Life Cycle Assessment on Biofuel Derived from Sweet Sorghum

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Outline

- ◆Present status for LCA on Biofuel in the World
- ◆Present status for LCA on Biofuel in China
- ◆Our work for LCA on biofuel
  - ➢Development of a draft version of a Model for the ethanol production chain
  - ➢Database for the Model
  - ➢ Case study
- ◆Next step

Intruduction

LCA-based Model can be used as a fundamental tool for helping decision-makers in the biofuel development sector:

- describes in a detailed way **all** the **activities**, **materials** and **energy vectors** involved in the two main phases of the biofuel production: the **agricultural** phase and the **bio-refinery** phase, taking also into consideration the materials' **transport**.
- utilizes data which are a realistic representation of particular local situations or statistical data referring to an average configuration for a defined region.

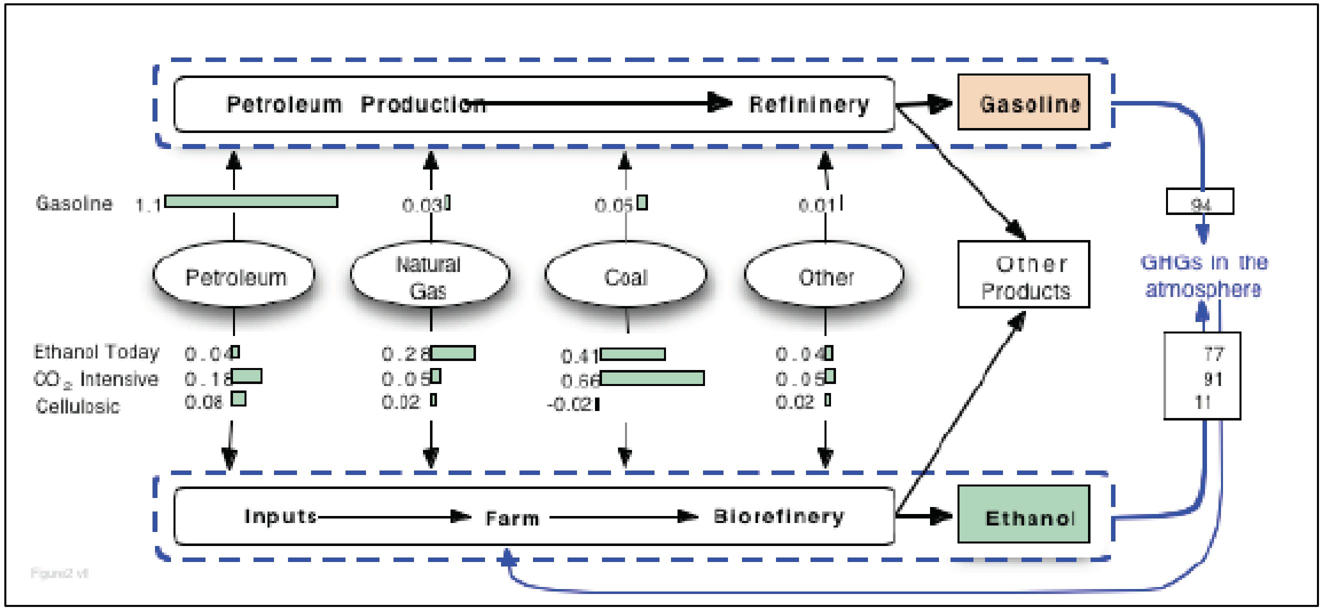
Present status in the world

Since 1995, with support primarily from the US Department of Energy's (DOE's), the GREET model has been developing at Argonne National Laboratory in US. A.

EBAMM study on ethanol from corn

- The Energy Research Group, University of California, Berkeley, developed a **Biofuel Analysis Meta-Model (EBAMM)**, which is structured to provide a relatively simple, transparent tool that can be used to compare biofuel production processes.
- EBAMM has been used to compare six published articles that illustrate the range of assumptions and data found for one biofuel, **corn-based ethanol**.

