CO_2 reduction by energy savings in industry in Denmark

Future Climate
Engineering Solutions

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In memory of Stefan Naef

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STRENGTH THROUGH KNOWLEDGE

Introduction

The Danish Socierty of Engineers completed in 2009 the The IDA Climate Plan 2050[1]. The plan describes the way in which Denmark can reduce its greenhouse gas emissions by 90 %, including energysupply, agriculture and industry in the first half of the 21st Century. IDA's Climate Plan 2050 is a scenario in which Denmark takes a marked step away from fossil fuel based energy to 100 percent renewable energy.

The IDA Climate Plan 2050 stands as the Danish Engineers suggestion for a Climate action plan for Denmark. We are still waiting for the Danish government to dicide a national plan. On this basis have IDA decided to focus on more detailed action recomandations within the the different sectors in the second phase of the Future Climate –Engineering Solutions Project.

This paper reports on the work of the IDA Working Group of Energy Saving in Industry[2]. The paper is also the primary contribution from The Danish Socierty of Engineers to phase 2 of the Future Climate project.

A transformation from fossil to renewable requires a range of changes not only in the energy system but also in buildings, in transport routes, eating habits and within research and development and not least within industry. There fore have the members of IDA continue the work on Energy savings in industry in 2011 witth a primary focus on how to realize the potentials all ready documented in the 2009 report.

The Danish Society of Engineers, 2011

[1] The IDA Climate Plan 2050, IDA 2009, www.futureclimate.info

[2] Leif Amby, Thy-Mors Afdelingen; Ebbe Kvorning Andersen, SGT; Michael Søgaard Jørgensen, SGT; Henrik Kragerup, Marie Louise Olin, Yngre Fagligt Forum.

Summery and conclusions

Trade and industry currently represent approximately 1/3 of Denmark's total energy consumption, and this is where the most profitable energy savings are to be found. If Danish industry implements all energy-saving schemes in trade and industry with a repayment period up to 7.5 years can energy consumption be reduced by more than 1/4 by 2015. This is a nessesary contribution if Denmark should meet the long term goal of EU member states to reduce CO_2 emissions by 80- 95% in 2050.

The technologies to implement the energy saving measures are currently in place. The challenge is to speed up industry.

IDA recommends the following means should be implemented:

- An energy-saving fund be used to offer advice and significant grants for investments in energy-optimised process technology.
- Public requirements stating that businesses must optimise their energy consumption by using the latest technology in both operations and new plants.
- Economic subsidies conditional on energy certification and achievement of agreed savings.
- All companies with an annual fuel and electricity consumption of over 5000 MWh ought to perform an energy inspection and process integration study at least once every three years, using external, quality-assured consultants.
  (Energy Consultancy for SME's. (Results-based remuneration of energy advisers.))
- Prizes of documented savings.
- Increased collaboration between companies in the energy - experience exchange groups.

Finally, research and development in the field ought to be given a much higher priority as the immediate gain for society of reducing industry's consumption of fuels and electricity far outweighs the advantages of converting supplies to renewable sources. This research and development shall be followed up by development of the market for new products. It ought to be mentioned that, to a certain extent, energy companies in Denmark today "purchase" energy savings from trade and industry. Payment for this typically amounts to DKK 100 – 250 /MWh, which is the equivalent of reducing the repayment period by a few months, or even up to a year.

The IDA Climate Plan 2050

The IDA Climate Plan 2050 describes the way in which Denmark can reduce its greenhouse gas emissions by 90 %, including energysupply, agriculture and industry in the first half of the 21st Century. IDA's Climate Plan 2050 is a scenario in which Denmark takes a marked step away from fossil fuel based energy to 100 percent renewable energy. This requires a range of changes not only in the energy system but also in buildings, in transport routes, eating habits and within research and development and not least within industry.

The plan is a simultaneous description of the way in which investments in technology and infrastructure can develop Denmark into a modern society based on renewable energy sources and efficient utilisation of all available resources.

