Energy Policy Toolkit on

Energy Efficiency in Industries

Experiences from Denmark

Danish Energy Agency

Abbreviations

DEA	Danish Energy Agency
DTI	Danish Technological Institute
EE	Energy Efficiency
EEO Scheme	Energy Efficiency Obligaton Scheme
EMS	Energy management Systems
EnMP	Energy Management Program
EnPI	Energy Performance Indicator
GHG	Greenhouse Gas
HVAC	Heating, Ventilation and Air Conditioning
IIP	Institute for Industrial Productivity
KPI	Key Performance Indicator
kWh	Kilowatt Hour
LEDS	Low Emission Development Strategies
LIEN	Large Industry Energy Network
PBT	Pay Back Time
PJ	Peta Joule (=1000 Tera Joule)
TJ	Tera Joule
SME	Small and Medium Sized Enterprise
WWF	World Wildlife Foundation

Introduction

Countries around the world face critical energy choices today that may have significant implications for many years to come.

Economic growth and future prosperity are challenged by rapidly increasing energy needs worldwide. The bulk of today's global energy production is based on unsustainable fossil fuels such as coal, oil and gas. This poses a serious climate threat as well as a threat to the livelihood of future generations and people living in adversely affected regions and countries.

The sustainable alternative to fossil fuels is energy efficiency and renewable energy. Strong national strategies to use energy much more efficiently than we do today should be the point of departure. To phase out fossil fuels and increase the production of renewable energy in parallel is another key aspect. Concrete actions by countries as well as international efforts to find solutions to mitigate global warming are needed.

Denmark has years of experience in sustainable energy transition. The Danish experiences in promoting energy efficiency and renewable energy could be relevant to countries that wish to make their energy systems more sustainable and less dependent on fossil fuels. Firmly rooted in measures adopted by a broad parliamentary majority Denmark has agreed to a 2020 target entailing :

- 35 % renewable energy in final energy consumption.
- 12 % reduction in gross energy comsumption compared to 2006.
- Minimum 34 % reduction in greenhouse gas emissions (GHG) compared to 1990.

This is in line with the Danish Government's long term target of making Denmark self-reliance on renewable energy in 2050.

Making bad choices with regard to energy mix, timing and scope of investments may lock in expensive energy infrastructure and pollution for decades. Therefore, decisions on energy efficiency aspects should be based on the best available guidance and experiences.

This energy policy toolkit shares Danish knowledge and experiences about handling barriers and improving energy efficiency in the industry. The industrial sector has huge unharnessed energy efficiency potentials and constitutes an opportunity for governments to improve the economy and competitiveness of industry. Furthermore, there are opportunities to mitigate climate change and air pollution through reduction in greenhouse gas emissions, as well as making significant investments in supply side power infrastructure unnecessary.

In order also to see the Danish policy on energy efficiency in industries in an international perspective, an article entitled "How policy can drive industrial energy efficiency across the globe" is included in the toolkit, as Annex A. The text is written – on request – by Julia Reinaud, who previously worked at the Institute for Industrial Productivity. It is here pointed out that this toolkit comes at a time when having effective energy efficiency policies in place for the industry sector could not be more important, and that energy efficiency policies do more than just help mitigate climate change. Improving energy efficiency brings with it a host of benefits to human health and the environment, generates jobs and drives economic growth. Furthermore, enterprises stand to gain too by saving up to 10-30 % of their annual energy use, and increasing their productivity, through better energy management. Thus the message is that energy efficiency offers a win-win situation for all.

This toolkit is drafted by the Danish Energy Agency's Centre for Global Cooperation under the Danish Ministry of Energy, Utilities and Climate. Centre for Global Cooperation publishes a series of energy policy toolkits providing specific, technical and concrete

Industry matters as a primary source for energy efficiency gains:

- Industry accounts for about one quarter of total global energy consumption.
- Energy management and existing technology provide a huge savings potential with short payback-periods.
- Many energy efficiency measures in industry are cost-effective. Not only do such measures save energy costs and improve competitiveness, they may also make costly investments in generation capacity unnecessary.
- Energy efficiency is not a strategic focus area in most industrial sectors. Therefore, governmental actions are necessary to initiate energy saving investments.

information on Danish experiences and lessons learned on tools and measures in promoting renewable energy and energy efficiency. They target practitioners, governmental energy experts and policy makers in emerging economies. The aim is to give qualified guidance to countries in their implementation of Greenhouse Gas (GHG) reduction measures and Low Emission Development Strategies (LEDS).

Comments to this policy toolkit, questions on Danish energy efficiency policy as well as queries on the Danish Energy Agency's Centre for Global Cooperation are most welcome. Please contact Ulla Vestergaard Rasmussen, Advisor, uvr@ens.dk, phone +45 3392 7571 or Steffen Nielsen, Special Advisor, srn@ens.dk, phone +45 3392 6696 or visit our website:

www.ens.dk/global-cooperation

Energy Efficiency policies for the Industrial Sector

Denmark has a long tradition of active energy policy, initiated by the first oil crisis in 1973. Over the years, numerous actions have been taken by broad consensus in the Danish Parliament to reduce the energy consumption by increasing energy efficiency and to increase the share of renewable energy.

A systematic Danish energy efficiency policy addressing the industrial sector took its beginning in the early 1990s. The energy consumption in industry had increased steadily until then. In 1990 the government launched an overall energy plan "Energy 2000" on how to reach its ambitious climate and energy policy goals. Analyses showed that cost effective CO_2 reductions were available in the industrial sector, but also that governmental action was necessary to overcome a number of barriers.

One important barrier was lack of both strategic priority of energy efficiency at company level and willingness to invest in energy efficiency measures in the boardrooms. In general, there was a need for improved knowledge and experience regarding energy saving potentials and on how to improve energy efficiency. In order to overcome these barriers it was decided to take action through four different measures; tax on energy, energy saving through legislation, subsidy schemes, and development of a number of supportive measures.

In 1993, a CO_2 tax on certain energy products, such as coal, oil and natural gas, was introduced in the Danish tax system. In order to ensure that the industry's competitiveness was not burdened by the new tax, energy-intensive companies had their CO_2 taxes, almost entirely, refunded, if they in return performed energy audits. In 1996, a the voluntary agreement scheme on energy efficiency was introduced as part of a comprehensive "green tax package", as more action was needed in order to reach the national CO_2 goal of 20 % reduction in 2005 compared to 1988. The green tax package comprised three elements:

- An increased tax on CO_2 emissions from fossil fuels used for industrial processes/ "green taxes"
- Options to get tax reimbursements on the CO_2 tax provided that the company made an agreement with the authorities on energy saving projects/ "Voluntary Agreements"
- Subsidies for energy saving projects.

The voluntary agreement scheme[1] has had a central role among the Danish Government's policy measures addressing energy efficiency in industry. The scheme has proven highly successful in achieving energy savings and efficiency without hampering the international competitiveness of Danish industry. The scheme has been strengthened several times based on a number of evaluations.

Another important energy policy measure in Denmark addressing all end consumer sectors, and thus also the industrial sector, is the energy efficiency obligations scheme. The scheme consists of an energy efficiency obligation with an annual binding energy saving target for all Danish energy distribution companies (electricity, heating, gas and oil). The scheme was introduced in 2006. The involved companies have a high degree of freedom of choice on how they chose to fulfil their obligations. The overall saving target has been increased gradually since 2006. The program is further described on page 22.

The Danish Industrial Sector

The final energy consumption in the Danish industry sector amounts to 128 PJ (2013), which represents approximately one fifth of the total final energy consumption in Denmark. The Danish industry sector is characterised by a large number of small and medium sized companies (SMEs), and a rather limited number of large, energy-intensive companies, e.g. in the cement, refinery and steel sector. The voluntary agreement scheme target heavy processes in large as well as SMEs, including also greenhouse heating, the production of foodstuffs and beverages, sugar, paper, bricks and glass.

Since around 1990, energy efficiency within the industrial sector has improved significantly in Denmark. The early 1990'ies was the beginning of the systematic Danish policy on realizing energy savings and improving energy efficiency in industry. Within the industry sector

1. The Danish voluntary agreement scheme is described in more detail on page 8-9.

Energy saving potential in Danish industrial sector by energy source and payback-period				
Energy source	Share of energy demand	2 years payback	4 years payback	10 years payback
Electricity	33%	14%	19%	41%
Fuels	67%	7%	12%	26%

Table 1. For fuel consumption, energy savings in processes like evaporators, drying processes and process heating/heat recovery represent the largest part of the saving potential, while utility systems (refrigeration plants, compressed air systems etc.) represent the largest part of the electricity saving potential.

the energy intensity decreased by 41.7 % from 1990 to 2013. Up to 1993, the energy intensity increased, while after 1993 there has been a continuing decrease. In the manufacturing sector, the energy intensity decreased by 0.8 % from 1990 to 1993 and by 47.7 % from 1993 to 2013. This development can be seen as an indication of the effectiveness of the energy efficiency policies applied in the industrial sector.

However, another reason for the decrease in energy intensity has been the significant structural changes with fewer high energy intensity industries during the same period. Regardless of the significance of the structural changes, there is no doubt about the impact and strong results of the Danish energy efficiency policy targeting the industrial sector[2].

Although the industry has focused on energy efficiency over a long period, there are still ways to save energy. An analysis, conducted in 2010, showed that there are a growing number of savings opportunities compared to previous analyses in the 1990'ties. There are several reasons for that. The well-known potential savings are still not realized, and continuously new technical and behavioural opportunities are developed. Changes in relations of production and energy prices also affect the saving potential. The total energy saving potential in Danish industrial sector in 2010 is shown in table 1.

KEY

Key points and recommendations from the Danish case:

- Energy efficiency is not a strategic focus area in most industries. Therefore governmental actions are necessary to initiate energy saving investments
- A combination of measures "Carrot and Stick" should be applied to stimulate a development towards an increased energy efficiency in the industrial sector
- Increased energy efficiency increases competitiveness of the industrial sector and often also leads to increased productivity.

2. Data from the DEA's Energy Statistics 2013: www.ens.dk/sites/ens.dk/files/info/tal-kort/statistik-noegletal/aarlig-energistatistik/energystatistics2013.pdf

Voluntary Agreement Scheme on Energy Efficiency

The Danish voluntary agreement scheme on energy efficiency for energy intensive industries was launched in 1996 and has been a cornerstone among measures to stimulate energy efficiency in this target group. The scheme was launched by the Danish government as a means of achieving the long-term goal of reducing CO_2-emissions in the Danish society by 20 % in 2005 compared to 1988. The scheme is administered by the Danish Energy Agency.

