Strategic Impacts of Breakthrough Energy Technologies

di Daniele Poponi

Abstract

The history of energy technologies developed and deployed from the onset of the industrial revolution is marked by strong discontinuities where socio-economic systems based on the dominance of an energy source and related energy conversion technologies embark in paths of relatively swift transformation driven by the invention and deployment of new energy technologies. Historical precedents suggest that the hypothetical development of breakthrough energy technologies in this century should be considered at least one among the various future technological scenarios of humanity. This article analyzes the strategic implications of the deployment of a non-fossil breakthrough energy technology in this century. The impacts on the energy industry will likely consist in a profound transformation of the incumbent system based on the extraction and conversion of fossil fuels. In a long-term scenario, a BET deployment in the electricity sector could well mean the end of conventional nuclear and coal as options for generating electricity. The growing diffusion of a non-fossil distributed breakthrough energy technology would make less compelling the extension, operation, and protection of the energy infrastructure for the international supply of hydrocarbons. The implications for environmental security would be significant as well. Such technology revolution has the potential to be a geopolitical game changer by affecting significantly the ability of sovereign states to pursue their strategic objectives.

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Energy futures beyond the 'business-as-usual' energy scenarios

Most of the future scenarios of the global energy system are either based on a linear extrapolation of current trends or assume a policy-driven acceleration in the deployment of some energy technologies that already exist in the market or are at the development stage (e.g., renewable energy technologies, nuclear, and coal capture and storage) to achieve policy-driven goals. However, the inherent limit of the 'Reference' or 'Best-Policy' scenarios is that they do not and cannot incorporate the effects of future major technological breakthroughs on energy supply. Such scenarios are inherently limited in their assumption of a mere continuation of historical trends. In other words, the way we see the technological future of humanity is necessarily biased by the existing technological status quo. In fact, what Karl Popper said on the impossibility of predicting future knowledge can well apply to knowledge leading to new energy technologies. For Popper, "no society can predict, scientifically, its own future states of knowledge," because this prediction depends on the possibility to describe salient features of such knowledge, an ability that can only be applied if one already possesses that knowledge[1] [2]

Yet it is obvious that in the last 400 years of history, human societies have been transformed by many technology discontinuities such as new energy prime-movers or energy converters, if we can so define the inventions of the steam engine, the internal combustion engine, the steam turbine, and the development of nuclear fission and its military and civilian applications. The history of energy technologies in the last three centuries did not quite match that of a baseline scenario that would have been hypothetically drawn before the industrial revolution.

Technological optimists can point to the fact that the 'technological civilization' has reached a point where there is a great and often unrecognized potential of applications in the energy sector from advances in several fields such as material science, microelectronics, nanotechnology as well as applied research based on advancements in quantum physics and research on advanced nuclear technologies. Basic and applied research in the above fields could well lead to an impressive acceleration of technological and economic viability of existing technologies, such as solar photovoltaics. As a result, the pace of technological innovation and market diffusion of the IT and consumer electronics industry in the last three decades could well be experienced by other technological domains, such for instance energy conversion technologies.

The strategic implications of the commercialization of a breakthrough energy technology (BET) will be discussed in the remainder of this article. In the scenario that will be analysed, a BET (or transformational energy technology) is not only demonstrated and commercialized, but successfully engineered in a mass production process so that the costs of energy generated in the first phase of market deployment are at least competitive or approaching competitiveness with those from the incumbent sources. Obviously, not only the energy industry but also government policy and international relations politics and relations will likely be affected by such technology revolution.

It should be premised that the aim of this analysis is not to evaluate the underlying scientific credibility or technological viability of 'exotic' technologies or the likelihood of deployment of very advanced forms of renewable energy technologies such as cellulosic biofuels or third-generation solar photovoltaics. The rationale for this work is basically that of a 'what-if' analysis aimed at discussing the implications of a hypothetical scenario.

Analysis of diffusion paths and market deployment of breakthrough energy technologies

If a BET technology is successfully commercialized, one might ask what the market growth or technology diffusion rate for this technology will be. Looking at historical trends of diffusion of conventional energy technologies or energy supply from fossil fuels with the aim of extrapolating possible market growth rates of transformational technologies in the 21st century can be misleading. Arguably, extrapolating diffusion rates for technologies deployed during the historical period that is

[1] Popper, Karl. 1957. *The Poverty of Historicism*. Boston, Beacon Press: p. vii.

