ENERGY: INSPIRATION FOR THE FUTURE

Editors

Piet Boonekamp
Heleen de Coninck

Energy: Inspiration for the future

Essays in honour of Jos Bruggink's retirement from ECN

Energy: Inspiration for the future

Edited by: Piet Boonekamp and Heleen de Coninck, ECN
2011, Amsterdam

Design: Ricoh, ECN
Copy-editor: Marlies Kamp, ECN
Lay-out: Manuela Loos, ECN

Published and distributed by Ricoh, ECN

Table of contents

Preface

This book is published at the occasion of the retirement of Jos Bruggink, who is turning 65 on July 9th, 2011. From 1979 on he worked in the unit Policy Studies of the Energy research Centre of the Netherlands (ECN), which started in 1976 as the Energy Study Centre. As the manager of the unit, from 1989 to 2004, he played an essential role in building an independent energy knowledge centre that is both well-rooted in the technical research at ECN and also plays a central role in supporting Dutch energy policy, while also holding a recognized position on energy and climate policy on the European and international level.

Jos' long-time wish is to write a book on energy futures addressing the global scale and covering the longer term. His 'liber amicorum' therefore is not just a book of love and appreciation for the contribution Jos has made to the energy field in the Netherlands and abroad. We hope this book will serve as an encouragement and a source of inspiration for Jos to write his book. The authors of this book, people Jos has worked with over the years, inside as well as outside of ECN Policy Studies, have made their contributions because they all feel a publication by Jos Bruggink on energy futures would definitely be worth reading.

The central theme in this volume is: Is it useful at all to study the energy future? Over Jos' career, the energy policy field has changed radically – and not. Since the late 1970s we have seen everything we could imagine and more: from dirt-cheap oil to crisis-prices, Chernobyl, the appearance of an environmental agenda to combat acidification and climate change, and liberalization of the energy markets in Europe leading to a radically changed role of the state in the energy system. At the same time, however, the energy system has been remarkably stable. We still drive cars that run on oil, we generate most of our power from a mix of fossil fuels and we heat our houses with gas. For the current questions, quantitative techno-economic analysis does not suffice; political, technological, social as well as economic issues all affect the outcome and put high demands on our ability to do integrated assessment and reflect critically on our assumptions.

This book bundles views on the future of a number of energy-related issues. Renewables are the fastest-growing energy source, but are coming from a low base. What does it take for them to make a difference? Marc Londo and Wim Sinke give their views on biomass and solar energy, respectively. Piet Boonekamp reflects on studying the energy future for the Netherlands and concludes that, despite all our efforts, there has been limited progress towards a secure, affordable and clean energy supply. However, in any energy future, energy saving is a no-brainer. Pieter Boot analyses the ambition and progress on a sustainable energy system in four North-western European countries, and how coordination between them could help their transition. Dolf Gielen discusses the role of innovation in all of this, and Bob van der Zwaan and Hilke Rösler talk about whether we can foretell anything at all about that process. Are the billions of people without access to modern energy finally going to get connected and what policy does that take? Jan Cloin and Tineke Roholl reflect on this question, while Raouf Saidi and Rahul Barua wonder about the promise of improved cook stoves. Lastly, Heleen de Coninck addresses the question what all these international developments mean for climate change, and which institutions can matter.

The authors were requested to base their contribution on their experience in specific working fields. Therefore, the book will cover selected issues related to possible energy futures. However, it does present a broad picture of elements that can play a role in the development of a sustainable energy system. It is our hope that the book does not only inspire Jos to use his talent for critical thought for his own work, but that the result is also useful for anyone interested in the way the energy (policy) system can or should evolve.

The publication of this book owes much to the contributors, who, out of appreciation for Jos Bruggink's work, have spent considerable private time writing their contributions. In addition, we would like to sincerely thank various colleagues from ECN Policy Studies who have put in their personal effort to publish this book, in particular the artistic skills of Manuela Loos, who was responsible for the layout and cover design, and the copy-editing by Marlies Kamp. Last but not least, ECN Policy Studies, currently under the lead of Remko Ybema, provided the means to print the book, and the printing was by Ricoh, the in-house print shop at ECN.

Piet Boonekamp and Heleen de Coninck *(editors)*
Petten, July 2011

Changing views in Dutch policy making and support by ECN

Piet Boonekamp

Introduction

One of the goals of ECN Policy Studies is to support policy makers in setting up a robust and cost effective energy policy for the Netherlands. Since 1980 the unit has produced numerous outlooks on energy and emission trends, based on calculations with energy models and the views of experts. One may wonder whether this has been successful, or even whether formulating a robust policy is actually possible. During this period several major new events took place that were not anticipated, nor were their effects fully understood by most people. Examples are the oil crisis, the acidification problem, the nuclear disaster at Chernobyl, the EU forced uptake of the liberalization of energy markets, and, of course, the emerging GHG problem. Time and again the effects of the new events had to be incorporated in new energy outlooks and in reformulated energy policy.

Obviously, attempts have been made to cope with emerging problems, possible trend breaks and other known but hard to quantify issues. This has been accomplished in part by formulating sets of energy scenarios with different assumptions on driving forces and restrictions. However, looking back, it is felt that a more fundamental approach is necessary to deal with new events. This paper tries to provide building blocks for such an approach, based on an analysis of the period from 1970 onwards.

First an overview is presented of the developments for:

- policy goals used in Dutch energy policy (secure, affordable and clean energy supply)
- options and concrete changes in the energy system to meet these goals
- major external events influencing the policy goals and options.

Option is defined here as a type of change in the energy supply system, in such a way that policy goals are realized to a larger extent. For instance, the option ‘diversification’ can contribute to security of supply. Options encompass different **concrete changes**, e.g. diversification can take the form of a shift from (Russian) gas to coal in electricity production. **Events** are developments that suddenly happen (e.g. a nuclear accident), have unexpected effects (e.g. tree dying due to acidifying emissions) or change the way trends are perceived (e.g. the Brundtland report on the importance of the greenhouse problem).

Given these developments, the following issues are analysed:

- How did the major events influence the options?
- Did the significance of policy goals change due to the events?

Finally, observations are made about overall trends and mechanisms, leading to suggestions on how to deal with future developments.

Policy goals

The goals of energy policy are a secure, affordable and clean energy supply. These three goals were already mentioned in the first White Paper on Energy of 1974 and are still valid.

Secure can be further divided into security of supply (SoS) and reliability of delivery. The first issue involves scarcity of resources and availability of primary energy carriers where it is needed. An example is the interruption of gas supply to Europe in 2006 due to a conflict between Russia and the Ukraine on gas payments. The second issue relates to the timely and appropriate delivery of secondary energy carriers, where capacity problems in refineries or outage for electricity networks play a role.

Affordable refers to the costs of energy to the economy in general, and competitively priced energy for industrial users in particular. What is affordable can be subject of discussion, but it is generally believed that the very high oil prices around 1980 contributed to the economic crisis at that time. Competitive prices are important for energy-intensive industries that often sell their products at the world market, e.g. aluminum and steel (electricity) or base chemicals and paper (gas or oil).

A **clean energy supply** means that the burden on the natural environment and/or human health is as low as possible. In practice the most important energy related issues are acidification due to SO_2 and NO_x emissions and the emission of CO_2 that contributes to the greenhouse effect. The risks of nuclear energy, e.g. discharges of radioactive substances, are also part of a clean energy supply.

Options to meet the goals

Energy policy has several options to attain the above-mentioned goals. These options were developed in the course of time when and where it was needed, even before energy policy was explicitly formulated in the first White Paper on Energy of 1974. Below, the following policy options are described: diversification, storage, savings, renewable energy, clean technologies and non-physical options.

Diversification of primary energy supply has been the main option with regard to a secure energy supply since the first oil crisis in 1973. At world level diversification meant substituting coal and nuclear energy for oil or gas. In the Netherlands, the focus was less on replacing gas due to the availability of large national gas reserves.

Diversification also served the goal of affordable energy costs, as coal prices were lower than oil and gas prices and nuclear electricity was (expected to be) cheaper than the fossil based alternatives. Some forms of diversification contribute to a clean supply, e.g. nuclear energy with regard to the CO_2 emissions. But this is not the case when replacing gas by coal in power stations. A special case of diversification is the use of liquefied gas (LNG) instead of gas through pipelines; here the flexible transportation mode over long distances can increase security of supply.

In the 1960s, coal was replaced in most end-use sectors by natural gas from the large Groningen gas field. Therefore, substitution between primary energy carriers was restricted to electricity production and part of industrial energy use. In transport only very recently options for replacing oil have become practical, e.g. natural gas or electricity. In the 1970s, the Borssele nuclear plant replaced fossil based plants. Substitution between gas and oil has been practiced in dual firing power stations up to the 1980s, substitution of gas by coal by retrofitting gas based power or, in the 1980s, by new coal power plants replacing old gas power. Recently LNG has started to replace import of gas through pipelines.

Storage of energy carriers is another option to enhance security of supply. For oil a strategic oil reserve is available in the Rotterdam area, to meet at least 90 days of oil demand in case of disruptions of oil supply. For natural gas the Groningen gas field with its large (spare) capacity acted as the swing producer for the Netherlands and part of Europe. In order to play this role as long as possible the gas in the Groningen field has been maintained as much as possible by restrictions on (new) gas use, and by giving priority to extraction of gas from small gas fields under the North Sea. When the capacity decreased, compressors were installed to compensate for the lower pressure in the gas reservoir and a peak-gas installation was built in the Maasvlakte area in the 1980s. In the nineties empty gas fields were used to create spare capacity for seasonal fluctuations. Electricity storage systems were hardly used, only in the form of flexible imports based on pumped hydro systems. Reliability was found in spare generation capacity above the maximum annual load and arrangements with large industrial users on interruptible supply.

Energy savings serve all three goals of energy policy; they lower the dependence on primary energy carriers from foreign sources, they lower the costs of energy use and they limit the various emissions. If the saving measures are cost-effective, they make energy use more affordable and they can also improve the competitiveness of energy intensive industry. Savings can be realised by reducing energy demand, e.g. by insulation of dwellings, or by a more efficient conversion of primary energy in secondary energy carriers. A specific example is combined heat and power (CHP), which saves energy compared to the separate production of electricity in power stations and heat production in boilers. However, because electricity production with CHP generally is based on gas, it does not always contribute to diversification.

Some effects of **renewable energy** sources are the same as for diversification. They lower the dependence on foreign energy sources (secure) and limit emissions (clean). However, in general they do not contribute to lower energy costs (affordable) and in some cases their output is not available when needed (reliability).

Clean technologies involve end-of-pipe measures that remove (a large part of) the unwanted emissions from the conversion process. This option only contributes to the goal of a clean energy supply. Due to the extra costs it does not favour affordable prices, nor does it improve the security of supply or the reliability. The earliest examples of applied clean technologies are desulphurization units, and low-NO_x burners in power stations and industrial boilers or furnaces. These technologies limited the acidifying emissions, which caused harm to nature, especially to forests. In the 1990s, the 3-way catalyst in cars and adaptations to diesel engines also limited other emissions, such as ozone, particles and hydro-carbonates, which are detrimental to human health. The use of low-sulphur fuels is not a technology option in itself, but it asked for removal technology in refineries. Finally, carbon capture and storage (CCS) is proposed to limit the CO_2 emissions of (coal) power stations or large industrial processes.

All previously mentioned options contribute to the goals by influencing the physical properties of the energy supply system in some way. **Non-physical options** contribute to the goals in another way, e.g. cheap gas for industry or power stations, contributing to affordable prices while limiting the emissions. The first case was applied in 1980 through the 'Giganten' scheme; the second one in 1989 when SEP imported Norwegian gas at 'coal-kWh' costs for the new Eems power plant. Another example is the Emission Trading System (ETS) that makes it possible to have more coal power (better security of supply), in combination with buying emission allowances (at the expense of affordability), without influence on CO_2 emissions attributed to the Netherlands (not harming the goal for clean).

Major external events

The major external events are listed in Table 1, including their (estimated) duration of influence on the options and goals.

The **first oil crisis** resulted in a physical reduction of oil supply to OECD countries by OPEC. Especially the USA and the Netherlands were hit because of their support for Israel in the 1973 war. But shortages were mitigated fast by redirecting oil transports, supply was back on track after a year, and oil prices dropped again. The sense of vulnerability influenced policy up to the 1990s. The vision on the **role of the Groningen gas field** changed completely during the 1970s. In the 1960s it was thought that the gas reserves should be exhausted as fast as possible before cheap nuclear energy would make it uncompetitive. In the 1970s this idea was abandoned and it was realised that the gas reserves could play a beneficiary role in the longer term. Restrictions on gas use were formulated in 1978, but due to its contribution to the government budget, this policy stagnated in 1981. When it became clear that many small gas fields compensated for the depletion of the Groningen field, the restrictive policy was abandoned altogether in the 1990s. The most important effect of the **second oil crisis** was the high price of energy, which was expected to last. However, the influence of this event on policy decreased after the price fall of 1986.

Table 1: *Overview of events with substantial influence on the energy supply system*

Event	Duration influence	Comments
First oil crisis	1973 – 1990	Gradual end of influence
Role of 'Groningen'	1978 – 1995	Role diminished in EU gas market
Second oil crisis	1979 – 1986	Sharp drop in prices by 1986
Acidification problem	1984 – 1995	Start and end year not precise
Chernobyl accident	1986 – 2005	New nuclear planned around end year
Brundtland report	1988 – 2008	End year > meeting in Copenhagen
EU policies	1992 – now	Acceleration after Treaty of Maastricht
Market liberalization	1996 – now	Questioned after network breakdown
Network breakdown	2003	New York and Italy
Gas disruptions	2006 – now	Strengthened by second disruption 2009
Copenhagen GHG	2008 – now	Kyoto Protocol in disarray
Fukushima accident	2011 – now	Influence remains to be seen

The start of the **acidification** problem cannot be pinpointed to one particular year. The problem was already highlighted in the 1971 report to the Club of Rome. This EU wide problem became an intensely debated issue in Germany in 1984, when it was claimed that one-third of the trees in forests were heavily damaged or dying (Grosse Waldsterben). In the first NMP (national environmental plan, [RIVM, 1989]) it was still a major theme, but more and more it appeared that the effect on trees was not as clear and urgent. However, the researchers hold on the effects in the longer term [PBL, 2010].

The **Chernobyl accident** led to radioactive precipitation all over Europe and restrictions on the use of crops and dairy products. The accident happened shortly before the official government decision to build two nuclear power plants, which plans were abandoned directly.

The **Brundtland report** was published at the end of 1987 and put the greenhouse problem, which for decades was discussed only in academic forums, on the global political agenda. Especially in the Netherlands the message came through loud and clear and it became the most influential event for energy policy in the 1990s. Recently it became clear that the Kyoto Protocol will not be extended; looking back the Copenhagen meeting of 2008 can be seen as the turning point.

EU-policies have gained more and more influence on Dutch energy policy. Here 1992 is taken as the starting point, because the Treaty of Maastricht gave the European Commission more room to formulate a policy to promote the internal market, including that for energy. This process led to a large number of directives (for energy efficient buildings, cars and appliances, for emission trading and for the structure of gas and electricity markets) and is still ongoing.

Market liberalisation for electricity and gas was put on the agenda in the 1995 White Paper on Energy. It influenced in particular the way energy policy should realise its goals, e.g. with market based instruments such as energy taxes and emission trading, instead of the former reliance on semi-governmental actors like distribution companies and social housing corporations. In the last decade the new market system was more or less implemented in the Netherlands and its function as a new driver of changes in the energy system subsided. This was strengthened by questions about the reliability of the market based electricity system (see network breakdown).

The **network breakdowns** in New York and Italy in 2003 caused major disruptions in electricity supply and raised many questions about the reliability of the system under a market regime. Moreover, interruptions of electricity delivery occurring in 2000 and 2001 in California proved to be to the result of a flawed design of the market system.

The **disruptions of Russian gas supply** to Europe in January 2006 and 2009, caused by a disagreement between Russia and Ukraine on payments for gas, showed that a third party can jeopardise a contract between supplier and consumer, leaving both Russia and the EU powerless to restore the situation. This development has again put focus on the vulnerability of Europe's gas supply, which is expected to grow in the future.

The **Copenhagen** meeting failed to produce agreements at worldwide level to limit the emissions of greenhouse gases. The exemplary role of the EU has not led to a change in behaviour of other countries in the world. Recently it became clear that the Kyoto protocol will not be continued after 2012.

The breakdown of several nuclear plants in **Fukushima** in March 2011 once again stressed the risks of nuclear power, although the effects in other parts of the world remained quite modest. The responses were mixed, ranging from a complete German nuclear exit to expansion as planned in China. The Dutch government has announced that it will continue with its plans for one or two units.

Overview of events, options and goals over time

The developments have been put on time lines from 1970 to 2011 (see Table 2). Each **event** is marked on the time line for the adjoining policy **goal** (see upper part). The time lines for the **options** were filled with concrete **changes** in the energy supply system (see lower part). The intensity of the colour of the time line depicts the importance of the goal (upper part) or the focus on the options (lower part) over the period.

Table 2: *Time line for events, options and goals in the period 1972-2011*

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Events (per goal)																				
SECURE																				
Security of Supply		**OC-1**				**Role Groningen**												Berlin		
Reliable delivery																				
AFFORDABLE																				
High costs		**OC-1**						**OC-2**								price drop				
Competitive prices										Giganten								Coal-gas parity		
CLEAN																				
Environment	Club v.Rome											**Waldsterben**								
Climate																	**Brundtland**			
Radiation								TMI							**Tsjernobyl**					
Options and changes																				
DIVERSIFICATION																				
Substit-coal	Mines closed												G to C			coal power				
Subst-nuclear		Borssele					Moratorium			MDE				2 PP						GHG-option
STORAGE																				
Emergency/peak			IEA/oil																LNG-peak	
Gasreserves	no exports			small fields			Restrictive		oil power		coal-ind.		import							
SAVINGS																				
End-use		Gas-oil-parity						NIP	WIR-ET											MAP
CHP									DH							CHP-ind.				
RENEWABLES															IPW					MAP
CLEAN TECHNOLOGIES						SG-PP			BIPC?						RR-SO2				SEP-Cov	

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Events (per goal)																				
SECURE																				
Security of Supply									Irak						**Ukraine**			**Ukraine**		
Reliable delivery									California			NY/Italy								
AFFORDABLE																				
High costs																	peak			
Competitive prices																				
CLEAN																				
Environment																				
Climate	**EU-policy**					Kyoto		Rio									**Copenhagen**			
Radiation																				**Fukushima**
Options and changes																				
DIVERSIFICATION																				
Substit-coal											coal+biomass			coal for export						
Subst-nuclear																			Borssele 2	
STORAGE																				
Emergency/peak				Alkmaar-peak			Langelo											gas-season		
Gasreserves					STEG, CHP										Storage, Gas-hub					
SAVINGS																				
End-use			VA				BM			EPR					S&Z					
CHP	CHP-JV		VA												horti-CHP					
RENEWABLES				10%	REB						MEP	EU-target					SDE			
CLEAN TECHNOLOGIES	Bugg.				3-way catalyst									NOx-trade			CCS	Electric cars		

OC = oil crisis
Peak = price hike 2008 for oil
Giganten = gas for coal-parity price
TMI = Harrisburg nuclear accident
Ukraine = disruption Russian gas supply
MDE = Public discussion on nuclear energy
NIP = National Insulation Plan
DH = District Heating
MAP = Environmental Action Plan distribution companies
VA = Voluntary Agreement on savings

BM = Benchmark covenant industry on efficiency
EPR = Energy Premium Scheme (savings)
S&Z = Clean & Efficient savings programme
IPW = Integral Wind Programme (R&D program)
MEP = Environmental Quality Electricity (subsidy scheme)
SDE = Stimulating Sustainable Energy (subsidy scheme) scheme
SG-PP = Selective gas supply for power plants to limit emissions
BIPC = Fuel Plan Power Plants
RR-SO2 = Removal of SO_2 from stack gas power plants
SEP-Cov = Covenant on technological measures against acidification

Effect of events on the application of options

The first research item regards the influence of the events on the options. In other words: what concrete changes occurred in the energy system of the Netherlands in response to the events?

The most concrete result of the **first oil crisis** was the establishment of the International Energy Agency at the OECD and the implementation of the strategic oil reserve mechanism. It also triggered the need for a more efficient use of resources, as highlighted already by the Club of Rome in 1971, through a stronger coupling of the gas prices to costs of oil products and by stimulating energy savings. The oil crisis also stimulated diversification to coal in electricity supply and reinforced the plans for three nuclear power plants of 1000 MW in 1985. However, these plans were postponed and at some point even extra oil was used (see role of Groningen).

The changing view on the **role of Groningen** by 1974 led to a stop on new export contracts or new power stations based on gas. In 1978 it led to restrictions on existing gas use, especially for large users such as power stations and industry. A peculiar aspect of the policy was the promotion of oil use instead of gas in dual firing power stations, quite opposite to international trends to limit oil use in power stations. The new role as swing producer for North-West Europe led to the 'small fields' policy, which stimulated the more expensive extraction of small gas fields under the North Sea. Another way to maintain the production capacity of Groningen as long as possible were import contracts with Norway and Russia from 1984 onwards. The role of Groningen as swing producer continued, but the goal of retaining the gas for the future was abandoned in 1984 when reserves proved to be much larger.

The **second oil crisis** was the main driver for diversification from the viewpoint of lower energy costs, especially for the international energy-intensive industry. In the White Papers on Coal (1980) it was envisaged to have one-third of electricity production on coal and also more coal use in industry for boilers. The White Paper on Nuclear (1981) envisaged the same fraction for nuclear power. In the meantime, the so-called Giganten scheme allowed for supplying cheap gas to power stations and large industrial users to improve their competitiveness in the short run, while at the same time enabling industry to lower the use of fuel oil. The high prices also stimulated further savings, with help of the National Insulation Program and the tax scheme for companies investing in saving measures (WIR-ET).

The **acidification** effects of SO_2 and NO_x emissions on nature and air quality led already in the 1970s to the use of gas instead of coal in power production, and later to the BIPC (Fuel Plan for Power Plants). The emergence of the problem of dying trees in the mid-eighties (which was later challenged) stimulated the prescription of low-sulphur oil products, de-sulphurisation at power plants and low-NO_x burners in large boilers and furnaces. In the transport sector it led to the 3-way catalyst for all new cars in the 1990s.

Due to the **Chernobyl accident** the final policy decision to build at least two large nuclear plants was abandoned. It blocked thinking about new plants for years, until public resistance gradually faded and it became an option to solve the greenhouse problem. Moreover, the production of existing plants (Borssele and Dodewaard) was questioned, but in the 1990s an extension of the lifetime of Borssele up to 2003 was already agreed on, and now it will even run until 2033. With coal at its planned contribution, other alternatives for nuclear were found in additional electricity imports (partly based on nuclear) and combined heat and power based on gas. In addition, renewable energy received more attention, as highlighted by the Integral Program Wind and the experimental wind farm of the combined electricity producers (SEP) in Sexbierum.

The **Brundtland report** strengthened all previous actions on resource use and environment, but it also introduced reduction of CO_2 emissions as a major new theme. Especially in the Netherlands it led to many actions on energy savings and the use of renewable sources, by government, industry (Voluntary Agreements) and electricity companies (Environmental Action Plan and Heat plan). It raised fundamental questions about the role of cheap energy as driver of economic growth (analysed in the Wolfson study on energy taxes). As part of a restructuring of the tax system, a regulatory tax (REB) for small scale use was gradually introduced from 1995 onwards. Coal power production was challenged, but could continue by combining it with biomass use. Finally, 'Brundtland' put clean technologies for CO_2 capture and sequestration (CCS) on the agenda.

EU policies on energy became much more influential after the Treaty of Maastricht, with the internal market for products and services as a main theme. The EU introduced much new policy on the role of the market in energy supply, especially for gas and electricity as coal and oil were already market driven. Other directives regarded labeling of appliances (1992), clean industrial installations (IPPC, 1996), energy savings in buildings (EPBD, 2002), emission caps and trading for CO_2 (ETS, 2003) and combined heat and power (CHP, 2004).

The **liberalization of energy markets** in the Netherlands anticipated on decisions to be taken at EU level. It was dealt with in the Third White Paper on Energy of 1995. One direct consequence was a stagnation of the saving activities as the focus of the energy sector shifted to surviving as a company in the new market. Another effect was that the coordinating role of SEP was lifted, and the optimization of production per plant to minimize total fuel use was abandoned at the cost of considerable extra fuel consumption. Moreover, for CHP the favourable ratio between high electricity prices (benefits) and low gas prices (costs) changed due to the market trends, and capacity extension in industry stagnated. A more fundamental effect of the market model was that new types of policy instruments had to be developed, e.g. the Regulatory Energy Tax (REB) on gas and electricity, introduced from 1995 onwards and the Emission Trading System (ETS) for large emitters in Europe.

