D5.1 Paper on emerging issues Major trends, challenges and emerging issues in Energy

Scanning for Emerging Science and Technology Issues
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SESTI working paper
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Major trends, challenges and emerging issues in Energy

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Contents

Introduction

The present document was prepared as the background material for the SESTI workshop on Energy. The objective of the present document is to help understand the wider context in the energy field characterized by specific trends and the challenges and present a selected number of emerging issues within context. The overall aim is to establish a common understanding about the main elements characterizing the area of energy so as to trigger discussions.

Taking energy as the example area, the objective of the workshop is to better understand what the needs of the policymaker are in order to make the decision to take up the emerging issue within the mainstream discussion in their community. By discussing the case issue of energy, feedback will also be sought on how to organize future workshops around new topics and develop briefs around new emerging issues. The workshop is envisaged to provide in depth information about what the needs of the users are in relation to the SESTI deliverables as well as the applied identification and selection process of early warning signals, and the processing procedures.

The energy field is vast in terms of aspects (S&T, socio-economic, environmental, cultural behavioural etc.), types of drivers, cross-cutting impacts and diversity of areas affecting and being affected. At the same time each different energy technology face its own peculiarities, challenges and needs while certain controversies also exist around some of them especially related to the production and use of nuclear power. These elements make the situation even more complex.

Naturally, a brief overview would not be possible to cover all these different aspects, perspectives, and peculiarities at the same degree of detail. Nor would it be desirable for the purposes of the SESTI workshop, as it would touch upon a wide number of issues only superficially. Thus, the present overview mainly tries to present adequately the major cross-cutting challenges and issues governing all the areas of energy policy and research without going into much detail in the technical specificities of given technologies. It is in this wider context that the policy implications of any new emerging issues and associated early warning signals have to be considered.

The structure of the document starts with a brief introduction to the policy context in the area of energy followed by the major trends and challenges identified in recent literature. This overview also includes a snapshot of some of the targeted scenarios and energy technologies promoted in the literature. Then follows a presentation of a selected number of new emerging issues and their associated early warning signals based on the SESTI methodology referring to the descriptions of expected impact and implications for policy in the appendix, which will be discussed during the workshop. A first attempt to relate the impacts and implications with the overall picture (sketched in the first chapter) is given in the third. The document ends with presenting some potential themes and areas of reflection in to feed the workshop discussions.

1. EU Energy policy context - Major trends, challenges and issues

1.1 EU Energy Policy Context

The main objectives of the EU Energy policy are clearly stated in the 2006 Green Paper[1]:

• Sustainability: (i) developing competitive renewable sources of energy and other low carbon energy sources and carriers, particularly alternative transport fuels, (ii) curbing energy demand within Europe, and (iii) leading global efforts to halt climate change and improve local air quality.

• Competitiveness: (i) ensuring that energy market opening brings benefits to consumers and to the economy as a whole, while stimulating investment in clean energy production and energy efficiency, (ii) mitigating the impact of higher international energy prices on the EU economy and its citizens and (iii) keeping Europe at the cutting edge of energy technologies.

• Security of supply: tackling the EU's rising dependence on imported energy through (i) an integrated approach – reducing demand, diversifying the EU's energy mix with greater use of competitive indigenous and renewable energy, and diversifying sources and routes of supply of imported energy, (ii) creating the framework which will stimulate adequate investments to meet growing energy demand, (iii) better equipping the EU to cope with emergencies, (iv) improving the conditions for European companies seeking access to global resources, and (v) making sure that all citizens and business have access to energy.

These specific targets are accompanied by concrete proposals referring to:

1. completion of the internal gas and electricity markets;
2. guaranteeing security of supply and solidarity between Member States;
3. ensuring a wide debate on the different energy sources, including costs and contributions to climate change;
4. dealing with the challenges of climate change in a manner compatible with its Lisbon objectives;
5. developing a strategic energy technology plan, making best use of Europe's resources, building on European technology platforms and with the option of joint technology initiatives or joint undertakings to develop leading markets for energy innovation.
6. developing a common external energy policy to react to the challenges of high and volatile energy prices, increasing import dependency, strongly growing global energy demand and global warming.

The latest development in the EU energy policy is illustrated in the Energy 2020 Strategy[2]. This consolidates the measures which have been taken so far and steps up activity in areas where new challenges are emerging. As specifically noted in the document while some progress has been made towards the Green Paper's goals, Europe's energy systems are adapting too slowly. Forthcoming enlargements of the EU will make this challenge even greater as the Union takes in countries with outdated infrastructure and less competitive energy economies. Energy 2020 also acknowledges that the existing strategy is currently unlikely to achieve all the 2020 targets, and it is wholly inadequate to the longer term challenges.

First and foremost, the strategy underlines the need to rebalance energy actions in favour of a demand-driven policy, empowering consumers and decoupling economic growth from energy use.

[1] CEC, (2006), 'GREEN PAPER, A European Strategy for Sustainable, Competitive and Secure Energy', COM(2006) 105 final, Brussels, 8.3.2006.
[2] CEC (2010), Energy 2020 A strategy for competitive, sustainable and secure energy, COM(2010) 639 final, Brussels, 10.11.2010

On the supply side, the priority must continue to be the development of secure and competitive sources of energy. Priority should be given to renewable energies and ensuring that the renewable energy sources and technologies are economically competitive by 2020. at the same time the strategy acknowledges that the contribution of nuclear energy, which currently generates around one third of EU electricity and two thirds of its carbon-free electricity, must be assessed openly and objectively. Research must be pursued on radioactive waste management technologies and their safe implementation, as well as preparing the longer term future through development of next generation fission systems, for increased sustainability and cogeneration of heat and electricity, and nuclear fusion (ITER).

In addition, ambitious energy and climate change objectives are adopted for 2020, the so called '20-20-20' targets, i.e. – to reduce greenhouse gas emissions by 20%, rising to 30% if the conditions are right, to increase the share of renewable energy to 20% and to make a 20% improvement in energy efficiency. The European Council has also given a long term commitment to the decarbonisation path with a target for the EU and other industrialised countries of 80 to 95% cuts in emissions by 2050.

EU energy and climate goals have been incorporated into the Europe 2020 Strategy for smart, sustainable and inclusive growth, adopted by the European Council in June 2010, and into its flagship initiative 'Resource efficient Europe' acknowledging that achievement of the EU's environmental policy goals depends on greater resource efficiency in the EU economy and internationally and that necessary measures concern many policy areas (Environment, Agriculture and fisheries policy, Climate Action, Research, innovation and industrial policy, Energy, Economic and Monetary Affairs, Regional policy, Trade and development policies, Taxation).

The new energy strategy focuses on five priorities:
1. Achieving an energy efficient Europe;
2. Building a truly pan-European integrated energy market;
3. Empowering consumers and achieving the highest level of safety and security;
4. Extending Europe's leadership in energy technology and innovation;
5. Strengthening the external dimension of the EU energy market.

1.2 Challenges and opportunities

Energy policy is set and implemented within a range of significant challenges. These refer to energy shortages, rising greenhouse gas emissions with severe consequences for climate change, high and unstable energy prices, leading to increased vulnerability of economies, and energy insecurity with concentration of current reserves of oil and gas in a few politically sensitive and countries.

EU greenhouse gas emissions will exceed the 1990 level by 2% in 2010 and by 5% in 2030. EU dependence on imported energy will increase from the current 50% to 65% by 2030[3].The problem of global climate changes requires fast and significant reductions in greenhouse gas emissions to stabilise the concentrations of these gases at a level which is sufficient to limit the increase of the global mean temperature to a level not exceeding 2°C above the pre-industrial levels. [4]

[3] EC, (2007), Trends To 2030 - Update 2007
[4] Öko-Institut and International Consulting on Energy (2006), The Vision Scenario for the European Union, Project sponsored by Greens/EFA Group in the European Parliament, Berlin, November 2006

The shift to a low-carbon global economy takes place against the background of an abundant supply of fossil fuels. This may lead to levels of greenhouse-gas concentrations well beyond 750ppm CO2e, with very dangerous consequences. In a BAU scenario energy users are likely to switch towards more carbon-intensive coal and oil shales, increasing rates of emissions growth. Even with very strong expansion of the use of renewable energy and other low carbon energy sources, hydrocarbons may still make over half of global energy supply in 2050.[5] In such a very possible scenario CO2 emissions would then be on a pathway that could severely threaten human well-being. Even with the moderation of fossil fuel use and effective CO2 management, the path forward is still highly challenging. Remaining within desirable levels of CO2 concentration in the atmosphere will become increasingly difficult. [6]

Large-scale uptake of a range of clean power, heat, and transport technologies is required for radical emission cuts in the medium to long term. The power sector around the world will have to be least 60%, and perhaps as much as 75%, decarbonised by 2050 to stabilise at or below 550ppm CO2e. Deep cuts in the transport sector are likely to be more difficult in the shorter term, but will ultimately be needed. While many of the technologies to achieve this already exist, the priority is to bring down their costs so that they are competitive with fossil-fuel alternatives under a carbon-pricing policy regime. [7]

At the same time alternative energy production should take into consideration water supplies. The future water needs of energy production and conversion can probably be met. However, as energy resources are stretched, unconventional sources become attractive (like oil sands, oil shales, deep gas shales) that require large amounts of water, further stressing current and projected systems.[8]

Finite fossil and nuclear fuel resources and the foreseeable concentration of fuel production in some politically sensitive regions is increasingly highlighting the problem of energy security.[9] By 2015, growth in the production of easily accessible oil and gas will not match the projected rate of demand growth. While abundant coal exists in many parts of the world, transportation difficulties and environmental degradation ultimately pose limits to its growth. [10]

In addition, there is an ever-increasing energy demand also even more intensified by the developing nations, including population giants China and India, which are entering their most energy-intensive phase of economic growth as they industrialise, build infrastructure, and increase their use of transportation. [11]

Geopolitics will continue to be a source of tension and uncertainty. Main challenges in this area refer to the changing geopolitical landscape accompanying China's and India's pursuit of equity in other countries' resources, especially oil and gas; the future path of China's political evolution and relations with its neighbours; Russia's strong-armed but unsophisticated handling of its gas dispute with Ukraine; growing uncertainties accompanying the expanding populism and changing political scene in

[5] Stern, N. (2006), 'Stern Review: The Economics of Climate Change', UK Treasury
[6] Shell International BV, (2008) Shell Energy Scenarios to 2050
[7] Stern, N. (2006), 'Stern Review: The Economics of Climate Change', UK Treasury
[8] WEC (2010), Water for Energy
[9] Öko-Institut and International Consulting on Energy (2006), The Vision Scenario for the European Union, Project sponsored by Greens/EFA Group in the European Parliament, Berlin, November 2006
[10] Shell International BV, (2008) Shell Energy Scenarios to 2050
[11] Ibid.

Latin America in terms of contribution of the region to global oil and gas supply; tensions developing over Iran's nuclear program in terms of stability in the Middle East and to oil markets; a just settlement of the Palestine–Israel problem which is so long overdue.[12]

Furthermore, the new challenge to 2020 is to provide the backbone for electricity and gas to flow where it is needed. Significant efforts need to be made to upgrade energy infrastructure particularly in Member States that joined as of 2004 as well as in less developed regions. Most important, Europe is also lacking the grid infrastructure which will enable renewables to develop and compete on an equal footing with traditional sources. Investment of around € 1 trillion will be needed by 2020 to replace obsolete capacity, modernise and adapt infrastructures and cater for increasing and changing demand for low carbon energy.[13] The grid of today, primarily based on national grids is not equipped to cope with the future requirements. New technical and economic concepts are required to make the transition to a truly European level.[14]

Energy efficiency features as one of the major means for tackling the problems of today and tomorrow. Yet, certain factors are working against a more efficient use of energy and these should be seen as additional challenges. These refer to behavioural changes in the population and there are several aspects, which are slowing down change in this context. Grasping the complexity of personal decision-making is necessary for intervention strategies to be successful. Research indicates that combined interventions, which integrate commitment to energy saving, goal setting, personal advice and frequent feedback "appear thus to give better results".[15]

Secondly, there is always the problem of possible "rebound effects", which means that the money saved by reduced energy use will be used for purchasing additional, energy-consuming appliances. Similar patterns have also be observed in car transport, where efficiency gains have not resulted in lower consumption, due to longer and more frequent trips and new energy-consuming equipments in the car. In addition, technological progress and social norms work against greater energy efficiency, because ever new appliances are needed to live up to certain requirements, for example, "connectedness". The main factor impeding change in how energy is used in households is, however, the lack of information on how much energy is spent for which purpose. [16]

Decentralization is also reported as a trend that presents particular challenges. Decentralisation affects the system architecture as more and more energy, especially electrical energy, is produced locally and has to be incorporated into the distribution system (the grid). Advanced ICT solutions allow for active demand-side management and direct interchange of information between the provider and the customer. The trend towards wireless and portable applications, now predominant in the ICT sector, will extend to the electricity business and may some day put an end to the customers' dependence on a grid connection. New actors with a much greater experience in dealing interactively with the customer, for example Google, are entering the energy business and will take

[12] Skinner, R., (2006), World Energy Trends: Recent Developments and their Implications for Arab Countries, Oxford Institute for Energy Studies, May 2006.
[13] CEC (2010), Energy 2020 A strategy for competitive, sustainable and secure energy, COM(2010) 639 final, Brussels, 10.11.2010.
[14] WEC (2010), Roadmap towards a Competitive European Energy Market.
[15] EFONET (2009), Evaluation Paper: Social Acceptance of New Energy Technologies and Energy Efficiency Measure, Deliverable 7.1, November 2009
[16] Ibid.

the trend towards decentralization further through innovations such as smart metering and control devices.[17]

On a positive tone, great opportunities are also present if the energy sectoral challenges are met in the right way. Environment and energy R&D and technologies are of the most attractive targets for large programmes and strategic initiatives. First, there is an increasing awareness that R&D in these domains is becoming a central issue. Second, the areas of business activities related to environment and energy are starting to represent an attractive source of entrepreneurial opportunities: market forecasts show that global demand for clean technology and environmentally friendly technology is likely to boom over the next decades. Based on the Innobarometer survey for 2009 companies felt that energy efficiency would be the main driver of innovation in the immediate future, with 32% of managers stating that increased demand for energy-efficient products and services provided the greatest opportunity for innovation over the next two years. A further 16% saw meeting the needs of older people as an opportunity to introduce new products and services, while another 12% pointed out the opportunities presented by increased demand for social, education and health services.[18]

Carbon capture and storage present a new opportunity for growth as is essential to maintain the role of coal in providing secure and reliable energy for many economies. There are also significant new opportunities across a wide range of industries and services. Markets for low-carbon energy products are likely to be worth at least $500bn per year by 2050, and perhaps much more. Individual companies and countries should position themselves to take advantage of these opportunities. [19]

1.3 Major trends and projections

There is abundance of scenarios in literature with projections of main trends towards 2030 or 2050. While there are variations in certain indicators there is remarkable agreement on one conclusion: a BAU scenario is not acceptable as it entails severe consequences both on energy and the environment. The trends that drive growth in energy demand and carbon dioxide (CO2) emissions associated with climate change continue to surge forward at an unrelenting pace.

Several organisations have elaborated energy scenarios to project major energy trends until 2030 or 2050 (EC – DG Tren, IEA, WEC, to name but a few) A consolidation of the major findings from various sources highlights that the world primary energy demand is expected to grow by 40% between 2007 and 2030, in which fossil fuels account for 77% of the overall increase in energy demand by 2030. Global energy-related CO2 emissions are projected to increase more than 50% between 2004 and 2030. In spite of the growing demand for coal, oil will remain the most sought-after fuel source, whilst natural gas consumption should continue to increase. EU dependency on oil imports will exceed 90% in 2030 and dependency on overall energy imports will rise to 66,6% by 2030. Energy and oil will play a key role in future power relations and defence policies.[20]

[17] Ibid.
[18] EC (2010), A RATIONALE FOR ACTION, COMMISSION STAFF WORKING DOCUMENT Accompanying document to the Europe 2020 Flagship Initiative, Innovation Union, COM(2010) 546, SEC(2010) 1161 final, Brussels, 6.10.2010,
[19] Stern, N. (2006), 'Stern Review: The Economics of Climate Change', UK Treasury
[20] Boden, M., Cagnin, C., Carabias, V., Haegeman, K., Könnölä, T., (2010), Facing the future: time for the EU to meet global challenges, JRC/IPTS

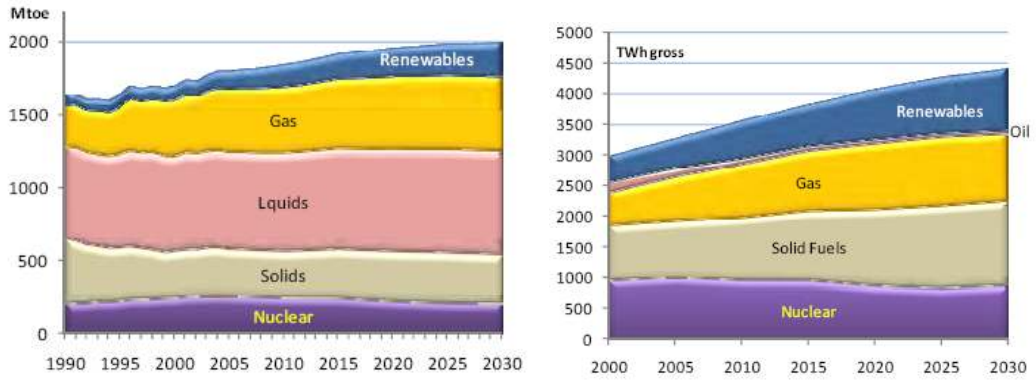
Such projections may slightly vary across different sources and they may come from public as well as private sector organisations. For example ExxonMobil expects that global energy demand in 2030 will be almost 35 percent higher than in 2005, even accounting for the recession that dampened energy demand in 2009. Demand will be particularly intense for electric power generation, which will comprise 40 percent of global energy demand by 2030. Oil and natural gas will remain essential, but other sources including nuclear and renewables (e.g., wind, solar and biofuels) will play an expanded role. [21]

Increase in energy consumption is also confirmed by several scenarios which also put special emphasis in the contribution of renewables and natural gas in meeting these increasing demands. For instance, the 2007 Baseline scenario of DG Tren[22], [23] finds that in 2030 primary energy consumption is 11% higher than in 2005, and will be overwhelmingly met by renewables and natural gas. Higher deployment of biofuels is the major driving force for greater renewables penetration in final demand (as distinct from renewables used for power generation, where hydroand wind are established sources with a great potential for further wind penetration).

Oil remains the most important fuel, although its consumption in 2030 exceeds the current level by only 6%. Oil demand increases by 12% due to growing transportation fuel demand and despite some replacement by gas and electricity in stationary uses. The share of fossil fuels in total energy consumption falls only marginally by 2030, while the gas share increases by 1 percentage point. The report further notes that after 2010 the agreed policies on nuclear and the replacement cycles for older plants lead to more nuclear plant closure than there will be new investment in nuclear. Overall, electricity shows the most important increase in final energy demand (+38% up to 2030). There is also strong growth of heat from CHP and district heating (+17%). Natural gas continues to make inroads for heating purposes (+14%). Solid fuels continue to decline strongly so that their use becomes more and more concentrated in some heavy industries. [24]

[21] Exxon Mobil. Outlook for Energy A View to 2030
[22] EC, (2007), European Energy and Transport, Trends To 2030 - Update 2007
[23] This scenario includes policies and measures implemented in the Member-States up to the end of 2006: • Completion of the internal energy market by 2010 taking into account derogations for electricity and gas market opening; • Energy efficiency (e.g. implementation of the building, CHP, labelling Directives, etc; national policies on e.g. education, information, public procurement, CHP, etc);the assumption that the CO2 agreement with the car industry(essentially fuel efficiency) for 2008/09 would be honoured had to be dropped but there is still considerable improvement assumed; • Renewables (e.g. implementation of measures under the electricity and biofuels Directives, ongoing national policies supporting RES deployment); • Nuclear (nuclear phase-out as agreed in certain Member-States, closure of existing plants in recently acceded Member-States according to agreed schedules; nuclear investment is possible in countries that have not ruled out nuclear or see such investment as unlikely for the medium term); • Promotion of clean and efficient technology including carbon capture and storage (CCS) – which is a possible option in the Baseline scenario3; • Climate change (continuation of the EU ETS over the projection period without extension to new sectors.
[24] EC, (2007), European Energy and Transport, Trends To 2030 - Update 2007

Primary Energy Consumption **Power Generation**



Source: EC, (2007), European Energy and Transport, Trends To 2030 - Update 2007

The structure of power generation changes significantly in favour of renewables, natural gas and solid fuels, whereas nuclear and oil lose market shares. Biomass use for power generation also rises considerably; solar PV displays high growth rates from a small basis, while the additional contribution from hydro power is small as a result of limited additional potential and environmental restrictions. Solid fuels increase their share in power generation as a result of prevailing high gas prices and in their function as replacement for nuclear. Nevertheless, gas continues to gain market share due to its advantages as clean, efficient and low carbon fuel. As a result of these changes towards fuels with zero or low carbon content (renewables and gas), carbon intensity of power generation declines. [25]

In relation to hydrogen, until 2030, fossil fuels, increasingly with carbon capture and storage (CCS), are expected to be the dominant source for production of hydrogen in Europe, while hydrogen from renewable sources will slowly phase in. However, there is still a large uncertainty with respect to the pace with which hydrogen can enter the market, as well as in the total investments required to bring hydrogen technologies to the market. [26]

As noted earlier a BAU scenario is not affordable. DG Tren Baseline scenario also warns for a decrease of carbon intensity post 2010 because of the nuclear phase-out becoming effective and the ensuing replacement of nuclear with coal, which is not sufficiently compensated by the further penetration of renewables. This in combination, with high oil and gas prices discourage further penetration of natural gas, which then leaves much scope for solid fuels in the Baseline scenario and makes it impossible for the CO2 targets to be met. [27]

Another major finding highlighted in all relevant reports is that the key driver of the post-2005 developments in world energy consumption is the rise in energy consumption among non-OECD countries. This is due to the higher projected growth rates in terms of economy and population. In fact, Asian non-OECD countries (including China and India) account for about 65% of the post-2005 increase in energy use.[28]

[25] EC, (2007), European Energy and Transport, Trends To 2030 - Update 2007
[26] L-B-Systemtechnik, Assumptions, visions and robust conclusions from project Phase I HyWyas, A European Road Map
[27] EC, (2007), European Energy and Transport, Trends To 2030 - Update 2007
[28] IEA, (2010), ENERGY TECHNOLOGY PERSPECTIVES 2010, Scenarios & Strategies to 2050

In the IEA Baseline scenario, CO2 emissions in India show the largest relative increase, rising almost fivefold by 2050. China also shows a substantial rise, with emissions almost tripling between 2007 and 2050. The United States show a much more modest rise, of 1% and emissions in OECD Europe decline by 8%. In the BLUE Map scenario, all countries show considerable reductions from the Baseline scenario: emissions in 2050 (compared to 2007) are 81% lower for the United States, 74% lower for OECD Europe and 30% lower in China, while India's emissions rise by 10%.[29]

Energy efficiency

Energy efficiency stands at the forefront of the means to achieve the energy and climate change targets. As stated in the second EU Energy Strategy Review (2008) package of energy efficiency proposals aims to make energy savings in a number of areas, such as reinforcing the key energy efficiency legislation on buildings and energy-using products, and enhancing the role of energy performance certificates as well as inspection reports for heating and air-conditioning systems. To improve efficiency in energy supply, the Commission has adopted guidelines to enable the uptake of electricity generation from highly efficient cogeneration installations.[30]

Through 2030, one of the most important "fuels" of all will be energy saved through improved efficiency. Energy saved through efficiency gains will reach about 300 quadrillion BTUs per year by 2030, which is about twice the growth in global energy demand through 2030. Most of the energy saved through efficiency will be in OECD countries.[31]

Nuclear energy

DG Tren's scenario projects that nuclear declines due to political decisions. The nuclear share falls from over 30% today to only 20% in 2030 despite considerable investment in new nuclear plants in countries without restrictions on nuclear. [32]

The EC acknowledges that nuclear safety is and will remain one of the absolute priorities of the EU. In this field several steps are already taken to establish the basic framework for nuclear safety while also recognizing the renewed development of nuclear energy in the EU and the need for stronger EU nuclear policy actions. The EU should – in the interest of all Member States – complete the legal framework for nuclear energy covering the area of nuclear waste management. A more harmonized approach could be introduced towards design certification and licensing, as well as in relation to civil liability and education and training aspects.[33]

Several MS have embarked on exploring opportunities for power generation offered by nuclear. The UK for example plans to examine whether recent changes in energy prices have changed prior negative assessments concerning nuclear as well as the other issues that would be raised by building new nuclear power stations. These other issues include all the characteristics of nuclear, including its

[29] IEA, (2010), Energy Technology Perspectives 2010, Scenarios & Strategies to 2050
[30] http://europa.eu/rapid/pressReleasesAction.do?reference=IP/08/1696&format=HTML&aged=0&language=en&guiLanguage=en
[31] Exxon Mobil. Outlook for Energy A View to 2030
[32] EC, (2007), European Energy and Transport, Trends To 2030 - Update 2007
[33] EC (2010a), State of play in the EU energy policy, Accompanying document to the Energy 2020 A strategy for competitive, sustainable and secure energy, SEC(2010) 1346 final, Brussels, 10.11.2010

creation of long-term liabilities such as nuclear waste; and how these liabilities should be managed and paid for.[34]

Taking into consideration social aspects in assessing energy technologies nuclear energy ranks lower than renewables. Coal technologies perform worse than centralized natural gas options; the latter are in the midfield and have thus ranking comparable to nuclear. The performance of CCS is mixed, i.e. fossil technologies with CCS may rank better or worse than the corresponding technologies without CCS, depending on which specific CCS option is used. Evaluation and perception of accident risks are known to be a highly sensitive and problematic issue. Among others, these results demonstrate the extent that policy can concretely influence technology penetration, when one considers e.g. that under a strong CO2 constraint, coal would almost be phased out in 2050, while under the assumption that security of supply constraint dominates the policy context, the coal share would remain double that of gas at the same time horizon of 2050. [35]

Regarding nuclear technologies, in 2007, the Sustainable Nuclear Energy Technology Platform (SNETP; www.snetp.eu) was launched with the endorsement of the EC. Its objective is to develop and implement a Strategic Research Agenda covering continued safe operation of current and new-build light water reactors (Generation II & III), the cogeneration of electricity and heat for industrial processes using High / Very High Temperature Reactors, and the development of Generation IV Fast Neutron Reactors (FNR) and closed fuel cycles for greatly increased sustainability. In particular, SNETP has established a Task Force of key industrial and research players to implement the European Sustainable Nuclear Industrial Initiative (ESNII) under the SET Plan. ESNII will design and construct Gen-IV FNR prototypes and demonstrators in order to demonstrate the technical, industrial and economic feasibility, increased sustainability through more efficient use of uranium resources, and reduction of waste volumes and lifetimes. Then, in November 2009, the Technology Platform for Implementing Geological Disposal of nuclear waste (IGDTP; www.igdtp.eu) was launched with the objective of coordinating the remaining R&D in the lead up to the construction and operation by 2025 of Europe's (and the world's) first deep geological repositories for high-level and long-lived radioactive waste. [36]

Nevertheless, there is no foreseeable consensus on the acceptability of nuclear power against the background of the possibility of large nuclear accidents and the manifold problems related to the handling of nuclear materials (from mining to processing of nuclear materials and the management of nuclear waste).[37]

1.4 A snapshot of scenarios

Baseline scenarios are accompanied by alternative scenarios where current challenges are tackled effectively and an energy secure future is granted. Below follows a brief presentation of some of them. It is interesting to see that realisation of these scenarios depends on technology developments but equally, if not more, on the degree to which international agreements are met, and local, public-

[34] DTI, (2006), Our Energy Challenge Securing clean, affordable energy for the long-term, Energy Review, Consultation Document, January 2006
[35] Ricci, A., (20010), Policy use of the NEEDS Results
[36] EC (2010a), State of play in the EU energy policy, Accompanying document to the Energy 2020 A strategy for competitive, sustainable and secure energy, SEC(2010) 1346 final, Brussels, 10.11.2010
[37] Öko-Institut and International Consulting on Energy (2006), The Vision Scenario for the European Union, Project sponsored by Greens/EFA Group in the European Parliament, Berlin, November 2006

private as well as global collaboration is achieved. As the WEC notes cooperation in energy and climate research development, deployment and demonstration is important between governments and industry, both nationally and internationally.[38]

The IEA BLUE Map scenario[39] brings significant security of supply benefits to all four countries or regions, particularly through reduced oil use. In OECD Europe, the electricity sector will need to be almost completely decarbonised by 2050. More than 50% of electricity generation is from renewable energy, with most of the remainder from nuclear and fossil fuels using CCS (the precise energy mix varies widely among individual countries, reflecting local conditions and opportunities). Deep CO2 emissions reductions in transport can be achieved through more efficient vehicles, a shift towards electricity and biofuels, and progressive adoption of natural gas followed by a transition to biogas and bio-syngas. For the United States, energy efficiency and fuel switching will be important measures in reducing CO2 emissions across all end-use sectors. Most of the existing generation assets will be replaced by 2050 and low-carbon technologies such as wind, solar, biomass and nuclear offer substantial abatement opportunities. Given the dominance of coal, China must invest heavily in cleaner coal technologies (such as CCS) and improve efficiency of coal use in power generation and industry (especially in energy-intensive sectors such as iron and steel, cement and chemicals). For India, the challenge will be to achieve rapid economic development — which implies a significant increase in energy demand for a growing population —the need for huge additional capacity creates a unique opportunity to build a low-carbon electricity system. Below follow the summary of the trends under the BLUE Map scenario vs. the Baseline scenario.

