Replacement of fossil fuels: the illusion of renewable energies and energy efficiency.

Daniel R. Rousse
t3e Industrial Research Chair
Department of Mechanical Engineering
École de technologie supérieure – Université du Québec
e–mail: daniel@t3e.info

ABSTRACT

This article aims to demonstrate that under an energy consumption growth that will be difficult to maintain below 1.5% until 2035 (IEA NPS or 450S), the current rates of implementation of renewable energy and energy efficiency will not be sufficient to maintain or even reduce our dependence on fossil fuels. The discussion is limited to the case of petroleum but could be extended to gas and coal. The problem of cheap energy shortage is discussed for the Canadian situation as an example, despite Alberta's tremendous oil reserves. Energy sobriety, which passes through educating people to make profound changes to their lifestyle, seems the only avenue to cope more smoothly to the shortage of cheap fossil fuels on the horizon of 2100. But to get there, there could only be one efficient way: to tax fossil fuels appropriately, consistently and increasingly to avoid a drastic change in prices due to a sudden shortage in a few years.

KEYWORDS

Fossil fuels, oil, energy efficiency, renewable energy, policies, taxation.

INTRODUCTION

Earth is a finite system and as humans consume or transform some of its non-renewable resources at a growing pace, humanity will undeniably miss them in a more or less near future and the rate at which we are getting closer to the shortage is increasing steadily each year. Energy is one of these resources.

The objective here is to try to demonstrate that our collective attempts to develop the so-called renewable energies combined with our efforts to reduce energy consumption will be insufficient to cope with the rapid shortage of traditional energy resources such as fossil fuels. The demonstration will be limited to the Canadian context although it could be transposed to all industrialised countries of the OECD. Behind this general objective lies the motivation to progressively modify our consumptions energy habits voluntarily before the energy market itself imposes a chaotic period because of an overwhelming pressure on the world economy. We should try to hit the bottom of the barrel as smoothly as possible.

ENERGY CONSUMPTION AND PRODUCTION

Combined picture for all types of energy

Several sources could be consulted such as CISStat, GIIGNL, Platts, Poten & Partners, the World Energy council, etc. The current discussion uses two among the most widely used references: the Key World Energy Statistics [1] published each year in September by the IEA, and the BP Statistical Review of World Energy [2] published yearly in June.

Figure 1 shows that for the last forty years, the world's primary energy production continues to grow which increases each year the pressure on the reserves. The good news is that OECD consumption declined (led by a sharp decline in Japan – in volumetric terms, the world's largest decline) [2]. But overall, the world's consumption increased by 2.5% in 2011. All of the net growth took place in emerging economies, with China alone accounting for 71% of global energy consumption growth. BP Statistics are somewhat different than those of the IEA but the trends remain. The increase is more or less linear for more than 40 years. In Figure 1, one should note the temporary decline in 2008 as the crisis was at its peak in the US.

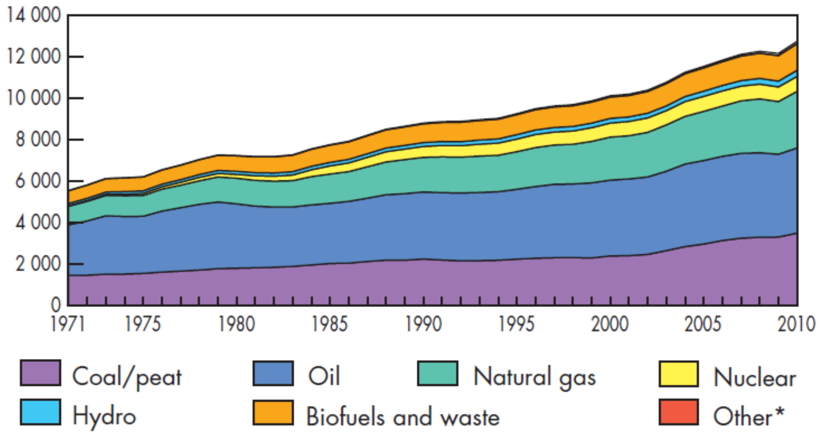

Figure 1. Total primary energy supply (TPES) per type (Mtoe) between 1971 and 2010 [1]

Figure 2 indicates that the total primary energy supply (TPES) increased from 6,107 Mtoe in 1973 to 12,717 Mtoe in 2010. This consumption that doubled in 40 years shows quite obviously, that the latest increases in energy consumption, which in the years 1920-1970 enabled lightning social, economic and technological developments, are no longer associated with an increase in the life quality in industrialised countries [3-5]. However, this issue goes beyond the scope of this work.

