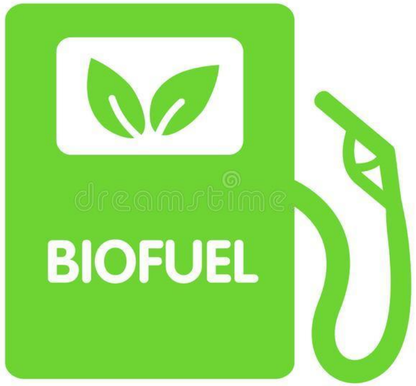
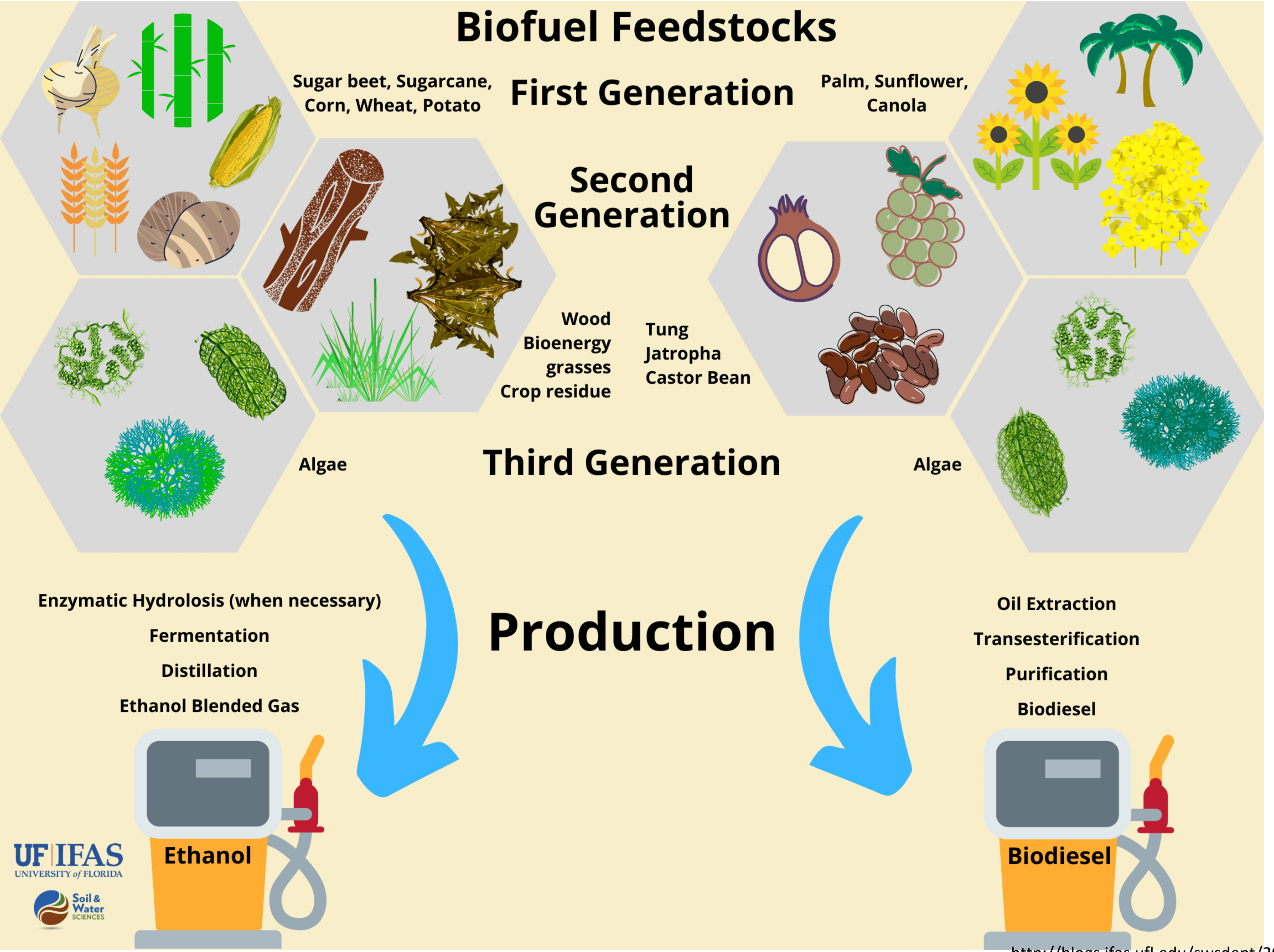
# Waste Derived Alternative Energy for Transportation Sector

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

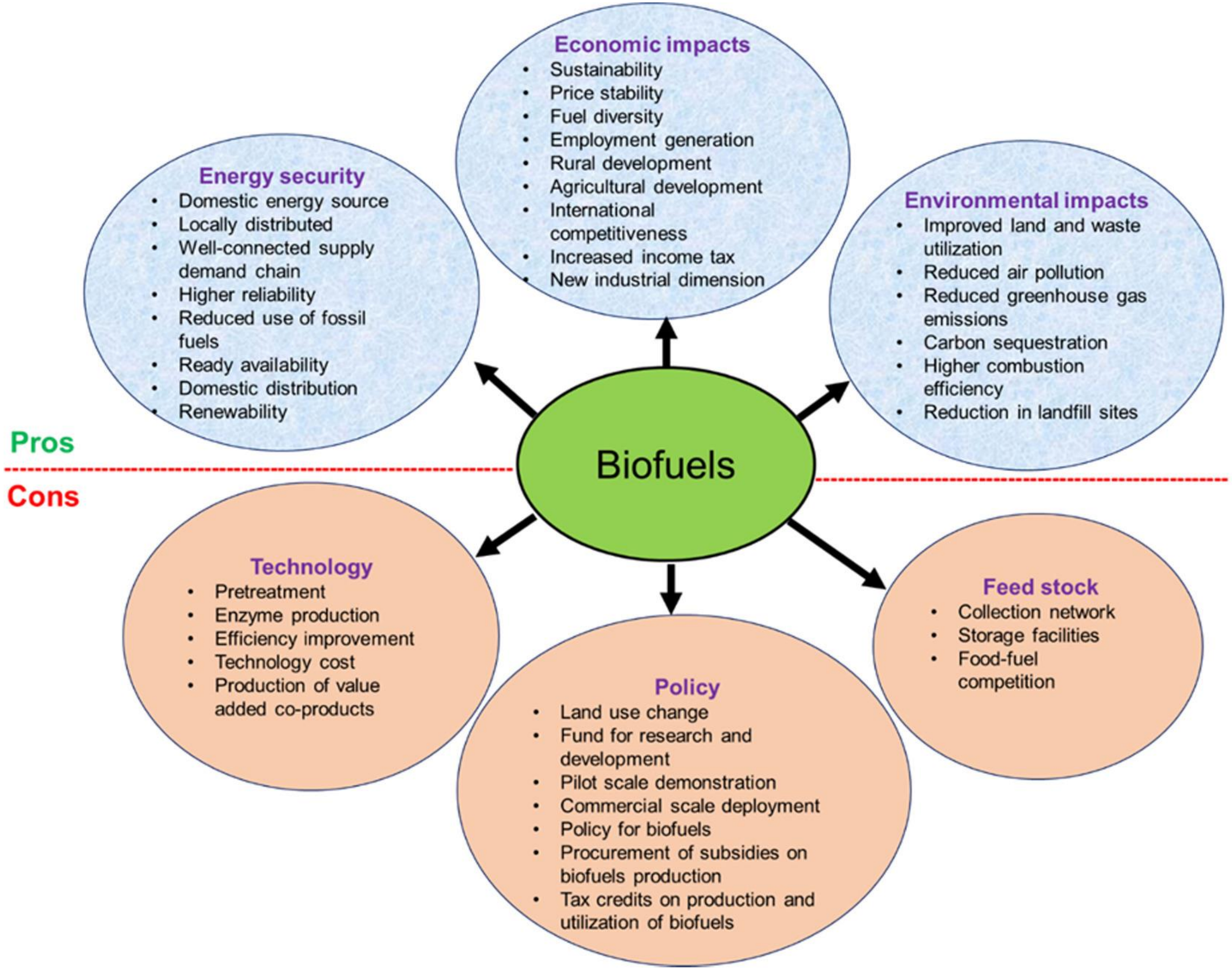



**Brajesh Kr Dubey, PhD**
Associate Professor
Environmental Engineering and Management Division
Department of Civil Engineering
**Indian Institute of Technology Kharagpur**