Up to 2010 there were about 230 companies with voluntary agreements covering about two thirds of the total fuel consumption and between a third and a fourth of the electricity consumption in the Danish industry and manufacturing sectors, corresponding to about 8-9 % of the national gross energy consumption.

"Carrot and stick"

The agreement scheme for energy intensive industries is voluntary, but based on a principle where companies entering the scheme will have economic incentives ("carrot") from extra work necessary ("stick"). Under the Danish legislation, the immediate economic benefit has been chosen to be an energy tax relief. For most energy-intensive companies the business case is simple: The tax relief exceeds the costs associated with being in the scheme.

The Danish voluntary agreement scheme is designed for companies with one of the following characteristics:

- The company operates certain energy intensive unit operations or
- The company's energy taxes exceed 4 % of the company's value added.

A total of 37 processes are defined by Danish law. The list of energy-intensive unit operations ("heavy processes") comprises for instance:

- Evaporator plants – for instance concentration of milk products.
- Drying processes – for instance drying of paper/pulp, proteins and chemical products.
- Distillation columns – for instance for concentration of alcohol and hexane.
- Kilns – for instance for production of cement, chalk and clay products.
- Furnaces – for instance for melting of glass, metals and minerals.
- Refinery products – for instance production of oil and gasoline products.

Requirements to an agreement company

A voluntary energy efficiency agreement is a 3-year contract entered between the company and the Danish Energy Agency. It is also possible for a number of companies in the same subsector to enter into a joint agreement with the Danish Energy Agency. A joint agreement consists of individual agreements and a number of common special investigations relevant to the subsector. An example of a subsector with a joint agreement with DEA is the Danish brick industry. The main requirements from the Danish Energy Agency to an agreement company – or group of companies - are:

- The company must implement and maintain a certified energy management system according to the global standard ISO50001.

- The company must carry out special investigations and projects focusing on their primary production processes, including thorough productivity analysis, optimization analyses and analyses of the control of the central process equipment.

- The company must implement all energy efficiency projects with a simple payback time of four years or less.

The energy management system and additional requirements by the Danish Energy Agency must be certified annually by an accredited body[3] verifying that the company:

- presents an updated annual breakdown of energy consumption by end-use.
- sets targets and budgets for energy consumption the forthcoming year.
- screens the company to identify possible energy saving projects.
- prepares action plan for investment projects the forthcoming year.
- implements all energy saving measures and projects with a simple payback time of less than 4 years.
- carries out special investigations for complicated energy saving areas.

- evaluates energy key performance indicators/ KPIs regularly.
- applies energy-efficient design methods when planning investments.
- carries out internal audits of procedures and reporting.
- arranges management evaluation of the scheme.
- follows the procedures for energy efficient design and purchasing.

The continued progress of these activities is secured by the certified energy management system. However, the experience has been that specific requirements such as the above-mentioned have to be set by the Danish Energy Agency to make the requirements in the ISO50001-standard more precise and easier to evaluate.[4]

Overall, the costs for being in the scheme have to be taken into account. To fulfil the obligations, internal time must be allocated to manage the scheme, certification costs must be expected, and furthermore, fees for external specialists must be expected. For most energy intensive companies these costs, however, are much smaller than the economic benefit (tax relief) and the energy savings.

For smaller companies, a certified energy management system will as general rule be too expensive to maintain. Therefore, the Danish Energy Agency - together with Danish Standards (accredited to certify energy management systems) - has introduced an "energy management light"-methodology for this target group (Annex C).

FACT

Factsheet

Evaluations of the Voluntary Agreement Scheme

In the period 1996 – 2013 more than 200 companies have joined the agreement scheme for shorter or longer periods. Several evaluations have been carried out to assess costs and benefits of the scheme and to adjust the approach and obligations of the scheme.

In 2005 an evaluation showed that the companies participating in the agreement scheme in average saved 4.8 % of their energy consumption in the period 2000-2003. In 2013 an evaluation showed that the agreement companies in the period 2006-2011 saved 5.4 % of their energy consumption in average.

In both evaluations it was concluded that the agreement scheme was the reason for more than half of the achieved energy savings. Furthermore, that the voluntary agreement scheme had highest influence in medium-large-sized companies, where energy-intensive companies – for instance within the cement sector - already had a strong focus on energy efficiency for simple business reasons.

In 2008, a comprehensive evaluation of all energy efficiency programs in Denmark was carried out. Among other parameters, additionality and cost efficiency of the programs were compared. The evaluation showed that the voluntary agreement scheme for energy intensive industries was cost-effective, and also that it was more cost-effective than the programs addressing the other sectors.

Further developments of the Voluntary Agreement Scheme

In spring 2014 a broad coalition of political parties decided to continue the successful voluntary agreement scheme to strengthen the competitiveness of Danish energy intensive companies. The scheme is projected to run from 2015-2020 with implementation of a certified energy management system according to the global standard ISO 50001 as a mandatory obligation.

The Voluntary Agreement Scheme is built on the experiences from the former Scheme which by its expiry of 2013, have resulted in systematic energy savings in companies by the implementation and maintenance of the energy management system. Approximately 1.400 production facilities within 68 different sectors spanning from production of food and beverage to molding of steel are included in the Voluntary Agreement Scheme.

3. In Denmark, Bureau Veritas (BVQI), Det Norske Veritas (DNV) and Danish Standards are accredited to certify energy management systems according to the global standard ISO50001.
4. In the Danish scheme, requirements to the breakdown of energy consumption, to carry out special investigations and to identify saving projects and implement those with payback less than 4 years, are more detailed than what is described in the ISO50001-standard.

KEY

Key points and recommendations from the Danish voluntary agreement scheme:

- The voluntary agreement scheme for the industrial sector is suitable for large and medium-sized industries consuming most of the energy used in the industrial sector – but in general smaller industries do not have resources for a certified systematic approach on energy efficiency.
- The scheme should combine "carrot and stick" – the industries would look for an immediate economic benefit if they are to enter an agreement that demands extra work efforts and investments to reduce energy consumption.
- Improved energy efficiency in the industrial sector necessitates a continued and long-term, systematic working effort – not just "quick fixes".
- The agreement voluntary scheme should describe in detail and "bottom-up" which actions industries must take to improve energy efficiency rather than setting overall requirements and improvement targets for each individual industry.
- In Denmark the voluntary agreement scheme for industry based on the principles above have shown to be among the most cost-efficient governmental initiatives to promote energy efficiency across all sectors.
- Energy management is an essential element in the Danish Voluntary Agreement in order to promote energy efficiency in the industrial sector. Experiences show that companies can reduce their energy consumption by 10-15 % by implementing energy management.

Energy Management

In Denmark, a compulsory energy audit scheme in the early 1990's paved the way for the development of the voluntary agreement scheme for energy intensive industries. The experiences from the compulsory scheme[5] showed that a traditional energy audit tended to address "quick fixes" mainly in easily accessible technical areas such as lighting systems, boiler tune-ups and improvement of insulation of steam piping systems and the likes.

An evaluation of these experiences made it clear that a more effective energy efficiency scheme for large industries should build on the following principles:

- A continued and systematic effort is necessary to improve performance year after year.
- An involvement of key persons inside the companies is necessary to address difficult technical areas.
- A clear management buy-in is important to secure a continued commitment at all levels.
- Budgets and targets should be set every year, and achieved results should be evaluated compared to these.

Based on these findings, the Danish Energy Agency initiated the development of a first standard for energy management. In 1999 the first standard, DS2403, was launched as a key element in the Danish energy agreement scheme for large energy intensive industries.

The Danish energy management standard DS2403 was based on the principles of the EU Eco-Management and Audit Scheme (EMAS), a management system developed by the European Commission for companies and other organizations to evaluate, report, and improve their environmental performance.

5. During 1992-1995, by law all energy intensive industries in Denmark should carry out general energy audits.

Energy Management Standard ISO50001

DS2403 has been an inspiration for the Irish Standard IS393 launched in 2006, which later formed the basis for the development of the European energy management standard EN16001. Today this standard has been replaced by the global energy management standard ISO50001. The management system is based on a cyclic "plan-do-check-act" approach, basically used in all management systems aiming at continued improvements (see Figure 1 below).

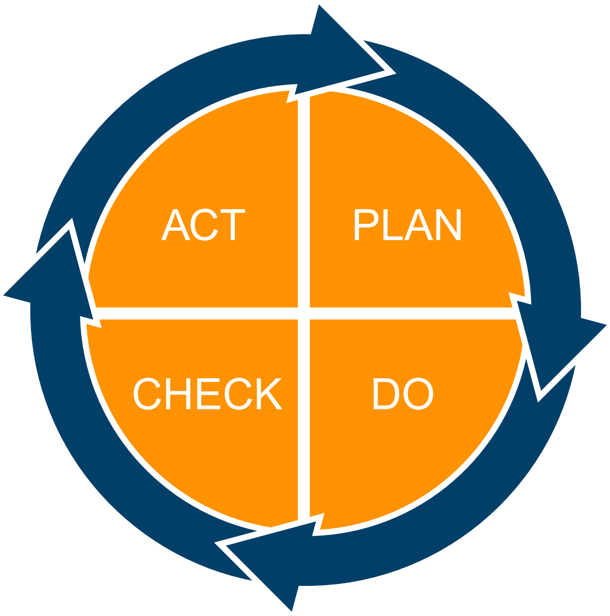


Figure 1. Cyclic approach of an energy management system aiming at continued improvements.

The annual cyclic efforts to reduce energy consumption comprise the following activities:

Plan

The company nominates an energy manager and builds an organization that supports activities. An energy review is carried out and targets for improvements are set.

Do

The company establishes procedures and documentation. These support the energy management system and train people to increase awareness towards energy efficiency in all relevant operations.

Check

The company monitors energy consumption and evaluates performance compared to targets. Deviations from planned development are analysed and corrective actions are implemented if necessary.

Act

The company management reviews results and performances of the energy management system. This ensures progress and continual improvement in the energy performance. Adjustments of the system might be implemented.

In Annex C, the fundamentals of ISO50001 are summarized along with simple energy management principles addressing also small and medium sized enterprises (SMEs).

