FUTURE FUELLED
BY KNOWLEDGE

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ENERGY, ENVIRONMENT, DEVELOPMENT.

OBJECTIVES WHICH NEED NOT BE AT ODDS.

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LETTER FROM THE CEO

JACEK KRAWIEC

PRESIDENT OF
THE MANAGEMENT BOARD
PKN ORLEN

Ladies and Gentlemen,

It gives me great pleasure to welcome you to another report from PKN ORLEN's 'Future Fuelled by Knowledge' project, initiated three years ago. This time, we decided to focus on the challenges of developing an economy and energy industry based on environmentally-friendly technology that also, in a variety of ways, stimulates growth.

The authors state that "To a large extent, the history of civilisation consists of watersheds in the conversion and use of energy which, to put it simply, have allowed humans to enhance their muscle power." This seemingly obvious conclusion becomes less obvious when we view it in the cold light of the EU's energy regulatory policy – a policy that, instead of encouraging ground-breaking technological innovation, is instead focused on promoting known solutions that are media-friendly and politically correct.

It is hardly a surprise that environmental issues have been at the forefront of energy industry debate in recent decades. The end of the 19th century was a time of euphoria over the possibilities offered by the discovery that we could unlock the energy in crude oil reserves, which in turn led to a boom period, based largely on oil fractions, for the chemical industry. With this technological revolution, people were able to drive, fly and sail faster and more safely than ever before; important new industries emerged, such as global tourism, and the age of plastic – a cheap, durable material available to everyone – was ushered in. And throughout all of this, hardly anyone raised any environmental concerns.

Fortunately, indifference to environmental issues is now a thing of the past. No one capable of reasonable judgement wants to leave behind a devastated, biologically defunct Earth for our future generations, and the energy industry relies on technology that is now an order of magnitude more sensitive to environmental issues than ever before. However, environmental protection cannot be the sole driving force in discussions about the future energy mix. Sustainable development, espoused by politicians, economists, environmentalists and business circles alike, requires a holistic view of the world. But the course of the public debate revolves only around the ‘environmentally friendly or not’ paradigm that is so easily subject to emotional judgement and inhibits dialogue that accommodates the full complexity of the contemporary energy industry. This new PKN ORLEN report, prepared by our experts in the Strategy Area under the title *Energy – Environment – Development. Objectives which need not be at odds*, is an invitation to an expansive, open discussion.

The beginning of this discussion asks questions about the challenges we face today in fostering sustainable development. First of all, we need an interdisciplinary knowledge, giving us more insight into the five principle aspects of energy: Where does energy come from? How do we make it available? How do we make better use of energy? How does this affect people and the planet? How can we make decisions about the future? These issues are dealt with as part of the many subjects taught at higher education institutions and in schools of business and management, covering areas such as energy physics, techniques and technologies, economics, risk management, environmental and climate research, as well as social research.

To answer these questions, we need to get representatives of all these disciplines involved in matter-of-fact, prejudice-free dialogue. We also need an environment where innovative, future-oriented technologies will have a chance to mature enough for their economic viability to be tested, and currently the European Union lacks both the dialogue and the environment. Instead, it subsidises technologies endorsed as being ‘right’, as well as the lobbyists for the *status quo* that benefit from public financial support. In this atmosphere, there can be no revolutions in energy storage technology – for example, storage of tidal power – when it is more profitable to invest in whatever is already enjoying the financial support of the authorities.

Our future energy mix depends on technologies which do not yet exist, and the longer we impede their development, the longer the future will take to become the present.

Jacek Krawiec

SUMMARY

Thirty years ago, there was a tug-of-war for primacy between two video recording technologies: VHS and Betamax. That war had no winner, as ultimately both gave way to DVD, which is itself now destined for oblivion as high-quality downloads from the Internet are cheaper and easier to get than ever before. One wonders what the digital media market would look like today if, for some reason, public money had been funnelled into those early video formats. That question must now remain unanswered, but the likelihood of the innovative DVD formats and cheap data transfer technologies being developed in such a scenario would have been much slimmer.

How is this story relevant to the energy industry? In fact, it is relevant to all sectors of the economy, since any state intervention that arbitrarily nominates and supports 'winners' compromises the optimal allocation of capital, intellectual resources and labour. In other words, it is a road to nowhere.

The European energy sector is a motor which can, and should, drive the European economy, and the role of the European administration is to drive this motor toward sustainable growth. Instead, they give the impression that they see the European energy sector as a test bed for all sorts of regulatory experiments and trials of their own choosing, and so far, they've only been spinning the wheels without putting it in gear. But it doesn't need to be like this, nor should it. In this report, we seek to demonstrate that the energy sector could be the key driver of the European economy, provided that we Europeans recognise technology's leading role in the process and introduce appropriate measures to support its development. In our view, it is not primary energy sources but the different methods of harnessing them that contribute, to a greater or lesser extent, to sustainable growth. We present arguments to support this view, and show where and how to make changes in the approach to the energy sector, in order to fully realise its potential in development of the European economy.

Finally, when preparing this report we were aware that it would not deal exhaustively with its subject. Our intention was instead to point out those aspects of thinking about the energy sector's future which have so far been either completely disregarded or addressed insufficiently.

1. Today's energy mix is the result of various conversion methods, where mature technologies based on primary energy stored by nature co-exist with new, experimental solutions relying on pure forms of energy. Of the little we know about the energy mix of the future, we do know that it will include the use of currently unknown technologies. In this respect, we stand in a similar place as to where we were a hundred years ago – no one then could have imagined that nuclear power would be a key building block in the next century's energy mix – or even as recently as a decade ago, before the upcoming shale gas boom had announced itself.

2. Technologies for energy production and use should be assessed using three equally important criteria, known as the Sustainability Criteria:

- Energy security,
- The degree of interference with the natural environment and climate,
- The cost of energy, which determines its availability to households.

3. Undoubtedly, environmental issues are one of the key issues in any discussion of the energy of the future (and rightly so), but in keeping with the underlying principles of sustainable energy and development, they should be neither its dominant theme, nor its only theme.
Despite this, they have utterly dominated the debate in the past few decades, which has had the effect of almost completely blinding decision-makers to technological progress that not only offers the means of reducing energy production costs and emissions, but that also causes constant shifts in the global energy landscape and in the available technologies that can be used to reach critical climate protection goals.

4. The price of energy has an important social dimension as it determines energy affordability and, consequently, the extent of energy poverty and exclusion.

Energy is the capacity of a physical system (matter) to perform work. Energy is infinite and changeless. It cannot be produced, renewed or destroyed. It can take different forms: one form of energy can be converted into another.

Forms of energy – examples:

- Mechanical energy – associated with motion, it is the sum of kinetic energy and potential energy,
- Thermal energy (heat) – associated with the random motion of atoms, it is measured as temperature,
- Electrical energy – from the accumulation of electric charges; electrodynamic energy, if the charges are in motion, or electrostatic energy if they are stationary,
- Chemical energy – released by breaking molecules,
- Nuclear energy – from the differences in the binding energy of nuclei.

Primary energy – energy forms found in nature that have not been converted or transformed, other than through natural processes. The concept of primary energy is used in energy statistics, in the compilation of energy balances, as well as in other fields of energetics.

Primary energy source – another concept from energetics, this refers to the energy forms that the energy sector requires to generate the supply of energy carriers used by the public. Primary energy sources fall into one of two categories: renewable or non-renewable.

Secondary energy – energy obtained by converting primary energy sources. One type of secondary energy is electrical energy, generated through the conversion of various primary energy sources, such as coal, crude oil, natural gas or wind.

Usable energy – the energy we use to satisfy our everyday needs (such as electricity or fuels).

5. In our world of globalisation, even the most affluent economies cannot afford to tolerate excessive energy prices, whether or not its citizens mind paying them, as they pose a threat to their competitive position and growth compared with other countries.

6. Primary energy sources fall into one of two categories: renewable or non-renewable. With targets for the increased share of renewable energy in total energy consumption built into the European Union's energy and climate policy since December 2008, the distinction has gained a new, economic significance, beyond the existing social dimension of energy being either 'clean' or 'dirty'. However, the division is still not clear-cut and the resulting regulatory uncertainty has had a negative impact on both the energy sector and the wider economy. Many of what we consider to be the primary energy sources (such as biofuels, biomass, nuclear energy etc.) are not naturally occurring, which calls their primary status into question. Being products of human activity and continuous technological advances, they are, in fact, secondary energy forms. Moreover, the renewable category includes both GHG emitters (biofuels, biomass[1]), and zero-emission sources.

1 From the point of view of climate protection, biomass from organic remnants that are a product of natural processes is different from biomass obtained from plants specifically cultivated for use as such.

7. Breakthrough technologies and revolutionary innovations ultimately reduce costs and win the economic competition by providing alternative solutions, a fact consistently proven by each ground-breaking invention in the energy sector. In contrast, the technologies currently employed to generate renewable energy all share a persistently high generation cost compared with other available techniques. Today, even the most advanced renewable energy technologies, which together account for more than 10% of global consumption, still require public subsidies to exist and therefore cannot be regarded as truly revolutionary.

8. With the future of the energy sector to be driven by as-yet unknown technologies, it is imperative that we search for new solutions that will revolutionise the sector and sustain its growth. In this context, financing mechanisms are of the essence – support for research and development projects in new technologies, both in the energy sector and beyond, is necessary to create a business climate that is conducive to innovation. And yet, not every new technology is ultimately innovative. Because it can't be known in advance which development projects will actually yield a competitive product, pouring public money into refining existing inventions is not advisable, as this leads to accumulation of business risk, which then turns into regulatory risk, which ultimately hampers innovation.

9. Government institutions, both at the national and supranational levels, have a major role to play in shaping the energy mix of the future. Their functions in the energy sector are inextricably linked with the state's duty to ensure energy security (or the timely supply of energy at a socially acceptable price), and to protect the natural environment. Given that the principles of energy sustainability give no precedence to environment and climate protection over economic growth, regulatory processes must reflect the need to ensure that the cost of energy (passed on to the end user through higher energy prices or higher taxes, or usually both) is socially acceptable.

10. Climate change is affecting the entire globe, not just individual continents or countries, and so its effective mitigation requires that climate policies also be coordinated globally. In this, the single greatest challenge to the prospect of reaching a worldwide agreement on climate protection is the controversy surrounding the actual division of emission reduction costs between individual countries.

Emissions are an inevitable by-product of economic growth. Developed countries, where rapid economic growth and massive greenhouse gas emissions are already a thing of the past, are demanding decisive climate protection measures from less affluent, developing countries, which still rely heavily on coal. Coal, of course, contributes the most to the global increase in emissions. This is why an agreement that could be even remotely fair is so difficult to reach.

Today, even the most advanced renewable energy technologies still require public subsidies to exist, and therefore cannot be regarded as truly revolutionary innovations fuelling the growth of civilisation. With the future of the energy sector to be driven by as-yet unknown technologies, it is imperative that we search for new solutions that will revolutionise the sector.

THE ENERGY LANDSCAPE IS MADE UP OF VARIOUS CONVERSION TECHNOLOGIES

Who among us would not like to live in a world free of smoke and fumes and safe from the threat of industrial disasters like Chernobyl and Fukushima? A world where energy is generated by the oceans' tides, the wind, sunshine and Earth's own internal heat. The prospect of a civilisation based on clean, emission-free energy is not only attractive, but also an unquestionably important part of the Earth's future climate balance. The benefits are obvious: primary energy from natural sources is almost cost-free, readily available one way or another anywhere on Earth, and inexhaustible. So far, the only downside seems to be interference with the natural environment – however beautiful they might look in photographs, forests of wind turbines and acres of solar batteries do disturb the rhythm of nature.