The **network breakdowns** in New York and Italy in 2003, and the interruptions in California in 2000 cast doubt on the reliability of the system under a market regime. The new EU directive on electricity supply and the Dutch Energy Report of 2002 paid much attention to assured reliability.

The lack of agreement in **Copenhagen** on the worldwide greenhouse approach, in 2008, did not have direct consequences in the short term because the EU did stick to its leading role in the world and to its earlier decided goals. However, the position of the Netherlands as forerunner, which was already deteriorating since 2000, changed to that of only meeting the minimum goals. Recently, doubt has been expressed [PBL, 2011] about the feasibility of realising the targets for renewable energy and CO_2 in 2020 with planned measures within the Netherlands.

The **disruptions in gas supply** from Russia in 2006 showed the risks of the large and increasing dependence on Russian gas, an issue that moved out of sight during the shift to a market based gas supply. It further stimulated storage facilities to bridge seasonal fluctuations, similar to the one built in Langeloo and the one planned in Alkmaar. It accelerated the development of a new transport route north of the Ukraine and a southern route for transport of non-Russian gas. However, for the moment diversification away from gas, to limit the increasing dependence, is not discussed.

The effect of the **Fukushima accident** on a decision to be taken on new nuclear plants was quite different from the situation after Chernobyl. The Dutch government announced that it would not change its plans for nuclear power in any way. Moreover, the German decision to stop with the nuclear option is seen as an opportunity for new nuclear power in the Netherlands.

Events and importance of policy goals

The second part of the analysis looks at the effect of the events on the relative importance of the three main policy goals. For this analysis the main goals have been split into:
- secure: security of supply and reliability of delivery
- affordable: costs to the economy and competitively priced energy for industry
- clean: emissions harmful to nature (SO_2, NO_x), to human health (air pollution, radiation) or both (ozone, CO_2).

For each of the sub-goals the deciding events are as follows. The goal **security of supply** has been influenced most by the disruption in oil supply during the first oil crisis, and to a lesser extent by the two gas disruptions due to the Ukraine-Russia dispute. However, the large gas reserves in the Netherlands have mitigated this problem so far. The **reliability of delivery** has never been an issue for gas. For electricity it became an issue during the liberalization of the market when black-outs occurred in California, New York and Italy. **Cost to the economy** was the prime concern after the second oil crisis, which led to the highest oil prices ever. The recent price hike for oil in 2008 had a much smaller impact due to the smaller role of energy costs for the economy and shorter duration of high prices.

Competitively priced energy for energy intensive industry was an issue after the second oil crisis, until the lowered gas prices, resulting from the 'Giganten' scheme, limited the difference with prices based on coal and/or nuclear. The possibility to import electricity and the market liberalization eased the problem further. It was only during the recent price hike in 2008 that competitiveness became an issue for a short while.

Harmful emissions to nature became an issue in the 1980s when trees were claimed to die from acidifying emissions. The issue disappeared from the agenda after the effect on trees was challenged, but emissions of SO_2 and NO_x were already cut significantly. As for **harmful emissions to human health**, large cuts were made as well, although small particles are still a matter of concern today. **Radiation** and its effect on human health became a very important issue after the Chernobyl accident, much more than after the accident in Harrisburg (TMI) in 1979 or the recent Fukushima accident. However, even the Chernobyl effect has faded away in the last decade with planned nuclear plants in many (developing) countries all over the world.

Changes in the priorities for the goals

Secure, in the form of availability, has been the most important goal since the first oil crisis. **Affordable**, referring both to cost to the economy and to competitive prices, became important after the second oil crisis. The priority of both goals faded after the drop in oil prices and ample availability of gas.

Clean gradually gained importance in the 1980s (acidification and radiation), but became the overriding issue in the 1990s (greenhouse problem). Recently secure, in the form of reliable deliveries, came back due to large-scale blackouts and two interruptions for Russian gas to Europe. **Affordable** is back on the agenda since the price hike in 2008 and the peak-oil discussion. But **clean** tends to become less important, as classic environmental problems have lost their sharpness, and concrete solutions for the greenhouse problem remain out of sight.

Overall it can be observed that at first a new goal overruled important earlier goals, but fading goals are being revived, although sometimes in a different form.

Changes for the options

Diversification has been an issue in the Netherlands since the first oil crisis, but less than abroad due to the large gas reserves in the Netherlands. It has been hindered by risks (for nuclear), emissions (for coal) or costs and reliability (for renewable). **Storage** has been an issue for oil since 1973 and for gas from about 1978 onwards, but mainly to maintain the role of Groningen as swing producer. Since the gas supply disruptions, storage has become an option in its own right. **Savings** have always been one of the options, either to limit dependence on foreign sources, to cope with high energy prices or to mitigate harmful emissions. **Renewable energy** only gained a real role in the 1980s after the nuclear option was blocked and the broad sustainability concept emerged from the Brundtland report. **Clean technologies** were particularly successful in the 1980s (SO_2, NO_x) and 1990s (air pollution of cars), but played no role for the new greenhouse problem so far.

Overall observations

Given the described developments for the whole period 1972 to 2011, some birds eye observations are made.

All events mentioned have been setbacks for one or more of the goals. They restricted solutions (such as Chernobyl for nuclear energy) or made it more difficult to attain the main goals (such as the emerging acidification and greenhouse problems for the 'clean' goal). There were no windfall events, such as technological breakthroughs that happened 'out of the blue'. One so-called breakthrough, the 'cold fusion process' published by Fleischmann in 1989 [Wikipedia], proved to be a hoax. One real positive event for society as a whole, the breakdown of the 'iron curtain', did not improve the energy situation in Europe and proved to make the gas supply from Russia less reliable due to the independence of Ukraine.

Planned changes in the energy supply system can be blocked by accidental events. The best example is the Chernobyl accident which froze the nuclear diversification option for decades. But the same could have happened to other planned changes, such as the introduction of the market concept in the nineties. Would this concept have survived if the black-outs like in New York or Italy in 2003 had occurred earlier at a European scale?

The introduction of options, in reaction to events, does not always lead to better achieving the goals of energy policy. Some options were very successful, such as **clean technologies** for limiting acidification or air pollution (except coal gasification). This is also valid for the option **energy savings** (including CHP), except for the period after 2000 when this option stagnated. The **storage** option was a relatively easy one, due to the presence of the Rotterdam oil industry, the properties of the large Groningen gas field for balancing demand and supply, and later the availability of suitable empty gas fields. However, the major **diversification** options appeared to create new problems (the shift to coal for the greenhouse problem and nuclear power for safety). The **renewable** option has only realised a marginal contribution to a changing energy supply so far. Finally, the **non-physical** option of cheap gas, to have competitive energy prices, was only possible in a past with large and increasing gas reserves.

With regard to the **security goal**, the problem of exhaustion of resources, looks less pressing now, due to a lower growth rate for worldwide energy consumption than expected in 1973, and more optimistic estimates for gas reserves. However, for oil the reserve-production rate has not improved in the past decades and the peak-oil discussion points at supply problems in the near future. The availability has been made more secure by emergency stocks (oil), storage in empty gas fields (gas) and spreading across different regions (African oil) and transport modes (LNG). Contrasting with this positive developments is the increasing dependence of Europe on oil (after the North Sea boom) and gas (with no major discoveries after Groningen, UK and Norway).

As to the second **goal 'affordable'**, no structural solutions have been found. The low prices from 1986 to 2000 were a matter of advantageous supply-demand ratios. The price hike for oil in 2008 shows that high energy prices are still possible at any moment and the peak-oil advocates expect these to become permanent. The contribution of options with stable production costs (nuclear, coal and renewable) are too low to make the economy insensitive to these disturbances. The only positive element is the much lower energy-intensity of the economy, thanks to energy savings, which limits the harmful effects of high energy prices.

As to the **'clean' goal**, some energy related problems have (to a great extent) been solved, such as the acidification problem and the air-pollution problem. However, a successful approach for the 20-year old greenhouse problem has not emerged and even becomes more and more questionable. Fukushima has shown that the advocated nuclear solution to many environmental problems is not without risks to society at large.

Currently, economic opportunities have become a fourth policy goal. In the past the set-up of an exporting industry was always an extra argument for government RD&D support on new energy technologies. Now a sustainable energy supply in general is seen as contributing to the economic development of a country. This new goal may favor the options renewable energy and savings.

Lessons for the future

The historic analysis shows that the mechanism of deliberate changes in the energy system, bringing the goals closer which in turn reinforces the changes, did not always work out. For instance, it has not been possible to attain a secure energy supply, or even to maintain the level of security of supply after the discovery in the large Groningen gas field. For the future this may be again the case for the 'clean' goal in relation to greenhouse gasses. If there is no view on a breakthrough at the international level it will become difficult for the EU to stick to their leading role. If the EU reiterates from this field, the greenhouse problem will not drive any more the changes in energy supply in the Netherlands.

Still, problems with attaining a goal do not mean that the options are not applied anymore. History shows that options like energy savings are applied for different reasons. At first, savings should lower the dependence on insecure energy sources, later they should also lower high energy costs and finally they should decrease harmful emissions. It is possible that in the future savings will be realized again to avoid high energy costs rather than to avoid CO_2 emissions. On the other hand, CCS as clean technology option serves only the 'clean' goal. The robustness of options should play a large role in future energy policy.

The government revenues from large gas reserves have been an openly debated interest in energy policy formulation, next to the three goals of secure, affordable and clean energy. Interestingly, this is not the case for other interests that may interfere with the goals and options. For instance, policy makers and environmental parties were surprised by Shell abandoning their PV business because their old oil and gas business offered better business opportunities. In most views on the future energy system an explicit analysis of possible opposing forces to the new sustainable options, due to existing adverse interests, is lacking.

In the past the importance of goals and the options to meet them changed time and again, often due to events. On the one hand a flexible policy approach is needed to cope with these changes, but on the other hand a stable policy is needed to provide the right long-term signals to investors. The UK climate law that states long-term goals, but offers flexibility in the way how to realise them, might be a suitable approach to integrate both demands.

Despite the lack of windfall events in the past one should still pay attention to possible positive events in the future. A first example is a strongly decreasing need for transport of persons due to ICT/communication developments. A second one is the recurrence of the so-called small ice age that has lowered the temperature with 1 to 2 degrees compared to 1400-1800 [Wikipedia]. The current continued absence of sunspots might indicate this. The first event helps to limit emissions, while the second one creates more time to find solutions.

Finally, one should look beyond changes in energy supply and at fundamental trends up to 2100. In the past, part of the improvements were realised by developments outside the energy domain, such as the decreasing growth of the population, the less energy-intensive structure of the economy and the lower economic growth due to crisis. These factors have contributed largely to a stabilising energy consumption after the large increases up to 1973. For the future a decreasing energy demand could results from a shrinking population and an economic growth with hardly consequences for energy, for example due to spending shifting to labour intensive services.

References

Dertig jaar Nederlands Energiebeleid (Thirty years of energy policy in the Netherlands), J.J. de Jong, E. Weeda, Th. Westerwoudt and A. Correlje, CIEP, 2005.

Energieverslag Nederland (Energy account for the Netherlands), ECN, 1993-2009.

Nationaal Milieubeleidsplan (NMP, National Environmental Plan), RIVM, 1989.

PBL, 2010: *Zure regen. Een analyse van dertig jaar Nederlandse verzuringsproblematiek* (Acid rain – An analysis of thirty years of Dutch acidification problems), E. Buijsman et al, Rapportnr. 500093007, PBL, November 2010

PBL, 2011: *Emissions and targets of GHG not included in the ETS 2013-2020, Analysis of the impact of the European Effort Sharing Decision for the Netherlands*, M. Verdonk, PBL, 2011

Stilstaan bij vooruitgang (Dwelling upon developments), Editor H. Hermans, Publication of the Ministry of Economic Affairs, 1990.

Various White papers on Energy (Energienota), Ministry of Economic Affairs.

Wikipedia: Cold fusion, Kleine IJstijd (Small ice age).

Changes in Northwest European energy systems: different views, no coordination yet

Pieter Boot

It has increasingly been accepted that Northwest European energy systems have to change and become more sustainable (Bruggink 2006, ECN 2007). Governments and energy companies acknowledge that a fundamental change in the energy system is needed and has to be organised (Eurelectric 2010). The pioneering Roadmap 2050 by the European Climate Foundation was a milestone in this respect (ECF 2010). It was a milestone in several ways: the electricity system was placed at the heart of the transition as the study argued that without a fundamental change in power an overall transition cannot be achieved; it argued that a carbon-free European power system by 2050 is technically feasible and financially defendable; and it illustrated how European cooperation may help all partners involved. The ECF study, to which ECN contributed (Boot and van Bree 2010), stimulated a plethora of activities by the European Commission, such as the Climate and Transport Roadmaps (Spring 2011), to be succeeded by the Energy Roadmap (Autumn 2011). At the same time individual countries developed their own views on changes in the energy system. These views have been developed in different political and cultural settings, with different aims – but assume some kind of common European approach.

The aim of this paper is:

- To investigate the backgrounds and approaches of the changes in the energy system in four Northwest European countries that are physically connected by transmission lines: Denmark, Germany, the Netherlands and the United Kingdom[1].
- To analyse the similarities and differences of these countries.
- To investigate whether more coordination between these countries would be useful, feasible and what it could look like.

These four countries have been selected as three of them have explicit energy transition approaches or long-term visions, whereas the Netherlands is developing a long-term roadmap and because they need each other physically to attain their ambitions - even when they perceive their neighbours as energy terra incognita[2].

The paper is organised as follows. Section 1 gives some indicators of the current situation in the four countries and presents their ambitions. Section 2

[1] It would be useful to include Belgium, France and Norway in a more extensive analysis. These countries are physically linked to the four, but differ remarkably in energy policy. Belgium has not had a government for over a year and struggles with the question to which extent energy and climate policies will be decentralised; France has some specific policy instruments. Norway has already 97% renewable power.

[2] Compare the remark by former IEA Executive Director Tanaka that the German decision on nuclear energy neglected the European dimension: ‘It is no German, but a European problem’ (Financial Times Deutschland, 16 May 2011).

sketches the main aims and driving forces, while Section 3 presents the different policy approaches and instruments under consideration. The next section discusses the choice of a top-down or bottom-up approach , investigates industrial opportunities, and elaborates on the strengths and weaknesses of the different trajectories. Section 5 goes back to the main question which progress in energy transition has been made, to which extent more coordination could be useful and which themes could be explored in this respect. This paper focuses on electricity as this is the part of the energy system in which the first big leaps forward are supposed to be made and interconnectivity is strongest.

Present situation and ambitions

Table 1 presents some key indicators of the electricity system in the four countries.

Table 1. *Fuel mix in power generation, 2007* [(1)]

[%]	Coal	Gas	Nuclear	Renewable	Renewable excl. hydro	CO_2 intensity [(2)]
Denmark	51	18	-	29	29	120
Germany	47	13	22	15	12	107
Netherlands	24	61	4	8	8	109
UK	35	42	16	5	4	112

(1) Gross electricity generation

(2) Share of coal weighs double, gas once, nuclear and renewable zero.

Source: European Commission, EU Energy and transport in figures, 2010.

Denmark and Germany are the kings of coal, despite their image of being a champion of renewable energy. If we exclude hydro - which was mainly installed decades ago - the achievement of Denmark with regard to ’new renewable energy’ is indeed impressive and the UK lags behind. The Netherlands and the UK have large shares of gas, while Germany and the UK have a significant share of nuclear. A simple indicator of CO_2 intensity shows that Denmark is most CO_2 intensive, whereas the other countries are comparable. All of them are more CO_2 intense than the EU average, which is influenced by its larger shares of nuclear and hydro power.

All four countries have presented their ambitions recently. As we are especially interested in the long-term ambitions, we will concentrate on those and deal with the 20/20/20 policies only in that context.

Table 2. *Ambitions, drivers and policy approaches in long-term energy policy*

	United Kingdom	Germany	Denmark	Netherlands
Main drivers	1. Climate 2. Costs 3. Industrial opportunities	1. Ethical 2. Climate 3. Industrial opportunities	1. Security of supply 2. Climate 3. Industry	1. Costs 2. Industrial opportunities
Main target 2030	CO_2 -60% Electricity fully decarbonised	30% renewable energy CO_2 -55%	-	-
Other ambitions 2030	Renewable 30%	Renewable electricity 50%	100% renewable electricity and heat	-
Ambition 2050	-80% GHG (legally binding)	Minimal -80% GHG, 60% renewable in fuel mix (80% of electricity, 10% CCS, rest peak)	100% renewable, no fossil fuels, of which 60-80% wind; - 75% GHG in energy system	-80% GHG
Illustrative fuel shares 2030 (power)	40% renewable, 40% nuclear, 15% CCS, 10% other gas (depending on relative costs)	No nuclear (after 2021), 50% renewable, CCS, gas/CHP	Electricity 40-70% of total energy demand: 45% wind, 20% heat pumps and solar, 35% biomass	Shares of renewable, gas, nuclear and coal; some CCS
Policy approach	Legally binding carbon budgets; strong incentives for offshore wind, spatial planning promotes onshore wind, green deal to promote efficiency	Decentralisation, monitoring, national dialogue, more R&D, national grid policy, spatial planning onshore wind	Fuel tax, obligations for fuel in district heating	Spatial planning onshore wind, gas roundabout; green deal with communities and companies
In favour of strengthening 2020 CO_2 target	Yes	Yes	Yes	No
New instruments to influence market structure considered	CO_2 minimum prices, contracts for differences, capacity market or long-term auction, Investment Bank	No firm intentions. Capacity market and carbon law under investigation; incentive storage needed?	Fossil fuel tax	-
2020 target % electricity Expected to be attained?	15% 35% According to CCC: yes	17.5% 35% According to Prognos et al: yes	30% 60% Government expects 33%	14% 35% Only 8-12% according to PBL

Main aims and driving forces

A first observation is that the driving forces of energy transition approaches differ. The ambition to attain a decrease of greenhouse gases is the main driver of the *UK* approach, followed by a clear aim to control costs and stimulate 'clean technology'. Meanwhile, the Britishperceive the change from exporter to importer of gas as a potential threat. The second and third aims are the main focus in *the Netherlands*, without mentioning a longer term greenhouse gas reduction target but acknowledging the European ambition of a 80% reduction (ELI 2011). Remarkably, the government of the country that more or less invented the concept of energy transition in actual energy policy (VROM 2007), abandoned the framework of a long-term approach in the year 2010. The need to control costs in the short term is felt so heavily that the long-term investments financed by the government are being postponed. The Netherlands restricts itself in trying to achieve the European 2020 targets. *Denmark* has placed security of supply at the heart of its ambition: it wants to be fossil free by 2050. Both climate ambitions and opportunities to develop a clean technology sector go hand in hand with the attempt to realise this aim. At first sight, *Germany* saw fundamental changes in its energy policy ambitions by changing the role of nuclear energy two times in one year: existing reactors were not allowed (until September 2010), their lifetime was extended with 12 years (until May 2011) and again they are not allowed within a decade. However, its long-term ambition to attain by far a majority share (80%) of renewable energy in its power fuel mix by 2050 as part of a greenhouse gas emissions reduction with 80% has not changed. We coin the main driver of German long-term energy policy 'ethical', adopted from the name of the advisory group that argued in favour of further strengthening the long-term approach and ending nuclear energy within a decade (Ethik Kommission 2011). The arguments of this advisory group were explicitly ethical by nature. Secondary, as in Denmark, are climate and clean technology arguments.

The Netherlands has no long-term approach yet, but expects to develop a Roadmap Climate 2050 by the end of 2011 (ELI 2011). Indeed, an integrated long-term strategy seems to be necessary because of four reasons:

- Without a strategy, governments don't have a 'story' to tell. And without a story, the general public tends to oppose most fuels. Coal is dirty, nuclear is dangerous, CCS is unknown, wind doesn't look nice and takes space, transmission lines are ugly and dangerous, solar-PV is too expensive – only gas is without apparent disadvantages, 'but has to be imported from Russia'. This resistance cannot be tackled without a clear story about the future and how it can be obtained.
- Investments in power generation and infrastructure have been unbundled due to European legislation. Without a clear guidance of investments in generation, investments in infrastructure are only coincidentally cost-effective – nobody would consider to invest in new trains without knowing whether track was available or not. However, investments in generation require some kind of view by the government on how climate and security of supply considerations are being weighed.

- As the share of intermittent renewable electricity (wind and solar) will increase, interactions between generation, infrastructure and demand-side response or storage options will strengthen.
- Without some kind of guidance, lock-ins in power generation are likely to occur. This is not valid only for the fuel mix and the relation with energy efficiency, but also for spatial planning (e.g. will it be obliged to use heat of fossil fuel burning, or will CO_2 storage be obliged – both possible obligations might lead to changes in (dis-) advantages of specific locations).

The three countries with a long-term view underline both the necessity to perceive the energy system as one integrated system, to take actions in the short-term that are also viewed from the long-term perspective, to make room for market forces which will be allowed to determine the fuel mix, but strive for stability in the form of a fixed and long-term framework for energy policy.

It is understandable that, if the aims differ, the approaches differ as well. The most typical of them will be sketched.

Fundamental approaches

The *United Kingdom* organised its long-term energy policy around the Climate Law. Basic elements of the 2008 Climate Law are (Client Earth 2009):

- A binding greenhouse gas emission reduction target of -80% by 2050.
- The call into existence of a Commission on Climate Change, which advises the government on specific five-year 'carbon budgets' and how to attain them.
- A framework of how and when the government has to react on this advice, in particular the eventual need to have three five-year carbon budgets in place.

The Commission on Climate Change already advised on four carbon budgets up to 2023-27 and the United Kingdom government accepted all of them, although the last one with minor changes from the advice[3]. The Commission on Climate Change is strongly convinced that a realistic timing of greenhouse gas reduction needs a more or less carbon free power system by 2030. Carbon intensity of power production should decrease from 500 g CO_2/kWh to 50 in 2030, an ambition which has been accepted by most UK stakeholders.

[3] The Commission on Climate Change advised to adjust the 2013-17 and 2018-22 budgets to reflect a strengthened level of ambition, which did not take place. It further advised to define a 2023-27 budget by domestic action only without relying on the use of international carbon credits. The UK Government confirmed the CCC proposal for the non-traded sector, but decided to meet the 2023-27 budget through domestic action 'as far as is practical and affordable' and to review the budget in 2014 for consistency with the European Emission trading System . If not, it will be possible to align the budget with the then actual European ETS trajectory (HM Government 2011). This decision offers more flexibility, but less certainty for investors.

The arguments are that (1) greenhouse gas reduction in power is cheaper and easier to realise than in other sectors;(2) large investments in electricity are needed whatsoever, so it is better to make them in a carbon free way; and (3) one cannot wait too long to achieve reductions as a yearly reduction of 4 - 5% after 2030 are the maximum that may be expected (and even this approach assumes a yearly increase in reductions from 0.8% in 1990-2008, 1.5% in 2009- 20 to 4.7% after 2030, which mainly has to be achieved by the fruits of innovation now). The UK government is convinced that early action is more cost-effective than pathways which delay action towards meeting the 2050 target. Delayed action could lead to higher overall costs due to lock-in to carbon-intensive technologies and increased pressure on supply chains (HM Government 2011).

As the main UK government target is to attain greenhouse gas reductions, the exact fuel mix by which this has to be achieved is of secondary interest. Expected costs are the main driver of a sketch of different possibilities (CCC 2011a). Both the Commission on Climate Change and the UK government are convinced of the relative cost advantages of nuclear energy: it is expected to be by far the least expensive way of power production by 2020, or in other words nuclear is expected to be the cheapest baseload and mid-merit option and gas-carbon capture and storage (CCS) and unabated gas plants are cheapest with lower load factors (in a central fuel and carbon price scenario), whereas onshore wind is an attractive investment option in general (CCC 2011a, 2011b). They underline the uncertainties of especially offshore wind costs and CCS. A possible fuel mix mentioned by the Commission on Climate Change in its most recent publication is 40% nuclear, 30-45% renewable, 15% CCS (both gas and coal based) by 2030 and the remaining part unabated gas-fired peak production (CCC 2011b)[4].

To attain its 2020 renewable energy target, the United Kingdom is backing especially offshore wind. The Commission on Climate Change is less certain whether this is cost-effective and advised to monitor carefully to which extent offshore wind costs will decrease sufficiently[5]. If not, it would be wise to invest more in onshore wind, even in face of local opposition.

The United Kingdom government is concerned that the existing electricity market arrangements will not be sufficient to realise its ambition of huge clean investments. Indeed, the actual market system with its emphasis on costs to be earned back in the short-term, actually stimulates investment in gas-fired power due to its low upfront costs: capital costs of gas-fired power are only 10% of expected levelised costs in 2030, against 70-75% for nuclear and offshore wind (CCC 2011a). Investments in renewable energy are being realised by separate incentive systems, in CCS by additional money for demonstration projects, but most ‘ordinary’ investments are in gas-fired power, which is considered to be risky from a low-carbon perspective given technical

4 Coal CCS would not comply with the required full sector decarbonisation by 2050 and therefore demonstration of co-firing with biomass is recommended.

