Umsókn til Tækniþróunarsjóðs

Verkefnislýsing og drög að viðskiptaáætlun

Haust 2009

BioFuel

Merkjið við þann flokk sem sótt er um	
Verkefnisstyrkur	
Frumherjastyrkur	
Öndvegisstyrkur	x
Brúarstyrkur	

15.10.2009

1 Special clauses

There are no special clauses in the project.

2 Summary

Íslenska:

Þjóðir heims horfa nú í auknum mæli til framleiðslu vistvæns eldsneytis í stað jarðefnaeldsneytis. Sótt er um öndvegisstyrk sem miðar af því að skoða mismunandi leiðir og þróa tækni til innlendrar lífeldsneytisframleiðslu.

Verkáætlunin gerir ráð fyrir umfangsmiklum rannsóknum við framleiðslu eldneytis úr lífamassa af ýmsum toga. Lífmassinn sem unnið er úr fæst sem úrgangur frá landbúnaði, iðnaði og heimilum.

Kannaður verður fýsileiki og hagkvæmni á framleiðslu mismunandi lífeldsneytis. Viðskiptaáætlun sem lögð er fram vegna innlendrar eldsneytisframleiðslu fram til ársins 2029 gerir ráð fyrir heildarveltu um 82 miljarða króna. Stofn- og rekstrarkostnaður er áætlaður um 33 miljarða króna og beinn hagnaður rúmir 36 miljarða króna. Þjóðhagslegur ávinningur er rúmir 13 miljarða króna vegna minni innflutnings á eldsneyti og minni losunar vegna notkunar jarðefnaeldsneytis.

Enska:

Increasing emphasis is now put on production of domestic alternative energy carriers which can replace the traditional fossil fuel used in the world today. The current grant proposal aims at investigating the feasibility of different routes towards biofuel production and develop the technology needed for such domestic fuel production.

The research plan consists of research and development for the production of biofuels from various sources. The biomass used as raw material for this production is obtained either as waster products from agriculture and home housholds or industry. Current business plan for the domestic fuel production estimates costs about 33 billion ISK but at turnover of 36 billion giving a profit of 13 billion over the next 20 years plus the environmental benefits.

Table of content

3 Desription of work

The main aim of this project is to fully cover the possibilities of producing all four main types of biofuels from resources available in Iceland.

This project is organised in three phases:

Phase I: Estimation of the types of biomass sources that is available or can be produced in Iceland. Analysis of the types of biofuels that could be produced from the biomass sources and the best known technologies needed for treating the biomass for maximum recovery or conversion of biofuels.

Phase II: Experimental work with the different types of biomass, in terms of, growing plants and microbes or collecting. Pretreatment of the biomass, conversion of the biomass by biological and/or chemical means will be done in the project.

Phase III: Economic evaluations, conceptual design of processes and feasibility study for different options and solutions of biofuel production in Iceland.

Thus, the project is divided into three phases. Work packages 1 to 3 take (Phase I) will be conducted in the first year of the project. Work package 4 (Phase II), the major laboratory research work, will be runned during the whole project time and work packages 4-7 (Phase III) related to economic evaluation, conceptual design and feasibility studies are mostly concentrated during the latter stages of the project.

Deliverables

The main deliverables of the project is increased scientific knowledge of production of biofuels from biomass (energy crops, agricultural waste and municipal solid waste). It is very important to decrease the use of fossil fuels in transportation in the next few decades. The European Union (EU) has put forward regulations concerning this issue and it is clear that Iceland has to participate fully in this matter. The use of ethanol and biodiesel from organic material (biofuels) is well known and no major technical modifications are needed for its use (pump stations and vehicles). Most car manufactures guaranty at least 5% (vol) ethanol and diesel mixed together with fossil fuels. Iceland has three possibilities to increase their use of biofuel and fulfill the EU regulations. Firstly, by importing biofuels, secondly by mixing biofuels in fossil fuel prior to import and finally by producing it from renewable raw material available in Iceland and mix it locally. This last option is the most feasible for Iceland if the cost is not too high. In Iceland there is a lot of unused biomass available and in the last couple of years, increased knowledge on thermophilic ethanol producing bacteria has been accomplished as well as studies on biodiesel production from waste oils. There are few technical problems concerning the production but the main obstacles up to day is the feasibility of different processes involved. Additionally, the proportion of the different biofuel type and its taxation is not known today.

In both earlier and ongoing projects at the University of Akureyri more than 80 strains of hydrogen and ethanol producing, thermophilic bacteria have been isolated as well as 20 strains of methanogens. These strains will be the basis for three of the four sub-projects applied for (biohydrogen, bioethanol and biomethane). The most powerful strain will be selected and experimentally tested. The data obtained will be the basis for the conceptual design and feasibility study for upscaling of the various processes. Possible outcome is a lower pretreatment costs of the various biomass used.

One deliverable will be estimate on the amount of raw material available for gasification, methane and ethanol production. Information on MSW and other organic waste will be made accessible, where composition, total amount and other important properties are described.

Another deliverable will be pilot scale production process for gasification and production of FT-diesel at SORPA. Also lab scale facilities for testing syngas and FT-diesel at ICI. The gasification pilot plant will be able to treat 1 ton of raw material per day. The FT-diesel catalytic synthesis from syngas will be able to produce 10000 liters per year.
Another deliverable is pilot scale production process for methane production at SORPA. It will be able to handle 10 tons in the same batch producing 1000 to 2000 Nm^3 of production gas.

Another deliverable will be report from ACU concerning cultivation of arable land and suitable plants for energy crops in Iceland. The report will contain information on land condition, use of artificial and natural fertilizers and conditions for sustainability of cultivation.

Feasibility studies for production of many types of fuel via different routes will be one of the main deliverables. The effectiveness of increasing methane production with thermophilic bacteria will be compared with landfill gas. Ethanol production using biomass and thermophilic bacteria and production of fuels from syngas obtained from gasification.

Other deliverables are possible new ways of fermenting syngas with Icelandic thermophilic bacteria that can possible produce ethanol and butanol from it.

<u>Other deliverables</u>:
If the production of biofuels will be sustainable in Iceland we will be less dependent on fossil fuel and the variation of gasoline and oil prizes demises

Iceland will adapt to the EU regulations concerning biofuels.

Increase of biofuels in Iceland will lower the increase of green house gases and will be a step into the right direction concerning international agreements, like Kyoto.

In Iceland the accessibility of green energy like geothermal and hydropower could be extra beneficial for the production of biofuels. This increases the sustainability of biofuel production from e.g. complex lignocellulosic biomass and increases the competiveness of the production in relation to imported fossil fuels.

Feasability study of the production of biofuels from Icelandic biomass is one of the main product of this project.

One of the main obstacle in Iceland is the lack of knowledge in the field of anaerobic microbiology and energy biotechnology. Although Iceland has the highest ratio of renewable energy world wide the knowledge in bioenergy has been very limited. This is probably because biomass energy has not been an issue in a country “overflowed” with geothermal and hydropower. In this project, the meaning is to educate one PhD candidate and seven (2) MSc candidates within the field of biofuel production from biomass. Apart from a strong academic gaining in the project there is a strong international links as well. A co-operation has been established with various partners from Finland and Sweden. Additionally, one aim in the project is not only to gain more scientific knowledge within the field but also to preserve it the near future.

Inventiveness

Biomass energy potential is addressed to be the most promising among the renewable energy sources (RES), due to its spread and its availability worldwide. Apart from that, biomass has the unique advantage among the rest of the RES, to be able to provide solid, liquid and gaseous fuels that can be stored, transported and utilized, far away from the point of origin. Due to the negligible amounts of sulfur and nitrogen biomass contains, the energy that is being utilized does not contribute to environmental pollution. Biofuels are generally considered as offering many priorities, including sustainability, reduction of greenhouse gas emissions, regional development, social structure and agriculture, security of supply.

Microorganisms have been rich sources for natural products, some of which have found use as fuels, commodity chemicals, specialty chemicals, polymers, and drugs, to name a few. The recent interest in production of transportation fuels from renewable resources has catalyzed numerous research endeavors that focus on developing microbial systems for production of such natural products. The trend has been that production of biofuels is moving from first generation to second generation fuels that are produced from waste material. Interest in cleaning greenhouse gases from geothermal plants and other industries with microorganisms has also gained more attention in the recent years. The reason for this increased interest is that it is known that petroleum reserves are a limited recourse and emit harmful greenhouse gases.

One of the goals of the EU is to increase the use of biofuels to about 5% in 2010 which means that there will be a market for biofuels in near future. What Iceland can do to reach this goal is to aim for 5% vol/vol mix of bioethanol to petroleum, 5% vol/vol mix of biodiesel to diesel and more use of biomethane on cars. It is really a question of whether we want to import all the biofuels that we need, or to produce it our self. Today 75% of vehicles in Iceland run on petroleum and only a few cars run on methane, electricity and E85 (15% petroleum and 85% ethanol). It would be a positive step forward for Iceland to be able to produce its own renewable fuel form what waste material that can be used and be less dependent on import of fossil fuel and decrease greenhouse gas emissions.

A project on the gasification technology and feasibility of using gasification to treat MSW and organic waste from agriculture is now ongoing. The project is mainly a desktop study that delivers data and information on available raw material, analysis of the raw material, description and status of the technology and economical feasibility of production of different types of fuel. The main interest is for FT-diesel and ethanol production but hydrogen, methanol and DME could be produced as well.

Work Packages

WP 1: Raw materials that can be used for biofuel production in Iceland

A lot of information is available from the study of ICI, SORPA and ACU (LBHÍ) about the availability of raw material for gasification. This will be made available for the project. More information will be gathered during the lifetime of the project to increase the depth of the analysis on available raw material whether it is a MSW or organic waste from agriculture or biomass from cultivation. SORPA is going to increase its categorization of waste into different waste streams which increases the separation and uniformity of the categories, i.e. organic waste, paper, metals, plastic and more that will make it easier to control the use of the waste. Information on the new categorizing system will be made available for the project. Information on cultivation of energy plants and possible land use for such cultivation will be made accessible for the project.