Table 1. World primary energy demand and energy-related CO_2 emissions by scenario (Mtoe)

			New Policies		Current Policies		450 Scenario	
	2000	2010	2020	2035	2020	2035	2020	2035
Total	10 097	12 730	14 922	17 197	15 332	18 676	14 176	14 793
Coal	2378	3474	4082	4218	4417	5523	3569	2337
Oil	3659	4113	4457	4656	4542	5053	4282	3682
Gas	2073	2740	3266	4106	3341	4380	3078	3293
Nuclear	676	719	898	1138	886	1019	939	1556
Hydro	226	295	388	488	377	460	401	539
Bioenergy*	1027	1277	1532	1881	1504	1741	1568	2235
Other renewables	60	112	299	710	265	501	340	1151
Fossil fuel share in TPED	*80%*	*81%*	*79%*	*75%*	*80%*	*80%*	*77%*	*63%*
Non-OECD share of TPED**	*45%*	*55%*	*60%*	*65%*	*61%*	*66%*	*60%*	*63%*
CO_2 emissions (Gt)	23.7	30.2	34,6	37,0	36,3	44,1	31,4	22,1

*Includes traditional and modern biomass uses.
**Excludes international bunkers.

Note: TPED = total primary energy demand; Mtoe = million tonnes of oil equivalent; Gt = gigatonnes

Source: Forecasts by International Energy Agency (OECD)

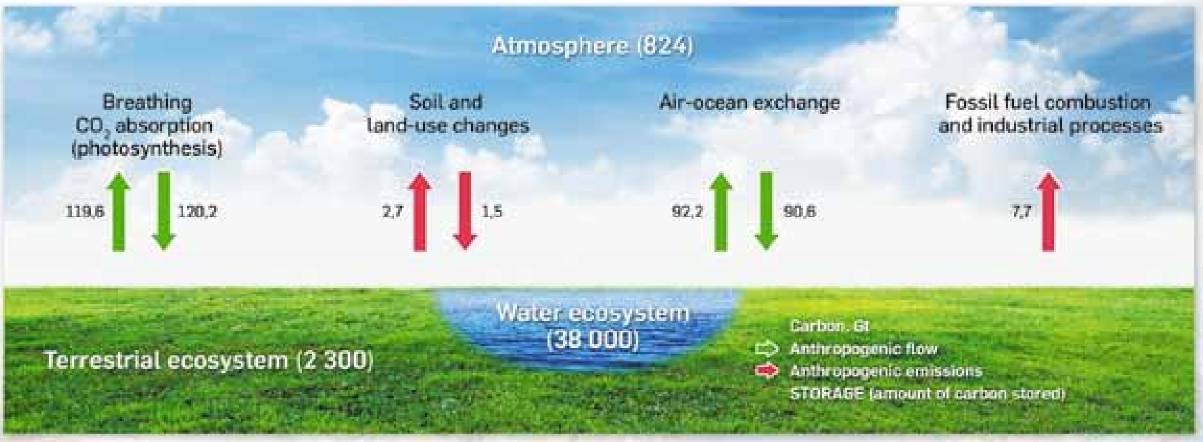
The 450 Scenario assumes strong policy action globally to put greenhouse-gas emissions on a long-term trajectory that will ultimately limit the global average temperature increase to 2°C. It results in global energy-related CO_2 emissions peaking before 2020 at 31.4 Gt and declining to 22.1 Gt in 2035. To achieve this emissions trajectory, the share of fossil fuels in total primary energy demand declines from 82% in 2011 to 63% in 2035.

Of the production technologies prevalent in global energy consumption today, those relying on fossil fuels (coal, crude oil and gas) are considered to have a heavy environmental impact. The extraction and combustion of these fuels continues to interfere with the environment and climate, although advanced technologies for fossil-based energy generation have considerably mitigated that interference. Another drawback of exploiting fossil fuels is their uneven distribution around the Earth, which gives certain countries a clear advantage over others and creates a network of more or less formal influences, referred to as 'the geopolitics of energy'. Moreover, access to limited resources carries a hefty price tag.

Nuclear energy falls somewhere in-between environment-friendly energy associated with innovative technologies, and old-fashioned, fossil-based energy. Its advocates emphasise that it is the only mature, proven, zero greenhouse emission energy conversion method, and that given the ever-growing demand for energy in the contemporary world it will be hard to build a low-emission economy without nuclear energy (Table 1)[2]. Its opponents, on the other hand, point to the environmental and health hazards posed by radioactive waste and to the risk of disasters with irreversible consequences. They argue that low-emission economies are possible without nuclear energy, despite there being no satisfactory global alternative.

Biomass and biofuels also fall somewhere in between fossil-based and zero-emission energy. Like fossil fuels, organic substances also emit CO_2 when combusted, but are widely regarded as an environment – and climate-friendly energy source, since the amount of CO_2 they emit is offset by the amount they absorb. Another school of thought says that serious thought should be given to the huge plant monocultures sown specifically for biofuel and biomass production, as these undermine the Earth's biodiversity and pose their own threat of environmental disaster. For example, it is hard to imagine the possible

Frame 1. CO_2 cycle in atmosphere (Gt)



Atmospheric CO_2 is controlled within biogeochemical cycles, which maintain stable levels of carbon in water, soil, air and living matter. At present, the carbon content of our atmosphere is about 824 Gt. In 2007, human-related (anthropogenic) carbon emissions were estimated at 9.2 Gt, with 7.7 Gt (28.5 Gt of CO_2) attributable to fossil fuel combustion, and 1.5 Gt to land cover changes (forest cover reduction, agriculture, etc.).

Source based on World Development Report, Development and Climate Change, Washington 2009, World Bank.

2 Nuclear energy features in each of the scenarios for the energy sector prepared by the International Energy Agency (OECD), with the demand for nuclear power at its highest level in the scenario most favourable to climate protection (Scenario 450).

effects of an aggressive disease affecting oil palm crops, extensively planted for biofuel production following the clearance of natural jungle in countries such as Indonesia. Another important consideration are fluctuations in food prices caused by sudden changes in demand for certain biomaterials, which are in turn attributable to regulatory measures supporting biomass and biofuel consumption. Moreover, the emission balance should take account of the release of greenhouse gases triggered by land-use shifts, which is very common when plants are grown for the purposes of energy generation (see illustration on Page 12).

SUSTAINABLE DEVELOPMENT DILEMMAS

"Delivering policies which simultaneously address energy security, universal access to affordable energy services, and environmentally-sensitive production and use of energy is one of the most formidable challenges facing governments – indeed some might argue that it is the most formidable, or even the most important"[3].

While the concept of sustainable energy[4] suggests that power generation technology should be assessed against three equally important criteria – energy security, emission levels and environmental interference, and the cost of energy as a factor in its availability to households – for several decades now its evaluation has unfortunately been dominated by just one of them. Energy sources and technologies have been classified as being either environmentally-friendly or harmful to the climate and the natural world, as if this was the only concern. Perhaps it shouldn't surprise us, given that civilisations have risen and fallen, one after another, entirely indifferent to their exploitation of environmental resources. A classic example is the Easter Islands, where the clear cutting of trees led to the collapse of its original civilisation. In Europe too, at the dawn of the Industrial Revolution, triggered and accelerated by massive consumption of coal and then crude oil, nobody was aware of the long-term effects that large-scale industry would have on the environment and climate. Over a hundred years passed before people woke up, at first in developed, democratic countries, to the severity of the problem. 1968 saw the founding of the Club of Rome, the first think-tank for politicians and businessmen dealing with global problems, including environmental threats. *The Limits to Growth*, a 1972 report prepared for the Club of Rome, was the first to acknowledge the threat of global environmental crisis and provided an inspiration to seek sustainable development models. This shift in thinking was largely prompted by the oil crises of the 1970s and 1980s, which redefined the concept of energy security to establish a stronger link between energy consumption and domestic energy sources. The call to reduce dependence on energy imports resulted in a search for technologies that could be used with domestic sources. On the back of these changes, Western European countries not only intensified their efforts to find domestic gas and oil deposits, but also began to develop nuclear power and solar and wind generation technologies.

Hardly any issue in the contemporary world has as many different shades and implications as energy generation. 3. Undoubtedly, the environment is one of the key issues in any discussion of the energy mix of the future (and rightly so), but in keeping with the underlying principles of sustainable energy and development, it should be neither its dominant theme, nor its only theme. After all, the key principle of environmental protection and sustainable development is a comprehensive, holistic world view. In this concept, all aspects of life and the world are interrelated, and seemingly separate problems are actually connected in a fine network of interdependencies. And yet green energy, frequently idealised, simplified and presented in a binary opposition to 'dirty and harmful' fossil fuels or 'dangerous' nuclear energy, has a large group of advocates, many of whom are oblivious to the complexity of the contemporary energy market and the growing number of new technologies designed to reduce emissions from energy production and conversion, as well as costs (and also in social terms).

3 *World Energy Trilemma. Time to get real – the case for sustainable energy policy. London*, 2012, World Energy Council, p. 4.
4 The concept of sustainable energy is based on the idea of sustainable development, which was introduced in the UN's 1987 Brundtland Report and defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (*Our Common Future.* Oxford 1987, Oxford University Press, ch. 2, par. 1.).

The environment is one of the key issues in any discussion of the energy mix of the future (and rightly so), but in keeping with the underlying principles of sustainable energy and development, it should be neither its dominant theme, nor its only theme. After all, the key principle of environmental protection and sustainable development is a comprehensive, holistic world view. In this concept, all aspects of life and the world are interrelated, and seemingly separate problems are actually connected in a fine network of interdependencies. Binary logic and a perspective focused exclusively on the environment impede any reasonable discussion on the subject.

TECHNOLOGY ENABLES THE USE OF ENERGY

Energy is a form of nature. The technology to convert primary energy into energy carriers is an undeniable achievement of human civilisation, without which primary energy sources would be of little value to us. For example, the world's immense oil reserves, which fuelled the gigantic civilizational leaps of the 20th century, were useless before the invention of the petrol engine. Today though, we know how to effectively harness the energy contained in the remains of the primordial organisms that make up fossil fuels. We are also experimenting with technologies that rely on the natural ability of plants, algae and bacteria to store energy, which can then be recovered by burning them. With various other experimental technologies, we are gradually making more and more effective use of primary energy in its pure forms as air movement, ocean waves and solar radiation. But since we have yet to learn how to store such energy, it must be used in real time, from wherever we can derive it and to wherever we can send it. One major obstacle to the use of such energy is its unpredictable supply – the wind does not always blow, the sun does not always shine. This is a serious drawback, currently mitigated by supplies of traditional energy, produced from fossil fuels. This, however, involves additional costs on building and maintaining reserve capacities, to be utilised as needed.

Looking at today's energy mix through the prism of mankind's achievements in energy use, we can see various energy conversion technologies at work. Mature technologies based on primary energy stored by nature co-exist with new, experimental solutions relying on pure forms of energy. Of the little we know about the *energy mix* of the future, we do know that it will include the use of currently unknown technologies. In this respect, we stand in a similar place as to where we were a hundred years ago – no one then could have imagined that nuclear power would be a key building block in the next century's energy mix – or even as recently as a decade ago, before the upcoming shale gas boom had announced itself. New technologies are being developed across all segments of the energy sector, from production and storage, transport and transmission, to the use of energy in the economy and in everyday life. We can and should speculate about technological development directions in the energy sector. For instance, it is very likely that revolutionary, game-changing innovations will be developed with respect to the use of solar energy and energy storage, but it is impossible to predict when or how this will happen[5].

It should be remembered that all technology, both long-established and at the conceptual or experimental stage, does to some extent affect the natural environment and climate. The impact of mature technologies, used

5 One revolutionary, world-changing technology in the energy sector was invented not where it was most expected (in energy storage), but in our ability to access the energy stored by nature. With the invention of fracking we have gained the ability to extract energy stored in certain fossil fuels directly from the source rock.

for a long time, are plain to see, but the effects of new and experimental technologies are not as immediately evident, due mainly to the small scale of their application and lack of sufficient knowledge[6]. For this reason, we must not rush to choose one above the other, or exclude any of them solely on the basis of current knowledge. As with any other technology, constant research and development is conducted on energy extraction and generation, and so their environmental impact can also change. For example, SO_2 and dust emissions from the burning of coal are much lower now than they were twenty years ago, but we must continue to keep a close eye on this process, while also paying attention to costs. While being central to the development of modern civilisation, energy is also a social good, whose price should not be a barrier to access for those with the lowest incomes.

