Solid waste management: Do biorefineries offer sustainability for crop wastes management?

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This lecture will cover:

- **Introduction - Centre for Biofuels, CSIR-NIIST & CSIR-IITR**
- **World energy scenario- consumption vis-à-vis production**
- **Energy for transport sector**
  - **Biofuels as sustainable fuels for greener climate**
- **Lignocelluose biomass-based biorefinery for the production of biofuels**

C S I R   M I S S I O N

To conduct scientific and industrial R&D that maximizes the economic, environmental and societal benefits for the people of India.

Map of India indicating locations of CSIR institutes

AMPRI	Advanced Materials and Processes Research Institute Bhopal-462 026, www.ampri.res.in
CBRI	Central Building Research Institute, Roorkee-247 667 www.cbri.org
CCMB	Centre for Cellular and Molecular Biology Hyderabad-500 007, www.ccmb.res.in
CDRI	Central Drug Research Institute, Lucknow-226 001 cdriindia.org
CECRI	Central Electrochemical Research Institute Karaikudi-623 006, www.cecri-india.com
CEERI	Central Electronics Engineering Research Institute Pilani-333 031, www.ceeri.res.in
CFTRI	Central Food Technological Research Institute Mysore-570 020, www.cftri.com
CGCRI	Central Glass and Ceramic Research Institute Kolkata-700 032, www.cgcri.res.in
CIMAP	Central Institute of Medicinal & Aromatic Plants Lucknow-226 015, www.cimap.res.in
CIMFR	Central Institute of Mining & Fuel Research Dhanbad-828 108, www.cmriindia.nic.in
CLRI	Central Leather Research Institute, Chennai-600 020 www.clri.org
CMERI	Central Mechanical Engineering Research Institute Durgapur-713 209, www.cmeri.org
CRRI	Central Road Research Institute, New Delhi-110 020 www.crridom.org
CSIO	Central Scientific Instruments Organisation Chandigarh-160 030, www.csio.nic.in
CSMCRI	Central Salt & Marine Chemicals Research Institute Bhavnagar-364 002, www.csmcri.org
IGIB	Institute of Genomics & Integrative Biology Delhi-110 007, www.igib.res.in
IHBT	Institute of Himalayan Bioresource Technology Palampur-176 061 (HP), www.ihbt.org
IICB	Indian Institute of Chemical Biology Kolkata-700 032, www.iicb.res.in
IICT	Indian Institute of Chemical Technology Hyderabad-500 007, www.iictindia.org
IIIM	Indian Institute of Integrative Medicine Jammu-180 001, www.iiim.org
IIP	Indian Institute of Petroleum, Dehradun-248 005 www.iip.res.in
IMMT	Institute of Minerals and Materials Technology Bhubaneshwar-751 013, www.rrlbhu.res.in
IMTECH	Institute of Microbial Technology, Chandigarh -160 036 www.imtech.res.in
IITR	Indian Institute of Toxicology Research Lucknow-226 015, www.itrcindia.org
NAL	National Aerospace Laboratories, Bangalore-560 017 www.nal.res.in
NBRI	National Botanical Research Institute Lucknow-226 001, www.nbri-lko.org
NCL	National Chemical Laboratory, Pune-411 008 www.ncl-india.org
NEERI	National Environmental Engineering Resarch Institute Nagpur-440 020, www.neeri.nic.in
NEIST	North-East Institute of Science and Technology Jorhat-785 006, www.neist.res.in
NGRI	National Geophysical Research Institute Hyderabad-500 007, www.ngri.org.in
NIO	National Institute of Oceanography, Goa-403 004 www.nio.org
NIIST	National Institute for Interdisciplinary Science and Technology, Thiruvananthapuram-695 019 www.niist.csir.res.in
NISCAIR	National Institute of Science Communication And Information Resources, New Delhi-110012 www.niscair.res.in
NISTADS	National Institute of Science Technology And Development Studies, New Delhi-110012 www.nistads.res.in
NML	National Metallurgical Laboratory, Jamshedpur-831 007 www.nmlindia.org
NPL	National Physical Laboratory, New Delhi-110 012 www.nplindia.org
SERC	Structural Engineering Research Centre Chennai-600 113, www.sercm.org

India's largest R &D organization with 38 laboratories, 50 field stations and with 17000 employees

C S I R

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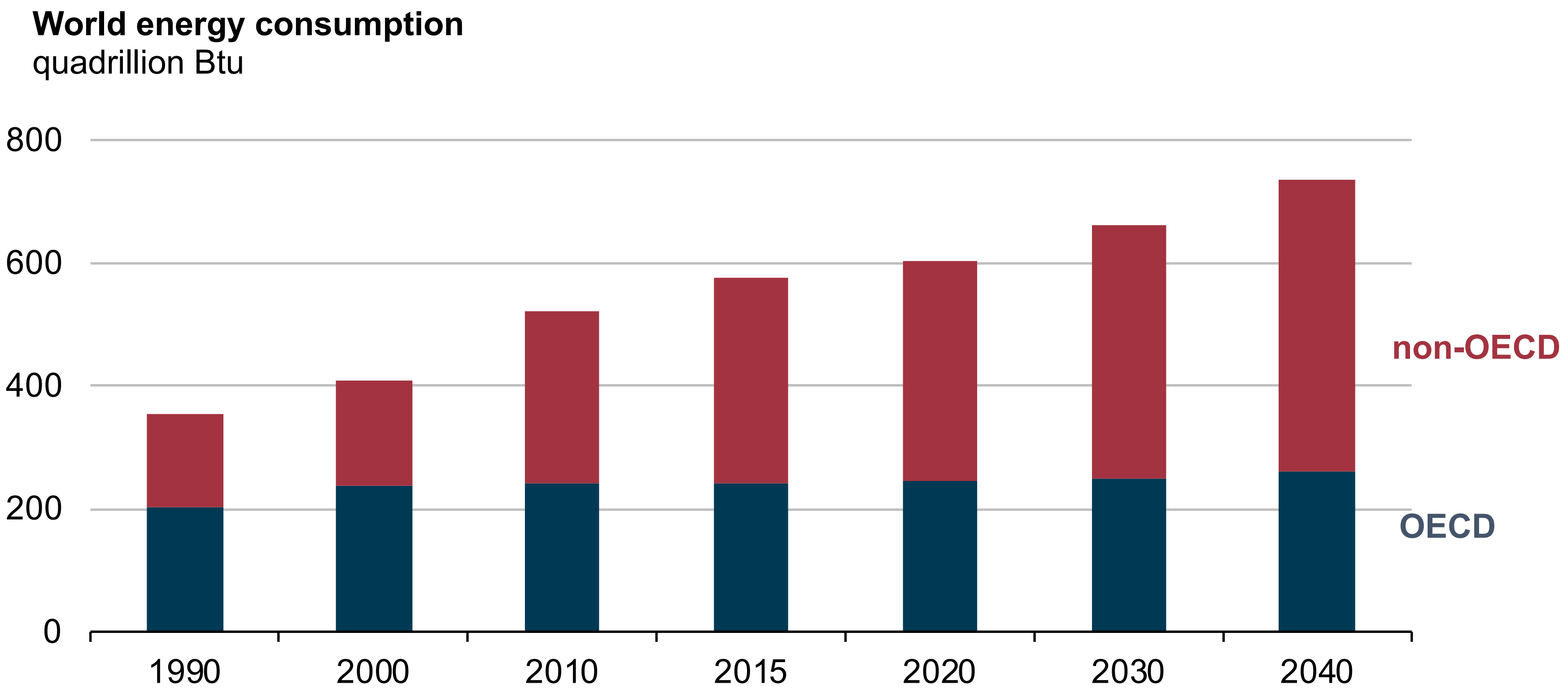
CSIR- Indian Institute of Toxicology Research