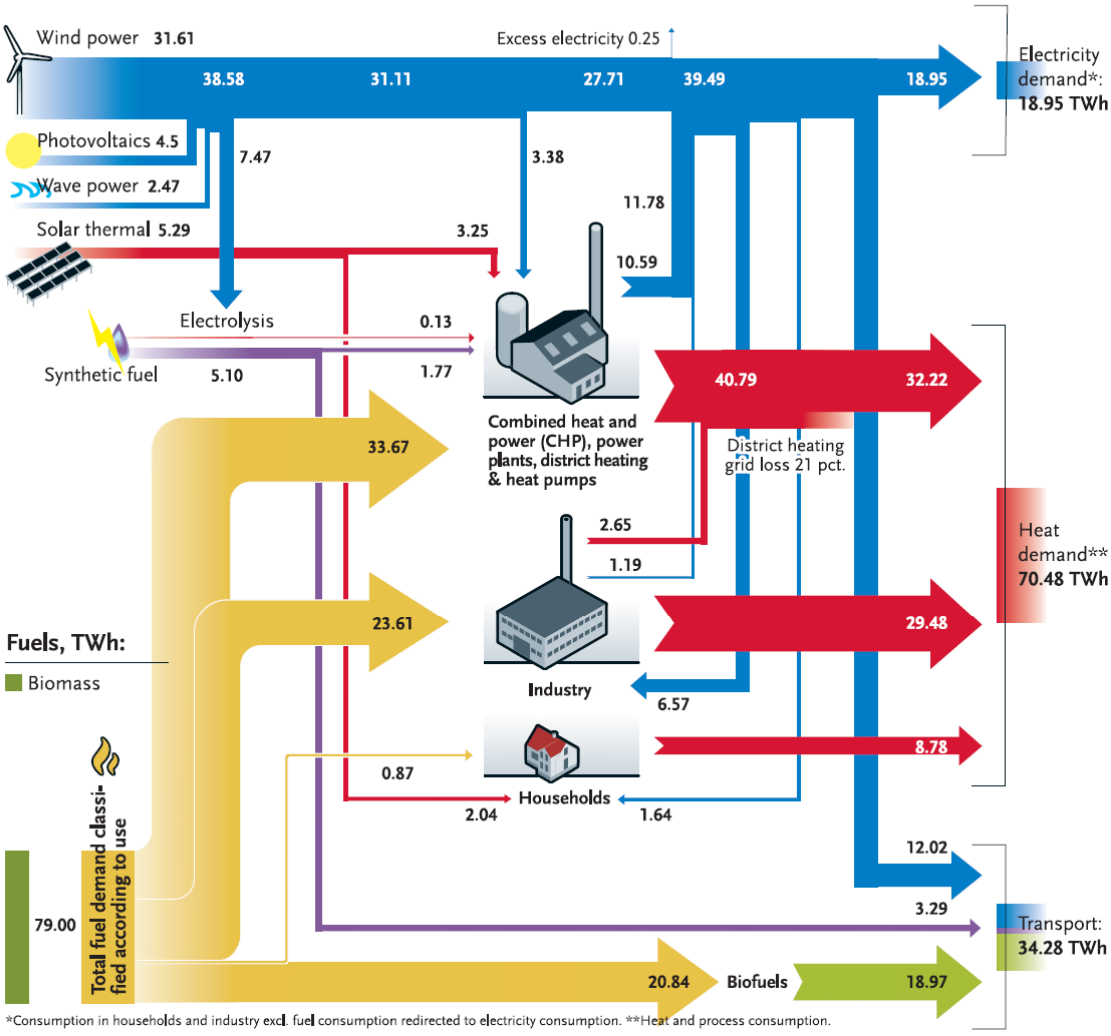
Wind turbines and biomass constitute the backbone of The IDA Climate Plan 2050 that is based solely upon renewable energy. In 2050, Danish greenhouse gas emissions will originate largely from agricultural production and the emissions that are linked with the Danish people's food consumption.

In The IDA Climate Plan 2050, 60-65 % of the electricity production is based on wind power. The majority of the combined heat and power production is based on biomass and waste and thus on stitutes the stabilising element of an otherwise fluctuating energy production. The remaining electricity and combined heat and power production are based on solar cells, wave power, geothermics and solar heat. Such a comprehensive development of renewable energy sources requires the initiation of a number of consecutive initiatives.

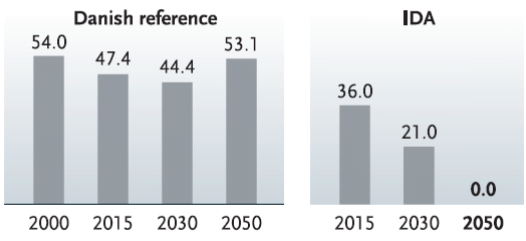
It will be necessary to increase research and development within the critical technologies. It is particularly important to also provide necessary opportunities to test and demonstrate the technologies and to establish innovation markets and feed-in tariffs that can support a market characteristic following the new technologies. In the windturbine area, it is also important to draw up a longterm development plan for off-shore and on-shore wind turbines as soon as possible.

