CIRCLE

LUND UNIVERSITY

Paper no. 2007/05

Industrial dynamics and innovative pressure on energy - Sweden with European and Global outlooks

Lennart Schön (lennart.schon@cirlce.lu.se)
CIRCLE, Lund University

Astrid Kander (astrid.kander@cirlce.lu.se)
CIRCLE, Lund University

Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE)
Lund University
P.O. Box 117, Sölvegatan 16, S-221 00 Lund, SWEDEN
http://www.circle.lu.se/publications
ISSN 1654-3149

WP 2007/05
Industrial dynamics and innovative pressure on energy - Sweden with European and Global outlooks

Lennart Schön and Astrid Kander

Abstract

The focus in this paper is on industrial dynamics and its impact on energy systems.. We highlight some fundamental patterns of this long-term dynamics, using the Dahmenian concept 'development blocks', with 'market widening' and 'market suction', and discuss the implications for innovative pressure in the energy sector. We discern three epochs in the historical data: the Traditional Areal Epoch, the Punctiform Industrial Epoch and the Modern Areal Epoch. Each epoch has its typical energy sources and encompasses some fundamental development blocks. The Modern Areal Epoch is in formation at the end of the 20th century; its innovations are still under incremental evolution, and we discuss its future potential - in particular in relation to those shifts in markets that presently occur due to global spread of industrialization and economic growth.

