,5
48	Iran	8000	3800	3800	1	0,5
49	Latvia	210	100	100	1	0,5
50	Malaysia	3100	1500	1500	1	0,5
51	Tajikistan	160	82	82	1	0,5
52	Turkey	4300	2000	2000	1	0,5
53	Canada	12 000	5500	5300	1	0,4
54	Chile	1300	630	600	1,1	0,5
55	Guatemala	350	180	170	1,1	0,5
56	Bangladesh	1100	510	480	1,1	0,4

57	Argentina	3100	1500	1400	1,1	0,5
58	Egypt	2900	1400	1300	1,1	0,4
59	Georgia	140	70	65	1,1	0,5
60	Bolivia	250	130	120	1,1	0,5
61	Italy	7700	3800	3500	1,1	0,5
62	India	25 000	12 000	11 000	1,1	0,4
63	Albania	96	46	42	1,1	0,4
64	Romania	1600	780	710	1,1	0,4
65	Thailand	4600	2200	2000	1,1	0,4
66	Nicaragua	150	77	69	1,1	0,5
67	Netherlands	4200	1900	1700	1,1	0,4
68	Slovak rep	750	370	330	1,1	0,4
69	Cuba	450	240	210	1,1	0,5
70	Uruguay	150	78	68	1,1	0,5
71	Senegal	130	68	59	1,2	0,5
72	Mongolia	130	70	60	1,2	0,5
73	Poland	4100	2100	1800	1,2	0,4
74	Russia	28 000	14 000	12 000	1,2	0,4
75	Portugal	1100	550	470	1,2	0,4
76	Algeria	1600	790	670	1,2	0,4
77	Iraq	1400	740	620	1,2	0,4
78	Denmark	920	490	410	1,2	0,4
79	Ukraine	5900	3000	2500	1,2	0,4
80	Honduras	200	110	90	1,2	0,5
81	Morocco	610	330	270	1,2	0,4
82	Kuwait	1100	590	480	1,2	0,4
83	Tunisia	380	210	170	1,2	0,4
84	Germany	14 000	7400	5900	1,3	0,4
85	Sweden	2300	1200	940	1,3	0,4
86	Switzerland	1200	640	500	1,3	0,4
87	Bahrain	400	220	170	1,3	0,4
88	Hungary	1100	590	450	1,3	0,4
89	Ireland	710	400	300	1,3	0,4
90	Luxembourg	200	110	82	1,3	0,4
91	Dominican rep	330	190	140	1,4	0,4
92	Botswana	85	49	36	1,4	0,4
93	Belgium	2900	1500	1100	1,4	0,4
94	Japan	22 000	12 000	8700	1,4	0,4
95	UK	9400	5300	3800	1,4	0,4
96	Korea S	9900	4900	3500	1,4	0,4
97	Mexico	7900	4400	3100	1,4	0,4
98	Spain	6600	3700	2600	1,4	0,4
99	Azerbaijan	520	300	210	1,4	0,4
100	Yugo	1700	990	690	1,4	0,4
101	Serbia	680	390	270	1,4	0,4
102	Oman	700	340	230	1,5	0,3
103	Costa Rica	210	120	80	1,5	0,4
104	Jamaica	200	120	80	1,5	0,4
105	Slovenia	310	180	120	1,5	0,4
106	Lithuania	390	200	130	1,5	0,4
108	El Salvador	210	130	84	1,5	0,4
109	Czech	1900	1100	710	1,5	0,4
110	Fr Yugoslav rep	130	77	49	1,6	0,4
111	Jordan	320	190	120	1,6	0,4
112	Saudi Arabia	6600	3200	2000	1,6	0,3
113	New Zealand	760	450	280	1,6	0,4
114	Moldova	140	87	54	1,6	0,4
115	Australia	5700	3400	2100	1,6	0,4
116	South Africa	5600	3400	2100	1,6	0,4
117	Greece	1500	920	560	1,6	0,4

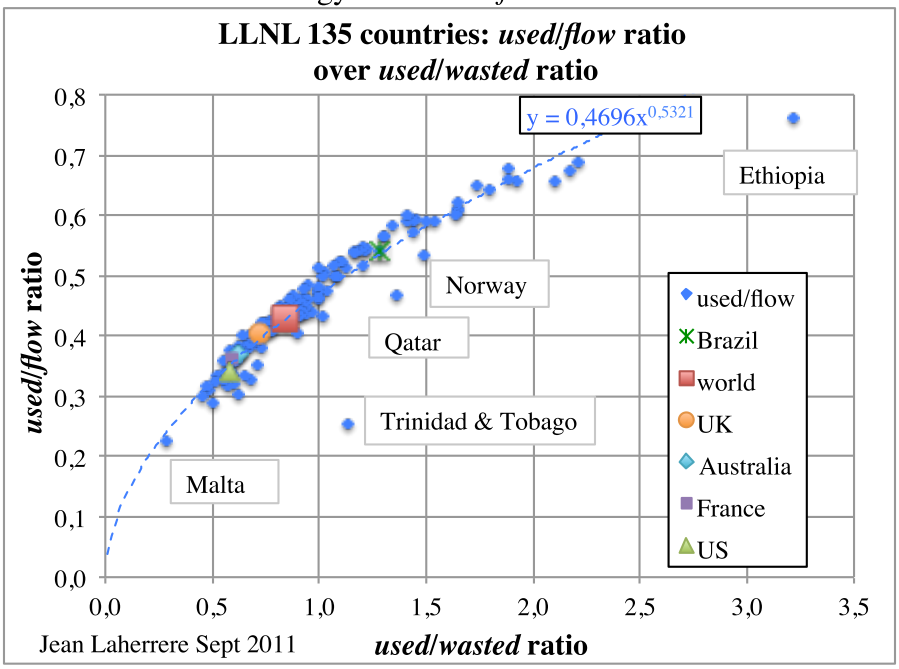
118	Israel	950	560	340	1,6	0,4
119	Taiwan	4700	2500	1500	1,7	0,3
120	Syria	830	470	280	1,7	0,3
121	France	11 000	6800	4000	1,7	0,4
122	Estonia	250	150	88	1,7	0,4
123	US	99000	58000	34000	1,7	0,3
124	Philippines	1700	1100	640	1,7	0,4
125	Libya	760	420	240	1,8	0,3
126	Bulgaria	860	520	290	1,8	0,3
127	Lebanon	170	110	61	1,8	0,4
128	Ecuador	490	290	160	1,8	0,3
129	UAE	3000	1900	1000	1,9	0,3
130	Cyprus	130	82	42	2	0,3
131	Singapore	2600	1500	750	2	0,3
132	Iceland	220	140	68	2,1	0,3
133	Brunei	120	80	38	2,1	0,3
134	Bosnia/Herzegovina	240	160	72	2,2	0,3
135	Malta	75	59	17	3,5	0,2
	World	490 000	250 000	210 000	1,2	0,4

In this ranking the most efficient countries are also the poorest, with little transport: Ethiopia = 0.3, North Korea = 0.5, Congo Democratic Republic = 0.5, Zambia = 0.5. The European countries are not very good: Germany = 1.3, UK = 1.4, France = 1.7, except Norway = 0.7 compared to Canada = 1 and US = 1.7. The worst country is Malta with 3.5.

The plot of the used/flow ratio versus the used/wasted ratio (inverse of the listed ratio above) displays a surprising simple trend. The least efficient are at the left and the most efficient at the right. The trend line is a very simple equation where

Used/flow equals about half the square root of used/wasted

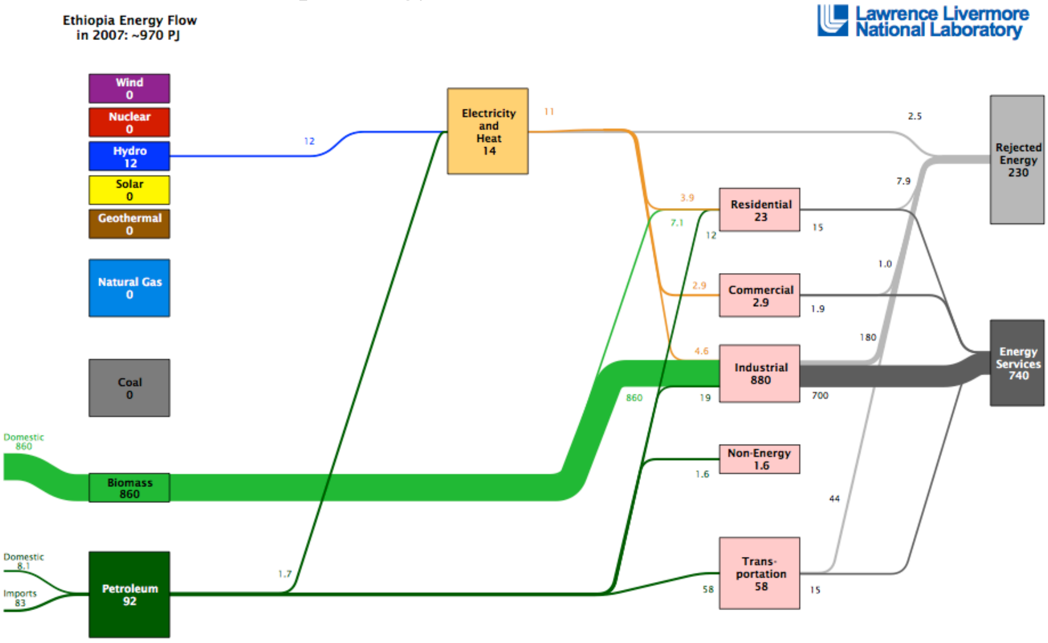
Figure 18: LLNL 135 countries energy flow: *used/flow ratio* over *used/wasted ratio*



Only countries with large converting plans like Trinidad and Qatar are below the trend. Ethiopia is also low, but for another reason.

