Sustainability Assessment of a Sugar Biorefinery Complex in Thailand

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Discussion topics

- Introduction to biofuels
- Bioethanol policy in Thailand
- Assessment of feedstock availability and greenhouse gas emissions
- The case of a sugar mill as biorefinery

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The Joint Graduate School of Energy and Environment

- Center of Excellence in Energy Technology and Environment established in 1998

- Research-based and Professional-oriented graduate programs in Energy and Environmental Technology & Management

- Sustainability Assessment Lab (SAL)'s research areas:
  - ❖ LCA of biofuels
  - ❖ LCA of power production
  - ❖ Ecolabelling and Certification
  - ❖ Sustainable development indicators




What are biofuels?

First Generation Biofuels		
Biofuel Type	**Biomass Feedstock**	**Production Process**
Vegetable/Plant Oil	Oil crops (e.g. rapeseed, sunflower, soybean, *oil palm, jatropha*, *coconut*, etc.) Algae	Cold pressing/ extraction
Biodiesel		Cold pressing/ extraction & transesterification
Bioethanol	*sugarcane, cassava*, sweet sorghum, sugar beet, grains	Hydrolysis and fermentation
Bio-ETBE	Bioethanol	Chemical synthesis

Second Generation Biofuels		
Biofuel Type	**Biomass Feedstock**	**Production Process**
Biodiesel	Vegetable oils and animal fat	Hydtro-treatment
Bioethanol	Lignocellulosic material	Advanced hydrolysis & fermentation
Synthetic biofuels	Lignocellulosic material (BTL, FT Diesel, Bio-DME)	Gasification & synthesis
Bio-hydrogen	Lignocellulosic material	Gasification & synthesis or biol.

Why are biofuels considered green?

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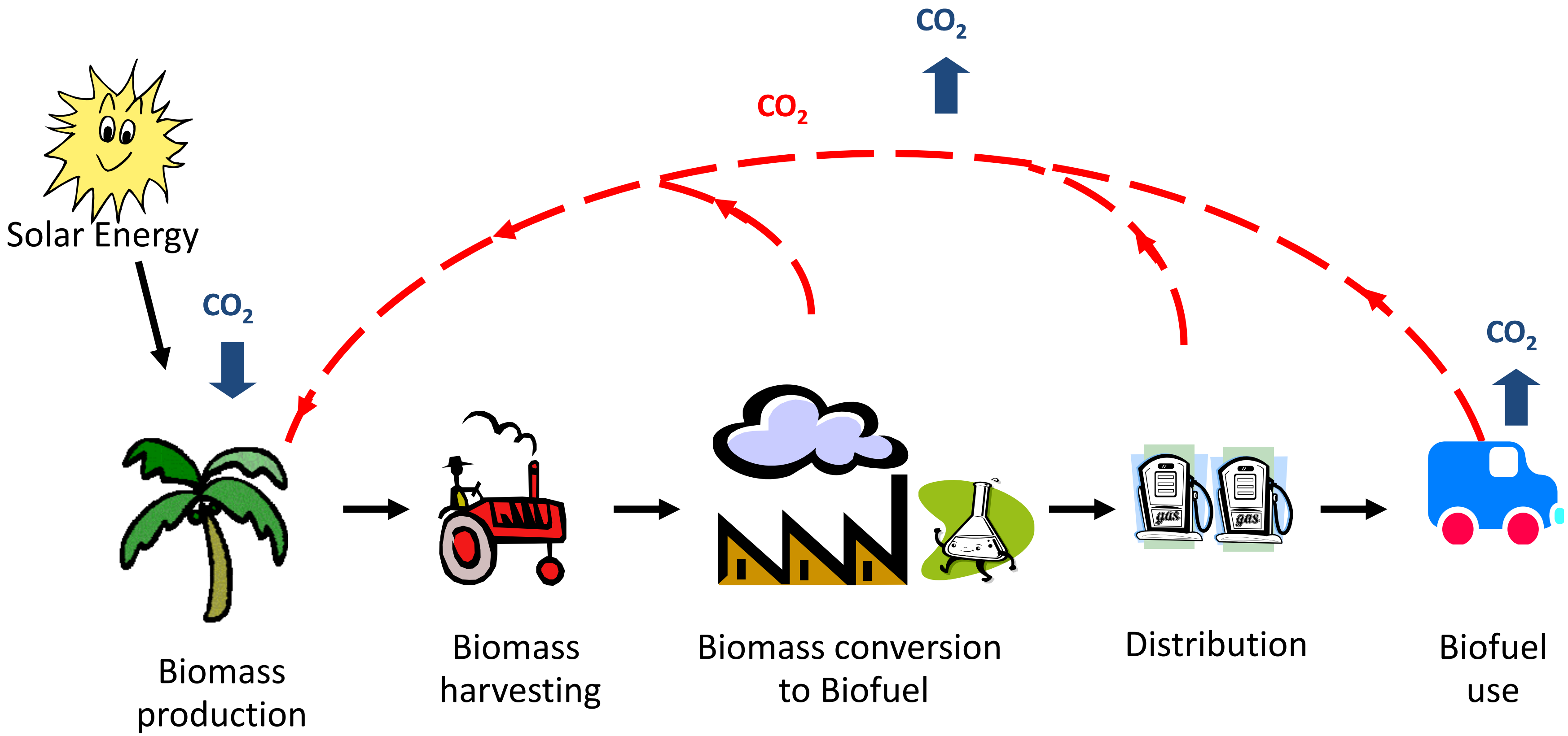