The comparison of ethanol vs. gasoline is performed taking into account the main phases of production and the related inputs.



Present status in China

- Tianjin University
  - The method of net energy analysis for bio-ethanol from corn was developed based on principles of life cycle inventory (LCI) analysis.
  - The energy ratios for dry and wet milling process were 1.25 and 1.04 respectively.
- Shanghai Jiao tong University
  - A life cycle energy assessment model of cassava-based fuel ethanol was established based on life cycle theory.

LCA on biofuel has been started in recent years in China, there is larger gap compared with other countries, such as methodololy and database etc.

Our Research

The program of the Joint Research Activity established between LAME (Energy Analysis and Modelling Laboratory, Politecnico di Torino,Italy) and CAAE includes the development of a model able to perform several kinds of analyses about biofuel production chains.

- **First phase:** develop a draft version of a Model for the **ethanol production chain**, able not only to analyse the associated material, energy and emission values, but also to find optimal solutions as far as **land utilisation** and **crop production** are concerned.
- **Second phase:** collect and critically analyse the **Chinese site specific data** on crop production for the calibration of the model.
- **Last phase:** the biofuel chain will be inserted into the more general Energy System (of a Province, a Region or the whole Country), where biofuels will compete with other fuels for fulfil the mobility demand, within particular scenarios.

Description of the biofuel chain

The aim of the work is to describe the biofuel chain as a **complete energy model system**, taking into account

- analyse the associated material, energy and emission values in agricultural and bio-refinery phases, by region and by crop
- the costs
- the amounts of pollutants

Related to all the activities involved **directly** during the farming or **indirectly** for the commodities **production**. It’s possible to include in the modelling the co-production and the emissions accounting for each phase.

Features of the Model

The main difference between this kind of approach and an usual LCA approach is the presence of an Objective Function to optimize (the minimization of total costs or the minimization of the emissions for the whole chain in order to account and compare the net energy gain for the reference year) instead of a simple comparison among energy consumptions or pollutant emissions that is generally the aim of the life cycle assessment.

Sweet Sorghum

- Chinese government insist the principle on development of biofuel--- **No food crops** as feedstock for biofuel production; **No existing arable land** for energy crops.