[2] Banks, Ferdinand. 2003. Energy Economics: A Modern Introduction. Boston, Kluwer Academic Publisher: p. 46.

referred to as the modern or industrial era (e.g., the steam engine or the internal combustion engine) and using these rates to project the diffusion of completely different technologies (e.g., not based on thermodynamics) in mature industrial economies can lead to very inaccurate predictions.

The scope for unprecedented growth rates of a BET might be based on the fact that the so-called ‘built-environment’ in mature industrial societies is inherently different or increasingly becoming so from that of societies that saw the rise of hydrocarbons and even the more recent deployment of renewable energy technologies. The built-environment is not only made of the technological level and of the economic structures, but also of the general interests and values of the society, the policy imperatives of the government, the ability to produce innovation, etc. Mature or post-industrial societies are becoming increasingly different socially, economically, and technologically from what they were before the IT revolution. This could well mean that the speed at which a breakthrough energy technology could progress from prototype to market diffusion might be unprecedented in the history of energy technologies. As a result, a widespread commercialization of a transformational technology may not take decades as it took to previous energy sources. In other words, the market diffusion of breakthrough energy technologies in the 21st century cannot be projected by looking at the current and past energy technology status quo.

The most important factor affecting technology diffusion will be cost. Production costs of the breakthrough technology and of the energy generated will likely decrease over time due to learning effects and economies of scale. The speed of technology diffusion will not only depend on costs but also on other factors such social visibility, complexity, technological interdependence, and the socio-institutional setting (e.g. the energy and environmental policies in place)[3]. Chances are that the socio-economic and institutional setting will be extremely conducive for an accelerated commercialization of a breakthrough energy technology in most of the countries. The combined action of the learning effect and of the economies of scale in the manufacturing phase can ensure that the breakthrough energy technology will rapidly achieve higher market shares even in the presence of dramatic reductions in fossil fuel prices.

The diffusion path of breakthrough energy technology can also vary according to which segment of the energy sector the BET will have its first applications. For example, a BET can generate as primary output either heat or electricity, or can consist of a process for producing alternative fuels (e.g., biodiesel or bioethanol) for use in internal combustion engines. In addition, even if the primary output is heat there can also be subsequent applications for electricity generation if the necessary stability or temperatures required for a Carnot cycle are reached. Lastly, though not discussed in the present analysis, there can also be innovations that substantially increase the efficiency of conversion or use of existing fuels.

Examples of potential candidate technologies are advanced forms of renewable energy technologies already in use (e.g., photovoltaics with carbon nanotubes), completely new technologies based on low-energy nuclear reactions (LENR), or nuclear technologies that have already been subject to some research (thorium-based fission or muon-catalized fusion).

As far as LENR are concerned, such processes and related technologies have already been under the scrutiny of intelligence organizations. An unclassified report prepared for the US Defense Intelligence Agency (DIA) “assesses with great confidence that if LENR can produce nuclear origin

[3] Grübler, Arnulf. 2003. *Technology and Global Change*. Cambridge, UK, Cambridge University Press: p. 354.

energy at room temperatures, this disruptive technology could revolutionize energy production and storage, since nuclear reactions release millions of times more energy per unit mass than do any known chemical fuel"[4]. The DIA analysts further highlight that "the potential applications of this phenomenon, if commercialized, are unlimited. LENR could serve as a power source for batteries that could last for decades, providing power for electricity, sensors, military operations and other applications in remote areas, including space"[5].

Impacts of BET diffusion on the energy industry

If a breakthrough energy technology is successfully commercialized in the next few decades, the current structure of the energy industry will obviously start to undergo a deep transformation. The more specific impacts of this transformation will depend first of all on what will be (a) the primary energy output of the technology (e.g., heat, electricity, fuel) and (b) the first market niches that will be subject to commercial penetration. For the sake of providing a more detailed and exemplificative analysis, the remainder of this section will discuss the impacts on the energy industry of a technology that can generate electricity.

