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PREFACE

Transport fuels are a crucial factor in achieving increasingly ambitious climate policy goals and a sustainable mobility system. Alternative propulsion systems need new or modified fuels, tuned to their specific requirements, and offer opportunities for reducing pollutants, greenhouse gases and noise.

The Austrian Ministry for Transport, Innovation and Technology (BMVIT) has therefore funded research and development of alternative fuels under its A3 (Austrian Advanced Automotive Technology) Programme since 2002, and now in the new A3plus Programme. To secure the market introduction of alternative propulsion systems and fuels, the BMVIT is supporting pilot and demonstration projects, including support for the users of these new technologies, with the goal of optimising these systems and fuels under real-life conditions.

78 R&D cooperation projects have been realised, with an overall budget of 40 million euros and sponsorship funding of 20.4 million euros; and a further 8 demonstration projects, with an overall budget of 7.4 million euros and funding of 3.4 million euros, have been put into action between 2002 and 2006. In 2007 another 18 R&D projects and 3 pilot projects have been selected for funding under the new A3plus Programme.

Austria's automotive industry includes some of the biggest supply-side companies worldwide. With 175,000 employees, it is strongly engaged in the engineering and production of propulsion systems and fuels. The BMVIT strives for synergies, based on its core competences in the areas of transport and technology policy, in order to secure the competitiveness of this industry through constant innovation. It is furthermore aiming to solve urgent transport and environmental problems by using new technologies.

International co-operation is a key factor for success in meeting global challenges, which are reflected by ambitious goals and mandatory national and EU targets for energy efficiency, security of energy supply and reduction of pollutants and greenhouse gas emissions. Austria therefore cooperates strongly with EU technology platforms, FP7 partners and the IEA. The Austrian Agency for Alternative Propulsion Systems and Fuels (A3PS), with its currently 27 partners, is an important instrument as a platform for international networking and co-operation between industry, universities, research institutes and the BMVIT in seeking to achieve these goals.

CHRISTA KRANZL
State Secretary for Innovation and Technology at the Austrian Federal Ministry for Transport, Innovation and Technology

EDITORIAL

Alternative fuels are a hot spot for the transport and energy industry as well as for the international research community, hence they are of strategic importance for technology policy makers. The market introduction of these fuels could solve environmental problems and secure the energy supply for the transport sector. This technological progress would ensure the competitiveness of the automotive industry as a key sector in Austria and prepare the global transport industry for challenges like tightening emission standards. The clear goal to meet European Commission obligations to reduce greenhouse gases by at least 20% by 2020 and for continued reduction of pollutants is a challenge not only for the vehicle industry but for the fuel industry as well.

Against the background of steadily rising oil prices and increasing dependence on oil imports from politically unstable regions, strong pressure to change the existing energy supply is evident. The transport sector is already responsible for a large share of overall energy consumption, likely to rise further in the future. Accordingly, concrete steps towards improving energy efficiency and developing alternative energy supply are indispensable.

The Austrian government has therefore decided to implement an Energy Fund in its government programme, with an investment volume of 500 million euros, and has set up the following additional targets to reach the ambitious goal of a 20% greenhouse gas reduction:

- Increasing the proportion of alternative fuels in the transport sector to 10% by 2010, and to 20% in 2020
- 5% of new registered cars are to be equipped with an alternative propulsion system (Hybrid, E-85, CNG, LNG, etc.)
- Increasing the proportion of renewable energy within total energy consumption to at least 25% by 2010 and (in relation to the present proportion) doubling it to 45% by 2020
- Nationwide implementation of E-85 and methane filling stations in Austria
- A doubling of biomass use by 2020
- Establishing a methane-based fuel with a bio-methane content of at least 20% by 2010
- Improving the regulatory framework for biogas feed-in

The European Commission has set similarly ambitious targets for European energy policy. Based on the already mandatory biofuels directive, with a proportion of 5.75% biofuels in 2010 (2008 in Austria), the EU is aiming to:

- Increase the proportion of alternative fuels in the transport sector to 10% by 2020
- Reduce CO_2 by 20 % – 30% by 2020
- Increase the proportion of renewable energy within total energy consumption to 20% by 2020
- Reduce average CO_2 fleet consumption to 120/130 g CO_2/km

Research and development are essential in achieving ambitious energy policy goals. The funding of R&D in the field of alternative fuels and new propulsion systems has to be increased substantially in order to realise a sustainable transport and energy system in the future. Only simultaneous innovations in fuel production, storage and vehicle technology will lead to a reduction in energy consumption and in greenhouse gas emissions.

Responding to this, the Austrian Ministry for Transport, Innovation and Technology had launched the R&D Programme "A3 – Austrian Advanced Automotive Technology" already in 2002, covering the entire innovation cycle from basic research to demonstration projects, education, mobility of researchers and international networking. A3 focuses on technology breakthroughs and not incremental improvements, and strives for synergies from interdisciplinary co-operation between industrial, university and non-university research and between suppliers and users of technologies in joint R&D projects. Lighthouse projects are another instrument used by the BMVIT in supporting the market introduction of alternative propulsion systems, through funding large pilot and demonstration projects, optimising technologies under real-time conditions, providing proof of successful operation and preparing the public for technological change.

The EU underpins its policy goals in a similar way by funding R&D in the 7^{th} Framework Programme, and through partnership with industry and research institutions in formulating the Strategic Research Agenda (SRA) of the EU Technology Platforms ERTRAC and BIOFUELS. The International Energy Agency (IEA) supports global R&D co-operations for a sustainable energy and transport system in its Implementing Agreements "Advanced Motor Fuels" and "Bioenergy".

This booklet constitutes the second volume in the series "Austrian Technological Expertise in Transport", providing a comprehensive overview of R&D projects and research institutions in the field of transport fuels in Austria, ranging from A3 and lighthouse projects funded by the BMVIT up to EU and international projects with Austrian participants. Since the first volume of this series of booklets has covered the theme "Hydrogen and Fuel Cells" (published in December 2007), projects for hydrogen as energy carrier have been omitted from the present booklet on fuels. Electricity as another energy carrier for alternative propulsion in electric vehicles will be covered in one of the next booklets of this series on hybrid vehicles, battery technologies and electronic steering control. The review article which follows provides a compact and balanced analysis of technological trends and a comparison of fuel options, before presenting the results of A3 and EU projects.

- > TRANSPORT FUELS: A CRUCIAL FACTOR AND DRIVER TOWARDS SUSTAINABLE MOBILITY
- > VEGETABLE OIL AND BIODIESEL
- > BIOETHANOL
- > SECOND-GENERATION FUELS – THE WAY AHEAD
- > BIOGAS FROM ANAEROBIC DIGESTION AS VEHICLE FUEL – REQUIREMENTS AND APPLICATION
- > COMPRESSED NATURAL GAS – CNG
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- > HYDROGEN – CARBON FREE FUEL
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- > TRENDS IN ENGINE DEVELOPMENT
- > CONCLUSION

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REVIEW ARTICLE ON TRANSPORT FUELS

TRANSPORT FUELS:
A CRUCIAL FACTOR AND DRIVER TOWARDS SUSTAINABLE MOBILITY

Against the background of imminent climate change and increasing dependence on energy resources from politically unstable regions, policy makers are setting ambitious goals to reduce greenhouse gas emissions, including those from the transport sector. To reach these ambitious targets, a wide range of technical options is available. Changes in the propulsion system require close co-operation between the fuel industry and powertrain developers. Apart from compressed natural gas (CNG) and liquefied petroleum gas (LPG), alternative fuels include sustainable fuels such as biodiesel, ethanol, biogas and second-generation fuels, as well as advanced fuels like dimethyl ether (DME). Besides the further improvement of existing combustion technologies, R&D is focussing on combustion processes for alternative fuels and new propulsion concepts such as monovalent gas engines, hybrid and pure electric vehicles, as well as fuel cell cars. The objective of all these developments is to improve drivetrain efficiency and to reduce emissions of pollutants and greenhouse gases.

Sustainable fuels can be produced using a large variety of different feedstock. In general, distinctions can be made between oil crops (rape, sunflower, etc.), starch or sugar crops (maize, grain, sugar beet, sugar can, etc.), lignocelluloses (straw, wood, miscanthus, corn stover, etc.) and other raw material like organic residues and waste products (manure, sludge, animal fat, etc.).

Direct CO_2 emissions from vehicles run on sustainable fuels are generally presumed to be zero. The exhaust gas contains the amount of CO_2 that was previously captured from the atmosphere by photosynthesis. Since fuel production is itself a source of CO_2 emissions, the actual impact on the climate must be assessed to take account of those effects. Contingent activities, such as cultivating the raw material (fertilizer, tractors), all transportation movements and processing therefore need to be monitored for emissions to gain an objective comparison. To take account of these so-called ‘upstream effects’, all activities necessary to provide the fuel at the filling station need to be included. Calculations are implemented using lifecycle assessments. The amount of these emissions is strongly influenced by the given circumstances. If cultivation is carried out in an ecological way, if transport distances are short and if processing uses green electricity, total emissions tend to be low. Best results can be obtained when the feedstock consists of residual products and waste products, because many upstream emissions can be factored out.

Converting the quantity of alternative fuel to a mileage figure is realised by looking at the individual energy densities of the different fuels. This is essential, especially when accounting for the actual substitution level of sustainable fuels. The energy density of biodiesel is about 8% lower than that of fossil diesel; the energy density of ethanol is about one third below that of fossil petrol. Therefore in order to substitute fossil fuels and to meet conventional propulsion efficiency, higher quantities of sustainable fuel are needed.

Pure vegetable oil is obtained by pressing oil seeds or oil fruits from oil crops; subsequently it can either be used directly or processed to obtain biodiesel through esterification. Waste fat (used cooking oil, animal fat) can also be used as feedstock for biodiesel production, after appropriate treatment. To guarantee sound use of pure vegetable oil and biodiesel, given that their fuel parameters diverge from diesel as used today, engines and vehicles need to be adapted, particularly when using alternative fuels in high concentrations or in pure form. Alternatively, vegetable oil can be treated with hydrogen to obtain hydrogenated vegetable oil, which can be used in diesel engines without any special requirements.

The ethanol currently available is produced from starch and sugar, originating from starch and sugar crops, where the starch is first metabolised into sugar by enzymatic decomposition and the sugar subsequently converted to ethanol through alcohol fermentation. Lignocellulose biomass represents another potential feedstock for future ethanol production. The ability to use lignocelluloses requires specific enzymes, in combination with special pre-treatments to facilitate the breakdown of cellulose material into its sugar components, in order to ferment it to ethanol. Use of pure ethanol requires special engine and vehicle adaptation.

Besides using biodiesel and ethanol in pure form, which requires certain vehicle adaptations, they are used as blends with conventional fuels, at up to 5% by volume. Due to the small proportion of sustainable fuels in these blends, there is no need to adapt either engine or vehicle. This fact means that the majority of sustainable fuel used in the transport sector is distributed as a blend, owing to the lack of a suitable vehicle infrastructure. E 85, an ethanol based fuel containing 85% ethanol, is offered as fuel for so called flexible fuel vehicles (FFVs), which can be operated with fuels up to 85% ethanol.

Sustainable fuels are usually grouped into first- and second-generation fuels. All sustainable fuels produced commercially using conventional techniques and any feedstock apart from lignocelluloses and celluloses belong to the first group; these include for example biodiesel from oilseeds and ethanol from corn or sugar beet. Besides being defined through their feedstock of wood- or straw-based raw material, second-generation fuels are often defined by their special production conditions, which offer the further possibility of using the entire plant for fuel production and therefore increasing the potential amount of feedstock (acreage performance).

Biogas is generated when organic material ferments under anaerobic conditions (without oxygen). Organic residues, plant parts which are presently discarded as waste, as well as all energy crops are potential raw material. The crude gas produced thereby needs further treatment, called upgrading, to improve the quality before it can be used as transport fuel. Biogas used as a transport fuel mainly consists of methane gas with a low content of impurities such as sulphur or carbon dioxide, and is therefore chemically similar to CNG.

CNG has already been in use as transport fuel for many years. It has about 25% lower CO_2 emissions than petrol, significant lower emission of pollutants and no particulate emissions. In Austria, the construction of a nationwide gas-fuelling infrastructure is in progress.

Biogas and CNG can be distributed through the existing natural gas grid to regular gas-filling stations, compressed and sold on-site. If no gas grid is available, additional logistic is needed.

LPG is also in use as transport fuel, especially in bus fleets (e.g. in Vienna). It offers advantages such as lower CO_2 and pollutants emissions and is cheaper than standard petrol or diesel fuel.

Agricultural land available for energy crop production being limited, the yield of sustainable fuel per acreage is an appropriate assessment parameter for evaluating sustainable fuels. Furthermore it has to be borne in mind that the production of sustainable fuels competes with supply of food and feed, as well as other interests like those of the paper and wood industry. It is evident that today's fuel consumption cannot be covered entirely with sustainable fuels.
Generally they offer advantages such as a reduction in CO_2 emissions and lower emissions of pollutants, but the long-term goal is an emission-free transport system. These are reasons why sustainable fuels are perceived to be part of the solution, i.e. as an intermediate step in moving towards the long-term introduction of vehicles powered by electric power or hydrogen.

At the moment, gradual electrification of motor vehicles is already under way. So-called hybrid vehicles are combining combustion engines and electric motors in order to improve vehicle efficiency. For both electric vehicles and hydrogen-powered vehicles, further improvements relating to battery technology, hydrogen storage and fuel cells still need to be realised in order to achieve market maturity. While neither technology itself causes direct emissions, it is necessary to focus on the energy production side too. If fuel production uses electricity originating from renewable sources, the overall balance of emissions is promising; if using electricity from conventional thermal power crops, however, electric and hydrogen-powered vehicles perform similarly to existing hybrid vehicles in terms of energy efficiency and greenhouse gas emissions.

The following chapters, written by experts from Austrian companies and R&D institutions, will guide you through the topic of existing and future alternative transport fuels.
The chapters give an overview of the social, technical and economic aspects of different alternative fuels. Advantages and disadvantages of various options are discussed, and you will find information on current trends in the fuel and automotive industries. All together, the chapters provide an interesting insight into the important topic of alternative fuels – helping to enhance transport efficiency and to reduce emissions.

VEGETABLE OIL AND BIODIESEL

VEGETABLE OIL FOR DIESEL ENGINES

Rudolf Diesel himself wanted to run his engines using vegetable oil. Scientific investigations were carried out into running engines on vegetable oil before World War II. The oil crisis in 1973 revived interest, and research was conducted around the world into the use of vegetable oil in conventional diesel engines. However, the tendency of vegetable oil to coking significantly limited running engines using pure vegetable oil.

Starting from Canada, the widespread planting of rape has been a successful development. Rape is a plant suited to regions with a temperate climate, and in Northern Germany the yield is 3 to 4 t/ha of seed. The seed can be processed using proven technology in industrial plants and in small-scale units at relatively low cost. A single hectare is sufficient to produce 2 tonnes of protein feed for animal nutrition and 1.3 tonnes of rapeseed oil. Through good farming practice, breeding measures and reduced expenditure on manure and pesticides, alongside advances in farming engineering, it has proved possible to reduce the costs of rape production by 70% in 35 years.

However, globally a range of further oils and fats are also being considered as raw materials. For instance, palm oil is economically attractive owing to its high yields (up to 7 t/ha), but is called into question on ecological and social grounds. The Jatropha plant promises sustainable production, particularly in arid regions, but a whole agricultural production system must be developed.

To use vegetable oil as a fuel, two strategies can be envisaged. Engines suitable for running on vegetable oil can serve niche markets, or if the properties of oil are adapted to the requirements of existing engines the whole diesel fuel market can be opened up.

BIODIESEL

is produced through alcoholysis of vegetable oil or animal fats. A triglyceride molecule is used with three molecules of methanol to produce three molecules of methyl ester and one glycerine molecule. Over the past decade, simple processes with low energy demand, high transformation rates and good product quality were developed to produce methyl esters ("FAME" = "fatty acid methyl ester"; "RME" = rape oil methyl ester).

Transesterification improves the diesel engine characteristics. Viscosity is reduced, the tendency to coking is compatible with the range found in diesel fuels, and the cetane number and lubricity are better than that of fossil diesel. Extensive investigations during the 1990s demonstrated that biodiesel is suitable for market-viable, series-manufactured vehicles. Groups of researchers in Austria (in Graz, Wieselburg and Vienna) were world-leading in this field. With national standardisation in Austria, for the first time anywhere in the world the preconditions were established for regulated trading of biodiesel.

Since 2004, EN 14 214 has specified the requirements for biodiesel as a pure fuel and as a mix component added to fossil diesel fuel. Since 2006, 4.4% biodiesel has been admixed to filling station fuel in Austria. The use of pure biodiesel requires car manufacturer approval. Although after 1990 there was success in securing approval for running on pure biodiesel, the automotive industry remains hesitant. In developing exhaust gas filter technology, no account was taken of the specific characteristics of biodiesel. Car manufacturers are accordingly limiting the admixture to a 5% level, and a 7 to 10% limit is under discussion. Approvals for running on pure biodiesel are only to be brought in for heavy utility vehicles.

RUNNING ON VEGETABLE OIL

requires modifications to the vehicle and to engines. On the development side, design measures need to be taken in respect of the injection engineering, the combustion chamber and in the design of pistons, piston rings and valves. To accelerate development the German Standardisation Organisation has drawn up a tentative DIN-standard for vegetable oil. The costs of development and the small market have proved obstacles to the introduction of Vegetable Oil Technology. To overcome this hurdle, the German Ministry for Agriculture has financed a demonstration project. Over 100 re-equipped tractors have been operated for several years using vegetable oil, with monitoring by scientists.

Overseen by scientists at FJ BLT, a project supported by Agrar Plus is underway in Austria. With assistance from the Ministry of Agriculture, Forestry, the Environment and Water Management and from the Regional Governments of Lower Austria, Upper Austria and Burgenland, and under the Kommunalkredit local authority loan scheme, a comprehensive monitoring project is being carried out into the practical use of 35 re-equipped tractors and the production of vegetable oil in small production units over the period end 2003 – mid 2008. The aim is to show under which conditions the use of vegetable oil as a tractor fuel on re-equipped series-manufactured tractors is possible, and what risks arise from this.

To assess the oil quality, samples are taken and analysed periodically from the oil mills, storage tanks and vehicle fuel tanks. In the first year, the introduction of quality assurance measures has seen success in complying with the requirements of the DIN tentative standard.

Building on the experiences in Germany, "two-tank systems" are also being used. These tractors are run using fossil diesel at low load and when in cold condition, and at high load using pre-heated vegetable oil, thereby reducing engine oil dilution and carbon built-up on engine parts. Power output when running on diesel and rapeseed oil is roughly the same. The fuel consumption is somewhat higher when running on rapeseed oil than on diesel. In terms of emissions, rapeseed oil offers improvements in CO and hydrocarbon emissions, with worse performance in terms of NO_x emissions.

For the engine oil, all tractors used products from a German manufacturer with relevant experience. The customary oil change periods were maintained. The average rapeseed oil content of the samples from the engine oil changes on a two-tank system was 4.6%, which was well below the corresponding level of 12.5% on one-tank systems. The final investigations have been underway since autumn 2007. For these, power behaviour and emissions are being assessed on the test bench and the degree of wear investigated by dismantling the engines. The programme will be rounded off in mid 2008 with a comprehensive report.