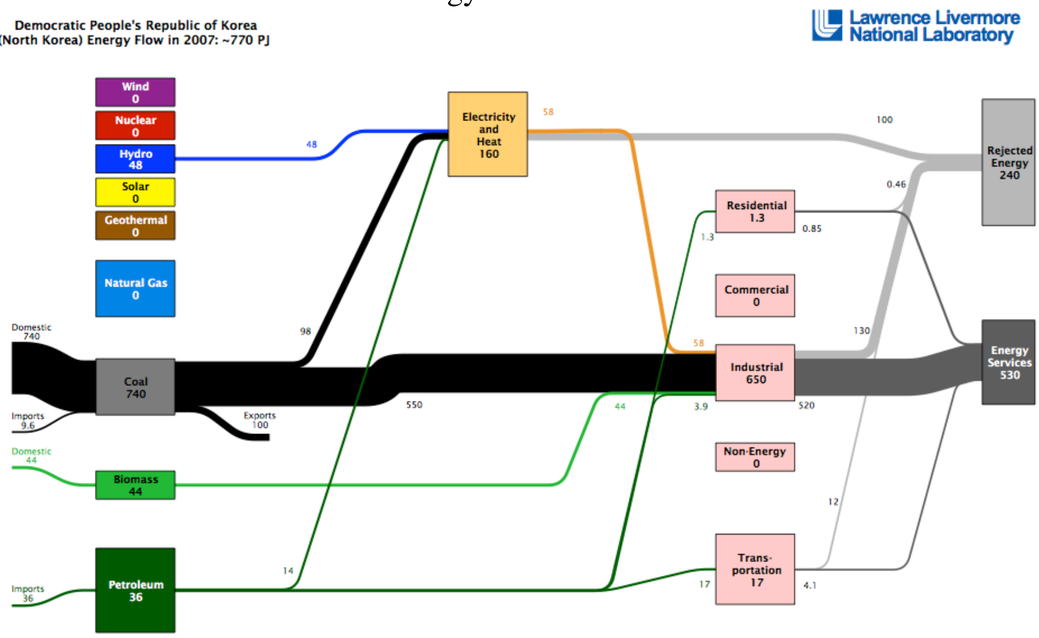
The Ethiopia graph shows that the poor efficiency transports are negligible and the most used energy for industry is biomass.

Figure 19: LLNL 2007 Ethiopia energy flow in PJ



North Korea uses mainly coal for the industry and transports are very small.

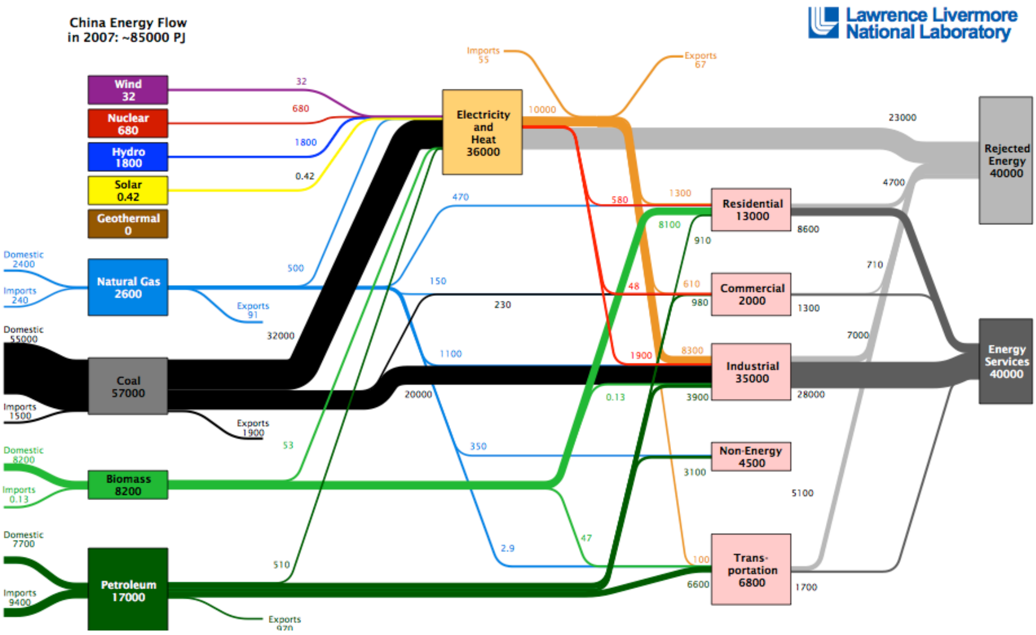
Figure 20: LLNL 2007 North Korea energy flow in PJ



Less than half of the countries (53) has a ratio lower or equal to 1

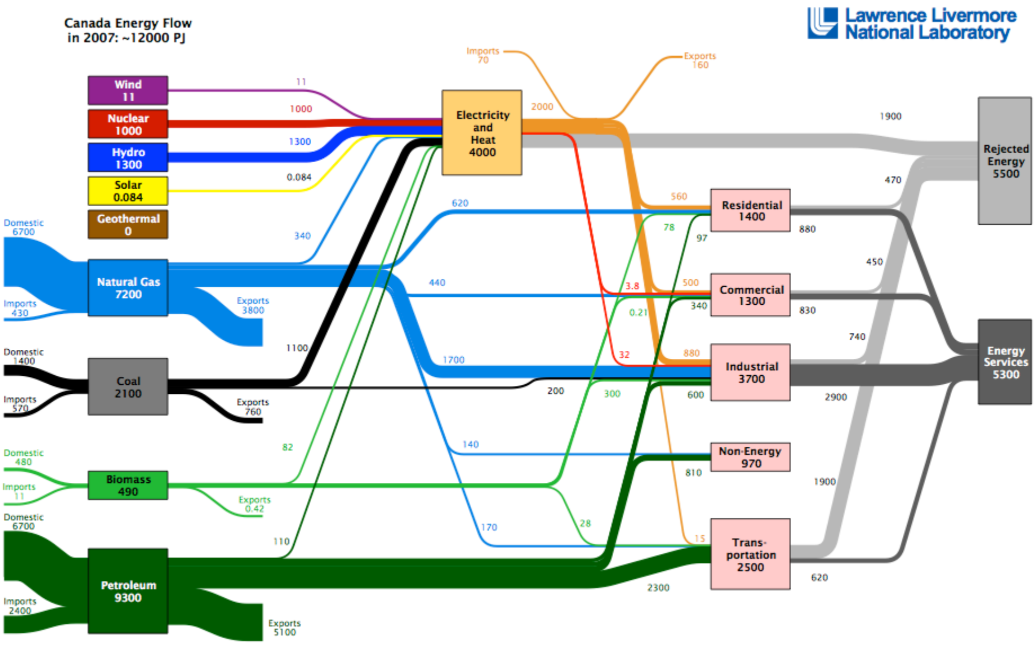
China has a ratio of 1 because the industry uses a lot of energy (35 000 PJ) compared to transport (6 800 PJ). It was in 2007 and it will be interesting to see the flow in 2011.