Two main sub-work packages are described below:

1.1. The objective is to survey different types of biomass in Iceland that potentially can be used as raw materials for production of biofuels, such as biodiesel (both FAME and HDRD), bioethanol, biohydrogen, biomethane and BTL fuels. The biomass is divided into three main categories:

- Biomass obtained by cultivation such as barley, grass, hemp and rapeseeds
- Organic waste
  - From agriculture such as hay, manure and straw
  - From households such as mixed MSW from households and sorted paper waste.
  - From industry and services such as biowaste from food production, restaurants and supermarkets, paper waste and timber waste.
- Sewage

The amounts of raw material will be estimated and predicted for coming decades, as well as availability and peaks of production during the year.

1.2. The objective is to estimate and predict emissions of biogas that can be upgraded to biomethane, from landfill sites in Iceland.

Milestones and targets: To estimate and predict the amount of different raw material available for biofuel production in Iceland.
Time schedule: Months 1 – 9 + additional information from cultivation of energy plants each year
MM: 3,5 (Mannvit 2,5 and ACU 1,0)
Performed by: Mannvit, ICI, ACU

WP 2: Types of biofuels produced in Iceland from various raw materials

Based on the results obtained in WP1, the experimental WPs and related projects the types of biofuels that can be produced from various raw materials in Iceland will be projected in details. In general material rich in acyltriglycerides is most suitable for production of biodiesel, lignocellulosic material is best suited for production of bioethanol, BTL fuels and even biohydrogen while manure and mixed municipal solid waste is most suitable for production of biomethane. This will though depend on the amounts and availability of the different types of raw material together with various economical factors.

Milestones and targets: To project in details the types of biofuels that can be produced in Iceland.
Time schedule: Months 3 - 9
MM: 3,5 (Mannvit 2,5 and ICI 1,0)
Performed by: Mannvit and ICI

WP 3: Pretreatment of biomass

2.1. Literature study.

2.1.1. Literature study will be performed on the types of pretreatment methods that are documented for the potential types of biomass for fuel production based on results from WP1 and WP2. The cost and energy consumption of different pretreatment methods vs. potential yield of biofuels will be estimated. The possibility of combining pretreatment processes for production of two or more biofuel types will be considered. The results will be applied in the following experimental WPs.

2.2. Pretreatment for gasification

2.2.1. A) by mixing feed streams in order to control moisture content to be less than 30%

2.2.2. B) drying of some raw material with geothermal energy (using hot waste water streams 50-55°C)

2.2.3. C) reducing size to fit the gasifier, by cutting and hacking

2.2.4. D) mix feed streams to balance the energy content by controlling the water content and/or adding landfill gas to gasifier. It is also possible to use the Windhexe system SORPA is buying that reduces and dries the waste and thereby fulfilling B) and C).

2.3. Pretreatment for methane pilot study:

Size reduction of MSW and blending for the right C/N ratio. The Windhexe system could be used to do the size reduction as well as drying the waste material. Other mechanical size reduction treatment could be used in case where drying is not needed. For some material it could be necessary to use enzymatic breakdown of cellulosic material under heating conditions by using hot waste water at 52-55°C to improve the conversion rate of cellulosic material.

Milestones and targets: To propose suitable and economical pretreatment methods for different types of biomass.
Time schedule: Months 3 - 12
MM: 7 (Mannvit 4, ICI 2, SORPA 1)
Performed by: Mannvit, ICI and SORPA

WP 4.1. Bioethanol

Since UNAK and Mannvit are already running a project on the production of bioethanol from lignocellulosic material supported from the Innovation Fund, this part is excluded from the application. However, that project (BioEthanol) will substantially strengthen the overall structure of the project. Instead, our focus on bioethanol in present investigation will be on the genetic engineering of thermophilic bacteria for more efficient production of ethanol from lignocellulosic material. Most of the work will be performed by Matis-Prokaria ehf. It is expected that by genetic engineering of approprioate strain ethanol production will be stabilized and increased by at least 30% compared to the wild strain making it suitable for commercial production of ethanol on cellulolytic waste biomass generated by farming and in industry.

Facility: Matís-Prokaria has state of the art facilities in molecular biology, microbiology and biomolecular research. This includes a very good high-throughput sequencing facility including a Biosystems Capillary DNA Analyzer 3730 and a recently acquired a FLX 454 sequencer from Roche for genome and metagenomic sequencing, robotic liquid dispensers, Beckman Biomek 2000, Packard Multiprobe II HT-ex, 24 (96 and 384) PCR MJ-Research PTC-225 EKTA protein purification FPLC station Dionex sugar analysis HPLC and number of biomolecular detection and analysis equipment for measuring volatiles and organic solvents (e.g. ethanol) such as gas chromatography and capillary electrophoresis apparatus.

In previous Bio-ethanol project, Matis in cooperation with University of Akureyri studied thermophilic ethanol producing bacteria, which were efficient hemi-cellulose degraders but were not capable of degrading cellulose. Other species found in this project, which degraded cellulose efficiently, produced mostly hydrogen.. The major goal of the currently proposed project is therefore to find organisms that combine cellulose utilization and ethanol production and improve them by genetic engineering.

The following sub-workpackages are proposed:

4.1.1. Strain screening program

A screening program for fermenting anaerobic thermophilic ethanol producers will be carried out. The first criterion for selection will be optimum growth rate at temperatures at and above 70°C. The quantity of ethanol formed and the ratio of ethanol and by-products will be examined. Substrate utilization range and physiological studies will be carried out, i.e. factors affecting ethanol conversion efficiency. Four or five most promising candidates will be selected for genetic engineering. In this part of the project a time lag is to be expected due to inherent delay because of time consuming isolations and long culturing times. However, we already have a variety of themophilic anaerobes in our strain collection some of which are new species and genera that could be investigated right away. Selected thermophilic anaerobic bacterial strains capable of degrading cellulose and hemicellulose will be characterized with respect to antibiotic resistance for subsequent genetic manipulation. Results will be reported and published in a scientific journal.

Milestones and targets: Obtain 4-5 strains, capable of efficient cellulose and hemicellulose degradation and production of ethanol and hydrogen, strains that are candidates for metabolic engineering.
Time schedule: Months 1-6
MM: 4 (3 mm Prokaria, 1 mm UNAK)
Performed by: UA, Prokaria

4.1.2. Physiology of growth and ethanol and hydrogen production

Batch and/or chemostat cultures grown at optimum temperatures will be used to assess the influence of the carbon source on the bioenergetics of the thermophilic anaerobes selected in 4.1.1. The growth characteristics and stoichiometry for cultures grown on different carbohydrates for example, but not limited to, starch, pectin, xylan, cellulose, cellobiose, and glucose will be estimated. Cell densities for growth on different substrates will be compared as well as the differences in specific rates of formation and relative quantities of acetate, ethanol, alanine CO_2, and H_2 produced. H_2 yields are generally higher in thermophiles than mesophiles, albeit with lower volumetric productivities due low cell densities in cultures. In order to overcome these limitations, fermentation studies will be carried out in order to optimize fermentation conditions and evaluate physicochemical factors that restrict growth of these organisms. Bio-fuel production will also be investigated in high cell density production using pre-grown condensed cell mass.

Milestones and targets: Retrive information on the basic metabolism and physiology of selected strains. Accordingly, select 3-4 strains for genome sequencing in 4.1.3
Time schedule: Months 1-12
MM: 5 mm (4 mm Prokaria, 1 mm UNAK)
Performed by UA, Prokaria

4.1.3. Genomic sequence analysis

Genomes of 3-4 strains selected according to results of 4.1.2, will be sequenced using the Roche FLX titanium sequencing system that Matis-Prokaria recently acquired. The size of each genome will not be evaluated with pulse field electrophoresis beforehand, yet common size of anaerobic bacterial genomes is around 3 mb. One run is enough to sequence 5-6 genomes, 4-5 mb in size, with ~20fold coverage. Therefore coverage > 20 fold is expected. Sequence reads will be assembled into contigs. Obtaining one complete contig for each genome is not a requisite; therefore, a gap filling procedure is not required. Each genome, comprised of several contigs, will be blasted and annotated accordingly. Genes encoding the key metabolic enzymes of the fermentation pathway will be identified.

Milestones and targets: Information on the genomic content of selected strains.
Time schedule: Month 10-15
MM: 4 mm

Performed by Matis-Prokaria

4.1.4. Design and construction of deletion/insertion modules

Ethanol production of two to three selected strains will be improved by applying genetic engineering, which is a powerful strategy to affect metabolic pathways and funnel them to a production of desired organic products. Pathways leading to undesirable by-products will be blocked by knocking out respective genes, and the reactions leading to formation of ethanol will be amplified by insertion of relevant genes. Obvious candidates for gene-knockout are the genes encoding for acetate kinase and the phospho-transacetylase, the key enzymes in the acetic acid formation, the lactate dehydrogenase the key enzyme in formation of lactate. Resultant inactivation of the pathways leading to the organic acid formation should prevent acidification and have beneficial effect on cell growth and cell densities. Potential target genes for insertion, *e.g.* to increase copy number for improved ethanol production, are genes encoding specific alcohol dehydrogenases and acetaldehyde dehydrogenase.

