4th JASTIP Symposium "Biomass to Energy, Chemicals and Functional Materials "
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Potentials of Global Biomass Energy and R&D of Biomass Refinery Technologies

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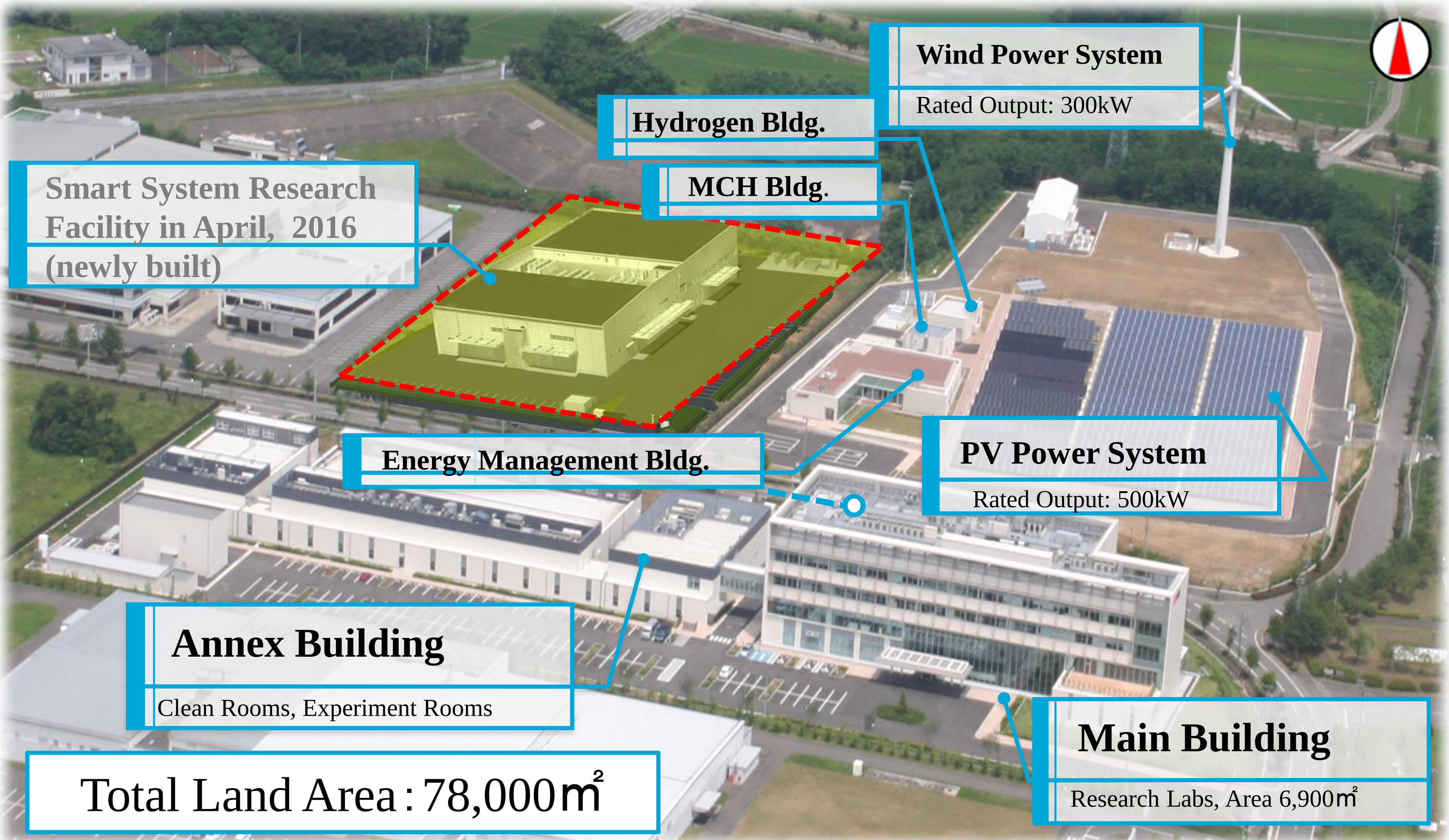
FREA
FUKUSHIMA RENEWABLE ENERGY INSTITUTE, AIST

FREA(Fukushima Renwable Energy Institute, AIST)

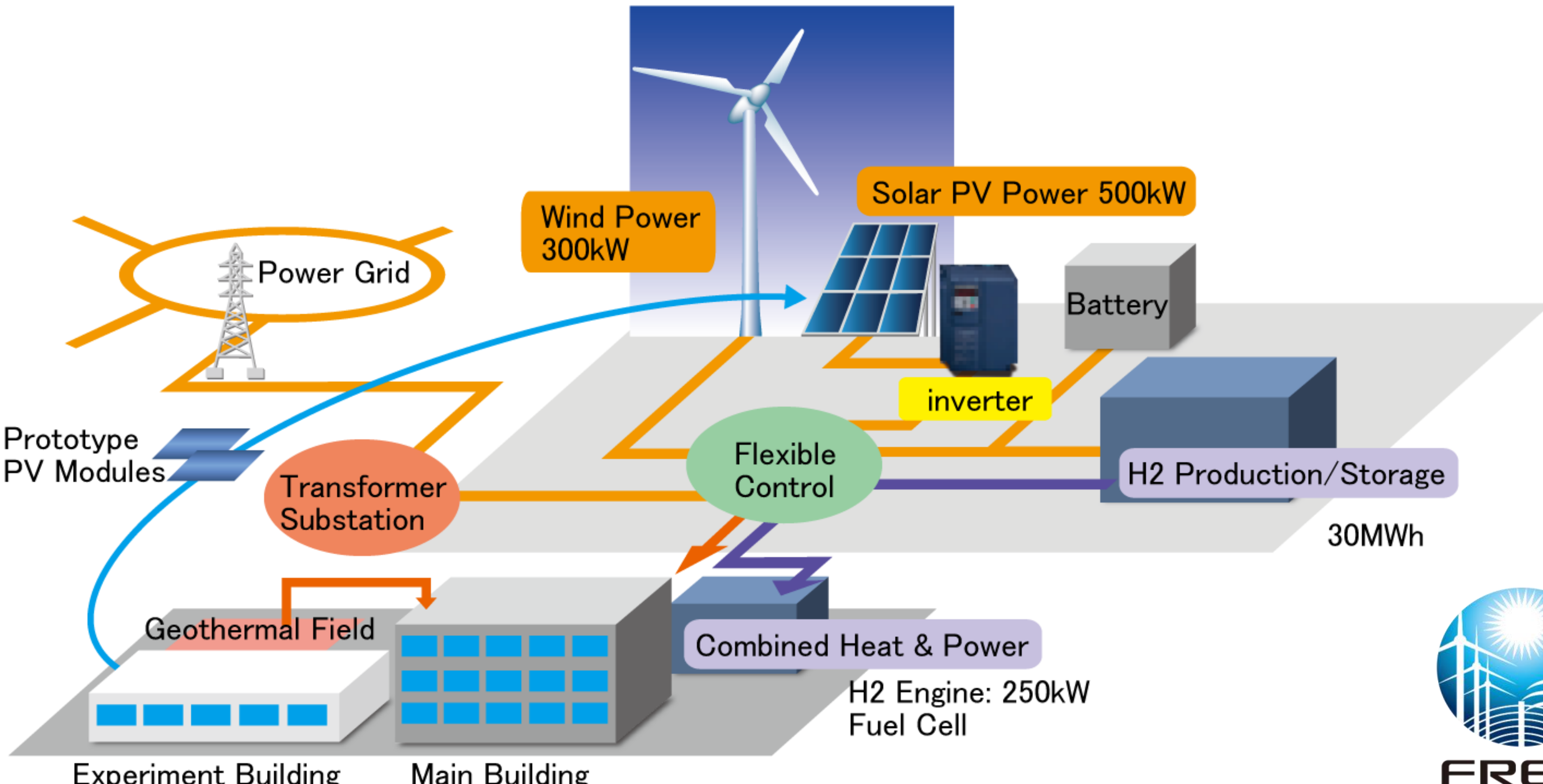
(Established in Koriyama City, Japan , in April, 2014)



Renewable Energy Network at FREA

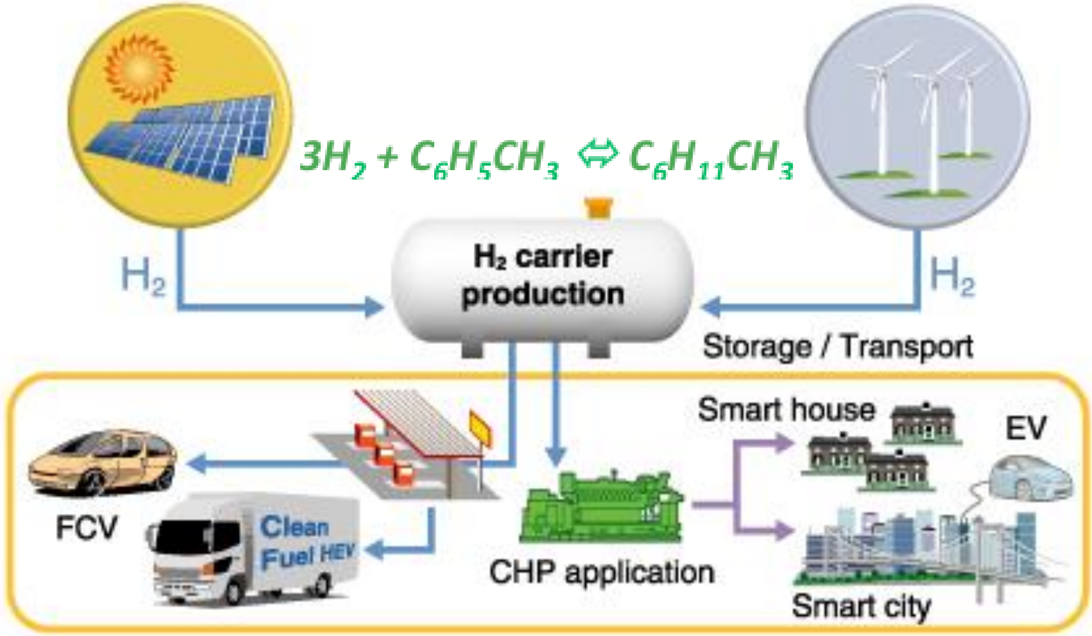
System R&D for renewable energies mass introduction

- MW PV, wind power integration with storage (batteries, hydrogen)
- ICT network for power generation forecast and system control
- Test bed for new technology (power electronics etc.), demonstration
- International standardization



Hydrogen Carrier Production / Application

- Hydrogen production from PV, wind turbine output
- Conversion to organic-hydrate (liquid at room temperature), large scale storage at high density for long term
- $3H_2 + C_6H_5CH_3 \leftrightarrow C_6H_{11}CH_3$ (methyl-cyclohexane)
  - Hydrogenation / dehydrogenation by catalytic reaction
- Combined heat and power application by engine / fuel cell
- *Utilization of O_2 from H_2O electrolysis for biomass to H_2 & fuels*



Major Developments of Biomass Policy in Japan

■After **the Great East Japan Earthquake and subsequent nuclear accident** happened, the biomass industrialization strategy was drawn as principle to create regional green industry and fortify an independent and distributed energy supply system.