BIOETHANOL

To conserve resources of fossil mineral oil raw materials, and to improve the CO_2 balance sheet, increasing use needs to be made of sustainable fuels. The use of biodiesel is already familiar to us and is state-of-the-art, whereas substitute biogenous fuel for the Otto engine is only now beginning to be used in Europe, in the form of ethanol. Currently the share for sustainable fuel in Austria is around 5%, although this level is set to be increased progressively to at least 10%.

ETHANOL FOR OTTO ENGINES

Ethanol as source of energy was already considered as a possible fuel at the time the car was invented. The starting product for fermentation is raw material containing sugars and starches. Whereas plants containing sugar (sugar beet, sugarcane) can be fermented directly, in grain the starch is first converted to sugar through enzyme action. The fermentation produces a product with an alcohol content of 18%, and using distillation this degree of concentration is increased to 90%. For admixing with petrol, in a further step the alcohol content is increased to close on 100%.

Ethanol has excellent characteristics for the Otto engine, as a pure fuel and when mixed with conventional petrol. Currently, 5% ethanol is admixed with petrol in Austria. Since the energy density of pure ethanol is low, engines need to be adapted to use pure ethanol.

Research work at Vienna University of Technology has shown that higher levels of efficiency with higher performance and lower emissions can be achieved using ethanol. Vehicles which can be driven on petrol-ethanol mixes of up to 85% (flexible fuel vehicles - FFV) are on the market in Sweden, Brazil and the US, strong efforts to implement such technologies are made in an E85 program by some companies in Austria too.

The Brazilian “Proalcool Programme” was the biggest market launch programme in the world. As early as 1997, 273 million tonnes of sugar beet were harvested out of which 13.7 million m3 of fuel were produced. Ethanol is primarily used in mixtures, and since 1999 a 26% admixture has been used. In recent years, automobile companies have launched FFVs on the Brazilian market, to great success. Now, however, the USA has overtaken Brazil. In 2007, to safeguard fuel supply, a total of 7 billion gallons of ethanol was produced in 115 plants from maize and grain, and the annual increase from 2007 to 2008 was 38%.

FUTURE POTENTIAL FOR ACQUISITION OF FUEL

The increasing use of ethanol as a supplement to or substitute for fossil fuels is, however, becoming increasingly controversial today. For instance, triggered by the extensive cultivation of suitable plants, there are fears of disruption to the ecosystem and ethical reservations against using plants such as grain, maize or sunflowers for energy, given that these crops are simultaneously the basis for food products. Nevertheless, the so-called first-generation fuels have already achieved global importance today. The USA and Brazil produce well over 30 million tonnes of ethanol annually.

By contrast, in the second-generation fuels (the development of which is being worked on by researchers at present) the fruit is to be used for food production and only the residual components or “waste” from the commercially-grown plant is to be used to produce energy. This would open up the way to a sustainable further increase in the share of biogenous products in fuel.

ADAPTING ENGINES TO RUN ON ETHANOL

If ethanol is to be admixed in higher proportions, then the engine needs to be adapted accordingly. Depending on the mix ratio, a higher octane rating, a lower thermal value and increased vaporisation heat can be obtained. Given the climatic conditions in Europe, admixing up to 85% ethanol is sensible. This requires adapted engine management parameters such as injection volume, ignition timing etc. Vehicles known as FFVs are adapted to run on any preferred mix ratio, up to 85% ethanol in the petrol. For engines working with a high ethanol content in the fuel, one of the requirements is that the valve seats need to be manufactured in tougher material, since the stress is somewhat increased and the lubricating properties are lower. Alcohol-resistant materials must be used for fuel lines and seals.

OPPORTUNITIES AND CHALLENGES FOR USE IN ENGINES

The future increased use of alternative fuels is therefore predicated on the development of adapted engines. The full potential of ethanol to increase efficiency levels can only be fully exploited by optimising the engine to the special characteristics of the fuel. As an example, mention should be made here of the higher knock rating, which allows the compression ratio to be increased. This results in an increase in thermal efficiency. This is not possible using conventional Otto engine fuel, due to knocking. Knocking comes about if, at full load, pockets of the fuel-air mixture ignite spontaneously subsequent to the spark plug ignition, due to the high pressure and the temperature. This is associated with extremely high stresses on the engine which, if they persist for too long, can result in destruction.

Moving the ignition point later guards against this stress, but it worsens the level of efficiency. This is not necessary at all with ethanol, or only to a significantly lower extent. This means that using ethanol not only brings benefits in terms of efficient conversion of energy, but the early combustion also means that the exhaust gas temperature is significantly lower than when running on petrol. The outcome of this process is significantly lower need for enrichment to cool the catalyst at high loads, meaning that additional fuel is saved. Future ethanol engines will come close to modern diesel engines in terms of their level of efficiency at full load.

If the option is taken for flexible operation using any preferred mixtures of ethanol up to 85% and petrol, as for example in FFVs, compromises must necessarily be made, since the engine must also work with the lower knock rating of conventional Otto engine fuel. In all cases, developments in terms of engine adjustments are certainly required, but no fundamental new designs.

However, using ethanol also brings about disadvantages. The high vaporisation heat and the high boiling point of ethanol can lead to difficulties with cold starting, particularly at very low ambient temperatures. This generates major challenges, in terms of injection strategy and the engine application, in order to vaporise sufficient fuel when starting. One possible solution is multiple injection per cycle on direct-injection engines. This can improve the vaporisation pattern and lower the minimum cold start temperature. In addition, the lower calorific value of ethanol compared with petrol (around a third lower) means that there is a greater volumetric fuel requirement. Whilst this means shorter periods between fuelling stops, the lower price means that there are no additional costs for the consumer. In addition to the advantages in fuel manufacturing, there are also lower CO_2 emissions from running the engine, due to the increased level of efficiency when running on ethanol.

SECOND-GENERATION FUELS – THE WAY AHEAD

Currently a range of liquid and gas sustainable fuels are being produced and researched; they are manufactured using various raw materials and various processes. Vegetable oil, biodiesel and ethanol are available on the market, an industrial plant has been constructed to produce hydrogenated fuels from plant oils, the use of biogas and vegetable oil in vehicles is being demonstrated, a demonstration plant to produce Fischer-Tropsch (FT) diesel from bio-synthesis gas is going into operation, serious consideration is being given to butanol and DME (dimethyl ether), processes for direct liquefaction are being announced, and studies are addressing the issue of hydrogen.

The raw materials can be sourced as principal products and by-products of agriculture and forestry, but also as coupled products from industry or as residual materials from waste management. In particular, the latter cover oils and fats of vegetable and animal origin, traditional plants containing starch or sugar, lignocellulose raw materials such as wood, straw and miscanthus, and also organic residual materials such as manure and organic waste.

The potential from sustainable fuels from domestic raw materials is limited by the competition for land area with food and raw materials. In a sustainable fuel-oriented scenario, where key societal demands are secure supply of high-quality food and maintaining an environment fit to live in, by 2020 it would be possible to generate up to 1.4 million toe of alternative fuels from domestic raw materials (e.g. 160,000 toe biodiesel, 120,000 toe ethanol from plants containing sugar or starch, 700,000 toe FT fuel from gasification of wood, wood waste and plants farmed as an energy crop, and 400,000 to 500,000 toe biogas from waste and plants grown as energy sources). The fuel demand in 2020 is estimated at 0.7 million toe petrol and 7.4 million toe diesel fuel, with around 80% of this being consumed domestically within Austria. This means that, using the uppermost assumptions, 22% of own demand can be met from primary domestic production.

Manufacture can involve mechanical, chemical, biochemical, thermo-chemical or petrochemical processes. Examples are pressing, esterification, fermentation, gasification, gas-synthesis and hydrogenation. The combination of processes and raw materials produces a range of possible options. Below, the probable options as considered today are described in fuller detail.

ETHANOL FROM LIGNOCELLULOSE

To extend the basis of raw materials, for some considerable time investigations have been pursued into the pulping and saccharification of lignocellulose raw materials. The raw materials being examined are wood, bark, straw, high-yield energy planting such as miscanthus, and also lignocellulose waste materials such as used paper. The areas of focus in research are mechanical pulping, hydrolysis, the production of enzymes and the genetic modification of micro-organisms, and the overall process itself. High conversion rates for cellulose and hemicellulose are sought, as is the comprehensive use of all by-products.

The “Roadmap for Cellulosic Ethanol” from the US Department of Energy is showing the way in which by 2030 30% of fuel demand in the USA can be met from lignocellulose. The strategy is reliant on whole crop maize, but grasses grown over several years such as switchgrass are being investigated. The research is being conducted in 10 national laboratories and at 200 universities. A series of companies are setting up demonstration plants, with public assistance. In Canada, the company IOGEN is producing ethanol from straw in a demonstration plant. Hand in hand with the market launch of ethanol, flex fuel vehicles are coming onto the market.

Europe, too, is engaged in research: for a number of years, Sweden has been operating a pilot plant using softwood; Denmark is building a demonstration plant for straw; and the European Commission is supporting basic research via the NILE Project. Austrian researchers are using similar approaches in seeking different objectives: with funding from Austria’s “Factory of Tomorrow” [“Fabrik der Zukunft”] Federal research programme and funds from the Upper Austria Land government, the “Green Refinery” is researching the linked production of lactic acid as an industrial raw material and biogas as an energy carrier, on a pilot scale.

HYDROGENATED VEGETABLE OIL AND “INNOVATIVE BIODIESEL”

Under the name NextBtL, VTT in Finland has collaborated with a Finnish mineral oil company to develop a hydrogenating process to produce hydrocarbons from fats and oils originating from plants and animals. For this, the raw material is treated with hydrogen, under the influence of a metallic catalyst, at between 250 and 350°C and at ambient pressure. The process produces mainly straight-chain hydrocarbons in the boiling point range of 180 to 350°C, and as a by-product CO_2 and water. The product exhibits favourable diesel-engine characteristics and can be mixed in any concentrations desired with fossil diesel. An initial industrial plant went into operation at the end of 2007 in Finland, with further plants planned in Europe and the Far East.
A similar process can be applied in mineral oil refineries. For this, oils and fats sourced from plants and animals are processed together with mineral oil-based intermediates and hydrogen in existing petrochemical plants.

The R&D work on biodiesel is concentrating on optimising processes, e.g. by increasing the yield and the use of by-products, with particular importance being attached to the high-value use of glycerine. In terms of its application, the main focus is on the selection of fatty acid spectra with favourable diesel-engine characteristics.

There is a common interest in the search for new fuels and in optimising raw materials chains. This requires societal, ecological and economic requirements to be brought into harmony. One highly promising approach appears to be the cultivation of the Jatropha plant in arid developing countries.

FUELS FROM SYNTHESIS GAS

Low-molecular gases are suitable for syntheses of all types. Given a free choice of synthesis gases, it is possible to produce a wide range of products, and especially fuels with a specifically-sought composition. Synthesis gas can be obtained through thermal gasification of biomass.

Austrian researchers hold a leading position worldwide in terms of gasification of biomass. In the demonstration plant in Güssing, researchers have succeeded – through research programmes ranging over many years and established on a broad footing – in developing a market-mature technology which is the envy of international experts the world over.

Bio-SNG, synthetic natural gas from biomass, can be produced using a relatively simple process. As part of the EU Project “BioSNG”, a demonstration plant for the production of synthetic methane is currently under construction in Güssing, and set to go into operation in summer 2008. The plant comprises a gas purification system, a methanation unit to convert H_2 and CO to CH4 and H_2O, and the gas treatment plant to bring it up to natural gas quality. The plant obtains the product gas from the existing biomass power station and will produce 100 m3/h of methane in natural gas quality. This is the equivalent of a power of 1 MW. The gas produced is used in a natural gas filling station and is being tested in practical use. During the pilot scale study, a 65% level of efficiency in gas production was achieved. As the residual heat is used in the plant, an overall efficiency level of 85% is anticipated.

Concrete plans for plants of this type are already underway in Switzerland and Sweden, and interest is also coming from France, Germany and Austria.

Methanol synthesis has been carried out on a major engineering scale since 1928. Using carbon monoxide, carbon dioxide and hydrogen and with the aid of catalysts at relatively low temperatures, methanol and water are formed in an exothermic reaction. Methane and higher hydrocarbons are formed in secondary reactions. To date, methanol from biomass has only been investigated for reaction kinetics and in the laboratory, and pilot or demonstration plants have not been constructed. >>

Fischer-Tropsch fuel synthesis was developed in Germany shortly after the First World War. Carbon monoxide and hydrogen are used as synthesis gas. The gas can be produced from coal, natural gas or biomass. During World War II, significant quantities of FT fuel were produced in Germany. Due to the fuel embargo, the company SASOL in South Africa built a coal-operated industrial plant which has been running successfully for decades. It produces liquid petroleum gas, petrol and heavy fractions which are onward processed using petrochemical processes (CtL = coal to liquid).

German industry is putting its faith in the "From Synfuel to Sunfuel" strategy ("Von Synfuel zu Sunfuel"), with synfuel referring to fuels from fossil synthesis gases, and sunfuel those produced from gasification of biomass (BtL = biomass to liquid). The diesel fraction of the intermediate product has outstanding diesel engine characteristics. BtL allows for a reduction in emissions of particles, hydrocarbons, carbon monoxide and nitrogen oxides. The CHOREN Industries GmbH is working intensively on a BtL process. Pilot scale testing has been conducted successfully, and a demonstration plant in Freiberg (Germany) is shortly to go into operation.

BIO-CNG: NATURAL GAS AND BIOGAS

Natural gas is composed almost entirely of methane, which is already being used in pressurised containers in considerable quantities in natural gas vehicles. Infrastructures for supplying vehicles are being introduced. Vehicle manufacturers have developed natural gas vehicles, and further models will come onto the market.

Biogas comprises around 60% methane and 40% carbon dioxide, and is produced from organic waste and agricultural biomass (such as maize silage, grass etc.) using anaerobic fermentation in a watery environment. Purified biogas can be fed into the natural gas grid, and infrastructures for natural gas vehicles could be used. Austria is supporting the introduction of a methane gas system for transport use through Bio-CNG projects.

LIQUEFACTION OF SOLID BIOMASSES

The hydrothermal upgrading process (HTU) developed by Shell aims to reduce the oxygen in biomass by releasing CO_2. Woodchips are used as the raw material, and drying is not necessary. The process operates at 200 bar, and for good reactions process optimisations are necessary. The product is solid or liquid and suitable as a raw material for fuel production using petrochemical processes. The works to date have not led to any more far-reaching implementation.

In catalytic low-pressure depolymerisation, the solid biomass is heated together with a catalyst in a liquid heating medium. By selecting suitable process conditions (temperature, pressure, catalyst), liquids are produced with similar characteristics to fossil fuels.

Pyrolysis is the term used to describe the anaerobic carbonisation of biomass, during which solid, liquid and gas components are formed. Pyrolysis produces a heavy, tarry and acidic liquid with a high water content, a high content of solids (coke, ash) and a calorific value similar to that of wood. Flash pyrolysis, at temperatures between 500 and 800°C, supplies a good yield of liquid components. Pyrolysis products with a high proportion of coke are termed "slurry". Both products are well-suited to thermal gasification to generate synthesis gas.

BIO-HYDROGEN

Hydrogen as an energy source for fuel cell drives is being researched intensively worldwide due to the possibility of emissions-free vehicles. Hydrogen can be produced in a similar manner to biogas, using a bio-engineering route or through thermal gasification. Hydrogen-based transport systems are not expected earlier than 2030, due to the high cost of R&D and due to the need for entirely new vehicle and logistics systems.

"WHICH IS THE BEST?"

The answer depends on the objectives, the framework conditions and the decisions already taken. As seen today, the following development appears sensible:

By 2020, market-viable sustainable fuels are set to dominate the scene. Europe has committed itself to biodiesel from rape and ethanol from grain and sugar beet. The arguments in favour of ethanol are the higher yields per hectare, and for biodiesel the more favourable energy balance sheet. The aims of the Biofuel Directive can be achieved through this, with the limiting factors being the available land area and the market for protein feeds. North America is committing to ethanol from maize, Brazil to ethanol from sugarcane.

The arguments for biogas are the highest yields per area and the simple process, which is also suitable for smaller plants. Using biogas in transport requires investments to expand the gas grid, to purify the gas and feed it into the network, and the construction of filling stations. Austria is supporting the expansion of infrastructure and of methane gas vehicle fleets through Bio-CNG projects.

After 2010, investments in new sustainable fuels are likely to show dividends. Europe is trusting to synthetic fuels and North America to ethanol from lignocellulose raw materials. Both processes build on cheap wood and straw-like raw materials. Since whole plants and residual materials such as straw are used, the available land areas can supply greater volumes. Success depends on development, access to cost-favourable raw materials and on the policy framework.

For Europe, it seems realistic to aim for a volume of 10 to 15% of today's fuel demand by 2020. If the expectations in research and development of transport systems are met, in the period around 2030 the changeover will begin to other transport systems, where the requirement will similarly be for sustainability.

BIOGAS FROM ANAEROBIC DIGESTION AS VEHICLE FUEL – REQUIREMENTS AND APPLICATION

Anaerobic digestion of agricultural waste as well as other organic wastes is a widespread technology in Austria and Germany for producing biogas. Besides the usual conversion to heat and power (CHP), upgrading to natural gas quality and feeding into the gas grid opens up new promising areas of biogas usage as a vehicle fuel. It combines the advantages of decentralized fuel production with the well established infrastructure of the natural gas grid.

POTENTIAL OF BIOGAS PRODUCTION IN SUSTAINABLE FUEL-BASED BIOREFINERY CONCEPTS

Today the challenge is to increase the sustainability of feedstock production for fuels by using innovative systems, processes and technologies. Sustainable land use strategies must be developed for supply of the biomass feedstock that are compatible with the climatic, environmental and socio-economic conditions prevailing in each region.

It is necessary to promote the transition towards "second generation biofuels" while supporting the implementation of currently available sustainable fuels, and further towards "biorefinery systems" which will be producing from a wider range of feedstocks, including waste and lignocellulose biomass (LA-EU Biofuels Research Workshop, Final Report, Sao Paulo 23-27. April 2007).

Sustainable fuel-based biorefinery concepts are systems in which food, raw materials for industry, and energy can be produced. The aim of sustainable biorefinery concepts is the development of integrated crop rotations that satisfy the demand for food and feedstuffs, as well as producing raw materials (e.g. oil, fat, organic acids) and energy (e.g. biogas and ethanol).

Combining a variety of technologies achieves a reduction in production costs and minimises use of fossil energy sources, whilst reusing excess materials and by-products. Thus the ecological footprint is minimised.

Figure 1 shows the diagram of a sustainable fuel-oriented biorefinery system. Biogas production is a key technology for the sustainable use of agrarian biomass as a renewable energy source within fuel oriented biorefinery systems. Biogas can be produced from a wide range of energy crops, animal manures and organic wastes. Thus it offers great flexibility and can be adapted to the specific needs of contrasting locations and farm managements.