The figure (next page) shows the 2050 energy scenario for Denmark. The IDA Climate Plan 2050 emphasises cost-effective solutions, which mean that energy streamlining and more efficient utilisation of nature's resources constitute a cornerstone of the plan. Energy efficiency and savings plays an very important role if Denmark is to develop an energy sysem based on renewable energy. All in all, the plan looks at the Danish energy consumption being reduced from 845 to 707 PJ by 2015, to around 556 PJ by 2030 and to around 442 PJ by 2050.

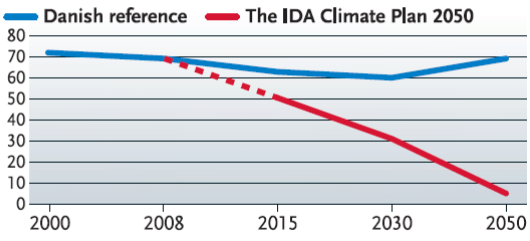
100% renewable energy. Primary energy supply, total: **122.86 terawatt hour (TWh)**



CO_2 emissions from the energy system (million ton):

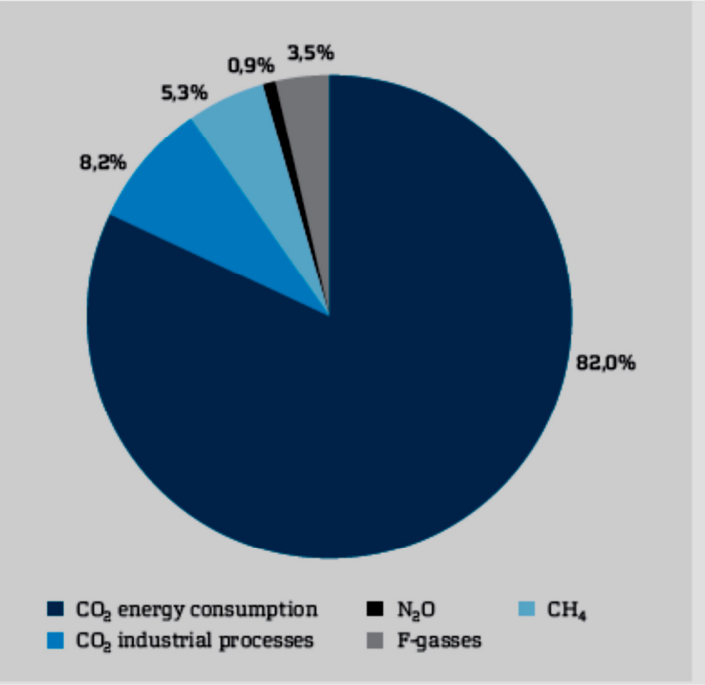


All Danish climate gas emissions in CO_2-eq (million ton):



Why focus on energy savings in industry?

CO2 emissions originating from industry's consumption of energy is by far the largest source of industry's total climate gas emissions. For this reason, The IDA Climate Plan 2050 focuses specifically on energyefficiency in industry. Emission of CO_2 from other industrial processes originates predominantly from the production of cement (~84 %), lime and limestone (~9 %), tile (~3 %) and metal (~3 %). In general, these CO_2 emissions are directly linked to the production of the products and can only be reduced by reducing the actual production volume or by CCS (carbon capture and storage).



Figur 1 Climate gas emission, distribution by type

Trade and industry accounts for 35 % of Denmark's total energy consumption: The largest sectors are manufacturing, which accounts for 49 % of the energy consumption of industry and commerce, and private service and agriculture. Fossil fuels account for 52 % of this energy consumption, renewable energy for 5 %, district heating for 11 % and electricity for 32 %.

The energy consumption of the manufacturing industry has remained fairly constant over the past twenty years. However, the consumption of trade and service industries has increased by approx. 1 % per year. The energy intensity, which is energy consumption relative to gross value added at a fixed DKK rate, is significantly lower today than in 1990 in most sectors. The fact that manufacturing enterprises show reduced energy intensity is particularly due to structural changes whereby sectors that

are light consumers of energy, such as the iron and metal industry, grew in proportion to other industries between 1990 and 2006. However, the intensity effect, which is a combination of a wide range of factors such as energy savings and substitution of fuel by, on the one hand, electricity and district heating (which entails savings in conversion loss) and, on the other, increased mechanisation and automation, was almost the same in 2006 as it had been in 1990.