GLOBAL ENERGY PRICES AND LOCALISED ACQUISITION COSTS

The price of energy has an important social dimension as it determines energy affordability and, consequently, the extent of energy poverty and exclusion[7]. Energy prices are a function of costs along the entire value chain – from the source of the primary energy to the end user.

Because 80% of all energy consumed globally comes from fossil fuels, it is their price that determines energy prices. Fossil fuel prices are quoted in an auction system on the international commodity markets that form the global market. Due to arbitrage between regional markets, price differences for the same fuel (crude oil, coal, gas) in different parts of the globe result from transport and distribution costs. In the case of energy carriers, an additional factor behind the differences in their prices lies in the taxes and surcharges imposed on quoted prices by national and regional institutions. It can thus be said that although energy prices are driven by global factors, they can be – and are – modified by national and regional laws.

An important component of the regulatory framework affecting energy prices to end users are regulations on protection of the environment and climate. Stricter environmental standards imposed on energy producers and consumers in a given area lead to higher energy prices for end users[8]. Therefore, when determining the value of primary energy sources and their extraction technologies based on the extent of their impact on the environment and climate, one should take into account the effect of the cost of environmental and climate protection on the price of energy supplied to end users, including households.

> Energy is a social good, whose price should not be a barrier to access for those with the lowest incomes.

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6 We have yet to understand the environmental and climatic impact of biomass and biofuels production. What is the total emission balance for these energy sources? What are the consequences of crop monoculture for the ecosphere and biodiversity? We have also yet to understand the environmental and climatic impact of manufacturing and installing wind farms and solar panels, especially in large groups.

7 7 Social equality in access to energy is one of the three main energy sustainability criteria applied by the World Energy Council. The other criteria are energy security and reduction of environmental and climatic impact. See *Policies for the future 2011. Assessment of country energy and climate policies*, http://www.worldenergy.org/documents/wec_2011_assessment_of_energy_and_climate_policies.pdf [access date: August 30th 2013].

8 Even if the state subsidises energy prices for end users, the cost of such subsidies ultimately comes back to them in the form of higher taxes.

The climate policy dilemma is the prisoner's dilemma[9]

In the global economy and energy sector, the economic and social consequences of the choices we make are not determined solely by our decisions, they are also affected by the actions of others. And as climate protection goals have been built into the economic policy, these relationships have strengthened. Global warming, which people are trying hard to counteract, is a global issue, as is the need to lower greenhouse gas emissions, and it is only when the world's largest economies join forces that global goals for the reduction of greenhouse gases can be achieved.

In our world of globalisation, even the most affluent economies cannot afford to tolerate excessive energy prices, whether or not its citizens mind paying them, as they pose a threat to their competitive position and growth compared with other countries. The rules of economics are unrelenting. The prices of globally traded products, as well as the energy prices set on international markets, are similar for everyone – the differences lie in the energy and labour costs per product unit. Countries where production costs are pushed up by stricter limits on greenhouse gas emissions and support for costly technologies automatically become less competitive. This translates into slower economic growth, less new jobs and a widening of the gap separating them from more competitive economies[10].

The history of oil crises has taught us that high fuel prices (both actual and expected) are a key factor in speeding technological advances in the energy sector. High prices lead to improvements in energy efficiency, making investment in technologies that save energy and use supplies more effectively worthwhile. Having learnt this lesson, Europe decided to introduce a trading scheme for carbon dioxide emissions (the EU ETS), which affects the energy market for fossil fuels. Concurrently, a system of subsidies for low – or zero – emission energy sources has been adopted on the assumption that once widespread, they would become commercially viable, despite having initially required substantial subsidies.

Technological progress has not left the fossil fuel sector behind, though. It is thanks to new technologies that we now have a better understanding and greater availability of fossil fuel resources[11], and one of the effects of their increased supply is the long-term stability of real prices. At the same time, production technologies are becoming less and less environmentally intrusive, whilst combustion techniques become more energy-efficient and less emission-intensive. For more than ten years now, new technologies deployed in North America have been used to extract natural gas and crude oil directly from the source rock. We are now witnessing an energy revolution, which has already resulted in the decoupling of natural gas and crude oil prices and a considerable decrease in gas prices, which in turn has triggered rapid development of the gas-fuelled energy sector. The effects of this energy revolution are already being felt in Europe, where the commercial viability of subsidised technologies is lengthening the period in which subsidies need to be provided. In manufacturing terms, this tends to increase the cost of energy consumption, as European products are losing their competitive edge on world markets to US products, manufactured with the use of energy several times cheaper than is available in the European Union. This gap is far from insignificant. In some industries, energy use counts for as much as 70% of total production costs.

9 The prisoner's dilemma – a problem in game theory. It is based on a non-zero-sum game involving two individuals where each player can get a reward by betraying the other, but both stand to lose if both betray.

10 Cooperation on reducing water and air pollution, proper waste management, limiting energy consumption and other crucial issues fits in with the theory of the prisoner's dilemma as a strategy which demands mutual effort. It is much easier and more convenient to refrain from action and take advantage of the efforts of others in preserving a clean environment – in other words, to employ a strategy of betrayal. But if everyone were to betray and pollute the environment, the world would soon become an oppressive place to live in.

11 These include new deep-water drilling technologies, as well as production of hydrocarbons from unconventional deposits.

The energy market is changing faster than administrative decisions can be made. At the time when the programme of subsidies for selected RES technologies was adopted, there were forecasts of a strong rise in energy prices. However, the outbreak of the gas revolution in the US had a delaying effect on that growth, as a result of which energy from renewable resources has yet to become profitable and so still requires subsidising.

WHAT ARE THE DISTINCTIVE FEATURES OF RENEWABLE ENERGY? CLASSIFICATION OF ENERGY SOURCES

The first two laws of thermodynamics claim that you cannot 'create' or 'destroy' energy. Instead, we consume the energy that already exists in nature by employing different technologies to extract it and convert it into usable forms. The constant advance of technology, sometimes gradual and sometimes in big leaps, allows us to expand the range of primary energy sources we are able to use. To a large extent, the history of civilisation consists of watersheds in the conversion and use of energy which, to put it simply, have allowed humans to enhance their muscle power. Man first learned how to make fire and utilise the energy produced from burning wood and organic substances, then reached out for coal, crude oil and gas, later learning how to release energy from radioactive disintegration. Now, we are experimenting with nuclear fusion, developing increasingly advanced technologies to tap into solar and wind power, and have harnessed nature's ability to store energy in plants and simple organisms for recovery by combustion.

Non-renewable energy sources are those in which energy has been stored by nature, such as hard coal, crude oil and natural gas. Their energy is then released by technological means of their production and subsequent combustion. The techniques behind the process have been known for centuries and their key principle (combustion) has not changed, so they are no longer in the industry's spotlight. A more crucial discovery in their history was that hard coal, crude oil and natural gas (in liquefied form) can be stored after extraction and transported over long distances. Consequently, these fuels can be treated just like any other commodities. While we still do not know the full size of the fossil fuel reserves remaining underground and how much can be extracted, one thing is certain – they are depletable[12].

With respect to renewable energy sources, the literature and statistics used for the purposes of research and analysis rely on the traditional classification, i.e. that Renewable Energy Sources are only those that derive primary energy from its naturally occurring forms, such as the wind, tides, rain, sunlight and geothermal heat[13].

Man-made sources designed to recover energy by combustion of plants and waste, either as solids or after their conversion into gaseous or liquid fuels, resemble non-renewable sources. This is because although we first utilise the power of nature to store energy, for example in plants, we then recover the energy either by direct combustion of the plants (biomass) or by combustion of a converted product (as with biofuel and biogas). Because – just like hard coal, natural gas and crude oil – biomass, biofuel and biogas are still natural energy sources, and our technological intervention only streamlines the storage process. In the traditional approach these sources are classified into a separate group of 'other' energy sources.

12 It should be borne in mind that just because a given resource is finite does not automatically mean that it will become totally depleted at some point, creating upheaval in the history of human civilisation. After all, the Stone Age did not come to an end because people ran out of stone. The current economic globalisation and high prices of certain commodities stimulate the development of alternative technologies and suppress the growth of global demand. We could easily imagine a world where there are still recoverable crude oil reserves that no longer play any significant role in energy production.

13 This is the classification applied by the leading think-tank researching the global energy sector, IHS CERA (Cambridge Energy Research Associates).

Similarly, nuclear energy (produced from enriched minerals) and water power generated by hydropower plants, assuming they have an efficiency of 100%, are also classified as separate energy sources. Neither source of energy is found in nature – they are instead a product of human ingenuity, and only part of the energy previously stored in a given source through man's endeavour can be released. As such, their renewable nature could be compared to the replacement of products, and has little to do with naturally replenishing forms of energy.

In the energy statistics compiled to inform economic policy, a broad classification of renewable energy sources is applied, whereby products of business activities used as feedstocks for energy systems are also considered separate sources of renewable energy. According to the International Energy Agency (IEA)[14], hydropower generated after water damming, as well as energy from biomass and waste produced by combustion of plant and waste solids, or after their conversion into gaseous or liquid fuels, are classified as renewable sources. Interestingly, this classification groups wind, solar and geothermal energy under the heading: Other Renewable [Energy]. Moreover, nuclear energy is also classified as a separate source of primary energy, not included in the renewable category.

The Polish classification of primary energy sources corresponds to the classification adopted by the International Energy Agency. Under the Polish Energy Law, renewable energy sources include wind power, sunlight, geothermal heat, as well as the energy of waves, currents and tides, river gradients, biomass, landfill biogas and biogas generated during sewage discharge or treatment, and decomposition of stored plant or animal remains[15].

Table 2. Classification of primary energy sources and their share in global energy consumption in 2010

Primary energy sources	% share in global energy in 2010	Classification IHS CERA	Classification IEA
Crude oil Hard coal Natural gas	32 % 27 % 22 %	Non-renewable energy	Non-renewable energy
Sun Geothermal heat Oceans	1 %	Renewable energy	Other renewable energy
Hydropower Biomass and waste	2 % 10 %	Other sources	Other renewable energy
Nuclear	6 %	Nuclear	Nuclear

Source: IHS CERA, MAE WEO 2007

14 *World Energy Outlook 2012*, IEA, November 2012, Definitions, pp. 643-648
15 Polish Energy Law of April 10th 1997 (consolidated text: Dz.U.2006.89.625), http://isap.sejm.gov.pl/DetailsServlet?id=WDU20060890625 [access date: 30/08/2013].

ARE SNAILS FISH? CLASSIFICATION DOES MATTER IN THE ECONOMY

Given the meaningful differences in the interpretation of what is and what is not a primary energy source, it might be worth asking the question, can our perception of and classification of primary energy sources affect the energy mix of the future, being the end toward which the existing regulations are being modified?

We should bear in mind that the energy mix of the future will be influenced by the relations between the expected long-term unit costs of energy production from a variety of sources. In the traditional commodity-based model of the energy sector, energy production costs in different countries are determined by global commodities prices, which gives countries rich in natural resources a potential competitive edge. Some have leveraged that advantage to accelerate their own growth, while others have not. The new model of the energy sector is oriented more towards innovative technologies, which are still in the development phase and rely on state support. In this model, the extent of state support in a given country is a considerable, and increasingly important factor in the cost of energy because it is the governments that decide on the degree of public assistance, and in the new model they have a much stronger influence over the competitiveness of their economies than in the traditional model.

In the innovative model of the energy sector, the manner in which the state supports new technologies is a fundamental issue, and we can distinguish two different approaches to industrial policy. The underlying assumption of both is that the energy sector is one of strategic importance, which must be developed under the state's control. Investments in the sector are extremely costly and have far-reaching consequences for energy security as well as the natural environment and climate, and thus it is crucial that the right decisions are made. This vests governments with a mandate to influence the energy sector's development. The mandate can be performed literally: the government makes decisions as to which of the sector's technologies to develop and which to declare obsolete, and devises relevant policy instruments to encourage business to pursue its vision (policy). But the government can also control the energy sector indirectly – by prioritising energy security as well as climatic and environmental protection issues, the state signposts the direction of the energy sector's development and designs technologically-neutral policy instruments. In this approach, the task of searching for and selecting energy production technologies is left to business, and this can help minimise the cost of implementing the government's priorities.