Figure 21: LLNL 2007 China energy flow in PJ



Canada has also a ratio close to 1, energy from transport (2500 PJ) is lees than industry (3700 PJ)

Figure 22: LLNL 2007 Canada energy flow in PJ

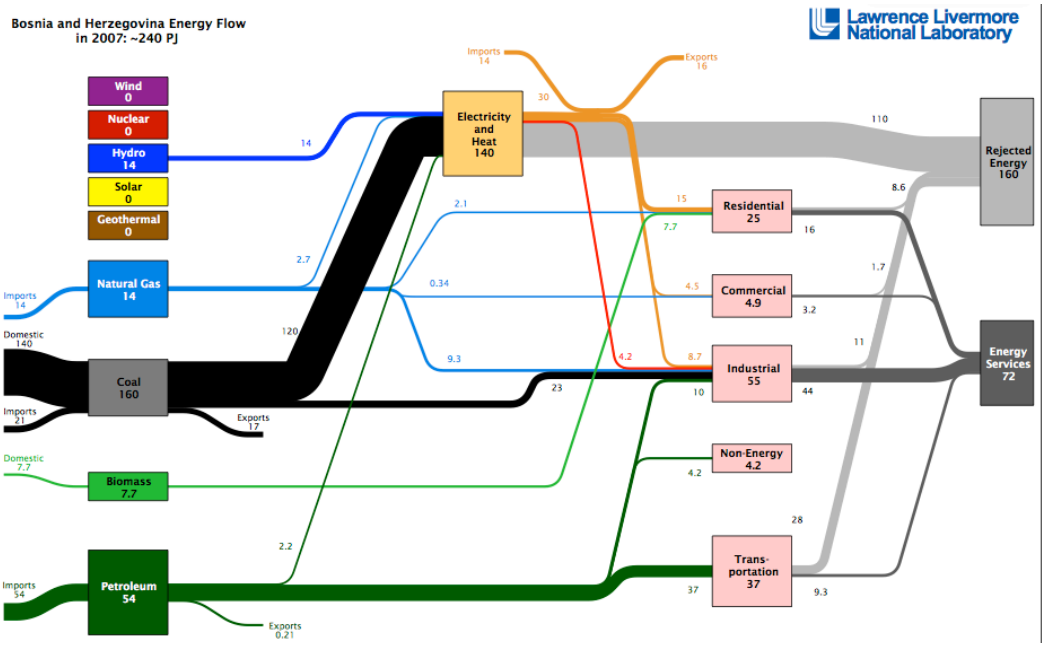


I was unable to find an energy flow from Canadian agencies, what a pity! Canada has lost control of its databases like the Canadian Geological Survey because budgets constraints. Happily the oil & gas producers association, the CAPP, publishes the best data.

The least efficient countries are Bosnia & Herzegovina (2.2) and Malta (3.5)

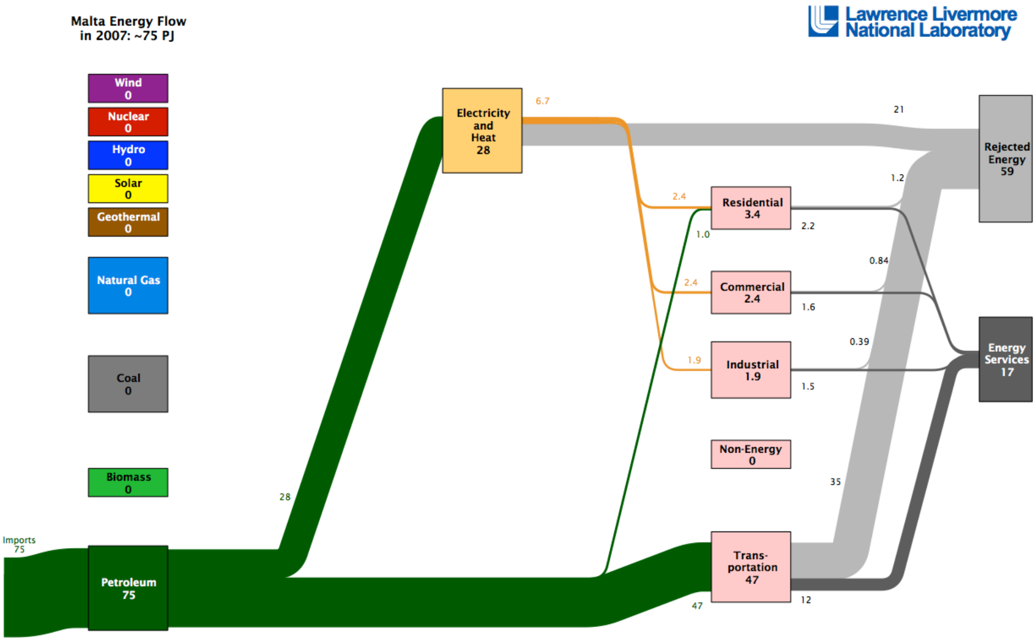
Bosnia has a very poor efficiency in electricity and heat

Figure 23: LLNL 2007 Bosnia & Herzegovina energy flow in PJ



Malta is very bad in energy efficiency, because all the energy comes from oil with important loss in transport and electricity conversion

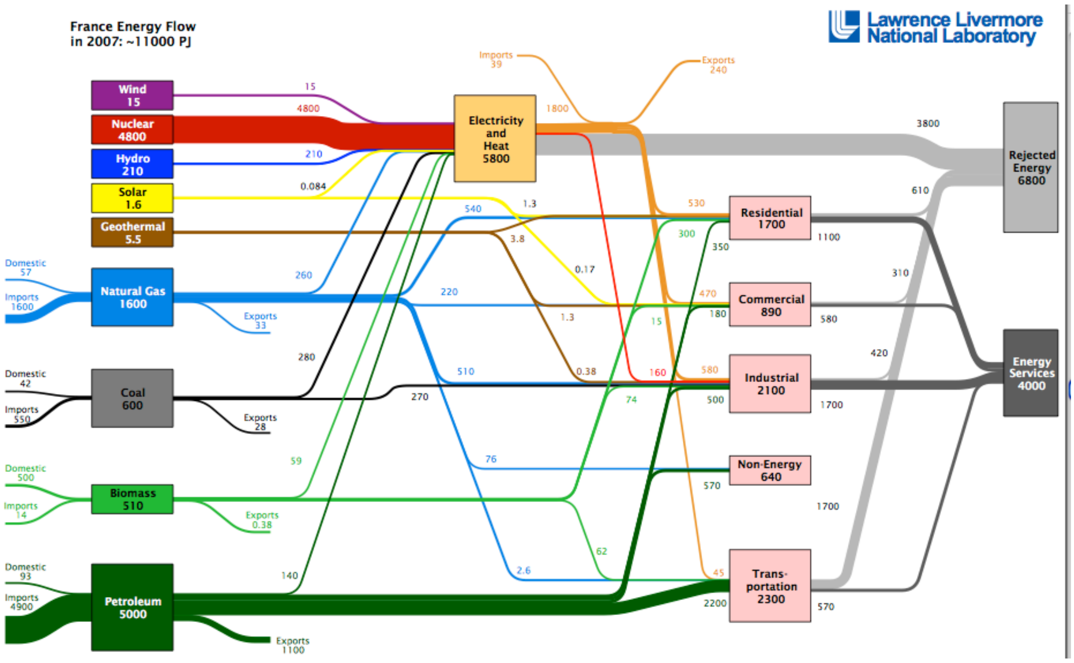
Figure 24: LLNL 2007 Malta energy flow in PJ



-France

France has a poor ratio of 1.7 because the energy of transports is higher than those of industry and the efficiency of electricity & heat (compare the grey to the orange) is less than in Canada

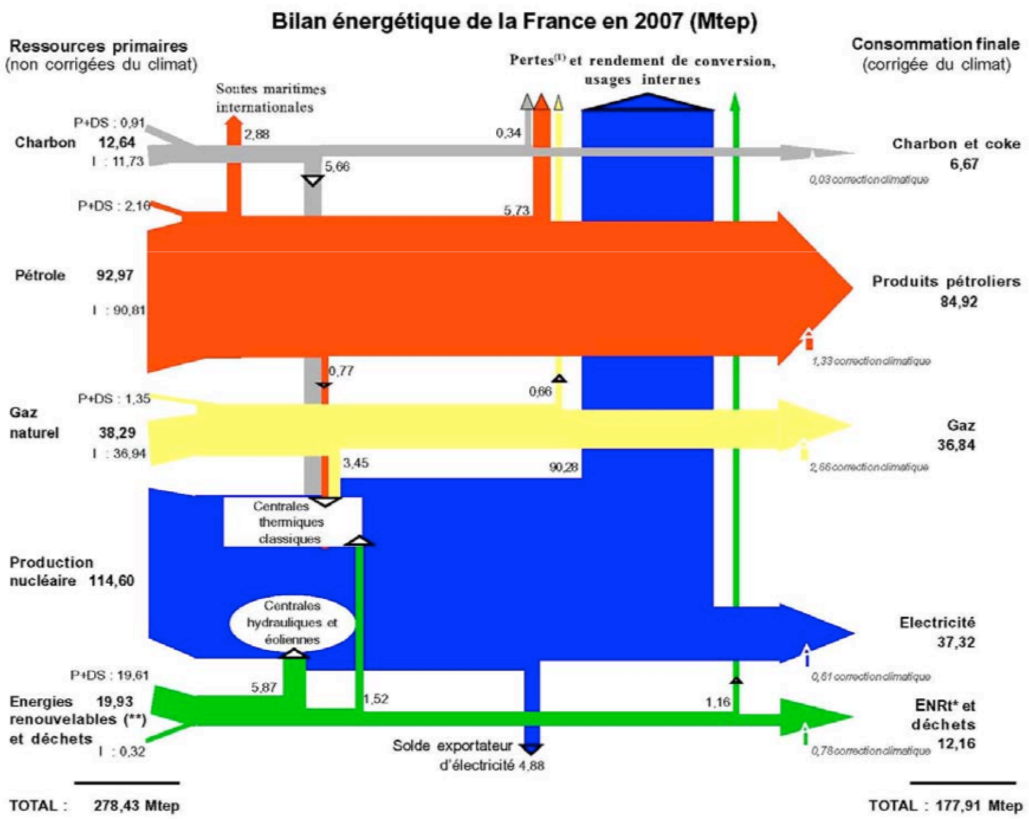
Figure 25: LLNL 2007 France energy flow in PJ