Modules for deletion/insertion of selected candidate genes in 1-2 strains will be constructed. Gene sequences flanking target genes involved in or affecting the ethanol metabolism in the respective bacterium will be isolated with PCR. Plasmid deletion cassettes containing these sequences flanking specific marker genes instead of the target genes will be constructed. Furthermore, insertion cassettes containing genes, for which increased gene-dosage in the cell may improve ethanol production according to genetic and metabolic data, will be designed and constructed. Hereby, the genes with a downstream marker gene will be flanked by respective sequences homologous to the target region. All gene cassettes will be constructed and cloned into conventional pUC plasmid derivatives in *E. coli* strains

Milestones and targets: Creation of deletion/insertion modules
Time schedule: Months 13-24
MM: 4 mm
Performed by Matis-Prokaria

4.1.5. Isolation and characterization of transformant strains revealing improved ethanol production

The selected thermophilic anaerobic bacterial strains in previous workpackages will be transformed with the respective deletion/insertion cassettes constructed in 4.1.4. Various transformation strategies, such as conjugation and electroporation, under different conditions, will be applied, as different methods may give different results for different strains. The *E. coli* plasmid DNA containing the insertion cassettes cannot replicate in the thermophilic anaerobes. Hence, resulting transformants isolated through marker selection, will likely be a product of a genome homologous recombination event. Gene deletion or insertion events will be analyzed and verified with PCR and Southern blot. Transformants will be cultivated in small scale and characterized with respect to ethanol production and formation of relevant by-products. Further modification of transformant strains will be attempted by creating double or triple mutants. As different selection markers will be used to isolate mutants of different phenotypes, a second mutation, e.g. lactate-, can be introduced to a previously mutated strain, e.g. acetate-, in either of two ways: 1: Transforming it, with already constructed deletion module (lactate-) constructed in 4.1.4 or 2: Transforming it with chromosomal DNA from respective deletion mutant containing the desirable mutation (lactate-) and harboring the appropriate selection marker not found in the host strain. A paradigmatic model strain with a double mutation will be constructed from two separate acetate- and lactate- *Thermanaerobacterium* strains created in previous Bio-ethanol project. The transformant double mutation strains will be cultivated in small scale and characterized with respect to ethanol production and formation of relevant by-products. It is expected that ethanol production will be stabilized and increased by at least 30% compared to the wild strain making it suitable for commercial production of ethanol on cellulolytic waste biomass generated by farming and in industry. Best strains will be selected for continued fermentation studies

Milestones and targets: Isolation of transformants exhibiting improved ethanol production
Time schedule: Months 22-33
MM: 4 mm
Performed by Matis-Prokaria

4.1.6. Fermentation of optimized production hosts

Selected transformants (2-3 different strains) will be fermented in large laboratory scale (1-10 l). Different substrates, oligosaccharide and polysaccharides, biomass, raw material, will be used as carbon source. Ethanol production will be analysed in detail in comparison with parent strains. Results will be used to evaluate their potential exploitation for bio-ethanol production for fuel.

Milestones and targets: Detailed information about metabolic pathways, from degradation of polysaccharides to production of ethanol.
Time schedule: Months 31-36
MM: 4 mm
Performed by Prokaria

An overview of the six work packages on time is thus as follows:

WP	Name of WP	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28-30	31-33	34-36
WP 4.1.1	Screening	■	■										
WP 4.1.2	Physiology	■	■	■	■								
WP 4.1.3	Genomic sequence				■	■							
WP 4.1.4	Deletion modules					■	■	■	■				
WP 4.1.5	Transformants modific.								■	■	■	■	
WP 4.1.6	Fermentation in host											■	■

WP 4.2. BioHydrogen and BioMethane

At the University of Akureyri more than 80 species of hydrogen producing bacteria from various geothermal areas in Iceland have been isolated. The capacity of hydrogen (and ethanol) production yields and rates have only been investigated for several of these strains (Örlygsson & Baldursson, 2007; Koskinen et al. 2008a; Koskinen et al. 2008b, Sveinsdóttir et al. 2009). In present investigation, a full screening of the potential of all of the strains will be investigated on various carbon substrates, both monomeric sugars (glucose and xylose) as well as polymetric carbohydrates (cellulose, xylan, pectin). The most promising strains will further be used on complex lignocellulosic material chosen in WP 1 & 2. This will be done together with selected strains of methanogenic bacteria that have been isolated in previous project at Unak. The project will be set up as Master program for two students and one scientist as part time (66%). Thus the number of man months (for all three years) is 30 for students and 24 for a scientist/supervisor. The main outcome of the project will be a deeper basic scientific knowledge on the phylogeny and physiology of thermophilic bacteria on their capacity of utilizing carbohydrates for hydrogen and methane production. Three to four scientific articles will be published from the data obtained.

Facility: At the University of Akureyri there has been build up an experimental facility to grow and investigate strict anaerobic thermophilic bacteria. This research facility is, to our knowledge, unique in Iceland with respect to a gas mixture system needed for this kind of research. Additionally, within the "energy biotech" group there are both continuous culture fermentors (BioFlo) and continuous stirred reactor (CSTR) that will be needed for some of the experimental parts of this project. The main analysis needed for the BioHydrogen and BioMethane project are the gases (H2 and CH4), the volatiles (acetate, propionate, butyrate, ethanol) and sugars. At UA the gases and volatiles are analysed with an Perkin Elmer Gas Chromatograph equipped with both FID (flame ionation detector) and TCD (thermal conductivity detector). The sugars are anlysed with High Pressure Liquid Chromatography (HPLC; Shimatzu).

Thus, the research facility at UNAK is very good for conducting the types of experiments applied for.

The following sub-work packages are set up:

4.2.1. Biohydrogen – hydrolytic bacteria

4.2.1.1. Estimation of carbohydrate degradation and hydrogen production rates and yields of thermophilic bacteria

Batch experiments will be done on all isolates that have been collected at UNAK on cellulose, xylan and pectin as well as on glucose (20 mM) and xylose (20 mM) to obtain data on their degradation capacity Hydrogen production rates (mmol H_2 l^{-1} h^{-1}) and yields will be determined by measuring H_2 during growth on monosugars. Additionally, degradation rates of carbohydrates will be determined to estimate the feasibility of the strains for pilot and full scale methanogenesis. This will be done by using gas chromatograph (GC) with a TCD (thermal conductivity detector). Of special interest are bacteria that can degrade polymetric lignocellulosic material without any pretreatment, i.e. strains that have the cellulases and hemicellulases needed. These strains can be used in simultaneous saccharification and fermentation (SSF).

Milestones and targets: Detailed information about hydrogen production rates and yields on mono-sugars and complex lignocellulosic material for all strains that belong to the culture collection of UNAK. Additionally, degradation rates of monosugars will be determined.
Time schedule: Months 1 - 6
MM: 4 mm
Performed by UNAK

4.2.1.2. Carbon utilization spectrum.

Carbon utilization spectrum will be done for all strains. All carbohydrates that are part of the building blocks of lignocellulosic material will be investigated (appr. 20 sugars and polymetric carbohydrates). All strains will be inoculated in anaerobic media with the appropriate carbohydrate and incubated for one week. Samples for volatile fatty acids and ethanol analysis and hydrogen will be taken in the beginning and at the end of the experimental time and measured by GC and HPLC and thus, an estimation of the versality of the strains will be obtained. The best strains (appr. 10 strains) will be continued with in the following work packages.

Milestones and targets: Detailed information on the substrate utilization versability for all strains that belong to the culture collection of UNAK.
Time schedule: Months 6-12
MM: 4 mm
Performed by UNAK

4.2.1.3. The influence of the partial pressure of hydrogen and substrate concentration on growth.

The influence of the partial pressure of hydrogen (pH_2) on hydrogen production and degradation of substrates (glucose) will be performed for the strains that produce highest yield and rates of hydrogen and are most versatile concerning carbon substrate degradation (see WP 4.2.1.1 and 4.2.1.2). This will be performed in 120 mL serum bottles on glucose (20 mM) with different gas to liquid ratios (see methodology in Örlygsson and Baldursson, 2007). The influence of substrate concentration on growth on hydrogen yields will be performed on the best strains obtained. Different initial glucose concentrations will be used (5, 10, 30, 60, 100 mM). Incubation time is one week and hydrogen production and glucose conversion (%) will be measured at the end of the experimental time and yields of mole H_2 per mole glucose will be obtained. All possible end products will be analysed for with GC and degradation of substrates with HPLC.

Milestones and targets: Information on the inhibitory effects of the *p*H2 on both hydrogen production rates and yields. The substrate concentration threshold for hydrogen production will be obtained for all strains
Time schedule: Months 12 - 18
MM: 4 mm
Performed by UNAK

4.2.2. BioMethane

4.2.2.1. Characterization of methanogens in the culture collection of UA

Many of the above mentioned hydrogen producers are interesting for either hydrogen production as end product or together with methanogens its converstion to methane . Of special interest are fermentative bacteria that degrade polymetric carbohydrates to acetate as the sole volatile end products and H_2 and CO_2 as gases, but these products are the main substrates acetoclastic and hydrogenotrophic methanogens use. In earlier projects, twenty thermophilic methanogens have been isolated (14 strains on H_2/CO_2 and 6 strains on acetate). All isolates will be submitted for 16S rRNA analysis for full characterization. This will be done at the premises of Prokaria. The methodology has been well documented in earlier projects on the phylogeny of anaerobic bacteria. Additionally pure cultures will be bought from culture collections e.g. DSMZ. All strains will be investigated in terms of methane production rates and yields from H2 + CO2 and acetate. The best strains will be used in the following work packages.

Milestones and targets: . Phylogenetic characterization of all strains as well as kinetic data on the growth rates and methane production rate of isolated methanogens
Time schedule: Months 1-9
MM: 4 mm
Performed by UNAK

4.2.2.2. <u>Hydrolysate experiments from lignocellulosic material – yields and rates of methane production</u>

Growth of selected strains (see 4.2.1.1 and 4.2.2.1) in lignocellulosic hydrolysates from chosen biomass (see WP 1 and 2) will be performed in different concentrations of HL's (2.5 – 10.0 g/L) to get insight into the influence of possible inhibition compounds produced in the various pretreatment used for different biomass (see WP 3). The best suited methanogens will be used in co-cultures with hydrolytic bacteria on hydrolysates made from lignocellulosic material (biomass and MSW).The experimental set up is directed towards the yields of methane (and hydrogen) obtained from the various biomass chosen. Pure cellulose (whatman paper) will be used as a control. Methane will be measured at the end of the experimental time (one week) and <u>yield</u> obtained as mmol methane/g substrate. Growth of the best hydrolytic and methanogenic strains will also be tested of several types of lignocellulosic material to test the <u>methane production rate</u>. This will be done in batch experiments with several concentrations of total solids. Various pretreatments will be used where parameters like acid, heat particle size will be varied. The methane production rate will be determined by GC by analyzing it during growth time. Pure cellulose (whatman paper) will be used as a control. All experiments will also be performed without any pretreatment to invesitigate the possibility to degrade the lignocellulosic material to biogas in SSF. Experimmental data will be used in the feasabilty study (WP 7).

Milestones and targets: The yield and rate of methane from various lignocellulosic material.
Time schedule: Months 6-18
MM: 10
Performed by UNAK

4.2.2.3. <u>Continuous culture on selected strains; optimization of hydrogen and methane production</u>.