One could argue that the first energy sources or technologies used in the electricity generation sector that could be impacted will be those with the highest costs of production, particularly where the industrial players have the lowest margins. For instance, when the BET enters the market for electricity generation, the first power sources that might experience a slow-down and eventually a reduction in absolute terms in their use could – at least in theory – be renewable energy sources (some of which have the highest costs of generating electricity relatively to conventional sources). However, as it will be discussed in the next section, it remains to be seen whether most of governments will let the renewable energy industry be hit by the technology newcomer.

If the BET technology is able to generate electricity for baseload power, one of the technology losers is likely to be conventional nuclear fission. Public acceptance for fission-based plants, particularly in developed countries, might go to record low levels even if in the first years of BET diffusion the conventional nuclear option would still be competitive. The public will quickly acknowledge that the implication of the introduction of a transformational technology is to make the continuation of conventional fission-based nuclear programs meaningless even in countries that have strong domestic nuclear industries. Conventional nuclear fission would likely not be considered a necessary option neither for energy security nor for climate change mitigation any more.

Another likely loser of such energy revolution will be coal, which in some OECD countries is already driven out of the market either as a result of climate mitigation technologies (except for possible applications of coal carbon capture and storage) or by shale gas. Countries which will have the opportunity of developing a strong domestic BET industry in the production segment and where market demand from final users is expected to be strong will feel less restrained in introducing a carbon tax, even where there are large coal domestic resources. However, most of the new global capacity in coal fired power plants in the next two decades is projected to be installed in China,

[4] Defense Intelligence Agency (DIA). 2009. Technology Forecast: Worldwide Research on Low-Energy Nuclear Reactions Increasing and Gaining Acceptance. DIA-08-0911-003 [Unclassified]: p. 1.

[5] DIA, 2009: p. 6.

India, and other emerging countries. So the projected growth in the use of coal in the next three decades (and so the related greenhouse gas emissions) might at most be only slowed down if the BET is not adopted quickly in these countries.

Natural gas demand for electricity generation will also be impacted by the BET diffusion, but most likely to a lesser degree than coal. The trend of decreasing prices due to the development of non-conventional gas resources, the multiplication of LNG terminals and other factors (e.g., stricter standards of emissions of air pollutants that penalize coal) could make natural gas demand less vulnerable than coal to the market penetration of BET, at least in the initial stages. Another factor that is favourable to natural gas with respect to coal is its lower carbon content, which should partly soften the combined impact of BET diffusion and climate change mitigation policies[6] [6]. The reduction in the growth of rate of projected natural gas demand due to the BET diffusion, combined with the increasing availability of non-conventional gas resources, might produce a deflating effect on natural gas prices even in demand 'hubs' outside of the U.S. In the long run, natural gas might further increase its competitiveness in the electricity sector at the expense of coal and nuclear, at least in OECD countries.

Impacts outside of the electricity generation sector will also be achieved because of the ongoing trend of electrification of a few sectors of final energy demand. Among these, the transportation sector is of strategic relevance because of the predominance of oil, a fuel with notorious energy security concerns. Assuming that in the short to medium run the BET will impact the transportation sector only indirectly through the diffusion of electrified vehicles, in the first phases of BET market deployment the oil industry might be relatively unaffected by this technology newcomer. Oil demand will still be driven to a large extent by the projected increases in demand for internal combustion vehicles expected in the next decades, particularly in developing countries. Furthermore, it will take a few decades for electrified cars to achieve significant market share in the private transportation sector to the extent of reducing demand for oil-derived fuels in absolute levels. However, the generation of cheap electricity from a non-fossil BET could be in itself an important driver for an accelerated market diffusion of electrified vehicles. Eventually, an increased production of electrified and other non-conventional vehicles (e.g., hybrid, fuel cells) combined with the commercialization of advanced biofuels has the potential to reduce the growth rate of oil demand sooner than most energy-efficient scenarios project. Eventually, the famous global peak in oil production might be reached, but not as a consequence of the depletion in conventional oil reserves and skyrocketing prices, but because of fuel-switching in the transportation sector towards alternatives. In the long run, slower growth and then progressive reduction in oil demand in absolute levels should be reflected in lower real prices, which will make the exploitation of oil resources with the highest costs of extraction less profitable. This means not only that the profitability of off-shore oil fields will be negatively affected, but also that the push for the development of non-conventional oil (tar sands and shale oil) might slow down significantly or come to a halt, even if technologies for the development of these resources are making them competitive with oil prices lower than 50$/barrel.