Currently, maize, sunflower, grass and sudan grass are the most commonly used energy crops. In the near future, biogas production from energy crops will increase and consideration needs to be given to growing energy crops in versatile, sustainable crop rotations. All activities must aim at sustainable use of the multifaceted cultivated landscape. In addition, more by-products from the agricultural, food and energy industries need to be integrated into a versatile biogas production.

One higher-level aim in the research on biogas production is the development of integrated crop rotations that supply food and feed, produce raw materials (e.g. oil, fat, organic acids) and energy (e.g. biogas, RME) and maintain and further promote a multifaceted cultivated landscape. This aim can be achieved via the following strategies:

- Food non-food switch: alternation of crops for the production of food, feed, raw material and energy
- Cascade utilisation: different parts of the same crop are used for different options, e.g. starch from maize corns and biogas from the remaining maize plant
- Choice of the optimum genotype and harvesting time: e.g. energy crops must produce high biomass yields and contain optimum nutrient patterns

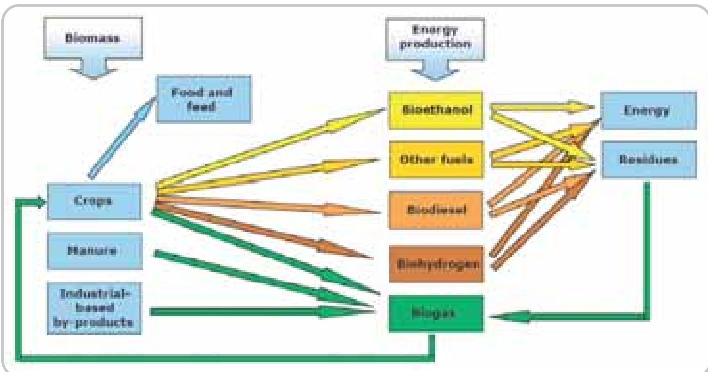


Figure 1: Diagram of a fuel oriented biorefinery system

The potential of biogas production will be greater than assumed so far when calculations are based on sustainable systems rather than on single crop digestion.
The possibility to produce biogas from biogenous local by-products/residual products in Austria, at the level of five to ten per cent of total volumes of natural gas, and to make use of it via the existing gas grid, is already in place. It follows that further plants such as those in Bruck a. d. Leitha and Pucking will rapidly be put in place (not least due to their high energy efficiency). BioCNG (with at least a 20% share of biogas) can then be exploited to further enhance the positive characteristics of CNG (20% reduction in CO_2, no engine-related particulates, no NO_x, etc.) to achieve greater CO_2 reductions.

Particularly in the area of transport, where CO_2 emissions in Austria have increased by 86% since 1990, the existing potential to achieve reductions needs to be used urgently. Biogas is the only second-generation fuel available today. Achieving the EU targets (-20% CO_2 by 2020) requires CNG and bioCNG now.

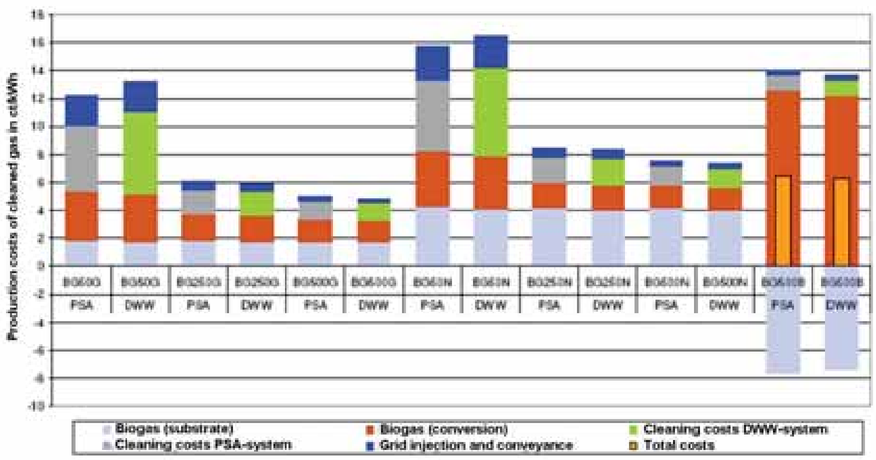
firing data	limits	unit
heating value	10,7 bis 12,8	kWh/m3
Wobbe – Index	13,3 bis 15,7	kWh/m3
relative density	0,55 – 0,65	
components		
hydrocarbons: point of condensation	Max. 0° at operating pressure	[°C]
water: point of condensation	Max.-8°C at 40 bar	[°C]

Table 1: quality requirements of natural gas in Austria (ÖVGW G31)

QUALITY REQUIREMENTS FOR BIOGAS AS A VEHICLE FUEL BY DISTRIBUTION OVER THE GAS GRID

The requirements of biogas for gas grid injection are given in Table 1, which is the general gas quality regulation following the ÖVGW rule G31 (ÖVGW – Richtlinie „Erdgas in Österreich. Richtlinie G 31 (Gasbeschaffenheit)“, Österreichischer Verein für das Gas- und Wasserfach, 2001). For the special purpose of biogas injection the ÖVGW rule G33 has been published which defines the additional requirements for biogas (ÖVGW – Richtlinie „Regenerative Gase – Biogas. Richtlinie G 33“, Österreichischer Verein für das Gas- und Wasserfach, 2006). Following the ÖVGW rule G33 biogas has to consist of more than 96 mol% methane.

The removal of carbon dioxide and sulphuric compounds are of major interest in biogas upgrading connected to special technologies. The total costs for the supply of upgraded biogas into the natural gas grid consist of biogas production, biogas conditioning, compression and injection. Figure 2 shows the upgrading of biogas is a major cost item of about 1–5 ct/kWh depending on the size of the plant and the technology selected. Depending on the substrate and scale of the plant, overall costs for the injection of biogas presently are between 5 and 16 ct/kWh, with the lowest values being calculated for biogas from waste products and plant capacities of 500 Nm^3/h in this study. Current projects target a cost of 4 ct/kWh for upgraded biogas from agricultural by-products.



Legend:

PSA	Pressure swing adsorption
DWW	Water scrubber
BG	Biogas plant
50-500	Nm/h raw biogas production
G	Substrate: Manure + 10 % energy plants
N	Substrate: Energy plants + 10% manure
B	Substrate: Separate collected organic waste

Colors of specific costs:

Light blue	Substrates
Red	Biogas conversion
Green	Upgrading costs (water scrubber)
Grey	Upgrading costs (PSA)
Dark blue	Injection and network access fee
Orange	Total costs (case organic waste)

Figure 2: Production costs (ct/kWh) of injected biogas

BIOGAS UPGRADING

Based on the requirements of the guidelines and the natural gas operators, the corresponding purification technology has to be chosen. Following components have to be purified to reach the claimed limit values: hydrogen sulphide (H_2S), ammonia (NH3), water (H_2O), siloxanes, carbon dioxide (CO_2).

The common commercial H_2S purifying methods are
- Biotrickling filter or bioscrubber (biological oxidation)
- Addition of ferric chloride to the fermentation substrate (sulphide precipitation)
- Impregnated activated carbon (catalytic oxidation)
- Iron oxide on steel wool (chemical sorption)
- Iron oxide pellets (chemical sorption)
- Scrubber with water, organic solvent or caustic soda (absorption)

The most common methods for the removal of H_2O are
- Cooling (condensation)
- Molecular sieve (adsorption)
- Polar solvent – glycol (absorption)

The most common methods for the removal of siloxanes are
- Gas drying systems and adsorption on activated carbon
- Adsorption on polymorphic porous graphite
- Absorption in Selexol®
- CO_2 scrubber

The most common methods for the removal of CO_2 are
- Scrubber (absorption)
- Pressure-swing-adsorption (adsorption)
- Membrane process (permeation)

UTILISATION OF BIOGAS AS A VEHICLE FUEL

Recent developments were directed towards the utilization of mixtures of natural gas and biogenous methane as a vehicle fuel. For this purpose the establishment of filling stations is directly connected to the field application of such a fuel. Currently about 100 public natural gas filling stations are in operation in Austria, with the goal to increase the number to 200 until 2010.

EMISSIONS FROM VEHICLES RUNNING ON (BIO-)METHANE COMPARED TO PETROL AND DIESEL

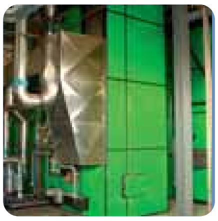
Comparing the utilization of natural gas as a vehicle fuel against petrol and diesel, some advantage can be shown over the liquid hydrocarbons in terms of emission reduction. Compared to a petrol driven passenger car following the EURO 4 standard up to

- 80% less carbon monoxide (CO)
- 20% less carbon dioxide (CO_2)
- 80% less non-methane hydrocarbons (NMHC)
- 20% lower global warming potential and 40 % lower ozone generation potential

Compared to a diesel driven passenger car following the EURO 4 standard equipped with a particle filter up to

- 10% less carbon dioxide (CO_2)
- 90% less nitric oxide (NO_x)
- 60% less non-methane hydrocarbons (NMHC)
- practically no particle emissions
- 10% lower global warming potential and 80 % lower ozone generation potential

Employing biogenous methane as a natural gas substitute, the emissions of carbon dioxide can be regarded as lower because of the biogenic origin of the substrates for biogas production. Following the GEMIS – model for CO_2 calculation for the whole biogas production and utilization chain, a CO_2 emission equivalent of 30 g/pkm (grammes per passenger kilometre) has been calculated for a model scenario, i.e. decentralized biogas production from manure and injection into the pipeline. In comparison the diesel passenger car shows emissions of approximately 120 g/pkm. Other emissions are significantly lower as well: SO_2: 0.03 – 0.05 g/pkm (diesel: 0.07 g/pkm), NO_x: 0.09 – 0.24 (diesel: 0.43), particles: 0.01-0.03 (diesel: 0.04). However, using other substrate for biogas production (energy crops) and assuming a non-optimal location of the biogas plant in terms of long transportation distances (50 km), the scenarios show that the benefit of biogas is strongly decreased. In these cases CO_2 equivalents between ca. 60 and 100 g/pkm have to be taken into consideration.



COMPRESSED NATURAL GAS – CNG

The European Community aims at reducing CO_2 emissions and dependency on oil by specifying that alternative fuels must power more than 20% of traffic by 2020. Sustainable fuels, such as biodiesel, ethanol or biomass-based synthetic fuels represent one part of the solution, but there is also the fossil fuels segment, where natural gas (CH4; methane) is set to contribute a total of 10%.

Natural gas consists of 98% methane and is delivered as a fossil resource via pipeline (gaseous) or ship (liquid). Methane is a high-quality fuel, due to the second-best H:C ratio of all alternative fuels, and is thus a forerunner of a possible hydrogen technology of the future. Like hydrogen, it cannot be liquefied at ambient temperatures and must therefore be stored under high pressure above 200 bars. This compression is done at the fuelling station and the product is afterwards referred to as CNG (compressed natural gas). Although no refining or other treatments are needed, the energy output of CNG is about 90% of the primary energy of natural gas; 10 – 13% of its energy is used as input for compression. Handling of CNG is non-critical, due to methane's non-toxicity, its high ignition temperature of 600°C (diesel 230°C; petrol 260°C) and added odour substances which make it possible to detect small concentrations below the volumetric ignition limit (below 0.01%).

Methane's high percentage of molecular hydrogen results in a reduction of CO_2 emissions of 20% compared with petrol, and 10% compared with diesel fuel. Engine developments exploiting the high Octane Number of methane allow a further reduction of CO_2 emissions. Furthermore local emission of pollutants is up to 90% lower compared to diesel engines. If blending of natural gas with biogas is taken into account, one part of the fossil fuel can be substituted and the CO_2 emissions coming from non-sustainable methane can thereby be further reduced.

Supplying the existing natural gas grid with biogas, straight from the purgation and quality assurance processes, is state-of-the-art. In Austria there are two plants for biogas production and feed-in into the natural gas grid, funded by the Federal Ministry for Transport, Innovation and Technology (BMVIT) as Lighthouse projects. They make about 900,000 m3 (Bruck a. d. Leitha) and 40,000 m3 (Pucking) of biogas available every year, in a quality matching that of natural gas.

However, even after compression to 200 bar, the low volumetric and gravimetric storage density is a major disadvantage of CNG. Due to its low volumetric energy density (6 MJ/l), CNG requires roughly four times the storage space of petrol (26 MJ/l) for the same amount of energy. This impacts on the costs of the storage materials. Furthermore, standard technology for high pressure storage (steel) is heavy and restricted to simple shapes (cylindrical), which result in a non-efficient package in terms of today's vehicle platform concepts. Modern lightweight vessels (carbon composite) would be much lighter and offer the possibility of free shaping, but are expensive. Due to the low gravimetric energy density of CNG (11 MJ/kg) compared to that of petrol (31 MJ/kg), the weight of stored CNG is about three times the weight of petrol for the same amount of energy. These disadvantages are not unique to CNG technology; hydrogen technology and battery systems suffer from the same problems.

Today CNG has a lower price than diesel on an equal energy basis. In the last two years the number of CNG fuelling stations in Austria has been tripled to 100, and is set to double again by 2010. To date, there are more than 1000 CNG vehicles on the road, consuming about 2 million m3 CNG per year. As the market maturity of CNG technology is already reached, the numbers of CNG vehicles is expected to rise. There are also new vehicle concepts like the MILA (figure 1) and the MILA alpin (figure 2) being presented to the public. The next step for CNG vehicles will be a switch from bivalent to monovalent operation. This will happen in a coordinated move as the number of fuelling stations and vehicle range increases.

To ensure proper market penetration, further milestones (like creating a consistent tax regime, raising the number of fuel stations above 200 and increasing the driving range beyond 600 km) need to be reached. An important step in this journey has already been accomplished by the 'CNG 600' project, funded by the BMVIT, which has demonstrated the concept of a monovalent CNG vehicle with a driving range of 600 km by manufacturing a prototype.

The monovalent use of methane means that the engine can be optimally adapted to the given framework conditions, which is not the case in bivalent use. It makes it possible to develop a combustion process for direct gas injection, under which the efficiency of a gas Otto engine can be improved by a further 10-15%, through a combination of stochiometric and lean running in the characteristic areas relevant to the driving cycle, as is being implemented by AVL. This means that specific CO_2 emissions values can be achieved which are below those for diesel engines.

In addition, it is proving possible to exploit the high knock rating of the gas in combination with the latest combustion chamber shapes to increase the power density, with the result that average engine pressures in gas operation of > 25 bar are possible with turbo-charging. In turn, this permits using direction-injection gas engines of this kind in hybrid drives, resulting in a further reduction in consumption through an adjustment (reduction) in engine piston capacity ("downsizing") combined with partial electrification of the drive. It has been possible to demonstrate, through appropriate driving cycle simulations, that using drive systems of this type the CO_2 output per km can be squeezed, even on vehicles in the Passat class (1500-1600 kg) to values < 80 g.

Finally, if biogas admixes are taken into account (e. g. 10-15% "virtual biogas" from sustainable production, without competing with the food and feed industry within the EU), it appears that net CO_2 emissions from mid-class vehicles (1500-1600 kg unladen weight) of the order of 70 g/km are feasible.

Figure 1 – MILA

Figure 2 – MILA alpin

Methane technology will focus on the following items which may come into serial production in the near future:

- Cost- and weight efficient pressure vessels in composite technology, featuring high synergies with high pressure hydrogen storage
- Innovative methane fuel management systems to assure powertrain performance and to integrate in actual vehicles architecture and diagnosis
- Integrated, assembled and tested methane fuel modules including emergency petrol tank (figure 3) and accurate fuel gauge relating to stored energy
- New platform concepts considering the specific geometric and interface requirements for methane, as well for other alternative storage systems such as hydrogen and battery

OPPORTUNITIES AND CHALLENGES:

Pros:

- Technology available now
- Low-cost path to simultaneous reduction of greenhouse gas and conventional emissions
- Good economy for the end user

Cons:

- Low number of fuelling stations, although growing fast
- Fuel storage

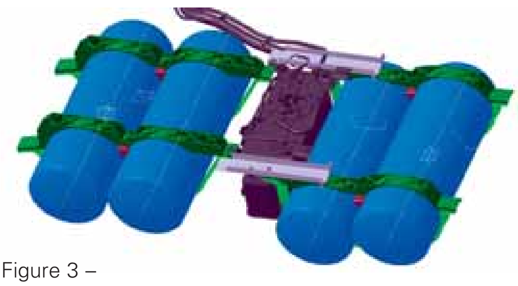


Figure 3 –
Methane fuel modules including emergency petrol tank

LIQUEFIED PETROLEUM GAS – LPG

The commonly-used name for automotive liquefied petroleum gas (LPG) is autogas. LPG is a mixture of hydrocarbon gases used as a transport fuel. It is composed mainly of propane and butane, with minor amounts of propylene and butylene. The exact composition depends on climate conditions as well as engine modifications. Generally more butane is used in summer, and in winter more propane. The most common blend is 60% propane and 40% butane gas. As LPG is a colourless and non-odorous gas, an odorant such as ethanethiol is added in order to detect leaks easily. The international standard for LPG fuel is EN 589.

LPG is formed on the one hand during refining of crude oil, and on the other hand occurs naturally in gas and oil fields.
At ambient temperature and pressure LPG is in gaseous state. LPG is supplied in pressurised steel bottles. LPG changes from the gaseous phase to liquid phase at a moderate pressure of about 8 bar, depending on the gas composition and temperature; e.g. approximately 2.2 bar for pure butane at 20°C, and approximately 22 bar for pure propane at 55°C. The following table lists the most important properties of LPG.

The density of LPG is higher than air, and the gas therefore tends to settle in low spots, such as basements. This circumstance has to be taken into account when planning filling stations and parking garages.

The same fuel is also used in stationary applications in similar gas engines for power generation. Lower exhaust emissions is one of the reasons why LPG is used as a transport fuel. In particular, it reduces CO_2 emissions by around 10% (measured in real bus fleet operation on LPG city buses in Vienna run by "Wiener Linien") compared to diesel buses, because of the better H:C ratio. The reduction in NO_x emissions by 30%, with almost no particulate emissions as well as no unburned hydrocarbon emissions, make LPG attractive as a fuel in densely populated areas with bad air quality.

Properties	Propane	Butane
Molecular Weight	44.09	58.12
Ignition Point	460°C – 580°C	410°C – 550°C
Boiling Point	- 42.1°C	- 0.5°C
Freezing Point	- 187.7°C	- 138.3°C
Gross Energy MJ/L (MJ/kg)		
per unit volume	25.5 (50.39)	28.7 (49.57)
Density @ 15°C kg/L	0.510	0.580
Litres per tonne	1960	1720
Motor octane number		
(MON) – EN589	95.4	89
Research octane number		
(RON) – ASTM	111	94.2

Table 1 Properties of propane and butane (source: www.lpgaustralia.com)

LPG is the most widely used alternative transport fuel, powering more than 9 million vehicles worldwide in over 38 countries. Its environmental benefits, practical advantages and overall effectiveness have already been widely demonstrated. In Austria the situation is slightly different. The largest Austrian city bus fleet in Vienna is running over 500 LPG buses. LPG as a transport fuel offers benefits in terms of costs and emissions for the fleet operator, and offers environmental benefits for residents. In contrast to that, only a further 165 buses and a single self-propelled unit using LPG as transport fuel are licensed in the rest of Austria, according to figures produced by Statistics Austria (2006). In strong contrast to other countries such as Italy or Australia, there are no LPG passenger cars licensed in Austria.