CSIR- National Institute for Interdisciplinary Science and Technology

World Energy Scenario

World energy consumption rises 28% between 2015 and 2040



—with most of the increase occurring in non-OECD countries

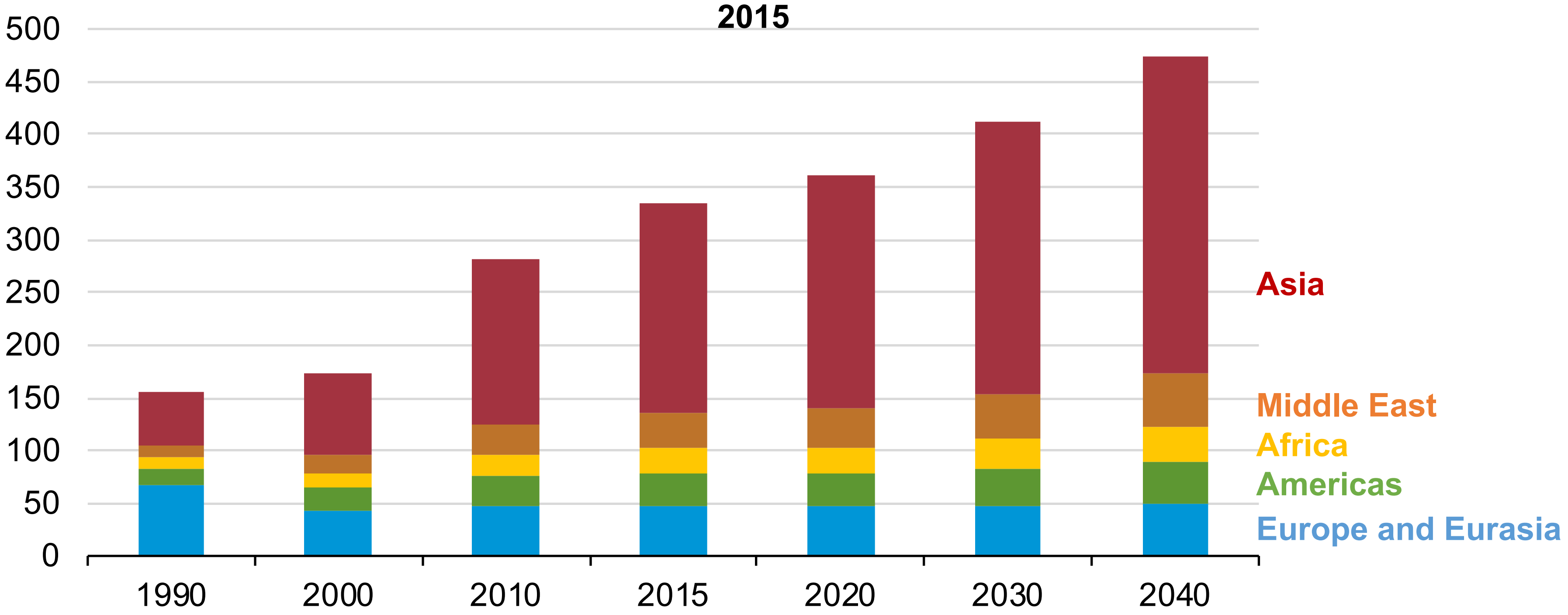
•World energy consumption increases from 575 quadrillion British thermal units (Btu) in 2015 to 663 quadrillion Btu by 2030 and then to 736 quadrillion Btu by 2040.

•Most of the increase in energy demand is expected to come from non-OECD countries, where strong economic growth, increased access to marketed energy, and quickly growing populations lead to rising demand for energy.

•Energy consumption in non-OECD countries would increase 41% between 2015 and 2040 in contrast to a 9% increase in OECD countries.

Asia accounts for most of the increase in energy use in non-OECD regions

- **Non-OECD energy consumption by region**
- quadrillion Btu



—but there is substantial growth in other regions

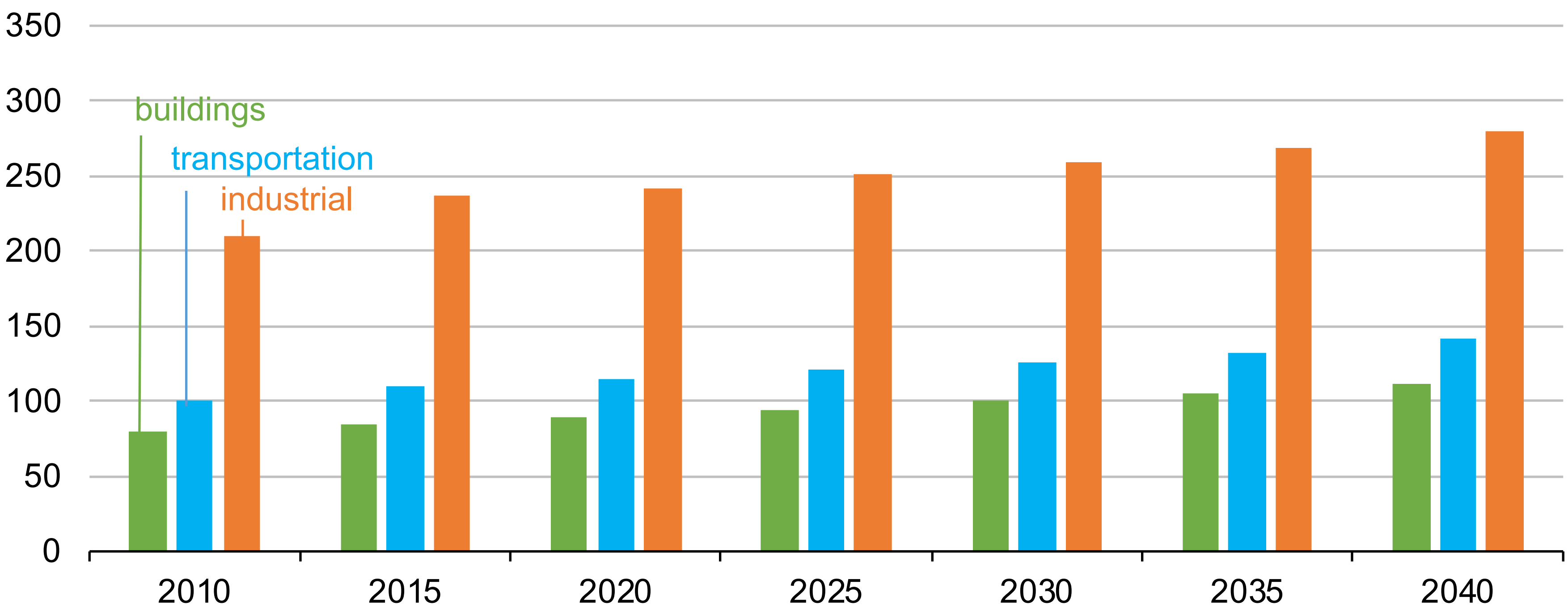
•More than half of the projected increase in global energy consumption occurs in non-OECD Asia, a region that includes China and India. Energy demand in non-OECD Asia is projected to increase by 51% (or by 102 quadrillion Btu) during the period of 2015–40. While much slower than the nearly 30% increase in energy use from 1990 to 2015, the projected growth in non-OECD Asia energy use still represents the largest regional growth in the world.

•Non-OECD regions outside of Asia are also projected to contribute to substantial increases in energy demand. Fast-paced population growth and access to ample domestic resources are both important determinants of energy demand in Africa and the Middle East, where energy use is expected to increase 51% and 45%, respectively, between 2015 and 2040.

•The smallest projected increase in energy demand is 2% in non-OECD Europe and Eurasia. Much of the low growth is related to Russia, where the population is expect to decline over the projection, and significant gains in energy efficiency are achieved by replacing older physical assets with more efficient ones.