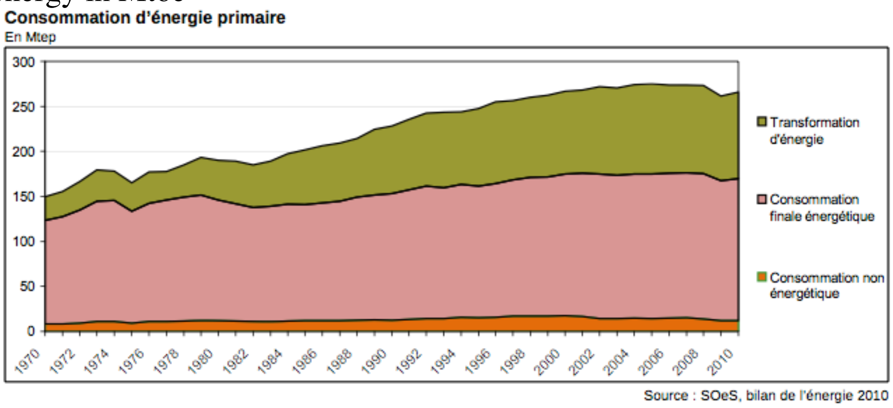
LLNL displays		PJ	Mtoe
-input		11 000	263
-output	wasted	6 800	162
	useful	4 000	96
	total	10 800	258

But the energy balance presented by the French government in Mtoe displays
-primary resources at 278 Mtoe (11 700 PJ)
-loss and efficiency of conversion at 98 Mtoe (4100 PJ)
-final consumption of 178 Mtoe (7400 PJ),

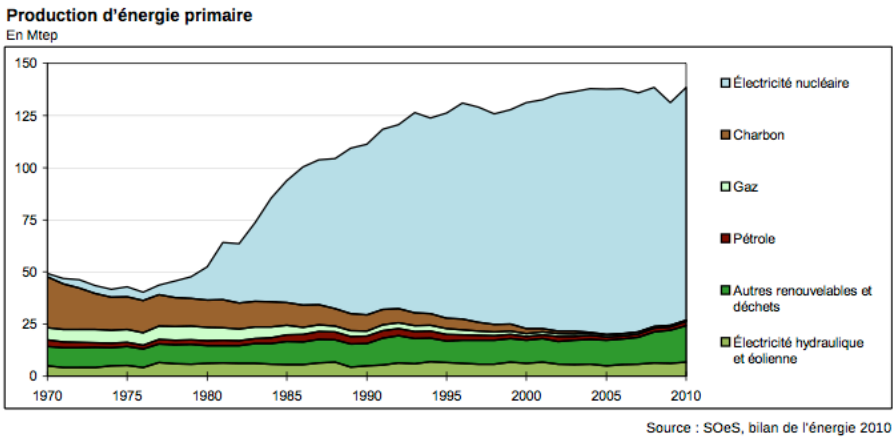
Figure 26: DGEMP 2007 France energy flow in Mtoe



For 2007 the DGEMP loss (for converting energy) of 98 Mtoe is short by 64 Mtoe compared to LLNL wasted: it means that the DGEMP does not include the loss of energy in transports and others, so their results cannot be compared.
In its 2010 (published June 2011) energy balance (*bilan energetique*) the energy loss is called energy conversion and represents 96 Mtoe for a final consumption of 157 Mtoe, the loss/used is then 96/157 = 0.6, quite far from the LLNL 1.7
It means that estimating the wasted is an interpretation and varies with the author. Only comparison coming from the same author could be considered as reliable, that is relatively but not in absolute terms.
The following graph 1970-2010 displays for France the part of non-energy, the part of conversion (loss) and the final consumption. It is obvious that the conversion grows more than the final consumption, that the efficiency decreases, and that there is a good potential for energy saving by reducing the loss in conversion.
Figure 27: DGEMP France primary energy consumption 1970-2010 with the loss by converting energy in Mtoe



The problem is that it is very difficult to plot the same graph using another method of energy conversion. The DGEMP, in a note, advises that the importance of loss depends widely on the method used to convert nuclear energy since 2001 (conversion by convention computed at one third of the heat)
The French energy primary production has changed considerably since 1980 with nuclear
Figure 28: DGEMP France primary energy production 1970-2010 in Mtoe

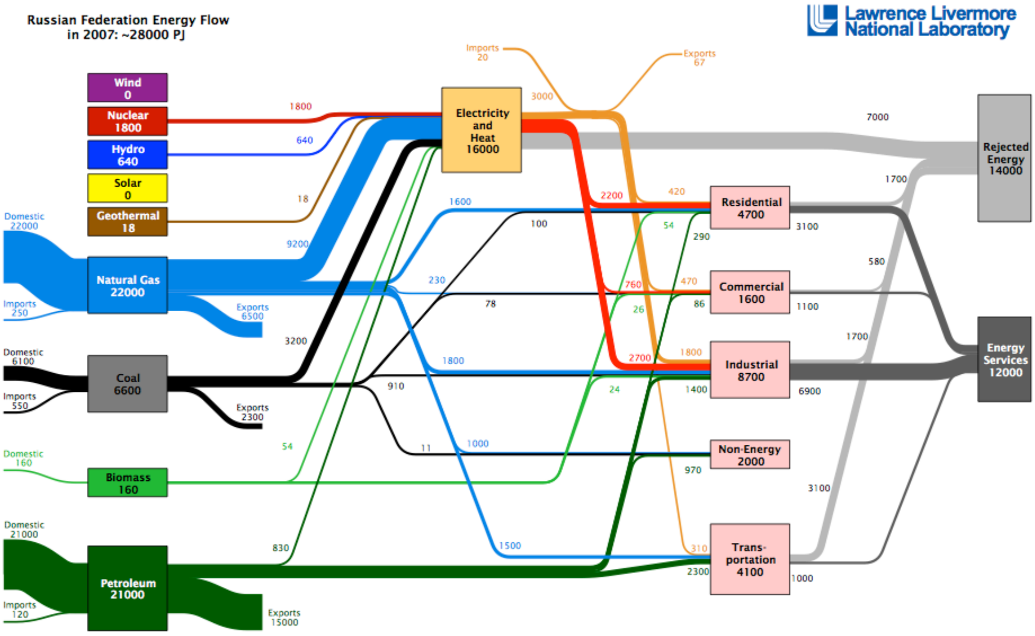


The consumption of primary energy is corrected versus the climate change by measuring a climate index (indice de rigueur climatique), which is based on the measure of the heating degree-days. For the 1973-2009 period, the correction derived from climate has varied from -1.5% to 3%.

The problem is that the correction changes with time, and the heating was assumed to start when temperature is below 17°C and later 18°C.
LLNL does not indicate if the data is climate corrected or not.

-Russia

Russia has a ratio of 1.2 with transports (4100 PJ) being lower than industry (8700 PJ) and residential (4700 PJ)
Figure 29: LLNL 2007 Russia energy flow in PJ



-UK

For the UK, the comparison of LLNL flow (ratio 1.4) with the flow published by DECC (former BERR & before that DTI) shows that the presentation and the basic data are different
Figure 30: LLNL 2007 UK energy flow in PJ

