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Session End of Growth?

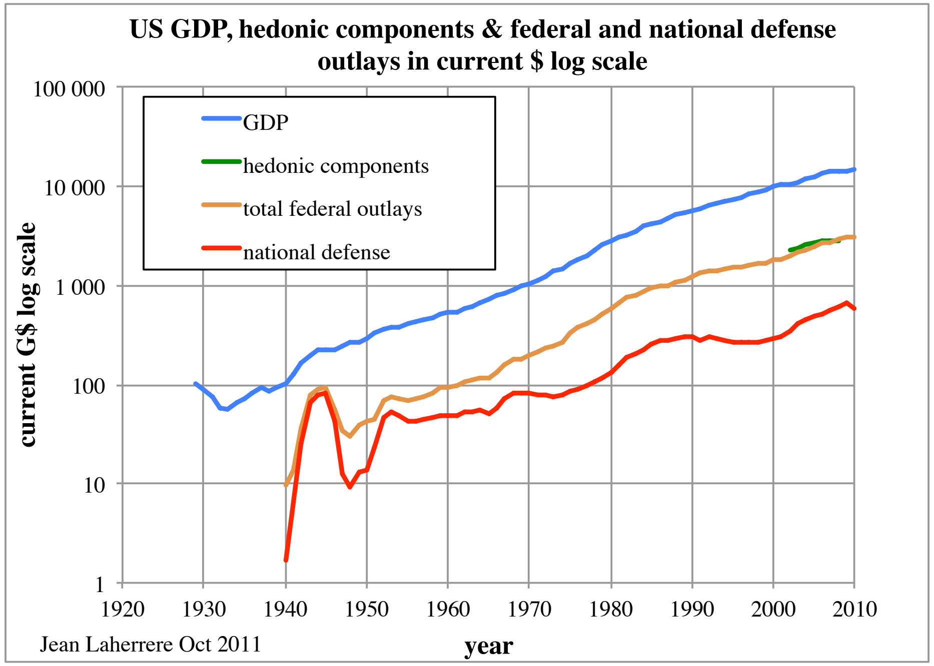
Saving energy: reliability of national energy flows

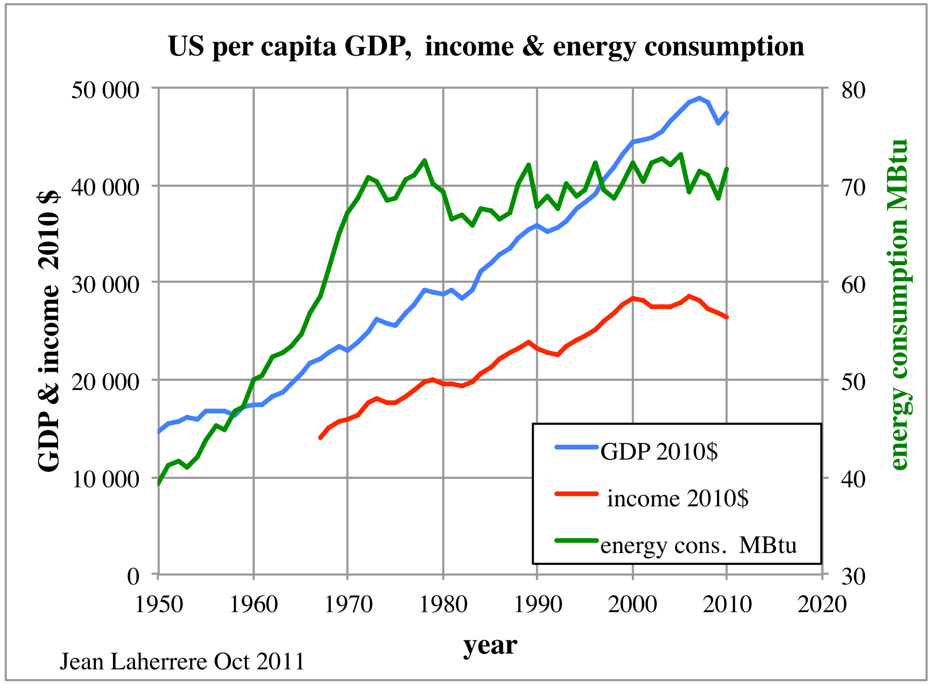
Jean Laherrère   President ASPO France

A long paper is available on the ASPO France site where more explanation and more graphs can be found.

End of growth? Which growth?

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





US per capita income = plateau since 2000, when GDP still increases, but energy consumption = plateau since 1972.

Saving energy is a must in a finite world and the most efficient way is to cut waste.

-1-Lack of rules and referees or bad rules

In any sport there are rules and referees with red cards to expel who is cheating.
In the energy domain, there are very few rules, which are contradictory and not respected.

-Unit

The **International System of Units (SI)** is the rule in science, 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 are forced to follow the SI, but it is barely done.
In 1998 the Mars Climate Orbiter probe crashed on Mars (150 M$), because the NASA sent the instructions in newton (SI) when Lockheed built it in pounds (non SI).
In 1974 the Elf first steel platform DP1 (105 m high) on the Frigg gas field sunk in the North Sea (300 M$), because of a confusion in units.
The SI energy unit is the joule = work of a force of 1 newton for a move of 1 meter or to lift an apple (100 g) by one meter. One gasoline tank (45 L) represents 1.6 GJ.
The non SI energy unit used in the US is the British Thermal unit or Btu (illegal in the European Union since 1979). But there are 8 definitions of Btu from 1.054 615 to 1.059 67 10^3 J.
US EIA energy reports are in quad = quadrillion Btu = 10^{15} Btu = 1.055 056 EJ.

The other non SI energy unit is the **tonne oil equivalent (toe),** but there are several definitions of the toe which can vary from 41. 85 GJ to 42 GJ (WEC).

In the European Union, any food should report its energy content in joule!
The energy content of one hamburger is about 1 MJ.

-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 possible 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, but = $(Gm)^3$ = 10^{27} m^3 ≈ 1 million earth volume!

-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, in order to avoid confusion the thousand should never be indicated by a comma or a dot, but by a space: US 2008 edition of the National Institute of Standards and Technology: Guide for the use of the International System of Units

-heat content by country

EIA oil	range 1 to 1.25
EIA NGPL	range 1 to 1.55
EIA dry gas	range 1 to 1.67

The 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 NG.

-density = specific gravity

IEA manual 2004: from 6.2 b/t to 8.3 b/t, median 7.3 b/t, but fuel oil is heavy <25°API, but also heavy <22°API. 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.

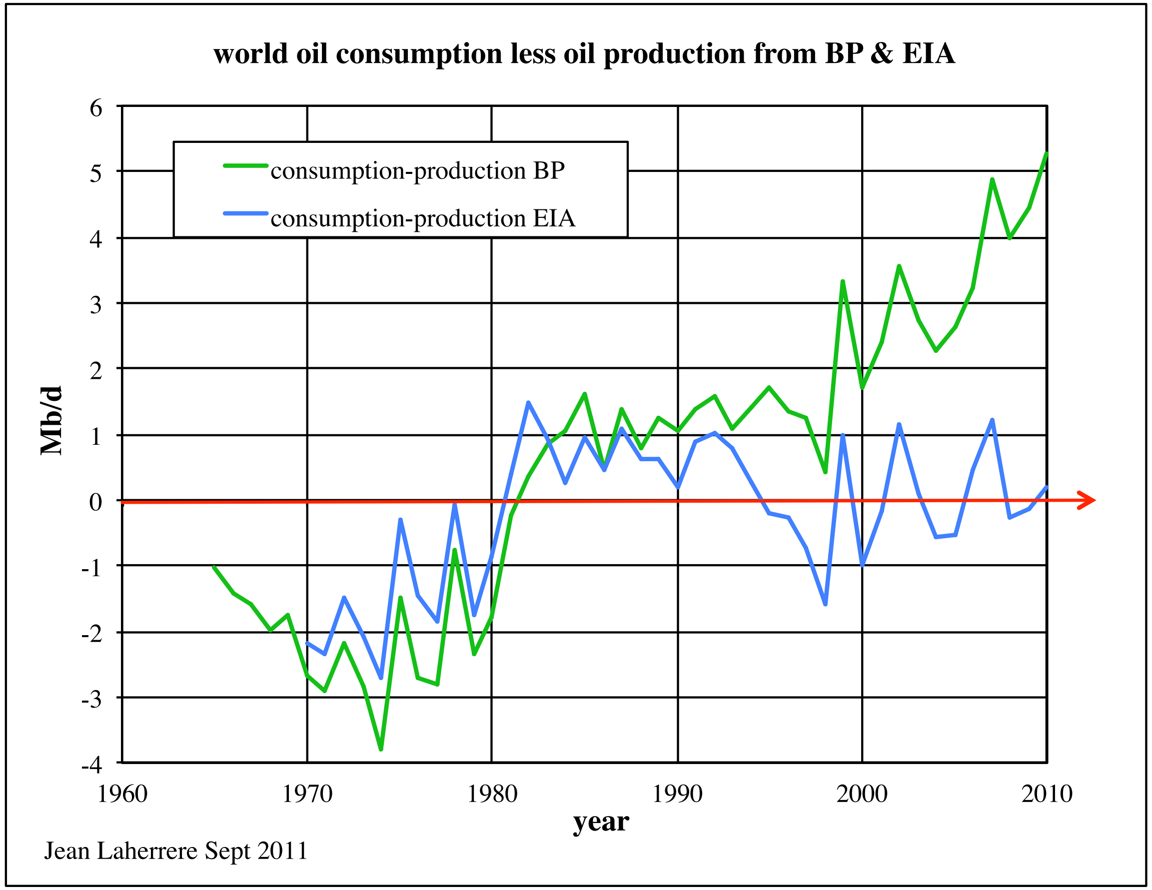
-definition of oil

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, but reports **oil consumption** where biofuels are included. Why does BP use the same term?

Figure 1: **World oil consumption minus oil production from BP & EIA**

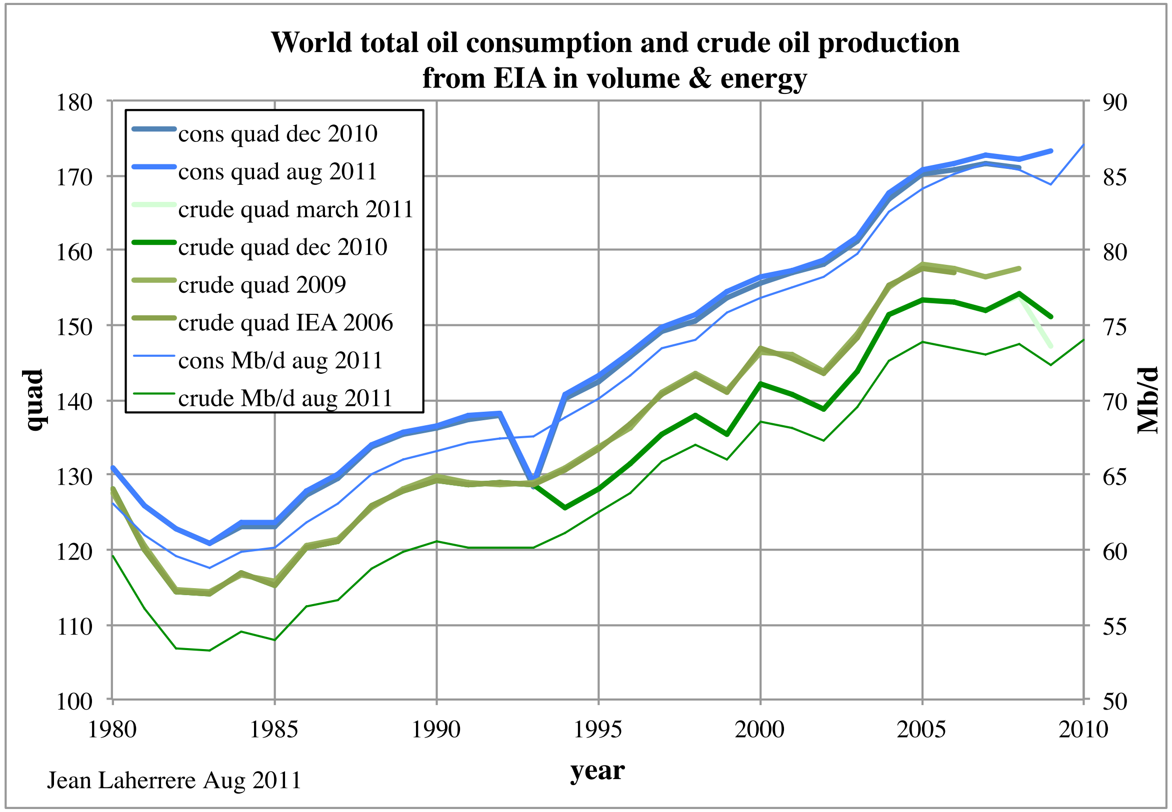


-energy equivalence

Oil is measured either in volume or in weight, rarely in energy.