The industrial sector continues to account for the largest share of energy consumption through 2040

•World energy consumption by end-use sector
quadrillion Btu



—but energy use in all other end-use sectors is projected to grow more quickly

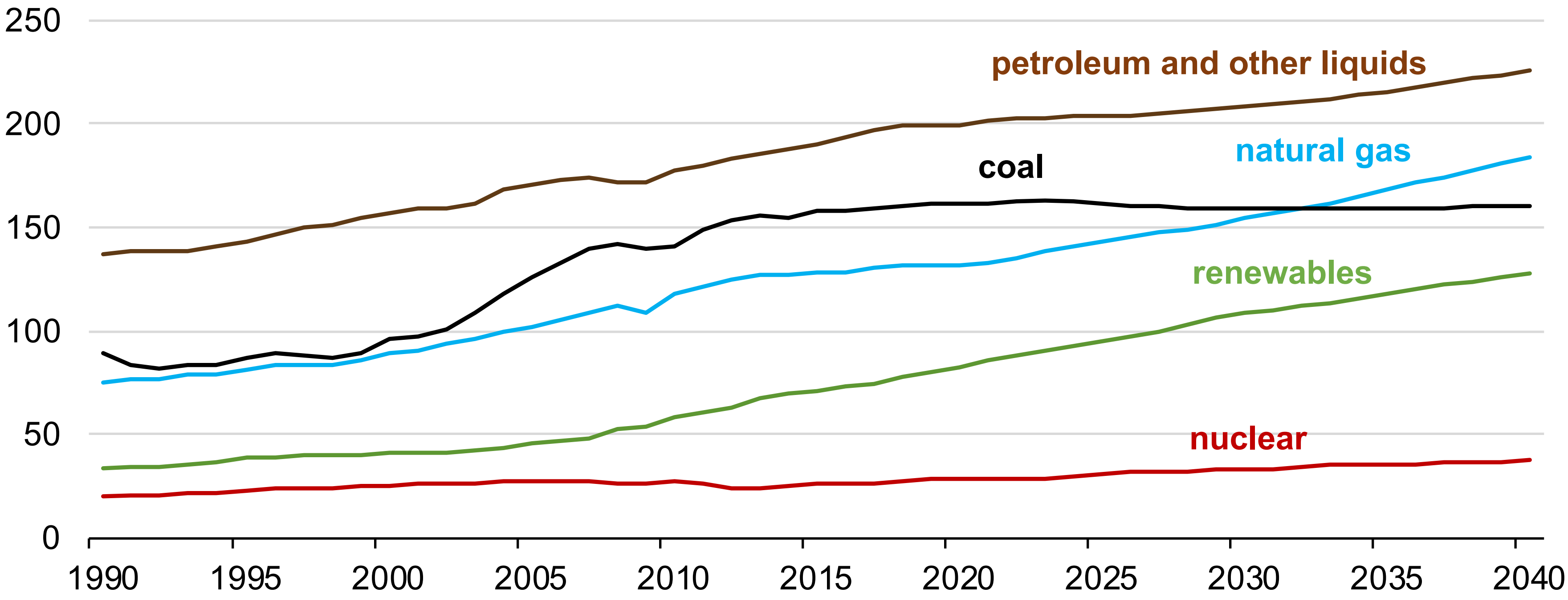
•The industrial sector, which includes mining, manufacturing, agriculture, and construction, accounts for the largest share of energy consumption of any end-use sector, accounting for more than 50% over the entire projection period. World industrial sector energy use increases by 18% from 2015 to 2040, reaching 280 quadrillion Btu by 2040.

•Although the industrial sector remains the world's largest energy-consuming sector throughout the projection period, energy demand in all other sectors grows more quickly than in the industrial sector in the Reference case. World industrial sector energy use rises by 0.7%/year from 2015 to 2040, compared with an increase of 1.0%/year for transportation and 1.1%/year for buildings.

•Most of the industrial sector energy use increase (89%) occurs in non-OECD nations. Industrial sector energy use in non-OECD countries grows by 0.8%/year in the Reference case compared with an increase of 0.2%/year in OECD countries..

Energy consumption increases over the projection for all fuels other than coal

- **World energy consumption by energy source**
- quadrillion Btu



—with renewables being the fastest-growing energy source

•Use of all fuels except coal grows throughout. Although renewable energy and nuclear power are the world's fastest growing forms of energy, fossil fuels are expected to continue to meet much of world's energy demand.

•Petroleum and other liquids remains the largest source of energy, but its share of world marketed energy will decline from 33% in 2015 to 31% in 2040. On a worldwide basis, liquids consumption increases in the industrial and transportation sectors, and declines in the electric power sector.

•Natural gas is the world's fastest growing fossil fuel, increasing by 1.4%/year, compared with liquid's 0.7%/year growth and virtually no growth in coal use (0.1%/year).

•Compared with the strong growth in coal use in the early 2000s, worldwide coal use is projected to remain flat—with declines in OECD regions and China offsetting growth in India and the other non-OECD Asian nations. Coal is increasingly replaced by natural gas, renewables, and nuclear power (in the case of China) in electricity generation. Industrial demand for coal also weakens.

Energy and Transport

Transport is central to modern society and demand for transport energy is very large. Globally, it accounts for

- 14% of global GHG (CO_2, methane and nitrous oxide) emissions, 20% of total energy use, 23% of CO_2 emissions
- Currently over 1.1 billion light duty vehicles (LDVs) and 255 million commercial vehicles
- Over 4.8 billion liters each of gasoline and diesel and 1.2 billion liters of jet fuel each day
- LDVs account for ~44% of global transport energy demand

Petroleum and transport closely linked

- Transport is essentially driven by liquid fuels –high energy density, ease of transport and storage, extensive infrastructure
- 95% of transport energy from petroleum
- 60% of petroleum goes to transport fuels

Demand for transport energy is growing at an average annual rate of 1.4%

- In non-OECD countries

Greenhouse gases (GHG) and other pollutants

- GHG impact depends on how electricity is generated. In many parts of the world, certainly India and most of China BEVs will cause more GHG than ICEV.

- India has reiterated that 75% of its electricity will come from coal for decades to come. Even in the UK, if additional electricity required is not renewable, GHG will go up with increasing BEV numbers.

- PM2.5, NOx and SO_2 also will be worse with use of coal as source of power.

- Human Toxicity Potential –"All other secondary environmental measures pale in comparison with the potential impact BEVs have on human health. … the decision to drive a BEV instead of an ICEV essentially shifts the damage to human life caused by car ownership, from a relatively small impact more localized to the vehicle in the case of an ICEV, to a relatively large impact localized to the mineral mine tailings in the case of a BEV…." http://www.adlittle.com/fileadmin/editorial_us/downloads/ADL_BEVs_vs_ICEVs_January_24_2017_USA.pdf

Biofuels as sustainable fuels to combat GHG emission

Main Drivers

- Import substitution/self reliance/security of supply
- Use for agricultural surpluses
- Bio-waste management
- Greenhouse gas credit (depends on assumptions)