Case: Danish Malting Group

Systematic energy management has made Danish Malting Group (DMG) one of the world's most energy efficient malt houses

Since 1996 DMG has had an agreement with the Danish Energy Agency to implement energy efficient measures. DMG has among others committed to introduce energy management and implement all energy reducing projects with a simple payback time less than four years.

DMG is certified according to the energy management standard ISO 50001. The major cost in the production of malt is the raw material barley. But if this is subtracted, utility costs, including energy taxes, make up the far largest part of the remaining costs (approximately 57 %). The fact that energy makes up such a large part of the cost motivates to make energy savings.

This motivation was taken seriously at DMG and a comprehensive optimization effort for the processes of the malting house was initiated with assistance from the international energy management standard ISO 50001. The result was a 43 % reduction in electricity consumption and 30 % in heat consumption for the period 1997-2014 – illustrated by figure 2 and figure 3. The energy saving efforts have made DMG one of the malt houses of the world using least energy per ton produced malt.

Energy management puts focus on process optimization

Through energy management DMG in this way has had a distinct focus on energy savings since the end of the 1990's. This has contributed to a focus on the energy consumption of the production processes and to get the work with process control and optimization started. Energy management has contributed to get the energy optimization started and to improve the results.

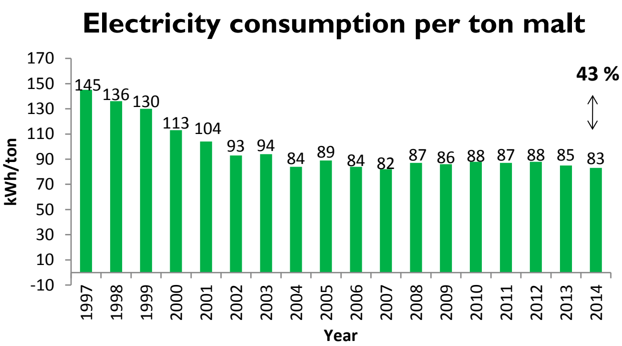


Figure 2. Development in electricity consumption per ton malt.

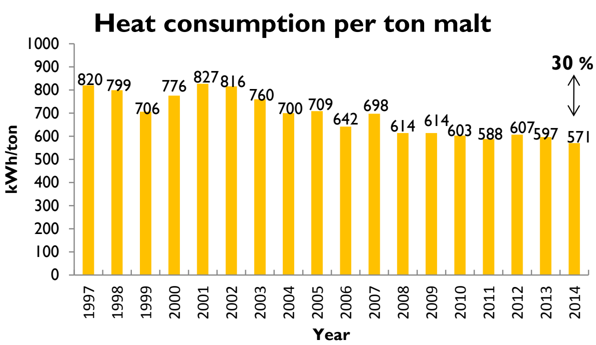


Figure 3. Development in heat consumption per ton malt.

Drying malt demands large amounts of energy

The most energy-intensive part of the malting process is the malt kilning. Here the grain (green malt) is dried and the most important aromatic components of the malt that contribute to the taste of later brewed beer are developed. The drying process demands large amount of energy. In fact 99,8 % of the plant's heat consumption and 58 % of its electricity consumption is consumed by the processes of drying.

Electricity consumption can be reduced by optimizing drying time and the fan speed

The large share of electricity was especially consumed by the fans that blow hot air through the grain to dry it. However, at DMG it has been realised that the fans only use one eighth of power if they are put on half speed. So even a smaller decrease in speed has a big reducing effect on the energy consumption.

In some parts of the malting process cooling is needed and this also weighs heavily in relation to the electricity consumption. At DMG like at other malt house facilities the cold outdoor air is utilised in the winter as free cooling. In the summer period cooling with an energy consuming system is necessary and

	DMG	DMG Poland	Russia	China
Electricity (kWh/tonne)	83	77	130	124
Heat (kWh/tonne)	571	665	670	1066
Water (m3/tonne)	1,6	4.4	3.7	6.8

Table 2. Seen in the chart is consumption numbers for DMG's malting houses in Denmark and Poland compared to similar malt houses in Russia and China, which have modern facilities with same construction as DMG.

DMG has moreover established intelligent control of the facility so electricity is only used when demand is actually there.

FACTS ABOUT DANISH MALTING GROUP

- One of Europe's largest malt houses
- The plant was completed in 1996 and is owned by Carlsberg Breweries
- Annually produces 115.000-125.000 ton of pilsner malt
- Has 24 employees
- Has an annual electricity consumption of 10.229 MWh (2014) and an annual gas consumption of 6.407 million Nm3 (2014)
- Annually emits 15.522 ton CO_2 (2014)

Heat consumption reduced by optimizing the heat supply

Heat consumption has especially been reduced by optimizing the facilities that produce process heat for themalt house. The most of the time a gas boiler is providing heat to the malt house. The gas boiler's efficiency has been increased from 90 % to 103 % by establishing an exhaust gas heat exchanger. It utilises the condensed heat from the exhaust gas which explains the efficiency over 100 %.

Even lower numbers than modern malt houses

Today DMG only uses 83 kWh of electricity and 571 kWh of heat per ton malt which is impressive numbers compared with similar malt houses. From table 2 it is seen that the numbers are significantly higher at similar Russian and Chinese malt houses which in fact have newer and more modern facilities and thus have the opportunity to be even more efficient. The leading position of DMG is alone due to the systematic optimization of the malt house's processes so that they match the actual demand of the malt house.

Technical Approach

The lessons learned from 20 years of energy efficiency programs in Danish industry are – among others – that the energy consumption pattern in energy intensive industries is far more complicated than in for example a building. Therefore much wider approaches must be applied in order to implement significant and cost-efficient energy savings. Areas as production processes, utility systems, maintenance and operator behaviour should all be in focus.

Such a broad approach can be described in the "Onion" diagram. The "Onion" diagram was originally introduced for energy efficiency purposes as a part of process integration studies[6], but has been refined and expanded under the Danish voluntary agreement scheme, see Figure 4.

The "Onion" diagram

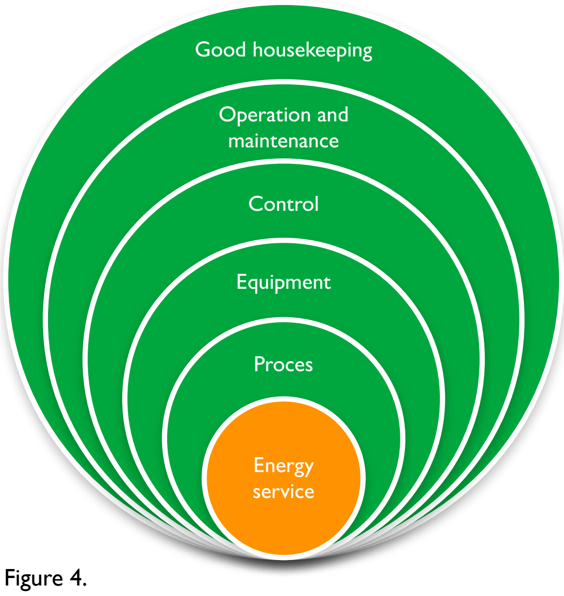


Figure 4.

The onion diagram aims to define a systematic "inside-out" approach to energy efficiency starting by questioning the core reasons ("the energy service") why a process or an area uses energy. Basic process parameters, design standards and product specifications can define most of the energy consumption in a facility and therefore also influence most of the energy-saving potential.

Upon such analysis, focus of energy-saving analysis can progress to address efficiency of the production process and equipment in the facility. Improvements of processes and equipment should be carried out only when it is clearly understood how the "energy service" influences energy consumption in the facility.

Finally, opportunities to optimize control and operation of equipment and processes can be identified. Often maintenance procedures will be an important area to address. In addition, operator behaviour ("Good housekeeping") can have significant influence on how efficient a facility is operated.

The "Onion" diagram is often simplified to at saying that "energy is used – and can be saved – twice": first time inside the production processes and second time by the utility systems supplying energy (steam, hot water, cooling, compressed air, electricity etc.) to the production processes.

The "Onion" diagram has been a cornerstone in Danish voluntary agreement scheme, but it has also been adopted by other national programs. An example is Sustainable Energy Authority of Ireland's program for large energy users, the Large Industry Energy Network (LIEN). The diagram has also been used as a key-methodology in programs for energy efficient design of new green field industries and buildings.

In Annex B, an example of an "onion" diagram analysis of an industrial process is described.

6. "Pinch Analysis and Process Integration, A Users Guide to Process Integration", I.C. Kemp, 1982

KEY

Key points and recommendations from the Danish case:

- A continued and systematic energy efficiency focus necessitates management buy-in to maintain focus, to involve the right people/competences, to evaluate progress and to allocate resources and budgets year after year.
- A certified energy management scheme according to ISO50001 (or similar) aiming at continued improvements is a cornerstone to tie systematic energy efficiency work together.
- To keep an energy management system on track, frequent (annual) and detailed evaluations of progress in each individual company must be carried out internally and by authorities.
- To achieve significant energy savings in large industries, both production processes and utility systems must be in focus.
- To address optimization of the most important areas, not just technical staff should be involved. Also product specialists and quality people (among others) can play an important role in re-defining important process parameters.
- Energy efficiency analysis of production processes and utility systems can be complex and time-consuming to carry out. Such analysis could be defined as "special investigations" and planned carefully to be successful.

Case - Chr. Hansen

Bacteria cultures at Chr. Hansen are stored at temperatures as low as -55°C.

Chr. Hansen is one of the world's largest suppliers of ingredients for the food industry, including in the form of lactic acid bacterial cultures, enzymes, antioxidants, flavouring and colouring agents. Worldwide the company has approximately 2,000 employees.

Chr. Hansen was among the first companies to fully apply the technical approaches developed in the Danish Voluntary Agreement Scheme (i.e. the "Onion" diagram). This happened during the planning and design of a new greenfield fermentation facility in the Copenhagen area during 1995-1996. Supported as a pilot project by the Danish Energy Agency, an external energy efficiency expert was hired to carry out a detailed review of all basic planning and design parameters for the project. As a part of this analysis, energy consumption in all processes and utility systems in the planned facility were analysed and significant changes were made in order to reduce energy consumption.

For instance, the expert identified significant opportunities to reduce the requirements for ventilation (HVAC) and cooling inside the production areas via a change of production parameters.

The total implemented energy saving from these improvements amounted to more than 30 % of the expected energy consumption at the facility. The extra investment to implement the improvements was paid back in less than 2 years.