Great potential in reducing heat consumption

The potential for energy savings on heat consumption (the consumption of fuel and district heating) and on electricity consumption is assessed in the short term (2015) and in the long term (2030 and 2050) with a repayment period of 2, 5 and 10 years.

In the over all calculation in Climate 2050 have the realistic potential been estimated to 7.5 years. Energy saving measures in industry would normally only be implemented if the repayment period was significantly shorter (around 2 to 4 years).

This is due to the fact that investments in energy savings compete with investments with a strategically higher priority. The reason why this report highlights the energy saving potential of a 7.5 year repayment period is partly due to the benefit to society and partly due to the fact that there is a need to achieve defined climate goals.It is, therefore, quite crucial that endeavours are made to increase enterprises' incentive to make energy savings by various regulatory means.

This covers all forms of heat consumption related to either indirect or direct heating with fuels or district heating and electricity. Therefore, heating of the business sector's premises is also included Table 1.

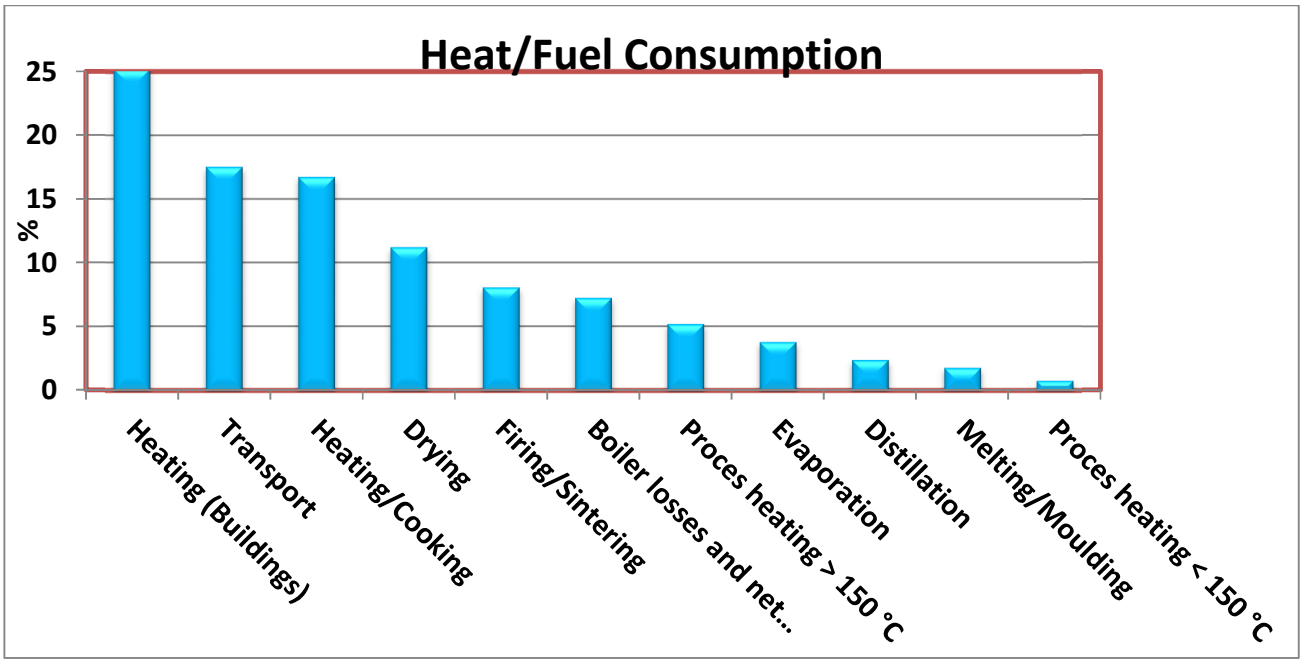
Table 1 potential savings in fuel consumption in industry, with the 7.5 year repayment period in the IDA climate plan 2050.

	2015	**2030**	**2050**
Savings in %	27 %	31 %	33 %
Savings in TWh	11.8	13.8	14.6

Source: Potential is calculated based on the technical background report; Energy savings in trade and industry, IDA 2009

With respect to industry's heat consumption, it is expected that there will be significant opportunities for savings in all end uses, in process integration and in the use of enzymes in production. Potential savings in fuel consumption with a 7.5 year repayment period are indicated in the table.