Keywords: Development blocks, innovation, energy epochs, biofuels

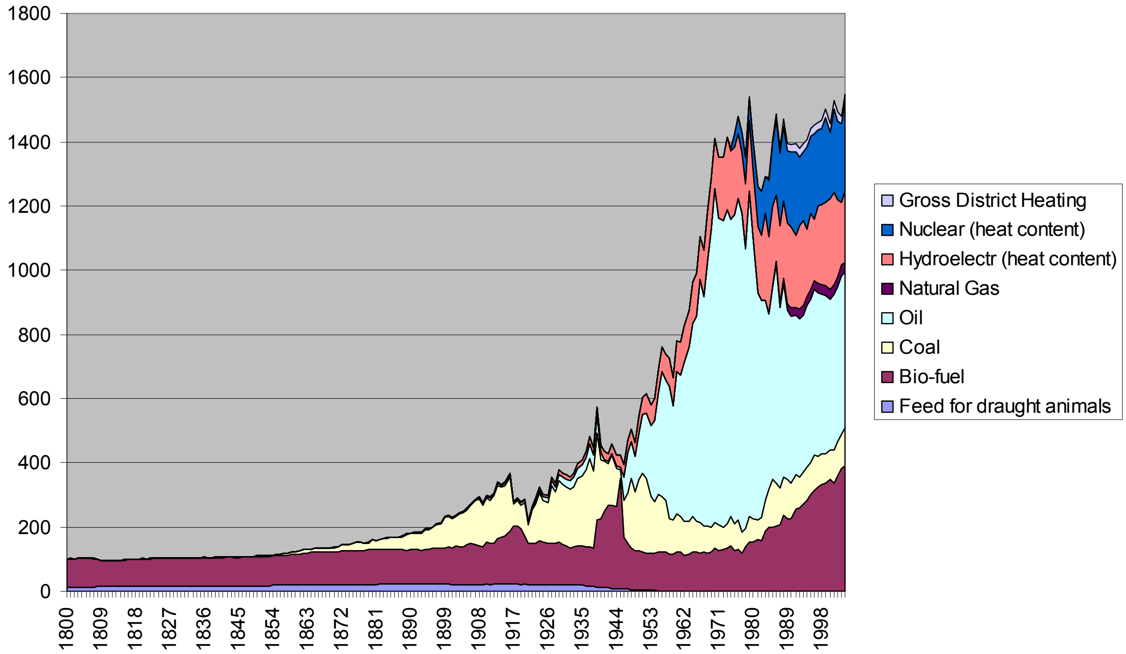
Introduction

This paper addresses the long-term pattern of evolution of energy systems. We propose a typology of three main epochs: the *Traditional Areal*, the *Industrial Punctiform* and the *Modern Areal*, that can be discerned in Swedish data, and partly in data for other European countries as well. Typologies, like the one we propose, always suffer from the weakness of being static, thus not "explaining" why one system changes over to another one. A perspective of industrial dynamism, put into the context of evolution of energy systems, is thus necessary in order to provide some perspectives on the forces operating to change the systems. Changes in relative prices work as one important stimulus for change in economic systems. Shifts in energy systems, when a new energy source has increased its share, has historically always been preceded by a period of lowered relative price of that energy carrier (Kander 2002). Here we focus on another price relation that puts the present transformation of energy systems into perspective: the price of energy relative to prices of manufactured capital goods. This indicator shows imbalances in the industrial system between the primary and secondary sector and highlights where the pressure to come up with innovations is the strongest. During the last century there has been a cyclical pattern in this price relation, a Rostowian pattern, and we propose that the industrial dynamism behind this pattern can be analysed from the Dahmenian concepts of *market widening* and *market suction*. (Schön 1990) Market widening means a shift in supply due to innovations, and market suction means a shift in demand in complementary activity due to the same innovations. Typically there will be an unbalance in the system until market suction stimulates sufficient new innovations in the complementary activities, lowering the demands or widening the provision of resources of the complementary kind. We show that the "normal" Rostowian long-swing pattern in relative prices is broken in the last couple of decades, with a continued increase in relative prices of energy, indicating that the innovative pressure is still very strong on complementary activities (energy markets) and that the transition to the Modern Areal Epoch so far has not widened the energy provision base sufficiently. On the demand side large scale market suction processes have taken place, increasing the energy demands due to the spread of industrialization to large and fast growing economies like India and China. The current innovative pressure on energy markets offers opportunities, but the imbalance between primary and secondary sectors in addition creates political tensions among nations, since access to energy sources is a necessity to avoid economic stagnation. Addressing and resolving these political tensions is necessary for European security in the coming decades.

Three Energy Epochs

We have in previous works outlined the Swedish energy history and have a fairly accurate picture of the long term growth in energy consumption specified with respect to energy sources (Schön 1990, Kander 2002). The growth of the different kinds of energy carriers and the total growth of energy in Sweden between 1800 and 2006 is depicted in figure 1.

Figure 1: Swedish long-term energy consumption, PJ, 1800-2004.



Sources: 1800-2000: Kander (2002), 2001-2004: Statistics Sweden.

On basis of this picture and further analyses we propose that the Swedish energy history is well described in terms of three energy epochs: the Traditional Areal, the Industrial Punctiform and the Modern Areal , see Table 1. The first two epochs are dominated by traditional area based sources (fuelwood, muscle energy) respectively industrial punctiform energy sources (coal, oil, nuclear power), and this is clearly visible in the data in graph 1. The third epoch has only recently begun, with a return to a dependence on area bound energy sources, and thus there is not yet any dominance of these sources in the graphs. However there is a strong political drive for progressing further in this direction, especially for climatic reasons.

Table 1: Three energy epochs

	Traditional Areal	**Industrial Punctiform**	**Modern Areal**
Time period	-1850	1850-1980	1980-
Energy provision	Fodder, firewood, wind, water, peat	Primary: Coal, oil, uranium Secondary: gas, electricity,	Biofuels (pellets, brickets, wastewood for district heating, spent pulping liquor), wind play an increasing role
Technical appliances	Ploughs, stoves, wind and watermills	Steam engine, electrical motor, combustion engine	Fuel cells
Economic Growth	Slow	Rapid	Rapid
Primary Energy Consumption	Stable	Rapid growth, except for the crises	Slow growth
Production structural changes	Stable	Relative expansion of industry and transports	Industry stabilizes its share (but energy light branches expand), transports increase, the rest of the service sector does not increase its share
Energy intensity	Declining	Declining during crises (WWI, WWII and Oil crises in the 70s), more or less increasing in between	Decreasing (from the 70s)

Traditional Areal signals that energy production is based on land areas with traditional (low knowledge intense) methods. Transports of energy carriers are limited and energy consumption is mainly confined to what the land (and wind and water) can produce in a certain locality. The consumption of energy is direct, so is there is not the process of transforming primary energy into secondary energy in industrial plants before consumption.

Motive power is achieved through muscle power and direct working water and wind power (mills) and the revolutionary invention of transforming combustible energy sources into motive power in steam engines has not yet diffused to any considerable extent. Economic growth is slow, but takes place without concomitant increases in energy consumption, so energy intensity (energy/GDP) declines. This has to do with more land being put under the plough without proportional increases in draught animals and thermal efficiency improvements of household stoves (Kander 2002).

The *Industrial Punctiform Epoch* means that the energy sources are harvested at particular sites, typically mines (Wrigley 1962). Fossil fuels are obvious examples, and later comes the extraction of uranium for nuclear power. Mining deep down in the earth to extract energy sources means that the energy base expands considerably, without much competition over the scarce land resource. During the Industrial Punctiform Epoch economic growth is generally fast, except for in crises and the industrial and transport sectors expand in relative terms. Mechanized production and new processes are introduced at a large scale. The result of the market widening for central innovations in energy technology and their diffusion into new areas of applications is a rapid growth of total energy consumption, mainly in the form of stored fossil fuels and uranium. However, innovations also increase the thermal efficiency as well as overall industrial efficiency. Thus, somewhat paradoxically energy intensity declines in most industrial branches (Schön 1990).