Figure 2 shows that whether in 1973 or in 2010, more than 80% of the total production comes from fossil fuels (86.7% in 73 and 81.1% in 2010). The share of nuclear power grew from 0.9% to 5.7% to reach 725 Mtoe in 2010. The total share of non-renewable energy is about 86% for more than 40 years. The proportion of biofuels, mostly made of agriculture or forest residues to cook and heat, remained stable at about 10%.

The interest for the upcoming discussion is that renewable energy shares increased from 0.1% in 1973 to 0.9% in 2010. This increase in production was then 108 Mtoe (from 6 to 114 Mtoe between 1973 and 2010) for the renewables in terms of nowadays understanding (solar, tidal, wind, hydro, geothermal, etc). During the same period there has been a need for an increase in production of 6,610 Mtoe. Hence, renewables were able to fulfill 1.6% of the energy demand increase over the last 40 years. What will be the figure for the next forty years?

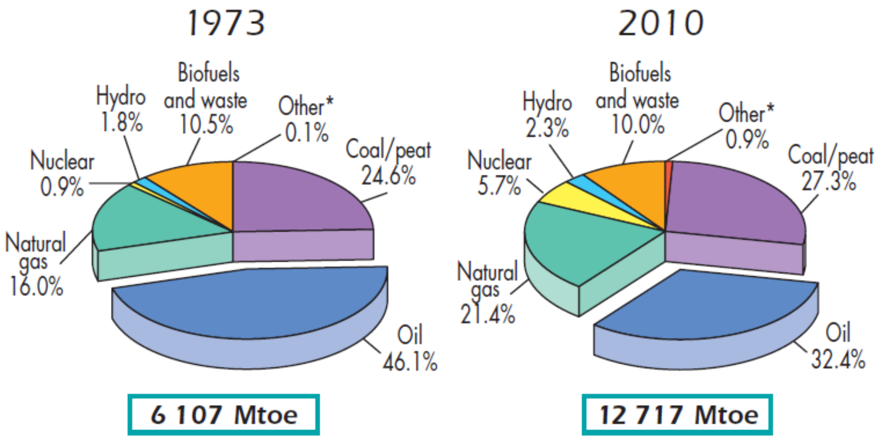

Figure 2. Proportion of the TPES per energy type (%) for the years 1973 and 2010 [1].

Petroleum consumption and production

With a share of 32.4% (Figure 2), the IEA indicates that the primary production of petroleum reached 4,120 MToe in 2010. The final consumption was 3,691 Mtoe [1]. The difference was used to generate secondary energy such as electricity plus the stock variations and losses. It is worth mentioning that for the same year, British Petroleum [2] indicates that the production was 4,032 MToe and that the final consumption was 3,945 Mtoe. These variations are normal as collecting the whole data requires to use different methodologies at different time. The factors that could explain these variations are not discussed herein.

For the purpose of the paper, the consumption will be supposed to equate four billion tons per year.

Petroleum reserves

To propose predictions on how long the reserves will last, an estimate of these reserves is required. To do so, one needs to understand what are the “reserves”. The reserves constitute the amount of a substance which can, with reasonable certainty, economically and technologically be extracted from the ground at a given time. Per extension, we denote “ultimate reserves” the fraction of the “resource” that we think should be exploitable in the long term. It is an estimate obtained from the analysis of geologic and engineering data. Finally, the “resource” encompasses all the matter that exists on earth, even in the most unrecoverable or unusable forms.

An interesting fact is that the declaration of national reserves is subject to no control from any international organisation which could confirm or infirm the real amount of reserves declared by the countries. For instance, since 1978 the reserves of Kuwait increase by nearly a four-fold.

Figure 3 shows that the total oil reserves increased from 1,032.7 Gb to 1,652.6Gb in 20 years. The conversion rate used by BP is 7.91 b/toe.

For the purpose of this paper, we will assume a proven reserve of 200 billion tons of oil.