Most significant energy savings can be achieved by using thermal pumps, if heat requirements are below 150°C, by converting industry's fuel consumption from fossil fuels to biofuels and by using enzymes for specific types of production. There is currently no thermal pump technology suitable for industry's heat requirements above 150°C (e.g. for the burning of cement and the melting of glass at around 1500 °C).



Figur 2 Potential distributed on areas/heat fueling consumption

In addition, there is potential for savings in heat consumption in various different industrial processes.Evaporation processes offer potential in the form of increased preheating, more evaporation steps, thermal and/or mechanical recompression of steam, substitution with reverse osmosis and improved process management.

There is also significant potential for savings in dehumidification processes and the following measures are expected to be implemented: Reduction of water content before thermal dehumidification through, e.g., improved mechanical drainage, preheating of raw materials, indirect dehumidification where possible and increased heat recovery.

In the fields of burning and sintering, potential savings are expected to originate from increased drainage before dehumidification, improved insulation of kilns, increased heat recovery, addition of additives that can reduce the required process temperature. In the case of fusion and moulding processes, savings are expected to come from improvements in insulation, increased heat recovery using thermal recuperators, increased preheating and the use of oxyfuel combustion.

Optimised process management, cascading distillation, other separation technologies such as membranes and additional and more effective column plates are expected to result in energy savings in distillation processes. As mentioned above, thermal pumps are the source of the greatest savings. It is expected that around a fifth of the achievable reduction in heat consumption can be gained by using thermal pumps. However, a proportion of the savings gained by the use of thermal pumps is offset by an increase in electricity consumption.

Industry's requirement for the heating of premises amounts to 25 % of industry's total heat requirement. According to Climate Plan 2050, it is expected that this requirement will primarily be covered by thermal pumps, excess heat produced by industry and passive as well as active solar heat. If this is to be achieved, heat requirements must be reduced by improving the insulation capabilities of the building shell of both existing buildings and new office buildings. The expected potential for savings on heat for industry's premises is included in Table 1, which shows total potential savings in industry's heat consumption.

It is estimated that around 100 % of industry's consumption of fossil fuels in Denmark will be able to be replaced by biofuels. However, it should be noted that the conversion to biofuels for industrial combined heat and power will reduce the electricity production of CHP plants to almost one third. It is assumed that enzymes will be able to be used in processes that represent 5 % of trade and industry's energy consumption (primarily heat) and the savings potential only applies to these processes.

Industry's electricity consumption must be reduced

Potential savings in the Danish industry electricity consumtion with a repayment period of 7.5 years are indicated in Table 2. It is assessed that the greatest potential is to be found in pumping, ventilation, cooling and compressed air. These technologies are still the most interesting areas with the greatest potential for energy savings. Even though massive efforts are beingmade to provide energy labelling for motors, pumps and ventilators, the rollout and implementation/replacement of energy-efficient components and the optimisation of the systems in which these components are incorporated remain outstanding issues.

Table 2 Potential savings in electricity consumption in industry, with the 7.5 year repayment period in The IDA climate plan 2050

	2015	**2030**	**2050**
Savings in %	32 %	43 %	45 %
Savings in TWh	7.2	9.8	10.2

Source: Potential is calculated based on the technical background report; Energy savings in trade and industry, IDA 2009

The most significant potential for savings in the field of lighting is expected to come from LED (light-emitting diodes) and a considerable breakthrough and substantial circulation is expected by 2015. In addition, it is expected that improved management (demand management) will result in potential energy savings in this area.

