Nordic Embassies, Denmark, Finland, Iceland, Norway, Sweden,
Nordic Council of Ministres, Realizing the Bioeconomy in the Baltic Sea Region – Workshop II,
Berlin,18th to 19th September, 2014

# The role of biorefineries in making the transition towards the bioeconomy

presented by:

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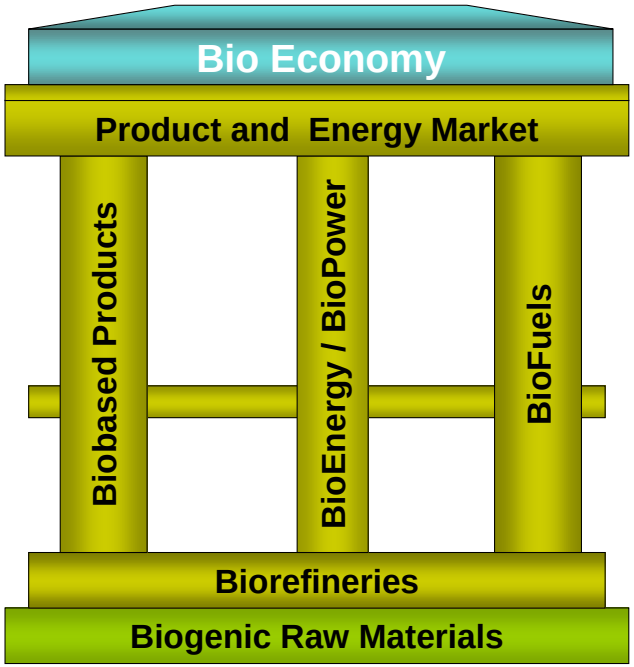
# The role of biorefineries in making the transition towards the bioeconomy

**Content:**

The role of biorefineries in making the transition towards the bioeconomy

**Biorefining is the transfer of the efficiency and logic of fossil-based chemistry and substantial converting industry as well as the production of energy onto the biomass industry.**

📖 Kamm B, Gruber, P.R., Kamm, M.;
Biorefineries, Industrial Processes and Products, Ullmann's Encyclopedia of Industrial Chemistry, 7th ed., WILEY-VCH, 2007, 2011




3-pillar model of a future biobased economy

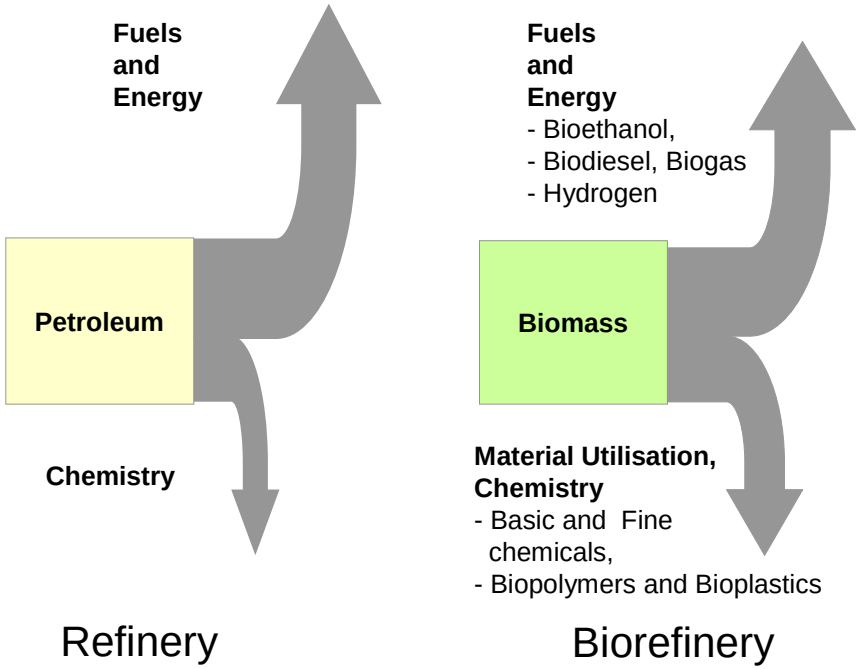
**It is absolutely necessary to develop solutions in three sustainable and biobased sectors:**

- **Biopower/Bioenergy (electricity and heat)**
- **Biofuels (transportation fuels)**
- **Biobased Products (chemicals/materials)**

**in context of a biobased economy.**


📖 European Commission (2012), Innovating for Sustainable Growth: A Bioeconomy for Europe, SWD 11 final, Brussels

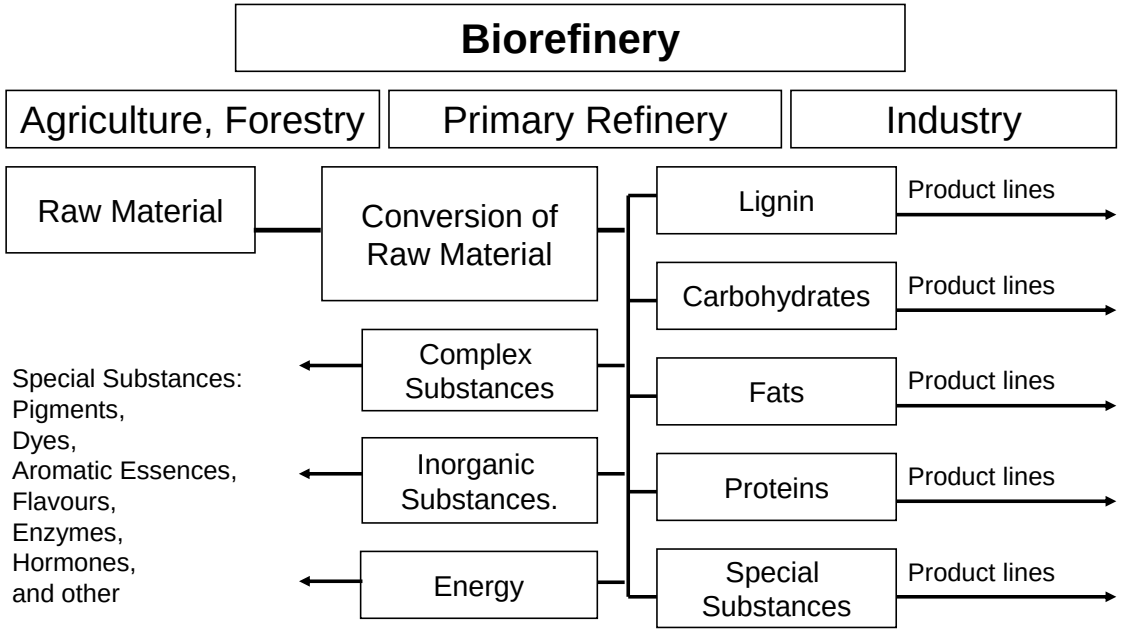
📖 "Biorefineries Roadmap" as part of the German Federal Government action plans for the material and energetic utilization of renewable raw materials, The Federal Government Germany, 2012.