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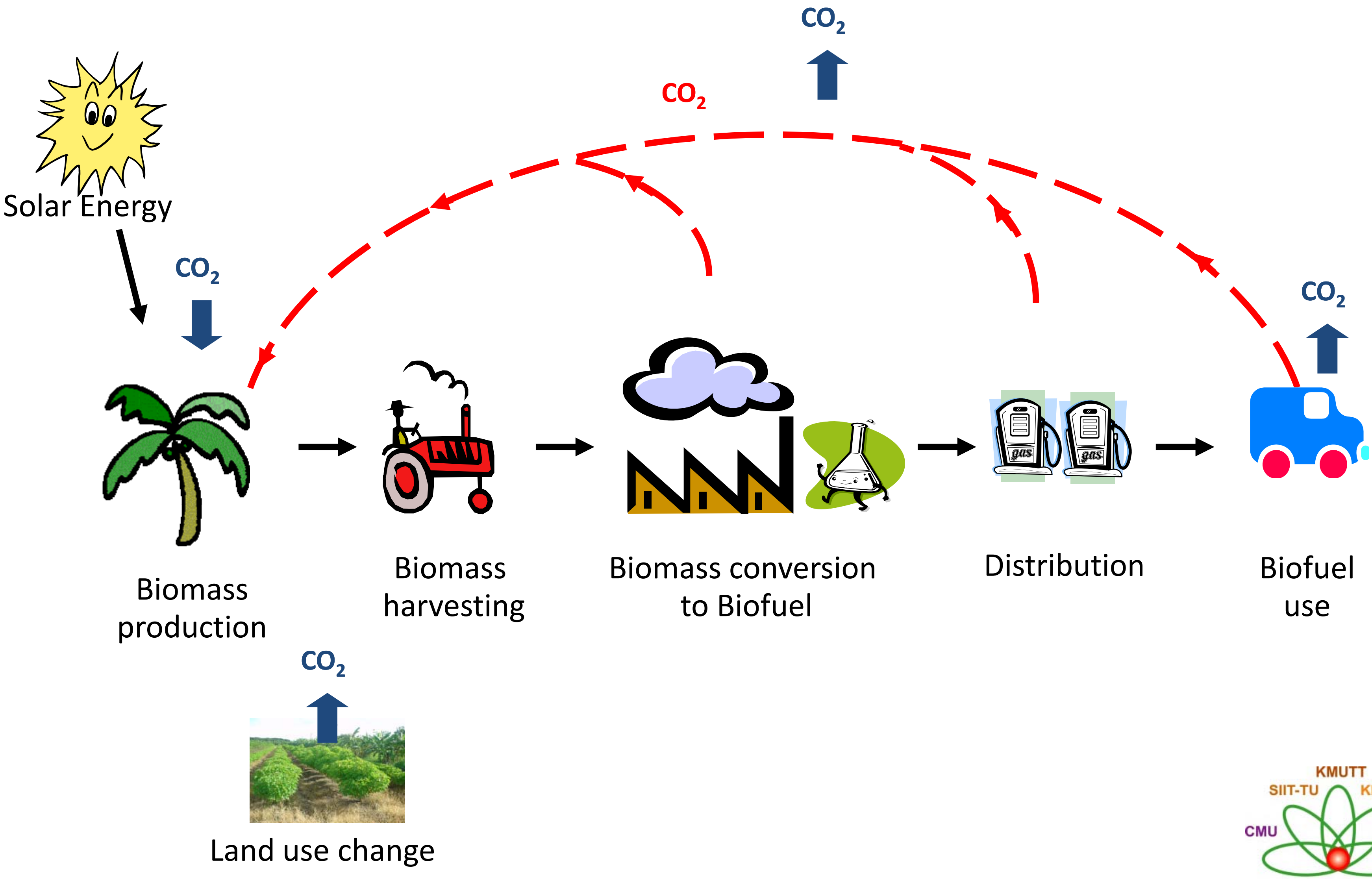