[38] WEC (2007), Deciding the Future: Energy Policy Scenarios to 2050
[39] IEA, (2010), ENERGY TECHNOLOGY PERSPECTIVES 2010, Scenarios & Strategies to 2050

Energy and emission trends under the IEA Baseline and BLUE Map scenarios: 2050 vs. 2007[40]

Baseline scenario	BLUE Map scenario
• Energy-related CO_2 emissions roughly double	• Energy-related CO_2 emissions reduced by 50%
• Primary energy use rises by 84%; carbon intensity of energy use increases by 7%	• Primary energy use rises by 32%; carbon intensity of energy use falls by 64%
• Liquid fuel demand rises by 57% requiring significant use of unconventional oil and synthetic fuels; primary coal demand increases by 138%; gas demand is 85% higher	• Liquid fuel demand falls by 4% and biofuels meet 20% of total; coal demand drops by 36%; natural gas falls by 12%; renewables provide almost 40% of primary energy supply
• CO_2 emissions from power generation more than double; CO_2 intensity of power generation declines slightly to 459 g/kWh	• CO_2 emissions from power generation are cut by 76%; its CO_2 intensity falls to 67 g/kWh
• Fossil fuels supply more than two-thirds of power generation; the share of renewable energy increases slightly to 22%	• Renewables account for 48% of power generation; nuclear provides 24% and plants equipped with CCS 17%
• Carbon capture and storage (CCS) is not commercially deployed	• CCS is used to capture 9.4 Gt of CO_2 from plants in power generation (55%), industry (21%) and fuel transformation (24%)
• CO_2 emissions in the buildings sector, including those associated with electricity use, nearly double	• CO_2 emissions in buildings are reduced by two-thirds through low-carbon electricity, energy efficiency and the switch to low- and zero-carbon technologies (solar heating and cooling, heat pumps and CHP)
• Almost 80% of light-duty vehicles (LDVs) sales rely on conventional gasoline or diesel technology; petroleum products meet more than 90% of transport energy demand	• Almost 80% of LDVs sales are plug-in hybrid, electric or fuel-cell vehicles; the share of petroleum products in final transport demand falls to 50%
• CO_2 emissions in industry grow by almost half, as industrial production increases	• CO_2 emissions in industry fall by around a quarter mainly thanks to energy efficiency, fuel switching, recycling, energy recovery and CCS
• Total investment in energy supply and use totals USD 270 trillion	• Investment is USD 46 trillion (17%) more than in Baseline; cumulative fuel savings are USD 112 trillion higher than in Baseline
• Non-OECD countries are responsible for almost 90% of growth in energy demand and account for nearly three-quarters of global CO_2 emissions	• Non-OECD countries achieve CO_2 emissions reduction of around 30% compared to 2007; OECD countries account for less than one-quarter of global CO_2 emissions, having reduced emissions by 70% to 80% below 2007 levels

The European Foundation for the Improvement of Living and Working Conditions has also published four different scenarios. Main drivers have been identified to be international agreements on climate and climate-friendly energy solutions, especially agreements on lowering CO2 emissions, and the level of technological breakthroughs achieved within renewables and other alternative energy solutions. The general learning perspectives from the different scenarios are as follows:

- Though much more profitable in the short run, relying on fossil fuels will result in increased dependency on ever-scarcer resources, low investments in R&D in renewables and an energy sector lacking in skilled labour due to a fading image.
- The technological breakthroughs cannot follow the pace of therequired changes. This obviously makes it a good idea for the energy sector to increase investment as fast as possible in a diverse set of technologies, including different renewable sources and CO2 storing techniques as well as energy efficiency solutions.
- The willingness to change and to invest much more in innovation, R&D and in making the transformation to renewable energy sources as the number one priority are key factors in all the scenarios to improving the sector's dusty image and thereby improving its ability to attract new and well-educated employees. [41]

Greenpeace presents the Energy Revolution Scenario ensuring a sustainable European energy supply with exploitation of existing large energy efficiency potentials at the forefront leading to a reduction in primary energy demand and thus achieving a significant share of renewable energy sources in the

[40] IEA, (2010), ENERGY TECHNOLOGY PERSPECTIVES 2010, Scenarios & Strategies to 2050
[41] EFL, (2008), Trends and drivers of change in the EU energy sector: Scenarios

overall energy supply system, and compensating for the phase out of nuclear energy, and for reducing the consumption of fossil fuels. Increased used of combined heat and power generation (CHP) is also promoted and replacement of fossil fuels for CHP by biomass and geothermal energy. [42]

The Greens (European Parliament) VISION scenario[43] is a normative scenario based on two main assumptions:
o All non-controversial greenhouse gas mitigation options should be used for the time horizon of 2030 so that an emission reduction of 30% can be reached by the year 2020 compared to 1990 levels and a significantly higher reduction after this date;
o The use of nuclear power should be phased out based on the existing phase-out policies of different Member States of the EU or a technical lifetime of 40 years; in other words, no significant lifetime of existing nuclear power plants should be assumed and no new investments in nu-clear power should be taken into account.
Key activities for realising this scenario include among others a strong focus on energy efficiency measures; with comprehensive efforts to avoid transport; ambitious efforts to increase the share of renewable energies in both the energy and the end-use sectors; and securing the necessary investments in the energy infrastructure to support CHP as a key technology for using hydrocarbons as well as bio-mass with the highest efficiency possible and to push forward the technology of CCS and other emerging technologies in the fields of renewable energies, energy efficiency and energy storage.

In Shell's Bleuprints scenario the key enabler is the introduction of a CO2 pricing mechanism using a carbon emissions trading scheme that begins in the EU and is progressively adopted by other countries, including the U.S. and, later, China. By 2050, one of the key revolutionary transitions is that economic growth no longer mainly relies on an increase in the use of fossil fuels. The scenario depends on electric vehicles in the transport sector, power generation from renewable energy sources, and coal-fired and gas-fired power stations around the globe equipped with CCS technologies by 2050. A second, more profound transition occurs at the political level, where there is increased synergy between national policies and those undertaken at the sub-national and international levels.[44]

The WCE scenarios are characterised by a global energy mix which evolves in different ways, degrees and timing. The report notes that there is potential to offset the reliance on fossil fuels by an energy mix that uses more nuclear power with adequate waste management, additionally hydro resources, and renewables including biomass and biofuels with an affordable, low carbon footprint. key drivers in all scenarios are efficiency gains from stronger standards for production and end-use choices and a value for carbon which is high enough to affect choices but low enough to avoid harmful costs to growing economies.[45]

[42] Greenpeace, (2005), 'Energy Revolution: A Sustainable Pathway To A Clean Energy Future For Europe A European Energy Scenario For Eu-25'
[43] Öko-Institut and International Consulting on Energy (2006), The Vision Scenario for the European Union, Project sponsored by Greens/EFA Group in the European Parliament, Berlin, November 2006
[44] Shell International BV, (2008) Shell Energy Scenarios to 2050.
[45] WEC (2007), Deciding the Future: Energy Policy Scenarios to 2050

1.5 Key Energy Technologies stressed in literature

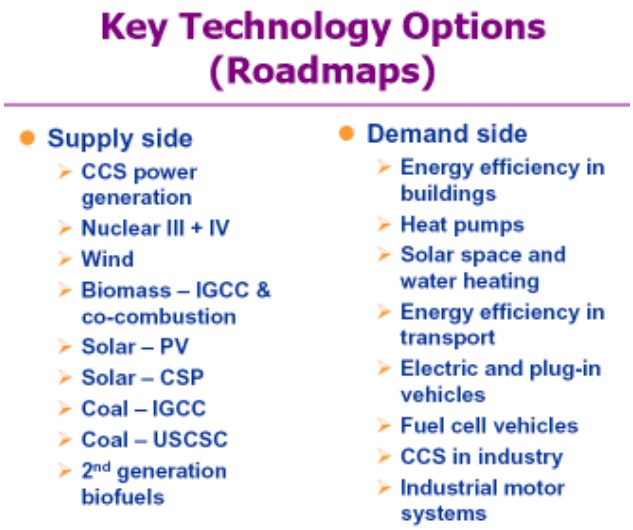
The SET Plan proposes to launch six European Industrial Initiatives (EIIs) in the areas of wind energy, solar energy, CO2 capture and storage, advanced nuclear fission, electricity grid as well as bio-energy. More Industrial Initiatives are actually in the development phase. The objective of the Industrial Initiatives is to pool together all stakeholders to define and implement ambitious technology programmes with the aim to support the reaching of the 20-20-20 targets. In addition, the SET Plan also proposed the setting up of the European Energy Research Alliance (EERA), pooling together major European research organisations and asking them to perform Joint Programming in areas related to energy technologies.

In June 2010, four European Industrial Initiatives on Wind, Solar, CCS and Grid have been officially launched in Madrid. At the same time as the launch of the four first Industrial Initiatives, four Joint Programmes under EERA have also been launched on Wind, Solar, Grid and Geothermal energy. Two other Industrial Initiatives on Advanced Nuclear Fission and Bioenergy are expected to be launched in November 2010 in Brussels. The preparation of the Initiative on Smart Cities has also started. [46]

The 7th Framework Programme deals with a wide portfolio of technologies: renewable energy technologies, making clean coal and carbon capture and sequestration an industrial reality, developing economically viable biofuels for transports, new energy vectors such as hydrogen and environmentally friendly energy usage (e.g. fuel cells) and energy efficiency; as well as advanced nuclear fission and the development of fusion through the implementation of the ITER Agreement. As noted in the Green Paper (2006), Europe should also invest in other possible future forms of energy, such as hydrogen and fuel cells, carbon capture and storage, large-scale renewable technologies such as concentrated solar thermal, as well as even longer term prospects such as methane hydrates.[47]

While highlighting that an energy technology revolution might be underway, IEA ETP 2010[48] notes that these efforts are only the first small steps in a long journey. IEA ETP 2010 estimates that to achieve the 50% CO2 emissions reduction, government funding for RD&D in low-carbon technologies will need to be two to five times higher than current levels. Reducing CO2 emissions ultimately depends on the uptake of low-carbon technologies by industry, businesses and individual consumers. To this end, improved understanding of the human dimensions of energy consumption, particularly in the residential and commercial sectors and in personal transport, are important. In the Work Energy Outlook (2008) certain key technologies and the respective roadmaps are outlined.

[46] EC (2010a), State of play in the EU energy policy, Accompanying document to the Energy 2020 A strategy for competitive, sustainable and secure energy, SEC(2010) 1346 final, Brussels, 10.11.2010
[47] CEC, (2006), 'GREEN PAPER, A European Strategy for Sustainable, Competitive and Secure Energy', COM(2006) 105 final, Brussels, 8.3.2006.
[48] IEA, (2010), ENERGY TECHNOLOGY PERSPECTIVES 2010, Scenarios & Strategies to 2050



Source: IEA (2008), World Energy Outlook

Regarding the technological composition of prospective EU27 vehicle fleets the diesel technology will have the highest share followed by gasoline. Simulation projects that in the short to medium term technologies like CNG and hybrid will be alternatives to today's petroleum based internal combustion engines (ICE), while in the medium term bioethanol becomes more important. Interestingly, in the long-term gasoline blended with bioethanol and burned in new highly fuel efficient combustion engines recapture part of the lost market share.[49]

The private sector also reveals some of their key focus areas. ExxonMobil believes that biofuels from photosyntheticalgae could someday play an important role in meeting the world's growing need for transportation fuels, while also reducing CO2 emissions. ExxonMobil expects to spend more than $600 million onthis project if research and development milestones are met. New technologies to make vehicles more fuel efficient include a lower-viscosity synthetic motor oil, new tire-lining technology that uses up to 80percent less material in the manufacturing process, and lightweight plastics for car parts. [50]

The FP Advisory Group on Energy notes that the needed energy technologies are not yet ready, and require extensive further R&D. Two critically important fields are energy for transport and conversion technologies for electricity and heat. Their report[51] presents the options and identifies key issues in relation to each[52]. End-use efficiency is identified as a further important area, with some R&D needs at a European level, and a need for an ambitious long term target.

The report concludes that the primary strategic focus for EU-funded energy R&D, then, should be on:
• Those technologies that can make a significant difference to consumption of fossil fuels in the immediate and short terms (e.g. renewables, innovative approaches with potential for significant energy efficiency improvements in widely used applications).

[49] TRIAS, (2007), Outlook for Global Transport and Energy Demand, August 2007
[50] Exxon Mobil. Outlook for Energy A View to 2030
[51] EC (2006), Transition to a sustainable energy system for Europe The R&D perspective, A summary report by the Advisory Group on Energy
[52] The list of R&D promoted under the two areas is attached in Annex I.

• Grid issues to allow for efficient operation of integrated distribution systems incorporating the demands of multiple small- and large-scale electricity and heat generation by diverse technologies.
• Longer term research likely to lead eventually to technologies that are sustainable from economic, social and environmental viewpoints over the long run (e.g. nuclear fission with generation IV and effective waste disposal/recycling technologies; nuclear fusion).
• Crosscutting R&D of central importance (e.g. materials, biotechnology, nanotechnology).
• Supporting the energy R&D infrastructures that are needed for progress.
• Novel and innovative R&D with high risk but also with high potential.

Nanotech is also reported as a potential major contributor to dealing with energy challenges. Research is now focusing upon new technologies which may result in significant reductions in PV costs and/or improvements in efficiency. Nanotechnology is anticipated to play an important part in this future. Indeed, it may be 20years before nanotech-based PV begins competing as a viable energy source with this example.[53] The various applications showing most promise are summarised in the following Table.

Summary of nanotech applications for energy processing

Material/technique	Applications	Time-scale (to market launch)
Power generation (PV technology)		
Polymer materials (organic).	Solar cells (pers. comm., Jenny Nelson, Imperial College London, 2 Dec 2002). Current developments aim to balance moderate efficiency with low cost. Another big advantage is that these layers can easily be incorporated into appliances. Current problems stem from the material's instability.	The research stage has advanced much more quickly than expected. As a result, polymer-based PV cells should enter the market in 5 years.
Combinations of organic and inorganic molecules.	Dye-sensitised solar cells made from a thin hybrid layer (pers. comm., Jenny Nelson, Imperial College London, 2 Dec 2002). These cells are potentially very cheap because fabrication is from cheap, low purity materials by simple and low cost procedures (Saxl, 2000). Photocatalytic water treatment.	Low power applications will enter market first. Limited commercialisation already occurring (e.g. by Sustainable Technologies International).
Quantum wells (inorganic).	Quantum-well solar cells (pers. comm., Jenny Nelson, Imperial College London, 2 Dec 2002). Current research is taking place in high-efficiency applications because the infrared part of the solar spectrum may be absorbed.	Pure research.
Nanorods.	These structures can be tuned to respond to different wavelengths of light forming cheap and efficient solar cells (Holister, 2002).	Long-term.
Fuel conversion/storage		
Improved fuel catalysts through nanostructuring.	Fuel conversion (Saxl, 2000).	Current – 3 years.
Nanotubes.	Fuel storage. E.g. a methane-based fuel cell for powering mobile phones and laptops is currently being developed. (Holister, 2002).	2 years.
Nanoparticles.	Vastly increased (e.g. x10) charge and discharge battery rate (Holister, 2002).	Distant.

[53] Huw Arnall, A., (2003), 'Future Technologies, Today's Choices, Nanotechnology, Artificial Intelligence and Robotics; A technical, political and institutional map of emerging technologies, Imperial College London University of London, A report for the Greenpeace Environmental Trust

Scenarios referring to the US situation in 2050[54] mention rechargeable nanobatteries in electric, flexifuel, and hybrid cars, as well as tailor-made artificial bacteria using photoelectrosynthesis as reliable and novel source of electricity production in new power plants. Japan, on another front, is mentioned as pioneer in energy conservation practices and China in car technologies and carbon capture and storage in coal-based power plants and in CO2-free oxygenated coal gasification (clean coal), a source of both electricity and methanol fuel.

The WETO-2030 mainly envisaged incremental improvements in large-scale power generation and in renewable technologies. The WETO-H2 scenarios incorporate new energy technology portfolios, including:

• Hydrogen production through chemical, thermo-chemical or electrical routes
• Carbon capture and storage options as add-ons to plants burning fossil fuel to make electricity or hydrogen
• Distributed electricity production, with or without cogeneration, from fossil fuel, renewable energy or hydrogen
• Very low emission vehicles with new power systems and carrier concepts, including cars powered by electricity or hydrogen
• Low and very low energy buildings with significantly improved thermal performances (meaning a reduction by a factor of 2 to 4 from the consumption of present buildings in each region); these can even be “positive energy buildings” when photovoltaic systems are integrated into the design.[55]

[54] Millennium Project, 2020 Global Energy Scenarios
[55] EC (2006), World Energy Technology Outlook – WETO H2

2. New emerging issues and related early warning signals

The SESTI project searches in a systematic way for new emerging issues that may be influential on the future research and innovation agenda in relation to policy agenda. The search uses different approaches as internet scanning , surveys, wiki, twitter and text mining (which are globally described in a Methodological Report "*SESTI Deliverable 3.1*: *Scanning for early recognition of emerging issues; dealing with the unexpected*" and a first report on Methods and Approaches "*SESTI Deliverable 3.2 (1) Methods and approaches used in scanning the environment for weak signals and emerging issues"* where also the search frame for the scanning of energy relevant new emerging issues is given. The search delivered an enormous amount of small and larger potential new issues for energy research and policy which were assessed on their potential impact and plausibility.

After synthesis of the most impact rich and plausible issues for energy this resulted in a selection of ten main issues with the following titles:

1. Hybrid nuclear technology, box of Pandora or salvation
2. Renewables from the desert (DESERTEC)
3. Biomimics as leading principle for real renewable energy
4. Deeper and further (mining) known and unknown risks
5. The unknown risk of Hydrogen economy, the importance of sustainable energy carriers.
6. Local production local consumption
7. Smart saving and using
8. Smart pricing
9. The need for smart storage and smart distribution
10. The unbearable risk of nuclear proliferation

The first 5 issues are described in the appendix of this paper and will be discussed during the workshop on 29 November 2010.[56] The issues descriptions are a selection form the systematic (scan) search to websites and articles, logs and so on, that claim new challenges, approaches, discoveries, breakthroughs and ideas on energy policy and research. The descriptions give a short summary that outline their novelty, their potential impact, their research (or factual) basis, their controversies, their conflicts or coherence of interests and their emotional or ethical aspects which together make the issues candidate as potential emerging issue with "great" impact. During the workshop we will discuss the issue descriptions to improve the descriptions and to assess the different aspects in a more inter subjective setting with electronic voting. Finally we will discuss their implications for energy policy and research in relation to the first chapter and the ways the issues can be monitored further and brought forward to the policy arena.

[56] This appendix includes the most important news items that were identified in relation to the specific issue as well as the chronological appearance of these items based on the Google News Timeline results.

3. Associated implications for Energy policy and research

This is a selection of some related implications on energy policy and research triggered from the emerging issues identified and analysed in the previous section.

A stronger nuclear component in the future energy mix?

Recent scientific and technological developments indicate that the potential of nuclear needs to be reconsidered especially given that the specific hybrid concept may be already utilized in 20 years time. If the approach shows to be successful this may lead to a renewed debate comparing nuclear promises with other promising technologies as solar, wind, geo-thermal, hydro and so on.
Stronger research efforts and investments in the direction of hybrid reactors may be decided. The debate of building new nuclear plants may gain stronger weight. At the same time solutions to tackle nuclear waste problems will become more imperative while cooperation on an international level will be crucial towards ensuring nuclear safety. Public opinion will remain decisive in terms of the degree to which policies and actions are put forward.

Renewables contributing also to world stability or instability?

The DESERTEC project proves the value of trans-national collaboration. Trans-national collaboration in the energy field can be a contributor to stability of relations in certain regions. At the same time however, certain questions are raised:
To what degree is international cooperation feasible and meaningful and under which energy technologies? What should be the leading question: Who we collaborate with? Or What we collaborate for (renewables, gas, nuclear, etc.)?
Will renewables production in such projects reach a competititve level against gas production so as to create fragile situations in the EU Foreign Policy i.e. EU relations with the MENA against relations with the East?
How can diversification in energy resources contribute to world stability or avoid instability?

Reconsidering Principles for Renewables Will inter-disciplinarity provide the vital solution?

Applying the bio-mimics principle to the production of renewables demonstrates the value of connecting different disciplines and may provide guidelines for defining sustainable renewable. Does this imply that the solution is not in alternative energy sources but in the alternative perspectives in treating the energy problems? Should there be stronger support of inter-disciplinary research across different fields such as nano-technologies, bio-technologies, ICT, etc.?

Carriers: what should be the acceptable trade-off in ecological footprint?

No specific case is only with advantages and no disadvantages. All alternatives in energy resources have their pros and cons. Although electricity features as a major component of energy future scenarios, its further support may cause significant disturbance of the ecosystem and climate. What should an acceptable trade-off be and how can this be set in order to minimize further ecological damages while trying to ensure energy resources?

A BAU scenario might be even more harmful than most think

The literature notes that a Business As Usual scenario would lead to unacceptable CO2 emissions with harmful consequences on the environment and climate change. The Gulf oil incident shows that unless the world breaks its dependence on oil the consequences may be more severe as the risks from accidents in deep sea drilling or similar actions will increase due to intensified efforts to find more reserves. The same stands also in the case of gas and nuclear which associate with numerous risks. So the underlying question is again what and if there should be a trade-off in ecological damage as no alternative solution to the energy problems comes with no risks at all.

4. Discussion themes and areas of reflection

Comprehensiveness of major trends and challenges - possible R&D and policy answers like prevention or mitigation

Novelty / importance / soundness of emerging issues and associated weak signals - plausibility, desirability, changeability, time horizon of emerging issues

- A stronger nuclear component in the future energy mix
- World relations based on energy (change of scene?)
- New paradigm ; from non carbon to carbon recycling , the need for interdisciplinarity
- Research governance and coordination needs at multiple levels
- Setting acceptable trade-offs in the future energy mix

Identification of knowledge gaps, needs for deeper or further monitoring and scanning, further study and research

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Annex I: Summary of transport options, and associated key issues

Time to widespread deployment	Technology	Key issues
Immediate/ Short term	Reduction in demand (smaller engine size; speed limits; transport mode switching)	No technological issues; is a matter of public policy and consumer behaviour change.
	Advanced high-efficiency ICEs	Ongoing R&D by the automotive industry has already produced major efficiency improvements; will continue; Europe is in the forefront of developments.
	Improved hybrid electric designs with petrol, diesel, biodiesel	Hybrid models already on the market; ongoing R&D by the automotive industry should produce refinements to all design aspects in the short term.
	Biodiesel; bio-ethanol as carriers	Technology already well established and new production capacity is under construction. Feedstock supply infrastructure needs urgent/significant development and support (limits to planting area are imposed by the needs of the food sector). R&D needed to support this; in particular, cost reductions, improved crops, and reduction of emissions involved in growing and harvesting/transport.
	Co-processing of biomass with fossil fuels	Development of hybrid processes used in existing refineries.
	Synthetic fuels from gas / coal Fischer-Tropsch	F-T process well established but capital-intensive; new processes beginning to be deployed but further R&D needed on process. Requires CCS for removal of CO_2 emissions.
	Biofuels from ligno-cellulosic feedstocks	Biorefineries processing ligno-cellulosic feed-stocks (e.g. from materials flows in the paper and pulp industries) could if successful give high-yield, low-cost biofuels; the chemistry, catalysts, etc, need extensive R&D.
	Electric vehicles (EVs) with advanced battery electricity storage	EVs are already on the market but with low range. Progress being made on battery designs to increase energy density. Would require dedicated electricity distribution network for charging. Would require major increase in electricity generation capacity. Lengthy recharging a problem. All-electric technologies do not play to automotive industry's current competitive strengths.
	Hydrogen with fuel cells	Demonstrator/concept vehicles already in operation with very high fuel efficiency but with on-board storage of H_2 at high pressure or cryogenic liquid. Requires large-scale production of H_2 from non-fossil sources or with CCS to avoid overall CO_2 emissions. Requires R&D on H_2 production and especially on compact storage. Distribution network required would be rather costly. PEM FCs require major cost reductions to compete with ICEs.
Long term	Air transport: hydrogen/ gas turbine	Major safety problems associated with on-board storage of liquid H_2. Otherwise, hydrogen/gas turbine technologies are well developed.

