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Uncertainty of Timing for Global Challenges and Problems with Transition to Renewable Energies

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Abstract.

What will come first – non-acceptable global warming or extinction of oil reserves? Both processes can bring substantial costs to the mankind, but their order has important economic implications. The answer to this question will either lower oil price in the long run or will lead to its further rise. It is very important for Russian economy. From the global perspective, both dangers should be taken into account, and transition to renewable energies is the only remedy for both. However, the optimal speed of this transition depends on temporal dynamics of both threats that is highly uncertain at this moment.

The goal of this paper is to review the problems with different renewable energies and to outlay different scenarios for the timing of major impact from global warming and oil peak.

The problems with renewable energies have mostly economic origin. The global resources of hydropower are limited. While wind is already cheap, it should be balanced due to stochastic supply. Solar energy also needs to be balanced and is still relatively expensive. Oil products and their liquid renewable substitutes (biofuels) will thus remain an important compliment to electricity in the long run. However, biofuels are competing with agriculture for land, and thus can replace only a limited fraction of energy.

The first signs of global warming bring the costs today and it comes as increased frequency of extreme weather phenomena (hurricanes, floods, etc). The rate of temperature increase has some range of uncertainty but it generally accepted that +2 degrees is an acceptable limit, and it might come in the middle of the 21st century. One of the policies to deal with it is not to extract all fossil fuels from the ground. However, it is highly likely that all oil will be extracted before global warming will have severe consequences. Since only biofuels can substitute oil in transport, given the current trend in transportation, peak oil can cause too much demand for biofuels that will be dangerous for food security. Both the price of oil and biofuels would rise to such level, that current level of transportation will be impossible. This can cause resettlement of people to smaller cities.

It is possible to conclude that while renewable energies represent a remedy, full transition will not be easy.

Keywords: renewable energies, transition, problems, global warming, peak oil.

JEL Codes: Q31, Q42, Q54.

1. Introduction

V.I.Vernadskiy was a great thinker who suggested the term of “noosphere” [1] as the product of interaction between human civilization and the nature. He suggested the dominance of Homo sapiens over other species, creation of global informational system and the control over global forces that can even change the shape of the Earth. The history has confirmed the validity of most of his predictions, but we also have got some problems from global changes of such scale. This paper is also about the global phenomena that are likely to dominate the global threats for mankind in the 21st century.

Global warming and peak oil are among the major threats for mankind that are very important in the 21st century. They are considered here together because there is one remedy for both - transition to renewable energies. Since the global development is driven by economic incentives, it is widely believed that markets will give correct and timely signals for the timing and speed of transition to renewable energies. In other words, if one day oil becomes too expensive, so that it is cheaper to replace it by solar electric power or biofuels, this will be done. And if the global warming can be prevented by elimination of fossil fuels that bring too much carbon to atmosphere, carbon permits will become so expensive, that market forces will drive them out. However, we observe many failures to reach international agreement on carbon emission limitation and the markets for trading carbon periodically collapse. At the same time, we see ups and downs of oil price, but mostly driven by political reasons. As for transition to renewable, EU makes plans to reach substantial fraction of them in energy portfolio, but at the same time its dependence on imported fossil fuels increase over time.

All these suggest that transition is not an easy process and market forces not always give correct and timely signals. It is important to use the results of other disciplines for the evaluation of both economic risks of different hazards from those threats. This will be done in the next section.

This paper is to show will stress very important policy implications of the order and timing of those challenges. The transition to renewable energies and energy saving are considered to be a proper answer to both. However, the speed of those processes might be not sufficient. Suppose that full transition to renewable energies does not occur before either GW (global warming) or FS (fossil scarcity) will reach some critical level, implying non-acceptable social cost. The problem is that present science cannot exactly estimate neither the level nor the social cost of global warming; it can do only

probabilistic estimate. On the other hand, we do not know the volume of non-discovered fossil fuels. Pessimists think that global oil reserves are just for 40 years, and oil peak will come soon.

Paper objectives. The first goal of this paper is to compare both dangers and to evaluate their influence on commodity markets, in particular, on price dynamics for fossil fuels. We are aware of great uncertainties in the structure of consequences of global warming and oil peak on the world economy. That is why we develop a highly stylized model that might be far from reality. It is also not clear whether the economic damage from both will be temporal in time or not. The role of discount rate is also very important for economic decisions. The second goal is to discuss renewable energy as the remedy for both threats and to review the problems with its full scale implementation.

Paper structure. Section 2 reviews the threats from global warming and peak oil, based on the interdisciplinary research. Section 3 presents a simple formal model that formalizes the threats as economic problem with uncertainties. Section 4 compares both hazards. Section 5 discusses the transition to renewable energies as a remedy to both threats and the problems (technical and economic) with its implementation. Section 6 concludes.

2. Dangers from Global Warming and Oil Peak

2.2. Global Warming

Global warming (GW) is currently considered as the major challenge of the 21st century. The global temperature index has increased by 0.5-1 degree C during the last century (see Fig.A4), being accompanied by substantial growth of CO₂ in atmosphere. If the trend continues, it will cause many damages to the nature: falling crops and desertification, melting mountain glaciers causing shortage of water, rising ocean level (see Fig. A5, A6)), etc. Scientists are uncertain about the temperature rise during the 21st century: it can be only 1.5 degrees in optimistic scenario and 4.5 degrees in pessimistic. The temperature rise also depends on the pattern of future emission reduction.