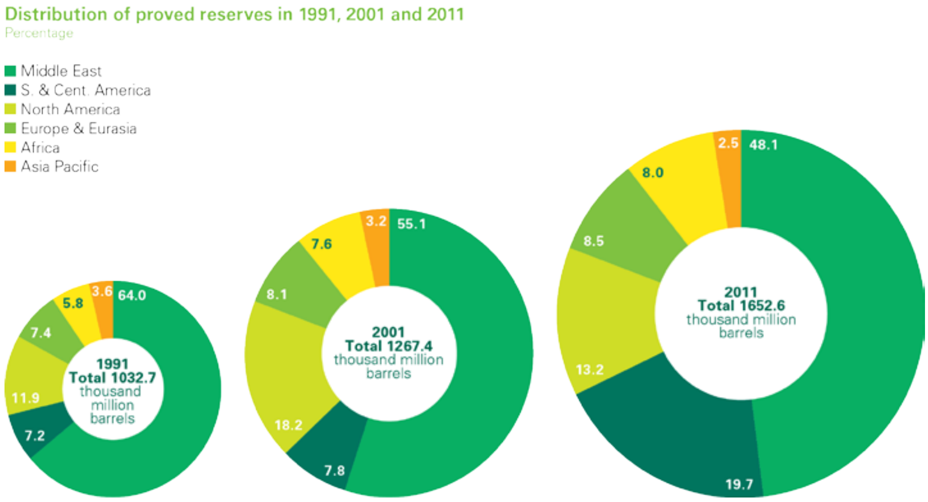

Figure 3. Distribution of proved reserves in 1991, 2001, and 2011 [2].

How long will reserves last?

To obtain our "autonomy" or reserves-to-consumption (or production) ratio, one should simply divide the amount of the reserves by an average consumption over the relevant period. Clearly, for the 2010-2011 data, we are going to run out of oil within 50 years provided a constant consumption and a constant estimate of the reserve over this period.

However, the rate at which the consumption increases or varies could be hard to predict in the future as the consumption, for instance, is strongly influenced by the market price (see Figure 1, year 2008). Nevertheless, according to the IEA [1], if the new politics to fight climate changes are enforced, the growth rate of consumption should be maintained at about 2%. Otherwise, if the states agree to limit the CO_2 concentration up to a maximum of 450 ppm (a more stringent scenario given the fact that we just crossed the 400 ppm threshold), the increase should be limited to 1.5% (Figure 4).

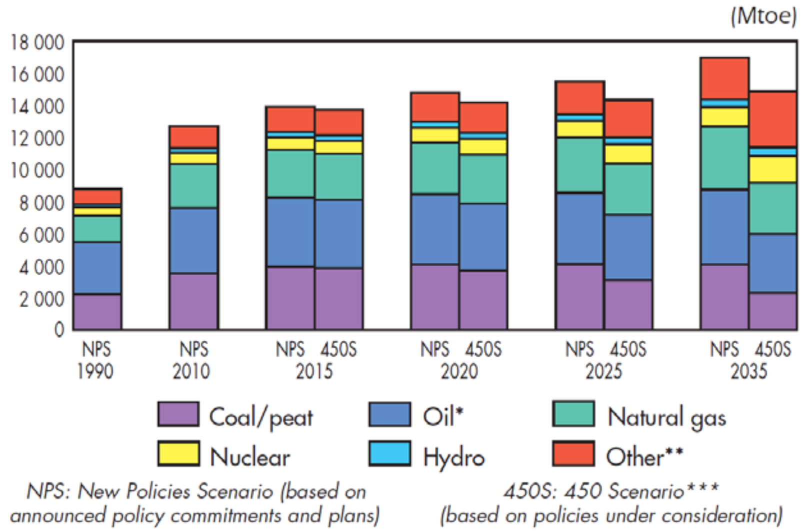

Figure 4. Predictions of the total primary energy production per type for the two acknowledged scenario: new policies scenario (NPS) and 450 ppm scenario (450 S) [1].

It is worth mentioning here that Figure 2 indicates an average annual increase of 2.93% over about 40 years. In Figure 4, whatever scenario is used, there should remain a net preponderance upon non-renewable energies by 2035 (about 75%). However, both scenarios indicate that the oil consumption should decline (450 S) or remain unchanged (NPS). An interesting thing to denote on this figure is that “Other” includes biofuels, waste, and renewables that are expected to collectively represent 25% of the production within 22 years (10% today).

We will conclude this first part of the section quoting the IEA : « Although the economic growth perspectives are uncertain on short term basis, in the New Policies Scenario the energy demand should increase by one third between 2012 and 2035 » [6].

The second part of the section insists on the fact that the reserves-to-production (R/P) ratio, strongly depends on the estimate of the reserves as the uncertainties on these are much larger that on the future production (or consumption). Until years 2000, the IEA denied the existence of peak oil (a concept that cannot be discussed herein). Nowadays, the IEA [6], the Association for the Study of Peak Oil and Gas (ASPO) [7] and the United States Department Of Energy (DOE) [8] all acknowledge that this peak should be within the end of the current decade. This indicates that the increase in the demand (pulled by Asia) will soon become incompatible with the rate and the size of new discoveries and the production of current wells that are slowly declining since 1960. In 2007 [6], the IEA predicted that by 2015 there would be an unbalance of 12.5 Mb/day between demand and offer if new oilfields are not found and if energy efficiency policies are not enforced. This pressure on prices will make reserves jump to avoid a clash but will they “really” increase?