Year	Policies
2002	Biomass Nippon Strategy
2005	Kyoto Protocol – Target Achievement Plan
2009	Basic Act for the Promotion of Biomass Utilization
2010	Basic Energy Plan (Revised)
2010	National Plan for the Promotion of Biomass Utilization
2011.3.11 Great East Japan Earthquake and Accident of Fukushima 1st Nuclear Power Plant	
2012	Biomass Industrialization Strategy <Feed-in Tariff started>
2014	Basic Energy Plan (Revised) ⇒ 2015 Revised FIT for Biomass Power Generation ⇒ 2016 Electricity Deregulation started from April

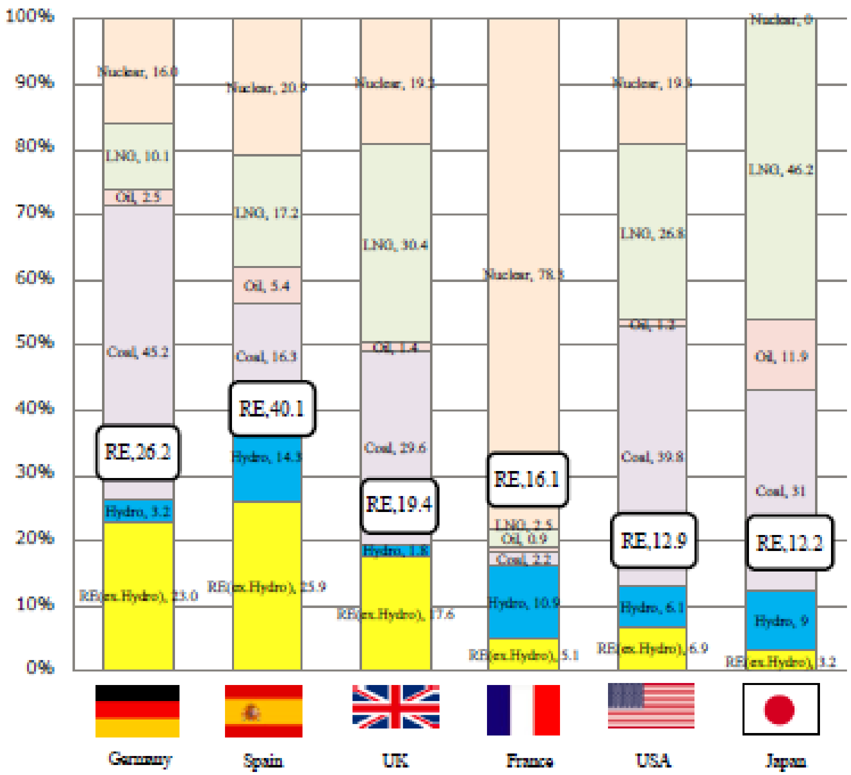
Source: Ministry of Agriculture,Forestry and Fisheries

Current State of Renewable Energy in Japan

Ministry of Economy, Trade and Industry
Agency of Natural Resources and Energy

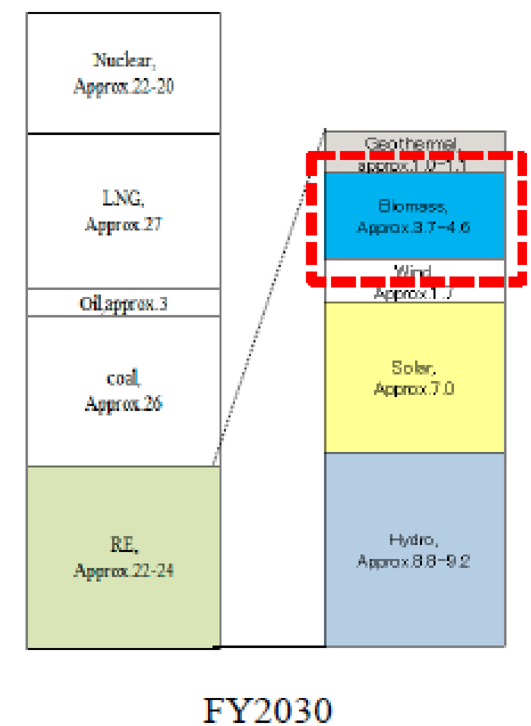
Renewable energy（RE）accounted for approximately 12.2% of power generation in 2014.
More specifically, hydroelectric power generated by large-scale dams, etc., accounted for 9.0%, with solar PV, wind, geothermal and **biomass** power accounting for 3.2%.

Composition of power generation by energy source(2014)



出典：日本/電源開発の概要」より作成（2014年度実績値）。
日本以外/2014年推計値データ、IEA Energy Balance of OECD Countries (2015 edition)

Composition of power generation by energy source in Japan(2030)



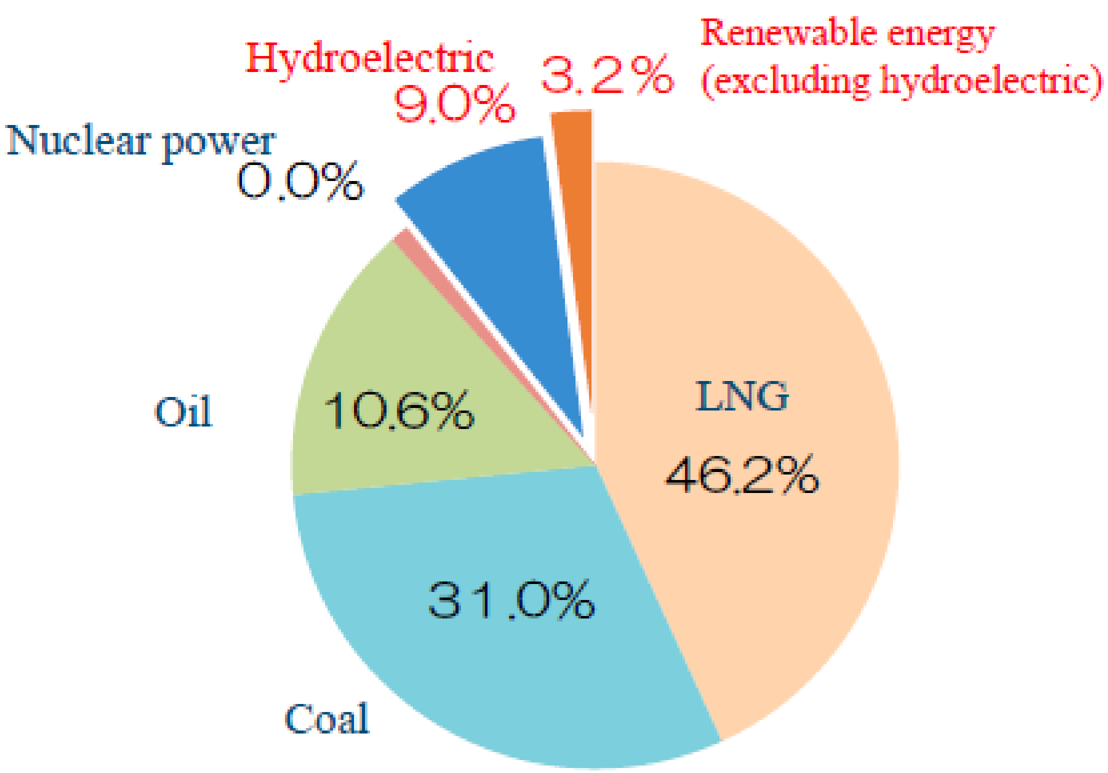
Source:Ministry of Economy,Trade and Industry

Current Status of Renewable Energy in Japan

Renewable energy accounted for approximately 10.7% of power generation in 2013.

More specifically, hydroelectric power generated by large-scale dams, etc., accounted for 9.0
with solar PV, wind, geothermal and biomass power accounting for 3.2%.

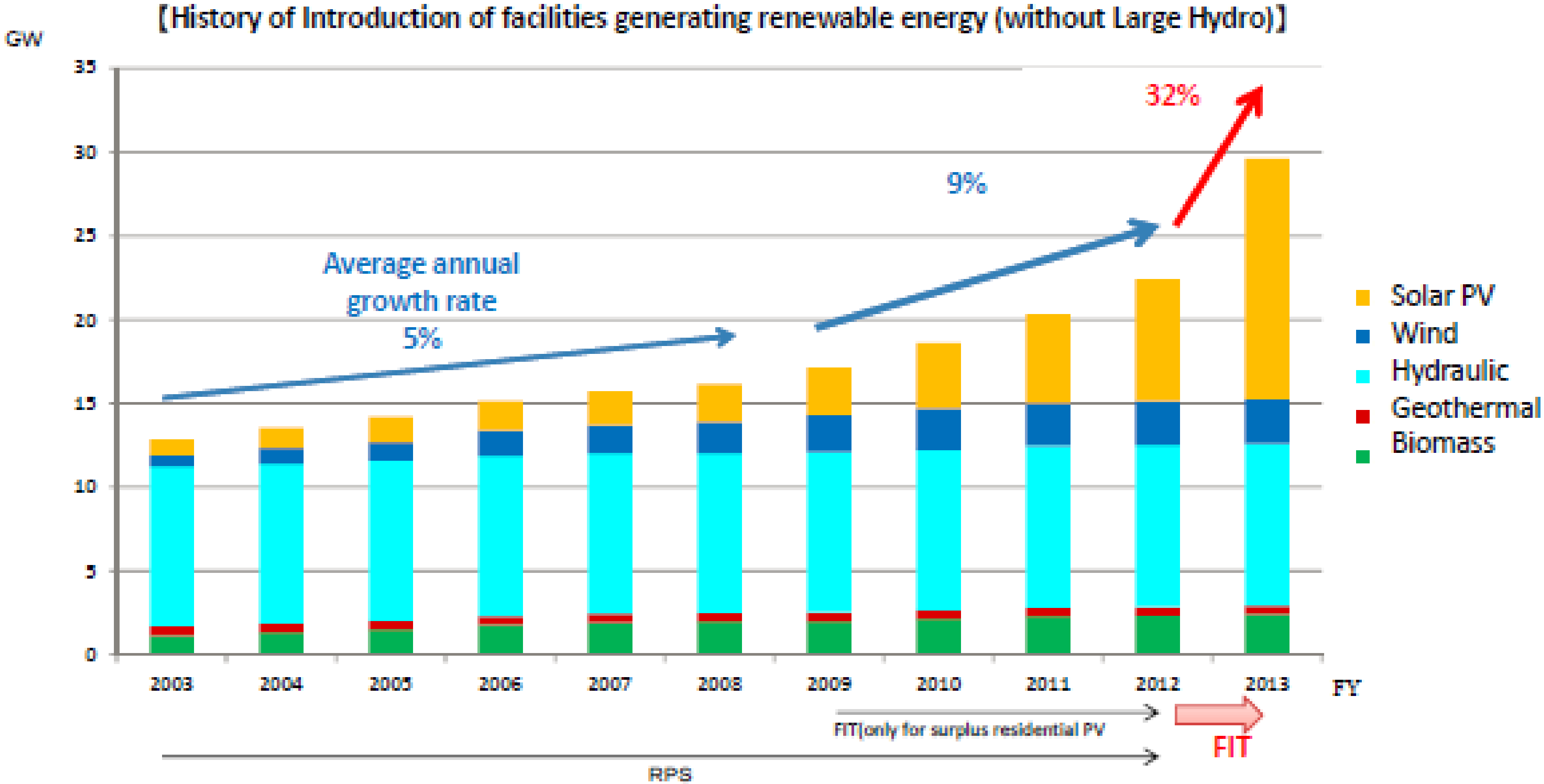
Composition of power generation by energy source in Japan (FY 2014)



Source: Federation of Electric Power Companies of Japan, *Composition of power generation by energy sourc*

History of Introduction of facilities generating renewable energy

- The main driver shifted to RPS in 2003, and then, to Feed-in Tariff in 2009.
- As business environment from the financial point of view was improved, investment in RE has been stimulated. In this surroundings, extension and upgrading of the grid and regulatory reform become more important than ever.