# Biofuel Feedstocks

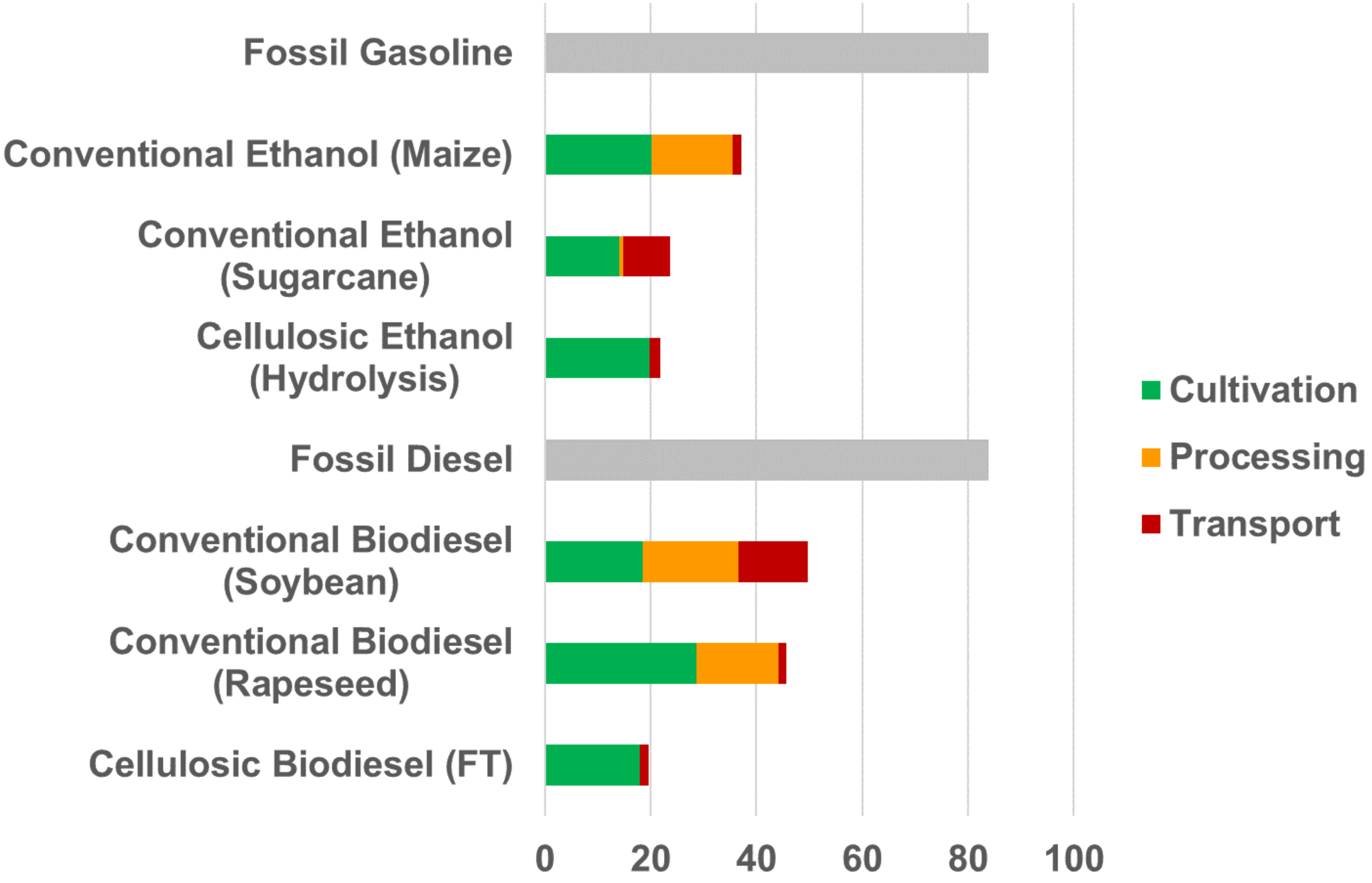


# Biofuel Feedstocks




http://blogs.ifas.ufl.edu/swsdept/2020/10/08/get-to-know-biofuels/

# Carbon Intensity of Selected Bioenergy Pathways ($gCO_2/MJ$)



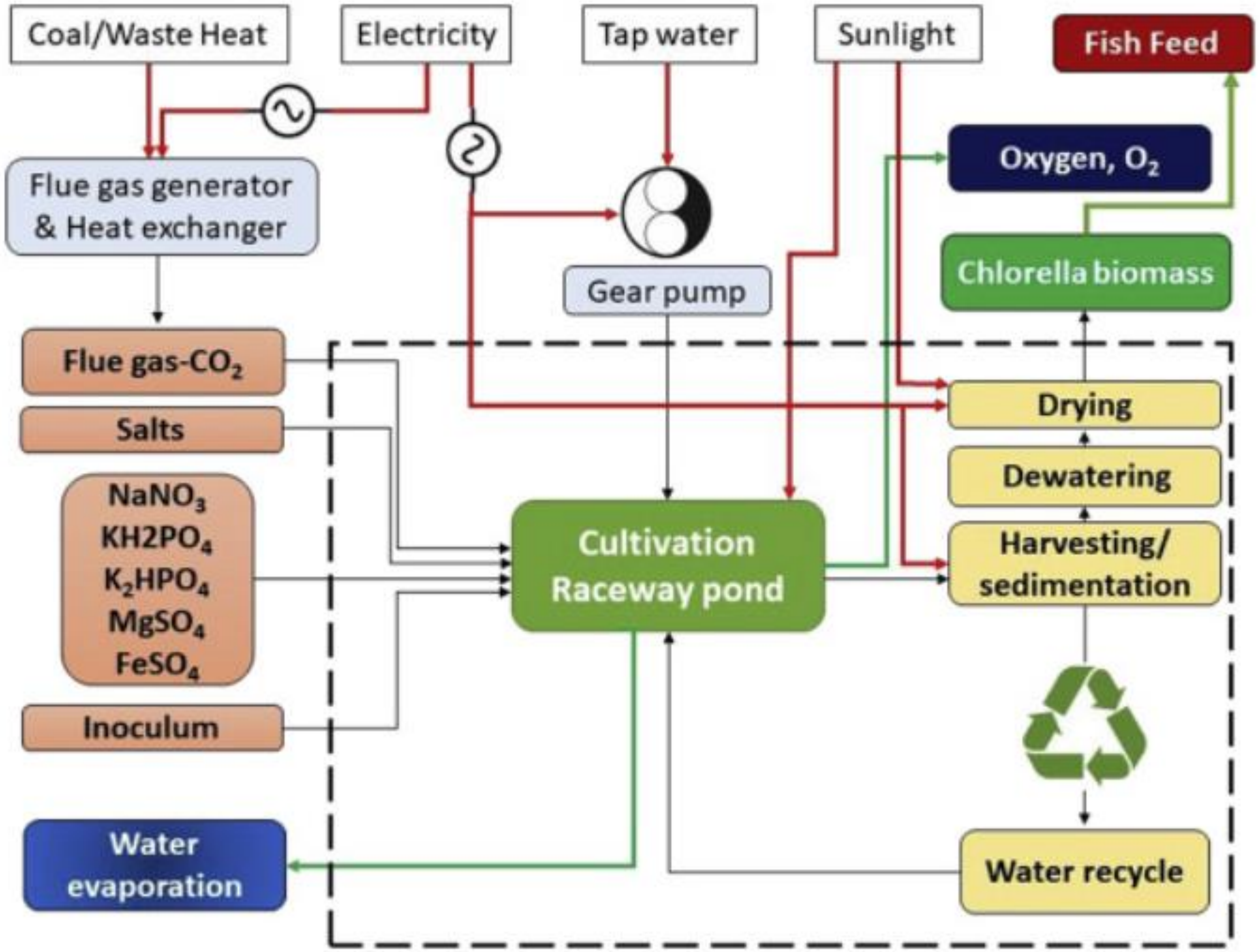

http://www.besustainablemagazine.com/cms2/prospects-for-liquid-biofuels-meeting-the-challenge-of-evs-and-low-oil-prices/

# Cradle-to-gate algal cultivation for biomass production and $CO_2$ sequestration LCA

Journal of Cleaner Production
Volume 258, 10 June 2020, 120703

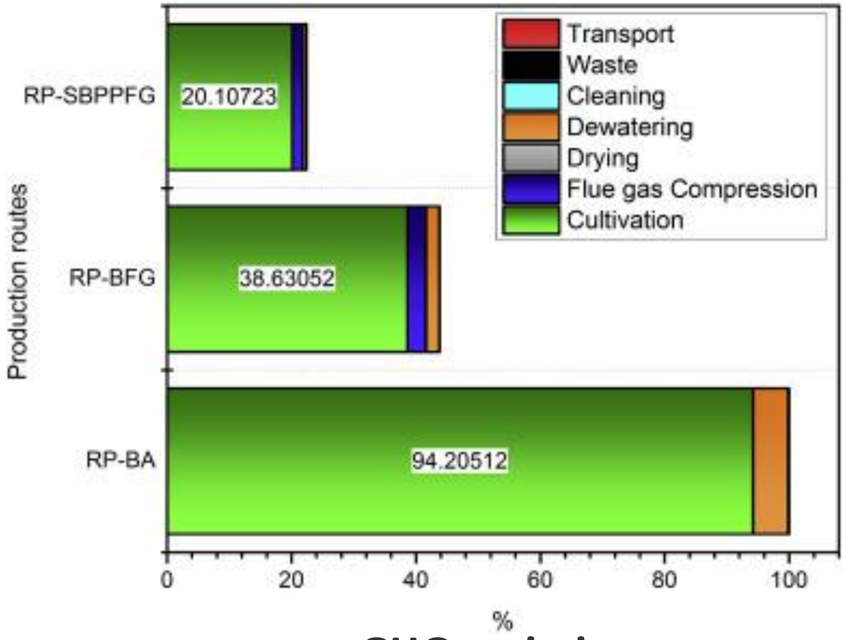
## A comparative life cycle assessment of microalgae production by $CO_2$ sequestration from flue gas in outdoor raceway ponds under batch and semi-continuous regime

Geetanjali Yadav [a], Brajesh K. Dubey [b], Ramkrishna Sen [a]

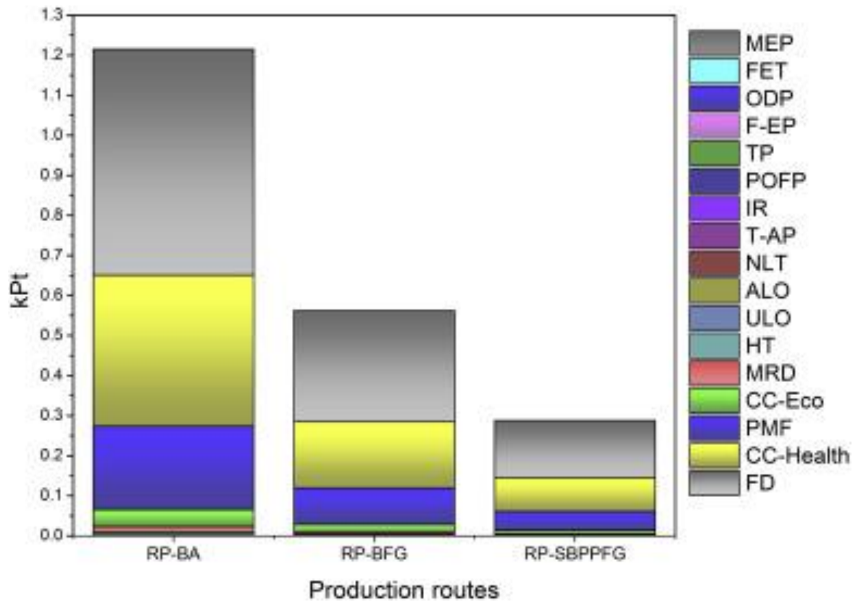



https://www.sciencedirect.com/science/article/pii/S0959652620307502?via%3Dihub#fig1