Of course, in its annual Medium-Term Oil Market Report (MTOMR) released May 14th 2013, the IEA’s [9] reports that the supply shock created by a surge in North American oil production will be as transformative to the market over the next five years as was the rise of Chinese demand over the last 15 years. Whatever that may be, we will run out of fossil fuels sooner or later. The long terms perspectives [10-11] should be considered with this type of announcements to get a more realistic overview when it comes to estimate the duration of the reserves.

The section will end with a simple comparison. When it comes to predictions, it might be interesting to compare the trivial exercise of the section to those reported in the literature. Figure 5 unfortunately confirms the above basic calculation: the production of oil should stop in about 50 years.

Figure 5 also depicts the R/P ratio for selected regions of the world indicating that soon in Europe the whole continent will be completely dependent on foreign energy (except for coal) and that the global economy equilibrium will then be jeopardized long before the last drop of oil is extracted from the ground. And, of course, this section solely deals with oil but similar trends are observed for natural gas and coal despite variables rates of growth of the demand and reserves.

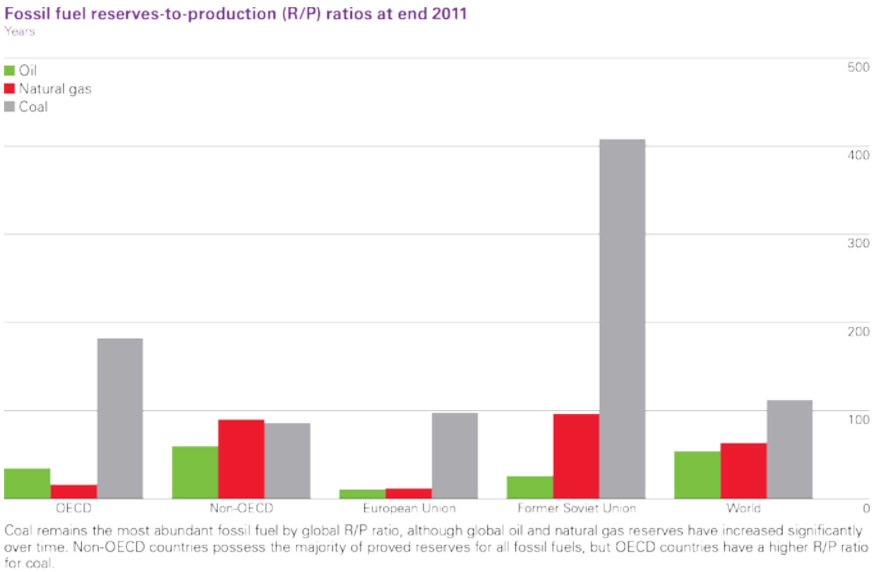

Figure 5: Fossil fuel reserves-to-production ratios at the end of 2011 [2].

HOW TO SMOOTHEN THE TRANSITION?

In the last section, the emphasis was put on the ever increasing global demand for energy combined with limited “reserves” that threatens us mostly by upcoming shortages due to the increasing scarcity of the resource. This section will try to exemplify that all so-called solutions to prepare a smooth transition to a post-fossil fuels society will come short to avoid humanity a very drastic change in its organisation. The discussion will be limited to the Canadian context but the reader is free to extrapolate to his own country.

To smoothen the transition, it is possible:

- to rely on new discoveries of oilfields,
- to replace of fossil fuels by renewable energy sources,
- to improve the energy efficiency of equipments and processes,
- to create grants and subsidies,
- to legislate,
- and to educate people so that they voluntarily use less resources (including energy)

This section will successively consider these possibilities.

New discoveries

Of course, new reserves will be made available despite they are becoming more and more scarce. Moreover, the impact of new oilfield findings is diminishing with the increasing demand of the world and could be quite limited in time. Finally, the price to exploit the future deposits of oil will rise considerably as we have to go further North or South, or further deep in the ground or below the oceans. For instance, in Canada, the Prime Minister goes in the Great North for at least one week every year to secure the sovereignty of Canada over these icy lands. The reason is below the surface. The Nordic countries that share a border with this area of the globe, all pretend that they are in right to exploit the reserves found beneath the artic seas. Figure 6 schematically depicts the distribution of this oil around the North Pole. The total reserves are estimated at 63.5 billion of barrels of crude oil [12]. This volume corresponds, for an average oil density, to 9,190 Mtoe. However, given the consumption rate of 2012 (4,120 Mtoe/y), these reserves should extend the world’s total reserves by a little more than two years. This represents a lot of money, indeed, but constitutes an insignificant amount of energy when it comes to the upcoming shortage.