In the technologically-neutral approach to industrial policy, the division of primary energy sources into renewable and non-renewable has no effect on the technology employed and is only statistically significant. However, if the state chooses to support specific technologies with the help of industrial policy instruments, the situation is completely different. Of key importance then is into which group a given technology is classified. If it falls into a group of technologies supported by the politicians, it will be developed with the aid of public funding, and if it doesn't, it may be developed on market terms (within a technologically-neutral industrial policy).

ENERGY PRICING MECHANISMS

More than 80% of the world's energy demand is met by the three main fossil fuels: crude oil, natural gas and coal. The flow of energy purchase and sale contracts between exchanges has led to the globalisation of commodity markets and prices, a phenomenon best exemplified by crude oil trading, the most liquid of these markets.

Several factors have contributed to the globalisation of the energy markets. Energy carriers, such as electricity or liquid fuels, are a homogeneous commodity that meet the varying requirements of specific energy consumer units (for instance, electrical appliances, engines and motors). But end users, being unable to distinguish between the products offered by individual suppliers, simply opt for those with the lowest price. Although the same energy consumer unit cannot be fed different types of fuel (for instance, a diesel engine won't run on petrol), it is possible to replace the unit itself with something more efficient that satisfies the same needs.[16] On an individual level, replacements (which must also account for the related capital cost) are made every few years. On a global scale, this process is happening all the time as a result of permanent shifts in relative prices, largely driven by technological advancement in the energy sector on both the supply and demand side of the market. In the latter, new types of energy consumer units affording greater fuel flexibility are gradually appearing on the market, with electric motors competing with combustion engines in passenger transport and LNG engines vying with diesel engines in heavy transport. On the supply side, the invention of new technologies for energy conversion, from both renewable and non-renewable sources, is exerting a lasting influence over price relations.

Thanks to the increasing interchangeability of primary energy sources and the development of raw material and commodity markets, we are witnessing the birth of a global energy sector where a shift in one segment or geographical region has the power to affect energy prices across other segments or regions.

New technology effect

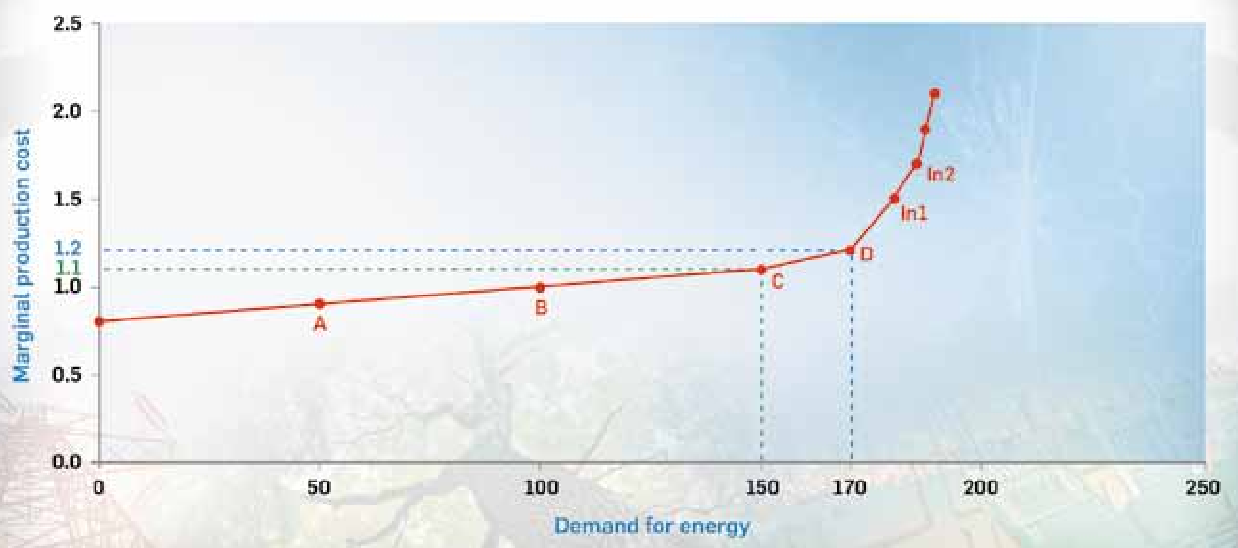
It wouldn't be a gross oversimplification to compare the energy sector to a global factory, where the primary energy extracted from crude oil, hard coal, natural gas and nuclear power is converted by a variety of means into energy carriers (liquid fuels, electric power or heat) in various parts of the world. This global factory is made up of many independent facilities, which differ in their technologies and generation costs. New, experimental processes exist side-by-side with mature, cost-efficient ones, battling with alternative solutions for supremacy in the global marketplace. And in either the near – or the long-term future, some of these will prove economically viable and become a fixture in the global energy mix. In the generation of any type of energy, the technology that produces a unit of energy at the lowest cost is always the first choice (Technology A). As cheap energy sources become less able to meet existing demand, the market price of energy rises, justifying its procurement from more expensive sources (Technologies B, C). This pattern repeats itself until the next most expensive method crashes against the demand-side barrier. If the global energy demand equals 150 units, Technology C is the marginal generation method (see Figure 1). The global energy price (the same for everyone) is determined by the generation costs of the most expensive producer, who is still finding demand for its energy and who, while relying on Technology C in our example, achieves returns that pay back invested capital and bring satisfactory profit at a price of 1.1[17]. Producers with technologies that create lower generation costs (left of C on the curve) achieve greater profits, while producers using technologies whose costs exceed that of the marginal technology (right of C on the curve) are unable to sell their energy and are priced out of the market. If global energy demand rises (as was the case in 2004, when China joined the WTO) by, say, 20 units, then a producer using the most expensive technology (D) to produce energy at a unit cost of 1.2 will be able secure a place on the market. But potentially innovative experimental technologies (In1, In2) operate at a loss when the price of energy is 1.2, due to excessive generation costs.

The energy pricing mechanism outlined above explains what happens when a revolutionary new generation technology enters the market (Technology In1). To succeed, this new technology must be cheaper than the marginal technology, based on which the price of energy is set (prior to the emergence of the new process, this was Technology D). As a cheaper solution, Technology In1 settles on a cost curve below the marginal technology, pushing more expensive solutions to the right.

16 The diesel engine owes its popularity with passenger transport to its higher fuel efficiency compared with petrol engines, and hence lower running costs.

17 In the energy industry, both the raw material and finished product (energy) are commodities. Therefore, the term 'spread' is often used to describe the difference between the price of the raw material and the price of the energy (as a product) derived from it. Thus defined, the spread covers all other operating and capital costs (profit).

Figure 1. Cost curve in the global energy sector



As a result, global energy demand (170) is then covered at a price of 1.1 (compare with the situation illustrated by Figure 1). With increased generation costs, Technology D is now running at a loss and will be withdrawn[18].

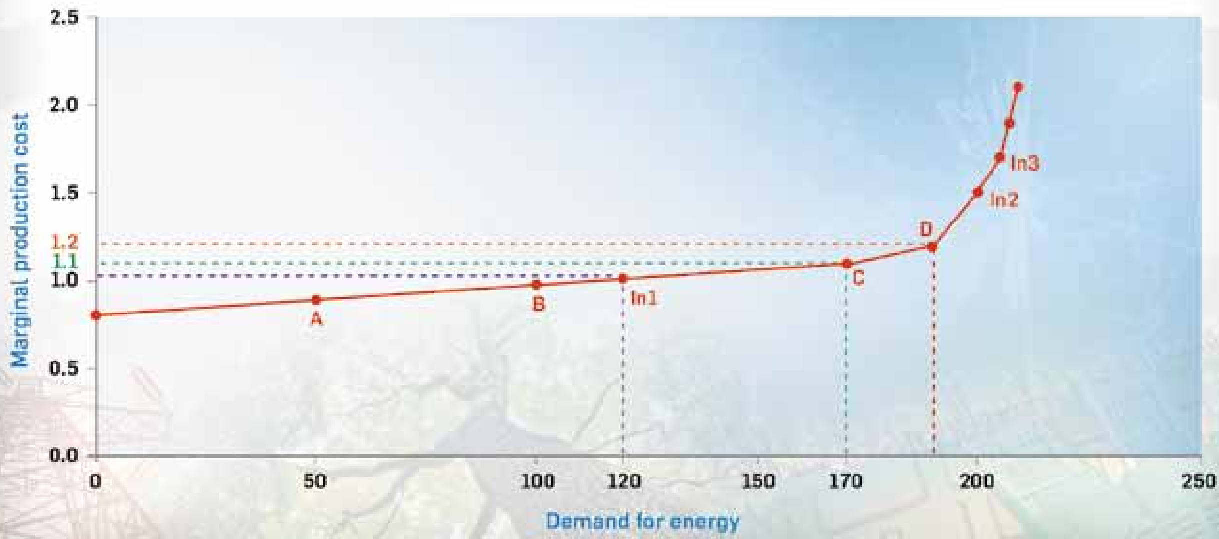
What happens if the cost of energy produced by a new technology exceeds its market price (as is the case with Technologies In2 and In3)? The new technology (new producer) could supply energy to the market at a loss (as customers are not inclined to pay more than the market price) for a limited period of time, over which the generation costs would either fall below the market price (the In1 Technology scenario would materialise) or the technology would go out of business (after the available financial aid has been used up). Subsidising generation technologies without appropriate exit strategies is detrimental from both the economic and social points of view, raising the unit price of energy for the final consumer, which ultimately always reflects the marginal generation costs regardless of the subsidy scheme in place[19].

Revolutionary innovations

One feature of revolutionary innovations in the power sector is that they ultimately lead to lower costs of energy used, and thus the technologies employing such innovations are the winners in the price competition (Figure 2)[20]. From a historical perspective, one can see that the revolutionary innovations are those that have made new fossil fuel resources available with new means of discovering deposits, by launching production from

18 Supplies of cheaper energy stimulate demand. As a result, even if the price ultimately remains unchanged, global energy consumption will rise.
19 The price of energy includes the cost of lost opportunities to use cheaper energy. Subsidised technology drives other technologies, which have already delivered economically viable energy, out of the market.
20 Energy prices do not always instantly fall, but we can see that there is always a decline in future price levels relative to those expected before the innovation.

Figure 2. Innovative technology effect – shift on the cost curve



previously discovered fields that were unworkable with the technology of the time, and that have brought about strong improvements in energy efficiency[21].

Despite increasing modernisation, coal-fired power plants still rely on technology that was revolutionary more than a hundred years ago[22], as do oil refineries, which despite ever more advanced upgrades, are also producing fuels based on more than a century-old technology[23]. But for a decade now, new technologies have been deployed in North America that extract natural gas and crude oil directly from the source rock, and the unexpected increase in global recoverable reserves of natural gas that followed their introduction marked the beginning of a 'golden age of gas'[24].

Meanwhile, renewable energy technologies are still waiting for their time. Wind turbines and solar panels, as well as fields of biofuel crops, are becoming a more and more common sight, and while the development of these technologies has boomed over the last two decades, the energy they produce is still not competitive and

21 For instance, one consequence of the oil crisis of the 1970s was a permanent reduction in demand thanks to advancements in oil efficiency (for example, more efficient, smaller-capacity car engines).

22 The world's first power plant was built in New York in 1882, and in the same year electricity was first transmitted – over a distance of 57 kilometres. Further power plants were opened in 1883, in Milan and St. Petersburg, and in 1884 in Berlin. In Poland, the first (steam-powered) power stations, which supplied mechanical energy to machine-building and textile plants as well as steelworks and mines, were constructed in the 19th century. The first municipal power plant in the Kingdom of Poland was built in Radom in 1900, followed by another one in Warsaw in 1902 (from Zbigniew Bicki, *Stan elektroenergetyki polskiej i podstawowe problemy rozwojowe* [The Condition of the Polish Power Industry and Principal Development Problems], Warsaw, PSE SA).