Challenges

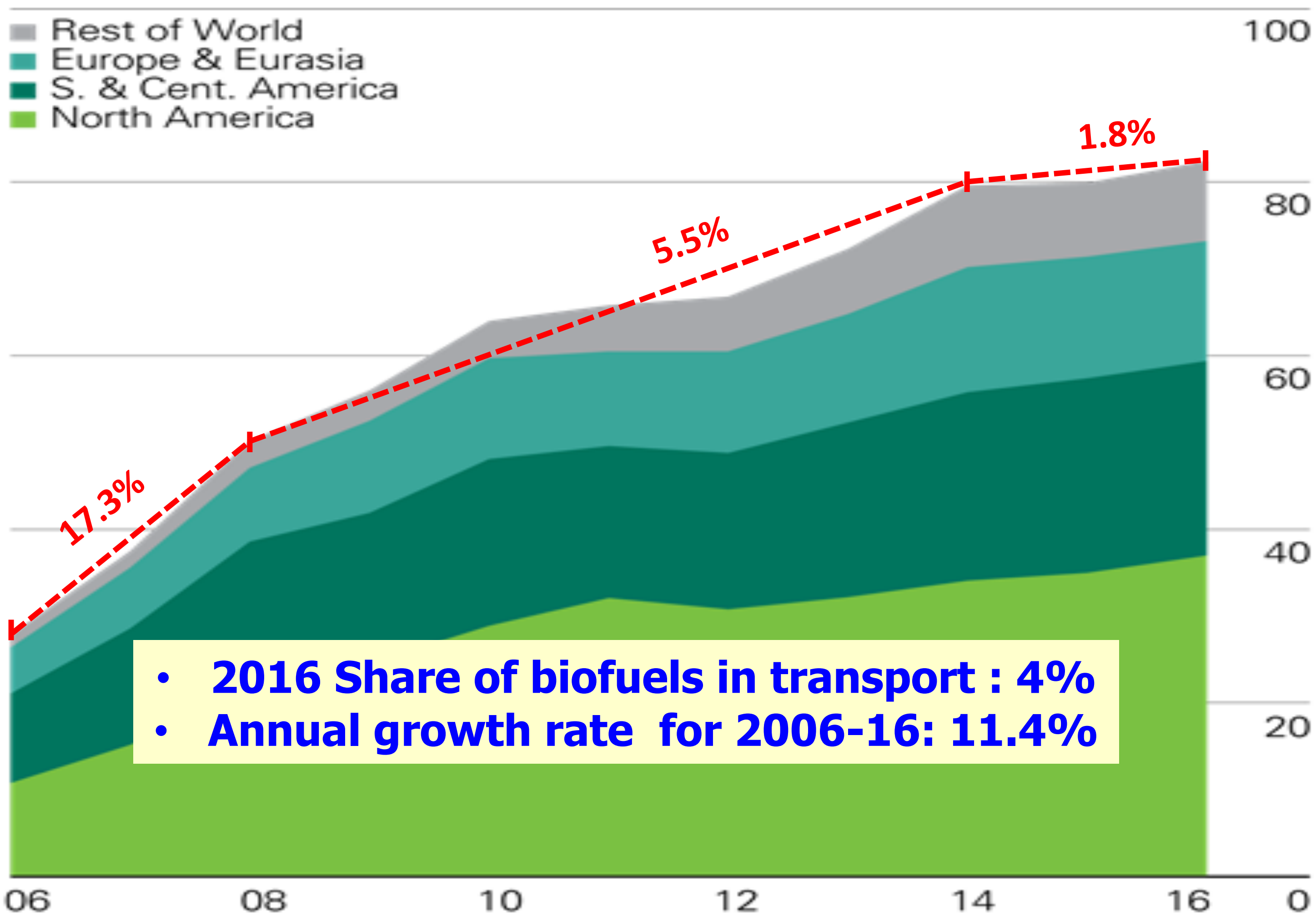
- Food vs Fuel - availability of land
- Higher costs per unit of energy
- Sustainability – deforestation, water and fertiliser use

Current Share

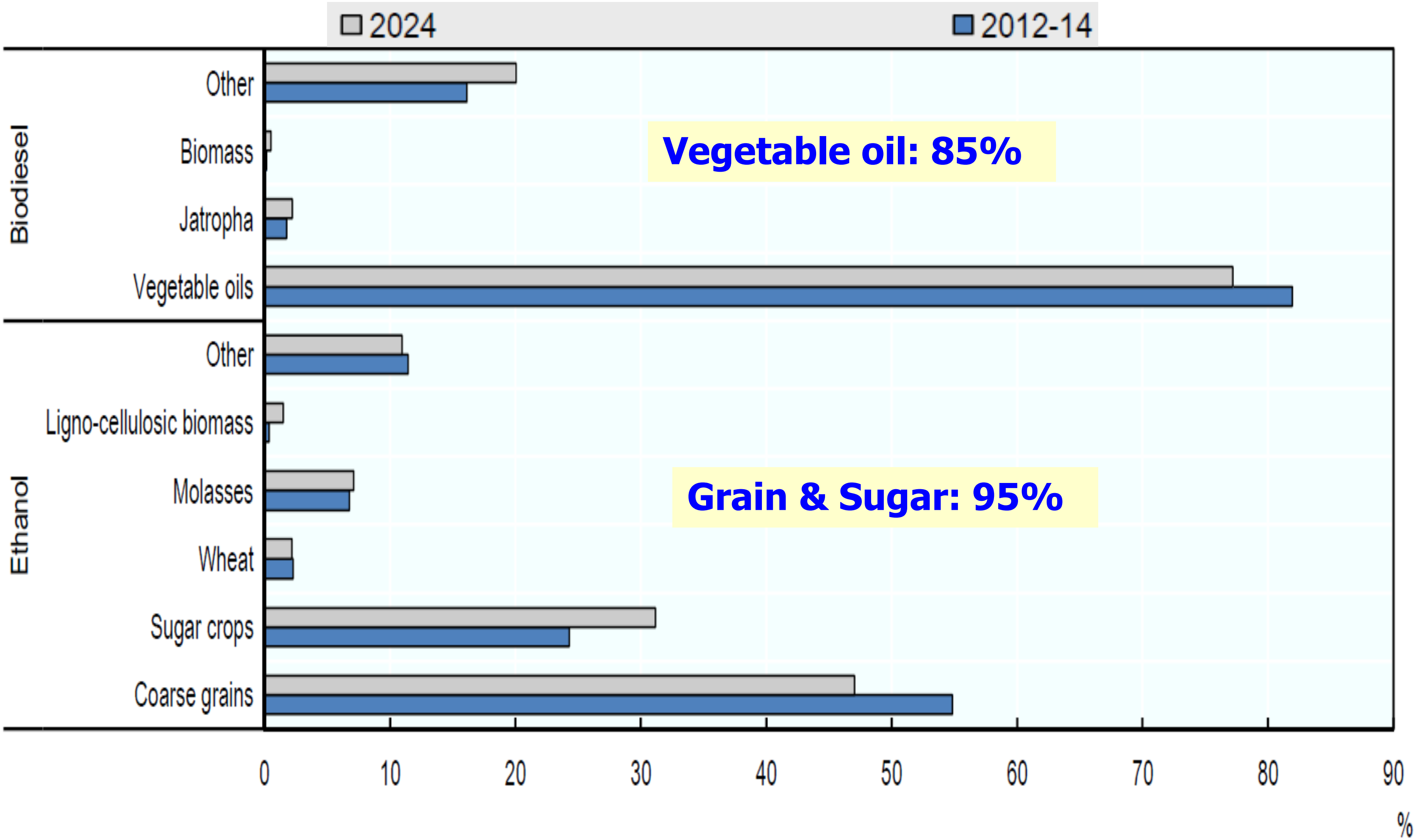
Around 2.0 % of transport energy demand. Primarily ethanol in gasoline (~100 billion liters per year)

World Biofuel Production

(BP Global, 2017)



