Lignocellulosic Ethanol: LCA based Technology and Policy Evaluation

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Presentation at workshop of the International Transport Forum:
Life Cycle Assessment Methods to Support India's Efforts to Decarbonise Transport
13 April 2021

Presentation Outline

- Transport sector and climate change
- Biofuel policy: Targets and current status
- LCA of lignocellulosic ethanol
  - Review of India specific studies
  - Rice straw to ethanol process
  - Comparison of different processing technologies
- Research gaps and future needs

Climate Change and India's Transport Sector

- India's total GHG emission in 2019: 132 million tonnes
- Transportation sector accounts for about 16%
- Private transport: 80% of the total transport emissions
- Rapid rise in private vehicle ownership expected
- Sustainable transport options: Biofuels and EVs

India's Biofuel Policy

- Biofuel policy: First draft (2003)
  - 20% ethanol blending by 2017
  - Based on non-food crops (molasses and residue)

- Biofuel policy: Recent revision (2018)
  - 20% ethanol blending by 2030 (currently 7-8%)
  - Sugarcane, molasses, residue, damaged and surplus food grains

- Biodiesel and advanced biofuels also considered

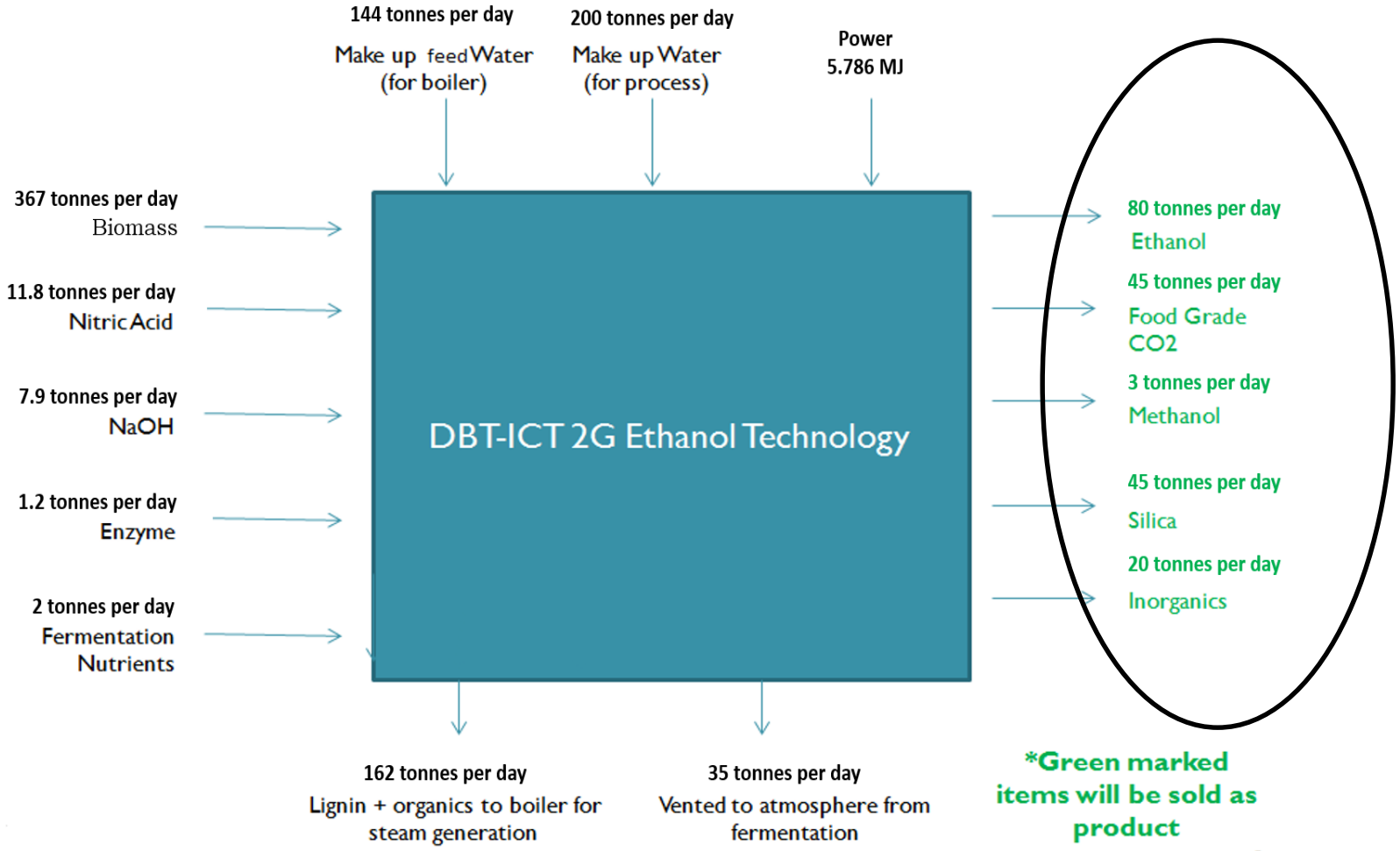
Plans for lignocellulosic ethanol

- 12 demonstration scale plants proposed to be set-up
- A combination of different feedstock and technologies
- Results expected to provide further policy guideline