23 The world's oldest oil well is located in Poland, in the village of Siary near Gorlice. Dug manually in 1852, this well, founded by Stanisław Jabłonowski, is the birthplace of crude oil extraction. The first oil mine in Poland was then established in 1854 on the initiative of Ignacy Łukasiewicz, in Bóbrka near Krosno, with the first Polish oil distillation facility opened in Ulaszowice near Jasło in 1856. One of the world's oldest refineries, dating back to 1884, is situated in Gorlice.

24 A term coined by the International Energy Agency in the *World Energy Outlook 2012* report, IEA, November 2012.

requires substantial public subsidies. Other renewable technologies (marine energy projects, next generation biofuels) are still in the testing or conceptual phase.

But the US-developed technologies recovering oil and gas directly from the source rock are a good example of the fact that revolutionary innovations (both environmentally friendly and cost-efficient relative to other solutions), can still emerge in places other than where they are intensively pursued and heavily subsidised.

Our knowledge of technologies that will shape the energy sector's future is limited, so much so that perhaps we cannot even imagine them for now. So in order to drive development, it is very important that we keep searching for new, game-changing technologies for the energy sector, with innovation financing solutions playing a vital role in this process.

The relationship between gas prices and the costs of experimental RES technologies

There is no way to plan future technologies before they actually arrive – planning can, in fact, only occur with regard to the development of existing solutions. While current RES technologies (wind turbines, solar panels, biomass and biofuel) have yet to become economically viable, the government seems to have concluded that once huge sums are injected into their development, they will eventually become more efficient, with a resulting drop in the cost of energy generation. This process is illustrated by the downward sloping curve of anticipated RES energy prices (learning curve).

Renewable power competes with energy sourced from fossil fuels, especially hard coal, which is emission-intensive and environmentally onerous. Given that coal prices are linked to 'the mother of all energy prices',

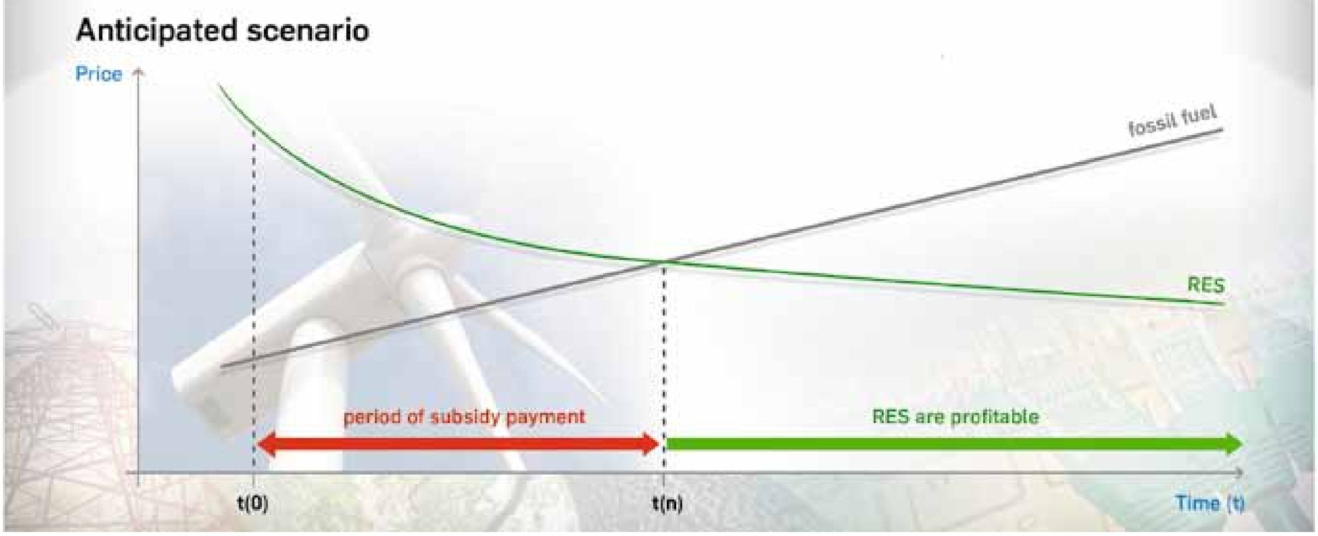
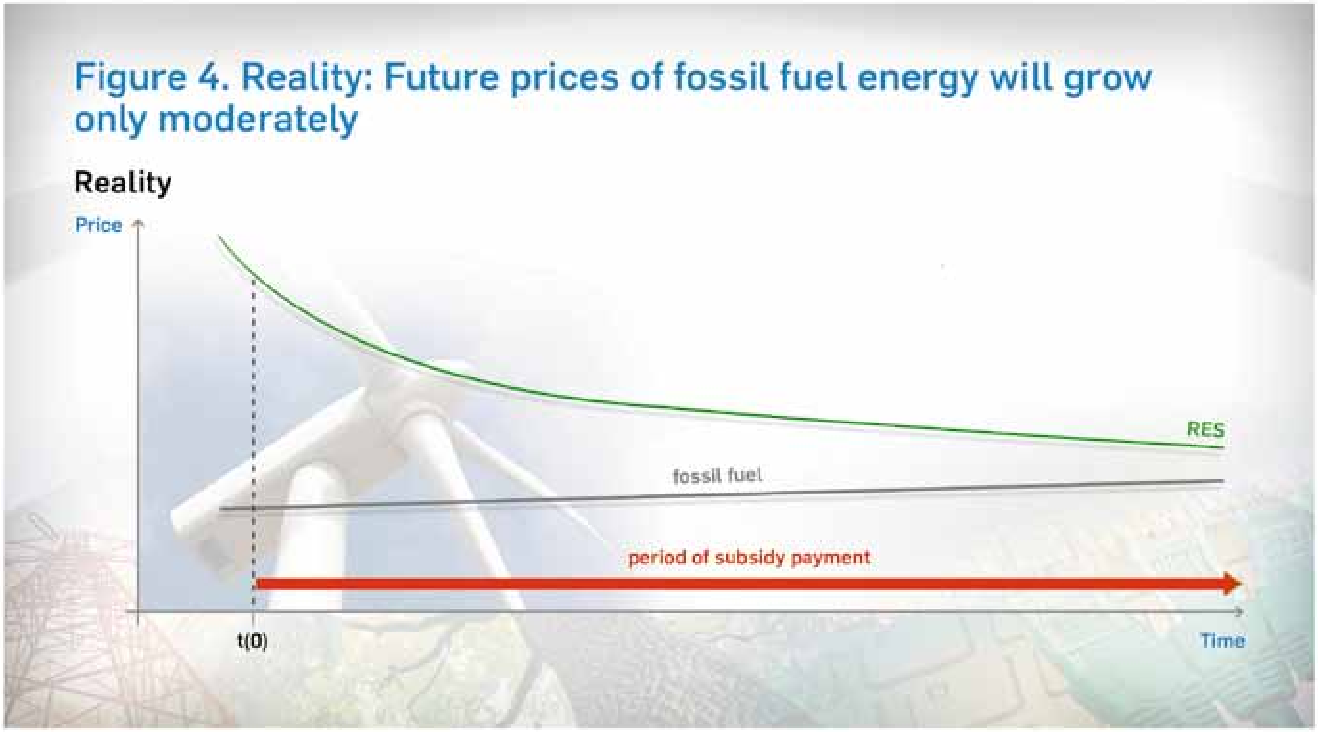


Figure 3. Anticipated scenario of RES energy price changes relative to fossil fuel energy prices at the time when the decision was made to subsidise RES technology



crude oil, and that crude oil reserves are depletable, the scenario anticipated at the time of the subsidies' creation was that fossil fuel electricity prices would be steadily rising, with further upward pressure from the imposition of a carbon emissions tax (mainly on coal-based power, as gas was considered a luxury fuel then). Accordingly, the subsidies on RES were to be a transitional measure, as the cost of renewable power was expected to eventually drop below fossil fuels' energy bills.

However, not all scenarios can be foreseen. The steep rise in oil prices since China's accession to the WTO, coupled with concerns over energy security in some countries with abundant oil and gas resources, intensified the search for hydrocarbons and the development of more sophisticated production technology. And thanks to the technological advances made in the extraction of hydrocarbons from unconventional reservoirs, the remaining fossil fuel reserves are now practically inexhaustible for the foreseeable future, with the result that crude oil and gas prices should decline and then flatten in the long term.

But this unexpected twist in the price trajectory of fossil fuel energy (flatness instead of a sharp rise) led to a change in the unit cost of RES energy relative to other energy prices, and the planned exit mechanism from the subsidy scheme was no longer feasible. Consequently, subsidies for selected RES technologies may prove to be an incessant burden on the taxpayer.

SUSTAINABLE ENERGY CRITERIA AND THE FIXED REGULATORY FRAMEWORK

The idea of sustainable energy postulates that energy policy priorities, such as the security of supplies and mitigation of environmental and climatic impact, be supported by a carefully selected set of measures that will prompt the private sector to search for and implement technologies meeting energy needs at the lowest possible cost, in alignment with social interest.

Each modern-day technology employed by the energy industry helps fulfil these objectives to a different degree. But given the current level of knowledge, it is impossible

Regulatory risk – the risk of changes to the legal business environment. Given the lack of available instruments that would insure business against the consequences of such changes, their estimated cost is fully charged to the costs of the projects exposed to the regulatory risk, which then undercuts their profitability.

to meet them all in full. For instance, it is impossible to have secure energy, derived chiefly from domestic sources, and demand that the cost of energy generation be kept at a minimum, when only the most environmentally friendly, zero-emission technologies are permitted for use. In Poland, coal-fired generation has fulfilled the objectives of economic viability and supply security, but fails to sufficiently meet those related to environment and climate protection. By contrast, Carbon Capture and Storage (CCS) facilities are in line with climate protection goals and do not compromise supply security, but are still unprofitable and need to be subsidised. This is also true of existing RES technologies, like wind farms and solar panels, that don't emit greenhouse gas and are thus less harmful climatically, while also generating power domestically – as long as the wind blows or the sun shines, they meet the energy security objective. For all that, they remain fairly expensive compared to other sources (such as coal or natural gas) which rules out their economic viability, and all the more so because of the need to ensure back-up capacities to support the grid in case of prolonged spells of cloudy weather or a lack of wind. In Europe, RES facilities owe their existence almost entirely to state-backed subsidies.

A fixed energy policy framework is a set of regulations and measures designed to steer the private sector's interest, either towards existing technologies or to the search for novel solutions, while avoiding situations where risks inherent in business choices would be unevenly distributed. Risk is factored into the costs of every business venture, but grants or subsidies supporting specific technologies at the expense of others lower the cost of their implementation, thus lowering the attendant risk. For this reason, a subsidised technology segment attracts much more business activity. However, since business is unable to properly assess the regulatory risk associated with the state's withdrawal of its subsidies, it should factor that risk into the cost of each new venture. This, of course, has the effect of driving up the cost of deploying new technology. As the energy sector transition is accelerated by public funds being funnelled into specific technologies (artificial reduction of business risk), this can in fact be a source of regulatory risk, which carries a much higher cost in social terms.

Climate protection

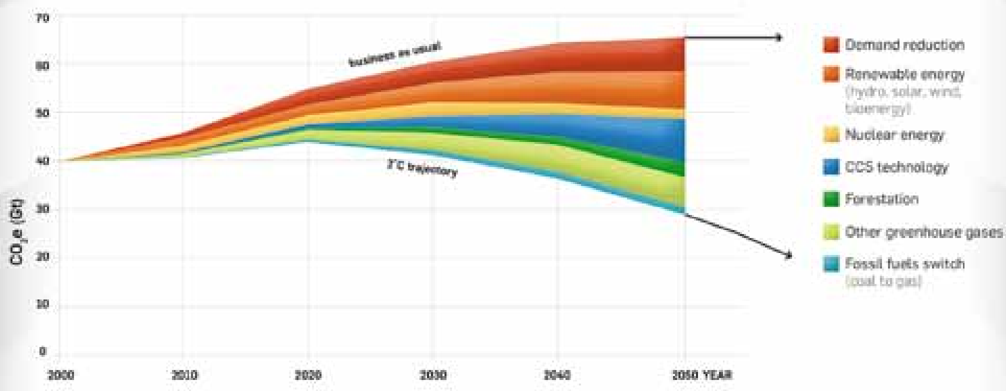
Historically, renewable energy sources have been closely linked to the issue of national energy security, or the need to ensure the continuity of energy supplies. Initially, concerns were focused on the depletion of domestic coal and global crude oil resources, while the oil crises of the 1970s and 1980s demonstrated that the continuity of energy imports was also at risk.