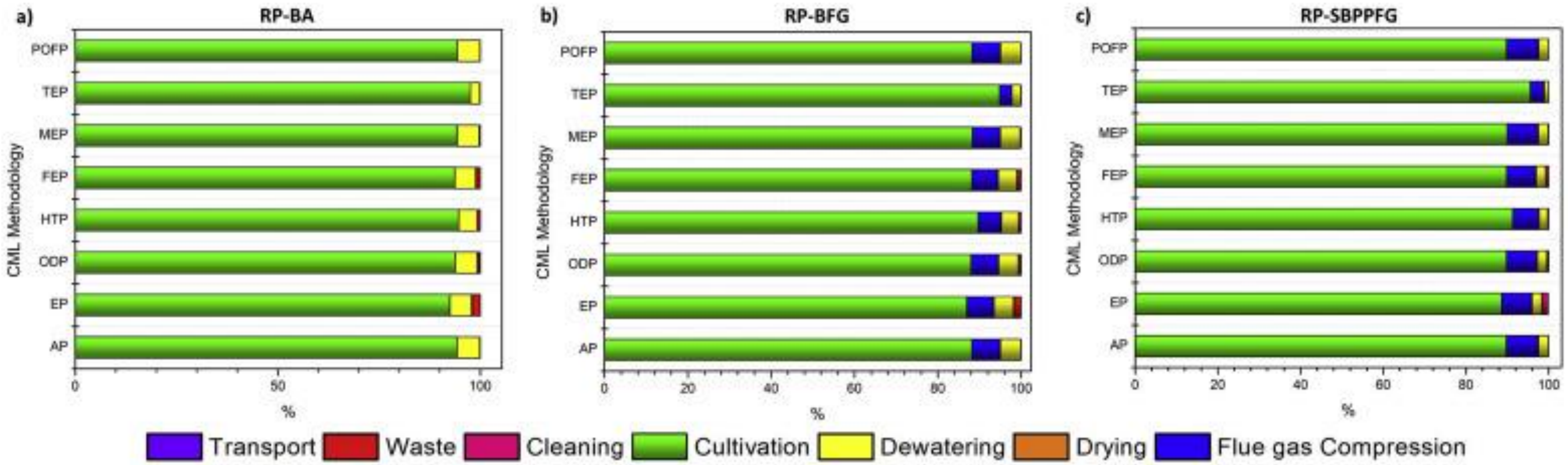
# Environmental Impact assessment




GHG emissions




Environmental impacts

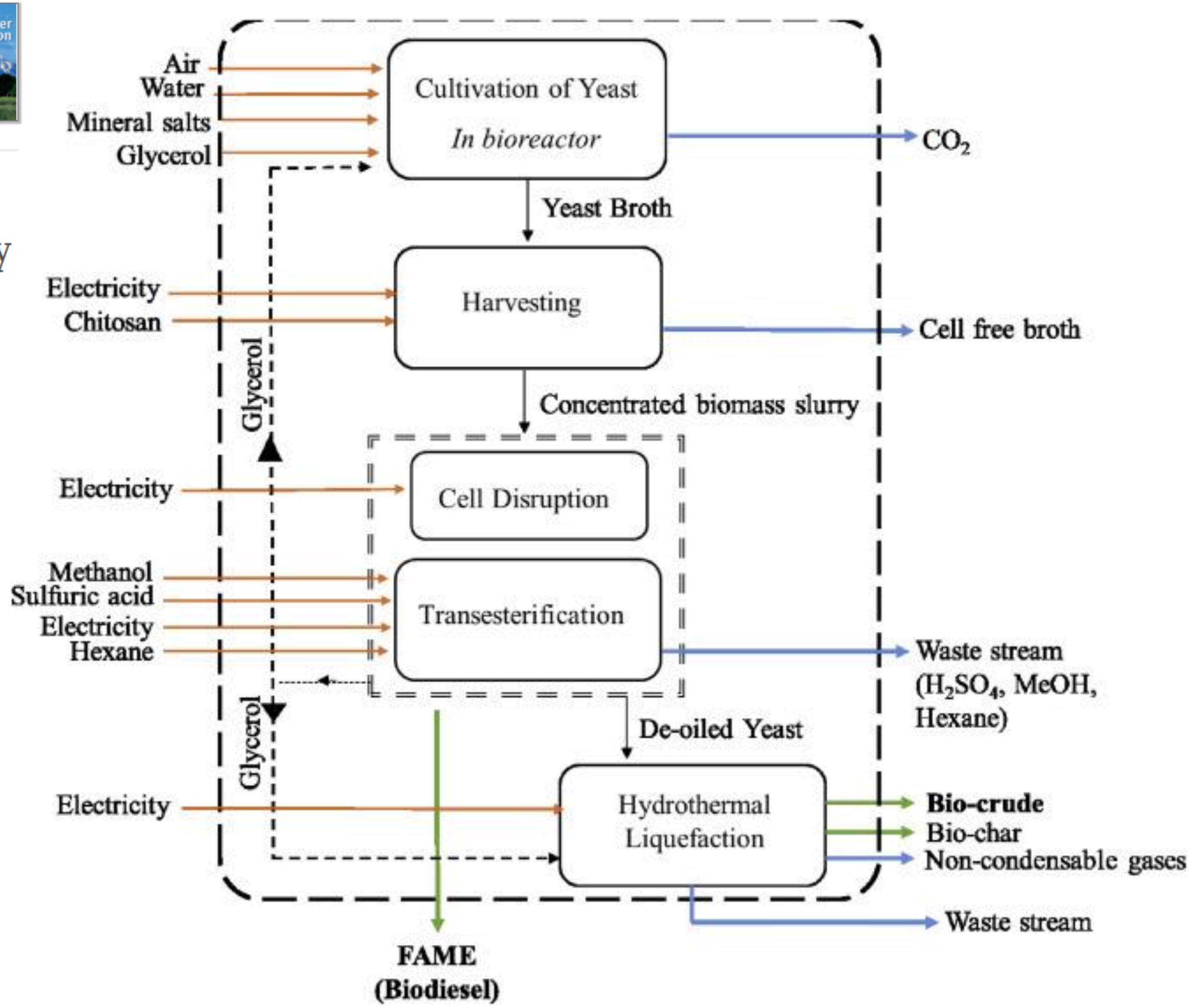


# System boundary used for yeast biorefinery in this study

ELSEVIER
Journal of Cleaner Production
Volume 271, 20 October 2020, 122349

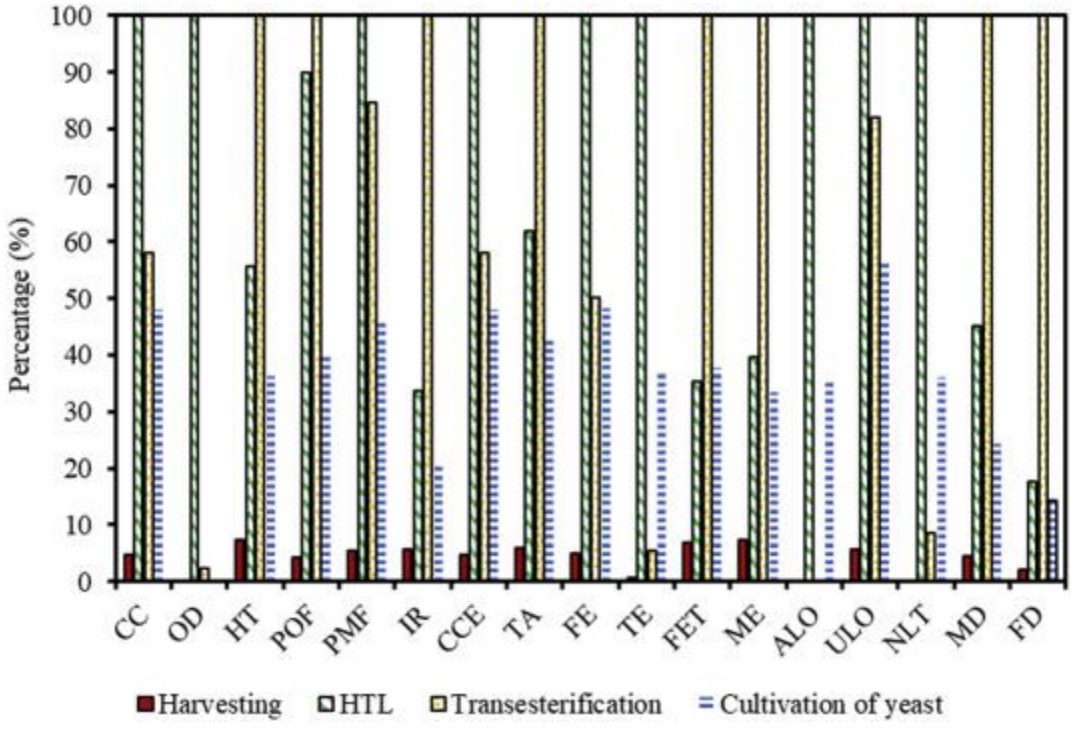
## Environmental impact analysis of oleaginous yeast based biodiesel and bio-crude production by life cycle assessment

Jayita Chopra [a], Bikash Ranjan Tiwari [b, 1], Brajesh K. Dubey [c], Ramkrishna Sen [a]

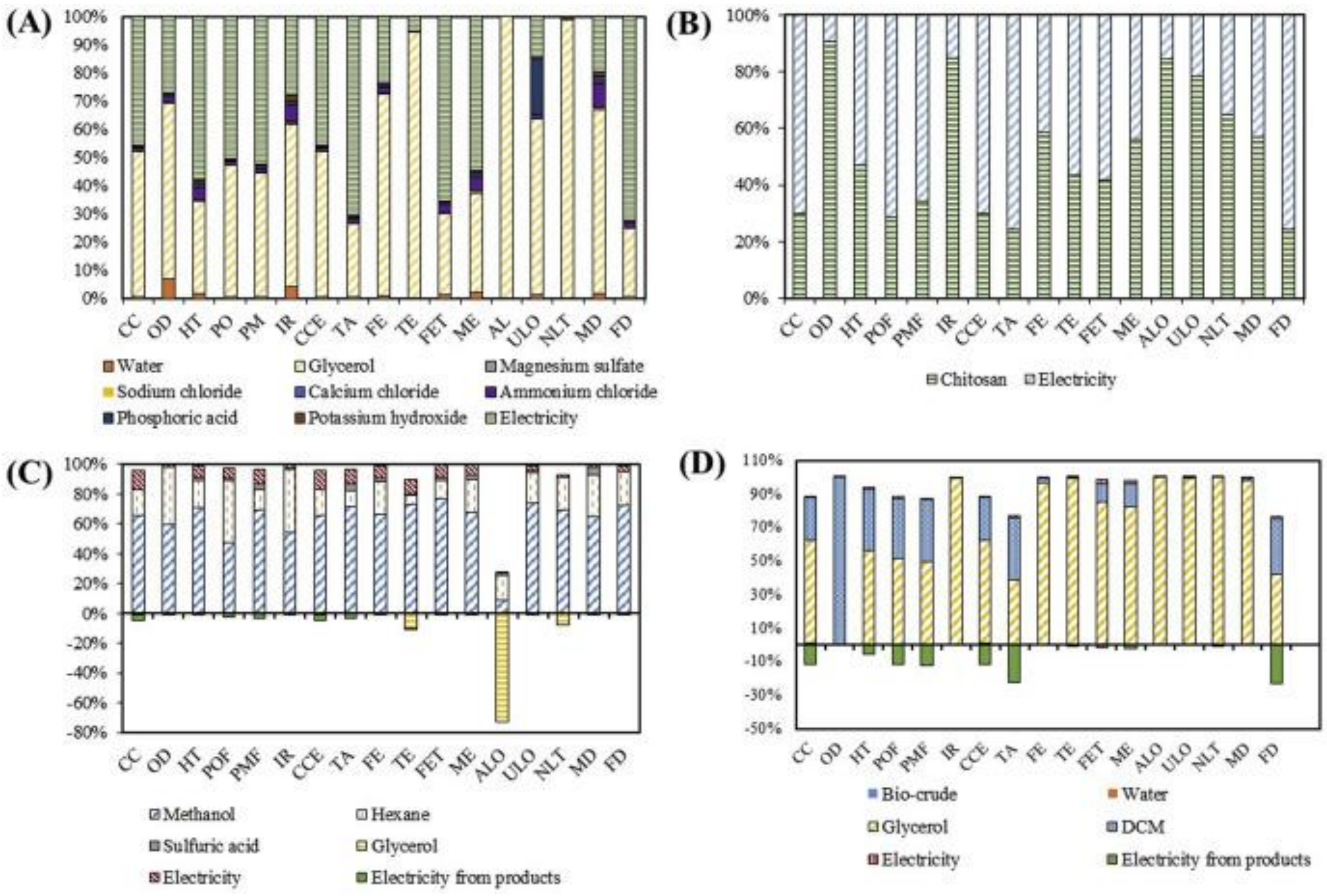



https://www.sciencedirect.com/science/article/pii/S0959652620323969

# impact of individual components in each sub-processes

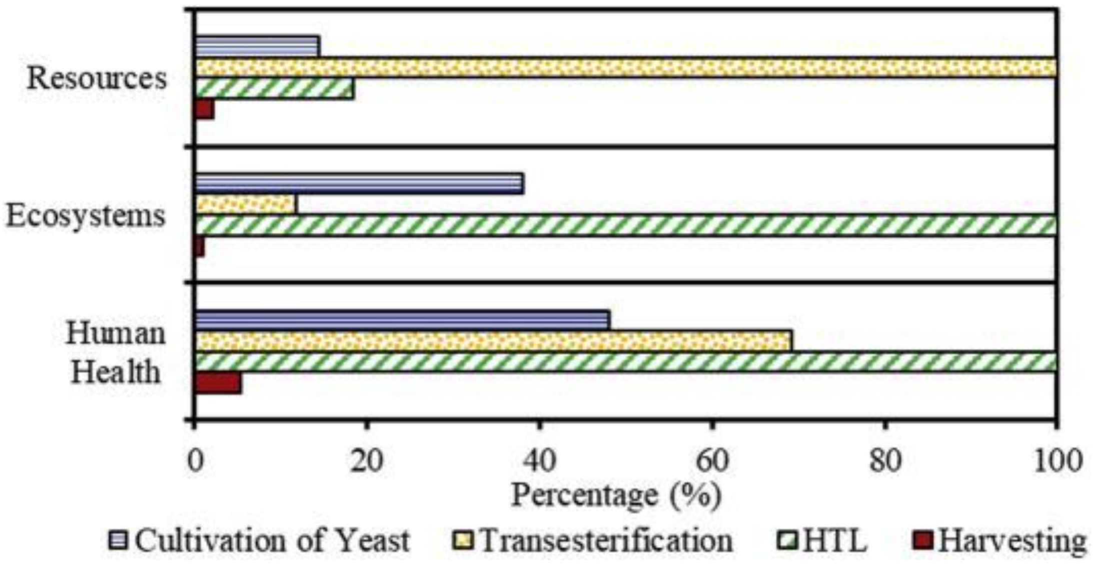



**Comparison between impact categories as depicted by mid-point indicators for the different sub-processes in yeast biorefinery**

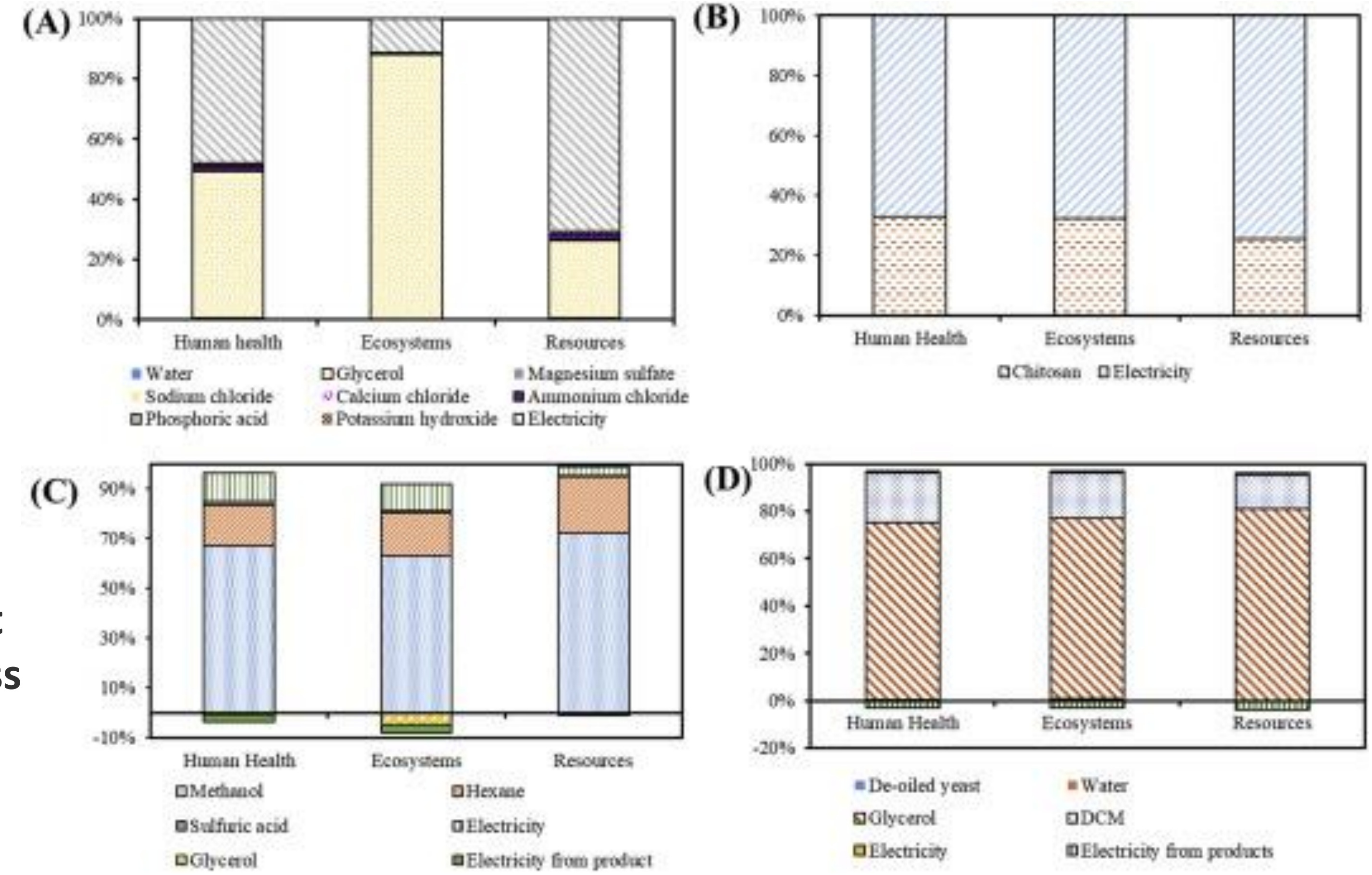



**Mid-point indicators (A) Cultivation of Yeast, (B) Harvesting, (C) In-situ transesterification and (D) Hydrothermal liquefaction**

