LOW CARBON SOLUTIONS FOR THE FOOD INDUSTRY

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Abstract

Globally seen, the agro-food sector is one of the great emitters of GreenHouseGases. Starting with agriculture, considering the transport, the processing and the retail, there are hundreds of options to reduce emissions to air, water and soil.

Most processes in food industry take place at a rather low temperature below 100°C and at moderate pressures. This situation offers possibilities for solar thermal heating and the utilization of waste heat. The large amounts of organic waste in the whole chain imply potentials for biogas processes, as often as possible combined with a cogeneration of heat and power. Large amounts of energy in the agro-food sector are used for storage, cooling and freezing; here as well are possibilities for energy efficiency and the use of renewable energy. Taking also into account the energy efficient options for transport and the possibilities of reusing water from the production processes for irrigation, the whole system starts to be sustainable.

Putting all these options together, one ends up with a low-carbon agro-food system, which in an optimal constitution ends up in a Zero-Emissions Agro-Food system.

Keywords

Food industry, biorefinery, low carbon, agriculture, process integration

1. Introduction

Amid growing concerns about climate change and long-term petroleum reserves, the food system looms large as a major user of fossil fuels and, as a result, producer of greenhouse gases (GHG). Indeed, these twin problems may be the significant drivers that catalyze change in the food system in the 21st century.

A Low Carbon Society was defined as one that will make an equitable contribution to the global effort of reducing greenhouse gases to a safe level combining both a high level of energy efficiency and security. The results of various studies demonstrated that reducing global carbon emissions by 50% is technologically and economically feasible. Energy efficiency, consumer responses and the choice of technologies for electricity generation play crucial roles in cutting CO_2 levels. Reduction in this order of magnitude are not possible through technological improvements alone, there is a need for structural and attitudinal changes.

There are different possible pathways to a low carbon economy. Clearly, no single measure or technology will suffice, and the precise mix in each country will depend on the particular combination of political choices, market forces, resource availability and public acceptance. To achieve Low Carbon Societies, all countries need innovations in their lifestyle, production and consumption patterns, and social infrastructure in addition to technological innovations.

For industry, the main possibilities for the reduction of GHGs will be:

- Increased efficiency in the conversion processes with an emphasis on cogeneration
- Process intensification and heat integration
- Zero-energy design for factory and administrative buildings
- A shift in energy resources from fossil to renewables
- Use of industrial waste heat for general heating purposes outside the company (regional heating systems)

2. STRATEGIES TOWARDS LOW CARBON ECONOMIES

"The term 'low carbon economy' boils down to functioning in an economy that can sustain itself within the earth's carbon limits. It is the solution to climate change, mainstreaming low carbon outcomes into all facets of life,… .

The building blocks encompass two elements. The first is the technical fix; aspects such as energy generation will be regional specific. The second element is the cultural solution: the way our communities and economies are built and interact." (Jenner K, 2006)

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There are various possible pathways to a low carbon economy. Clearly, no single measure or technology will suffice, and the precise mix in each country will depend on the particular combination of political choices, market forces, resource availability and public acceptance. The implementation of a Low Carbon Society will involve the deployment of low carbon technologies and changes of social models and lifestyles. It will require early target setting across all economic activities. Developing countries' transition to a Low Carbon Society must go in hand with their projected economic growth. Here, international co-operation is required to mobilise the necessary finance and technological expertise.

The emphasis in the technology debate should be placed not only on mitigating and adapting to climate change but also on sustainable human development and, in particular, on poverty alleviation. Low-carbon technology should therefore be celebrated as a means by which countries can address human needs and reduce poverty, develop new economic opportunities and markets and create good quality jobs (Global Climate Network 2009).

Several countries already developed a plan for a transition to a low carbon society (e.g. UK and Japan). Figure 1 illustrates how in Japan a 70% reduction goal should be achieved. (NIES 2008). This study shows quantitative roadmaps for introducing countermeasures and policies for reducing CO2 emissions by 70% until 2050 compared to the 1990 level in Japan. This study analyses roadmaps for reducing CO2 emissions by 70% by 2050 minimizing the total cost from 2000 to 2050 while satisfying the future service demand assumed in two scenarios. A list of 600 options (around 400 technological countermeasures and 220 policies) was prepared. The period necessary for implementation and the expected costs were assessed based on literature reviews, expert judgments, and market surveys. For all sectors the analysis follows three guidelines:

- Reduction of service demand
- Improvement of energy intensity
- Improvement of carbon intensity.

Figure 1 illustrates the sectoral contribution (including a small share from CCS) of the three guiding principles in order to achieve the 70% emission reduction goal.

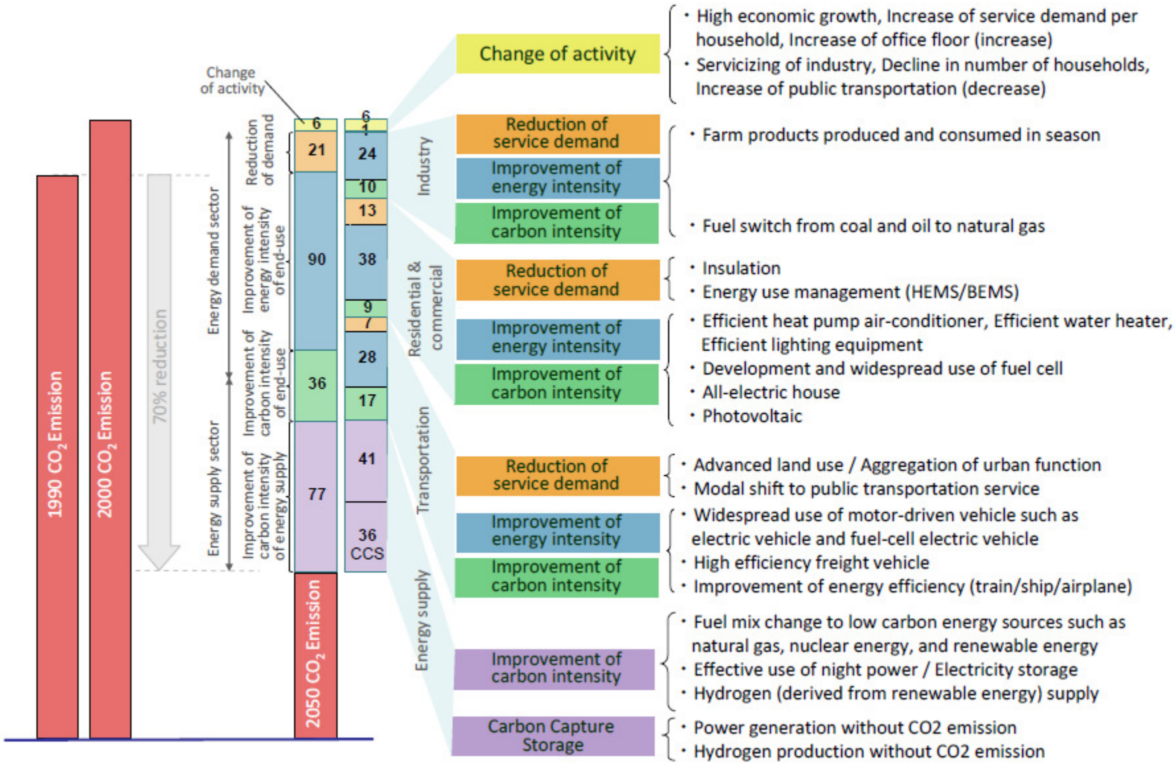


Figure 1: Strategy for a 70% reduction of CO_2-emissions in Japan till 2050 (National Institute for Environmental Studies, 2008