FACT

Factsheet

Special Investigations

In the Danish Voluntary Agreement Scheme, it has been experienced that it is difficult for the companies to carry out complex energy saving analyses. This is because the company culture mostly is focused on production management.

Therefore the Danish Energy Agency has set strict requirements that more complex energy saving analyses must be defined as "special investigations" and that these should be carefully planned including:

- Clear ownership in the organization.
- Well-described activities.
- Allocated resources.
- Budget for consultants and investments.
- Timeline for investigations.

More than 1,000 special investigations have been carried out in Danish voluntary agreement companies. Experience has shown that more than 30 % of these investigations have led to significant implemented energy savings.

Administration and Management of the Voluntary Agreement Scheme

To a large extent the success of the Danish voluntary agreement scheme builds on the fact that the Danish Energy Agency has established a small, specialized and dedicated team to administrate and develop the scheme over the years.

Firstly, while annual control of the agreement companies have been outsourced to external, accredited companies within energy management systems (ISO50001), the Danish Energy Agency has had its own resources to negotiate and - if necessary adjust agreements - as well as to review progress reports from the companies etc.

This close contact to the companies has been crucial in order to continuously understand progress and barriers towards success of the scheme, and hereby to develop/change requirements and recommended focus areas as new lessons have been gained. Also, new legislation or changes in energy prices/taxation have often influenced the choices of technical focus areas to address by the companies.

Secondly, the Danish Energy Agency has continuously sought close dialogue with industry in order to understand priorities and new agendas for integrating energy efficiency activities with company life. For certain periods, an industrial advisory board, with experts from the relevant industries, has been formed to guide the Danish Energy Agency in developing the agreement scheme into new areas and ways of working. Furthermore, the board has been used to define necessary supportive measures to stimulate a positive development of the scheme.

Finally, frequent evaluations of the agreement scheme have been carried out by independent parties. This has been done in order to assess achieved energy savings, cost efficiency and new barriers towards continued success of the scheme.

From close cooperation with industries and industrial experts, the lesson learnt has been that supportive measures targeting the industrial sector should take into consideration that industries usually do not have the time to read and apply comprehensive guidelines, information materials and case stories. The lessons are:

- Industry wants to see immediate economic advantages
- Industry wants to see easily accessible solutions
- Industry wants to see new technology

Financially supported pilot and demonstration projects hosted by voluntary agreement companies have also been a successful way to demonstrate new approaches to energy efficiency to decision makers, investors and others.

FACT

Factsheet

Supportive Measures

A range of supportive measures have been applied by the Danish Energy Agency to develop and secure the success of the Danish Voluntary Agreement Scheme for energy intensive industries. For example:

- A consultant scheme has been developed in order to support industries with specialist competences within energy efficiency of industrial processes and utility systems.
- Technical guidelines, fact sheets and case-stories have been promoted. Especially show-cases and demonstration projects have been a successful way of communication.
- A "toolbox" development project was initiated and managed by industry people aiming at demonstrating tools and methods within energy management and energy performance indicators.
- A range of surveys and assessments have been carried out to establish a database for industrial energy use. For example surveys of energy saving potentials, review of experiences from special investigations, and analysis of potentials for use of renewable energy.

The supportive measures have been planned and managed/administered by the Danish Energy Agency to identify new focus areas and to inspire the industries to initiate new steps within energy efficiency. However, to a large extent the aim has also been to inspire energy consultants and utility companies to find new ways of developing their business.

KEY

Key points and recommendations from the Danish case:

- A well-managed voluntary agreement scheme requires a dedicated team for continued follow-up, control and development.
- The agreement scheme should regularly be evaluated to assess achieved results, cost efficiency and barriers towards improving energy efficiency by independent parties.
- The responsible authority should take lead in identifying and developing new approaches, findings and technologies, and these should be promoted continuously via pilot- and demonstration projects if successful.
- Development of an agreement scheme requires close dialogue with industries and industrial experts to understand new agendas, challenges and ways to integrate energy efficiency activities with company life.
- Surveys and data platforms are crucial to identify energy saving potentials and manage priority of new focus areas.

Case: Novozymes

Systematic focus on energy efficiency

As a part of the agreement with the Danish Energy Agency to implement energy efficient measures, Novozymes has worked systematically with among other energy management after the ISO 50001 standard, energy-conscious planning and energy optimization at the production facility in Kalundborg. Many solutions have afterwards been used at other production sites in Denmark and the rest of the world. These are now leading identification of new energy efficient measures locally at sites outside Denmark.

The agreement with the Danish Energy Agency has contributed to generate a substantial focus on the company's energy consumption. For example the agreement implies that the company must define a comprehensive energy strategy and objective and also appoint an energy responsible employee.

The company has appointed energy responsible employees for every area of expertise, so that every process – fermentation, cleaning, granulation and environmental technology – has an energy responsible employee attached. This makes specialization possible and thus generates a larger outcome of the work with energy savings.

FACTS ABOUT NOVOZYMES

- The company's energy consumption globally was in 2014; 4188000 GJ = 1,163,000 MWh.
- The company has increased its energy efficiency with 43 % from 2005-2014.
- Energy efficiency was improved with 3 percentage points from 2013-2014.
- The company has reduced its carbon emission by approximately 56 % from 2005-2014.
- The company is focusing on reducing transportation e.g. by transporting more products at the time. Thereby energy consumption and carbon emission is kept at a minimum and at the same time lead to cost savings for the company.

Novozymes set a new operational energy and CO_2 target in 2014. Novozymes aims at reducing CO_2 intensity (measured as metric tonnes of CO_2 emissions per gross profit) of their operations by 25 % by 2020, compared with a 2014 baseline. This new target was framed in this manner to be consistent with climate science and the Sectoral Decarbonization Approach.

Expressing Novozymes' performance in terms of CO_2 intensity (where gross profits indicates the company's added value to the economy) will make their performance easy to communicate, understand and compare with sectoral peers. This science-based approach will enable Novozymes to understand their efficiency at reducing CO_2 emissions across business segments in a homogeneous, consistent and transparent manner.

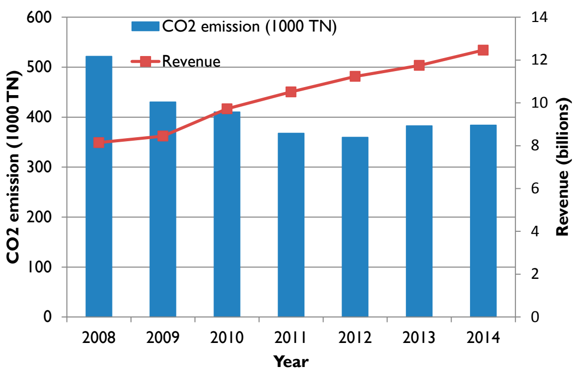


Figure 5. The turnover rises while the carbon emission decreases.

The production is an important priority

Working with energy savings for example means using LEAN that focusses on reduced energy consumption and minimized waste. Practically this for example means a focus on combining the right mixture of raw materials and enzyme producing microorganisms in smaller test facilities in order to determine the optimal recipe for how, the enzymes can gradually be produced large-scale at the same time ensuring most possible product per energy unit.

Waste water is used for energy generation

As a part of the agreement with the Danish Energy Agency and included in the effort to minimize waste from the enzyme production, Novozymes in 2010 committed to study whether the waste water from the enzyme production at the Kalundborg facility could be used for energy purposes.

Earlier the wastewater had been treated aerobically. However, this method meant that approximately 50 % of the organic content in the waste water was converted into sludge. Through the study it was documented that the waste water from the enzyme production could be treated in an anaerobic treatment facility. The method causes only 10 % of organic material in the waste water to be converted into sludge, while the remaining 90 % is transformed into methane; a gas that can be used to generate energy in the form of electricity and heat.

In 2013, Novozymes completed the implementation of the anaerobic wastewater treatment plant at their site in Kalundborg, Denmark. The biogas reactor utilizes wastewater to generate energy. When operating at full capacity, the reactor will cut costs and reduce CO_2 emissions by approximately 20,000 tons annually.

Energy savings in production methods

The actual production of enzymes takes place in large tank installations, which ensures the best capacity utilization and energy efficiency. The company works widely to obtain energy saving in both the actual production methods and in the energy supplies.

By using energy management and through the energy responsible employees the following steps have been implemented:

ACTIONS THAT SAVED ENERGY

- Excess heat from gas turbine has been reused to heat water for cleaning
- Replacement of process equipment using significant amount of energy with new and more energy efficient process equipment
- Temperature of liquid used for the cleaning of process equipment has been optimized
- Heat recovery from condensate had led to significant CO_2 and energy savings
- Cooling systems, compressed air system and machinery are optimized and attuned to the demands of the production
- Operators and technical staff are educated in energy efficient operation of the facilities
- The energy consumption of each batch is monitored, so key figures can be developed at an ongoing basis.

Even more energy savings using enzymes

In industrial processes even small amounts of enzymes can replace large amounts of chemicals, energy and water. Product analyses show that 1 kg of Novozymes enzyme on average results in 100 kg carbon reduction at the costumers, while it only costs less than 10 kg carbon to produce.

Novozymes estimates that customers avoided 60m tons of CO_2 emissions in 2014 by applying the products, the equivalent of taking approximately 25m cars off the road. This is an increase of 8m tons compared with 2013 and was driven primarily by increased sales and performance of solutions for biofuels, household care and textiles.

Case: Novo Nordisk

Novo Nordisk is a global healthcare company with 90 years of innovation and leadership in diabetes care. Headquartered in Denmark, Novo Nordisk employs approximately 40,000 employees in 75 countries, and markets its products in more than 180 countries.

In 2005 Novo Nordisk initiated a reinforced focus to optimize the energy consumption at its global production sites aiming at reducing global CO_2 emissions by an absolute 10 % below a 2004-baseline by 2014. The target equalled a relative reduction of approximately 65 %, based on the company's estimated growth. In 2006, Novo Nordisk became one of the first members of the WWF Climate Savers programme.