# impact of individual components in each sub-processes

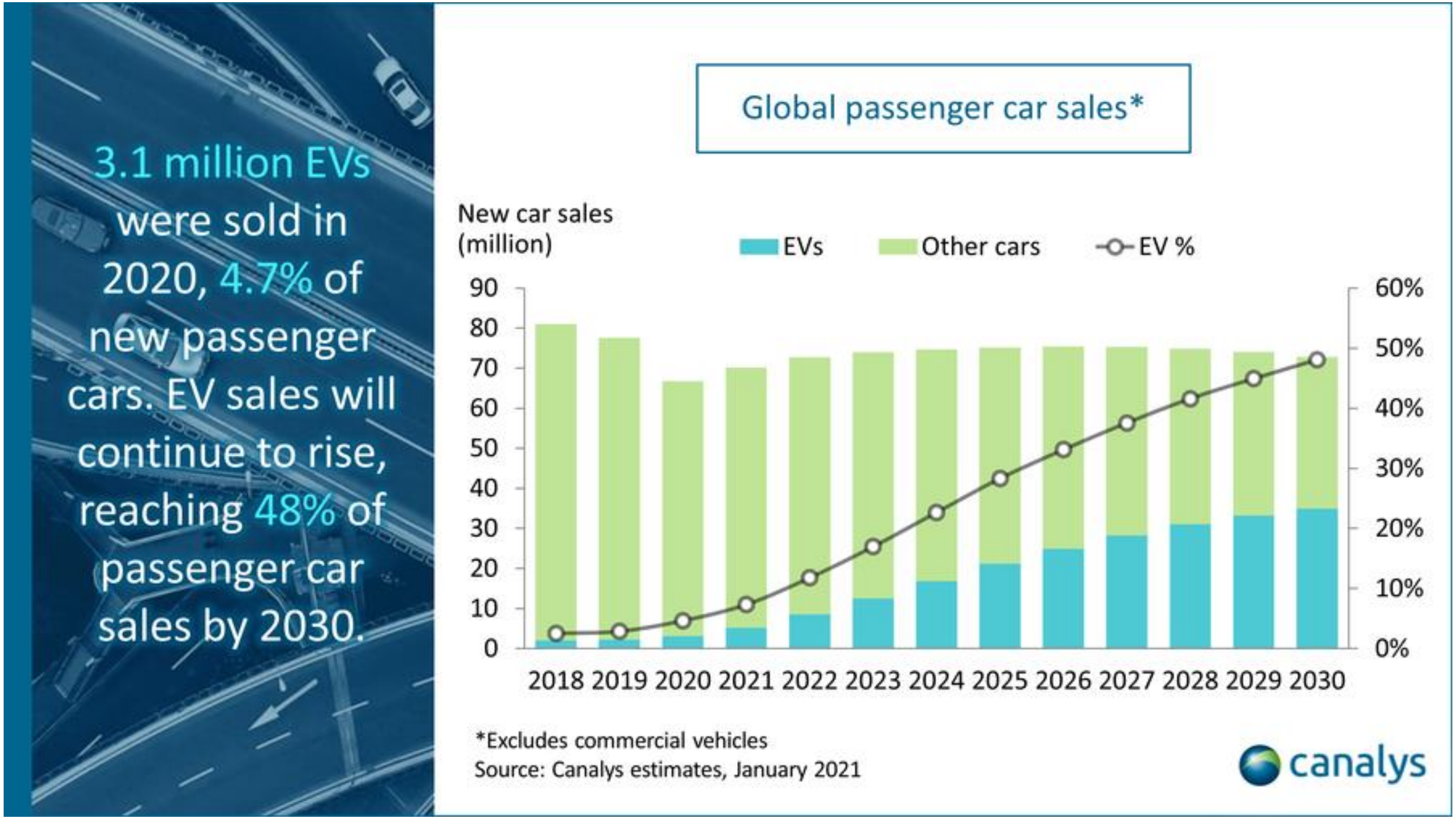



**Comparison of damage assessment at the end-point level of the sub-processes of yeast biorefinery process**




**End-point indicators (A) Cultivation of Yeast, (B) Harvesting, (C) *In-situ* transesterification and (D) Hydrothermal liquefaction**

# Global Electric car sales



# Indian Electric Vehicles

**mint**

Home > Auto News > Race for electric vehicles: India plans to ramp up incentives

## Race for electric vehicles: India plans to ramp up incentives


An electric vehicle charging station connected to a Daimler AG Smart compact electric automobile in Germany (Bloomberg)

6 min read . Updated: 29 Mar 2021, 11:10 AM IST

Lee Kah Whye, ANI

The year is 2023. A Singapore resident decides to buy a car. Not just any car but the latest electric vehicle (EV) produced by the new gleaming high-tech Hyundai factory in Jurong, an industrial town in Western Singapore. She whips up her smartphone and personalises her new car.

She surmises that cream colour seats, a shocking pink exterior coat plus the performance model which can go from 0 to 100 km/h in 3 seconds would be nice and proceeds to make paymen using her bitcoin account. The next day, she heads out to Jurong to watch the factory put the final touches on her brand-new ride and proudly drives her car to show off to her friends a Marina Bay Sands.

× Close

**BUSINESS INSIDER INDIA**

## India's electric vehicle startups charge up with funding as everyone from the government to Mukesh Ambani and Elon Musk have their eyes on the sector

SANCHITA DASH | MAR 23, 2021, 09:26 IST


An electric vehicle charging station in Mumbai BCCL

- As India moves towards the probability of a sustainable future, electric vehicles take the centre stage of most discussions.
- Here's a look at Indian EV startups that have raised funding in the last one month, including Ola Electric which i reportedly in talks with marquee investors for its latest funding round.
- As of 2019-20, India has sold over 3.8 lakh electric vehicles and buyer interest is higher than ever before.

**INDIA CLIMATE DIALOGUE**

Home Science Impacts Mitigation Adaptation Negotiations Policymaking A

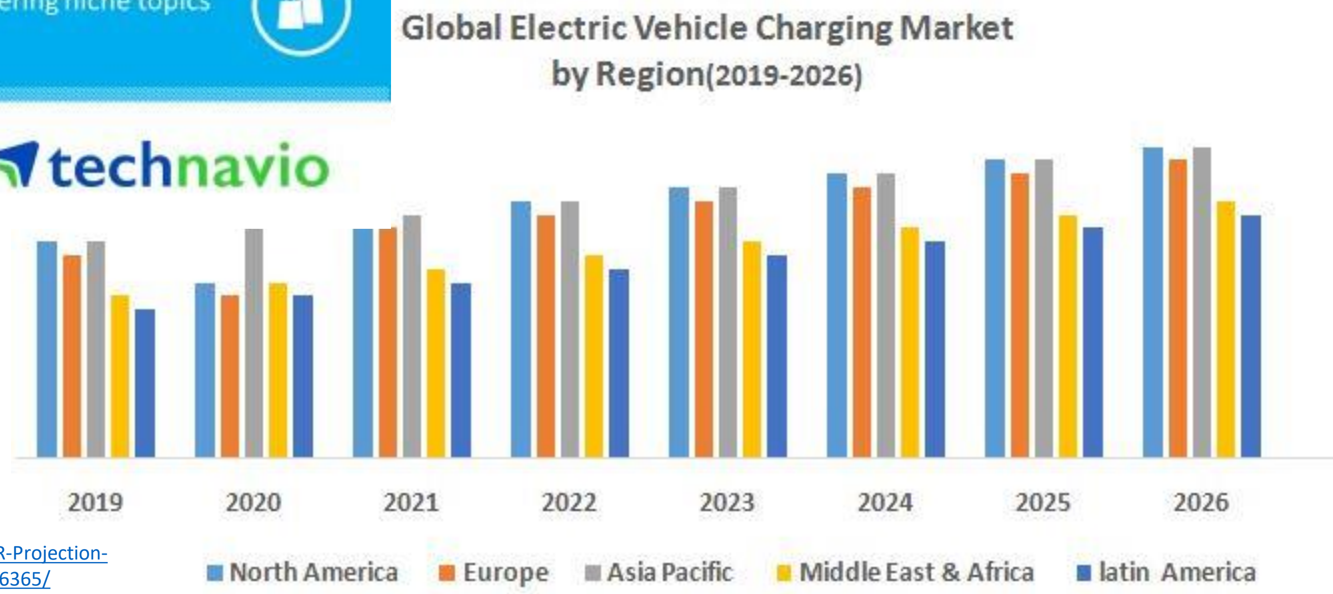
## Electric vehicle financing in India to touch USD 50 billion by 2030

by Soumya Sarkar | Mar 17, 2021

*India's plans to transition to electric mobility require investments to the tune of USD 266 billion but significant barriers have to be overcome in adoption and financing*


Electric vehicle penetration is expected to rise rapidly in India (Photo by Justin Kase / Alamy)

# Global Electric vehicles Charging Market

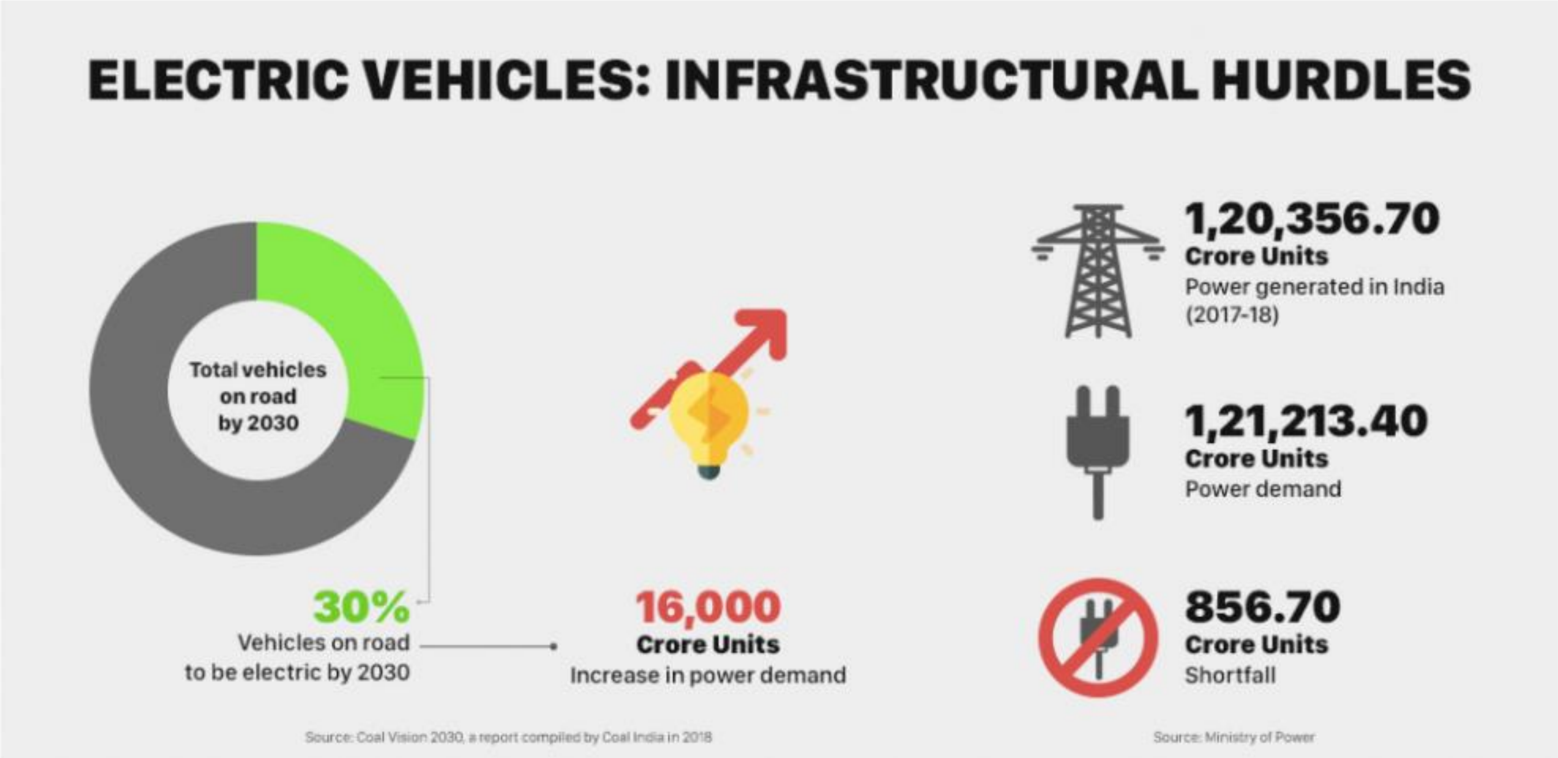

https://www.businesswire.com/news/home/20191112005454/en/Global-Electric-Vehicle-EV-Charging-Station-Market-2019-2023-33-CAGR-Projection-Over-the-Next-Five-Years-Technavio; https://www.maximizemarketresearch.com/market-report/global-electric-vehicle-charging-market/16365/

# Impact of EV charging on electricity needs of India

According to Mr. Phokela, growing EV penetration is likely to boost electricity demand, which may put additional strain on the electricity networks leading to more load shedding than what is currently being experienced in many parts of the country. An EV with a daily commuting distance of 30–40 km will need the energy of almost 6 KW from local DISCOM (electricity distribution companies), which is almost equivalent to the daily power needs of a small family. Hence, adding one more EV in the area would mean an increase in power requirement similar to that of one more family. This has presented a challenge on the power generation companies as the shift from fuel to electricity requires an increase in electricity production.