3. The relevance of the agro-food sector to climate change and pollution

Food processing industry is interlinked with agriculture and regional development. On the one hand it plays an important role in the economic development of every country. On the other hand there is general agreement that production, processing, transport, and consumption of food accounts for a significant portion of the environmental burden imposed by any countries around the world. In food-processing sectors solid waste is normally the primary area of concern due to its huge amount. Additionally solid waste from food-processing plants is especially high in nitrogen and phosphorus content. Beside solid waste, wastewater is considered as the second part of caused environmental pollution. Although the food processing industry has the large amounts of wastewater discharged, wastewater is characterized as non-toxic, only contains few hazardous and persistent compounds. Generally a strongly growing food processing industry greatly magnifies the problems of waste management, pushing the management of waste streams as well as pollution to the forefront of environmental challenges.

Food processing companies and farms are a great consumer of fresh water. Although irrigation is necessary in many areas, the utilisation of treated waste water is rather unusual.

The same is true for the recycling of minerals from biological wastes as a fertilizer to the fields. Uncontrolled deposit of organic waste can significantly contribute to pollution of ground waters and rivers.

More than this, the food industry contributes directly and indirectly to global warming. The emissions from the supply chain have to be considered as well

Agriculture

Agricultural lands occupy 37% of the Earth's land surface. Agriculture accounts for 52% and 84% of global anthropogenic methane and nitrous oxide emissions. Agricultural soils may also act as a sink or source for carbon dioxide (CO_2), but the net flux is small. Many agricultural practices can potentially mitigate greenhouse gas (GHG) emissions, the most prominent of which are improved cropland and grazing land management and restoration of degraded lands and cultivated organic soils. Lower, but still significant mitigation potential is provided by water and rice management, set-aside, land use change and agro-forestry, livestock management and manure management (Smith 2007).

The main GHG-emissions in agriculture origin from the fertilizers used and from the fuels for the machinery, but also from the land use change. In some cases there might be first treatment operation already at the farm, like silage or crop drying, causing GHG-emissions there. Significant CH_4 emissions come from cattle growing (ruminant animals) and from rice fields. Large N_2O emissions origin from fertilized soil.

Processing

The processing of agricultural products to food is resource intensive. Water and energy are needed in high quantities and qualities. Most of the processes need only low temperature heat. For cleaning, pasteurization, cooking, blanching, drying and most other operations in the food industry, no temperatures above 100°C are necessary. Pasteurization might be one of the only processes above 100°C. Due to the low temperatures heat can easily be provided from renewables or waste heat from cogeneration plants (gas engines). The food and drink industry is one of the main users of refrigeration.

For many businesses refrigeration costs can account for up to 50% of all electricity used on site. New legislation in Europe will mean businesses using refrigerant R22 (an HCFC) in their systems will need to replace them before 2010 when they are due to be phased out under EU regulations on ozone-depleting substances. The potential for large environmental damage from refrigerants is clear: 1kg of refrigerant R134a has a global warming potential 1,300 times greater than that of 1kg of CO_2, so any small leakage through failure to maintain equipment could reduce the environmental benefits of CO_2 energy-efficiency.

Packaging

Packaging fulfils an important role in our lives. It protects food and other goods on their journey from farm or factory via warehouses and shops until they arrive at homes, offices or wherever they are used. The key role of packaging is to avoid spoilage and damage in the supply system and in the home. And yet, recent surveys show that consumers believe packaging is the top environmental problem in relation to the products they buy. Alongside addressing these concerns, packaging policy needs to contribute to greater resource efficiency and the fight against climate change, as part of the wider goal to reduce the overall environmental impacts of our supply chains.

Plastic bags are a severe environmental problem in many developing countries. Using only bio-materials for centuries, many people are not aware of the persistence of industrial polymers in the environment.

Transport and storage

For the food sector transport is a key issue, since a number of losses in quality and amount takes place here. Improving transport is important for the economic and social development in developing countries. Transport provides access to markets, jobs, education, and health care. Air pollution from motorized transport is still responsible for the premature death of thousands of people and is estimated to cost about at least 1% of GDP in many of the Asian cities. Transport-related carbon dioxide emissions (CO_2) emissions are expected to increase 57% worldwide during 2005–2030, and transport in developing countries will contribute about 80% of this increase. Most of the current greenhouse gas emissions in the transport sector and virtually all the expected growth in emissions come from private cars, light duty vehicles, and trucks.

Retail and wholesale

Retailers are at the end of the supply chain, it consists of the sale of goods or merchandise from a fixed location, such as a department store, boutique or kiosk, in small or individual lots for direct consumption by the purchaser. In retail stores the main energy consumption, and thus the main emissions of GHG origin from cooling and lighting. Depending on the geographical situation, also heating might be of relevance.

Consumers

Consumer's behaviour might have the most significant impact on the emissions of GHGs in the whole food chain. Although this might not be a technical issue, it should be mentioned here. The agro-food sector has to provide enough and healthy food for world's population, but at present, the global distribution is uneven in many aspects. Statistics say that 14% of the word population is starving while 24% of the adults are overweight. A global transition to a low met-diet (as also recommended for health reasons) would help to reduce the mitigation costs to achieve a 450 ppm CO_{2eq} stabilisation target by about 50% in 2050 compared to the reference case (Stehfest, 2009). Apart from a reduction in methane and N_2O emissions, vast agricultural areas would become unused, mostly as a result of reduced cattle grazing, and could take up large amounts of carbon. Shifting worldwide to a healthy low-meat diet would reduce the costs of stabilising greenhouse gases at 450 ppm CO_2 eq. by more than 50%.

4. Low Carbon Approaches in the Agro-Food sector

Figure 2 shows the most important units in an agro-food system including some low-carbon options through the utilisation of solar technologies and the conversion of organic residues into energy carriers.