LCA studies of 2G ethanol in India

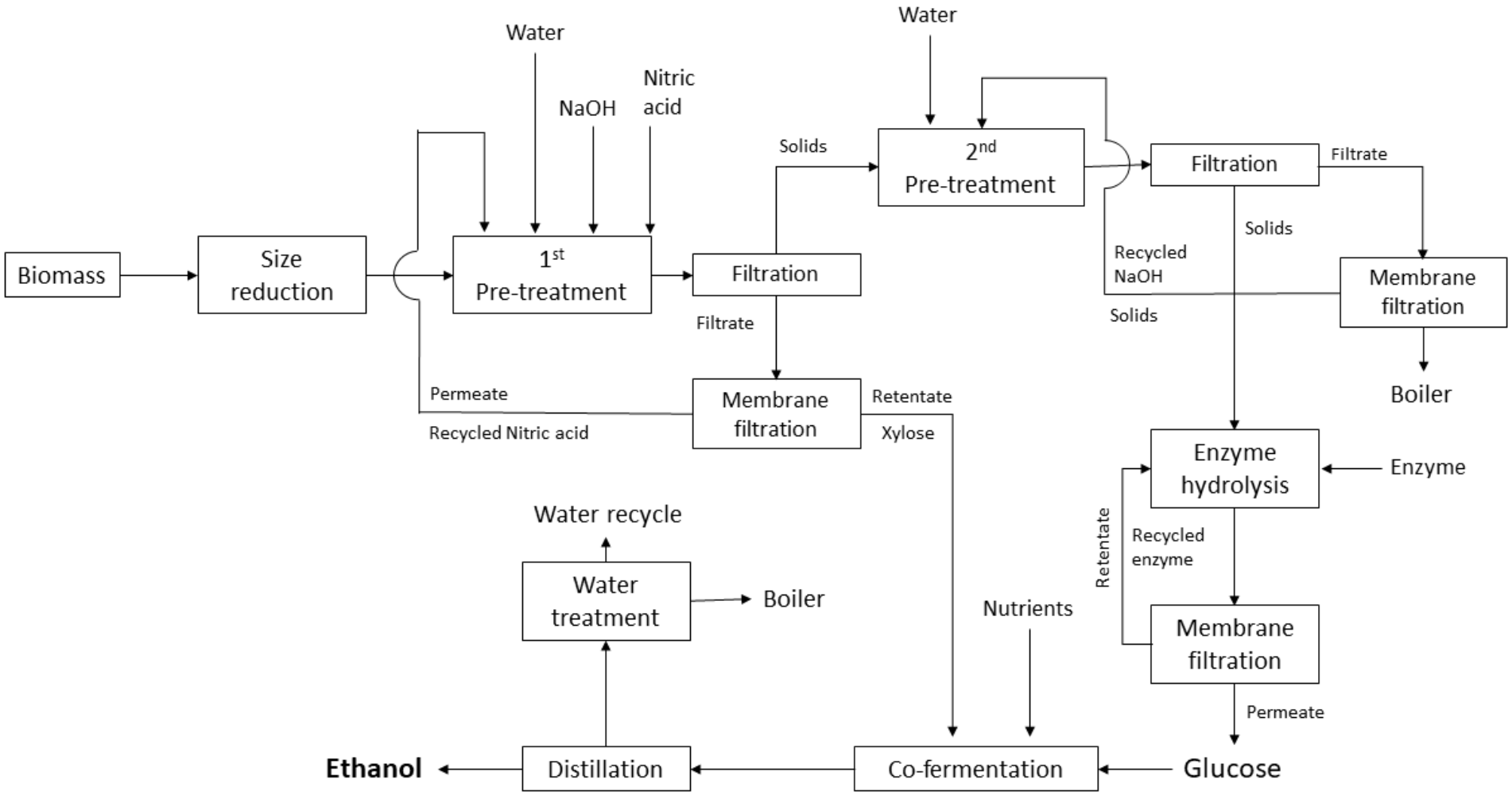
Study	Scope	Result (kg CO2 eq. per liter of EtOh)
Kadam et al. (2002)	Bagasse for ethanol production vs open burning	**3.88-5.45**
Mandade et al. (2015)	Different feedstock and NREL process	**0.2-1.8**
Soam et al. (2015)	Molasses to ethanol	**0.43-6.42**
Soam et al. (2016)	Rice straw with IOC pilot plants for DA and SE	**1.14-1.22**
Soam et al. (2018)	Rice straw with modified IOC technology (electricity co-production)	**-0.26 to -0.58**

Ethanol Production from Rice Straw: Process Developed by ICT, Mumbai*



* Sreekumar et al. (2020), *Clean Technology and Environmental Policy*. 22: 409-422