The best hydrolytic and methanogenic strains will be tested further in continuous culture. Batch assays only give an indication on how good the strains are. In continuous culture the pH and partial pressure of hydrogen can be kept stable and substrate level increased. The continuous culture will be done in special bioreactors where the maximization of hydrogen production can be archived. Continues stirred tank reactor (CSTR) will be used and supplemented with carrier material to maximize biomass in the reactor. CSTR reactor as described by our earlier work (Koskinen et al 2008; see state of art) will be used to keep optimal conditions with manipulations of hydraulic retention time (HRL) and carbon loading rate (LR) in the CSTR which will give higher yields and maximization of hydrogen production.

Milestones and targets: Maximization of the hydrogen and methane production rates and yield under optimal conditions.
Time schedule: Months 15-30
MM: 10
Performed by UNAK

4.2.2.4. Upcaling from laboratory scale to pilot scale

SORPA in relation to other participants will set up a pilot plant for methane production which has the aim of producing methane by using different strains of bacteria. Some of these bacteria are thermophilic strains that have been screened and characterized by UNAK (WP 4.2.2.1 – 4.2.2.3).

The first phase is to set-up the facilities where about 10 tanks that each can handle approximately 1 m^3 of raw material and each tank is equipped with heating system and temperature control for small scale controlled experiments. The experimental set up for the trials are to test promising thermophilic strains at different temperatures and on different biomass i.e. organic waste (MSW, industrial waste, food waste, sewage, paper) and agricultural residues (hey, straw and manure). The waste material will have different V/S ratios (volatile/solid) and the experiments will be done with different V/S ratios. A total of 140-160 experiments will be performed during the 3 years period as each experiment takes up to 40 days from start to finish. Several thermophilic strains at different temperatures will be tested and about 8 different categories of waste (120-140 experiments) and 20 experiments to optimize the best strain that can produce the most methane on 2 categories of waste.

Subtask 1:The first year will be used to build and test the system for small scale methane production. About 20 experiments will be done during the second half of the first year.

Subtask 2: The second year will be used to make 60 experiments to test different conditions of methane production.

Subtask 3. The third year will be used for for the optimization of the best strains from obtained from experimental data obtained from the first two years. The heating system for the fermentors will be geothermal as there is plenty of low heat geothermal water in Iceland around 55-60°C. By using such energy source the methane production will be more efficient as there is no need to use part of the methane to heat the tanks.

UNAK will choose the strains to be tested and temperature conditions for the experiments. This part of the project will be performed by a master student. SORPA and UNAK will supervise the student in his work. Also ACU has ongoing small researches on methane production from agricultural waste and will assist in evaluating the raw material of agricultural origin and can compare the pilot scale results with their results.

Measurements that need to be done are total production of gas measured as Nm^3, total methane in the gas and other chemicals in the gas such as H_2S, ammonia and moisture. There will also be measurements of gas production per hour or day.

The experiments will be compared to methane production of known cultures of mesophilic methanogenic strains. It is hoped that the new thermophilic strains will increase the speed of digestion and produce more amount of gas i.e. utilize the raw material in a more efficient way.

The estimated investment cost is about 4 million iskr and operational cost excluding manpower is 3 million/year.

Full scale methane production based on the results of this WP will be planned at the end of the project and implemented after the project has finished.

Milestones and targets: Maximization methane production rates and yield under optimal conditions.
Time schedule: Months 1-36
MM: 29 (Sorpa 11.5 mm; UNAK 13 mm, Mannvit 9 mm, ACU 7 mm)
Performed by Sorpa, UNAK, Mannvit, ACU
SORPA will provide the facilities and equipment (reactors) plus supervision. UNAK will provide the methanogenic strains with kinetic data already obtained and a master student will be partially involved in the data analysis of the pilot scale fermentors. Mannvit will be involved in the design of the 1000 m3 pilot scale fermentors. ACU will assist in estimation of agricultural residues and comparsion of data obtained at their facilities with present investigation.

An overview of the seven work packages on time is thus as follows:

WP	Name of WP	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28-30	31-33	34-36
WP 4.2.1.1	Hydrolytic bacteria	■	■										
WP 4.2.1.2	Carbon spectrum			■	■								
WP 4.2.1.3	Partial pressure of H2					■	■						
WP 4.2.2.1	Methanogen - characteriz.	■	■	■									
WP 4.2.2.2	Hydrolysates - yields and kinetics			■	■	■	■						
WP 4.2.2.3	Continuous cultures						■	■	■	■	■		
WP 4.2.2.4	Pilot scate studies	■	■	■	■	■	■	■	■	■	■	■	■
	Small scale	■	■	■	■								
	Different condition tests					■	■	■	■				
	Optimization									■	■	■	■

4.3. Gasification and FT-diesel production

4.3.1. <u>Plasma gasification</u>

The intention is to produce syngas from real waste from different categories in order to estimate total syngas production of different waste streams and the effect on the composition of the syngas, especially the amount and ratio of CO and H_2.

4.3.1.1.Gasifier construction.

A small plasma-torch gasifier will be hired or built where one 150-250 kw plasma torch will be used. It is estimated that it will take about one year to construct the gasifier with a cooling system, installation of the torch and collection system for the syngas. It is estimated that this will cost between 15 and 20 million iskr. The gasifier capacity is estimated to be able to gasify 1 ton of waste per day.

4.3.1.2. Gasification of biomass

In the second year the different biomass waste streams will be gasified and the syngas will be collected and analyzed. The gasifier will be used to gasify different MSW, industrial waste, organic waste of different kind, hazardous waste, plastic material and more. SORPA is going to increase its categorization with a new separation system that will allow easier handling of different waste categories and that will make it easier to control the feeding system for the pilot gasifier and all gasification in the future.

The experimental set-up will be based on gasification of single category of waste and also on mixing different categories to measure the influence on composition of the syngas. The waste categories will be partly the same as for the methane production. Analyzes will be done on total syngas production and energy content measured as MJ/Nm^3. Special care will be taken to keep the water content of the waste material less than 30% as the energy content of the syngas can be influenced by it as well as the energy consumption of the gasifier. Chemical analyzes will be done on the syngas to measure H_2 and CO content, percentage of water vapor, methane, sulfur and alkali compounds.

For comparison 3-4 of the chosen waste categories will be send in a container to a gasification station abroad and gasified and analyzed there for comparison of the results of the small scale production in Iceland. There are several places that can gasify the waste and it is estimated that this cost could be about 3-4 million iskr.

The gasifier will be set-up at SORPA in collaboration with ICI and ICI will be operating the gasifier in collaboration with SORPA and do necessary analysis on the syngas.

Some of the syngas produced during the second year will be used for fermentation by thermophilic bacteria characterized by UNAK. Syngas produced in year two will be tested in fermentation by UNAK in order to produce both ethanol and butanol. UNAK will first use artificial syngas in year one to test some strains for ethanol and butanol production where the ratio of CO and H_2 will be varied in order to find strains that are most suitable for our syngas production. In year two real syngas will be produced from different waste categories that can have different ratios of CO and H_2 and the strains chosen will hopefully be the best suitable ones. The best strains in year two will be used to produce 100 liters of ethanol and 100 liters of butanol from some of the syngas produced in year three.

4.3.1.3. Syngas production for FT-diesel production.

The third year will mainly be used to produce syngas for a FT-diesel production via catalytic reaction and for fermentation into ethanol and butanol. The syngas production will be optimized for FT-diesel production by striving to keep the ratio of H_2/CO as close to two as possible by controlling the input raw material, the water content and also it is a possibility to use landfill gas to put into the gasifier to control the H_2/CO ratio. Use of landfill gas as a feedstock for the gasifier could increase the production of FT-diesel and can substitute electrolytic hydrogen to increase the production of FT-diesel. For ethanol production it could be better to have the ratio close to one.

Necessary pretreatment for the raw material will be taken care of in WP3.

Milestones and target: Production of syngas from different waste streams and evaluation of compositon and quality. Also production of syngas for further processing for FT-diesel
Time schedule: Subtask 1: 1-12, subtask 2: 13-24 and subtask 3: 25-36
MM (ICI 13 mm, Sorpa 6 mm)
Participants: ICI and SORPA

4.3.2. FT-diesel production

4.3.2.1. Lab-scale catalytic experiments on syngas

In the first year the production of FT-diesel will be tested by doing lab-scale catalytic experiments on syngas where the equipment will be tested on artificial syngas and then on the syngas produced in the second year. These experiments need to be done in order to test the catalysts in a lab-scale environment and estimate how much cleaning of the syngas is needed for production. It is especially important to clean all sulfur and chlorine material from the syngas.

4.3.2.2. FT-diesel synthesis plant construction

During the second year a pilot scale FT-diesel synthesis plant will be constructed in order to produce about 10.000 liters per year. The catalysts tested in the first year will be used. The catalysts tested will be commercial catalysts based on Fe and cobalt. The temperature in the reactions will be 210-260°C and the pressure between 15 to 40 bars in the FT-diesel production. The pilot scale FT-diesel plant will be situated on the same site as the gasifier, so the syngas can be directly catalyzed from the gasifier after cleaning of syngas. If possible a M.Sc. student will operate part of the tests needed.

4.3.2.3. FT-diesel tests

The FT-diesel will be tested by cetane number, chemical analysis, and tests on machines in order to verify its quality according to standards.
ICI in collaboration with SORPA will operate the FT-diesel production and do the lab scale experiments.
Feasibility studies will be performed under WP 7.

Milestones and target: Construction of pilot plant and production of FT-diesel from syngas Evaluation of the FT-diesel.
Time schedule: subtask 1: 1-12, subtask 2: 13-24 and subtask 3 , 25-36
MM (ICI 8 mm, SORPA 3 mm)
Participants: ICI and SORPA

An overview of the six work packages on time is as follows:

WP	Name of WP	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28-30	31-33	34-36
WP 4.3.1	Plasma gasification	■	■	■	■	■	■	■	■	■	■	■	■
WP 4.3.1.1	Gasifier construction	■	■	■	■								
WP 4.3.1.2	Gasification of biomass					■	■	■	■				
WP 4.3.1.3	Syngas production									■	■	■	■
WP 4.3.2	FT-diesel production	■	■	■	■	■	■	■	■	■	■	■	■
WP 4.3.2.1	Lab-scale catalytic experiments	■	■	■	■								
WP 4.3.2.2	Plant construction					■	■	■	■				
WP 4.3.2.3	FT-diesel production - lab scale									■	■	■	■

WP 5: Calculation of the amount of various biofuel types that can be produced in Iceland

Based on the results obtained in WP2, the experimental WPs and related projects the amount of biofuels that can be produced from potentially suitable biomass in Iceland will be calculated. The results will be compared to newest fuel forecast of National Energy Authority of Iceland and potential share of biofuels of future fuel consumption will be predicted. Further, the saving in greenhouse gas emissions will be estimated.