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Expected benefits of biofuels

- Use of biofuels as an alternative transportation fuel
  - utilize local feedstocks – reduce imports
  - provide energy security
  - ensure steady income for farmers in rural areas
  - improve air quality?
  - help to reduce GHG emissions
- Several alternative feedstocks
  - Biodiesel: oil palm, jatropha, used cooking oil, coconut
  - Bioethanol: cassava, molasses, sugar cane juice

BIOFUELS POLICY IN THAILAND

15-Year Alternative Energy Plan for Thailand

- Short Term (2008-2011): Focusing on promoting the proven alternative energy technologies with high potential sources such as: *biofuels, heat and power generation from biomass and biogas*. The financial support measures will be fully implemented.

- Medium Term (2012-2016): Promoting the alternative energy technology industry and supporting the development on new prototype of alternative energy technology for a higher cost-effectiveness. This includes promoting *new technologies for biofuel production*.

- Long Term (2017-2022): Promoting new technologies of alternative energy which are cost-effective. Supporting Thailand to become the *hub of biofuel export* and exporting the alternative energy technology in the ASEAN region

Source: Ministry of Energy, Thailand

BIOETHANOL IN THAILAND

กรมพัฒนาพลังงานทดแทน
และอนุรักษ์พลังงาน
กระทรวงพลังงาน

Bioethanol Development Plan 2008 – 2022

- Start E20 (08)
- Start E85 + FFV (09)
- Number of FFV = 2,000 (10)
- Selling Gasohol E10 countrywide (11)
- Number of FFV = 390,000 (15)
- Number of FFV 1,070,000 (19)

	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22
Ethanol demand (M.litres/day)**	1.24	1.34	2.11	2.96					6.2						9.0
Budget (Million baht)	-	28	60	30					160					280	