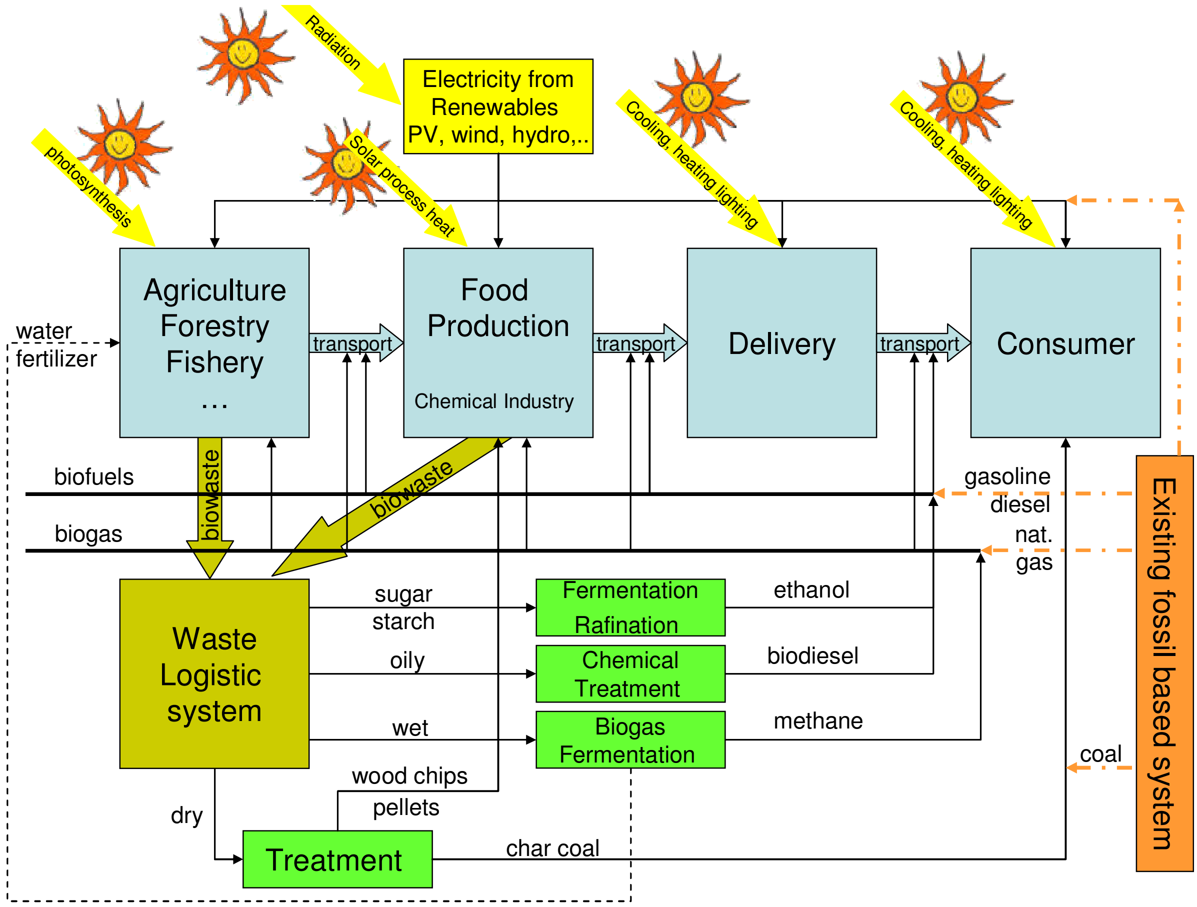


Figure 2: The food system in a low-carbon design

The food industry, one of the most carbon-intensive in the world, is by far the largest indirect contributor to GHG emissions. The figures given by http://www.lowcarbonlife.net suggest that producing and distributing food creates over five times the volume of the most energy-intensive manufacturing industry: iron and steel. This isn't just about the carbon costs of transporting foodstuffs. The whole chain of supply is a huge user of fossil fuel from fertilizer on the fields to customers' cars going to supermarkets. This chapter suggests that the food industry in developed countries adds over 2 tonnes of greenhouse gases to the individual's total emissions every year, or about one sixth of the total. This figure may actually be too low, since it excludes the carbon dioxide and methane emitted by the soil in intensive agricultural systems. This is still higher than some estimates: a recent UK government study put the total at 8 per cent of the UK's energy needs, but omitted consideration of fertilizer production, packaging costs and methane from cows, though it does include the costs of running supermarkets.

Significant industries are often locked into levels of carbon use inconsistent with CO_2 reduction needs, e.g. steel industry, cement, housing stock, food industry. In such cases, minor alterations –e.g. to price regime –will not be enough to bring about change of speed and magnitude required. Addressing "lock-in" requires change at the regime level, not simply "business as usual" changes.

Agriculture

The highest mitigation potential is expected from:

- restoration of cultivated organic soils,
- improved cropland management (including agronomy, nutrient management, tillage / residue management and water management (including irrigation and drainage) and set-aside / agro-forestry
- improved grazing land management (including grazing intensity, increased productivity, nutrient management, fire management and species introduction, and
- restoration of degraded lands (using erosion control, organic amendments and nutrient amendments.

Lower, but still substantial mitigation potential is provided by:

- rice management, and
- livestock management (including improved feeding practices, dietary additives, breeding and other structural changes, and improved manure management [improved storage and handling and anaerobic digestion].

An underestimated potential so far might be the utilisation of organic residues as resources for chemical products and fuels. Recently, European researchers have analysed the potential of different options for mitigating greenhouse gas emissions from dairy production in Europe. The most cost-efficient measures are those that simultaneously reduce emissions of several greenhouse gases from the whole production chain, such as biogas production. The researchers identified considerable possibilities for emissions reduction in the dairy farming industry. Biogas production from anaerobic digestion of the produced manure could be a very efficient and cost-effective way of reducing GHG emissions. The efficiency of this mitigation measure depends on the amount and quality of organic matter used for co-digestion, and how much of the thermal energy produced is exploited. A reduction of GHG emissions by up to 96% was observed when all thermal energy produced was used to substitute fossil fuels (Weiske 2006).

Agro-based low-carbon systems have an indirect effect on employment opportunities, education, demographic transition, poverty, indoor pollution, health welfare and they have gender- and age-related implications. In the poor countries the industrial production processes still lack of resource efficient and clean-technologies. Up to six hours a day is required by some households to collect wood and dung for cooking and heating. In areas where coal, charcoal or paraffin is commercially available, these fuels take up a large portion of the monthly household income. Inadequate equipment and ventilation means that these fuels, burned inside the house, cause a high toll of disease and death through air pollution and fires. The health indicators have the sub-theme of social safety, income poverty, income inequality, health, assess to energy, conversion, distribution and use of materials and energy. Seen from a broad angle, development of agro-based zero emissions systems encompasses the strengthening of material income base as well as an enhancement of capabilities and enlargement of choices.

High efficient technologies, process intensification, heat integration

Our worldwide manufacturing, processing industry, distribution, and even disposal systems have evolved with support from the legal laws and practices over more than 100 years that encouraged the rapid conversion of natural resources into the finished products. To some, the land appeared so vast it could absorb any amount of environmental pollution while giving up its wealth endlessly. Today everyone knows this was an illusion: we might not do this any more. The suitable waste disposal sites are becoming difficult to find as urban areas expand and industrialization. Environmental pollution is spreading because of increasingly economic and industrial development in most of developing countries.

While concepts to minimize, reuse and recycle wastes proposed have not solved thoroughly the negative effects on environment and human population, zero emissions concepts have arisen. It implies the optimization through an integrated system of processes and requires the industries to redesign manufacturing processes to efficiently use both raw material within the process and waste towards the aim of sustainability. It means that utilization of waste can be brought back to at sustainable levels in closed loop processes, bearing the phenomenon of industrial metabolism (Nguyen 2008, Norio 1999).

We must admit that in the production emissions are

(i) in-efficient usage of raw materials, energy, and capital,

(ii) definitely bad for the environment, and

(iii) costly for the treatment of the waste which is generated in the production processes.

Moreover, environmental pollution in many recent years does not stop at one location or country, it could impact on all global environment because our world as a system which connects to space and time. All land, sky, ocean, river, mountain, biodiversity is an interacting natural system.