The impact on the specific energy sources is only 'one side of the coin', the other side being the actual energy market players. If the BET relies on a free source of energy input, such for example an advanced solar technology combined with storage, the actual cost of electricity generated will

[6] Michaelowa, A. and Butzengeiger, S. 2012. "Climate finance and backstop technologies" in: Michaelowa, A. (ed.): *Carbon markets or climate finance?* Routledge: p. 222-254.

depend only on capital (the actual equipment cost), installation, and maintenance costs, with no fuel expenses. This kind of cost structure implies that the first important change in the energy industry will be the in the composition of the market players and their weight in the market. The energy business will increasingly be a game played by manufacturers and installers, an industry structure that is quite different from the fossil fuel production chain with its extraction (upstream), transportation (e.g., pipelines, oil and LNG tankers for fossil fuels), and downstream segments. If the BET manufacturing phase can be considered a sort of parallel of the fossil fuel upstream sector, the transportation infrastructure and needs of the BET are going to be dramatically different from those required for fossil fuels.

In terms of market players, even if the BET is developed initially by small companies, established multinational conglomerate corporations with activities in the power generation sector (e.g., production of turbines, production of solar modules, nuclear engineering) will likely seize the new profit opportunity and invest to become major manufacturers of the transformational technology.

The large-scale commercialization of a BET can produce impacts that will reverberate in the general productive structure of economies as it has been known until now. In general, an unprecedented shift in the way energy is converted and possibly in the degree of centralization of the energy system (e.g., a change towards a more decentralized system) will have ramifications throughout the whole economic system. This means that the impacts of an energy revolution will not only be limited to the energy sector but will also affect several other sectors of the economy. For instance, there is likely to be an economic impact also on all the linked industries (e.g., the suppliers of raw materials to the BET industry vs. those suppliers dependent on the conventional energy industry), the energy-intensive industries, and the financial sector, too.

To sum up, as a result of the deployment of a BET for electricity generation, incumbent sources such as coal, nuclear fission, and non-conventional oil might exit the energy picture sooner than would be realistically thinkable with the most ambitious scenarios based on energy efficiency and deployment of 'conventional' renewable energies, nuclear, and coal capture and storage.

Strategic implications for governments

An energy technology revolution will affect the ability of many governments to achieve their long-term goals (strategic interests) as well as the means of achieving these goals (strategic planning). The government response to a BET revolution will vary widely from country to country according to the economic and strategic interests at stake It is likely that not all governments will have a 'laissez-fare' approach towards the market commercialization of a BET but will adjust the existing energy, environmental, fiscal, and industrial policy framework according to how the new technology affects national interests or objectives. Whether a country will be a loser or winner of the new energy game will depend on several factors, the most important of which are obviously its pre-existing energy dependence (the percentage of primary energy imported with respect to domestic demand), the costs of its energy supply, and its ability to establish and develop a domestic manufacturing base coupled with a strong domestic market. A basic rule of thumb to determine how geopolitical impacts will vary among two hypothetical countries can be the following: *ceteris paribus* (e.g., given the same domestic manufacturing capacity of BETs and energy dependence) the country that has the highest energy cost per unit of GDP will obviously benefit more from the BET revolution.

The first winners of this revolution are likely to be the lead-country or lead-countries, the pioneer(s) in developing or acquiring the know-how and in establishing a manufacturing capacity for the breakthrough technology. The countries that are be able to establish industrial champions for production of the BET in the early stages of diffusion of the technology will be able to maintain more easily a competitive edge on the competitors, or those countries that will try to establish a manufacturing capacity at a later stage (second-tier manufacturers). Potential lead-countries in the manufacturing of BET are those countries that already are manufacturers of advanced energy technologies and also have know-how in strategic and related R&D sectors. Significant benefits can also accrue to early adopters, or countries which do not necessarily manufacture the BET technology but can become important markets for demand, as long as BET diffusion crowds out costly energy imports.