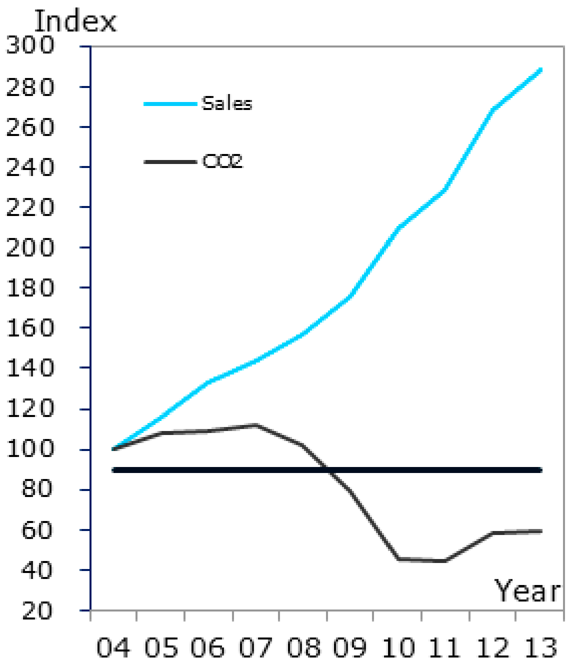


Figure 6. Development in sales and CO_2-emissions at Novo Nordisk 2004-2013.

Three levers should ensure the target for production sites:

- CLEAN® (Novo Nordisk version of LEAN).
- Specific Energy efficiency projects.
- Renewable energy.

All three levers have contributed to meeting the target in 2014 while at the same time sales have grown year on year. The combination of traditional energy reduction methods and LEAN has resulted in increased energy efficiency and less production waste:

- Energy efficiency and the relative energy consumption (kWh/ton product) have improved:
  - being able to produce more with less through various process optimisations
  - optimising utilities, incl. e.g. ventilation, cooling, illumination.
- Avoiding waste (lost product) by stabilizing processes and standards.

The integration of LEAN and energy efficiency was in 2004 proposed as an element under the Danish voluntary agreement scheme as a strong approach to accelerate improved energy efficiency in more complicated process areas – Novo Nordisk has been very successful in making use of LEAN tools in identifying energy savings and still see process (LEAN) optimisations as the main driver of energy efficiency.

Energy Efficiency Obligation Scheme for Utility Companies

Energy efficiency is not a strategic focus area in most industries. Therefore requirements to payback-periods of energy efficiency investments are usually strict: Often a payback period of 1– 2 years is the maximum acceptable and investments with longer time horizons are considered as risky.

Since 2006 a reinforced focus on energy efficiency in Denmark has included stimulating energy efficiency investments in end-user sectors in Denmark, including the industrial sector, via an "Energy Efficiency Obligation Scheme". The overall objective of the scheme is that utility companies – for electricity, gas, district heating and oil – are to help increase the savings efforts in all sectors (with some limitations in the transport sector). This scheme is a market oriented approach, where utility companies via the energy bill are allowed to recover the costs of the savings via the tariffs on the energy bills of the consumers. The utility companies involved are under an obligation to use these funds to identify and implement a certain amount of energy savings. The utility companies report their savings to the Danish Energy Agency via their branch organizations each year. There are no limitations regarding geographical areas, sector focus or energy sources from which energy savings can be reported.

The scheme was launched in 2006 with an annual target to implement energy savings of 2.95 PJ. This target, which has been raised gradually, amounts to 12.2 PJ per year from 2015 until 2020, equivalent of approximately 3 % of total final energy consumption in Denmark (without transport). The Energy Efficiency Obligation Scheme is based on the following principles:

- An agreement is entered between the Danish Minister of Energy, Utilities and Climate and distribution companies represented by the professional bodies within electricity, natural gas, oil and district heating regarding an annual obligation to implement and report energy savings.

- The professional bodies of the utility companies distributes the sector's target among the respective utilities (the energy saving obligation is in practice proportional to their annual energy sales) and the utilities shall document and the implemented energy savings.

- The utility companies are allowed to finance the costs to implement the savings via an extra cost on the energy prices to all consumers, late 2012 of the magnitude 0.06 Euro/kWh saved on average.

- Each obligated utility can choose a strategy for which measures to apply and report implemented energy savings, for instance:

    - To enter partnerships with external consultancy and affiliated service companies to deliver projects. These companies can e.g. provide advice at a reduced price or free of charge, provide subsidies or a combination.

    - To operate a subsidy scheme supporting energy efficiency investment projects.

- Each utility company shall annually participate in a benchmarking of costs related to operate the scheme – next to reported savings.

- In 2013 transportation was included as a sector but only a small number of predefined energy saving projects are allowed.

The scheme is anchored at utility companies because these are close to consumers and expected to play a broad and stable role as service providers in the future energy system. In order to promote cost-effectiveness the costs of the individual utility companies are available to the public.

One result of this scheme is that a comprehensive and widespread energy saving business has developed in Denmark over the past 10 years. In addition, new approaches, partnerships and financing mechanisms are continuously developed solely via commercial market mechanisms.

In figure 7 one can see the most used technologies to improve the efficiency and the development in the use of these technologies. It must be noted that there is much innovation within energy efficiency in Denmark and improvements in existing and new technologies but also how they can be applied happen continuously hence old technologies can be used again and create new savings.

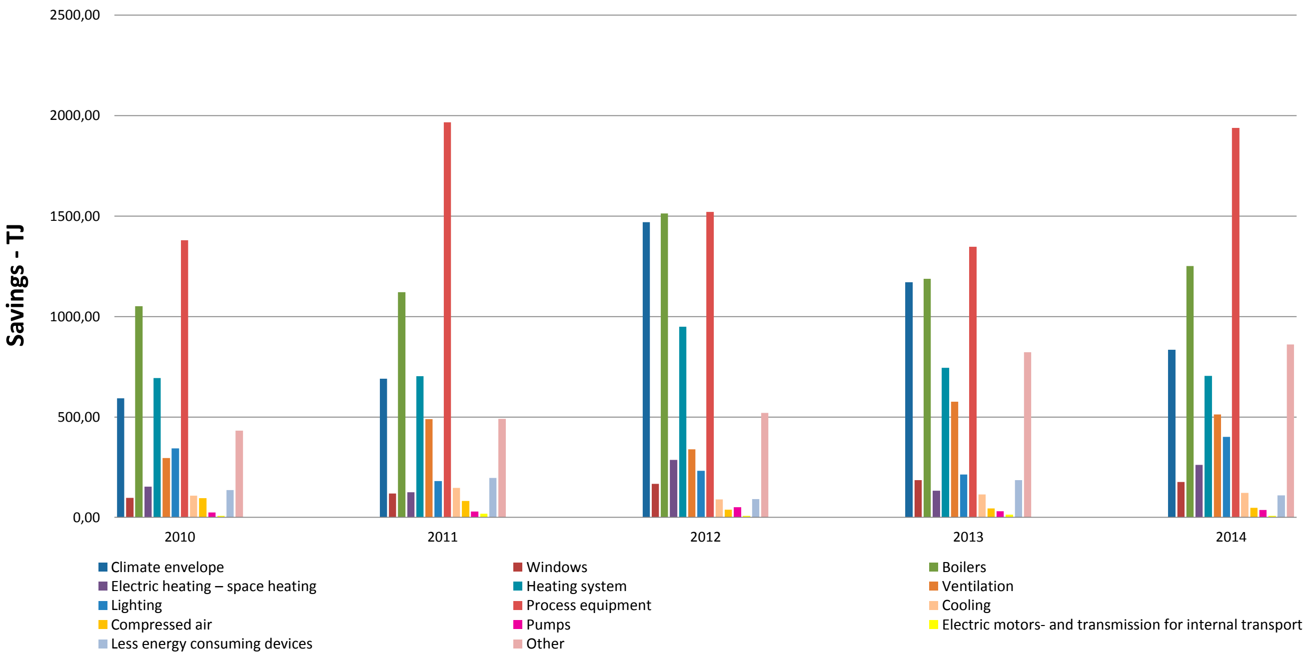


Figure 7. Development of savings found in different technologies

In annex D you can find a list of Danish companies and organisations working with energy efficiency.

An independent evaluation carried out in 2008 showed that the scheme is considered cost-effective, also when including the increase in costs to consumers.

The main principle is self-control. The utilities are responsible for verification, documentation and reporting and they must have systems for independent quality control and annual audits. The Danish Energy Agency carries out random control of documentation etc. on an annual basis.

The scheme makes a difference in decreasing Denmark's total energy use and an econometric analysis from an evaluation made between 2014 to 2015 showed that the net effect inclusive spill over effects can be up to 74 % in industries (it is not methodically possible to make the same analysis in households).

In table 3 below, planned and realized savings for each utility area for 2012 and 2014 are summarized.

(TJ/year)	Annual Target 2010–2012 (TJ)	Reported Saving 2012 (TJ)	Annual Target 2013–2014 (TJ)	Reported Saving 2014 (TJ)	Total
Electric utilities	2.900	4.412	4.500	3.212	7.624
Natural gas utilities	1.100	1.357	2.000	1.961	3.318
District heating companies	1.900	2.521	3.700	3.759	6.280
Oil companies	200	233	280	261	494
Total	6.100	8.524	10.480	9.193	17.717

Table 3. Reported savings (TJ) from the Energy Efficiency Obligation Scheme in 2012 and 2014

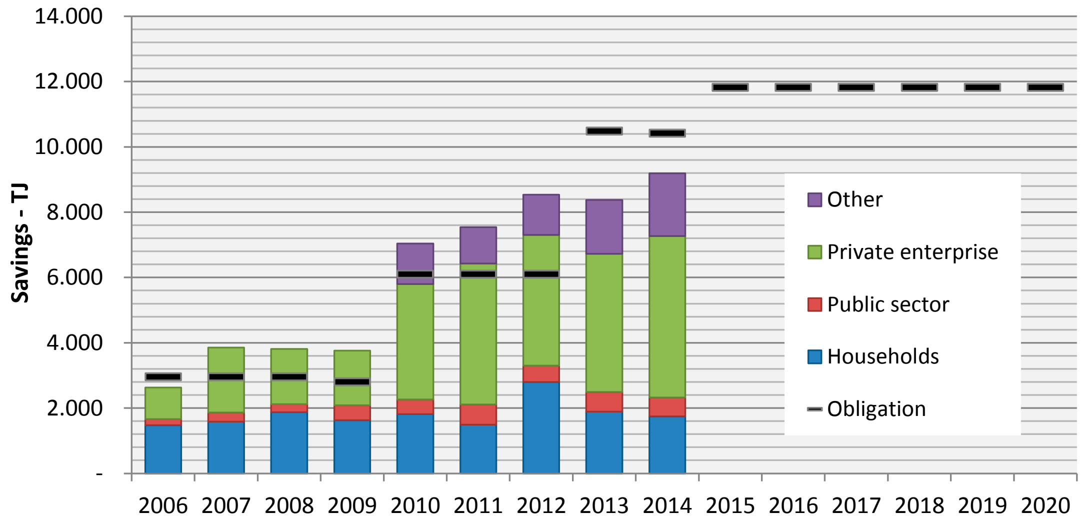


Figure 8. Reported energy savings 2006 – 2014 broken down by sector. The annual savings targets are shown by the black lines.