**Biobased industrial products can only compete with petro-chemically based products if the raw materials are optimally exploited and a variety of value-creating chains are developed and established.**

**→ development of substance-converting basic product systems and multi product systems, especially biorefineries.**

**Biorefineries combine necessary technologies between biological raw materials and the industrial intermediates and final products.**




**After providing code-defined basic substances (via fractionation) it is necessary to develop industrially relevant Product Family Trees.**



📖 Kamm, B.; Kamm, M.; Principles of Biorefineries. *Appl. Microbiol, Biotechnol., (AMB)*, **64** (2004) 137-145

**Currently four Biorefinery Systems are forced within research, development and practice:**

- **The Whole Crop Biorefinery (WC-BR)**

  **raw material: cereals, maize etc..**
- **The Green Biorefinery (G-BR)**

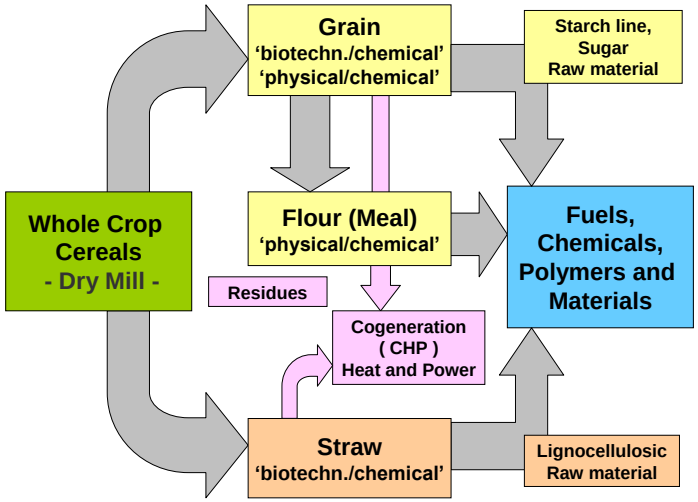
  **raw material: 'nature-wet' biomasses, green grass, lucerne, clover, immature cereals a.o..**
- **The Lignocellulose Feedstock Biorefinery (LCF-BR)**

  **raw material: 'nature-dry' biomasses, wood, straw, corn stover, cellulose-containing biomass and waste.**
- **The Two-Platform Concept**

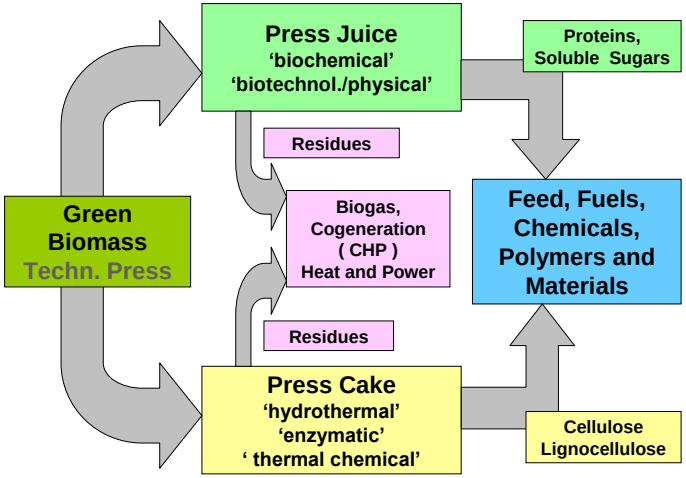
  **production of syngas and/or sugar as platforms for biobased products and fuels.**

📖 Kamm, B.; Kamm, M.; Principles of Biorefineries. *Appl. Microbiol, Biotechnol., (AMB)*, **64** (2004) 137-145

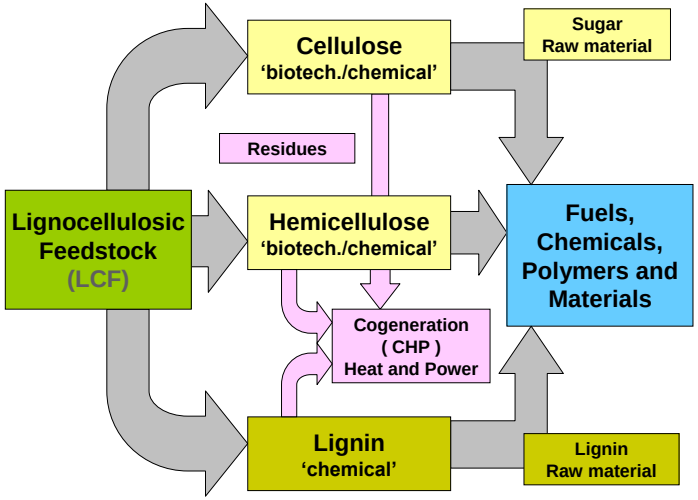
## Whole Crop Biorefinery (dry mill)