The *Modern Areal Epoch* means that innovation and capacity building are important for the production and utilization of areal bound energy sources. This is a response partly to environmental threats from global warming, partly to rising energy prices and partly to the insecurity of becoming dependent upon oil from politically unstable regions like the Middle East or nations that use their oil and gas exports for political purposes, like Russia. Biofuels in this period, unlike the Traditional Areal Epoch, is not only consumed directly by households, but also distributed as district heating or used for plants that combine heat and electricity production. Wind power is not used (as in the traditional energy areal epoch) for small local use for grinding purposes, but in large plants for electricity generation, which is distributed in the large scale electricity nets.

While we find the typology of three energy epochs very suitable for describing the Swedish energy history the third epoch is less pertinent for other European countries. The transition from Traditional Areal epoch to the Industrial Punctiform System took place with different timing in Europe, with England being the clear leader and other countries following. Tables 2 shows that by 1850 England was already completely dominated by fossil fuels consumption (90%) and in the Netherlands the share was 40%. Sweden and Spain at the time only had 2% of their energy supply covered by fossil fuels. Sweden as a cold country was outstanding in its high firewood consumption and the share of total energy was 73%, while Italy, Spain and the Netherlands had relatively more muscle energy.

By 1950 the Netherlands had become almost as dependent on fossil fuels as England & Wales, and Sweden, Spain and Italy had increased their fossil fuel share tremendously. Sweden and Italy at the time were outstanding in generating electricity by other means than fossil fuels (hydropower), see table 3.

By 2000 it is clear that the countries vary considerably with respect to their transition into the Modern Areal Epoch. Sweden is the only country of these five that has a substantial share directly covered by biofuels (23%). However, the electricity generated by other means than fossil fuels has increased its share in all countries, and part of it comes from renewable sources, see table 4. Therefore some indications of the Modern Areal Epoch are present also in other European countries.

Table 2. Composition of energy consumption in 1850 (%)

	England & Wales	Sweden	Netherlands	Italy*	Spain
Muscle	7	25	38	41	50
Firewood	0	73	11	51	46
Wind, Water	2	<1	10	1	2
Fossil fuels	91	2	41	7	2

* *1861.*

Source: Kander, Malanima, Gales and Rubio (2007), Warde (2007)

Table 3. Composition of energy consumption in 1950 (%).

	England & Wales	Sweden	Netherlands	Italy	Spain
Muscle	3	6	10	27	27
Firewood	0	21	0	17	12
Wind, Water	0	<1	0	0	0
Fossil fuels	97	64	90	47	59
Primary electricity	0	9	0	10	2

Source: see Table 2.

Table 4. Composition of energy consumption in 2000 (%).

	England & Wales	Sweden	Netherlands	Italy	Spain
Muscle	2	2	2	4	4
Firewood	0	23	0	2	0
Fossil fuels	90	40	88	88	88
Primary electricity	9	33	10	6	7

Source: see Table 2.

The high Swedish figures of biomass can be compared with the EU average of 3.4% from biomass in primary energy in 2001. To increase this share to 8.5% in 2010, as suggested by the European Commission is possible, but not likely to take place (European Commission 1996). Most estimates of potentials for biomass production in Europe claim that the prospects for increasing the biomass share substantially are great (even though they differ in the figures they come up with) mainly through growing energy crops on set- aside agricultural land (Berndes et al 2003). However, there are many conflicting interests in land (food production, preserve nature for the sake of biodiversity etc), which is likely to increase the price of land and land related products. This in turn will increase the innovative pressure on areal energy provision.

Industrial dynamism

The basic concept for the analysis of industrial dynamics related to technological change is *'development blocks'* – once conceptualized by the economist Erik Dahmén (1950,1970,1988). Another concept with some similarities to the development block was launched by economists in the 1990s, namely General Purpose Technology (Bresnahan and Trajtenberg 1995, Helpman, 1998). Some radical innovations in the energy system, such as the steam engine, the electrical motor and the combustion engine, developed into technologies for nearly all purposes. This was however a drawn-out processes over generations. The concept development block, that combines the characteristics of the innovation with economic relations, captures the main dynamics of this process. The basic innovation enters into different development blocks over time on its path to becoming a General Purpose Technology (Enflo, Kander and Schön 2007).