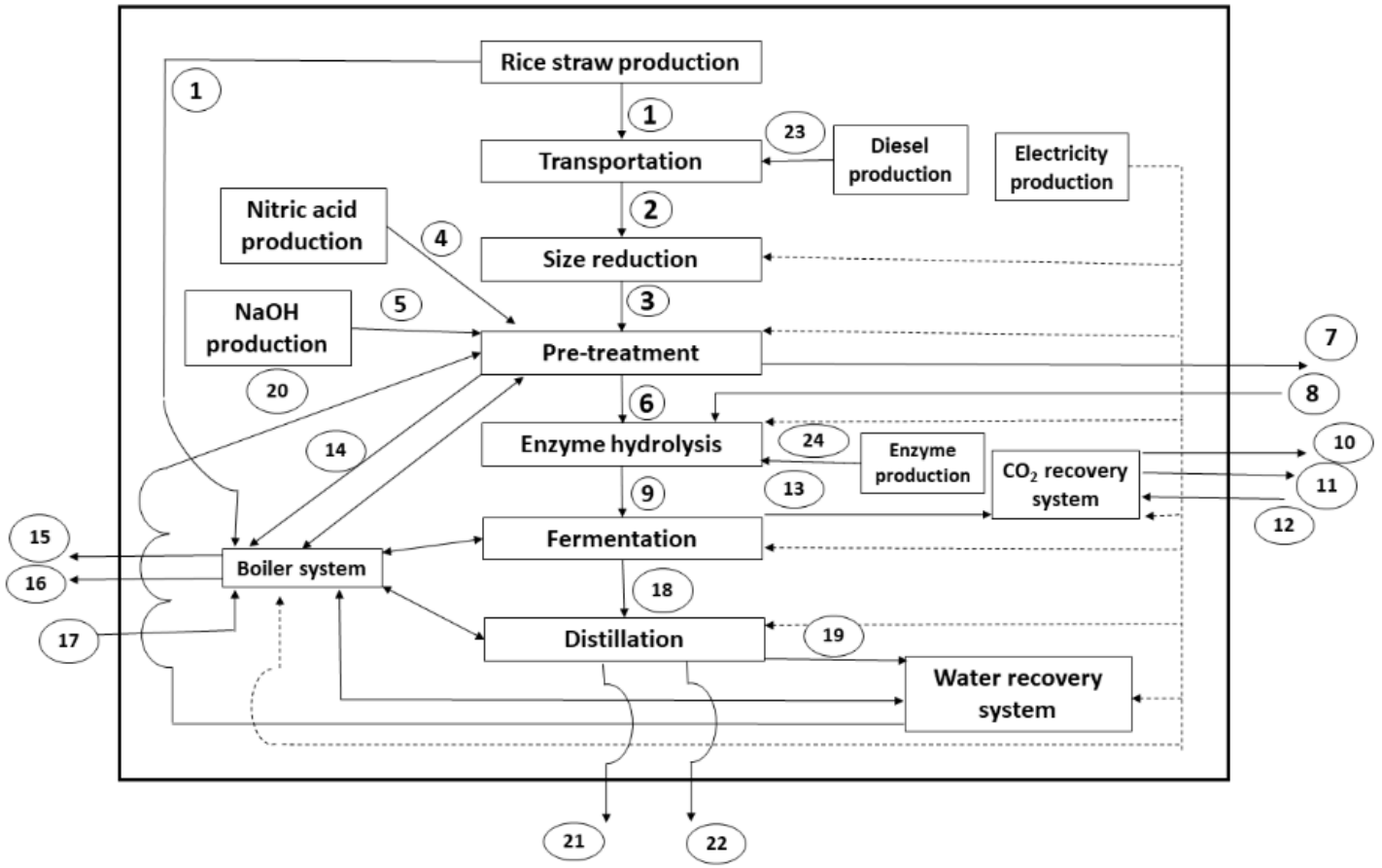
Ethanol Production from Rice Straw*



* Sreekumar et al. (2020), *Clean Technology and Environmental Policy*. 22: 409-422

LCA set-up

- Functional Unit: 1 liter
- Life cycle inventory:
  - Process: experiments
  - Transport: Contractor
  - Chemicals and farming: Ecoinvent®
- OpenLCA 1.7
- ReCiPe (H) mid-point indicators