The strategic benefits to lead-manufacturers and early-adopters of a breakthrough energy technology can be expressed in a broad range of indicators related to energy security (reduced energy imports which is reflected into reduced vulnerability to supply shocks of hydrocarbons), environmental security (lower air pollution and emission of greenhouse gases which is reflected into reduced health costs and physical damage from extreme weather events), and economic security (improved trade balance and greater economic affluence). All of these benefits are more generally reflected in greater national security intended in a broad, non-conventional acceptation[7]. Such non-conventional definition of national security is not based on military threats and territorial integrity but on (a) the quality of life of the inhabitants of a state and (b) the range of policy choices available to the government of a state or to private, nongovernmental entities within the state[8].

Energy imports are the main component of the trade balance deficit of many OECD countries that have seen their energy dependence increase substantially in the last few decades. One reason for these countries to accelerate the diffusion of a BET is to improve their trade and current account deficits. Two important cases are those of Germany and Japan, which have significant trade balance surpluses even in the presence of significant energy dependence, with energy imports totalling 60% and 80% of their energy supply, respectively. If these two countries become lead markets of a transformational energy technology, the ability to achieve their strategic goals or even to pursue more ambitious goals will increase significantly.

For fossil fuel exporting countries, the pace of diffusion of the transformational technology will matter, because the faster its market deployment, the greater the downward pressure on fossil fuel prices will be. In this scenario of a global 'gold-rush' to a new energy source, conventional fossil fuel producers might have to face the prospect of an environment of permanently low prices. This scenario is considered extremely unlikely or even impossible by most of fossil fuel exporters today. However, revenues from fossil fuel exports in these countries might be reduced not only by the BET deployment in itself but by a combination of factors on top of the BET diffusion such as radical improvements in energy efficiency (e.g., a greater efficiency of ICE-based vehicles), and increasing supply from shale natural gas, non-conventional oil, and advanced biofuels. The impact of all these factors can be large enough to depress fossil fuel prices to such levels to force producers to cut their government budgets, for example by reducing expenditures on defence and infrastructure. The strategic consequences of a BET deployment can be better understood if one

[7] Romm, Joseph J. 1993. *Defining National Security*: *the Non-Military Aspects.* New York, Council on Foreign Relations Press.

[8] Ullman, R.H. 1983. "Redefining Security", *International Security*, 8 (Summer): p.133.

considers how dependent several national government budgets are on revenues from hydrocarbon exports and how important are state-owned oil companies for the economies of these countries. For instance, revenues of OPEC member nations in 2012 totalled more than 1,000 billion dollars, an all-time record. Lastly, low hydrocarbon prices might exhaust the firepower of sovereign-funds of exporting countries in the globalized economy.

To the extent where the BETs deployed are able to achieve lower costs of energy generation than the incumbent sources, BET diffusion will make it less costly to achieve GHG emission reductions. Lower GHG emission paths driven by BET deployment will likely make the more costly and technologically controversial options for climate change mitigation (e.g., climate engineering or coal capture and storage) redundant. Lower GHG emissions due to BET deployment is also reflected into a lower likelihood of extreme weather events (EWE) in the long run and in improved environmental security of all those countries that are most vulnerable to climate change impacts. In fact, the expected increased frequency of EWE like floods, droughts, and tropical storms that many expect to result from increasing concentrations of GHGs in the atmosphere can be for some countries as disruptive as to be rightfully considered a threat to the national security.

Rather than supporting the deployment of BET, a few countries (not necessarily only hydrocarbon exporters) might try to slow-down the commercialization of BET or to shield some incumbent industries. One of the purposes for controlling or slowing-down the market penetration of the BET might be to facilitate the active involvement of some domestic conventional industries or shielding other industrial players these from excessive damage. For example, it seems unlikely that governments will let the growing renewable energy industry collapse by discontinuing established support measures, particularly where a strong domestic renewable energy industry is in place. Another case in point is that of countries that have champions in conventional nuclear fission technology. One of the rationales for a 'shielding' policy could be that of pursuing a "portfolio approach" of non-fossil fuel technologies, rather than having a single technology dominating the energy market in the long run. Another rationale for such government intervention could be that of assuring an 'orderly' transition away from the fossil fuel economy to a new economy based on BET. To many stakeholders, this pro-active role of governments might seem justified in order to give more time to the incumbent industries to adapt to the energy revolution and to enter profitably the new business.