In the past, the EIA was reporting the world oil supply and crude oil production in volume (Mb/d) and in energy (quad = Btu), but there were mistakes, now EIA has stopped reporting world oil production in energy, it is 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 for consumption 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 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.
For electricity, to convert the MWh into toe, there are two methods :
-*consumption equivalence* estimating the amount of oil which burned will deliver the same amount of heat, where MWh = 0.086 toe,
-*production equivalence* estimating the amount of oil in a thermal plant which will deliver the same MWh, where MWh = 0.222 toe,
The difference is a ratio of 2.6!

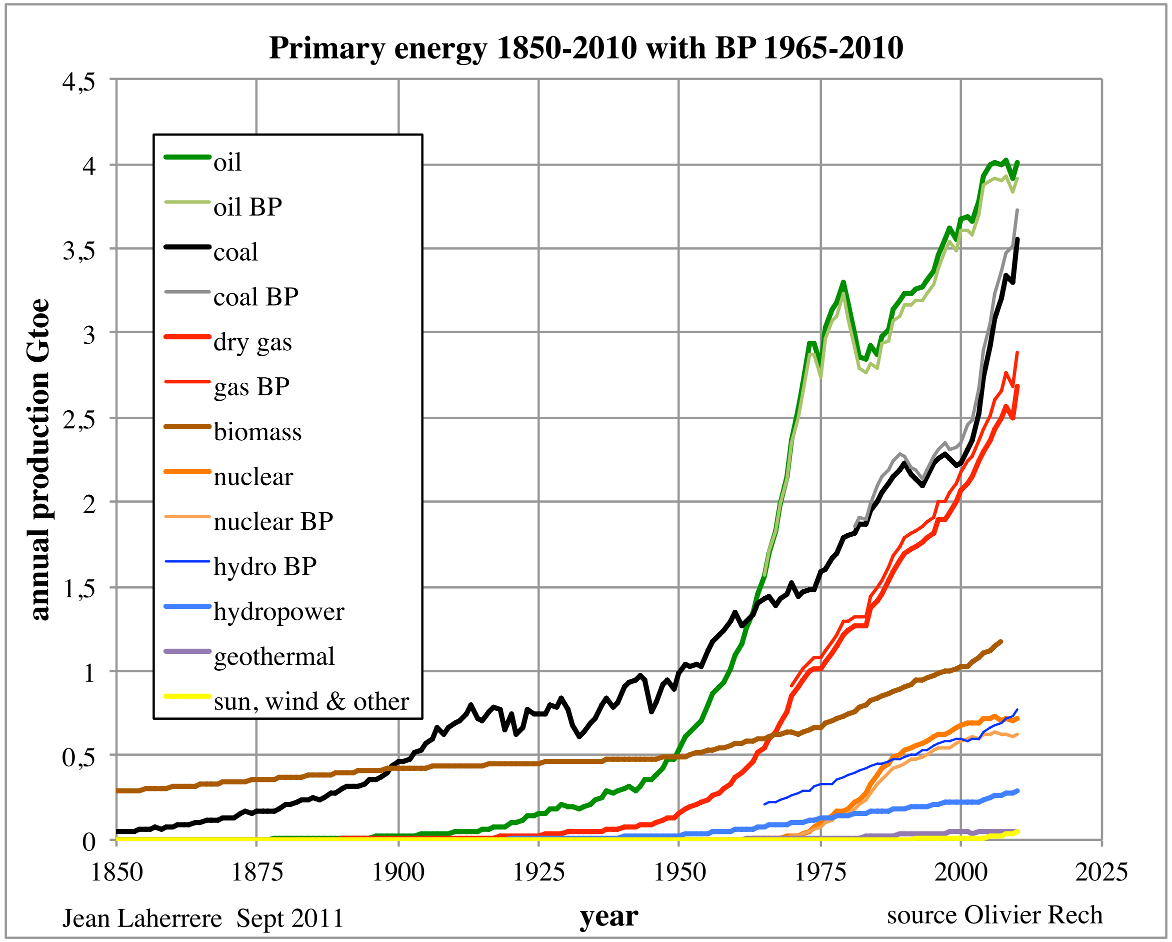
-**France example of change in energy equivalence**

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 percentage of nuclear in France primary energy in 2001 moves from 30.8% with the old method to 38.8% with the new method: it is a large **increase by 26%.**
The final energy consumption was reduced by 25%!

This example shows that energy equivalences are not very reliable.

Comparing the primary energy from a 1865-2010 synthesis (mainly IEA) and BP 1965-2010 the discrepancy is small 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**



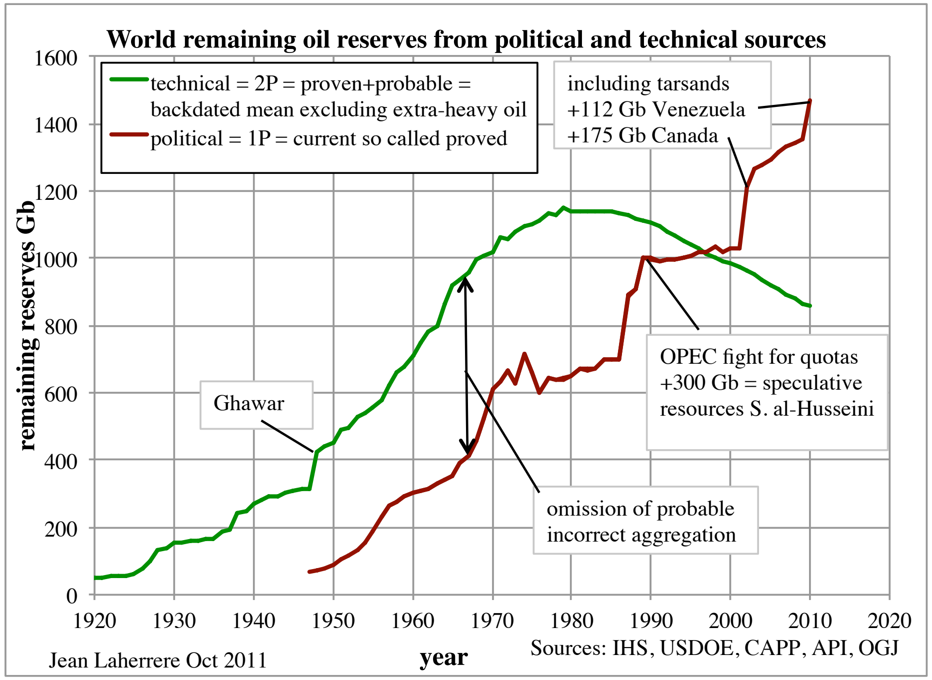
Biomass is very difficult to estimate because of the large amount of non-commercial biomass (in particular dungs). BP does not report biomass.

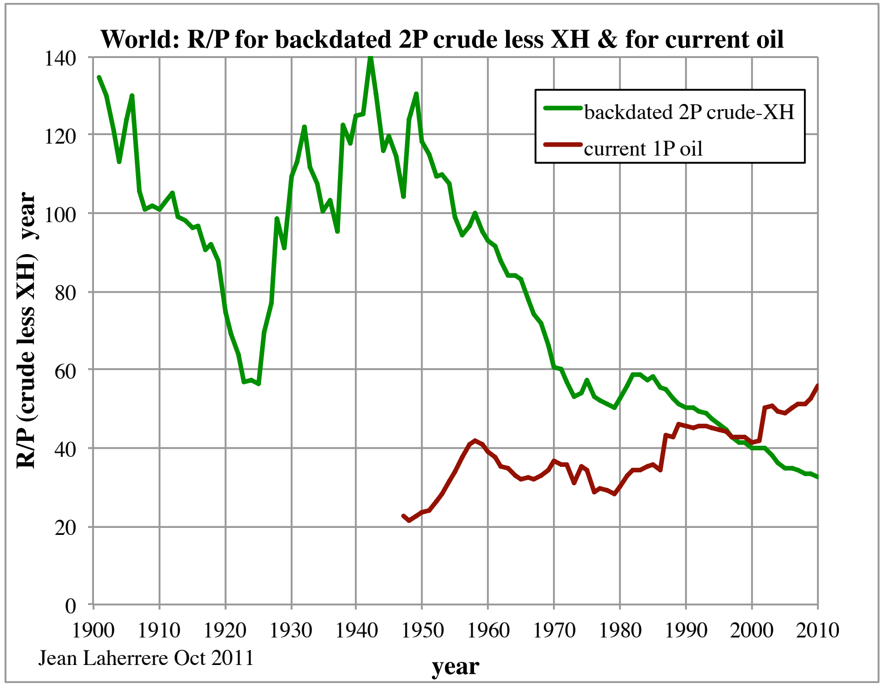
-reserves

The US SEC rule (up to 2010) obliges to only report proved reserves = 1P, based on very old 1977 SPE definitions, forbidding to report probable reserves, when most operators decide the development on the ***net present value*** based on ***mean* reserves** = proved + probable = 2P. US reserve growth is partly due to the omission of probable reserves, but mainly due to the incorrect arithmetic addition of field proved reserves to obtain the US proved reserves, underestimating the reality by about half.

Figure 4: **World remaining oil reserves from political/financial and technical sources**

Figure 5: **World R/P from backdated 2P crude less XH oil and current 1P oil**





Economists have only the public political wrong data, when the technical data is confidential.

Economists do not think wrong, they think on wrong data.

-2- US energy flow charts

The Lawrence Livermore National Laboratory (LLNL, funded by USDOE) provides the energy flow charts for the US from 1950 to 2009 in quads, except 1995-2002 in PJ.

But the evolution with time of the annual LLNL reports shows that there is no rule and that **each author does what he wants, trying to do different than his predecessor.** It is not a team effort!

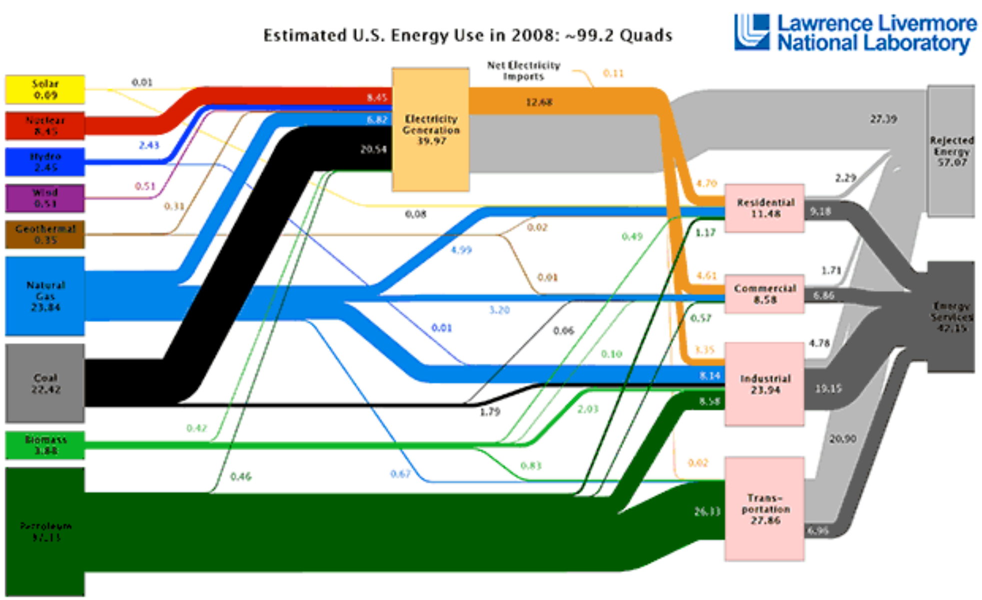
The graph displays on the left energy use and at the right two outputs: lost energy (called rejected energy from 1950 to 2009, except 2001 and 2002) and useful energy (called energy services since 2003).