This explains the small number of LPG filling stations in Austria and close to the Austrian border (12 in 2007).

The following list gives a good overview of the advantages and disadvantages of LPG, as seen from the viewpoint of Austria's largest LPG fleet operator (source: "Der Betrieb mit Flüssiggas als Alternative zum Dieselantrieb – © Wiener Linien")

OPPORTUNITIES AND CHALLENGES:

Pros:
- Low operating costs due to low purchase cost and exemption from petroleum tax
- Lower emissions than diesel buses
- No need for additives, due to the high octane number, a well-defined mixture preparation, and a combustion process with almost no residues
- Lower noise emissions due to a smooth combustion process, and therefore longer engine lifetimes
- Lower stress on the motor oil, given the absence of particulate emissions and lack of dilution with the fuel that would result in lower viscosity

Cons:
- Higher cost for the gas engine in comparison with a diesel engine, and higher maintenance costs
- Increased weight of the vehicle, and higher space demand for the storage tanks
- Additional inspections of pressurised storage tanks on the vehicle and in the fuelling stations
- Costs for adapting the garages

Taking everything into account, one can say that the low fuel costs and significant lower emissions are the main advantages of LPG fuel. The limited number of fuelling stations in Austria is a hurdle to be overcome for successful market introduction of LPG passenger cars. LPG is therefore facing a "chicken and egg problem" similar to CNG and hydrogen fuel, where the fuel industry is waiting for a larger number of vehicles on the market and OEMs are waiting for the fuelling infrastructure.
Vehicles consume more than 16 million tonnes of LPG worldwide per year, the equivalent of around 8% of global LPG consumption. LPG is not a new alternative fuel but offers advantages in terms of significantly lower emissions and an attractive cost structure, especially for use in fleet operations.

HYDROGEN – CARBON FREE FUEL

As a carbon free energy carrier, hydrogen has gained attention in research activities worldwide. In principle, hydrogen can be produced from renewable energy sources. Combustion in engines results in very low emissions and the conversion in fuel cells takes place without any emissions. The first research centre for hydrogen in Austria has been in operation on the premises of Graz University of Technology since 2005 (Figure 1)

Figure 1: HyCentA facility (Hydrogen Center Austria)

PRODUCTION

The amount of hydrogen produced globally is 600 billion Nm^3 per year. 40 % of production comes from industrial processes where hydrogen is a by-product. Reformation of fossil hydrocarbons is widely used for the large-scale-production of the remaining 60 %. The most cost-effective process is steam-reforming of short chain hydrocarbons such as methane. Efficiency of up to 80 % can be achieved. Natural gas, water, and energy are used, the energy coming from the natural gas. However, as the steam-reforming process is based on fossil hydrocarbons, it produces CO_2.
The production of hydrogen from water using electrolysis is emission-free if the electricity required is produced from renewable energy sources such as wind, water or solar energy. In electrolysis, efficiencies of up to 75 % can be achieved. Furthermore the by-products oxygen and heat can be used.

PHYSICAL AND CHEMICAL PROPERTIES

Hydrogen is an odourless and colourless gas with a density approx. 14 times lower than air. The following table lists some properties of hydrogen.

Property	**Liquid phase:** (1 bar, -250 °C)	**Gas phase:** (1 bar, 0 °C)	**Compressed gas:** (350 bar, 0 °C)
Density	70.8 kg/m3	0.09 kg/m3	23.5 kg/m3
Gravimetric calorific value	120 MJ/kg, 33.33 kWh/kg		
Volumetric calorific value	8.5 MJ/dm3 2.36 kWh/dm3	0.01 MJ/dm3 0.003 kWh/dm3	2.82 MJ/dm3 0.78 kWh/dm3

Mixtures with air:	
Lower explosion limit	4 Vol% H_2 (λ = 10.1)
Upper explosion limit	75.6 Vol% H_2 (λ = 0.13)
Ignition temperature	585 °C
Min. ignition energy	0.017 mJ (λ = 1)
Max. laminar flame velocity	up to 3 m/s
Adiabate combustion temperature	ca. 2100 °C
Wobbe-Index	48.7 MJ/Nm^3

MARKET PENETRATION AND MARKET POTENTIAL

For ecological reasons and for reasons of security of energy supply, mid-term to long-term hydrogen has a high market potential in the fields of energy and vehicle engineering. For commercial reasons, however, high market penetration cannot be expected in the near future.
Given the lack of local emissions, a primary target for the introduction of hydrogen technologies is the public transport companies. Vehicle and filling station infrastructures are currently becoming established across Europe, and are supported by a variety of EU projects (e.g. HyWays, HyFLEET:CUTE, Roads2Hy, etc.).
In energy engineering too, hydrogen applications can be found in niche areas at the moment. To guarantee future supply of energy, it is necessary to promote alternative energy sources worldwide. In this context, hydrogen can be used as energy storage for the excess energy produced by renewable energy sources during peak production. The stored hydrogen can be converted back into electricity or combusted in internal combustion engines or fuel cells.
Besides using hydrogen in fuel cells and internal combustion engines, its combustion in turbines is of interest.

STORAGE

Hydrogen is stored as compressed gas, as liquid at very low temperatures or in physical or chemical compounds. For storage and distribution of large quantities, the liquid form is favoured because of the higher energy density. For automotive applications, storage as compressed gas with pressures between 350 bar and 750 bar is also widely used. For mobile applications, storage in compounds such as methane is a further possibility.

OPPORTUNITIES AND CHALLENGES:

Pros:
- Carbon-free energy carrier which can be produced from a variety of energy sources
- Renewable energy cycle and environmentally friendly if electrolysis and green energy is used (e.g. wind, water or solar energy)
- Very low emissions in combustion engines and no emissions in fuel cells

Cons:
- Currently economically not competitive with fossil fuels
- High technical standards for infrastructure and applications
- Low acceptance of gaseous energy carriers

At present a number of technical and economical challenges still have to be met concerning production, distribution and application of hydrogen. Nevertheless it is expected that mid-term to long-term hydrogen will play an important role as energy carrier.
An up to date survey covering all aspects of hydrogen can be found in the reference book "Wasserstoff in der Fahrzeugtechnik" by H. Eichlseder and M. Klell published 2008 by Vieweg+Teubner.

ELECTRICAL ENERGY AS FUTURE VEHICLE FUEL

Due to the constantly increasing market of hybrid vehicles electrical energy gains a new significance as a fuel, especially with regard to its potential for realising energy-efficient vehicles with reduced CO_2 emissions. The key to sustainable electric mobility are appropriate energy storages, including a corresponding charging infrastructure and the provision of electrical energy from renewable sources.

VEHICLE CONCEPTS (EV, HEV, PLUG-IN)

Given the diverse legal, social, ecological and economic requirements placed on the vehicles of tomorrow, hybrid electric vehicles (HEV) are widely seen as a promising vehicle concept and by that investigated intensively. The combination of a traditional internal combustion engine with an electrical drive opens up a broad range of vehicle concepts, which vary in terms of the degree of hybridisation or electrification (Figure 1). The degree of electrification can basically be defined by the size of the energy storage, which therefore constitutes a key component of the vehicle.

ENERGY STORAGE SYSTEMS AS THE MOST IMPORTANT COMPONENT

Increasing electrification is only possible due to improved energy storages. In the last years, nickel metal hydride and especially new lithium ion cells have enabled the development of new batteries with the necessary energy density for HEV and EV applications (Figure 2).

Whilst from the engineering point of view the cells are already largely suitable for series applications, there is still improvement potential on the system level especially in terms of cost reductions and improved implementations of safety concepts (e.g. relays, fuses, etc.). For realization of efficient and well-performing vehicles application-specific selection of the energy storage is essential. Comprehensive simulations are required to select the optimal battery technology and design efficient energy storage systems (energy and power density, energy management, thermal management, etc.).

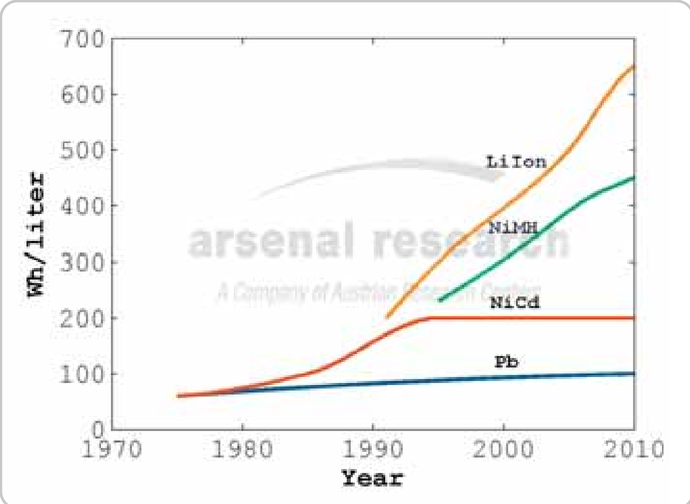


Figure 2:
Estimated performance increase for different battery technologies (energy density)

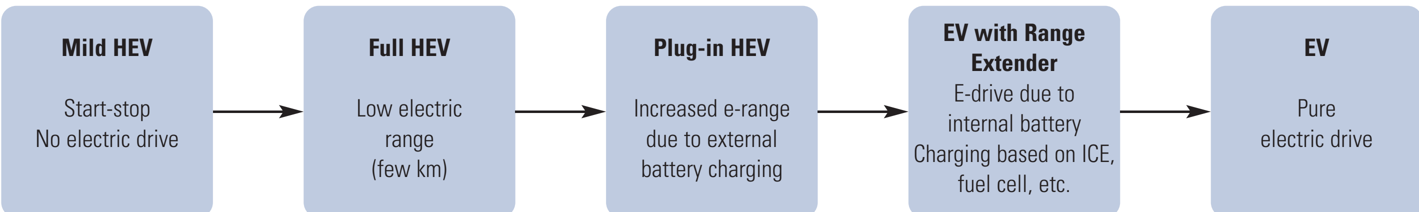


Figure 1: Development path Hybrid vehicle (HEV) – Electric vehicle (EV)

ADVANTAGES AND DISADVANTAGES OF ELECTRICAL ENERGY AS A FUEL

In the public mind, using electrical energy for fuel is always associated with the disadvantage of limited range, which however is an inherent system characteristic of any vehicle. By contrast, the real disadvantages currently are still related to the costs. The rapid advances in batteries, both in terms of the specific energy content and costs, show that electrical energy is becoming increasingly more competitive as an alternative fuel. This is also reinforced by the fact that the energy for these vehicles can be supplied CO_2 free or CO_2 neutrally (using PV, hydroelectric, or wind power).

(CHARGING) INFRASTRUCTURE

The possibility of providing a suitable infrastructure for alternative vehicles constitutes a key precondition for broad market introduction of these technologies. The costs of developing a viable infrastructure, and if required the supply logistics, are critical as to whether a new technology can be established. A key advantage for the development of an electric charging infrastructure is the fact that in Austria practically every home has an electricity supply. But in developing an infrastructure of this kind, certain framework conditions need to be considered, such as the connected power required to charge an electric vehicle in an acceptable time. Electric vehicles with an energy storage of 20-30 kWh require a connected power of 20-30 kW to charge the vehicle in one hour. Connected power at this level is not available everywhere. In addition the load on the electricity networks has to be taken into account. This indicates that different concepts need to be pursued in developing a suitable charging infrastructure. At the same time, given the ease of technical implementation, a dense network can be established relatively cost-efficiently.

PROVIDING THE ELECTRICAL ENERGY

An important factor in the introduction of any new fuel, alongside the requisite infrastructure, is its “production“ or supply. Postulating a CO_2-free electrical energy supply requires the usage of renewable, like photovoltaic (PV), hydroelectric and wind power. The energy demand for a SMART class electric vehicle can be provided by a PV unit with about 14 m2 (basis for the calculation: approx. 10 kWh/100 km and about 15,000 km/year). For the entire Austrian vehicle fleet (excluding trucks), currently totalling around 4 million vehicles, this would correspond to a required area of about 5.6 km2.

At the same time, the installed power of PV plants is rising continuously. In Germany, the total energy produced using photovoltaic is already around 3000 GWh (= energy equivalent of about 2 million vehicles). In 2007, an additional 1100 MWPEAK of PV units was installed in Germany (= 600,000 vehicles). This shows that the potential to power electric vehicles using PV is relatively high. At the same time, however, the grid capacity and management has to be taken into account to cope with the loads from renewable energy sources such as PV or wind energy. A systemic analysis, from the energy supply to the vehicle, is required in order to evaluate various scenarios.

MARKET PENETRATION AND MARKET POTENTIAL

The assertiveness of new technologies is determined by a wide range of influencing factors. These include legal framework conditions (CO_2 emissions limits etc.), alongside factors such as operating costs or procurement costs. Particularly in terms of operating costs, electric vehicles offer a major cost advantage. A comparison shows that with operating costs of about € 225 per year for an electric vehicle, a conventional vehicle would need to achieve a fuel consumption of around 1.25 litres per 100 km to match this.

Nevertheless, customer acceptance plays the most important part in assessing any vehicle. This is significantly influenced by factors such as design, safety and performance. New concepts, such as the Tesla Roadster, have important impact in this context and are contributing significantly to strengthening the market positioning of electric vehicles.

TRENDS IN ENGINE DEVELOPMENT

OTTO ENGINE

The Otto engine has the lowest emissions today. The disadvantage is its unfavourable part load efficiency level and thus the associated high consumption. Approaches to optimise the engine are wide-ranging: downsizing with supercharging, tiered engine operation under part load, load dilution, variable valve control and cylinder control.

Development efforts are primarily being directed towards the following efficient solutions:
- Direct injection with homogeneous operation and supercharging
- Direct injection with variable mix and thus possible lean operation: the advantage of appealing reductions in fuel consumption and CO_2 of around 20% is counter-balanced by the elaborate NO_x exhaust gas after-treatment.

New ignition systems are also in development:
- Laser ignition: this allows for reliable ignition with a free choice of ignition point – applied on high-lean concepts or high EGR rate concepts
- Homogeneous combustion processes (known as HCCI or CAI) point still further into the future: They make effective reductions in consumption and NO_x achievable through ultra-lean running. However, use is only suitable for low load conditions; and a further aspect is an increase in hydrocarbons and CO emissions and the complexity involved in applications with non-stationary operation.

GAS-OTTO ENGINE

Fundamentally, the gas-Otto engine is very similar to the conventional petrol engine. However, the high knock rating exhibited by the gas allows for higher compression ratios and thus improved thermodynamic efficiency levels. The disadvantage is the greater difficulty in converting the non-combusted methane, due to its high chemical stability. With a view to CO_2 reduction, this engine type is of particular interest, since the high proportion of hydrogen in the fuel means that around 25% less CO_2/km is emitted than with petrol combustion.

A particular advantage is that these engines can similarly be realised as:
- Direct injection with homogeneous operation and supercharging
- Direct injection with variable mix and thus possible lean operation. To be able to utilise the advantages of high knock rating in achieving supercharging and high compression ratios, however, it will be necessary to equip this kind of petrol engine to cope with peak pressures of up to 150 bar.

DIESEL ENGINE

High efficiency and thus the lowest consumption at high torque (using supercharging) justify the current triumphant march and increasing market share for the diesel engine. Addressing its disadvantages, such as the lack of NO_x after-treatment and high costs, are primary development goals for the future. The main areas of focus break down as follows, and all are likely to increase acceptance levels for the modern diesel engine:

- Optimising the combustion process within the engine (variable swirl etc.),
- Injection: greater, and more precise, injection using piezotechnology, higher pressures etc.
- Extending exhaust gas after-treatment: comprehensive use of particulate filters and use of efficient De-NO_x systems, such as the SCR process,
- Homogeneous charge compression ignition (HCCI), as already been mentioned for the Otto engine, is of particular interest in the diesel engine in terms of NO_x reduction and preventing particulate discharge.

However, the threat hanging over this is the associated rise in costs, which could restrict the use of diesel engines with efficient exhaust gas purification to the top-end price segment.

ENGINE REQUIREMENTS IMPOSED BY ALTERNATIVE FUELS

Substitute fuels with the biggest market possibilities are currently as follows:

- Petrol: ethanol, biogas and natural gas
- Diesel: vegetable oil, biodiesel, BtL (synthetic biodiesel) and GtL (synthetic diesel)

ETHANOL

If ethanol is to be admixed at higher percentage ratios, then the corresponding engine adaptation which is needed is dependent on the mixing ratio, conditional on the high octane rating, calorific value and high evaporation heat.

- Up to around 20% running on ethanol, adapted pipes and materials are sufficient
- Up to around 85% running on ethanol, adapted engine controls are needed (injection volume, ignition timing etc.) or the flex-fuel vehicle (FFV) concept needs to be implemented.

Pure running on ethanol offers the biggest potential for optimised engineering for:

- Newly-developed direct injection combustion processes
- Supercharging/Downsizing

The chemical composition of ethanol offers the fundamental potential for a reduction in emissions of pollutants – an argument backed not just by the ratio of carbon atoms to hydrogen atoms, but also the oxygen binding which is beneficial for combustion.
The particularly beneficial combustion pattern achieves an extremely good level of efficiency, capable of reaching the level for modern diesel engines at full load.

BIOGAS AND CNG

Given a sufficiently widespread network of filling stations, monovalent versions of the combustion engine make sense in order to fully exploit the advantages of this fuel. Biogas and CNG have the advantage of a high knock rating and ignition temperature, meaning that the engine compression ratio can be significantly increased, with positive effects on consumption and in reducing CO_2.
A key area of focus for future research projects will be estimating potential in terms of biogas quality and monovalent engine outfitting, looking at the compression ratio and parameter settings on adapted gas engines. As the combustion of biogas – similarly to natural gas – requires significant changes, particularly with regard to exhaust gas temperature but also in the composition of the exhaust gas, specially-adapted exhaust gas after-treatment designs need to be developed to realise extremely low exhaust gas emissions, in order to come very close to the pollution-free engine.



VEGETABLE OIL

Natural, non-esterified vegetable oils were originally envisaged only for large diesel engines using a whirl chamber combustion process, particularly in agriculture.
More recently, cars are also being run on this fuel, something which has only been made possible through key adaptations to the injection system, the mix formation and the combustion process.
Going forward, the main focus of development needs to be on the mix preparation parameters, in order to ensure emissions patterns in line with modern diesel vehicles. This involves both the hardware and the software. For NO_x emissions, at present improvements can only be achieved if the engine application is changed, with an adverse effect on particulate matter (PM) values.

BIODIESEL

Biodiesel is a fuel which is very similar to conventional diesel in terms of its characteristics, with one small difference. The higher boiling point makes particulate filter system regeneration more difficult. For that reason, general approval of this fuel has been restricted to the latest engines for the time being. Further development work is a primary criterion with regard to this. The development potential can be estimated by analogy to the conventionally-run diesel engine.