Annex II: Summary of electricity/heat conversion technology options, and associated key issues

Time to widespread deployment	Technology	Key issues
Short/ immediate term	Low/medium temperature solar thermal applications for hot water, heating, cooling, industrial processes, etc	Already widely deployed (worldwide installed capacity in 2003: 109 GWth). R&D needs include materials R&D, including advanced insulation and energy storage materials. R&D needed on solar cooling, to provide higher performance and lower costs, and for application in the industrial sector. Public policies to stimulate the market are needed.
	Combined Cycle Gas Turbine (CCGT)	Well known and widely deployed. High efficiency, low relative emissions, low cost, flexibility in operation makes it an attractive choice for utilities in the short term.
	Nuclear fission (Gen III/III+)	Advanced designs already available and under construction. Low fuel utilisation, waste disposal/recycling and public acceptability problems remain. Major R&D investment needed on waste disposal and recycling, including innovative approaches such as partitioning and transmutation in accelerator driven systems or in reactors.
	Wind energy (including offshore/deep offshore	Needs better predictability of wind/power output. Next-generation wind turbines require advanced materials/improved controls. Costs of construction (including undersea electricity transport) and operation for deep offshore represent a barrier. System and grid issues very important as wind capacity grows (see below).
	System integration [not a conversion technology but grid issues represent a major barrier to development of the European electricity system]	Short term: R&D in progress on grid issues focusing on reliability, economic, environmental, and legal/regulatory aspects of operation of the liberalised markets for electricity (and gas). Short to mid term: R&D needs on the interaction of the grids for electricity and gas; integration of large amounts of undispatched but rather centralised electricity generation sources (e.g. large wind farms); integration of distributed electricity generation sources. Mid to long term: R&D needs include development of 'smart grids'; and the interaction of the grids for natural gas and hydrogen. Progress is being made, but grid issues will remain central to the development of the future European electricity, natural gas and hydrogen systems).
	Solid biomass	May represent the most efficient use of biomass for energy. Technology already available for co-combustion of coal with biomass, but R&D needed for cost reduction and development of gasification technologies. Well suited for distributed generation with use as combined heat and power. R&D also needed in areas such as gasification of black liquor, and burning of corrosive crops.
	Fuel cells (SOFC, MCFC)	R&D needed for cost reduction and on materials; suited for smaller, distributed applications IT-SOFC holds promise but R&D needed (e.g. to improve ion transport and hence also efficiency].

Time to widespread deployment	Technology	Key issues
	Geothermal energy (including deep geothermal – HDR/HFR)	Technologies for low-depth geothermal well established, but suitable sites are limited, though low-depth geothermal/heat pumps have no such limitation. Deep geothermal (>3km) holds promise but very high costs and further R&D needed.
	Carbon capture and storage (CCS)	A critical technology for continued use of fossil fuels for electricity but also for other uses (e.g. synthetic fuels), especially coal, though CCS will involve important losses in efficiency. Many projects currently under way but many R&D issues remain, including improved/new separation/capture processes, and testing viability and safety of different CO_2 storage options, along with legal and public acceptability issues.
	Cleaner use of coal (steam/ gas turbine, combined cycle) with CCS	Well established already, but R&D needed for higher efficiencies (higher operating temperatures, new materials).
	Advanced fossil fuel plants (super/ultra-supercritical steam Integrated Gasification Combined Cycle (IGCC), with CCS	Technologies available and being deployed but an ongoing programme of R&D is needed to develop new materials and integration of clean coal power generation with CCS. Requires carbon capture and storage if coal use is to be an option in the mid to long term.
	Solar photovoltaic (PV)	Already available but breakthrough R&D needed if low-cost mass production of PV is to be achieved. Off-grid applications are already cost-competitive; if costs can be reduced, the potential is high also for grid-connected electricity. Further R&D on integration of PV with building design/construction. R&D needs for PV exist in basic and applied research, demonstration, and in socio-economics, standardisation, QA and environmental issues.
	Solar thermal power plants	Systems in operation or starting construction but major cost reductions still needed, together with materials research. Considerable potential in southern Europe.
	Ocean energy (wave, sea current)	Many competing small-scale designs available now, with some about to be deployed with grid connection. Remains to be established whether current technologies will be able to make a sizeable contribution, though potential is very high.
	Nuclear fission – Generation IV	Generation IV Forum assessing six designs, including high-temperature and fast breeder designs. Fast breeder fission could improve fuel utilisation by an order of magnitude. New materials are needed. Many substantial R&D needs mean market introduction of G.IV reactors will not appear before 2030.
Long term	Nuclear fusion	ITER project will remain the focus for R&D for some decades. Acceptable power ratio, continuous operation and high costs mean fusion will not be deployed till post-2050.

Annex III: Descriptions of New emerging Issues for Energy Research and Policy

Title: Hybrid nuclear energy, box of Pandora or salvation

Domain of relevance: Energy

Subdomain of relevance: nuclear fusion, fission,

Keywords: nuclear, energy , fission, fusion, proliferation, peace, weapons, costs of nuclear disarming, choices energy mix

Short description

In the Science Daily of Jan. 29, 2009 an article was placed about a realistic design of a nuclear plant that uses nuclear fission to ignite nuclear fusion. The title of this article was ***"Nuclear Fusion-Fission Hybrid Could Contribute To Carbon-Free Energy Future".*** The design was proposed by by scientists from the University of Texas in Austin[57] Advantages of this technique would be that fusion could become applied much earlier than foreseen in present fusion development programs and could be used to create fission processes that burn the elements that are the product of the many Light Water Nuclear fission plants that are now burning uranium in the US.

The centerpiece of which is a high power Compact Fusion Neutron Source (CFNS) made possible by a crucial invention. The CFNS would provide abundant neutrons through fusion to a surrounding fission blanket that uses trans uranic waste as nuclear fuel. The fusion-produced neutrons augment the fission reaction, imparting efficiency and stability to the waste incineration process.

The idea for a hybrid reactor is not completely new, already in 1970 the Fusion technology department of the university of Wisconsin worked out the concept of a nuclear fusion (tritium based) – fission hybrid power plant.

In 2008 we see a revival of this interest in the LIFE project that works out the concept of a hybrid reactor based on the use of nuclear laser inertial confinement fusion that ignites the fission in such a way that it can burn up the charge of nuclear warheads. Also here the prediction is that through the use of hybrids we can reach the use of nuclear fusion within 20 years from now , produce CO2 fee energy, prevent or destroy nuclear waste that otherwise should be stored underground and could even contribute to non proliferation by gradually burning up nuclear arms.

Till now no strong reactions have come from other energy areas except from fusion scientist who state that the advantages of the ideas should not be overestimated because the major principle of the hybrid will be fission with the coinciding risks, furthermore they have some doubts about feasibility issues.

[57] Kotschenreuther, Mahajan and Prashant Valanju, of the IFS, and Erich Schneider of the Department of Mechanical Engineering

Impacts /Implications

The ideas that were put forward in 2009 are powerful in respect of the fact that they break through the timeline of using fusion in energy plants, fusion seems always to stay away 50 yrs from now (both major concepts Nuclear Inertial Laser Confinement (NIF) and plasma stabilization (ITER) are still far away from autonomous application) while in this hybrid concept it may be already utilized in 20 years from now. In the LIFE project the hybrid idea was even proposed one year earlier.
If the approach shows to be successful this may give a renewed boost for nuclear fission as well as nuclear fusion development. It may be expected that a renewed debate will follow to compare nuclear promises with other promising technologies as solar, wind, goe, hydro and so on. It may very well lead to stronger research efforts and investments in the direction of the hybrid reactors. Furthermore it may lead decisions regarding existing and planned nuclear plants in anticipation of the solution for the waste problem.
World wide the idea may be propagated to use hybrids for the destruction of nuclear warheads in a world wide nuclear non proliferation strategy.
This development could lead to a much stronger nuclear component in the future energy mix.

Evidence base / storyline

Although there may be doubts about the feasibility it seems that nuclear physicist are interested in further testing out the ideas which may cause some change in research lines within nuclear physics.
The fact that the ideas revive in 2009 after a disappearance for 30 years and that they are brought forward by serious research institutions that are linked to the nuclear arms program indicates that there may be more non public evidence base.
As said before some nuclear physicists reacted with scepsis on feasibility and real advantages (fission risk as melt down etc will stay).

Plausibility

The issue seems plausible and should be monitored closely to determine European strategy?
A European study on feasibility, pro's and cons should be conducted. UK laboratory seem to be involved in the development of the laser induced confinement fusion –fission idea.

Novelty

The idea of hybrid fusion-fission energy production is not new and connected to the Fusion bomb that is triggered by fission bomb units that compress the fusion core. So we can already see articles in the public press in 1974. Still the concept stays away out of public and political debate for decades, last two years the concept seems to become revitalized at least from certain parts of the scientific community and can be considerered as (re) newed.
At the moment the attention is still limited and not many people in policy and in the scientific community will have heard about the revival of the concept, although MIT already pre published some critical remarks that were not going about the principles of a hybrid plant but mainly on the security aspects In Google time line we can find one article in 1974 about a study to the concept , 1 article in 1980 about the plans for a hybrid plant in Russia , 1 article in 1982 for the plans of a plant in the US, in 1987 an article on unknown risk of Hybrid nuclear energy. Than in 2000, 2002 and 2004 hybrid nuclear energy is mentioned as option for futuristic interstellar travel by NASA. In 2009 and 2010 in total 7 articles are describing the idea of hybrid nuclear plants that can be used as clean energy producers burning nuclear waste coming from the scientific community.

Critical/open questions…

Drivers & Inhibitors

CO2 emission is increasing despite all efforts. There is a growing energy demand in the world. US is striving for energy independency. The element of destroying nuclear waste and even nuclear arms is pushed forward. The ideas contain what we may call the non proliferation paradox. Using fusion-fission hybrid to get rid of the nuclear material produced by fission reactors that proliferate nuclear bombs.
The CO2 focus of the renewable energy discussion in combination with the focus on nuclear waste promotes this way of thinking within the nuclear community. The ideas will for the moment compete with other lines of thought on development of pure nuclear fusion and on improving nuclear fission.
Important inhibitor may be the security discussion of the fusion reactor with fission blanket.

Desirability aspects

On the short term existing nuclear research groups may not like the idea. Also green parties will not like the idea and will stress the risk of accidents.

Interests at stake

There may be military interests at stake (there is a growing problem on obsolete nuclear war heads).
Exploiters of nuclear power plants may see a challenge for investment but need policy makers to align. In countries where nuclear plants are accepted the ideas may be embraced. Development may lead to less force behind development of renewables as solar , wind , bio etc.

Emotional aspects

Nuclear energy has since the 1960's an negative charge due to the growing knowledge on radiation risks, nuclear waste and growing historical awareness on the use of atom bombs at the end of WW2 combined with the growing threat of mutual annihilation during the cold war. Small and large accidents as well as near accidents with nuclear power plants created not only real damage to health, crops and ecosystems but also strong negative emotional reaction (the Chernobyl syndrome). The invisible trans-border character of radioactive contamination may lead to international conflicts.
The link between nuclear arms and nuclear power plants also leads to negative perception of nuclear as a whole.
Never the less we can see that nuclear is more or less accepted in many countries.
The linkage of the hybrid nuclear plant to diminish or even destroy nuclear waste as well as to help to disarm, may countervail part of the negative image but cannot prevent "wild card " accidents.

Changeability aspects: Policies

Development of the hybrid line needs strategic investment that has to be added to the nuclear energy research budget or found within the nuclear energy budget. Before this analysis has to be made on feasibility and pro's and contra's. The development in the US needs to be monitored closely.
Steps in this need public debate because of the further scientific and engineering progress and emotional aspects? Any technology development in this direction should be closely watched on safety and environmental aspects.

Source of inspiration / Initial discovery point

Search string followed: energy breakthroughs nuclear fusion fission
Than: http://techpulse360.com/2010/03/05/major-fusion-breakthrough-claimed-power-plants-that-burn-nuclear-waste/

Signals /Early Indicators

Early warning could be found in the R&D funding in countries as USSR, China, Japan, Korea to the topic of hybrid fusion and fission reactor and the connected devices in the articles as well as the institutions presently involved. Part of the decisions may be hidden in secured environment (Defense).

Major Fusion Breakthrough Claimed: Power Plants That Burn Nuclear Waste

http://techpulse360.com/2010/03/05/major-fusion-breakthrough-claimed-power-plants-that-burn-nuclear-waste/

The skeptics of Hybrids at MIT : http://web.mit.edu/fusion-fission/WorkshopTalks/skepticsvg.pdf

The Plasma Fusion – Fission hybrid

http://www.sciencedaily.com/releases/2009/01/090127131654.htm
Nuclear Fusion-Fission Hybrid Could Contribute To Carbon-Free Energy Future

ScienceDaily (Jan. 29, 2009) — Physicists at The University of Texas at Austin have designed a new system that, when fully developed, would use fusion to eliminate most of the transuranic waste produced by nuclear power plants.

The invention could help combat global warming by making nuclear power cleaner and thus a more viable replacement of carbon-heavy energy sources, such as coal.

"We have created a way to use fusion to relatively inexpensively destroy the waste from nuclear fission," says Mike Kotschenreuther, senior research scientist with the Institute for Fusion Studies (IFS) and Department of Physics. "Our waste destruction system, we believe, will allow nuclear power-a low carbon source of energy-to take its place in helping us combat global warming."

Toxic nuclear waste is stored at sites around the U.S. Debate surrounds the construction of a large-scale geological storage site at Yucca Mountain in Nevada, which many maintain is costly and dangerous. The storage capacity of Yucca Mountain, which is not expected to open until 2020, is set at 77,000 tons. The amount of nuclear waste generated by the U.S. will exceed this amount by 2010.

The physicists' new invention could drastically decrease the need for any additional or expanded geological repositories.

"Most people cite nuclear waste as the main reason they oppose nuclear fission as a source of power," says Swadesh Mahajan, senior research scientist.

The scientists propose destroying the waste using a fusion-fission hybrid reactor, the centerpiece of which is a high power Compact Fusion Neutron Source (CFNS) made possible by a crucial invention.

The CFNS would provide abundant neutrons through fusion to a surrounding fission blanket that uses transuranic waste as nuclear fuel. The fusion-produced neutrons augment the fission reaction, imparting efficiency and stability to the waste incineration process.

Kotschenreuther, Mahajan and Prashant Valanju, of the IFS, and Erich Schneider of the Department of Mechanical Engineering report their new system for nuclear waste destruction in the journal Fusion Engineering and Design.

There are more than 100 fission reactors, called "light water reactors" (LWRs), producing power in the United States. The nuclear waste from these reactors is stored and not reprocessed. (Some other countries, such as France and Japan, do reprocess the waste.)

The scientists' waste destruction system would work in two major steps.

First, 75 percent of the original reactor waste is destroyed in standard, relatively inexpensive LWRs. This step produces energy, but it does not destroy highly radiotoxic, transuranic, long-lived waste, what the scientists call "sludge."

In the second step, the sludge would be destroyed in a CFNS-based fusion-fission hybrid. The hybrid's potential lies in its ability to burn this hazardous sludge, which cannot be stably burnt in conventional systems.

"To burn this really hard to burn sludge, you really need to hit it with a sledgehammer, and that's what we have invented here," says Kotschenreuther.

One hybrid would be needed to destroy the waste produced by 10 to 15 LWRs.

The process would ultimately reduce the transuranic waste from the original fission reactors by up to 99 percent. Burning that waste also produces energy.

The CFNS is designed to be no larger than a small room, and much fewer of the devices would be needed compared to other schemes that are being investigated for similar processes. In combination with the substantial decrease in the need for geological storage, the CFNS-enabled waste-destruction system would be much cheaper and faster than other routes, say the scientists.

The CFNS is based on a tokamak, which is a machine with a "magnetic bottle" that is highly successful in confining high temperature (more than 100 million degrees Celsius) fusion plasmas for sufficiently long times.

The crucial invention that would pave the way for a CFNS is called the Super X Divertor. The Super X Divertor is designed to handle the enormous heat and particle fluxes peculiar to compact devices; it would enable the CFNS to safely produce large amounts of neutrons without destroying the system.

"The intense heat generated in a nuclear fusion device can literally destroy the walls of the machine," says research scientist Valanju, "and that is the thing that has been holding back a highly compact source of nuclear fusion."

Valanju says a fusion-fission hybrid reactor has been an idea in the physics community for a long time.

"It's always been known that fusion is good at producing neutrons and fission is good at making energy," he says. "Now, we have shown that we can get fusion to produce a lot of neutrons in a small space."

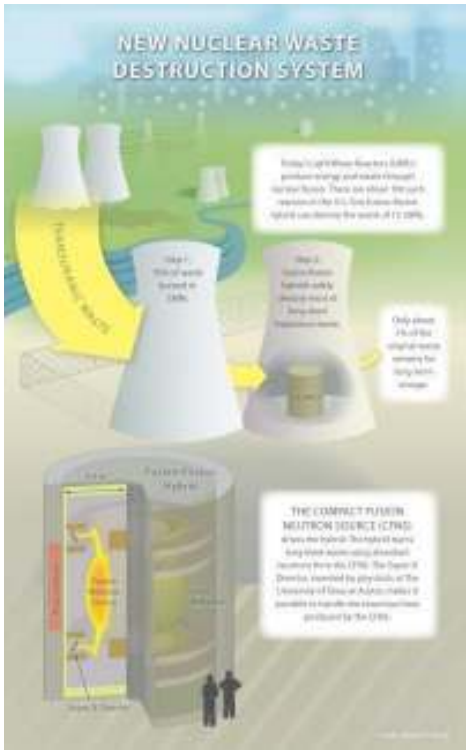
Producing an abundant and clean source of "pure fusion energy" continues to be a goal for fusion researchers. But the physicists say that harnessing the other product of fusion-neutrons-can be achieved in the near term.

In moving their hybrid from concept into production, the scientists hope to make nuclear energy a more viable alternative to coal and oil while waiting for renewables like solar and pure fusion to ramp up.

"The hybrid we designed should be viewed as a bridge technology," says Mahajan. "Through the hybrid, we can bring fusion via neutrons to the service of the energy sector today. We can hopefully make a major contribution to the carbon-free mix dictated by the 2050 time scale set by global warming scientists."

The scientists say their Super X Divertor invention has already gained acceptance in the fusion community. Several groups are considering implemented the Super X Divertor on their machines, including the MAST

tokamak in the United Kingdom, and the DIIID (General Atomics) and NSTX (Princeton University) in the U.S. Next steps will include performing extended simulations, transforming the concept into an engineering project, and seeking funding for building a prototype.

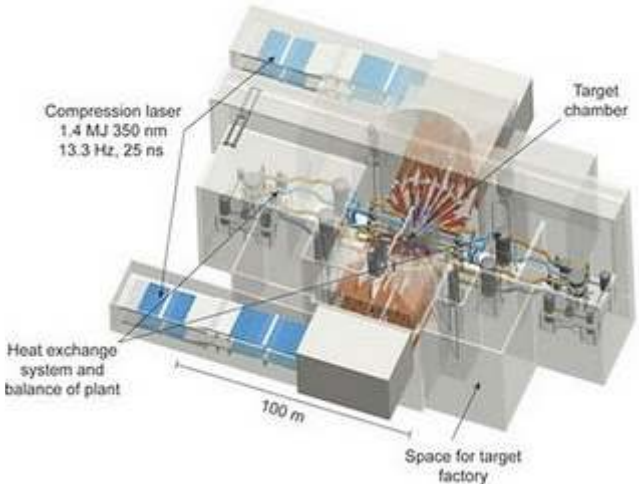


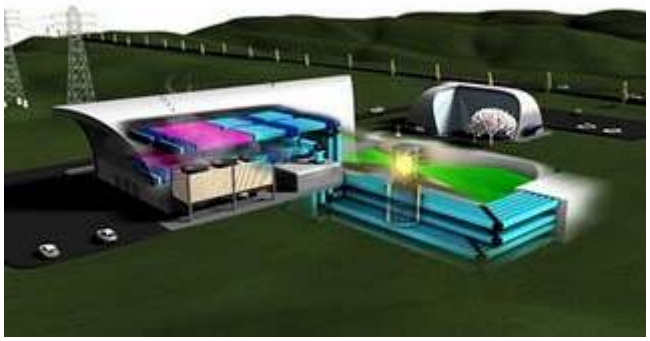
The Inertial Confined Fusion –Fission hybrid

http://nextbigfuture.com/2008/12/proposed-laser-ignition-fusionfission.html

December 09, 2008

Proposed Laser ignition Fusion/Fission Hybrid Commercial Power by 2030





LIFE, an acronym for Laser Inertial Fusion-Fission Energy, is an advanced energy concept under development at Lawrence Livermore National Laboratory (LLNL).

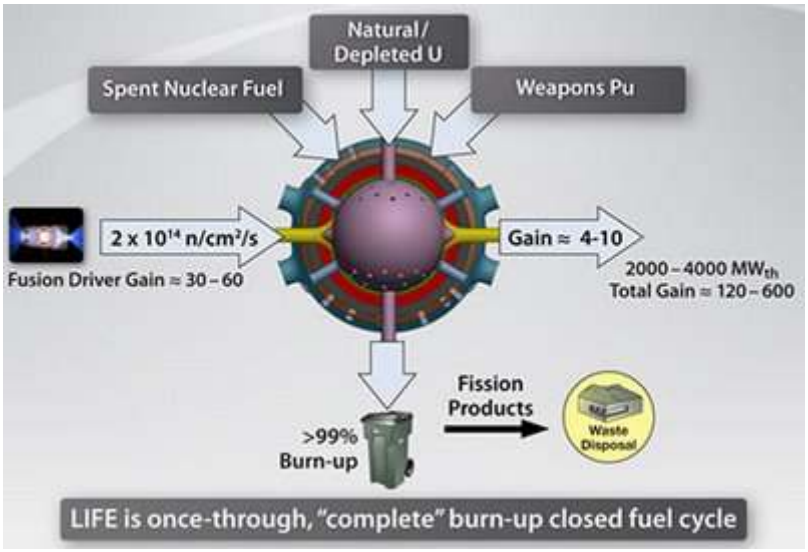
Conceptual design for a LIFE engine and power plant based on National Ignition Facility (NIF)-like fusion targets and a NIF-like laser operating at an energy of 1.4 megajoules (MJ) at a wavelength of 350 nanometers (ultraviolet), with a 2.5-meter-radius target chamber and with the final optics at a distance of 25 meters from the target. The National Ignition Campaign will begin during 2009, and ignition and fusion energy yields of 10 to 15 megajoules (MJ) are anticipated during fiscal years 2010 or 2011. Fusion yields of 20 to 35 MJ are expected soon thereafter. Ultimately fusion yields of 100 MJ are expected on NIF. The LIFE system is designed to operate with fusion energy gains of about 25 to 30 and fusion yields of about 35 to 50 MJ to provide about 500 megawatts (MW) of fusion power – about 80 percent of which comes in the form of 14.1 million electron-volt (MeV) neutrons with the rest of the energy in X-rays and ions. This is an approach which would be as good as and in some ways superior to liquid flouride thorium reactors. Improvements in lasers and cost reduction with laser components would meet the requirements of this project if current trends continue. A success with aneutronic nuclear fusion such as might occur with Bussard Inertial electrostatic fusion, dense plasma focus fusion would likely be superior to this. It would be worthwhile to fund several of these vastly superior approaches to nuclear fission and fusion for a billion or few billion each in order to get many multiple trillions

of payoff with a homerun energy success. Even partial success with one of these approaches could deal with all of the current nuclear waste (unburned fuel) which would cost tens of billions to store in a place like Yucca Mountain.

This approach to fusion generates approximately 10**19 14.1-MeV neutrons per shot (about 10**20 neutrons every second). When used to drive a subcritical fission "blanket," the fusion neutrons generate an additional energy gain of four to ten depending upon the details of the fission blanket, providing overall LIFE system energy gains of 100 to 300. (EROI 100-300)

The fission blanket contains either 40 metric tons (MT) of depleted uranium; un-reprocessed spent nuclear fuel (SNF); natural uranium or natural thorium; or a few MT of the plutonium-239, the minor actinides such as neptunium and americium, and the fission products separated from reprocessed SNF.

With the appropriate research, development and engineering program, LIFE engines could begin to provide electricity to U.S. consumers within 20 years, and could provide a very significant fraction of U.S. and international electricity demand by 2100.



Fusion-fission engines have not advance beyond the discussion stage because powerful high-average-power lasers and other required technologies did not exist. Similarly, accelerator-based schemes never advanced past the conceptual study phase, in part because a complete nuclear fuel cycle – including uranium enrichment and nuclear waste reprocessing – was still required to generate economical electricity.

Ignition experiments designed to accomplish National Ignition Facility (NIF's) goal will begin in 2010, and successful demonstration of ignition and net energy gain on NIF will be a transforming event that is likely to focus the world's attention on the possibility of ICF as a potential long-term energy option.

By integrating fuel generation, energy production and waste minimization into a single device, the LIFE engine requires neither enrichment nor reprocessing, and there is no need to remove fuel or fissile material generated in the reactor. LIFE engines can use fuels without prior enrichment and then burn them so completely that virtually no weapons-attractive material remains at the end of a plant's life.

In addition to burning natural uranium, a LIFE engine can use for its fuel the two waste streams generated by LWRs – spent nuclear fuel (SNF) and depleted uranium (DU) left over from the process used to enrich uranium.

The LIFE engine extracts more than 99 percent of the energy content of its fuel, compared to less than 1 percent of the energy in the ore required to make fuel for a typical LWR. Higher fuel utilization means that far less fuel is required to generate the same amount of energy. A 1,500-megawatt LIFE power plant could operate for 50 years on only a small roomful of fuel.

A proof-of-principle LIFE fission cycle (from startup through greater than 99 percent fuel burnup) could be demonstrated with a one-fifth scale LIFE engine within less than 10 years.

Starting from as little as 300 to 500 MW of fusion power, a single LIFE engine can generate 2000 to 3000 megawatts thermal (MWt) in steady state for periods of years to decades, depending on the nuclear fuel and engine configuration. The source of "external neutrons" drives the sub-critical-fission blanket and makes the LIFE engine capable of burning any fertile or fissile nuclear material, including depleted uranium and spent nuclear fuel.

The LIFE engine is not without its challenges, however. In order for the LIFE project to manifest itself as a demonstration power plant by the year 2020, the price of fusion targets must be decreased, new long-lived materials must be developed, and low-cost DPSS lasers are needed to reduce the cost of the laser source itself.

"Experts predict that the cost of diodes used in DPSS lasers will continue to decrease significantly over the next several years," says Diaz de la Rubia. "Building on the anticipated success of NIF, LIFE engines offer a pathway toward sustainable and safe nuclear power that significantly mitigates nuclear-proliferation concerns and minimizes nuclear waste."