5 CCC mentions that in 2007-10 onshore wind costs have risen 20%, costs for gas-fired plants (CCGT) have risen 25%, nuclear plants 40% and offshore wind with a stunning 70%.

and economic uncertainties around gas CCS.

In theory, the European CO_2 cap, if sufficiently restricted in time, will guarantee greenhouse gas reduction and gradually lead to an increase in the CO_2 price. However, the UK government is convinced that additional instruments are necessary. It considered both a 'subsidy strategy' (comparable with the actual renewable energy approach) and a 'risk reduction strategy' and preferred the latter one. In a risk reduction strategy investors are offered certainty in advance about the price at which they can sell given quantities of electricity, removing the risks created by fluctuating carbon, gas and electricity prices and demand uncertainty – thus reducing the cost of capital while still leaving the private sector with the construction and operational risks.

In July 2011 the UK government set out proposals for a path breaking Electricity Market Reform (EMR)(DECC 2011). This EMR consists of four elements.

- A carbon price floor will be introduced from April 2013. In the 2011 budget it was announced to be around 15.70 Pounds/ton CO_2 (18 €), rising to 30 Pounds/ton CO_2 in 2020 and 70 in 2030 (in real 2009 prices).
- Feed in Tariffs with Contracts for Differences (FiT CfD) from 2014 for low-carbon generation. A FiT CfD is a long-term financial contract providing stable and predictable revenue streams for investors in low-carbon electricity generation. The FiT CfD will consist of three parts and leaves space for technology specific filling in. Fort intermittent (mainly wind power) and baseload (especially nuclear) power it will be 2-way, with support payments to the generator if the market reference price is below a defined strike price and vice versa. The strike price for intermittent load will be determined administratively but potentially by tenders from 2017 onwards. The reference price will be linked to the day-ahead market. For baseload the strike price will be determined administratively or through bilateral negotiations. The reference price will be linked to the year-ahead market. For flexible generation (CCS) generators will receive a fixed payment, coupled with a requirement to make difference payments when the market reference price exceeds a defined strike price. This strike price will be linked to the marginal costs of the generation technology. Much detailed design work remains to be done, like the methodology to calculate market reference prices, the level of various strike prices and the length of the contracts.
- A Capacity Mechanism. Two options are under consideration. One is a strategic reserve in which contracted capacity will be called upon when economic. Another option is a market mechanism to conclude reliability contracts which would provide contract holders with fixed payments, whilst requiring them to make difference payments when the market price exceeds a defined strike price. The government expects to take a decision around the turn of the year. Of course, a relation exists between the capacity mechanism and the FiT CfD that has to be investigated and decided on.
- An Emissions Performance Standard (EPS) to be set initially at 450 g CO_2/kWh for new plants and significant refurbishments and life extensions, except CCS demonstration plants. It will not be retrospective and is subject to regular reviews. The

initial EPS implies that unabated coal-fired power plants cannot be built from the second half of 2013. In the longer term, the EPC could be used to give a clear regulatory signal to reinforce the economic signals as described above.

The UK government expects that the EMR package will be less expensive than the existing financial incentive for renewable energy. Instead of rising average consumer bills by around 200 Pounds from 2010 to 2030 without reform, this will be limited to around 160 Pounds (Allen&Overy 2011).
Many more detailed decisions have to be made, especially about the potentially complex interactions between the FiT CfD and the capacity mechanism and the institutional arrangements of the FiT CfD. But the Electricity Market reform is an important and even fundamental new approach with a huge potential to provide the clarity and certainty that investors need. At first sight, it seems somewhat strange that the United Kingdom interferes in the European market, but due to limited transmission capacity, the government considers the danger of 'leakage' to the Continent to be limited and as illustrated in paragraph 2.1 the expected British adequacy problems are by far the largest in the Northwest European market. Next to the Electricity Market Reform, new gas-fired plants should be suitable for retrofit with CCS. At the same time, the Committee on Climate Change acknowledges increased interconnection 'with Europe' is necessary to provide greater system flexibility and addressing potential problems with intermittency.
The *German* long-term approach started with a 80% greenhouse gas reduction target by 2050 as well, but linked much more with ambitions to stimulate renewable energy. Germany erected visible milestones of renewable energy ambitions: 30% in 2030 (50% in the power system), 45% in 2040 (65% of power) and 60% by 2050 (80% of power). In this way the power system has to be close to fully renewable by 2050, next to some coal-fired carbon capture and storage (BMWi and BMU 2010).

It is somewhat unclear how Germany wants to attain these targets. Is most visible and well-known policy instrument is the feed-in tariff for renewable power (Erneuerbare Energie Gesetz, EEG). By means of this tariff, Germany has reached an increase in renewable power from 6.4% in 2000 to 16.8% in 2010 (BMU 2011). The end of nuclear energy complicates matters. On the one hand, most players in the German arena welcome the decision as implying a laboratory for the accelerated switch to renewable energy. On the other hand, it is difficult to see how the necessary increase of renewable energy production can be implemented. In 2000-10 the annual increase of renewable energy in the fuel mix has been constantly 1 percent. Nuclear energy takes 23%. Therefore, the annual increase should double, regardless emerging problems of intermittency, spatial planning, the adaptation of the increase and the large increase of capacity. Further, the flipside of this impressive increase is the cost burden of the feed-in tariff. Not only did the costs increase with the larger production of renewable energy, also the *average* 'subsidy'[6] to renewable energy increased considerably.

[6] Formally, the German feed-in tariff is no subsidy as the German state budget is not involved. Actually it functions in the same way as a subsidy.

Table 3. *Nominal additional costs of renewable electricity in Germany*[(1)]

	Average remuneration [c/kWh]	Wholesale price [c/kWh]	Total remuneration [bln €]	Additional remuneration [bln €]
2000	8.5	1.9	1.2	0.9
2004	9.3	2.8	3.6	2.5
2008	13.9	6.9	9.0	4.7
2010	15.4	4.4	12.3	8.3

(1) One has to detract the wholesale price from the average remuneration to calculate the additional remuneration.
Source: BMU, Entwurf EEG Erfahrungsbericht 2011.

Main cause of the huge increase of additional remuneration for renewable energy, next to the increased production, is the popularity of solar-PV in Germany. Solar-PV delivers 9% of German renewable electricity but takes 40% of additional costs. Due to the relatively generous ‘subsidy’ level compared with strongly decreased costs of solar-PV panels (mainly imported from China), it became very profitable for German households and firms to install solar-PV. By decreasing the ‘subsidy’ to levels which have been announced beforehand and depend on the volume installed in a preceding year (when more is installed than expected, the ‘subsidy’ level will decrease more strongly), the German government hopes to control the cost explosion.

It is understandable that the German government strives for a change of this national system into a more European approach by 2020 (BMWi and BMU 2010). However, to some extent, aims of industrial policy and cost restriction are contradicting. One of the main arguments for ambitious renewable energy targets and policy is the conviction that this will stimulate German clean energy technology, such as national production of wind turbines and solar-PV equipment. In theory, it could be less expensive to attain European renewable energy targets in a way more in line with comparative advantages of the individual countries: it is cheaper to produce solar power in Italy or Spain than in Germany. However, German solar-PV companies have less close links to Spanish or Italian construction and installation companies than to German ones, and Germany was afraid a more common European approach would negatively influence their competitive position. ‘If it were to happen that German money will develop markets in southern Italy and Spain and we end up importing our energy, then the whole transformation wouldn’t make sense and it would lose its backing in Germany’, Environment minister Roettgen told in January 2011 (Germany’s coming civil energy war, European Energy Review 31 January 2011). Apparently, this fear is somewhat less for the longer term and therefore Germany backs a more joint renewable energy approach in the decades after 2020. This is also due to the high expected costs of the energy transition. Although the German Ministry of Environment several times expected to be able to announce a maximum level of renewable energy subsidies in the near future, the scenario study published in 2010 sketches a different picture. The average additional cost (EEG Umlage) has already increased from 1 c/kWh in 2008 to 3.5 ct presently which is expected to stay until 2020, decrease to 2 – 3 ct in the decades thereafter but increase again to 4 – 5 ct/kWh, as the expected volume of renewable energy could increase faster than the cost per kWh might decrease. As the additional yearly costs will have to be paid for 15 – 20 years, this financial burden is impressive. Other observers also expect a doubling of the EEG Umlage. The scenarios of the Energy Concept expected 20-30% of the German power demand in 2050 to be imported (renewable energy due to lower costs in southern Europe, but also nuclear energy)(Prognos et al 2010). Interconnection capacity could increase 2.5 fold.

Already more than a decade Germany did not accept new nuclear plants. Its position towards existing ones has changed frequently. In September 2010 the lifetime of existing nuclear reactors had been extended with 12 years on average. Since May 2011 the government view is all nuclear plants, next to those already in moratorium yet, have to close in 2015-21.[7] As Germany is a country with a relatively large share of coal in its fuel mix and produces both lignite and (subsidized) hard coal, it is understandable that coal-CCS is an important part of the German long-term view. The country has a demonstration plant running. Following the 2010 scenario studies, the Ethical Commission also advised the German government to investigate whether additional market incentives such as a capacity market would be necessary. It is unclear whether and when this will be implemented. Currently the German government is working on an incentive scheme to provide large additional capacity especially for small and medium-sized – usually municipally owned - power companies.

The chairman of the Ethical Commission had considered four conditions to be fulfilled before proposing the 'Atomausstieg': energy prices were not allowed to increase considerably, greenhouse gas emissions should not increase, imports would not be necessary and security of supply should not deteriorate (RP Online 11 April 2011). It is unclear how some of these conditions will be met, although the end of German nuclear will be gradual. The stabilisation of greenhouse gas emissions is relatively easy due to the European emission cap. However, a scarcity of CO_2 allowances by itself will induce a higher CO_2 price. It depends on supply and demand conditions in North West Europe to which extent the electricity price will increase[8] and utilisation of existing coal and gas-fired plants will be heightened. Due to the length of planning procedures and investment decisions, it is difficult to imagine that scarcity will not increase and the only option that may be implemented quickly is gas. At least in the very short term electricity export from the Netherlands and France has increased. Our impression is that at least 2 of the 4 conditions are very difficult to meet, which underlines the view that Germany has taken its

[7] The eight oldest have to close this year, the other ones between late 2015 and the end of 2021.

[8] The energy intensive industry expects an increase of wholesale prices with 30% until the end of this decade (Financial Times May 31, 2011). The German research institute DIW computed a wholesale price increase of 22% if all nuclear plants would end, and 6% if the moratorium would be kept (Kemfert and Traber 2011).

decision on ethical grounds.

Denmark has a strong tradition of security of supply policy. Already in the 1980s it stimulated district heating networks and wind electricity. Advised by a Climate Commission in September 2010 (Klimakommissionen 2010), the government decided to move 'from coal, oil and gas to green energy' in February 2011: all energy has to be renewable by 2050 (Danish Government 2011). Part of this ambition is that 60 to 80% of all electricity has to be powered by wind; the remaining part is biomass in CHP.

One of the 'hidden secrets' of Denmark is the realisation of a stabilisation of overall energy demand already for several decades.[9] It strives to continue this trend with a 6% energy demand reduction by 2020. Main instrument of this system change is, next to strong regulation, a new gradually increasing tax on fossil fuels, to be spent partly on subsidies for renewable energy. Effect of this tax is expected to be both an increase in renewable energy and decrease of fossil fuel demand, plus a further electrification of the energy system (e.g. heat pumps will become cheaper, biomass in district heating will become cheaper, heating oil becomes more expensive).[10] Denmark strives for a further integration of the northern European electricity market, especially with Norwegian hydropower.

At this moment *the Netherlands* does not have a long-term approach in its energy policy. This is partly due to its emphasis on cost reductions, but also to a strong decoupling of energy and climate policies. Whereas Denmark and the United Kingdom have a joint ministry of energy and climate change, and Germany has one ministry responsible for both renewable energy and climate policies[11]. The Netherlands government is of the opinion that energy and climate ambitions and policies are separate issues. Therefore, its recent energy White Paper (ELI 2011) did not deal with the period after 2020. A long-term approach may possibly be expected in the Climate 2050 roadmap, to be published by the ministry of Infrastructure and Environment in Autumn 2011. In the meantime, the Netherlands tradition of energy transition has shifted to energy innovation. Transition teams of electric vehicles and 'green gas' – both are supposed to have comparative advantages in the Netherlands – are still

[9] An important question is how this could happen. The European Odyssee-Mure project has looked at energy efficiency in the four countries. In 1997-2007 the Netherlands was the only country with an increasing primary energy demand. Energy intensity declined most in the United Kingdom. However, energy efficiency improved most in the Netherlands (1.4% yearly) and Germany (1.3%), against 0.8% in the United Kingdom and Denmark (Ademe 2009). Therefore, a large part of the Danish achievement had been due to a somewhat lower economic growth and to behavioural changes.

[10] The Climate Commission suggested to introduce a temporary compensation scheme for existing power plants to prevent an increase in electricity imports. The government introduced a more general tax reduction for energy intensive industry.

[11] The German ministries of Environment (renewable energy, climate, nuclear safety) and of Economic Affairs (energy policy in general) often have difficulty in finding common ground.

on track.

The Netherlands perceives itself more than its neighbors as a part of the Northwest European energy system. It allowed investments in coal-fired plants due to its comparative advantage at sea in the expectation that older plants would be closed and investments in CCS would be feasible. It strives for investment in nuclear as it is expected that this will remain part of the North West European fuel mix. However, it is struggling with renewable energy as the Dutch government has installed a strict financial cap on the amount of subsidy to be spent in the next years and hopes a system of obligations (on biomass in coal-fired plants, possibly to be extended to low cost options in general) could be a useful addition.

Top-down or bottom-up, industrial opportunities, strengths and weaknesses of the approaches

Before we move to the relative strengths and weaknesses of these approaches, a remark has to be made on the overall approach and political settings in the four countries.

The *United Kingdom* has a clear 'top down', relatively technocratic approach. The transition is legally driven and all three major parties agree with this. The Commission on Climate Change is chaired by a former chairman of the employers organisation, which stimulates inclusion of the business community. Costs and the economic framework of the electricity system are important issues to be considered. 'People' or 'citizens' do not appear in the papers.

The opposite is the case in *Germany*. The Ethical Commission explicitly speaks about 'civil engagement' as a main driver of change and pleas strongly in favour of further decentralisation to local governments and 'cooperative ownership' of renewable energy. At the same time, however, NIMBY opposition to more onshore wind and especially transmission lines is relatively strong in Germany. At least three of the four main political parties agree with the main aspects of the energy transition (the ruling Christian Democrats, Social Democrats and the Green Party – the ruling Liberal party is more hesitant and had to be convinced to end nuclear energy by 2021/22).

Somewhat comparable is the case in *Denmark*. Its long-term policy has been prepared independently from the government, and the government carefully tried to include all main political parties in its approach (the actual Social Democratic opposition party is a long-time proponent of renewable energy). Decentralisation and inclusion of cities and cooperative ownership are important aspects of the Danish approach.

As *the Netherlands* does not have a long-term policy yet, it is more difficult to observe underlying tendencies. The Netherlands probably has a stronger division between parties striving for further climate policies, but often at the same time against new nuclear reactors (Social Democrats, Green Party) and those strongly opposed against more active climate policy but in favour of new nuclear (the new anti immigration party, but also to some extent the ruling Liberal and Christian Democratic parties). A new trend is an emerging local approach. Cities want to become 'carbon free' or something equivalent. Sometimes, the local community is a driver, sometimes local entrepreneurs perceive opportunities. For example, the actual drivers of Dutch CCS policy are the city of Rotterdam which proposed demonstration activities and an CO_2 pipeline under sea, and the North Netherlands provinces with its Energy Valley that tries to combine a strong position in gas, new coal-fired power plants with CCS, and use of biomass. The Netherlands has difficulty in defining consistency in its approach over time (ambitions, instruments). An important exception is the common view on the importance of gas – both the need to extend production if possible, use the swing capacity of the large Groningen field as long as possible, the need to divert supply routes, to become a 'gas roundabout' and to increase the share of 'green gas' are broadly supported. As most Dutch political parties are relatively pragmatic, a fundamental discussion about the future of the existing nuclear plant has never really taken place – and when a political discussion was held in 2006, arguments of public costs were decisive.

The creation of *industrial, or broader economic opportunities* has gained importance in the recent past. In the past, competitiveness of industries due to affordable energy prices has been a key factor of energy policy. This is changing. Industry has become less important in Denmark and the UK. The German ethical considerations weigh more heavily. In the Netherlands it still is a main political factor and one of the reasons to accept or promote new coal and nuclear power plants. Next to the traditional three aims of energy policy – sustainability, affordability and reliability – a fourth one has been added. This is not the place to deal with this issue at length, but some remarks can be made before we draw overall conclusions. Actual strength of German and Danish clean energy sectors is by far larger than the UK and Dutch ones, which can be illustrated by the importance of clean energy technology (renewable energy and energy efficiency).

.

Table 4. *Renewable energy industry, 2008*

	Absolute (bln €)	Relative (share of GDP) [%]
Denmark	7.5	3.5
Germany	17	0.8
Netherlands	1	0.3
United Kingdom	2.5	0.2

Source: Roland Berger 2010

Especially in Germany, the production of the renewable energy sector increases fast: to 26.6 bln € in 2010 compared with 16.8 in 2008. Main case of this increase are the financial incentives for solar-PV, as has been explained. It is questionable of course whether a large share of subsidies is a wise way to stimulate new investments and a fierce discussion has been pursued on this subject in Germany. On the one hand, the unsustainability to continue large subsidies has been mentioned. On the other hand, the increase of exports and especially of components, engineering and services has been pointed at. Especially Denmark has been successful in this respect and German exports of equipment and components have increased from 11 to 25 bln € in 2006-10 (Blazejczak et al 2011). More in general, three main conditions seem relevant to be successful in this respect: (1) focus in Research and Development, (2) offer long-term continuity and predictability to investors, (3) create a strong market pull instead of only market push. Conditions 2 and 3 are in the heart of fundamental energy changes. Apparently, up to now Denmark and Germany have been more successful in this respect than the Netherlands and United Kingdom.

This offers already some arguments for *strengths and weaknesses*. The UK approach is solid by its legally binding target, intelligence and beauty of arguments, breadth of considerations. Its weakness is the neglect of localities and citizens. The Danish approach does not have a clear weakness as it is both solidly argued, politically broadly backed, and strongly linked with citizens and local communities. A relative weakness – for which the Danes cannot be blamed – is that it is only possible to be implemented in cooperation with especially Sweden and Norway for the backup and storage of its intermittent power system. The strength of the German system is the opposite of the UK approach – its strong backing by the population, although it remains to be seen how NIMBY problems will be solved. Its weakness is a relative neglect of costs which could backfire (both the ending of nuclear and stimulus of renewable energy) and low attention to policy instruments. The weakness of the Dutch approach is its neglect of a long-term approach whatsoever. Especially the interaction of infrastructure investments and investments in clean power will be difficult (Boot, de Jong and Buijs 2010). On the other hand, one might argue that as long as the approaches of the big neighbors Germany and the United Kingdom differ so much it is better to wait and see which arguments will weigh more heavily in the European arena. The Dutch strength is its pragmatism. Whereas the United Kingdom already formulates the necessity of a 40% share of nuclear in the power mix, it could well be possible that a Dutch permit to construct one safely will be given by 2014, earlier than a British one. Denmark and Germany have been more successful in creating industrial opportunities, although against large financial costs in the German case.

Coordination needed before fundamental changes may succeed

Four Northwest European countries have ambitions in transforming the energy system within a few decades. Main drivers differ. The United Kingdom aims for efficiency in the approach, Germany has strong ethical considerations and promotes renewable energy, Denmark wants to become independent from fossil fuels and the Netherlands does not want to spend too much public money. The ambitions do not reflect the actual situation, in which Denmark depends heavily on coal and Germany has the largest share of nuclear. The Netherlands does not have a long-term vision yet, but its ambitions reflect relatively more its actual circumstances with a high share of gas in the fuel mix. Industrial opportunities play an important additional role in the ambitions of the countries and in this respect Germany and especially Denmark are better placed yet than the UK and Netherlands, although industrial

competitiveness of energy prices could be at risk in Germany.
All of them are aware of the necessity of international coordination, but this is only partly reflected in their activities. Especially Germany acts independently from its neighbors, although it expects to become a large importer of electricity. A lack of coordination is problematic as (1) shortage or excess of national capacity has become irrelevant in countries with strong interconnections, such as Germany, Denmark and the Netherlands and (2) the strength or weakness of transmission lines does not look at national boundaries. If German power flows from north to south and its internal transmission capacity is insufficient, the electrons will travel via the Netherlands.

Which kind of coordination would be feasible in a situation in which policies drivers differ? Three options may be looked at.

1. A 'minimal approach' is to look at those issues in which the opinions run parallel. This has been the approach of the Pentalateral Forum of the Netherlands, Belgium, Luxemburg, France and Germany. Information of expected capacity growth and reduction has been shared, interconnection has been used more efficiently and eventually electricity markets have been coupled. The United Kingdom and Denmark could join this activity.
2. One step further would be to consider a more joint approach of policy instruments. One example is outstanding: all countries agree that some kind of harmonisation of the national incentive systems for renewable energy is necessary. This surely will not happen if neighboring countries walk opposing pathways as is the case nowadays. The United Kingdom considers introducing a feed-in premium (as the Netherlands has), while Germany investigates a combination of the existing feed-in tariff with a premium. However, the Netherlands intends to end the feed-in premium and to install a kind of obligation for suppliers which is intended to be abolished in the United Kingdom. It could be investigated whether the countries could start with sharing models and information on additional costs of renewable energy with the aim of narrowing the additional sums to be paid; and whether a joint effort of investigating advantages and disadvantages of the different incentive mechanisms can be made. Maybe it could be agreed that major changes in the incentive systems will be made only after consulting the partner countries. In this way a gradual alignment could take place and eventually a joint opinion could be worded in European discussions.
3. A 'maximum approach' would be to strive for a joint incentive mechanism. As long as the main drivers in the different countries differ, such an attempt does not have a huge chance in being successful.

Another issue is the formulation of the long-term European ambitions. All four countries have accepted the European -80% greenhouse gas emissions reduction ambition and three of them have agreed upon the necessity to strengthen the 2020 -20% GHG reduction target (the Netherlands not). It seems to be beneficial for all four to agree upon a new approach for the years 2030 or 2035, as all of them are of the opinion that the European ETS has to be a crucial instrument to drive the transition. It could be easier to agree on a 2030-35 target than to change the

2020 one. This could be a combination of three elements:

- A national target, somewhat in the range of -50% around 2030 compared with 1990.
- An agreement on the cap that would be necessary to underline the effectiveness of the European Emission trading System, again in the range of -50%. A discussion whether 'leakages' like CDM are acceptable or not could be part of the agreement and could be proposed jointly in the European discussion.
- An investigation whether additional instruments like a minimum CO_2 price, capacity market, auctions or contracts for differences could be strived for.

In this way a 'bottom up' approach of the electricity market could be looked at. It is not necessary to agree on all main drivers to make this a worthwhile attempt. Indeed, not only climate ambitions would be pursued, but also security of supply ambitions, clean air and economic opportunities. Such a pragmatic approach could be a actual step forward in the change of the energy system. In this way more coordination between the four countries could set an example for 'bottom up' cooperation in a EU context. Countries such as Belgium, France or Norway have not been analysed in this paper, but could possibly join this approach.

This coordination has to search for an optimum between international and local tendencies. International, as the main energy companies have outgrown national boundaries, which has brought enlarged capacities to invest. But also local, as the 'hearts and minds' of local people have to experience the necessity and benefits of an energy transition. Energy transition against the people will not succeed, it has to be in their interest. The coordinated story lines have to be developed in such a way that local people experience it as being *their* story.