Energy efficiency

One of the ways to reduce energy consumption is to implement energy efficiency incentives. That is either to obtain the same level of service from a system for less energy or more output from this system for the same amount of energy.   In Canada, the energy efficiency improved 16% since 1990 [13]. This improvement permitted Canada to spare 1,560.4 PJ (37,2 Mtoe) since then. The Canadian study is based on a factorisation method to estimate the effect of energy efficiency on its economy and by sectors of activities. The factorisation allows separating the variations according to six factors: activity, structure, weather, service level, capacity utilization rate, and energy efficiency itself. Figure 7 shows the evolution of secondary energy consumption, with and without energy efficiency, in Canada between 1990 and 2009.

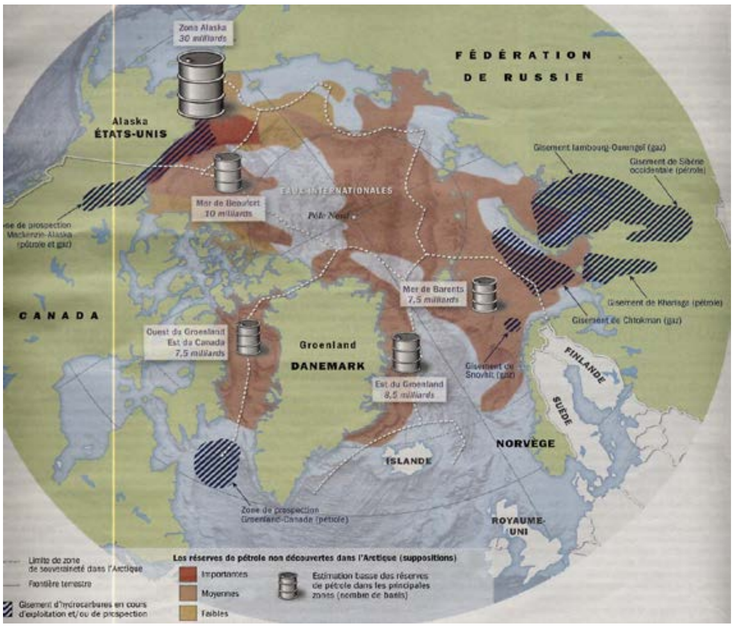

Figure 6: Arctic oil reserves [12].

Figure 7 indicates that without an important and constant improvement in energy efficiency, the consumption would have raised by 46% instead of 23%. The average annual increase over the period was then about 1.5%

These results nevertheless indicate that energy efficiency reduces the increase in Canadian energy consumption but cannot prevent its increase. Canadians use more and more energy each year. Figure 8 shows that in 2011 Canada ranked among the top countries for energy consumption per capita, with more than 6 toe/year/cap.

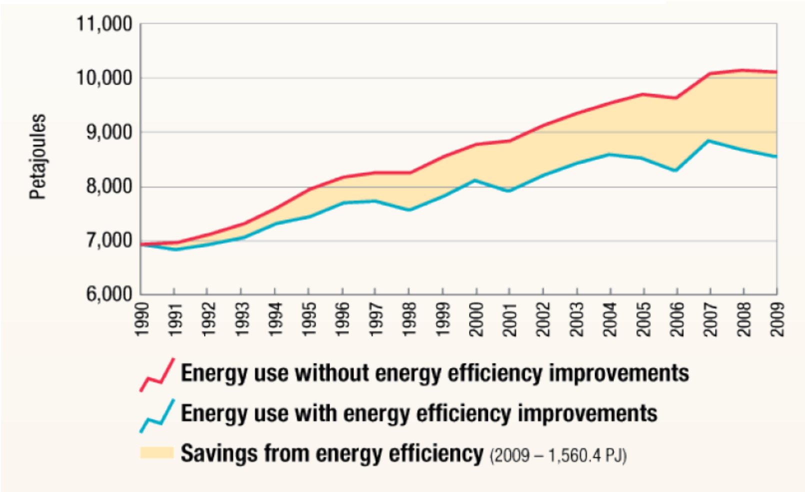

Figure 7. Secondary energy use, with and without energy efficiency improvements, in Canada between 1990–2009 [13].