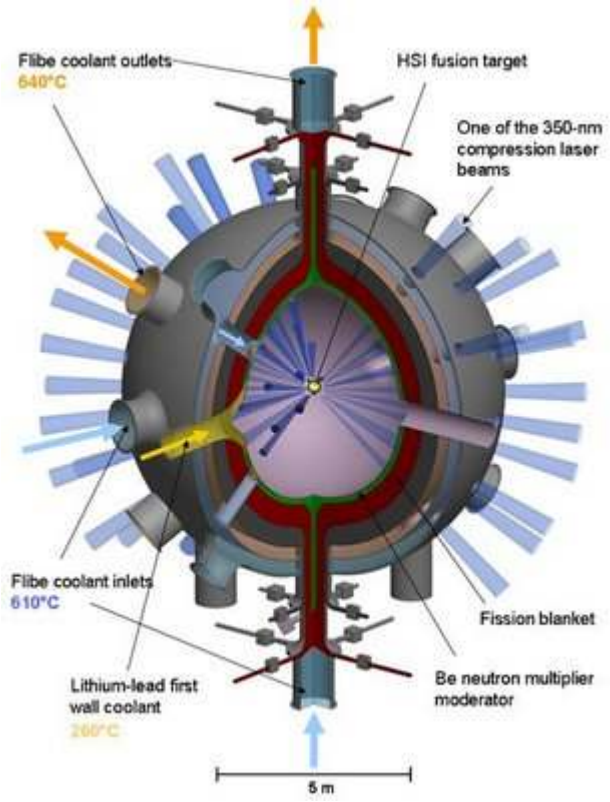
Meeting the Technical Challenges

A number of technical challenges must be overcome along the path to commercial LIFE engines by the year 2030. The key issues in the development of a LIFE fusion-fission engine are:

Achieving robust fusion ignition and burn on the National Ignition Facility (NIF).
Initial ignition experiments on NIF will begin in 2009, with the first credible attempts at achieving thermonuclear fusion in 2010 (see How to Make a Star). Success at NIF will pave the way for development of the fusion "front end" of the hybrid LIFE engine.

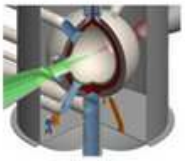
Development of a high-repetition-rate laser fusion driver.
NIF will execute one laser shot every few hours. A LIFE engine needs to execute 10 to 15 shots per second (see Inertial Fusion Energy). To achieve this high repetition rate, the LIFE fusion driver will need to use diode-pumped solid-state lasers (DPSSLs) instead of the flashlamp-driven lasers used in NIF. Experts predict that the cost of the diodes used in DPSSLs will continue to decrease significantly over the next several years, and many technologies required for DPSSLs have been demonstrated with the Mercury laser system at LLNL.

Inexpensive fusion targets.
LIFE engines will require several hundred million low-cost targets per year. The targets must be injected into the center of the LIFE chamber at a rate of 10 to 15 per second. Progress in the development of the technologies required to manufacture these targets has been made at General Atomics (GA) in San Diego, CA as well as at Livermore. Livermore and GA materials science experts believe technologies for low-cost, large-volume target manufacturing can be adopted from other industries.



Fission fuel and issues associated with the operation of the fission engine.
The "first wall," or innermost shell, of the fission blanket will be exposed to large fluxes of fast neutrons and X-rays. Ongoing research in Japan, the European Community and the United States is focused on developing new structural steels that are suitable for both fusion and fission reactors and also to the LIFE engine environment. Researchers are also investigating and producing new forms of fission fuel capable of withstanding extreme environments for increasingly longer periods. Fissile material burn fractions as high as 85 percent have already been achieved in the kind of pellet fuel form required for a LIFE engine burning highly enriched fissile fuel or plutonium.

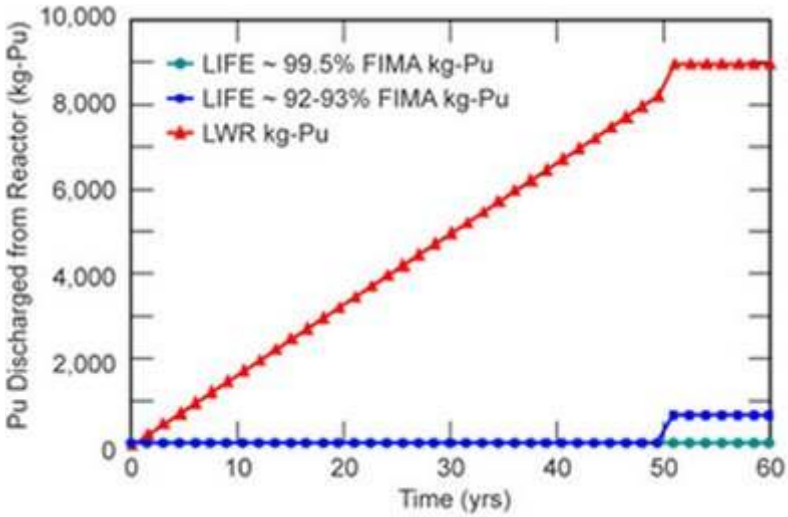
The LIFE engine is *not* a light water reactor (LWR)

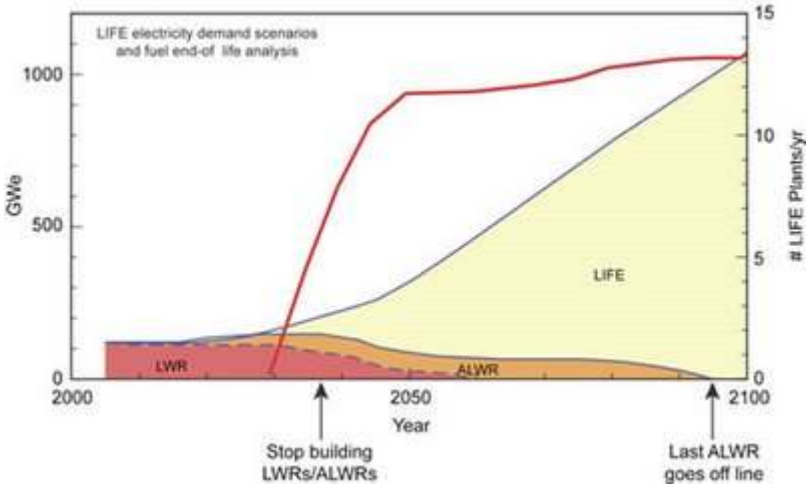


LIFE Engine

- Must maintain k_{eff} = 1 to operate
- Neutron source is fission only
- Fission spectrum moderated to thermal
- Control systems based on delayed neutron neutrons
- System extremely sensitive to reactor dynamics
- Reactor shutdown by control rod insertion (SCRAM)

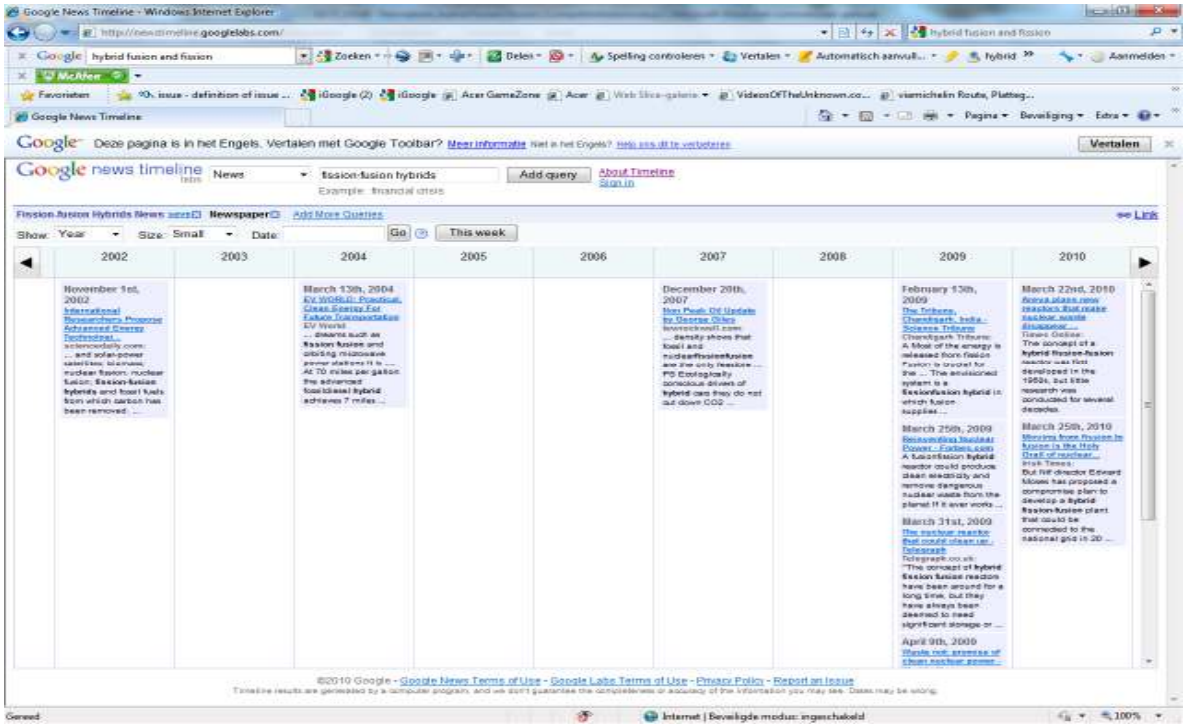
- Always subcritical / cannot go critical
- Neutron sources are fusion targets, Be(n,2n) and fission blanket
- Neutron spectrum peaks at 14 MeV, includes energies down to thermal
- Control systems based on fusion target output
- System insensitive to reactor dynamics
- LIFE shutdown by turning the laser off and removing decay heat



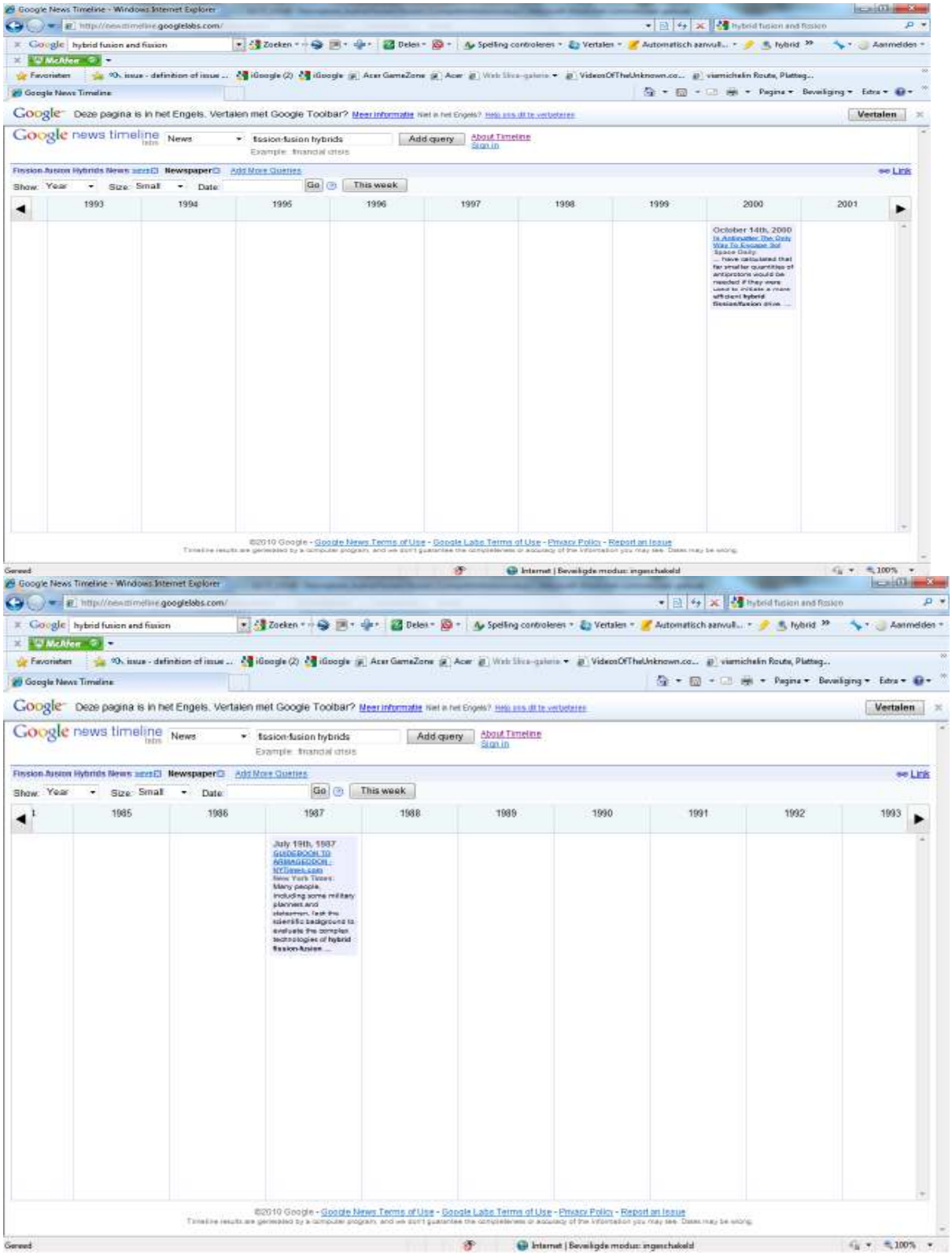


Google news timeline

Google News Timeline is a web application that organizes search results chronologically. It allows users to view news and other data sources on a browsable, graphical timeline. Available data sources include recent and historical news, scanned newspapers and magazines, blog posts, sports scores, and information about various types of media, like music albums and movies. Below follows the results of the search for news related to fission-fusion hybrids going back to 1974.



Project funded under the Socio-economic Sciences and Humanities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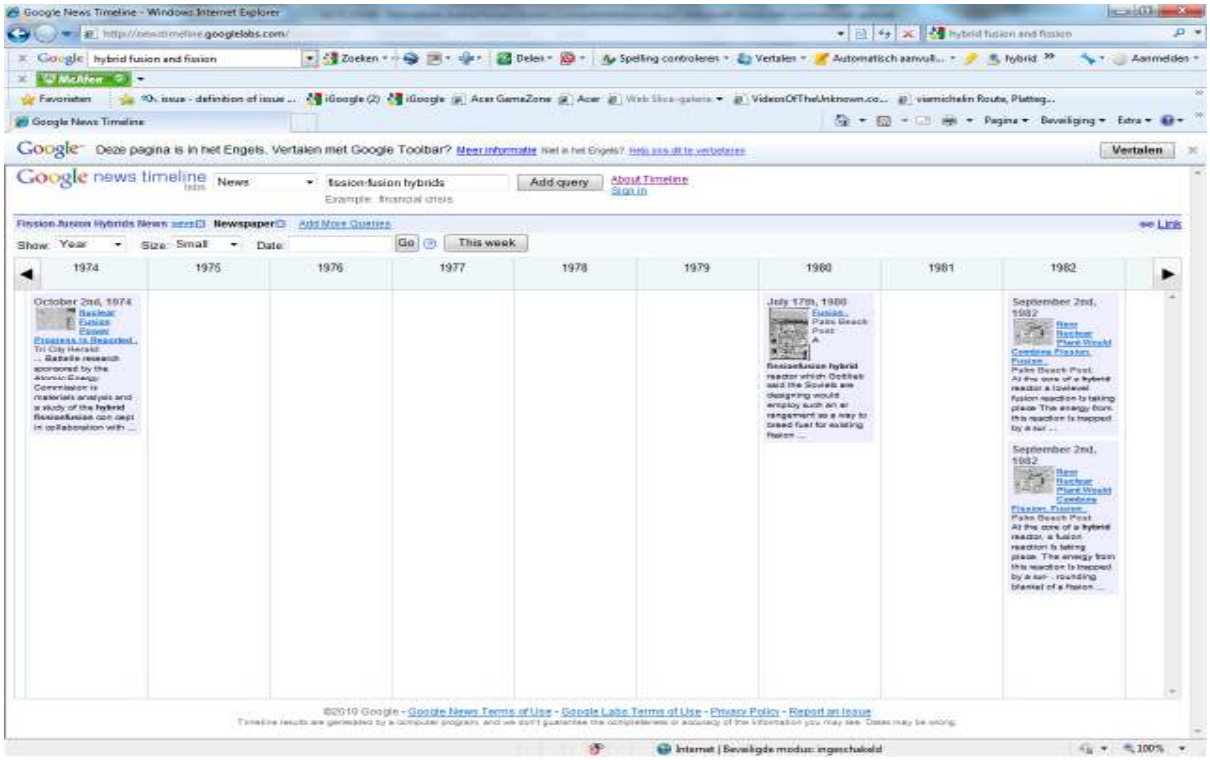
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Vertalen
Deze pagina is in het Engels. Vertalen met Google Toolbar?

Title: Renewables from the deserts (desertec)

Domain of relevance: Energy

Subdomain of relevance:renewable, coordinated foreign policy

Keywords: renewables, solar, wind, grid, international cooperation

Short description

The DESERTEC foundation and its related Industrial Initiative GmbH (Dii) focuses on the development of large solar energy plants in desert areas in Middle East and North Africa (so called MENA countries) for the European Market , using DC electricity cables (supergrid technoloy) and for large the realisation of scale production of irrigation water to increase agricultural production in the regions. The foundation and Industrial Initiative started their activities in the beginning of 2009 .
The ideas of DESERTEC and the associated Industrial Initiative were prepared by the Trans-Mediterranean Renewable Energy Cooperation (TREC) network an studies of the German Aerospace Center. These were presented by its President (His Royal Highness Prince Hassan bin Talal of Jordan) to the European Parliament in 2007. The industrial initiative is growing and the ideas of the foundation are expanding to other locations where desert areas may be exploited for solar and wind energy production. The EP and EC are responding positively and supported further studies.
The arguments for the approach stress the importance of renewable energy production and international cooperation with the MENA countries as well as the necessity of fast development of the prosperity of MENA countries (which also could lead to better chances for peace).

Impact/Implications

The successful implementation of this kind of grand ideas may have an enormous boost for other ideas that are based on the mutual international win-win relations that are connected to ecological sustainabilitity. The focus on North Africa enhances the cohesion of Europe with this part of the world and is also of importance for the need of stable southern neighbors which also serve as a buffer for migrant flows from poorer regions in Africa.
The ideas of DESERTEC have lead to a variety of similar project ideas all around the world that concentrate on the use of Deserts for solar energy production (United States, Australia, New Sealand and Asia) and may lead to a substantial increase of the solar energy in the future energy mix.

Evidence base / storyline

Studies of the German Aerospace Center are at the basis of the ideas. The Technical feasibility of the solar plants and their production and the transport though DC lines seems not to be contested. There are however doubts on the feasibility of the economic aspects (price per kilowatt) and local political stability (solar may be more vulnerable than oil production?).

Plausibility

The plausibility of the DESERTEC ideas depends on its economic aspects and the political will of all countries involved. Another concern may be the use of relative scarce materials in the solar panels.

Novelty

Since the start of the Foundation of DESERTEC the ideas on the use of Deserts for energy production for agricultural and industrial regions seem to gain momentum in public debate but are still not very widely known to relevant research communities.

Critical/open questions…

Drivers & Inhibitors

Increasing CO2 emission requires sustainable forms of energy production. Geopolitical considerations, and development of stability in MENA are a European interest. There is however a trade off with gas- supply from the East (Russia) which also should be taken into account.
Further development of solar energy cells and solar energy plants that increase the efficiency and reduce the economic costs and use of ecological constraining materials may enhance the economic feasibility. Solar energy in general may suffer of scarce resources since they are produced with either scarce materials or materials that by products of environmentally hostile mining. Also the construction of grid connections to the desert is dependent on scarce resources like copper.
Financial crisis and regional instability may slow down willingness and capacity for investments.

Desirability aspects

Interests at stake

It is clear that the initiating companies but also other companies that are involved in the development and deployment of solar and wind cell energy may have large interests.
The MENA countries may profit as well as the European Community not only economically but also in creating stable relationships.
Vested interest in present energy supply for electricity production and transfer (like Norwegian or Russian gas) as well as in competing renewable areas (like nuclear or local wind solar) may oppose the ideas.

Emotional aspects

Reaction on DESERTEC seems to be emotionally positive in general. Some fears have been expressed on energy dependency of MENA and on security of supply due to instability in the countries that were mentioned in original ideas. Therefore the concretization of plans focuses on Algeria. Local emotional reactions are not known (but may cause trouble).

Changeability aspects: Policies

It is clear that the further development of DESERTEC like plans, deserves attention of Research and innovation policy and from Foreign policy. For further development large investments are needed that should be weighted against alternatives as nuclear or emphasize on local production.

Source of inspiration / Initial discovery point

At the beginning of the SESTI project – idea of desert use for solar was an issue in the Netherlands Horizon scan (2005) – during a presentation on the potential of Africa in a EFONET workshop in 2009 the DESERTEC initiative was mentioned. Search string followed: breakthroughs solar deployment.

Signals /Early Indicators

The speech of His Royal Highness Prince Hassan bin Talal of Jordan (former president of the Club of Rome) in 2007 to the EP was indicating that there was a strong lobby starting to advocate the ideas of DESERTEC. Early signals on the development of these ideas could have been found in the discussion of the Trans-Mediterranean Renewable Energy Cooperation, which was founded in 2003 by the Club of Rome and the National Energy Research Center Jordan. At that moment these ideas were not spreading to wider communities, although references to these kind of ideas was made in the Netherlands horizon scan of 2007.
After the speech Prince Hassan in the EP and the positive sounds from the EC the attention grew in the world press and lead to a growing interest of companies and people for the ideas of the foundation that now seem to spread worldwide (to Australia, North America, New Sealand etc). Next to this there is an increase of interest for the connected Industrial cooperation which now focuses on the Sahara.

Further signals will to monitor are official decisions of governments of the countries where the DESERTEC foundation spreads his ideas, as well as investments of companies in concrete DESERTEC oriented projects.

Also reactions of competing areas of energy production should be monitored.

In Google news timeline DESERTEC was mentioned in 3 articles in 2008, which raised to an average of 10 yearly articles in 2009 and 2010

Original lead : http://www.desertec.org
For the industrial cooperation : http://www.dii-eumena.com/

http://www.desertec.org/downloads/articles/press_release_en_05.pdf
http://www.desertec.org/en/global-mission/questions-answers/#c807
http://www.bloomberg.com/news/2010-10-26/sahara-solar-energy-needed-to-ease-reliance-on-russia-eu-says.html
http://www.scientificamerican.com/article.cfm?id=solar-cells-prove-cleaner-way-to-produce-power
http://green.blogs.nytimes.com/2010/03/17/more-firms-join-desertec-solar-project/

Original presentation of the idea of DESERTEC

The consortium consists of the DESERTEC Foundation, Munich Re, Deutsche Bank, Siemens, ABB, E.ON, RWE, Abengoa Solar, Cevital, HSH Nordbank, M & W Zander Holding, MAN Solar Millennium, and Schott Solar.[5][6][8][18] Press investigations point to a number of more interested parties - among them ENEL , Électricité de France, Red Eléctrica de España and companies from Morocco, Tunisia and Egypt.

http://www.reuters.com/article/idUSTRE57N00920090824?pageNumber=1&virtualBrandChannel=11613

Europe's Saharan power plan: miracle or mirage?

Sun, Aug 23 2009

By Tom Pfeiffer, 23/08/2009

RABAT (Reuters) - A 400 billion euro ($774 billion) plan to power Europe with Sahara sunlight is gaining momentum, even as critics see high risks in a large corporate project using young technology in north African countries with weak rule of law.
Desertec, as the initiative is called, would be the world's most ambitious solar power project. Fields of mirrors in the desert would gather solar rays to boil water, turning turbines to electrify a new carbon-free network linking Europe, the Middle East and North Africa.
Its supporters, a dozen finance and industrial firms mostly from Germany, say it will keep Europe at the forefront of the fight against climate change and help North African and European economies to grow within greenhouse gas emission limits.

Others warn of numerous pitfalls, including Maghreb politics, Saharan sandstorms and the risk to desert populations if their water is diverted to clean dust off solar mirrors.
They say the concentrated solar power (CSP) technology behind Desertec involves greater costs and risks than the fast-growing patchwork of smaller-scale photovoltaic cell installations that generate most of Europe's solar energy today.
Desertec's founders are lured by the fact that more energy falls on the world's deserts in six hours than the world consumes in a year.
"The Sahara offers every advantage you want -- proximity to Europe, virtually no population and more intense sunlight," said George Joffe, a research fellow and Maghreb expert at Cambridge University, who is not affiliated to the plan.
"It would be mad to pass up this opportunity."
Proposed by the Club of Rome, an international group of experts that suggests solutions to global problems, Desertec became an industrial project last month when reinsurer Munich Re hosted its launch at its headquarters in the Bavarian capital.
"We have a special relationship with climate change: it affects our core business, the insurance of weather-related natural catastrophes, which count among the most expensive losses we have to bear," said Peter Hoeppe, Head of Munich Re's Geo Risk Research department.

EMISSIONS GOALS
Many European governments aim to cut their greenhouse gas emissions by 80 percent below 1990 levels by 2050.

Desertec's backers say it would also be a positive gesture from the developed world to countries of the Middle East and North Africa, which stand to suffer most from the more frequent droughts and desertification blamed on global warming.
They have yet to draw up a business plan or specify how it will be funded but hope to recruit shareholders and partner companies from a variety of countries.
Desertec officials say the Sahara could one day deliver 15 percent of Europe's electricity, but expect the plan to advance in small stages with completion not before 2050.
Supporters of more established solar energy technology, such as photovoltaic cells, argue decentralized generation will prove more popular as falling prices make the heavy infrastructure needed for CSP unviable.
They also think European governments, which already accept the risk of importing energy from north African countries such as Algeria, would given the choice opt for the security of producing renewable energy within their own borders.
"Sahara power for northern Europe is a mirage," said Hermann Scheer, a member of Germany's parliament and head of the European Association for Renewable Energy.
"Those behind the project know themselves that nothing will ever come out of this," said Scheer, an architect of renewable energy policy in Germany, which included a strong emphasis on photovoltaic technology.
Scheer said the costs of Desertec were being downplayed artificially and its technical capabilities over-estimated.

"EVERYONE LOVES IT"
Desertec would need 20 or more efficient, direct-current cables each costing up to $1 billion to transmit electricity north beneath the Mediterranean.
CSP installations placed in the Sahara generate around 30 percent more power per area than in southern Spain, according to Morocco's renewable energy agency CDER.
"Desertec can help reduce emissions in Europe and foster economic and social development in northern Africa, so everyone loves this project," said Santiago Siage, head of Desertec consortium member Abengoa Solar.
Abengoa is developing installations combining CSP with combined-cycle gas power generation in Morocco and Algeria.
Southern countries that import most of their energy like Morocco, Tunisia and Jordan would also benefit from Desertec.
Morocco buys in 96 percent of its energy and subsidizes fuel to make it more affordable for the poor, a massive drain on state resources that could be used to fight poverty and bring services to isolated rural areas.
The Moroccan government says Desertec could solve Morocco's energy dependency and leave plenty of power for Europe.
"Morocco doesn't have even 1 percent of Europe's energy consumption, so let's be realistic," said Said Mouline, the head of Morocco's renewable energy agency. "We would be generating enough power for us, and for export, for the next 100 years."