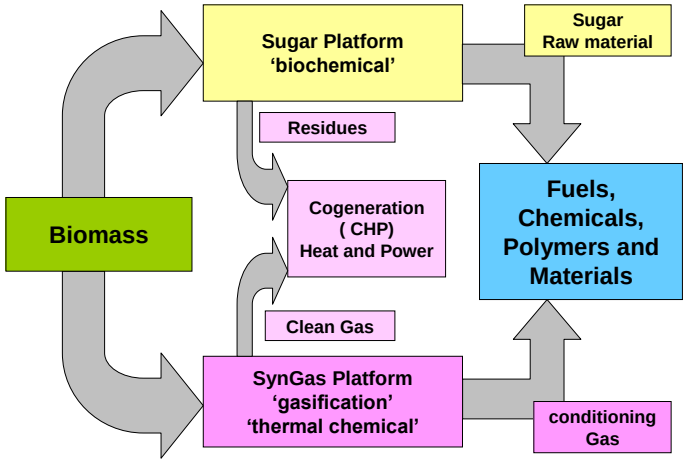

## Green Biorefinery




## Lignocellulosic Feedstock Biorefinery



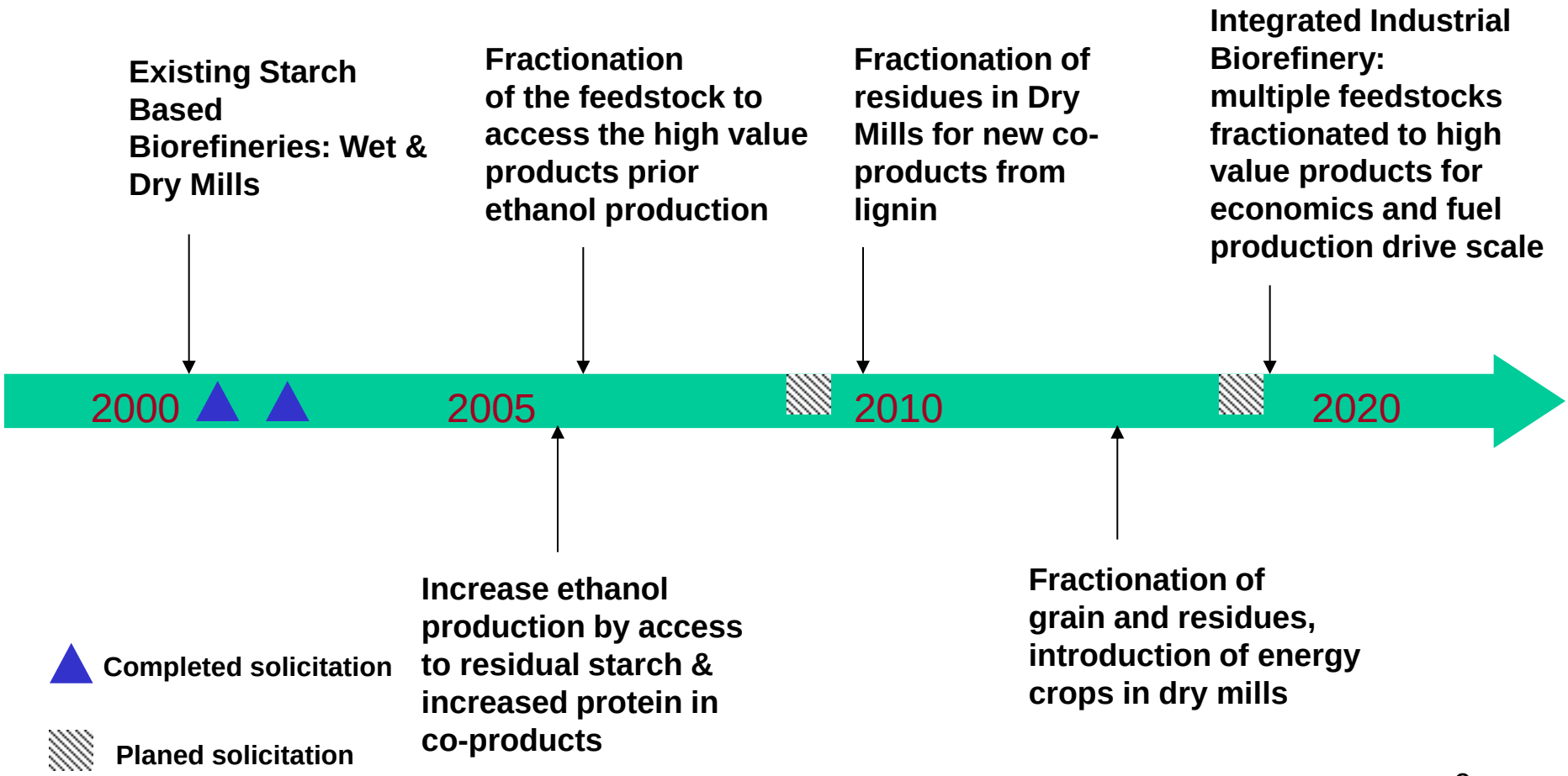

## The Two-Platform Concept






📖Kamm, B.; Gruber, P.R.; Kamm, M.; Biorefineries, Industrial Processes and Products, Wiley-VCH, 2006, 2010

# Integrated Biorefinery -Technical Objectives & Future Solicitations






Kaempf, D.; 1st International Biorefinery Workshop, Washington D.C.; July 20-21, 2005

## Existing biorefineries, Phase I, (Selection)

| Plants | Raw material | Country |
|---|---|---|
| Sugar and Ethanol production | Sugar cane | Brazilia<br>27 billion litre/a |
| Corn hydrolysis and Ethanol Production | Maize corn | U.S.A.<br>54 billion litre/a |
| Corn hydrolysis/ Sugar and Ethanol production | Cereal Corn<br>Sugar beet | EU<br>4 billion litre/a |



📖 Assessment Technical Status, 2013

## Existing biorefineries, Phase II, (Selection)

| Kind of BR | Raw material | Country |
|---|---|---|
| Corn hydrolysis & Lactic acid fermentation & PLA production | Corn (maize) | U.S.A.<br>200 kt LA/a<br>140 kt PLA/a |
| Corn hydrolysis & 1,3-Propandiol Fermentation | Corn | U.S. A.<br>45 kt PDO/a |
| Ethanol-Fermentation &Dehydration &PE Production | Sugarcane | Brazil<br>200 kt PE/a |
| LCF biorefinery Ethanol & Lignin for energy | Wheat straw | Spain<br>5,000 litre/a<br>Germany<br>1.000 tons/a |



📖 Assessment Technical Status, 2013

## Biorefineries in construction in Europe, Phase II (Selection)

| Kind of BR, Country | Raw material | Main-Products |
|---|---|---|
| Cellulosic Ethanol, U.S. | Corn waste<br>Switch Gras | Ethanol<br>*500 million gal<br>Prod: 20.000 gal |
| LCF biorefinery Research Consortium Germany | Beech wood<br>(180kg/d) | Sugars, Lignin |
| Booregard, Norway | Wood<br>(1 t/d) | Sugars, Lignin |
| Green biorefinery Industrial Consortium Austria | Grass<br>(5t/h) | Lactic acid, amino acid, Fibres, biogas |
| Green biorefinery Industrial Consortium Germany | Alfalfa/ wild mix grass<br>(30kt/a) | Proteins, Lactic acid, Animal feeds, Biogas |