However, Kyoto protocol was not signed by all countries, while emission trading permit scheme in Europe ended with price collapse, causing the destruction of incentives to reduce emissions. In order for the scheme to work (causing shift from coal to gas), the carbon price should be close to 30-50 euro per ton, but it is much lower today.

While emission reduction should be on international agenda, the level of its priority over other problems is still quite uncertain. This uncertainty comes from lack of scientific knowledge about both the physical consequences of growth of carbon in atmosphere and on the associated social cost of climate change. Countries are also asymmetric here: Russia may gain more benefits in Siberia, while Mediterranean countries can suffer desertification. While it is generally agreed that the total cost for the world of each degree added is positive, the absolute levels of associated costs are highly uncertain. And those costs can trigger the policy of how much fossil fuels (and of what type) should be extracted, where we should set the global limit.

We have quite substantial uncertainties about its dynamics, costs and possibilities to influence it. Fig. A6 lists different types of hazards from global warming. Not only the link between their relevance and global warming level is uncertain, but also the economic cost of each hazard.

So far, the rise of global temperature during the last 50 years just by 1 degree has been observed. Indeed, we observe more frequent climate extremes; but are they due to this 1 degree change? When the level of global ocean will start to rise substantially due to ice melting? When we get plus 3 or plus 5 degrees? Most scientists in climate change agree that many unacceptable changes will occur when the average global temperature will rise to 3-5 degrees. But how much fossil fuels should we burn to get there? In the recent IAEE conference in Dusseldorf the following numbers were presented by F.Holz et al (2013) and in IPCC's 5th Assessment Report [10]. There are 416 Gt of coal in reserves of conventional gas, 662 of oil and 1832 of coal. Besides, there is also non-conventional oil and gas. All this makes above 3000 Gt of coal. But catastrophic consequences for climate change will occur, if we burn 1000 Gt. So we should shift to renewable before all fossil fuels are extracted. But who has given this magic number of 1000? Yes, it is in literature, but literature of global warming is not yet based on solid research grounds. It may happen that this border of 1000 is fuzzy, and be something between, let say, 500, and 5000. Also we do not know what does "unacceptable change" mean exactly.

Another question is whether we can reverse the process. Mora et al (2013) found that if unacceptable changes would occur after 2 degrees of warming, then under BAU scenario they found that such changes will happen in 2047, while for emission stabilization scenario this will happen in 2069. This means that our policies might only postpone unacceptable global warming but cannot stop it.

2.2. Scarcity of Fossil Fuels

However, the global scarcity of fossil fuels (FS) might be another challenge to the mankind. While the known reserves of all fossil fuels are more than for 200 years of use (at current consumption), known reserves of conventional oil are only for 40 years. But what will happen if Saudi Arabia and/or Russia overestimate its reserves? There is “oil peak” theory saying that oil production will peak globally, i.e., supply cannot be increased even if demand will grow. The term has been introduced by Hubbert King [3,4] who has correctly predicted the maximum of US oil production to occur in 1970. Hubbert's initial peak oil projections of 1956 (see Fig. A2) had depended on geological estimates of ultimate recoverable oil resources. In 1974, Hubbert predicted that peak oil would occur in 1995 if current trends continue. However, in the late 1970s and early 1980s, global oil consumption actually dropped.

Since that time oil has peaked in many producing countries, and soon can peak globally. However, it is difficult to estimate its exact timing. According to Matthew Simmons, the author of *Twilight in the Desert: The Coming Saudi Oil Shock and the World Economy*, “peaking is one of these fuzzy events that you only know clearly when you see it through a rear view mirror, and by then an alternate resolution is generally too late.” The high variety of predictions for future dynamics of oil production confirms this statement (Fig. A3)

Salameh [5] says that conventional oil has already peaked in 2006, but not all scientists agree with that. In any case, there is also non-conventional oil (tar sands). When oil prices became above 70 \$/bbl, it became profitable for Canada to exploit them produced (but economic and environmental costs are high). The share of non-conventional oil will rise sharply (Fig. A1). At present, there are many oil substitutes (like shale oil), but their resources are also finite. This will only increase the uncertainty of peak oil timing but not stop it.

In 2005, The US Energy Department Report (2005) states: the United States Department of Energy published a report titled Peaking of World Oil Production: Impacts, Mitigation, & Risk Management.[124] Known as the Hirsch report, it states, "The peaking of world oil production presents the U.S. and the world with an unprecedented risk management problem. As peaking is approached, liquid fuel prices and price volatility will increase dramatically, and, without timely mitigation, the economic, social, and political costs will be unprecedented. Viable mitigation options exist on both the supply and demand sides, but to have substantial impact, they must be initiated more than a decade in advance of peaking."

Will this peak be at 90, 100 or 120 bbl/d, nobody knows. Also it is not clear if it will happen in 10, 20 or 30 years. There are also studies about potential severe consequences of oil peak as a global shock to economy with very high costs, if it comes unexpectedly. (see, for example, Robert and Lennert, 2010). Yes, we got rid of oil almost completely in electricity production and to high extent in heating, but we have no other fuel yet for air transport even on paper, and we need few decades to make transition away from oil in other transport.