BtL (BIOMASS TO LIQUIDS) AND GtL (GAS TO LIQUID)

BtL, a biogenous second-generation fuel, and GtL, its conventional equivalent, come very close to the ideal of designer fuels, and guarantees best quality at the most demanding tolerances. Conventional diesel engines can therefore run on it without problems. The key advantages are:

- High cetane values, and thus reduced ignition delay,
- Sulphur-free, therefore no sulphate formation and easier exhaust gas after-treatment,
- No aromatics, and designable characteristics.

This facilitates further engine optimisation and the development of new combustion processes. Similar to experiences gained in GtL, the expectation is that in terms of emissions pure BtL remains vastly superior to diesel.

To sum up, the use of BtL means:

- Significantly lower particulate matter raw emissions facilitate engine applications at the lowest NO_x emission levels
- Blends of GtL with conventional diesel are generating anticipation of disproportionately large potential for improvements.

CONCLUSION

The EU Directive 2003/30/EC of the European Parliament and of the Council of May 8th 2003 on the promotion of the use of biofuels or other renewable fuels for transport, which provides for mandatory use of sustainable fuels in the transport sector, was transposed into Austrian national law in November 2004 (BGBl. 417/2004).

The legally binding EU directive calls for substitution of 5.75% of fossil fuels used for transport purposes by 2010. Austria is aiming to achieve this target already in October 2008. These short-term targets can only be accomplished through immediate use of first-generation fuels. Given the amount of fuel needed for substitution, only biodiesel and ethanol are available in sufficient quantities.

In view of rising feedstock prices due to the limited land available for energy-related biomass production, one of the most important criteria in evaluating the performance of a sustainable fuel production pathway is the potential mass output obtained from one hectare of cultivation. Since different feedstock can be gathered to produce a specific sustainable fuel, there can be quite big differences in fuel yield within a pathway.

The table displays, from left to right, the type of fuel, the used feedstock, the amount of actual yield (dry weight) and the amount of fuel derived from the feedstock. The two columns on the right side aim to relate these actual yields to mileage, by considering the energy density or the number of vehicles that can be powered for one year from a single hectare of planting, taking into account the average mileage. Depending on the feedstock, the amount of fuel obtained from one hectare varies by a factor of 2 for biogas, and by a factor of up to 3 for ethanol.

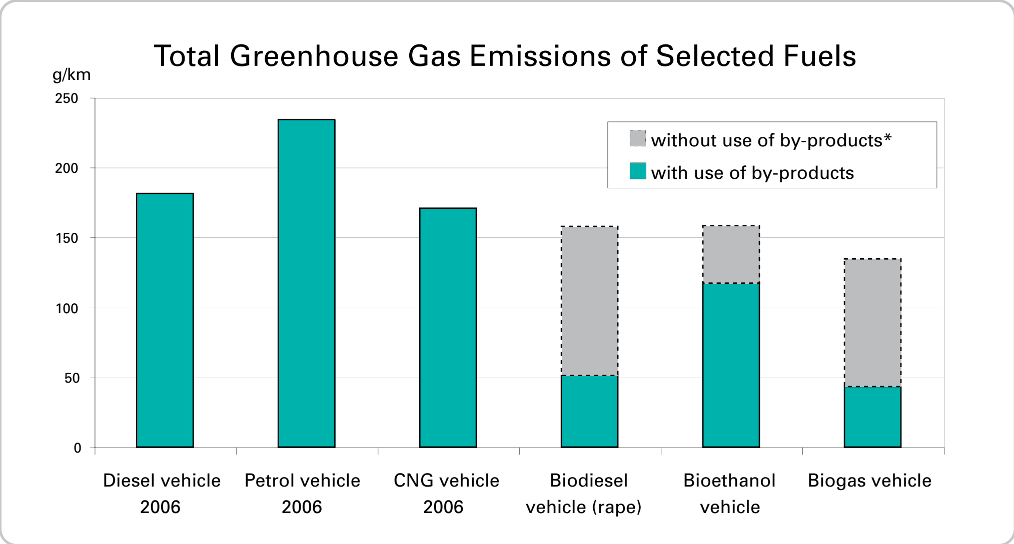
For holistic assessment of fuel options the added values through recycling or by-products have to be taken into account. Production of biodiesel and vegetable oil yields oil cake and ethanol production provides protein feed. Energy recovery from waste (forest residues, straw, manure, sludge, animal fat) improves the eco-balance.

Currently ethanol and biodiesel face a period of high feedstock prices. These high prices result from a highly speculative feedstock market, combined with a bad wheat and corn harvest in 2007, the fast-growing market for energy crops, and rising demand for food and feed. High prices, combined with changing regulatory and fiscal framework conditions, can have a massive impact on the fuel market. To secure a successful introduction of alternative fuels, sound legal and fiscal framework conditions are of outmost importance.

With regard to the statements in the editorial (where the different influences on GHG emissions figures are reported), the following chart reflects typical Austrian circumstances, such as common agricultural practices and production plants currently in place for sustainable fuels, as well as typical emissions for conventional fuels. However, the per hectare performance figures have to be relativised, because additional by-products obtained besides fuel might serve as substitute for other products. These by-products accrue in different amounts, depending on the particular sustainable fuel feedstock combination. Besides the potential for reducing emissions, the diagram also shows the maximum possible influence of by-products, where these are taken into account.

Sustainable Fuel	Feedstock	Yield [t] / Hectare [ha]	Amount of Fuel [l] / Hectare [ha]	Mileage [km] / Hectare [ha]	Vehicle / Hectare x Year
Biodiesel	Rape	2,848	1,200	18,500	1.1
Vegetable Oil	Rape	2,848	1,200	18,400	1.1
Fischer-Tropsch diesel	Forest	4,020	820	13,300	0.8
Fischer-Tropsch diesel	Poplar	12,000	2,450	39,700	2.3
Ethanol	Wheat	4,730	2,110	19,300	1.5
Ethanol	Maize	6,080	3,630	33,200	2.6
Ethanol	Sugar Beet	13,340	6,220	57,000	4.4
Ethanol (lignocell.)	Straw (corn)	3,440	1,135	10,400	0.8
Ethanol (lignocell.)	Straw (maize)	7,740	2,554	23,400	1.8
Biogas	Greenland	7,623	2,120	30,700	2.4
Biogas	Pasture	11,880	3,280	47,500	3.7
Biogas	Grass	13,002	3,950	57,200	4.4
Biogas	Maize silage	14,850	4,920	71,200	5.5

Source: preliminary study of the biomass action plan from the Austrian energy agency, with own calculations regarding vehicles per hectare and year (diesel vehicle average mileage: 17,053 km; petrol vehicles 12,942 km)



* By-products are ancillary products which original when biofuels are produced. Using these products may substitute for production of similar products (fertiliser, feed, glycerine), thereby contributing to a reduction in emissions. This reduction is treated as a credit item in the balance sheet for biofuel greenhouse gas emissions.

To understand the true nature of a specific sustainable fuel production operation, detailed data needs to be assessed in depth in relation to the particular processing plant and feedstock, as well as looking at the means of transport and the transport distances involved. Taking the entire lifecycle of different sustainable fuels into account is crucial in order to fulfil the premise of reducing the effects on climate change through using sustainable fuels.

In addition to climate-related emissions, other pollutants originating mainly from vehicle operations (such as particulate matter, nitrogen dioxide or hydrocarbons) are of prime importance, particularly in urban contexts. Some sustainable fuels promise partial reductions, but since different vehicle adaptations, as well as fuel grades, blending rates and engine load have major influence on the actual emission level, the mitigation potential of sustainable fuels is commonly publicised as a tendency rather than in terms of detailed figures. Gaseous fuels (CNG, biogas and LPG) have the greatest potential, due to their physical properties. All components of emissions are greatly reduced (NO_x and particulate matter about 95%), while there is a slight increase in hydrocarbons recorded. Ethanol produces positive effects on combustion due to its higher oxygen content (35%), which allows for higher compression ratios and temperatures. The quantitative reductions are to some extent higher than those of gaseous fuels, but the magnitude is similar – hydrocarbons are the only pollutant where an increase is observed. Biodiesel and pure vegetable oil offer reduction in hydrocarbon emissions, while NO_x and particulate matter emissions tend to increase slightly.

Up to the designated proportions, sustainable fuels used for fuel blending can use the existing infrastructure. All other alternative fuels face the "chicken and egg problem", where the car industry is waiting for an adequate fuelling infrastructure and the fuel industry is waiting for a critical mass of vehicles running on sustainable fuels. Higher blends, pure biodiesel and ethanol require modifications to the fuelling stations as well as to engines. Gaseous fuels such as LPG, CNG and biogas need a separate, costly fuelling infrastructure. Due to the fact that new concepts for fuel distribution and fuelling are required, hydrogen and electric charging are seen as a long term option.

Hybridization, CNG and biogas technology are considered as pathfinders for future vehicle technology. The trend towards electrification of the propulsion system and the development of monovalent gas vehicles is clearly apparent. For a future emission-free vehicle technology, both technologies are important pieces of the jigsaw in moving towards the hydrogen or pure electric vehicle. No matter what the propulsion technology of the future will be, we need a considerable increase in the energy efficiency of the propulsion system. Depending on local framework conditions, different technical options result in drastic improvements in terms of greenhouse gas emissions as well as local emissions. Generally vehicle technologies – including alternative fuels – need to be further intensively investigated in order to meet the challenges of the future and one day become capable of offering zero-emission transportation.

- ENVIRONMENTALLY-FRIENDLY URBAN BUS AND GOODS TRAFFIC SYSTEMS
- STRAW PYROLYSIS
- BIO-SOFC DRIVE
- BIOETHANOL
- BIOETHANOL IN THE OTTO ENGINE
- BIOSNG FUELLING STATION
- CNG600-MONO
- HEAVY DUTY ZERO EMISSION (HDZ)
- ALTANKRA
- BIOGAS IN THE OTTO ENGINE
- BTL IN THE DIESEL ENGINE
- CEP2020
- ICUT

A3-PROJECTS

ENVIRONMENTALLY-FRIENDLY URBAN BUS AND GOODS TRAFFIC SYSTEMS

Clean fuels and zero emissions in central urban areas

The primary goal of this one-year project is to find alternative and clean solutions for urban bus and goods traffic that can be applied in the short and medium term. Reducing emissions by using alternative fuels and propulsion technologies is of primary interest.

The principal purpose of the project was to devise a concept for improving air quality in densely-populated outlying urban areas, as well as presenting different propulsion principles using alternative fuels and soft hybrid drives.

To determine the influence of bus and goods traffic on overall pollution levels, a series of measurements were conducted in May 2003 on a radial highway (Hietzinger Kai) in Vienna. With the help of these measurements, it could be demonstrated that nitrogen oxide (NO_x) emissions from heavy traffic continue to be underestimated in the technical literature.

Alternative technical solutions for pollution-free propulsion concepts are proposed and discussed. Natural gas, biodiesel and alcohol fuels, as well as hybrid concepts, are examined using ecological and economic criteria. Gas-powered concepts (natural gas and liquid petroleum gas) in particular are sensible alternatives to conventionally-operated vehicles with diesel engines in the short and medium-term. Given adequate geographical coverage of hydrogen refueling stations, fuel cell technology will be a good long-term alternative because running vehicles on this technology does not cause emissions of pollutants. This is particularly attractive for inner-urban transportation.

Conversion strategies, including a market analysis, are presented for municipal authorities and fleet operators. These conversion strategies demonstrate methods to implement the proposed solutions. These strategies are intended to assist decision-makers active in the bus and goods transportation sector.

Information about the project, the project partners and links to further information can be found at the Internet homepage "www.sauberer-stadtverkehr.info".

INFO
Project management:
Vienna University of Technology – Institute for Internal Combustion Engines and Automotive Engineering
Project partners:
Wiener Linien GmbH & Co KG, ÖAMTC Academy

STRAW PYROLYSIS

Straw pyrolysis – alternative fuels from biogenous wastes and residues (straw, reeds)

One of the challenges of modern times lies in using biomass materials, such as straw, in the production of fuels. The low energy density of straw is not consistent with transporting this material to centralised installations. In consequence, exploiting this material in decentralised yet cost-effective facilities will be required. Pyrolysis, i.e. thermal breakdown under hermetically sealed conditions, provides one option for the treatment of straw.

Two methods are applied for the production of process-related oils, gases and charcoal:

1. Gasification: at 1,000°C, straw is converted into a synthesis gas consisting of CO and H_2. Diesel oil is synthesised from this gas by the Fischer-Tropsch process. The efficiency of this method is about 50%: one tonne of straw produces 135 litres of diesel oil. The rest of the energy content is consumed during this process.
2. Oilification: using flash pyrolysis of straw at approximately 500°C, the main product, in addition to CO and charcoal, is an oil containing a wide variety of hydrocarbons. This would appear to be a promising method: flash pyrolysis (very rapid heating followed by the rapid chilling of primary pyrolysis gases) can recover up to 75% of this oil, with approximately 10% process losses.

To date, flash pyrolysis has mainly been carried out in fluidised bed installations. The drawbacks of this technology are the complexity of process control, which will only allow cost-effective operation of installations above a certain size, and the presence of sand residues in the resulting oil, which precludes its use in engines.

Employing the ablative method, straw is applied to a heated rotating disc. Heating rates of the order of 10,000°C/s can be achieved. As in the case of fluidised bed installations, the primary pyrolysis gases must be chilled rapidly. In this case, however, process control is both simpler and cheaper, thereby allowing the construction of installations with smaller capacity. One project partner has completed this process for the first time in the laboratory using wood chips, and a pilot plant has been operating for two years. The main advantage of this method is its economical scalability toward smaller units. This is a precondition for processing straw, because straw is only available locally and the price of straw depends heavily on transportation costs. Despite redesigning the laboratory plant to process straw, it proved to be less suitable for straw than for wood: pyrolysis did not proceed according to flash-pyrolysis conditions, which would be characterised by rapid heating-up of the straw at the rotating heating plate to about 475°C.

As a consequence the percentage of charcoal formed in the process was significantly higher (about 24%) than was expected from previous experiments using a fluidised bed reactor (10-15%). The usual water content of pyrolysis oil from dry biomass (i.e. with a low residual moisture content of about 10%) is about 30%, which means two thirds of the water is formed during the pyrolysis process. The pyrolysis of straw using the ablative method accomplished in the laboratory plant produced a pyrolysis oil with a water content of between 40- 45%. As a consequence of this high water content, the pyrolysis oil obtained separated into two distinct phases: a tarry phase and a watery phase. Therefore this oil could not be used as a fuel for the specially-adapted diesel engine, as was the case with pyrolysis oil from wood.

It was concluded that the feed mechanism for the process, in particular, has to be redesigned for straw. Therefore a completely new mechanical design was conceived especially with for straw and similar biomasses; this new design can be realised in a considerably less complexe manner. A patent application has been submitted for this design, and a laboratory plant is already under construction.

The main advantage of flash pyrolysis over the simple extraction of heat from biomass by combustion is the quality of the resulting end products and the variety of potential applications. Essentially, combustion generates heat only, and will only be efficient in large units –straw is not cost-effective in either of these respects. Flash pyrolysis, on the other hand, produces charcoal and acetic acid as by-products, in addition to synthetic oil.

INFO
Project management:
University of Vienna – Institute of Risk Research
Project partners:
Vienna University of Technology – Institute for Internal Combustion Engines and Automotive Engineering, OMV AG, Organisationseinheit der TU Wien – Technische Versuchs- und Forschungsanstalt

BIO-SOFC DRIVE

Development and demonstration of a SOFC-battery hybrid drive powered by biogenous fuels

Development and fleet testing of fuel-cell battery hybrid vehicles using SOFC fuel cells and biogenous fuel. Comparison of different propulsion technologies (diesel, diesel + exhaust NO_x reduction, fuel-cell electric hybrid). Demonstration of the bio-SOFC drive in ecologically-sensitive areas of use in Austria.

The bio-SOFC (Solid Oxide Fuel Cell) drive project is investigating an innovative and environmentally-friendly vehicle drive – a fuel cell hybrid drive – in a small fleet test using several vehicle platforms. A micro-tubular SOFC fuel cell is used as a range extender for battery-powered vehicles, in order to achieve a significant improvement in the biggest weakness in electric vehicles, namely their range. The implementation of a SOFC system also makes it possible to use it as a charging device for the battery, since the micro-tubular solution has already demonstrated the necessary dynamics and cycle endurance.

An optimised battery and drive management system also improves the vehicle's propulsion system in that the greatest possible level of energy is recovered, lower fuel consumption is achieved, and the stresses on the fuel cell are constant. Existing electrically-powered vehicles are being supplemented with an "on-board charging device" which continuously tops up the battery charge.

This produces the following advantages:
- Increased vehicle range by comparison with conventional electrically-powered vehicles;
- Waste heat from the fuel cell can be used to heat the vehicle;
- The battery charge is topped up when travelling downhill, due to brake energy recuperation, which results in an additional fuel saving.

Biodiesel is used as the fuel, thus the test can be carried out using the existing infrastructure, including in outlying areas such as tourism-oriented communities. In addition, tests are being conducted using other biogenous fuels. Small delivery vehicles, minibuses, a boat and a measurement vehicle ensure that a qualified assessment can be made regarding practicability in a representative range of applications. Internationally, range extenders are viewed as a key future solution for the fuel cell in vehicles, since the high-temperature fuel cell makes the use of renewable fuels possible. Further investigations and analyses include user satisfaction, the effects of fuel quality, comparisons with conventional propulsion systems and general information about the benefits and applicability of the SOFC-battery hybrid drive.

INFO
Project management:
ALPPS Fuel Cell Systems GmbH
Project partners:
Arsenal Research GmbH, FJ BLT Wieselburg, ÖGUT – Österreichische Gesellschaft für Umwelt und Technik, CLIMT Claassen Industrie Management Trading GmbH, ÖAMTC Österreich, MLU – Monitoring für Leben und Umwelt GmbH, Tourismusverband Werfenweng, Blaguss Reisen GmbH, Graz University of Technology – Vehicle Safety Institute

Particular attention is also being paid to specialist support from independent agencies which deal with safety issues, provide training for users, assess environmental impact etc. The project is running over two years, with the first year given over to preparing the technical solution and the second year to operating the vehicles. The aim is to demonstrate the suitability of this solution for practical implementation.

Development steps planned:
In a first project phase the power needs for the "Range Extender" have been found by simulation of various possible operating conditions for cars and for buses. In parallel the possibilities for risk free installation of the fuel cell have been evaluated by crash test simulation and finally by a real crash test.

In a further phase, two sample vehicles will be equipped with range extenders based on IC engine. A modern exhaust treatment employing PF and $DeNO_x$ systems will be installed to verify the principle and serve as benchmark for the fuel cell. In a later phase the ICE will be replaced by fuel cells.

BIOETHANOL

Bioethanol from sugar and starch – an environmentally friendly alternative fuel available in the short term

The European Union Directive 2003/30/EG on conserving resources of fossil crude materials means that there has to be an increase in the use of biogenic fuels. The use of biodiesel is well known and state-of-the-art, but there is hardly any use of biogenic petrol.