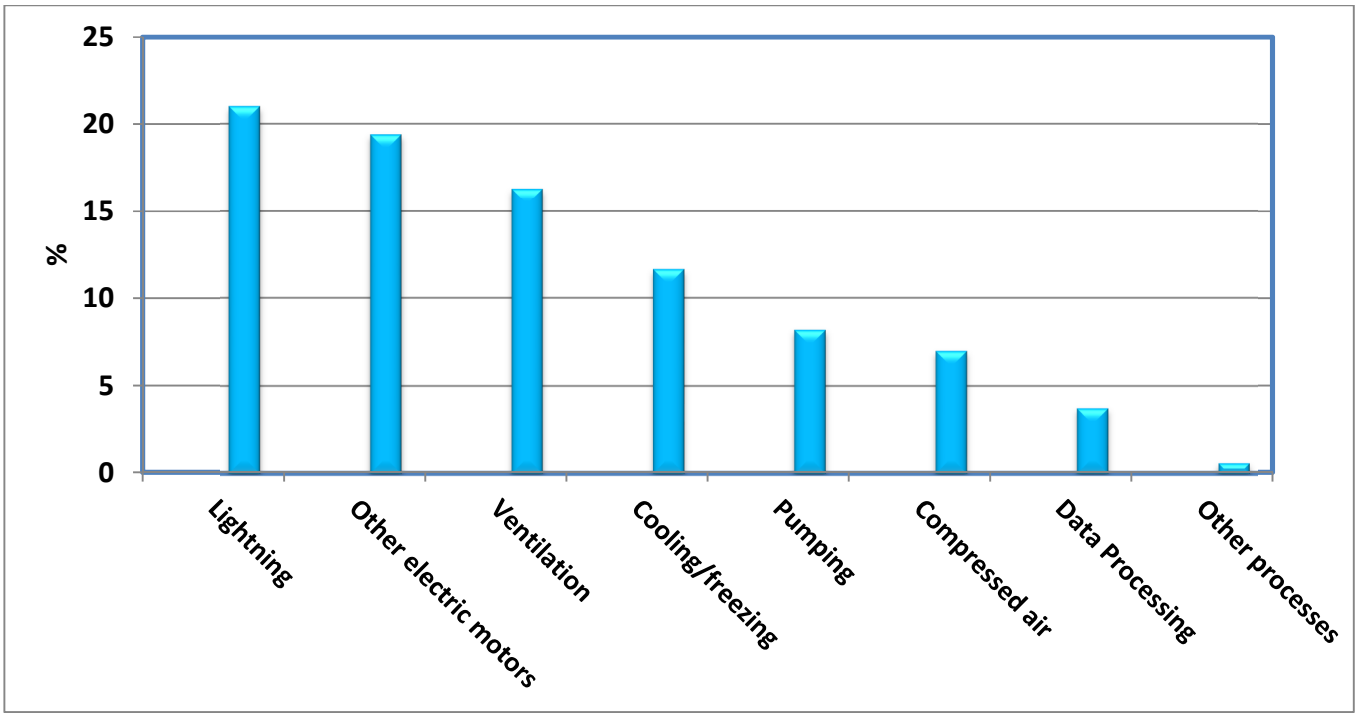


Figure 3 Potential distributed on areas/electricity consumption

With respect to pumping, cooling and ventilation, savings potential is expected to arise primarily from the use of highly efficient components, the reduction of requirements, optimised control and an increase in maintenance. In addition, it is expected that the use of Permanent Magnet Synchronous Motors (PMSM) will result in considerable energy savings, particularly in pumping and ventilation. From the point of view of cooling, free cooling, solar protection features and absorption cooling will provide potential for future energy savings.

The use of compressed air shall be replaced wherever possible by direct electrical operation or by the use of highly efficient, oil-free compressors. Furthermore, significant energy savings can be made if loss through leakage is reduced. In the field of industrial electric motors, in addition to the development of more efficient motors, it is expected that reducing the need for an energy service and the optimisation of demand management will provide opportunities for savings.

In the fields of fusion and other process heat based on electricity, it is expected that the optimisation of material consumption (optimisation of feed systems in foundry moulds), minimisation of fusion and

shortening of holding and idle times will provide potential for savings. In the field of injection moulding, in particular, the use of all-electric machines will provide significant opportunities for energy savings.

How do we get energy savings rolling?

It should be stressed that the savings potential can only partly be realised by the companies themselves in their ongoing efforts to reduce costs and optimise production and by the natural replacement of equipment and processes. In order to achieve great results, a broad range of mechanisms will be required that can motivate and force companies to initiate energy savings.

Table 3 Large enterprices and SMEs

	Employees	**Turnover**	**Energy**	**Energy**
Large enterprices	40 %	43 %	~35 %	85 PJ
SME's	60 %	57 %	~65 %	158 PJ

Source: CONCITO 2011

SMEs are central to the Danish economy. According to the Centre for Entrepreneurship and Small Business (CESPO) SMEs employs approximately 40% of the Danish workforce, while large companies employ approx.60%. Looking at the total turnover, SMEs account for about 57% and large businesses for 43%. But when looking at the energy use, the SME's are consuming about 2/3 of the energy, Table 3.

SME has in general another approach to wards investments and staff related to the energy consumption than large companies. Large companies are often working on a longer time scale than SMEs, who on the hand in general are strong on flexibility. Flexibility and readiness for change is in many cases a challenge to energy savings.