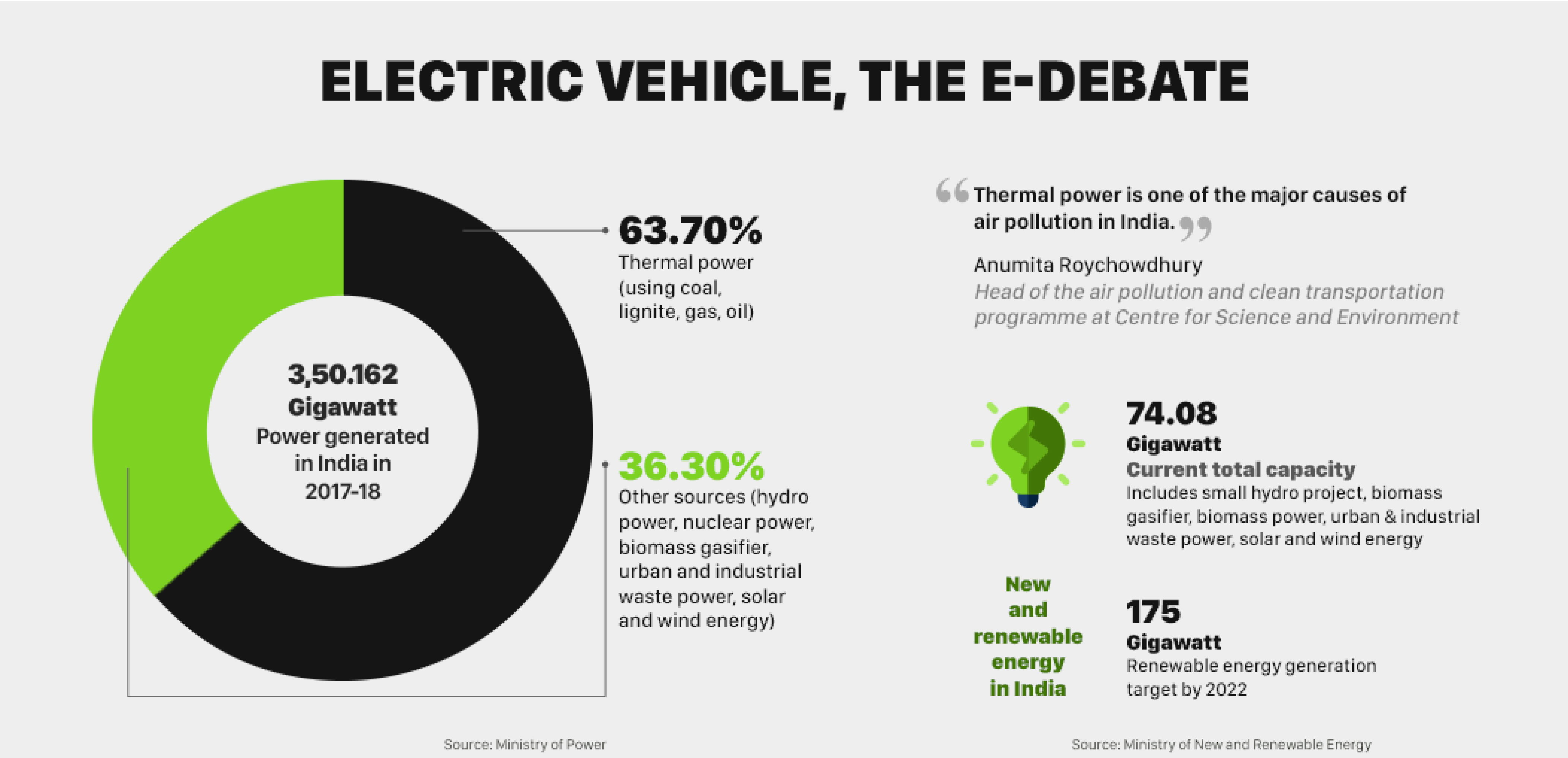
According to a study done by Coal India in 2018 titled 'Coal Vision 2030', e-mobility is likely to be a key "demand driver of electricity" and assuming a market share of 15 per cent by 2030, EVs could result in increased power demand of nearly 16,000 crore units of electricity by 2030. According to the Ministry of Power (MoP), India generated 1,20,630.6 crore units of power in the year 2017-18.

Along with an increased demand for electricity, there will be an increased risk of overloading of local transformers especially during peak hours when most EV owners would charge their vehicles. According to EAI, the overloading can be tackled by encouraging off-peak charging among users by offering discounted rates




https://swachhindia.ndtv.com/india-push-to-go-electric-status-of-charging-infrastructure-for-electric-vehicles-32631/

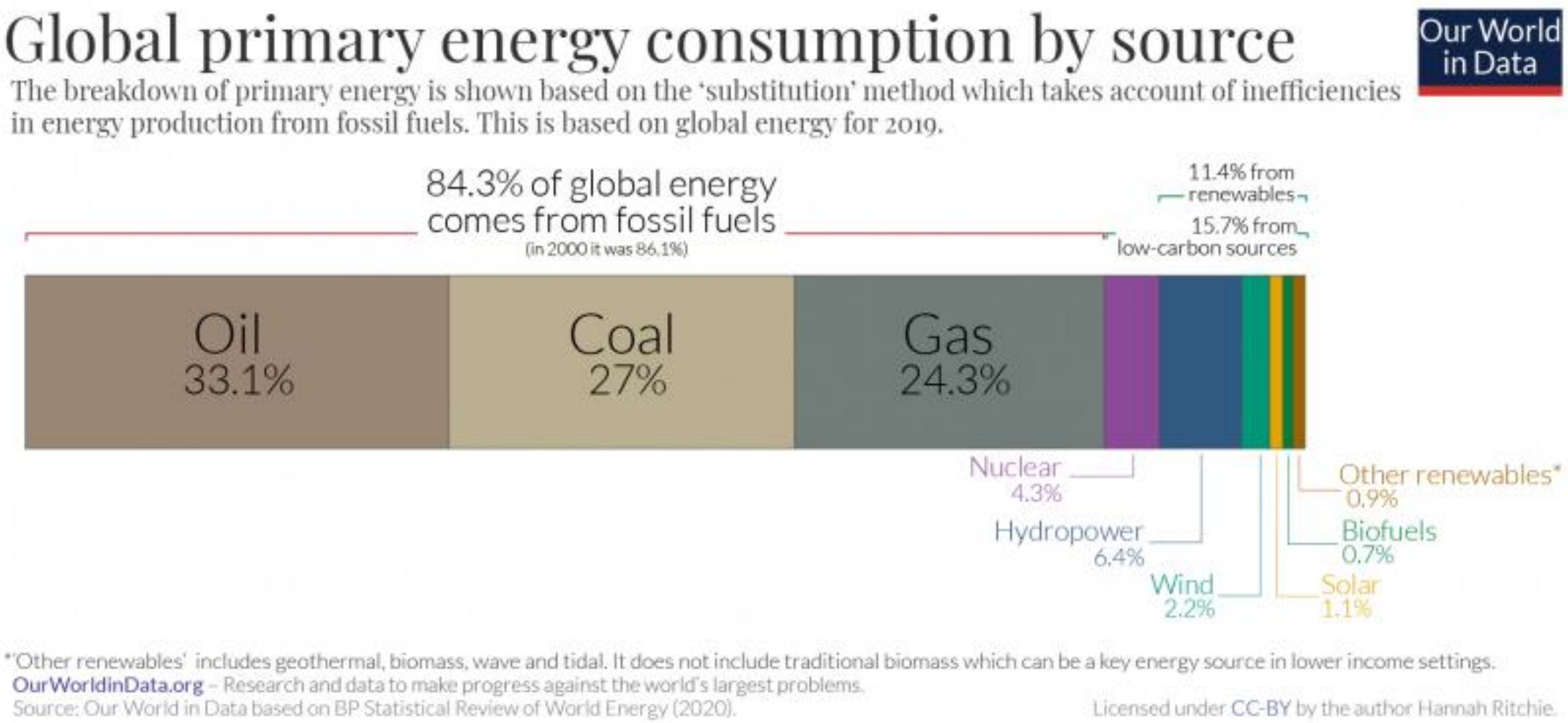
# Impact of EV charging on electricity needs of India




**Using solar-based charging stations for EVs will also help in taking off additional load from the grid and ensure energy security. At present, according to the MoP, the renewable energy capacity of the country stands at 74.08 Gigawatt out of the total power production of 349.288 Gigawatt. As per the data from MoP, about 25 Gigawatt of renewable energy, is currently coming from solar energy. The Ministry of New and Renewable Energy (MNRE) targets to generate 175 Gigawatt of renewable energy by 2022 to cater to the demands of EVs and other energy efficiency initiatives.**

https://swachhindia.ndtv.com/india-push-to-go-electric-status-of-charging-infrastructure-for-electric-vehicles-32631/

# Global Energy Mix




http://www.besustainablemagazine.com/cms2/prospects-for-liquid-biofuels-meeting-the-challenge-of-evs-and-low-oil-prices/

# India Energy Mix (Q4 2020)

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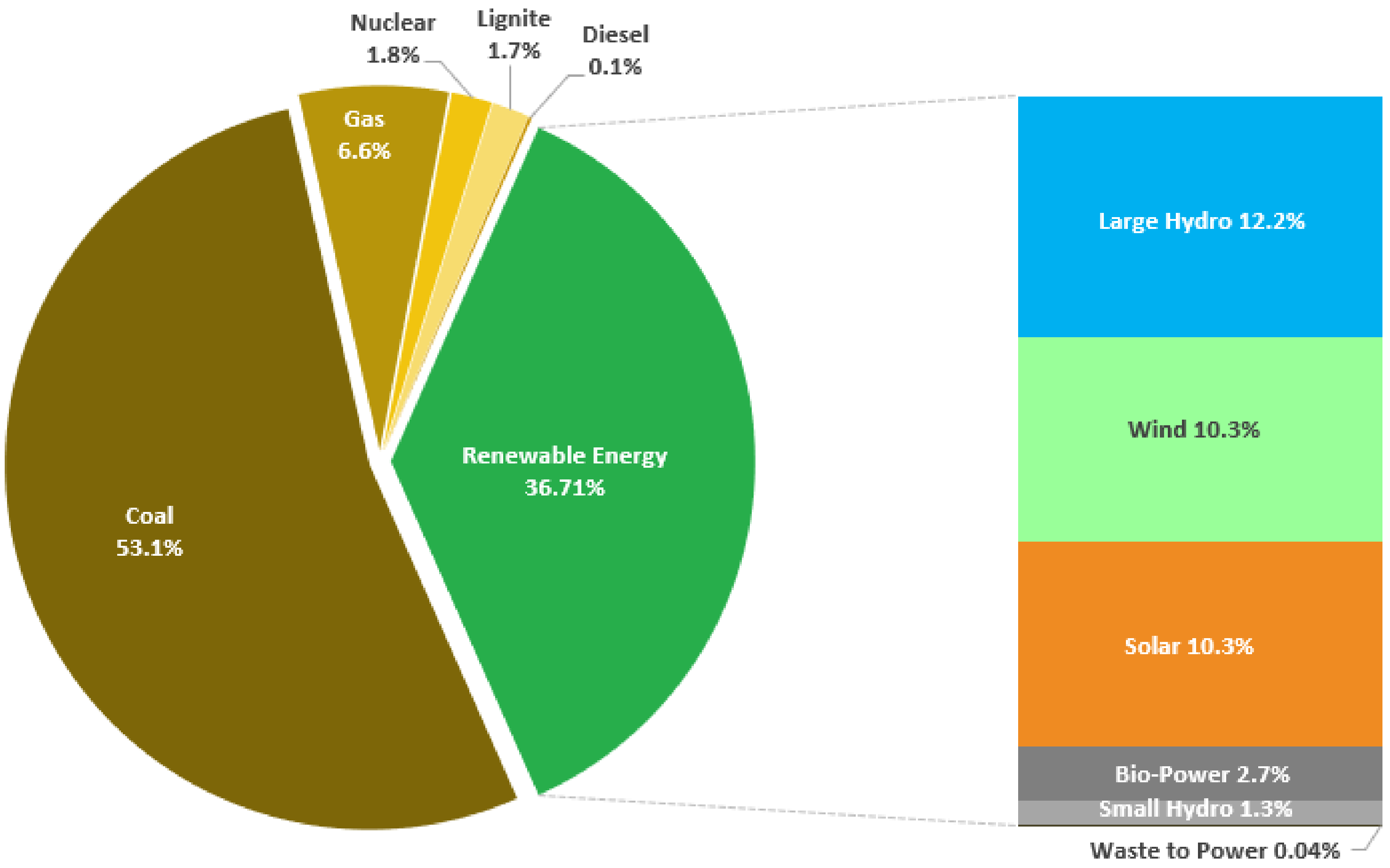
MERCOM
INDIA RESEARCH