An important issue is that we are not ready to meet peak oil in time. WEO 2013 [11] predicts that by year 2035 in new policies scenario EU will make substantial progress in transition to renewable energy, while globally the share of renewables will grow modestly, from 13% in 2011 to only 18% in 2035. Consumption of biofuels will increase from 1.3 mboe/d in 2011 to 4.1 mboe/d in 2035. This will be only about 5% of present oil consumption. Biofuels will meet 8% of road-transport oil demand.

These numbers show the speed of transition – it is not fast enough to meet suddenly arriving peak oil. That is why financial instruments (like rise of oil price) will not be able to stimulate fast transition, and the mankind has to face all negative cost of peak oil. Given the discovery of substantial reserves of non-conventional oil (especially in Canada and Venezuela), peak oil can be postponed by few decades (from conventional peak oil, that might be already today, see Fig.A3), but it will definitely arrive.

Its consequences will be more pronounced than from global warming and can last for few decades. It is likely that in several decades after its start the way out will be discovered, contrary to the consequences of global warming, that might be non-reversal. These ideas will be reflected in the model that follows.

3. The Model

In the baseline scenario it is assumed that no significant efforts will be taken in global reduction of CO₂ emissions to acceptable level and in global transition to renewable energies. How it is possible to compare the danger for the mankind from non solving those problems during acceptable time period? Such a danger definitely exists. While there are many talks about global transition to renewable energies, there is still some skepticism about the speed of implementation (Wirl & Yegorov, 2013).

The reduction of discovered oil reserves was predicted by King Hubbert [3] for a particular country (USA), and now there are theories about possibility of global oil peak in the coming years. However, there is an uncertainty about its exact timing: pessimists tell that it is coming already this decade, while optimists think that this will be in 20-40 years. The situation with natural gas is better: the current proven reserves are for 70 years, but there is still higher speed of new discoveries than depletion. Finally, shale gas revolution is doubling the known gas reserves, making it not scarce for at least a century. The known reserves of coal are for 200 years. While all these numbers are finite, high economic discounting of future (about 3-10% if we use banking interest rate) makes those problems too distant for “economically rational” present generation.

What about climate change? We have an observed increase of an average global temperature by 0.5-1 degree in the last 50 years, and most likely it has anthropogenic character. But we do not know exact hazard and its composition from the next degree of temperature increase, and so on. Most scientists consider the 2 degree increase barrier as acceptable, and derive the patterns of global reduction of CO₂ emissions that would satisfy this goal. However, others think that 3 or 4 degrees can be an acceptable limit. We also have quantitative uncertainty in the relationship between concentration of CO in atmosphere and global warming. And we do not know the threshold below which the global processes (like ice melting and an increase in the ocean level) are reversible.

Given all those uncertainties, it makes sense to deal with a simple model of hazard dynamics from global warming and fossil fuel scarcity. Since we use exponential discounting in future, it is mathematically easier to deal with exponential dynamics of hazard cost as well. First of all, it is increasing and convex function ($C' > 0$, $C'' > 0$). Second, it does not add mathematical complexity.

3.1. Cost of Global Warming

None of economic models are correct, but some are useful. We have too little information today to suggest a good model, but we will demonstrate some economic policy consequences on a simple caricature of reality. The first question: what is finite over time? It is likely that any irreversible changes to climate are likely to have very long living economic implications in the form of cost for mankind.

That is why we assume that the social cost of global warming changes exponentially over time, but the power of exponent has some distribution:

$$C_{GW}(t) = A \exp(kt). \quad (1)$$

Assume also that the global economy has constant population (this is indeed not so unrealistic assumption today, when demographers have theories of its stabilization at the level of about 10 billion people) and that economic growth is b , giving the dynamics of value of output $Y(t) = B \exp(bt)$ (this does not account for environmental cost). Assuming that r is discount rate, the overall (expected) utility is given by:

$$EU = E \int_0^{\infty} e^{-rt} (B e^{bt} - A e^{kt}) dt \quad (2)$$

Suppose that k is uniformly distributed in the interval $[k_1, k_2]$. Then the integral (2) is given by

$$EU = \frac{1}{k_2 - k_1} \int_{k_1}^{k_2} dk \int_0^{\infty} e^{-rt} (B e^{bt} - A e^{kt}) dt. \quad (3)$$

The inner integral converges for all trajectories with $k < r$ and diverges for all trajectories with $k > r$. If $k_2 < r$, it is always converges. We will focus on this case for the moment.

Let us calculate the expected utility.

$$EU = \frac{B}{r-b} + \frac{A}{k_2 - k_1} \ln \left[\frac{r-k_2}{r-k_1} \right].$$

This utility is positive if $B (k_2 - k_1) / (r - b) > A \ln[(r - k_1) / (r - k_2)]$. Several factors can influence this outcome.

This happens when initial economic output B is relatively high comparing to initial cost of global warming, and this is the real case. If economic growth rate, b , is higher than the maximal growth rate of damage cost, then intertemporal utility will always remain positive, and the ratio of positive to negative term will grow. This means that hazard from global warming is relatively low and can be easily compensated by economic growth. In this case the k can be misperceived and should be paid less attention in future than we believe today.

It may also happen that $k_1 < b < k_2$. Then under some trajectories economic cost of global warming will offset economic output in future. Now the discount rate r plays crucial role. For high discount we simply do not care what would happen with the world in many years from now, since we enjoy more short term horizon where the balance of benefits and costs is still positive.