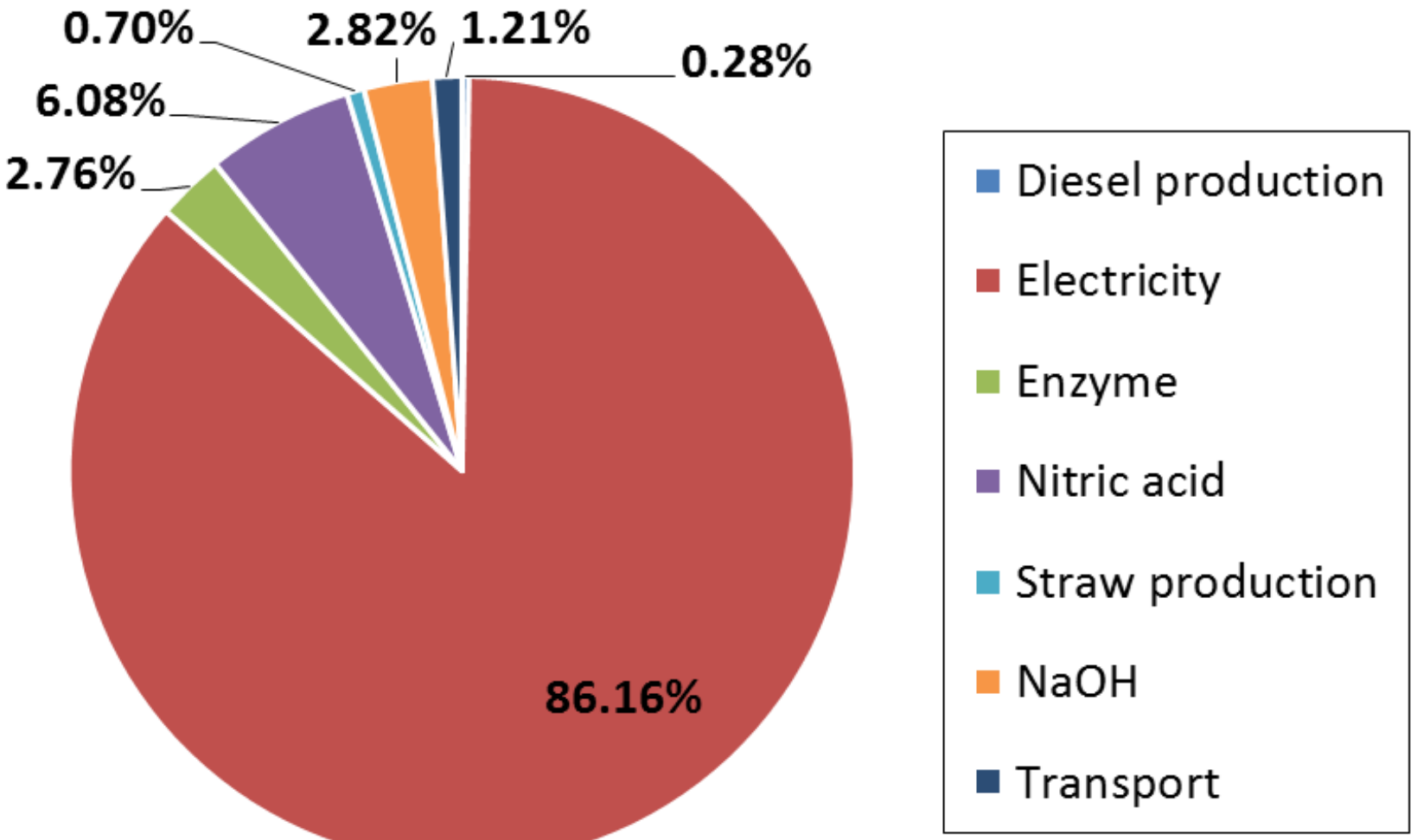


1: Rice straw
2: Transported biomass
3: Size
4: Nitric acid
5: Sodium hydroxide
6: Pre-treated stream
7: Silica
8: Process water
9: Hydrolysed stream
10: Food grade CO_2
11: CO_2 emission
12: Steam
13: CO_2 produced
14: Feed to boiler
15: Emissions from boiler
16: Inorganics
17: Feed water
18: Fermented stream
19: Feed to water recovery
20: Recovered water
21: Methanol
22: Ethanol
23: Diesel
24: Enzyme
: steam exchange
: electricity usage

LCA Results for 1 liter Using Economic Allocation

Impact category	**Reference unit**	**Impact value**
Acidification	Mole H+ eq.	0.066
Climate change	**kg CO_2 eq.**	**2.818**
Freshwater ecotoxicity	CTUe	17.217
Freshwater eutrophication	kg P eq.	0.002
Ozone depletion	kg CFC-11 eq.	9.191E-08
Particulate matter/Respiratory inorganics	kg PM2.5 eq.	0.008
Photochemical ozone formation	kg C2H4 eq.	0.045
Resource depletion - mineral, fossils and renewables	kg Sb eq.	1.835E-05
Resource depletion - water	**m^3**	**0.027**
Terrestrial eutrophication	Mole N eq.	0.191