## India - Cumulative Installed Power Capacity Mix (%)

Renewables (including Large Hydro) comprise ~36.71% of India's total installed capacity, with solar accounting for ~10%. Among renewables, solar accounts for ~28% of the installed capacity



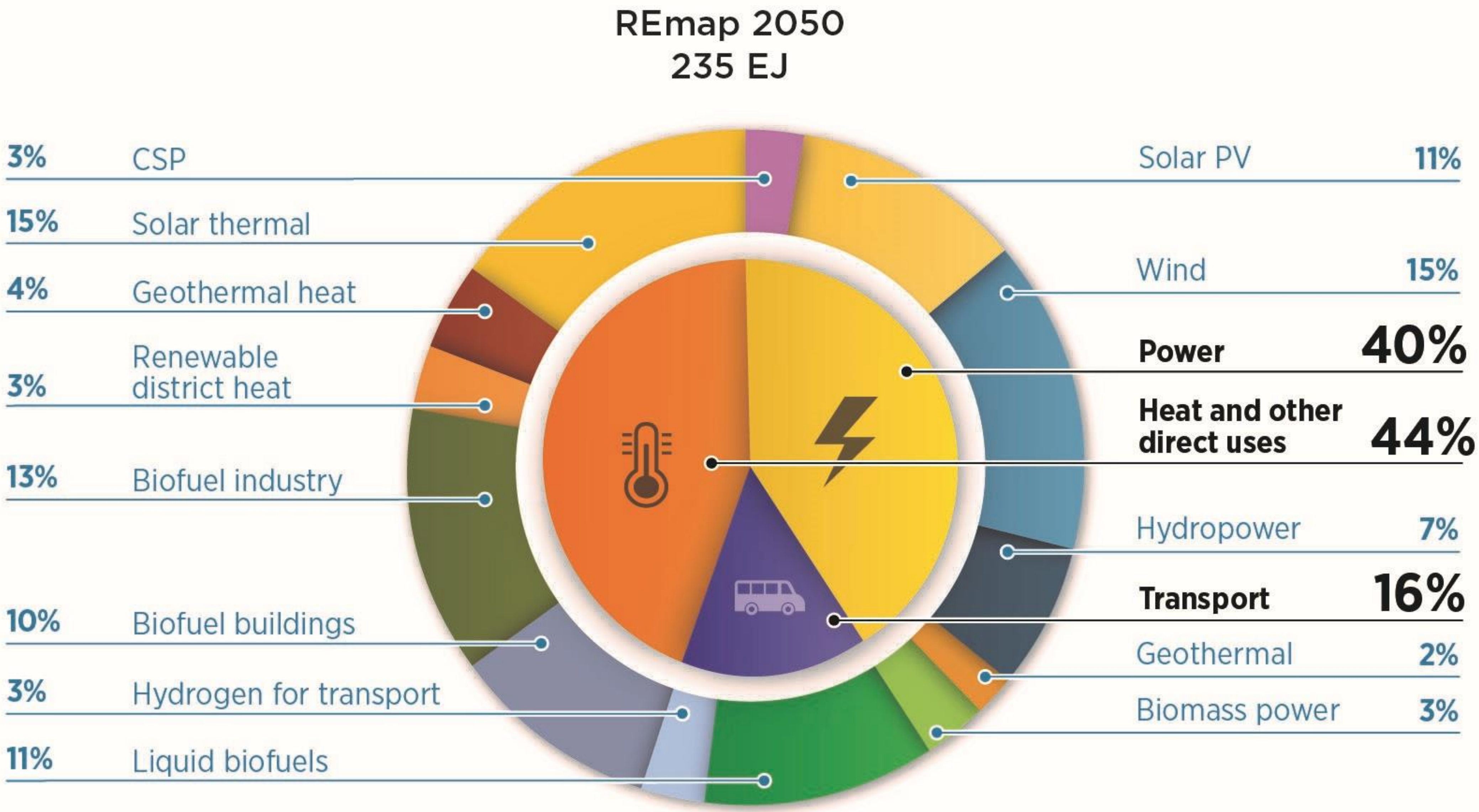

*Data from CEA, MNRE, Mercom India Solar Project Tracker (Installed Capacity as on 31 Dec 2020)*

*Source: Mercom India Research*

https://mercomindia.com/india-renewable-power-installations/


I FEEL SO DIRTY !
DIESEL
I FEEL SO CLEAN !
ELECTRIC

# Renewable Energy Market Predictions by IRENA




http://www.besustainablemagazine.com/cms2/prospects-for-liquid-biofuels-meeting-the-challenge-of-evs-and-low-oil-prices/

# Hydrothermal Liquefaction

Nie and Bi *Biotechnol Biofuels* (2018) 11:23
https://doi.org/10.1186/s13068-018-1019-x

Biotechnology for Biofuels

RESEARCH Open Access

CrossMark

## Life-cycle assessment of transportation biofuels from hydrothermal liquefaction of forest residues in British Columbia

Yuhao Nie[1] and Xiaotao Bi[1,2*]

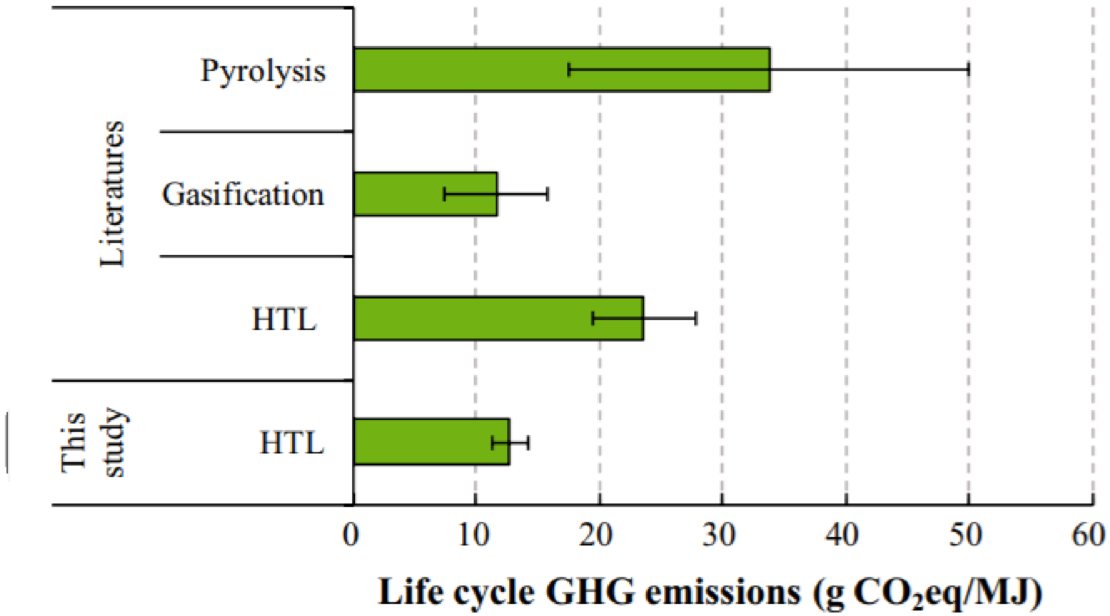
**Abstract**

**Background:** Biofuels from hydrothermal liquefaction (HTL) of abundantly available forest residues in British Columbia (BC) can potentially make great contributions to reduce the greenhouse gas (GHG) emissions from the transportation sector. A life-cycle assessment was conducted to quantify the GHG emissions of a hypothetic 100 million liters per year HTL biofuel system in the Coast Region of BC. Three scenarios were defined and investigated, namely, supply of bulky forest residues for conversion in a central integrated refinery (Fr-CIR), HTL of forest residues to bio-oil in distributed biorefineries and subsequent upgrading in a central oil refinery (Bo-DBR), and densification of forest residues in distributed pellet plants and conversion in a central integrated refinery (Wp-CIR).

**Results:** The life-cycle GHG emissions of HTL biofuels is 20.5, 17.0, and 19.5 g $CO_2$-eq/MJ for Fr-CIR, Bo-DBR, and Wp-CIR scenarios, respectively, corresponding to 78–82% reduction compared with petroleum fuels. The conversion stage dominates the total GHG emissions, making up more than 50%. The process emitting most GHGs over the life cycle of HTL biofuels is HTL buffer production. Transportation emission, accounting for 25% of Fr-CIR, can be lowered by 83% if forest residues are converted to bio-oil before transportation. When the credit from biochar applied for soil amendment is considered, a further reduction of 6.8 g $CO_2$-eq/MJ can be achieved.

**Conclusions:** Converting forest residues to bio-oil and wood pellets before transportation can significantly lower the transportation emission and contribute to a considerable reduction of the life-cycle GHG emissions. Process performance parameters (e.g., HTL energy requirement and biofuel yield) and the location specific parameter (e.g., electricity mix) have significant influence on the GHG emissions of HTL biofuels. Besides, the recycling of the HTL buffer needs to be investigated to further improve the environmental performance of HTL biofuels.

**Keywords:** GHG emissions, Life-cycle assessment, Hydrothermal liquefaction, Transportation biofuels, Forest residues, British Columbia