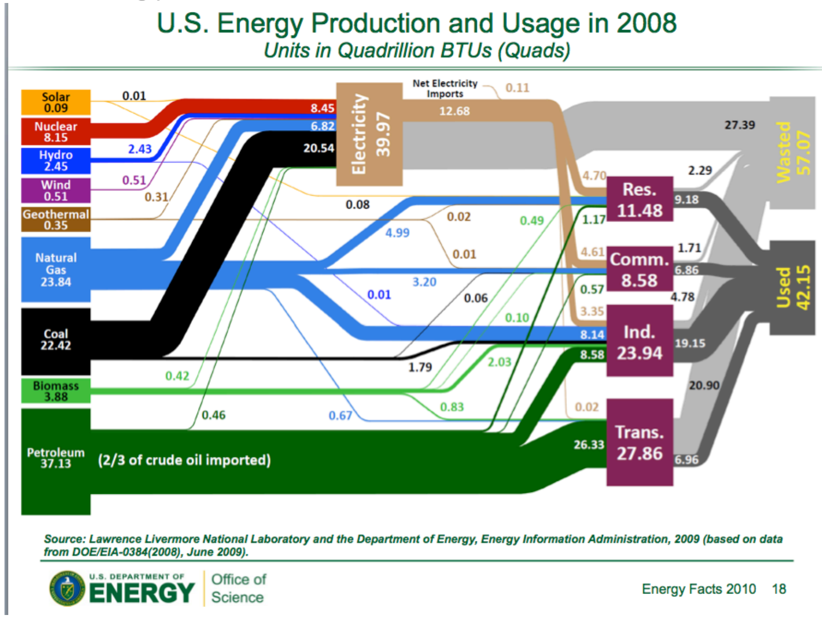
For 2008, the LLNL publishes the following graph almost identical to the graph from the USDOE (Office of Science), except *rejected energy* = ***wasted*** and *energy services* = ***used.***

There is no consensus on energy wording within the US scientists!

Figure 6: **US 2008 energy flow from LLNL**

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

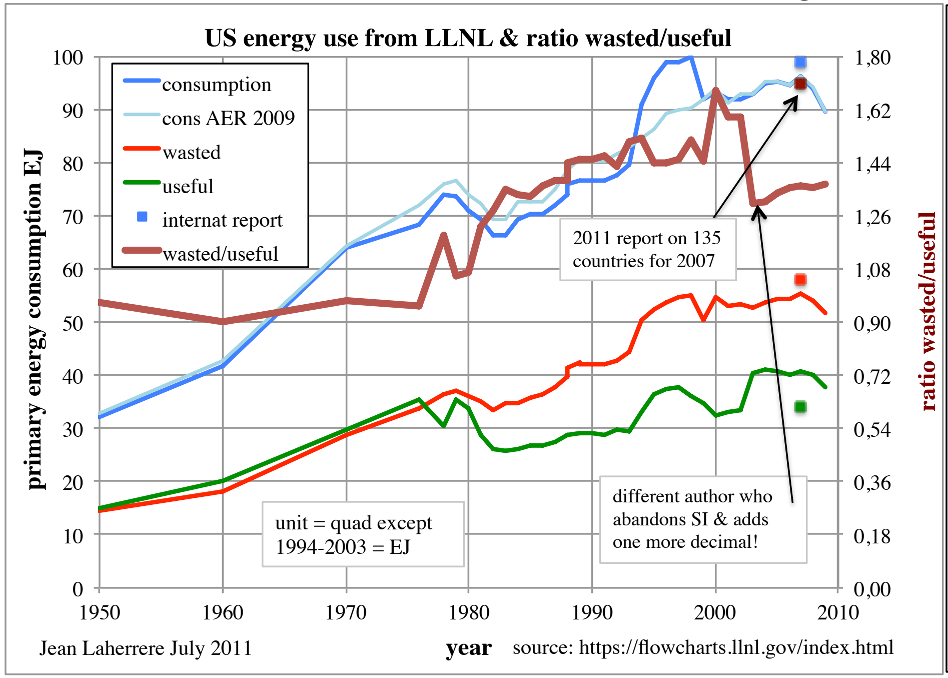


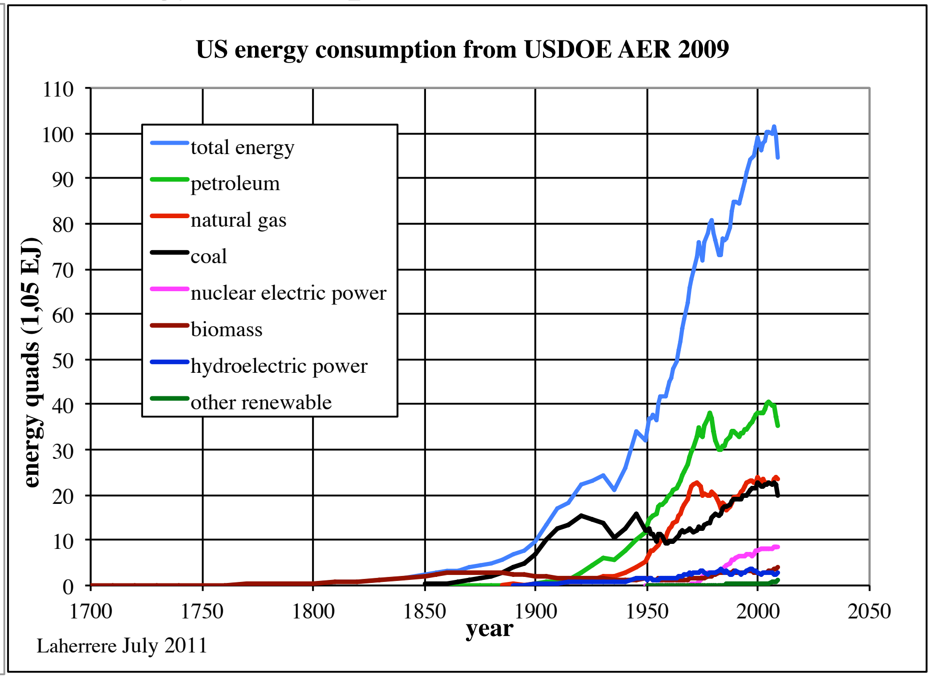


There are many differences between LLNL and EIA/AER 2009

Figure 10: **US energy use from current LLNL & wasted/useful ratio with AER 2009**

Figure 11: **US energy consumption from USDOE AER 2009**



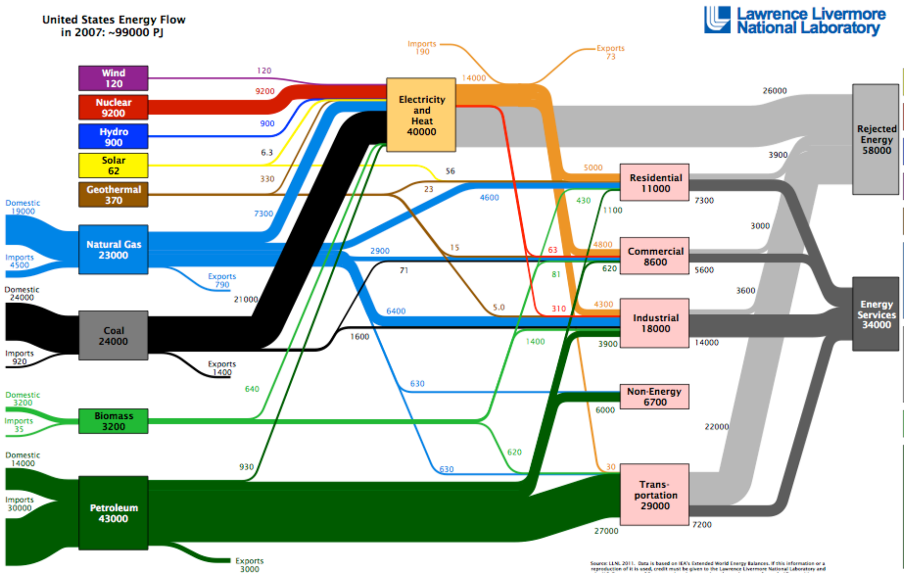


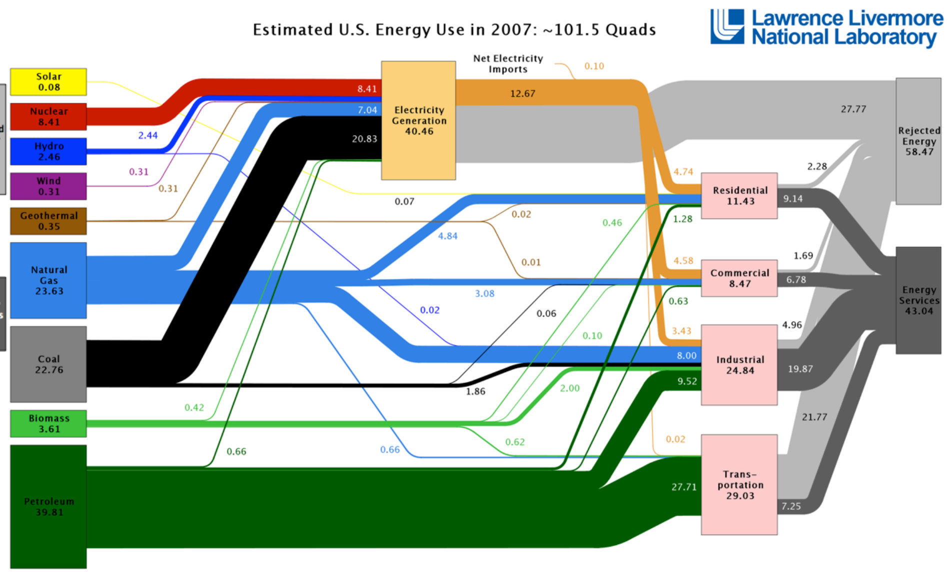
The US wasted/useful ratio was below 1 before 1976! It is now about 1.7.

The current LLNL data is obviously wrong, but no correction can be found in the archives!

The AER 2010 was announced last year for July 2011, but is not yet published at mid-October.