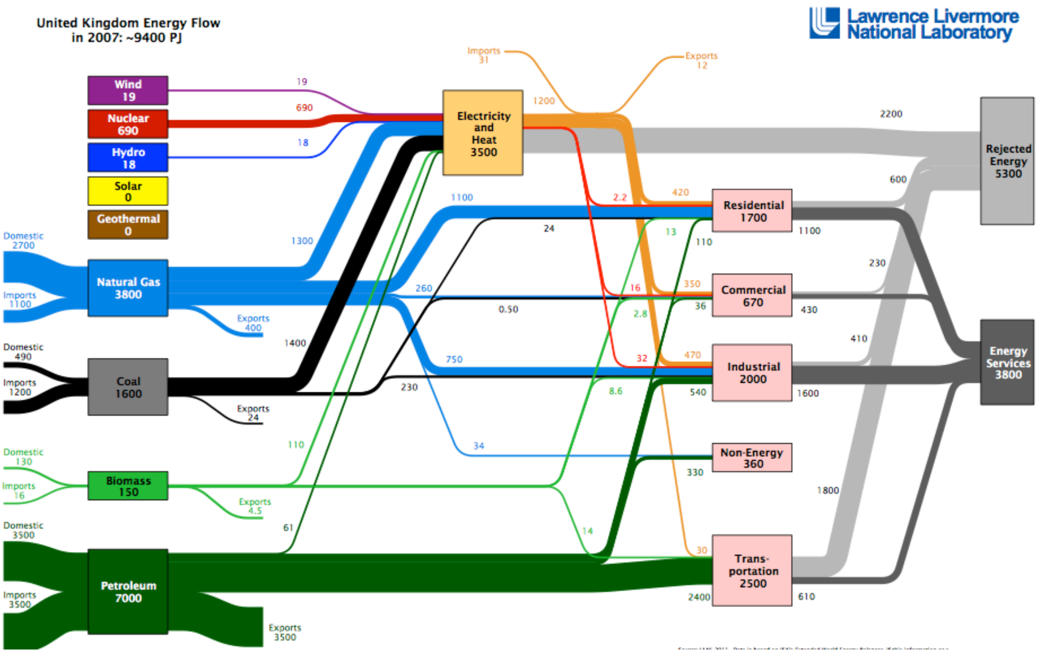
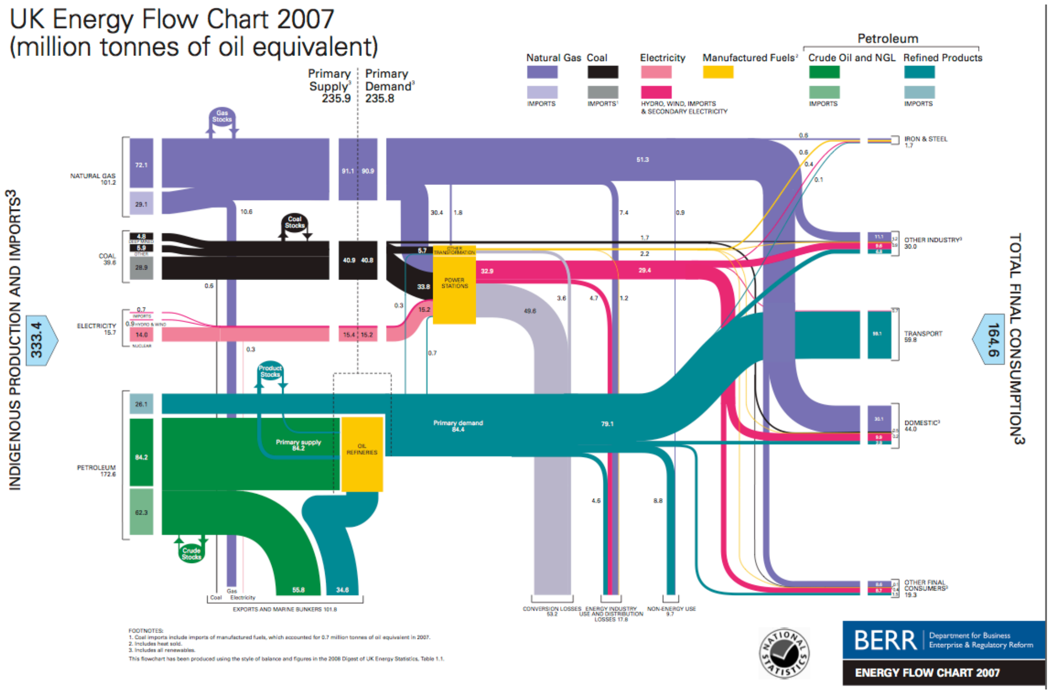
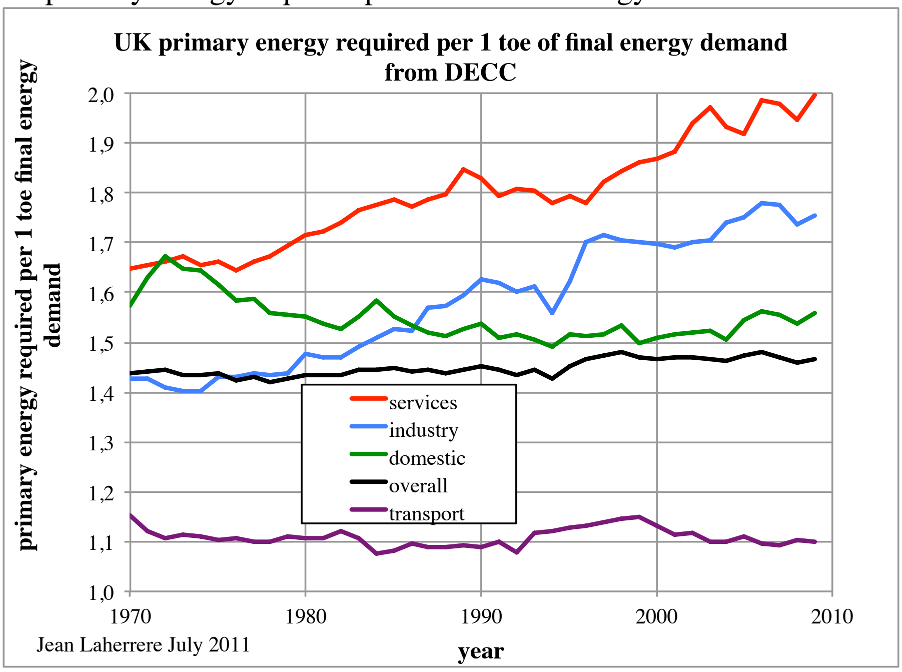


Figure 31: DECC 2007 UK energy flow in Mtoe



DECC reports the amount of primary energy necessary to obtain one toe of final energy where for 2009 average =1.5 toe; transport = 1.1; industry = 1.75; services = 2.

Figure 32: UK primary energy required per toe of final energy demand from DECC



It is striking that the transports request 1.1 toe, that is stable since 1970 when services went from 1.6 to 2 toe.

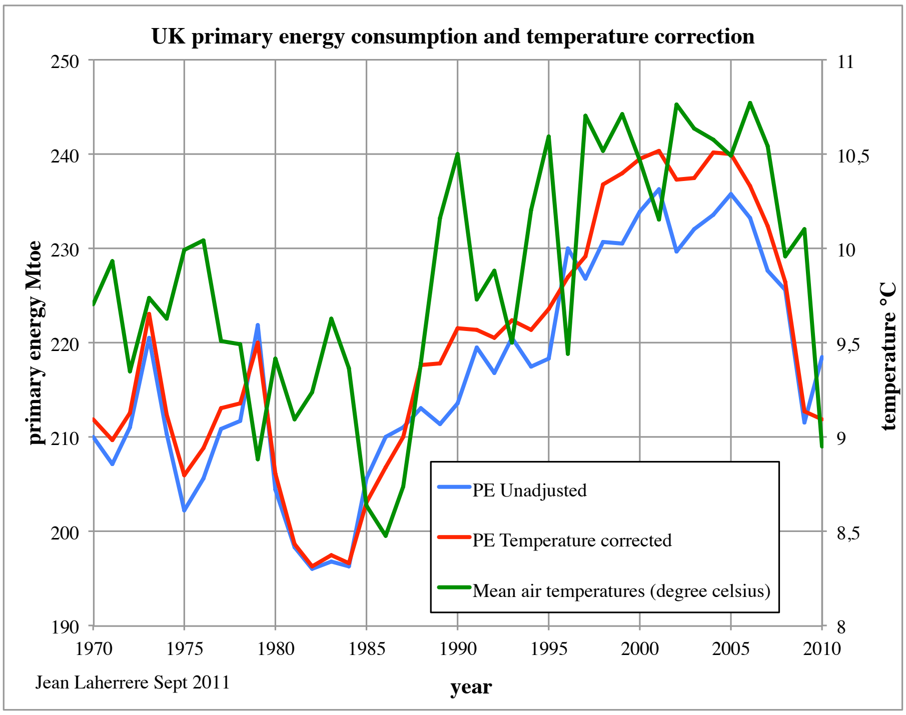
It is completely contradictory when compared to the LLNL UK graph where the transport is 2500 PJ on which 1800 PJ (72%) is considered as wasted. It is possible for DECC data to lead to a conclusion opposite to the LLNL graph

The correction of the UK primary energy consumption derived from temperature is important from -8 to +8 Mtoe for the period 1970-2010.

The plot of primary energy consumption and UK mean air temperature, which varies from 8 to 11 °C, is surprising, because it seems to correlate, the corrected PE peaked from 2001 to 2005, when temperature peaked from 1997 to 2006: coincidence?