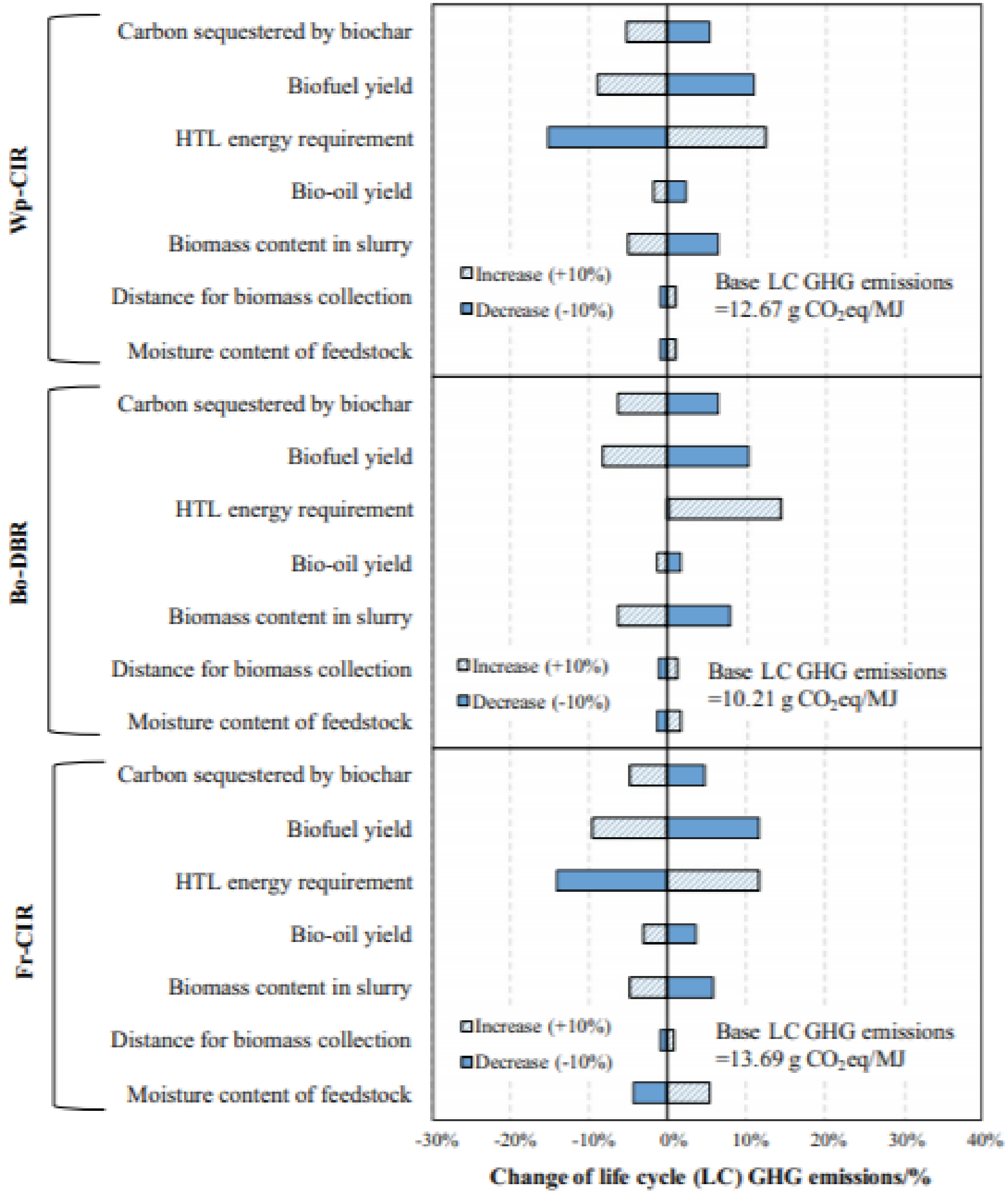



Comparison of HTL biofuel life-cycle GHG emissions results with literatures

Nie, Y., & Bi, X. (2018). Life-cycle assessment of transportation biofuels from hydrothermal liquefaction of forest residues in British Columbia. *Biotechnology for biofuels*, *11*(1), 1-14.

- For scenario 1 (denoted as Fr-CIR scenario), the collected bulky forest residues from each FDP are directly transported to the central integrated refnery for conversion.
- For scenario 2 (denoted as Bo-DBR scenario), forest residues are frst converted to bio-oil at distributed biorefneries and then transported to a central oil refnery for upgrading.
- For scenario 3 (denoted as Wp-CIR scenario), forest residues are frst densifed to wood pellets at distributed pellet plants located at FDPs and then transported to the central integrated refnery for conversion.

(Nie and Bi, 2018).



Sensitivity analysis of net life-cycle GHG emissions of HTL biofuels for different scenarios

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Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

# Life cycle assessment of bio-jet fuel from hydrothermal liquefaction of microalgae

Marie-Odile P. Fortier[a], Griffin W. Roberts[b], Susan M. Stagg-Williams[b], Belinda S.M. Sturm[a,*]

[a] Department of Civil, Environmental, and Architectural Engineering, The University of Kansas, 2150 Learned Hall, 1530 West 15th Street, Lawrence, KS 66045, USA
[b] Department of Chemical and Petroleum Engineering, The University of Kansas, USA

## HIGHLIGHTS

- A life cycle assessment of bio-jet fuel from wastewater algae was performed.
- We used experimental data from algae cultivation through hydrothermal liquefaction.
- We performed Monte Carlo and sensitivity analyses with ranges of parameter values.
- Transport of moderately dewatered algae increased life cycle climate change impacts.
- Collocation and heat integration reduce life cycle greenhouse gas emissions by 76%.

## ARTICLE INFO

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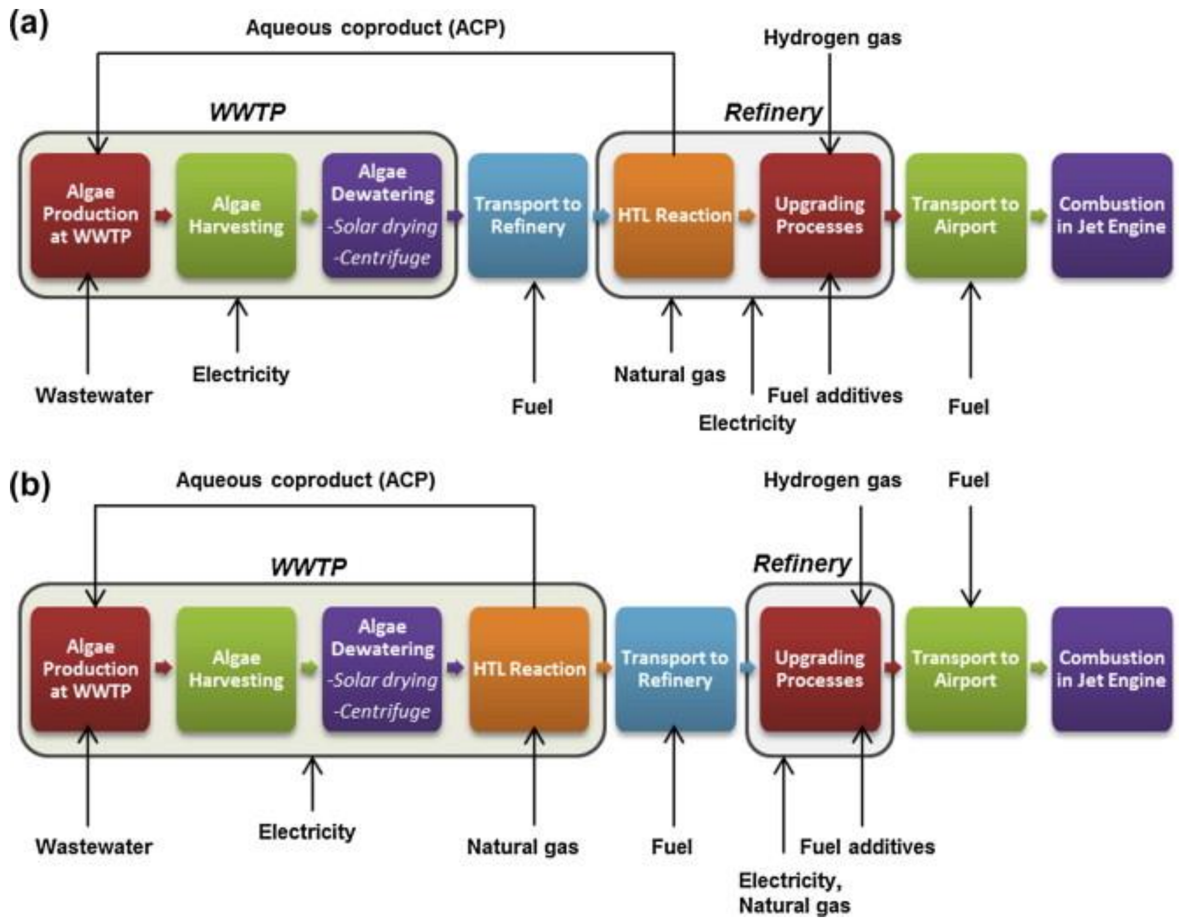
*Keywords:*
Algae
Bio-jet fuel
Life cycle assessment
Hydrothermal liquefaction
Wastewater

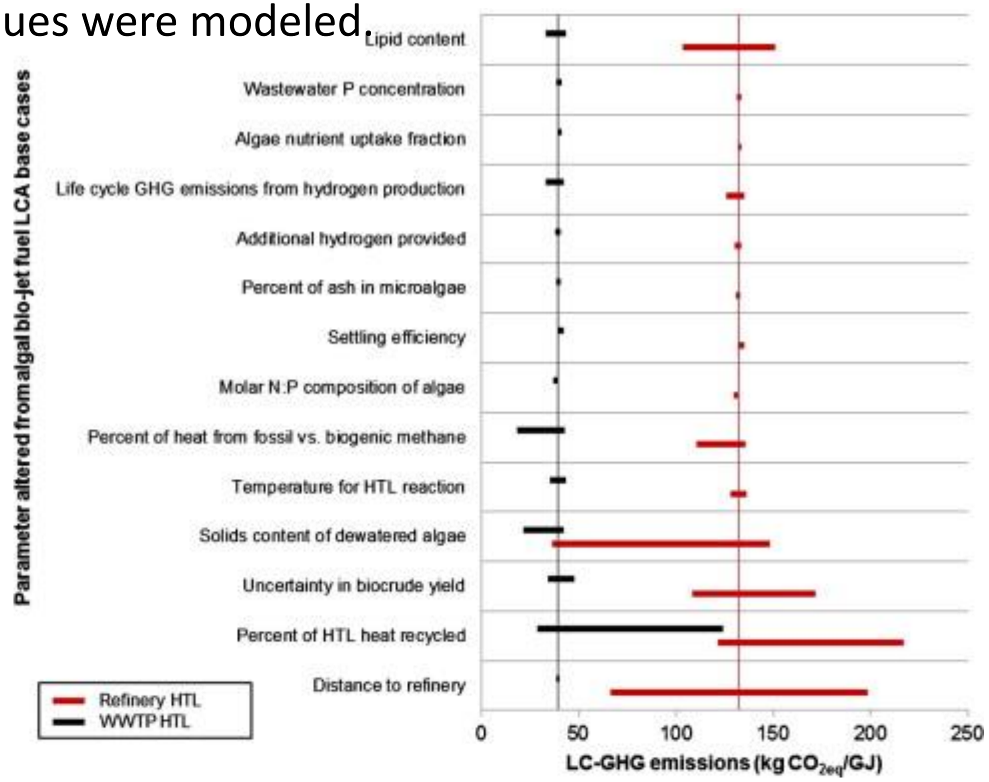
## ABSTRACT

Bio-jet fuel is increasingly being produced from feedstocks such as algae and tested in flight. As the industry adopts bio-jet fuels from various feedstocks and conversion processes, life cycle assessment (LCA) is necessary to determine whether these renewable fuels result in lower life cycle greenhouse gas (LC-GHG) emissions than conventional jet fuel. An LCA was performed for a functional unit of 1 GJ of bio-jet fuel produced through thermochemical conversion (hydrothermal liquefaction (HTL)) of microalgae cultivated in wastewater effluent. Two pathways were analyzed to compare the impacts of siting HTL at a wastewater treatment plant (WWTP) to those of siting HTL at a refinery. Base cases for each pathway were developed in part using primary data from algae production in wastewater effluent and HTL experiments of this algae at the University of Kansas. The LC-GHG emissions of these cases were compared to those of conventional jet fuel, and a sensitivity analysis and Monte Carlo analyses were performed. When algal conversion using HTL was modeled at a refinery versus at the WWTP site, the transportation steps of biomass and waste nutrients were major contributors to the LC-GHG emissions of algal bio-jet fuel. The LC-GHG emissions were lower for the algal bio-jet fuel pathway that performs HTL at a WWTP (35.2 kg $CO_{2eq}$/GJ for the base case) than for the pathway for HTL at a refinery (86.5 kg $CO_{2eq}$/GJ for the base case). The LCA results were particularly sensitive to the extent of heat integration, the source of the heat for HTL, and the solids content of dewatered algae. The GHG emissions of algal bio-jet fuel can be reduced by 76% compared to conventional jet fuel with feasible improvements in those sensitive parameters and siting HTL at a WWTP. Therefore, it is critical that transportation logistics, heat integration of biomass conversion processes, and nutrient supply chains be considered as investment and production of bio-jet fuels increase.