The search for technologies that could produce energy from domestic sources other than fossil fuels was first oriented toward inexhaustible and renewable sources. Energy efficiency also gained in importance as a development goal, following the incremental rise in crude oil and energy prices in the wake of the oil crises. At first, the energy sector sought to improve efficiency at the micro level (fuel-efficient car engines, efficient consumer units), but gradually became aware of the opportunities for efficiency improvements on a macro level (intelligent power grids, electricity storage, electrification of transport).

Frame 2. Where are the biggest opportunities for emissions reductions?

According to reports and research results, a range of measures is required to reduce the emissions of CO_2e*, so that the temperature increase stabilises at 2°C above the pre-industrial level.

Range of measures aimed at reducing emissions of CO_2e

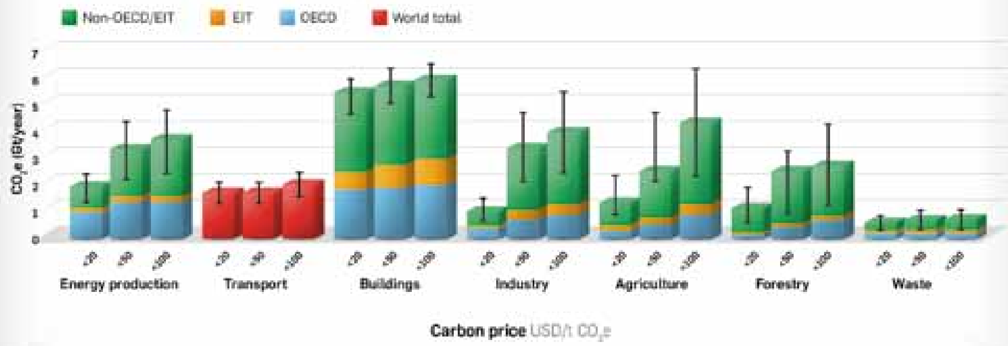


Source: World Development Report, Washington 2009, World Bank

*CO_2e – GHG emissions as equivalent of carbon dioxide emissions

The graph above shows the share, over time, of key measures undertaken to reduce emissions of greenhouse gases (GHG), and lower the intensity of emissions in the case of business as usual to achieve a stabilised temperature of 2°C above the pre-industrial level.
Interestingly, by 2050 the scale of the effects of demand reduction, the introduction of renewable energy and the use of Carbon Capture and Storage (CCS) technology will all be similar. The contribution of CCS technology to reducing greenhouse gas emissions will increase significantly in the years 2030-2050 (it is currently regarded as being crucial to the achievement of the emissions reduction scenario), with an important contribution from the reduction of greenhouse gases (except for CO2) emitted primarily by the agricultural sector.

Potential emission reduction CO_2e



* Black vertical lines show the reach of the global potential for emissions reduction

Source: World Development Report, Washington 2009, World Bank

The above graph shows the potential for reduction of greenhouse gas emissions in different country groups and different industries, by CO2e emissions price. Buildings have the greatest potential for emissions reduction, where the greatest reductions can be achieved by savings in energy demand or, in other words, by proper insulation of buildings and use of intelligent heating/cooling systems. Of the country groups shown in the graph, it is the developing countries that have the greatest potential for emissions reductions. The sensitivity of the potential for emissions reductions to increases in the price of CO2e emissions is also illustrated. An increase from the near-current level of USD 20 to USD 50 per tonne of CO2 would cause strong reactions in all except the transport sector. A further rise from USD 50 to USD 100 per tonne, would result in considerable emissions reductions from agriculture and forestry, surpassing the total reductions in other sectors of the economy.

The 1992 Earth Summit in Rio de Janeiro (the United Nations Conference on Environment and Development) and the signing of a declaration on a code for man's conduct towards the environment and climate defined a new direction for the energy sector's development: the reduction of greenhouse gas emissions, particularly carbon dioxide.

Once the climate priority was included in the energy policy, technologies aimed exclusively at reducing carbon dioxide emissions into the air were placed on the list of desirable new technologies. This has had two major consequences. One of the primary goals was to accelerate the economy's transition to low-emission energy sources. This process was already taking place spontaneously on the back of growing fossil fuel energy prices, which on the one hand stimulated improvements in energy efficiency through the development of technologies limiting the consumption of energy per unit, and on the other, increased the viability of RES technologies. An added cost was then imposed on carbon dioxide emissions, to make energy produced from fossil fuels even more expensive and accelerate the growth of RES by increasing the benefits of R&D into new energy production technologies using sources other than combustion of organic substances. However, the greatest progress to date has been brought by activities expanding the definition of technologies classified as using renewable energy sources, to include sources emitting previously-absorbed carbon dioxide. As a result, biomass was included in the list of renewable energy sources, regardless of the manner of its production, despite its significance to the final balance of carbon dioxide emissions from this source[25].

Because of the conviction that fossil fuel resources were finite and that their prices would be steadily rising, when drafting its energy and climate policy (focused on supporting selected RES technologies), the European Union underestimated the pace at which technologies for the exploration and production of conventional fuels would develop. These technologies have since yielded a several-fold increase in natural gas and crude oil reserves compared to earlier expectations, as well as significant emissions reductions with the replacement of coal by crude oil and natural gas. Unfortunately, they have also stolen the limelight from other crucial issues, such as the thermal efficiency of buildings (see graphs on previous page).

BUSINESS AND REGULATORY RISK (REGULATORY COSTS)

When exploring for new, revolutionary innovations in the energy sector, it might be a good idea to seek inspiration from the experience of the IT sector, which owes its incredibly rapid growth to the countless inventions and patents that redefined that market, led by the demands of its end consumers rather than its producers. Five years ago, Microsoft's CEO Steve Ballmer would have sneered at phones without a keyboard, while today, in response to customer demand, his company has launched the touch-screen Surface tablet. By analogy, the future energy sector will also likely be dominated by innovations created to meet consumer needs, with the use of technologies available today and those currently in the R&D stage.

The development of the R&D sector can be stimulated, but the effects of such support cannot be planned for before the market makes its choice, as no one can authoritatively declare that technology A has future potential while technology B is a dead end. In business, betting on the wrong horse can be a costly error, potentially ending in bankruptcy. But the market doesn't crash when this happens, as the void is quickly filled by another player. This is business risk. However, when bets are made by public officials, the costs of a potential bankruptcy are incomparably higher and it is often the taxpayer who is made to pay them, either directly or indirectly. This is regulatory risk. The high cost of regulatory risk also stems from the fact that government authorities are reluctant to admit to their mistakes, while also being heavily lobbied by the beneficiaries of their choices.

25 This significance lies in the fact that biomass from forest waste has a different emissions balance than biomass from specially cultivated energy crops, which must have the emissions from their soil cultivation added to the total balance.

In business, betting on the wrong horse can be a costly error, potentially ending in bankruptcy. But the market doesn't crash when this happens, as the void is quickly filled by another player. However, when bets are made by public officials, the costs of a potential bankruptcy are incomparably higher and it is often the taxpayer who is made to pay them, either directly or indirectly.

The problem with renewable energy sources today is that they could be compared to business horses, picked and bet on by way of administrative decisions. But, as it is not the role of public authorities to manage business risk, only technology that is already in place is picked, as the government hopes that this approach will reduce the risk involved. The chosen technology is then produced and implemented on a large scale, thanks to generous subsidies, and this is how **public funds petrify technologies, instead of prompting the search for new, better options. This is also just one of the reasons behind the stagnation of the EU's economy**: on the one hand, innovation is highly prioritised (in the Lisbon Agenda), and on the other, existing technologies are heavily subsidised, which hinders the inflow of capital to truly innovative companies.

THE ROLE OF THE STATE IN THE ENERGY SECTOR: COST OF SECURITY

The future of the energy sector has long been one of the hottest political issues, both in the context of national energy security and in the wider, global context of climate protection and the transition to a low-emission economy. In order to meet these challenges, there is no doubt that we need changes as profound and innovative as those brought about by the IT revolution, which have altered the way we communicate and turned the world into a global village.

The future of the energy sector cannot be predicted, let alone planned, but it can and should be consciously designed. Government institutions, both at the national and supranational levels, have a major role to play in shaping the energy mix of the future. Their functions in the energy sector are inextricably linked with the state's duties to ensure energy security (or the timely supply of energy at a socially acceptable price), and to protect the natural environment, although their performance doesn't require constant or direct involvement in the energy production process.

In many countries, energy producers are owned by the state, with the process concentrated in large, strategically important enterprises having the relevant production technologies and economies of scale, and the kind of massive capital expenditure that requires state guarantees. But this landscape has been changing along with the development of RES technology. A particularly vivid example of this trend is distributed generation, also called prosumer generation, which involves the use of alternative energy sources (wind turbines, solar panels, waste incinerators or geothermal pumps) to produce energy for one's own needs, with the option of selling any excess power to the grid operator. Here, the state doesn't have to be involved in either the installation or financing (with commercial bank loans) of these micro-generators, as its role is confined to setting safety standards, grid connection regulations and laws on grid extension through the connection of a large number of microgeneration plants[26].

At each stage, large-scale energy production has various side effects, including soil, water and air pollution

26 Massive-scale development of prosumer generation would require the state to re-define its strategic role, by shifting its focus from the security of highly concentrated production (its current focal point) to the security of energy off-take, transmission and distribution systems.

Prosumer generation – a new, important trend in the energy sector, involving the use of small renewable energy sources (wind turbines, solar panels, waste incinerators or geothermal pumps) to produce energy for one's own needs, with the option to sell any excess to the grid operator.

affecting local communities, ecosystem changes and negative landscape transformations. The state is responsible for mitigating these adverse effects by establishing rules for, and imposing fees on, the use of natural resources, and by imposing requirements to be met by energy generation systems. In the regulation-making process, it should be ensured that end user costs (higher taxes and energy prices), while being socially acceptable, also pose no impediment to economic growth.

In the case of a permanent increase in energy production costs in one area only, *ceteris paribus* this area would become less competitive compared with other regions, where no such increase had been effected. It would make no difference whether producers included additional costs in their energy prices, or kept the price unchanged in compliance with regulatory caps. In the first case, the mechanism leading to loss of competitiveness is fairly obvious: higher energy prices translate into higher product prices, weaker demand, lower income and slower economic growth. In the second case, the returns on energy projects decline owing to lower margins, and the volume of production decreases in relation to demand, which inevitably leads to higher energy prices. Even if consumers were willing to cover additional costs incurred by producers through higher taxes (as has recently happened in Germany and Denmark), investing in the highest-taxed regions is unattractive in an open economy.

CLIMATE POLICY, OR THE DISPUTE OVER COST DIVISION

Climate warming, which we are trying hard to counteract, is a global phenomenon and as such requires globally coordinated action. The measures adopted by the EU (and so far, only by the EU) are bound to fall short of its aims, since the leader is not being followed: the European economy is becoming less competitive, without any benefit to the climate, as high-emission businesses are relocating to regions with more lenient climate policies in a process referred to as 'carbon leakage'.

A great challenge to the prospect of reaching a worldwide agreement on climate protection is the actual division of emission reduction costs between individual countries. Attributable to economic growth, the problem of CO_2 emission and its excessive atmospheric concentration compared to the pre-industrial period has been primarily caused by countries which have enjoyed the fastest growth over the past 150 years – countries with the most advanced technologies and highest GDP per capita.