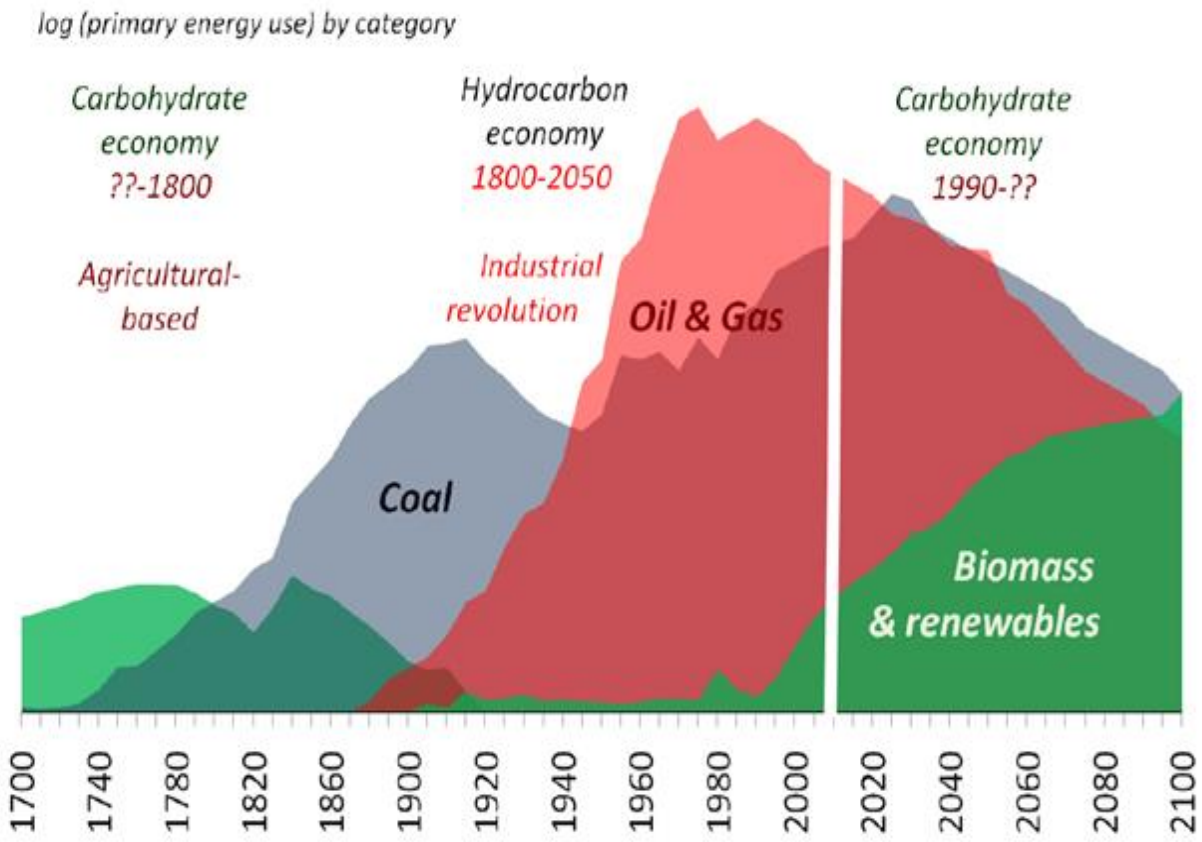


(From various sources including JPEA statistics, NEDO wind power generation statistics, hydrogenation capacity studies, geothermal surveys, and actual RPS/feed-in tariff figures)

Note: FY2013 figures show Mar. 2014 status

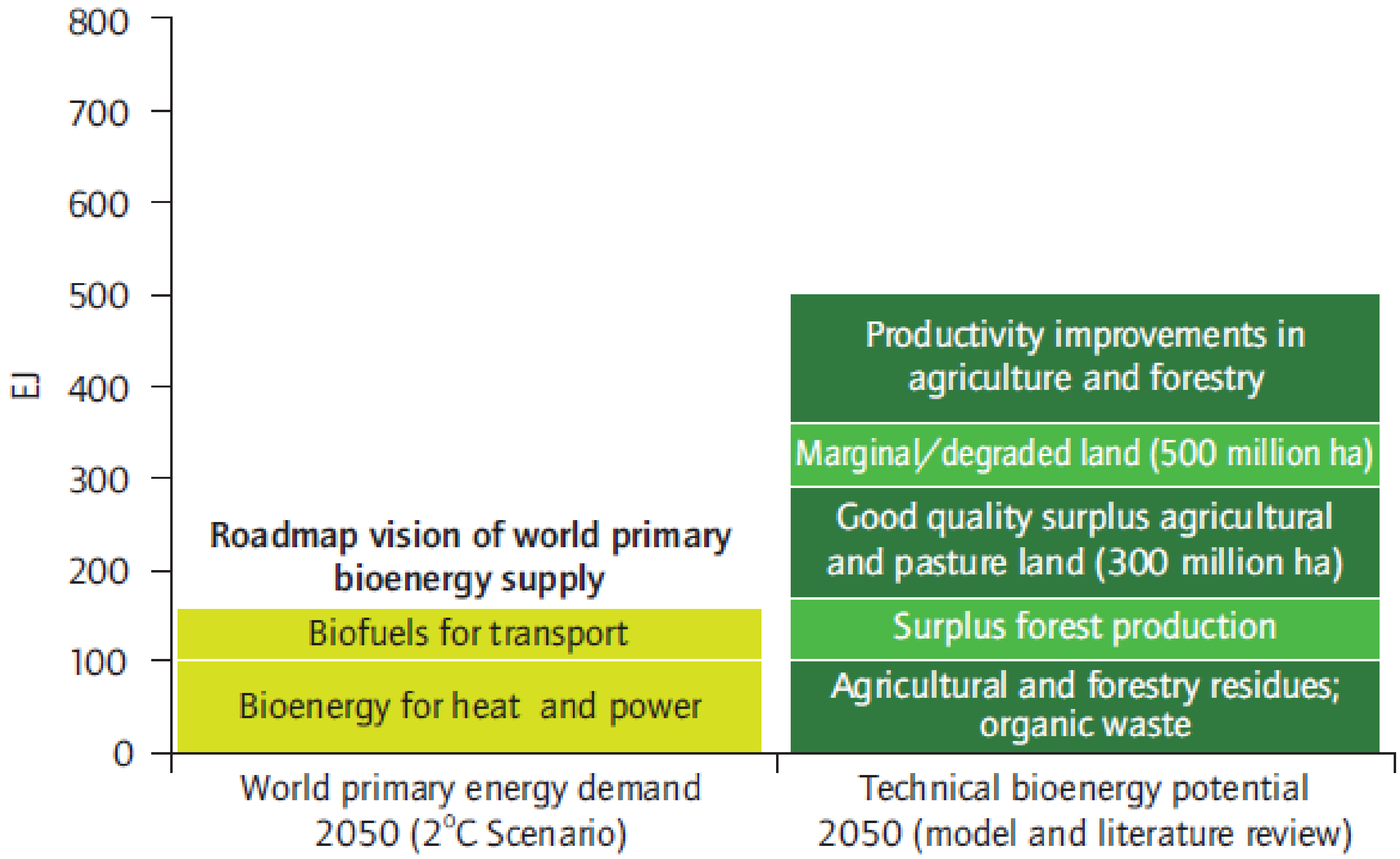
Current Situation of World Energy

Looking Back and Forward



Source : IEA Task39 Work Shop, September 2008

Biomass Supply Prospects – Uncertainties Remain



< Source: Based on IPCC SRREN, 2011 >

- Total biomass demand for heat, power and biofuels reaches 8-11 billion tons in 2050
- Intermediate targets should be adopted to enhance international biomass trade, and assess costs and impact on sustainability

IRENA
International Renewable Energy Agency

Biofuel Potential in Southeast Asia:

Raising food yields, reducing food waste and utilising residues

Table S-1 Residue potential for 2050 (PJ/year) – 25% collection of harvest residue

Country	Harvest Residue	Process Residue	Total Residue	Residue for Feed	Residue for Fuel	40% to Biofuel (Energy Content)	Share of Liquid Fuel Use in 2012
Indonesia	1 079	653	1 732	306	1 426	570	31%
Malaysia	104	59	163	87	76	30	5%
Philippines	393	288	680	303	377	151	44%
Thailand	641	578	1 220	226	993	397	51%
Viet Nam	508	353	861	426	435	174	37%
WORLD	49 278	29 730	79 008	32 877	46 131	18 452	19%

IRENA analysis (Appendix I)

[2] Projected yearly growth in food supply is globally 1.3% through 2030 (ranging from 0.8% in developed countries to 2.4% in Sub-Saharan Africa) and 0.7% from 2030 through 2050 (ranging from 0.3% to 1.9%).

[3] Projected annual growth in meat consumption is globally 1.4% through 2030 (from 0.6% in developed countries to 2.7% in Sub-Saharan Africa) and 0.9% from 2030 to 2050 (from 0.2% to 2.6%).

Table S-2 Residue potential for 2050 (PJ/year) – 50% collection of harvest residue

Country	Harvest Residue	Process Residue	Total Residue	Residue for Feed	Residue for Fuel (Primary Biomass)	40% to Biofuel (Energy Content)	Share of Liquid Fuel Use in 2012
Indonesia	2 158	653	2 811	306	2 505	1 002	55%
Malaysia	208	59	267	87	179	72	12%
Philippines	785	288	1 073	303	770	308	91%
Thailand	1 282	578	1 861	226	1 635	654	84%
Viet Nam	1 015	353	1 368	426	942	377	79%
WORLD	98 555	29 730	128 285	32 877	95 409	38 163	39%

IRENA analysis (Appendix I)

Table S-3 Biomass potential from higher yields in 2050 – yield gap closure case

Country	Land Freed (M ha)	Biomass Potential 150 GJ/ha (PJ/year)	40% to Advanced Biofuel (PJ/year)	Liquid Transport Fuel Use 2012 (PJ)	Potential Share of 2012 Fuel Use
Indonesia	4.26	638	255	1 822	14%
Malaysia	1.27	190	76	596	13%
Philippines	6.87	1 031	412	339	122%
Thailand	3.45	518	207	780	27%
Viet Nam	2.91	436	174	475	37%
WORLD	551.71	82 757	33 103	97 456	34%

IRENA analysis (Appendix II)

Table R-1a Residue potential for 2010 (PJ/year) – 25% collection of harvest residue

Country	Harvest Residue	Process Residue	Total Residue	Residue for Feed	Residue for Fuel
Indonesia	816	494	1 311	205	1 106
Malaysia	77	44	121	60	60
Philippines	297	218	515	193	322
Thailand	476	429	905	160	745
Viet Nam	384	267	651	270	381
WORLD	34 341	20 838	55 179	19 440	35 739

Table R-1b Residue potential for 2030 (PJ/year) – 25% collection of harvest residue

Country	Harvest Residue	Process Residue	Total Residue	Residue for Feed	Residue for Fuel
Indonesia	1 016	615	1 631	261	1 370
Malaysia	96	54	150	70	80
Philippines	370	271	641	259	382
Thailand	592	534	1 126	182	944
Viet Nam	478	333	811	363	447
WORLD	43 914	26 597	70 510	25 155	45 355