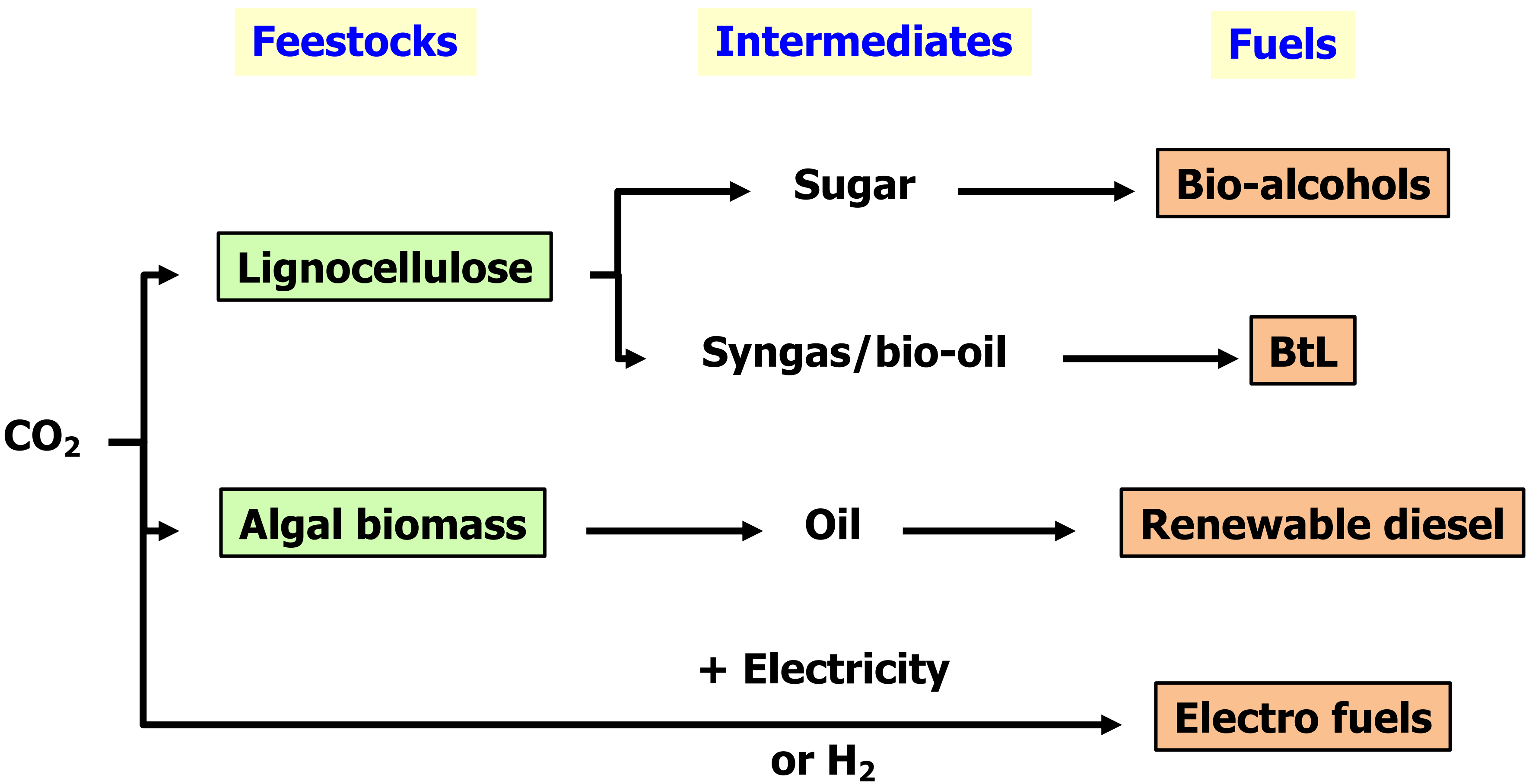
Share of Feedstocks for Biofuels
(OECD/FAO, 2015)



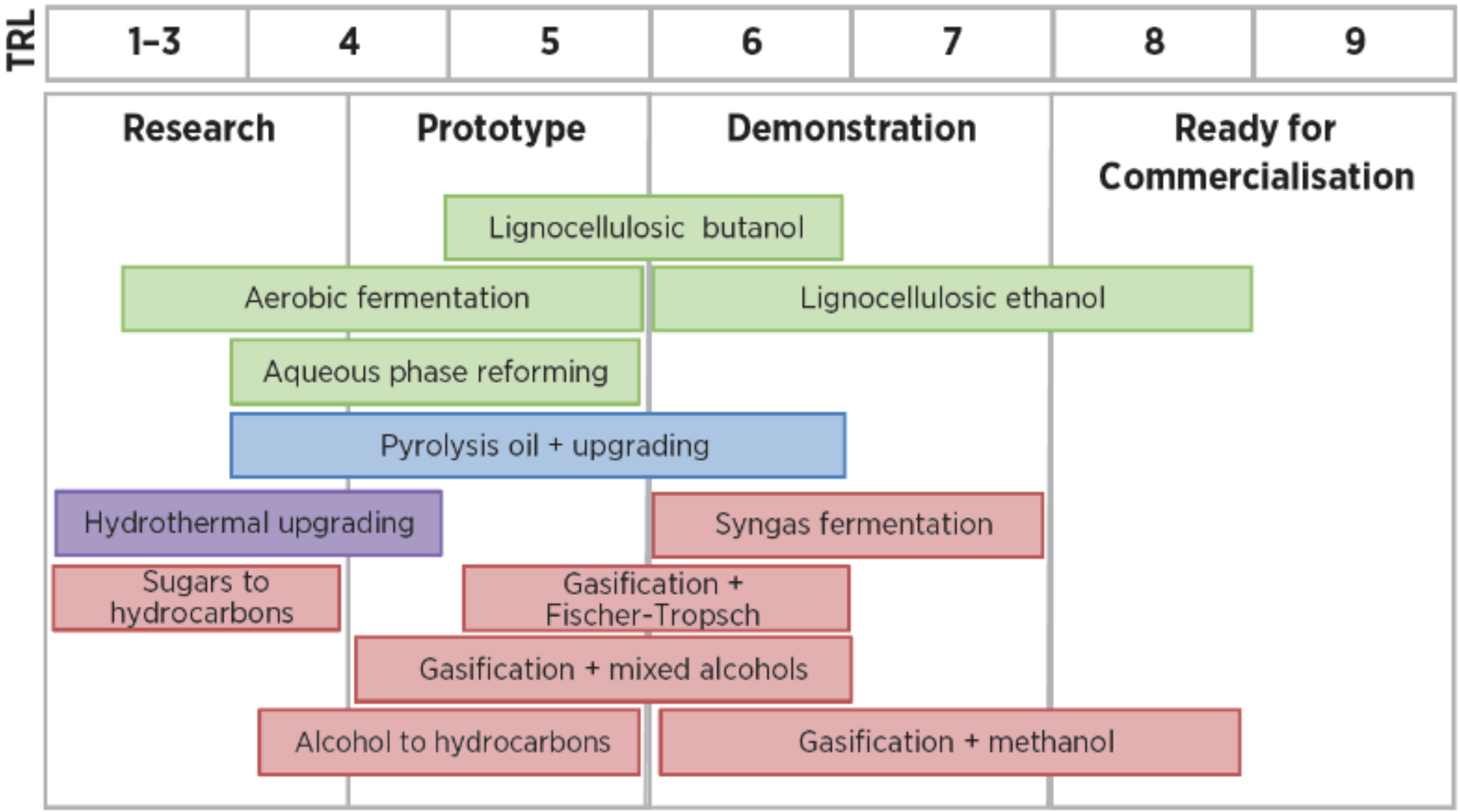
Issues for Conventional Biofuels

- **Shortage of feedstocks**
- **Low CO_2 reduction effect**
- **Blending limits (≤ 10% for ethanol, ≤ 20% for biodiesel)**
- **Only for road sector**