Calculations and optimizaton of fuel production from gasification and syngas production will be made from different kind of raw material. This part will be performed by ICI.

Mil**estones and targets:** To estimate the amount of biofuels that can be obtained from potentially suitable biomass in Iceland.**Time schedule:** Months 16 - 33

MM: 3 (Mannvit 2 mm; ICI 1 mm).

Performed by: Mannvit and ICI

WP 6: Conceptual design

The production processes for selected biofuels with regard to the results obtained in WP5 will be conceptually designed with regards to Icelandic conditions. Even though the production processes for first generation biofuels are relatively well known and established, they must be adapted to specific conditions, such as possible utilization of geothermal steam. Production of second generation biofuels, such as bioethanol and biohydrogen from lignocellulosic raw materials, HDRD from acyltriglycerides and BTL fuels from syngas/bio-oil obtained by gasification/pyrolysis of biomass are more complicated and in some cases not fully developed. As reliable conceptual designs as possible are essential for the feasibility study to be performed in WP7.

M**ilestones and targets:** Conceptual design of the production processes for selected biofuels with regards to Icelandic conditions.
Time schedule: Months 16 - 33
MM: 8 mm
Performed by: Mannvit

WP 7: Feasibility study

The objective is to carry out a detailed feasibility study for the production of selected biofuels in Iceland (see WP6) based on the results obtained in previous WPs of the project. The deliverance will be a comprehensive report which can be used as a base for business planning.

Feasibility study of fuel production from syngas made from gasification of waste material and biomass will be done based on results from ongoing project as well as this project. The economical factors concerning the gasification process will be estimated from real results from syngas experiments and compared to literature values. The feasibility of producing FT-diesel and ethanol will be considered. Ethanol and butanol production will also be estimated using thermophilic bacteria from UNAK. The use of electrolytic hydrogen and/or landfill gas to increase production of fuels from syngas will also be considered.

Feasibility of producing methanol, methane or hydrogen from syngas as an alternative to FT-diesel and ethanol production will be analyzed.

Milestones and targets: To obtain a detailed feasibility study for the production of biofuels in Iceland.

Time schedule: Months 20 - 36

MM: 12 (Mannvit 8 mm and ICI 4 mm)
Performed by: Mannvit and ICI

WP 8: Coordination and Manangement

See below.

WP 9: Presentation

All partners in the project will participate in the presentation of the project. One workshop will be held in the end of the first year where all partners will present their sub-project. This workshop will be open for public and will be advertised. During the third year (30 months) of the project a symposium will be held where the main outcome of the project will be presented. Well known specialists (both Icelandic and internation) will be invited as speakers to cover all the main focus areas within the project.

The aim is to publish relevant scientific data in international journals. The aim is to publish at least four scientific articles from the biohydrogen and biomethane projects in which the UA has the main responsible.

A homepage will be established by all partners but the University of Akureyri will be responsible. The main aim is to establish a cluster of interested partners on biofuel production in Iceland. All interested partners in Iceland will be invited to present their field of research at this homepage. Valuable links to other international web sites will be made available as well as detailed information of the BioFuel project applied for.

M**ilestones and targets:** To present the project both nationally and internationally. To build up a homepage and form a cluster within partners interested in the field of biofuels.
Time schedule: Months 1-36
MM: 11

Performed by: All partners. UA has 6 mm, others one each

An overview of all the work packages in time scale is thus as follows.

Progress and milestones

WP 1	Raw material	■	■										
WP 2	Types of biofuel		■	■									
WP 3	Pretreatment		■	■									
WP 4.1	BioEthanol	■	■	■	■	■	■	■	■	■	■	■	■
WP 4.2	BioH2 & CH4	■	■	■	■	■	■	■	■	■	■	■	■
WP 4.3	Gasification	■	■	■	■	■	■	■	■	■	■	■	■
WP 5	Calculations						■	■	■	■	■	■	
WP 6	Conceptional design						■	■	■	■	■	■	
WP 7	Feasability study							■	■	■	■	■	■
WP 8	Management	■	■	■	■	■	■	■	■	■	■	■	■
WP 9	Pesentation				■						■		

Deliverables

The following milestones are put forward in the project:

After 6 months:

- WP 1) Estimation and prediction of the amounts of different raw material available for production of biofuels in Iceland, and peaks of production during the year – a status report ready
- WP 2) A detailed projection of the types of biofuels that can be produced in Iceland – a status report ready.
- WP 4.1. Screening fo four to five thermophilic strains that are good candidates for metabolic engineering.
- WP 4.2) All strains that belong to the strain collection of UA have been tested concerning hydrogen production rates and carbon utilization spectrum
- WP 4.2) All methanogenic strains that belong to the strain collection of UA have been tested concerning methane production rates and phylogeny

After 12 months:

- WP 1) Estimation and prediction of the amounts of different raw material available for production of biofuels in Iceland, and peaks of production during the year – Final report ready
- WP 2) A detailed projection of the types of biofuels that can be produced in Iceland – Final report ready
- WP 3) Proposition of suitable pretreatment methods for different types of biomass based on the experimental results and economic factors.WP 4.2. Information concerning metabolism and physiology of selected strains obtained.
- WP 4.2) All strains that belong to the strain collection of UA have been tested carbon utilization spectrum
- WP 4.2) Preliminary studies on yields and rates of hydrogen and metane production in hydrolysate experiments from various types of biomass

- WP 4.2) Charcterization and physiological studies on methanogenic bacteria have been completed as well as kinetic experiments on methane production rates.
- WP 4.2. Test system for small scale methane production has been build
- WP 4.3) Construction of a pilot scale gasifier with a cooling system plus installation of the torch and the collection system for the syngas is finalized
- WP 4.3) Production of FT-diesel has be tested in lab-scale catalytic experiments on syngas where the equipment has been tested on artificial syngas and then on the syngas produced in the second year.
- WP 9) A home page of biofuel cluster in Iceland has been opened.
- WP 9) A workshop on biofuel cluster in Iceland has been performed

After 18 months:

- WP 4.1) Identification of genes encoding key metabolic enzymes, accordingly, construction of deduced metabolic network of relevant cells, design of experiments involving genetic manipulation.
- WP 4.2) Physiological experiments on the partial pressure of hydrogen on selected hydrogen producing strains have been completed. Two scientific articles submitted for publication.
- WP 4.2) Studies on yields and rates of hydrogen and metane production in hydrolysate experiments from various types of biomass finalized.

After 24 months:

- WP 4.1) Creation of deletion/insertion modules.
- WP 4.2) Effects of substrate concentrations on hydrogen production have been completed.
- WP 4.2) More than 60 experiments to test different conditions of methane production have been finalized.
- WP 4.3) Different waste streams have been gasified and the syngas collected and analyzed. Different types of biomass (MSW, industrial waste, organic waste of different kind, hazardous waste, plastic material etc) will be used. SORPA has introduced a new separation system for different waste categories.
- WP 4.3) FT-diesel synthesis plant has been constructed that can produce 10.000 liters per year.
- WP 5) Rough estimates of the amount of biofuels that can be obtained from potentially suitable biomass in Iceland has been obtained
- WP 6) Conceptual design of the production processes for selected biofuels with regards to Icelandic conditions – a status report is ready
- WP 9) A home page of biofuel cluster in Iceland has been fully established.

After 30 months:

- WP 4.1) Isolation of transformants exhibiting improved ethanol production.
- WP 4.2) Hydrolysate experiments on various lignocellulosic material with cocultures of hydrogen and methane producing bacteria completed. Two scientific articles submitted for publications.

After 33 months:

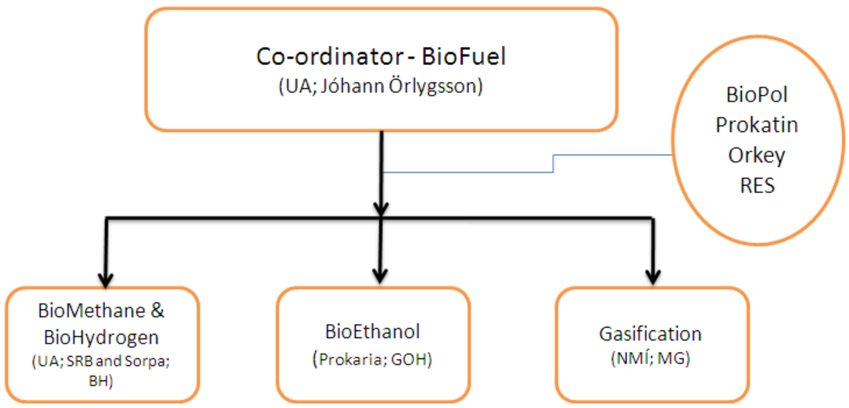
- WP 5.1) Estimation of the amounts of different biofuels that can be obtained from potentially suitable biomass in Iceland- final report is ready
- WP 6.1) Conceptional designs for biodiesel, bioethanol, biohydrogen and biomethane production processes- a final report is ready
- WP 9) A conference on biofuel production – potential in Iceland has been held.

After 36 months (end of project):

- WP 4.1) Detailed information about metabolic pathways, from degradation of polysaccharides to production of ethanol.
- WP 4.2) Selected strains on specific biomass in two stage hydrolysis and methanogenic reactors are completed. All experimental data completed.
- WP 4.2) Pilot scale methane production experiments with selected methanogenic strains isolated in earlier wp have been performed. Experience of using geothermal heatings system for the pilot scale reactors have been obtained.
- WP 4.3) Syngas production has been produced for FT-diesel production from different waste streams.
- WP 4.3) The FT-diesel has been produced in lab-scale and has been tested cetane number, chemical analysis, and tests on machines in order to verify its quality according to standards.
- WP 7.1) A detailed feasibility study for the production of biodiesel, bioethanol, biohydrogen and biomethane in Iceland – final report is ready

Coordination and management

The project coordinator will be Professor Jóhann Örlygsson (UA). He will coordinate all subprojects and be responsible for all deliverances to the Innovation Fond concerning the progress of the project. Four other coordinators will be in the project. Guðmundur Óli Hreggviðsson (Matis-Prokaria) will be responsible for the experimental part in the BioEthanol. Ásgeir Ívarsson (Mannvit) will be responsible for WP 1-3, and WP 5-7. Steinar Rafn Beck (UNAK) will be responsible for the BioHydrogen and BioMethane experimental part together with Bjarni Hjarðar (SORPA). Magnús Guðmundsson (ICI) will be responsible for the plasma gasification of biomass.