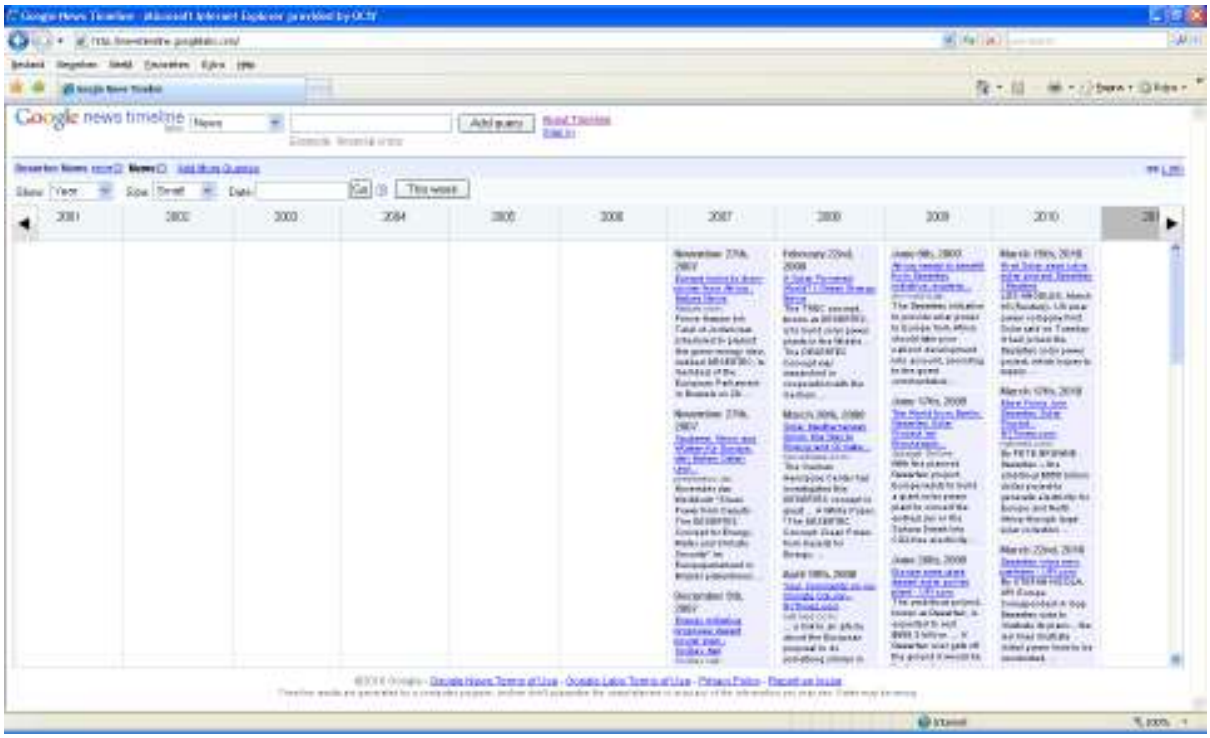
EXPLOITATION?
Among hazards facing the scheme is the fact that Desertec would need tight coordination between governments to succeed, yet Maghreb states have tried and failed for two decades to integrate their economies and deepen political ties.
The border between Morocco and Algeria is shut and relations are poisoned by a disagreement over the Western Sahara.
Morocco says it has already identified sites to place the curved solar mirrors, not deep in the Sahara but in populated areas just north of the desert to ensure a supply of water to clean mirrors and cool turbines.
Algeria has the biggest chunk of desert and private Algerian firm Cevital has signed up for Desertec, but Africa's second-largest country is isolated and struggling to reform a Soviet-style economy after a brutal civil conflict in the 1990s.
The government has tightened terms on inward investment and says it will only work with Desertec if it allows partnerships between Algerian and foreign firms and a transfer of technology.

"If these conditions are not met, we are not interested," said Algerian Energy and Mines Minister Chakib Khelil. "We don't want foreign companies exploiting solar energy from our land."
Analysts play down the risk to Desertec's infrastructure posed by Al Qaeda-aligned rebels based in Algeria, saying investment risks pose a far bigger problem.
"There is the risk of expropriation of assets, reneging on license agreements, corruption and bureaucratic red tape which could stop things getting off the ground," said Henry Wilkinson of Janusian Security Risk Management.
Wolfram Lacher of Control Risks consultancy agreed: security risks can be managed, but the project could become entangled in broader talks between the EU and North Africa on energy, investment and trade.

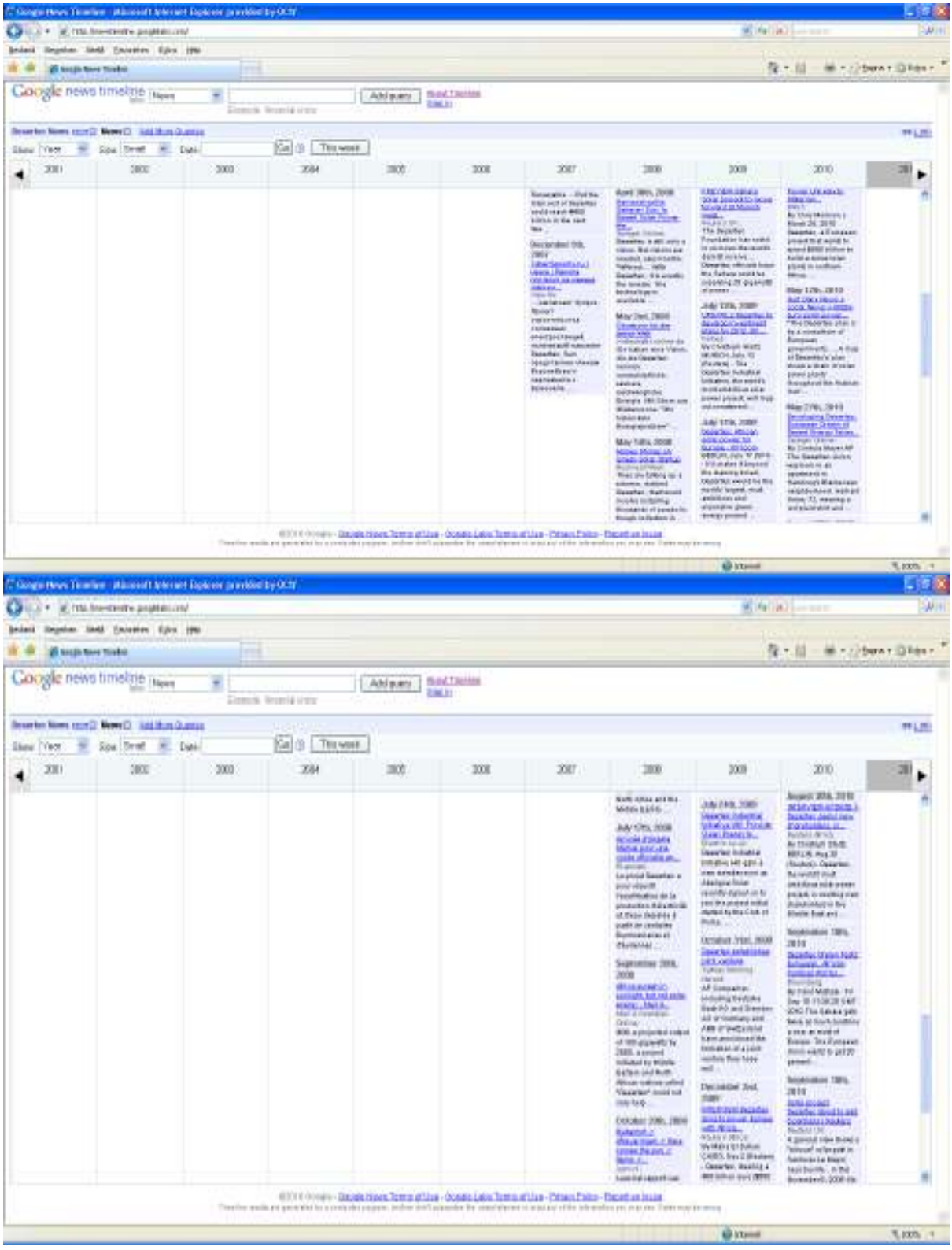
(Additional reporting by Erik Kirschbaum, Christoph Steitz, Jonathan Gould and Hamid Ould Ahmed; Editing by Gerard Wynn and Sara Ledwith)

Google timeline

Google News Timeline is a web application that organizes search results chronologically. It allows users to view news and other data sources on a browsable, graphical timeline. Available data sources include recent and historical news, scanned newspapers and magazines, blog posts, sports scores, and information about various types of media, like music albums and movies. Below follows the results of the search for news related to DESERTEC going back to 2007



Project funded under the Socio-economic Sciences and Humanities



Title: Bio-mimics as leading principle for real renewable energy

Domain of relevance: Energy

Subdomain of relevance: renewable energy

Keywords: renewable, solar, biomass, biomimics, sustainability

Short description

Ideal renewable energy production uses CO2 for its own construction and should be based on mimicking biological concepts which implies it should not only sequestrate CO2 but also utilize CO2 for the production of energy carriers.
Many of the energy sources that are considered to be renewable are characterized by either a reduced level of CO2 emission and/or lower levels of other ecological damage or risk. Although solar and wind are energy sources that theoretically could be seen as energy sources that could be harvested without CO2 production it is known that the production of solar cells and solar (furnace) plants as well as wind mills require materials that become available through mining but also the application of energy that produces CO2. This applies also for nuclear energy plants.
Although the amount of input energy and material may differ for each technology it is clear that the present concepts are far from CO2 neutral and clean.
The ideal renewable energy therefore would be a source that in stead of producing CO2 is using CO2 for its own production. Nature provides the perfect examples of this source in the form of chloroplasts in plant cells that use CO2, water (and a minimum of minerals) for their construction and that produce Carbo-Hydrates as sugar and polysaccharides which are easy to transfer in different types of fuel.
The use of plants to produce fuels like alcohol therefore may be seen as a CO2 neutral source of energy. Unfortunately this way of production of energy competes for agricultural areas and other areas that play a role in natural sequestration of CO2 and is therefore considered to be less sustainable. Nevertheless agricultural and forestry waste can be used as a CO2 recycling and therefore neutral source of energy, provided that a surmount of sequestration is created to compensate the CO2 that is released by the use of the fuel. The use of the biological (-inspired) pathways for energy production and conversion or even storage seems to be underused in this respect. This could alter by modifying agricultural crop in a way that it can produce food and at the same time waste that is easy to converse to energy and/or by using and acquiring knowledge on the biological systems to create artificial systems that produce energy carriers in a similar and perhaps more efficient way than the biological models and that can be placed in areas where sequestration of CO2 can be increased substantially like in desert areas.
The development of biologically inspired energy production therefore is attracting gradually increasing attention also within nanotechnology.

Impact/implications

If solar energy would become available through the use of bio-mimics this would have great impact on energy production, since it would be as close as we can get to a real sustainable way to produce energy , by catching

sunlight on areas to sequestrate the over- emission of CO2 and by producing fuels that are completely recycled. A more close by impact is that the bio like (use of natural CO2 sequestration) solutions may be preferred in the development of renewables.

Evidence base / storyline

Although much ongoing work is seeking to understand basic processes of photosynthesis and chemical conversion, such as light harvesting, electron transfer, and ion transport, application of this knowledge to the development of fully synthetic and/or hybrid devices is still in its infancy. To develop systems that produce energy in an efficient manner, it is important both to understand the biological mechanisms of energy flow for optimization of primary structure and to appreciate the roles of architecture and assembly. Whether devices are completely synthetic and mimic biological processes or devices use natural bio molecules, much of the research for future power systems will happen at the intersection of disciplines.

In 2007 the National Academies of the US and the Keck Foundation held a meeting to discuss the development of new applications for nanotechnology with the goal of identifying challenges where the convergence of nano science and physical and biosciences could provide a revolutionary outcome. One area clearly in need of new technologies is biological and bio-mimetic methods of energy conversion. Within this broad area, focus was given to two specific applications: the conversion of solar energy into useful electrical or chemical energy and the production of power for *in vivo* medical devices.

Plausibility

It is clear that improved biomass use for energy productions has certain plausible prospects, if the artificial reproduction of biological energy conversion processes is feasible within a relevant time frame is less clear. But it is certainly an area that needs to be examined and followed very closely.
Solar cells can be seen as the reverse of device that produces light like light bulbs and screens, here we saw that the pathway went from low energy efficient concepts using heated wires and gases and electron beams to biologically inspire high energy efficient devices as LED. For solar cells a more fast track could be made to biologically inspire high efficient (under different light regimes) devices to collect solar energy in different storable energy carriers.

Novelty

Using biomass for energy production has been already long time part of the energy discourse, the idea to use ecological principles for energy production is rather new and comes from nanotechnology and ideas around improving energy efficiency and sustainability of biomass producing systems.

Critical/open questions…

Drivers & Inhibitors

Increasing CO2 emission requires sustainable forms of energy production. Bio-mimics and improving biomass producing natural systems provide a way to be close to natural sustainability this idea may be a powerful driver, although as always with competing other renewables as competitors.
Although the use of these bio concepts seems to be natural it should be clear that fulfilling the growing energy demand of the human population even with the most sustainable solution always adds flows of energy and substances to the ecosystem for biological systems this mainly implies water , oxygen and carbon-dioxide (CO2)

plus nutrients as nitrates, sulphates and magnesium. The beauty of the bio- inspired concept is that accumulation in the atmosphere could be regulated.

Desirability aspects…

Interests at stake

The ideas are promoted from the nanotechnology foresight corners which have a particular research interest. Successful application may compete with other renewable concepts. The principle of bio like solar energy production may be in the interest of oil industry because it does not necessarily imply the choice for Hydrogen, The idea of CO2 recycling allows also carbon containing energy carriers.

Emotional aspects

The emotional aspects are unclear, on one hand the ideas appeal to a very clean approach of energy production on the other hand it may be perceived as manipulation of nature which is a sensitive area.

Changeability aspects: Policies

Developmental aspects need a clear research agenda also to steer present solar and other renewable energy concepts into a more "bio-like" sustainable mode. In Germany there is a project that uses wood (sequestrated carbon) in stead of aluminium or other metals to construct windmills.

Source of inspiration / Initial discovery point

Search string followed: breakthroughs bio -energy

Signals /Early Indicators

Plea of the NAAS for biological and bio-mimic approaches:
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1459341/

Mimicking Nature, Water-Based 'Artificial Leaf' Produces Electricity

http://www.sciencedaily.com/releases/2010/09/100924121218.htm

Scientists Mimic Chloroplasts - Meaning Solar Cells That Fix Themselves
http://www.science20.com/news_articles/scientists_mimic_chloroplasts_meaning_solar_cells_fix_themselves

Approaches for biological and biomimetic energy conversion

Out of : http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1459341/

Proc Natl Acad Sci U S A. 2006 April 4; 103(14): 5251–5255. PMCID: PMC1459341
Published online 2006 March 27. doi: 10.1073/pnas.0506694103.

ABSTRACT http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1459341/

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Approaches for biological and biomimetic energy conversion

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Contributed by
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This article highlights areas of research at the interface of nanotechnology, the physical sciences, and biology that are related to energy conversion: specifically, those related to photovoltaic applications. Although much ongoing work is seeking to understand basic processes of photosynthesis and chemical conversion, such as light harvesting, electron transfer, and ion transport, application of this knowledge to the development of fully synthetic and/or hybrid devices is still in its infancy. To develop systems that produce energy in an efficient manner, it is important both to understand the biological mechanisms of energy flow for optimization of primary structure and to appreciate the roles of architecture and assembly. Whether devices are completely synthetic and mimic biological processes or devices use natural biomolecules, much of the research for future power systems will happen at the intersection of disciplines.
Keywords: biotechnology, nanotechnology, photosynthesis, photovoltaic

Recently, the National Academies and the Keck Foundation held a meeting to discuss the development of new applications for nanotechnology[¶] with the goal of identifying challenges where the convergence of nanoscience and physical and biosciences could provide a revolutionary outcome. One area clearly in need of new technologies is biological and biomimetic methods of energy conversion. Within this broad area, focus was given to two specific applications: the conversion of solar energy into useful electrical or chemical energy and the production of power for *in vivo* medical devices. The following sections will provide both an economic perspective on current photovoltaic (PV) technology and an overview of the various research efforts toward using or mimicking biological systems to improve current and future energy-conversion systems.

The total energy consumption in the United States in 2004 was 99.74 quadrillion Btu (British thermal units) (1.05×10^{20} J), and this value has been increasing at a rate of ≈1.4% per year since the early 1980s. Currently, ≈22% of the energy is provided by coal, ≈23% from natural gas, 37% from petroleum (excluding alcohol), 8.2% from nuclear power, 2.7% from hydroelectric sources, and 2.8% from wood, waste, and alcohol. Solar energy accounts for <0.1% (1).

The average solar radiation available for a flat-plate collector in the U.S. is 5 kW·h/m^2 per day (1 kW·h = 3.6×10^6 J). Conservatively, 100 million residences, each with an available roof area of 90 m^2, receive ≈5×10^{19} J of solar energy, which is equal to half of the annual energy consumption in the U.S. Typical commercially available PV cells offer nominal efficiencies of ≈15%, with higher levels attainable up to a theoretical efficiency for silicon PV cells of 32%; however, a significant fraction of the installation costs are related to infrastructure, such as supporting framework, wiring, power inverters, and grid connections. For example, in a study published in 2003 of a 35-kW PV array (2), the total reported cost was $239,945 ($6.86/W), with infrastructure comprising 35–40% of the total amount. This system saved $2,678 per year in energy costs compared with the preinstallation expenditures. If, hypothetically, the same installation could be made with cells at 1/10 the current price and 32% efficiency but the same infrastructure costs, the system would cost ≈$100,000 and save ≈$8,000 per year. Based on these values, it is apparent that improving efficiency and reducing device costs is vital to using PV technologies but that addressing infrastructure costs will also be necessary.

The losses in energy conversion associated with the fundamental behavior of silicon can be overcome by using alternative materials and structures, some of which may be designed to mimic natural biological processes. Although direct solar-to-hydrogen conversion methods may prevent some of the losses associated with fully photosynthetic systems (see below), they are limited by a thermodynamic efficiency of 13–15% (3). More recent calculations suggest that this limit may be higher for terrestrial systems under special circumstances [for example, the energy needed to hydrolyze water can be reduced by using waste heat and appropriate photosensitizers and catalysts (4)], but the losses associated with storing and transporting the hydrogen and in converting it into electricity still remain.

The following sections of this paper will focus on materials and devices that use synthetic and/or hybrid approaches to mimic natural photosynthetic energy-conversion processes.

Photosynthesis.
Photosynthesis involves a complex set of reactions that start with the absorption of a photon. The resulting energy can be converted into ATP or fed into a light-independent process that results, in the presence of chlorophyll, in the conversion of carbon dioxide and water into carbohydrate, oxygen, and water. Oxygenic photosynthesis also results in the production of oxygen and is used by plants, algae, and oxyphotobacteria. Anoxygenic photosynthesis occurs in simpler organisms, such as green and purple photosynthetic bacteria, and produces a carbohydrate, a reduced acid, and water from carbon dioxide and molecules such as hydrogen sulfide or an organic acid, which serve as electron sources.

The energy absorption and transduction scheme depends on both spatial and molecular configurations. The reaction center is a protein complex in which photon energy is converted to an electrochemical potential in the form of charge separation across a membrane. The primary electron donor is either chlorophyll or bacteriochlorophyll, and the electron receptor is bacteriochlorophyll (type I) or bacteriopheophytin (type II). In type-I reactions, the electron travels from an iron–sulfur complex in the reaction center to other iron–sulfur molecules and finally into ferrodoxin, a water-soluble protein that can be transported away from the membrane. In type-II reactions, the electron is passed to a quinone electron acceptor and then to a second quinone. When this second quinone receives another electron (from a separate reaction), it forms a quinol, which can be carried away by diffusion.

Photon capture and energy transfer to the reaction center are highly dependent on an antenna structure that acts as a light harvester to increase the frequency and effective cross section for absorption. Spontaneous absorption of a photon has been estimated to happen at a rate of 1.7×10^{-2} to 1.7×10^{-3} per s (5). There is a practical limit to antenna molecule size; calculations based on either energy-transfer times or hopping kinetics result in a limit for antenna size of ≈200 chromophores (5).

The electron donor for each reaction in photosynthesis can be characterized by the energy of the photon that is used: photosystem I (PSI) functions at 700 nm (1.77 eV) (1 eV = 1.602×10^{-19} J), photosystem II functions at 680 nm (1.82 eV), green sulfur bacteria function at 840 nm (1.48 eV), and green nonsulfur bacteria function at 870 nm (1.43 eV). For comparison, the high-energy photons in the UV region have energies in the range of 3.10–4.28 eV. The difference in energy between the absorbed photon and the electron donor is lost as heat, just as the excess energy is lost when a high-energy photon is absorbed by a silicon PV cell. Most plants are not able to deal with the excess energy of UV photons and often do not absorb them at all. If these high-energy photons were absorbed, they might reduce the genetic stability of the plant's genome (6), destroy the light-harvesting complex (7), or induce apoptotic-like (programmed cell death) changes (8). Photons of lower energies are also not used for photosynthesis. It is possible to calculate the energy efficiency of green plants, given the spectral distribution of light at the Earth's surface; the net energy has been shown to have an upper bound of 9.2% (9). Because some of this energy is consumed by the plant, a maximum net efficiency of ≈5% is commonly reported (9–11).

Summarizing the sources of energy losses in natural photosynthetic processes provides a means to prioritize synthetic efforts (12): 47% of the energy from the available incident solar radiation is lost because the energy falls outside of the range that is used. Thirty percent of the absorbed energy is lost to incomplete absorption or absorption that does not feed the photosynthesis process. Twenty-four percent of the useable absorbed energy is wasted because of the degradation to the energy level that can be processed by the photosystems. Sixty-eight percent of the remaining energy is used to create chemical energy in the form of glucose. Finally, in an ideal system, 30–40% of the glucose is used by the plant for its natural processes.

Light-Driven Proton Pumps.
Bacteriorhodopsin has been recognized as one of a few natural light-driven proton pumps (13, 14). After absorbing photon(s), these proteins cycle through a series of intermediate conformations that result in a proton being transported to the outside of the cell. Purified halorhodopsin has been shown to change its transport mechanism as a function of the wavelength of incident light, from a single-photon chloride transporter to a two-photon proton pump (15). Site-specific mutants of bacteriorhodopsin were able to reproduce this behavior (16), showing that the ion specificity can be designed. Functional bacteriorhodopsin has also been transfected into naturally nonphotoactive organisms (17, 18), introducing the possibility of producing specialized organisms that are optimized for solar energy conversion.

Using Biological Systems.
Artificial systems to mimic photosynthesis have been fabricated by self-assembling heterolayers of proteins. One approach has been to layer photochromic proteins such as GFP with organic molecules such as viologen through Langmuir–Blodgett techniques (19). Similarly, a protein-based photodiode was fabricated by using layer-by-layer assembly of cytochrome *c* and GFP onto gold substrates. The cytochrome *c* was covalently tethered to the gold surface, and GFP was chemisorbed onto the cytochrome *c* layer (20); the device produced reproducible photocurrents with repeated on/off cycles. Photosynthetic reaction centers from purple bacterium have been incorporated into devices by self-assembling them using polyhistidine tagging of gold-indium tin oxide surfaces and stabilizing them with surfactant peptides before coating with a protective organic semiconductor layer (21).

Bacteriorhodopsin and other light-driven proton pumps have also been used to generate photocurrents as isolated proteins. Some of the earliest work (16) found that surfaces coated with the protein could produce a

transient signal similar in behavior to normal photoreceptors; this phenomenon has been shown to function at a variety of electrolyte/electrode interfaces (22, 23). Although these findings were quickly extended into efforts to make artificial retinas (24) and protein-based optical storage devices (25–29), issues of interfacing the proteins with conventional semiconductors led to the development of synthetic or modified bacteriorhodopsin devices using organic cations.[ll]

PSI has been used recently as an optical trigger for a retinal prosthesis (31). The concept was based on previous work on retinal prosthesis in which patterned electrical stimuli where shown to elicit visual perceptions (32). The isolated PSI reaction centers were able to produce >1 V, which is sufficient to trigger neural responses. The ability to reconstitute plant proteins into mammalian cells to mimic physiological function provides an interesting glimpse at the potential for future hybrid systems.

For many protein-based devices, harnessing the natural energy-transfer process for devices requires that the molecules be patterned with specific directional and spatial orientation (33, 34). There has been much work done to develop methods to assemble both bacteriorhodopsin and PSI into oriented, two-dimensional arrays (35, 36). Bacteriorhodopsin has the capability of assembling *in vitro* into stable, well ordered two-dimensional arrays (28). Koyama *et al.* (33) used antibodies to mediate the orientation of purple membrane monolayers and demonstrated that the greatest photocurrent was observed when the cytoplasmic side of the purple membranes was directed to the electrode, with opposite and random orientations producing the weakest and intermediate values, respectively. Similar to the bacteriorhodopsin work, Greenbaum and coworkers (34) found that self-assembling PSI on organosulfur-modified gold substrates imparted stability in laboratory experiments and for long-term storage. By controlling the directionality of PSI, electrostatic potentials of single PSI reaction centers could be measured through Kelvin force probe microscopy under dark–light illumination (34).

Fully and Partially Synthetic Systems: Artificial Photosynthesis.
Efforts to mimic natural photosynthetic processes have been under way since 1912, when Giacomo Ciamician (37) envisioned artificial photosynthesis to be “the photochemistry of the future.” Considerable progress has been made both to understand the molecular mechanisms of photosynthesis and to develop synthetic and engineering methods to extend the biological processes to synthetic systems (38–40). In the last 20 years, there have been significant efforts to synthesize and engineer artificial light-harvesting antennae and reaction centers, and a wide variety of donor and acceptor molecules and macromolecular architectures have been produced and characterized (41, 42). Recently, the advent of nanotechnology has provided a wealth of materials (nanoparticles, nanowires, carbon nanotubes, fullerenes, etc.) that exhibit novel physical, chemical, and optical characteristics that can be harnessed to improve existing methods of energy transduction (43–46).
In almost all cases, whether the devices are composed of natural biomolecules or synthetic organic or inorganic molecules, the architecture and spatial arrangements at multiple length scales have proven to play a pivotal role (39, 41, 47). Although it is very difficult to reproduce the dynamic physics of biological self-assembly outside of living systems, applying similar noncovalent chemistries and using traditional engineering methods to produce well ordered systems have been shown to be plausible methods for producing artificial photosynthesis (40, 48–50).

In photosynthesis reaction centers, photo-induced energy flow is controlled through a series of spatially arranged chromophores that are electronically coupled to produce a gradient such that energy is transferred from absorbed photons to the reaction center. Because spatial precision is critical to this energy-transfer process, extensive work has explored the synthesis and characterization of modular architectures where photoactive components are linked together covalently in a precise manner (20, 41, 42, 51–53). The ability to couple donor and acceptor molecules covalently allows one to overcome the limitations of diffusion. It also allows one to probe systematically how chain architecture, distance between donor and acceptor, and differences in their energy levels affect energy transfer and charge separation.

One of the earliest architectures synthesized and probed was molecular dyads where multiple types of chromophores were linked into linear, one-dimensional chains. Dimers composed of porphyrin or chlorophyll were first shown to mimic the reaction center special pair (BChl *b*) (54, 55). The dimers were followed by molecular dyads consisting of a carotenoid polyene and chlorophyll to mimic the properties of the light-harvesting antenna (38, 51, 56), because the carotenoid increases the solar absorption cross section of chlorophyll and transfers excitation energy to the chlorophyll.