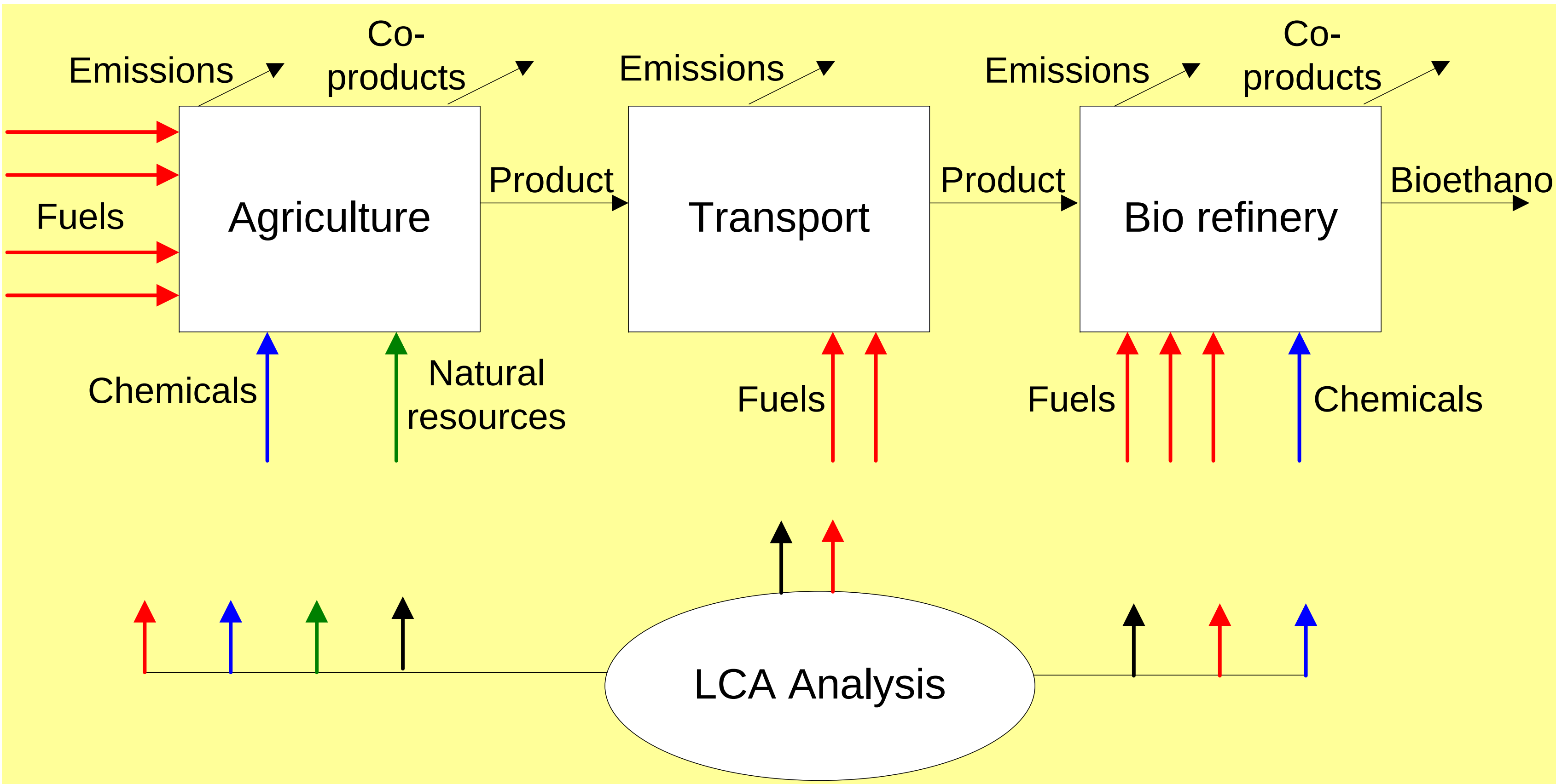
- **Sweet sorghum**, as one of the energy crops in China, has been selected as feedstock to produce bio-ethanol.
- The first bio-ethanol pilot facility taking sweet sorghum stalk as feeding has been built in Heilongjian province in 2006, with annual output capacity of 5000t(60% ethanol).