Even if government policy to regulate or slow-down the diffusion of transformational energy technologies will have to face a strong public opposition in democratic regimes, it may be the case for some fossil fuel exporters with less democratic regimes which might even consider blocking the BET market commercialization outright. The policy priority of governments of fossil-fuel exporting countries can be expected to be that of limiting the economic damage in terms of lower revenues. But some of the fossil fuel exporters might feel that they have no choice but to try to jump into this technological bandwagon in its early stages of development in order to establish a national technological and industrial capacity. The risk is to be a fossil fuel exporter for a few more decades but then a technology importer for ever.

Fossil fuels themselves are a relevant source of revenues (excise taxes on petroleum fuels, VAT on electricity and refined oil products, etc.) even for governments of countries that are energy importers. It can be expected that, all other things being equal, these revenues will decrease in line with the reduction in the absolute demand of fossil fuels. Therefore, taxation will have to be restructured in order to ensure stable revenues. As already said, any policy in industrialized and developing energy importing countries aimed at slowing down market diffusion of a BET in order to safeguard government revenues will likely be met by a massive outcry from the public, and be extremely risky for the political elites.

Effects on inflation of the BET deployment may be relevant to policy-makers, who will wonder about the implications of an economic environment where one of the main drivers of inflation, namely the price of conventional energy commodities, might start to follow a decreasing path in real terms.

Two interesting case studies for assessing the impacts of a BET revolution can be that of United States and Russia. Due to the shale gas revolution, the United States are currently building a competitive advantage over its economic competitors in the energy-intensive industries. If a BET is first developed and manufactured in United States and the US industry is able to maintain a technological edge over the second-tier producers (or imitators) from other countries (that will likely struggle to develop their own BET industry through development of domestic technologies or reverse engineering), then in theory there might be two different competitive advantages summing up to the benefit of the USA. However, the final net effect for US economic security and for that of other countries might be not so simple to assess, due to the likely complex dynamics of the domestic competition between the BET industry and the fossil fuel industry in the USA and the international technological spill-over effects. It can also be the case that other countries can develop their own BET industries relatively quickly (even if they will not be technological leaders in the first stages), and this diffusion can reduce the competitive advantage that the USA currently is building up for the shale gas revolution. As far as Russia is concerned, its economy is notoriously dependent on hydrocarbon exports, and obviously a BET revolution might adversely impact its long-term economic outlook. However, Russia has a strong scientific, mining and industrial resource base and there is a significant potential in terms of human and natural capital to make up for the reduction in demand for oil and gas and to accelerate the transition towards an economy much less dependent on hydrocarbon exports.

In sum, even if the impacts of a BET revolution might not be as radical as to disrupt the economies of most fossil fuel exporters, one of the likely effects of the BET revolution can be that of levelling off the competitive advantages that some countries currently have in terms of lower energy prices for their respective energy-intensive industries. These lower costs of energy can be due to various factors such as availability of domestic coal, lax environmental standards, a strong domestic conventional nuclear industry, and the development of non-conventional fossil fuel sources. All of these advantages will obviously be less effective in the presence of a globalized BET industry producing energy generation devices in different manufacturing hubs around the world.

For all the afore-mentioned points, it will not be an easy task for policy-makers to manage the transition from a fossil fuel economy to an economy based on a more diversified mix of technologies where a breakthrough energy technology becomes gradually dominant. This task will be even more daunting if in parallel to a BET revolution there will be other structural changes in the industrial economies, such as an acceleration in nanotechnology-based production processes (3D printing). The combined deployment and diffusion of BET and nanotechnology-based production process can determine unpredictable effects for the status quo of productive specializations across countries ('who produces what product and at what cost').

Implications for international security

The market commercialization of a transformational energy technology can have significant effects not only on the *status quo* of the energy industry and the domestic policies of governments, but also on the structure and dynamics of relations among countries. In view of the potential to radically change the world's economy and to increasingly impact global politics, a BET revolution can by all means also be considered as a geopolitical game-changer.