However, when the discount moves down and becomes below the maximal growth rate of cost from global warming, $r < k_2$, we face first mathematical problem related to nonconvergence of integral. In this case the growth of cost cannot be offset by discounting, and we get the utility of minus infinity. Even if this happens only for some possible trajectories, this already becomes unacceptable, and we have to combat global warming. Note that we need really low discount for that.

It is useful to do some calibrations. We know from global warming literature that the global temperature can increase between 2 and 5 degrees Celcium over the 21st century. What level of k does it impose? No such estimations are known to us, and this gives additional uncertainty. Suppose that an increase by 1 degree will lead to growth of economic costs of global warming by x . Suppose also that temperature growth will be linear in time. Let us try to give some estimates of x . If harm is coming moderately, then we can assume 5 degrees increase can mean cost increase by factor $e=2.71\dots$. Since $k=1$ means increase by factor e in 1 unit of time (year), an increase by factor e in 100 years requires multiplier 0.01. Let us assume that in 100 years temperature increase will occur linearly in time and cumulatively on 5 degrees. Then $k=a \frac{dT(t)}{dt}$, and $dT(t)=T(t)-T(0)=ct$, where $c=0.05$ for pessimistic scenario of 5 degrees growth (and $c=0.02$ for optimistic scenario of 2 degrees growth) over a century. Since $kt=act$ and

kt=1 for t=100, we have k=ac=0.01. For c=0.05 this gives a=0.2. Now we can fix a=0.2 and find that for optimistic scenario with c=0.02 we get k=ac=0.004. Thus for our moderate assumption of damage growth we get uncertain k between 0.004 and 0.01. Adding uncertainty on damage growth can only increase this range, let say, to $0.002 < k < 0.02$.

Now let us compare this rough estimation of k with discount, r, that prevails in modern economy. Note that our calibration requires mapping of 1% annual interest rate (proxy for the discount) into 0.01. Indeed, 1% discount prevails in some developed economies at present, but the long term average is higher, close to 3%. In such economies like Russia it is rarely below 10%, or 0.1. This means that the condition $k_2 < r$ holds for global economy at present. What does this mean? It means that markets should not be sensitive to the future hazard of global warming, if we have rational perception of future hazard and its growth over time. Unless the global interest rate will drop below 1-2%.

3.2. The Hazard from Oil Peak

Now consider the influence of oil peak. Many models in environmental economics assume that oil substitute comes immediately when oil price hits some threshold. However, we did not observe it for any data in the past (including the peak of 148 \$/barrel from summer 2008). Most likely, this transition to oil substitutes from renewable energies will take some time T (also uncertain, but we skip this complexity in our model) independently on oil price. Thus, the timing of oil peak t^* (random variable, let say, with uniform distribution between 0 and 40 years) will create a period of costs to cope with oil peak. For the sake of simplicity, we assume this cost to be constant (K) and to have duration of T. Moreover, we assume that economic growth fully stops for this period.

Thus, the economic utility in the sub-model of oil peak has the following shape for a particular realization t^* :

$$U_{op} = \int_0^{t^*} e^{-rt} B e^{bt} dt + (B e^{bt} - K) \int_{t^*}^{t^*+T} e^{-rt} dt + \int_{t^*+T}^{\infty} e^{-rt} B e^{b(t-T)} dt .(4)$$

We can calculate those integrals.

$$U_{op} = \frac{B}{r-b} - \frac{Bb}{r(r-b)} e^{-(r-b)t^*} (1 - e^{-rT}) - \frac{K}{r} e^{-rt^*} (1 - e^{-rT}).$$

4. Comparison of both hazards

It is important to compare this threat with one from global warming. Both utilities, U_{gw} and U_{op} , have the same positive term, $B/(r-b)$, that describes baseline utility in the absence of global warming or oil peak, and the negative term, measuring the corresponding hazard, H_i . The negative terms in both expressions thus correspond to cumulative hazard from both challenges. The hazard from global warming,

$$H_{gw} = \frac{A}{k_2 - k_1} \ln \left[\frac{r - k_1}{r - k_2} \right],$$

depends crucially on the difference between the maximal growth rate of damages over time with economic discount. The hazard from oil peak,

$$H_{op} = \frac{Bb}{r(r-b)} e^{-(r-b)t^*} (1 - e^{-rT}) + \frac{K}{r} e^{-rt^*} (1 - e^{-rT}),$$

depends positively (loss is larger) on K (intertemporal cost of peak) and its duration (T). At the same time, it depends negatively on the time before peak, t^* . This hazard also depends on discount r in a complex way.

Fig. 1 shows hazard density with discount of 2%, while Fig. 2 does it for 10%. As we see from Fig.1 (relevant for OECD countries), the economic hazard from global warming has very low decline in time. This happens because of high variation of possible growth rates of damage over time. The hazard from oil peak is not much discounted, since it will come in few decades. But still it may happen that public opinion on the cost of global warming is higher. The values of cumulative hazard at Fig. 1 are comparable (0.228 vs 0.249). Still, it may happen that $H_{gw} < H_{op}$.