There are two central characteristics of the development block: innovations and complementarities. Radical innovations in particular have the propensity to create new complementarities – i.e. new dependencies are established between specific functions or properties within the production process or between production and infrastructure or institutions. It takes time, however, to bring forth the complementarities and in this process bottle necks and imbalances appear that in turn may stimulate further investments, accelerating the transformation and structural change of the economy.

This process of transformation has two main dimensions that Dahmén labeled *market widening* and *market suction,* later translated somewhat misleadingly as 'supply push' and 'demand pull'.

Innovations in secondary products (capital goods)

Market widening is the most dynamic part in the process since it is the direct consequence of the radical innovation. The innovation shifts the supply function, lowering the price of a certain good or service, and hence extending the use of it when old technologies are substituted for or new areas are opened. The price effect may be enforced if there are economies of scale or network externalities involved that augments technical efficiency and consumer values. This dynamics is even further enforced if demand is highly price elastic leading to great volume increases – in such cases there are strong growth pushes.

Innovations in primary products (energy)

Market suction, or demand pull, arises mainly due to the complementarities that are specific to the development block. Innovative market widening leads to shifts in demand for complementary factors to the radical innovation in the secondary products, such as new competencies, services or *primary energy.* These have a lower elasticity in the supply function, i. e. are more difficult to increase the production of, at least in the short or middle term, which results in price rises that also attract investments and innovative behavior, which add to the dynamism of the development block. With successful complementary innovations the relative price of the complementary factors, such as energy, eventually falls. If no such extension of the ability in supplying key inputs (such as energy) appears, this dynamism may be cut short.

Innovations on the primary products side, as a response to market suction, may lead to further market widening. Thus, if an innovation reduces the use of a certain input (such as energy) for a particular energy service, the overall effect may be reversed since the lower price and the volume increase may lead to an increase in the total use of that input (a mechanism also called *rebound effect or 'take back' effect*). Mostly the concept 'rebound effect' only refers to the market widening for a particular application of an innovation, for instance more kilometers traveled by car when car engines become more energy efficient. However, market widening in the Dahmenian sense is more dynamic and entails new applications for the innovation, such as the combustion engine expansion from cars to trucks, ships and airplanes. It may thus be useful to distinguish between *market widening for a single application* (giving rebound effects) and *market widening into new applications* (giving production structural effects that also may increase energy use).

Imbalances and change

In the breakthrough periods of radical innovations, the positive contribution to productivity from technical change tends to be hampered by bottlenecks from unfulfilled complementarities (Schön 1991, 1998). Thus, periods of industrial revolutions are characterised by severe imbalances in growth. A productivity paradox, i.e. rapid technical change coinciding with slow productivity growth, was recognized in conjunction with the computer in the 1980s but it also appeared with the breakthrough of electricity in industry at the turn of the century 1900. (David 1990, Schön 1990). The positive effects from innovations upon productivity and growth span a long period with successive development blocks.

When the complementarities are accomplished, the factors within a block mutually increase their marginal returns and productivity is enhanced. The development block approach is evolutionary in the sense that growth is not an even process but rather discontinuous over time, involving a struggle between new and old combinations or blocks in the economy - a struggle that intensifies in periods of creative destruction.

In Swedish industrial and social development electricity is central to a number of development blocks with strong potentials and complementarities. The electrification of industry required large investments in the generation and distribution of electrical power and in the development of the electro-technical industry and of industries consuming electricity. This had to be achieved simultaneously. The dynamism is further strengthened by economies of scale in the network. Thus, combined technological and institutional change have cleared the way for successive integration of the grid from local, to regional, to national and to European scale with concomitant effects on the price structure, leading to shifts in supply and demand functions for electricity. (Schön 1990, 1991)

Furthermore, one can notice a pattern - presented in Schön: 1994, 2000a, 2000b - with two phases in the long term transformation process based upon a number of radical innovations that have great potentials of creating development blocks. New technologies in the fields of energy, communication and transportation are of particular importance in this respect. In *a first phase* denounced as industrial revolutions, basic innovations appear within the *spheres of production*. Their application and early diffusion is very much a process of technical change creating strong tensions between old and new parts in the production processes. A *second phase*, roughly a generation later, has a stronger focus on developing the *infrastructure* based upon the new technology. Such a development, when the technology becomes part of the backbone of society, is based very much upon experience of the new technique and of the social and institutional adaptations that occurs. Thus organizational change at a wider scale comes to the forefront.