Table R-1c Residue potential for 2050 (PJ/year) – 25% collection of harvest residue

Country	Harvest Residue	Process Residue	Total Residue	Residue for Feed	Residue for Fuel
Indonesia	1 079	653	1 732	306	1 426
Malaysia	104	59	163	87	76
Philippines	393	288	680	303	377
Thailand	641	578	1 220	226	993
Viet Nam	508	353	861	426	435
WORLD	49 278	29 730	79 008	32 877	46 131

Table R-1d Residue potential for 2010 (PJ/year) – 50% collection of harvest residue

Country	Harvest Residue	Process Residue	Total Residue	Residue for Feed	Residue for Fuel
Indonesia	1 633	494	2 127	205	1 922
Malaysia	154	44	198	60	137
Philippines	594	218	812	193	619
Thailand	951	429	1 380	160	1 220
Viet Nam	768	267	1 035	270	766
WORLD	68 681	20 838	89 519	19 440	70 079

Table R-1e Residue potential for 2030 (PJ/year) – 50% collection of harvest residue

Country	Harvest Residue	Process Residue	Total Residue	Residue for Feed	Residue for Fuel
Indonesia	2 032	615	2 648	261	2 386
Malaysia	192	54	246	70	176
Philippines	740	271	1 011	259	752
Thailand	1 184	534	1 718	182	1 536
Viet Nam	956	333	1 289	363	926
WORLD	87 828	26 597	114 424	25 155	89 269

Table R-1f Residue potential for 2050 (PJ/year) – 50% collection of harvest residue

Country	Harvest Residue	Process Residue	Total Residue	Residue for Feed	Residue for Fuel
Indonesia	2 158	653	2 811	306	2 505
Malaysia	208	59	267	87	179
Philippines	785	288	1 073	303	770
Thailand	1 282	578	1 861	226	1 635
Viet Nam	1 015	353	1 368	426	942
WORLD	98 555	29 730	128 285	32 877	95 409

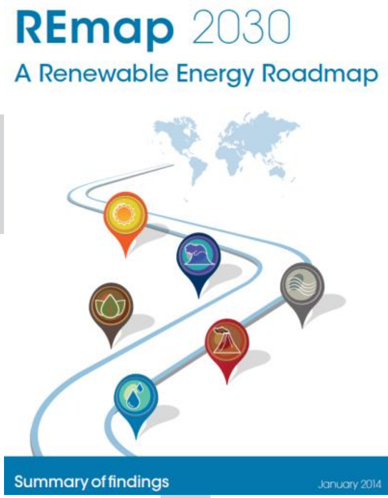
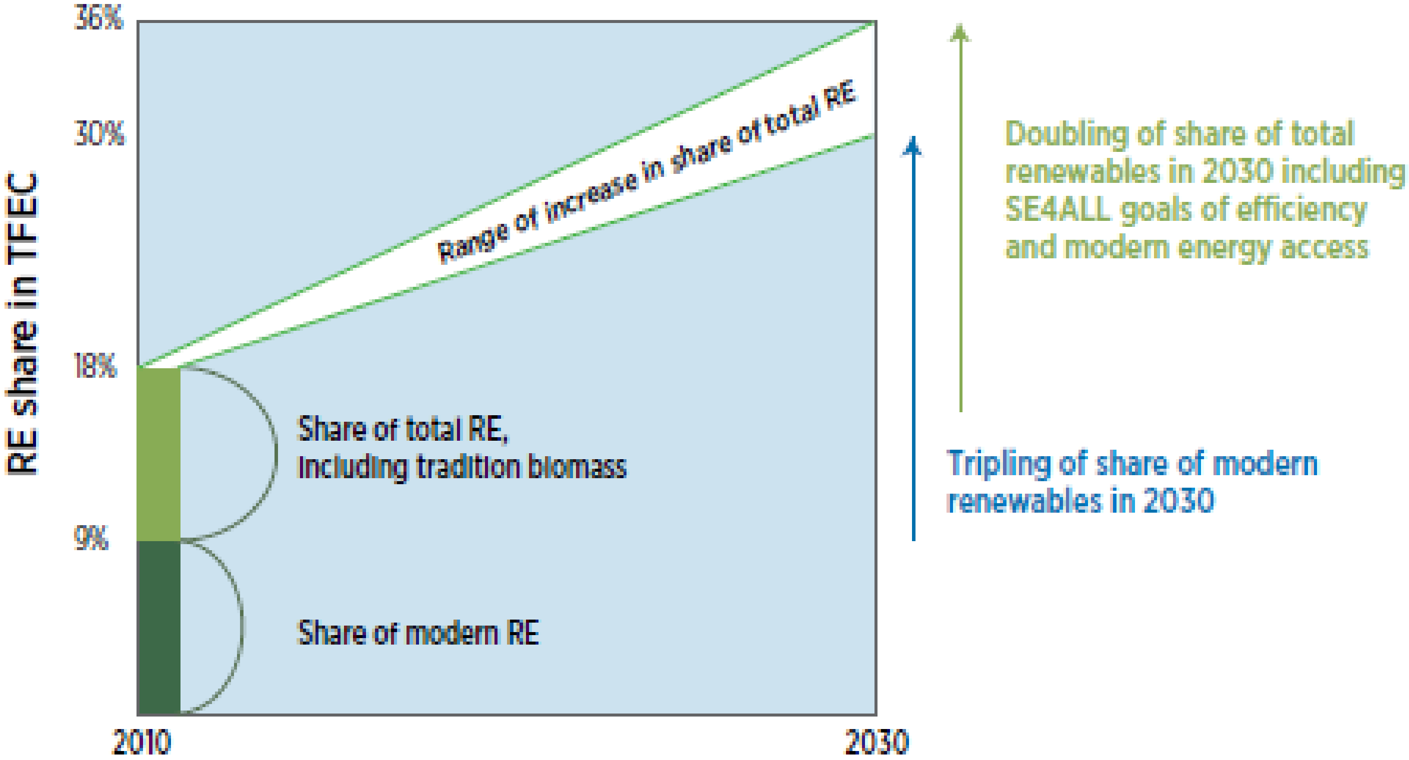


Figure 1. Doubling the share of renewables by 2030



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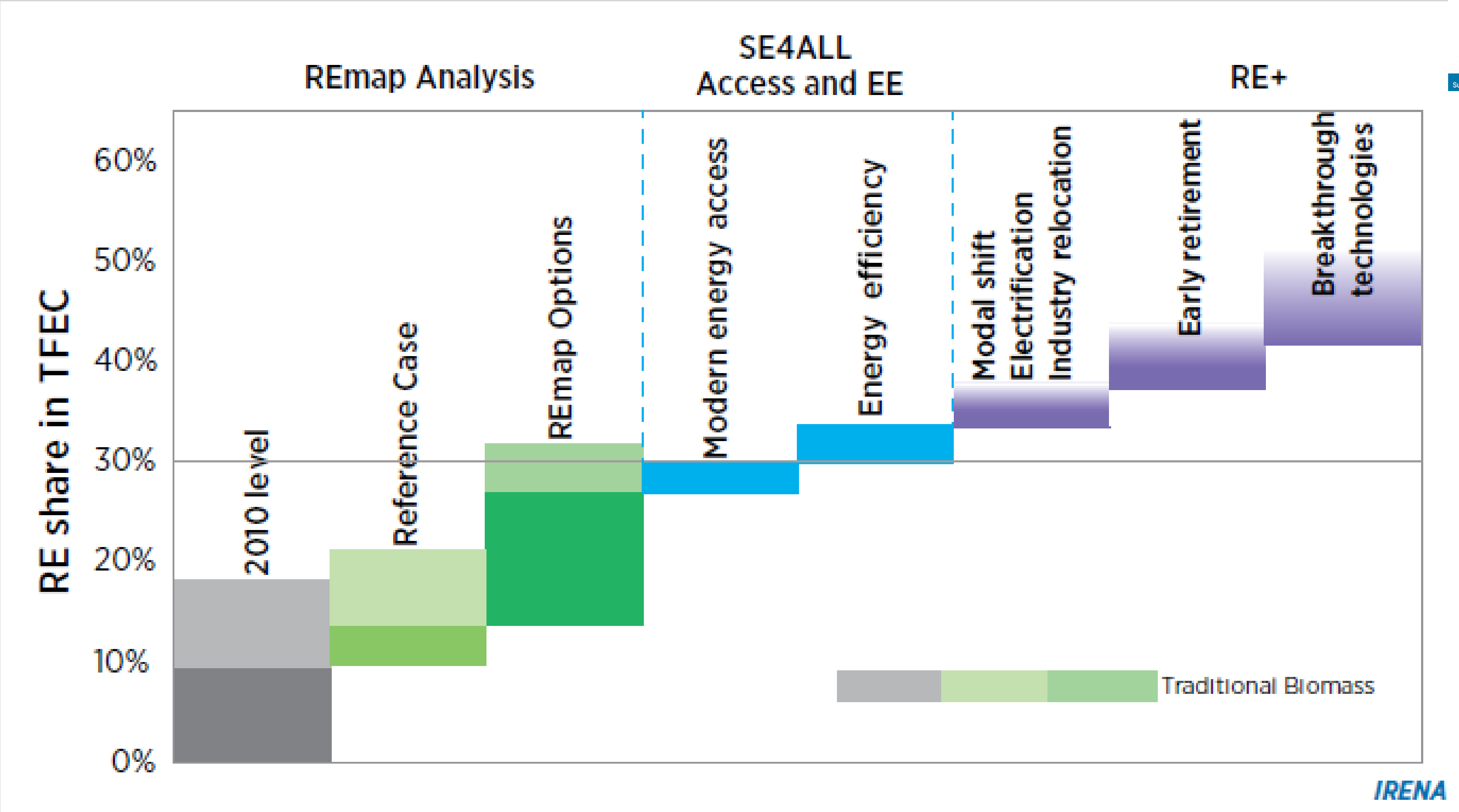
Doubling the share of renewable energy implies a tripling of the share of modern renewables.

Note: The world currently gets 18% of its energy from renewables, but only 9% is modern renewables, and the other 9% is traditional biomass, of which only part is sustainable. On the path towards a doubling of sustainable renewable energy, modern renewables therefore need to replace traditional biomass almost entirely. As a result, the share of modern renewables more than triples from 9% in 2010, to 30% or more by 2030.