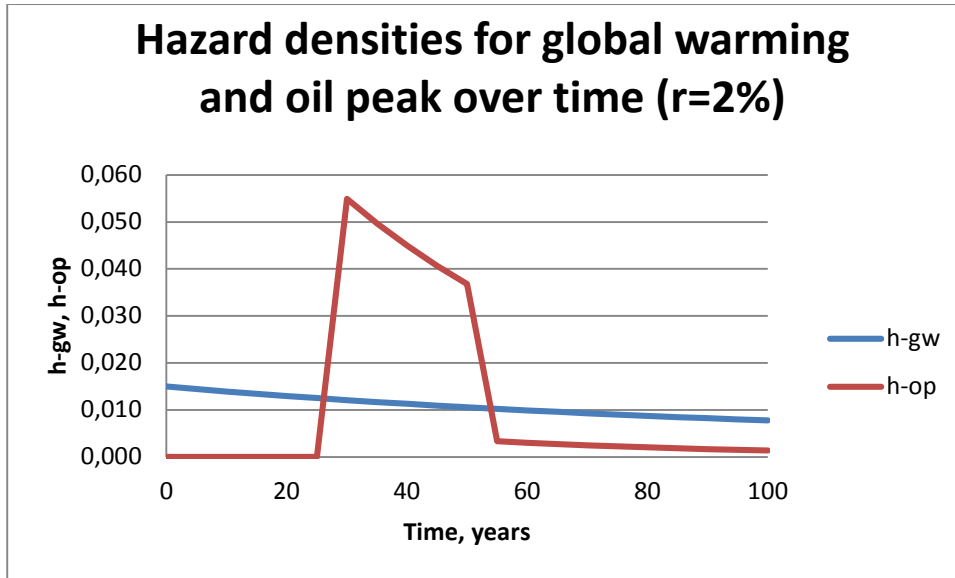


Fig. 1. Vision of future hazard density from global warming (h-gw) and oil peak (h-op) for annual discount $r=2\%$.

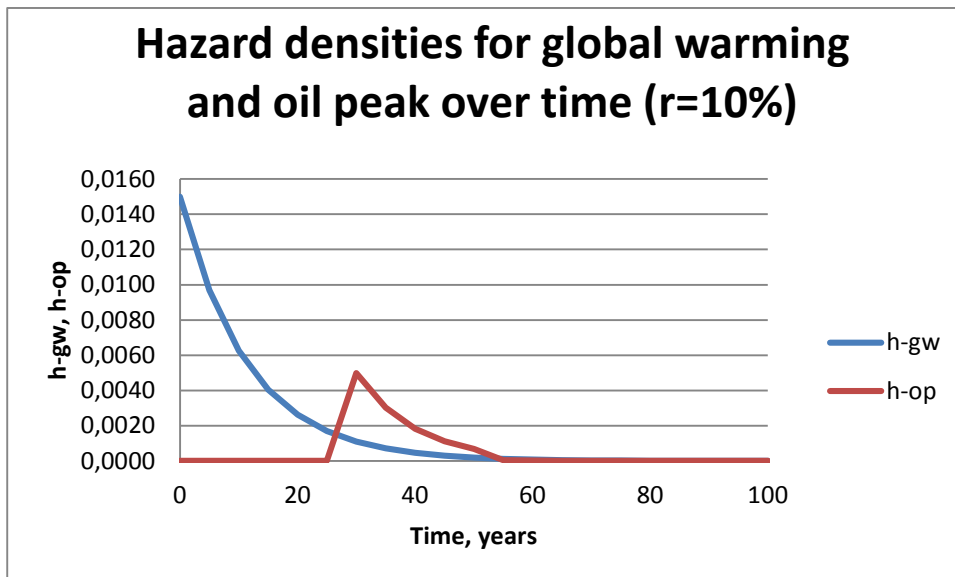


Fig. 2. Vision of future hazard density from global warming (h-gw) and oil peak (h-op) for annual discount $r=10\%$.

The vision as on Fig.2 is typical for developing countries that are also exporters of oil. Contrary to the case of low discount (2%), the case of high discount sees little harm from oil peak (this is far away in time), but the hazard from global warming is also declining fast over time. Here we can have reverse: $H_{gw} > H_{op}$.

4.1. Economic Implications

Further we will analyze economic implications. First, we see that perceived expected harm from both oil peak and global warming depends on the believed path of future costs. We never experiences any of those yet (but when we will, it will be too late), but we might overestimate the danger from global warming. What will happen if the majority will believe that we should stop extracting fossil fuels (before they end) to combat global warming? The price of oil will not grow (or grow not much). In fact, developing countries (oil producers) will have in mind Fig.2 and panic more about negative consequences from global warming already in the coming 2-3 decades, when oil peak will not yet reveal itself.

Suppose now that our vision on global warming was too pessimistic (realized path of economic externalities grows not so fast over time), comparing to our vision of hazard from consequences of oil peak. Before oil peak we then treated oil as “bad”, and price of it was modest. Moreover, holders of oil reserves could have sold them to buyers (especially from OECD countries). They could rationalize such decision on the belief that some oil will never be extracted (due to global warming concerns). When (after new information arrives) the world revises the hazards, it starts to value oil at high extent, and its price sky-rockets. At the short horizon, there is no substitute for oil in air industry (except from biofuels, but there price is also rising due to competition with agriculture for land), and R&D will require several decades.

5. Transition to Renewable Energies

The transition to renewable energies is a remedy for both threats. If it will start with proper speed today and globally, most likely major dangers will be averted. However today we have not sufficient technologies and economic incentives for such transition. Wirl and Yegorov (2014) analyse the problems with different renewable energies. While wind is already cheap, its supply is random and thus needs to be balanced. Solar energy also has supply heterogeneous over time, but it is also more costly at present. Substantial fraction of biofuels in energy portfolio will threaten food supply security because of competition for arable land. Hence, while transition to a modest fraction of renewable energies is not a problem, full transition might be problematic (even technically at present) and practically non-implementable under short term horizon

when the discussed crises would give clear market signal for the necessity of such transition.