📖 Technical Assessement, 2013

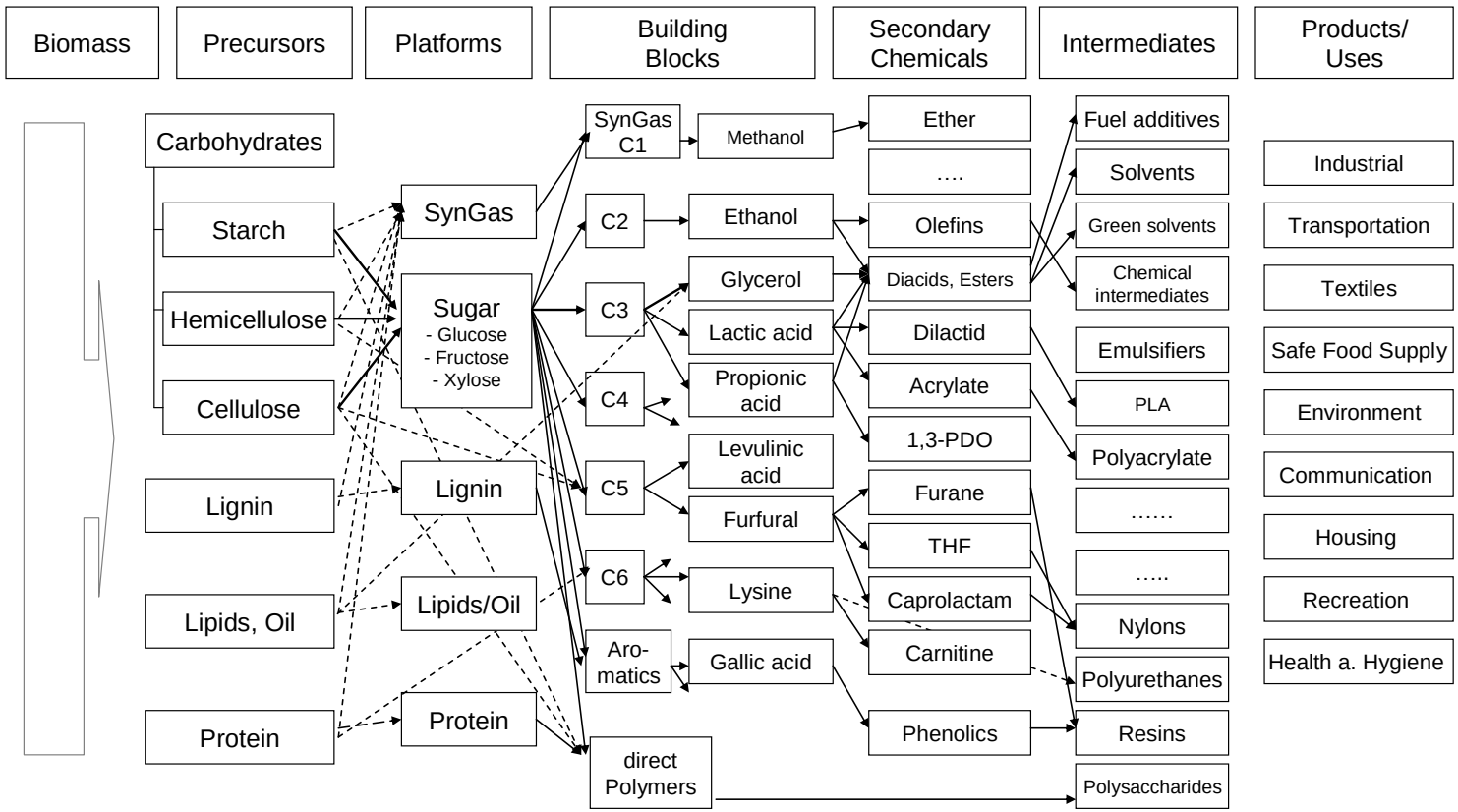
# Integrated Biorefinery Options

| | | |
|---|---|---|
| **Hydrolysis**<br>**Acids, enzymes** | **Sugars and Lignin** | **Use:**<br>**Fuels**<br>**Ethanol**<br>**Biodiesel**<br>**Hydrogen**<br>**Power**<br>**Electricity**<br>**Heat**<br>**Chemicals**<br>**Plastics**<br>**Solvents**<br>**Chemical Intermediates**<br>**Phenolics**<br>**Adhesives**<br>**Furfural**<br>**Fatty acids**<br>**Acetic Acid**<br>**Carbon black**<br>**Paints, Dyes, Pigments, Ink, Detergents etc.**<br>**Food & Feed** |
| **Gasification**<br>**High heat, low oxygen** | **Synthesis Gas** | |
| **Digestion**<br>**Bacteria** | **Bio-Gas** | |
| **Pyrolysis**<br>**Catalysis, Heat, Pressure** | **Bio-Oil** | |
| **Extraction**<br>**Mechanical, Chemical** | **Carbon-Rich Chains** | |
| **Separation**<br>**Mechanical, Chemical** | **Plant Products** | |



📖 Kaempf, D.; 1st International Biorefinery Workshop, Washington D.C.; July 20-21, 2005

# Model of biobased Flow-chart for Biomass Feedstock






🕮 Kamm, B.; Gruber, P.R.; Kamm, M.; Biorefineries, Industrial Processes and Products, Wiley-VCH, 2006, 2010

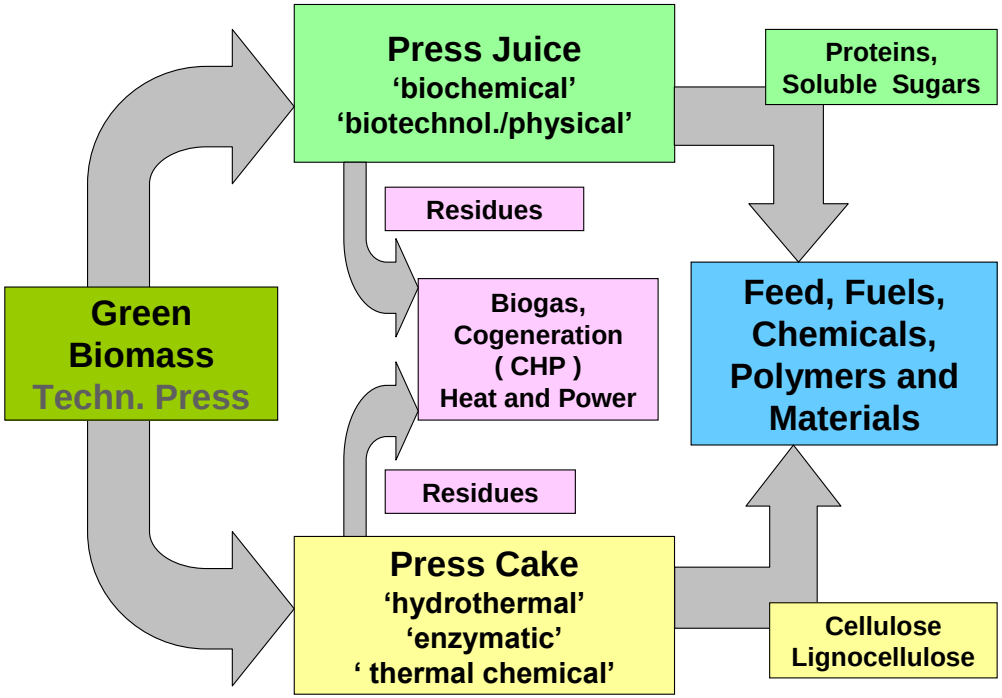
**Biorefineries present :**

- **Complex and integrated systems of sustainable technologies based on biological raw materials.**
- **Economically self-consisting enterprises and economic entities.**
- **Bearing pillars of the future biobased economics.**
- **Motors of research and development in the 21th century.**

**One fundamental task in the biorefinery topic is the development of biorefinery demonstration plants, close to Industry, agro-industry, and forest-industry.**