The second phase of infrastructural development is of course also dependent upon a further innovative development of the technology that widens the scope of application, with e.g. more powerful, more efficient and more flexible engines. A more efficient infrastructure is developed and technology becomes more standardized. It is only in this second phase that radical innovations such as the steam engine, the electrical motor, the combustion engine or, still within the prospect, microelectronics become pervasive technologies for most purposes in modern societies of different vintages.

At this stage growth potentials expand. Markets widen both geographically and socially when modern technologies become available to many. When growth rates and total volumes increase, demand for primary inputs becomes even more pronounced, Complementary innovations that will widen the resource base of materials and energy become crucial for the furthering of growth. Thus, the development of an infrastructure with railways from the mid-nineteenth century was crucially dependent upon new steel processes as well as more efficient steam engines. The mid-twentieth century expansion of 'golden growth' with infrastructures built upon motorization and electrification was heavily dependent upon great increases in energy supply and in material producing technologies.

In table 1 some characteristics of market widening and market suction are presented. It is especially worth noticing their effects on growth and energy prices relative to manufactured capital goods.

Table 1: Two principle features of a development block

	Market widening **= shift in supply due to innovation**	**Market suction** **= shift in demand in complementary activity due to innovation**
Radical Innovations	Technical appliances (e.g. original and new motor)	Energy provision (primary energy - secondary energy – delivered energy)
Incremental Innovations	Increased thermal energy efficiency	Reduced losses in refinement and transportation

Prices	Relative price decrease of technical appliances	Relative price increase of primary/secondary energy until this sector can meet up with the demand.
Growth effects	Positive growth effects	Bottlenecks may hamper growth

The Rostowian Price Pattern

Market widening and suction are not phases but simultaneous forces in a development block. However, the process is cumulative in the sense that reactions by the complementary sector to market suction may lead to innovations that give rise to further market widening. The time perspectives in reactions differ between sectors. Generally supply functions in primary sectors (energy) are less elastic than in secondary sectors (manufacturing). Walt Rostow once observed that there are long wave-like swings in the price relation between primary and secondary products that fit quite well into the periods of successive innovative changes of industrial revolutions and infrastructural development respectively (Rostow 1978). Thus, with innovative changes in industrial production markets have widened and demand for primary inputs has increased. The response of the primary sector has been slower, though, and the relative prices of industrial products and primary products have shifted. Over some decades, however, there has been a response in the primary sector combining increased capacity in production and transportation with innovations in the handling and processing of materials and energy. This response has been crucial for long term growth to be sustained.

Figure 2 . Price ratio between machinery and primary energy 1885-2006. 1910/12=1

Sources: Schön (1988, 1990), Ljungberg (1990), Kander (2002), Statistics Sweden

In figure 2, the price ratio between secondary and primary products is represented by machinery equipment and energy carriers respectively since 1885. Until around 2000 there is a clear Rostowian pattern. Relative machinery prices peak around 1890, 1930 and 1970, and the peaks are followed by very distinct relative price falls in the periods 1895-1915, 1940-1955, 1970-1985 under the impact of market widening from innovative machinery and increasing demand of energy. The latter sector is slow in expanding supply but this market suction leads in turn to a reaction with falling energy prices during the 1920s and 1960s in lieu of the adaptive enlargement of primary production up to the peaks in relative machinery prices (peaks that precedes international crises). The time pattern is however broken from 2000 when this latter phase of relatively falling energy prices due to supply response is missing. Thus, relative machinery prices continue to fall - this indicates a global shift not only with the diffusion of innovations in the secondary production sector but also with an increase in labour supply and a concomitant increase in energy demand relative to supply at a much larger scale than before. This prolonged relative price increase of energy is a symptom of insufficient innovative response in the energy supply sector so far.

Concluding discussion: Innovative Pressure during the Modern Areal Epoch

There is a strong innovative pressure on energy during the Modern Areal Epoch. During the last decade, the energy sector has been unable to respond but by relatively rising energy prices (Figure 2). Can we expect a more innovative response in the near or medium long term? The answer depends on the relative strength of the growing demand for energy and the innovations that are able to amplify energy supply and cut down on energy demand.

During the last decades, global industrialization has accelerated. The rapid growth of the Chinese and Indian economies since 1980 means that global growth has reached levels of all-time high and this signifies that global supply and demand shifts occur at new levels. It also means that the interplay between market widening and market suction processes becomes even more powerful.