In the short term, it is possible to substitute bioethanol for conventional petrol relatively quickly, as long as its percentage in the mixture is fairly low (up to 5%). The capacities for bioethanol production will increase considerably in the next few years; therefore a major interest in terms of the Austrian and European economy lies in identifying which upper-level percentage (e.g. 10%) of this biogenic fuel can be added to the existing fuels (without any technical changes to the vehicle fleet), without resulting in problems for the user or even for the distribution chain under Austrian or central European conditions.

Another essential target for investigation is to understand the technical changes required on the vehicles to achieve high and maximum percentages of ethanol mixing (up to 85% or even 100%). This would open the way to improved engine configuration andto benefits in terms of emissions and efficiency. In addition to the abolition of CO_2 emissions, a complete biofuel for petrol engines could be designed.

With these preconditions satisfied, a vehicle fleet test identified the problems that can arise in day-to-day use, and how far the existing infrastructure might need to be modified to guarantee trouble-free use of fuel with lower amounts (E5, E10) or a high amount (E85) of bioethanol. Therefore one major part of this project was to investigate the usability of bioethanol in different mix ratios in petrol engines, and the influence on cold start performance or lubricity.

There appeared to be hardly any significant changes in emission patterns for everyday use when running fuel mixtures with a lower amount of bioethanol (E5, E10). All cars used gained the approval of the manufacturers for running on mixtures up to 10% bioethanol.

For the Flexible Fuel Vehicles – which allow the use of mixtures with a high amount of bioethanol (E85) – there were again hardly any problems in everyday use, but there is still some potential for optimizing cold start performance. It was also found that, as for common fuels, a special winter quality is needed (e.g. dry vapour pressure has to be increased).

INFO
Project management:
Vienna University of Technology – Institute for Internal Combustion Engines and Automotive Engineering
Project partner:
AGRANA Bioethanol GmbH, Ford Motor Company (Austria) GmbH, Forschungsgesellschaft für Verbrennungskraftmaschinen & Thermodynamik mbH, General Motors Austria GmbH, ÖAMTC Österreich, OMV Refining & Marketing GmbH, Porsche Austria GmbH

BIOETHANOL IN THE OTTO ENGINE

Ecological use of bioethanol in future engines

A promising way to decrease traffic-related CO_2 emissions while increasing traffic itself is to combine using partly CO_2-neutral, biogenous fuels with highly efficient engine technologies like downsizing and turbo charging.

Therefore the use of biogenous ethanol fuels in a modern, turbocharged DISI engine was investigated. Full load, part load and operating map investigations have been conducted on a motor test bench. The behaviour of the engine in terms of power and emissions has been measured and analysed.

Important results from the full load investigations are the break specific fuel consumption as well as the air-fuel ratio. Thanks to the wide variety of fuels in this part of the project, it proved possible to identify a clear tendency towards better engine performance with increasing anti-knock properties in the fuels, both with and without ethanol content.
The typical and predicted behaviour of ethanol fuels could also be confirmed in the part load investigations for the project: higher break specific fuel consumption, due to a lower net calorific value of ethanol as well as shorter ignition delay and duration of combustion.

The operating map investigations showed that the use of fuels containing 5 to 10% of ethanol or up to 15% of ETBE is possible without significant changes in terms of the engine control unit. It was possible to confirm the result gathered in the full and part load investigations for the whole operating range of the engine.

INFO
Project management:
Vienna University of Technology – Institute for Internal Combustion Engines and Automotive Engineering
Project partners:
AGRANA Beteiligungs-Aktiengesellschaft, OMV Refining & Marketing GmbH, Volkswagen AG

BioSNG FUELLING STATION

BioSNG fuelling station Güssing

The biomass gasification plant was installed in Güssing in 2001 to produce a high-quality synthesis gas from biomass chips. The innovative technology employed makes use of fluidised bed steam gasification. In addition to the coupled generation of electricity and heat, a range of fuels can be produced using the synthesis gas. In particular, the production of renewable natural gas (BioSNG) from wood by producing synthesis gas for high-capacity plants is of interest. As part of the EU Project "BioSNG", the production of this renewable natural gas from wood is being demonstrated. The BioSNG produced is expected to be of a quality suitable for use in gas vehicles, amongst other applications. The EU Project "BioSNG" concentrates on the production of BioSNG. Practical implementations are only conducted around the fringes of the project. The cut-off point between the Austrian project and the EU Project "BioSNG" is effectively the hand-over point of the gas produced. The BioSNG which the gas station requires will be removed at a defined point and will be fuelled into the test cars.

The advantage of this mainly renewable natural gas (BioSNG) is the possibility of achieving high levels of efficiency. This makes it a possible energy source for cars of the future, an objective which is also consistent with the European strategy. In the framework of this project, a BioSNG station for vehicles will be established and operated at the CHP Güssing. The BioSNG produced will be compressed to the required pressure, stored and fuelled into various test vehicles via gas stations. The quality of the BioSNG used will be subject to ongoing monitoring and targeted adjustments. The performance of the test vehicles used will be studied, to document the effects of using BioSNG with different qualities, offering large-scale research and demonstration of the suitability of 100 % BioSNG from wood for use directly in vehicles.

Firstly, the concept for the BioSNG-station will be developed. This includes the design and detailed engineering. Afterwards the BioSNG station will be constructed and taken into initial operation. During these activities, an economic assessment of the specific costs of BioSNG as a vehicle fuel will be carried out; this will be continued during the BioSNG station operation and test vehicle monitoring, through to the end of the project. Since a public transport company is interested in using natural gas-fuelled buses of this kind, a study will be conducted into the possibilities of integrating natural gas buses into the public transport network.

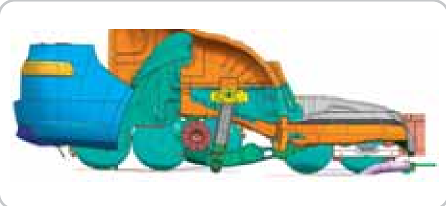
The final result should be the operation of a fully functional gas station for BioSNG. Scientifically proven long-term experience concerning the operation of BioSNG in conventional gas vehicles will be very important in the future, mainly with regard to the quality of BioSNG required for safe and problem-free use in gas vehicles. All general conditions will be taken into account in assessing economic efficiency, so that economic construction and operation is facilitated for further projects based on BioSNG. Moreover this field presents an important contribution towards achieving the target objectives for Austria and Europe, especially on environmental and climate issues.

INFO
Project management:
Biomasse Kraftwerk Güssing GmbH & Co KG
Project partners:
Renet Kompetenzknoten Güssing Forschungsinstitut f. Erneuerbare Energie GmbH, Bauer Poseidon Kompressoren GmbH, Vienna University of Technology – Institute for Internal Combustion Engines and Automotive Engineering, Vienna University of Technology – Institute of Chemical Engineering, General Motors Austria GmbH, Gemeindeverbund Personennah-verkehr Pinka- und Stremtal

CNG600-MONO

Monovalent natural gas-powered vehicle with a 600 km range, achieved by using a new light-weight tank

The programme target – 600km range using a concept close to serial conditions – has been demonstrated and was validated virtually and by experiment in a prototype vehicle.



CUSTOMER VIEW

A market study – carried out by ÖAMTC Academy – found that 94% of those interviewed are very interested in news about protecting the environment. Alternative propulsion systems in all vehicle segments are considered important by 97% of those interviewed. Pleasing vehicle handling and range over 500 km are essential to their purchase decisions.

FEATURES

The CNG (compressed natural gas) 600 prototype vehicle presented is more than competitive with existing vehicles in terms of range, weight, costs and efficiency.
An optimised monovalent powertrain concept was created by Vienna Technical University; i.e. capable of running on 100 percent methane!
Particle, CO_2 and NO_x emissions are marginal.

The vehicle's fuel system is characterised by innovative composite pressure vessels, with new valve technology by VENTREX Automotive. This valve technology features a more functional and cost efficient design compared with current products on the market.

INFO
Project management:
MAGNA STEYR Fahrzeugtechnik AG & Co KG
Project partner:
Vienna University of Technology – Institute for Internal Combustion Engines and Automotive Engineering, ÖAMTC Academy, Consultant Engineer Herbert Kitzler, Ventrex Automotive GmbH, Opel Special Vehicles GmbH

The prototype – based on a standard Opel Zafira CNG – was upgraded with an Austrian-made 6-speed transmission, a start-stop system by MAGNA STEYR, energy saving daytime running light and low-friction tyres.

The programme target – 600km range – was exceeded; CO_2 emission is around 120g/km at constant 100 kph.
This cost-favourable vehicle concept also satisfies current demands in terms of interior space, comfort and adaptability.
The monovalent (natural gas or biomethane) propulsion, means that the petrol-related components would be omitted in a serial product, which would roughly offset the additional costs of the CNG-600 components.

FORECAST

After concept confirmation and a 20 month development phase, this vehicle is capable of reaching maturity for serial production. Together with VENTREX Automotive (fuel feed), MAGNA STEYR will supply and integrate the system 'ready to rail'.
The first generation VENTREX Automotive valve system will go into serial production in 2008.

The prototype vehicle's capability will be demonstrated in practice by a 600 km run through Austria this spring. Partly for its involvement with this project, the '2008 European Powertrain Frost & Sullivan Award for Industry Innovation & Advancement of the Year' went to MAGNA STEYR.

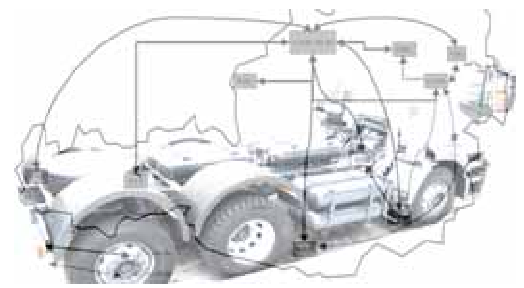
HEAVY DUTY ZERO EMISSION (HDZ)

Cleaner bus and goods traffic in Austria

The object of this project is to analyse the potential reduction of emissions from heavy duty vehicles in inter-urban traffic. To this end, low-emission and emission-free technologies will be investigated, the impact of their potential deployment will be analysed, specifically with regard to transit operations on busy routes, and potential obstacles will be identified.

The object of this project is to investigate options and development potential for the deployment of extremely low-pollutant propulsion systems – ultimately in pursuit of zero emissions – for buses and long-distance goods vehicles. A CNG concept was developed as a medium-term solution. The results show that integrating the tank system (based on the available tank systems) in today´s truck-trailers for a cruising range of about 1000 km is difficult, but the lower operating costs associated with CNG operation could be an important incentive. In addition to this, integrating a hydrogen-powered fuel cell unit was analysed as a long-term approach in developing a zero emission concept. Systems used to date in heavy duty vehicle traffic reveal fuel cell technology being applied especially for shipping. The supply of alternative fuels for heavy-duty traffic use (e.g. hydrogen) can be achieved in many different ways. One possible starting-point for implementing an infrastructure for new energy sources could be fleet fuelling. Conversely, it appears that supplying fuel from purely regenerative sources for heavy-duty traffic use is in any event practically impossible.
The concrete requirements concerning low-pollutant drive propulsion systems for heavy-duty traffic were examined by studying operations at a logistics company. The evidence suggests that for the concrete application, a distance of at least 1000 km has to be covered without any refuelling stops.

For the routes examined as part of the project, detailed calculations of CO_2 and pollutant emissions were executed. In conclusion, it can be stated that semi-trailer trucks produce between 70% and 90% of emissions on the routes studied, making them the dominant polluters. Data for other road users calculated for the A1 Westautobahn to serve as an illustration reveals that about 80% of the kilometres are travelled by passenger cars, but these account for only 55% of CO_2 emissions. With regard to pollutants subject to formal limits, passenger cars contribute 53% of particle emissions and 30% of nitrogen oxide emissions. Comparing the emission levels for the base year 2005 and the scenario of 2020 indicates significant potential for reducing NO_x, particulate und CO_2 emissions through using CNG, LPG und H_2 for heavy duty traffic.



INFO
Project management:
Vienna University of Technology – Institute for Internal Combustion Engines and Automotive Engineering
Project partners:
Vienna University of Technology - Institute of Electric Plant and Energy Management, ÖAMTC Academy, ECHEM Kompetenzzentrum für Angewandte Elektrochemie GmbH, Neoman Bus GmbH / Kompetenzzentrum Sonder-Transportsysteme, DHL Express (Austria) GmbH, Vossloh Kiepe GmbH

ALTANKRA

Scenarios for economic feasibility of alternative propulsion systems and fuels in individual transport until 2050

This study investigates if and under which conditions individual alternative propulsion systems and fuels will become economically relevant in Austria.

INFO
Project management:
Vienna University of Technology - Institute of Electric Plant and Energy Management
Project partner:
AVL List GmbH, Joanneum Research Forschungsgesellschaft mbH

To alleviate the problems currently associated with the increase in energy demand for individual motorised transport (the rising consumption of fossil-based energy sources and associated increase in greenhouse gas emissions), further research and practical implementations are being pursued world wide looking at alternative propulsion systems – hybrid drives, drives using natural gas or biogas, fuel cell vehicles, and electric drives – and new alternative energy carriers – bioethanol, biogas, biodiesel, hydrogen from renewable energy sources, synthetic fuels, electricity.

The core objective of this project is to analyse whether, under which boundary conditions, to which extent and when the aforementioned alternative propulsion systems and fuels can be of economic relevance in Austria. To meet this objective, the impact of the following key parameters is being investigated in four scenarios:

- Possible trends in the energy price level (low-price and high-price scenario)
- Technical efficiency increases and cost reductions -for specific technologies;
- Changes in policy framework conditions (taxes, subsidies, etc.).

The major conclusions of this analysis are:
In a “business as usual” (BaU) scenario with fuel prices for conventional fuels increasing only moderately, overall vehicle numbers increase continuously and the major effect is a strong “hybridisation” of vehicles, see Figure 1. In a scenario with high oil prices and targeted introduction of “green” policies, overall vehicle numbers stagnate or even decrease slightly, and electric as well as hydrogen powered cars gain significant market shares from around as early as 2030, Figure 2. Yet a major characteristic of all investigated scenarios is that the diversity of propulsion systems and fuels used increases significantly.

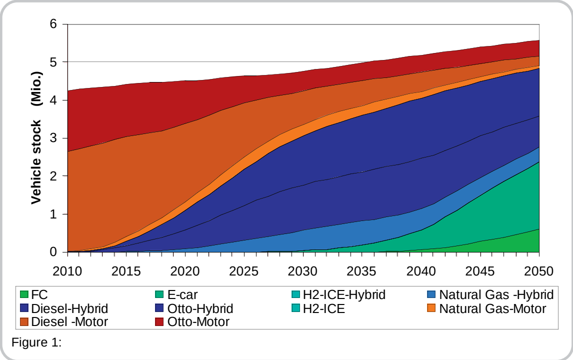


Figure 1:
BaU scenario with modestly rising energy prices

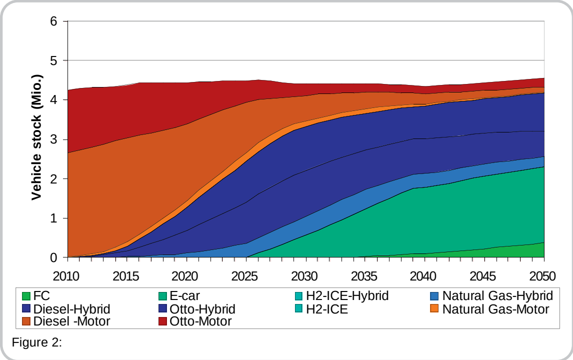


Figure 2:
Scenario with clearly rising energy prices and ambitious policy measures

BIOGAS IN THE OTTO ENGINE

Use of biogas and assessment of potential in a modern Otto engine

One of the alternatives to conventional fuels is CNG (Compressed Natural Gas). Both the numbers of vehicles running on CNG and the number of filling stations offering CNG are constantly rising. The essential key argument in favour of CNG vehicles is the 20% to 25% lower CO_2 and greenhouse gas emissions compared to petrol vehicles. In addition, the exhaust emissions from CNG vehicles are practically free of particulates, soot and sulphur. A further reduction in CO_2 emissions is possible if the gas, which consists mainly of methane, is not obtained from fossil sources but is produced from biogenous raw materials. This gas (known as biogas) is already being produced in some plants, but generally exhibits varying proportions of methane and other hydrocarbon components, which means that its use in combustion engines on a broad basis needs to be investigated first and protective measures introduced as necessary. Starting from the positive experience already made with CNG, the suitability of various qualities of biogas for automotive use is to be investigated. In this context the main focus should be on the effect of varied methane fractions in the biogas on the engine operating performance. Those fractions should be geared to the German dual system for high and low quality natural gas.

In addition to the practically closed CO_2 cycle, biogas exhibits a further advantage in that methane – the main constituent of the gas – offers very favourable characteristics for use in Otto engines. Methane has a knock rating of 130 RON and an ignition temperature of 650°C, which means that the compression ratio of engines can be increased significantly. This leads to positive effects on thermal efficiency and thus results in further reductions in fuel consumption and CO_2 emissions. To date, this effect has barely been exploited in natural gas vehicles, since the absence of a comprehensive network of filling stations has meant that vehicles were equipped for dual-fuel use. This results in a compression ratio adapted for use with conventional petrol, which has a lower octane number compared to biogas.

Having biogas available alongside natural gas in future, it makes sense to equip the combustion engine for monovalent use in order to exploit the advantages of these fuels. Therefore a further major focus of this research project is to estimate the potential of an SI engine (optimally adapted for biogas operation), in terms of compression ratio and parameter adjustment.

Since clear changes in the combustion of biogas are to be expected with regard to emission temperature and emission composition, an exhaust aftertreatment concept has to be developed in order to assess the achievable potential, taking into account present and future emissions regulations. In this context the main focus is set to be on investigating different coatings for the catalytic converter, looking at their conversion ratios for methane emissions.

Beside the investigations on the combustion engine, a study is to be carried out to exemplify state-of-the-art for the production of biogas as well as for processing of different gas qualities. The aim is also to demonstrate the costs of biogas in relation to gas quality. A further point is the discussion of new directives.

INFO
Project management:
Vienna University of Technology – Institute for Internal Combustion Engines and Automotive Engineering
Project partners:
ÖAMTC - Österreich,
OMV Gas International GmbH,
General Motors Austria GmbH,
General Motors-Powertrain Germany GmbH

BTL IN THE DIESEL ENGINE

Use and potential of the biogenous designer fuel BTL (biomass to liquid)

Within the scope of this project, the potential of so called designer fuels (e.g. BTL) is to be investigated, particularly in terms of emissions, performance and consumption patterns when used in an internal combustion engine. The engine provided especially for this purpose was assembled on a test bench, and all necessary sensor systems were installed. A first test cycle and initial reference measurements were carried out using CEC-standard diesel fuel.

The fuels provided have already been analysed to determine chemical composition. The results represent a basis of information indicating the areas where effects are to be expected, and suggesting the extent to which varying the engine's combustion-relevant parameters can contribute to optimising the use of the fuel under consideration. In particular, the high cetane number and the small proportion of additives and iso-iso-paraffins indicate, even in standard adjustment, that improvements in emission characteristics can be expected. The shortened ignition delay due to the high cetane number results in a change in the centre position of combustion and therefore requires adjustments to the injection timing and quantity.