Major Paths for Advanced Biofuels

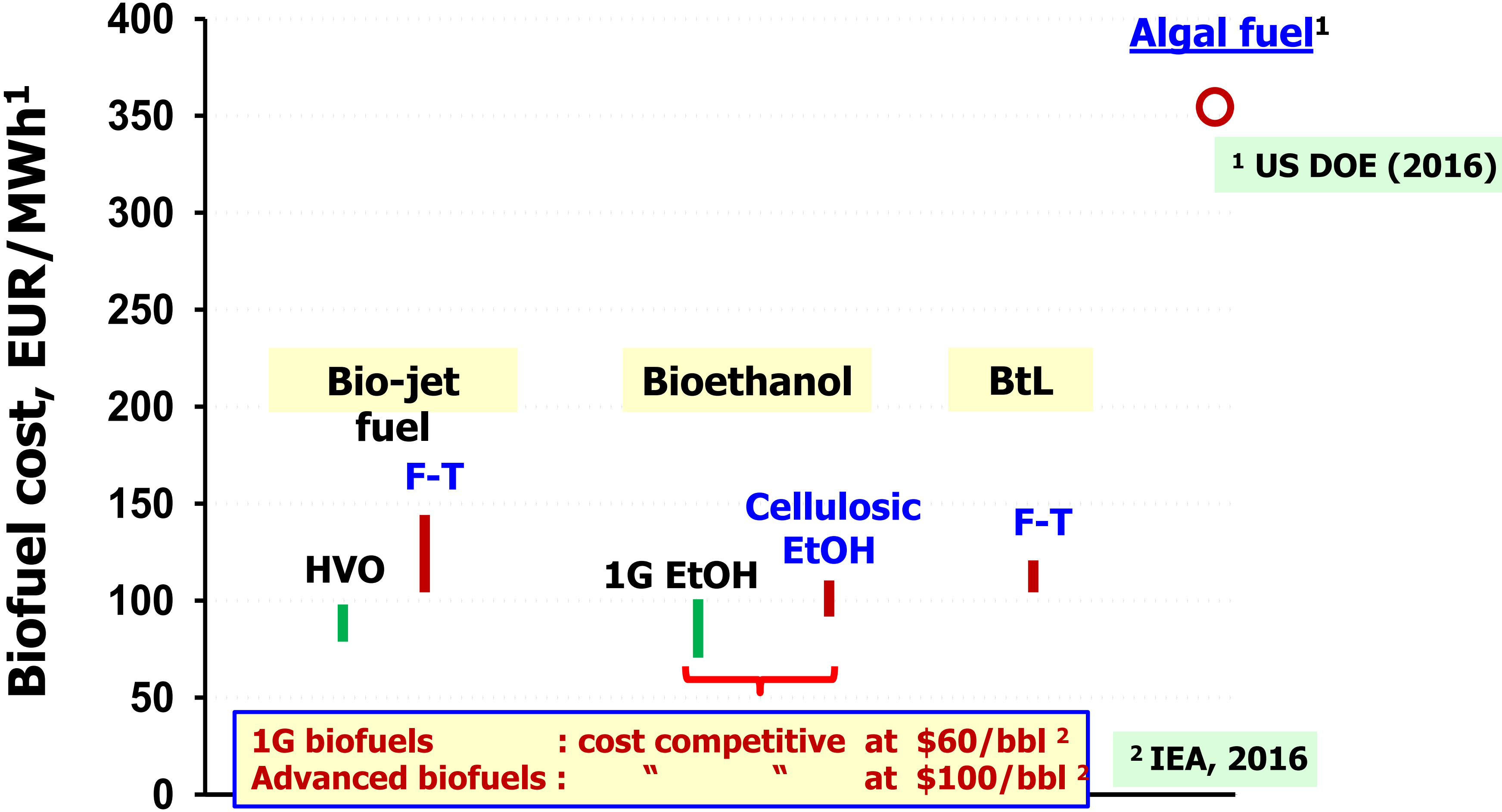


Status of Biofuels Technologies
(IRENA, 2016)



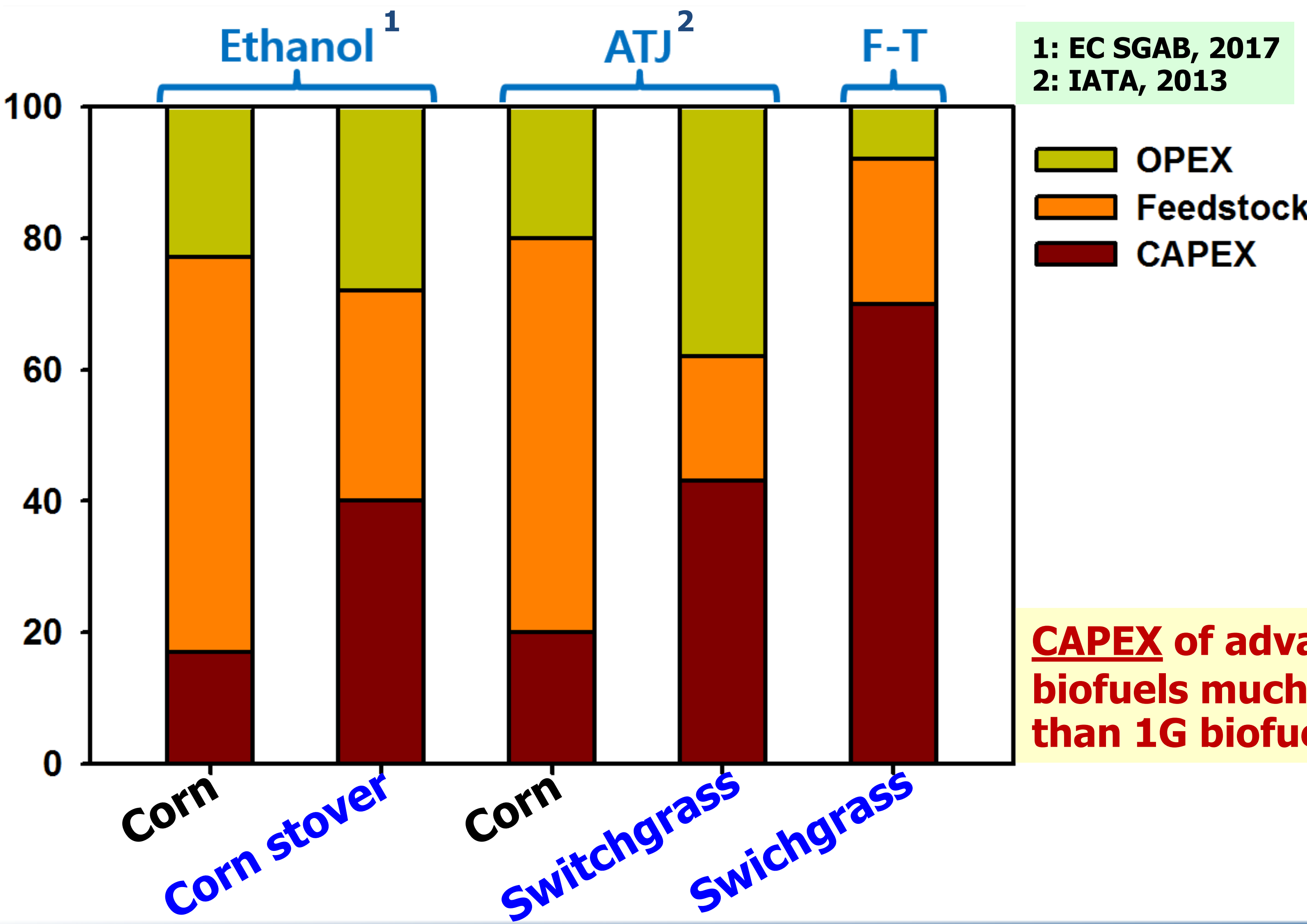
Production Costs of Biofuels

(EC SGAB, 2017)