In terms of energy security, the BET deployment can dramatically reduce the dependence of energy importers on fossil fuel exporters, including hydrocarbon producers in geopolitically unstable areas. Where hydrocarbon imports will be likely reduced, for example in the lead-market and the early adopters, concerns related to energy security will gradually become less relevant for foreign policy. The need to protect oil-tanker sea lanes and to patrol 'chokepoints' (e.g., the Hormuz Strait) will likely be less compelling over time. Energy importing countries that have the capacity to deploy the BET will suddenly find themselves with more leverage in their hands in the global energy game. This leverage – the ability to lessen energy dependence upon other countries - is related to the possibility to accelerate the dissemination of the breakthrough technologies through active government support. What response in terms of foreign policy the countries that negatively impacted by the technology revolution will pursue is a matter of even higher speculation. Bhattacharyya argues that "A viable substitute for oil in the transport will bring a sea change in the energy markets: importing countries will discover that the golden goose is no more laying golden eggs. Countries sitting on huge oil reserves and hoping wind-fall gains in the future when oil becomes scarce in other areas would be the worst hit. The transition could be violent and could make the world a lot more unsafe place"[9].

In view of the vital character of hydrocarbon exports for countries that do matter for the stability of the global economy, it's not entirely unthinkable a scenario characterized by a concerted global effort to control or manage the market deployment of BETs in order to prevent a destabilization of hydrocarbon producing countries.

Of significant importance are the geopolitical implications of the possible loss of importance of conventional nuclear power from the introduction of a transformational technology generating electricity. For example, in a post-BET world, initiatives for the development of nuclear power for civilian purposes will have no reason to be undertaken in all those countries that have enough capacity to manufacture BETs or to integrate it in their energy supply. The rationale for building new nuclear power plants will also be less compelling even for those countries that do not have a BET manufacturing capacity but can still be early adopters in the demand segment. As a result, it will be more difficult to shelter programmes to build nuclear weapons under the umbrella of civilian uses.

If the BET will be successfully used for transportation applications, the aforesaid DIA report indicated that a new revolution in military affairs is set to take place with significant implications. The introduction of BET is predicted to free armed forces so equipped from many logistical constraints related to fossil fuel sources and supply lines as also from cumbersome and hazardous nuclear fission reactors in the case of surface vessels and submarines[10] . The DIA analysts conclude

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[9] Bhattacharyya, Subhes C. 2011. *Energy Economics*. London, Springer-Verlag: p. 426.

[10] Carpentier de Gourdon, Come. 2013. Personal communication.

significantly that a BET used for military transport "could produce the greatest transformation of the battlefield for US Forces since the transition from horsepower to gasoline power"[11].

Lastly, the accelerated deployment of a non-fossil BET will also be reflected in improved environmental security at the global scale. The displacement of fossil fuel consumption will result in lower emission paths of GHGs relatively to even the most optimistic emission scenarios from the Intergovernmental Panel on Climate Change (IPCC). As a result, some of the climate change impacts that are expected to occur under a scenario where no BET is deployed and that are going to affect negatively international security will be avoided. One of such impacts is reduced fresh-water flow on international river basins such as the Nile, Jordan, Tigris-Euphrates, and Indus where demand is expected to increase, a scenario that might escalate into so-called 'water-wars'[12].

Conclusions

The deployment and diffusion of a breakthrough energy technology has the potential to produce profound economic changes and to be a geopolitical game-changer in the 21st century. The geopolitical and geo-economic standing of the 'technology winners' can increase significantly. The financial and strategic clout of fossil-fuel (coal, natural gas, and oil) exporters is likely to decline, although the net impacts for some of these countries might not be necessarily negative in the long run. In fact, chances are that the rift between geopolitical winners and losers of a new energy revolution should gradually get narrower over time. In light of the risks that the global environmental challenges pose to the continuity of the technological civilization, it is more likely that the benefits that a new energy transition driven by a transformational energy technology will have on international security will far outweigh the negative impacts.

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[11] DIA, 2009: p.6.

[12] Poponi, Daniele. 2003. *Energy and Environment as Non-Conventional Dimensions of Italian National Security*. Report submitted to the Military Centre for Strategic Studies, Rome.