In order to describe all the relevant effects on the environment caused by using different fuels (fossil and alternative), a Lifecycle Assessment has to be conducted, taking account not only of the use inside the vehicle, but also of the pre-processes (raw material extraction and production, and fuel production). To become familiar with the Lifecycle Assessment tool, the international standards (ISO 14040 and ISO 14044) were investigated, as well as recent relevant studies. A comparison of the software tools available for compiling Lifecycle Assessments led to the GEMIS software being selected. After creating the conceptual basis, the boundaries of the system to be analysed will be defined precisely, and in a further step the data research will start. The research activities to evaluate the process technology for producing the primary synthesis gas and the subsequent downstream treatment to produce BTL, conducted by the project partner PROFACTOR, are currently being completed.

INFO
Project management:
Vienna University of Technology – Institute for Internal Combustion Engines and Automotive Engineering
Project partners:
Austrian Research Centers GmbH – ARC, BMW Motoren GmbH,
Shell Austria GmbH,
Shell Global Solutions GmbH

CEP2020

Clean Energy Pathways 2020 for Sustainable Mobility

The Austrian automotive industry has been a major player in alternative propulsion system development, has already developed outstanding solutions and is permanently working towards a higher market penetration of these systems. From the customer viewpoint, the desire for clean, alternative propulsion systems is steadily increasing because metered emissions recorded at sites close to roads are exceeding specified limits, and further having regard to seemingly impossible Kyoto targets; this view is shared by vehicle fleet operators as well as public entities and private individuals. However the development of the market in alternative propulsion systems is strongly linked to the supply of clean energy carriers such as CNG and biofuels. These gaseous energy carriers also demand new storage technologies. Furthermore the long term performance of these propulsion systems has not yet been analysed under real-life conditions. The Clean Energy Pathways 2020 project combines efforts by the automotive industry and major energy suppliers and stakeholders within European and transatlantic scientific research and industry to work together towards new propulsion systems on basis of the gaseous energy carriers.

To assess potential use in vehicle fleets over long operational periods, light- and heavy-duty commercial vehicles with different operational performances are being investigated. Furthermore the application of methane and virtual biogas and the influences of energy supply on operation are being evaluated. Running CNG fleet vehicles with high mileages and CNG buses for demonstration and evaluation purposes is, for the first time ever, permitting long-term monitoring of clean propulsion systems, based on innovative real life in-car measurement systems. The findings will be supplied to the participating private and local authority fleet operators for future vehicle purchasing. Long-term experience of operating familiar concepts is explored with a demonstration of next generation CNG vehicles based on current research studies. Running on methane as well as on virtual biogases is being investigated through these progressive concepts.

To make the promising potential of alternative propulsion and energy systems attractive for new generations and to access the creativity of young researchers, in parallel to the other activities a competition is being held to find the most energy efficient vehicle. Project findings are also being included in new learning programmes at the Vienna University of Technology.

Finally, the project is rounded off with a presentation of the results and the winners of the competition, with an accompanying expert meeting.

INFO
Project management:
Vienna University of Technology – Institute for Internal Combustion Engines and Automotive Engineering
Project partners:
EVN AG, ÖAMTC Academy – scientific association for mobility and environmental research, Ventrex Automotive GmbH, Magna Steyr Fahrzeugtechnik AG & Co KG, Verband der Chemielehrer Österreichs, Naturtaxi und Mietwagen GmbH, NÖ Landesakademie, Mercedes-Benz Technology, NEOMAN Bus GmbH, University of California at San Diego

ICUT

Innovative Clean Urban Transport

In this project, clean innovative concepts for alternative propulsion systems and fuels were adapted and improved. The systems were then tested in the service operations of Graz City Buses (working with the bus operators GVB and Watzke), and in passenger car fleets. The findings with regard to suitability for practical use, costs, emission patterns and customer acceptance are to be evaluated. Advice regarding future applications will also be provided.

The majority of city buses and taxis currently use diesel engines. Without exhaust gas after-treatment they are not particularly eco-friendly, because of particulate and NO_x emissions and given the use of fossil fuels and associated greenhouse gas emissions. The advantage, however, is that diesel engines are very reliable and offer the user a high level of efficiency.

There are real disadvantages hampering the broader application of alternative propulsion systems and/or fuels to some extent, such as cost or security of fuel supply, in addition to uncertainties regarding some new technologies. As an example, the functionality of future EURO 5 technologies, in combination with biofuels, has not yet been adequately studied and resolved. A further key barrier to the use of alternative fuels is the lack of clear information and guidelines regarding problems and possible solutions which arise in practice when converting fleets of vehicles. This project deals with these problems and possible solutions are discussed. Some key aspects are now described.

INFO
Project management:
Graz University of Technology – Institute for Internal Combustion Engines and Thermodynamics
Project partners:
Robert BOSCH AG, Ceram Catalysts GmbH, Grazer Stadtwerke AG, Karl-Franzens-Universität Graz – Institut für Chemie, Watzke GmbH, Roth-Technik GmbH

In this project, GVB city buses were equipped with an open particulate removal system from Remus, and Watzke city buses were fitted with wall flow filters from Baumot. Possible problems from combining the use of exhaust gas after-treatment systems with alternative fuels were examined. For this task a proportion of the buses were driven with conventional lube oil, the others with a ‘5W30 low ash’ oil from Shell. Part of the bus fleet was run using bio-diesel, the others using conventional (fossil) diesel. GTL from Shell was also tested in a bus and in a passenger car. In the first series of tests, on a roller test bed for heavy duty vehicles, the differences in emissions behaviour using various combinations of particulate filters, fuel properties and lube oil were examined. In the next step, the technologies were demonstrated and tested in the ‘field’. The condition of the particulate filters and lube oil were checked and documented regularly. This data shows the ability to regenerate the filter and the level of ash content in the filter, as well as the lube oil dilution. For the engines running on the ‘5W30 low ash’ oil, average fuel consumption was found to be lower by more than 1% and the exhaust gas backpressure levels on the filters were increasing slower than with the conventional lube oil. With the GTL the expected reductions in NO_x and particle emissions were found. The use of bio-diesel did not show the expected reduction in particulate emissions on all the buses tested. To clarify this phenomenon, further investigations are being completed, since the different emissions behaviour of the buses would hamper comparability of results from long-term field testing.

In parallel, an innovative system for controlling SCR catalysts for NO_x reduction in SI engines is being developed. The system should be able to adapt to the different NO_x emission levels when buses are run with different fuel qualities. The corresponding hardware and software will be studied on the test bed from May onwards. In autumn the first bus will be equipped with the system for field testing and further improvements.

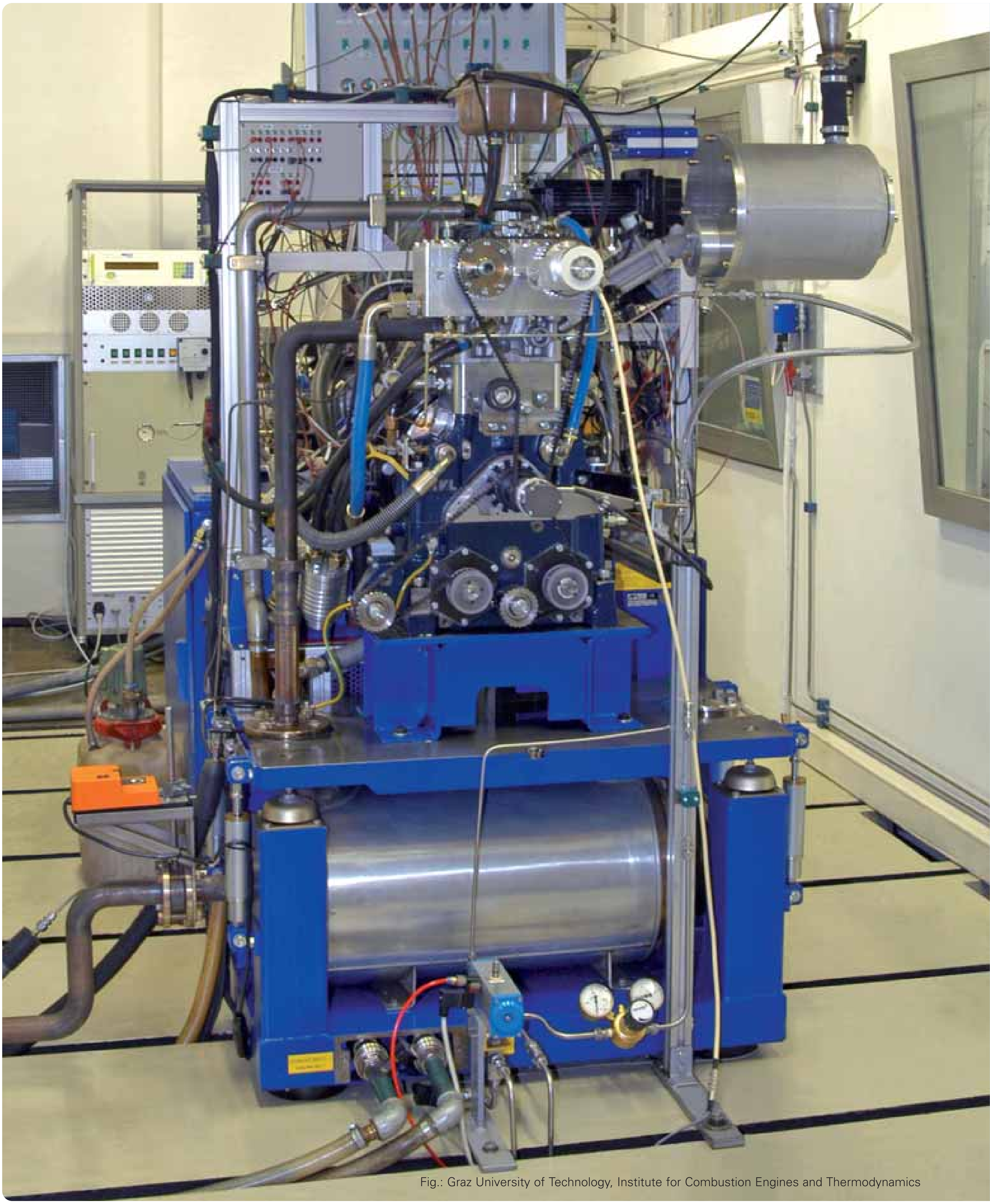
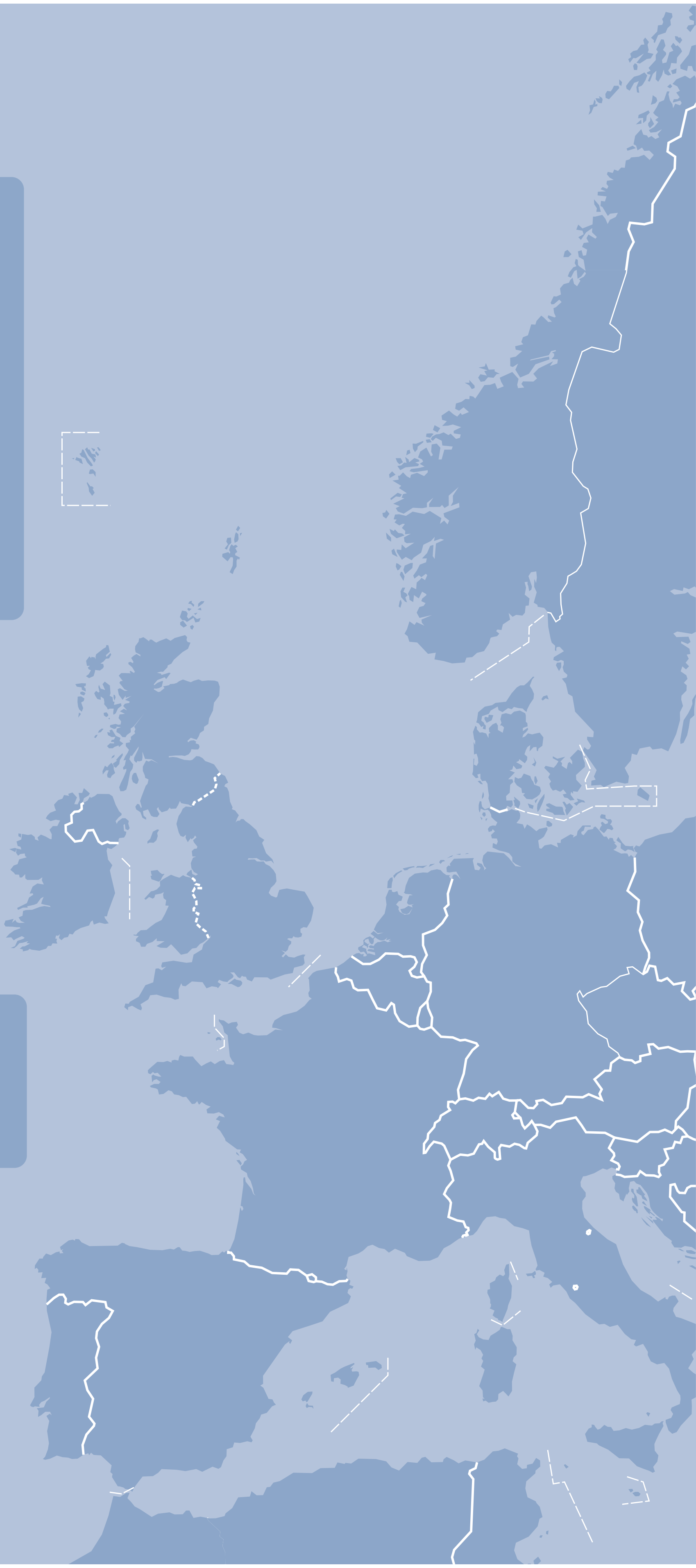


Fig.: Graz University of Technology, Institute for Combustion Engines and Thermodynamics

> BIO-SNG
> CLEANENGINE
> ECO-ENGINE
> EU-AGRO-BIOGAS
> GREEN
> NICE
> RENEW
> ULYSSES



EU-PROJECTS

BIO-SNG

Demonstration of the Production and Utilisation of Synthetic Natural Gas (SNG) from Solid Biofuels

The objective of this project is to realise and demonstrate the production of Synthetic Natural Gas (SNG) from solid biofuels within an innovative, large scale gasification plant which is in operation in Austria and to use this motor fuel in energy efficient vehicles.

Major tasks are:
- Assessment and optimisation of the biomass provision
- Engineering and erection of an SNG production plant with a capacity of 1 MW in Güssing
- Research into optimising gasification and the gas cleaning
- Research into methane synthesis and SNG cleaning
- Operation and optimisation of the SNG plant
- Demonstration of the utilisation of Bio-SNG in vehicles
- Technical, economic and environmental evaluation of the process
- Process simulation

INTRODUCTION

Methane derived from biomass is an important option for achieving the policy objective for increased use of alternative motor fuels. Methane can easily be fed into the existing natural gas pipeline grid, making use of the existing infrastructure, and can then be used with available technology, in particular within vehicle fleets. The EC directive 2003/55/EC encourages this option.
Initial successes have been achieved in using methane from digestion of biomass on a small scale, with several plants in various European countries already in operation.
The bio-SNG project covers the realisation and demonstration of synthetic natural gas (SNG) production, based on an innovative thermo-chemical gasification process, which is also suitable for large scale plants.

BIOMASS – GASIFICATION

The gasification process, which has been demonstrated in Güssing for the first time, is based on the steam gasification of biomass in an internally circulating fluidised bed. The heart of the plant, the fluidized bed steam gasifier, consists of two connected fluidized bed systems. In the gasification zone, the biomass is gasified at approximately 850°C, with steam being fed in. By utilising steam instead of air as the gasifying agent a nitrogen-free product gas with a low tar content and a high heating value is produced, which is an ideal basis for the synthesis of methane.
To maintain the energy balance for the gasification process, additional heat has to be fed into the gasifier. Any carbon which is not completely gasified (coke) is transported into the combustion zone together with the circulating bed material (sand), which acts as a heat carrier, and is burned. The exothermic reaction in the combustion zone provides the energy for the endothermic gasification with steam.


Figure: research- and demonstration SNG plant in Güssing

GAS CLEANING

Similarly already installed and tested in Güssing is the cooling of the producer gas, with the waste heat being fed into the district heating grid. After that a filter and a scrubber follows, to remove dust and tars. The gas quality thereby achieved is sufficient to fuel a gas engine, which is installed to produce electricity. For methane synthesis, however, further cleaning steps are necessary. Compounds of sulphur (such as H_2S, mercaptanes, thiols) have to be removed to a ppm – level, along with higher hydrocarbons (volatile compounds, particularlyaromatics).

METHANATION

In the methanation step, the upgrading of the producer gas to SNG is performed by the synthesis of CO and H_2 to methane (CH4) at temperatures between 300 and 400 °C. The reaction is heterogeneously catalysed on the large surface of a porous nickel catalyst. The reaction is highly exothermic and the heat must be removed in-situ from the process.

SNG – CLEANING

In the SNG cleaning the raw SNG is compressed and essentially separated from NH_3, CO_2 und H_2, before being dried. The gas thereby obtained conforms to natural gas grid specifications. A hydrogen rich gas stream is recycled to the synthesis reactor, to maximise the yield of CH4.The CO_2 is separated as well and used as a strip gas in the gas cleaning or recycled to the post combustion chamber of the gasifier.

Austrian partners:

REPOTEC – Renewable Power Technologies Umwelttechnik GmbH

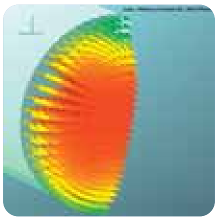
Vienna University of Technology – Institute of Chemical Engineering

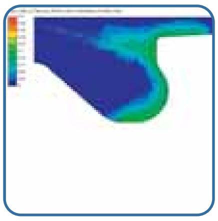
Biomasse Kraftwerk Güssing GmbH & Co KG

CLEANENGINE

Advanced technologies for highly efficient Clean Engines working with alternative fuels and lubes

According to car manufacturers EUCAR consortium, beyond the year 2010 the share of engines running on alternative fuels will depend mainly on: legislation, the availability of a mature new technologies infrastructure for alternative fuels, availability of modified/synthetic fuels and lubricants, costs, and customer acceptance. CLEANENGINE addresses 3 of these main aspects; research activities will be focused on the development of modern clean engines based on liquid biofuels coming from biomass (like biodiesel and bioethanol), and environmentally friendly and ash-free lubes and/or lubrication concepts. The impact of biofuel and bio-lube usage on current small (ship), medium (car) and large (ship) diesel and/or petrol engine configurations will be evaluated and compatible optimised solutions in materials, geometry and after-treatment will be developed, taking into account lifecycle assessment methodologies.





The main effects will be:
increasing engine efficiency (by reducing internal friction and improving combustion); adapting them to use up to 100% pure biofuel to reduce emissions at source (very heavy reduction in CO_2 emissions, taking into account the complete lifecycle of the biofuels, even down to zero CO_2 emissions when using 100% biodiesel); reductions in NO_x, CO and PM when using mixtures of oxygenated biofuels as bioethanol; improving technological and industrial practice related to the use of alternative fuels in combination with environmentally friendly lubricants.