RE = renewable energy; TFEC = total final energy consumption

Figure 4. The stepping stones towards a doubling of renewable energy

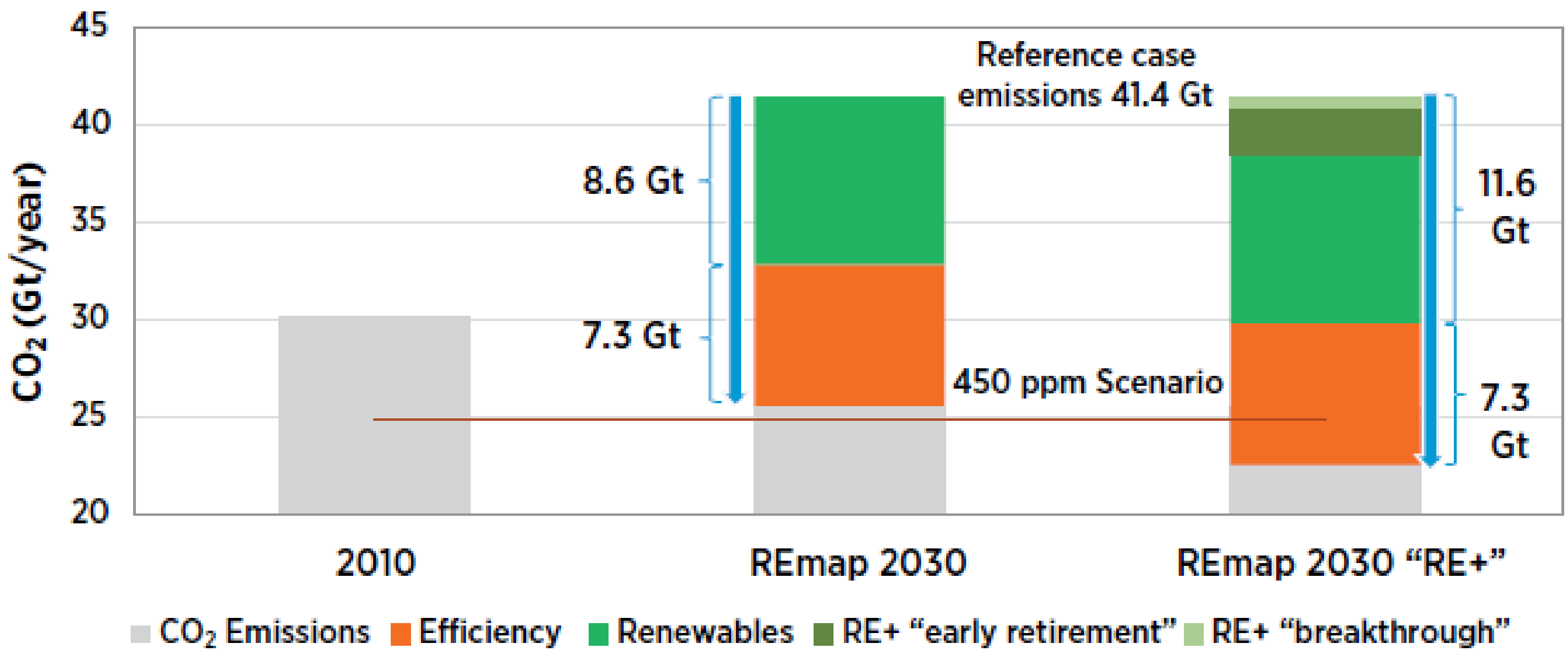


The world can double its share of renewable energy in total final energy consumption by 2030.

Note: The shaded areas indicate traditional biomass. The Reference Case represents the renewable energy share by 2030 based on the policies in place in the 26 REmap countries. The REmap Options show the additional growth by 2030 based almost entirely on modern renewables, with traditional biomass being reduced to less than 2% of the TFEC. The blue bars represent the SE4ALL objectives of modern energy access and energy efficiency (EE), which bring the share of renewables up to around 34% by 2030. The purple bars, RE+, represent other fields of action that can be pursued to take the share of renewables even further.

RE = renewable energy; TFEC = total final energy consumption

Figure 10. Carbon dioxide emissions under REmap 2030



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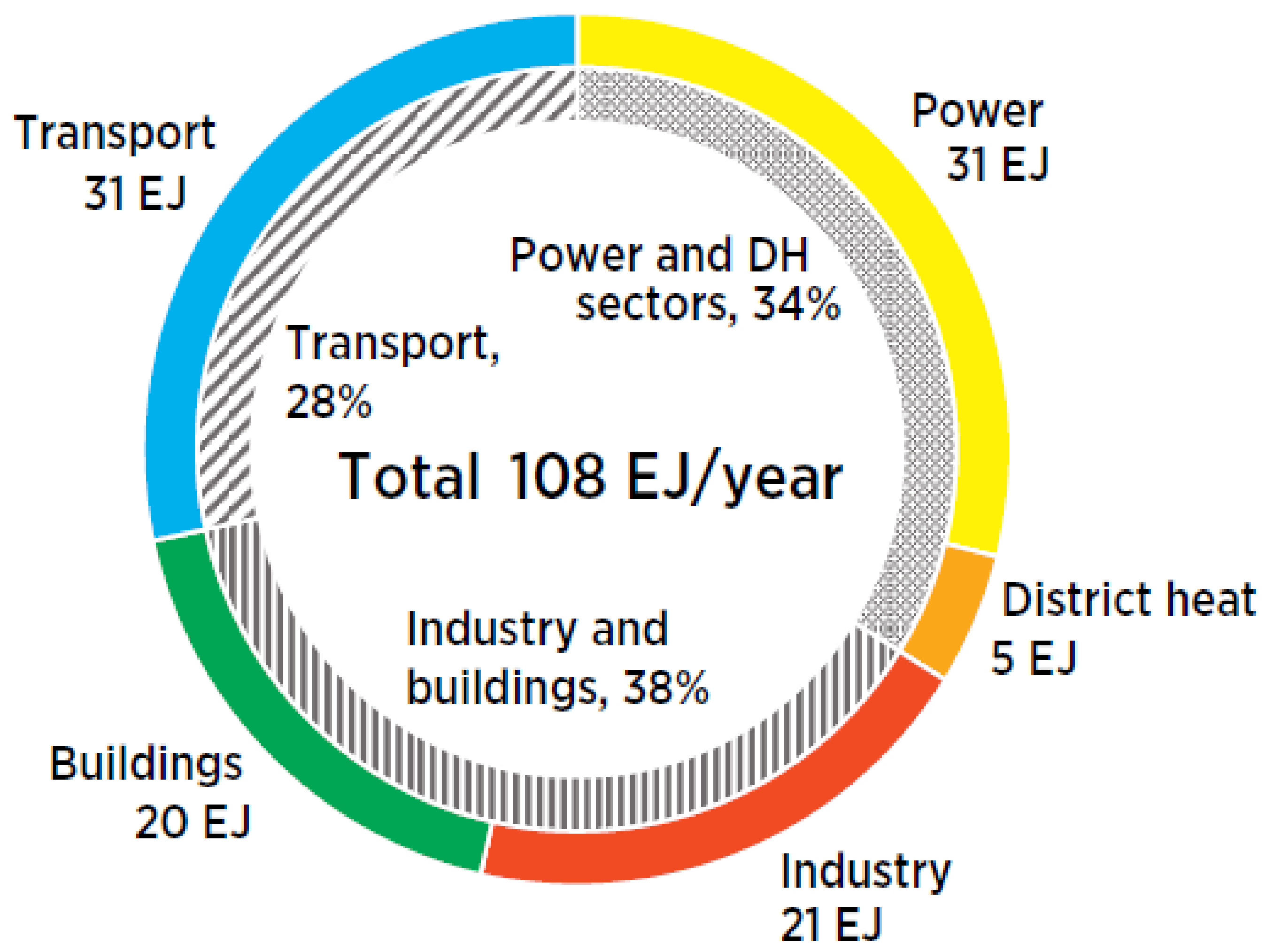
Renewable energy can provide half of the CO_2 emission reductions needed in 2030 from the energy sector.

Note: Only emissions resulting from fossil fuel combustion are shown. CO_2 emission savings from energy efficiency are based on its share in total emissions in the IEA's World Energy Outlook (WEO) 2012 (IEA, 2012b). IRENA applies this share to the total Reference Case emissions of 41.4 Gt of CO_2 to estimate approximately 7.3 Gt of CO_2 emission savings related to energy efficiency in REmap 2030.

Figure 14. Global biomass demand by sector in REmap 2030 (in primary energy terms)

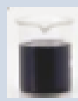
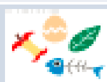
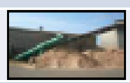
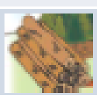


Biomass is versatile and can be used to provide power, transport and heat.

Target of biomass utilization by type (2020)

Ministry of Economy, Trade and Industry
Agency of Natural Resources and Energy

National target of average utilization ratio is set for each type of biomass to promote high utilization biomass based on their types and to clarify the necessary measures to be taken on the national level.

Type of biomass	Amount generated annually (2009)	Present and target utilization ratio 2009→2020
1 Animal waste 	Approx. **88 million tones**	90% → **90%**
2 Sewage sludge 	Approx. **78 million tones**	77% → **85%**
3 Black liquor 	Approx. **14 million tones**	100% → **100%**
4 Waste paper 	Approx. **27 million tones**	80% → **85%**
5 Food waste 	Approx. **19million tones**	27% → **40%**
6 Sawmill wood residue 	Approx. **3.4 million tones**	95% → **95%**
7 Wood waste from construction 	Approx. **4.1 million tones**	90% → **95%**
8 Non-edible parts of food crops 	Approx. **14 million tones**	85% → **90%**
9 Forest off-cuts 	Approx. **8 million tones**	0% → **30%**

Note: 1 Black liquor, saw mill wood residue, forest off-cuts are dry-weight, all others are wet weight.
2 Target for energy crops is 400,000 carbon tones produced by 2020.

Source: Ministry of Agriculture,Forestry and Fisheries

Scheme of Sustainable Asian Biomass Strategy

=> ASEAN+6 and Asia-Pacific Collaborations

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Best Practice Scenario and System for Sustainable Biomass Utilization Models in East Asian Countries

Total Promotion of Biomass Asia Strategy
Extensive Win-Win Collaboration in Asia
International R&D Joint Projects on Biomass,
Especially agriculture and engineering fields