[1](EUR/MWh)/3.6 = €/GJ

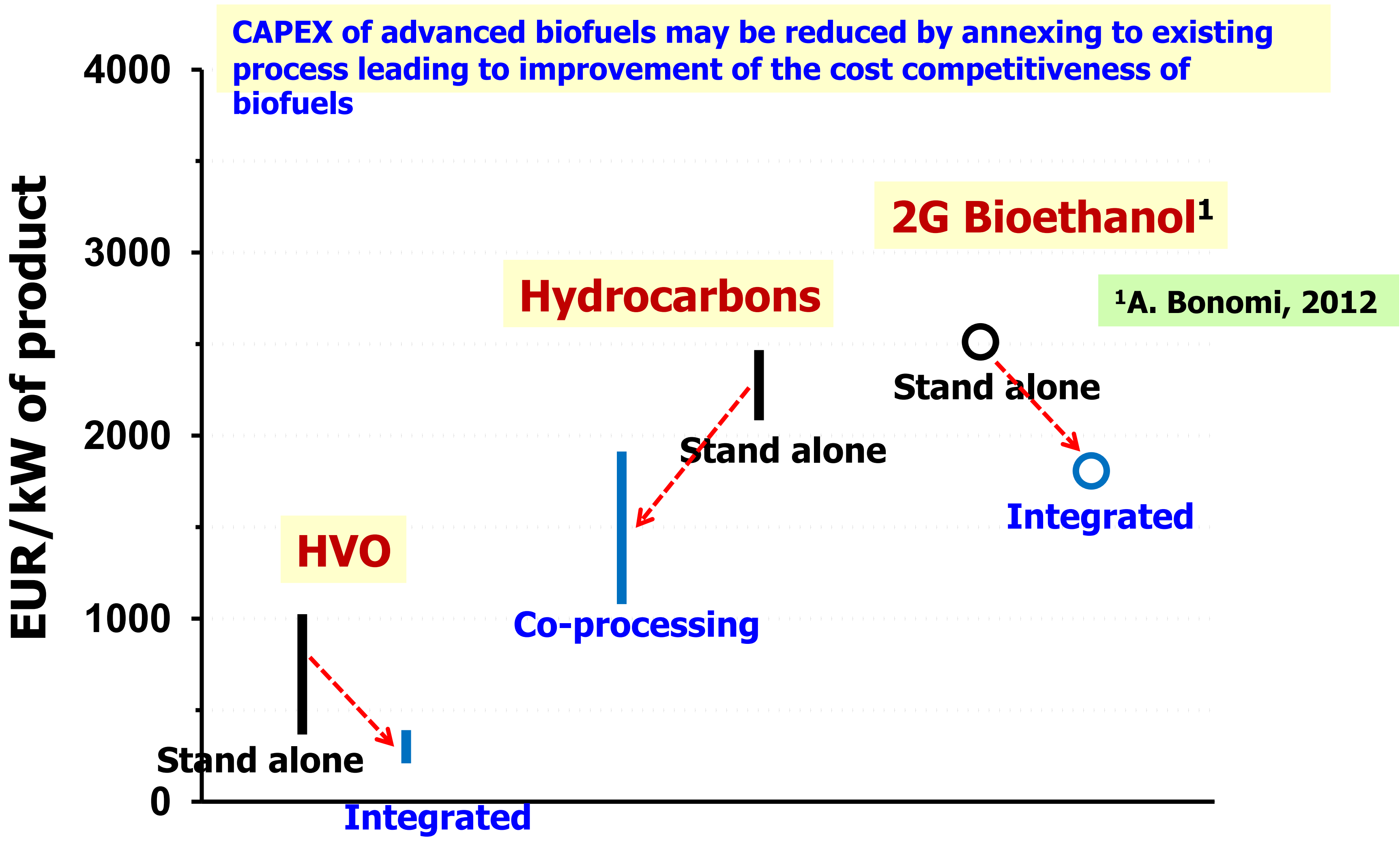
Contributions of Biofuels Costs



1: EC SGAB, 2017
2: IATA, 2013

<u>CAPEX</u> of advanced biofuels much higher than 1G biofuels

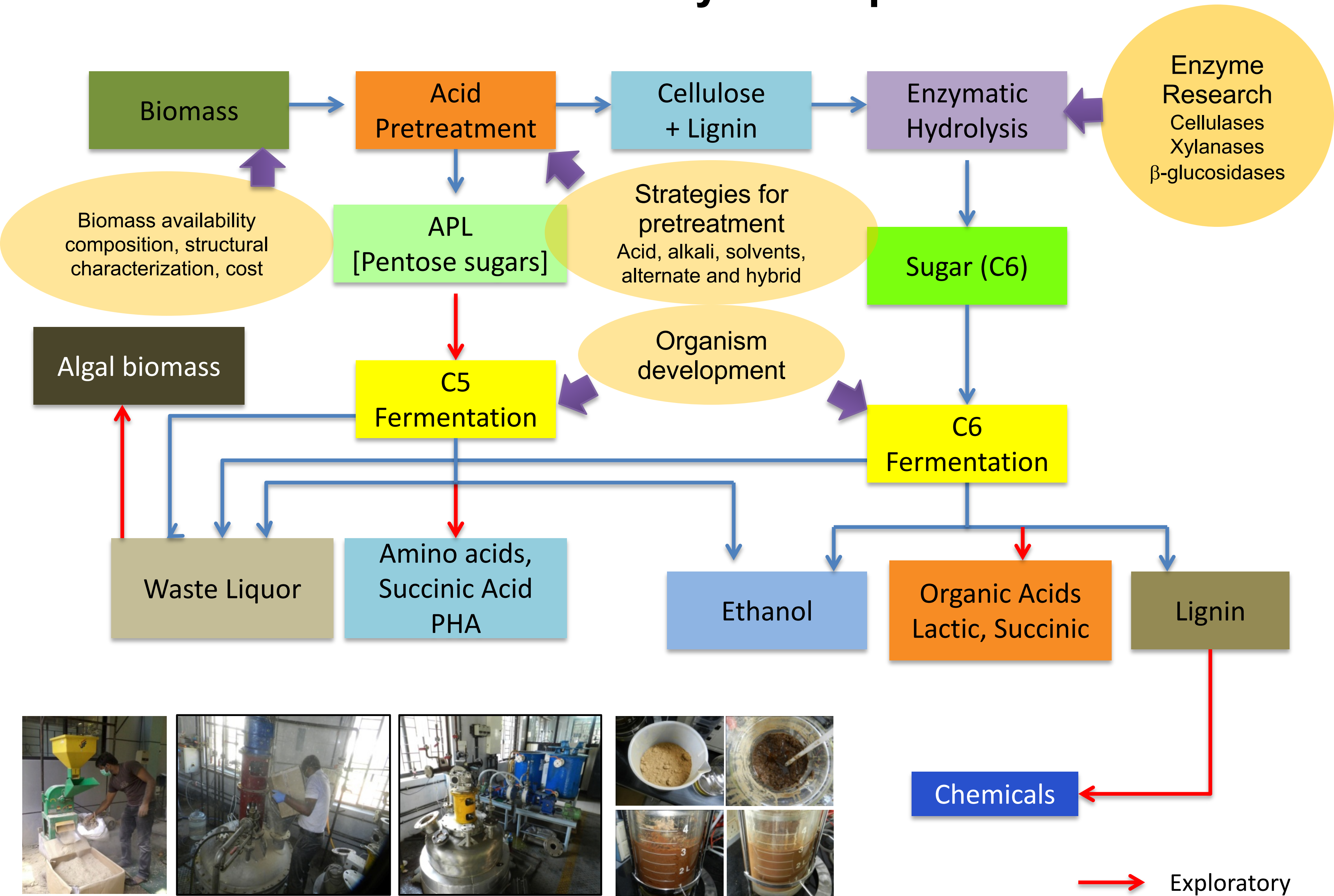
Investment Intensity
(EC SGAB, 2017)