The advantage that can be gained in this project will help in consolidating strategic knowledge for the European large industrial partners (Fuchs, Fiat, Arizona Chemicals, Guascor, Ecocat) and the SME's (Firad, Abamotor), assisted by research centres of excellence (BAM, TEKNIKER, AVL, OBR). They will all be able to compete world-wide using the results gained in this project, especially in the new emerging markets for 'clean engines'.

Austrian partners:
AVL List GmbH

ECO-ENGINE

Energy conversion in ENGINES

The objective of the ECO-Engines proposal for a NoE is to set-up a Virtual Research Centre (VRC) on advanced engine combustion modes for road transport, with special emphasis on the use of alternative and renewable fuels, and to establish it as a world reference in the field.

The VRC will provide a structure for networking the excellence of European research on all aspects of new generations of high efficiency, low CO_2 and noise, near zero emission engine combustion processes like CAI, HCCI or CCS, and other emerging highly promising techniques. This will contribute to the EC objective of developing and promoting future generations of more environmentally friendly powertrains and vehicle concepts for road transport, using cleaner and renewable energy sources. Multidisciplinary research will address the topics of experimental techniques (including optical diagnostics and ultra low emission measurement), combustion simulation, energy and engine related aspects and combustion control.

The VRC will result from integrating the activities of major actors in the field in Europe, with the aim of durability beyond the end of EC funding. Work will provide all necessary means for the VRC to centrally and jointly manage knowledge, resources and research actions: setting up a central database, internal communications via a non-public web site, developing standard methodologies and procedures, exchanging personnel, sharing use of existing equipment and joint planning of future equipment, realigning existing research actions and defining new common research actions. Emphasis will be put on disseminating knowledge and exploiting results. The major action in this regard will be to set up a common integrated education and training programme aimed at students, researchers and engineers all over Europe.
Other actions to spread excellence include creating an ECO-Engines public web site, disseminating results in congresses and publications, intense collaboration and exchanges with related FP6 IPs, and specific actions aimed at SMEs.

Austrian partners:
AVL List GmbH

EU-AGRO-BIOGAS

European Biogas Initiative to improve the yield of agricultural biogas plants

FARM BASED BIOGAS PLANTS: CLEAN ENERGY FOR THE FUTURE
Creating energy from biogas is one of the most promising technologies for sustainable development and links policy areas as diverse as agriculture, climate change, rural development and, of course, energy. The EU funded project EU-AGRO-BIOGAS aims to optimise existing biogas technologies and to devise clear standards and guidelines for designing and operating biogas plants.

TOWARDS HIGHLY EFFICIENT BIOGAS PRODUCTION
The use of renewable energies is considered an integral part of current and future energy concepts. Within these concepts, biogas production plays an important role. Biogas itself may be used for a number of purposes, such as electricity production or heating.
Should CNG vehicles gain a greater market share in the future, biogas could become more important as a biofuel for road transport.
However, while biogas production in the European Union is increasing, it is still not sufficiently efficient. Therefore, the EU-AGRO-BIOGAS project analyses and identifies the most important factors responsible for the current lack of efficiency in biogas plants:

- Determining the optimized mixture of agricultural residues and special energy crops is crucial for increased efficiency, and the team will analyze several selected European biogas plants in this regard.
- The project will establish an online EU database containing information on the materials used for biogas production ("substrates")
- A variety of field trials will be conducted to optimize the conversion of agricultural residues into biogas
- As a major technological advance, an early warning system will be developed which will alert users to problems in the fermentation process within the biogas plant
- Last but not least, the project will significantly optimize the conversion of biogas to electricity or heat.

EUROPEAN EXPERTS WORKING TOGETHER TO ACHIEVE THE SAME GOAL
The project is coordinated by the Vienna based University of Natural Resources and Applied Life Sciences, Department of Sustainable Agricultural Systems. EU-AGRO-BIOGAS brings together leading biogas experts with different competences from all over Europe. Within the project, leading universities are cooperating with key industry players in order to strengthen the biogas sector in Europe.

Austrian partners:
University of Natural Resources and Applied Life Sciences, Vienna – Division of Agricultural Engineering

GE Jenbacher

RTD Services

www.eu-agrobiogas.net

BENEFITS
In addition to the technological optimization of biogas conversion, and the resulting increase in efficiency, there are a number of other positive long term impacts associated with EU-AGRO-BIOGAS. The project will create substantial benefits for a number of stakeholders such as farmers (added revenue and cost savings) and the public (reduction of greenhouse gas emissions and biogas related odours).

Through its activities EU-AGRO-BIOGAS will contribute to building a "greener Europe" by using biogas

GREEN

Green Heavy Duty Engine

The development of HD engines is undergoing a rapid step in its evolution. Increased demand for fuel efficiency, emissions and global competition are the driving forces.
The HD (Heavy-Duty) engines operate under constraints much more severe than those of passenger cars, such as:

- Higher durability of the engine and of the related after-treatment (up to 1,000,000 km);
- Higher mechanical and thermal stress on the engine (heavier load factor);
- Higher pressure – in terms of reliability, investment and fuel economy.

The above constraints characterise HD engines in terms of their more general applications: not only in trucks and urban vehicles, but also in rail traction and inland waterway vessels covered by directive 2002/765.
New technologies will help us in meeting future emissions and fuel consumption targets, by:

- A new combustion process enabled by variable components;
- New control strategies;
- Considering the engine and the exhaust after-treatment as ONE system;
- Considering sustainable fuels. The main objective of GREEN is to perform research leading to sub-systems for a heavy-duty engine.

The objectives should be achieved with strict boundary conditions for:

- A competitive cost base;
- Highest fuel conversion efficiency of the Diesel cycle, to achieve near-zero pollutant emissions and significant reduction of CO_2 under real operating conditions.

The project puts emphasis on diesel engines for trucks and rail applications and on natural gas engines for city transport applications. The combination of innovation and durability is strongly supported. The research targets have been chosen to go beyond the demands of all current legislation, with a view to possible intensification of requirements after year 2010 to focus on near zero emissions under real operating conditions (for Diesel NO_x 0.5 g/kWh, PM 0.002 g/kWh, ETC Cycle BSFC = 204 g/kWh, with corresponding targets being set for natural gas).

Austrian partners:
AVL List GmbH

NICE

New Integrated Combustion System For Future Passenger Car Engines

The four year Integrated Project "New Integrated Combustion System for Future Passenger Car Engines (NICE)" is being promoted by the European automotive industry at its highest level of responsibility. The main objective of NICE is to develop a new integrated combustion system that is able to match the highest fuel conversion efficiency currently achievable on the DI diesel engine (43%), independently of the type of fuel (i.e. fuel neutral), while complying with a zero-impact emission level. Exploiting the knowledge gained and the technologies realised for an integrated combustion system of this kind, innovative Diesel and Otto cycle engines are being developed; these can be considered as by-products of the NICE research. These by-products will allow Europe to maintain its leadership in the production of internal combustion engines over the years 2010 – 2015, while allowing completion of the integrated combustion system in an innovative powertrain, capable of covering the years up to 2020.

Austrian partners:
AVL List GmbH

Graz University of Technology –
Institute for Internal Combustion Engines and Thermodynamics

The fully flexible powertrain will be characterised by very high fuel conversion efficiency, mainly using newly-designed biofuels and/or alternative fuels and gas, under the given emission constraints. The IP NICE is framed as four sub-projects:

- Enhanced HCCI Diesel / CAI Otto combustion process under transient operation;
- Compressed/Spark Ignition Variable Engine; based on petrol or diesel engines, combining the advantages to create a new combustion system with high EGR, supercharged and adapted to biofuels;
- Future Gas internal combustion engines with diesel-equivalent fuel consumption;
- Improved CFD tools and modelling.

The main R&D objectives of these sub-projects are:

- A sensible increase of the HCCI/CAI region in the engine map;
- Bio-fuels specifications geared to the new combustion system;
- Combining various electronic control units (ECU) to define new advanced systems, including ECU algorithms, real-time models and software tools for automatic validation, hardware-in-the-loop tests and calibration;
- Advanced control systems for mixture preparation and combustion, required to adapt the injection and combustion strategy to the fuel composition identified;
- A predictive, affordable and "practically useful" digital tool describing new low-emission high-efficiency combustion processes.

ULYSSES

Future Propulsion as ONE System

The objective of the 4 year CA ULYSSES is to construct a platform for exchanging information and strategic planning of specific EC funded research projects. These projects deal with new propulsion technologies/concepts based on IC engines running enhanced quality fuels, including alternative and renewable fuels, for on-road vehicles; extension to rail and waterborne propulsion will be also considered.

The CA will:

- Identify project linkages;
- Promote project integration, thus improving synergies and facilitating technology transfer
- Accelerate dissemination and analysis of project outcomes.

It will thereby make a substantial contribution to EC projects in achieving the strategic targets of:

- Compliance with future EU pollutant emission limits;
- Reducing CO_2 emissions;
- Delivering security of energy supply based on new fuels.

The CA activity is characterised by 4 work packages:

- Analysing propulsion systems, looking at future fuel scenarios;
- Assessing international state-of-the-art, identifying gaps and needs in RTD activities, defining and updating joint RTD strategy and plans;
- Co-ordinating cross-fertilisation and dissemination of project outcomes;
- Providing the basic infrastructures needed to operate the CA.

Two aspects take into account the changed conditions of FP6 and FP7 as compared to FP4 and FP5:

- The content: the aim is full implementation of the potential of the IC engine technologies developed in the former projects, by considering the three elements – fuel, powertrain (engine and gear box) and after-treatment – as ONE System able to combine low emissions and high efficiency with handling future fuel characteristics;
- The partnership: the contribution to innovating the technology comes not only from vehicle manufacturers (Fiat, DaimlerChrysler and Volkswagen) and an engine specialist SME (META-Ricerche), but also from research institutes (AVL and FEV), a fuel company (to be identified) and the French vehicle manufacturer association.

Austrian partners:
AVL List GmbH

RENEW

Renewable fuels for advanced powertrains

This project aims to develop, compare, (partially) demonstrate and focus on a range of fuel production chains for motor vehicles. Lignocellulose biomass sources are used as feedstock to produce synthesis gas from which various vehicle fuels can be derived: Fischer-Tropsch liquids (BtL), methanol/DME, ethanol (thermo-chemical pathway) and methane (CH_4).

The project develops and evaluates the respective processing technologies with a view to producing cost-effective premium fuels for existing and future combustion engines from a wide range of bio-feedstocks.
The project started in January 2004 and lasted for 48 months.

The main project targets were:
- Fuel production using the cheapest, most efficient energy chain
- Production costs 70 cents / litre petrol equivalent
- 3,500 litres yield per ha and year
- Premium fuel quality, for environmental improvement
- Benchmarking of different production processes
- Determination of best choice feedstock

Alternative thermo-chemical gasification and fuel synthesis processes are considered through 4 vertical sub-projects, while 2 horizontal sub-projects cover technology assessment and training. Two pilot-produced fuels (BtL and DME) are submitted to extensive motor-tests by 4 leading European car manufacturers within in this project, with other fuels being made available for tests in other projects. It is envisaged that this procedure will lead to the introduction of favourably priced biomass-derived fuels for motor vehicles from 2010 onwards.

SP1 focuses on the production, production development, analysis and test of BtL fuels from lignocellulose biomass using the Choren CARBO V® gasification process with Fischer-Tropsch synthesis and subsequent refining stages.
SP2 concentrates its research activities on optimising three different gasification routes (dual fluidised bed, pressurised entrained flow gasification and circulating fluidised bed) and Fischer-Tropsch synthesis.

SP3 investigates the full technical and commercial impact of DME/methanol production from black liquor at a pulp mill located in Mörrum, Sweden. The engineering study will address technical plant features in syngas handling and conversion as well as fuel logistics, handling and trading for both DME and methanol.

SP4 focuses on research and development for optimising the thermo-chemical production pathways for ethanol from lignocellulose biomass and is also supplying comparative data for the enzymatic pathway of ethanol production.
SP5 includes analysis of biomass potential in Europe, the lifecycle assessment from well to tank, and a technical and economic assessment of available production routes for BTL fuels from lignocellulose biomass.

SP6 will transfer results from the project, provide training by means of a summer school and web based training courses, and implement a concept which favours gender mainstreaming.

RENEW involves 32 partners and the partners from Austria are:
- Vienna University of Technology; Institute of Chemical Engineering
- Biomasse-Kraftwerk Güssing GmbH & CO. KG
- Europäisches Zentrum für Erneuerbare Energie
- REPOTEC – Renewable Power Technologies Umwelttechnik GmbH

Europäisches Zentrum für Erneuerbare Energie is responsible for the co-ordinating Sub-project 5, and the other Austrian partners (Vienna University of Technology; Institute of Chemical Engineering, Biomasse-Kraftwerk Güssing GmbH & CO. KG and REPOTEC – Renewable Power Technologies Umwelttechnik GmbH) are mainly involved in Sub-project 2 and concentrate on the development of Fischer-Tropsch diesel (BioFiT) from biomass via dual fluidised steam gasification.

At the biomass CHP Güssing, a dual fluidised bed reactor is being installed to gasify biomass with steam. The product gas consists mainly of hydrogen, carbon monoxide, carbon dioxide and methane. The gas is cooled down in a heat exchanger and cleaned in a two-stage cleaning system to achieve a quality that can be used without problems in a gas engine. At the end of 2007 the gas engine had been operated for more than 30,000 hours, evidence of the high quality of the gas cleaning system used.
During the EC project RENEW, lab-scale FT synthesis was designed, constructed and operated, using about 7 Nm3/h of the product gas (PG) from the biomass CHP Güssing. This FT unit has been in operation since summer 2005 and converts the PG at 25 bars in a slurry reactor into FT products. The additional gas cleaning of the raw PG consists of several steps. Firstly, an RME scrubber is used to dry the gas. After the compression step, chlorine is separated using a sodium aluminate fixed bed. Organic sulphur components are hydrated using an HDS catalyst and the H_2S is chemically separated with zinc oxide. Both operations are realised in fixed bed reactors.
In 2005 an iron-based catalyst was used for FT synthesis, which was followed by a cobalt-based one, both produced by the University of Strasbourg. In 2007 it was replaced with a commercial FT catalyst. With this commercial catalyst, up to 0.3 kg/h of raw FT product could be produced under the above-mentioned conditions in this laboratory FT unit. The diesel fraction of the FT product consists mainly of paraffins, giving these fuels excellent properties, e.g. a cetane number between 70 and 80, and free of sulphur and aromatics.

Currently there is much ongoing discussion about the best process route from biomass to biofuels. One strategy is centralised fuel synthesis in large conversion facilities, with maximised fuel output and optimisation through economies of scale. However, given the scattered availability of biomass and the political wish for regional development especially in central Europe, other options must be considered as well. One promising alternative under the concept being put forward here is the design of an "energy centre for the future", which not only supplies transport fuels but also provides electricity and district heating in the small to medium scale up to 100 MW biomass fuel power. As even low temperature heat can be used in plants of this size, high overall efficiencies of > 80 % are obtainable. This produces the highest possible CO_2 savings, which is clearly the most compelling argument for the use of biofuels. In addition, co-generation of electricity results in outstanding flexibility in process design. Moreover, simplified synthesis operation can be achieved as, for instance, reforming can be omitted. Hence production costs can be cut to below 0.9 €/l, and the development time to successful demonstration and commercialisation of second-generation biofuels can be reduced considerably.

Austrian partners:
Vienna University of Technology – Institute of Chemical Engineering

Biomasse-Kraftwerk Güssing GmbH & CO. KG

Europäisches Zentrum für Erneuerbare Energie

REPOTEC – Renewable Power Technologies Umwelttechnik GmbH

www.renew-fuel.com
www.ficfb.at

AUSTRIAN INSTITUTIONS IN THE FIELD OF TRANSPORT FUELS

AGRANA GmbH	www.agrana.com
arsenal research GmbH	www.arsenal.ac.at
Austrian Research Centers GmbH	www.arcs.ac.at
AVL List GmbH	www.avl.com
Bauer Poseidon Kompressoren GmbH	www.bauer-poseidon.at
Biomasse Kraftwerk Güssing GmbH & Co KG	www.eee-info.net
Blaguss Reisen GmbH	www.blaguss.com
Ceram Catalysts GmbH	www.ceram-catalysts.com
CLIMT Claassen Industrie Management Trading GmbH	www.climt.at
Consultant Engineer Herbert Kitzler	
ECHEM Kompetenzzentrum für Angewandte Elektrochemie GmbH	www.echem.at
Europäisches Zentrum für Erneuerbare Energie	www.eee-info.net
EVN AG	www.evn.at
FJ BLT Wieselburg	blt.josephinum.at
Forschungsgesellschaft für Verbrennungskraftmaschinen und Thermodynamik mbH	fvkma.tu-graz.ac.at
GE Jenbacher GmbH & Co OHG	www.jenbacher.com
Gemeindeverbund Personennahverkehr Pinka- und Stremtal	
General Motors Austria GmbH	www.gmeurope.com
Graz University of Technology – Institute for Internal Combustion Engines and Thermodynamics	fvkma.tu-graz.ac.at
Graz University of Technology – Vehicle Safety Institute	www.vsi.tugraz.at
Grazer Stadtwerke AG	www.gstw.at
HyCentA Research GmbH	www.hycenta.tugraz.at
Joanneum Research Forschungsgesellschaft mbH	www.joanneum.at
Karl-Franzens-Universität Graz – Institut für Chemie	chemie-graz.at
Magna Steyr Fahrzeugtechnik AG & Co KG	www.magnasteyr.com
MLU – Monitoring für Leben und Umwelt GmbH	www.mlu.eu
Naturtaxi und Mietwagen GmbH	www.ck-airportservice.at
NÖ Landesakademie	www.noe-lak.at
ÖAMTC Akademy – scientific association for mobility and environmental research	www.oeamtc.at/akademie
ÖAMTC Österreich	www.oeamtc.at
ÖGUT – Österreichische Gesellschaft für Umwelt und Technik	www.oegut.at
OMV AG	www.omv.com
Organisationseinheit der TU Wien – Technische Versuchs- und Forschungsanstalt	www.tuwien.ac.at
PROFACTOR GmbH	www.profactor.at
Renet Kompetenzknoten Güssing Forschungsinstitut f. Erneuerbare Energie GmbH	www.eee-info.net
REPOTEC - Renewable Power Technologies Umwelttechnik GmbH	www.repotec.at
Robert BOSCH AG	www.bosch.at
Roth-Technik GmbH	www.rothtechnik.eu
RTD Services	www.rtd-services.com
Tourismusverband Werfenweng (Werfenweng Tourist Board)	www.werfenweng.org
Umweltbundesamt	www.umweltbundesamt.at
University of Natural Resources and Applied Life Sciences, Vienna – Division of Agricultural Engineering	www.boku.ac.at
University of Vienna – Institute of Risk Research	www.irf.univie.ac.at
Ventrex Automotive GmbH	www.ventrex.com
Verband der Chemielehrer Österreichs	www.vcoe.or.at
Vienna University of Technology – Institute for Internal Combustion Engines and Automotive Engineering	www.ivk.tuwien.ac.at
Vienna University of Technology – Institute of Chemical Engineering	www.vt.tuwien.ac.at
Vienna University of Technology – Institute of Electric Plant and Energy Management	www.ea.tuwien.ac.at
Watzke GmbH	www.watzke-bus.at
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