KEY

Key points and recommendations from the Danish case:

- Consider cost recovery through energy tariffs laid on consumers as a secure and stable way to finance energy savings.
- A subsidy scheme operated by competing independent bodies can be successful in stimulating development of an "energy efficiency market" and increasing cost-efficiency of a subsidy scheme.
- Closeness to consumers and knowledge of local conditions are important factors for successful implementation of the energy savings scheme.
- Independent control and benchmarking of a EEO scheme is important in order to minimize administrative costs and secure transparency of cash flows, among other aspects.
- Evaluation of a EEO scheme is important in order to assess additionality and adjust rules for how to operate the scheme.
- Close collaboration between the energy sector and government in the formulation and implementation of the agreement.
- Continues and targeted information about the agreement is important
- Keep the rules simple and build the system step by step.

Key Messages

Industries account for a fourth of global energy consumption and hold a great potential for cost-effective energy efficiency measures.

Energy efficiency has positive effects on human health, the environment, job creation, economic growth and also on the company's bottom line and its competitiveness. Despite of these benefits energy efficiency is not a strategic focus area in most industries. Therefore there is a need for governmental actions to initiate energy efficiency instruments. These instruments should be developed in collaboration with various stakeholders. The Danish case shows that formulating voluntary agreement schemes requires close dialogue with industrial experts to understand new agendas, challenges and methods for integrating energy efficiency measures.

Increased energy efficiency in the industrial sector is not about quick fixes. It is therefore necessary with a long-term perspective and a systematic working effort. A combination of measures with a carrot and stick approach should be applied to stimulate energy efficiency in industries.

Analyses of energy efficiency in production processes and utility systems can be both time-consuming and complex. These analyses must therefore be carefully planned and certified energy management schemes, such as ISO50001, can serve as foundation to systemize energy efficiency activities.

Surveys and platforms for sharing data are essential to get information about energy savings potentials and can further be used to prioritize activities. Concrete advice about solutions and energy savings measures can be both through broad information campaigns or efforts specifically targeted towards specific companies.

Responsible authorities should identify and encourage new methods and technologies regularly. These can be promoted though demonstration projects and the good example should be used to inspire and disseminate knowledge about energy efficiency measures.

Annex A

How policy can drive industrial energy efficiency across the globe

By Julia Reinaud, Policy and Programs Director, Institute for Industrial Productivity

This toolkit comes at a time when having effective energy efficiency policies in place for the industry sector couldn't be more important. How governments set the stage for industry to cut their energy use and reduce their greenhouse gas emissions is a measure of how committed they are to mitigating the threat of climate change.

Of course, energy efficiency policies do more than just help mitigate climate change. Improving energy efficiency brings with it a host of benefits to human health and the environment, generates jobs and drives economic growth. And enterprises stand to gain too by saving up to 10-30 % of their annual energy use, and increasing their productivity, through better energy management.

Energy efficiency, in fact, offers a win-win situation for all. And it's because of the benefits that virtually every country across the world now has energy efficiency policies in place specifically for industry, or is in the process of designing these policies for future implementation.

About the Institute for Industrial Productivity (IIP)

IIP is a non-profit organization that provides companies and governments with information about the best energy efficiency practices to reduce energy costs and prepare for a low carbon future. It identifies, analyses and shares best practices, tools and information that can boost efforts to reduce industrial energy intensity and greenhouse gas emissions while improving productivity.

Website: www.iipnetwork.org

Denmark's innovative approach and why it cannot be replicated in all countries

Denmark has been leading the way in energy efficiency policy for many years. Since Denmark introduced energy-saving agreements for large industrial firms in 1996, many other countries have followed suit. As early as 1999, Denmark made their energy management system standard the cornerstone of the agreement scheme. Here again, many countries followed the trend.[7]

Denmark stayed ahead by building an innovative, tailored policy package that matched the unique characteristics of its industry and provided both "carrots and sticks" for industry to become more efficient. Policies were also tailored for big and small industrial firms, recognizing that the latter do not have the same resources to be systematic in their approach to energy efficiency.

Taking stock of these efforts, Denmark has successfully stimulated companies to adopt energy management systems. It has created an enabling market for energy efficiency and built the capacity of energy manager practitioners.

Having studied energy efficiency policies across the globe in great detail, at IIP we are acutely aware that the key to success is for governments to understand both the constraints and drivers within industry, like Denmark has done. This is simply because there is no one policy package that can work for all countries. Each country has different economic, social and environmental priorities – and consequently, their policies must be different. China, for example, has energy efficiency policies that are mandatory and focused on technology, energy management and performance standards. While China's policies target the biggest industrial emitters, banks and energy service companies also have a role to play in meeting the country's energy conservation goals. In Australia, the government requires large companies to assess their energy efficiency potential and disclose the results to both the public and company shareholders. Voluntary agreements, like those in place in Denmark, have been applied in countries such as Ireland, Sweden, the US and the Netherlands, and each country provides a specific set of rewards or penalties in case of non-compliance. India, on the other hand, has relied largely on the trading of energy-saving certificates.

7. See IIP's energy management program database for more examples: iipnetwork.org/databases/programs

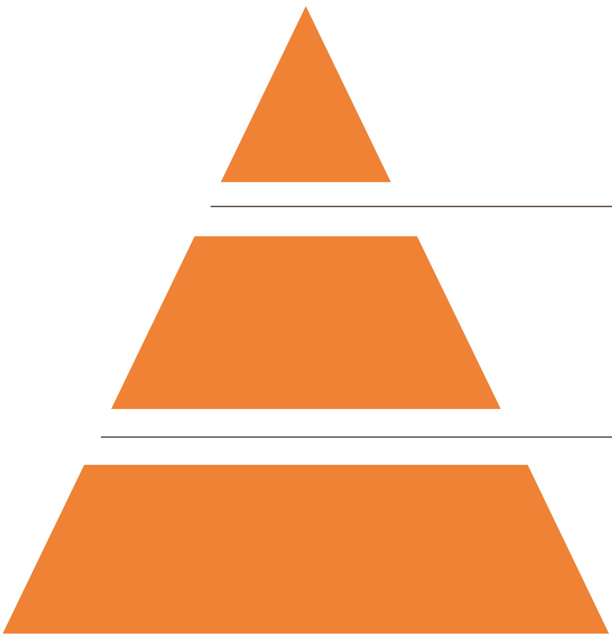
Effective policy packages: removing the barriers and stimulating the drivers

Despite the mix in policy approaches, many countries have battled with the same obstacles in their attempts to drive energy efficiency in industry. Many corporations tend to overestimate the risks of energy efficiency, underestimate the benefits, or believe that other drivers and factors can deliver a better value proposition to shareholders. These false beliefs have resulted in widespread reluctance by industry to invest in energy efficiency initiatives.

Policies, therefore, have had to focus determinedly on removing these barriers and driving industry to improve their energy performance.

To be effective, government-initiated energy efficiency policies and programs must have a combination of drivers, incentives and support mechanisms at their heart. These include policies that set the minimum bar for effort amongst industry, like targets and performance standards; supporting and enabling policies such as financial incentives; and tools and resources that help industry to create their own programs and measures to improve energy performance and learn from their peers. On IIP's online database, we have classified and organized examples of these policy types into a "Policy Pyramid" to demonstrate the connections between various policies, measures and implementation tools.[8]

As part of this set of policies, governments must also include measures that incentivize companies to continually identify energy efficiency opportunities. Systematic energy management has been perhaps one of the most effective approaches to capturing these potentials, and both companies and governments worldwide are now making great strides in this work. It was the Danish and Irish governments that were the first to drive the implementation of energy management programs (EnMPs) in firms. EnMPs have since been implemented by many other governments at the national and state/provincial level, as well as by big companies such as DuPont, BASF, 3M and Dow Chemical. 3M Canada achieved a 15.2 % energy performance improvement over two years because of its EnMS.



Effort-defining Polices

Interventions that motivate and drive energy efficiency, energy savings or GHG emissions reduction.

Supporting Measures

Carrot-and-stick policies that encourage action and address or alleviate barries.

Implementation Toolbox

Guidelines, tools, templates ect. that support the above policies.

Figure 10.

8. See IIP's policy database for detailed information on energy efficiency policies from around the world: iipnetwork.org/databases/policy

Is policy doing enough to overcome the climate challenge?

Even though many countries are working hard to increase industrial energy efficiency, there is still room to do more. International efforts to improve industrial energy efficiency have fallen well short of the potential 25 % reduction identified by the International Energy Agency. If it was realized, that potential would mean an 8 % reduction in global energy use and a 10 % reduction in global CO_2 emissions.

Of course, capturing this energy efficiency potential within the industrial sector is challenging. More could be achieved if countries were to mandate the implementation of energy efficiency measures in large industrial firms, as Denmark has done for those companies that have joined the agreements scheme and have identified measures with a payback below four years.

In the future, alternate and complementary channels should also have an increasingly important role in delivering energy efficiency. These include the contributions of third parties, such as energy providers, multinational companies, multilateral and commercial banks and industry associations, many of which have already started initiating large-scale energy management programs. Utilities, in particular, play a key role in driving energy efficiency in industry and other sectors. As we've seen in the case of Denmark and in the US, utilities can help drive the uptake of international standards, such as ISO 50001. This could have even more success if large buyers used their knowhow to stimulate, or even demand, better energy performance from their suppliers.

We also see a significant opportunity to scale public-private collaboration across the world. Denmark has proven that this model works, especially by engaging utilities, industry associations and energy service companies to participate in the national effort.

It's clear that a lot has been achieved in energy efficiency policy around the world over the past decade, but the next ten years will perhaps be the most important. While government plays a vital role in driving industry to change, that transformation must also come from industry itself – whether in Denmark or elsewhere. And by doing so, all parties stand to gain – whether it's preserving the environment, strengthening the economy, or improving the bottom-line.