Main Area for Planting Sweet Sorghum in China

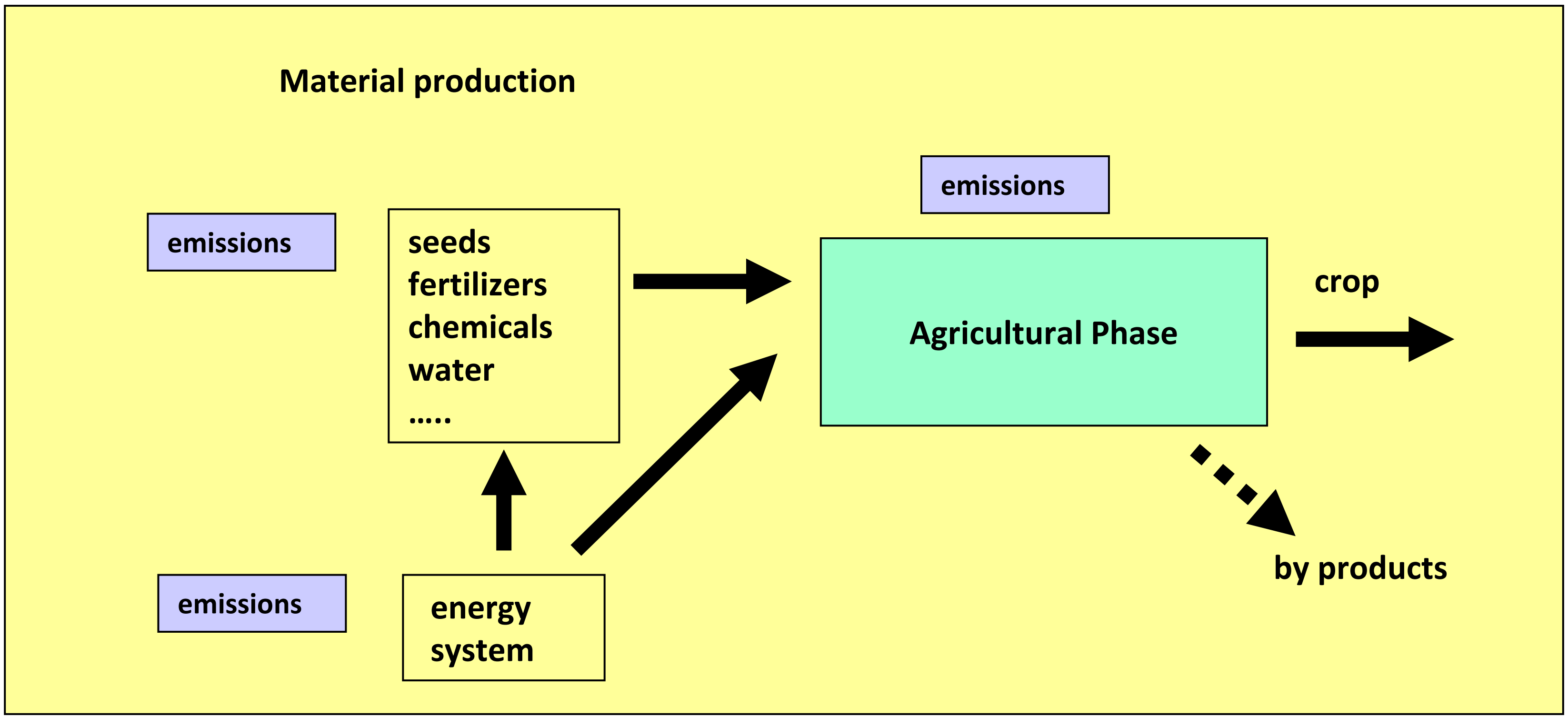
Our Research

- Developed the **sweet sorghum ethanol model**
- Selected **Chinese site specific data** from Inner mongolia wuyuan county and Heilongjian huachuan coutry
- Evaluated net energy output, emission and cost-benefit statues for two cases.