A relevant question is whether the rapidly growing economies in China and India are now proceeding along the energy development trajectories of the earlier industrialisers in Europe, or whether they are leapfrogging and rapidly entering the Modern Areal Epoch. Significant for the Modern Areal Epoch is the decline in energy intensities (see table 1). China managed to lower its energy intensity substantially between 1980 and 2000, but then it leveled out and since 2003 the intensity has increased. Structural change at the industry and sector (sub-industry) level actually increased energy intensity over the period of 1980-2003 (Ma and Stern 2006). This allows the interpretation that China is stuck in the growth of the development blocks around the combustion engine and electricity, rather than in the growth of energy light sectors such as ICT and BioTech. This may indicate that domestic demand from basic needs and construction has become more important in China.

Globally, innovations take place in response to rising energy prices and environmental concerns and innovative pressure is centered within the two main development blocks of the Modern Areal Epoch : ICT (Information and Communication Technology) and BioTech (Biotechnology). These two development blocks are partly integrated, since much of BioTech relies heavily on ICT for its evolution, for instance microprocessors that manage production in more energy efficient ways. One branch of Bio-Tech is dealing with the options of amplifying energy supply by increasing the availability and efficiency of biomass production and conversion.

Crucial for future energy costs are the prices of energy for transportation, and the innovative pressure is hence presently strong on the production of liquid fuel and gas from solid fuels such as biomass. Automotive biofuels have only recently become commercially viable. To date such biofuels are however still produced through a traditional distilling process of sugar-rich biomass grown in fields (sugar beets, grain or sugar canes). In the so called *second generation of biofuels* more efficient use of more varied biomass will be possible, enabling for instance the use of forest waste products for biofuel production and the supply on the market may widen substantially.

The potential for increasing area bound energy supply is of course a matter of conflicting interests in land. Food supply is one competing interest. With growing income levels dietary changes will certainly take place towards more meat, dairy products and beverages that demands relatively more land. A second reason for conflicting interests is the wish to cultivate crops in a more environmentally friendly way, with less pesticides etc, something that will reduce the yields per hectare. There are thus conflicting environmental interests here: between the use of land for energy crops to decrease greenhouse gas emissions and between the use of land for low external input (LEI) farming, which is considered to produce more healthy food (Ericsson and Nilsson 2006). A third conflict is with biodiversity: to have more plantations for biofuels will threaten wildlife and extinct many species. A fourth conflict is over water-supplies; in cases of water shortage, should the water be used for food production or for biofuels? The most crucial issue in historical light is, however, whether the Modern Areal Epoch is able to overcome the limitations posed by the Traditional Areal Epoch, where Punctiform energy sources paved the way for further economic growth. This is a matter of knowledge creation, competence and technical solutions in relation to the enormous energy requirements of present economies.

In principle there are of course other options for innovative response from the energy sector than expanding the use of areal energy sources. All fossil fuels have environmental costs that are severe, and in addition the global supply is limited. The only one of these options that does not come in conflict with the goal to decrease green house gases is to expand the use of nuclear energy. However, also uranium is limited and this option entails severe security problems, in peacetime, and even more so as in wartime.

In conclusion we can sum up by saying that although important innovations are taking place both on the energy supply side and on the demand side, it is likely that these are insufficient in the foreseeable future to outbalance the growing energy demand from industrialization in China, India, Russia and other fast growing economies. The development blocks are still unbalanced and the market suction responses in the energy sector are too weak in relation to the industrial market widening. Therefore we foresee that the increase in energy prices compared to industrial products will continue. Apart from augmenting political tensions over energy issues, this imbalance challenges the innovative capabilities in Europe, dependent upon substantial imports of energy, and poses great potentials for increasing profits in energy technologies.

Reference List

Berndes, G., Hoogwijk, M.; van den Broek, R. (2003) The contribution of biomass in the future global energy supply: a review of 17 studies, *Biomass and Bioenergy* 25 (1): 1-28.

Bresnahan, T. F. & Trajtenberg, M. (1995), General Purpose Technologies:’Engines of Growth’?, *Journal of Econometrics* vol. LXV, pp 83-108.

Dahmén, E, (1950), *Svensk industriell företagarverksamhet. Kausalanalys av den industriella utvecklingen*. Del I-II. IUI, Stockholm.

Dahmén, E. (1970), *Entrepreneurial activity and the development of Swedish industry, 1919-1939*, The American Economic Association, RJ Irwin, Homewood Ill.

Dahmén, E. (1988), 'Development Blocks' in Industrial Economics, *Scandinavian Economic History Review*, vol. XXXVI:1, pp 3-14.

David, P.A. (1990), The Dynamo and the Computer: an Historical Perspective on the Modern Productivity Paradox, *American Economic Review*, vol. 80.

Ericsson and Nilsson (2006): Assessment of the potential biomass supply in Europe using a resource-focused approach, *Biomass & Bioenergy* 30: 1-15.