Applicants have contacted several companies and academic organizations concerning interest within the research field applied for. Among them are the biotechnological companies Prokatin in Reykjavík and BioPol in Skagaströnd, the biomass company Orkey in Akureyri and RES, The school of Renewable Sciences. All are very interested in participating within the cluster that will be set up in the project. The affiliates and web pages of the support companies are:

RES | THE SCHOOL for RENEWABLE ENERGY SCIENCE

www.res.is

BioPol www.biopol.is

ORKEY www is not available

prokatín www.prokatin.is

In the beginning of the project a start up meeting will be required to coordinate the various work that is planned in the project. Three other types of meetings will be held in the project. A cluster meeting will be held once a year where participants and other partners who are interested in biofulel research will meet and discuss. In the first cluster meeting the coordinator will present the home page that will be established in the project and offer participation of others interested partners. The third type of meetings are the project meeting where all project leaders will be present and the overall procedure of the project is the main agenda. This will be held two times a year.
Finally, each sub-coordinator will have two meetings every year with all participating partners in their project (sub-project meeting). The time schedule of meetings is thus as follows:

Meetings	**1**	**4**	**7**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**
Start up meeting	X											
Cluster meeting			X				X				X	
Project meeting		X		X		X		X		X		X
Sub-project meeting	X		X		X		X		X		X	

One of the aim of all participants in this application is to build up a cluster where all active members of this application will be participating. The project coordinator will be responsible for builing up a home page and has already applied for web domain (biofuel.is) for this purpose. One of the main aims of this “BioFuel cluster” apart from conventional meetings is to present the data obtained in the project to the public. Therefore, applicants will obligate themselves to held one workshop and one conference during the project period. Both events will be open to public.

Time schedule: Months 1 - 36
MM: 6 mm
Performed by: UA

Connections between partners and to others

Most of the participants of the project have a ongoing research cooperation. UA and Mannvit signed a five year agreement of co-operation in 2007 in “Energy-biotechnology” The main objective was to strengthen the co-operation between the partners in research and technological advances in the field of energy biotechnology. This involves defining new research projects. Unak and Mannvit have participated together with Prokaria in the project “BioEthanol” sponsored by the Innovation fond from 2006 and 2008. This project continued on a more “production basis” with UA and Mannvit again supported by the Innovation Fond (2008 – 2010). The UA and Mannvit have together with the biotechnological company Prokatin participated in two main projects on thermophilic chemolithotrophic bacteria. Firstly, on the project “Protein from Hydrogen” where the main aim was to use thermophilic bacteria to oxidize hydrogen and produce single cell proteins. Secondly, the project “Utilization of sulfur oxidizing bacteria for bioremediation” was started in 2007. Here the main aim is to utilize sulfur oxidizing bacteria to grow on hydrogen, hydrogen sulfide and carbon dioxide with the main emphasis on utilization of gases from geothermal power plants. The UA focused mostly on the bioprospecting and physiology of the microorganisms involved. Prokatin is operating a unique research facility at Nesjavellir power plant for research on biotechnological applications using geothermal gas. Today, Prokatin is taking a step further and is constructing a ISK 100 M pilot plant facility at the Hellisheiði power plant in cooperation with Reykjavik Energy and Mannvit engineering which has responsibility for the design, scale up as well as technical advice. The coordinator has been in a close cooperation with foreign research groups in previous and ongoing projects. In the project BioHydrogen (2003 – 2007) sponsored by the Nordic Energy Research a close cooperation has been with a research group from The Technical University of Tampere in Finland (TUT). One student at that time (Steinar Rafn Beck) was in Finland for six months in 2006 and two students from UA stayed in Tampere for two months in 2007. Dr. Perttu Koskinen (Ph.D student) stayed for three months at UA in the summer 2006. This ongoing cooperation has been very fruitful and e.g. resulted in four joint publications between UA and TUT.

Mannvit has vast experience in supervising and designing various processes regarding both chemical and biological processes. The company, based on three well established engineering companies VGK, Hönnun and Rafhönnun, has been involved in various projects concerned with bio fuels.

Mannvit has recently conducted feasibility studies on biodiesel production from canola, waste vegetable oil (WVO) and animal fat (AF) in Iceland and has been the leading consultant for Orkey. In the last year Mannvit has established a small scale research facility in its facilities in Akureyri. This research facility has mainly been used for research on biodiesel production from WVO and AF. In 2008 Mannvit obtained a grant from Akureyri’s

Regional Growth Agreement for bio diesel production from WVO and AF. The company has designed and built equipment to produce up to 50L of biodiesel in batch production, as well as a distillation system to purify the biodiesel. In February/March 2009 a student from The School for Renewable Resources (RES) graduated with her M.Sc. thesis on the potential biodiesel production from WVO and AF in Iceland. This project was supervised by Ásgeir Ívarsson at Mannvit. The Akureyri Regional Growth Agreement has supported this project again for further R&D work. With minor changes, the same equipment can be used, for pilot scale biomass pretreatment, and ethanol fermentation processes. Other projects excluding projects which are in co-operation with UNAK and Prokatin which have been adressed, are polyol projects in China and South-Africa. Mannvit designed, and supervised the setup of polyol plants in these countries. Polyols are value added chemical produced from e.g. glucose through a chemical process various other feedstock can be used in this process, such as glycerol.

Mannvit also has experience in methane collection design and purification, and various methane production systems. The methane collection and rinsing system at Álfsnes (Sorpa, MSW landfill) was supervised and designed by employees of Mannvit.

ICI (innovation Center of Iceland (ICI, formerly ICETEC) did a small scale production experiments on biodiesel that finished in 2006. The experiments were made on fish, animal fat and waste vegetable oil. The project was successful but did not continue.

In 1999 ICI (former ICETEC (Technolgical Instute of Iceland)) made a study on production of methanol from CO_2 and electrolytic hydrogen but was considered too expensive
Now there is an ongoing feasibility study to produce methanol and DME from CO_2 from aluminum plants and other large scale industries and electrolytic hydrogen. This project is the collaboration between ICI, Hekla, Orkustofnun, Mitsubishi and the ministry of industry. Mitsubishi has the technology including the catalyst technique to produce methanol in this way. DME is produced with a catalyst from the methanol.

Another project that ICI is involved is in development of new catalysts for production of methanol done in collaboration with CRI and Efnaferli hf.

A project on the gasification technology and feasibility of using gasification to treat MSW and organic waste from agriculture is now ongoing. The project is mainly a desktop study that delivers data and information on available raw material, analysis of the raw material, description and status of the technology and economical feasibility of production of different types of fuel. The main interest is for FT-diesel and ethanol production but hydrogen, methanol and DME could be produced as well.

Other energy related projects have been in relation to hydrogen production and use in collaboration with .e.g. Islensk Nyorka.

SORPA is the only company in Iceland that produces methane and has made several studies on methane production in collaboration with Mannvit. The daughter company Metan hf takes care of distribution and wholesale. The available methane that Metan produces can serve 4500 to 5500 cars (Halldórsson og Einarsson, 2001, Halldórsson etal 2006). SORPA could easily increase the production of methane if the market would expand. The possible new raw material is about 30 thousand tons of organic matter that could produce methane under controlled conditions. This organic material in high conversion methane production could typically produce about 15 million Nm^3 which is equivalent to 15 thousand tons of gasoline.

The Agricultural University (AUI) has done several studies on methane production from organic material from agriculture and they have a small scale facility to produce methane from diverse material. They have also done several studies on available material from agriculture that could be used for fuel or energy production.
There are also ongoing studies on available land for cultivation of energy plants as well as research on the cultivation of energy plants that could grow in Icelandic climate.

Cost and finance

Lykiltölur fjárstreymis	1. ár	2. ár	3. ár	Samtals
Tekjur	0	0	0	0
Kostnaður	62.981	62.981	62.981	188.943
Eigið framlag	30.481	30.481	30.481	91.443
Sótt til annarra	2.500	2.500	2.500	7.500
Sótt til TÞS	30.000	30.000	30.000	90.000
Mismunur	0	0	0	0

University of Akureyri: For the University of Akureyri, one man month (mm) for a specialist, one mm is 429 ISK, On that amount operational expenses are 35% (chemicals, equipment and other laboratory cost is used) and then 20% overhead. Similarly, cost for student is 328 ISK and the same rules concerning operational cost and overhead are used. Thus, mm for a specialist at Unak costs 695 ISK and for student 531 ISK. For coordination the cost for one mm. is 659 TKR, but no operational costs are included only salaries and overhead. Own financing is from on going research projects runned by UA sponsored by NER and by the research fond of the University of Akureyri. This research money is garantied for the next 18 months.

Mannvit: The cost of one man month (MM) of an engineering specialist at Mannvit is 939 thousand ISK. The cost divides into salaries cost (722 thousand ISK), operational expenses that are 10% of the salaries cost (72 thousand ISK) and overhead that is 20% of the salaries cost (144 thousand ISK).

Prokaria: The cost of one man month (MM) is 460 ISK for a specialist and 360 ISK for an assistant. Overhead is 100% and the operational cost 35%.

ICI, ACU and SORPA: Two specialists (III) will work within the project. The salary cost is based on the rate from Research Centre of Iceland (Rannis), which is 5773 iskr.

Overhead cost for ICI is 90% of the salary cost but for the others it is 20%.
Consumables are because of chemical analysis and the operation of lab and pilot scale production.
Travel: cost because of meetings and visit to Gasification Company
Service: specialized measurement of chemical contents, analysis of syngas abroad.
Contributions of the partners are both the overhead cost and also part of the operational cost.