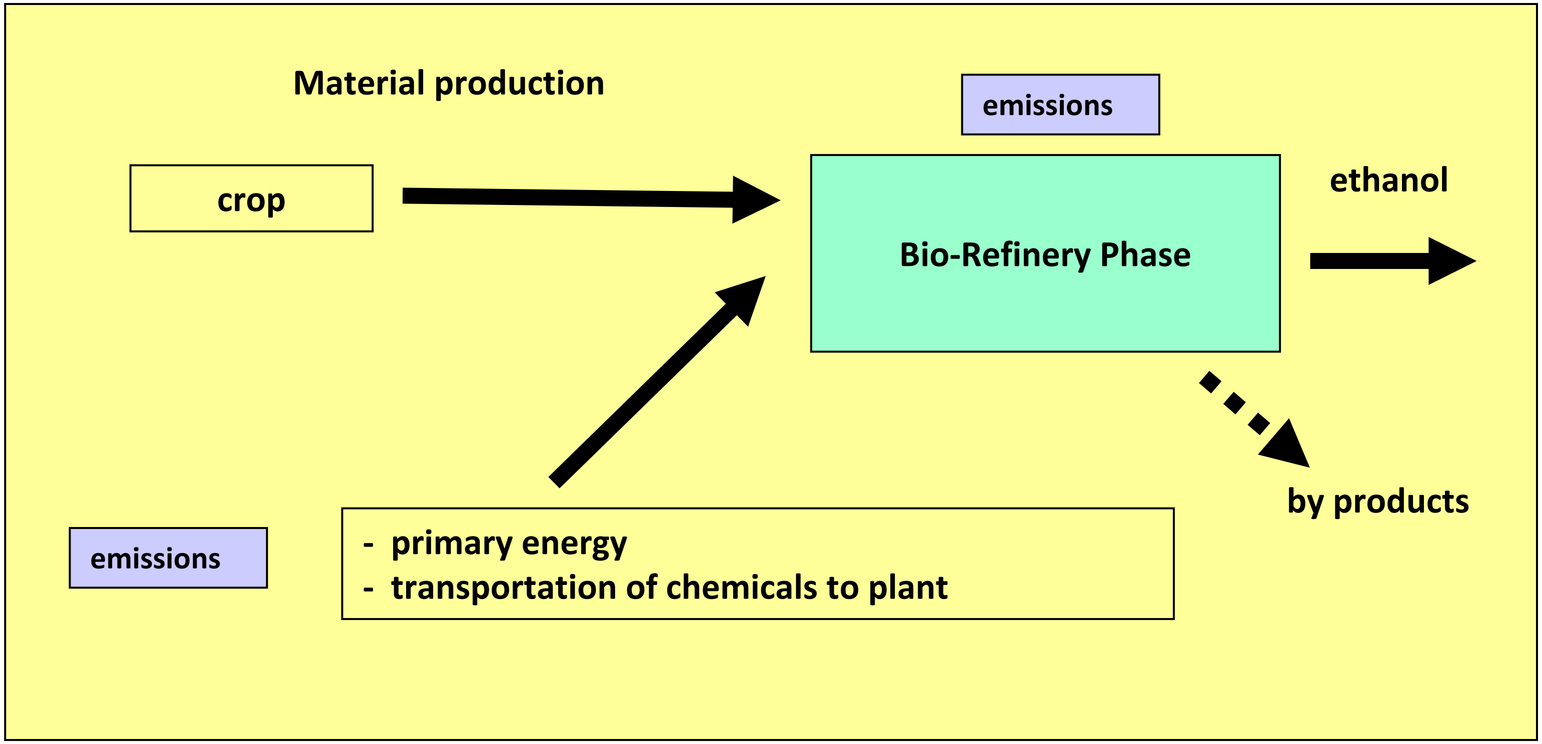
System boundary for ethanol derived from sweet sorghum