About Julia Reinaud

Julia leads IIP's policy activities and programs, managing the Paris team as well as overseeing technology and communication projects undertaken at the global level. Julia was previously an energy and climate policy analyst at the International Energy Agency, working on climate, trade and energy policy issues. She has a PhD (with distinction) in Economics and Industrial Organization and a Masters in Corporate Strategy and Industrial Organization from University Paris Dauphine. (Julia Reinaud is now Senior Advisor for the European Climate Foundation.)

Annex B

Example of Technical Approach

The "Onion" diagram illustrated below acts as tool to address all relevant areas of energy efficiency for an industrial company.

Each layer of the diagram addresses specific issues of a certain kind. Preferably the work-flow should be "inside-out":

- The "**energy service**" is the core reason why energy is required for a specific area or process. For example, an "energy service" can be a "clean room" or a required "duration of a cleaning process (CIP/SIP)" in a pharmaceutical facility.
  The "energy service" can always be challenged. For example, in case it is necessary to maintain a very high air change rate in the "clean room" – can the reasons why the room is not clean be isolated, reduced or removed?

- The "**process**"-layer is the type of process selected to achieve the energy service. For example the most commonly used "process" to achieve a clean room is "filtration of air using filters with high air change rate". Also the "process" selected to achieve a certain "energy service" can be challenged. For example, "filtration of air" and air circulation with a high level of air change (and thereby high energy consumption) can be replaced by ventilation principles with lower air change rates or other more energy-efficient solutions while ensuring the air quality necessary for clean rooms.

- The "**equipment**"-layer deals with the type and efficiency of the equipment to be installed in order to fulfil the "process". Numerous aspects can be optimized in large HVAC systems for clean rooms. These include the degree of recirculation of air, the type and efficiency of heat recovery, the efficiency of fan installation (Specific Fan Power, SFP), etc.

- The "**control**"-layer deals with the accuracy of control systems required to optimise plant operation in order to minimise energy consumption when loads vary and the demands for the "energy service" change. Variable Speed Drive control and selection of bandwidths for temperature and humidity will also be important areas to analyse when designing an energy-efficient control strategy for HVAC systems, for example. Often, KPIs must be established to ensure that control strategies are operating correctly.

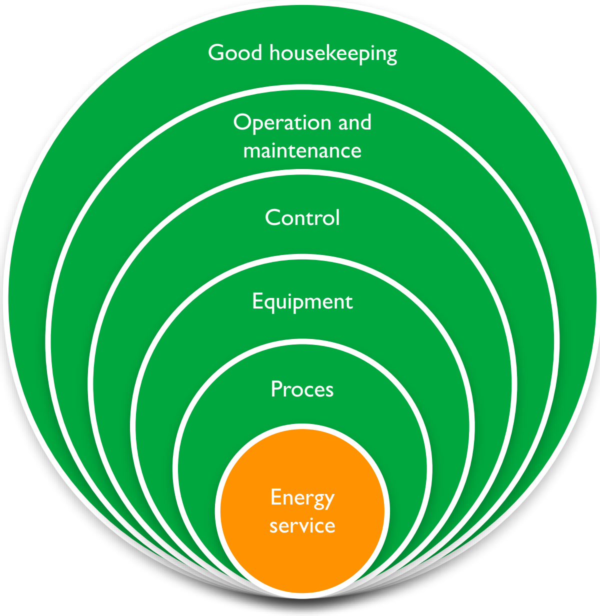


Figure 11. he "Onion" diagram.

- The "**operation and maintenance**"-layer must ensure that all utility systems and process equipment have a structured maintenance plan to ensure that the energy efficiency conforms to the level established at the design stage.
  For example, experience has shown that regular cleaning of heat exchangers is often not implemented in many sectors. The result is that energy efficiency of carefully designed utility systems and heat recovery systems (all with low delta Ts) is significantly impaired over time.

- The "**good housekeeping**" layer comprises a wide variety of focus areas to ensure that a facility is operated for optimum energy efficiency.
  Although housekeeping procedures can comprise basic instructions such as switching off lights when leaving an empty room, areas like operator training related to cleaning stations (CIP) and production processes are much more significant factors for the energy-efficient operation of a facility.

An energy-saving analysis based on the "onion" diagram can often identify significant energy saving potentials in a facility. Difficult issues will often be raised, which might make it necessary to involve various parts of the organization. For instance, the Quality Department often has significant influence on production parameters and product quality.

CASE

An example of the use of the "Onion" diagram for an autoclave system is shown in Figure 9 below. The autoclave is designed for the sterilization of small "stents" to be inserted into the human body during surgery. After production the stents are placed in a plastic bag with sterile water, and the bag is placed on a tray in an autoclave for heating to 120C for 50 minutes. After removal from the autoclave, the bags are manually put in boxes and sent to hospitals for use during surgery.

To operate the system a large steam boiler station delivers heat to the autoclaves, and a compressed air system maintains a stable pressure in the autoclaves to prevent the bags from exploding when heated to 120 °C (above the atmospheric boiling point for water at 100 °C).

An "Onion" analysis of this design reveals numerous and significant energy saving opportunities that can be taken into consideration during the planning and design stages of a new autoclave system:

Energy service

The energy service (the core reason why energy is used) is obviously designed to "kill" bacteria on the stents, so that they remain sterile when unwrapped during surgery in a hospital. However, good design practice will also address the following issues:

- It does not appear logical that although they are sterilised in the production facility the stents are subsequently packed manually in a non-sterile environment. Therefore it should not be necessary to sterilise the plastic bags in the production process when, in reality, the bags are re-sterilised during surgery?
- Furthermore, it does not appear logical that sterile water is used when filling the bags because in reality this water is sterilized 3 times when also taking the sterilisation in hospital into account.

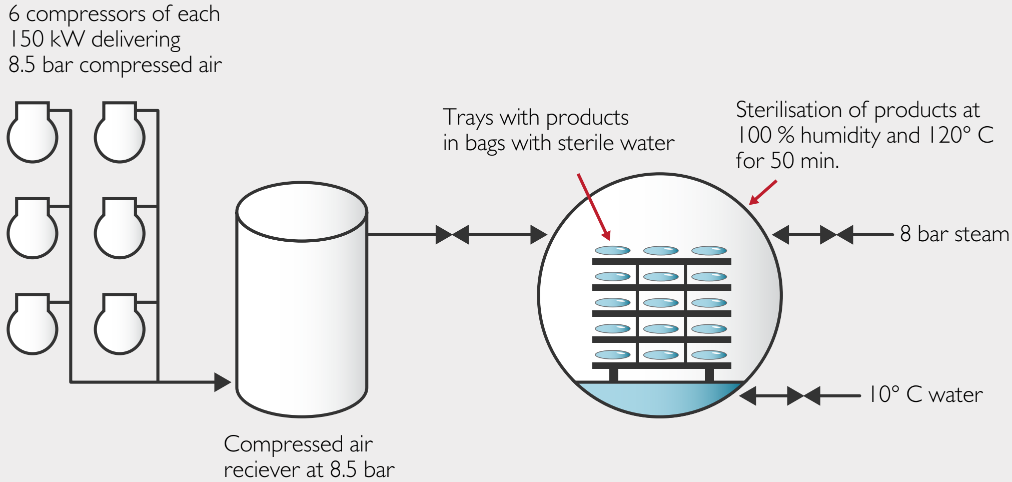


Figure 12. Autoclave for sterilisation of healthcare products

Process

The product developers and the clients in this example have chosen a process in which the stents are sterilized by thermal treatment in a bag filled with sterile water. Nonetheless, alternative processes can be considered:

- For example, it might be possible to use other and possibly more energy-efficient sterilisation methods such as chemical sterilisation, microwaves, X-rays, vacuum packed tubes, etc. This is a "delicate" question to raise during a design process, but nevertheless crucial when evaluating the efficiency of the overall process from an **energy point of view.**

Equipment

Once the decision has been made to use thermal sterilisation as the preferred process, alternative methods could be evaluated. Alternative methods could be:

- Hot water or warm air system. Hot water sterilisation is widely used in the food industry; however, mostly at temperatures below 100 °C, which means that systems do not have to be pressurized. The advantage of a hot water solution is that the heat from sterilisation can be recovered relatively easily. This allows the heat supplied for one batch to be recovered and used for the next batch, thereby keeping thermal energy consumption at an absolute minimum. This is not possible with a steam-based system, which means that energy consumption will be at least 50 % higher.

Control

The control of the process aims to ensure that all bags reach their target temperature of 120 °C for a period of 3 minutes or more. Digital tags are placed on each tray so temperatures can be logged and products can be traced after production. Nonetheless, important process parameters can be considered:

- The sterilisation time of 50 minutes is very high when compared to the required 3 minutes. For that reason it is realistic to ask whether the process design and control system can be improved. Actually, a pressurized hot water system as proposed above would ensure a better heat transfer. This would allow for a shorter process time.
- The compressed air pressure of 8½ bars is significantly higher than the boiling pressure in the plastic bags of approximately 2.1 bars. This results in very high power consumption by the compressed air plant. Power consumption by the compressed air system can be reduced by more than 70 % if the system is designed to operate at a pressure closer to what is needed by the process. Another benefit is that a much smaller compressor station could be installed, thereby reducing the investment costs.

Operation and Maintenance

The main questions related to operation and maintenance of the system is how leaks of air and heat can be avoided and how the idle load of compressors and boilers can be kept at a minimum.

- It is essential that the system is delivered with ready-to-use maintenance instructions to cover areas such as leak detection etc. Enquiries should also be made to see whether monitoring systems (e.g. air meters, steam meters, etc.) can be used to provide information about key aspects of the process.

Good Housekeeping

Recommendations regarding "good housekeeping" are usually more generic. However, since these often influence operator behaviour, they can have a significant impact on energy efficiency.

- In the autoclave system, several aspects relating to operator behaviour can be questioned, including: how are autoclaves managed (filling, venting, cleaning), etc.?

Many of the questions above might be complicated or time-consuming to answer – and answers might necessitate involvement of different parts of the organization (for example the Quality Assurance department, process specialists, manufactures, costumers).

But it is the experience that the "onion" diagram is a strong and systematic methodology covering all relevant aspects of the energy saving potentials; even in complicated processes and utility systems.

Its methodology is also highly recommended when designing new industrial facilities. Numerous demonstration projects have been implemented in this area in Denmark.