These wealthy countries are demanding decisive climate protection measures from less affluent, developing countries, which still rely heavily on coal. Coal, of course, contributes the most to global emissions. Unfortunately, the wealthy countries also show no willingness to participate in the cost of reducing emissions in proportion to their own contribution to the excessive concentration of carbon dioxide in the atmosphere, effectively thwarting all efforts to reach a fair worldwide agreement on climate protection.

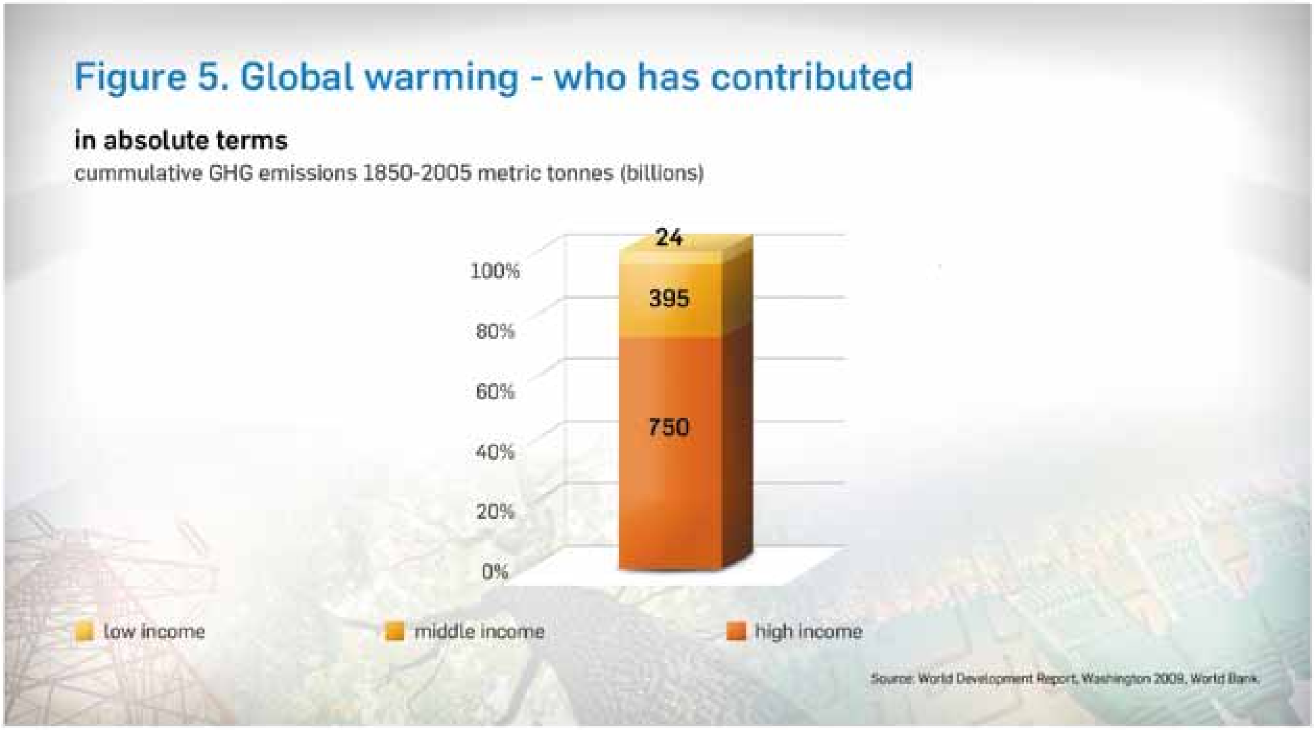


Figure 5. Global warming - who has contributed
in absolute terms
cummulative GHG emissions 1850-2005 metric tonnes (billions)
100%
80%
60%
40%
20%
0%
24
395
750
low income
middle income
high income
Source: World Development Report, Washington 2009, World Bank.

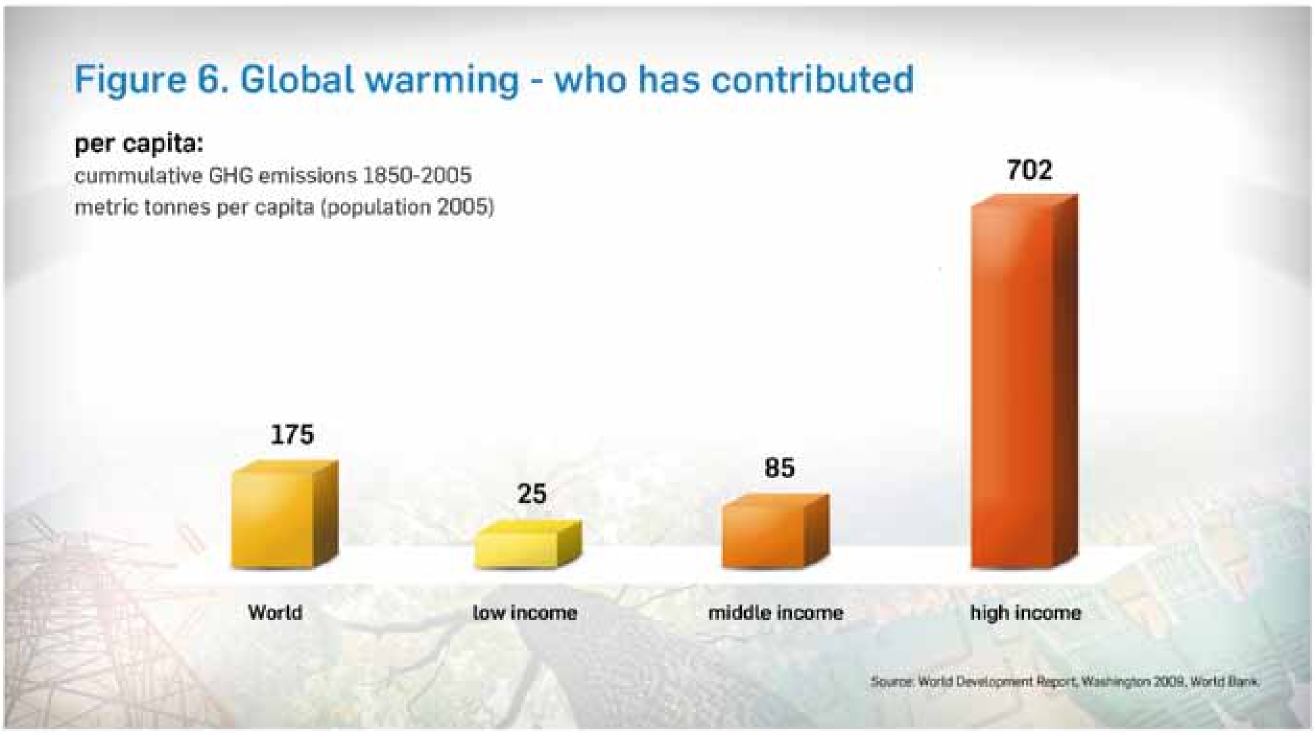
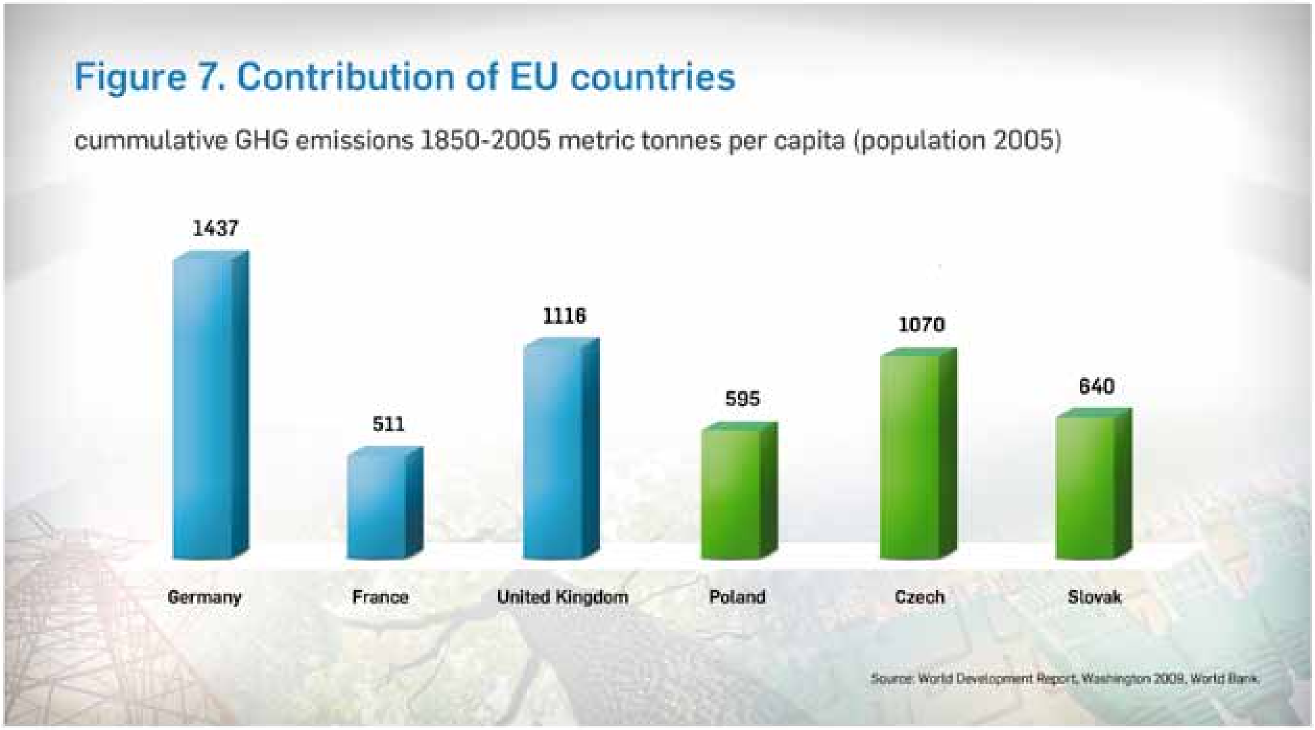


Figure 6. Global warming - who has contributed
per capita:
cummulative GHG emissions 1850-2005
metric tonnes per capita (population 2005)
175
25
85
702
World
low income
middle income
high income
Source: World Development Report, Washington 2009, World Bank.



INNOVATION AS A WAY OF DEVELOPING NEW TECHNOLOGY

The choice of energy production and conversion technology should be, to the greatest possible extent, left to the private sector. Where, then, do we look for, revolutionary, economically viable energy technology? The answer is, among innovative projects.

From the economic perspective, innovations are new projects (products, services, technologies) that have already found a mass market and have proved to be financially profitable. By this definition, it is impossible to predict if a new project will or won't actually be innovative. Hence, innovative projects present a different risk profile than traditional business projects (for example, modernisation), as their success (mass-marketed and financially profitable) is uncertain. The risk profile of such projects is characterised by an extremely high rate of expected return in the event of success, since their probability of success is statistically low, they have relatively long implementation periods, and investors need to commit (and thus freeze) large sums of capital.

In the case of energy innovations, a mass market and mass approval are easy to secure: the need for energy is universal, and cheap sources will always jostle the costly ones out of the market. But what does pose a problem is project financing, which is additionally compounded by regulatory risk. Although generous EU subsidies for renewable energy sources and increasingly popular climate bonds do exist, these resources are wiped out in subsidisation of economically unfeasible technologies.

A separate issue affecting development of renewable energy sources in the EU is the way in which they are co-financed, which occurs through allocation of public funds to existing solutions at the cost of supporting riskier, more innovative projects. The energy sector, however, calls for a different model of financing innovation. The process of facilitating energy innovations must involve three groups of entities: scientific (producing ideas for RES), business (purchasing RES and generating energy, or

Climate bonds – debt securities issued by businesses, banks and local government to finance investment projects that advance the development of a low-emission economy.
According to HSBC's methodology, which, as described in a 2013 report, addresses seven investment areas in a low-carbon economy (transport; energy; climate finance involving, for example, securities issued by environment banks; buildings and industry; agriculture; waste and pollution control; water), the total value of bonds in 2013 supporting climate protection was USD 346bn (having grown from the 2012 level of USD 174bn). This data relates to bonds issued since 2005, still outstanding in March 2013. According to HSBC, 1,200 bonds issued by 260 entities met the criteria for climate bonds.

manufacturing products reducing its consumption), and the state (co-financing science and ensuring energy security).