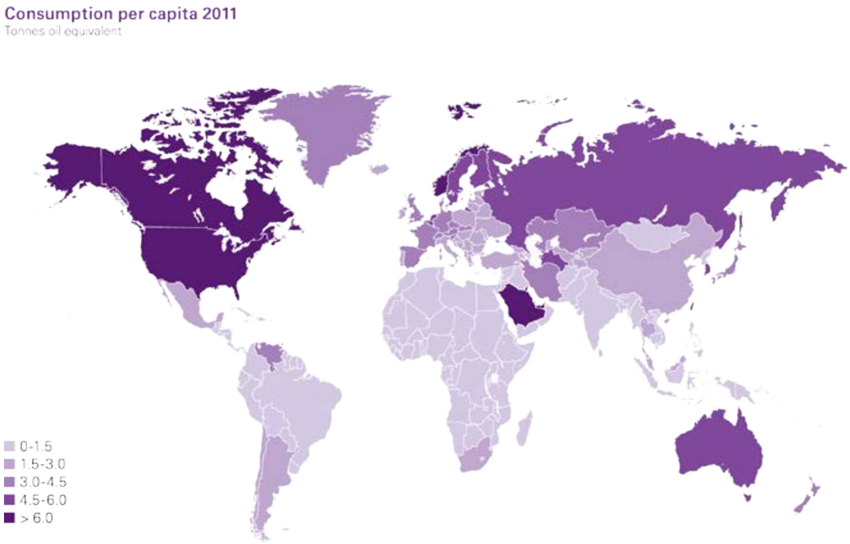

Figure 8: Consumption of primary energy per capita, 2011 [2]

Renewable energies

The previous subsection showed that energy efficiency cannot restrain the energy appetite of Canada and that its economic growth is linked with its energy consumption growth. What about renewables?

Among the types of renewable energies, except hydro power for which more than 65 000 MW are implemented, the most widely used in Canada is wind-power. In 2013, the installed capacity (peak power) is 6,568 MW (it was 5,265 MW in 2012, a yearly 24.7% increase which is above the worlds 19% increase for the same period) [14]. Canada is then among the top 10 countries for wind power implementation (9th behind Italy, the UK and France) [15]. The distribution of this capacity is shown in Figure 9. On the other hand, the total photovoltaic capacity installed is below 100MW in Canada.

In 2009, the total amount of primary energy consumed was estimated at 11,896.7 PJ [13] or, when converted into electric power 3.3 $\times 10^6$ GWh. If the predictions of growth of the NPS scenario of the IEA (+2 %/year) are used to extrapolate the energy consumption of Canada in 2025, the increase should then be 969 000 GWh.

However, if an overall Utilization Factor of 30% is employed for Canadian wind mills, these would have produce for 2013 about 17 200 GWh. This implies that to compensate the increase in energy consumption solely by wind power, the installed power would have to be multiplied by 50. If we can project that Canada will limit its increase to 1.5% over the next decades, this factor drops to 37. This represents an average rate of implementation of 28,100MW per year over the next 12 years or a growth rate of nearly 40% each year.

This shows that whichever type of renewable energy Canada wants to implement to maintain its current fossil fuels and nuclear power consumption, the country will have to considerably increase the penetration rate of these technologies and integrate them in its vast distribution network.

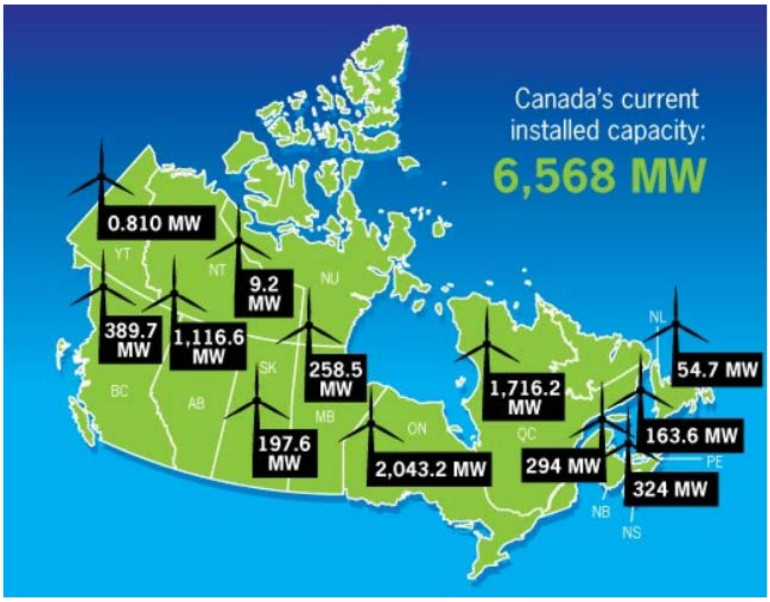

Figure 9. Canadian current installed capacity, 2013 [14]