Annex C

ISO50001 Fundamentals

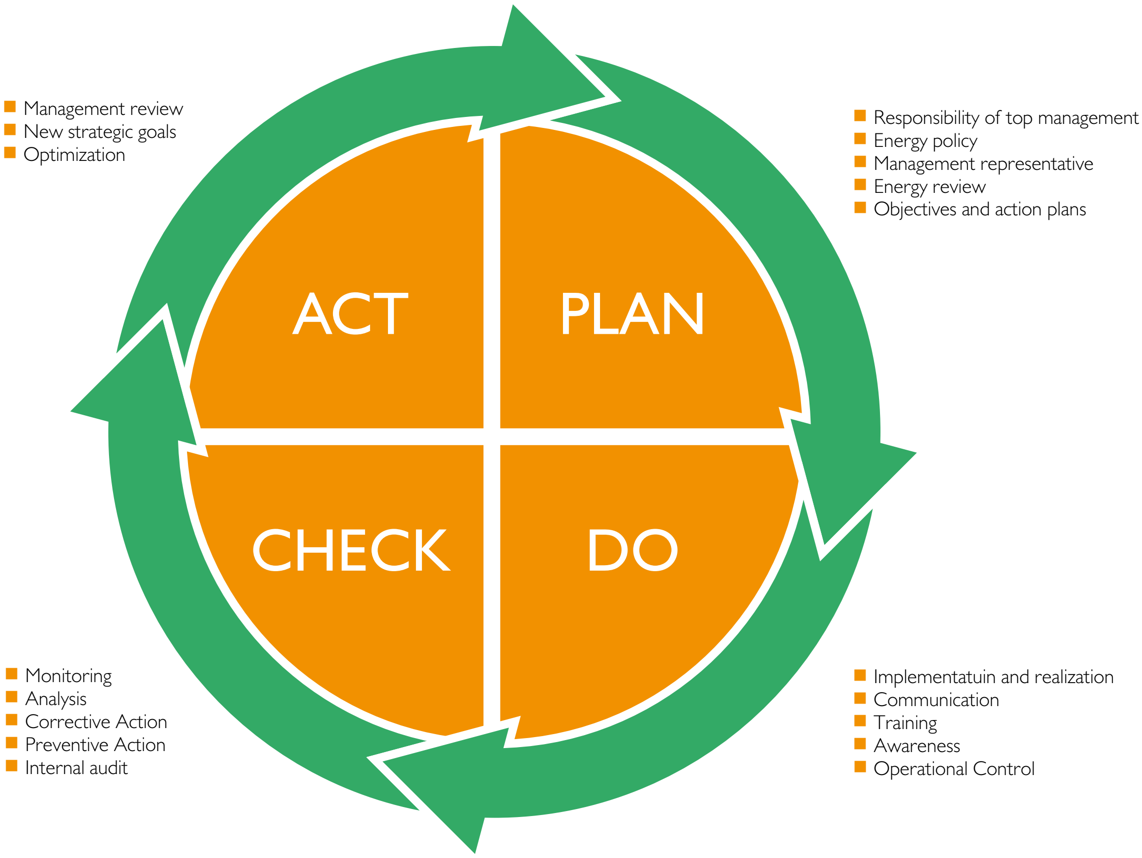


Figure 13. The cyclic "plan-do-check-act"-energy efficiency work in an organization.

The ISO50001-standard has been adopted worldwide and is thoroughly described in standards in each individual country. In figure 13, the overall activities covered by each phase of the cyclic "plan-do-check-act"-energy efficiency work in an organization are outlined.

The standard describes which procedures and work principles to follow. They are not precise in terms of how to carry out, for instance, an energy review; or how to establish the right energy performance indicators (EnPIs) to monitor energy consumption.

According to Danish experiences, a standard like ISO50001 will not be enough to secure quality of energy efficiency work in a large energy-intensive industry. The standard should therefore be supplemented by guidelines and requirements for which actions to take.

In the Danish voluntary agreement scheme, the Danish Energy Agency set as a key-requirement to implement working principles from ISO50001, but next to that, the agreement scheme sets additional requirements for how to carry out various tasks; for example:

› Energy usage should be presented in breakdowns of a certain level of detail (by end-use).

› Energy saving projects are to be identified by saving potential and payback periods.

› All energy saving investment projects with pay-back less than 4 years must be implemented.

› Complex energy saving analysis must be nominated as "special investigations" and carefully planned.

› New investments should be planned following a guideline on "Energy Efficient Design".

The accredited companies verifying the agreements in each individual case evaluate both ISO50001 procedures and progress of the specific requirements listed above.

Energy Management "light"

It must be emphasized that energy management according to ISO50001 sets quite comprehensive requirements for procedures and evaluation forms. Therefore such an approach is not suitable for all organizations. Especially companies in the SME segment have relatively few competences in such areas and should apply more simple approaches.

In view of this, the Danish Energy Agency together with Danish Standards has prepared an energy management "light" guide for SMEs, where basic principles and activities are described (in Danish). In addition to this overall guide, more general and shorter guides, addressing SME in specific sectors, e.g. the hospital sector have been developed.

- In that respect, the energy management "light" system is not a certified scheme, but recommends an organization to address the cornerstones of an efficient energy management system, i.e.:
- To define a target for the energy saving effort.
- To organize the right team for the effort.
- To map energy consumption.
- To elaborate an action plan.
- To establish relevant EnPIs to monitor energy consumption.
- To let management evaluate progress regularly.
- To establish simple annual procedures to follow.

Besides SMEs, the energy management "light" principles has been adopted by many energy users in widely different sectors. These include municipality buildings, large offices and hospitals, among others.

Annex D

Danish companies and organisations within energy efficiency

Energy efficiency has been on the agenda in Denmark the last four decades. The strong focus on using energy more efficiently has also fostered many highly skilled companies and organisations within the sector. State of Green which is your online entry point for all relevant information on green solutions in Denmark and around the world, have gathered a list of these companies or organisations working within energy efficiency. In the link after the name you can explore solutions, learn about products and connect with companies and organisations.

ABB (http://stateofgreen.com/en/profiles/abb)

AKJ INVENTIONS (http://stateofgreen.com/en/profiles/akj-inventions)

ALECTIA (http://stateofgreen.com/en/profiles/alectia-a-s)

ALFA LAVAL (http://stateofgreen.com/en/profiles/alfa-laval)

ALTIFLEX (http://stateofgreen.com/en/profiles/altiflex)

AMPLEX (http://stateofgreen.com/en/profiles/amplex)

ATEA (http://stateofgreen.com/en/profiles/atea)

ATKINS DANMARK (http://stateofgreen.com/en/profiles/atkins-denmark)

BA SYSTEMS (http://stateofgreen.com/en/profiles/ba-systems)

BRÜEL & KJAER VIBRO (http://stateofgreen.com/en/profiles/bk-vibro)

BRUNATA (http://stateofgreen.com/en/profiles/brunata)

CENERGIA (http://stateofgreen.com/en/profiles/cenergia-energy-consultants)

CLIMAWINTECH (http://stateofgreen.com/en/profiles/climawintech)

CONDAIR (http://stateofgreen.com/en/profiles/condair)

CORE (http://stateofgreen.com/en/profiles/core)

COWI (http://stateofgreen.com/en/profiles/cowi)

DACS (http://stateofgreen.com/en/profiles/dacs)

DANFOSS (http://stateofgreen.com/en/profiles/danfoss)

DANISH ENERGY MANAGEMENT (http://stateofgreen.com/en/profiles/danish-energy-management)

DANISH RENEWABLE ENERGY (http://stateofgreen.com/en/profiles/danish-renewable-energy)

DANISH TECHNOLOGICAL INSTITUTE (http://stateofgreen.com/en/profiles/danish-technological-institute)

DANTHERM AIR HANDLING (http://stateofgreen.com/en/profiles/dantherm-air-handling)

DEVELCO PRODUCTS (http://stateofgreen.com/en/profiles/develco-products)

DONG ENERGY (http://stateofgreen.com/en/profiles/dong-energy)

EC NETWORK (http://stateofgreen.com/en/profiles/ec-network)

EKOLAB (http://stateofgreen.com/en/profiles/ekolab)

EMD INTERNATIONAL (http://stateofgreen.com/en/profiles/emd-international)

ENOPSOL (http://stateofgreen.com/en/profiles/enopsol)

EXHAUSTO (http://stateofgreen.com/en/profiles/exhausto)

EXODRAFT (http://stateofgreen.com/en/profiles/exodraft)

FAKTOR 3 (http://stateofgreen.com/en/profiles/factor-3)

FISCHER LIGHTING (http://stateofgreen.com/en/profiles/fischer-lighting)

GÖRLITZ LUKIA (http://stateofgreen.com/en/profiles/goerlitz-lukia-a-s)

GREEN LAB FOR ENERGY EFFICIENT BUILDINGS – GLEEB (http://stateofgreen.com/en/profiles/green-lab-for-energy-efficient-buildings-gleeb)

GREEN TECH CENTER (http://stateofgreen.com/en/profiles/green-tech-center)

GREENWAVE SYSTEMS (http://stateofgreen.com/en/profiles/greenwave-reality)

GRIDMANAGER (http://stateofgreen.com/en/profiles/gridmanager-a-s)

GRONTMIJ (http://stateofgreen.com/en/profiles/grontmij)

GRUNDFOS (http://stateofgreen.com/en/profiles/grundfos)

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SCANENERGI SOLUTIONS (http://stateofgreen.com/en/profiles/scanenergi-solutions)

SCHNEIDER ELECTRIC (http://stateofgreen.com/en/profiles/schneider-electric)

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SIEMENS (http://stateofgreen.com/en/profiles/siemens)

SIMSERVICE (http://stateofgreen.com/en/profiles/simservice-a-s)

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ZAPHEAT (http://stateofgreen.com/en/profiles/zapheat)

Danish Energy Agency

The Danish Energy Agency is responsible for handling all national and international agreements and tasks linked to the production, supply and consumption of energy in Denmark. The Agency also deals with efforts to reduce emissions of greenhouse gases, and oversees the legal and political frameworks for reliable, affordable and clean supply of energy in Denmark.

The Danish Energy Agency's Global Cooperation collaborates with China to combine sustainable future energy supplies with economic growth. The initiative is based on four decades of Danish experience with renewable energy and energy efficiency, transforming the energy sectors to deploy increasingly more low-carbon technologies.

The agency is part of the Danish Ministry of Energy, Utilities and Climate.

Read more at:
www.ens.dk/en/policy/Global-cooperation

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Read more at:
http://stateofgreen.com/en/sectors/energy-efficiency.