The cost of methane pilot plant will be around 4-5 million ISK and the cost of gasifier about 15- 20 million ISK and FT-diesel pilot plant about 5 million ISK. The total investment cost will therefore be 25-30 million ISK. Also the lab scale facility at ICI will cost at least 1 million ISK/year.

Other cost in the project. Travelling cost is because of meetings and visit of ICI to companies that use plasma gasification to gain knowledge of the state of the art. The highest travelling cost is on UNAK because of the coordination responsibilities. Additionally, relatively high cost is on UNAK on external services because of workshops, conference and to make a home page for the biofuel cluster.

4 Business plan

Market analysis summary

The National Energy Authority (Orkustofnun) forecasted last year that the overall consumption of fossil fuels in Iceland for vehicles, machinery, ships and boats will be about 490 thousand tons this year (2009). According to the forecast the consumption is divided as follows:

- 121 thousand tons of diesel and 169 thousand tons of gasoline by vehicles.
- 62 thousand tons of diesel by machinery.
- 150 thousand tons of marine gas oil and heavy fuel oil in total by fishing vessels.

Due to the ongoing financial crisis the fuel consumption by vehicles and machinery will be lower than forecasted, possibly 20-25%.

Currently the share of renewable fuels in the overall fuel consumption in Iceland is minute. Only 0,13% of the fuel consumed by vehicles is renewable or about 200 tons annually on oil basis. No machinery, boats or ships in Iceland are running on renewable fuel.

In 2008 a total number of 111 vehicles (passenger cars, trucks and buses) in Reykjavik and surrounding communities were running on methane from the landfill site in Alfsnes. Additionally, small amounts of bioethanol and biodiesel are being imported, as B5 and E85 respectively. Biodiesel blend is sold commercially; however, the ethanol was only used by a small fleet of three flexi-fuel cars in 2008. Additionally few cars are running on electricity and hydrogen in Reykjavik.

Market segmentation
The production will be sold by retail oil companies. The proposed production of biofuels, as a result of the project, is:

Proposed annual production of biofuels in tons.

Year	Biodiesel		Bioethanol	Biohydrogen	Biomethane	Biopropane	FT diesel	As fossil oil equivalent
	FAME	HDRD						
2015	10.600	0	9.000	130	1.100	0	0	16.500
2020	10.800	12.900	50.500	300	1.600	800	40.000	97.100
2025	10.900	16.900	48.200	270	1.900	1.000	52.000	112.200
2030	10.900	16.900	51.000	310	2.300	1.000	52.000	114.500

The share of the produced biofuels of the total fuel consumption by vehicles, machinery and fishing vessels will be 3% in 2015 and will have increased to 23% in 2030 calculated on oil basis as shown in the table below:

The share of produced biofuels of the forecasted fossil fuel use, renewable fuel use and total energy use of vehicles, machinery and fishing vessels on energy basis.

Year	Share of biofuels of forecasted		
	Fossil fuel use	Renewable fuel use	Total energy use
2015	3%	229%	3%
2020	16%	381%	19%
2025	25%	233%	23%
2030	25%	198%	23%

Industry analysis

Today there are only two producers of renewable fuel in Iceland, i.e. Sorpa/Metan which upgrades landfill gas and Skeljungur (Shell) operates hydrogen station where hydrogen is produced on site by electrolysis.

Target market segment strategy

Market needs

There is an interest, especially governmental, in increasing the share of renewable fuels in the overall fuel consumption in Iceland. Compared to most European countries, Iceland lies far behind. The EU target for the share of renewable fuels for vehicles is 20% (on energy basis) of the total fuel consumption in 2020.

Implementation of liquid biofuels, such as biodiesel (FAME and HDRD), FT diesel and alcohols (biomethanol and bioethanol), is simpler than of most other potential renewable fuels as it does not demand new technology concerning engines, fuel tanks, filling systems or distribution systems. Most diesel vehicles and machinery, although depending on manufacture's warranties, can run on blends of fossil diesel and biodiesel containing at least 20% FAME by volume. Most ship and boat engines can run on pure FAME. As HDRD and FT diesel have very similar chemical and physical properties as fossil diesel fuel it can be use unblended on all diesel engines. Alcohols can be used on conventional gasoline engines as up to 10-15% mixture in gasoline by volume, depending on warranties and regulations. Mixtures that contains alcohols in higher concentrations, such as 22% (E22 and M22) and 85% (E85 and M85) can be used on flexi-fuel vehicles.

Implementation of gaseous fuels, such as hydrogen, methane and propane, is more complicated, but the use of these fuels is expected to increase in the future, especially by larger vehicles such as trucks.

Market trends and growth

The use of renewable fuel for vehicles has been slowly increasing in recent years. According to the prediction of National Energy Authority, the share of renewable fuel for vehicles will reach 9,2%, which equals about 23.800 tons on oil basis, in 2020 and 22,3%, which equals about 50.800 tons on oil basis, in 2030. The consumption of renewable fuel by machinery and fishing vessels is predicted to increase considerably much slower.

SWOT analysis

Strengths

- Production of biofuels in a sustainable way.
- Strong technical collaboration.
- Participation in other R&D projects that are linked to this project.

Weaknesses

- Limited access to risk capital.
- Uncertainty in development of 2nd generation biofuels.

Opportunities

- Increased interests in renewable fuel in forthcoming years.
- Albeit current financial crisis, the price of crude fossil oil is predicted to rise markedly in forthcoming years, reaching at least 70 USD/bbl in 2020.
- Utilization of other types of feedstock such algae and bacteria.

Threats

- Import of “cheap” biofuels.
- Other alternative fuels.
- Possible chances in taxation policy (unlikely).

Objectives

The objective is to develop and/or establish following:

- Process for production of biodiesel (FAME and HDRD) from acyltriglycerides rich biomass.
- Process for production of ethanol and hydrogen by fermentation of lignocellulosic biomass.
- Process for increased yield of biomethane (up to 20%) from conventional anaerobic digestion of biomass.
- Process for production of bioethanol and FT diesel by gasification of carbon rich biomass.

Establishment of these production processed will provide vehicles, machinery and fishing vessel in Iceland with 23% of the required energy.

See attached Excel file for analysis of investment costs, financing and annual turnover.

Production of biodiesel (FAME and HDRD) and biopropane from acyltriglycerides rich biomass

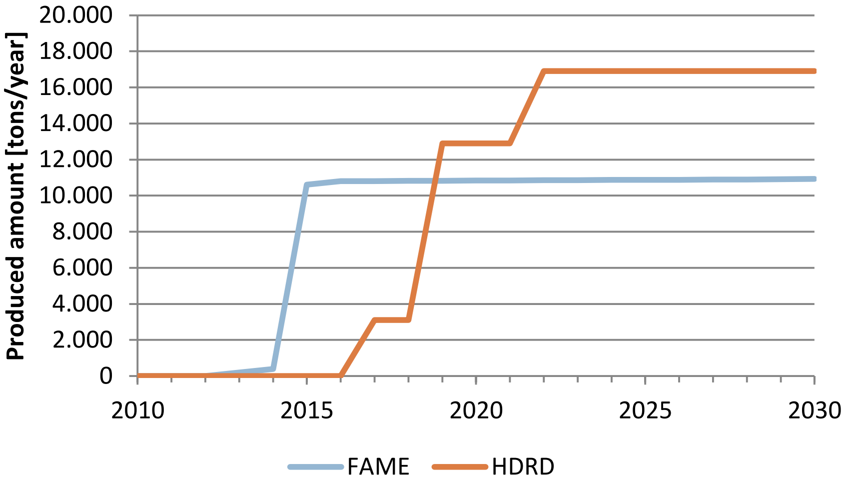
Several companies plan to begin production of FAME in next few months from acyltriglycerides rich waste, such as waste vegetable oil and fat cut-offs from meat processing plants. There are also plans on utilizing various types of organic waste from fishing-related industries.

From 2013 the collection of waste vegetable oil will continuously improve and other types of waste, as mentioned above, will be utilized. In 2015 use of vegetable oil from cultivation of rape plants (or other suitable oil plants) will result in production of 10 thousand tons of FAME. Glycerol will be refined from 2014.

From 2017 production of HDRD form a acyltriglycerides rich waste and vegetable oil from cultivation will begin. The production will reach 16-17 thousand tons in 2022. For each ton of HDRD produced about 62 kg of biopropane are formed. In 2022 the yielded amount of biopropane will be about 1 thousand tons.

As clarified in **"Target market segment strategy", FAME and HDRD can be used on diesel engines in vehicles, machinery and fishing vessels. Biopropane can be blended into methane and used on methane vehicles.**

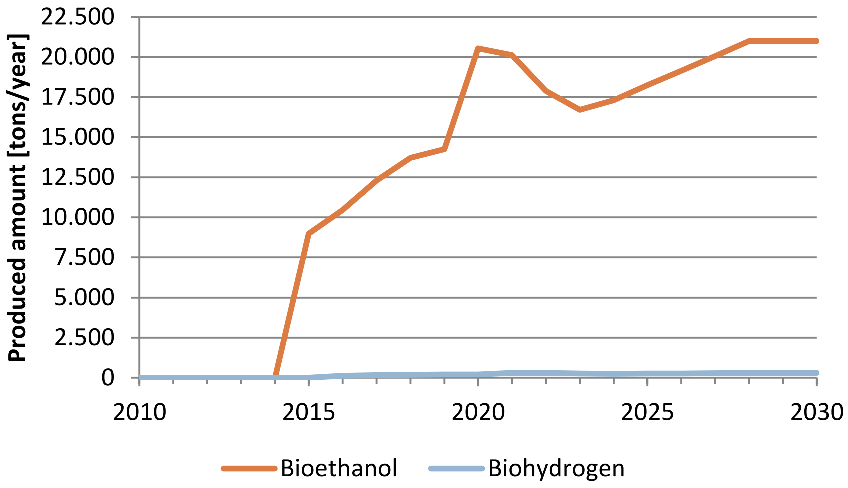
Production of FAME and HDRD from acyltriglycerides rich biomass from 2010 to 2030.



Process for production of bioethanol and biohydrogen by fermentation of lignocellulosic biomass

A pilot plant will be operated from 2012 for three years (a part of the project "Líf-Etanól"). If the pilot production will be successful, a full scale plant will be built yielding annually 8.970 tons of ethanol in 2015, 20.540 tons of ethanol 2020 and 18.240 tons of ethanol 2025. Further, the plant will yield up to 300 tons annually of hydrogen and undetermined amount of various by-products which potentially will be sold to farmers and chemical manufactures.