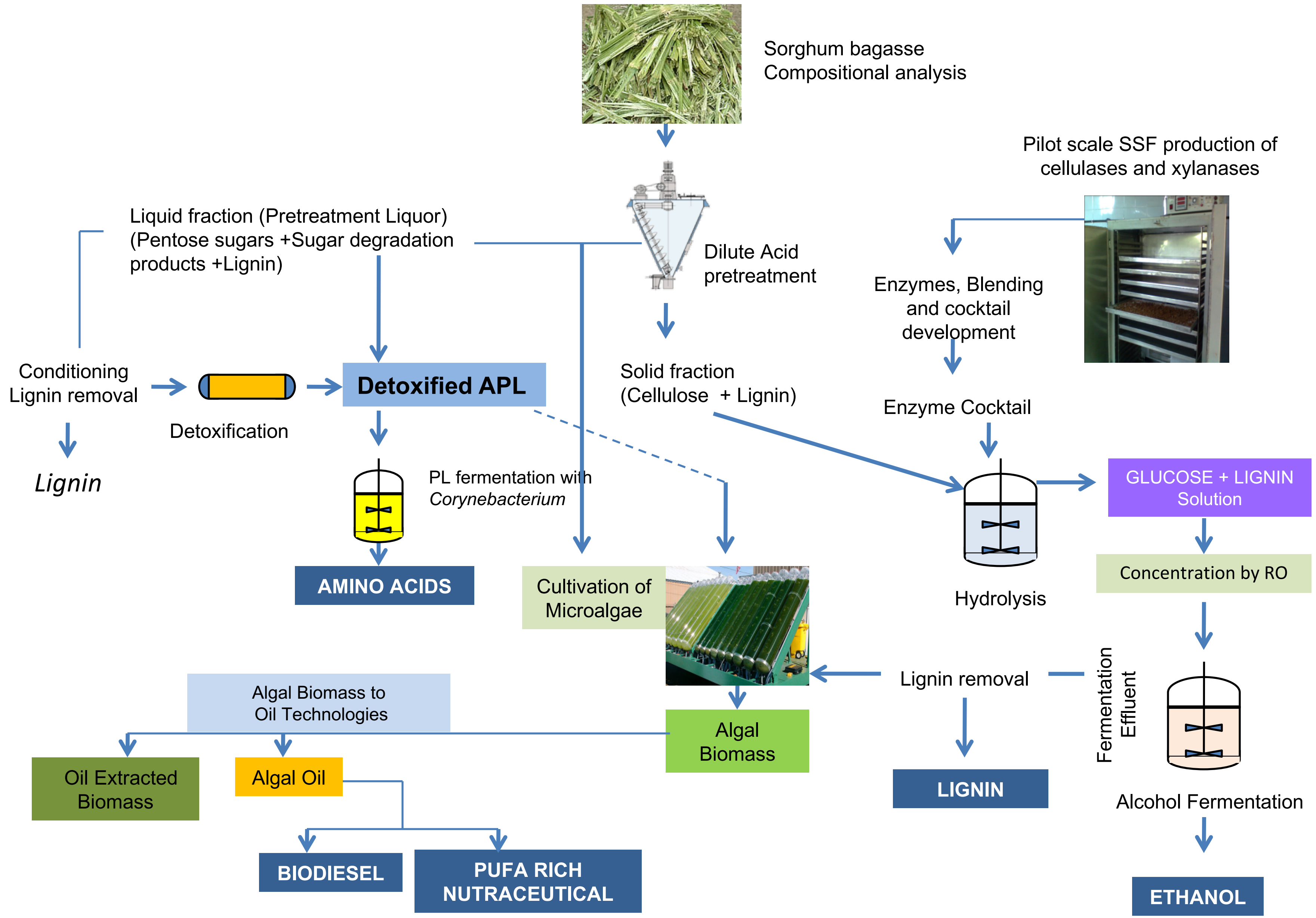
Bioenergy from agro-industrial wastes

Bioethanol from agri-residues

Centre for Biofuels- Biorefinery Concept



Sorghum bagasse based biorefinery: Ethanol + valued addition of byproduct streams



Bioethanol Pilot Plant

Milling of biomass

Pretreatment reactor.

Solid liquid separation

Slurry after Pretreatment

Combined liquid fraction (APL)

Distillation of Alcohol

Alcohol Fermentation

Hydrolysis Reactor

Solids separated from slurry

ETHANOL Lignocellulosic ethanol pilot plant (100kg/batch) capacity

Commissioning of SSF pilot plant

Temperature Range – 23-40 °C

Relative Humidity Range - 50-90 %

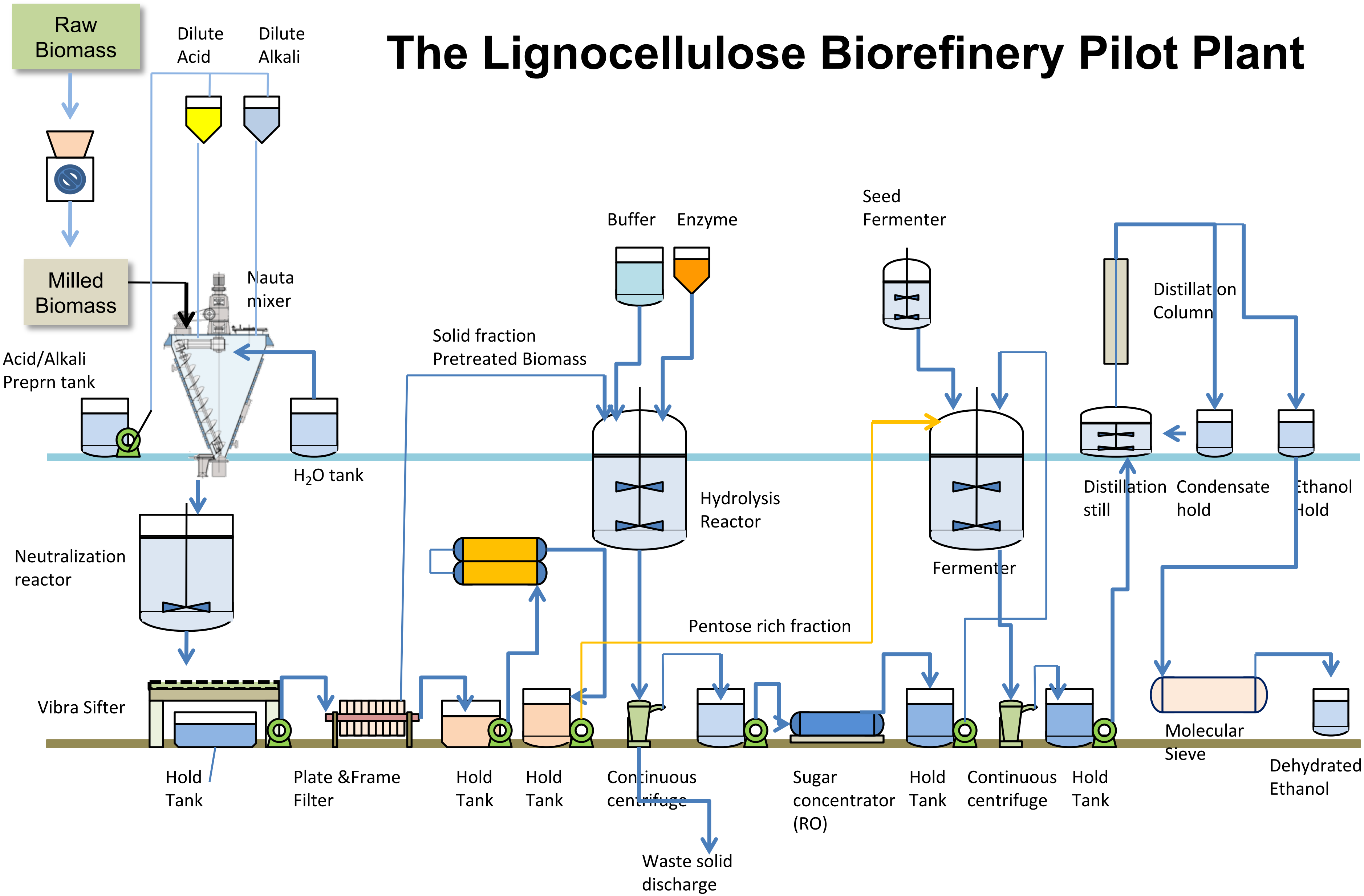
Operation: Programmable temperature and humidity cycles.

Continuous operation capable

HEPA filtered air inlet and outlet

Capacity 51 x 45 x 5 cm trays (108 nos) = ~ 50kg capacity per batch

The Lignocellulose Biorefinery Pilot Plant



Our partners, collaborators and facilitators

TIFAC

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Department of Science & Technology
Government of India

CSIR

Naturol Bioenergy, Hyderabad

Godavari Biorefinery, Sameerwadi

Kerala State Bamboo Corporation

MAPs Enzymes Pvt Ltd

CSIR-NCL Pune, CSIR-IICT Hyderabad, MNNIT Allahabad, TERI New Delhi, ICT Mumbai
EPFL Switzerland; UBP France; UFPR Brazil; QUT Australia
HTBS, Pune; Scigenics India Pvt Ltd, Chennai

Acknowledgements

Prof Konstantinos Moustakas

TeamBiotech, CSIR-NIIST; CSIR-IITR
My colleagues, PhD students and projects fellows
Funding agencies and Collaborators

Thank You