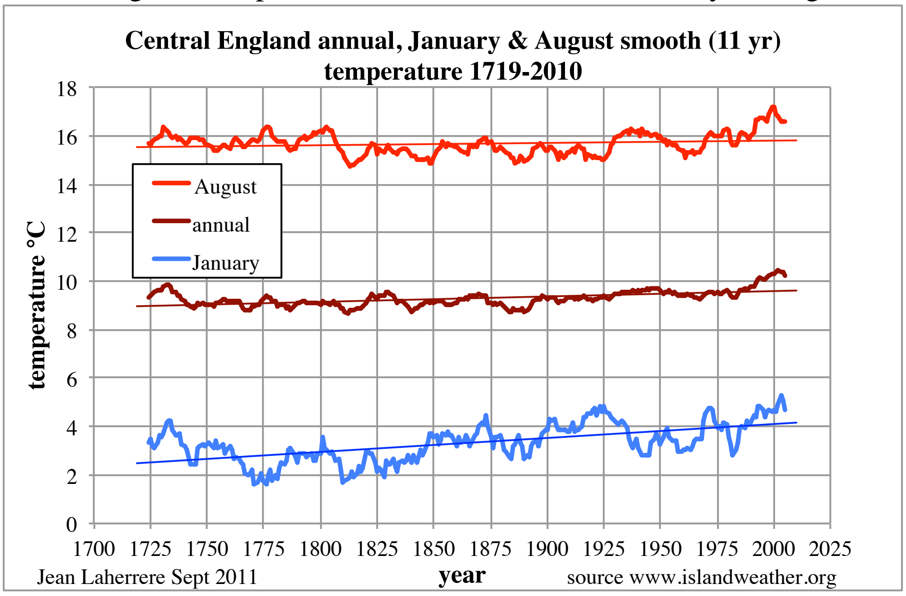
This shows that it is always dangerous to confuse correlation and causality!

Figure 33: UK primary energy required primary energy consumption and temperature correction



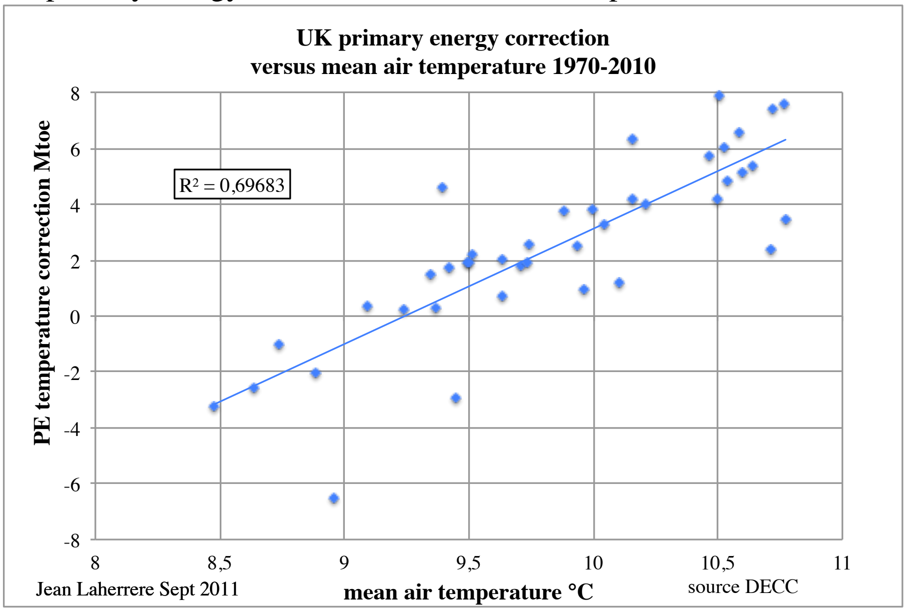
The longest historical temperature record is for Central England (in fact from 1659) is plotted from 1719 to 2010 with a smooth value (on 11 years), which displays no growth for August and a significant growth for January. The main problem of measured temperature is that most stations are now within urban agglomerations.

Figure 34: Central England temperature 1719-2010: annual, January & August



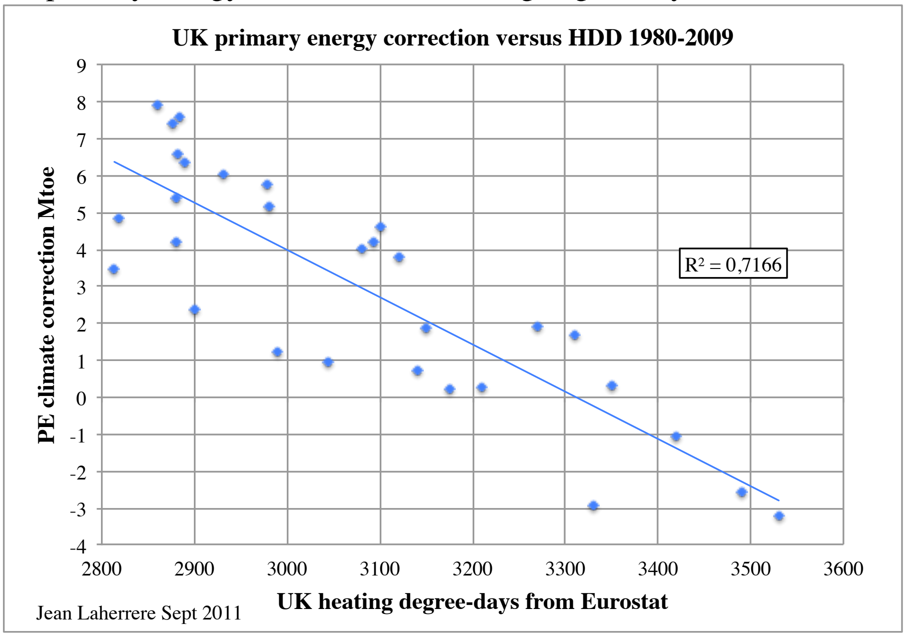
The correction of the primary energy due to climate is compared to the mean air temperature and the linear trend is poor (R2 =0,7), because the correction is derived from the heating degree-days HDD, which can be high when the mean annual temperature does not change. The base (the part above does not count) of HDD is 15.5 °C, when in France and in the US it is 18°C (65°F).

Figure 35: UK primary energy correction and mean air temperature 1970-2010



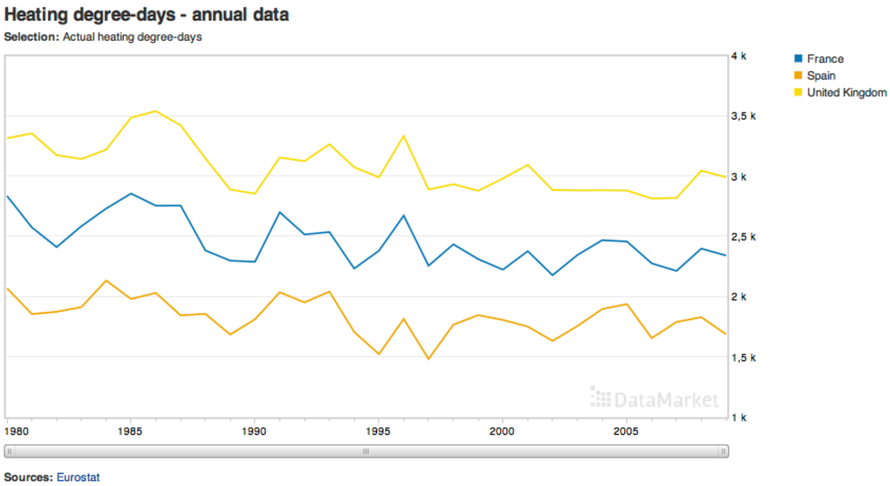
The plot of PE correction versus HDD should be better, but it is nearly not the linear trend has a R2 of 0.72, which is poor, when the PE corrections are supposed to stem from HDD.

Figure 36: UK primary energy correction and heating degree-days from Eurostat 1980-2009



Eurostat reports the HDD of the EU countries and the plot for UK, France and Spain displays a similar declining trend from 1980 to 2009

Figure 37: UK heating degree-days (thousand) compared to France & Spain 1980-2009



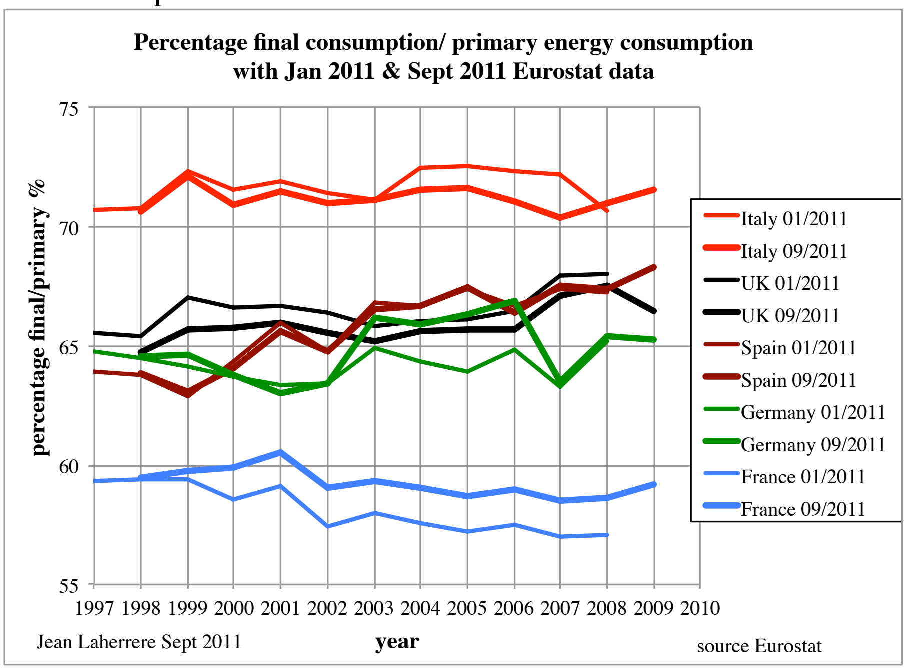
However heating degree-days is not an accurate tool, and the correction should be handled with care http://www.energylens.com/articles/degree-days

Eurostat reports the primary energy consumption and final energy consumption in Mtoe and it is interesting to compare the decreasing percentage of Italy, Spain, the UK, Germany and France.