Size and turnover of the company plays an important role when looking at how to get energy savings rolling. To a great extent, energy savings and energy efficiency measures in industry depend on the financial implications. When it comes to short term improvements, it is almost entirely the financial and normative mechanisms that are effective.

When compiling a package of mechanisms, it is important to analyse the way in which taxes that will make energy more expensive and investment grants that will make savings cheaper can be combined so that both initiatives promote improvements to the cost-effectiveness of savings. Taxes on energy consumption, in particular the heating of premises, have already been imposed on industry and, all things being equal, increased taxes will increase a company's interest in reducing energy consumption.

Taxes and quota schemes such as CO_2 quotas are toolswhich are relatively easy to use but which, unfortunately, have some serious side effects. The energy expenses of the greater part of industry only amount to 0.5 – 2 % of turnover whereas, in energy-intensive companies, they account for 10 %. Thus, even the smallest percentage increase in energy expenses has an enormous impact on the competitiveness of these companies (unless their competitors throughout the world are also subject to similar increases).

Subsidies for energy-saving measures do not impair competitive capacity. On the contrary, they will improve it by reducing the level of costs. This can be done by establishing a fund to promote and provide subsidies for energy-saving measures in manufacturing companies. The budget of this type of fund ought to total DKK 800 million per year (~100 mill. €). As industry's annual energy costs amount to around DKK 15 billion a year, a fund of this size would shorten the repayment time for energy-saving initiatives by 2 to 3 years.

The effect of contribution schemes will be increased if they are directly connected to a business's energy savings, either in connection with changes in existing plant or in relation to benchmarking of new buildings. This will thereby result in a (fund) solution that supports active energy savings – potentially in connection with ESCO[3] businesses – and which thereby has a direct effect on repayment times. Financial instruments based on subsidies or loan schemes are generally more positively received by the business sector and a fund for the implementation energy-efficient measures will shorten the repayment period by between two and three years. This is the equivalent of an increase in savings potential of between 8 and 19 percentage points.

The need for research and development

Research into and development of new technologies constitute the foundations of a radically changed energy system and are crucial to the possibility of developing new strong Danish commercial positions in the energy field. It is equally important to ensure that means are available to carry out full-scale demonstrations of the new technologies when the technologies are to be brought from the laboratory out onto the commercial market.

Since the expenses for a demonstration plant in particular add to the costs, the funds for researchinto and the development and demonstration of efficient and renewable energy technologies should be increased to DKK 4 billion a year in 2020.

Research and development ought to be given a much higher priority as the immediate gain for society of reducing industry's consumption of fuels and electricity far outweighs the advantages of converting supplies to renewable sources. This research and development shall be followed up by development of the market for new products. It ought to be mentioned that, to a certain extent, energy companies today "purchase" energy savings from trade and industry. Payment for this typically amounts to DKK 100 –

[3] Energy service companies, or ESCO companies, are another type of financial instrument. These companiescan finance a company's savings projects and are paid via the energy savings gained.

250 /MWh, which is the equivalent of reducing the repayment period by a few months, or even up to a year.

More information about efficiency improvement

Information mechanisms already contain many tools and models that can be used to implement energy efficiency measures. Therefore, what is needed is support for the dissemination of these tools. This can be provided by training designers, sales personnel and consultants. Finally, success stories and methods can be spread via network activities related to energy management and efficiency improvement.

Good tools are important in order to overcome barriers such as a lack of knowledge and ideas and too little time. These tools are intended to support ongoing discussions and information exchange and, in the long term, they will make it easier to act in an energy-conscious manner when purchasing and designing.

One thing that is needed is training of the staff that design, purchase and operate the systems. However,sales personal also need to be trained so that they are aware of the potential for reducing energy. Finally, an increase in the range of training courses aimed at the consultancy market could promote efforts to introduce energy efficiency measures by increasing the prevalence of competent energy consultants. Companies may be inspired to get started themselves if they hear others' experiences of energy saving.

Experiences can be passed on through brochures, articles, open-house events etc. One particularly efficient way of passing on knowledge is through the participation in groups made up of representatives from like-minded companies. With the aim of benchmarking of energy consumption, they can discuss good and bad experiences of their activities make a mutual commitment to introduce new initiatives and report on the results.

These groups may, for example, discuss one application at a time; they may start by discussing pump systems one year and ventilations systems the next. Thus, this is an activity that can easily be handled by existing company networks and organisations.