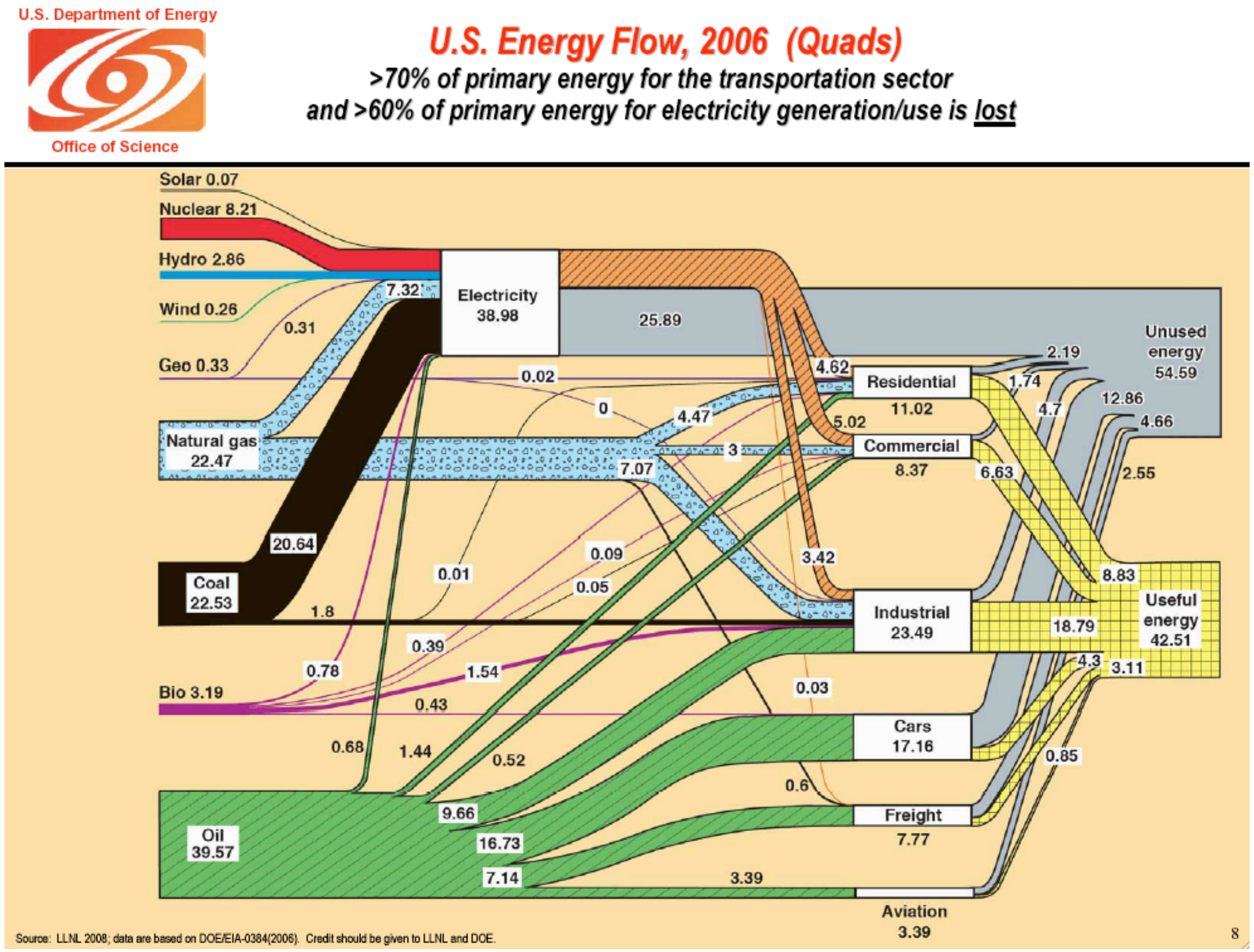
In the 2011 international report on the energy flows of 136 countries for 2007 given in PJ, the US wasted/useful ratio is 1.7, when the ratio from archives in quads is 1.4.
The large discrepancy is on the US useful energy being 40 800 PJ when it is 34 000 PJ in the 2011 international report, that is 17% lower.
This discrepancy is ignored by LLNL, which changes values without any warning!
Figure 12: **US 2007 energy flow from the LLNL 2011 international report** (Smith, Belles & Simon) **in PJ**
Figure 13= **US 2007 energy flow from the LLNL current report** (unknown author) **in quad**





Efficiency for transportation is taken at 25% for US, like every other country = arbitrary and wild guess!
Efficiency for residential, commercial, industrial is taken at 80% = arbitrary and wild guess!

Figure 14: **USDOE 2006 energy flow with in the title:**
>70% of primary energy for transportation and > 60% for electricity generation/use **is lost**

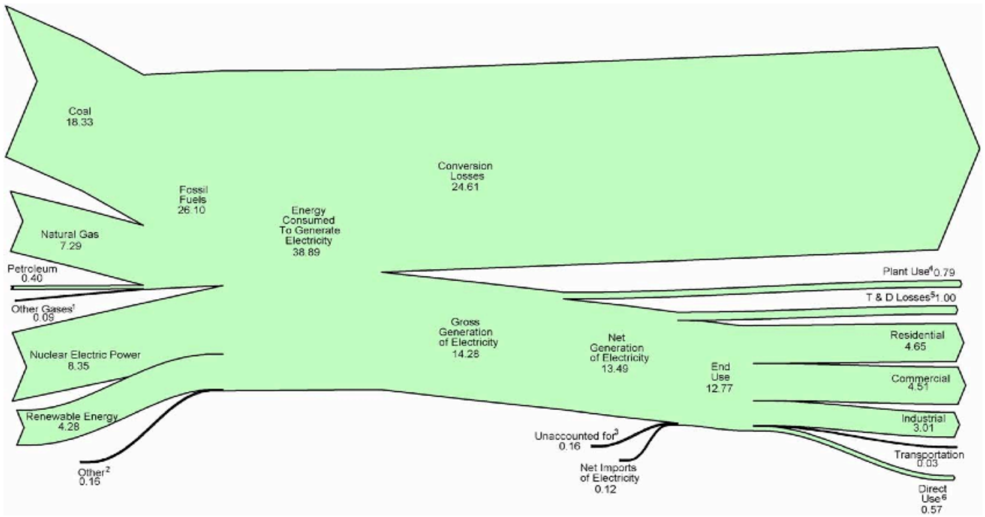


Efficiency for cars and aviation is taken at 25%, but at 40% for freight.
In 2008 USDOE changed useful energy into used, and unused energy into wasted.

In the 2009 US electricity flow, the lost/generated ratio is 1.72 = 63% loss

Figure 16: **USDOE 2009 electricity flow**

Figure 8.0 Electricity Flow, 2009
(Quadrillion Btu)



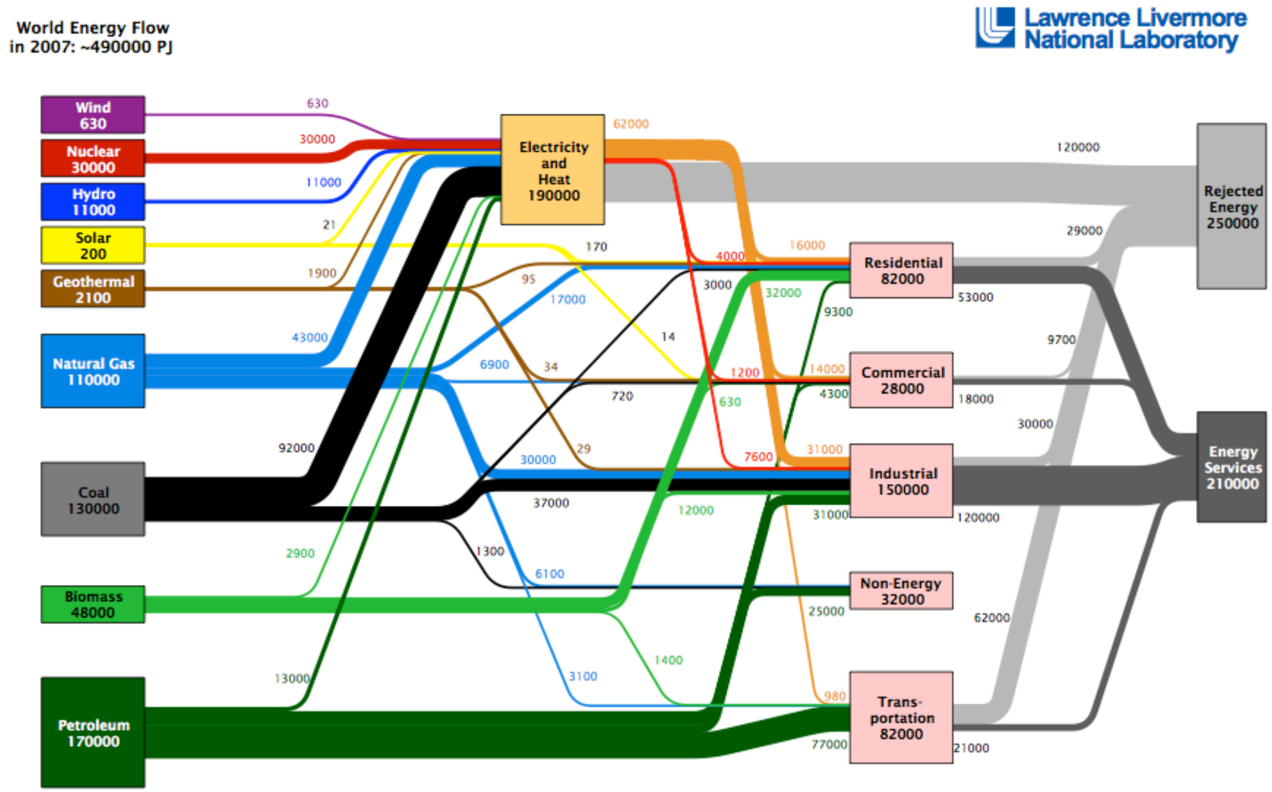
The *wasted/used ratio* for the **US states in 2008** shows that Florida and California waste more than the average, when Texas and Louisiana waste less! Energy is given in quad with many decimals for the States.

State	energy use	wasted/used ratio	loss %
Florida	4.1527	2.24	69
California	7.7086	1.45	59
US	99.2	1.35	57
Texas	11.4854	1.10	52
Louisiana	3.3877	0.75	43

-3-LLNL flowcharts on 136 countries for 2007

The LLNL has published on March 2011 the energy flows of 136 countries in 2007.
The data are given in PJ with only two significant digits: it is the way that it should be always reported.
For the world energy flow, the *used energy* (called also *useful energy* and now *energy services*) is 210 000 PJ when the *wasted energy* (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 76% is lost!
For the electricity 63% is lost!

The conventions for energy equivalence adopted by France (DGEMP) in 2001, in order to be in line with the IEA rules have changed considerably the percentages of the French energy mix in 2001, as shown below comparing with the BP editions 2002 & 2011(significant changes on the second digit)