But it is a pity to find that the data from Eurostat between January 2011 and September 2011 could change drastically. For example, France's final consumption was reported as 157.094 Mtoe in January 2011 but as 161.15 Mtoe in September 2011. Eurostat reports energy in Mtoe with three decimals, but the tens digit can change by 4 units.

Eurostat should remove all decimals when reporting and add a note that even without decimals, the reported value is highly uncertain and can change drastically in a few months!

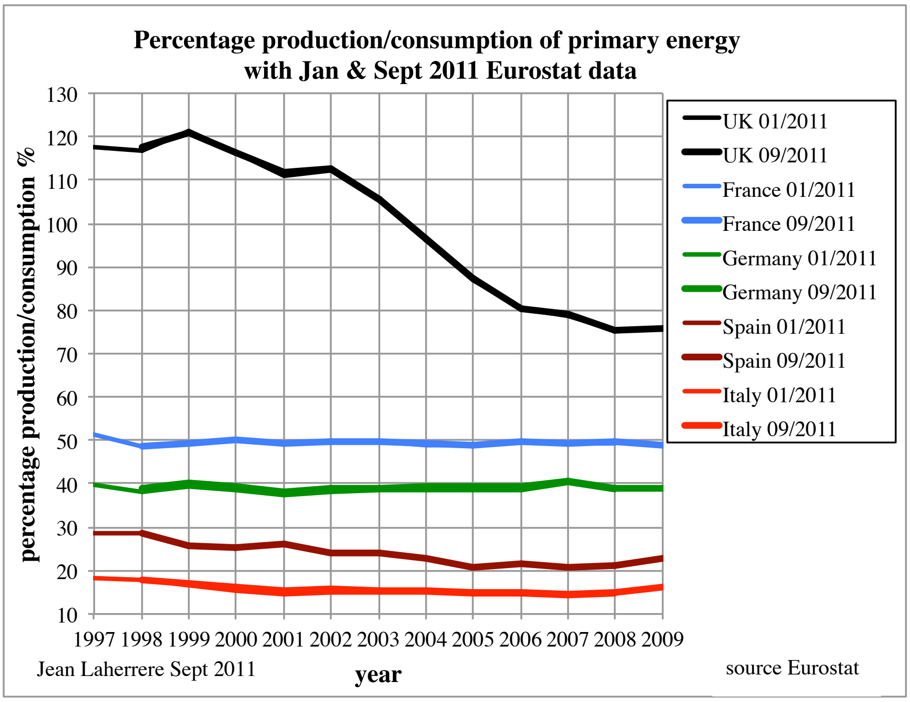
Figure 38: percentage final energy consumption over primary energy consumption from Eurostat Jan 2011 & Sept 2011 data



On the January 2011 data, the conclusion is for France was that the ratio is declining, but in the recent September 2011 data, the ratio is just on a bumpy line! France is below the other Europeans countries because France produces 80% of its electricity from nuclear plants, but the nuclear equivalence is arbitrary and could change in the future.

In contrary the change in Eurostat January 2011 and September 2011 for the ratio production of primary energy over consumption of primary energy does not vary much

Figure 39: ratio primary energy consumption over final energy from Eurostat Jan 2011 & Sept 2011 data



It is obvious that the UK's energy independency is rapidly declining and that Italy's is very low.

-Australia

For Australia the comparison between the LLNL (USDOE) data and the Australian data is difficult

For 2007, the LLNL estimates waste at 3400 PJ and useful at 2100 PJ (ratio 1.6), when Geoscience Australia (http://www.orer.gov.au/publications/pubs/australian-energy-flows2006-07.pdf) estimates losses at 1800 PJ and *end use* at 3900 PJ, but ABARE http://www.abare.gov.au/publications_html/energy/energy_09/auEnergy09.pdf is also different, estimating the negative transformation at 3900 PJ.

I really do not know how to say who is right and who is wrong, I can only say that the data is contradictory.

Figure 40: LLNL 2007 Australia energy flow in PJ

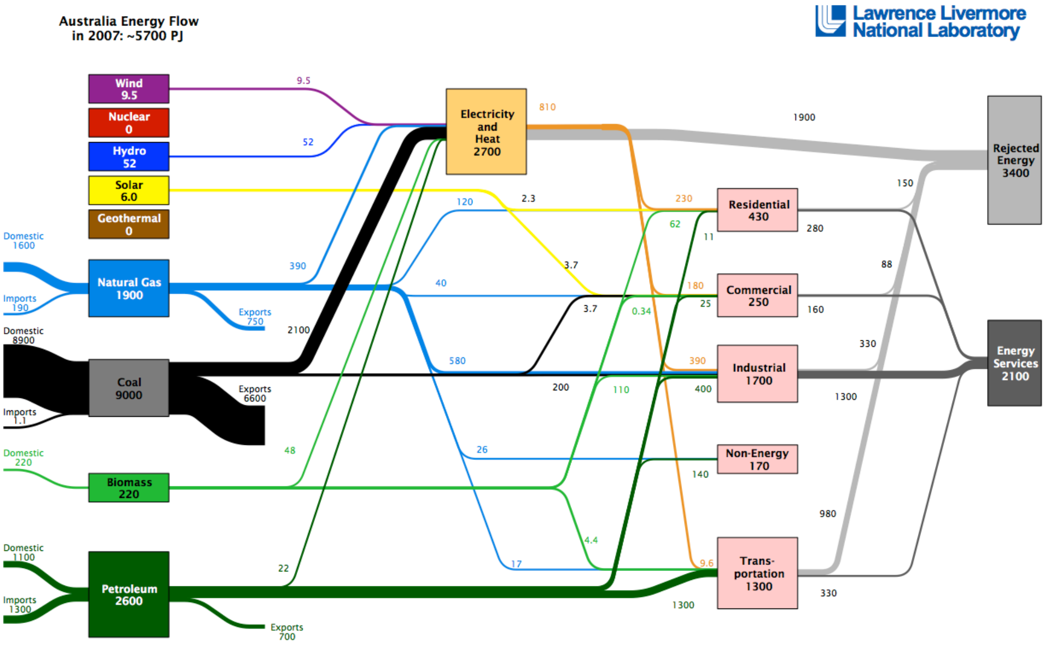
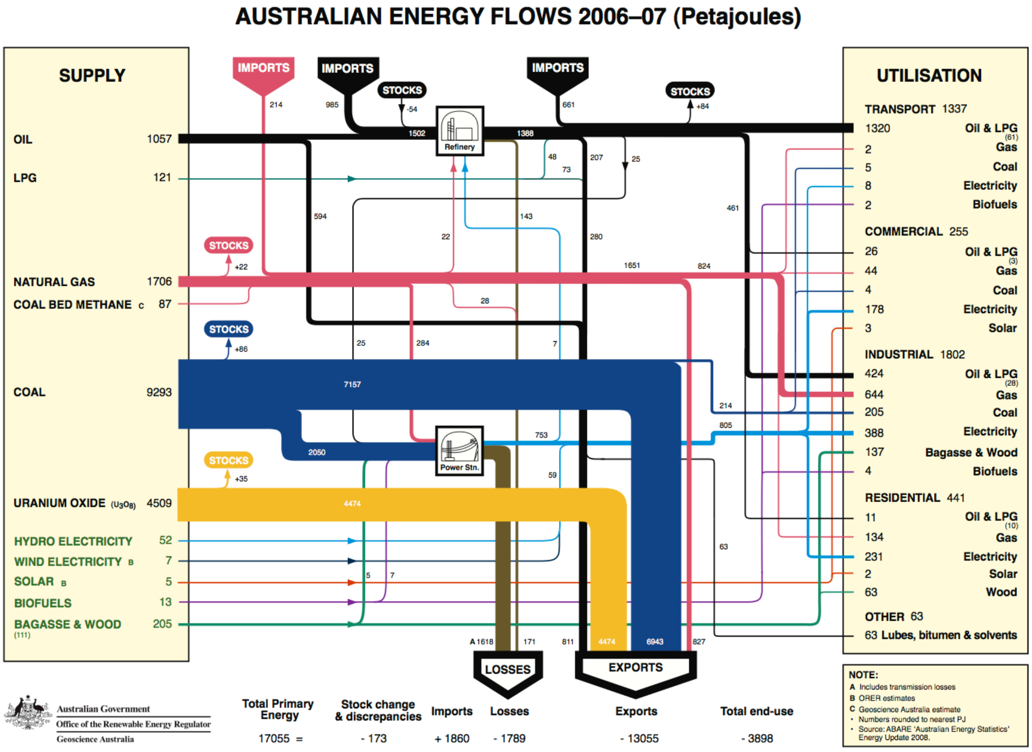
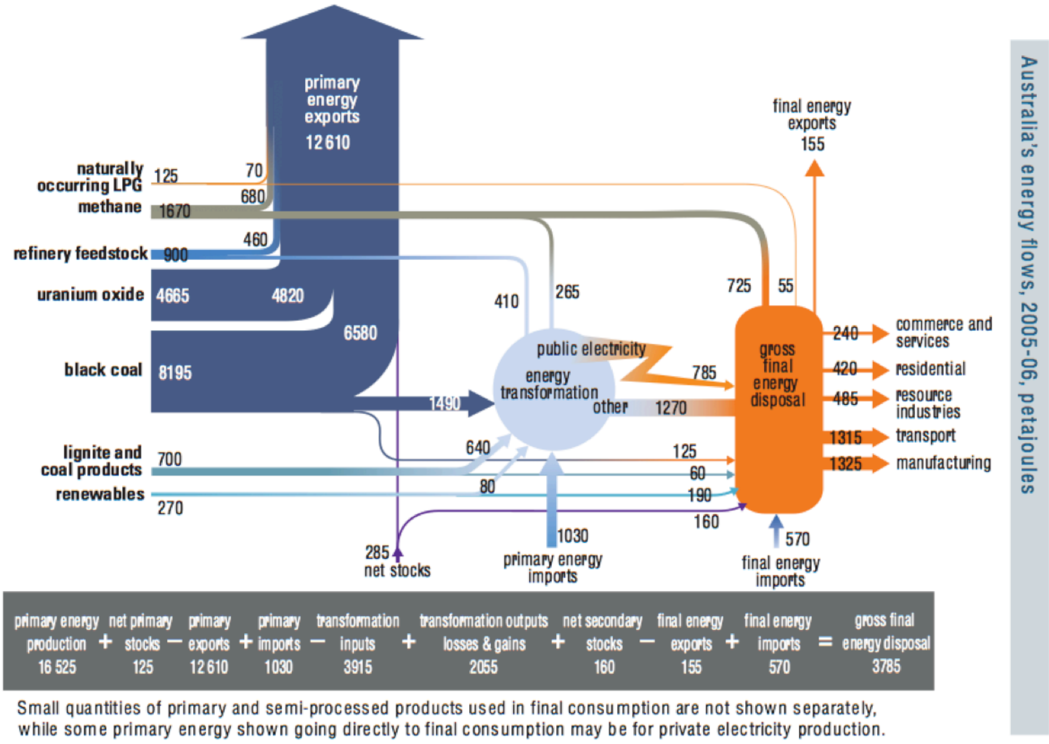