Due to the high energetic value of the raw materials, it can be possible to operate food processing plants without energy from outside like in breweries (Gahbauer 2009), or in sugar cane industries (ABB 2009). A precondition for that is of course an optimized energy recovers system and energy efficient equipment in the plant.

- Energy efficiency has become the first step to controlling and stabilising greenhouse gas concentrations because it is the most cost-effective and fastest option. Hence, it slightly improves the energy system by reducing losses and overload; it could reduce the investments in energy infrastructure; it will help mitigate energy price increases and volatility by easing short- and medium-term imbalances between demand and supply; and it will also help reduce CO2 emissions and increase energy security. Additionally, energy efficiency offers non-energy benefits, such as reducing operating costs; growth in productivity; improvements in product quality, capacity utilisation, and worker safety; waste reduction and pollution prevention.
- Process Integration (PI) goes beyond conventional energy audits to look at the overall plant processes and systems and their interactions. Through the systematic and rigorous analysis of processing steps, utility systems, and their interactions, PI studies determine the most efficient use of energy, water and raw materials.
- Electric motors are used in many processes within the food industry. Energy efficiency can be met by ensuring current motors are well maintained and are used at

the required speed; lowering the speed of a motor by 20% can produce an energy saving of 50%. Using new motors, such as higher efficiency motors can produce savings of up to 3-4%. The implementation of automatic sensors or encouraging staff to turn off motors that are not in use may also produce significant savings.

- Co- and trigeneration (cogeneration of heat, cold and electricity) has to become a standard technology in any industry. Especially in the food sector, where cooling is essential, this waste heat is available almost for free. Low temperature heat can be used for cleaning and drying processes.

Packaging

Packaging policy should minimise the environmental impact of packaging over its whole life cycle, without compromising its ability to protect the product. This starts with optimising packaging through (DEFRA 2009):

- designing it in line with sustainability principles, and with re-usability, recyclability or recovery in mind – as a standard
- delivering real reductions in packaging, under existing and new voluntary agreements
- market innovation and development which meet the growing demand for re-useable and recycled packaging, across all types of packaging.

It continues with maximising the recycling of waste packaging, through:

- more recycling by householders; recycling schemes that collect all the main packaging materials and are easy to use;
- local authorities and businesses treating waste packaging as a resource, leading to more recycling by businesses, and a new emphasis on quality in household collection and sorting;
- working from where we are now towards the recycling rates achieved by the best performers.

Increasing the share of renewable content in packaging can lower its carbon footprint. The concept of renewable materials – sourcing resources that can be replaced or replenished at a rate equivalent or greater than their use, with minimal environmental damage – also fulfils the internationally accepted definition of sustainability as given by the Brundtland Commission: "[to meet] the needs of the present without compromising the ability of future generations to meet their own needs." UNEP workes in the field of Design for the Environment (DfE) and published manuals that also can be used for LC-strategies in the agro-food sector (UNEP undated).

Transport

By 2050, the radical decarbonisation of transport will be characterised by cleaner fuels, greener technology and a shift to renewable sources of energy (E-Mobility). A wide range of technologies will be in play delivering substantial reductions in emissions from road and rail. The actions that we will have to take in the short to medium-term will deliver further efficiency gains from existing technology and will lay the foundations for a switch to new, greener technology in the longer-term[1].

- This will primarily be delivered through advances in the efficiency of the internal combustion engine. Alongside this, new ultra-low emission vehicles will be available on the mass-market. Together, this will mean that, for example, new cars will emit on average 40 per cent less CO_2 than they do today.
- New vans will be subject to an ambitious performance framework for CO_2 reduction – analysis suggests that this could deliver significant improvements in fuel efficiency.
- Reducing emissions from heavy good vehicles is also vitally important and we will determine and implement the best combination of regulation, support for investment and best practice in order to achieve this.

And there will be a shift to cleaner technology in public transport. Energy efficiency improvements and greater electrification will deliver a lower carbon rail system. Technology improvements will also be flowing through for aviation and shipping with more radical developments out to 2050. These will come from a combination of measures, including better fuel efficiency and improvements to operations, as well as the use of market-based measures to drive technological change.

Sustainable bio-fuels can provide a low carbon alternative to fossil fuels. Promoting the use of these is an important part of LC strategies to 2020 and but mainly thereafter to 2050. The agro-food sector will be the main supplier of resources for biofuels and will therefore be strongly affected by this development.

[1] Adapted from: Department for Transport 2009

Use of renewable energy

Renewable resources of energy are (almost) GHG-neutral. But the arguments for using them are much wider. Renewables reduce the dependency from energy imports and safe local financial resources. Local production of energy creates (green) jobs and income. The choice for the right technology has to be made on basis of the energy service needed.

Electricity

Electricity should be used for high temperature heat, light, information (TV, ICT,…) and mobility with increasing importance. Low carbon electricity generation focuses on renewable energy resources such as wind, solar - PhotoVoltaic (PV) and Concentrating Solar Power (CSP) – hydroelectric power but also new technologies are emerging/maturing such as ocean energy, combined heat power (CHP) based on biomass and fuel cells. Three stages of the electrical energy supply chain have been identified and the technology and future perspectives enabling a low carbon electrical system discussed accordingly. The three stages are (de Jong 2009):

a) Low carbon electricity generation. Covering generation from renewable energy sources and low carbon fossil fuel alternatives.
b) Low carbon electricity networks. Covering, electrical transmission and distribution through future electrical networks, or smartgrids, and the quality of supply.
c) Low carbon electricity services. Covering ancillary services provided for grid operators as well as for end-users when implementing storage or electrical transport, for example.

Heat

As there is an increasing diversification of energy, and avoidance of fossil fuels, there are many options to substitute the out of date, polluting technologies. Low temperature heat (<100°C) should be provided by solar thermal plants and heat pumps as much as possible. High temperature heat can come from the combustion of biomass and from electricity.
Biogenic sources like wood and bamboo are reasonable alternatives to coal and oil in many heating applications. In general their use is less efficient as with oil and gas and the air emissions are worse. LC-strategies therefore have to care also about boiler efficiencies and well maintained heat distribution systems. For low temperature heat, solar thermal collectors can be used. Most drying operations on the farms and small companies could be performed or at least supported by solar dryers (fruit drying, tea drying, …). There is a lot of expertise around and many plants are in operation successfully (see e.g. WWW.PEN.NET.IN).

Depending on the sector and specific operations of the industrial process there are a number of ways that heat can be saved and reused, therefore improving the competitiveness of the company. There are specific steps that can be taken for improving the generation of industrial heat, and reuse of this heat witch improves the overall energy efficiency of the process. The "EINSTEIN energy audit" (http://iee-einstein.org/) saves a part of the energy waste heat; and introduces it in the production process once again, increasing the thermal efficiency. The objective of its energy optimisation analysis is to collect and analyse the data with methods of consistency checking and benchmarking, and thus realize the process optimization through heat integration, between different processes. Based on a reduced heat demand "EINSTEIN" shows the technical alternatives for the integration of renewable energy supply systems and evaluates them in a detail cost calculation.