Distribution of climate change impact



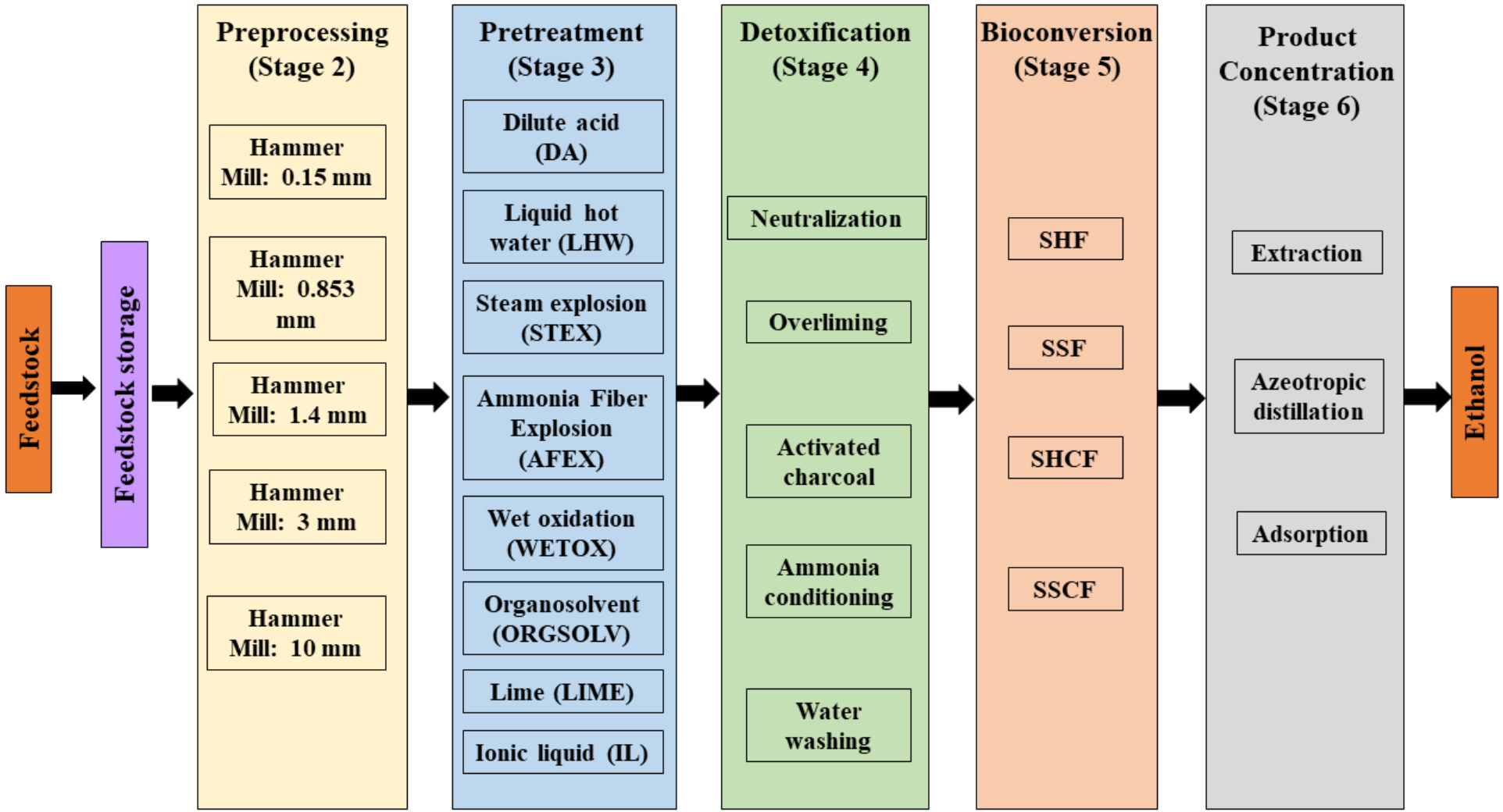
Considering avoided impacts (displacement)

	Conventional Electricity	Hydro electricity
Base case	**3.785**	0.520
Considering side products	**3.335**	0.070
Considering rice straw management	**3.185**	-0.080
Considering boiler fuel	**1.294**	-1.971
Considering petrol replacement	**-0.392**	-3.657

Impact of allocation on GHG emission

	No allocation	Economic allocation	Physical allocation
Diesel production	0.010	0.008	0.004
Electricity	3.282	2.428	1.285
Enzyme	0.093	0.078	0.039
Nitric acid	0.225	0.171	0.093
Straw production	0.026	0.020	0.011
NaOH	0.104	0.079	0.043
Transport	0.045	0.034	0.018
Total	**3.785**	**2.818**	**1.493**

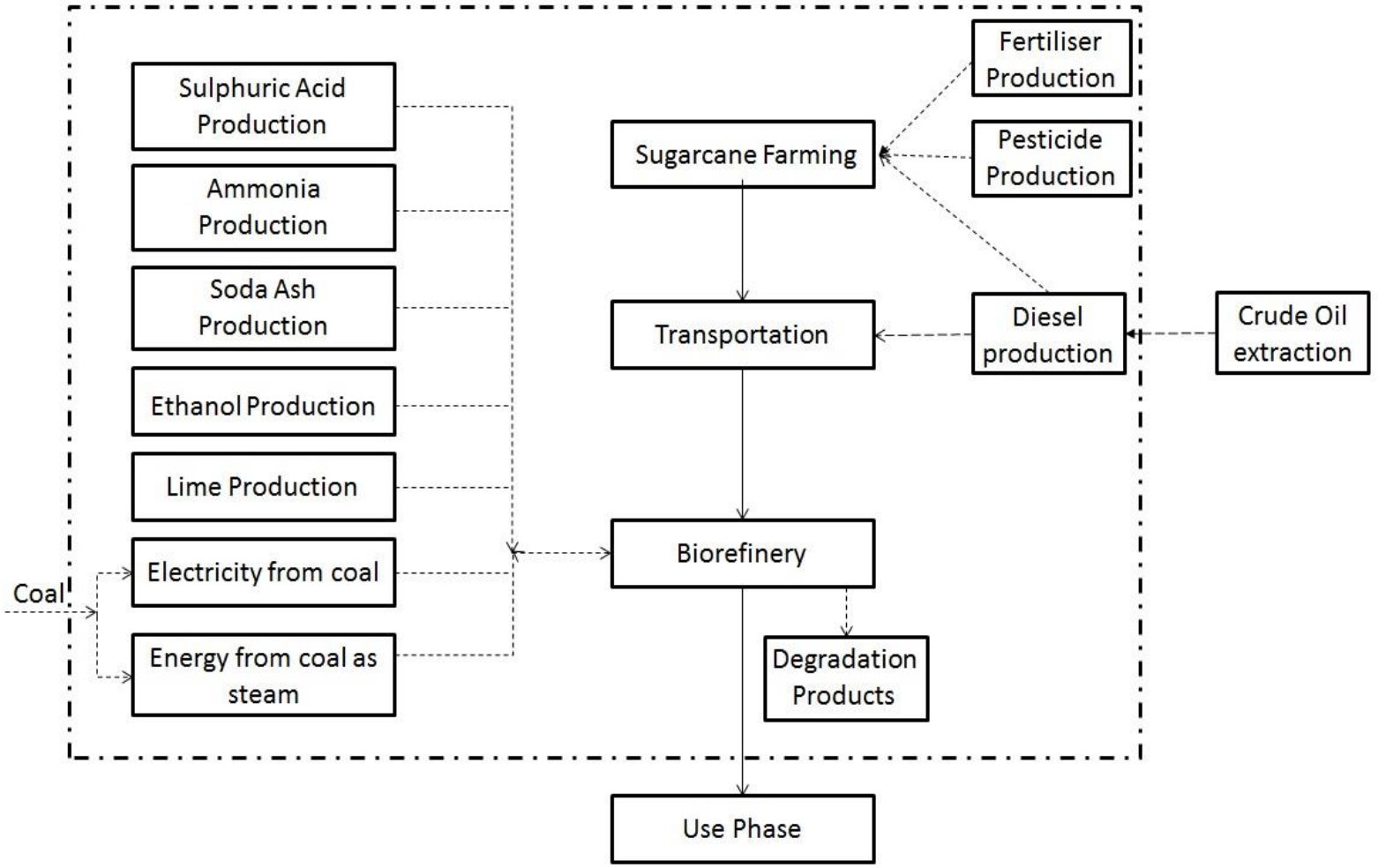
Life cycle assessment based comparison of different lignocellulosic ethanol production routes*