Figure 41: Geoscience Australia 2007 Australia energy flow in PJ



ABARE shows in its flow chart a central sink called *public electricity*, *energy transformation* and *other*. In the title the transformation loss is 3915 PJ

Figure 42: ABARE 2005-2006 Australia energy flow in PJ

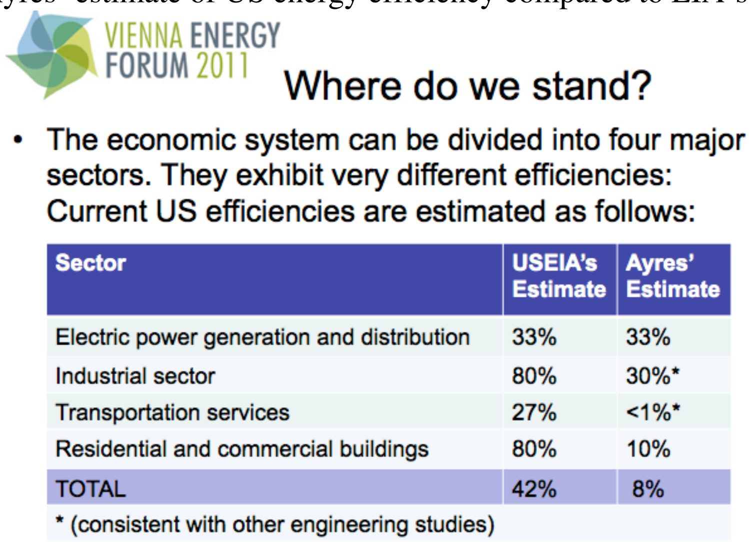


-4-Energy efficiency: exergy

In the Vienna energy forum 2011, Robert Ayres presented a paper on Energy efficiency. *Useful energy* is called *exergy*, but it is almost impossible to find historical data on *exergy*, so it is a theoretical subject without any reliable open database.

Ayres presents an interesting estimate of US energy efficiency very different from EIA (in fact LLNL) estimate: he estimates an efficiency for transports at <1% (Dewulf & Langenhove 2002), when EIA takes 27% (in fact 25% 1950 to 2009, except 20% 2002 to 2000); an efficiency for residential and commercial buildings at 10%, when EIA takes 80% and an efficiency for industrial sector of 30%, when EIA takes 80%!

Figure 43: R.U.Ayres' estimate of US energy efficiency compared to EIA's estimates



Sector	USEIA's Estimate	Ayres' Estimate
Electric power generation and distribution	33%	33%
Industrial sector	80%	30%*
Transportation services	27%	<1%*
Residential and commercial buildings	80%	10%
TOTAL	42%	8%

This shows clearly that energy efficiency is estimated with a huge range and needs to be better discussed to reach a consensus.

Conclusions

Looking at the international energy flow 136 charts issued by the LLNL for 2007 seems to be very interesting because LLNL estimates, within the output, what is wasted and what is useful. This breakdown can help to make plan on how to save energy by finding in each country where energy is wasted.

Unfortunately there is no other organization doing the same worldwide estimate.

But looking in detail into the way where the amount of wasted energy is estimated, like the amount of useful energy, it seems that there are many sources of inaccuracies:

-energy final consumption is badly measured and the data changes often , when the accuracy of the measure is never estimated, yet despite that many ridiculous decimals are given

-the energy data is often corrected because of the climate, but these climates correction varies and increases the inaccuracy of the measure

-each energy source, that is measured in many different units (volume, weight, heat, energy, power) is converted in energy being either PJ or Mtoe from equivalence factors which are arbitrary and that change which time. France is an example of equivalence changes where the percentage of nuclear electricity increases by 26% and final energy consumption decreases by 25%, which shows drastically that equivalence matters a lot, yet these equivalence standards are never discussed.

-because there is no consensus about rule, no referee and no red card, each author who wants to appear different changes the previous method, units and often wording

The comparison with the LLNL charts in countries, where national agencies publish their own energy flow charts, leads to the conclusion that they cannot be compared and it is almost hopeless to estimate the accuracy of the data and the meaning of changes.

The only conclusion is:

- only charts from the same author and in the same paper (same date) could be compared

-a serious study on the subject of energy measures, accuracies and consensus on methodology need to be done worldwide, but only between scientists because the subject is too political.

At least a range of assumptions on energy equivalences and energy efficiencies should be acknowledged and the range on primary and final energies clearly stated.

We now live in a consumption society based on consumption growth and cheap energy.

We need to change our way of life, taking into account that the world is finite and that growth cannot remain constant for ever in a finite world and we have to save energy.

Saving energy by using better tools (like car with better mile per gallon, house with better insulation) is good, but it is much better to not use tools or consume useless products (less driving, less eating to stop obesity).

The policy of *keep consuming* to *keep jobs* by borrowing leads us to the present economical and financial crisis, with increasing unemployment.

The only solution is to stop supporting the present trend and to change our way of life.

But each step will help and to stop wasting we need to see where is the waste (outside the obvious waste of food = 50% in the US, 33% in the UK) in energy (food is energy).

Heat is either a goal or a nuisance.

Converting wasted heat into electricity is a must (thermoelectrics? Alphabet energy?).

Up to now, only the LLNL energy flow charts show us the amount of waste for every country, but they should be improved and be made more reliable. Most national energy agencies should try to publish similar charts showing at the end what is waste and what is useful.

But before at the world level, we need to agree to definitions, rules, referees and red cards.

PS: my broken English was corrected by Herve Duval (he translated Richard Heinberg's book *The party's over* in French "Pétrole la fête est finie!")