Agricultural Phase



Bio-refinery Phase



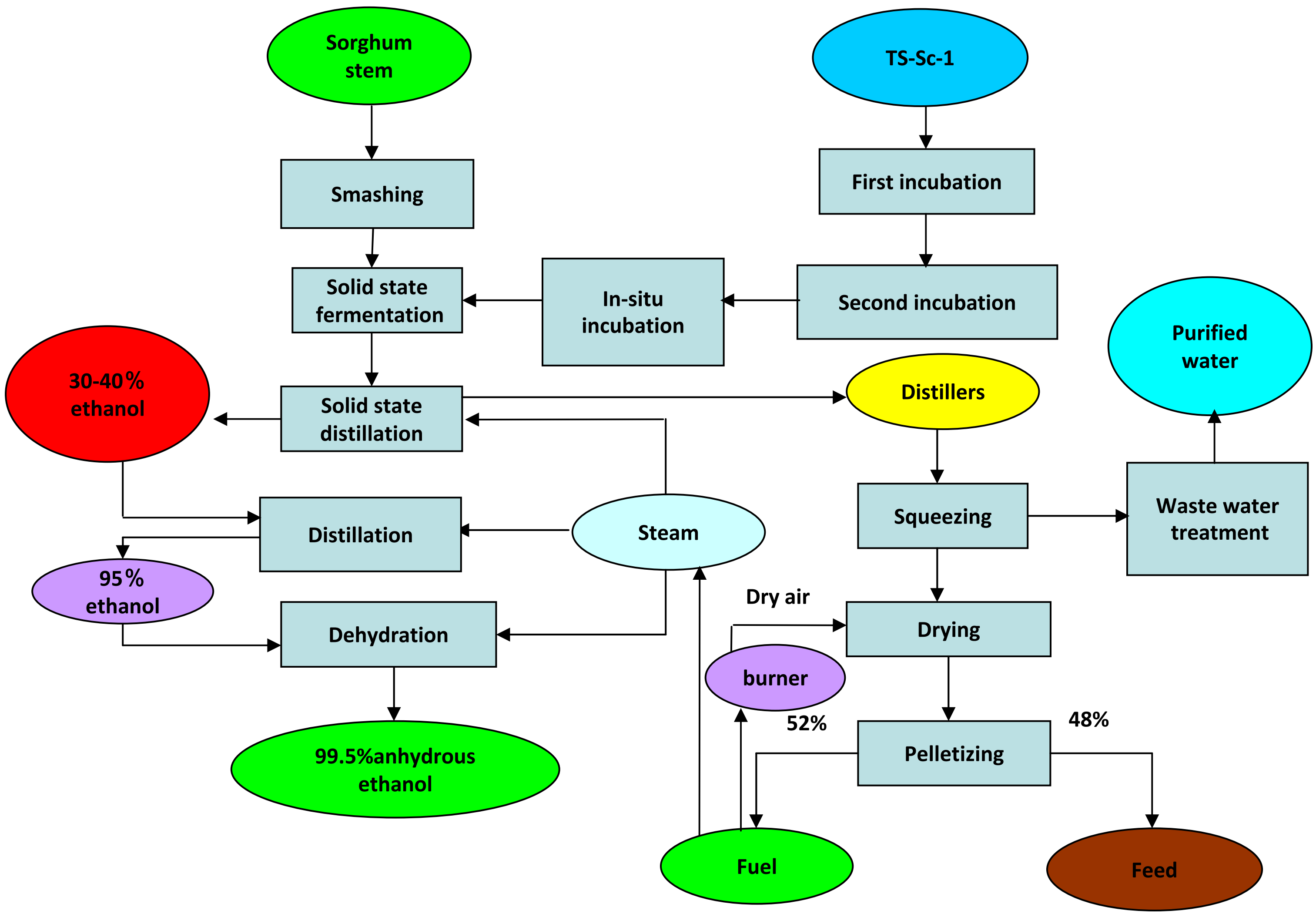
Model Development

- Based on **What‘s Best!** To develop
  - An add-in to Excel that allows you to build large scale optimization models in a free form layout within a spreadsheet.
  - (LINDO SYSTEM INC) combines the proven power of linear, non linear and integer optimization with Microsoft Excel -- the most popular and flexible business modelling environment in use today.