Cold

In several food industries and especially where heat-sensitive food is being processed, the production halls and storages must be kept at a controlled temperature in order to maintain high food quality. The objective of cooling processes in the food industry is to reduce or maintain the temperature of a product in a lower level for a period of time. Cooling, chilling, cold stabilization and ageing are the typical processes included in this category, and the integration of technologies like absorption cooling, cryogenic cooling or using a plate heat - exchanger for pre-cooling ice water with ammonia can save energy, save money and be more ecologically friendly.

Fuels

Petroleum products are the main source of energy in most enterprises. There are several technologies on the market to convert biomass into fuels. Depending on the type of biomass source, the following classification can be used:

- Biomass containing sugar and/or starch: fermentation to ethanol
- Biomass containing oils: chemical processing to bio-diesel
- Biomass of wooden structure:
    - gasification to syngas followed by a catalytic conversion to liquid fuels, or
    - pyrolysis (these technologies are at present not available in small scale), or
    - production of char coal (bio-char)
- Wet waste biomass: fermentation to biogas (methane)

The production of biogas is extremely important, since it can be done on any scale and the product (methane-rich gas) can be used for heating, electricity generation and/or – after a cleaning process – for diesel engines in cars.
By means of the Fischer Tropsch process it is possible to obtain liquid fuel from gasified biomass. In the gasification the biomass is converted to gas, and than used to make syngas (a mixture of hydrogen and carbon monoxide) which is later used in the Fischer Tropsch process to polymerize into diesel size molecules.
A process called HTU can be used to convert biomass into high quality diesel. Particularly suitable feedstock is residue from agriculture and forestry, domestic organic waste, and also peat. In bio refineries the HTU process can play an important role to convert organic residues to a renewable energy fuel. In the HTU process, biomass is reacted with liquid water at a high temperature and pressure (300-350 °C and 120-200 bar) to obtain a fuel with a relatively high heating value.

Integration of the production steps into the agricultural system

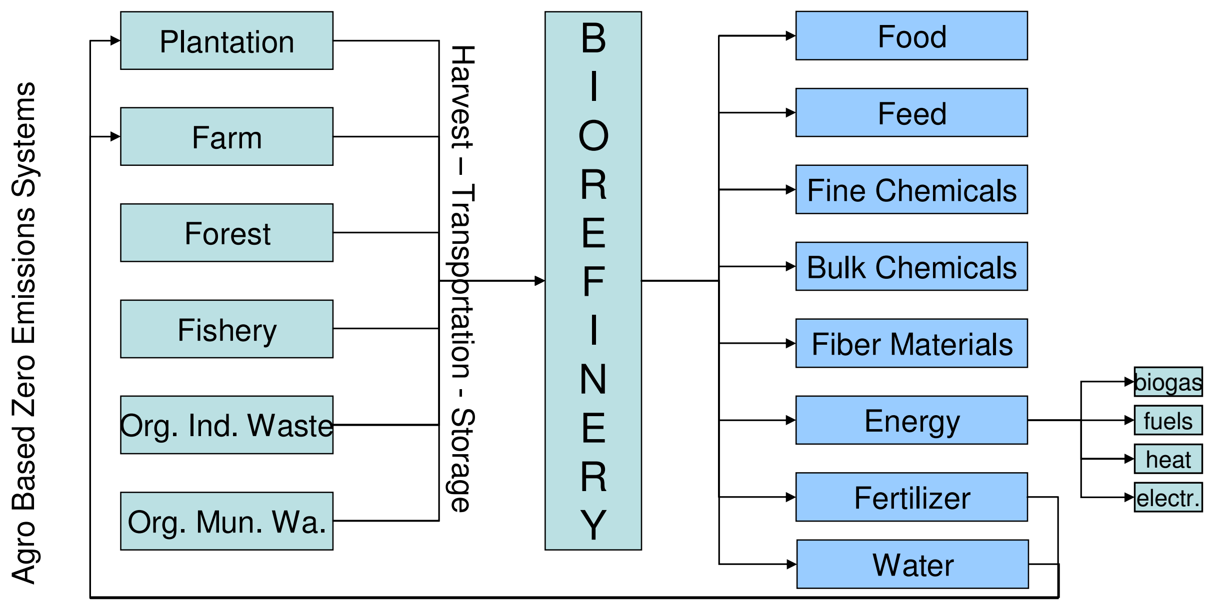
'Zero emissions' is a new approach that powers industry and economic growth and is now also powering the protection of human health and the environment. Today agro-based industrial zero emissions systems (AIZES) enjoy significant adoption in many countries around the world and widespread attention from the research community. Not only does AIZES address the fundamental scientific challenges of protecting human health and the environment at the local and national level; it accomplishes this in an economically beneficial way. 'Zero emissions' is a completely new approach to a sustainable and resource efficient economic development. A zero emissions system is the next stage in the evolution of concepts for the control and reduction of emissions from the processing and manufacturing industries. Also, defined as production processes that reduce the generation of waste, energy loss and the consumption of input materials, for instance through the utilization of waste (liquid and solid) as process inputs, the concept has been referred to as pollution prevention at source. In particular such production processes offer the possibility of creating an ecosystem in a loop of materials. By using the skills, techniques, and expertise that are central to waste management and eco-efficiency, practical implementation of zero emissions systems realizes notable results towards the aim of a sustainable development.

Biomass refineries

A biorefinery is a facility that integrates biomass conversion processes and equipment to produce food, feed, transportation bio-fuels, power and chemicals from biomass. The biorefinery concept is analogous to today's petroleum refinery, which produce multiple fuels and products from raw oil. The biorefinery approach strongly contributes to the development of worldwide bio-energy policies and low-carbon systems.

There are several advantages from a biomass refinery:

- Locally:
  - More income for agriculture
  - New jobs in processing agro resources
  - Local production of fuels and materials
  - Closing cycles of water and minerals
- Globally
  - Slowing down of climate change



Modified from Janis Gravitis; A Biochemical Approach to Attributing Value to Biodiversity – The Concept of the Zero Emissions Biorefinery

Figure 3: Product Hierarchy for an agro-based Zero Emissions System

The design of a biomass refinery system in a region follows a strategy:

- Add further processing industries to existing plants and/or industries
  - Convert wastes from farms and industry into new products (value added)
  - Convert organic wastes from farms and industry into energy carriers (biogas, liquid and solid biofuels,…)
- Design Zero Emissions Systems around existing plants
  - Use bio-energy and solar technologies in existing production
  - Reuse water in agriculture
- Search for new plants

- New plants in the agro-sector could be used for new products and new markets

Feedstocks for biorefineries mentioned in literature are:

- Agricultural, Forestry
  - grass, hay, straw, clover, alfalfa, green cereals
  - bamboo, cashew nut, moringa
  - animal farming, slaughter houses
  - eucalyptus, forestry residues
- Organic waste from industry
  - glucose syrup, beet molasses
  - fruits (pineapple pulp, grapes and canola seed press cake …)
  - beverages (fruit juices, beer,…)
  - fish and seafood
- Other
  - water hyacinth
  - algae

Use of waste biomass

Biomass is broadly recognized as one of the most important sources of renewable energy worldwide, and the reckless disposal of this rich source of energy into landfills is not an option these days. Apart that:

- landfills lead to landfill gas emissions (40-60% methane, 60-40% CO_2 and about 1% other contaminants - most of which are known as "non-methane organic compounds" or NMOCs) with a high global warming effect
- landfill gas can cause explosions
- a New York study of 38 landfills found that women living near solid waste landfills where gas is escaping have a four-fold increased chance of bladder cancer or leukemia (http://www.rachel.org/en/node/4467)

It should not be surprising that there are a number of methods to use this energy from the waste biomass, mitigating the GHGs in this way, and increasing the energy efficiency. In the light of ecological awareness processes are being developed where the energy efficiency is higher, the fuel more practical to manage, and with as high a heating value as possible. There is a database collecting the composition and heating values of different types of biomass waste (http://www.ecn.nl/phyllis/). One of the gases with a high Global Warming

Potential (GWP), over a lifetime of 20 years, is methane, but this gas has a high heating value and can be used as an energy source. That is why local anaerobic digesters could be a good solution to reducing the amount of waste in the landfills, therefore reducing landfill methane emissions, and producing energy at the same time.