References

Ademe (2009), Overall Energy Efficiency Trends and Policies in the EU 27

Allen & Overy (2011), UK Electricity Market Reform

Blazejczak, J. et al (2011), Oekonomische Chancen und Struktureffekte einer nachhaltigen Energieversorgung, *DIW Wochenbericht* Nr 20

BMU (2011), *Entwurf EEG Erfahrungsbericht*, Berlin

Boot, P.A. and B. van Bree (2010), *A zero-carbon European power system in 2050: proposals for a policy package*, ECN-E—10-041, Petten

Boot, P.A., J. de Jong and B. Buijs (2010), *Energy Policy and the Northwest European Market*, CIEP

Bruggink, J.J.C. (2006), *Op weg naar de duurzame energievoorziening. De toekomst van het transitiebeleid voor energie en milieu*, ECN Petten

BWi and BMU (2010), Bundesministerium fuer Wirtschaft und Technologie, Bundesministerium fuer Umwelt, Naturschutz and Reaktorsicherheit, *Energiekonzept*, Berlin

CCC (2011a), Committee on Climate Change, *The Fourth Carbon Budget*, London

CCC (2011b), Committee on Climate Change, *The Renewable Energy Review*, London

Client Earth (2009), *The UK Climate Change Act 2008 – Lessons for national climate laws*, London

Danish Government (2011), Energy Strategy, Copenhagen
DECC (2011), Department of Energy and Climate Change, *Planning our electric future: A White Paper for secure, affordable and low-carbon electricity*, London
ECF (2010), European Climate Foundation, *Roadmap 2050: a practical guide to a prosperous, low-carbon Europe*
ECN (2007), *De belofte van een duurzame Europese energiehuishouding, Energievisie van ECN en NRG*, ECN-E--07-061, Petten
ELI (2011), Ministerie van Economische Zaken, Landbouw en Innovatie, *Energierapport*, Den Haag
Ethik Kommission (2011), *Sichere Energieversorgung, Deutschlands Energiewende*, Berlin
Eurelectric, *Power Choices, Pathways to Carbon-Neutral Electricity in Europe by 2050*, Brussel
HM Government (2011), *Implementing the Climate Change Act 2008, The Government's proposal for setting the fourth carbon budget, Policy statement*, London
Kemfert, C. and T. Traber (2011), Atom-Moratorium: keine Stromausfaelle zu befuerchten, *DIW Wochenbericht* Nr. 20
Klimakommissionen (2010), *Green energy – the road to a Danish energy system without fossil fuels*, Copenhagen
Prognos et al (2010), Prognos, EWI, GWS, *Energieszenarien fuer ein Energiekonzept der Bundesregierung*, Basel, Koeln, Osnabrueck
Roland Berger (2010), *Stimulering van de economische potentie van duurzame energie in Nederland,* Amsterdam
VROM (2007), *Nieuwe energie voor het klimaat, Werkprogramma Schoon en Zuinig*, Den Haag.

Energy technology and innovation policy: the value added of models

Dolf Gielen

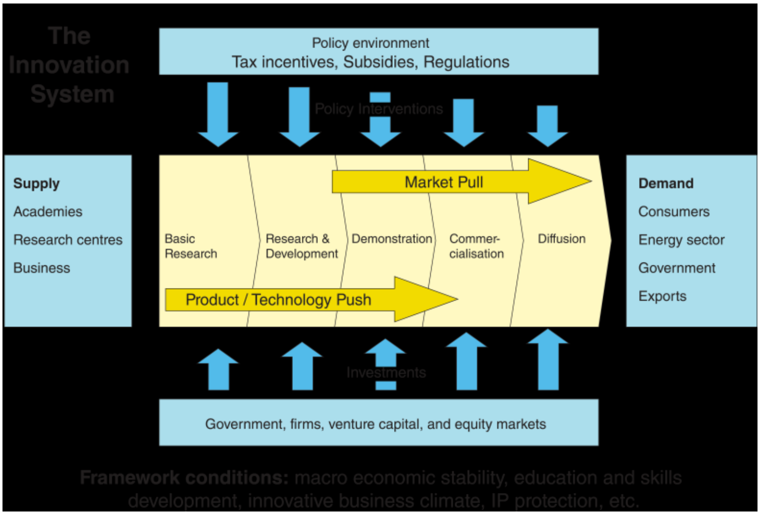
Introduction

Innovation is high on the agenda in many countries. It is seen as a way to achieve economic growth and create jobs. Innovation appeals to the private sector as it can create new markets. Energy policy makers tend to think more in terms of challenges where needs drive technology developments. A better understanding of innovation and the possibility to guide and use it can add new tools to the policy toolbox. The following discussion provides an overview of various aspects of energy technology innovation.

Innovation and innovation policy

Technological change is widely considered a key factor for enhanced productivity, reduced cost, reduced environmental impact and reduced poverty. Technological change is driven by changing resource endowment, technology cost reductions, emergence of new technologies and changing social and policy frameworks.

Innovation is the process from invention to widespread deployment of a new technology. Typically it is divided into invention, Research and Development, demonstration and deployment. Innovation can occur in the form of new processes and technologies, but it can be broader and also encompass new forms of organization of work etcetera. The following discussion focuses on technical innovation only.



Source: IEA, 2008

Figure 1: *Technology innovation chain*

In an economy where other production factors are constant, productivity growth is the only engine of growth. Technological innovation results in productivity growth and is therefore of great interest to policy makers around the world.

Innovation can be driven by supply or by demand factors. Supply factors include research funds, the number of researchers, the size and scope of research labs and universities. Demand factors are social, economic and environmental factors that create the environment in which a technology must compete. Governments can influence supply factors and demand factors through their innovation policy.

The innovation process is not well understood, especially the initial steps how ideas are generated. There is general agreement that the costs for innovation go up exponentially as one moves from invention to full scale deployment. There is also consensus that the cost ramp-up from prototype to wide deployment requires a lot of funds. As this transition is usually left to the private sector with limited funds, this financing can pose an insurmountable barrier, the so-called 'valley of death'.

The IEA monitors OECD country R&D spending, which is in the order of USD 10 billion per year. Time series indicate a halving compared to the peak spending 20 years ago, and only a modest increase in recent years. Based on this decline it is argued that this is not sufficient. However, the argumentation is weak as government R&D spending outside OECD is not monitored in the same level of detail. More importantly, private sector energy R&D spending is not documented. As spending is not properly monitored, the efficiency and effectiveness of R&D cannot be properly monitored. This knowledge gap acts as a major barrier for expanding the funding.

Energy innovation policy can have a number of goals such as reduced fuel import dependency, enhanced energy access, or reduced environmental impacts. Another factor is the build-up of indigenous economic activity. Energy innovation touches upon many aspects of government policy and is therefore rarely the terrain of a single ministry.

Opinions diverge on whether governments should 'pick winners' or 'create a suitable environment for innovation'. The advocates of the latter approach argue that governments have a poor record at picking winners because they lack the necessary information. Therefore the innovation should be left to the markets. However, advocates of the former approach argue that new technologies may face very different barriers depending on their development path and therefore a tailor-made support system is needed.

Innovation can generate high returns. The fact that innovation creates such returns raises the question if the support level should be raised substantially, and which support level would be appropriate. This can be assessed fairly accurately for the deployment stage, but far less so for the earlier stages of the innovation chain. In the case of solving climate change through mitigation, some argue that energy R&D levels should be doubled, whereas others claim that it should be increased tenfold. The lack of rigid understanding of the efficiency and effectiveness of funding acts as a barrier for policy making.

The understanding of innovation is hampered by the fact that success stories are widely publicized but failures are all too often hidden. However, for every success story there are many failures. Hydrogen fuel cell vehicles, biomass gasification, cyclone converter furnace for iron making are all in the latter category. Still, failure need not be forever: electric vehicles were tried more than a century ago when ethanol production from wood was a thriving industry. The risk of failure is a major impediment for smaller players to innovate rapidly. But even success can be a problem. If older technologies become redundant, this poses a problem for the equipment manufacturers and the users of the older technology. Such vested interests can act as a brake on innovation and various strategies are applied by them. This also creates a conundrum: the large industries that would have the deep pockets needed for innovation are the ones who may lose most from the emergence of new energy technologies, and may therefore not support such development wholeheartedly. The oil majors are a typical example. While some of them have ventured into biofuels or renewable power generation, their success in this field has been limited, amongst others because their strategies have wavered. In due course other players have emerged.

Is energy technology different from other technology?

Energy technologies can be divided into energy supply and energy demand technologies. Energy supply includes the extraction of resources, their transformation into energy commodities and their transportation and distribution to reach markets. Energy demand technologies are those that convert final energy commodities into energy services.

From a consumer perspective, energy supply technologies are generally of low interest: the way electricity is generated is not a concern, as long as electricity prices and supply reliability are not affected.

On the demand side, the consumer interest is usually not energy use per se. The consumer is not interested in the consumption of gasoline, but in the transportation service. The consumer is not interested in the output of the heating stove but in the provision of a warm house. As a consequence, consumers are largely indifferent to the type of energy that is used. This allows for a high level of flexibility. Energy carriers are interchangeable in many services. It is the price and convenience that are decisive.

Many types of energy equipment are also characterized by a long life span. This acts as a brake on technological change, especially in mature markets. The replacement rate for existing equipment determines the maximum uptake rate for new equipment, unless equipment is phased out before the end of its technical life. Power plants, buildings and industrial plants are particularly affected.

Technological progress in energy is limited by the thermodynamics of energy conversion. Steam of a given temperature can only be converted into electricity with a certain efficiency. Higher temperatures require new materials. Decades of research have been focused on such new materials. Progress has come down to the level of a few percentage points per decade.

Many energy technologies are mature: steam cycles have been around for two centuries; combustion engines for cars were invented 125 years ago; gas turbines are half a century old. These mature technologies form the backbone of the energy system. At the same time, new fundamentally different energy technologies emerge such as plug-in electric vehicles, PV systems or fuel cells. But it takes decades for these new technologies to get a sizeable market share. This is different from for example the mobile phone competing with fixed landlines or the internet competing with letters by mail. The lack of blatantly obvious enhanced performance explains the slow transition**.**

Innovation in the field of renewable energy: a case study

Renewable energy is a typical field where innovation has largely been driven by government policies. CSP solar power generation was originally developed in the US, driven by government support programmes following the energy crises of the 70's and 80's. PV technology was originally developed in the US as part of the space programme, related to the cold war (continuous energy supply for satellites). The Brazilian Proalcool programme drove the sugar cane based ethanol production. In Europe, more recently, feed-in tariffs in Germany and subsequently in other countries have driven the successful development of wind technology.

Less visible but also significant are for example the biogas and solar water heating programmes in China, and modern cooking stoves introduced in China, India and parts of Africa. So the success stories are there, but their impact has been modest so far.

Patent analysis suggests a continuous growth of inventions. Around 215,000 patents have been filed in the areas of waste and biomass, solar, fuel cell, ocean, geothermal, and wind power technologies, during the period of 1998 - 2008. A patent mapping study was conducted by UNEP/EPO/ICTSD (2010) that focused on six main renewable energy technologies. Solar energy, wind energy, ocean energy, geothermal energy, hydropower, and bioenergy were considered. The study showed that between 1978 and 2006, the annual number of patents increased by a factor two to six. For hydro and geothermal, the patenting rate doubled. For biofuels it increased fourfold. For wind it increased fivefold and for solar it increased sixfold.

The high growth rates for solar PV and for wind have resulted in a very significant increase of the rate of deployment of these technologies. The study also found that countries leading the patent activities are Japan, US, Germany, the Republic of Korea, UK, and France. Together, these countries, account for almost 80 % of all patent applications in the renewable energy technologies reviewed. At the same time, some emerging economies are showing specialization in certain fields. China, for example, shows notable patent activity in the area of solar PV.

However, granting of patents is not equal to practical use. Unfortunately, there exists no public database of patent licenses and the payments made for such licenses. Quoting of patents in patent applications is another indirect method to judge their value. Rapid price reductions for certain types of equipment such as PV modules also suggest rapid innovation. But these estimation methods are all rather indirect.

US president Obama recently commented that ‘we need to reach a level of research and development we haven't seen since the height of the Space Race’. However, the energy challenge is more daunting than the Apollo Project, because energy is needed for virtually all economic activities. Therefore what is needed is a programmed revolution, not a collection of projects.

The rationale for government intervention is to overcome barriers that cannot be overcome by the market without support. This includes R&D support, support for the development of supply chains and technology clusters (critical mass), and guaranteed prices above market levels that allow for technology learning (such as feed-in tariffs).

A clear understanding is needed of what the barriers are and how certain policy instruments can contribute to overcoming this barrier. Feed-in tariffs make sense if high cost for early investments and financing risk for projects pose problems. Feed-in tariffs make no sense if import levies or poor resource quality limit the use of certain technologies.

The use of models

Models can help to:
- project long term energy demand,
- explore the competitiveness of technologies under different scenarios,
- develop robust technology portfolios.

The most widespread and successful use of models for energy technology innovation relates to technology learning (cost projections) and competition of technologies. This approach focuses on the technology deployment stage. Modelling is not widely used for invention or R&D, which is mainly because projections make no sense if the basic mechanisms are not understood.

Models can be used to generate projections. A projection is a best guess of what would happen under a certain set of assumptions. If a model is used that accounts for technology interactions, competing options and technological change, the model analysis provides insights that are not easily obtained from more simple analytical approaches. As with all projections, reliability tends to decrease as the time horizon is broadened. Still, it is possible to calculate developments for 10-25 years ahead with some level of accuracy. Only developing countries with potentially exponential growth pose a challenge. Scenarios analysis is one way to deal with uncertainty in projections. The policy framework is one of the key parameters and many studies compare business-as-usual with alternative policy scenarios.

Models can also help in scenario analysis. Scenarios represent a more sophisticated analysis approach compared to projections. Scenario analysis is one way to deal with specific types of uncertainty ('known unknowns'): key variables are identified and a set of projections is developed that explores the impact of the key variables on the solution. Models help to ensure consistent assumptions across scenarios and they can be used to design technology portfolios. For example, the analysis can focus on robust technologies (that occur in all scenarios), on comprehensiveness (technologies that occur in any one scenario) or other criteria can be applied in the development of the scenario. The outcome of the analysis is a technology portfolio on which the innovation policy can focus. The approach also accounts for technology interactions such as chain and system effects. For example, use of electric vehicles requires a recharging infrastructure; an ambitious end-use efficiency policy may slow down the uptake of new energy supply technologies. Scenarios are not suited to deal with sudden unexpected breakthroughs. The discovery of electricity as energy carrier was such a breakthrough. Today a new low-cost low-weight electricity storage technology could revolutionize the car industry. However such 'unknown unknowns' occur rarely.

Innovation strategies

A successful renewable energy innovation strategy requires identification of a dedicated innovation model adapted to renewable energy technologies. The position of individual technologies within the innovation cycle must be assessed and the gaps and bottlenecks hindering their diffusion must be analysed. Strategies must consider (Grubler et al., forthcoming):

- Creating/enabling knowledge flows for technology learning and spill-overs;
- Balancing of government interference and free market approaches;
- Local policies to productively harness the international flow of energy technologies;
- Definition and creation of policy stability and credible commitments for innovation;
- Coherent incentive structures for the target technology innovation system;
- A systemic approach throughout supply chains and the technology life cycle;
- The balancing of diversity and technology experimentation vs. well-structured portfolios;
- How to maximize efficiency and effectiveness of limited RD&D budgets;
- Better founded RD&D budgeting needs to meet policy targets.

Conclusions

Innovation is key for technology transitions. Energy innovation, especially invention and R&D, is not well understood. This poses a challenge for policy making and policy needs analysis. Certain characteristics of the energy system make that innovations takes time and tend to be incremental. The characteristics of the energy system also explain why governments tend to play a more important role in energy innovation than in other sectors. As the energy system is fairly mature and changes take time, policy relevant model analysis for the coming years or decades tend to focus on deployment, especially on technology learning. A number of general guidelines can be formulated for innovation energy strategies. Today, models are especially useful in the deployment stage for learning and investment need analysis. Patent analysis is a popular tool for invention and R&D analysis, but it is focused on trends and activity levels. Future work must focus on a better understanding of the efficiency and effectiveness of invention and R&D. A heuristic approach could be one way ahead. Finally, innovation in developing countries deserves special attention, and the benefits and possibilities of North-South and South-South cooperation for innovation need to be explored further.

References

Grubler, A. et al. (forthcoming) *Knowledge module 24: The energy technology innovation module.* Global Energy Assessment. IIASA.

IEA (2008) *Energy technology perspectives.* IEA/OECD.

UNEP/EPO/ICTSD (2010) *Patents and clean energy: Bridging the gap between evidence and policy.* Geneva.

Modeling long-term energy scenarios: Why!?

Bob van der Zwaan & Hilke Rösler

Abstract

The predictive value of long-term energy scenario models is close to none. Why then do we use these models, notably for ongoing activities of the IPCC? This essay briefly describes two recent examples demonstrating that particularly integrated assessment models that simulate or optimize energy-economy-climate interactions possess no practical use when it comes to forecasting: nuclear energy and hydrogen technology. We also point out that long-term energy scenario modeling may nevertheless provide useful insight, but for different purposes, such as answering 'What if' questions.

Nuclear energy

Whether nuclear power can contribute to sustainable development has been a subject of analysis for at least a decade (see e.g. Bruggink and van der Zwaan, 2002). Arguments can be made in support of the environmental sustainability of nuclear energy, while others can be brought forward that are at clear loggerheads with it. Irrespective of its multiple handicaps and drawbacks, among which especially (but not only) radioactive waste, reactor accidents and nuclear proliferation, nuclear energy can in principle play a part in mitigating global climate change. It has been argued, however, that in order to do so it needs to be expanded significantly, by at least a factor of three this century (Sailor et al., 2000). Concerns over climate change, air pollution and energy security have increasingly dominated the energy policy agenda over the past decade – issues that nuclear energy could contribute to alleviate. Yet even while these concerns stimulated considerable public discussion on energy technology futures, they did not generate a development worthy of the denomination 'nuclear renaissance', terminology understandably much appreciated by proponents of nuclear technology. Indeed, the global construction rate of nuclear power plants, although recently significantly increased with respect to a decade ago, during the past few years still fell well short of the speed observed in the 1970s and 1980s. Nevertheless, an expansion over the coming century by a factor of three – which would have yielded multiple challenges of untested proportions at a world scale – could perhaps just about have been imaginable (van der Zwaan, 2008) – that is, before March 2011.

After the Chernobyl accident in Ukraine 25 years ago, the accidents in the reactors and spent fuel cooling ponds of the Fukushima Dai-ichi nuclear power plant in Japan in March 2011 have generated a second landslide change in how people today view the technology. As a result, a global increase of nuclear energy by a factor of three this century, in order for it to meaningfully contribute to controlling climate change, is now pretty unlikely. The Japanese government has committed itself to halt a previously agreed expansion for the nation's nuclear power capacity. The federal government in Germany has returned to its prior deal with electricity companies to phase out nuclear power over the course of the coming decade, while Switzerland will follow suit with a similar plan. In June 2011 in Italy the population has expressed overwhelmingly its opinion in a second referendum on the subject since 1987 not to engage in the construction of nuclear reactors domestically. More countries with domestic nuclear energy production in especially the developed world may still follow these examples. Several countries though seem for the moment to remain firm in their desire to (continue to) reserve a role for nuclear energy in domestic electricity generation. Among these are notably China and India, and others in Southern and Eastern Asia, but this category also includes countries in e.g. Eastern Europe, such as Poland, as well as nations in the Middle East and the Gulf region, like Egypt, Turkey and the United Arab Emirates. In other words, reactions to the Fukushima accident are diverse and generate different impacts across the globe. Whereas on aggregate nuclear power may still modestly grow over the decades to come – the decrease in some parts of the world compensated by growth in other parts – a real role for nuclear power in international efforts to mitigate global climate change seems now rather small: quite unexpectedly so.

The long-term energy scenario models used by many analysts at numerous research institutions cannot be used to anticipate these, and other sorts of, 'black swan' events and the accompanying major shifts in technology preference.

Hydrogen technology

During the past decade an economy based on hydrogen as energy carrier seems to have passed through a cycle of popularity. Given that the use of hydrogen as fuel does not directly involve emissions of greenhouse gases or air pollutants, support programs were set up by the European Commission to stimulate the use of hydrogen, for instance in buses across several European cities (CHIC, 2011). The International Energy Agency spent considerable effort analyzing the deployability of hydrogen technology (IEA, 2005). The Netherlands Organisation for Scientific Research dedicated a program to study a broad series of sustainable hydrogen topics (ACTS, 2011). Hopes were high in many communities for the large-scale adoption of hydrogen technology throughout Europe. Extensive academic research as well as practical deployment experience has demonstrated, however, that the challenges for a widespread introduction of hydrogen technology remain important. These relate especially to issues of safety, infrastructure and costs. In terms of costs, it was pointed out that learning phenomena for the several stages of an economy relying on hydrogen as fuel – hydrogen production, transportation and combustion – are likely to be limited in scope at best. In fact, they proved to only really exist for the most innovative part of the 'well-to-wheel' chain of the use of hydrogen, i.e. the manufacturing of fuel cells for the combustion stage (Schoots et al., 2010), and hardly for the more mature steps of hydrogen production and transportation (Schoots et al., 2008; van der Zwaan et al., 2011). More generally, it was shown that possible cost reduction effects through learning-by-doing in general should be evaluated carefully, may not exist for all technologies or components, and could be severely hampered by (scarcity-induced) material cost constraints – hence the need to be less optimistic about their 'extrapolability' than commonly assumed (Ferioli et al., 2009). This is probably in particular true for hydrogen technology.

The above are mostly rational arguments to explain why the popularity of hydrogen technology a decade ago was on the rise, several years later started to decline, and today seems to be significantly compromised. The hydrogen hype appears at present largely replaced by one built around electric vehicles with batteries as means for the storage of electricity as principal energy carrier. One of the obvious reasons is the existence of elaborate power transmission and distribution networks. Perhaps equally important, however, for explicating the apparent shift in focus and interest from hydrogen-based to battery-based transportation modes are arguments of a more subjective nature. Like with social acceptance in the field of nuclear energy, public preference and opinion have important, sometimes even dominant, roles to play in the diffusion of a new technology. This also pertains to the energy sector and in this case notably the transport sector. Subjective explanations go beyond matters of personal consideration and public opinion, and may involve factors like taste and fashion. Could, for example, the popularity of iPhones and iPads and their smart phone and tablet equivalents from Apple's competitors – all powered through electric chargers – end up spilling over to a preference for plug-in electric cars equipped with batteries, inspired by Apple's brand appeal? It is hard to say, but social scientists exercise in explaining how consumer preferences may sometimes go in unexpected ways. In this light a switch from the current generation of fossil-fuelled vehicles to electric cars with batteries is perhaps more imaginable than a transition to vehicles with on-board hydrogen tanks as fuel storage medium. But only time will tell. Typically, developments of this kind, fed by matters of personal tastes, interests and habits, are intrinsically hard to predict. There is little doubt though that technology preference and choice go through cycles of popularity and may be affected by a variety of independent trends. In our case these may well lie beyond the energy sector per se.

Long-term energy scenario models have great difficulty in, if not cannot be used at all for, anticipating or simulating major shifts in technology choice based on the multiple dimensions of consumer preferences, let alone evolutions in taste and fashion.

What if?

What then are long-term energy scenario models useful for? We argue that they serve in particular one (and perhaps only one) main purpose: answering 'What if' questions. In other words, these models constitute a valuable instrument to test the robustness of scenario assessment results and to quantify the impact of changes in certain economic, social or technical developments. Suppose the value of a variable reflecting one such development alters, what then is the expected effect in energy, environmental or economic terms? This type of question can in principle be answered with an energy scenario model, with varying levels of precision depending on the type of model used. Models in this field abound, commonly categorized in three distinct groups: bottom-up (such as TIAM-ECN), top-down (like DEMETER) and hybrid (e.g. WITCH). It is fundamentally impossible to assign probabilities to the different scenarios generated by these models, irrespective to which group they belong. One of the merits of models belonging to each of these categories though is that the scenarios produced with them are at least to some degree internally consistent. For example, these models can ascertain that an energy option can only be expanded in conformity to the physical or economic potential of the natural resource that it relies on. Alternatively, a type of car in the transport sector can only obtain a certain market share if the associated industrial sector produces the volume of fuels sufficient to operate the corresponding number of vehicles.

The first of the listed models, TIAM-ECN, yields the richest energy technology description. During the course of 2010 it has been adapted to analyze, amongst others, developments and technologies in the transport sector, both globally and at the European level (Rösler et al., 2011). One of the preliminary findings with TIAM-ECN is that the development of a hydrogen-based transport sector may be an optimal long-term choice, rather than transportation based on electric vehicles that use batteries as storage medium. While these intermediate results need to be further tested and verified, an important insight already now seems that they cannot be obtained with models that involve a much shorter time frame. Indeed, with short-term oriented models electric vehicles prove economically typically more attractive, because one can effectively employ the current expansive national and regional infrastructures for power transmission and distribution. This observation delivers an important reason for long-term energy scenario modeling: lessons can be learned that cannot be obtained with a more short-term perspective. With today's colossal challenge of global climate change control, and the establishment of sustainable development more broadly, the long-term is ultimately what really matters.