6. *Conclusions and Policy Implications*

The idea of this paper was to show that uncertainty of global challengers (global warming and peak oil) can imply quite different behavior of future oil prices, that is important for both oil exporters and importers.

The owners of oil reserves (including Russia) can be fooled, if they underestimate the danger from oil peak and/or overestimate the hazard from global warming. We are playing global lottery game, with a lot of uncertainties (and even information manipulation). We have to understand how resource owners can be stripped from their assets.

Another important issue (highly relevant for Russia) is its high discount value. Even if we forget for a while about considered hazards, it is simply not rational to exploit oil in parity with Saudi Arabia, given that the latter have more oil resources in all scenarios. If Russian discount rate would jump from 10% to 2% (and even intermediate 5%), it would revise its production path, cut oil production and save it for future generations. Partly it will recover some current benefits from rising oil price.

As for transition to renewable energies, it will take quite substantial time, and economic incentives either from peak oil or unacceptable global warming might come too late to implement it in proper time, while incentives before such crises might be too low for proper implementation of full transition to biofuels.

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Appendix: Figures

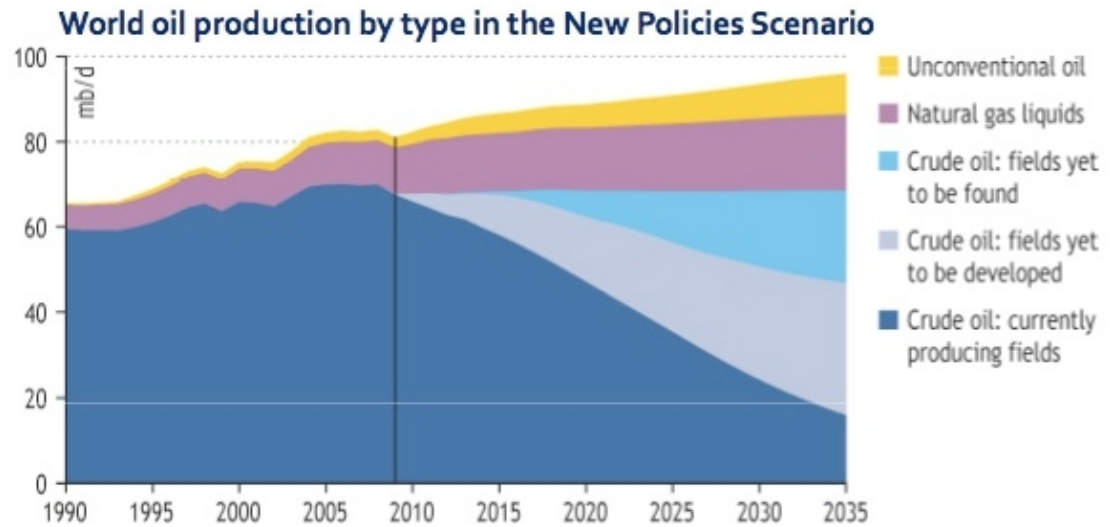


Fig. A1. Future oil production forecast. *Source:* The International Energy Agency's (IEA) World Energy Outlook 2010.

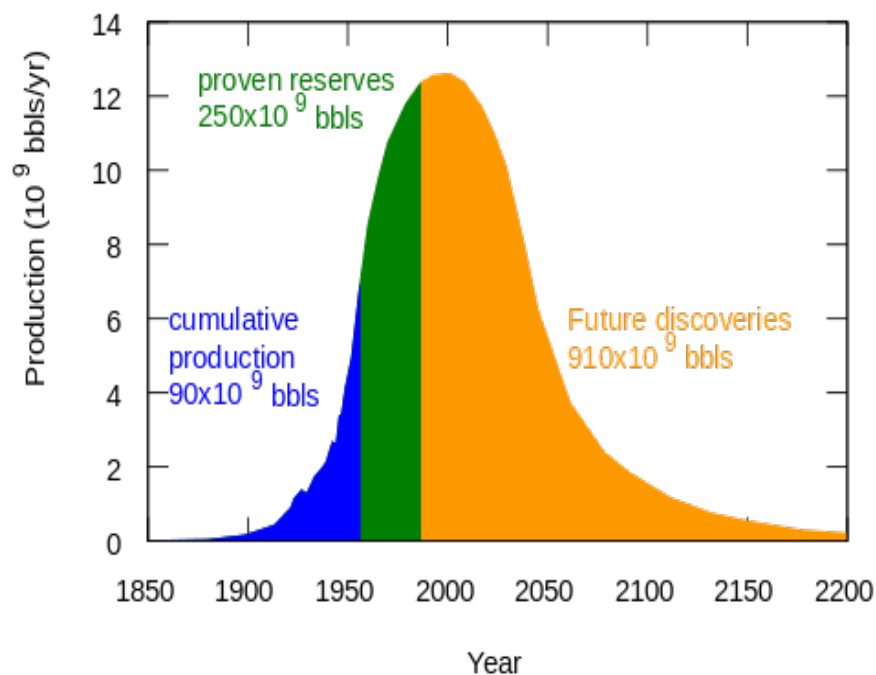


Fig. A2. Illustration to peak oil theory of Hubbert King. *Source:* reprint from H.King (1956) in http://en.wikipedia.org/wiki/Peak_oil