Depending on the type of biomass, we can use it to different purposes. Burning forestry, agricultural and urban biomass is the simplest way of waste usage. Although there exist more elaborate and efficient methods to obtain fuel from the waste biomass; anaerobic digestion is used broadly as a way to obtain an energy rich biogas composed mainly from methane and carbon dioxide. The biogas is normally produced from livestock manure, food processing waste etc.

Recycling of water for irrigation

In places with a low rain frequency recycled water could be a key part of maintaining a sustainable water supply. Stormwater, greywater and recycled water are all alternative water supplies that, when treated as required, are suitable for a range of purposes, including irrigation, industrial processing, and to keep public and recreational spaces green. Greywater is any washwater that has been used in the home, except water from toilets. Dish, shower, sink, and laundry water comprise 50-80% of residential "waste" water. The local benefits of water recycling are:

- the conservation of drinking quality water
- use of recycled water for irrigation
- a 50 – 70 % reduction in fertilizer usage when used for irrigation
- frees up water for the environment
- reduces the amount of treated effluent discharged into rivers, bays and oceans

Recycled water has been in common use throughout the world for more than 30 years. Places such as California and Israel effectively use recycled water as a key component of managing their water resources. In some countries water recycling is happening now, Sydney, Australia, plans to provide 12 % of all of its water needs with recyclable water. At the International Water and Sanitation Centre (IRC, http://www.irc.nl/) there are is lot of useful information on water recycling and sustainable water usage. The next link describes a successful water recycling to irrigation programme taken place in Tanzania (2006 - 07), in which a reduction in income poverty at household level for a total of 80 farmers was achieved. http://portal.worldwaterforum5.org/wwf5/en-us/Lists/Kyoto Prize Application Form/DispForm.aspx?ID=79.

Low carbon buildings

As it is important to produce energy in a clean way, also it is important to use it in an efficient manner. The standards used in construction are changing, and the pilot projects for energy efficient "smart cities" are giving good results (http://concertoplus.eu, http://www.civitas-initiative.org/main.phtml?lan=en). There are several Europe wide projects that are trying to improve the quality of life of its citizens while at the same time avoiding the emission of thousands of tonnes of CO_2 per year. These actions include modifications, such as fenestration, rigorous shell improvement and isolation, upgrading of heating systems, and domestic hot water supply system.

The improvement of many constructed objects, that a lot of times are located in the city centre, results much more expensive than the initial investment of constructing the objects to run in a clean, energy efficient way. The plans for the low carbon buildings include refurbishment of the existing buildings to bring them to the lowest possible energy consumption levels (e.g. passive house standard or level of efficiency that is justified by age, technology, architectural constrains) maintaining or increasing performances and comfort. This would include innovative insulation material (solid insulation, vacuum insulation, vacuum windows, cool roofs, etc.) The technology installed in these constructions need to have innovative hybrid heating and cooling systems from biomass, solar thermal, ambient thermal and geothermal with advanced distributed heat storage technologies. Day lighting and efficient electrical lighting should therefore be considered first.

In order to save energy, and therefore cut down on GHG emissions new retail centers should be built by the modern standards of "Low Carbon Buildings", which require a more generous initial investment but reduce the monthly electrical bill since heating and cooling are not necessary or necessary to a much lower degree.

Carbon capturing and sequestration (CCS)

As a need to face the worldwide threat of global warming and climate change, CO_2 storage and sequestration is being seriously studied as a method of capturing CO_2 produced in fossil fuel energy generation facilities and large CO_2 production industries. Carbon sequestration is a solution for long term storage of CO_2 as an alternative to venting it into the atmosphere. Since we need to store thousands of millions of tons of CO_2 we can not build containers, but must use natural reservoirs, such as old gas and oil fields. These seem to be one of the best solutions for CO_2 storage, since there is sufficient knowledge gained with oil and gas extraction. Another suitable option for CO_2 storage seems to be saline aquifers. These are porous rocks deep below ground that are full of salty water that is of no use for drinking or agriculture. Although there is not that much knowledge on the geology or engineering of this method, it is supposed that the Know-how from the oil and gas extraction can be applied in a satisfactory manor. There has also been some discussion among the scientific community if the CO_2 could be pumped into the ocean and stored there, but it seems that the possibility of ruining the natural carbonate equilibrium is quite big, so this could backfire and release even bigger amounts of CO_2 into the atmosphere.

For now the technology available for carbon capturing is all experimental, which is practically a synonym to being expensive. The EU Commission predicts that Carbon capture and storage technologies will become cost-competitive within a carbon pricing environment by 2020-2025. Approximately 85 % of the power sector's greenhouse gas emissions in the US are derived from coal, and that accounts for about half of the electricity production. Due to this huge market potential giants like Dow Chemical Co. and Alstom SA are investing big on solvents like amine, or ammonia carbonate; both ammonia based solvents. But the problem is that once bound to the CO_2 molecule it is quite difficult to retrieve the solvent, therefore making the process expensive. A CO_2 capturing plant is able to consume up to 30 % of a coal power plant energy production, and there are plans to try and lower it to 15 % in the next ten years.

The only CCS technology suited to small units in agricultureal areas is "Terra Preta" or "Biochar". Terra preta (literally "black earth" in Portuguese) refers to expanses of very dark, fertile anthropogenic soils found in the Amazon Basin. Terra preta owes its name to its very high charcoal content, and was indeed made by adding a mixture of charcoal, bone, and manure to the otherwise relatively infertile Amazonian soil over many years. The production of Terra Preta could have two effects simultaneously: sequestration of Carbon and an increased fertilisation of the soil (http://news.mongabay.com/bioenergy/2008/11/national-geographic-documentary-on.html).

Low carbon lighting systems

An ongoing incentive is to design houses and offices in such a way, that daylight can be used as much as possible. Most simply, daylighting is the practice of using natural light to illuminate building spaces. Rather than relying solely on electric lighting during the day, daylighting brings indirect natural light into the building. Daylighting reduces the need for electric lighting and connects people to the outdoors, as it provides pleasing illumination at a fraction of the cost of the most efficient electric lights. There are studies that show a correlation between the lack of natural light and several health problems, such as hormonal unbalance and vitamin-D deficiency (http://www.thedaylightsite.com/filebank/Daylighting Legislation and Health.pdf, and http://www.thedaylightsite.com/presentations_s.asp?tp=1022&catid=26&y=2009).