A significant challenge for artificial photosynthesis is the ability to achieve long-lived charge separation and prevent charge recombination (41, 52, 57, 58). One way to address this challenge has been to integrate successive energy gradients into covalently linked molecular dyads that will quickly shuttle electrons away from the excitation site to more stable sites. A molecular triad made up of carotene, porphyrin, and naphthoquinone (C-P-Q) demonstrated photoinduced charge separation that could be stabilized up to several microseconds (59). A molecular linear pentad consisting of carotenoid-polyene-metallated (Zn) porphyrin-freebase porphyrin-diquinone [C-P_{Zn}-P-Q_A-Q_B] has been shown to perform efficient photoinitiated electron transfer and produce a charge-stabilized state with an overall quantum yield of 0.83 and a lifetime of 55 s. The molecular order of the pentad was critical for charge stabilization because it was constructed such that all of the possible electron transfer pathways would converge to the same final charge-separated structure (60). Much of this work has recently been extended using fullerenes (C_{60}) as the electron acceptors; examples include triads such as a porphyrin-bearing fullerene covalently linked to a carotenoid polyene (41, 57, 61–65).

Electron transfer properties of molecular wires, in which donor and acceptor molecules are covalently linked by molecular bridges (donor–bridge–acceptor, DBA), have also been studied as model systems for short-range energy transfer (53, 66). Although the electronic structure of these systems typically limits the distances over which efficient charge separation can occur, Wasielewski, Ratner, and coworkers (53) reported in 1998 a set of tetracene (donor) pyromellitimide (acceptor) DBA molecules with nearly distance-independent electron transfer. Their results emphasize the importance of energy matching between donor and acceptor molecules to achieve efficient energy transfer, even at distances as large as 40 Å.

Light-harvesting and energy-transfer properties of linear photoactive polymer systems have also been investigated (67–69). In some of the earliest work, a trapping molecule was attached to the polymer backbone, and the effect of trap sensitization through excitation of the main polymer chromophore was studied (70). One of the major difficulties of using linear polymeric systems, however, is that light harvesting and directional energy migration are impeded by polymer chain folding, especially in response to solvent, temperature, and arrangement of pendant groups (52, 71). Because of these issues, rigid, shape-persistent macromolecules such as dendritic systems may provide certain advantages over linear architectures (52).

Since their introduction by Tomalia *et al.* (72) and Newkome *et al.* (73) in 1985, many dendrimers have been synthesized and investigated (74). The wheel-like and spherical structures of multiporphyrin and dendrimer arrays provide a scaffold for attaining directional energy transfer, allowing excitation energy to cascade efficiently from the periphery to the core. Furthermore, the highly branched nature of dendrimers and multiporphyrin wheels allows coupling of more than one donor moiety per acceptor moiety that can be used to increase the molar absorptivity (52, 75–78). Building blocks for these structures have included transition metal complexes (ML_n), metal-free and metal-chelated porphyrin groups, and various other conjugated photoactive units (20, 42, 52, 76, 77, 79). Jiang and Aida (80) synthesized dendrimers from aryl ethers with a photoisomerizable azobenzene core and demonstrated that a five-generation azobenzene dendrimer could photoisomerize upon infrared excitation. Their work leads to the possibility of using such materials to harvest and channel low-energy photons for chemical transformations.

Natural photosynthesis depends on energy flow between noncovalently assembled chromophores. Noncovalent self-assembly techniques are being developed for synthetic photoactive devices (48, 50, 81–83). Although some of the materials are self-organized through chemical interactions to produce larger scale arrays,

others are organized on surfaces by using techniques such as Langmuir–Blodgett films or synthesized by assembling encapsulated materials into or onto host–guest inorganic matrices. Wasielewski *et al.* (47, 84) recently reported that xanthene-linked green chromophores tetrafunctionalized with perylene-bis(dicarboximide) were highly efficient at both light harvesting and ultrafast charge separation. The researchers attributed this efficiency to the molecules' ability to self-assemble into stacked arrays with defined orientations between adjacent planar aromatic groups (47, 84). Self-assembled monolayers of carotenoids and chlorophylls on titania surfaces showed long-lived photoinduced charge separation due to a reductive quenching of the pheophytin molecules upon pheopytin excitation at 670 nm (81). The stable charge separation was proposed to be due to either the conjugated backbone of the carotenoid-polyene, which withdraws positive charges from the tetrapyrrole, or to positive charge-hopping between the aggregated carotenoids. As mentioned earlier, nanostructured inorganic matrices have also been used to direct and spatially confine the orientation of multichromophore systems. Calzaferri *et al.* (50) used zeolites as a host material and inserted various dyes and electron acceptors into the nanometer channels, using either gas-phase or ion exchange techniques. The narrow channels confined the molecules to form single, linear, one-dimensional molecular chains within each pore. The mutual orientations of the encapsulated dyes ensured efficient energy-transfer processes whether energies were injected from or into the stopper molecules that capped the ends of the dye-loaded channels.

Similar to the photoisomerization work described earlier (80), much research has focused on increasing the absorption cross section of new materials by capturing both the high- and low-energy photons that are normally lost. One approach is to use all of the available energy of high-energy photons by generating multiple excitons from a single absorbed photon. Ellingson *et al.* (85) reported multiple exciton generation by using PbSe and PbS quantum dots; Qi *et al.* (86) have also reported similar results with polymer–quantum dot blends (86). The ability to capture and use all of the energy from a high-energy photon greatly improves the overall energy efficiency of solar energy conversion. Related work in optical storage and imaging with two-photon (87, 88) and three-photon (30) absorption could provide the materials and methods to use the energy from low-energy photons to provide a means to capture the lower energy tail of the solar spectra not currently being used.

A large number of materials have been developed that can harvest photons and efficiently transfer the energy to moieties that stably separate charged species (the basis of an electrical potential). Coupling these materials and devices into full systems for power generation has been much more challenging. Moore and coworkers (40) demonstrated the feasibility of coupling light harvesting with the generation of chemical potential energy: one of the few examples of a system built completely from synthetic constituents. Their system was based on self-assembled liposomes containing both the C–P–Q (carotene–porphyrin–naphthoquinone) molecular triad and CF_0F_1-ATP synthase. When the liposomes were irradiated at 633 nm, they produced ATP by a proton gradient that formed across the lipid bilayer through redox reactions between the embedded C–P–Q triad and the lipophilic quinone.

Although an enormous amount of research has been conducted to develop biological and biomimetic methods for energy production, significant challenges remain. One grand challenge that remains is to transfer the high level of performance seen in laboratory-based photoactive reactions and systems into commercial devices. Harnessing solar power with biological or biomimetic systems is clearly an activity that would benefit from multidisciplinary efforts. There is a great need for those who work at the molecular and atomic levels to collaborate with those who best understand the physical properties and engineering of complex systems. The era of nanotechnology, especially the bridging of the disparate fields, offers opportunities to challenge the conventional wisdom regarding the efficiency and cost effectiveness of alternative energy sources.

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http://www.science20.com/news_articles/scientists_mimic_chloroplasts_meaning_solar_cells_fix_themselves

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Scientists Mimic Chloroplasts - Meaning Solar Cells That Fix Themselves

By *News Account*
Created *Sep 5 2010 - 4:20am*
It would seem that mimicking nature would be among the easiest things to do for science. After all, it's right there, in front of us, happening for millions of years.

Take plants, for instance. Every day they absorb sunlight and turn it into energy but our solar technology is bordering on laughable and, if solar lobbyists get there way and it gets more subsidies and even mandates, criminal.

The issue science has is that the sun's rays are highly destructive to man-made materials and that leads to a gradual degradation of many systems developed to harness it.

Plants don't suffer the same way because they constantly break down their light-capturing molecules and reassemble them from scratch, so the basic structures that capture the sun's energy are, in effect, always brand new. Casual observers might see a leaf as a static photocell but it is recycling its proteins about every 45 minutes.

Maybe we can do it too. A group writing in *Nature Chemistry* says they have created a set of self-assembling molecules that can turn sunlight into electricity, in that the molecules can be repeatedly broken down and then reassembled quickly, just by adding or removing an additional solution.

What they discovered is that in the molecules used for photosynthesis in plants, the reactive form of oxygen produced by sunlight causes the proteins to fail in a very precise way. As Michael Strano, the Charles and Hilda Roddey Associate Professor of Chemical Engineering at MIT, describes it, the oxygen "unsnaps a tether that keeps the protein together," but the same proteins are quickly reassembled to restart the process.

Closeup of the test cell the team built to measure the properties of the self-assembling photosynthetic system. Credit: Patrick Gillooly, MIT

This action all takes place inside tiny capsules called chloroplasts that reside inside every plant cell — and which is where photosynthesis happens. The chloroplast is "an amazing machine," Strano says. "They are remarkable engines that consume carbon dioxide and use light to produce glucose," a chemical that provides energy for metabolism.

To imitate that process, Strano and his team, supported by grants from the MIT Energy Initiative and the Department of Energy, produced synthetic molecules called phospholipids that form discs; these discs provide structural support for other molecules that actually respond to light, in structures called reaction centers, which release electrons when struck by particles of light. The discs, carrying the reaction centers, are in a solution where they attach themselves spontaneously to carbon nanotubes — wire-like hollow tubes of carbon atoms that are a few billionths of a meter thick yet stronger than steel and capable of conducting electricity a thousand times better than copper. The nanotubes hold the phospholipid discs in a uniform alignment so that the reaction centers can all be exposed to sunlight at once, and they also act as wires to collect and channel the flow of electrons knocked loose by the reactive molecules.

The system Strano's team produced is made up of seven different compounds, including the carbon nanotubes, the phospholipids, and the proteins that make up the reaction centers, which under the right conditions spontaneously assemble themselves into a light-harvesting structure that produces an electric current. Strano says he believes this sets a record for the complexity of a self-assembling system. When a surfactant — similar in principle to the chemicals that BP has sprayed into the Gulf of Mexico to break apart oil — is added to the mix, the seven components all come apart and form a soupy solution. Then, when the researchers removed the surfactant by pushing the solution through a membrane, the compounds spontaneously assembled once again into a perfectly formed, rejuvenated photocell.

"We're basically imitating tricks that nature has discovered over millions of years" — in particular, "reversibility, the ability to break apart and reassemble," Strano says. The team, which included postdoctoral researcher Moon-Ho Ham and graduate student Ardemis Boghossian, came up with the system based on a theoretical analysis, but then decided to build a prototype cell to test it out. They ran the cell through repeated cycles of assembly and disassembly over a 14-hour period, with no loss of efficiency.

Strano says that in devising novel systems for generating electricity from light, researchers don't often study how the systems change over time. For conventional silicon-based photovoltaic cells, there is little degradation, but with many new systems being developed — either for lower cost, higher efficiency, flexibility or other improved characteristics — the degradation can be very significant. "Often people see, over 60 hours, the efficiency falling to 10 percent of what you initially saw," he says.

The individual reactions of these new molecular structures in converting sunlight are about 40 percent efficient, or about double the efficiency of today's best commercial solar cells. Theoretically, the efficiency of the structures could be close to 100 percent, he says. But in the initial work, the concentration of the structures in the solution was low, so the overall efficiency of the device — the amount of electricity produced for a given surface area — was very low. They are working now to find ways to greatly increase the concentration.

Citation: Moon-Ho Ham, Jong Hyun Choi, Ardemis A. Boghossian, Esther S. Jeng, Rachel A. Graff, Daniel A. Heller, Alice C. Chang, Aidas Mattis, Timothy H. Bayburt, Yelena V. Grinkova, Adam S. Zeiger, Krystyn J. Van Vliet, Erik K. Hobbie, Stephen G. Sligar, Colin A. Wraight&Michael S. Strano, 'Photoelectrochemical complexes for solar energy conversion that chemically and autonomously regenerate', Nature Chemistry (2010) doi:10.1038/nchem.822

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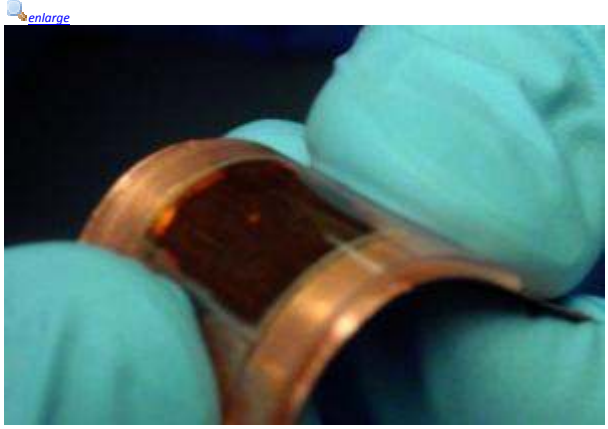
Mimicking Nature, Water-Based 'Artificial Leaf' Produces Electricity

enlarge



Just as real leaves do, water-gel-based solar devices can act like solar cells to produce electricity, new research shows. (Credit: Dr. Orlin Velev, North Carolina State University)

ScienceDaily (Sep. 24, 2010) — A team led by a North Carolina State University researcher has shown that water-gel-based solar devices -- "artificial leaves" -- can act like solar cells to produce electricity. The findings prove the concept for making solar cells that more closely mimic nature. They also have the potential to be less expensive and more environmentally friendly than the current standard-bearer: silicon-based solar cells.

The bendable devices are composed of water-based gel infused with light-sensitive molecules -- the researchers used plant chlorophyll in one of the experiments -- coupled with electrodes coated by carbon materials, such as carbon nanotubes or graphite. The light-sensitive molecules get "excited" by the sun's rays to produce electricity, similar to plant molecules that get excited to synthesize sugars in order to grow, says NC State's Dr. Orlin Velev, Invista Professor of Chemical and Biomolecular Engineering and the lead author of a paper published online in the *Journal of Materials Chemistry* describing this new generation of solar cells.

Velev says that the research team hopes to "learn how to mimic the materials by which nature harnesses solar energy." Although synthetic light-sensitive molecules can be used, Velev says naturally derived products -- like chlorophyll -- are also easily integrated in these devices because of their water-gel matrix.

Now that they've proven the concept, Velev says the researchers will work to fine-tune the water-based photovoltaic devices, making them even more like real leaves.

"The next step is to mimic the self-regenerating mechanisms found in plants," Velev says. "The other challenge is to change the water-based gel and light-sensitive molecules to improve the efficiency of the solar cells."

Velev even imagines a future where roofs could be covered with soft sheets of similar electricity-generating artificial-leaf solar cells.

"We do not want to overpromise at this stage, as the devices are still of relatively low efficiency and there is a long way to go before this can become a practical technology," Velev says. "However, we believe that the concept of biologically inspired 'soft' devices for generating electricity may in the future provide an alternative for the present-day solid-state technologies."

Researchers from the Air Force Research Laboratory and Chung-Ang University in Korea co-authored the study. The study was funded by the Air Force Research Laboratory and the U.S. Department of Energy. The work is part of NC State's universitywide nanotechnology program, Nano@NC State.

NC State's Department of Chemical and Biomolecular Engineering is part of the university's College of Engineering.

Story Source:

The above story is reprinted (with editorial adaptations by Science*Daily* staff) from materials provided by **North Carolina State University**.

Journal Reference:

1. Hyung-Jun Koo, Suk Tai Chang, Joseph M. Slocik, Rajesh R. Naik, Orlin D. Velev. **Aqueous soft matter based photovoltaic devices**. *Journal of Materials Chemistry*, 2011; DOI: 10.1039/c0jm01820a

North Carolina State University (2010, September 24). Mimicking nature, water-based 'artificial leaf' produces electricity. *ScienceDaily*. Retrieved November 8, 2010, from http://www.sciencedaily.com /releases/2010/09/100924121218.htm

Note: If no author is given, the source is cited instead.

The solar-powered electric hornet (New Scientist)

Out of: http://tahoe-is-walking-on.blogspot.com/2010/11/zoologger-solar-powered-electric-hornet.html

Wednesday, November 10, 2010

Zoologger: The solar-powered electric hornet (New Scientist)

15:00 10 November 2010 by **Michael Marshall**

For similar stories, visit the **Zoologger** Topic Guide
Zoologger *is our weekly column highlighting extraordinary animals – and occasionally other organisms – from around the world*
Species: *Vespa orientalis*
Habitat: throughout south-east Europe, north-east Africa and south-west Asia, and Madagascar
Humans have been trying to build solar cells since the late 19th century, but despite over 100 years of work we still don't get very much energy out of them. Our efforts are put to shame by the oriental hornet, which had solar cells long before *Homo sapiens* first walked the earth.
Oriental hornets live in underground colonies. The workers prepare their home by digging into mud and then filling it with hexagonal cells much like those of bees. It has been known since the late 1960s that these insects are much more active in the middle of the day, unlike other wasps which tend to be most active in the early morning.
That may seem an inconsequential lifestyle detail, but the late Jacob Ishay of Tel Aviv University in Israel and his colleagues have shown that it is a clue to something more significant: oriental hornets have solar cells built into their skin.

busy busy

The colony's workers spend their time clearing soil out of the nest. During the summer months they do much of this hard work in the heat of noon, whenultraviolet radiation is at its strongest. It turns out that the hornets have evolved some ingenious adaptations to harvest sunlight.
Marian Plotkin of Tel Aviv University and colleagues used advanced microscopes to examine a hornet's exoskeleton, or cuticle. Most of the cuticle is brown, but a few sections are yellow. These colours mark the hornet as a venomous insect, and therefore best avoided by potential predators, but the pigments are also involved in mopping up solar energy.
Both the brown and yellow cuticles are made up of many layers laid on top of each other, around 30 in the brown and 15 in the yellow. The brown areas contain melanin, a pigment also found in human skin, while the yellow areas contain xanthopterin.
Plotkin found that the brown cuticle is covered with grooves, while the yellow cuticle is covered with oval-shaped lumps. Both absorbed 99 per cent of the visible light falling on them.
What's more, the grooves on the brown cuticle are fairly regularly spaced, Plotkin found. As a result, the cuticle surface mimics a series of slits, which act as a diffraction grating, trapping yet more light inside the cuticle layers.
The team also built a solar cell that successfully used xanthopterin to harvest light.

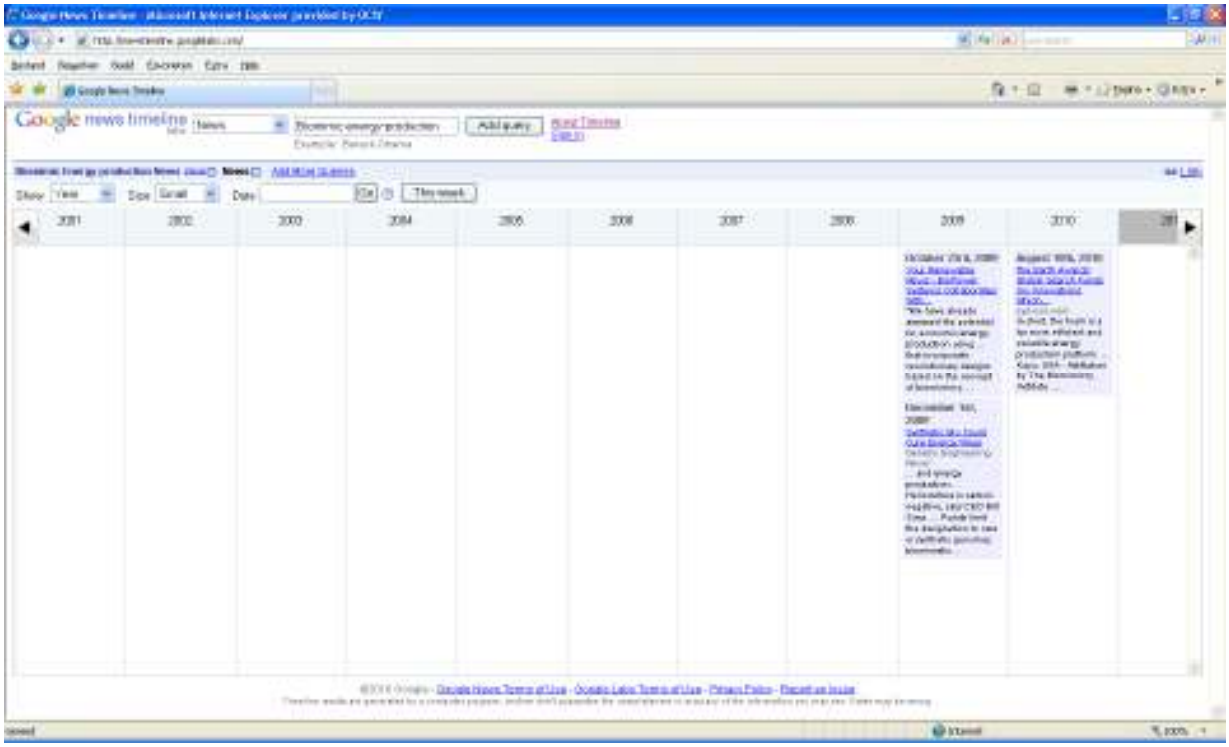
So much power

The hornet can definitely transform solar radiation into electricity, as shining light on the cuticle generates a small voltage. But what does the insect do with it?
One possibility is that it might harness the electricity to power enzymes in the yellow cuticle. Last year Ishay and Plotkin showed that enzymes in these regions perform metabolic functions similar to those of livers in mammals, and that they are more active when the insects were exposed to ultraviolet light.
Alternatively, it might help keep the hornets at a comfortable temperature. They can stay active when air temperatures are as high as 40 °C, and they may do so partly by converting some of the heat energy into electricity which they then store and convert back to heat when conditions became chilly.
The electricity might also give the hornets' wing muscles an extra jolt of energy. Anaesthetised hornets wake up faster, and immediately fly away, if ultraviolet light is shone on them. Solar power indeed.
Journal reference: *Naturwissenschaften*, DOI: 10.1007/s00114-010-0728-1

POSTED BY TAHOE AT 8:25 PM

Google timeline

Google News Timeline is a web application that organizes search results chronologically. It allows users to view news and other data sources on a browsable, graphical timeline. Available data sources include recent and historical news, scanned newspapers and magazines, blog posts, sports scores, and information about various types of media, like music albums and movies. Below follows the results of the search for news related to biomimic energy production.



Title: The unknown risk of Hydrogen economy , The importance of sustainable energy carriers?

Domain of relevance: Energy

Subdomain of relevance: renewable energy, the energy carriers and storage perspective, risk, climate, Ozone layer

Keywords: renewables, solar, sustainability, hydrogen, risks

Short description

The industrialisation of western countries founds its basis in the abundance of fossil fuels like coal, oil and gas , which were easy to transport and to store but which all contribute to the CO2 emission that is suspected to change our climate. To reduce CO2 emissions it is considered that Carbon-hydrate molecule should either be hydrated or completely replaced by Hydrogen or electricity. In the discussion on safety of these other carrier systems we see a lot of focus on regular safety measurements as testing of materials, design of storage and transport systems and devices and so on. For hydrogen and light carbohydrates however there may be risks of a different kind that are more comparable of the RISK of CO2 emission. Since these light energy carriers are lighter than most of our atmospheric molecules they will be spreading in higher air layers causing different physical properties of the atmosphere and chemical reactions that may also have effect on atmos-and biosphere. Some speculative but not contested articles in scientific papers on this were published around 1965 and later around 2003 to 2008. Just like the CO2 connected climate debate the issue of light carbo-hydrate and hydrogen molecules lays around the corner to be activated again, as soon as Hydrogen will be applied on a wider scale. In earlier publication when the idea of Hydrogen was promoted, the risk of hydrogen leakage to the atmosphere and its effect on cloud formation and the Ozone layer was mentioned but considered to be minimal

Impact/implications

The debate around fossil fuels has focused a lot on the Green house effects of Carbon economy. Carbon fuels are however quite easy to store and transport, which seems to be less easy with their renewable competitors as Hydrogen and electricity. Therefore these alternatives should be thoroughly assessed also on their ecological impact and footprints since they require large scale infrastructural investments that create new path dependencies. For Hydrogen economy this impact may be laying in emission (leakage of hydrogen) for electricity in the scarce or environmental unfriendly materials used for transport and especially for storage.

Evidence base / storyline

Hydrogen and carbon hydrates are lighter than normal air molecules it is logic to assume that escaped gases from a hydrogen economy will disperse in the atmosphere. Main effect will be oxidation with Oxygen that causes more Vapor creation on higher air layers where the concentration of H2 becomes denser and where still enough Oxygen or Ozone is available to react. The consequences therefore may be cooling of the climate. Another effect may be that Ozone is taken away since this is more reactive with Hydrogen than O2. In itself these ideas are not contested but estimations of effects show of course many differences. Another problem may arise with the use of hydrated fuels which still contain carbon molecules (like CH4 methane) but which also may be lighter than air which usually are considered as green house gases with stronger effects than CO2 , this discussion is more connected to the potential use of methyl hydrate reserves that are stored on cold ocean bottoms.

Plausibility

It is plausible that a hydrogen economy cannot prevent hydrogen gas to leak to upper layers of the atmosphere and that this will react with Ozon and Oxygen, causing additional clouds , the evidence that this will cause a serious climate effect is still hypothetical (as it is in fact with CO2).

Novelty

The concept or idea that Hydrogen economy may affect the atmosphere is not new, as soon as the idea of hydrogen economy came forward authors mentioned the inevitable leakage but put ii aside as a minor problem (without further study). In 2003 and later we see some attempts to predict what may happen. These studies show more effect than originally expected. The emergence or novelty of the attention has more to do with the expectation that increased use of hydrogen may evoke renewed debate on the issue, which is important for the final choice of main energy carriers and storage mechanisms.

Critical/open questions…

Drivers & Inhibitors

The need for CO2 reduction in connection with the climate debate cases a call for so called sustainable energy carriers which are superior to fossil fuels in respect of their disturbance of the ecosystem and climate.
Since the implementation of new carrier systems requires huge investments that finally create path-dependent developments, critical thoughts may be stalled.

Desirability aspects

Interests at stake

Developers of H2 dependent systems have an interest in their development and deployment. It is to be expected that research and development of each energy carrier system creates its own promoters and believers.

Emotional aspects

H2 economy is promoted as a clean alternative for fossil fuel and many people put their hope in it, if risks may be greater than foreseen emotional reaction may follow.

Changeability aspects: Policies

Debate and further research are needed to ascertain the desirability of H2 as energy carrier and storage mechanism, compared with other alternatives that are considered to be sustainable as electricity or recycled CO2 through the use of biofuels. The result may be that all carriers have severe constraints, the path dependency of the choices of today are therefore extremely important.

Source of inspiration / Initial discovery point

http://yly-mac.gps.caltech.edu/Reprintsyly/z_Bibliography_soozen/N146Tromp_2003.pdf

http://www.esac.pt/Emas@school/EMAS@SCHOOL/Publicacoes/Outros_projectos/kikuchi2006.pdf

Signals /Early Indicators

The use of hydrogen till now is minimal.
If doubts raise investors will choose either for electric concepts or hydrogen concepts.