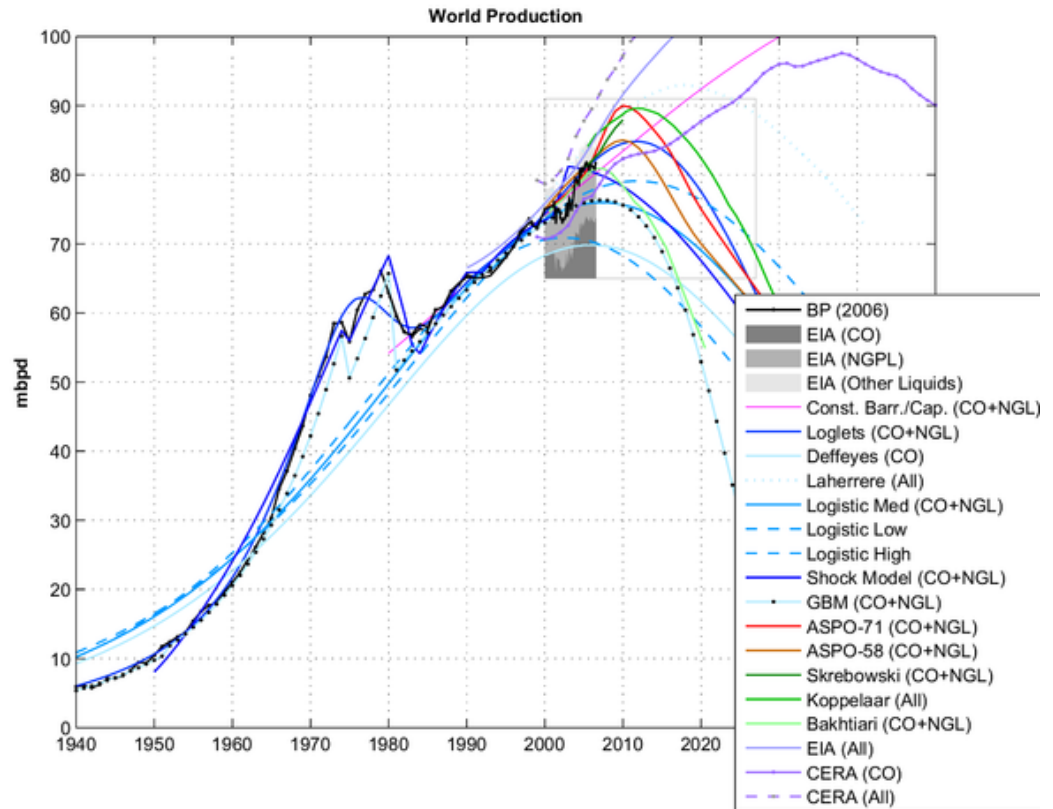


Fig. A3. Different scenarios for world oil production. *Source:* The Oil Conundrum. DAINA. 16 January 2011. ISBN 978-0-9644741-1-6; see also http://en.wikipedia.org/wiki/Oil_peak

(b) Observed change in average surface temperature 1901–2012

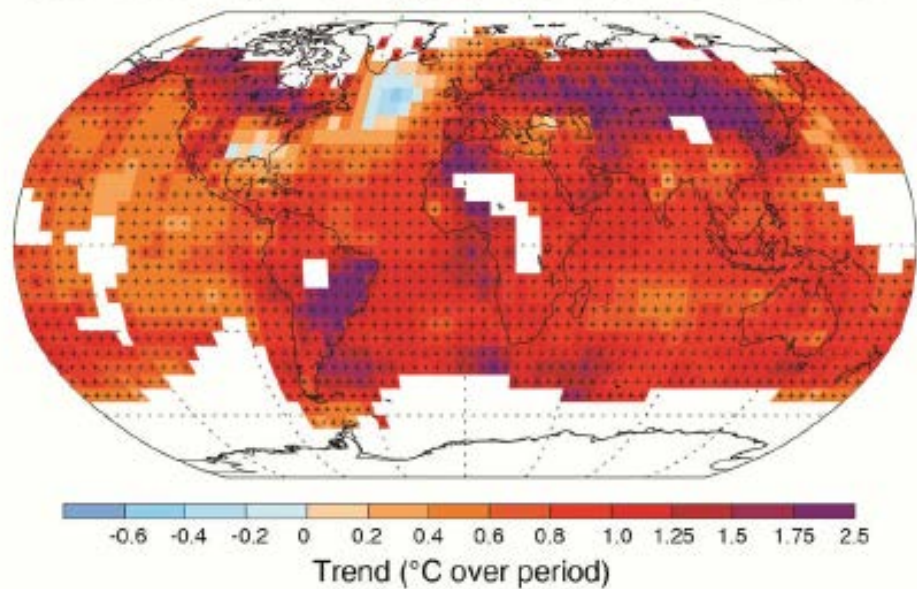


Fig. A4. Regional variations of temperature change. *Source:* IPCC Fifth Assessment Report 2013.