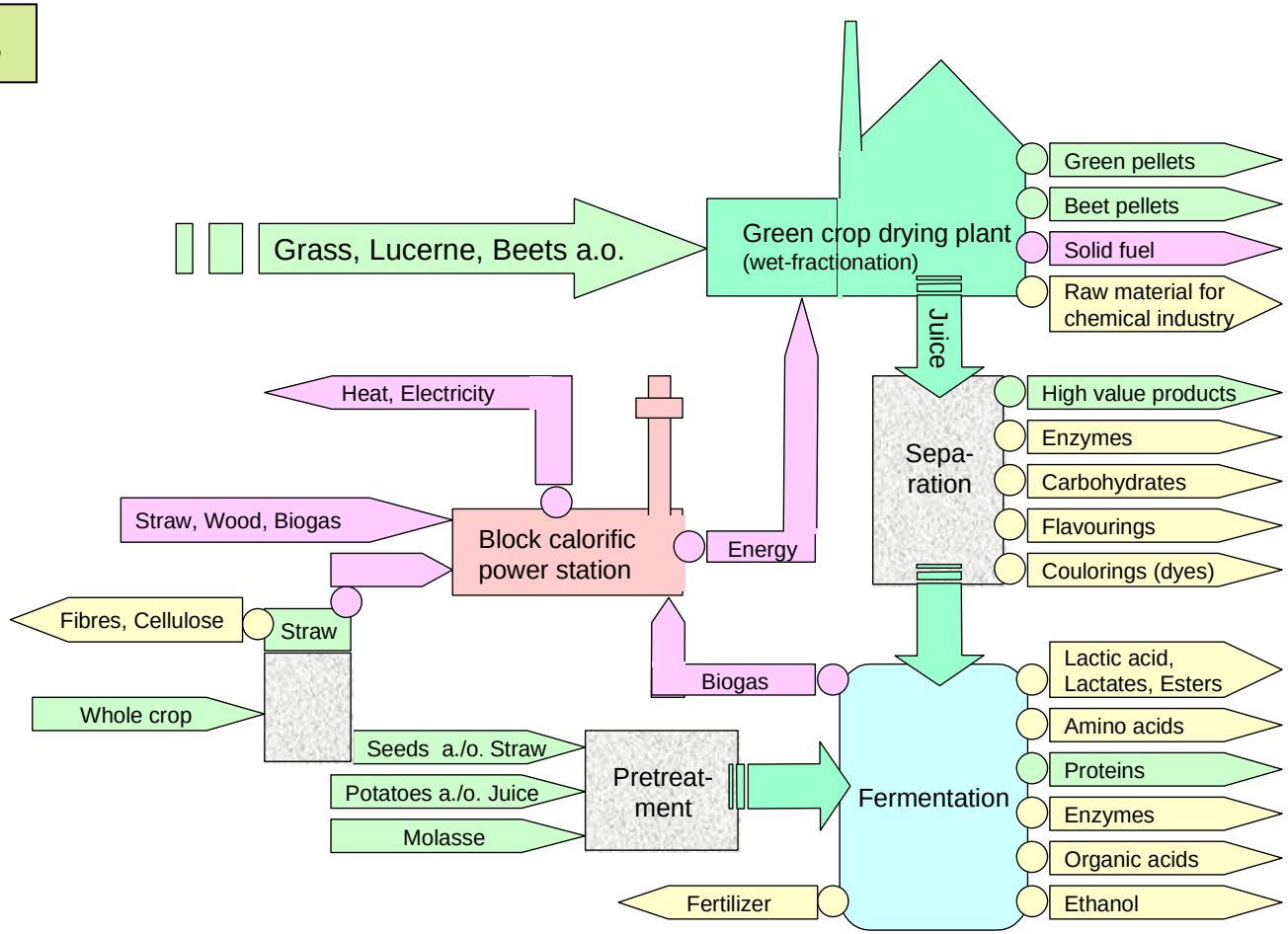
**Two example will be presented**

## Green Biorefinery



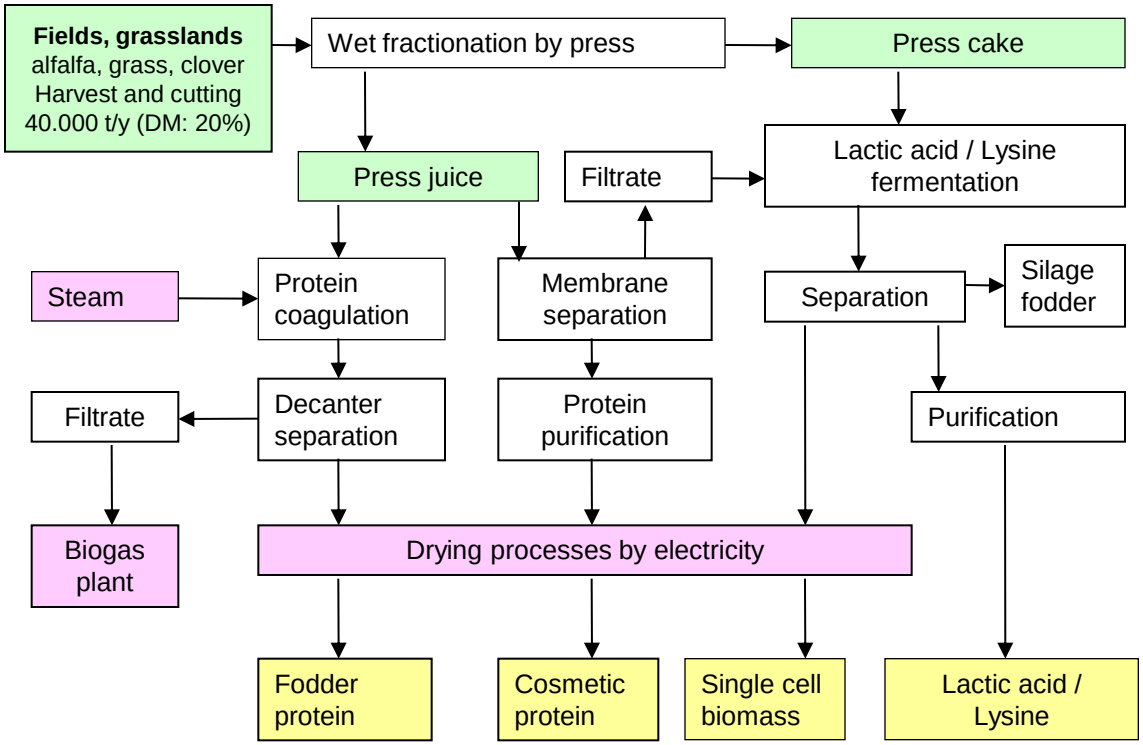

**By primary production of photosynthesis in green crops more than 20 tons of dry matter as well as 3 tons of proteins per hectare in temperate climates can be obtained per year.**

# Products




Start of construction 20014, Primary Biorefinery Selbelang‘
Tier 1: 8.000 t DM (8 mo/y); Primary products: pellet, chlorophyll, Prenacell® fibre, Lactic acid, Proteins, biogas-energy; Construction cost: 6,2 Mio EURO (Basic enginering)

Example:
Selected and simplified processes of a green biorefinery






📖 Schönicke, Kamm, CLEAN 2009 (37) 1

**Green Biorefinery** **scenario 1:** **Lactic acid**

**input:**

| | | quantity | unit |
|---|---|---|---|
| Cut green biomass (Lucerne, Clover, Grass) | DM: 20 % | 40.000 | t |
| Heat | | 2.200 | GJ |
| Electricity | | 1005 | MWh |

**output:**

| | | | |
|---|---|---|---|
| Silage fodder | DM: 40 % | 13.000 | t |
| Fodder-Protein 80 % | DM: 90 % | 400 | t |
| Cosmetic-Protein 90 % | DM: 90 % | 29 | t |
| Lactic acid 90 % | DM: 90 % | 660 | t |
| Residue to Biogas plant TS: 2 % | | 17.690 | t |
| Single cell-Biomass (as Fodder-Protein 60 %) | DM: 90 % | 33 | t |



🕮 Schönicke, Kamm, CLEAN 2009, 37 (1)

**Green Biorefinery** **scenario 2:** **Lysine**

input:

| | | quantity | unit |
|---|---|---|---|
| cut Green Biomass (Lucerne, Clover, Grass) | DM: 20 % | 40.000 | t |
| Heat | | 2200 | GJ |
| Electricity | | 500 | MWh |