France 2001 primary energy in Mtoe

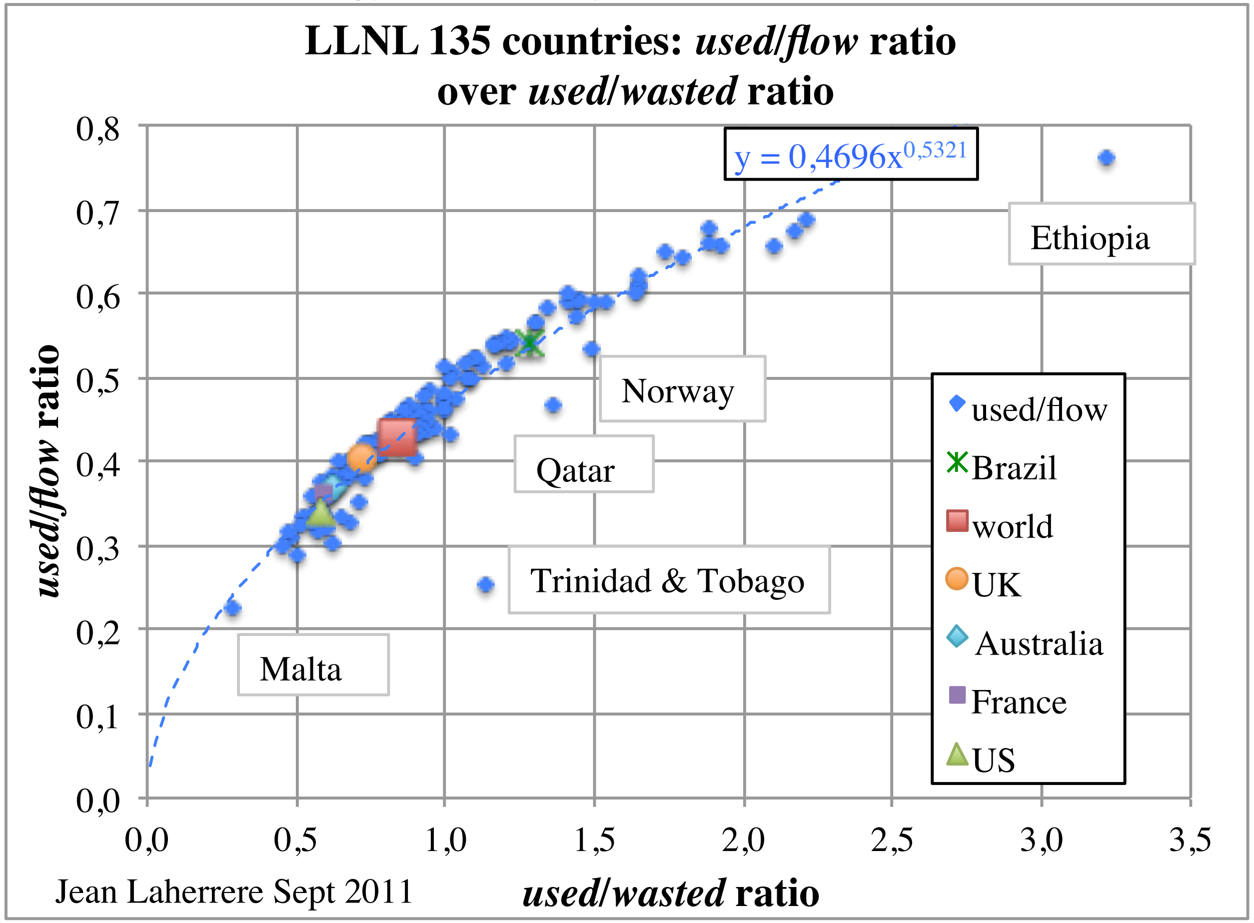
	DGEMP		BP 2002	BP 2011
	New method	Old method		
Coal	11.9	11.9	10.9	12.1
Oil	96.5	99	95.8	95.5
Gas	37.2	37.2	36.6	37.5
Nuclear	104.4	79.1	94.9	95.3
Hydro, wind, sun	6.8	17.7	18.1	17
Other renewables	12.2	12.1		
Total	269	257.1	256.4	257.4

BP is then close to the old DGEMP estimate for hydro, wind, sun!

In a ranking of the **wasted/used** ratio, 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 ratio above) displays a surprising simple trend. The least efficient (Malta) are at the left and the most efficient (Ethiopia) at the right.

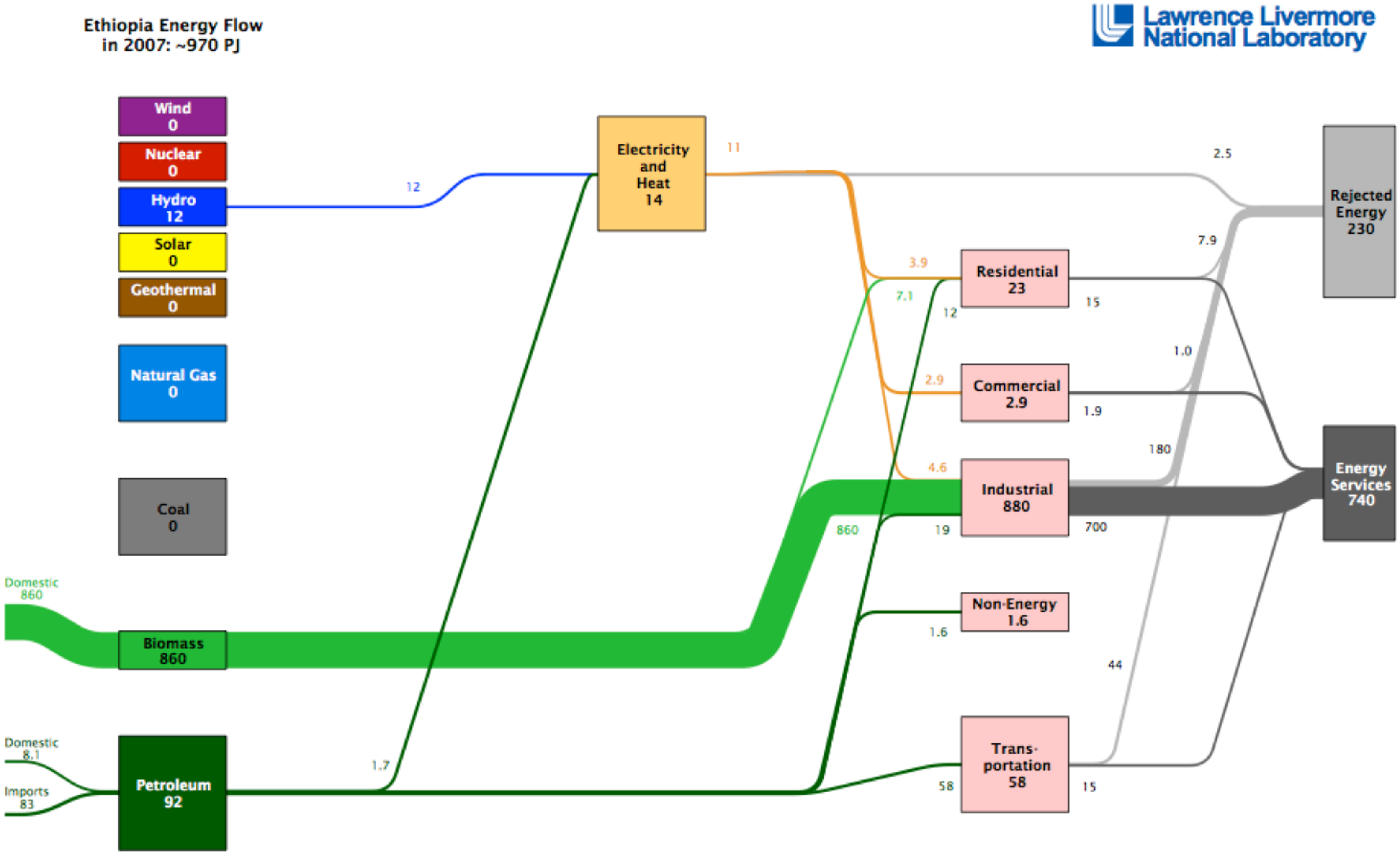
Figure 18: **LLNL 135 countries energy flow: *used/flow* ratio over *used/wasted* ratio**



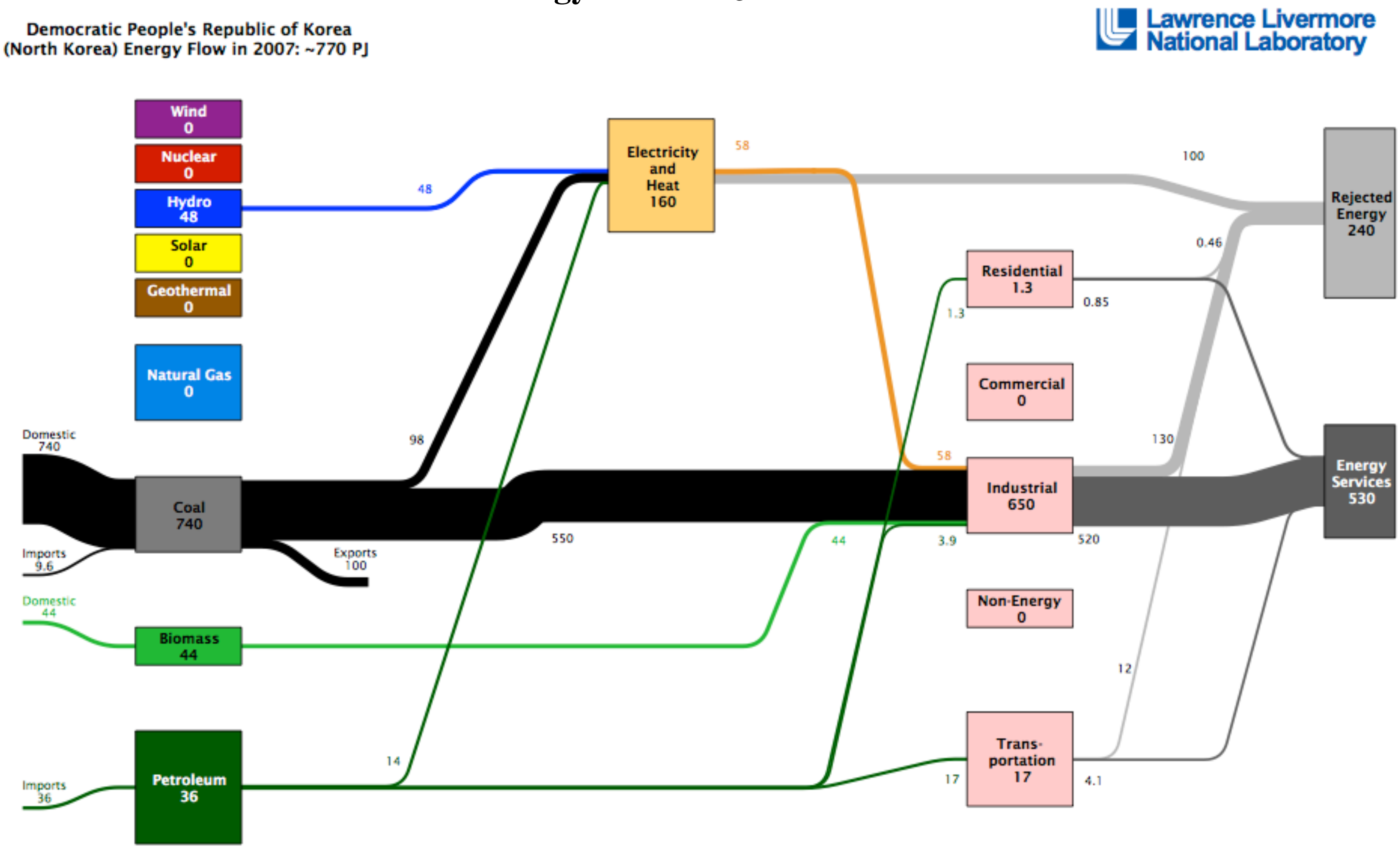
Only countries with large converting plans like Trinidad and Qatar are below the trend. Ethiopia is also low, but for another reason.