Technology, IP, Human resources

Resources, Economical development, Technology transfer

Energy, Materials, CO_2 reduction：
CDM&JCM⇒Sustainable Development

Foresight of ASEAN Agricultural Residue in 2030

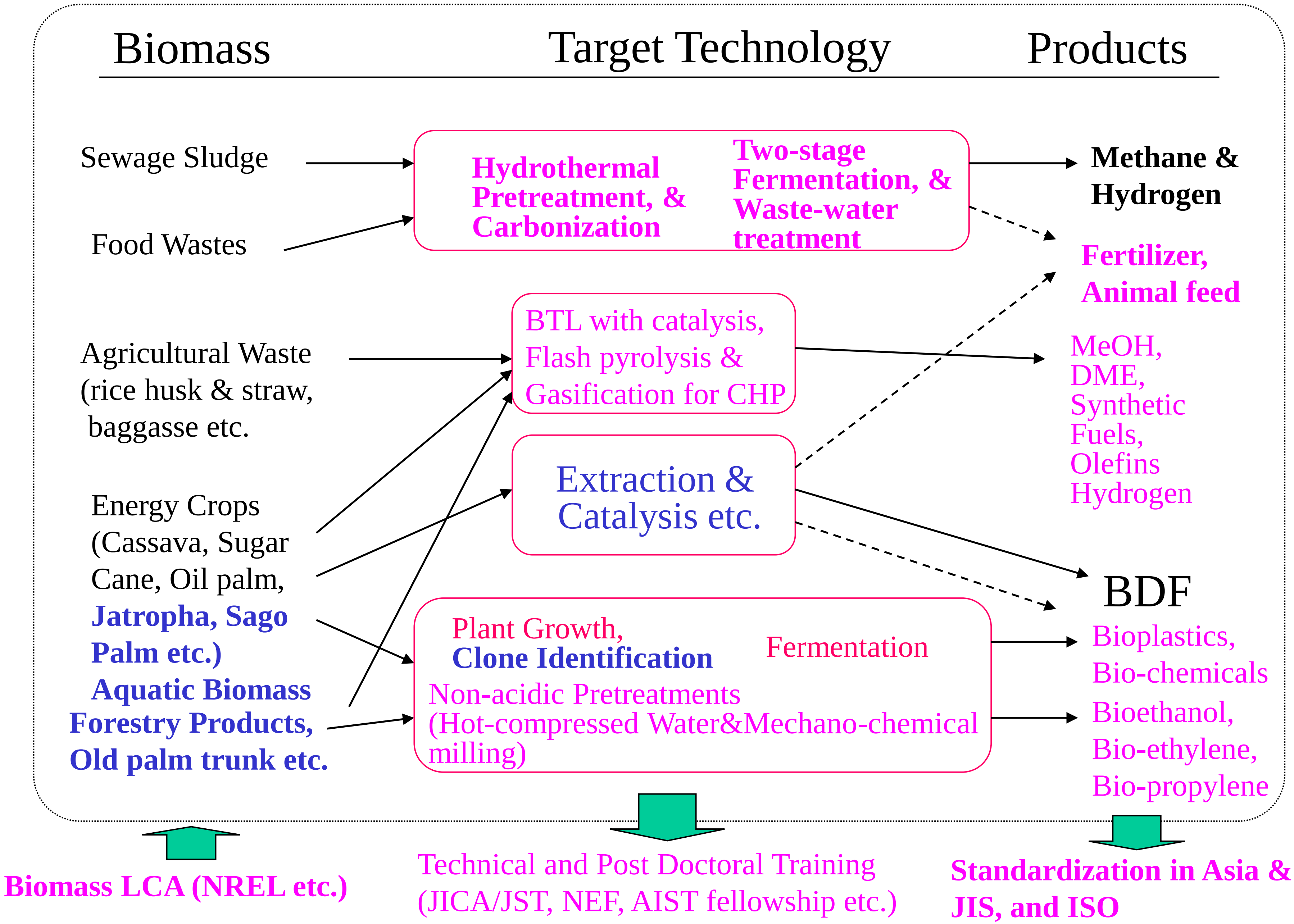
(Converted into Ethanol x1000 kL)

Type of Agriculture	Sugar cane	Cassava	Corn	Rice	Palm oil	Coconut	Total
Utilized part	Bagasse Filter cake	Lees Stems Leaves	Stems Leaves Cores Husks Fibers	Straw Husks	Shell Tuft	Shell Fiber	
Thailand	4,441	1,123	2,038	13,702	1,128	186	22,618
Malaysia	108	20	42	873	15,024	115	16,182
Indonesia	8,606	2,349	14,499	19,334	24,684	2,584	72,056
Philippines	2,555	187	5,572	6,265	32	5,186	19,797
Vietnam	1,319	388	3,906	12,696	0	137	18,446
Myanmar	1,392	20	1,421	7,161	0	132	10,126
Cambodia	16	40	400	2,436	0	16	2,908
Laos	72	12	327	1,511	0	0	1,922
Total	18,509	4,139	28,205	63,978	40,868	8,356	164,055

* The figures in yellow background are the promising quantities for producing ethanol

Source : NEDO Research Report in 2007

Target Technology & Products for Biomass Utilization



Future Needs for Alternative Transportation Fuel

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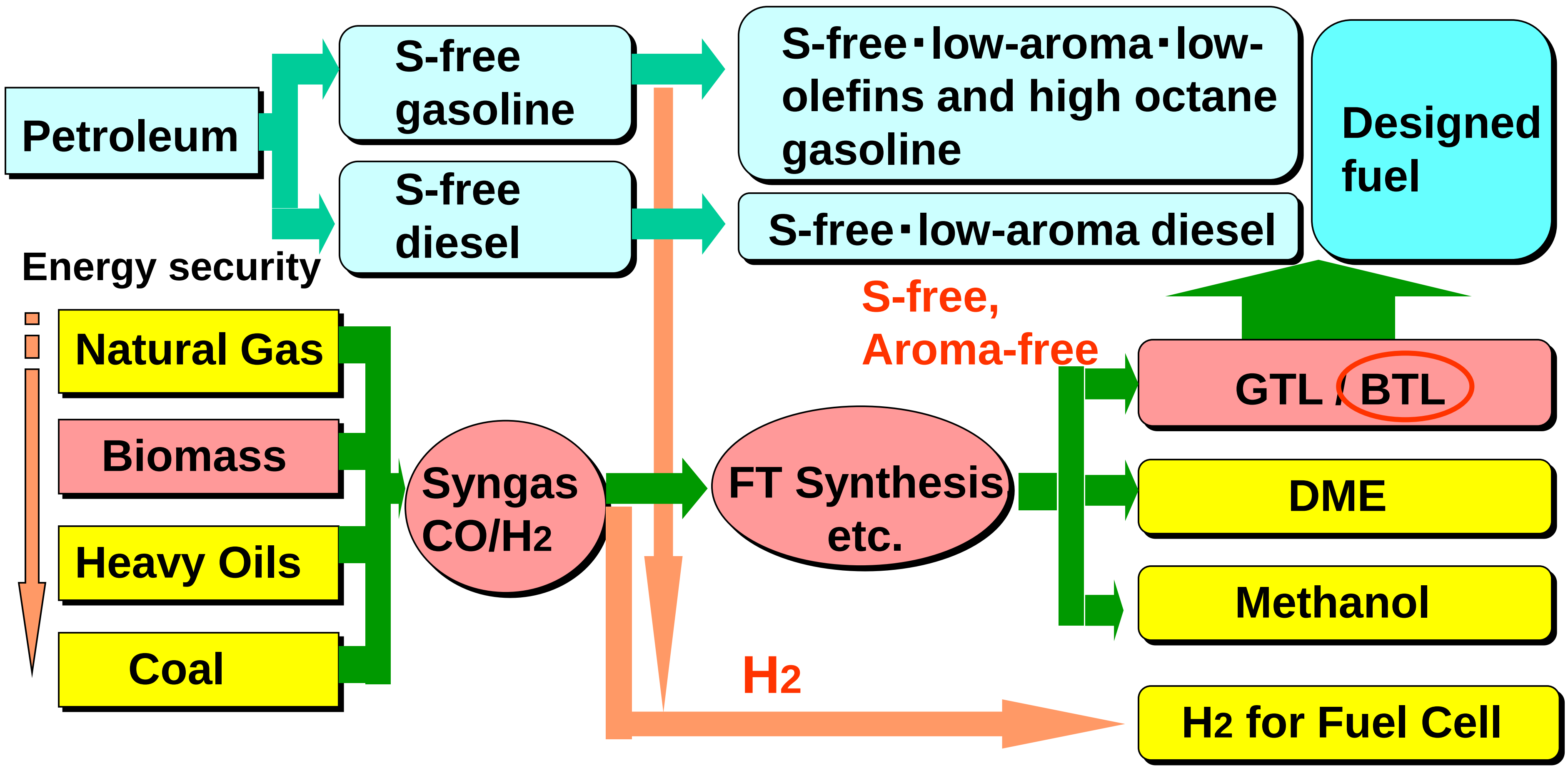
2000-2010
Fuel technologies for urban environment

2010-2020
Fuel technologies for mini-minimizing fuel consumption

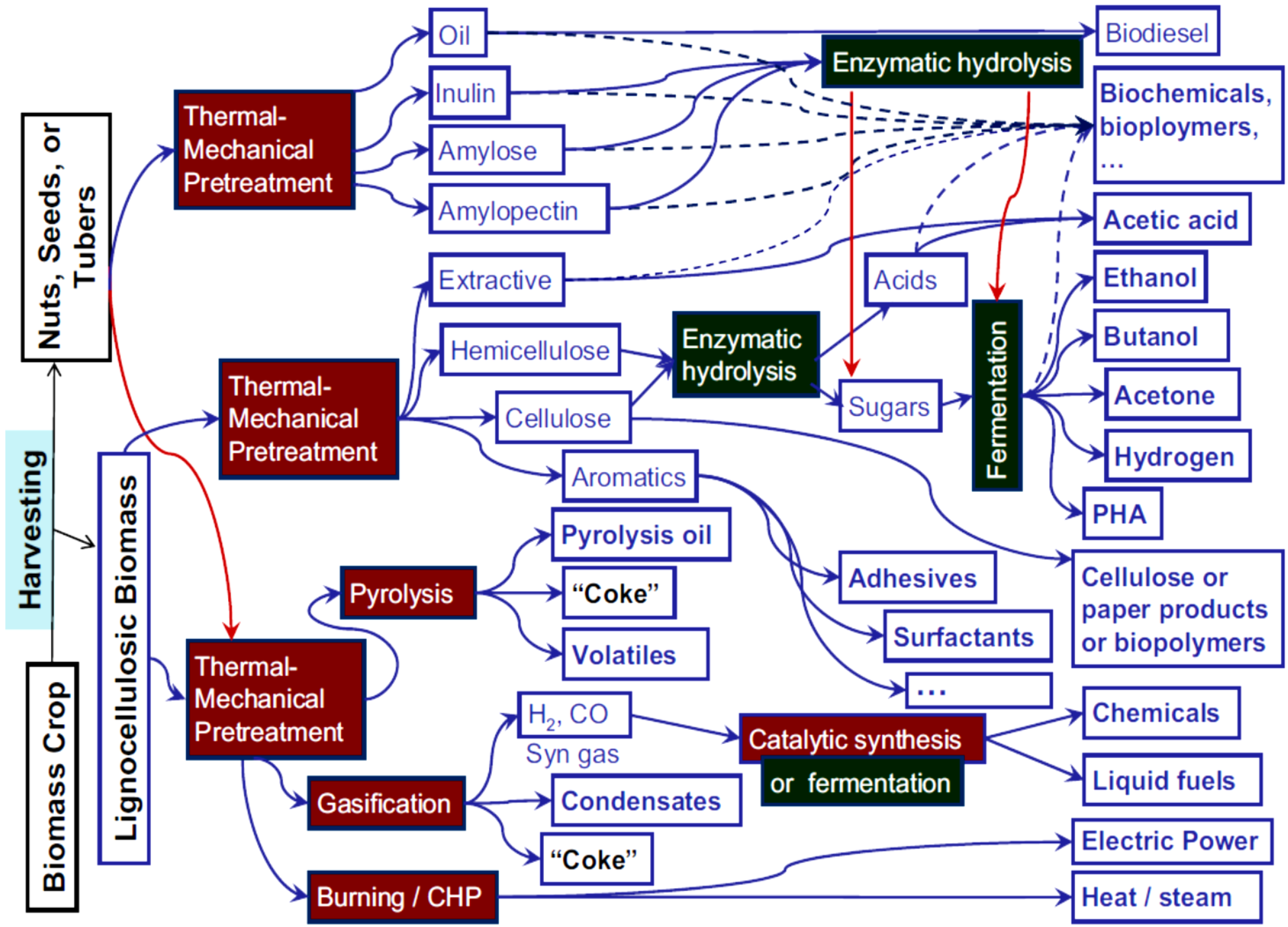
2020-

*PM,NOx reduction
*Advanced end-of-pipe technologies

*CO_2 reduction
*New engine system/new fuel



Overall Biomass Refinery Scheme



Principles of Biomass Refining Technology

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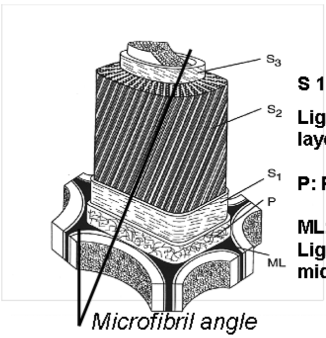
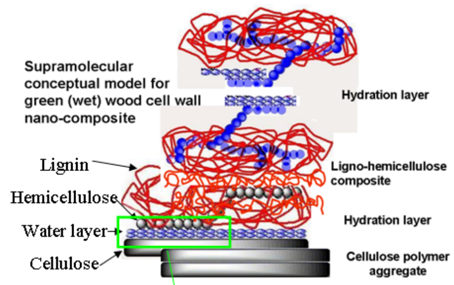
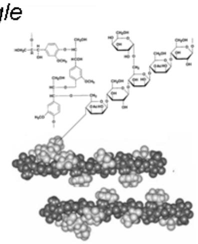
To overcome "Biomass Recalcitrance": responsible for the high cost of lignocellulose conversion.