* Murali and Shastri. *Biofuels*. 10.1080/17597269.2019.1670465

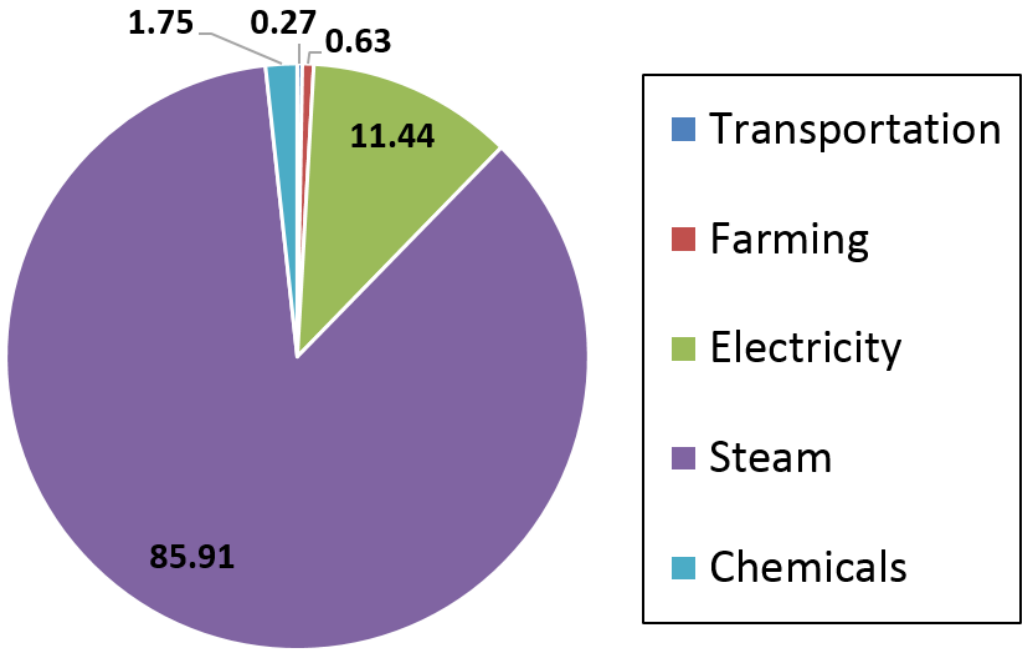
LCA Set-up

- Functional Unit: 1 MJ
- Life cycle inventory:
  - Process: Literature
  - Chemicals and farming: Ecoinvent®
  - Transport: Literature
- OpenLCA 1.6
- ReCiPe (H) mid-point and TRACI