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**

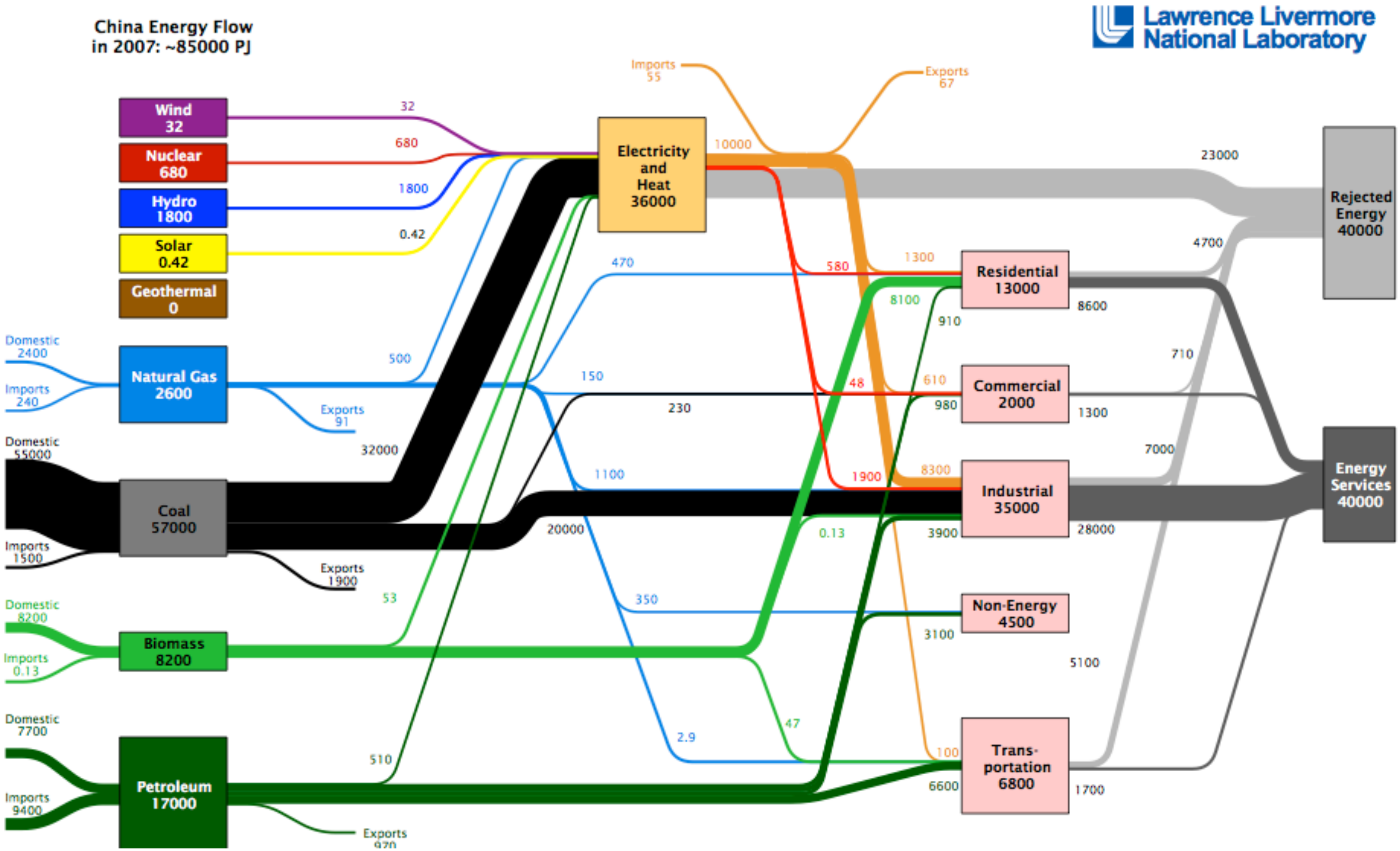


North Korea uses mainly coal for the industry and transports are very small.
Figure 20: **LLNL 2007 North Korea energy flow in PJ**

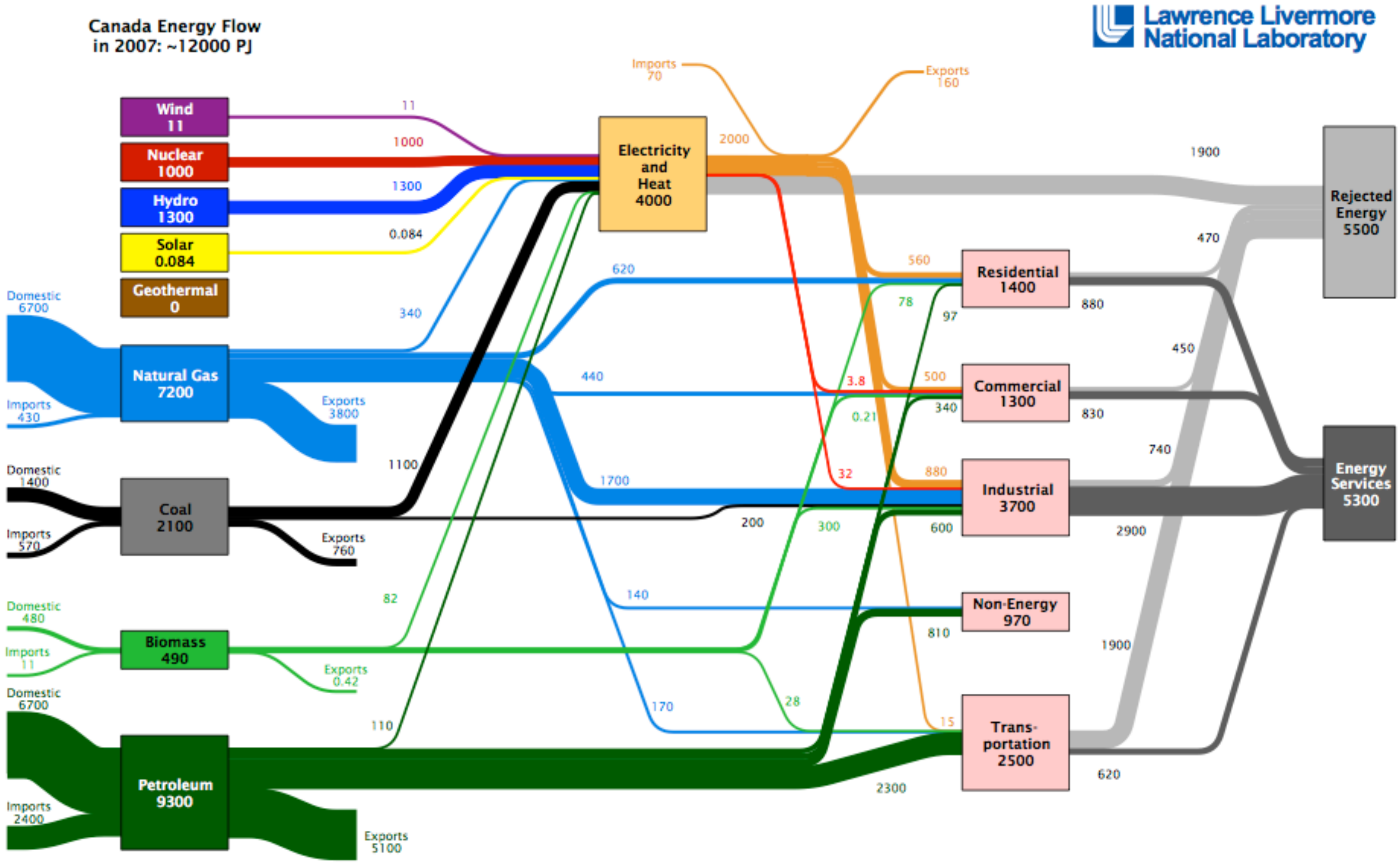


Less than half of the countries (53) have a ratio lower or equal to 1
China has a ratio of 1 because the industry uses a lot of energy (35 000 PJ) compared to transport (6 800 PJ).
This was in 2007 and it will be interesting to see the flow in 2011.

Figure 21: **LLNL 2007 China energy flow in PJ**



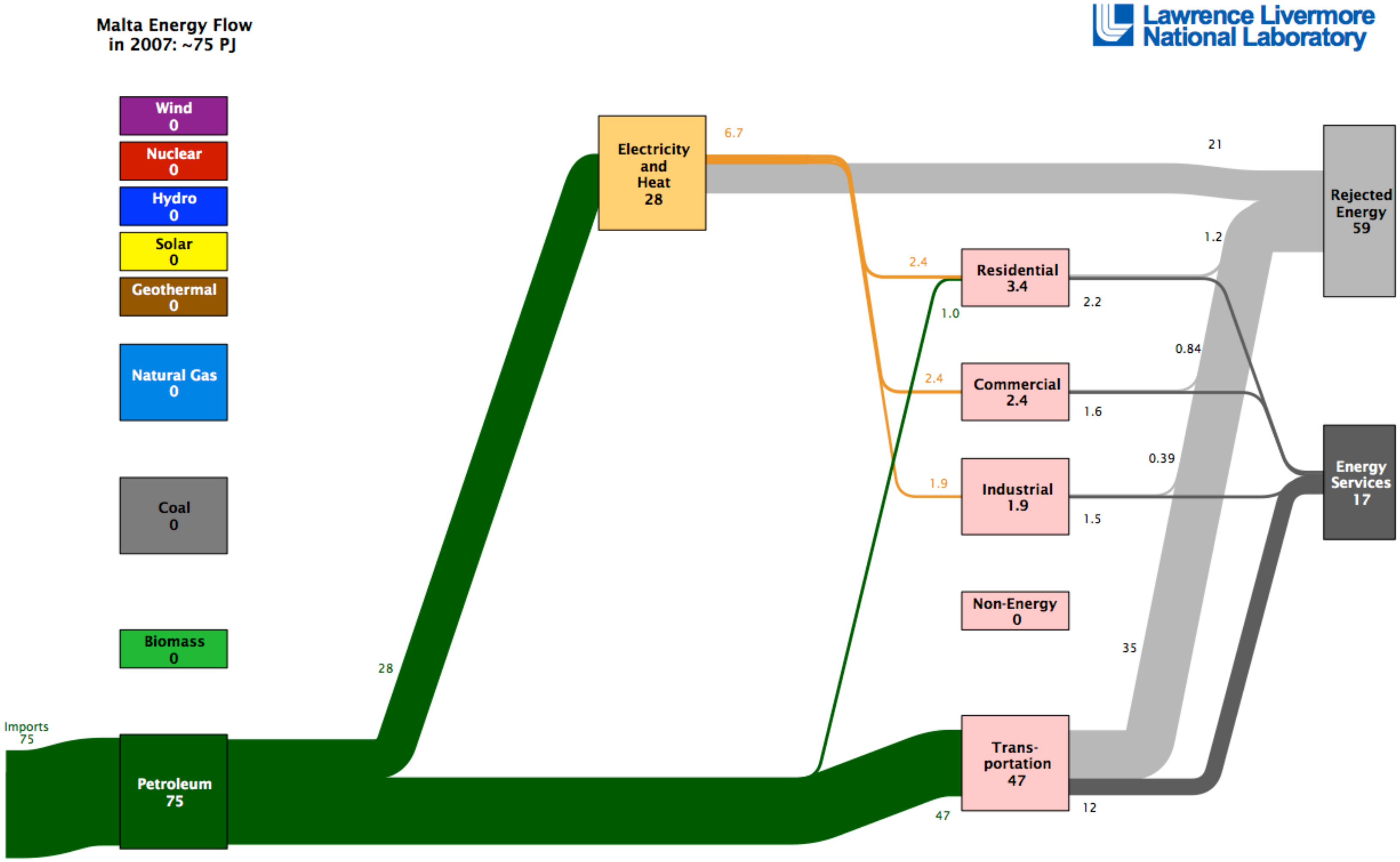
Canada has also a ratio close to 1, energy for transport is less than for industry
Figure 22: **LLNL 2007 Canada energy flow in PJ**



I was unable to find an energy flow from Canadian agencies, what a pity!