A few other examples indicate what long-term energy scenario models can be useful for. Suppose we would want the transport sector to be dominated by electric cars equipped with batteries, rather than hydrogen-fuelled fuel cells (e.g. because one expects electricity to be generated more easily in environmentally beneficent ways than hydrogen), what would the cost reductions need to be for the former in order to make it the optimal option? This question was answered in a recent exercise with the TIAM-ECN model (van der Zwaan et al., 2011). Suppose one would want to phase out nuclear energy as climate management option in favor of coal-based plants complemented with CCS technology, how much will the improvements in CCS need to be in order to render it economically the most cost-efficient option and let 'clean coal' appear as dominant alternative in the optimization solution? The answer is provided in a publication based on an analysis with the WITCH model (Tavoni and van der Zwaan, 2011). Suppose CCS is accompanied by physical leakage of CO_2 from the geological formation in which it was stored, what then are the climate mitigation costs incurred, and how much leakage would be allowed from a climate control perspective? The DEMETER model has proven fit for providing insight into this relevant question (van der Zwaan and Gerlagh, 2009). Suppose an 'air capture' technology is developed that allows 'washing CO_2' from the atmosphere for subsequent use or storage (Lackner, 2010), could it be cost-effectively used to reach a stringent climate control target? The models above in principle allow for investigating the potential role of such a technology, under varying assumptions regarding its costs, as well as inspecting the corresponding feasibility and global price tag of reaching a maximum of 2˚C for the global average atmospheric temperature increase, as currently professed by the international climate policy community.

The above constitutes a concise exposé of why it continues to be important, even in a research environment that needs to adapt to a reality of becoming more market-oriented, to also pay due attention to – scientifically typically more fundamental – long-term analysis. One cannot investigate long-term environmental challenges with short-term models only. As a matter of fact, long-term energy scenario models are often essential to set the backdrop for the operation of short-term ones. Furthermore, insights can be obtained with long-term models unachievable with, and sometimes quite different from, results derived with short-term frameworks of analysis.

References

ACTS, 2011, *Advanced Chemical Technologies for Sustainability,* Sustainable Hydrogen program, Netherlands Organisation for Scientific Research, NWO, www.nwo.nl.

Bruggink, J.J.C. and B.C.C. van der Zwaan, 2002, *'The role of nuclear energy in establishing sustainable energy paths*', International Journal of Global Energy Issues, 18, 2/3/4.

CHIC, 2011, *Clean Hydrogen in European Cities project*, last consulted in June 2011 at http://chic-project.eu/.

Ferioli, F., K. Schoots and B.C.C. van der Zwaan, 2009, *'Use and Limitations of Learning Curves for Energy Technology Policy: a Component-Learning Hypothesis',* Energy Policy, 37, 2525-2535.

IEA, 2005, *Prospects for Hydrogen and Fuel Cells,* International Energy Agency, OECD, Paris, France.

Lackner, K.S., 2010, *'Washing carbon out of the air,'* Scientific American, June 2010, 66-71.

Rösler, H., J.J.C. Bruggink and I.J. Keppo, 2011, *'Design of a European Sustainable Hydrogen Model'*, Report ECN-E--11-041, ECN, Petten, The Netherlands.

Sailor, W.C., D. Bodansky, C. Braun, S. Fetter and B.C.C. van der Zwaan, 2000, '*A Nuclear Solution to Climate Change?',* Science, 288, 19 May, 1177-1178.

Schoots, K., F. Ferioli, G.J. Kramer and B.C.C. van der Zwaan, 2008, *'Learning Curves for Hydrogen Production Technology: an Assessment of Observed Cost Reductions'*, International Journal of Hydrogen Energy, 33, 11, 2630-2645.

Schoots, K., G.J. Kramer and B.C.C. van der Zwaan, 2010, *'Technology Learning for Fuel Cells: an Assessment of Past and Potential Cost Reductions',* Energy Policy, 38, 2887-2897.

Tavoni, M. and B.C.C. van der Zwaan, 2011, *'Nuclear versus Coal plus CCS: A Comparison of Two Competitive Base-load Climate Control Options',* Environmental Modeling and Assessment, 16, 5, 431-440.

van der Zwaan, B.C.C. and R. Gerlagh, 2009, *'Economics of Geological CO_2 Storage and Leakage',* Climatic Change, 93, 3/4, 285-309.

van der Zwaan, B.C.C., 2008, *'Prospects for Nuclear Energy in Europe',* International Journal of Global Energy Issues, 30, 1/2/3/4, 102-121.

van der Zwaan, B.C.C., I.J. Keppo and F. Johnsson, 2011, *'When and How to Decarbonize the Transport Sector?',* Working Paper.

van der Zwaan, B.C.C., K. Schoots, R. Rivera-Tinoco and G.P.J. Verbong, 2011, *'The Cost of Pipelining Climate Change Mitigation: an overview of the economics of CH_4, CO_2 and H_2 transportation',* Applied Energy, 8, 3821-3831.

The silent revolution: solar energy on its way to large-scale use

Wim Sinke

Introduction

Solar electricity may become competitive in major parts of the total global electricity markets within a decade. It is not cost reduction that is expected to be the limiting factor for market growth in the longer term, but rather integration into the grids for very high degrees of penetration (>100%), unless technical and policy-related preparations are started in time. Solar energy has the potential to become a main supplier of energy for the world: heat, electricity and fuels.

Great future, but when?

It is mentioned in almost every publication about solar energy: in one hour the earth receives an amount of solar energy equal to the total annual human energy consumption. This statement is very important and meaningless at the same time. Important, because it illustrates that the theoretical potential of solar energy is huge; meaningless, because it does not say anything yet about the possibilities for practical use. In scientific terms: the theoretical potential should not be confused with the technical potential, let alone the economic or realisable potential. Nevertheless, the technical potential is also enormous and in any case much bigger than the current global energy consumption [WEA, 2000]. Therefore, there is broad consensus that solar energy in its various forms (heat, electricity and fuels) offers great possibilities for the future global energy system. Unfortunately, this is also where consensus currently ends. When comparing scenarios, roadmaps and visions it becomes clear that estimates of the possible market growth of solar energy, and thus of the contribution of solar energy to the total global energy consumption over time, still vary greatly [GEA, 2011]. According to some, solar energy may still play a rather marginal role by 2050, while in others, solar energy is predicted or assumed to be a mainstream technology and a major contributor by then. At first sight this may seem to result from different estimates of possible cost reductions, but upon a more thorough analysis it becomes clear that it simply shows the complexity, the impossibility or even the unwillingness to make (other) quantitative statements about the future. In other words, there is ample room for very different views on the future. Also, views may evolve over time, as is illustrated by the scenarios published by the International Energy Agency [IEA1, 2010] and Greenpeace & EPIA [Greenpeace & EPIA, 2011]. Such an evolution may be the expression of changing expectations about possible technology and market developments (based on past developments surpassing expectations) or of an increased sense of urgency that something has to be done about climate change or other problems the world is facing. In the case of the IEA it is probably both, whereas in the case of Greenpeace & EPIA it is mostly the former.

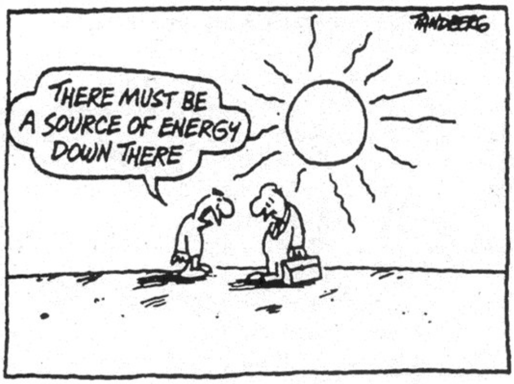
The many faces of solar energy

Solar energy can be used to generate low- and high-temperature heat, electricity and fuels. The latter (solar fuels) is not to be confused with biofuels, which are based on some form of biomass conversion.

Solar *heat* (alternatively: solar thermal energy) is partially mature technology and is used on a large scale in a number of countries, mostly in the form of small domestic hot water systems for tap water heating. Larger systems (optional with seasonal storage) for space heating of houses and offices as well as industrial systems for process heat are not yet fully developed and applied on a large scale, even though they provide great opportunities and are thus a valuable building block for a sustainable energy system.

Solar *electricity* can be generated directly using solar cells (photovoltaic conversion; PV) or indirectly using concentrating solar power (CSP) [IEA2, 2010], in which high-temperature heat is generated first, followed by electricity generation using a conventional thermal cycle. PV is technically mature in the sense that reliable systems have been on the market for decades. Economically, PV is not yet mature, since it can only compete in niche markets so far. However, prices are coming down rapidly and PV is expected to be able to compete in a major part of the entire total global electricity market already by the end of this decade′ [Breyer, 2010; DoE, 2011]. Compared to PV, which had an installed capacity of 40 GW at the end of 2010, CSP has only been applied on a very modest scale so far, although this technology is speeding up recently [EurObserv'ER, 2011]. Although some early systems have already been in operation for several decades, CSP has a limited track record and the number of companies involved in manufacturing and installation is still small. Expectations are high, however, especially since CSP normally comes with (heat) storage and can – in principle - be combined with sea water desalination. Both features make CSP an attractive part of the future sustainable energy portfolio.

Solar *fuels* are in a totally different stage of development. There are no commercial products yet. The term 'solar fuels' refers to a wide range of concepts to use sunlight for the direct production of gaseous or liquid fuels. A prominent example is light-induced water splitting to form hydrogen and oxygen, but also simple hydrocarbons like methanol can be synthesized, using the infamous CO_2 as one of the ingredients. Solar fuel 'reactors' can be based on inorganic materials or on organic materials. The latter are usually 'bio-inspired'. There is a somewhat diffuse boundary between solar fuels and biomass/biofuels, especially when it comes to (for instance) genetically modified microorganisms. If solar fuels would become available on a large scale, the portfolio of solar energy technologies would be complete, since all forms of energy currently used can then be generated used sunlight as a source. Solar fuels would form a desirable alternative to biomass, because the sun-to-fuel efficiency can typically be an order of magnitude higher and solar fuel generation would not require fertilizers, would not suffer from diseases and would not need large amounts of water (apart from what goes in as fuel ingredient), to name just a few important aspects. Unfortunately, the scientific and technological challenges of solar fuels are still huge. Therefore, many governments and an increasing number of companies are investing heavily in R&D. It remains difficult to say when solar fuels might enter the market in significant quantities, but it is likely to take at least another decade.



Copyright: Greenpeace

Solar energy's growth champion: photovoltaics

PV has shown impressive and (to many) unexpectedly rapid technology development and market growth. PV manufacturing has recently moved into the gigawatt-scale (per company, that is), market growth has been over 50% per annum *on average* and a wealth of conversion concepts and technologies is available commercially, demonstrated in pilot production or subject of research in many labs worldwide. As a result of the combined effects of volume in manufacturing and installation and technology development the prices of turnkey systems have come down drastically. Lowest system prices are currently (mid 2011) in the range of 2 to 3 €/watt-peak, which translates into generation costs of less than 0.10 €/kWh for selected systems in sunny regions and a stable investment climate (the latter relates to the cost of capital). Moreover, costs and prices are expected to decline further and 2020 target levels for utility-scale systems range from less than 1 to 1.5 €/watt-peak [DoE, 2011; GEA, 2011; IEA1, 2010]. The target of the SunShot Initiative of the US Department of Energy [DoE, 2011] is to make PV electricity competitive on utility scale before 2020. Small rooftop systems and building-integrated systems typically come at somewhat higher prices than utility-scale systems, but that may change when standardization and prefabrication are successfully implemented. After 2020, prices could decrease even further to a level close to 0.5 €/watt-peak [GEA, 2011; IEA1, 2010]. The lowest corresponding generation costs are roughly 0.02-0.03 €/kWh [GEA, 2011]. One might thus say: the question is not *whether* PV will become a success, but rather in *which* form(s), *where* and *when*.

City of the Sun, Municipality of Heerhugowaard, NL

Germany's leadership

The rapid development of PV obviously has a reason and a price. Simplifying the global developments over the past decade into one sentence: 'We are where we are in PV thanks to Germany'. Without the efforts of our neighbours this would be the year 2000 in PV, or even 1995. Thanks to its feed-in system, Germany has by far the biggest market for PV systems in the world. Currently about 3% of all electricity consumed in Germany is generated by PV. Germany also leaves behind all other countries in terms of per capita spending on PV R&D. Thanks to Germany, the global PV sector has progressed along the learning (price-experience) curve and the German electricity users and tax payers have literally paid the learning costs for the rest of the world. Although this has been done deliberately, with the aims of rapidly deploying renewable energy and building a strong industry sector, the many billions involved have triggered a major public and political debate, especially because a large part of solar module manufacturing has recently shifted to China. On the other hand, the recent nuclear accident in Fukushima and the following decision to rapidly phase out nuclear energy has added an interesting new dimension to this debate.

Internationally, Germany has been both praised and criticized for its PV policy. Praise came - as expected - mainly from people, companies, organizations and countries active in PV and wanting developments to go as fast as possible. It emphasized the fact that Germany 'got things really going', showed vision and ambition and demonstrated that the future (at least to a certain extent) can be shaped. Critics argued that market growth was too rapid to allow proper learning and thus was unnecessarily costly. By shifting financial resources for market deployment to technology development and innovation the total costs to bring PV to competitiveness could be decreased, see Figure 1 [Sinke, 2010]. This, on the other hand, might substantially increase the time needed for PV to gain impact. It has also been argued that the distance between Germany and the rest of the world was too big, resulting in an unstable development (when German PV policy coughs, the global PV sector gets a flu) and, at a different level, that one should develop cheaper renewable energy options first, or leave solar energy to sunny countries. There is probably no 'right or wrong' in this discussion, just different aspects of, and perspectives on the global development. Depending on the priorities set, one can arrive at very different conclusions about the best approach.

Looking at global solar energy developments from a distance

The rapid development of PV as triggered by German policy undoubtedly has flaws. The question is whether that is a problem. Bringing PV to maturity and competitiveness will cost the world a few hundred billion euros [Sinke, 2010]. This is the total investment needed from the birth of the technology in the early fifties of the last century to the point where PV can stand on its own feet. After that, PV deployment will become profitable and may generate revenues for the world (in various forms) that are a multiple of the investments. Considering the fact that the investment yields a sustainable energy technology with a huge potential that can be applied worldwide in many different application forms, a few hundred billion is a modest amount of money. 'Peanuts for the world as a whole, but too much for one country alone' [Sinke, 2010]. The 'problem' was therefore not so much Germany's ambitious policy, but rather the lack of significant action by most other countries in world. Fortunately, Germany now gradually gets company of other countries such as Italy, the USA and China. This may enable to continue the rapid development of PV that we have seen over the past decades and create a more robust global market.

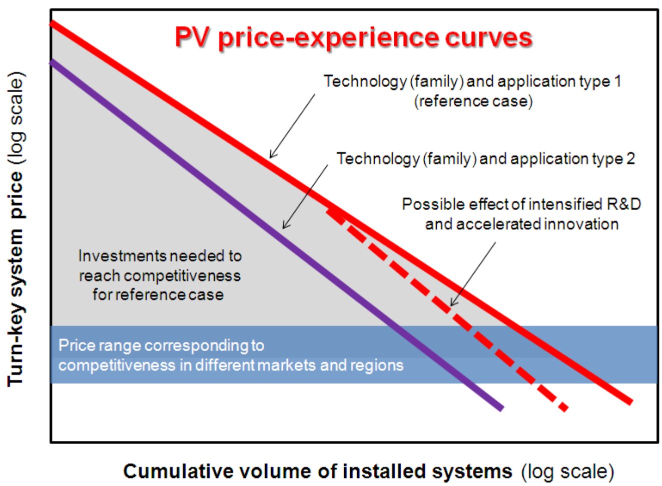


Figure 1. *Schematic view on the price reduction of photovoltaic systems as function of the cumulatively produced and installed volume. The effects of technology improvements are implicit in the curves*

Clearly, bringing PV to competitiveness is just one of the challenges that are faced. Another one is to integrate PV systems into the electricity grids. When the degree of penetration of PV and other renewables becomes high (in the order of, or even (much) higher than 100% on the basis of generating capacity), modifications to the grid and to the ways in which grids are operated become necessary. Since major forms of applications are expected in the built environment (including the physical infrastructure) as well as in 'the field', in all parts of the world, different levels of the grid infrastructure need to be considered: from high-voltage interconnections to local distribution grids. Ultimately, some forms of storage will be needed [FVEE, 2010]. Since some grid adaptations are time-consuming compared to the rapid development of PV seen recently, grid integration may even become a time-limiting factor for very large-scale deployment of PV in parts of the world. It is emphasized that grid integration is not a *problem*, but preparations on technical and policy and regulatory levels need to start in time and probably earlier than previously expected, in view of the rapid development of PV.

Another crucial factor for very large-scale deployment of PV is integral sustainability. This refers to the supply chain (materials availability), to cradle-to-cradle design and several other aspects of the technology and its use. Currently, most of the discussion is on the use of non-earth-abundant materials such as indium, tellurium and silver and on the use of toxic substances such as cadmium (in the form of cadmium telluride). There is no consensus on whether or not materials availability (or: price) may become a serious issue and neither on the desirability of the use of cadmium telluride, which happens to make the lowest cost solar modules available on the market today. It is clear, however, that high-performance, non-toxic, earth abundant alternatives are available at only somewhat higher (and ever decreasing) costs, so the world does have a choice.

Outlook

There is little doubt that PV systems will become available at low prices, allowing generation of solar electricity at competitive costs. The technical and economical potentials are huge and not limiting growth to the terawatt scale. Large-scale deployment is therefore expected to be rather dependent on other factors, such as possibilities for integration into the grid. The latter includes the financial models applied when grid adaptations and storage are implemented as part of the overall transition process, not just the introduction of PV. Although it remains difficult to make quantitative statements on the growth of PV in the longer term, the technology is clearly beyond the tipping point. This is evidenced by the fact that an increasing number of business models are introduced which do not rely on explicit subsidy (although they do rely on net metering for the immediate future). PV is here to stay and to grow.

References

Breyer, Ch., Gerlach, A. 2010, *Global overview on grid parity event dynamics,* Proc. 25th European PV Solar Energy Conference, 5283-5304.

DoE, 2011. SunShot Initiative, see www1.eere.energy.gov/solar/sunshot/.

ESF, 2008. *Harnessing Solar Energy for the Production of Clean Fuel,* European Science Foundation (2008), www.esf.org/publications/science-policy-briefings.html.

EurObserv'ER, 2011. See www.eurobserv-er.org/pdf/baro203.asp

FVEE, 2010. *Energiekonzept 2050, Eine Vision für ein nachhaltiges Energiekonzept auf Basis von Energieeffizienz und 100% erneuerbaren Energien*, ForschungsVerbund Erneuerbare Energien (FVEE), 2010. www.fvee.de/fileadmin/politik/10.06.vision_fuer_nachhaltiges_energiekonzept.pdf

GEA, 2011. *Global Energy Assessment,* IIASA, Vienna, Austria (in press).

Greenpeace & EPIA, 2011. *Solar Generation 6*, Greenpeace International and European Photovoltaic Industry Association, see www.epia.org/publications.

IEA1, 2010. *Technology Roadmap Solar Photovoltaic Energy*, International Energy Agency, Paris, France.www.iea.org/papers/2010/pv_roadmap.pdf.

IEA2, 2010. *Technology Roadmap Solar Concentrating Solar Power*, International Energy Agency, Paris, France.www.iea.org/papers/2010/csp_roadmap.pdf.

Sinke, 2010. W.C. Sinke, *Technology diversity: blessing or curse?* Future Photovoltaics 2 (Sept. 2010), www.futurepv.com/.

WEA, 2000. *World Energy Assessment: Energy and the Challenge of Sustainability*, UNDP, New York, ISBN 92-1-1261-0. See also the 2004 update of WEA www.undp.org/energy/weapub2000.htm and www.undp.org/energy/weaover2004.htm.

The trouble with biofuels

Marc Londo

Elements for a biofuels strategy given several global energy futures

Intro

Collapse (Diamond 2005) describes and analyses the fall of societies such as the Vikings on Greenland, the Easter Island Polynesians and the Mayas, but also more recent cases of all-society crises such as the Rwanda genocide. Regardless complex combinations of differing causes for collapse in each individual case, their stories also appear to have a common cause: environmental damage and exhaustion of natural resources. While some of this damage occurred through processes that were not understandable to these cultures, other cause-effect relations must have been clearly visible to the inhabitants. It's an almost romantic thought to imagine how the man felt who cut down the last tree on Easter Island; a more daunting question might be why his society allowed him to do so. Some of these processes are clearly relevant to the way modern bioenergy may develop in the coming decades, biofuels for transport in particular.

Biofuels and the criticism to them

Indirect land use change as biofuels' Achilles' heel

The public debate on biofuels has been fierce, intensive and polarized in the past years. The use of food crops for the production of bioethanol and biodiesel (so-called first generation biofuels) would have allegedly led to the food prices hike in 2007/8, contributed to spurring deforestation in the tropics, and would overall have led to net additional greenhouse gas emissions.

The fundamental mechanism at hand is indirect land use change, or ILUC: the mechanism by which use of agricultural feedstocks for biofuels leads to a reduced availability of these feedstocks on the global market for food, and the resulting upward pressure on agricultural commodity prices provides an additional incentive for deforestation.[12]

In the heat of the debate, nuances disappear and it almost seems that all biofuel and bioenergy options are equally contestable, while all experts broadly agree that for example the sustainability of the use of residues from agriculture, forestry and food processing is not or much less subject to dispute. However, residues are also linked to land use, although much less directly. And generally, the entire bioenergy sector should worry about the issue of ILUC as the possibly unsustainable use of one kind of

[12] The European Commission has set out several review studies on the issue, on which basis EC (2010) concludes that the issue is not yet sufficiently explored to come to policy conclusions. In contrast, Fritsch et al. (2010) conclude that there is sufficient evidence to come to an ILUC factor in greenhouse emission profiles of biofuels. Many studies have been done on the issue, by research institutes as well as NGOs.

biomass: if first generation biofuels will lead to environmental damage, the entire sector may suffer from waning public acceptance for bioenergy, be it factually rightful or not.

Bioenergy in perspective

Biomass was the dominant energy source for mankind through most of its history. In the fossil age of today, biomass supplies about 10% of our primary energy (IEA 2010), mostly traditional biomass in developing countries. Most energy scenarios expect the role of biomass to increase again, given future fossil resource scarcity and climate change mitigation challenges. Biomass is one of little options currently available to replace oil as a resource for liquid fuels. While passenger transport may turn to powertrains based on hydrogen and electricity, long-distance road transport, aviation and shipping will probably need to rely on liquid fuels for a long time. Most scenarios for 2050 (IEA 2010, Shell 2010, WWF 2011) envisage primary biomass use to rise to 60-200 EJ/y by 2050, mainly depending on assumptions regarding global ambitions in renewables and climate change mitigation. Potential availability of biomass residues and forestry surpluses could suffice to meet this demand: the IPCC Special Report on Renewables (IPCC 2011) estimates this between 100 and 250 EJ/y; the WWF study has an estimation in-between of 140 EJ/y (WWF 2011). However, energy crops might also be needed; fast-growing woody or grassy crops as well as conventional agricultural crops such as oilseed and sugar/starch crops. Agricultural crops might also be needed for the production of conventional 1^{st} generation biofuels such as biodiesel, for which the availability of some specific residues with limited availability may not suffice. Potentials for energy crops vary widely: Estimates given by IPCC and WWF (2011) of around 100 EJ both contain strong disclaimers about their significant uncertainty: developments in human diet, food and feed demand, agricultural productivity and livestock efficiency can make or break this potential, essentially reducing it to zero or increasing it to several hundreds of EJ. As an indication of land use implications: the WWF potential of 100 EJ requires almost 700 Mha of land, minor compared to total global land mass of 13,000 Mha but a substantial amount compared to current arable land use of 1500 Mha. Therefore, current challenges in bioenergy directly relate to land use issues. The introduction of offshore-cultivated algae can reduce this land pressure for bioenergy. Its technical potential, however, is still highly uncertain and is surrounded by various implementation challenges.

Key arguments of the biofuel optimists

Many messengers from science and industry insist that the importance of ILUC is currently greatly overrated. In their reasoning, the following arguments dominate. In the first place, there is plenty of global potential for the improvement of agricultural yields, feeding the world and delivering biomass for energy. And an essential condition for mobilizing this potential would be an attractive price level for crops. As for the negative impacts, they argue that the causal chain between biofuels production e.g. deforestation is long, complex, and subject to a manifold of other factors influencing it. For example, the use of e.g. oil seeds for biodiesel co-generates substantial amounts of protein meals, a useful animal feed. And agricultural markets are strongly influenced by policy, hardly transparent and only moderately liquid: not a good context for straightforward application of the rules of demand and supply. And finally, deforestation is caused by a run for tropical hard wood and facilitated by corruption and poor maintenance of indigenous people's property rights: definitely evils worth fighting against, but no things biofuels should be blamed for. Besides: the impact of e.g. the EU renewable energy directive's mandatory target in transport leads to a relatively negligible demand for agricultural feedstock. All in all: there's plenty of evil in the world, but don't put the blame on biofuels.