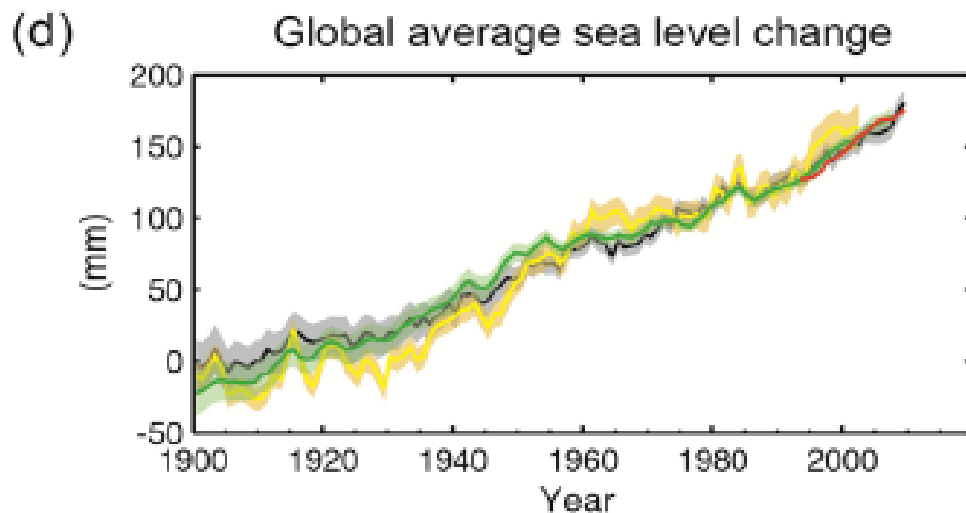


Fig. A5. One of the hazards from global warming in the sea level rise. The dynamics in the 20th century is reproduced from: IPCC Fifth Assessment Report 2013.

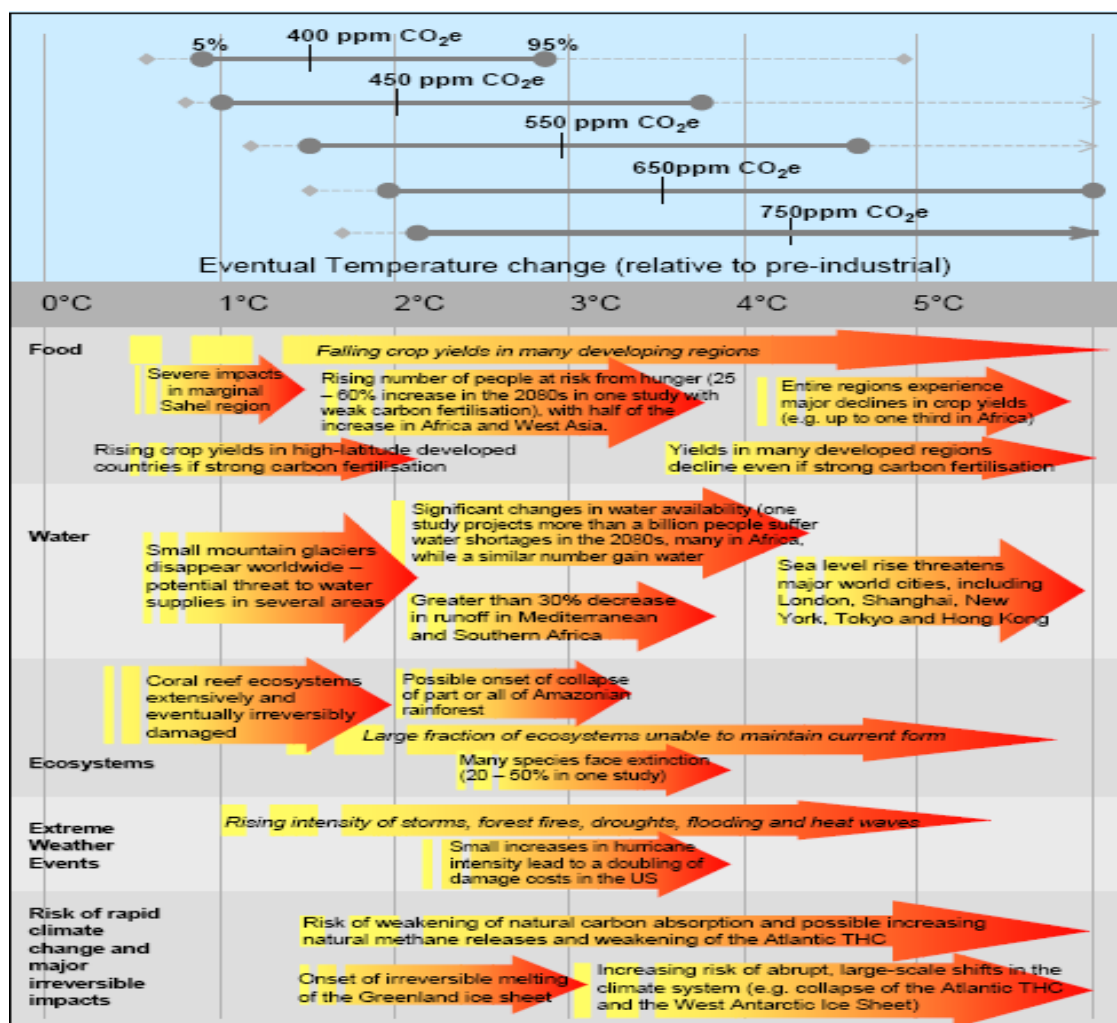


Fig. A6. Hazards from global warming. Source: Stern report.