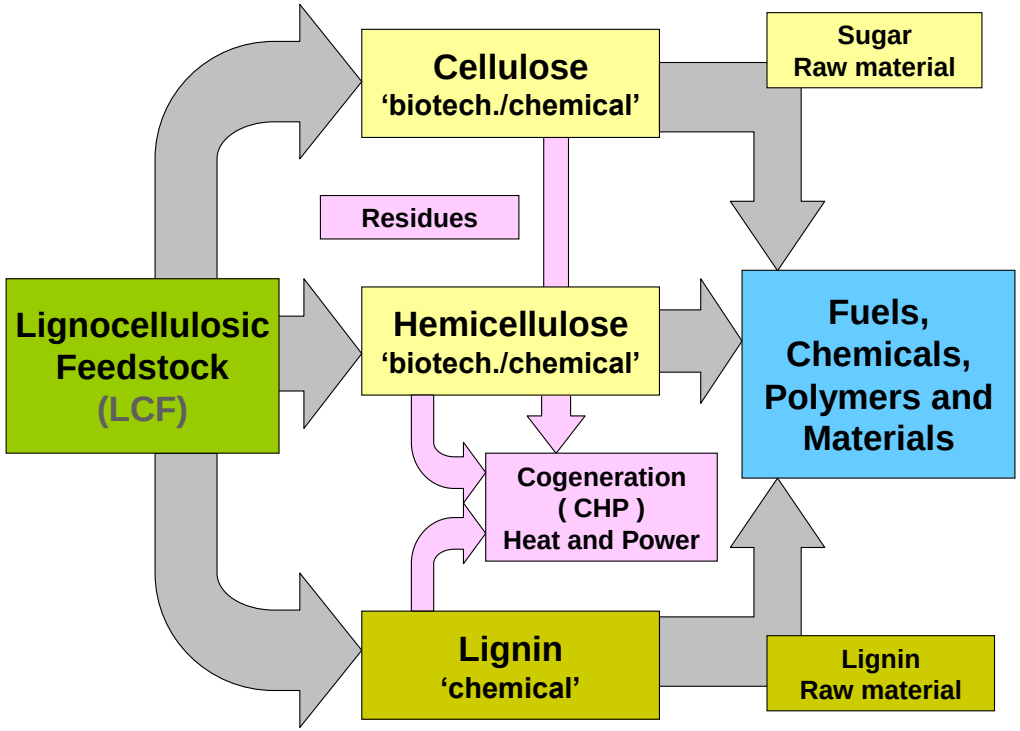
output:

| | | | |
|---|---|---|---|
| Silage fodder | DM: 40 % | 13.000 | t |
| Fodder-Protein 80 % | DM: 90 % | 400 | t |
| Cosmetic-Protein 90 % | DM: 90 % | 30 | t |
| Lysine–HCl, 50% | DM: 90 % | 620 | t |
| Residue to Biogas plant DM: 2% | | 17.770 | t |
| Single cell-Biomass (as Fodder-Protein 60 %) | DM: 90 % | 31 | t |

📖 Schönicke, Kamm, CLEAN 2009, 37 (1)

# LCF Biorefinery Demonstration Plant

**The Icelandic ethanol-oriented biorefinery based on lignocelluloses**
**Model project – Demonstration Plant – 20.000 tons lignocelluloses/year**




**General Scheme of a Lignocellulose Feedstock Biorefinery**

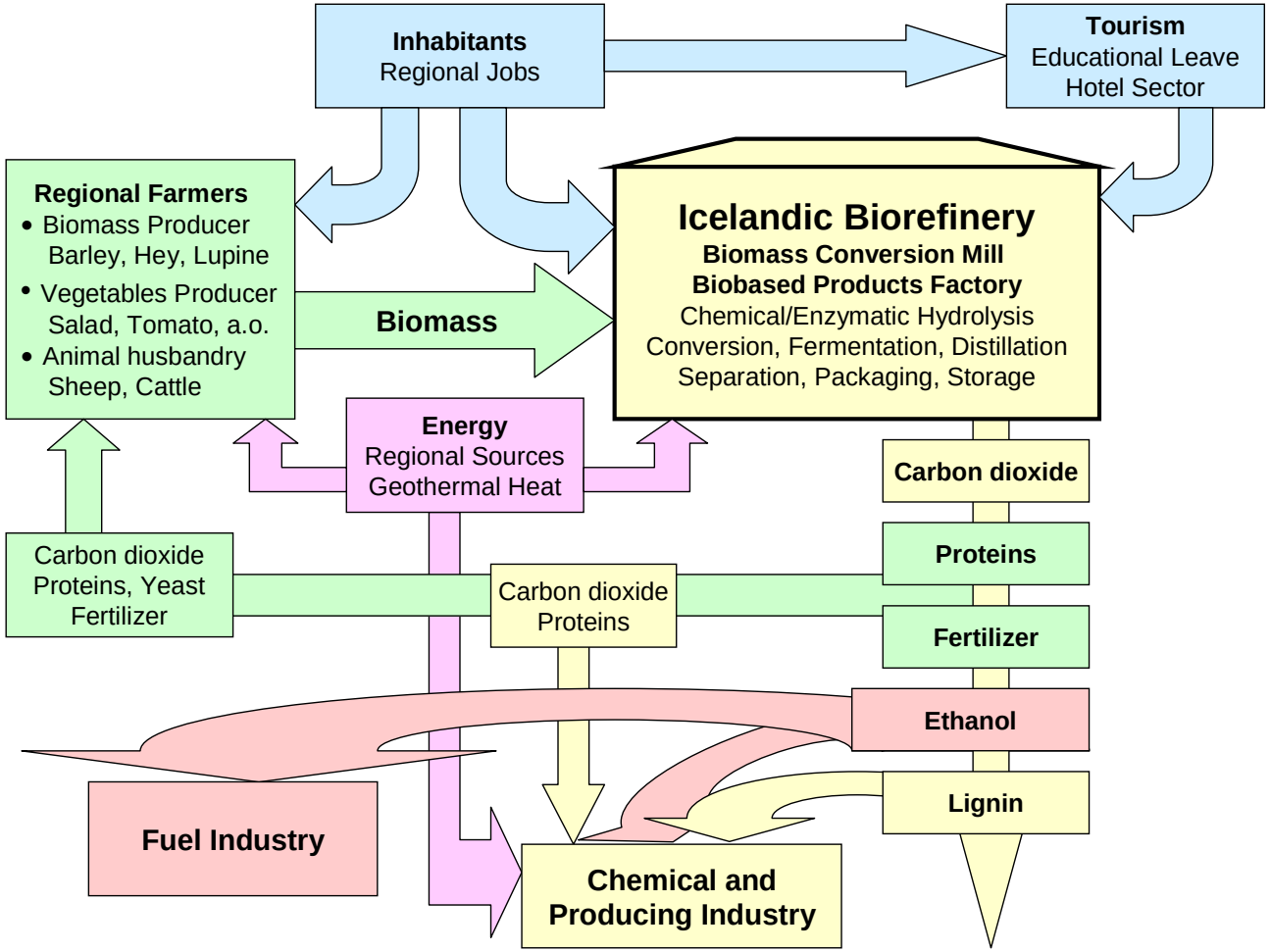
## Tab. : Sources of lignocelluloses

| No. | Source Groups | Examples |
|---|---|---|
| group 1 | **existing landscape species** | softwood, hardwood, reed (Schilf), reed grass, switch grass, dry grasses etc. |
| group 2 | **fast-growing plantations** | poplar (Pappel), willow (Weide), locust (Robinie), wood grass, eucalyptus, sudan grass |
| group 3 | **landscape conservation** | old forest, residual wood and under-wood from forestry, switch grass, dry grasses, hay, straw |
| group 4 | **process lignocelluloses** | straw, corn stover, press cake from crop drying plant, ethanol plants and oil mills, by-products from cereal mills, whole crop refineries, paper mill and pulp industry |
| group 5 | **used materials and waste** | timber (Bauholz), used wood, recovered paper, cellulosic municipal solid waste |