Key arguments of the biofuel critics

The critics on bioenergy, quite often NGOs but some scientists as well, do not dispute that land use change is a process driven by a complex blend of drivers. Their main argument is that the impacts such as deforestation are real and urgent, and that aggressive biofuel policies only make the situation worse. Furthermore, in contrast to the demand for food, biofuels demand is almost entirely policy-driven: policy makers can actually steer and stop biofuels development. For the longer term, they question the levels to which agricultural productivity may still increase, partly on biophysical considerations (e.g. how much additional irrigation is still possible globally), partly for the simple reason that there have been unsuccessful programmes on productivity growth in developing countries for decades already: apparently it's not only technicalities limiting this. Finally, some critics distrust the message of optimists that the biofuels issue can lead to overall better land use policy, something we will need anyway in order to meet the challenges of feeding a still growing world population without entirely compromising the planet. All in all: the planet may be on the verge of a crisis, and don't make matters worse by introducing biofuels.

Some remarks

To a certain extent, biofuel advocates and opponents are arguing on different levels. From a systems analysis perspective, the mid- to long-term perspective on bioenergy potentials is only indicatively known, and science is progressing in identifying the key factors affecting it, including the policy opportunities for steering them. From this perspective, it is simply irrational to abolish bioenergy. On the other hand, in the imperfect world we live in, food price volatilities, drainage of peatlands and deforestation are happening on the ground. Even if the effect of biofuels on them is uncertain and possibly limited (as has already been shown for the 2007/8 food price hike), a mere precautionary principle would urge policy makers to tread this field with consideration. Besides, the simple picture of putting food crops into a fuel tank is so easy to visualize that in the public arena the blame will certainly be with biofuels. In conclusion, a careful policy strategy on biofuels is clearly needed, as both careless development and categorical refusal of biofuels are not the way to go.

Future storylines for biofuel deployment

Such a strategy will need to take into account how the essential driving factors for biofuels may develop in the years to come: climate change mitigation and reducing fossil oil dependency. The climate change mitigation driver is problematic in at least two ways. In the first place, it stands or falls with collective action, which creates a classical prisoner's dilemma. This dilemma might only be overcome when there is a common sense of urgency (and a shared action perspective). However, current status of climate negotiations allows for the impression that particularly the momentum for climate change policy is faltering.[13]

And in the real world, it's questionable whether the effects of climate change on the ground will enhance this sense of urgency. Extreme weather events are also part of natural variations, and effects like sea level rise come gradually. Instead of a clear and acute 'crisis', climate change may merely have the characteristics of the slowly heating water in which the frog finally gets boiled. In contrast, an oil peak can be much more aggressive, visible and acute, affecting all.[14]

With a relatively inelastic demand curve and a nearby run-out of flexible, fast-on-stream additional production capacity, the oil market seems to be prone to rapid overheating. Besides, an oil price peak makes almost everything more expensive and can be (through the energy costs of food production) just as life-threatening to the poor as a climate-change induced drought. Therefore, we will here focus on two scenarios, in which the severity of an oil price peak is the distinguishing factor. That is to say, it's not the question whether supply limitations will occur, but merely whether these occur through a relatively gradual process of price increases or by a sharp crisis-like peak with unprecedented price levels.[15]

[13] Obviously, there have been many successes in climate change policy to counter this statement. With climate change as a key argument, the European Union has laid down strong ambitions for greenhouse gas emission reduction, renewables and energy efficiency in 2020 and beyond, and member states like the UK and Sweden have already adopted far-reaching mitigation strategies. However, on a global level emissions by the EU will gradually become less relevant in the coming decades, particularly with the increasing emissions of non-OECD countries. The negotiations on post-Kyoto efforts show that it is difficult to find a common ground for a global mitigation strategy.

[14] Particularly in the transport sector, the impact of high but foreseeable oil prices affects end-user costs much more strongly than high but foreseeable CO_2 prices (if these would also be transposed to the end user), For example, Bruggink and Rösler (2010) show that a hypothetical fuel cell vehicle reaches break-even with a gasoline ICE when either oil prices reach slightly over 200 $/bbl ($CO_2$ price at zero) or when CO_2 prices reach 500 €/tonne (oil price kept at 80 $/bbl).

[15] These scenarios are relatively loosely based on the 'scramble' and

'blueprint' scenarios by Shell (2008), which mainly differ in the way societies address future resource scarcity and climate change: by strategies mainly based on self-interest or by coordinated efforts, respectively.

'Crisis': If a sharp oil peak comes tomorrow

If the world faces a fast and sharp oil price increase in the short term, with price levels of several hundreds of dollars for some time, there will probably be a global 'Umwertung aller Werte' in many respects. It may require extremely high oil prices, but there will be a price level at which some biofuels will be able to compete with fossil fuels without further policy support. Biofuels might even be able to respond more rapidly in an oil supply crunch than non-conventional fossils such as tar sands and gas- or coal-to-liquids: the capital intensity of biofuels production is lower and lead-times for getting new production on-stream can be shorter. The resulting autonomous growth of biofuels will lead to a strong additional urge for agricultural land expansion and severe indirect land use change effects. In such a case, the current societal debate on abolishing policy support to biofuels may even turn into a call for discouraging policy stimuli, such as additional taxation of biofuels, which may be lost in the 'rush for oil alternatives' that would start in such a crisis. Attention for climate change mitigation runs the risk of being entirely marginalized in such a case, as policy makers primarily concentrate on national interests in a world of scarcity, and may shift to adaptation efforts instead of collective mitigation policies in the climate change dossier.[16]

[16] Already competitive is bioethanol in Brazil, but particularly in developed countries biofuels are considerably more expensive than their fossil equivalents. This gap will only be overcome at high oil price levels, particularly as biofuel commodity prices will also respond to oil prices: 25-50% of agricultural crop production costs are fuel costs.

'Smooth': If we experience a more gradual oil peak process

If the world faces a more gradual increase in oil prices, there is basically more time to develop alternative options. For biofuels this means the introduction of 2nd generation biofuels, produced from lignocellulosic materials such as forestry residues and various wastes, and possibly algae-based biofuels (sometimes coined 3rd generation). This would mean that the acute pressure on land from the biofuels sector would remain limited, and there would still be some prospects for developing integrated land use and climate change mitigation policies. This can then include the development, implementation and maintenance of sustainability frameworks for biofuels, and integrated strategies for dealing with land use change. This would remain important, as residual streams for 2nd generation biofuels will not suffice if this sector would develop to significant levels of feedstock demand, and cultivation of dedicated lignocellulosic crops (such as short-rotation forestry) comes in sight.

Implications for a policy strategy on biofuels

With these two scenarios in mind, the challenge is to find some robust elements for a policy strategy on biofuels. Without having the pretention to be complete, some points stand out:

- *It is better to abolish policy support to conventional, 1st generation biofuels*. Currently, this policy already leads to public outcry and waning support for bioenergy in general. In a crisis scenario, negative impacts of these biofuels are most likely to increase further to levels that should be prevented, assuming that sustainability frameworks currently in development will not be implemented timely nor be sufficiently robust to prevent these impacts; in a smooth scenario there will be sufficient time for a shift towards advanced biofuels that are currently not land-based, leaving 1st generation biofuels obsolete. The argument that conventional biofuels are a stepping stone for advanced biofuels in terms of market and infrastructure development is not convincing either: both feedstocks and conversion technologies for advanced biofuels are too much unlike conventional ones to allow these to really serve as a step-up.
- *Integrated land use policy for the globe is urgently needed.* Even if 1st generation biofuels would not be further stimulated, there is still ample reason to strive for a more integrated and sustainable way of dealing with global land resources. Deforestation, peat land drainage and land grab are part of a much more complex sustainability issue than current biofuels only, and substantial further development of sustainable lignocellulosic bioenergy chains will depend on it. This merely requires socio-political innovations, not technological ones: it essentially means quantifying all benefits and costs of land use, and developing mechanisms to align the interests of all actors involved to a common optimum. This means introducing policies to break through well-known mechanisms as the tragedy of the commons and prisoner's dilemmas on a global scale. And it not only relates to wider energy issues, including options such as hydro and wind, but also to our common food and development future.
- *Sustainability frameworks are key, but should go beyond the chain level*. Sustainability criteria and monitoring systems are essential for responsible introduction of any kind of biofuel. However, most current efforts in e.g. the different roundtables for sustainable soy, palm, etc. focus on the production chain, including direct and use change. As indirect effects are crucial as well, such frameworks should address or link up to the integrated land use policy efforts mentioned in the bullet before.
- *Strong support of novel biofuels generation is important*. As mentioned, 2nd and 3rd generation biofuels generate no or far less demand for cropland, but their production technologies are still in a demo stage at best. Therefore, support for research, development, demonstration and deployment (RDD&D) is essential. During their market introduction however, monitoring will be needed as to prevent that their feedstock demand exceeds what can be delivered by e.g. residues before land use policy is sufficiently developed to sustainably accommodate new demand for (lignocellulosic) cropland.

- *Policy makers should worry about residues as well.* Currently residue-based bioenergy chains are broadly considered sustainable. However, if an oil peak would come, the energy content of residues will probably rise significantly. This may lead to all kinds of now unforeseen dynamics, e.g. unexpected feedstocks being used for energy causing new scarcity issues in their existing markets; therefore it is worthwhile pre-thinking the currently unthinkable.

Outro

In one of the final chapters, Diamond (2005) further addresses the question why societies have or have not responded adequately to the threats of a societal collapse as a consequence of environmental damage and resource exhaustion. Obvious reasons for failure are the inability of societies to foresee negative consequences or to recognize them when they occur, e.g. due to lack of knowledge in the causal relations between the damage and their activities, and the misleadingly gradual pace of processes. A third reason, however, is the unsuccessfulness of many past cultures in even trying to solve their problems when they experienced them and knew their causes. This can often be attributed to conflicts between personal and collective interests, and time trade-offs.

Not only individuals and companies, but also governing elites have shown many times in history that self-interest on the short term often prevails over the long-term common good. The current issue of global land use has many characteristics that make it hard to address, as many processes go gradually, causal mechanisms are complex and prisoner's dilemmas are ubiquitous. While natural sciences can help address the first two characteristics, strategists will essentially need a lot of 'political economy' thinking, taking into account both the good and the bad sides of human nature in order to come to successful strategies.

References

Bruggink, J.J.C (2005): The next 50 years: Four European energy futures. ECN, Petten.

Bruggink, J.J.C (2009): Dealing with Doom: tackling the triple challenge of energy scarcity, climate change and global inequity. Paper presented at the EU Conference on Sustainable Development, Brussels, 26-28 May 2009.

Bruggink, J.J.C and H. Rösler (2010): The economic feasibility of a sustainable hydrogen economy. In: Stelten, D. and T. Grube: Proceedings of the 18th World Hydrogen Energy Conference. May 2010, Essen.

Diamond, J.(2005): Collapse; How societies choose to fail or succeed. Viking, New York.

EC (2010): Report from the commission on indirect land-use change related to biofuels and bioliquids. Brussels, European Union.

Fritsche, U.R., K. Hennenberg and K. Hünecke (2010): The 'iLUC Factor' as a Means to Hedge Risks of GHG Emissions from Indirect Land Use Change - Working Paper. Öko Institut, Darmstadt.

IEA (2010): Energy Technology Perspectives 2010; Scenarios and strategies to 2050. IEA, Paris.
IPCC (2011): Special Report on Renewable Energy Resources and Climate Change Mitigation. Technical Summary. Cambridge University Press, Cambridge.
Shell (2008): Energy scenarios to 2050. Shell International, The Hague.
WWF (2011): The energy report; 100% renewable energy by 2050.
WWF/Ecofys/OMA, Gland.

Note

In some stylistic elements, this essayistic paper is clearly making use of two documents that greatly inspired the author in his work at ECN: Bruggink (2005) and Bruggink (2009).

Markets for clean cookstoves: A think piece for development cooperation positioning

Raouf Saidi & Rahul Barua

Introduction

Clean cookstoves are experiencing a resurgence of international attention as issues of energy poverty become of increasing importance in discussions surrounding climate and development. Greater knowledge of the hazards of indoor air pollution caused by the traditional use of biomass, and the growing momentum of recent and successful cookstove activities has moved the international community to action. The formation of the Global Alliance for Clean Cookstoves, as an industry body to accelerate the dissemination and adoption of clean cookstoves, has increased the prominence of local clean cookstoves markets around the world, and provided impetus for donors and civil society organizations to clarify their positions in making universal access to clean cooking facilities a reality. In light of this aim, greater understanding of the complementarities and strengths of actors in the cookstove market may be necessary to help determine market positions, and particularly those of development cooperation actors, which are most appropriate for future collaboration.

Recent shifts in development strategy have embraced market based concepts in approaching the challenges of poverty, and the provision of access to clean cooking facilities for the world's poor is no exception (Bilateral Donors Statement, 2010; Simonis, 2007). This has manifested into an objective of promoting financially sustainable cookstove enterprises which construct and disseminate improved cookstoves throughout low income communities, utilizing either existing or new value chains (Kees and Feldmann, 2011; GVEP, 2009). Such enterprises may provide important employment creation opportunities within the direct energy value chain, decrease social hardship for stove users and producers, and improve stove performance in terms of efficiency, carbon emissions, and indoor air pollution.

Given that at least part of the new urgency to address clean cooking is to harness momentum from recent successes in the global clean cookstove market, it is important to view these in the context of historical activity and lessons learned. As the private sector plays an increasingly important role in the dissemination of clean cookstoves, the role of development cooperation partners becomes less clear, begging questions of whether the direct involvement of the latter is required in cookstove markets, and if and how roles may be fundamentally altered.[17]

Despite having to exercise caution in project implementation, it is clear that international development agencies and

[17] For example, some consider the provision of direct and indirect subsidies necessary for the scaling-up of clean cookstoves, while others maintain that projects or enterprises that depend on permanent subsidy are not at all beneficial (Gaul, 2009; Shell Foundation, 2005).

partners bring a wealth of experience and capacity for implementation to the cookstoves market. Simultaneously, private sector actors may rely on technological and business innovation to craft flexible entrepreneurial approaches, unhindered by development budgets, timelines or objectives, yet often face institutional barriers which they are ill-equipped or ill-incentivized to confront.

In this brief discussion paper, such tensions within the clean cookstove market are discussed to highlight where new thinking for the positioning of development cooperation may be helpful. Using two recent advanced cookstove initiatives underway in Rwanda, the strengths of the private sector and the implications of these for the positioning of development actors are highlighted. This paper argues that, following years of project experience and experimentation, development cooperation actors no longer have a direct implementation role within the clean cookstoves market. Rather, development actors should adopt market support roles as purveyors of valuable market information, and enablers of institutional strengthening required by clean cookstove entrepreneurs.

An overview of the clean cookstoves market

Dialogue surrounding clean cookstoves is often aggregated into one market describing cooking solutions for poor households. In practice, however, clean cookstove interventions can be characterized by product, the setting of the end user, or the value chains leveraged. These distinctions have important implications for the nature of project implementation and business development. Below, a non-exhaustive review of clean cookstove classification is provided, to acclimatize the reader to various segments comprising the clean cookstoves market. Following the review, a number of 'shaping forces' influencing clean cookstove activities are discussed, to highlight potential tensions existing between organizations and the accelerated dissemination of clean cookstoves.

Market segmentation and examples

Domestic vs. institutional stoves

Domestic cookstoves are of two varieties: portable and installed. A household which currently cooks on a three stone fire may acquire one or more portable improved cookstoves, or alternatively may have a stove installed in their kitchen. Institutional cookstoves are almost always installed, and are meant for institutions such as schools, restaurants, hotels, prisons, and hospitals. These stoves require large amounts of fuel and thus are more likely to purchase part of their cooking fuel requirements. Because of this, rural institutions are a comparatively more accessible consumer segment than rural households, as the financial benefits from improved stove efficiencies may be readily seen.

Rural vs. urban stoves

In many low income markets, a distinction between rural and urban cookstoves can be made, generally based on the availability of cooking fuels. Urban households are more likely to use charcoal stoves, as biomass such as firewood and residues are less available. Rural households may cook on open fires, or rely on stoves fueled by traditional forms of biomass. An important distinction is that rural population groups are largely not in the cash economy, and therefore collect fuels themselves.

Biomass vs. non-biomass stoves

Related to the above, cookstoves may also be distinguished according to the type of cooking fuel used. Domestic cookstove designs vary greatly amongst a diverse range of cooking fuel sources, including: firewood, charcoal, biofuel, biogas, kerosene, LPG, solar energy, and electricity.

Local vs. foreign production origins (also, existing vs. new value chains)

Another critical segmentation for clean cookstoves is that of production origin. Cookstoves can be self-produced in-country by the end user, or produced and distributed by a diverse range of local organizations and enterprises. On the other hand, an increasing number of cookstove designs and activities are leveraging economies of scale provided by mass production *(stoves can also be mass produced in-country).*Production origin contributes greatly to the design, implementation and outcomes of a cookstove activity or business.

Simple vs. advanced cookstoves

A final way to view the clean cookstoves market is the distinction between simple and advanced technology cookstoves. Simple cookstoves represent low or incremental technological innovations corresponding to stove design, production, and usability. Such cookstoves are largely categorized as only reducing the amount of fuelwood or charcoal consumed during cooking. Advanced stoves display features of technological innovation as a result of dedicated research and development; in addition to reducing fuel requirements, such stoves also reduce the amount of harmful pollutant arising from incomplete combustion. Advanced stoves are further distinguished by having features such as integrated fans, or pyrolytic chambers to improve stove performance. In certain cases these stoves can require custom feedstock for use; requiring organizations to integrate vertically along the value chain, and undertake activities encompassing more than just stove producer or end-user segments.

Organizations involved in the clean cookstoves market

Current activities in the clean cookstoves market are largely shaped by objectives in support of achieving the Millennium Development Goals (MDGs). Alarming statistics regarding the health impacts of indoor air pollution caused by the traditional use of biomass for cooking have supplemented prior knowledge of hardship and gender inequity issues surrounding cooking in low income communities. For these reasons, development agencies and civil society organizations have remained consistently involved in the household energy market for over 30 years.

The unexpected success of the mobile phone industry in reaching consumers at the base of the pyramid (BoP) has inspired project developers, entrepreneurs and development cooperation policy makers to now attempt to value the financial potential of adjacent BoP markets, including the cookstove markets. Carbon finance has supplied entrepreneurs entering the clean cookstove market with additional incentives in doing business at the BoP, and many now consider carbon credits an important stream of revenue.

More recent participants within the clean cookstoves market are actors that can be considered part of the international climate mitigation community, or the inclusive business sector. Greater knowledge of both the warming influences of black carbon and deforestation rates that may be attributed to unsustainable biomass use for household energy, has provided grounds for the climate community to acknowledge clean cookstoves as a potentially tractable source of carbon abatement. Although still nascent, carbon finance project developers and market support organizations have steadily increased activities targeting clean cooking activities.

The recent inclusion of the international climate mitigation community and (international) business community has led to a diverse marketplace, with common but differentiated objectives for the actors involved. In addition, developing country governments are increasingly expected to initiate domestic cookstove programs, for example through inclusion of household energy targets within Poverty Reduction Strategy Papers, or the development of national Biomass Energy Strategies. The activities of non-market actors may introduce several forms of market distortion, ranging from donors subsidizing multi-national companies (MNCs) to enter the market, to local government programs financing artisan production of improved cookstoves. It is important to understand that while the overarching objectives of actors may be similar, diversity in implementation approaches can undermine progress towards achieving universal access to clean cooking facilities.

Shaping forces in the clean cookstove market

Employment and participatory approaches

It is commonly acknowledged that the encouragement of high employment and participatory approaches to project design are critical factors for the success of clean cookstove activities (GIZ, 2011), and contributes positively to sustainable development. The professionalization of existing artisan groups, the collection of user input in stove design and dissemination, and the creation of income generating activities help to provide a sense of ownership, mitigating risks of project failure or abandonment.

While these notions surrounding participatory approaches are widely implemented across a range of project activities and business endeavors, questions regarding the necessity of job creation within the direct stove production value chain have been prompted, particularly by recent private sector approaches. Should the development of high numbers of low skilled jobs (i.e. in stove liner production or stove assembly) continue to be considered as critical for the success of household energy interventions? For example, advantages in production quality that arise from a high-volume approach to stove manufacturing may decrease operational challenges for entrepreneurs, and ease barriers related to the use of local product standards. The potential for local job creation in such an approach is decreased, however is it not feasible that other mechanisms for creating local value could be implemented within a stove program (or business), to further the adoption and sustained use of an introduced stove? This is a relatively recent dialogue initiated by recent advances in stove technology and manufacturing, but one which has specific relevance to the nature of cookstove interventions.

Quality control, standards, labeling and branding

Quality control is considered hugely important for stove dissemination programs. Market spoilage is an ever present risk in low income markets, as consumers are highly sensitive towards product functionality and consumptive investments energy (GVEP, 2009). Stoves should be durable and long-lasting; however after-sales service or replacement warranties can also be put in place.

There are no real ambiguities regarding the importance of quality control, however it has important implications for the design of an activity and the actors involved. The actor that has most influence on the success of these schemes is the local government. The degree of institutional capacity, governance and rent-seeking activities are factors that strongly determine both the quality of the designed scheme – in terms of the selected criteria and thresholds – and whether private party actors will adhere to the regulation.

Product development and acceptability

Perhaps the clearest lesson from the history of cookstove experiences is the need for adequate product development and acceptability testing. Anecdotes of stoves unfit for local tastes and preferences are common in rural energy literature (GIZ, 2011), and now influence the pilot stage of most stove activities. Additionally, improved stoves are increasingly recommended to be marketed as aspirational products (GIZ, 2011). In such a 'pure' market environment, end users are regarded as consumers making a conscious choice for stove use, rather than assuming the role of beneficiaries of a project activity. The extent to which stoves must be locally acceptable is uncontested, but there seems to be a mismatch in what can be considered acceptable. Must improved stoves be incremental in design and performance to account for local tastes, or can the foreign designs, and production methods, of advanced stoves also be considered aspirational products? Can the desire for an attractive, desirable stove overcome barriers of local tastes and cultural preferences? Such questions are increasingly being posed within the clean cooking community, as many businesses trend away from 'incremental' stove approaches, and introduce newly designed products to the marketplace.

End user costs

A product which is affordable for the target consumer is paramount to commercial activities in low income markets. What is considered affordable, and how people can pay for stoves remains within the realm of market research and business planning for stove enterprises. Must stoves be below $10 for the BoP segment, or can $100 stoves also be marketed successfully?

Tensions in lessons learned between simple and advanced cookstove approaches

Within this brief review of shaping forces for cookstove activities, tensions between the established knowledge on cookstove approaches using incremental technologies, and recent advanced cookstove activities emerge. The illustrative comparative analysis below, of incremental improved cookstoves and advanced cookstoves, highlights some of these tensions. Note that this table is meant more to illustrate aspects for discussion rather than be regarded as a definitive comparison between these two classes of stoves.

Table 1. *Simplified comparative analysis of incremental and advanced cookstove designs*

Segment	Incremental improved cookstoves	Advanced cookstoves
Example stoves	Rocket, JIKO	Save80, CleanCook (Project Gaia), LuciaStove, Gasifier stoves
Advantages	• High cultural acceptability • High local employment creation • Decentralized operations • Low capital investment required • Low end user costs • Leverage local and existing value chains • Utilize locally available input materials	• High carbon reduction • High health emissions reductions • Aspirational products – improved cooking experience • High potential for business model innovation • Management experience and capacity • Economies of scale and quality control in manufacturing
Disadvantages	• Low technology, not completely clean cooking experience • Lower carbon benefits • Few health emissions benefits • Challenges in quality control • Decreased security of supply (stove construction and fuels) • Management capacity and operational sustainability a challenge • Fragmented supply and distribution chains	• Higher end user costs • Decreased opportunities for local employment creation • Decreased cultural acceptability of universal designs • Decreased post-sales maintenance services available • High capital investment in R&D and production facilities

Case studies from Rwanda

In the context of the preceding discussion, two cookstove initiatives currently underway in Rwanda illustrate the potential of the private sector to introduce technological and business innovations that may detract from established thinking within the clean cookstove market. Each of these initiatives takes advantage of the technology research and development capabilities of the West, mature business management experience, and large-scale, high quality manufacturing capacities.