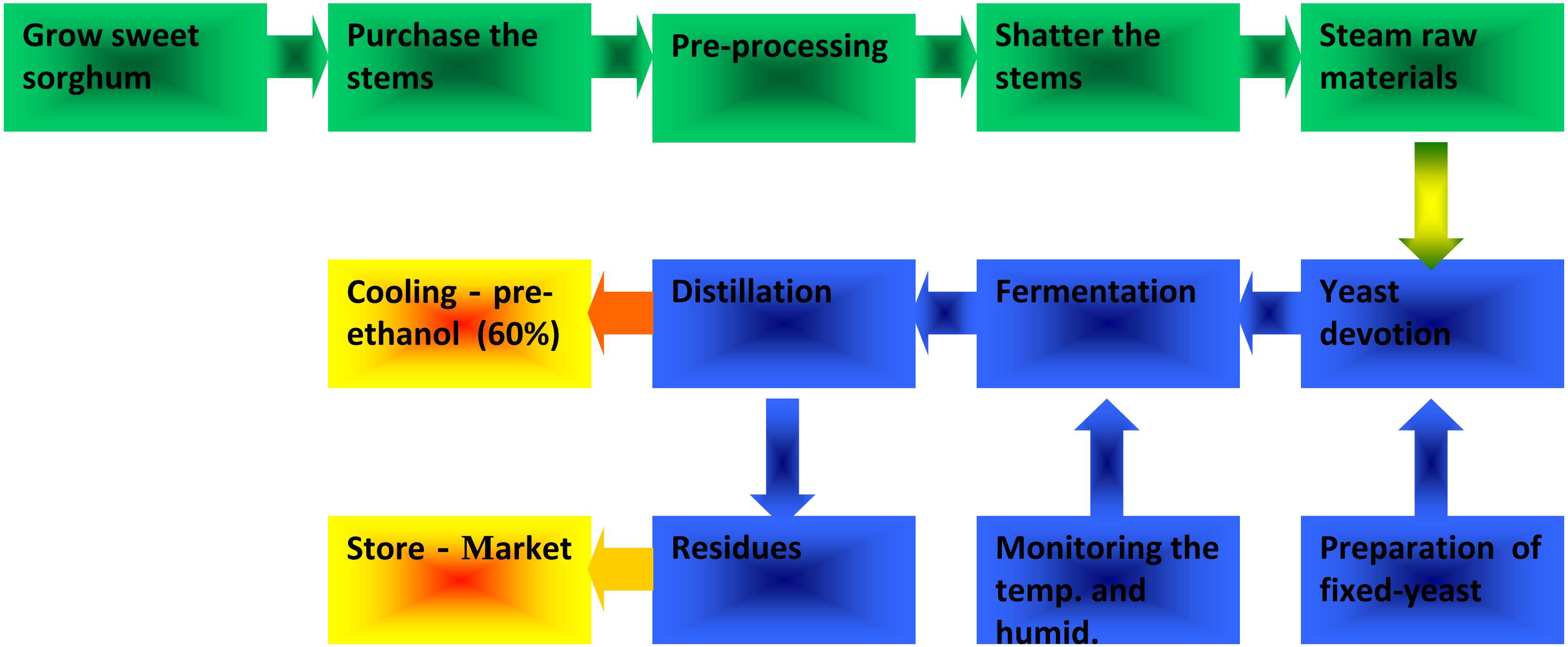
Conversion technology

- In Inner Mogolia, use **ASSF** (Advanced Solid State Fermentation) technology researched by Tsinghua university to LCA on refinery phase
- In Heilongjiang, use traditional solid fermentation technology to LCA on refinery phase


Advanced Solid State Fermentation (ASSF) Flow chart



Traditional Solid Fermentation Techniques Flow chart



Agricultural phase

Typical input for the Agricultural Phase

Sweet sorghum farming requires a significant number of chemical inputs, such as nitrogen, phosphate, and potash.

In addition, fossil energy is used to operate farming machinery, to pump water for irrigation, etc.

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Agricultural Phase	Description	Region 1: Heilongjiang province								
Nitrogen (MJ/kg)	1									43.7
N Application rate (kg/ha)	2									600.0
Phosphorus (MJ/kg)	3									6.8
P2O5 application (kg/ha)	4									0.0
Potassium (MJ/kg)	5									6.8
K2O application (kg/ha)	6									0.0
Lime (MJ/kg)	7									1.8
Lime application (kg/ha)	8									0.0
Herbicide (MJ/kg)	9									261
Herbicide application rate (kg/ha)	10									15.2
Insecticide (MJ/kg)	11									268.4
Insecticide (kg/ha)	12									0.8
Seed (MJ/kg)	13									0.0
Seed rate (kg/ha)	14									15.0
Transportation of inputs to farm (MJ/ha)	15									259.2
Tranport energy (MJ/kg)	16									0.41
Gasoline (MJ/ha)		47.0	MJ/kg	0.0	L/ha	0.7	kg/L			0.00
Diesel (MJ/ha)		44.0	MJ/kg	81.0	L/ha	0.8	kg/L			2993.76
Natural gas (MJ/ha)	17	55.0	MJ/kg	0.0	m3/ha	0.7	kg/m3			0.00
LPG (MJ/ha)				0.0	L/ha	0.5	kg/L			0.00
Electricity (MJ/ha)										0.00
Energy used in irrigation (MJ/ha)	18			0	MJ/ha				*	0
Vertical pumping (MJ/ha)	19			0	MJ/ha	OK!!			*	0
Horizontal pumping (Distribution) (MJ/ha)	20			0	MJ/ha				*	0
Farm labor (MJ/ha)	21			0	MJ/ha				*	0
Animal labor (MJ/ha)	22			0	MJ/ha	OK!!			*	0
Human labor (MJ/ha)	23			650.16	MJ/ha				*	650.16
Labor transportation (MJ/ha)	24									0
Farm machinery (MJ/ha)	25									0
Inputs packaging (MJ/ha)	26									0
Total Agricultural Phase (MJ/ha)										34019.8