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**

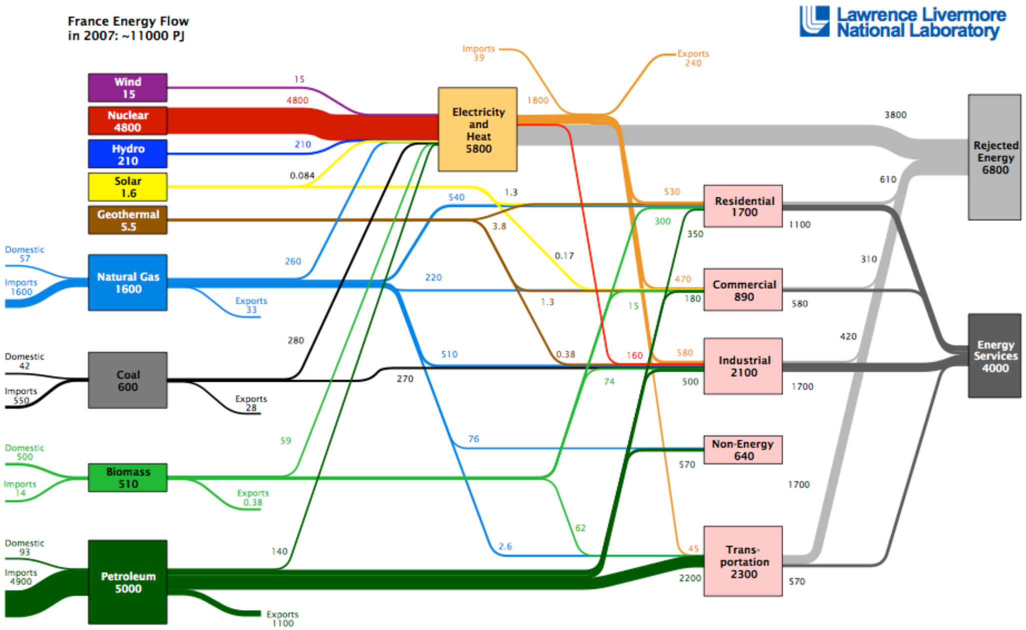


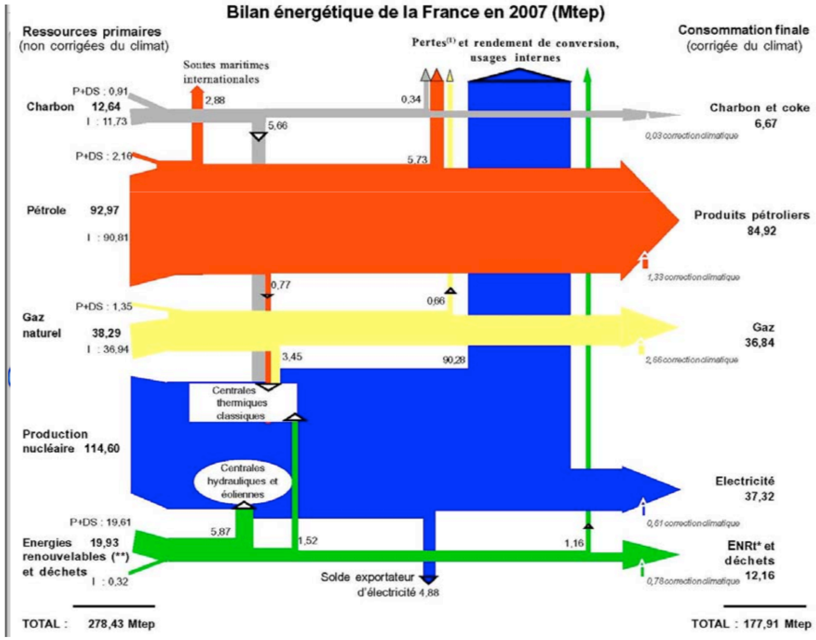
-France

France has a poor ratio of 1.7 because the energy for transports is higher than for industry

Figure 25: **LLNL 2007 France energy flow in PJ**

Figure 26: **DGEMP 2007 France energy flow in Mtoe**





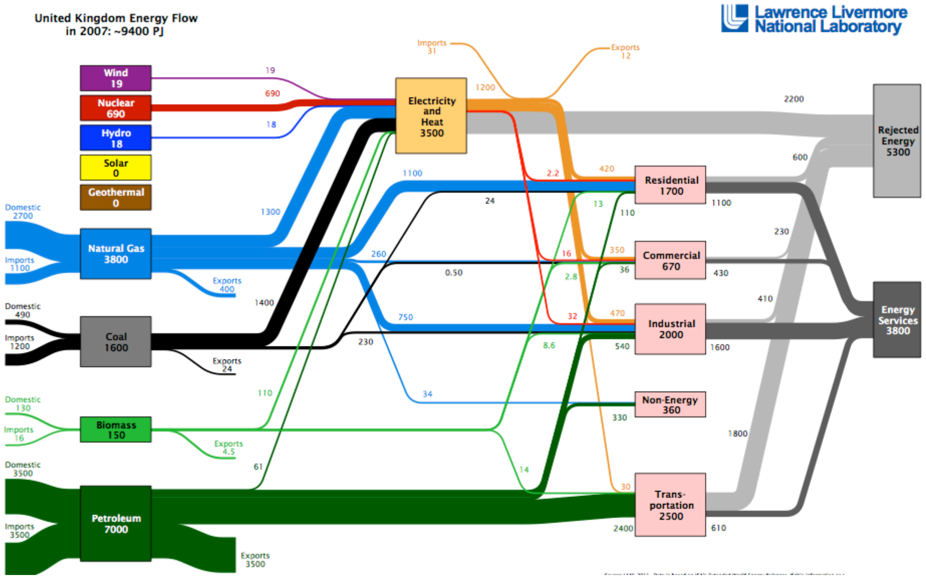
For 2007 the DGEMP loss (for converting energy) of 98 Mtoe is short by 64 Mtoe compared to the LLNL wasted: it means that the DGEMP does not include the loss of energy in transports and others and their results cannot be compared: ***wasted/used* ratio** = 1.7 LLNL, = 0.6 DGEMP

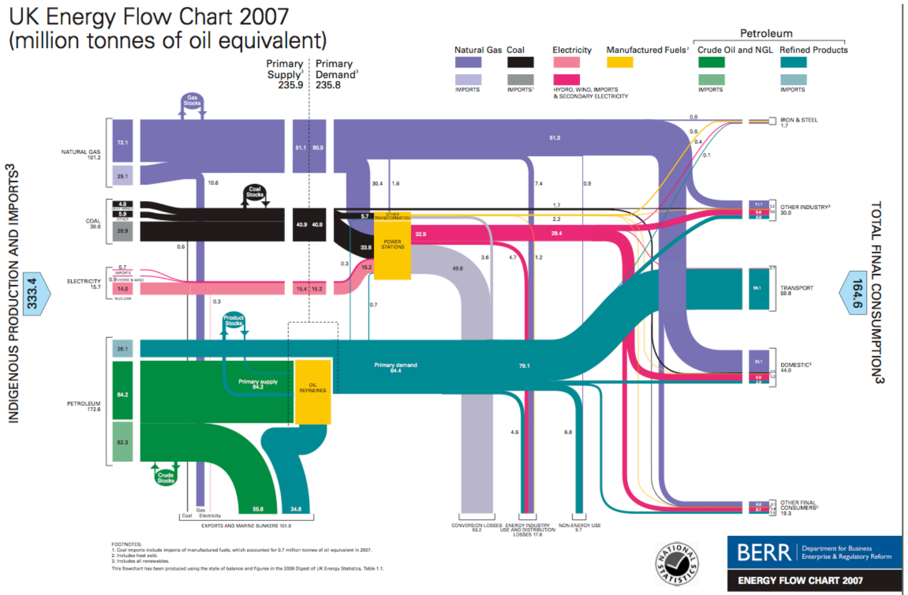
-UK

For the UK, the comparison of the LLNL flow (ratio 1.4) with the flow published by the DECC shows that the presentation and the basic data are different

Figure 30: **LLNL 2007 UK energy flow in PJ**

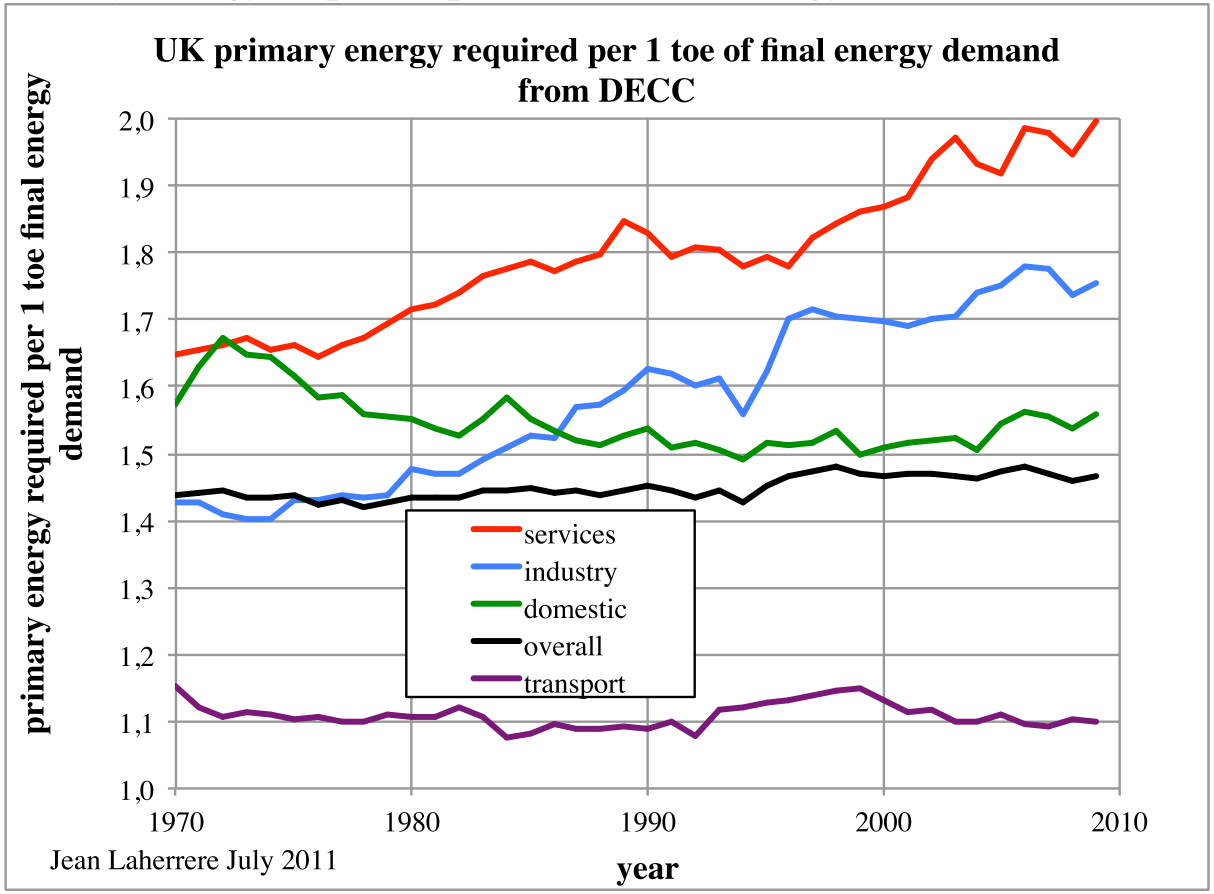
Figure 31: DECC 2007 UK energy flow in Mtoe





The DECC reports the amount of primary energy necessary to obtain one toe of final energy, where for 2009: overall =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**