Cell wall structure: Natural nanocomposite

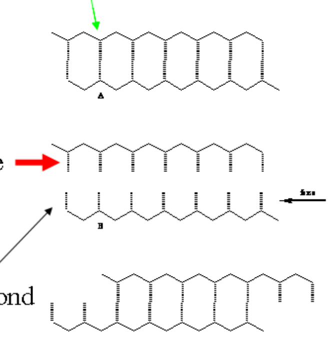
Supramolecular structure of cell wall







Conformational homology between cellulose and hemicellulose – strong non-covalent H-binding (Koshijima & Watanabe, 2003)

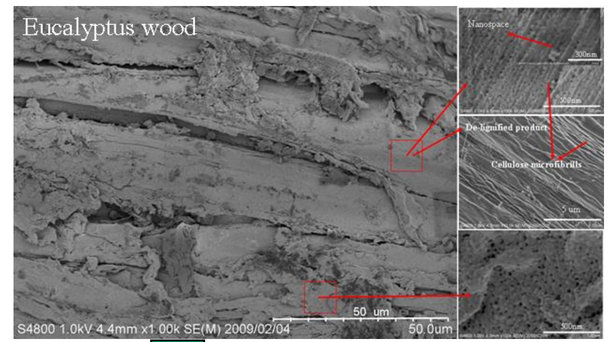


Low energy to break down hydrogen bond between structural water molecules

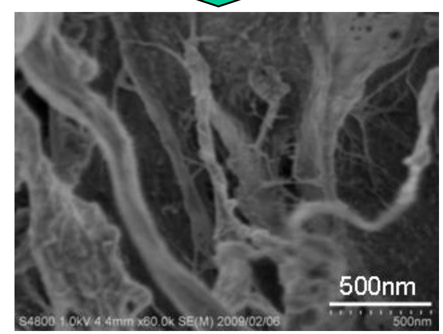
Robert Franich, Roger Newman & Stefan Hill

Ce

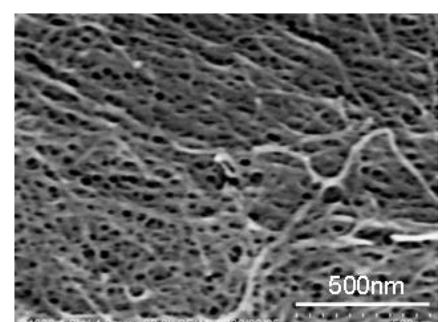
Nanospace formation between cellulose microfibrills by HCW treatment



Nanofibrillation by the combined method of HCW treatment and wet-milling process

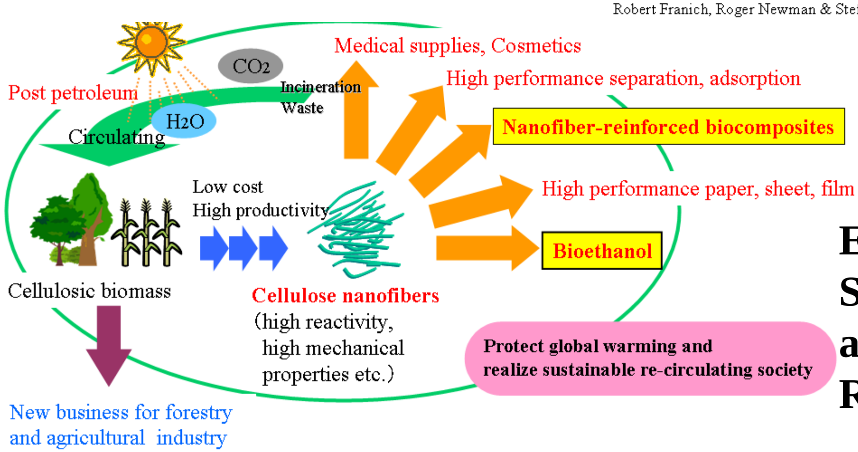


Morphology of the fibrillated products by wet-milling after the hot compressed water (HCW) treatment.



De-lignification of wet-milled product

Enzymatic Saccharification and Lignin Recovery



Strategy for Biomass Platform by Combined Bio- & Chemical- Processes

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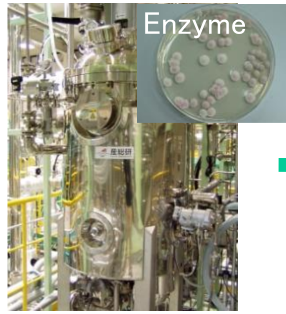
Nano-cellulose fiber production By hydrothermal and mechano-chemical pretreatments



Enzymatic Saccharification in high conc. solution

Fermentation by Innovative Bio-Processes

Alcohols (Butanol, Iso-butanol etc.)

Lactic Acid etc.

Functional and Value-added Products such as Bio-surfactants and Bio-materials

Woody Biomass

Biomass Refinery Technology

Bio-Process Conversion

Production of Biomass-derived Chemicals

Target 1 : Sugar Platform

Target 2 : Syn-Gas Platform

Syntheses of Bio-DME &Hydrocarbons

Catalytic Production of Bio-Chemicals

Gasification

H_2
CO
CO_2
N_2
H_2O
H_2S
COS
ダスト
タール

Syn-Gas

Gas Cleaning&Storage

Catalytic Reactions

Bio-DME & Intermediates

Bio-materials

Olefins such as propylene

Aromatics etc.

METI/NEDO's Current Projects of Biofuels

1. Element Technology Development for the 2nd Generation Biofuel

◆ Useful element technology development for biofuels

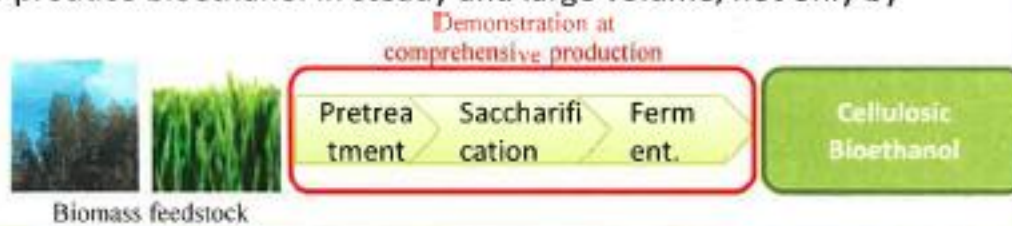
→ Aim to increase total productivity in integrated process of biofuel production from cellulosic biomass by developing and refining individual element technology such as improvement technology for plants growth and productivity in certain conditions, cutting-edge technology in saccharification and fermentation process, etc.

2. Development of Integrated Production System for the 2nd Generation Biofuel

◆ Development of an Innovative and Comprehensive Production System for Cellulosic Bioethanol

→ Aim to develop integrated production system to produce bioethanol in steady and large volume, not only by domestic production but by development import.

- ○improvement technology for feedstock cultivation, harvest, transport
- ○production technology demonstration at pilot plant
- ○study for sustainability of biofuels



3. R&D for the 3rd Generation Biofuels

◆ Strategic Development of Next-Generation Bioenergy Utilization Technology

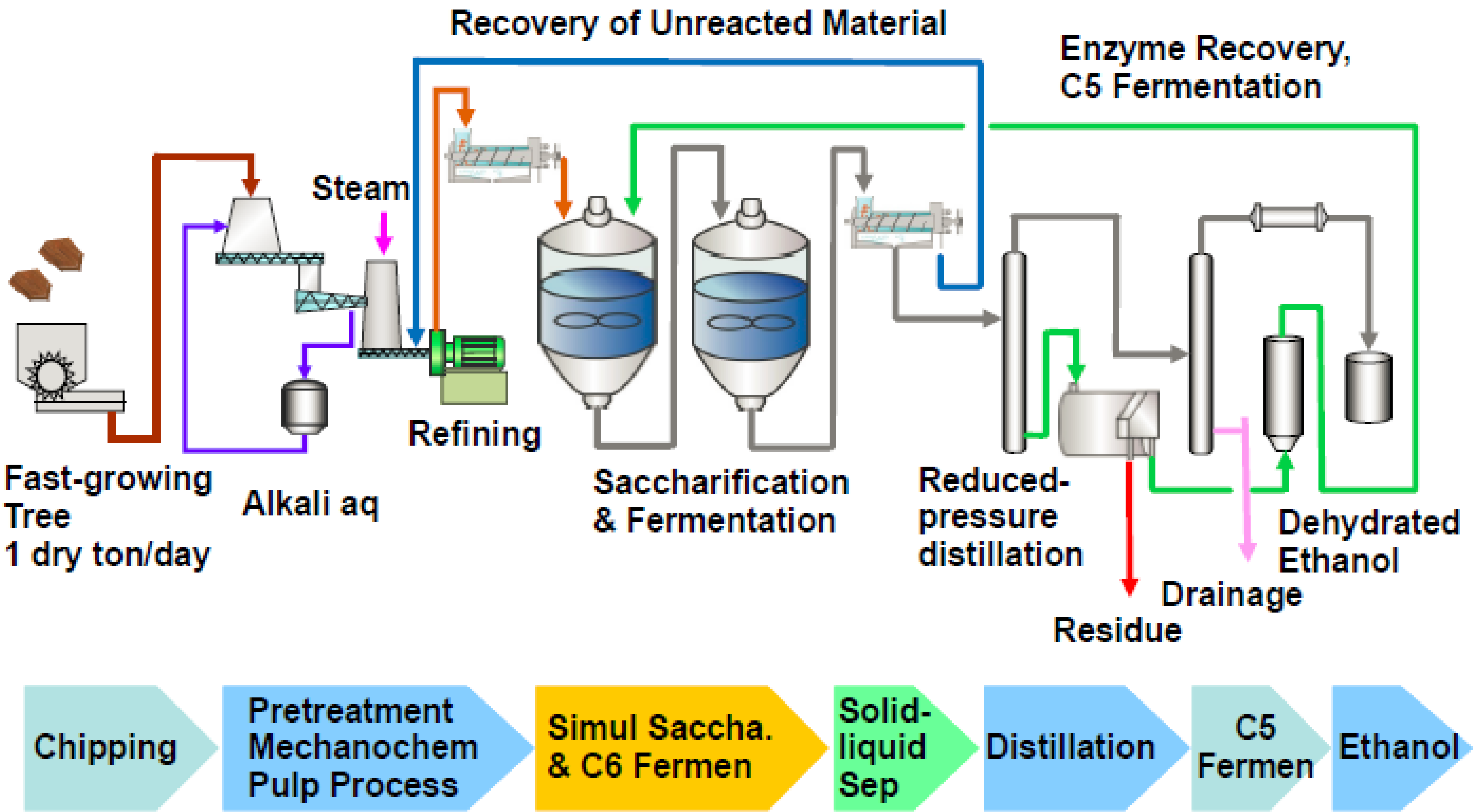
→ Aim to further broaden and diversify biofuel resources which do not compete with food supplies by conducting technology R&D on Microalgae-derived biofuel production, biomass gasification and liquefaction, etc.