Energy policies

Subsidies. Many national or local governments offer subsidies that allow an investor to “artificially” lower the pay-back period of energy efficiency programs implementation or the capital cost invested into the development of a product in energy efficiency. In Québec, a provincial territory (called Province in Canada), when the national electricity society (Hydro-Québec) ended its program at the end on the 1990, the whole energy efficiency market collapsed. This shortage of subsidies led to several bankruptcies and to the closure of energy efficiency departments across the Province. Such politics are then artificial in the sense that the implementation of projects of energy efficiency in institutions, businesses and industries or into the development of technologies, are not permanent, but dependent on public grants offered to the market.

Feed-in tariffs. Germany first and then France can be considered as European leaders in such politics. In Canada, Ontario (another Province) is the most well-known example of government that rely on feed-in tariffs to promote renewable energies. These tariffs, that reached 0.80$/kWh, permitted a massive implementation of solar farms throughout the province. On contrary, in all other Provinces but Alberta (8 local governments), photovoltaic does not generate such interest as these governments just implemented net metering policies. In Quebec, for instance, the buyback tariff is only 0.075$/KWh or about 10 times less than the record high in Ontario. As a results, photovoltaic is almost insignificant in Québec.

Moreover, just like in France, when the tariffs decreased in Ontario last year, the industry quickly readjusted the rate at which projects were developed. This also indicates that feed-in-tariffs are just another artificial way to sustain the market.

Legislation. Restrictive legislation permit long term changes to energy consumption habits. The French “Régulation thermique 2020” [16], is such an example which illustrates a real (and courageous) will to implement changes. In short, by 2020, all new constructions in France will have to be at least net-zero or better on an annual basis. Hard to implement and control, the legislation (not discussed here) is controversial and challenged by many. But for sure, such legislation always modifies the economic shape of the domain of application. It requires an enormous courage and a vision that are not frequent. But the real impact and success is quite hard to predict. Its real effects on the market are tough to predict and may bring some undesired and uncontrolled contractions of the economy especially when the action of one country is isolated while the markets are open.

Royalties. The actual debate on Natural Resources in Quebec allowed realizing that the model of royalties paid by mining companies to the Government of Quebec (imposing an artificial penalty on the resource production) may jeopardize the whole sector of activities. During the months the Quebec government hesitated to come with the legislation, the whole mining sector has slowed considerably which led to significant layoffs. This again is partly due to a different (lower) taxation in other countries. So instead of taxing the production of a good, why not taxing its consumption?

Taxation. To enable the government investment in reducing our dependence on oil, why not finance directly with proceeds from the sale of the latter? This sale ax could be based on the carbon emission of energy, for instance. In contrast, to this day in America, the exploration of new oil fields companies are those that have the most significant tax incentives and measures in the field of energy.

What the author of this article proposes is not to implode the global economy, but gradually to adopt the solution suggested by many and among them Jancovici and Grandjean [17]. In their 2006 opus, both humorous and pamphleteer, the authors propose to increase sales taxes on fossil fuel.

The advantages of this solution are obvious: economic effort better distributed, extension of the life of the reserves, less brutal shock and control over the global economy, reinvestments of the tax in the above-mentioned programs, lower pay-back periods of energy efficiency projects, more capital funds available for research in renewable energies, etc...

The main advantage of a controlled (progressive increases) sales price for fossil fuels is that governments directly control the effects on the local and global economy. Of course, a liter of gasoline at 5$ or 10$ will have a tremendous impact on the way we live, but it would make the transition to the post-fossil fuels society less painfull.

This proposal opposes the theory of sustainable development to that of sustainable degrowth that will not discussed here. Nevertheless, something has to be done as in its "World Energy Outlook

2011" [18], the International Energy Agency notes that "little evidence to suggest that the change required in the direction of global energy trends (either) started."

Energy sobriety

Changes caused by the last two types of policies mentioned in the last subsection, however, can jeopardize a government that is often reluctant to show the political courage required to induce necessary changes. What is important to start with more conviction and readiness, is a public education of young people, to the devastating effects of our energy consumption on the future of our economic and social systems (the environment some will point out, but this issue is not specifically addressed here).