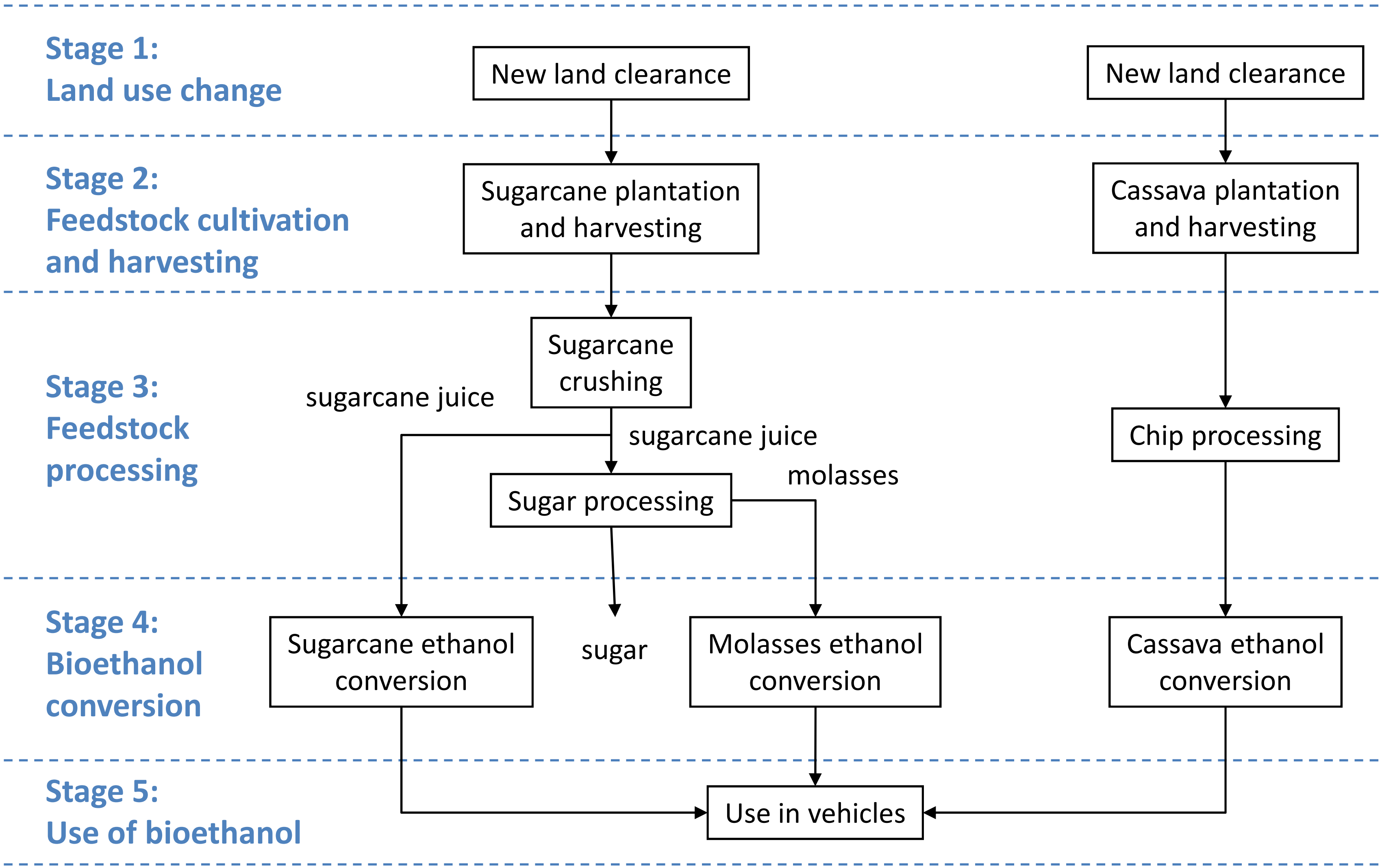
Ethanol Market
- To create stability of ethanol production
- Give support to increase efficiency of bioethanol transportation system and bioethanol storage for export

Ethanol Production
- To promote ethanol production from molasses and cassava
- To promote ethanol production from sugarcane
- To promote related industries from bioethanol e.g. Acetic and Ethylacetic manufacturing

Raw material
- Increase cassava yield from 3.5 tons/rai to 4.5 tons/rai in 2012
- Increase sugarcane yield from 11.8 to 15 tons/rai/year in 2012
- To create stability of feedstock supply for ethanol production

R&D
- R&D on ethanol production from cellulose & Algae
- To promote ethanol production from cellulosic material and/or algae
- To create value added of waste from ethanol production e.g. spent wash
- Test research on the utilization of E85

Evaluating the impact of long-term bio-ethanol production plan on GHG emissions



Source: Silalertruksa and Gheewala (2011)

Life cycle GHG performance of bio-ethanol from various feedstocks

Feedstock	Estimated GHG emissions ($kg\ CO_2eq$/ L biofuel)		Net avoided GHG emissions compared to gasoline[h]	
	Baseline	Range	Baseline	Range
Molasses	0.68[a]	0.65[b] - 3.46[c]	64%	66% - (-82%)
Cassava/ Dried chips	0.96[d]	0.77[e] - 1.92[f]	49%	59% - (-1%)
Sugarcane juice	0.5	0.26[g] – 0.5	72%	82%[c]–76%

a Average GHG emissions of three molasses ethanol plants, Allocation factor (AF) of sugar:molasses = 4:1.
b A molasses ethanol plant which used bagasse as fuel.
c A molasses ethanol plant which used coal as fuel and AF of sugar:molasses = 8.6:1.
d Ethanol produced from dried chips cassava in Thailand and ranges of GHG emisission were reviewed from various studies [Silalertruksa and Gheewala, 2010; Nguyen et al. 2007; Hu et al. 2004]
e Cassava ethanol plant which used biomass as fuel
f Cassava ethanol plant which used coal as fuel.
g Sugarcane in Brazil (sugar juice) [Macedo et al., 2004]
h Estimations based on energy content of ethanol = 21.2 MJ/L; energy content of gasoline = 32.4 MJ/L
Thus, a litre of ethanol will produce the same performance as 0.65 litres of gasoline.
Gasoline fuel-cycle GHG emissions = 2.9 kg CO_2eq./litre gasoline