Solar-hydrogen electricity generation and global CO_2 emission reduction

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Abstract
The relative costs and CO_2 emission reduction benefits of advanced centralized fossil fuel electricity generation, hybrid photovoltaic-fossil fuel electricity generation, and total solar electricity generation with hydrogen storage are compared. Component costs appropriate to the year 2000–2010 time frame are assumed throughout. For low insolation conditions (160 W m mean annual solar radiation), photovoltaic electricity could cost 5–13 cents kWh^{-1} by year 2000–2010, while for high insolation conditions (260 W m^{-2}) the cost could be 4–9 cents kWh^{-2}. Advanced fossil fuel-based power generation should achieve efficiencies of 50% using coal and 55% using natural gas. Carbon dioxide emissions would be reduced by a factor of two to three compared to conventional coal-based electricity production in industralized countries. In a solar-fossil fuel hybrid, some electricity would be supplied from solar energy whenever the sun is shining and remaining demand satisfied by fossil fuels. This increases total capital costs but saves on fuel costs. For low insolation conditions, the cost of electricity increases by 0–2 cents kWh^{-1}, while the cost of electricity decreases in many cases for high insolation conditions. Solar energy would provide 20% or 30% of electricity demand for the low and high insolation cases, respectively. In the solar-hydrogen energy system, some photovoltaic arrays would provide current electricity demand while others would be used to produce hydrogen electrolytically for storage and later use in fuel cells to generate electricity. Electricity costs from the solar-hydrogen system are 0.2–5.4 cents kWh^{-1} greater than from a natural gas power plant, and 1.0–4.5 cents kWh^{-1} greater than from coal plant for the cost and performance assumptions adopted here. The carbon tax required to make the solar-hydrogen system competitive with fossil fuels ranges from $70–660 $tonne^{-1}$, depending on the cost and performance of system components and the future price of fossil fuels. Leakage of hydrogen from storage into the atmosphere, and the eventual transport of a portion of the leaked hydrogen to the stratosphere, would result in the formation of stratospheric water vapor. This could perturb stratospheric ozone amounts and contribute to global warming. Order-of-magnitude calculations indicate that, for a leakage rate of 0.5% y^{-1} of total hydrogen production — which might be characteristic of underground hydrogen storage — the global warming effect of solar-hydrogen electricity generation is on the order of 1% the impact of the hybrid system. Impacts on stratospheric ozone are likely to be minuscule.

Potential Environmental Impact of a Hydrogen Economy on the Stratosphere

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DOI: 10.1126/science.1085169

Tracey K. Tromp,[1] Run-Lie Shia,[1] Mark Allen,[2] John M. Eiler,[1] Y. L. Yung[1*]

The widespread use of hydrogen fuel cells could have hitherto unknown environmental impacts due to unintended emissions of molecular hydrogen, including an increase in the abundance of water vapor in the stratosphere (plausibly by as much as ~1 part per million by volume). This would cause stratospheric cooling, enhancement of the heterogeneous chemistry that destroys ozone, an increase in noctilucent clouds, and changes in tropospheric chemistry and atmosphere-biosphere interactions.

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REPORTS

Potential Environmental Impact of a Hydrogen Economy on the Stratosphere

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The widespread use of hydrogen fuel cells could have hitherto unknown environmental impacts due to unintended emissions of molecular hydrogen, including an increase in the abundance of water vapor in the stratosphere (plausibly by as much as ~1 part per million by volume). This would cause stratospheric cooling, enhancement of the heterogeneous chemistry that destroys ozone, an increase in noctilucent clouds, and changes in tropospheric chemistry and atmosphere-biosphere interactions.

Hydrogen fuel cells, which produce energy from the controlled oxidation of molecular hydrogen (H_2), are a proposed alternative to conventional fossil fuels (*1*). Their use would likely result in substantial reductions in urban pollution from soot, nitrogen oxide gases, and sulfate, but they could also have hitherto unknown environmental impacts due to emissions of H_2. H_2 is an important trace constituent [~0.5 part per million by volume (ppmv)] of the atmosphere (*2*, *3*) and participates in atmospheric chemical cycles of H_2O and various pollutants and greenhouse gases (*4*, *5*). Its modern budget is influenced by anthropogenic emissions (such as car exhaust) but is dominated by photochemical reactions in the atmosphere and uptake in the soil (*3*, *6*, *7*). It is difficult to foresee the magnitude of H_2 emissions associated with a hydrogen fuel cell economy, both because the current budget of H_2 is poorly known and because the technical details and scope of the future fuel cell industry can only be guessed at. In principle, a perfectly efficient system of hydrogen production, transport, and oxidation would involve no H_2 emissions (it would all be oxidized to H_2O). In that case, the evolution from fossil fuel combustion to hydrogen fuel cells would actually result in a reduction of anthropogenic H_2 emissions, because fossil fuel combustion is a source of H_2.

However, on the basis of experience with technologies associated with the transportation of natural gas and other volatiles, it seems likely that systems of H_2 production, storage, and transport will involve losses to the atmosphere. The magnitude of these losses will naturally depend on the amount of effort expended to contain them but have been reasonably projected to be on the order of 10% (*8*). Losses during current commercial transport of H_2 are substantially greater than this (*9*), suggesting to us that a range of 10 to 20% should be expected. If so, and if all current technologies based on oil or gasoline combustion were replaced by hydrogen fuel cells, then anthropogenic emissions of H_2 would be on the order of 60 to 120 Tg/year, or roughly four to eight times estimates of current anthropogenic H_2 emissions (15 ± 10 Tg/year). In that case, contributions from human activity would dominate the budget and result in approximate doubling or tripling of the annual production of H_2 from all sources combined. More or less dramatic scenarios are equally imaginable, but clearly the potential impact on the H_2 cycle is great.

H_2 added to the troposphere freely moves up and mixes with stratospheric air, and the oxidation of H_2 is a source of stratospheric H_2O (*10*). Therefore, increasing the source of H_2 to the atmosphere, unless compensated by an equally vigorous increase in rates of processes that destroy hydrogen, should moisten the stratosphere. This would result in cooling of the lower stratosphere (*11*) and the disturbance of ozone chemistry, which depends on heterogeneous reactions involving hydrochloric acid and chlorine nitrate on ices of H_2O (*12*).

Here, we report the results of models of atmospheric chemistry and transport that estimate the effects that an increase in H_2 emissions would have on stratospheric temperatures and on concentrations of stratospheric H_2O and ozone. We examine the atmospheric chemistry of H_2 using the Caltech/JPL 2-D model, which has been described elsewhere (*13*–*15*). This model solves the continuity equation for all important long-lived species and includes all the chemistry recommended by NASA for stratospheric modeling (*16*). To assess the potential impact of an increase of H_2 in the atmosphere, we ran our model for two cases: (a) concentrations of H_2 and CH_4 are assumed to equal their approximate current global annual means at Earth's surface; and (b), the same as (a), except that the concentration of H_2 at Earth's surface is raised to 2.3 ppmv (about four times the current global annual mean). Intermediate cases are discussed below. Figure 1 presents simulated vertical profiles in concentrations of H_2 and CH_4 in the stratosphere for these two cases and a comparison of case (a) with recent measurements. The results for case (a) show that the model correctly describes the relation between H_2 and CH_4 concentrations in the lower stratosphere, which reflects the balance of photo-oxidative reactions that are important for converting H_2 and CH_4 to H_2O. The model prediction for the vertical profile for H_2 for case (b) is the dashed line in Fig. 1. Figure 2 (contour lines) shows the concentration of water vapor (in ppmv) as a function of altitude and latitude in the stratosphere in January in the standard model, case (a). The model correctly simulates the increase in H_2O with altitude and latitude from the oxidation of H_2 and CH_4. The low concentration in the tropical tropopause region is the result

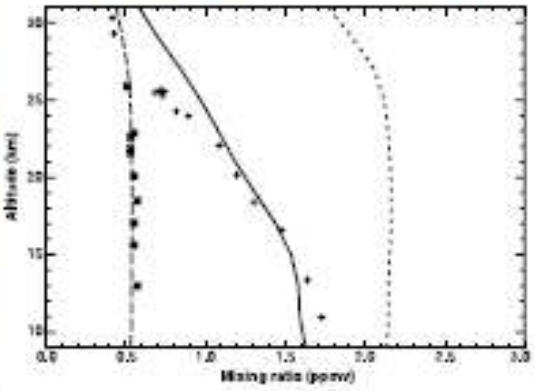

Fig. 1. Mixing ratios of CH_4 (solid line) and H_2 (long-dashed line) simulated by our two-dimensional model for January at 60° to 70°N for case (a). The H_2 mixing ratio for case (b) is given by the short-dashed line. The data (asterisks and crosses) are from the SOLVE balloon measurements (*22*). The model uses a pressure coordinate, with altitude $z = H \ln(p_s/p)$, where the scale height (H) = 6.96 km, p = pressure, and p_s = surface pressure; z is approximately equal to the geometric altitude.

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of upwelling air that has been dehydrated by the tropical cold trap. The change in stratospheric water content, as computed by the difference between case (b) and case (a), is shown by the color contours in Fig. 2. As expected, the additional quantity of H_2O is highest (~30%) at high altitudes, where most of the H_2 becomes oxidized.

Based on our modeling results, the increase in stratospheric water content caused by a quadrupling of the H_2 mixing ratio at Earth's surface (Figs. 1 and 2) would result in a negligible (<1%) change in abundances of stratospheric ozone due to homogenous gas-phase reactions alone. However, this increase in stratospheric water vapor would have several indirect consequences, including lower stratospheric temperatures. Colder temperatures would create more polar stratospheric clouds, delay the breaking up of the polar vortex, and thereby make the ozone hole deeper, larger (in area), and more persistent (in spring). The direction and approximate magnitude of resulting changes in temperature and ozone concentration can be approximated as follows: An increase of 0.5 ppmv in stratospheric H_2O will cool the lower stratosphere by 0.5°C (*11*). Based on the climatology of the National Centers for Environmental Prediction Reanalysis data (*17*), this will increase the area of the northern polar vortex by 7% and that of the southern polar vortex by 4%. Finally, empirical data suggest that the polar vortices last 5 to 8 days longer when there is a 0.5°C temperature drop (*18*). It is known that a colder vortex that lasts longer results in greater loss of ozone (*19*). Figure 3 depicts the percentage of ozone column density change. The O_3 depletion is about 5 to 8% in the boreal spring in the northern polar region, and about 3 to 7% in the austral spring in the southern polar region. The reason for the larger change in the north versus the south is that the Antarctic ozone hole is already "saturated," whereas the Arctic ozone hole is not and has the potential to become more like the Antarctic.

The model predictions outlined above suggest that anthropogenic emissions of H_2 could substantially delay the recovery of the ozone layer that is expected to result from the regulation of chlorofluorocarbons. However, we also note that the lower levels of chlorofluorocarbons expected several decades in the future should lead to less destruction of stratospheric ozone for a given amount of stratospheric moistening and cooling (*20*). Thus, the real consequences of a hydrogen economy will depend, in part, on whether it develops within about 20 years, when chlorofluorocarbon levels remain high; or more than 50 years in the future, when chlorofluorocarbon levels have substantially decreased. Alternatively, we may devise a strategy that regulates the growth of the fuel cell industry, so that the impact on the ozone layer is minimized.

The model results presented in Figs. 1 to 3 suggest that a fourfold rise in surface H_2 concentrations, such as might occur because of large rises in anthropogenic emissions, will lead to substantial moistening and cooling of the lower stratosphere and substantial decreases in stratospheric O_3. Figure 4 shows the magnitude of these effects predicted by our model for smaller and larger changes in H_2O concentration in the lower stratosphere. Cases (a) and (b) correspond to one and four times the current H_2 concentration, respectively.

Predicting the rise in H_2 concentration at the surface in the future will require better knowledge of several factors. First and most clearly, we must have an understanding of the emissions that could be produced by technologies associated with a hydrogen economy. It is likely that such emissions could be limited or even made negligible, although at some cost against which potential environmental impacts must be balanced. Second, a large, possibly dominant, sink of H_2 from the atmosphere is uptake in soils (*3*, *7*, *21*). The mechanisms of this uptake and its variation with time and location are poorly understood, and it is unclear how the global rate of uptake would respond to an increased flux of H_2 to the atmosphere. It is possible that this process could entirely compensate for new anthropogenic emissions, although

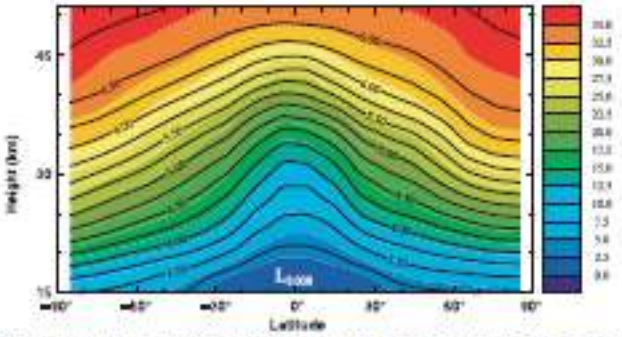

Fig. 2. The background H_2O mixing ratio (given by contours in units of ppmv) and the increase of stratospheric H_2O in January due to the assumed fourfold increase of H_2, computed using the Caltech/JPL 2-D model (given by color in % change). The altitude is defined as in Fig. 1.

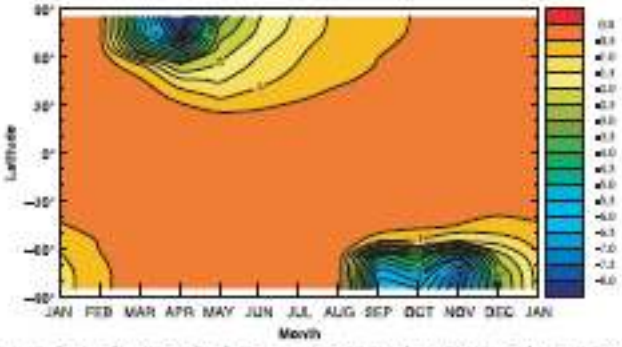

Fig. 3. Latitudinal and seasonal distribution of column ozone depletion (in %) due to an assumed fourfold increase of H_2, simulated by the Caltech/JPL 2-D model.

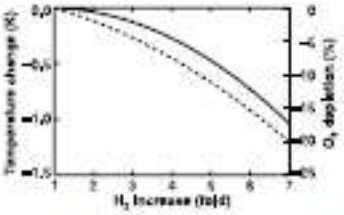

Fig. 4. The temperature changes at 74°N in the lower stratosphere (solid line) (*11*, *23*) and the resulting maximum ozone depletion in the northern polar vortex (dashed line) caused by the increase of H_2O. Cases (a) and (b) in the text correspond to a one- and fourfold increase of H_2O, respectively.

Penetration of hydrogen-based energy system and its potential for causing global environmental change:

Scoping risk analysis based on life cycle thinking

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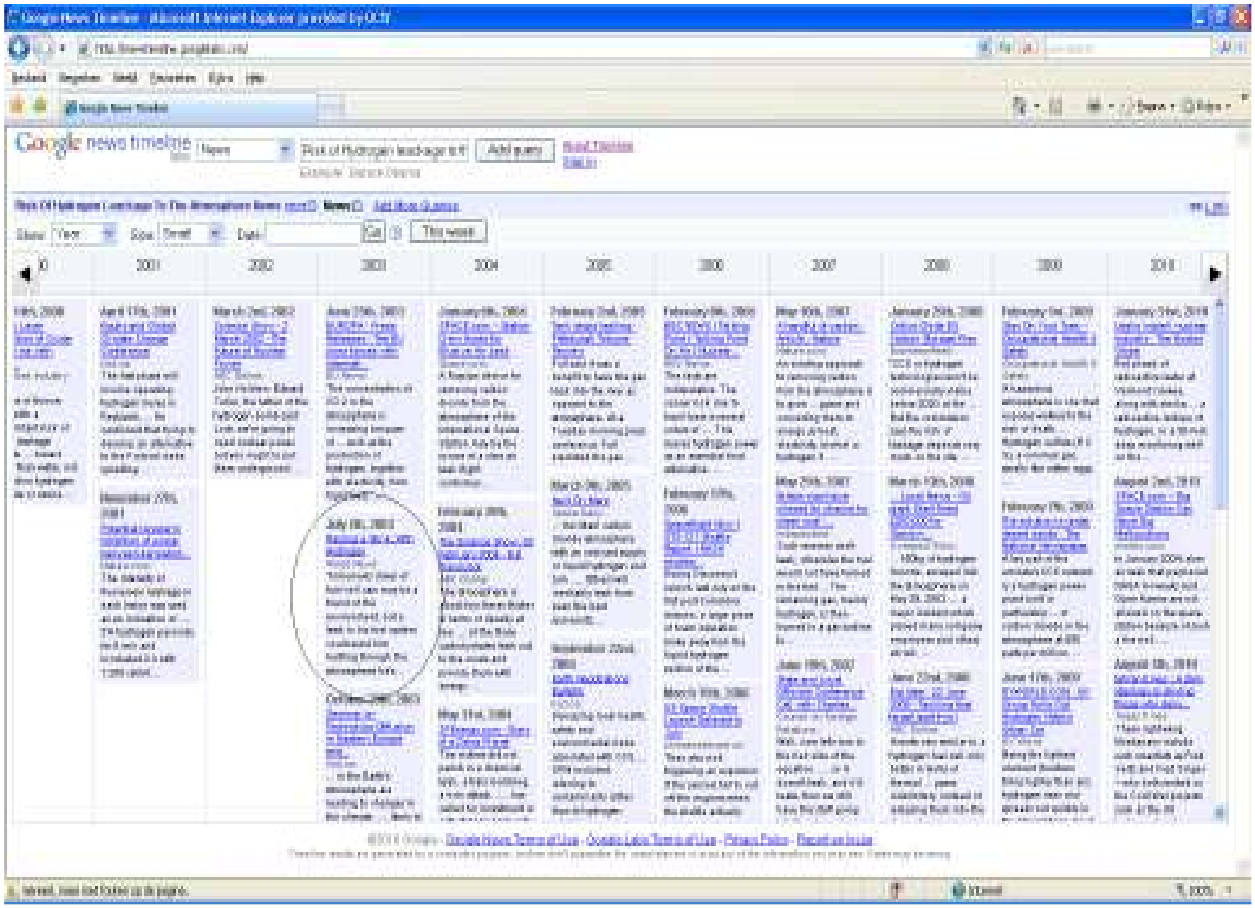
Abstract
A hydrogen-based economy seems superficially to be environmentally friendly, and many people have worked toward its realization. Today hydrogen is mainly produced by decarbonizing fossil fuels (e.g. natural gas), and in the future decarbonization of both fossil fuels and biomass will play a leading role in the production of hydrogen. The main purpose of this paper is to suggest the identification of potential environmental risks in terms of blife cycle thinkingQ (which considers all aspects from production to utilization) with regard to the hydrogen-based economy to come. Hydrogen production by decarbonization results in CO_2 emissions. The final destination of the recovered CO_2 is uncertain. Furthermore, there is a possibility that hydrogen molecules will escape to the atmosphere, posing risks that could occasion global environmental changes such as depletion of stratospheric ozone, temperature change in the stratosphere and change of the hydrides cycle through global vaporization. Based on the results of simulation, requirements regarding the following items are proposed to minimize potential risks: hydrogen source, production and storage loss.

Keywords: Alternative energy; Global change; Life cycle thinking; Hydrogen production; Potential risk

Google timeline

Google News Timeline is a web application that organizes search results chronologically. It allows users to view news and other data sources on a browsable, graphical timeline. Available data sources include recent and historical news, scanned newspapers and magazines, blog posts, sports scores, and information about various types of media, like music albums and movies. Below follows the results of the search for news related to risks of hydrogen leakage going back to 2003.



Project funded under the Socio-economic Sciences and Humanities

Title: Deeper and further, known or unknown risks

Domain of relevance: Energy

Subdomain of relevance: fossil fuels, mining

Keywords: oil, gas, methylhydrates, deep sea , deep sea floor, antartic, tar sands, shelloil

Short description

The search for fossil fuels reaches out for reserves that are more remote and much harder to exploit than the sources that were discovered last century. While the mining of these fuels was already under pressure under the climate change debate, oil companies started to exploit on places where the potential environmental damage is may be enormous. Examples are oil recovery from tar sands in Alaska, deep sea oil drilling and the recent claims of different countries on the rights to exploit the North pole for mining. The recent oil spill in the Gulf of Mexico shows that these new areas cause special risks not only for the environment but also for the economics of exploitation which are somehow neglected in an irrational way. It is very surprising that despite of the enormous financial losses of BP (that nearly went bankrupt) and the ongoing environmental disaster the oil companies went into a "business as usual" mode after the disaster.
This can only be explained by a deep framing of oil companies on their core business of exploiting oil with only some lip services to renewables are made and where innovation only can be seen as going deeper and further without reflection on other possibilities. It is clear that the money of BP that now is lost with the Gulf incident could have much better been invested in renewable energy sources. But since this is not the core business of BP the search for risky exploitation is going on.
This phenomenon raises serious questions: one is about the irrational framing of the present energy choices by existing business models that stay dependent on oil also if this may mean enormous losses of the companies involved and tremendous impact on environment and public health. The other concerns the neglect of environmental issues concerning remote areas as the Antarctic and the open sea.

Impact

The amount of oil leaked is enormous and equals more or less the first and largest leak accident with land drilling known as the Lakeview Gusher in the US[58]. The environmental and economical damage was tremendous, BP sets aside 7 Billion USD to cover all monetary expressed claims, but the damage to littoral and sea life stocks and sea-ecosystem may be permanent. Long term consequences in the food chain may have effect on human health as well.
Under normal consequences reconsideration of the concept of deep sea drilling would be justified, as was done with nuclear strategy after Chernobyl. This can still happen but a novelty seems to be that the major attention was given to blaming and shaming and looking for technological failures, which distracts the reconsideration of the concept of deep sea drilling in respect to other solutions for our energy needs. The fact that the spill only

[58] That took place around 1910 and which was followed by many serious incidents afterwards. This spill is known as the largest land drilling accident and showed the controlling problems of land drilling accidents. The lakeview Gusher poored out oil over land over a period of 16 months.. The area is now still land marked as an oil shelf desert.

lead to a temporarily moratorium on deep sea drilling of the US suggests that the vested interest may lead into further increased risks for environment and economical damage and that the oil industry stays in the Business as usual mode It is however difficult to see whether the business model can survive more accidents of this seize.

Evidence base / storyline

Observation

Plausibility…

Novelty

The Gulf oil incident is an unprecedented leakage into the deep sea, which leaves the character of the impact uncertain in the years to come. The real new aspect is the absence of a successful strategy to close this kind of sources while deep sea drilling has already grown to amazing proportions , this also reveals the emerging danger of irrational behavior of oil companies and governments that are inter twinned in their vested interests. Deep sea drilling is not only happening around the US but also in sea near china India and in South America.

Critical/open questions…

Drivers & Inhibitors

Business as usual and vested interests seems to be key driver.. Somehow the inhibiting factor of the potential of renewables and protectors of the environment has vanished.

Desirability aspects

Interests at stake

It seems that oil companies see business as usual which is drilling, only deeper and further as their interest. Whether this is logic is not clear. The consequences of the disaster were threatening large vested interest in the UK as employment and pension funds which made the evaluation and handling of the disaster a case of diplomatic relation between the US and the UK which unfortunately leads to a very technocratic approach on who did not close a tap and who did not follow safety instructions, this blankets the conclusion that should be drawn on the main fact that it is principally wrong to drill somewhere where you cannot plug the hole within a reasonable amount of time. Now BP has been saved a more open evaluation is needed that takes into account that the present choices are too much framed by institutions and vested interests which blocks the road to real sustainable solutions. An important aspect here is that the constitution of leading staff of oil companies that mainly consists of geologists and engineers and drilled drill co-thinkers may blind the eyes also of very large companies. Which on the long run may imply even larger disasters? This applies probably for all oil companies in the world. On the other side is the long term interest of world environment which seems to have lost its strong advocates.

Emotional aspects

Vested interests and employment within companies may block the innovation needed. On the long run you would expect emotional reactions concerning the environment (BP has done its outmost best to keep oil drenched birds from television). On the internet we can already see some concern of Green Peace.

Changeability aspects: Policies

Clarity is needed on the consequences of the recent oil spill as well as on the risk of other places of deeper and further exploitation. The complete cynical monetarisation of the disaster and the lacking reaction of environmentalists changes the political playing field however.
The logic of saving BP from bankruptcy is clear but it should lead to reconsideration of energy policy and not only of safety technology and regulation within oil companies Like in Nuclear energy complete safety is an illusion. Therefore oil companies take the risk of full bankruptcy if they do not succeed to change their course to real renewables.
A dialogue between countries and multinational oil companies should take place that should focus on the risk of the present framing of companies towards the business as usual approach that not only endangers the lives of people but also the economic position (can BP survive another accident as this one) of the companies and the world environment.
The risk for Europe should be chartered.

Source of inspiration / Initial discovery point

Remote views of the seize of the disaster area of the Gulf of Mexico oil spill.

Signals /Early Indicators

The BP gulf incident is not the first one, 10 years before a similar accident happened also in the Gulf of Mexico. Other spills with similar or larger seize were caused by wars.
Accidents with remote and deep sea oil exploitation should be monitored world wide.
Further investments in further and deeper exploitation should be monitored as well as near by accidents and accidents.
Analysis of former disasters should be reviewed.

http://en.wikipedia.org/wiki/Oil_spill#Estimating_the_volume_of_a_spill

Gulf of Mexico Oil Spill (2010)

http://topics.nytimes.com/top/reference/timestopics/subjects/o/oil_spills/gulf_of_mexico_2010/index.html

The New York Times

Monday, November 15, 2010

Chris Graythen/Getty Images

Updated: Nov. 8, 2010

The Latest

The lead investigator for the presidential panel investigating the BP oil spill said that he had found no evidence of shortcuts taken to save money by anyone involved in drilling the doomed well. Fred H. Bartlit Jr., a prominent trial lawyer hired to lead the panel's inquiry, disputed the findings of other investigators, including members of Congress, who have charged that BP and its main partners, Transocean and Halliburton, had cut corners to speed completion of the well, which cost $1.5 million a day to drill.

Overview

An explosion on April 20 aboard the Deepwater Horizon, a drilling rig working on a well for the oil company BP one mile below the surface of the Gulf of Mexico, led to the largest accidental oil spill in history.

After a series of failed efforts to plug the leak, BP said on July 15 that it had capped what it had named the Macondo well, marking the first time in 86 days that oil was not gushing into the gulf. Nearly five months after it blew out of control, the federal government finally declared the well dead on September 19th, after pressure tests confirmed that cement that had been pumped into the bottom of the once-gushing well through a relief well formed an effective, and final, seal. The Macondo well and the two relief wells were to be abandoned, following standard industry practices.

Nearly five million barrels of oil had gushed from BP's well, according to estimates by government scientists, an amount that outstrips the estimated 3.3 million barrels spilled into the Bay of Campeche by the Mexican rig Ixtoc I in 1979.

The oil from the gulf spill first made landfall in Louisiana. But in June, tar balls and oil mousse began to reach the shores of Mississippi, Alabama and Florida. Shortly thereafter it began to hit shore, smearing tourist beaches, washing onto the shorelines of sleepy coastal communities and oozing into marshy bays that fishermen have worked for generations.

By August, the slick appeared to be dissolving far more rapidly than anyone expected. The long term damage caused by the spill, however, is still uncertain, in part because large amounts of oil spread underwater rather than rising to the surface. On Aug. 20, a new study published in the journal Science confirmed the existence of a huge plume of dispersed oil deep in the Gulf of Mexico and suggested that it had not broken down, raising the possibility that it might pose a threat to wildlife for months or even years.