European Commission. Energy for the future: renewable sources of energy. COM(96)576, Brussels, 1996.

Helpman, E. ed. (1998), *General purpose technologies and economic growth*, MIT Press, Cambridge Mass.

Kander, A. (2002) *Economic growth, energy consumption and CO2 emissions in Sweden 1800-2000,* Lund Studies in Economic history 19, Almqvist & Wicksell International, Lund.

Kander, A., Malanima, P., Gales, B., and Rubio, M. (2007), North versus South. Energy transition and energy intensity in Europe over 200 years, in press for *European Review of Economic History*

Kander, A., L. Schön and Enflo, K. (2007) Identifying Development Blocks – a New Methodology, forthcoming in *Journal of Evolutionary Economics*.

Ljungberg, J. (1990) *Priser och marknadskrafter i Sverige 1885-1969*. En prishistorisk studie. Diss. Lund.

Ma, C. and Stern, D. I. (2006) China's Changing Energy Intensity Trend: A Decomposition Analysis, *Rensselaer Working Papers in Economics* 0615.

Rostow , W.W. (1978), *The World Economy. History and Prospect*. Macmillan, London.

Schön, L. (1988), Historiska nationalräkenskaper för Sverige 1800-1980: Industri och hantverk. Lund.

Schön, L. (1990), *Elektricitetens betydelse för svensk industriell utveckling*. Vattenfall, Stockholm.

Schön, L. (1991), Development blocks and transformation pressure in a macro-economic perspective - a model of long-term cyclical change, i *Skandinaviska Enskilda Banklen Quarterly Review*, Vol. XX: 3-4, pp 67-76.

Schön, L. (1994), *Omvandling och obalans. Mönster i svensk ekonomisk utveckling*. Bilaga 4 till Långtidsutredningen 1995. Stockholm.

Schön, L. (2000a), *En modern svensk ekonomisk historia. Tillväxt och omvandling under två sekel*. SNS Förlag, Stockholm.

Schön, L. (2000b), Electricity, Technological Change and Productivity in Swedish Industry 1890-1990, *European Review of Economic History*. Vol. V:2, pp 175-194.

Statistics Sweden, www.scb.se, tables: Bruttotillförsel av energi per år, PJ, Slutlig användning för energiändamål, 2001-2004.

Warde, P. (2007) *Energy Consumption in England & Wales 1560-2004*, Naples: CNR-ISSM , forthcoming.

Wrigley, E. A.(1962): "The Supply of Raw Materials in the Industrial Revolution", p 1- 16, in The Economic History Review, volume 15, no 1

CIRCLE ELECTRONIC WORKING PAPERS SERIES (EWP)

CIRCLE (Centre for Innovation, Research and Competence in the Learning Economy) is a multidisciplinary research centre set off by several faculties at Lund University and Blekinge Institute of Technology. CIRCLE has a mandate to conduct multidisciplinary research and education on the following issues: Long-term perspectives on innovation, structural change and economic growth, Entrepreneurship and venture capital formation with a special focus on new ventures, The dynamics of R&D systems and technological systems, including their impact on entrepreneurship and growth, Regional innovation systems in different national and international contexts, International comparative analyses of national innovation systems and Policy design based on policy learning,

The CIRCLE Electronic Working Paper Series are intended to be an instrument for early dissemination of the research undertaken by CIRCLE researchers, associates and visiting scholars and stimulate discussion and critical comment.

The working papers present research results that in whole or in part are suitable for submission to a refereed journal or to the editor of a book or have already been submitted and/or accepted for publication.

CIRCLE EWPs are available on-line at: http://www.circle.lu.se/publications

Available papers:

2007

WP 2007/01
Path-following or Leapfrogging in Catching-up: the Case of Chinese Telecommunication Equipment Industry
Liu, Xielin

WP 2007/02
The effects of institutional change on innovation and productivity growth in the Swedish pharmaceutical industry
Malmberg, Claes

WP 2007/03
Global-local linkages, Spillovers and Cultural Clusters: Theoretical and Empirical insights from an exploratory study of Toronto's Film Cluster
Vang, Jan; Chaminade, Cristina

WP 2007/04
Learning from the Bangalore Experience: The Role of Universities in an Emerging Regional Innovation System
Vang, Jan; Chaminade, Cristina.; Coenen, Lars.

WP 2007/05
Industrial dynamics and innovative pressure on energy -Sweden with European and Global outlooks
Schön, Lennart; Kander, Astrid.