On 18 March 2008, the European Commission adopted a regulation on non-directional household lamps which would replace inefficient incandescent bulbs by better and more efficient alternatives (such as improved incandescent bulbs with halogen technology and compact fluorescent lamps) between 2009 and 2012. Although many public places have already the energy efficient kind, in many homes there are a lot of conventional incandescent bulbs. Switching all of the lights to compact fluorescent bulbs would reduce electricity needs for lighting by almost three-quarters. In the same MEMO (MEMO-09-368) the Commission defined which are the phased out lamps (A. conventional incandescent lamp (GLS), B. conventional halogen lamps), and which are the available alternatives (A. Conventional low-voltage halogen lamps; B. Halogen lamps with xenon gas filling (C-class); C. Halogen lamps with infrared coating (B-class); D. Compact fluorescent lamps (CFLs); E. Light-emitting diodes (LEDs)).

Reduction in post-harvest losses

After produce is grown, it is harvested, transported, stored, retailed and made ready for consumption. In all of these steps, losses occur. Data on post-harvest losses are hard to obtain and only a few surveys have been published (NEAA 2009). Estimates of losses vary between 2 and 23% from production to retail sites, for developed countries depending on the commodity. For developing countries, the ranges have been estimated to be even larger; up to 50%. In contrast, food losses by consumers are estimated to be higher in developed countries than in developing countries (Kader, 2005): in the United States, these losses have been estimated at around 25% of edible food available (Kantor et al., 1997). In the Netherlands, estimates range from 13 to 25%, of which about 50% is unavoidable, such as losses in peelings (Milieu Centraal, 2007). Expectations are that losses will increase due to the consumption of more perishable commodities in the future. Thus, there is much scope to improve the efficiency of the total food chain.

In developing countries post harvest losses occur mainly for three reasons:

1.) Due to the proliferation of storage insects (only a low moisture content of less than 12% can reduce their multiplication);

2.) Rodents cause high quantity losses in stored grain as they consume part of it, and they contaminate the grains with urine and hair;

3.) The multiplication of fungi due to excessive humidity in particular Aspergillus spp. which produce dangerous toxins (Aflatoxins) which make grain unfit for human consumption. Aflatoxins, even in lower concentration are carcinogenic and at higher concentration acute toxic (http://fsrio.nal.usda.gov/document_fsheet.php?product_id=48).

Options for reducing post-harvest losses are to:

- enhance knowledge of farmers on timing of harvests and improvement of storage practices
- improve the infrastructure from field to market
- increase awareness of the problems of spoiled food in those preparing the food for consumers

5. CASE STUDY: GREEN BREWERY – LOW CARBON PRODUCTION IN BREWERIES

With a market share of app. 50% of the Austrian beer market the Brau Union Österreich significantly influences the development of the energy demand in the brewing industry in the past years.

For breweries much effort has been done lately in research and plant development to reduce the energy demand of the processes, visible through a large number of papers and publications. Typical energy demand figures, such as 24-54 MJ/hl for wort boiling, can be found in literature for different processes (Priest 2006; Kunze 2007). However, in some breweries the real specific energy demand per area is unknown and improvements can therefore be hardly identified even if benchmarks are known. The project “Green Brewery” was conducted as a cooperation between industry and research to identify possible solutions to reduce the fossil CO_2 emissions in the thermal energy generation for breweries, based on a detailed analysis of real case studies.

Innovative energy concepts depending on the production capacity, the site and the products have been developed in 3 Austrian case studies and possibilities of production without fossil fuels have been demonstrated applying energy efficiency, heat integration and a combination of renewable energy sources.

The methodology to develop sustainable energy concepts is based on a stepwise approach that has been successfully applied in several studies for solar process heat integration (Brunner, 2008).

- Data acquisition of all energy data within the company (energy demand and energy availability)
- Calculation of the overall energy balance of the company

- Reviewing of possible measures for enhancing energy efficiency (technological improvements, best available technologies, reduction of heat losses etc.)
- Calculation of the (theoretical) minimal heating and cooling demand with external energy sources
- Design of a heat exchanger network (heat integration)
- Definition of the heat demand that can be sensibly covered by solar thermal applications or other renewable energy sources
- Design of the renewable heat supply system
- Economic analyses

In the first case study much effort was put into measurements of the energy demand of the single steps of the brewing and filling processes. This experience could be used in the later case studies where the focus was put on the most energy demanding processes and for less energy intensive processes figures could be calculated based on the experiences of the experts. The calculation of the energy balances was done on different levels: per process, per production unit and over the whole production. With this procedure the minimal energy demand of each process step could be calculated and the losses caused by energy distribution and conversion could be clearly identified. It was demonstrated in all case studies that especially the energy distribution is of high importance in breweries, due to the batch process cycles and the open steam network that is often found in breweries.

Good housekeeping is the basis for each efficiency study and is achieved mainly by the personnel itself triggered over awareness building: optimisation of regulations, exchange of steam traps, insulation etc.

Technological improvements are of high importance in energy efficiency studies, as much energy can be saved with the application of new technologies. However, due to ongoing depreciation periods or due to the requirement of short payback periods, the investment in new units is not always easily possible.

For heat recovery, the focus point in each study is the warm water household including the brew water system. In breweries, heat recovery from the cooking process for brew water production is a standard measure. Vapour condensers or vapour compression systems are two of the most common solutions. Each of these systems influences the brew water and warm water household of a brewery significantly.

The pinch analysis was applied to identify the maximum savings than can be achieved by heat recovery in breweries. The solutions were analysed in detail, especially on their influence of storage tanks levels and temperature profiles. Because of the batch operation in breweries, intelligent storage design on the right temperature levels is a key issue in the solution generation.

Based on the decreased energy demand after heat recovery, considerations on renewable thermal energy supply were done. These considerations focussed on the energetic use of the own residues of the breweries and the use of solar thermal process heat. Practical tests were conducted for the potential of converting residues in biogas: batch fermentation tests under mesophile conditions were carried out with different raw materials and the gas yield and quality was analysed. For the consideration of other renewable energy solutions calculation tools were applied, such as T-Sol simulations for solar process heat.

Development of the “Green Brewery concept”

Results of the research project were compiled in a “Green Brewery concept”, a calculation tool for guiding breweries towards CO_2 neutral energy supply. The Green Brewery concept comprises the following areas:

i) a quick comparison of the main energy benchmarks for all the brewery sections, globally or separately (unit by unit);
ii) detailed energy balance for the brew processes;
iii) indication of optimal aim-targets for the production and energy savings in breweries;
iv) calculation of potential heat recovery;
v) concrete ways to integrate renewable energy (solar, biogas, biomass, geothermal) to the brew process;
vi) list of the best available technologies for breweries (production, energy consumption, savings) and
vii) calculation of potential energy that can be recovered from brewery by-products or residues (e.g. biogas from spent grain).

The Green Brewery concept is divided in 3 main sections:

i) Setting of brewery process data as well as optimization targets to be achieved,
ii) Opportunities for process optimization in breweries and
iii) recommendations for better energy uses and savings in breweries.