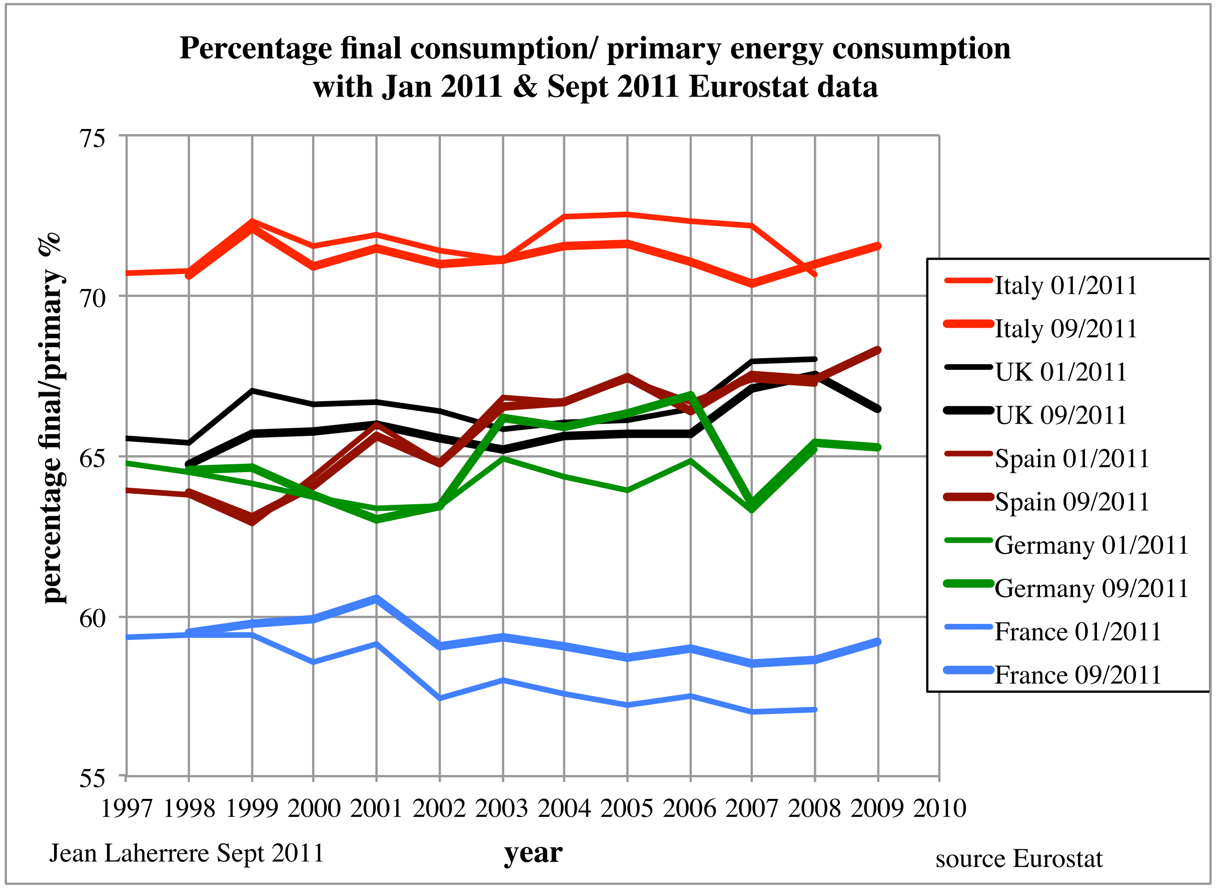


It is striking that the transport is stable at 1.1 toe since 1970, when services went from 1.6 to 2 toe.

It is completely contradictory with the LLNL UK graph where for transport 72% is considered as wasted.

It is possible with the DECC data to lead to a conclusion opposite to the LLNL graph.

Eurostat reports the primary energy consumption and final energy consumption in Mtoe and it is interesting to compare the decreasing percentage of Italy, Spain, 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.
Figure 38: **percentage final energy consumption over primary energy consumption from Eurostat Jan 2011 & Sept 2011 data**



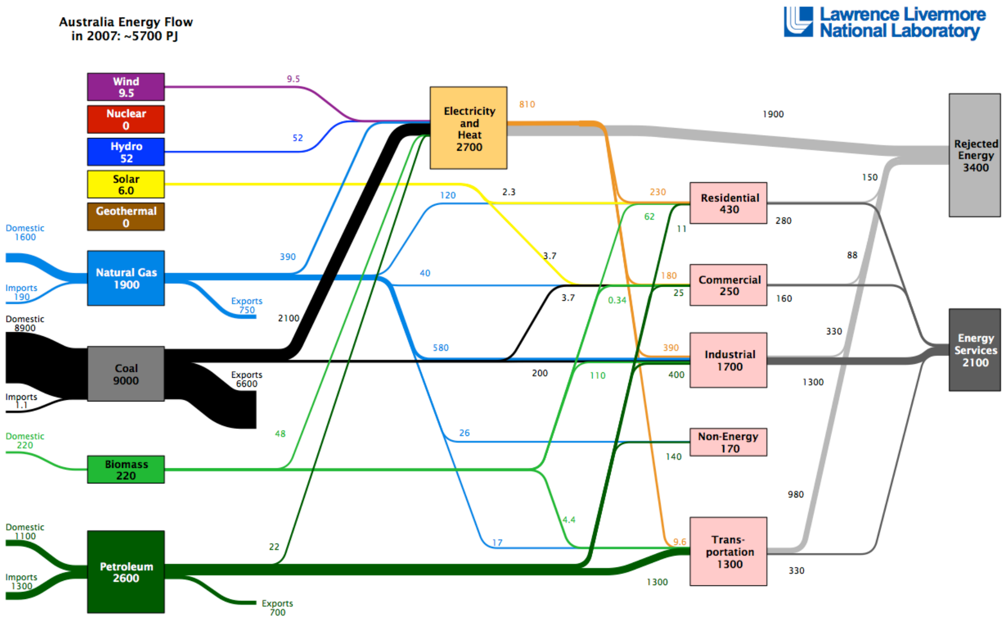
-Australia: three different graphs

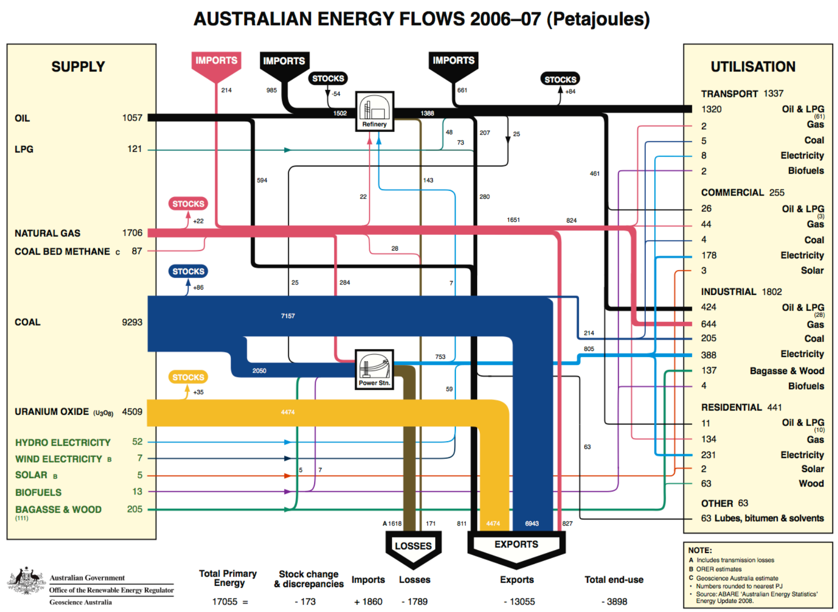
For Australia three energy flow graphs are available from 3 sources: all different!

For 2007, the LLNL estimates waste at 3400 PJ when Geoscience Australia estimates losses at 1800 PJ, but ABARE estimates the negative transformation at 3900 PJ.

Figure 40: **LLNL 2007 Australia energy flow in PJ**

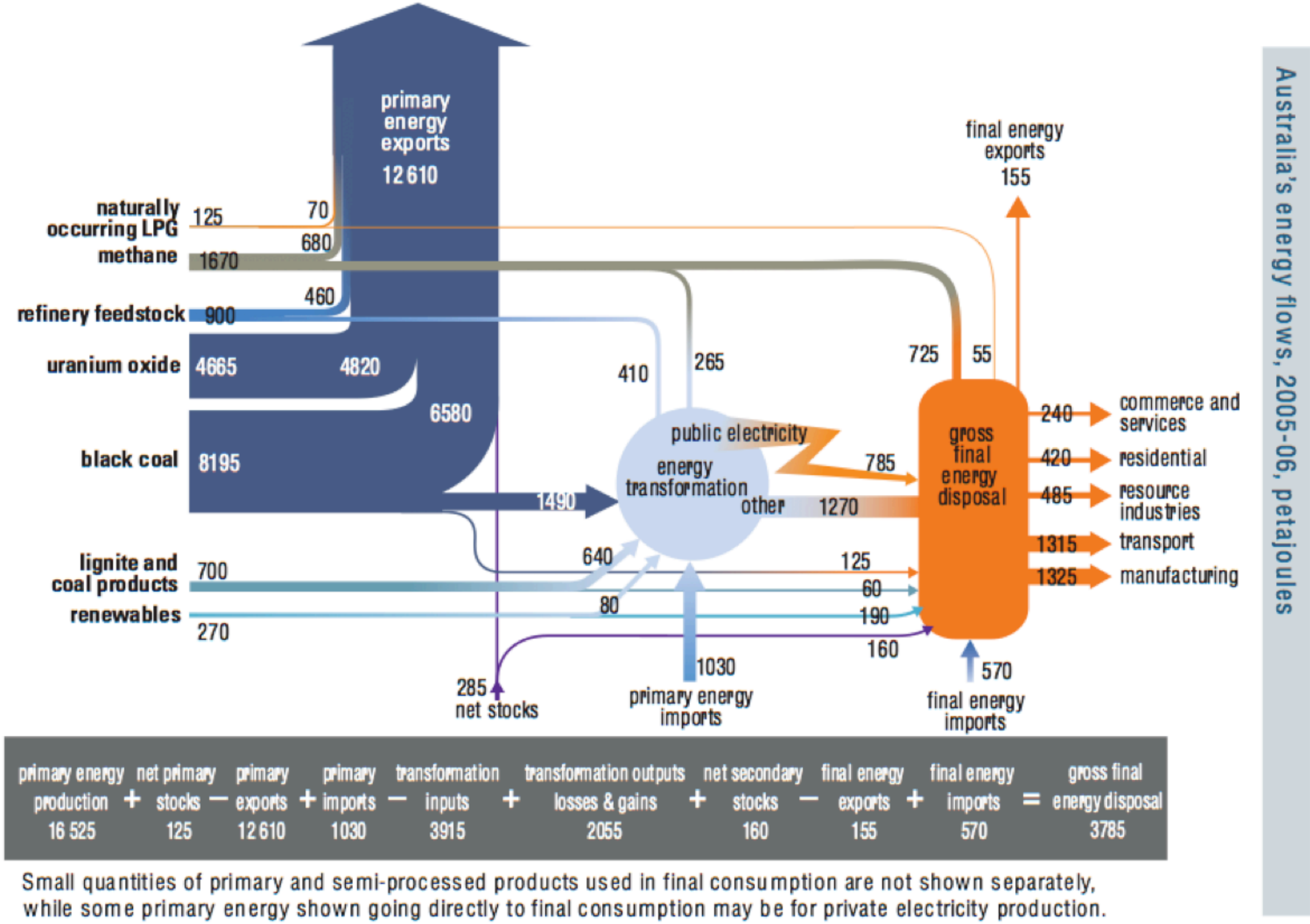
Figure 41: **Geoscience Australia 2007 Australia energy flow in PJ**





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

ABARE shows in its flow chart a central sink called *energy transformation*.
In the sink well input = 3915 PJ and output = 2055 PJ, loss = 1860 PJ = 48%
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 rather a theoretical subject without any reliable open world database.

Ayres presents an interesting estimate of US energy efficiency very different from EIA (in fact LLNL) estimate: he estimates efficiency for transports at <1%, when EIA takes 27% and for residential & commercial buildings at 10%, when EIA takes 80%!

Figure 43: **Ayres' estimate of US energy efficiency compared to EIA's estimates**

VIENNA ENERGY FORUM 2011

Where do we stand?

- The economic system can be divided into four major sectors. They exhibit very different efficiencies: Current US efficiencies are estimated as follows:

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%

* (consistent with other engineering studies)

This shows clearly that energy efficiency is estimated with a huge range and needs to be better discussed to reach a consensus, or at least acknowledge the difference.

Conclusions

The 136 international energy flow charts issued by LLNL for 2007 look very interesting, because they report what is wasted.

Unfortunately their estimate, which is in fact an interpretation, is very questionable based on arbitrary energy equivalences and energy efficiencies.

A range of assumptions should be clearly reported, estimating the accuracy of the results.

LLNL and USDOE current charts vary with author in data, unit and wording, because there are no rules.

Many wrong and useless decimals are usually reported, well below the real inaccuracy of the measure, inaccuracy, which is never estimated.

We need to change our way of life, taking into account that the world is finite, needing to save energy.

Saving energy by using more efficient tools is good, but it is much better to use less energy (less driving, less eating to stop obesity).

Heat is either a goal or a nuisance.

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

But to stop wasting energy, we need to see where is the waste (apart from the obvious waste of food = 50% US, 33% UK, food is energy).

Every national energy agency should publish reliable energy flow charts showing what is really wasted and what is really used.

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