Each of these stakeholders pursues its own objectives: the scientists seek high approval and good opinions, which are taken into account in further funding decisions; the state (institutions and officials) seek the rubber-stamps approving the expenses, while the businessmen chase the profits.

All of them, though, share an aversion to excessive risk. Scientists carry out research projects which are supported by funding. The findings from research into RES are not products which the business sector would be interested in buying, as they involve high, immeasurable cognitive risk. After all, it is uncertain whether the results of their theoretical research and laboratory experiments will be confirmed by other scientists, repeated or obtained again on a larger scale. Even venture capital business only takes an interest in innovations that are already at the prototype stage, when they can be tested to see how they work. (Although these still involve a high risk that is unacceptable to energy producers). In Poland (and in throughout the EU), the state provides financial grants, which are designed in such a way as to be used to co-finance research projects, but can by no means contribute to the reduction of business risk. This situation has its roots in the structure of the financial sector, with banks as its core element.

If we are to develop innovations, we must focus on several issues, the most important being the provision of financing for two stages of innovation: the feasibility study and prototype development (demo installation). On the one hand, these two stages in the process of turning ideas into commercial products fall outside the domain of scientific inquiry and research funding, and on the other hand, they are too risky for business players. This financing gap has already engulfed far too many ideas, but the problem would be solved if the feasibility study and, to a certain extent, prototype development were covered by public funds. Moreover, the economy needs solutions that enable businesses to invest in high-risk projects. Success in creating a climate for innovation won't be achieved by reducing the risk of a single innovation, or the original developer's risk; it is, however, possible and advisable to lower financing risks by creating project portfolios. This method has been implemented in a number of countries, including the United States, where private venture capital is successfully used to finance innovations.

If a given country lacks such capital, an innovation financing system should be established with the aid of financial engineering, which will force business and the state to collaborate. As with science, the state should finance innovations from taxes with no expectation of returns on every single project, and count instead on revenue from future production taxes. Under such a system, business will generate the funds with a view to earning profit.

Figure 8. Innovation financing

In order to facilitate innovation, risks must be financed along the whole value chain, from the idea to the implementation. But the current system does not provide for the financing of two important stages: the feasibility study and prototype development.
This gap should be filled by public and private financing, the latter involving venture capital funds that give the opportunity to invest in high-risk projects.

ARE CHEAPER FOSSIL FUELS A THREAT TO THE DEVELOPMENT OF RENEWABLE ENERGY?

Fossil fuels, including natural gas, are no threat to future RES technologies. In fact, the opposite is true – each new discovery of recoverable oil and gas buys the time necessary to develop the RES-based technologies that will revolutionise the market. Such new additions to commercially recoverable reserves of natural gas (which produce half the carbon emissions of coal) could help release public funds tied up in subsidy schemes for the existing, inefficient renewable technologies, and possibly divert the money to truly innovative projects. These latter are a necessity since the technologies applied today, with their deficiencies and extra costs discovered only after a given solution is implemented on a large scale, stand no chance of successfully responding to the challenges lying ahead of the energy sector. For example, a single renewable power unit (or transducer), such as a wind turbine or solar cell, has relatively low generating capacity. To increase that capacity, the physical size of the entire system needs to be expanded, which presents various technological and environmental hurdles.

The EU, including Poland, provides no ways of financing two stages of the work on innovations: the feasibility study and prototype development (demo installation). On the one hand, these two stages in the process of turning ideas into commercial products fall outside the domain of scientific inquiry and research funding, and on the other hand, they are too risky for business players. This financing gap has already engulfed far too many ideas.

Figure 9. Growth in the size of wind turbines since 1985.
Have we reached the limit?

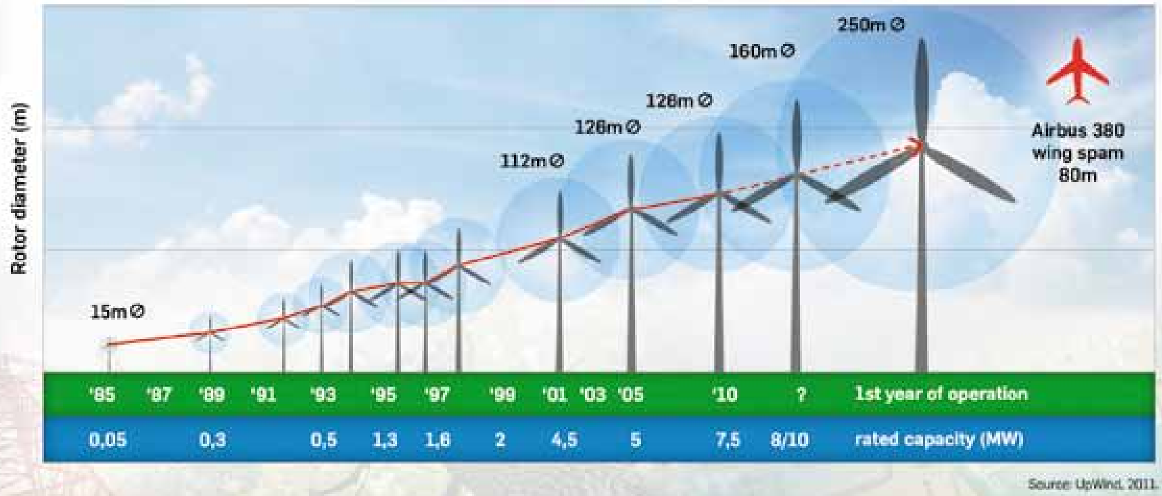
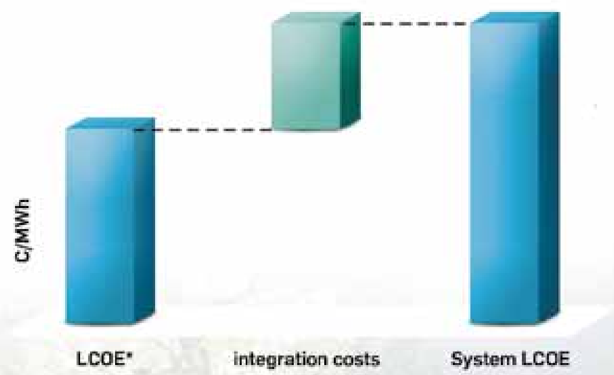


Figure 10. The total capital cost of a renewable energy project needs to include the grid integration costs



* LCOE - the full life - cycle costs of a technology per generation unit.

Integration costs increase as the installed capacity of a unit rises.
At the initial implementation stage, the integration costs are unknown or are significantly underestimated.

When deployed on a large scale, the output fluctuations characteristic of these generating units present difficulties in power off-take, which in turn puts constraints on installed capacity. What is more, such large-scale deployments (significant to the country's overall energy demand) require that vast stretches of land be off-limits for other uses, while the economic efficiency of a unit may differ from its process (engineering) efficiency: commercially viable in stand-alone or small-scale applications, they may prove too costly when implemented on a utility scale (Figure 10).

Another major drawback is that wind and solar stations require gas-fired backup capacity, which provides power when the wind slackens or the sun doesn't shine. Consequently, wind and solar farm development should go hand-in-hand with new gas-powered facilities. However, the former are a threat to the latter as gas-fired capacity stands idle, and is hence unprofitable, when power is generated from renewable sources. The need to secure stand-by capacity inflates the cost of a project and harms its economic viability, as the price paid is for installed capacity rather than actual power output.

By way of illustration, let us assume that a country chooses to rely solely on wind farms. Since the wind sometimes dies down and stand-by generation from other sources is required, two power systems need to be installed instead of one, or end users will never be certain that the lights in their homes won't suddenly go out. By the same token, the costs of power off-take run high in renewable projects, as the grid needs to be adjusted to the significant instability of renewable output. Therefore, the profitability estimate of a renewable energy project should take into account the cost of backup generation, as well as the balancing costs incurred to maintain grid stability. These integration costs inflate the total cost of operation of the power system, and place a heavy burden on end users.

CONCLUSIONS

1. **Energy sources should be viewed through the lens of technology.**

2. **Sustainable development is as much about economic growth as it is about environmental protection and the security of supplies.**

3. **Government policies on environmental protection, climate change and energy security also need to address economic issues, including access to energy for all.**

4. **The regulatory framework should take into account the relative maturity of a generation technology.**

5. **Climatic objectives cannot be attained in isolation.**

6. **Support for innovation should be a mainstay of climate policy. Promoting existing technologies hinders the achievement of this goal.**

One advantage of assessing energy sources from the technological perspective is that it allows for departure from the misleading classification of primary sources as either clean (wind and solar) or dirty (fossil fuels), and instead focuses on the question of how far a given technology contributes to the achievement of sustainability priorities.

The security of supplies, one of the three strategic priorities for sustainable development, is best met by those technologies which tap into indigenous primary energy resources. For the European Union, the ability to achieve this is strongly correlated with the degree of its internal economic integration – the deeper the economic ties, the more inclined the member states are to regard Europe's primary energy resources as secure.

The next priority on the list is to curb the energy sector's environmental and climatic footprint. But rating generation technologies in terms of their contribution to the achievement of that priority is tricky, for at least two reasons. Firstly, all energy generation technologies interfere with the environment, and their impact simply depends on the scale of their deployment. As regards new technologies at an early implementation stage, their footprint is hard to measure due to their limited application. Secondly, in order to obtain a meaningful profile of the environmental impact of a given technology, emissions need to be tracked and compared across the entire cycle (from energy generation to final use), and allocated in their entirety at the place of consumption. In practice, emissions are allocated at the place of extraction of primary energy resources, which completely distorts the process cycle emission profile.

The third priority is equal access to energy, and is a socio-economic approach that dictates that the final cost of energy must not be excessive in relation to national income levels. The cost of the first two sustainability goals is paid by taxpayers in higher energy bills or taxes, which together make up the total cost of energy that has to be borne by a household. The larger the proportion of that cost in the household's income, the further away the idea of equal access to energy slips.
Individual technologies fit differently into this priority triangle, and when the final choice is made, one or two of the priorities are usually partly sacrificed to accommodate the others. Simultaneous improvement in all three dimensions rarely happens, and then usually only as an outcome of revolutionary innovation.

So, an important conclusion, which deserves a prominent place in the assessment of new technologies is that while decision-making on energy security, the environment and climate rests with the state, the third objective (cost of energy to income) depends directly on the first two and is determined by economic forces. Decisions driven by energy security and environmental protection concerns must also factor in their impact on total energy costs to income. Producing energy at the cheapest possible price and keeping it within socially accepted standards of energy security and environment and climate protection is also a must, if the European Union is to reinforce its competitive position relative to its trade partners.

In the globalised economy and globalised energy sector, the prices of globally traded products, as well as the energy prices set on international markets, are similar for everyone – the differences lie in the energy and labour costs. The least efficient countries will inevitably face a deterioration of their competitive position, which can only be preserved if higher energy costs per product unit are compensated for with sufficiently robust effects from technological and organisational advancement, and by restraining the nominal wage growth optimally below the productivity growth rate, a measure unlikely to win immediate social acceptance.

The technologies available today are not enough to rise to the challenge of ushering in a low-carbon future, and although they may all effect some improvement by 2020, it is only nuclear power that can provide a substantial addition to the supply of low-carbon energy within this time frame. Therefore, in order to alleviate future reliance on nuclear sources, the energy and climate policy must rest on a strategy designed to stimulate the development of future technologies today.

Building a low-carbon economy is predominantly a technology challenge, an assertion that leads to two main conclusions for energy and climate policies. The first is that the technologies of the future (of which little or nothing is known today) are bound to play a key role in the process, hence the decision on which of today's technologies to support is a gamble, with the cost of related risks borne by taxpayers and energy consumers. The second is that the success of energy and climate policies lies in an innovation economy, therefore its primary focus should be on incentivising new technologies and devising a support scheme tailored to the specific needs and lifecycles of innovative technology projects.

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