Furthermore, each activity has been initiated independent of public sector support, despite a national government cookstove program also underway in the country. The Ministry of Infrastructure of Rwanda (MININFRA) has recently begun an improved cookstoves program for both urban and rural areas, implemented by UK-based NGO Practical Action. Both urban and rural programs contain three stages of implementation: stove selection and design, training of trainers, and promotion and marketing. Only incremental stove solutions have been selected in the program, including a modified Kenyan JIKO and variations of the mud Rocket stove. The primary project beneficiaries include informal artisans and local cooperatives; however the Rwanda Bureau of Standards is also being targeted. Other relevant stakeholders, such as rural finance institutions, carbon project developers, and established entrepreneurs such as those profiled below, have not been included in the scope of the program.

Case 1: atmosfair-ENEDOM Save80 Cookstove Project

The atmosfair-ENEDOM Save80 stove project is a joint venture between the German carbon project developer atmosfair and a biomass energy enterprise based in Kigali, ENEDOM. The project is under development as a CDM Programme of Activities (PoA); atmosfair has assumed the leading role as the Coordinating and Managing Entity (CME) of the PoA, and ENEDOM currently leads on the ground implementation as an Implementing Entity (IE). All future CDM Programme Activities (CPAs) attached to the PoA will be contained within Rwanda, however stove designs apart from the Save80 may eventually be included.

Product and vision

The project activity is built around the German designed and manufactured (but locally assembled) Save80 stove. The Save80 stove, contrary to the logic of most advanced stoves designed for rural energy, continues the practice of relying on fuelwood for household cooking needs. Due to the efficiency of the stove design and the accompanying WonderBox for heat retention, fuelwood requirements for cooking are reduced by up to 80% as compared to traditional fires. According to the Managing Director of ENEDOM, Jean Marie Vianney Kayonga, a typical 5-person household in Rwanda uses the equivalent of up to three 40kg sacks of charcoal for cooking needs per month, equating to roughly 1080kg of fuelwood consumed per month.[18] To provide the same level of cooking energy services, through heat generation using the Save80, and heat retention in the WonderBox, a family is only required to use the equivalent of 216kg of fuelwood per month (Personal communication, 2011).

[18] Where 9kg of fuelwood is approximately required to produce 1kg charcoal.

There are a number of unique advantages and innovations delivered to the Rwandan clean cooking market through the Save80 project, however in this paper we will focus on two. First, the project is the first cookstove activity to take advantage of programmatic carbon finance in the country, and second, is the only cookstove activity promoting a 'reverse' energy transition to fuelwood from charcoal for urban households.

Use of programmatic carbon finance

The Save80 can only be purchased in Germany. The manufacturer is said to closely protect technical details of the stove, and limits its use to promising project activities; however as more projects take place, discussions of local manufacturing are underway. The retail price of each stove is approximately €110, however atmosfair plans to sell the stove to ENEDOM at a price of approximately €40. atmosfair carries a balance of €70/stove as risk which it aims to recoup through the sale of Gold Standard CERs from the CPA (and presumably, the eventual PoA). The expected carbon finance revenue stream, currently sized to be provided by 40,000 CERs/year, will accrue directly to atmosfair. However, an internal agreement between atmosfair and ENEDOM allows ENEDOM to profitably sell the stove far below the stated retail cost to end users.

Technological innovation for paradigm shifts in fuelwood consumption

Given that a primary environmental motivation for the use of improved, clean cookstoves is to reduce unsustainable rates of fuelwood consumption, the Save80 seems an unlikely solution. However, its development and implementation allows for the challenging of conventional wisdom on fuelwood and stoves in developing countries. The promotion of fuelwood stoves allows for the bypassing of biomass supply and demand complexities introduced by the charcoal value chain. In Rwanda, the use of inefficient carbonization methods is widespread, contributing to increased deforestation and greater losses in fuelwood. Profits captured through the sale of charcoal are often held disproportionately by charcoal investors, leaving tree growers and laborers employed during carbonization relatively marginalized. This scarcity in fuelwood and fragmentation of the charcoal chain has led to steadily increasing charcoal prices in Rwanda over the past 20 years. As the Save80 project requires the purchase, transport, drying, and retailing of improved fuelwood (an activity to be undertaken by ENDOM) to end users, a large inefficiency in the cooking fuels market can be diminished.

A second intriguing feature of the Save80 approach concerns the sustainable management of fuelwood plantations. Fuelwood for consumption or carbonization is currently sourced from private, small-scale forest owners, however the Government of Rwanda is considering the use of large, public plantations for sustainable fuelwood harvesting. The dissemination of efficient, wood burning stoves such as the Save80 may allow for greater certainty in fuelwood demand, as well as absolute decreases in expected demand. This combined management of fuelwood supply and a known demand for consumption may reveal opportunities to link the benefits of REDD+ finance directly to issues of energy poverty, although the avoidance of issues related to double counting would require further research.

Largest challenges in developing the project

The largest challenge in developing the project, cited by ENEDOM, is the ability to pay of end users. Even at a subsidized price, far below retail cost, selling the stove to household of low and irregular income will comprise a primary challenge. ENEDOM has approached a number of microfinance institutions as well as Savings and Credit Cooperatives (SACCOs) in Rwanda, however has noted that many are wary of developing energy access loan products, particularly for a purely consumptive investment, such as stoves.

In addition to end user finance, project development of a PoA was cited as a challenge for the atmosfair-ENEDOM collaboration. Programmatic CDM is the most relevant and perhaps largest opportunity in international finance for rural energy entrepreneurs; however developers are hesitant to exploit PoAs due to their complexity, high risk, and comparatively high transaction costs in validation and verification. Developers point to methodological barriers which preclude streamlined implementation of PoAs, however are generally not incentivized to undertake the expensive and long-term process of methodology development for BoP applications.

Case 2: INYENYERI

INYENYERI is a social enterprise in the product pilot stages of business development, based on a stove and fuel energy access solution, the LuciaStove. INYENYERI was founded by an experienced American entrepreneur, Eric Reynolds, who has previously raised millions in venture capital and overseen the operations of three sustainable businesses in the US. Reynolds has partnered fully with the Red Cross of Rwanda and the Red Cross of the Democratic Republic of the Congo (DRC) to develop and implement the business, with activities beginning in mid-2011 in Western Rwanda.

Product and vision

The LuciaStove is a stove and fuel pellet solution for the clean cookstoves market. Originally designed by an Italian engineer, the stove contains a fully pyrolytic chamber which produces a blue cooking flame. The stove parts are currently manufactured in Italy only, however once shipped, can be assembled locally. Biomass fuel pellets, also produced locally, are the only fuel which can be used in the stove and approximately 25% (by weight) of which are converted to biochar after cooking.

There are two novel features of INYENYERI's approach to the cookstove market that are largely enabled by the technological R&D embodied in the LuciaStove and pellets. First, the stove and fuel combination allows for an elaborate and sophisticated business model that builds on current market opportunities and historical experiences. Second, INYENYERI delivers a refreshing and aspirational approach to cookstoves; not only for stove users, but also for the broader clean cookstoves community.

Elaborating an inclusive business model

The INYENYERI business model is highly tailored to the business environment of low income communities in urban and rural Rwanda. Developed from a central, socially-oriented mission, early stages of the business build from a single value proposition of providing stove users an improved cooking experience and an opportunity to generate household income *through stove use*. This is a highly innovative value proposition for the stoves market.

In collaboration with Red Cross organizations, INYENYERI stoves will be distributed to Rwandan households below cost through a system of local 'hubs', each located less than 5km of the end user household. Initially, local hub activities are expected to include: the collection of dry biomass and biochar, pelletization, the distribution of fuel pellets, end user training, and the establishment of end user 'biochar accounts'.[19] Pellets in rural areas will be distributed freely in return for unprocessed dry biomass, to encourage a transition from freely available fuelwood and biomass residues. This mechanism is also envisioned as payment for households which act as the main suppliers of dry biomass for pelletization. On use of the pellets and delivery of biochar, households can contribute to dedicated 'biochar accounts' that may be converted into cash for productive products available at the hub locations (Personal communication, Reynolds, 2011).

The 'free' rural business model is expected to be viably cross-subsidized by pellet sales to urban households, as these households are largely unable to source dry biomass for pelletization. Additionally, urban households are already acclimated to ongoing charcoal sales. The price of INYENYERI pellets is modeled to be currently cost competitive (if not advantageous) with charcoal per BTU, and is expected to become more attractive as urban charcoal prices increase.

[19] In later stages of the business, a second tier of larger 'super hubs', are envisioned as large scale pellet production and power generation facilities

Delivering aspirational solution

The INYENYERI stove and pellets solution provides an aspirational solution for stove users as well as the broader clean cookstoves community. For end users, INYENYERI stoves represent modernity and status; a fast, blue cooking flame may be highly desirable as may be ownership of a shiny metallic stove. Further, INYNENYERI founder Eric Reynolds maintains that improved cookstoves which prolong reliance on fuelwood and charcoal can only provide half-hearted solutions to the cooking challenge; as both issues of indoor air pollution and deforestation are only partially addressed. Rather than mitigate the pressing impacts surrounding the traditional use of biomass, INYENYERI aims to preclude them completely.

Largest challenges in developing the project

According to Reynolds, the largest challenges in developing the project include the collection of market information, and the assembling of a qualified team. To address the information challenge, Reynolds is undertaking his own elaborate market surveys through partnership with the Red Cross organizations of Rwanda and DRC. Knowing the difficulty of this activity and the utility of the information collected, Reynolds aims to make all collected data open source for use by academics and rural energy practitioners.

In assembling a team, Reynolds cites a lack of technical and managerial capacity from local candidates. Although the ultimate vision of INYENYERI is to be a Rwandan energy company fully owned and operated by a Rwandan management team, Reynolds foresees international talent will be necessary to grow the business during pilot stages.

Discussion and recommendations

The above case studies show two current activities that are under development in Rwanda, and highlight the strengths of the private sector in the clean cookstoves market. Despite the strengths and unique innovations delivered by these initiatives, there is still a clear need for the expertise generated by years of development cooperation in cookstove interventions. Below we discuss two positions for development cooperation actors, based on historical experience and current needs of the private sector: first as purveyors of market information, and second as enablers of institutional strengthening.

Development cooperation actors as purveyors of market information

Market intelligence database for business planning: The experience of development cooperation actors in conducting household energy surveys and baseline studies has provided a wealth of best practices and methodologies applicable for rural energy businesses. However, extensive market studies are often expensive and untenable for startup entrepreneurs. Development cooperation can leverage project design and implementation experience, local networks, and best practices to fill a large and instrumental gap in business development; by compiling previous experiences, undertaking extensive household energy surveys, and storing this data in an open source database for impartial access by entrepreneurs, academics, and practitioners.

Product research and development: Corresponding to the above, decades of cookstove interventions have yielded a number of lessons learned from a product design perspective. Data of regional variations in cooking practices applicable to cookstove design should be readily accessible to stove innovators. Further, accounts of product failures should be readily available such that similar mistakes are not repeated.

Educating investors: Development cooperation actors should leverage influence and credibility to educate investors about viable cookstove enterprises in low income markets. Without appropriate education, the potential profitability which may arise from the sales of $5 appliances to the world's most remote communities is an unlikely candidate for attracting commercial SME finance, let alone significant venture capital. If development cooperation is serious about moving towards market-based solutions for poverty, development agencies should not play the role of investor; rather, agencies should increasingly engage the commercial financial sector and professional investors in development related enterprises.

Educating end users: Development cooperation is further suited to utilize budgets for the widespread education of stove users. Similar to HIV/AIDs awareness campaigns, national campaigns educating stove users about the hazards of indoor air pollution would be instrumental in accelerating the uptake of improved stoves. Such a campaign would be an effective marketing tool that should be designed such that it may be leveraged by all entrepreneurs in a marketplace. Low income communities may be highly skeptical of information coming from 'outsiders' regarding daily, household tasks; an information campaign led by the local government could further provide credibility to the products and services offered by clean cooking entrepreneurs.

Networking and knowledge exchange for entrepreneurs: Some of the largest challenges for inclusive business entrepreneurs is market information; first, that there is a low amount of information available, and secondly, that acquiring relevant information is costly and time consuming. However, market information does not only have to refer to data points relevant to business planning – it can also include relevant organizational data, including competitors, investors, partners, distributors, academic institutes, CSOs, and business development service (BDS) providers. Given the ubiquitous and global position of development cooperation actors, networking and knowledge exchange activities is a strength that may be easily leveraged and hugely beneficial to rural energy entrepreneurs. Annual cookstove conferences, both international and local, may allow for an accelerated diffusion of information regarding technologies, business models, and interested investors.

Development cooperation as enablers of institutional strengthening

UNFCCC and carbon finance: The opportunity presented to the clean cookstoves market by the PoA is important, yet elusive. Challenges in transaction costs and methodology development are barriers which individual project developers are not incentivized to confront alone. As in the early stages of small-scale CDM activities, and the carbon market as a whole, development cooperation actors can effectively confront institutional barriers preventing entrepreneurs from capturing value from the global carbon market.

Technical and management capacity building at local universities: As pointed out directly in the INYENYERI case study above, local human resources remains a pressing challenge for rural energy enterprises. The renewable energy (RE) education and training expertise of the West can be leveraged in developing countries, to design not only technical curriculums, but also management curriculums highlighting the opportunities and strategies of business at the BoP. The development of technical RE curricula should be accompanied by exposure to principles of entrepreneurship, management and accounting.

Product standards and quality: As is currently underway in Rwanda, interaction with local standards bureaus may have significant impact on the success of technology introduction and diffusion. Businesses can leverage the standard in branding and penalize partners producing below a benchmark level of quality. The development of product standards, however, is also an activity too costly for one private sector actor to undertake. Development agencies may work with technical universities, ministries, and private sector associations to work towards standards development.

Conclusion

The tone of this discussion paper may sound such that the authors are describing development cooperation and private sector initiatives uniquely, as in each having distinct approaches characterized by technologies and implementation strategies applied. However, such a strict dichotomy does not exist, and the implementation designs of cookstove projects and businesses often overlap. The aspects of clean cookstove activity that this discussion paper aims to shed light on are the strengths that development and private sector actors can bring to the market, and the implications these comparative strengths have for the positioning of development cooperation.

In discussing two cases from Rwanda, we illustrate that given the recent advances in both technical and business model innovation developed from private cookstove initiatives, development cooperation partners should no longer assume an implementation role in cookstove market activities. Rather, agencies should use decades of experience, expertise, and networks to support business development activities of the international private sector, either through the provision of market information, or the strengthening of institutions relevant to the clean cookstove market. This paper suggests that such support should diverge from preferential treatment – that is, the direct financing of a particular private party, end-user region or technology – and should aim to create a 'level playing field', both in terms of technology and parties involved. Although the benefits for donors to encourage prolonged work with reliable local partners are evident, in the long run this may encourage inefficiencies, retard technological innovations and reduce the desire and incentive of local partners to perform. This demands not only a different approach from development cooperation partners and donors, but requires increasing their own capacity to take new and alternative actions while ensuring that the acquired expertise is available in a consistent expertise base.

Finally, when considering the cookstove market, both case studies from Rwanda and experiences in other similar countries show that the demand for cooking fuels is ever present and rising. High economic growth and the rapid expansion of the share of population in urban areas are increasing the pressures on the supply chains for traditional cooking fuels, such as fuelwood and charcoal. It can be argued that it is these new characteristics, related to economic growth and urban expansion, that are defining a new reality; that traditional, charity based projects are not flexible enough to take active part in these markets. Rather than directly implementing stove projects, the longevity and consistency of organizational relationships held by development partners can facilitate private party actors and local governments; with the confidence and tools to create not only a self-standing market, but one which fosters resilient and scalable innovations.

References

Bilateral Donor's Statement in Support of Private Sector Partnerships for Development, 2010. Available at: http://www.enterprise-development.org

Gaul, M. 2009. Subsidy schemes for the dissemination of improved stoves. Available at: http://www.gtz.de

GIZ, 2011. Unpublished. Lessons learned from improved cooking stove projects.

Global Village Energy Partnership (GVEP), 2009. Cookstoves and Markets: Experiences, Successes, and Opportunities. Available at: http://www.gvepinternational.org

Kees, M. and Feldman, L. 2011. The role of donor organizations in promoting energy efficient cookstoves. Energy Policy

Personal communication, Eric Reynolds. Two separate interviews in April and June 2011.

Personal communication, Jean Marie Vianney Kayonga. Three separate interviews in Feb, April, and June 2011.

Shell foundation. 2005. 'Enterprise solutions to poverty'. Available at: http://www.shellfoundation.org

Simonis, P. 2007. 'Successful Scaling-up of Improved Cooking Technologies in Eastern Africa'. Presentation. Available at: http://www.giz.de.

Climate mitigation and energy for all: is there a role for international collaboration?

Heleen de Coninck

Bonn, June 10th, 2011. At the end of the first week of the two-week UNFCCC Climate Change conference, the venue of the negotiations on an international treaty to address climate change, the chair of the Adhoc Working Group on Long-term Cooperative Action (AWG-LCA) confirms the agenda. With a straight face, he thanks the hundreds of delegates from all over the world, who have just spent a full week on an agenda (an agenda!), for their constructive work on agreeing on what needs to be discussed during this meeting.

Vienna, June 21st, 2011. At the Vienna Energy Forum, Arnold Schwarzenegger is in his element. Back in his home country, leaving behind his family troubles, he inspires the room by calling for moves towards a green economy. The green economy, he states, is like a four-legged stool. It is not only supported by a climate change agenda – a stool with one leg is not stable. It needs to be supported by the generation of green jobs, by making clear the health benefits of a green economy, and by arguments for energy security of supply. Applause! The meetings goes on to discuss global targets for universal energy access, for energy efficiency and for renewable energy.

These two examples of more or less formalised forms of generating international momentum for solving the energy and climate problem could not be more different. While the UNFCCC process has, for years, been in such a sorry state of stand-still that delegates congratulate each other when they have agreed on the most minor issues, the reinvigorated sustainable energy process, initiated by UN Energy under the chairmanship of the United Nations Industrial Development Organisation, glows with positive energy, new ideas and belief in cooperation. But what can we expect?

The aim of this essay is to investigate what changes affect international collaboration on energy and climate, and what the past can teach us about the future of simultaneously addressing the two. What are our new insights, are we using them and what can we expect? By critically looking at the past and the current situation, one can not only arrive at valuable lessons, we can also see that conditions change all the time leading to new opportunities – it can save us from the trap of cynicism about international collaboration that looms around the corner.

Climate and energy negotiations in the past

International negotiations on climate change are very formalised. In 1992, the United Nations Framework Convention on Climate Change was agreed at the World Summit on Sustainable Development in Rio de Janeiro, along with two other conventions (biodiversity and desertification). The UNFCCC, which every country has ratified, agreed on a more concrete

Kyoto Protocol, with emission reduction targets for developed countries, a global carbon market and voluntary participation for developing countries. The Kyoto Protocol reflected the contemporary international consensus at the time about the dominant role of constructed markets that price externalities and the need for unconstrained economic development of the developing world. The information provision of the UNFCCC is also heavily formalised: the Intergovernmental Panel on Climate Change, an international institution itself, is the official supplier of scientifically sound information on climate change.

International collaboration on energy is organised in a completely different way: countries with common interests seek collaboration. This resulted in a range of intergovernmental organisations reflecting different economic and political interests in the current energy system, with only the weakest forms of collaboration reaching full membership. OPEC represents the interests of oil exporters, the IEA those of high energy consumers (and often energy importers), the IEF attempts to reconcile the interests between importers and exporters. Any attempt to form a more global coalition to represent the global public good of a stable, clean, affordable and accessible energy system has so far failed. Also, energy access was not included in the Millennium Development Goals, although it is now sometimes called the 'unwritten 9th MDG'.

For energy, various international institutions (a.o. FAO, UNEP, UNIDO, UNDP, UNFCCC and the World Bank. Since 2007, UNIDO is chairing UN Energy) are attempting to align their activities in a UN-platform called UN Energy. During its lifetime so far, UN Energy has not led to significant global benefits. The contradicting interests and priorities of the UN agencies involved, and the resulting hassle over task distribution, are not helping its effectiveness. The Vienna Energy Forum, organised by UNIDO which is currently chairing UN Energy, may change that by putting energy access for poor people high on the agenda.

It is already a near-impossible mission to negotiate an agreement on climate change with huge economic interests between different countries partly diametrically opposed (Coninck, 2009). The formal nature of the UNFCCC is often seen as a great advantage over the messy reality of global energy governance. But lately it is hard to see the institutional infrastructure for climate change as an advantage anymore. The UNFCCC and its Kyoto Protocol, including their provisions of full membership and rigid division of the world in developed and developing countries are a clear case of an institutional lock-in. In a rapidly changing world, the slow and entrenched UNFCCC negotiations are unable to respond to new developments.

New global developments relevant to energy and climate change

How has the world changed compared to when the UNFCCC was first agreed and energy collaboration started? First, the development paradigm that underpinned the UNFCCC and its Kyoto Protocol is slowly toppling. The distribution of the global economic momentum has changed significantly. While the developed countries still have higher average incomes, the world's growth is increasingly taking place in the developing world. Even in the field of technological development and innovation, where the position of the industrialised countries seemed untouchable, some emerging economies are catching up fast.

In addition, increases in domestic income inequalities have confused the traditional distribution of the world into 'poor countries' and 'rich countries'. Most of the world's poor now live in middle-income countries (Sumner, 2010). India's population consists of 500 million people who can be counted as the 'Base of the Pyramid', but there also of some 50 million people, almost the size of France's population, who have incomes on par with mean incomes in the industrialised world (Chakravarty et al., 2009). This schizophrenic situation of many developing countries complicates reaching agreement on an treaty that is quite intrusive on economic development considerably.

Also energy markets globally have undergone tremendous changes. Oil prices have been varying by a factor four over the past ten years, leading to innovation and the exploitation of unconventional oil. Something similar is now taking place with shale gas. Most energy systems have not changed much in response and are just paying the price. Impacts of high oil prices have been high for the poor whose only means for lighting is with inefficient kerosene lamps, and whose electricity access is often provided by diesel generators. In addition to these direct effects, the surge in energy prices could lead to more resource-cursed countries (Sachs and Warner, 2001) and petro-dictatorship (Friedman, 2008).

Climate change mitigation and energy are often linked. Intuitively, people living in industrialised countries are fearful of 'one billion Chinese owning a car' and 'a coal-fired power plant every two weeks'. And indeed, although the one billion cars are still a long way off, the Chinese economic boom has led to a tremendous rise in emissions but also to the lifting of hundreds of millions of people out of poverty. The fear for the environmental pressure that the billions of poor people in the world would incur if they would all develop to the level in the developed world has led to environmental and sustainable development policies in developing countries.

One of the consequences is that some countries, including the Netherlands, have stipulated that their energy access targets can only be met through renewable energy. The arguments for such interference in country matters include that for off-grid solutions, renewable energy can be the best solution, but primarily it is defended from the viewpoint of sustainable development and reduction of greenhouse gas emissions globally. But what would be the impact of providing electricity and clean cooking fuels based on fossil fuels to some 2 billion people who currently lack it?

Suppose these people would use some 14 kg of LPG for cooking per household (Reddy, 2002) of 4,5 people, which has an emission factor of 3.1 $kgCO_2/kg$ propane, and 100 kWh of electricity per person from a coal-fired power plant that emits 0,937 $kgCO_2/kWh$. A simple calculation results in total CO_2 emissions as a consequence of full energy access with fossil fuels of around 423 $MtCO_2$ - a mere 1,5% of global GHG emissions in

2010 for helping almost 30% of the global population develop, resolving huge health problems and alleviating poverty. There is much to say for providing modern energy access to the global poor, but not for making technology choices for them. If developed countries want to do climate change mitigation policy in low- and middle-income countries, they should not aim their policies at the energy poor. Their policies should aim at making industrialisation policies more sustainable, as that is where emissions are fast-rising and that is where there is ability to pay for environmental interventions.

One global development could make reaching energy access and climate targets easier: the rising degree of urbanisation. The UN estimates that by 2030, only 40% of the global population lives in rural areas (UN, 2010). Urban dwellers in developed countries are more energy-efficient than rural dwellers, both in their heating and cooling demand and in their transport emissions. It is easier and cheaper to provide urban dwellers access to energy than rural dwellers. Public transport infrastructure is also more viable and more easily organised in urban areas, if spatial planning is properly done. Approaching things on a city level can facilitate public involvement, as the targets are not vague and global but can be related to in the local context. But there are also challenges. There is often a lack of data on the level of cities, and new actors – mayors, city councils, etc – need to be made aware and engaged. And cities and provinces are not parties to in the UNFCCC negotiations.

Which international institutions can facilitate these changes?

The evaluation of the first 20 years of the international collaboration on climate change gives a mixed story. On the one hand, the UNFCCC and the Kyoto Protocol have raised awareness, led to lots of initiatives and projects, to a carbon market in the EU and a carbon price in developing countries through the CDM and even to some emission reductions.