Labelling schemes

Energy labelling has helped significantly improve the efficiency of household appliances and could also be used to advantage by industry for appliances that are sold in large quantities. Energy labelling makes it easy to select an energy-efficient solution and no prior training of the purchaser is required. In other cases, in which equipment is not so simple, projects can be required to be based on energy-conscious design; thus, the need for an energy service is assessed, alternative solutions are identified and overall finances presented. In the same way as companies are required to have environmental approval, a scheme could be envisaged whereby companies receive energy certification. They will be required to document energy-efficient design. Finally, a verifying body may be linked to the process in order to provide certification of the energy-efficient design.

In the case of existing systems in energy-intensive companies, energy saving potential can be thoroughly examined every five to ten years. The process may include the participation of experts or

persons accredited in the industry in question as well as the processes applied. This will ensure that the energy inspection focuses on the most important and most energy-consuming processes instead of auxiliary equipment.

In companies that consume less energy, an energy inspection can be based on current schemes for energy labelling of buildings and compulsory ventilation inspection, both of which could be extended to include production buildings. At the same time, compulsory schemes could be introduced for several other areas, such as lighting systems, fridge-freezers etc.

The concept of the agreement is to reward energyintensive companies if they behave in an energy-efficient manner. However, the concept seems to be ”losing its shine” and, therefore, it may be necessary to change the scheme and make it voluntary so that all companies that join the scheme are rewarded with a tax reduction and/or with investment grants for energy savings. The requirement could be the same as that of the Dutch scheme which stipulates that a company must be among the top 10 % in the world when benchmarked after a few years.

In connection with the expansion of the circle of players in the field of energy efficiency measures, certification schemes may promote the activities of energy consultants and the introduction of energy management. Thus, international efforts to standardize energy management, ESCO and energy efficiency and simulation will be able to operate together with existing management systems such as ISO 9001, ISO 14001 and others, and this will ensure that energy management is integrated into management systems. Similarly, certification of energy consultants will aid quality assurance and the marketing of energy consultancy.

A range of opportunities

Both the financial and information mechanisms can operate together with normative mechanisms, such as energy labelling, that both support the involvement of staff in climate change activities and form a basis for subsidy schemes. An increase in control of energy reviews and energy inspections in companies can help increase the focus on energy consumption.

However, this is generally met by a negative response from the business sector and ought to be incorporated in government efforts to simplify rules. It is also assessed that formalised energy management, e.g. in the form of certified management systems, has a positive effect, although this is again dependent on interaction with, primarily, the financial mechanisms. However, the combination of certification options and legal requirements may create greater synergy with the financial incentives so that the long term potential can be realised.

New motivation to energy savings - conclusions and recommendations

Trade and industry currently represent approximately 1/3 of Denmark's total energy consumption, and this is where the most profitable energy savings are to be found. If Danish industry implements all energy-saving schemes in trade and industry with a repayment period up to 7.5 years can energy consumption be reduced by more than 1/4 by 2015. This is a nessesary contribution if Denmark should meet the long term goal of EU member states to reduce CO_2 emissions by 80- 95% in 2050.

SMEs are central to the Danish economy. SMEs employs approximately 40% of the Danish workforce, while large companies employ approx.60%. Looking at thetotal turnover, SMEs account for about 57% and large businesses for 43%. But when looking at the energy use, the SME's are consuming about 2/3 of the energy.

SME has in general another approach to wards investments and staff related to the energy consumption than large companies. Large companies are often working on a longer time scale than SMEs, who on the hand in general are strong on flexibility. Flexibility and readiness for change is in many cases a challenge to energy savings.

This paper has presented several public means to create motivation for energy savings in industry.

List of means:

- Funds for the promotion of and grants for energy-saving measures. (~100 mill. €)
- Grants for research, development, demonstration, market development and verification of new, energy-saving technologies. (~15 mill. €)
- Subsidies to be granted when binding agreements on energy management are entered into with individual companies.
- All companies with an annual energy consumption of over 5000 MWh to perform an energy inspection every 3. year.
- Labeling schemes for products and energy certification of new plants
- Grants for investments in energy-optimised process technology.
- BAT requirement in both operations and new plants
- Economic subsidies conditional on energy certification
- Prizes for documented savings.

Special focus on SME's:

- Energy Consultancy for SME's. (Results-based remuneration of energy advisers.)
- Increased collaboration between companies in the energy - experience exchange groups.