These are the generations of young people today, who will induce profound changes tomorrow that were however urgent to implement yesterday. The reason for this compression of time is the rapid pace of social and economic changes that allowed cheap and available fossil fuels. These rates of change have, somehow, overtaken the human being in its ability to respond to changes that it has self-imposed to its lifestyle and to the terrestrial ecosystems.

With an increasing proportion of voters pushing for legislation having a dampening effect on our energy growth, reduce our impact on the environment, and comprehensively change our relationship to the Earth, the governments will become more inclined to adopt what appears almost unthinkable today because of the dictates of the global economy. It is only education to energy sobriety that will allow societies to accept the legislations needed to curb our consumption.

CONCLUSION

Oil reserves

This article briefly tried to show that it is difficult to accurately assess the duration of oil (or other fossil fuels) reserves. However, if the duration of the oil reserves is not 50 years, as stated in the simple calculation presented above or as proposed by BP, the amount of the reserves combined with our ever increasing consumption nevertheless suggest major structural and organizational changes in energy dependant societies. Sudden and rapid changes are expected because in less than five years, the “peak of oil production” will be generally acknowledged by all societies and more stringent energy policies should be implemented then.

Renewable energies and energy efficiency

The article than showed, by use of the example of a particular country, Canada, that the growths of renewable energy and energy efficiency will not match the world’s appetite when fossil fuels reserves will decay. The argument was solely based on the ability of both strategies to maintain Canadian fossil fuels consumption to a constant level, not to lower it. Hence, the author suggests that more efforts should be done in these areas but that these will fall short anyway if they are the only strategies in our basket.

Legislations and energy sobriety

This paper supports the idea that only legislation and more specifically taxation will influence significantly the rate of transition to a less energy-intensive society. In the absence of legislation and further taxing of fossil fuels today, the end of cheap oil may lead to a very sudden shock in our global organization later. Well before exhaustion apprehended, scarcity will exert tremendous pressure on societies to reorganize so that they become less dependent on energy.

So we are already facing a double threat to energy: shortage of adequate and secure supplies at affordable prices in addition to irreversible harm to the environment by excessive consumption. Deep societal changes based on education to energy sobriety should then be planned in any strategy of sustainable development of societies, in addition to all the considerations that we talk during each World Economic Forum.

ACKNOWLEDGMENTS

Financial support for this study was provided by the t3e industrial research chair and its financial partners; the author would like to acknowledge their invaluable contributions.

NOMENCLATURE

Symbols :

Mtoe	Million of tons oil equivalent
Gb	Billion of barels
GWh	Gigawatt-hour
MW	Megawatt
PJ	Petajoule
TPES	Total Primary Energy Supply

REFERENCES

1. IEA, *Key World Energy Statistics*, 82 p., 2012.
2. BP, *Statistical Review of World Energy*, 48 p., 2012.
3. Siegel, C. *The End of Economic Growth*, Preservation Institute, 56 p. 2006. (http://www.preservenet.com/endgrowth/EndGrowth.pdf)
4. Meadows, D.H., Meadows, D.L., Randers, J., *A Synopsis, Limits to growth, Universe, The 30-year Update*, 28 p., 1972, http://www.sustainer.org/pubs/limitstogrowth.pdf
5. Schumacher, E. F. *Small is Beautiful: Economics as if People Mattered*. New York: Perennial Library, 1973.
6. IEA, *World Energy Outlook*, 2006.
7. ASPO, http://www.peakoil.net/, consulted 12th Jan 2013.
8. Hirsh, R., Bezdek, R., et Wendling, R., *Peaking of World Oil Production: Impacts, Mitigation, & Risk Management*, 91 p., 2005.
9. IEA, *Supply shock from North American oil rippling through global markets*, http://www.iea.org/newsroomandevents/pressreleases/2013/may/name,38080,en.html, consulted 14th May 2013.
10. NIC, National Intelligence Council, *Global trends 2025: A transformed world*, Chapters 3 and 4, 120 p., 2008.
11. BP, *Energy Outlook 2030*, 88 p., 2012.
12. COURRIER INTERNATIONAL, octobre, 2008.
13. RNCAN, Energy efficiency trends in Canada, 1990 - 2009, OEE, Public Works and Government Services Canada (PWGSC), 2011.
14. CANWEA, http://www.canwea.ca/, consulted 29th Jan 2013.
15. WWEA, The World Wind Energy Association, Half year report, 8 p., 2012.
16. RT 2020, http://www.reglementationthermique.net/, consulted 4th Feb 2013.
17. Jancovici, J.M., et Grandjean, A., *Le plein s'il vous plaît!*, Points Sciences, 186 p., 2006.
18. IEA, *World Energy Outlook*, 2011.