On the other hand, however, the UNFCCC has not reached its self-stated aim of ‘preventing dangerous human interference with the climate system’. The two largest emitters do not have emission reduction targets under the UNFCCC regime - China because it is exploiting its developing country status and did not get targets under Kyoto, and the United States by withdrawing from the Kyoto Protocol all together. Several developed countries that have ratified Kyoto are not complying, in particular Canada and Japan, thus undermining the balance in the Kyoto Protocol. There are few politicians who can resist the lead of the United States to put economic interests first, especially during an economic crisis, and hence it is not surprising that there is a deep crisis of trust between the countries emerged. And at the height of this crisis of trust, the countries have to negotiate on follow-up agreements on emission reductions.

The current slow pace of the climate negotiations in the UNFCCC and the absence of any hint of a way out is leading to the conclusion that a post-Kyoto treaty in the UN may not be the right place. The UNFCCC should focus on its core tasks of a neutral arbiter:

- facilitate and review inventories of greenhouse gas emissions and emission reductions;
- maintaining the CDM institutional infrastructure to help country emission reduction pledges and potentially domestic emissions trading schemes, such as the ETS;
- providing independent information services and facilitating information exchange and learning between parties to the UNFCCC;
- helping areas along that show promise in the negotiations and that require global involvement, such as REDD and adaptation**.**

While the UNFCCC and the Kyoto Protocol have delivered agreement and output, the results of the mitigation negotiations since 2007 are almost absent. They certainly do not justify the enormous investments. The Copenhagen and Cancun pledges result could have been achieved without the climate conferences under the continuous hope of legally binding targets. Rather, while the Kyoto Protocol still promoted them, the impasse in the international climate negotiations is stifling national and local initiatives to really address climate change.

The UNFCCC lessons of globally agreed targets for greenhouse gas emissions also contain lessons for emerging targets for energy access, renewable energy and energy intensity. A major policy insight is that a target alone is not enough and has limited meaning unless there is real support for reaching it. This support should include international finance and business as well as politicians and voters. Arnold Schwarzenegger's four-legged stool should be made visible from the very beginning of negotiations, and local stakeholders should, in an organised manner, be invited to the table on topics where they can play a constructive role.

We have seen that an overly formalised, top-down process like the UNFCCC process is unlikely to deliver, even when there is apparent support for agreed targets. An energy-aimed process that combines local and industry interests with international guidance and inspiration will not be easy, but it will bring a new dynamic. Betting on the crippled horse of targets under the UNFCCC, whether for an effective post-2012 climate regime or for an agreement on energy, is not going to win the battle against the energy and climate problem.

References

Chakravarty, S. A. Chikkatur, H.C. de Coninck, S. Pacala, R. Socolow, M. Tavoni (2009): Sharing global CO_2 emission reductions among one billion high emitters. Proceedings of the National Academy of Sciences doi: 10.1073/pnas.0905232106.

Coninck, Heleen, de, 2009. Technology rules! Can technology-oriented agreements help address climate change? PhD thesis VU Amsterdam, Netherlands.

Friedman, Thomas L., 2008. Hot, Flat, and Crowded. New York: Farrar, Straus and Giroux, New York, NY.

Reddy, A. K. N., 2002. Energy Technologies and Policies for Rural Development, in Energy for Sustainable Development: A Policy Agenda, T. B. Johansson, J. Goldemberg, eds. Published by UNDP, The International Institute for Industrial Environmental Economics (IIIEE), and The International Energy Initiative (IEI).

Sachs, J., and A. Warner, 2001. The curse of natural resources. European Economic Review 45 (2001) 827-838.
Sumner, Andy, 2010. Global poverty and the new bottom billion: what if three-quarters of the world's poor live in middle-income countries? IDS working paper, September 2010: http://www.ids.ac.uk/index.cfm?objectid=D840B908-E38D-82BD-A66A89123C11311F.
UN, 2010: http://esa.un.org/unup/p2k0data.asp

Energy and development policy - How to obtain universal access in 2040?

Jan Cloin and Tineke Roholl

Introduction

According to IEA/UNDP (2010), policy makers in the developing world face an enormous task: to provide 2.5 billion people with modern cooking energy and 1.4 billion people with access to electricity. IEA claims that even with strong policies, these figures will hardly change in the next decade as the population increases. This paper aims to explore the practical aspects of providing universal access to energy. To help us understand the challenge better, we introduce two imaginary characters: Ms Thambe in Zambia, who we want to cook clean, and Mr. Zindi in Zimbabwe, who we want to have affordable electricity. Ms. Thambe and Mr. Zindi stand example for the billions of people that are considered 'Energy Poor'.

Energy Poverty – introducing the main elements

The main problem of the energy poor is that they cannot dispose of energy for basic needs to survive and to develop. These basic needs can be divided into three broad categories: energy for cooking and heating, energy for lighting and communication and energy for productive uses.

Most poor women in developing countries rely on biomass for their **cooking and heating** needs as alternatives are too expensive or unavailable. Cooking on three stones is not optimal, but it always works and cooking is required for survival. Gathering wood is a heavy burden, it costs time and its utilisation normally leads to a smoky cooking environment, but using other fuels for cooking is often too costly.

Most poor people choose to spend a significant share of their income on energy services for **lighting and communication**. For lighting, people buy kerosene, candles or batteries to continue their activities after dusk, mostly at much higher prices and lower service level than in the developed world. In addition, increasingly households value communication through mobile phones, radio, TV, computers and all these appliances require electricity to operate. Especially in rural communities, this electricity comes mainly from stand-alone applications that are typically more expensive than in the developed world.

In order for people to have the liberty to engage in more economic activities, access to **productive forms of energy** creates opportunities to significantly increase the return on their labour time. This includes small companies engaging in welding, carpentry, sowing, food processing and all activities for which direct manual labour as an input only is not sufficient. Especially if these interventions are combined with the unleashing of an enlarging market for their products, impact on incomes can be realised.

Energy in development: riding different waves

The challenges for the Energy Poor to improve their utilisation of energy have been addressed from various angles in the past. From the start of development interventions in the 1950-60s, energy has been regarded as an **infrastructural input** into the mix that requires developing countries to grow. Within a country's infrastructural needs, services such as potable drinking water, access to sanitary facilities, roads and in later years information technology were considered essential conditions without which development, mostly measured by means of growth in GNP, would not be able to take place. Energy in this view equals fuels for transport and electricity for production. This view is still held today and the basis for continuing investments in transmission lines, regional power pools and investment in large scale power plants (increase supply, transmission and distribution of electricity).

The position and relevance of energy in development policy has been boosted by environmental concerns, specifically the use of wood for cooking to avoid deforestation. As a result of that, energy also played a strong role as development input on the micro level, which was in turn further enhanced by the focus on gender aspects during the 1980-90s. Many interventions thus focused on the reduction of the input of wood/charcoal for **cooking energy** as a micro-intervention at household level, by making the supply chain of charcoal more efficient or by planting fast growing trees. This approach has merged some of the agricultural and forestry agendas with energy interventions and is now the basis for forestry (increase supply of firewood) and efficient cook stove (decrease demand of firewood) interventions.

The increasing price and the apparent depletion of fossil fuels further boosted a platform for the application of **renewable energy**, particularly solar energy, wind energy, hydro power and a range of biomass technologies such as liquid biofuels and biomass gasification. This approach was based on the assumption that these technologies could provide energy at lower cost in the long run for developing countries. With current energy prices, many renewable energy systems in remote places have payback times that are within commercially acceptable ranges compared to diesel generators. Typically, development interventions provide subsidised electricity for social infrastructure or provide electricity at market prices to households and enterprises. With advancing LED technology and lower PV module prices, solar lanterns are increasingly looked at for an intermediate solution for charging cell phones and providing light at prices significantly lower than kerosene.

With the establishment of the Kyoto Protocol in 1997 and its flexible mechanisms such as the Clean Development Mechanism (CDM) in the early 2000s, the eyes of the energy community were focused on yet another opportunity for financing the role of energy, namely to contribute to the decrease of **greenhouse gas emissions** to avoid imminent climate change through fuel switching, renewable energy and energy efficiency. Even though it was widely expected that this development could become a significant funding source in the long run, it turned out that the most viable greenhouse gas reduction is investment in industrial processes, large scale energy efficiency and only after that fuel switching and large-scale renewable energy. The combination of CDM and energy for the poor has not taken off.

Even though there has long been strong indications about the harmful influence of **indoor air pollution**, only in the last decade strong statistical evidence has become available that indoor smoke kills an estimated 1.5 million women and children per year (WHO, 2010). There is now increasing attention to address this problem through various improved cook stoves, chimneys and awareness campaigns, partly overlapping with the health and gender development agendas. The task is still enormous: based on the experiences in the past decades it has become apparent that even if we were to parachute 2.5 billion cookstoves across poor parts of Asia and Africa, it would still not lead to a change in cooking behaviour.

Recently, a new emphasis has been put on the importance of **energy provision to enable economic growth**. While research indicates that energy provision should not be considered the only intervention leading to economic growth it becomes clearer that energy should be part of a multi/sectoral approach before impact can be expected (Kooijman, 2008). This insight is even more relevant considering the increasing urbanisation in the world and the realisation that the vast majority of poor people have to find alternatives to subsistence agriculture.

Listing the various ways in which energy has been addressed indicates how much it is a multi-dimensional concept in itself, but also that the problem of 'Energy Poverty' has rode different waves of 'fashionable' ideas through which energy agenda was supported and / or financed.

The evolving aid agenda

Throughout the history of development aid, there has always been a strong element of enlightened **self-interest**. This is based on the premise that who does good will receive good at some point, but also by representing national interests in development interventions. This has been done by using products produced in the donor country during energy-aid projects or by ensuring indirectly national interests are strengthened (tied aid). As of recently, this has led to various forms of public-private partnerships.

In the past two decades, through growing concerns that aid is not working effectively, there has been a strong focus on **showing concrete results** as an indicator of progress. This has also helped to show taxpayers results in terms of number of people with access to a certain level of energy services, with an aim to firm up the support for development expenditure.

Over the past decade, calls to **align** donor interventions with the national policies as well as to **harmonise** aid interventions with other donors have become louder. In some cases this has led to sector-wide approaches, where the donor community together with the recipient country have established a multi-annual plan in the energy sector. In practice, this does not always lead to more ownership, but the amount of 'noise' within the development sector seems to have decreased thanks to improved consultation.

Finally, by combining various elements of the environment and climate change agendas, there has been a call for encouraging '**green growth**' within developing countries. This term is defined by the UN as: 'Environmentally sustainable economic growth for the well-being of all' (UNEP, 2009) and requires for example the consideration of full environmental costs of energy options to be considered. As the environmental costs include forest depletion, fossil fuel depletion, impact on water use, generation of waste and contribution to climate change, the concept of green growth covers most points mentioned above that have affected energy on the development agenda.

Summarising, Figure 1 below indicates the context that shapes energy and development policy, with the aim to provide improve the energy utilisation of the 'energy poor'. But where are Ms. Thambe and Mr. Zindi in this story?

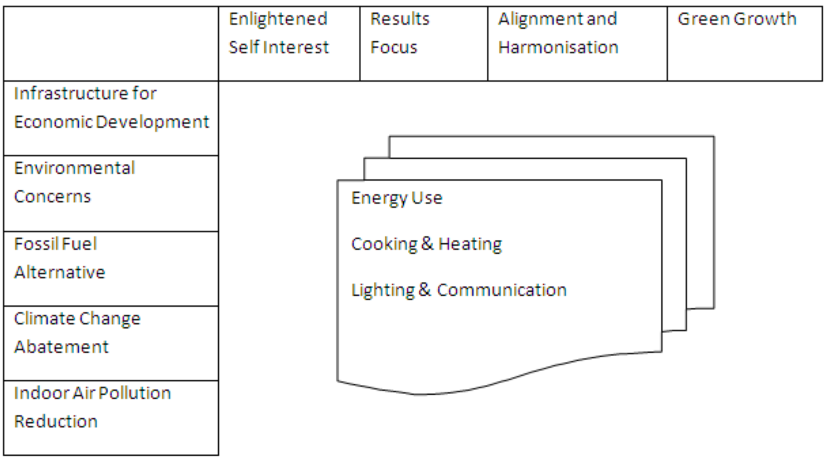


Figure 1: *Sphere of influence around energy aid*

Matching development policy with the real problems of the 'energy poor'

With the wealth of knowledge of 60 years development assistance, it could be expected that a rational solution for the 'energy poor' would be around the corner. This is not the case because a) all insights, experience and knowledge are not available at one point; b) current research is still contributing to new insights, particularly in the socio-economic sphere; and c) the interventions take place in a changing environment of increased globalization, developing technologies and changing consumer needs. Another problem is that energy poverty policy is still approached in a rather technocratic way, with little attention to the real problems, dreams and desires of the target group. Therefore, a renewed focus to improve the lives of Ms. Thambe and Mr. Zindi is required. How can they be assisted?

Energy and poverty in 2040

Looking forward, what is a possible outcome for the energy poor 30 years from today? Can we 'statistically' assume that Ms Thambe will cook cleaner? Can we take the chance Mr. Zindi has been targeted in a micro-credit scheme to buy a solar lantern that also charges his phone?
As energy use is very much linked to income, and economic projections show that the income of more people will rise, it is likely that more people will be able to climb the 'energy ladder' (VU/ECN, 2009) towards more expensive but more efficient and cleaner energy sources. To enable these rising incomes, it is necessary however to invest in all forms of energy generation and energy infrastructure with priority to the sources that have the lowest cost to society. *Therefore, for infrastructural investments, development funds should invest or promote investments in energy options that provide energy against least costs, including environmental cost*. For mass electrification this could mean a coal fired power plant is in principle supported even though there are environmental costs associated with its contribution to climate change, its water use and the depletion of fossil fuels. These cost should be part of the overall cost-benefit analysis. It will have to be looked at on a case-by-case basis but means development funds should not be restricted to renewable energy only. The lower the cost of energy, the higher the chance is that Mr. Zindi's house will be electrified by 2040.

Will the private sector solve the problems of the 'Energy Poor'?

The impression exists that with an (externally determined) need for improved cooking or heating, there is a latent demand for improved cooking products and / or clean fuel. Also, for lighting and communication, a demand for small amounts of electricity in rural areas is assumed. However, the question is whether Ms. Thambe connects her hurting eyes or the increased incidence of lung problems between the women in her village with the smoky environment of her kitchen. Moreover, it remains to be seen whether this 'potential demand' can be served with commercial products that provide a sufficient service level, are cost-effective and have the impact that is required to solve the development problem at stake.

If affordable products would be available and companies would address this need, the potential profits would have to be very high as the commercial risks of operation in a developing country are vast. In parallel with the mobile phone revolution in Africa, once the people understand the advantages of a new product, willingness to pay is high and products almost 'sell themselves' through social marketing. As Mr. Zindi realises that he can charge his cell phone at home and does not have to walk to the nearest charging point, and as Ms. Thambe realises that she can cook the same meal while collecting less fuel wood, their willingness to pay will increase. Similar with the soft drinks market, also very developed in every remote corner in Africa, the business model is based on recurring income. Even the kerosene market for lighting is a recurring income market.

Most (renewable) off-grid energy solutions however are based on single sale business models. *Therefore, development policy needs to investigate further how recurrent income-type models can be applied in test-casing business approaches towards (renewable) energy solutions. The prospect of high profits should not be a deterrent for development policy but rather a sign that a sustainable model might be found.* The role of development interventions and local government would be to 'softly' regulate the private sector (quality control) and inform Ms. Thambe for example on the dangers of indoor air pollution.

The continuing call for alignment and harmonisation will likely lead to larger scale interventions with multiple donors. This means moving away from 'projects' but implementing long term programmes in close collaboration with national governments. As recipient governments typically consider their most important energy problem to be the national (urban) electricity provision, *it is important that donors remind policy makers in developing countries about the daily drama unfolding in the smoky kitchen.* Ms. Thambe's health and productivity, and of her children, are directly affected. Mass marketing might eventually move people to seek different ways of cooking, however experience with other awareness programmes indicates that a long term commitment is required, especially to reach the poorer part of the population.

Conclusion

Energy as a development policy topic has benefitted from various 'fashions' of thinking in environment, climate change and renewable energy, while development policy itself has been subject to changing approaches as well. Even though the currently dominant approach of green growth and the inclusion of environmental costs in energy supply provides a good approach for energy policy in developing countries, the core challenges of the energy poor still concern clean cooking and affordable access to small amounts of electricity. These issues should be approached in the most cost-effective way, to enable reaching as many poor as possible through investment in least-cost technologies and supporting opportunities through the private sector.

Only with careful and long term policies that break loose from the trends can we identify policies with concrete results that will assist Ms. Thambe and Mr. Zindi and avoid having to admit that, by 2040, we had various innovative projects, but we failed in the attempt to make a difference.

References

ECN/VU (2009): Greening the African Energy Ladder - The role of national policies and international aid
IEA/UNDP (2010): Energy Poverty Report
Kooijman (2008): The Power to Produce. The role of energy in poverty reduction through small scale Enterprises in the Indian Himalayas
UNEP (2009): Green Economy Report
WHO (2011): Health in the Green Economy.

About the authors

Rahul Barua

Rahul Barua is a PhD candidate at the Institute for Environmental Studies (IVM) at the Vrije Universiteit Amsterdam. His work focuses on applications of sustainable energy for household cooking, charging and lighting, and mechanical power in rural areas of Rwanda, Mozambique, and Kenya. Prior to studying business and sustainability, Rahul gained practical experience in technical sales and marketing in the United States. Apart from his PhD work, he has contributed to applied research projects with UN-HABITAT (Nairobi), Endeva (Berlin) and NL Agency (Utrecht).

Institute for Environmental Studies, VU University, Netherlands
Rahul.barua@ivm.vu.nl

Piet Boonekamp

Piet G.M. Boonekamp (1948) finished his study at the Technical University of Eindhoven with a thesis on a model of the Dutch energy supply system. In 1978 he joined ECN and worked on energy model building at national level, cogeneration and end-use savings and executed the National Energy Outlook. Currently he is working on monitoring and evaluation of energy and emission trends, both at national and international level.

Energy research Centre of the Netherlands (ECN)
boonekamp@ecn.nl

Pieter Boot

Dr Pieter Boot is head of the department of Climate, Air and Energy at PBL Netherlands Environmental Assessment Agency and fellow at the Clingendael International Energy Programme (CIEP). He is an economist by profession and holds a PhD from the Free University, Amsterdam. He had a long carlooeer in different ministries in the Dutch government, most recently as Director of Energy and Sustainability and Deputy Director-General of Energy and Telecom (2001-08) in the Ministry of Economic Affairs. From 2008 to 2009 he was affiliated with the International Energy Agency as Director of Sustainable Energy Policy and Technology.

Netherlands Environmental Assessment Agency (PBL), Netherlands
Pieter.boot@pbl.nl

Jan Cloin

Jan Cloin has been working with energy in developing countries for the past 12 years. After his study Electrical Engineering (BSc) and International Development Science (MSc) he worked in Southern Africa and the Pacific Islands towards sustainable application of solar energy, wind energy, and biofuels. Between 2008 and 2011 he was policy advisor at the Ministry of Foreign Affairs, implementing the Dutch Renewable Energy Programme. Currently Mr. Cloin is technical manager of a solar and hydro power programme for public infrastructure in remote areas of Mozambique.

FUNAE, Mozambique
jancloin@funae.co.mz

Heleen de Coninck

Heleen de Coninck works as a programme manager in International Energy and Climate Issues at ECN Policy Studies. At ECN she worked on international climate policy, rural electrification, the Clean Development Mechanism, CO_2 capture and storage, capacity building in developing countries and policy interactions. From 2002-2005, she coordinated the IPCC Special Report on Carbon dioxide Capture and Storage. Heleen graduated in Chemistry and in Environmental Science at the University of Nijmegen in the Netherlands. After her studies, she worked as atmospheric chemistry researcher at the Max Planck Institute for Chemistry in Mainz, Germany. In 2009, Heleen finished a PhD on technology in the international climate regime at the VU University Amsterdam in collaboration with Princeton University in the United States.

Energy research Centre of the Netherlands (ECN)
Deconinck@ecn.nl

Dolf Gielen

Director of the IRENA Innovation and Technology Centre in Bonn - IITC. Previously he was Chief of the Energy Efficiency and Policy Unit at the United Nations Industrial Development Organization (UNIDO), Vienna and Senior Energy Analyst at the International Energy Agency, Paris. Dolf Gielen worked for ECN Policy Studies from 1992 till 2000.

International Renewable Energy Agency (IRENA), Germany
dgielen@irena.org

Marc Londo

Marc Londo is manager of the Energy Innovation and Society group of ECN Policy Studies, in which the transition towards a sustainable energy economy is analysed by both techno-economic approaches and methods from the social sciences. Apart from studies related to energy innovations, his main expertise is in biomass energy.

Energy research Centre of the Netherlands (ECN)
londo@ecn.nl

Hilke Rösler

Hilke Rösler works as scientific researcher in the group Energy Innovation and Society within the ECN unit Policy Studies. She specializes in the use of energy system models like MARKAL and TIMES to do techno-economic analyses. In an ongoing project she is using the TIAM-ECN model for studying the feasibility of a sustainable hydrogen economy and the competition of electric and hydrogen cars plays a crucial role.

Energy research Centre of the Netherlands (ECN)
rosler@ecn.nl

Tineke Roholl
Since 2008, Head of the Climate and Energy Division of the Ministry of Foreign Affairs, where she is – among others- responsible for the implementation of the Promoting Renewable Energy Program. This program aims at an increase of investments and related capacity building of renewable energy in developing countries. Previous positions were also related to the development cooperation programs of the Dutch Government. She was based a.o. in Ethiopia, Eritrea and Sri Lanka.

Ministry of Foreign Affairs, Netherlands
Tineke.roholl@minbuza.nl

Wim Sinke
Prof. Dr. Wim Sinke, senior Staff member Programme & Strategy Solar Energy at ECN, is the coordinator of the extensive European Integrated Project on wafer based silicon photovoltaics: CrystalClear. As Chairman of the Working Group on Science, Technology & Applications, Wim Sinke contributed considerably to the development of the Strategic Research Agenda of the European Photovoltaic Technology Platform. He received the prestigious ‘Becquerel Prize’ for his pioneering work on wafer based silicon photovoltaic cells and modules. Prof. Dr. Sinke studied experimental physics at Utrecht University and received a doctor’s degree in 1985. He became project leader solar cells at the FOM-Institute for Atomic and Molecular Physics in Amsterdam. In 1990 he joined the Energy research Centre of the Netherlands (ECN) to set up and lead a new group on photovoltaics.

Energy research Centre of the Netherlands (ECN)
sinke@ecn.nl

Raouf Saidi
Raouf Saidi is an expert in sustainable energy technology in developing countries. He was the sole representative of the Free Energy Foundation in Mali identifying potential local entrepreneurs to sell small amorphous solar panels and founded a company that introduced solar applications in Nigeria. At ECN he worked on European Carbon Capture and Storage projects as well as energy efficiency and access issues in developing countries. Currently he is actively engaged in the ‘IS-Academy’ for renewable energy to research the potential role of aid money to stimulate business models for low-carbon technologies in several east African countries (Rwanda, Kenya and Tanzania), and CASINDO (Capacity development and strengthening for energy policy formulation and implementation of sustainable energy projects in Indonesia), where he heads the technical work group for regional energy efficiency planning.

Energy research Centre of the Netherlands (ECN)
saidi@ecn.nl

Bob van der Zwaan

Dr. Bob van der Zwaan, a physicist and economist, is senior scientist at the Policy Studies department of the Energy research Centre of the Netherlands (ECN) in Amsterdam and at Columbia University's Earth Institute in New York, and is adjunct professor at Johns Hopkins University's School of Advanced International Studies in Bologna. He is co-director of the International Energy Workshop, member of the Council of the Pugwash Conferences on Science and World Affairs, and lead author for Working Group III of the Intergovernmental Panel on Climate Change. He is (co-)author of around 100 articles in peer-reviewed scientific journals.

Energy research Centre of the Netherlands (ECN)
Vanderzwaan@ecn.nl

Energy: inspiration for the future

In the energy system, are we dealing with doom or dawn? In this collection of articles and essays, in honor of Jos Bruggink turning 65 and leaving the Energy research Centre of the Netherlands (ECN), various energy experts give their views on specific aspects of our energy future.

The stage is set with developments so far. These include sudden incidents (Chernobyl), occasional disruptions (oil crisis), upcoming problems (acidification and greenhouse gases) and deliberate changes (liberalization of energy markets). Over the years, progress has been made towards to a secure and affordable energy system in the developed world, but a clean energy system is still a long way off. In developing countries, energy access is still a challenge.

But that does not stop the experts from thinking about solutions, which is what the authors in this book do. Some take a look at the contribution of technologies and innovation policy. Others focus on the developing world where different technologies and policies are needed. Finally experts reflect on the overall framework for solutions, at European and world level, and the possibilities of energy analysts to contribute to this process.