# Model of the Icelandic ethanol-oriented biorefinery based on lignocelluloses

**Green SeePark Mývatn**

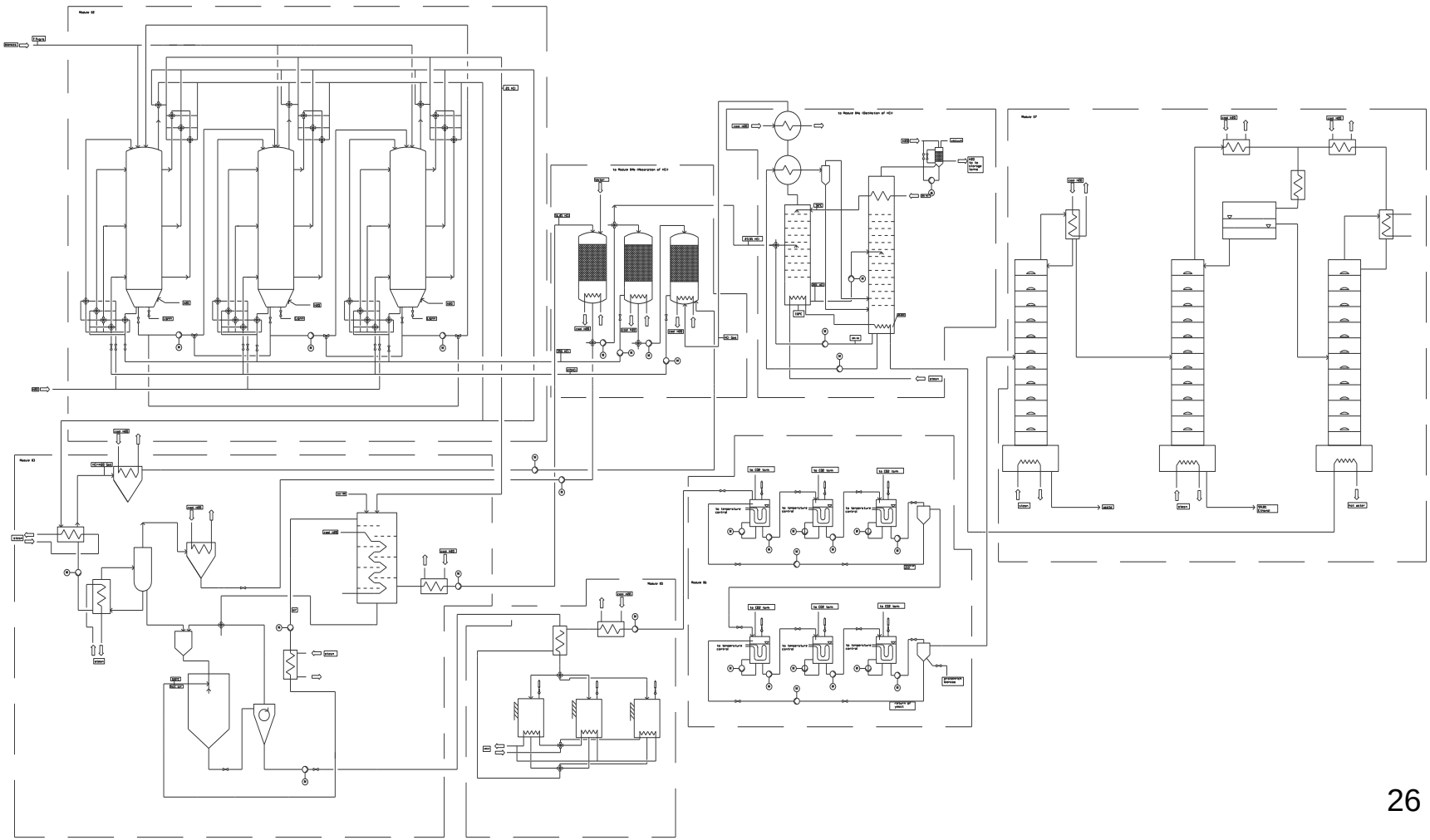
Modern Life, Working and Recovery with Nature in Northern Iceland



# The Icelandic ethanol-oriented biorefinery (demonstration plant) - corner data

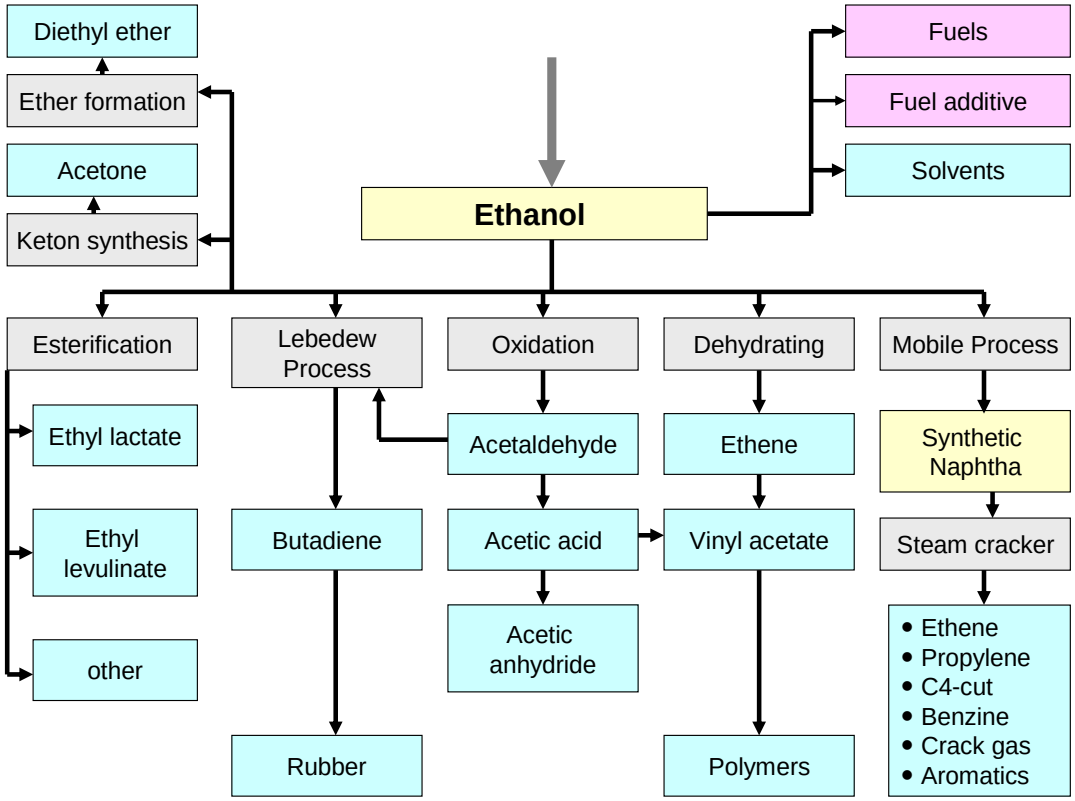
| | amount / prizes | notes |
|---|---|---|
| Raw Material | | |
| Lignocellulosic biomass (mix) | 20.000 tons/year | hey, lupine straw, barley straw |
| Main Technologies | | |
| Acid hydrolysis, Sugar fermentation | | modified “Bergius/Rheinau” process |
| Main Process Energy | | |
| Geothermic steam | 1,25 €/ton | steam: 170°C /7 bar |
| Plant basis/Location | | |
| LC-Feedstocks | | South Iceland, near Fludir |
| Main Product (Phase I) | | |
| Ethanol for E10 Fuel | 7 Mio litres/year | 0,46 €/litres |
| Operating Company | | |
| Icelandic Biomass Company | | Main Seat : Reykjavik, IS |
| Total costs | 10 Mio € | Incl. accompanying R&D |