Net feedstock balances (after accounting for the projected bio-ethanol demand)

Net balance (M.ton feedstocks/year)		2008	2009	2010	2011	2016	2022
Scenario 1: Low yields improvement	Molasses	0.13	0.54	0.65	0.62	0.23	(0.17)
	Cassava	3.50	0.54	(2.11)	(3.61)	(13.00)	(20.95)
	Sugarcane		4.33	8.26	8.49	7.03	6.24
Scenario 2: Moderate yields improvement	Molasses	0.13	0.81	1.13	1.31	0.81	(0.08)
	Cassava	3.50	1.23	0.64	1.19	(6.95)	(20.63)
	Sugarcane		10.24	18.75	23.55	19.60	8.23
Scenario 3: High yields improvement	Molasses	0.13	0.81	1.13	1.31	1.42	1.44
	Cassava	3.50	1.23	0.64	1.19	(0.23)	(0.48)
	Sugarcane		10.24	18.75	23.55	32.79	41.18

Numbers in parentheses indicate shortfall

Scenario 1: Crop yields are projected to grow as usual as if there is no policy on biofuels development
Scenario 2: Crop yields are anticipated to be improved as per the government's short-term policy targets in Thailand's 15 years renewable development plan
Scenario 3: Crop yields are projected to increase to reach the genetic potential of the cassava and sugarcane varieties

Source: Silalertruksa and Gheewala (2010)

GHG emissions of future bio-ethanol production systems in Thailand including LUC

GHG indicator	Year	Case 1	Case 2	Case 3	Case 4	Case 5
Average GHG emissions from bio-ethanol (kg CO_2-eq/L ethanol)	2011	1.39	1.39	0.48	0.48	0.48
	2016	1.75	3.16	0.76	2.18	0.49
	2022	1.84	3.7	0.85	2.71	0.49
GHGs emissions reduction compared to gasoline (%)	2011	27%	27%	74%	74%	74%
	2016	8%	(67%)	60%	(15%)	74%
	2022	3%	(95%)	55%	(43%)	74%