Production of bioethanol and biohydrogen from lignocellulosic biomass.

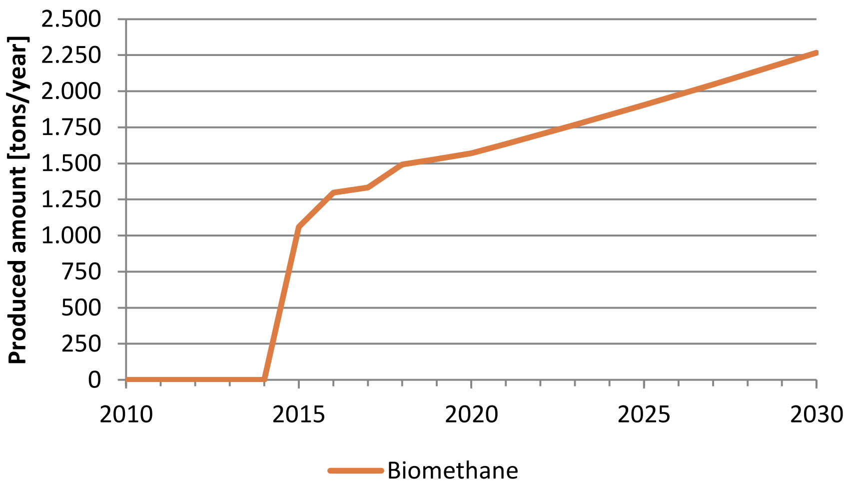


As clarified in "**Target market segment strategy", bioethanol can be blended into gasoline and sold as e.g. E5, E10, E22 or E85. The use of E22 and E85 will demand flexi-fuel vehicles. It is expected that the trend in vehicle manufacturing will be toward that all considerably large share of cars marketed in Europe will be flexi-fuel within 5-10 years. It's also noteworthy that flexi-fuels vehicles that can operate on high-methanol mixtures can also operate on ethanol. Hydrogen will be used on hydrogen powered vehicles or ships.**

Process for increased yield of biomethane (up to 20%) from conventional anaerobic digestion of biomass

As a result of the project a methane bacteria, capable of increasing the methane yield of conventional anaerobic digestion systems up to 20% will be obtained. The increased production of methane is estimated to be 1.060 tons in 2015, 1.570 tons in 2020 and 1.910 tons in 2025.

Production of biomethane by increased yield .

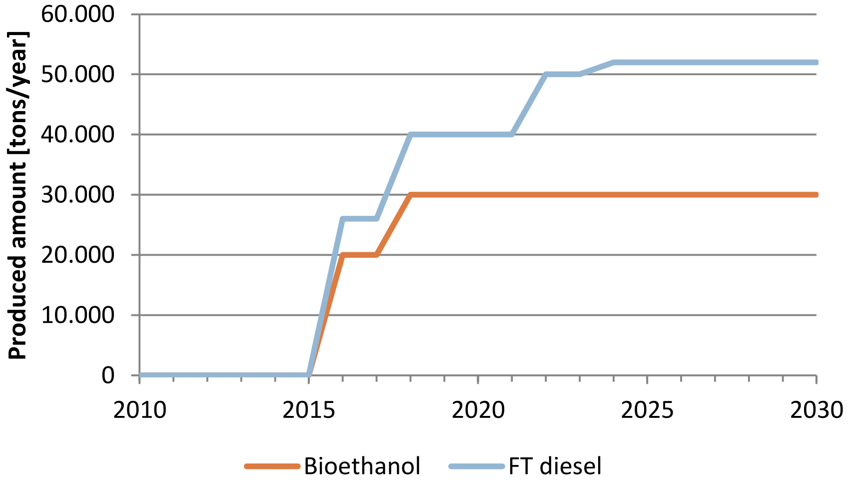


As clarified in "**Target market segment strategy" biomethane will be used on methane vehicles, especially larger trucks.**

Process for production of bioethanol and FT diesel by gasification of carbon rich biomass

As a result of the project production of bioethanol and FT diesel by gasification of organic waste and energy crop will begin in 2016. The processes will yield 20 thousand tons of bioethanol and 26 thousand tons of FT diesel in 2016. The production will be increased stepwise to reach 30 thousand tons of bioethanol in 2018 and 52 thousand tons of FT diesel in 2024.

Production of bioethanol and FT diesel by gasification from 2010 to 2030.



Bioethanol will be used as described above. As clarified in "**Target market segment strategy" FT diesel can be used on diesel engines in vehicles, machinery and fishing vessels.**

Opportunities

The main opportunities are:

- Improved competitive position of Icelandic industry due to savings in foreign currency due to decreased import of fossil fuel and even also because of possible export of by-products. Overall, the biofuel production will increase the total turnover in Icelandic industry.
- The situation of Iceland towards EU directives concerning use of renewable fuel in transportation and landfilling of organic waste.
- Establishment and development of entrepreneur companies. Production of biofuels in Iceland will open opportunities for innovative companies in development of production processes, catalyst, biotechnological methods etc.
- New business opportunities for farmers by utilization of agricultural land that is not used today.
- As emissions of green house gases will decrease considerably by the use of biofuels instead of fossil fuels, will increase Iceland's flexibility when it comes to implementation and development of energy demanding industry with regards to the future international protocols (after 2012, when the Kyoto protocol ends).
- Increased energy security due to domestic fuel production.

The project will also increase, in general, the knowledge of biotechnology and conventional chemical engineering in Iceland.

Value

Turnover (revenues), NPV:	**81.601** m.kr.
Profit/loss before taxes, NPV:	**36.311**m.kr.
Value for users:	**13.313** m.kr.

Method

The project is a cooperation between two universities, the largest engineering company in Iceland, the largest company handling waste in Iceland, a biotechnological company as well as the innovation center organization. Future scenario
Over the last few years, biofuels have gained worldwide interests for their potential to reduce green house gas emissions, improve energy security, and enhance rural development. At the same time, reports on the environmental and societal costs associated with biofuel production have stirred up a storm of controversy. Nevertheless, there remain several silver linings – in terms of on-going developments in feedstock selection and production technologies – that may yet allow biofuels to fulfill their promise as a viable source of renewable energy.

Biomass could play a large and important role in a future sustainable energy supply as a source for modern energy carriers as electricity and transportation fuels. Especially the introduction of biofuels is attractive because it is one of very few options for low CO_2 emission transport systems against (eventually) reasonable costs, and because it decreases or spreads fuel dependency. Of the many conceivable biofuels, fuels from lignocellulose biomass are the most attractive, because they allow for a higher fuel yield per hectare, have better projected economics, their feedstock requires less additional energy for growth and harvest and can be grown under many different circumstances in contrast to annual crops that require good-quality land.

At the end of the 3 year project time there will be report on the feasibility study of bioethanol, biodiesel, biomethane, biohydrogen and FT diesel. If the results are positive the project will turn to interested investors. With interest of investors it is intended to scale up to pilot scale where each process can be further developed. It is not foreseen that there will be a fully developed product until the year 2015, except perhaps for biomethane. Bioethanol and biodiesel can be used directly on vechicles (E5, E10, B5 and B10) whereas methane and hydrogen needs further internal structure to be rationalized. The future prospect for Iceland is to be able to meet the EU regulation and use up to 5% biofuels mix in the fossil fuels. The aim is to be able to produce at least up to these demands if not more. Development in renewable energy is not certain in this time. Some car manufacturers have announced that they will manufacture twin-cars which will even be on the market next year. Thus it can be expected that their market share will increase in the next years and the use of fossil fuels will decrease.

Kostnaðaryfirlit SAMÞYKKTUR KOSTNAÐUR **(Allar upphæðir í þús.kr.)**

Kostnaðarliðir ↓	Verkefnis-stjóri	1. ums.	2. ums.	3. ums.	4. ums.	5. ums.	6. ums.	Samtals 1. árið:	Áætlun síðari ára	
Upphafsstafir:	JÖ	HA	Mannvit	Mat-Pro	NMÍ	Sorpa	Land. HA	2009/10	2010/11	2011/12
Laun og launatengd gjöld:	2.196	6.510	8.664	3.000	6.530	4.875	1.950	33.725	33.725	33.725
Rekstrarvörur, efni o.fl.:		2.280	866	2.050	300	5.000	150	10.646	10.646	10.646
Aðkeypt þjónusta:	1.700				200	1.000		2.900	2.900	2.900
Ferðir og fundir:	600		200	200	200	200	150	1.550	1.550	1.550
Afskriftir áhalda og og tækja:								0	0	0
Samrekstur og aðstaða:	440	1.752	1.733	3.000	5.870	975	390	14.160	14.160	14.160
A: Viðurkenndur kostn.:	4.936	10.542	11.463	8.250	13.100	12.050	2.640	62.981	62.981	62.981
Fjármögnunarliðir ↓	Verk.stj.	1. ums.	2. ums.	2. ums.	4. ums.	5. ums.	6. ums.	2009/10	Áætlun f. síðari ár	
Eigið framlag (aðstaða, laun):	2.536	2.342	5.763	4.150	6.300	8.050	1.340	30.481	30.481	30.481
Greiðslur til verkefnisins:								0		
Framlag annarra, þá hverra: NER		2.000						2.000	2.000	200
Framlag annarra, þá hverra: Rann.sj. HA		500						500	500	500
B: Fjármögnun samtals:	2.536	4.842	5.763	4.150	6.300	8.050	1.340	32.981	32.981	32.981
C: Sótt um til TÞS:	2.400	5.700	5.700	4.100	6.800	4.000	1.300	30.000	30.000	30.000
Hlutfall (C/A):	48,6%	54%	50%	50%	52%	33%	49%	48%	48%	48%
Mannafli:	Mann-mán.	Mann-mán.	Mann-mán.				Mann-mán.	Alls	Mann-mán.	Mann-mán.
Sérfræðingar:	4		12	1	10	8	3	38	38	38
Aðstoðarfólk:		6		7				13	13	13
Annað:		12						12	12	12
Alls:	4	18	12	8	10	8	3	63	63	63