- ○identify and develop high- oil producing strain
- ○high-efficiency culture, condensation, extraction technology

- ○low-cost gas refining technology
- ○high-efficiency synthesis/reforming technology in low pressure condition, etc.

NEDO Project 2

Dev of a Comprehensive Bioethanol Production System From Fast Growing Trees Using Mechanochemical Pulping



Achievements – Pilot Plant in Hiroshima, Japan –

Development of a Comprehensive Bioethanol Production System From Fast Growing Trees Using Mechanochemical Pulping

Biomass System Analysis and Simulation

To establish economically feasible process for large-scale biomass conversion;

1. To develop biomass system simulation technology,
   Ground database (DB) should be constructed.
2. To design economic feasible total system for biomass.

The simulator can be used for optimization, economic & environmental analysis.

INPUT

Wood DB
- Structures
- Molecules
- Elements
- …..

Cost DB
- Devices
- Processes
- Products
- …..

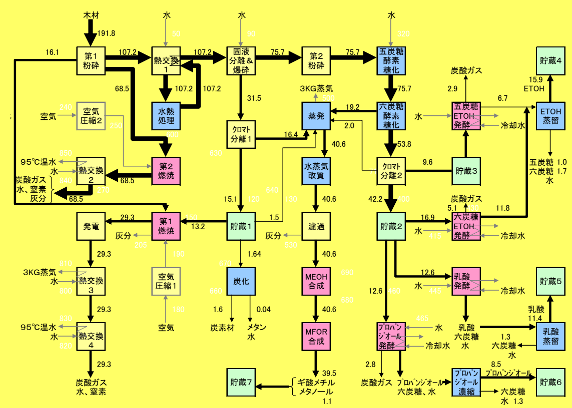
Thermo DB
- Calorie
- Moisture
- Enthalpy
- Entropy
- …..

Process DB
- Separation
- Fermentation
- Chemical
- Thermal
- …..

→ **Simulation**

Analysis
- Mass & energy analysis
- Cost analysis

Ex.: Process model for ETBE & BTL



→ **OUTPUT**

- Carbon balance
- Energy balance
- Efficient

- Impact (LCA)
- Economics

- Cost recovery

System simulation of BTL process

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Steam reforming

$WOOD + H_2O \rightarrow$

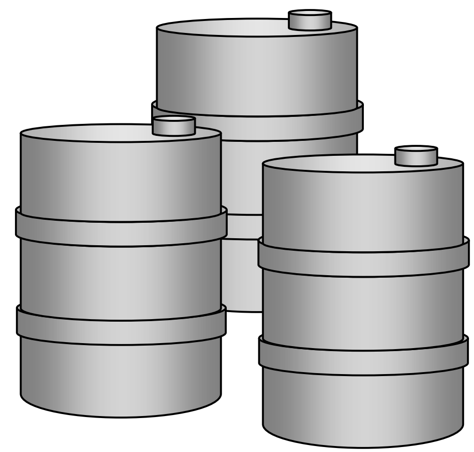
$H_2 + CO + CO_2 + CH_4 + HCs$

$+ Tar + Char$

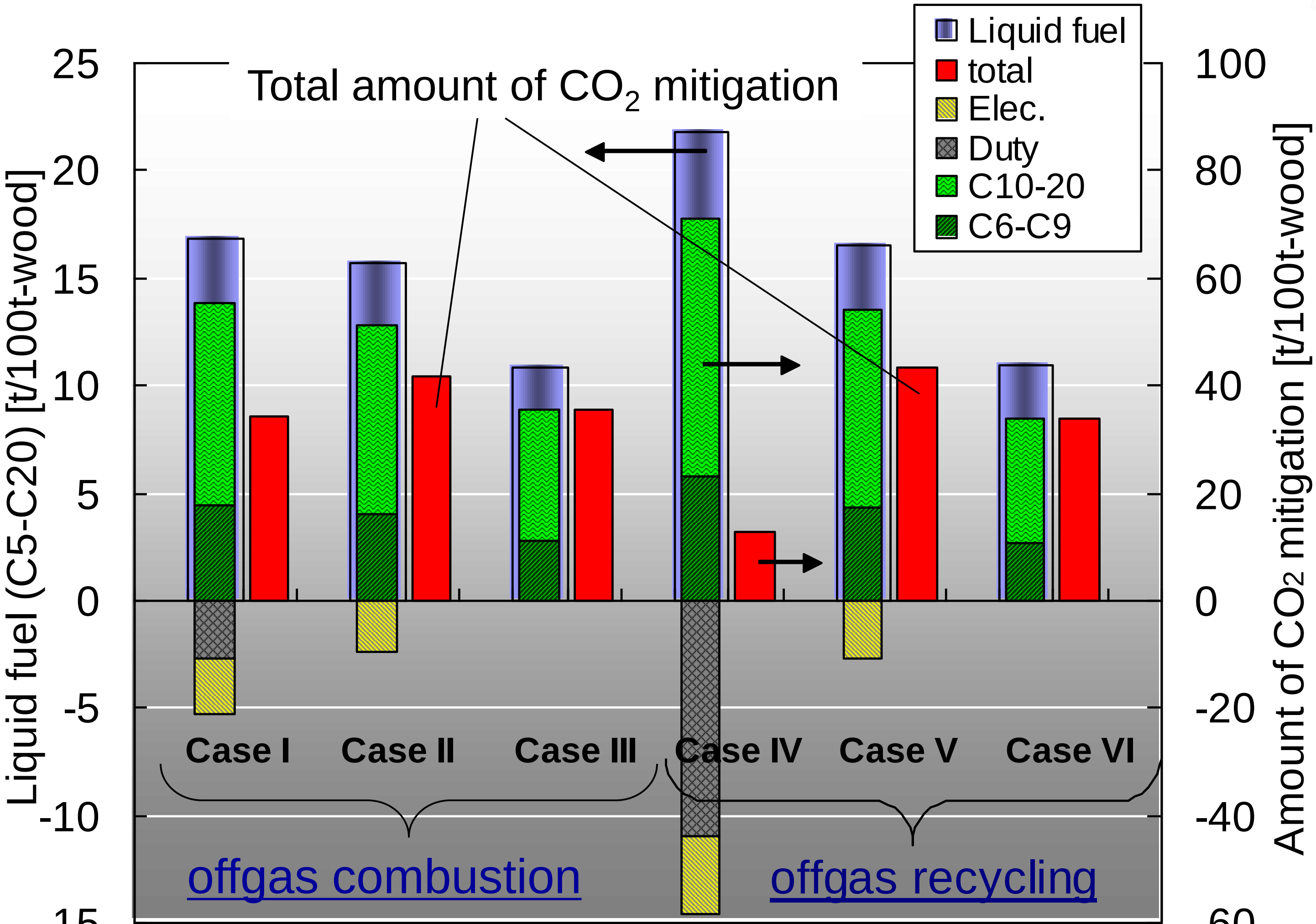
Fischer-Tropsch(FT) synthesis

$nCO + (2n+1)H_2 \rightarrow C_nH_{2n+2} + nH_2O$ (paraffin)

$nCO + 2nH_2 \rightarrow C_nH_{2n} + nH_2O$ (olefin)



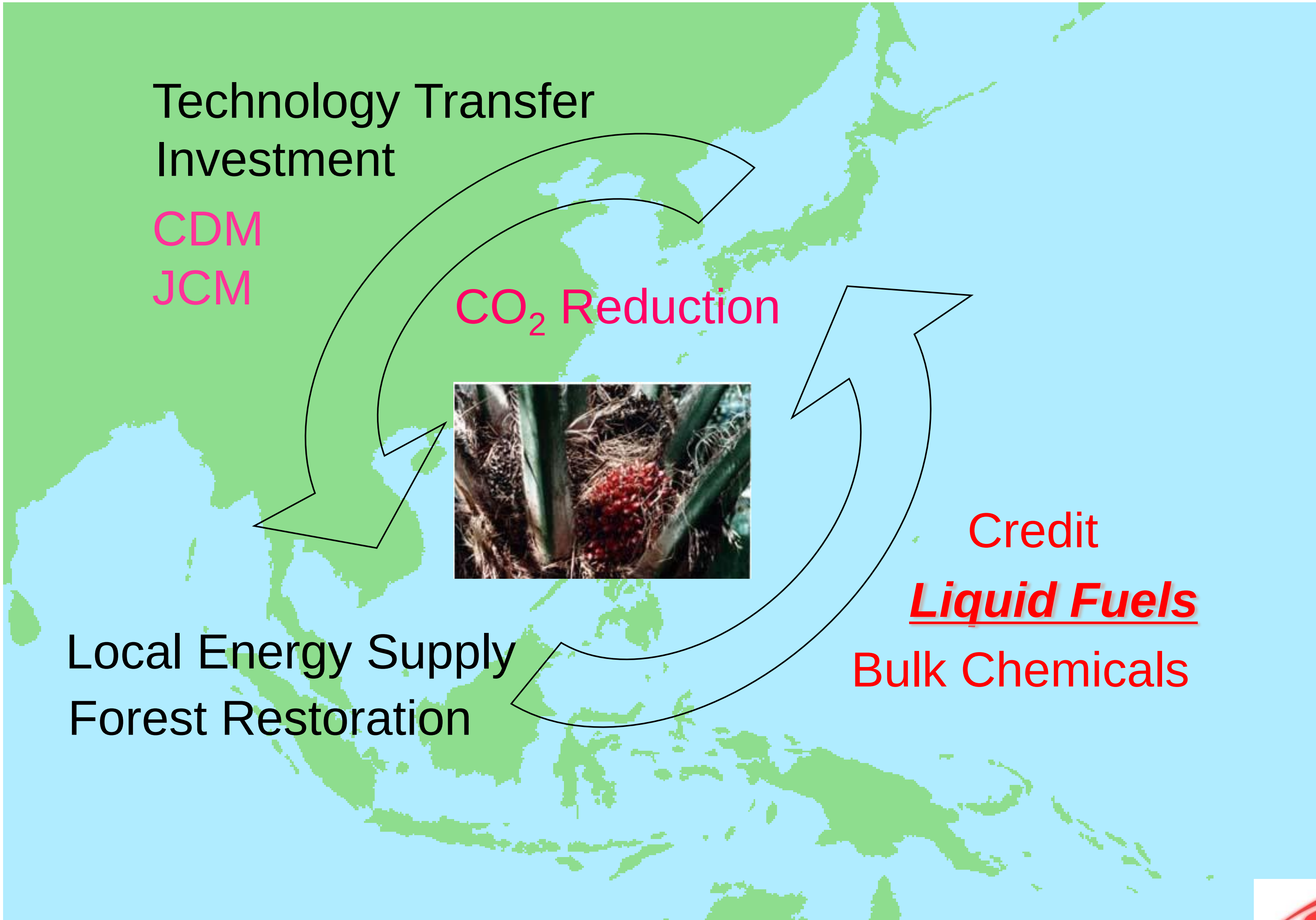
BTL liquid fuel



■/■ CO_2 mitigation t-CO_2 /kL-product	1.60	2.11	2.584	0.466	2.06	2.45

without fossil fuel

Effective Utilization of Biomass with Asian Partners



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Thank you !

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