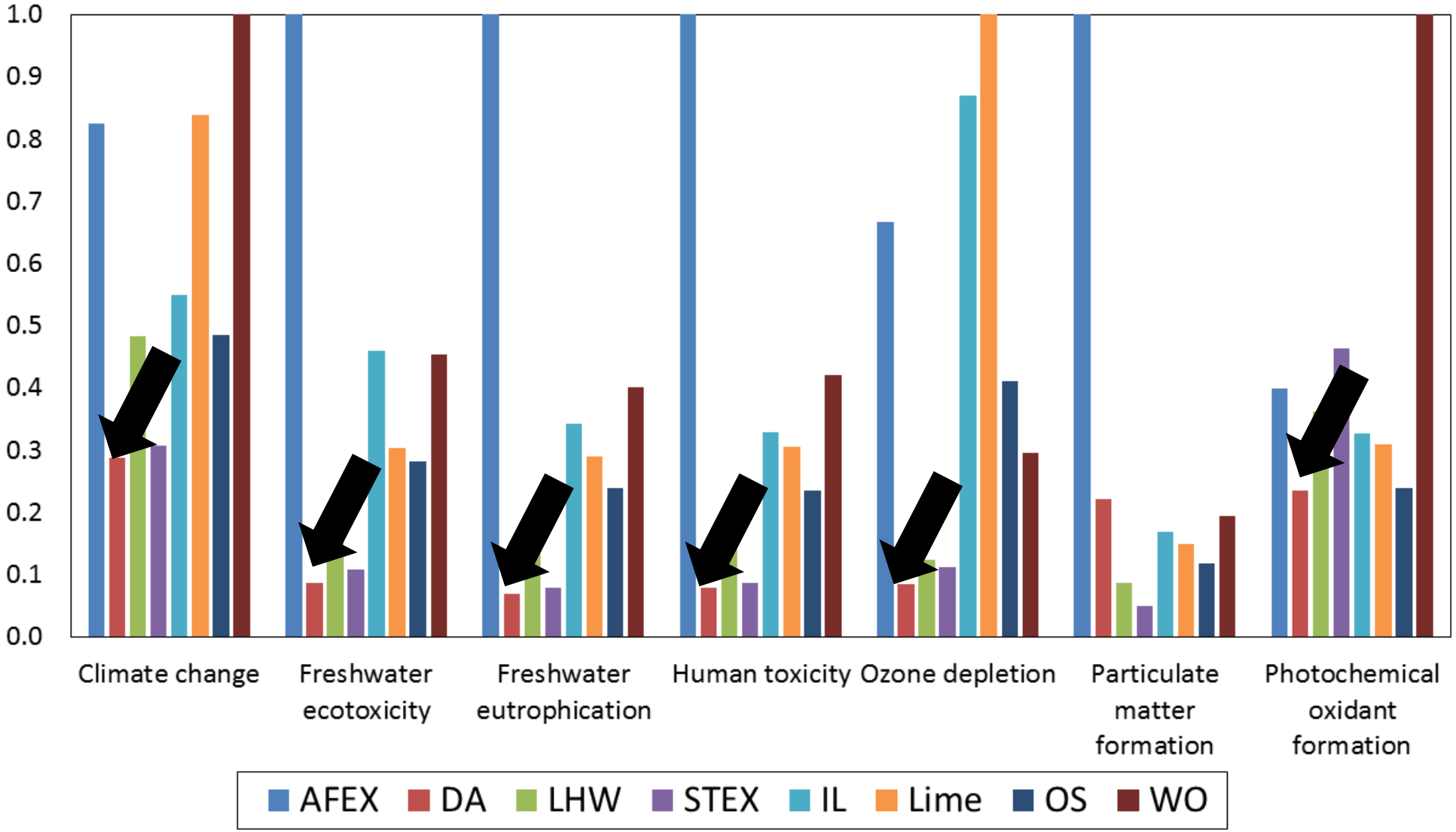


Energy during separation major contributor to climate change impact

Impact category	Impact (for 1 liter of ethanol)
Climate change (kg CO_2-Eq)	**3.144**
Fossil depletion (kg oil-Eq)	0.1226
Freshwater ecotoxicity (kg 1,4-DCB-Eq)	3.467E-03
Freshwater eutrophication (kg P-Eq)	1.562E-04
Human toxicity (kg 1,4-DCB-Eq)	0.1269
Ozone depletion (kg CFC-11-Eq)	7.504E-09
Particulate matter formation (kg PM10-Eq)	1.220E-02
Photochemical oxidant formation (kg NMVOC)	1.442E-02
Water depletion (m^3)	1.153E-03



Dilute acid pretreatment was better in most impact categories



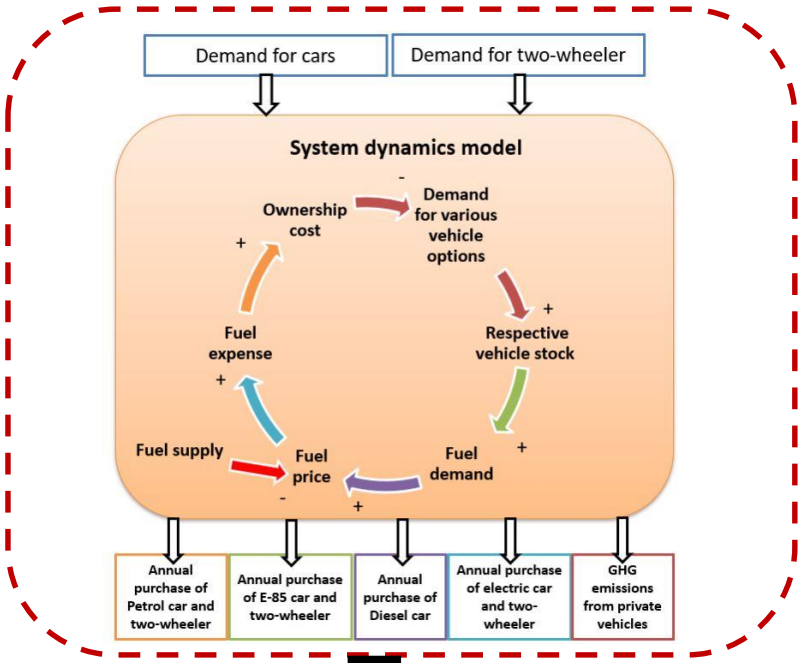
Research Gaps: Biofuels and LCA in Indian Context