# The Icelandic ethanol-oriented biorefinery – Main process modules



# Advantages of the production of Ethanol

**Ethanol is not only a fuel, but also a basic chemical for a lot of solvents, products and materials**



## Summary

**Regional Biorefineries are also in other regions - without geothermic energy- profitable.**

**For process energy it's possible to use:**

- **The Lignin fraction, approx. 30% in lignocelluose**

the heating value (calorific value) of Lignin lies between 13 MJ/kg and 19 MJ/kg (DM) (wood: 18 MJ/kg, heating oil: 30-35 MJ/kg).

- **Biogas Cogeneration: Heat and Power (Electricity).**

## The Icelandic Ethanol-oriented biorefinery – Summary

The Icelandic Ethanol-oriented Biorefinery (demonstration plant) can produce **7 Mio litres Ethanol/year.**

The Icelandic Ethanol-oriented LCF-Biorefinery is profitable!

**7 Mio l** Ethanol (pure) is equivalent to **70 Mio E10 petrol.**

E10 petrol is normal petrol with 10% Ethanol.

Each Icelandic Inhabitant could to refuel approx. **233 Litres E10 petrol** per year.

# The Icelandic Ethanol-oriented Biorefinery – Summary

**Why is such (small scale) Ethanol-oriented LCF-Biorefinery profitable?**

- **Research and development supported by European Commission (BESUB project) and the Icelandic Government.**
- **Iceland has a very efficient and low price non-fossil energy market (geothermic energy). Hence, energy-intensive processes (e.g. acid recovery) are so economically and environmental-friendly.**

- **Private Operating Companies, Finance and Government to act in concert.**
- **Economical biomass and product markets could be organized (without subsidy).**

## Outlook

**Several requirements to enter the phase of development of Industrial Biorefinery Technologies and Biobased Products:**

- **To increase the production of substances on the base of biogenic raw materials in the ordinary plants of production of cellulose, starch, protein, sugar and oil.**
- **To get the commitment of the chemistry, particularly the organic and technical chemistry, for the concept of biobased products and biorefinery systems.**
- **To force the combination of biological and chemical conversion of substances.**
- **To introduce and establish biorefinery demonstration plants.**

# Contact

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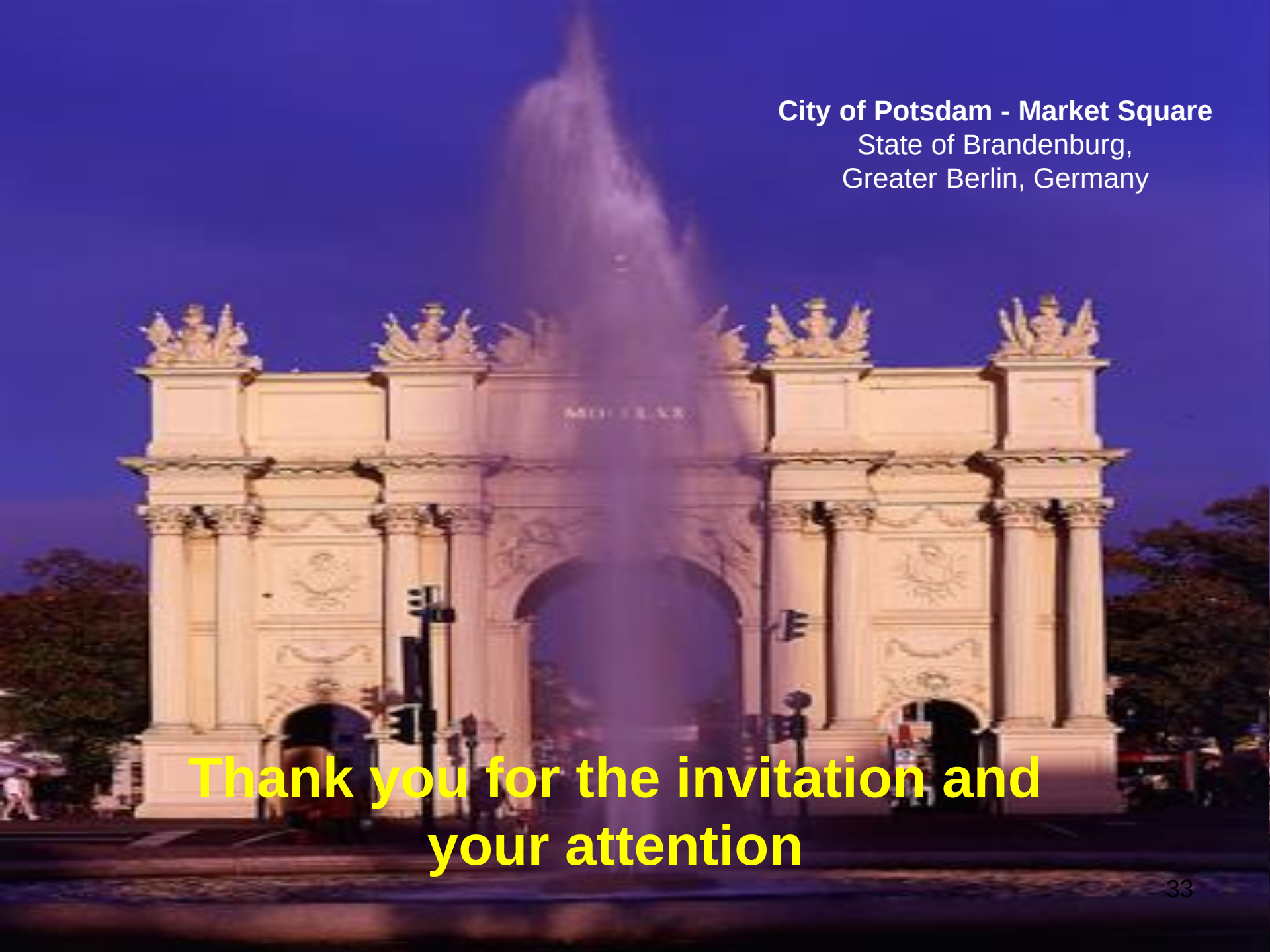
Potsdam and Teltow in the Greater Berlin, Germany



**City of Potsdam - Market Square**
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**Thank you for the invitation and your attention**