Breweries can be evaluated in the first main section, where factual process data is entered. Green Brewery concept covers the main unit operations in a brewery such as boiler house, brew house, refrigeration, fermentation, compressed air, beer storage and packing. All the brewery units are linked in the concept to process checkpoint list, which values are updated according to current best practices (Figure 1). As the basic information is set to the Green

Brewery concept, the energy balance is then carried out. Optimal aim-targets are checked easily from a benchmark list created in the concept (Figure 4). Furthermore, it is possible to check the overall heat balance of the brewery and to compare all heat sources and sinks. Detailed energy balances of each brewery area can be accessed as well, where intensive energy steps and/or improvement targets can be identified.

zurück zu Checkpoints

BENCHMARKING ENERGIE KENNZAHLEN

Branchenkonzept > Energiebilanz - Checkpunkte Energie > Auswertung Checkpoints

Checkpoints - Auswertung

Vergleich mit Benchmarks und Zustand der letzten Woche/letzten Monate

Allgemein - thermischer Energieeinsatz	Derzeitige Kennzahlen		Benchmarks	Ergebnis	Maßnahmen
Spezifischer Energiebedarf	57,3	MJ/hl	< 40 MJ/hl Prozessenergiebedarf, < 65 MJ/hl Gesamtenergiebedarf (inkl. Heizung)		
Anteil des erhobener Prozessenergiebedarf (Branchenkonzept) am Gesamtenergieeinsatz	75%	%	65-70% (Rest Heizung oder Systemverluste)		
Heizbedarf	121,5	kWh/m².a	70 kWh/m².a für Produktionsgebäude		Heizbedarf analysieren und Optimierungsmaßnahme
SUDHAUS					
% externe Erwärmung Brauwasser (nicht aus WRG)	5,2%		0-20% je nach Wasserbedarf der Abfüllung		
Energiebedarfsverhältnis Sudhaus (real zu ideal)	1,96	-	1,1		Verluste im Sudhaus überprüfen
Effizienz Wärmeübertragung Würzekühler	8,3	ΔT log	5-7		Wärmetauscher reinigen bzw. Fläche vergrößern
Effizienz Wärmeübertragung Würzeerhitzung	9,7	ΔT log	5-7		Wärmetauscher reinigen bzw. Fläche vergrößern
Effizienz Wärmeübertragung Wärmetauscher Brüdenkondensat	5,9	ΔT log	5-7		
Energiebedarf Brüdenverdichter	4,8	kWh/hl verdampft	3,5-4,5		Brüdenverdichter prüfen
CIP Heißwasserbedarf im Sudhaus	120	m³/Woche	100 m³ bei 30 Suden a 700 hl		
Effizienz Wärmerückgewinnung gesamt aus Sudhaus (Verhältnis maximal rückgewinnbare Warmwassermenge zu erzeugter Warmwassermenge)	1,00		1		

Figure 4: Overview of results presented in a list of simple achievements (greens means positive and red negative, details given elsewhere in the programme)

The Green Brewery concept covers also possible opportunities for process optimization in breweries. This part of the concept includes a list of energy efficient technologies for every unit of the brewery. An overview of new technologies and brewery process parameters is provided with brief descriptions and references. Finally the third section deals with the potential for different renewable energy supply for breweries. Information and small calculation procedures for energy from biomass, biogas, solar thermal, district heating and heat pumps are given. Also one of the subsections here deals with the potential of energy generation from own resources. Based on the data entered on the specific breweries the potential of energy generation from waste water and biogenic residues can be calculated.

The project “Green Brewery” has proven that a low carbon production can be successfully realised in technical but as well in economic terms. The minimal thermal energy demand that can be reached in the considered breweries with 1 million hl production capacity is as low as 37 MJ/hl. Here some energy distribution losses which cannot be fully eliminated in existing breweries are already included. However, the case studies showed that the possibilities for reaching this target depend on the production cycles and the packaging processes, especially on the balance between hot water demand in brewing and packaging. For heat recovery it could be shown that even for breweries with existing vapour recovery systems (mechanical vapour compression) 25% of the energy can additionally be recovered over intelligent heat integration systems. Based on the vast possibilities of heat recovery in the low temperature range, solar thermal energy has to be sensibly placed within the energy supply system. The batch fermentation tests showed that for a brewery with a production capacity in the range of a million hectolitres the energy yield from biogas out of spent grain and other biogenic residues for breweries can be as high as 36 MJ/hl. Biogas from waste water, as already realised in a number of breweries, can additionally increase this figure. Biogas boilers potentially can handle high energy transfer rates which is necessary to supply some energy intensive processes in the brewery, if the existing heat exchange facilities should not be altered. Also, a retrofit of the existing boilers is not too demanding.

Overall, the project „Green Brewery" has shown a saving potential of over 5.000 tons of fossil CO_2 emissions from thermal energy supply for the three breweries that were closely considered: For the brewery ***A*** it could be shown that the total fossil gas demand can be substituted by efficiency measures and the integration of renewable energy sources. This corresponds to saving of 1,200,000 Nm^3 fossil gas (basis 2007) and a reduction of fossil CO_2 emissions of 2,670 tons per annum. In the brewery ***B*** the proposed measures can reduce 1,100 MWh/a of the thermal energy demand and 1,000,000 Nm^3 fossil gas can be balanced as CO_2 neutral gas when biogas is produced from spent grain of the brewery and fed into the central gas distribution net in a neighbouring city. For a CO_2 neutral energy supply in the brewery ***C*** a supply of the hot water supply line with biomass can be recommended under the given framework conditions of the brewery. Additionally energy supply for some processes by a hot water line on a lower temperature is recommended to enable connection to the local district heating grid the integration of solar thermal process heat.

Based on the calculations and considerations in the case studies it can be concluded that a brewery with optimised heat recovery and comparable production capacities in brewing and packaging can fully supply its energy demand by own resources. Here, the heating demand is not included which can be covered by low temperature heat from solar thermal or from district heating networks. The results of the studies show that biogas production from all residues (waste water and spent grain) is one of the most promising alternatives for renewable energy supply for the three case studies. Due to the large potential for heat recovery the integration of solar thermal process heat has to be checked in detail for Austrian breweries. The construction of new plants or plants, that partly supply processes with hot water (mashing, bottle washing machine) and slightly higher global radiation of other sites will favour solar process heat as a sensible alternative.

The Green Brewery concept has been developed as an important tool to reduce emissions and to process performance optimization over a period of time in breweries, including guidance for decisive actions to take place in future in order to improve process manufacturing. However, it is necessary to have expert know-know and consistent industrial data to carry out a reliable analysis, because many parameters have to be defined to show a complete picture of the brewery. The Green Brewery concept is aimed as a living tool that can be extended according to user needs. Also, the checkpoint list of program has to be updated periodically according to the best engineering practices in brewery and user needs.

6. Conclusions

The agro-food sector at present has lage emissions to air, soil and water, because it does not use most of the great potentials for efficiencies, internal recovery and reuse of water, materials and energy. More than this, solar thermal energy could be utilized much more.

The use of all these options would make the production chain of food from agriculture to the consumer CO_2-neutral. This would be a rather easy and cost effective measure in the abatement of global warming.

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