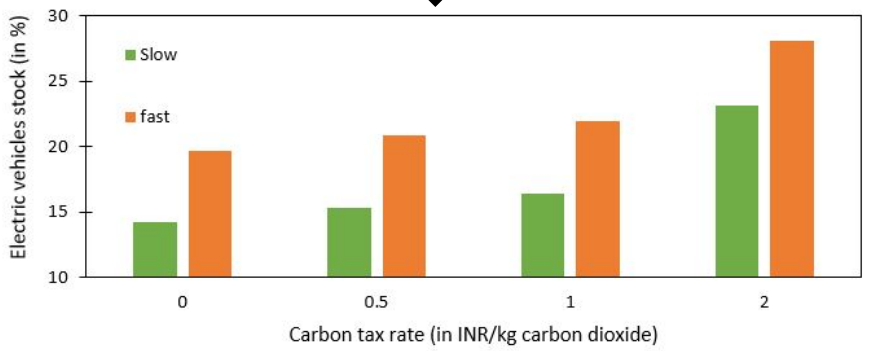
- India specific inventory data (particularly agriculture)
- No LCA of petrol and diesel in India for comparison
- LCA of grain based ethanol production
- LCA from process development stage
- LCA as part of larger decision making framework

Adoption of transport technologies: Use of LCA results for policy making

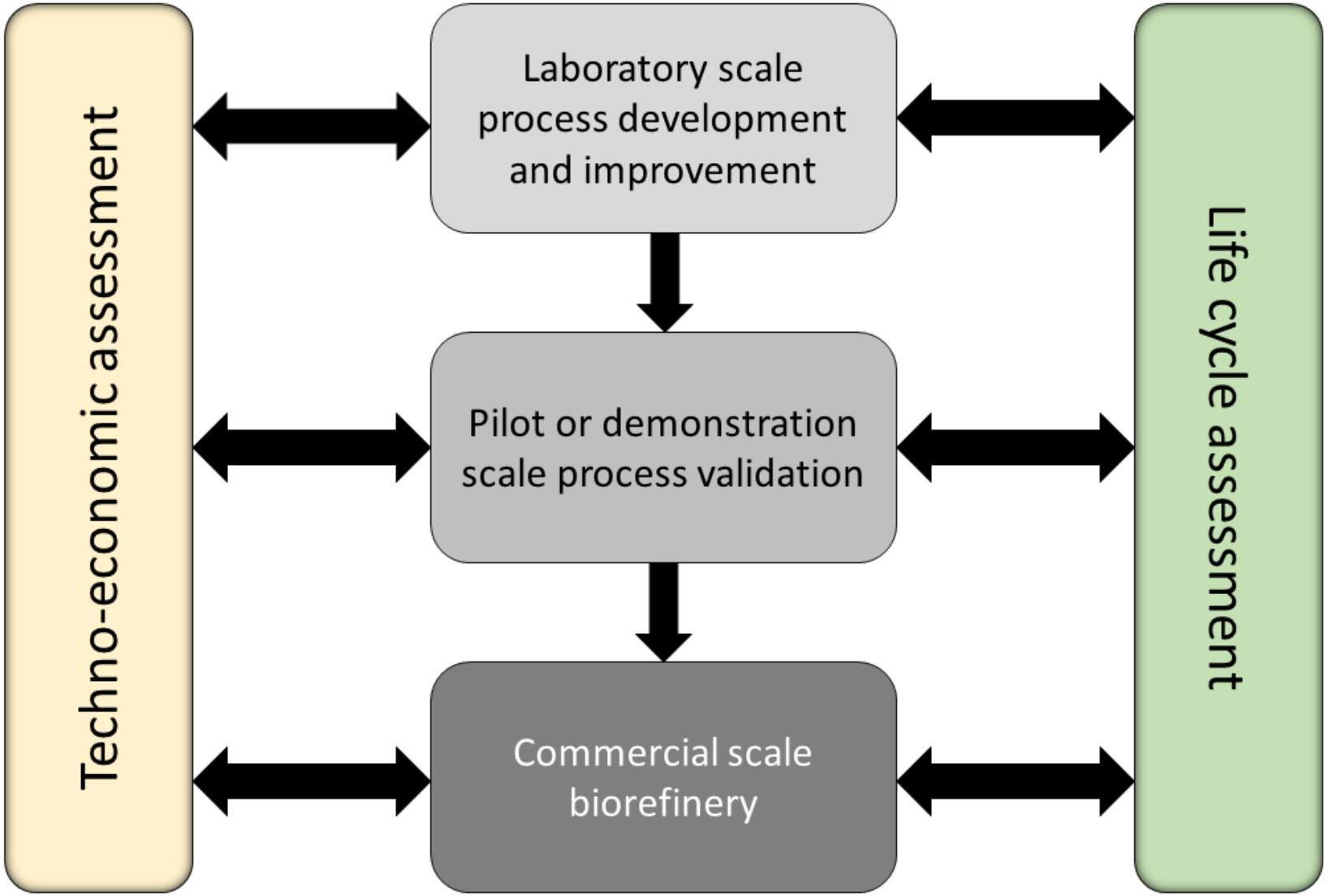
Carbon tax

LCA of transport options





Concurrent Science and Engineering for Sustainable Technologies



Thank you!

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