In September 2010, two independent researchers at Columbia University announced that the federal government, after several missteps, had accurately estimated the amount of oil spilled at nearly 172 million gallons; 185 million gallons, a statistical match when the margins of error are figured in, had actually leaked from the broken well, they said.

Many other consequences will likely ripple out for a long time to come: investigations by the Justice Department and Congress into the cause of the spill, new regulations imposing tougher review for deepwater drilling, new leadership for BP as the oil giant struggles to repair a shattered reputation.

The Explosion

A confidential survey of workers on the Deepwater Horizon in the weeks before the oil rig exploded, commissioned by Transocean, showed that many of them were concerned about safety practices and feared reprisals if they reported mistakes or other problems.

In the survey workers said that company plans were not carried out properly and that they "often saw unsafe behaviors on the rig."

According to a separate 112-page equipment assessment also commissioned by Transocean, many key components — including the blowout preventer rams and failsafe valves — had not been fully inspected since 2000, even though guidelines require inspection of the preventer every three to five years.

The two Transocean-commissioned reports echoed the findings of a maintenance audit conducted by BP in September 2009. But the Transocean-commissioned reports indicate that maintenance concerns existed just days before the explosion and the rig owner was aware of them.

Information coming from a variety of sources about the events that led up to the blast paint a picture of a complex operation that went awry just as it was drawing to a close.

Drilling logs from the Deepwater Horizon suggest that shortly after midnight on the morning of the explosion, attention had turned to temporarily plugging and capping the well so the rig could disconnect and move to another job. Halliburton, the contractor hired by BP to provide cementing services, had spent the past several weeks cementing each new segment of the well into place. Halliburton was also responsible for plugging it.

BP and Congressional investigators have raised questions about the cementing, suggesting that the seal might have been faulty and failed to keep gas from rising up in the well. According to BP, the cement work took longer than normal, and there were concerns that the quality of the cement might have been compromised by contamination with mud. Halliburton executives have said that the company adhered strictly to the specifications provided by BP for the cementing of the well.

The Government's Response

The Obama administration failed to act upon or fully inform the public of its own worst-case estimates of the amount of oil gushing from the blown-out well, slowing response efforts and keeping the American people in the dark for weeks about the size of the disaster, according to preliminary reports from a presidential commission investigating the accident, issued in October 2010.

From the beginning, the response effort was bedeviled by a lack of preparation, organization, urgency and clear lines of authority among federal, state and local officials, as well as BP. The government repeatedly underestimated how much oil was flowing into the Gulf and how much was left after the well was capped in July, leading to a loss of faith in the government's ability to handle the spill and a continuing breach between the federal authorities and state and local officials, the presidential commission reported in October.

The reports from the commission also say that about two weeks after the BP rig exploded, the National Oceanic and Atmospheric Administration asked the White House for permission to make public its worst-case models for the accident, but the request was denied.

The tenor of the reports indicates that the White House, cabinet officers, Coast Guard commanders and senior government scientists will shoulder a fair amount of blame for the response to the accident.

On April 29, just after estimates of the size of the spill were increased from 1,000 barrels a day to 5,000 (they eventually reached 60,000), President Obama announced that the federal government would get involved more aggressively in fighting the spill, and Homeland Security Secretary Janet Napolitano designated the spill as "of national significance."

Interior Secretary Ken Salazar, who early in the crisis vowed to "keep the boot on the neck" of BP, threatened to push the company out of the way. But Mr. Salazar soon backed off, conceding to the reality that BP and the oil companies have access to the best technology to attack the well.

The White House said that the government would not allow any new offshore drilling until an investigation was conducted into the spill and whether it could have been prevented. But the Interior Department continued to issue permits and waivers for drilling projects in the gulf that were already underway, leading critics to say the ban was being interpreted too narrowly.

After the White House announced it would open civil and criminal investigations into the oil spill, BP said it will cooperate fully with any inquiry, which may also extend to Transocean, Halliburton or Cameron, the company that manufactured the blowout preventer that failed to function after the explosion.

On June 15, Mr. Obama gave his first Oval Office speech, in which he used the crisis to press for sweeping change in energy policy. He also appointed former Mississippi Governor Ray Mabus as long-term recovery coordinator and demanded that BP set up a multibillion-dollar escrow account to compensate the victims.

The following day, top executives of BP went to the White House and agreed to create a $20 billion fund to pay claims for the spill. The fund will be independently run by Kenneth Feinberg, the mediator who oversaw the 9/11 victims compensation fund. BP also said it would not pay further dividends to shareholders in 2010.

Tony Hayward, BP's chief executive, and other executives faced harsh questioning from Congress, and oil company executives speaking at a Congressional hearing publicly blamed BP for mishandling the well that caused the disaster.

Representative Edward J. Markey, the chairman of the House Energy and Environment Subcommittee, released an internal BP document on June 20 showing that the company's own analysis of damage to the well bore resulted in a worst-case estimate of 100,000 barrels of oil leaking into the Gulf of Mexico each day. Mr. Markey said the document provided a sharp contrast to BP's initial claim that the leak was just 1,000 barrels a day.

Mr. Hayward was replaced in late July by Robert Dudley, BP's Mississippi-born managing director, after Mr. Hayward's repeated stumbles alienated federal and state officials as well as residents of the Gulf Coast.

Impact on Energy Policy

The deadly explosion and the resulting spill complicated Mr. Obama's plans to expand offshore oil and gas drilling, and doomed a bipartisan energy bill in the Senate in 2010. Mr. Obama announced plans to split the Minerals Management Service, the agency that oversees offshore oil drilling, into two parts, one to inspect oil rigs and enforce safety and the other to oversee leases for drilling and collect royalties.

Mr. Obama ordered a halt to virtually all current and new offshore oil drilling activity pending a comprehensive safety review. He acknowledged that oversight had been seriously deficient, but said that offshore drilling would have to remain a part of the nation's sources of energy for at least the near future.

He also began a push for action on energy legislation, hoping to capitalize on growing public anger toward BP and other oil companies, but the sweeping legislation that had been on the table before the spill dwindled and eventually died in the Senate.

In August, the administration announced that it would revise the process used for granting deepwater drilling permits to require more extensive review. White House officials recommended that the Interior Department suspend use of so-called categorical exclusions, which allow oil companies to sink offshore wells based on environmental impact statements for supposedly similar areas, while the department reviews the environmental impact. Permits for the Macondo well were based on exemptions written in 1981 and 1986. The waiver granted to BP in April 2009, as part of the permitting process for the doomed well, was based on the company's claim that a blowout was unlikely and that if a spill did occur, it would cause minimal damage.

Blowout Preventers

After the explosion, investigators focused on the failure of a component on the well's blowout preventer that is supposed to close off a well spewing out of control. The device, called a blind shear ram, is the only part of the blowout preventer that can completely seal the well. Minutes after the explosion, at least one rig worker hit an emergency button, which is supposed to trigger the blind shear ram within about 30 seconds, and then disconnect the rig from the well. But the blind shear ram never fully deployed.

An examination by The New York Times revealed the chasm between the oil industry's assertions about the reliability of its blowout preventers and a more complex reality. It reveals that the Minerals Management Service, repeatedly declined to act on advice from its own experts on how it could minimize the risk of a blind shear ram failure.

It also shows that the Obama administration failed to grapple with either the well-known weaknesses of blowout preventers or the sufficiency of the nation's drilling regulations even as it made plans in March to expand offshore oil exploration.

Records and interviews show that blind shear rams can be surprisingly vulnerable. There are many ways for them to fail, some unavoidable, some exacerbated by the stunning water depths at which oil companies have begun to explore.

They also can be rendered powerless by the failure of a single part, a point underscored in a confidential report that scrutinized the reliability of the Deepwater Horizon's blowout preventer.

The Struggle Underwater

BP clashed with the federal government over its use of dispersants, chemicals sprayed on the spill that were meant to break up the oil in the hope that it would settle to the bottom.

For weeks BP tried without success to reactivate the seal-off valves on the dead blowout preventer. Then it lowered a 40-foot steel containment chamber in an effort to funnel escaping oil to a ship on the surface, but that failed when an icy slush of gas and water stopped up the device.

In a maneuver called a "top kill," BP planned to pump heavy drilling fluids twice the density of water through two narrow lines into the blowout preventer to plug the runaway well. However, this tactic, though initially promising, failed when it became clear that the pressure of oil and gas escaping from the well was simply too powerful to overcome. With this disappointment, BP and government officials announced they had abandoned efforts to plug the leaking well.

BP engineers used submersible robots to cut off a portion of the pipe the oil was gushing through to give a new cap a better target to fit over, and pumped antifreeze down into the space to try to prevent ice buildup. They then eased the cap in place, and slowly began closing vents that had been left open to minimize pressure that might lift it off. By June 5, officials reported that they were siphoning off as much as 10,000 barrels a day, even with only one of four vents closed.

In mid-July, after 86 days of oil gushing into the gulf, the leak was finally stopped when BP managed to install a much tighter-fitting cap on the well a mile below the sea floor, then gradually closed a series of valves.

Prospects for Recovery

The effect on sea life of the large amounts of oil that dissolved below the surface is still a mystery. Two preliminary government reports on that issue have found concentrations of toxic compounds in the deep sea to be low, but the reports left many questions, especially regarding an apparent decline in oxygen levels in the water.

And understanding the effects of the spill on the shorelines that were hit, including Louisiana's coastal marshes is expected to occupy scientists for years. Fishermen along the coast are deeply skeptical of any declarations of success, expressing concern about the long-term effects of the chemical dispersants used to combat the spill and of the submerged oil, particularly on shrimp and crab larvae that are the foundation of future fishing seasons.

Yet as the weeks pass, evidence is increasing that through a combination of luck (a fortunate shift in ocean currents that kept much of the oil away from shore) and ecological circumstance (the relatively warm waters that increased the breakdown rate of the oil), the gulf region appears to have escaped the direst predictions of the spring.

And preliminary reports from scientists studying the effects on marshes, wildlife and the gulf itself suggest that the damage already done by the spill may also be significantly less than was feared — less, in fact, than the destruction from the much smaller Exxon Valdez spill in Alaska in 1989.

The scientists caution that much remains unknown, and that oil spills can have subtle effects that last for decades. Layers of oil are being found buried beneath the surface, both onshore and deep at sea. In blog posts from a research vessel in the gulf, Samantha Joye, a professor of marine sciences at the University of Georgia, reports that she observed a layer several centimeters thick on the sea floor, 16 miles from the wellhead, that she says was not a result of natural seepage.

In August, top administration officials said that 75 percent of the oil had evaporated, dissolved or been collected. But the presidential commission said in October that the government's own data did not support such sweeping conclusions, which were later scaled back. A number of respected independent researchers have concluded that as much as half of the spilled oil remains suspended in the water or buried on the seafloor and in coastal sludge, and that it will be some time before scientists can paint an accurate picture of the ecological damage.

Claims and Settlements

People and businesses seeking a lump-sum settlement from BP's $20 billion oil spill compensation fund will most likely have to waive their right to sue not only BP, but also all the other major defendants involved with the spill, according to internal documents from the lawyers handling the fund.

The fund is being administered by a prominent Washington lawyer, Kenneth R. Feinberg, who also handled the 9/11 victims compensation fund.

People affected by the spill seeking final settlements face a choice similar to that faced by the 9/11 victims: If they decide to sue instead of accepting a settlement, they could face years of litigation; and if they decide to accept the settlement, it could come before the full damage from the spill is known.

A key difference between the spill fund and the Sept. 11 victim compensation fund is the matter of geographic proximity. The 9/11 fund took that issue into account, but it was less controversial because that fund focused on compensating people injured in the terrorist attacks and families of those killed rather than adversely affected businesses.

Legal experts said that the eligibility criteria for oil spill settlements, including the emphasis on proximity, make intuitive sense, but they will cut out large sectors of businesses and people that were indirectly but nonetheless deeply affected by the spill.

The possible provision in the final oil spill settlement protocol requiring people to waive their right to sue companies other than BP that were working on the rig is also expected to face protest, legal experts said.

As state and federal officials, individuals and businesses continue to seek additional funds beyond the minimum fines and compensation that BP must pay under the law, the company has signaled its reluctance to cooperate unless it can continue to operate in the Gulf, which accounts for 11 percent of its global production.

On Sept. 1, BP warned Congress that if lawmakers pass legislation that bars the company from getting new offshore drilling permits, it may not have the money to pay for all the damages caused by the spill, and ambitious restoration efforts that officials want the company to voluntarily support will be imperiled.

In an internal report released Sept. 8, BP claimed that it was a series of failures involving a number of companies that ultimately led to the spill. Citing “a complex and interlinked series of mechanical failures, human judgments, engineering design, operational implementation and team interfaces,” the 193-page report deflected attention away from BP and back onto its contractors, especially Transocean and Halliburton.

While it puts some responsibility on BP for errors made — such as misreading pressure data that indicated a blowout was imminent — the report tries to undermine the notion that the company acted with gross negligence. Yet because of its authorship, it is unlikely to carry much weight in influencing the Department of Justice, which is considering criminal and civil charges related to the spill. The report is far from the final word on possible causes of the explosion, as several other divisions of the federal government, including the Coast Guard and Bureau of Ocean Energy Management, Regulation and Enforcement, are also investigating.

November 11, 2010, 5:43 pm

Arctic Drilling Poses Untold Risks, Study Concludes

By LESLIE KAUFMAN

An image of a an oil-spill response vessel from a Shell commercial promoting Arctic drilling.

Science

Now that the moratorium on deep-sea oil and gas drilling has been lifted by the Obama administration, the battle for the Arctic is heating up again.

The suspension of deep-sea drilling was of course a reaction to the disastrous blowout in the Gulf of Mexico that gushed from April to July, producing the biggest offshore oil spill in the nation's history. The moratorium was lifted last month, about six weeks before a Nov. 30 expiration date.

As soon as it was lifted, my colleague Cliff Krauss reported last week, Royal Dutch Shell began lobbying eagerly to get final approval for its long-delayed plans for exploratory drilling in Alaska's Beaufort Sea. The petro-giant is paying for national advertising as part of a campaign to convince the public and the government that it is taking safety precautions that would prevent the kind of catastrophe that unfolded in the gulf from happening in the Arctic.

Yet the Arctic is well known to be more fragile ecologically than the gulf. And on Thursday, the Pew Environment Group released a detailed report brimming with charts and maps that explores the question of how well the government and industry would be equipped to deal with a blowout and spill there. The report concludes, not so well. And here are some word-for-word highlights on why:

- The Arctic Ocean is a unique operating environment, and the characteristics of the Arctic OCS [outer continental shelf] — its remote location, extreme climate and dynamic sea ice—exacerbate the risks and consequences of oil spills while complicating cleanup.
- Oil spill contingency plans often underestimate the probability and consequence of catastrophic blowouts, particularly for frontier offshore drilling in the U.S. Arctic Ocean.

- The impact of an oil well blowout in the U.S. Arctic Ocean could devastate an already stressed ecosystem, and there is very little baseline science upon which to anticipate the impact or estimate damage.
- Oil spill cleanup technologies and systems are unproved in the Arctic Ocean, and recent laboratory and field trials (including the Joint Industry Project) have evaluated only discrete technologies under controlled conditions.
- Certain environmental and weather conditions would preclude an oil spill response in the Arctic Ocean, yet an Arctic spill response gap is not incorporated into existing oil spill contingency plans or risk evaluations.

So the researchers concluded that far more study is needed of the Arctic marine ecosystem. Modeling should be devised to project the trajectory of oil flow in sea ice conditions should a spill occur, they added.

And deployment exercises should be conducted to determine how effective a spill response would be in such a remote, sparsely populated region "before introduction of new offshore oil spill risks," the report said. (The study includes a detailed critique of Shell's planning scenarios in the Chukchi and Beaufort Seas.)

In other words, the study's message is that the Arctic is not ready for such deep-sea drilling operations.

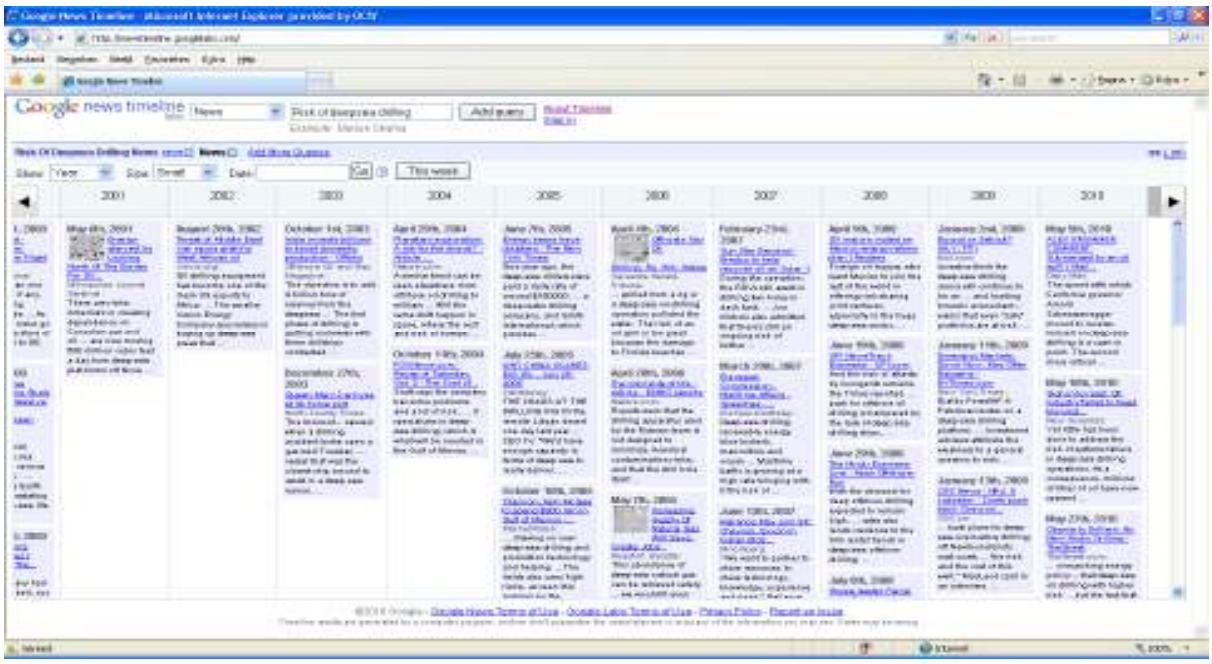
Asked about the Pew report's conclusions, a Shell spokeswoman, Kelly op de Weegh, said in an e-mail that the company had "taken extraordinary steps to compensate for the harsh conditions we expect to encounter in the Arctic, and that is evident in all aspects of our program, including ice management, a commitment to oil spill response and new baseline science."

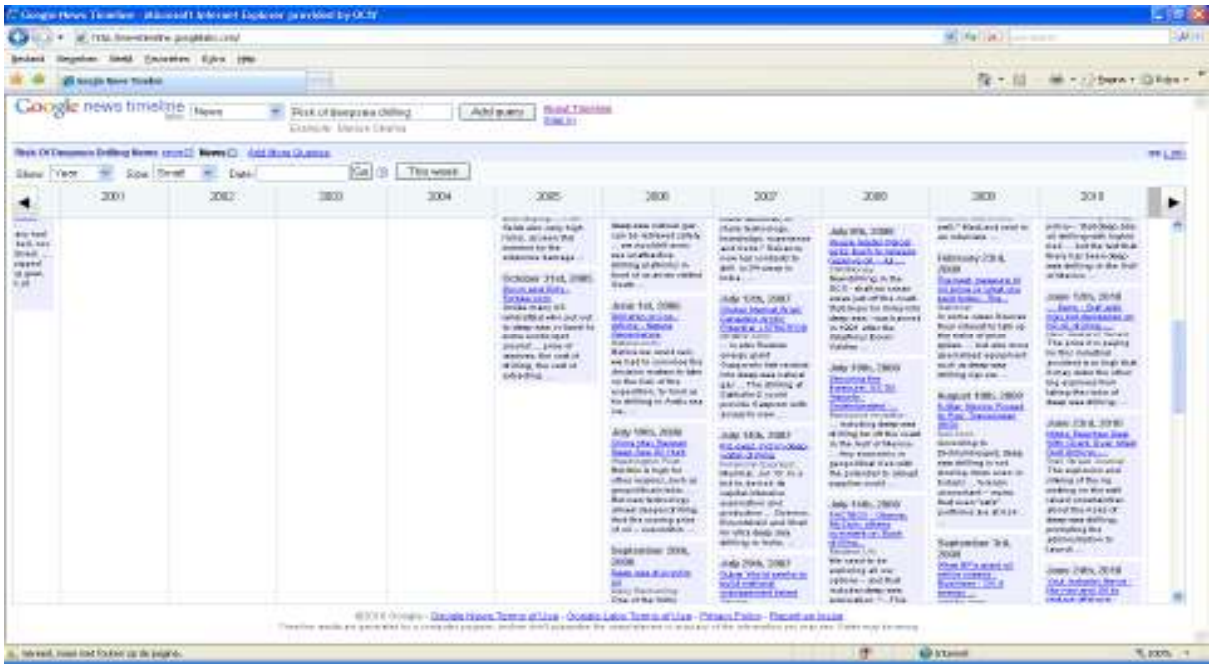
"Our Arctic exploration plan has been scrutinized by regulators, stakeholders and the courts, and we look forward to demonstrating once again that we can operate safely and responsibly in the Arctic," she added.

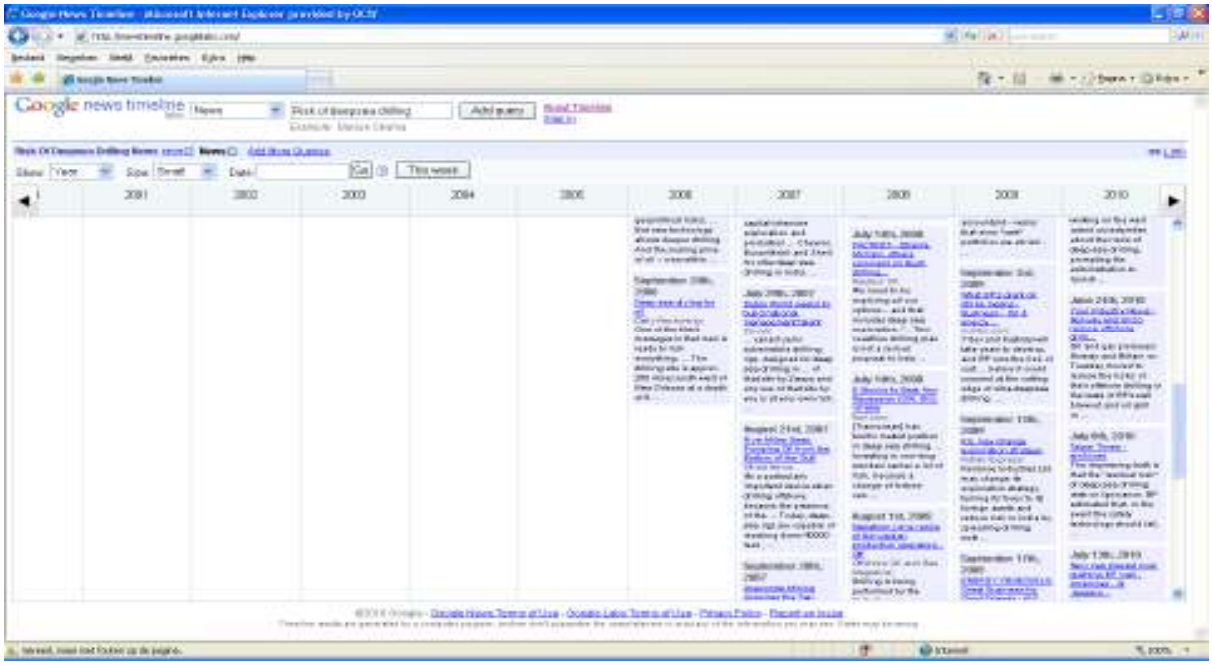
The study's conclusion was also disputed by lawmakers who support the drilling. "I disagree with Pew's insistence on an unspecified moratorium on Arctic development, because the perfect set of conditions simply never occurs," Senator Mark Begich, Democrat of Alaska, said in a statement. "I'll continue to push the Obama administration for responsible Arctic development now to help meet America's energy, national and economic security."

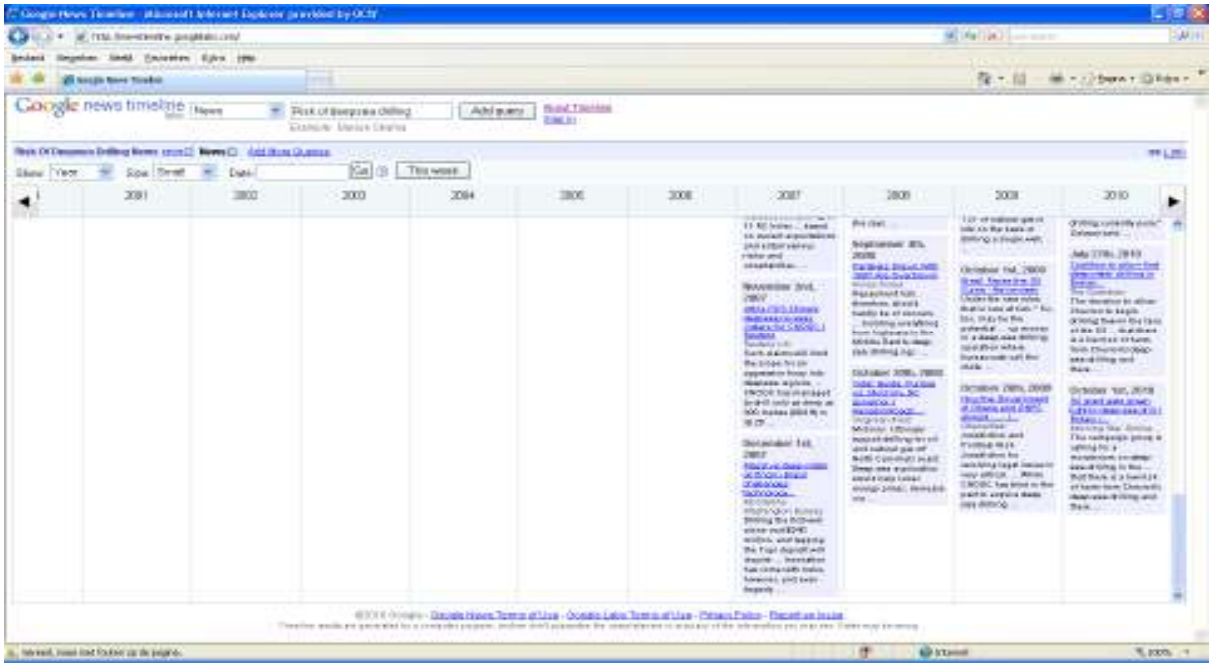
Google timeline

Google News Timeline is a web application that organizes search results chronologically. It allows users to view news and other data sources on a browsable, graphical timeline. Available data sources include recent and historical news, scanned newspapers and magazines, blog posts, sports scores, and information about various types of media, like music albums and movies. Below follows the results of the search for news related to risks of deep sea drilling going back to 1995.









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