2006

WP 2006/01
The Swedish Paradox
Ejermo, Olof; Kander, Astrid

WP 2006/02
Building RIS in Developing Countries: Policy Lessons from Bangalore, India
Vang, Jan; Chaminade, Cristina

WP 2006/03
Innovation Policy for Asian SMEs: Exploring cluster differences
Chaminade, Cristina; Vang, Jan.

WP 2006/04
Rationales for public intervention from a system of innovation approach: the case of VINNOVA.
Chaminade, Cristina; Edquist, Charles

WP 2006/05
Technology and Trade: an analysis of technology specialization and export flows
Andersson, Martin; Ejermo, Olof

WP 2006/06
A Knowledge-based Categorization of Research-based Spin-off Creation
Gabrielsson, Jonas; Landström, Hans; Brunsnes, E. Thomas

WP2006/07
Board control and corporate innovation: an empirical study of small technology-based firms
Gabrielsson, Jonas; Politis, Diamanto

WP2006/08
On and Off the Beaten Path:
Transferring Knowledge through Formal and Informal Networks
Rick Aalbers; Otto Koppius; Wilfred Dolfsma

WP2006/09
Trends in R&D, innovation and productivity in Sweden 1985-2002
Ejermo, Olof; Kander, Astrid

WP2006/10
Development Blocks and the Second Industrial Revolution, Sweden 1900-1974
Enflo, Kerstin; Kander, Astrid; Schön, Lennart

WP 2006/11
The uneven and selective nature of cluster knowledge networks: evidence from the wine industry
Giuliani, Elisa

WP 2006/12
Informal investors and value added: The contribution of investors’ experientially acquired resources in the entrepreneurial process
Politis, Diamanto; Gabrielsson, Jonas

WP 2006/13
Informal investors and value added: What do we know and where do we go?
Politis, Diamanto; Gabrielsson, Jonas

WP 2006/14
Inventive and innovative activity over time and geographical space: the case of Sweden
Ejermo, Olof

2005

WP 2005/1
Constructing Regional Advantage at the Northern Edge
Coenen, Lars; Asheim, Bjørn

WP 2005/02
From Theory to Practice: The Use of the Systems of Innovation Approach for Innovation Policy
Chaminade, Cristina; Edquist, Charles

WP 2005/03
The Role of Regional Innovation Systems in a Globalising Economy: Comparing Knowledge Bases and Institutional Frameworks in Nordic Clusters
Asheim, Bjørn; Coenen, Lars

WP 2005/04
How does Accessibility to Knowledge Sources Affect the Innovativeness of Corporations? Evidence from Sweden
Andersson, Martin; Ejermo, Olof

WP 2005/05
Contextualizing Regional Innovation Systems in a Globalizing Learning Economy: On Knowledge Bases and Institutional Frameworks
Asheim, Bjørn; Coenen, Lars

WP 2005/06
Innovation Policies for Asian SMEs: An Innovation Systems Perspective
Chaminade, Cristina; Vang, Jan

WP 2005/07
Re-norming the Science-Society Relation
Jacob, Merle

WP 2005/08
Corporate innovation and competitive environment
Huse, Morten; Neubaum, Donald O.; Gabrielsson, Jonas

WP 2005/09
Knowledge and accountability: Outside directors' contribution in the corporate value chain
Huse, Morten, Gabrielsson, Jonas; Minichilli, Alessandro

WP 2005/10
Rethinking the Spatial Organization of Creative Industries
Vang, Jan

WP 2005/11
Interregional Inventor Networks as Studied by Patent Co-inventorships
Ejermo, Olof; Karlsson, Charlie

WP 2005/12
Knowledge Bases and Spatial Patterns of Collaboration: Comparing the Pharma and Agro-Food Bioregions Scania and Saskatoon
Coenen, Lars; Moodysson, Jerker; Ryan, Camille; Asheim, Bjørn; Phillips, Peter

WP 2005/13
Regional Innovation System Policy: a Knowledge-based Approach
Asheim, Bjørn; Coenen, Lars; Moodysson, Jerker; Vang, Jan

WP 2005/14
Face-to-Face, Buzz and Knowledge Bases: Socio-spatial implications for learning and innovation policy
Asheim, Bjørn; Coenen, Lars, Vang, Jan

WP 2005/15
The Creative Class and Regional Growth: Towards a Knowledge Based Approach
Kalsø Hansen, Høgni; Vang, Jan; Bjørn T. Asheim

WP 2005/16
Emergence and Growth of Mjärdevi Science Park in Linköping, Sweden
Hommen, Leif; Doloreux, David; Larsson, Emma

WP 2005/17
Trademark Statistics as Innovation Indicators? – A Micro Study
Malmberg, Claes