Numbers in parentheses indicate higher GHG emissions than gasoline

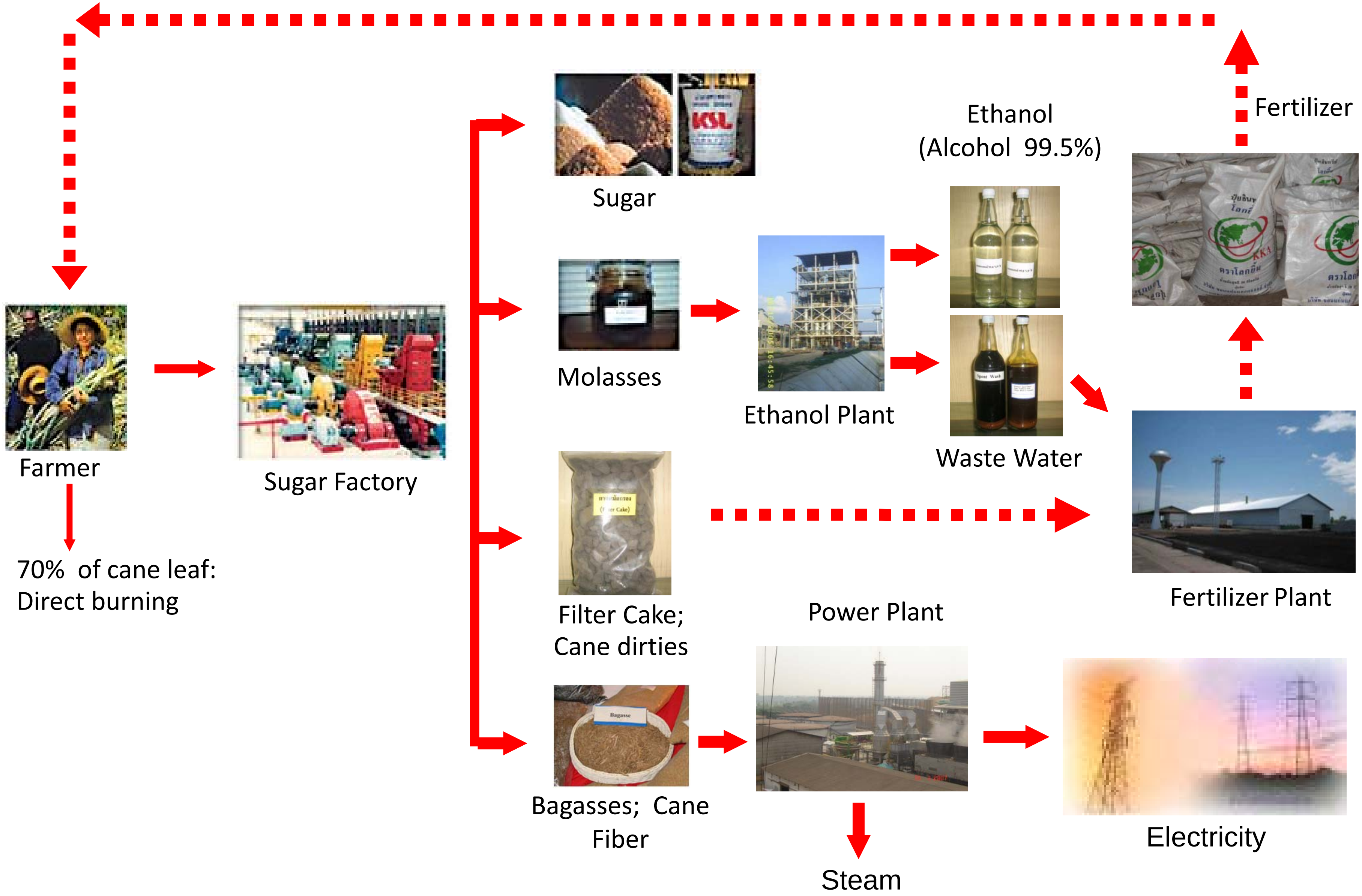
Case 1: New plantations for both cassava and sugarcane will take place on grassland
Case 2: New plantations for both cassava and sugarcane will take place on forest land
Case 3: Same as Case 1 but ethanol systems widely adopt sustainability measures e.g. waste utilization and biomass energy
Case 4: Same as Case 3 but new plantations of cassava and sugarcane take place on forest land
Case 5: No expansion of new cultivated areas as cassava and sugarcane yields are projected to increase to reach the genetic potentials of the current varieties. Sustainability measures adopted

Source: Silalertruksa and Gheewala (2011)

Summary of results – bioethanol

- For the case of no new cultivated area (Case 5), in year 2022, GHG reductions of 4.6 M tonCO_2e (74% reduction compared to gasoline) are possible provided improvement options such as below are also encouraged:
  - Increasing feedstock productivity by improving soil quality with organic fertilizers
  - Implementing energy conservation measures promoting use of renewable fuels in ethanol plant
  - Preventing the sugarcane trash burning during harvesting by used it as fuel in sugar milling
  - Enhancing waste recycling program from ethanol plants such as biogas recovery, organic fertilizers and animal feed
  - Providing technical knowledge associated with cassava ethanol production to industry

Biorefinery complex in Thailand



Environmental Assessment

	Ethanol (kg CO_2e)				Gasoline (kg CO_2e)
	Base Scenario	Scenario 1		Scenario 2	
		0%	35%		
Production	13.50	5.91	8.38	11.20	5.04
Use	-	-	-	-	21.66
Total	13.50	5.91	8.38	11.20	26.70

Note: *Results based on reference flow of 14.95L ethanol which is equivalent to 9.89L gasoline*
Scenario 1: Percentage of cane trash burning (base case is assumed as 70%)
Scenario 2: Utilization of excess steam

Benefits of sugarcane biorefinery:

- A reduction of GWP by 50% for ethanol as compared to gasoline (Base scenario)
- A further reduction by 70% and up to 80% when cane trash burning is reduced or avoided (Scenario 1)
- A potential additional 10% GHG savings from utilisation of unused steam (Scenario 2)

Source: Gheewala et al. (2011)

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THANK YOU

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