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Refinery phase

Including pre-processing, solid fermentation, distillation, and co-products processing

Biorefinery phase		距离km	公斤乙醇消耗秸秆量kg	耗油量L/kg.KM	柴油热值mj	密度KG/L		
Transportation of feedstock to biorefinery (MJ/L)	27	20	16	0.00005	44	0.8		0.5632
Thalli (MJ/kg)	28							20
Thalli Application (kg/L)	29							10
Energy used in pre-processing	30		MJ/ton	0	MJ/L			0
Crushing or cutting (MJ/L)	31	25	90	0.072	MJ/L	OK!!		0.072
Sterilizing (MJ/L)	32	0	0	0	MJ/L			0
Pressing (MJ/L)	33	0	0	0	MJ/L			0
Liquid fermentation (M/L)	34					#REF!		
Solid fermentation (MJ/L)	35	25	90	0.072	MJ/L			0.072
Distillation (MJ/L)	36	25	90	0.072	MJ/L			0.072
Primary energy (MJ/L)	37				MJ/L			0
Electricity (MJ/L)		40	144	0.1152	MJ/L	OK!!		0.1152
Coal (MJ/L)				0	MJ/L			0
Natural gas (MJ/L)	38			0	MJ/L			0
Diesel (MJ/L)		蒸汽（ton）	蒸汽热值 （MJ/L）	0	MJ/L			0
Biomass (MJ/L)		22.02	2520	44.39232	MJ/L			44.39232
Waste water treatment (MJ/L)	39							0

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Case Study Result 1

In Inner Mogolia Case:

- The Net Energy Value(NEV, MJ/L)in the whole Sweet sorghum ethanol production is 73.44

  Input energy:49.089 (Agricultural phase:24.494,
  Refinery phase: 24.595)

  Energy content of ethanol:21.2

  Co products credit: 5.89(grain)+95.44(pellets)

- Co-products, such as grain and cellulose pellets (for fuel) are taken into account.

Case Study Result 2

In Heilongjiang Case:

- The Net Energy Value(NEV, MJ/L)in the whole Sweet sorghum ethanol production is -11.21

    Input energy:29.43

        Agricultural phase:22.85,
        Refinery phase(60% ethanol content): 6.58

    Energy content of ethanol:12.72

    Co products credit: 5.5+ ???

Co-products, such as grain, are taken into account.

Next step

- The Biofuels Spreadsheet Model has been tested (links, optimization solver, structure,) by using literature data and calibrations have been successfully made. The whole procedure demonstrated to be user-friendly and flexible. And the next step as below:
  - To update and improve the biofuel chains by using reliable site depending data
  - to consider new crop chains and
  - new regions (for bio-ethanol production and the biogas production)
  - to insert these chains into a complete local energy system and, above all
  - to describe the supply/demand mechanisms including the competing commodities and technologies

Finally, the aim of the program is,

in order to have an useful tool for the decision making process.

We are looking forward to collaborating with you

Thank you!