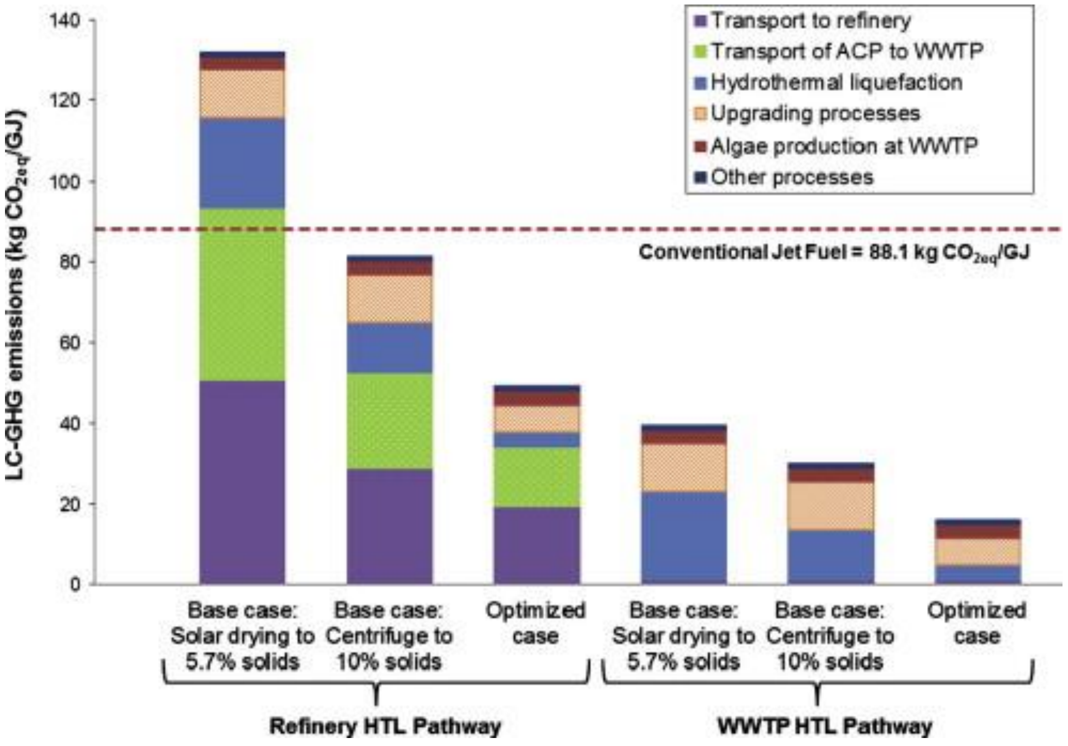
The life cycle foreground process chains for the (a) Refinery HTL and the (b) WWTP HTL algal bio-jet fuel production pathways with selected major inputs shown



Sensitivity analysis for the modeled parameters of algal bio-jet fuel production. The bars span the difference in the algal bio-jet fuel LC-GHG emissions when a parameter is changed from its minimum to its maximum value. The base case LC-GHG emissions for the Refinery HTL and the WWTP HTL pathways are shown as baselines. The parameters that are excluded in this graph resulted in a less than 2 kg $CO_{2eq}$/GJ difference when the maximum and the minimum parameter values were modeled.




Algal bio-jet fuel LCA results for each case analyzed compared against the life cycle climate change impacts of conventional jet fuel. The "Other processes" category includes three processes that were combined due to their comparatively small LC-GHG emissions: algae harvesting; transport to an airport; and combustion in a jet engine.



# Loop the waste into energy sector

# Hydrothermal Carbonization _ Future of waste to energy

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ART AWARDS News / Education Today / News / IIT Kharagpur researchers develop 'zero loss' process for wet municipal solid waste management

## IIT Kharagpur researchers develop 'zero loss' process for wet municipal solid waste management

*With this technology, waste management can be reached to zero waste level.*

## Sikkim Researcher turns organic municipal solid waste into a coffee scented coal

Ads by Google organic waste west sikkim north sikkim

Home » Environment » Sikkim Researcher turns organic municipal solid waste into a coffee scented coal


Hari Bhaktha Sharma – Future CM (Carbonization Man)

# HTC of the organic fraction of MSW

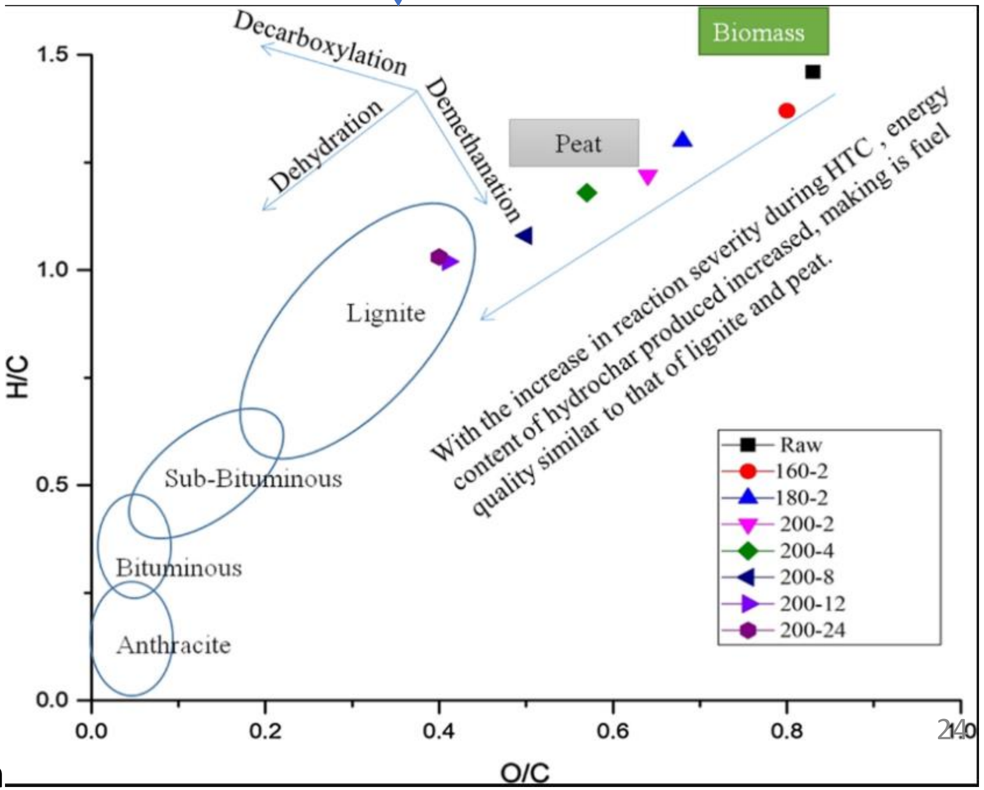
Yard Waste

Food

Reactor

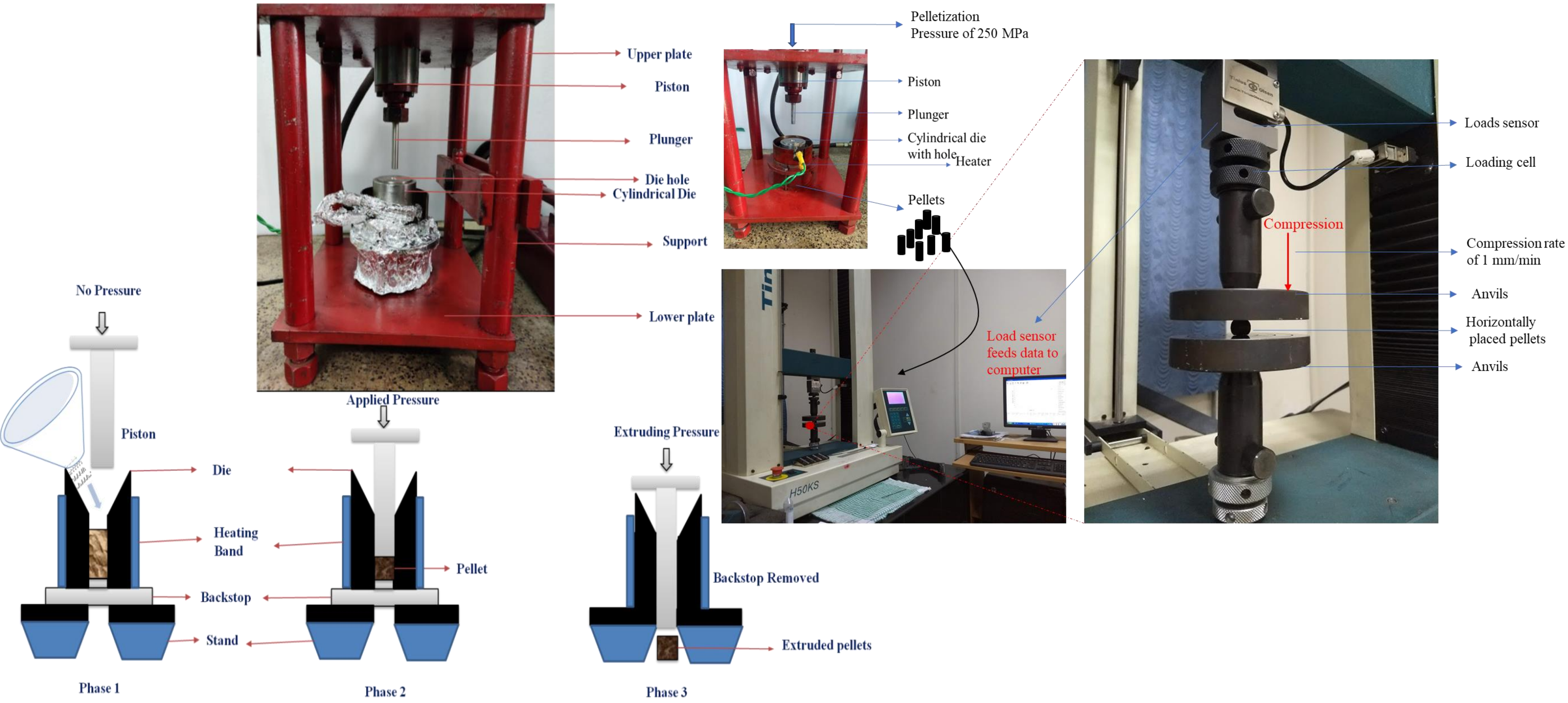
Hydrochar

Fuel Pellets

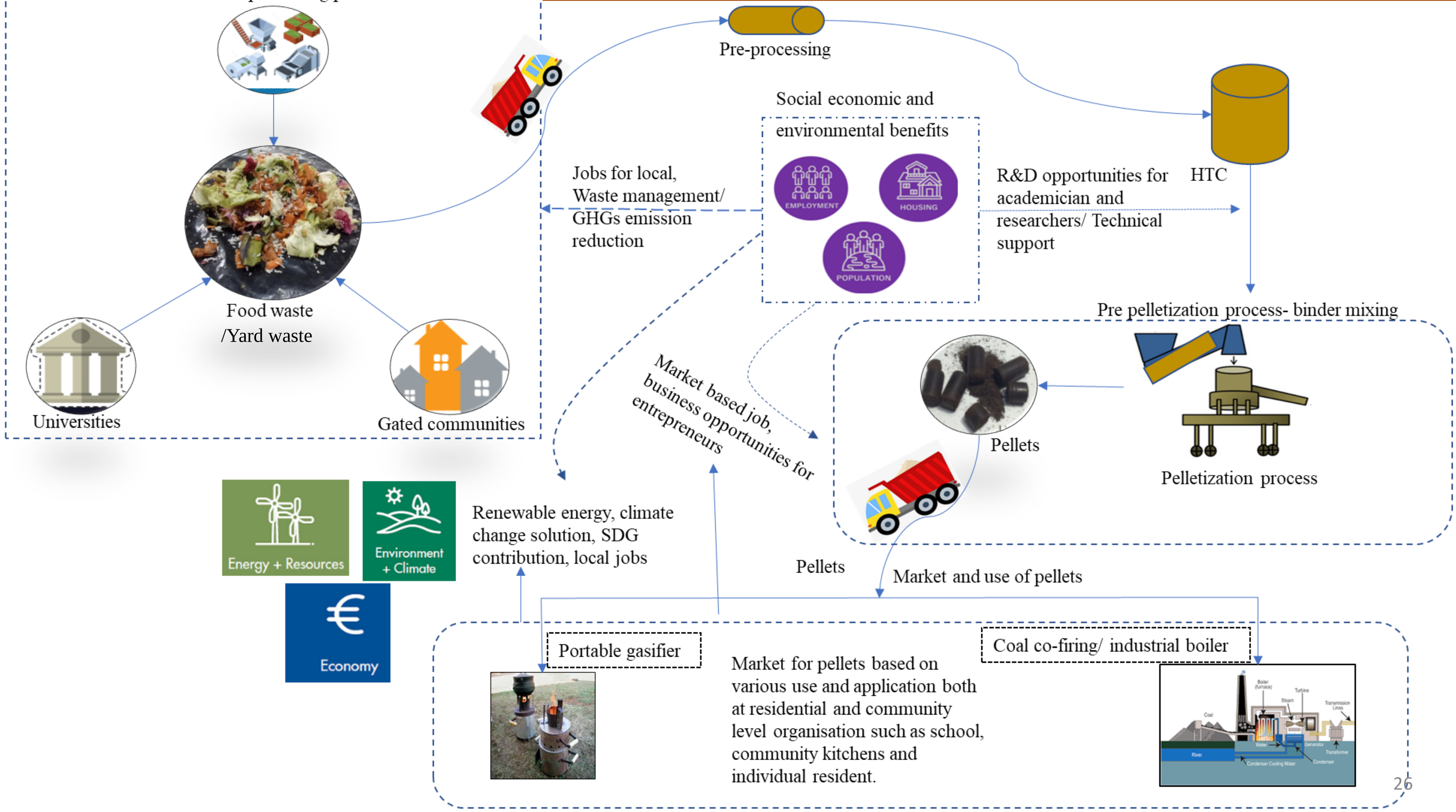



Van Krevelen diagram

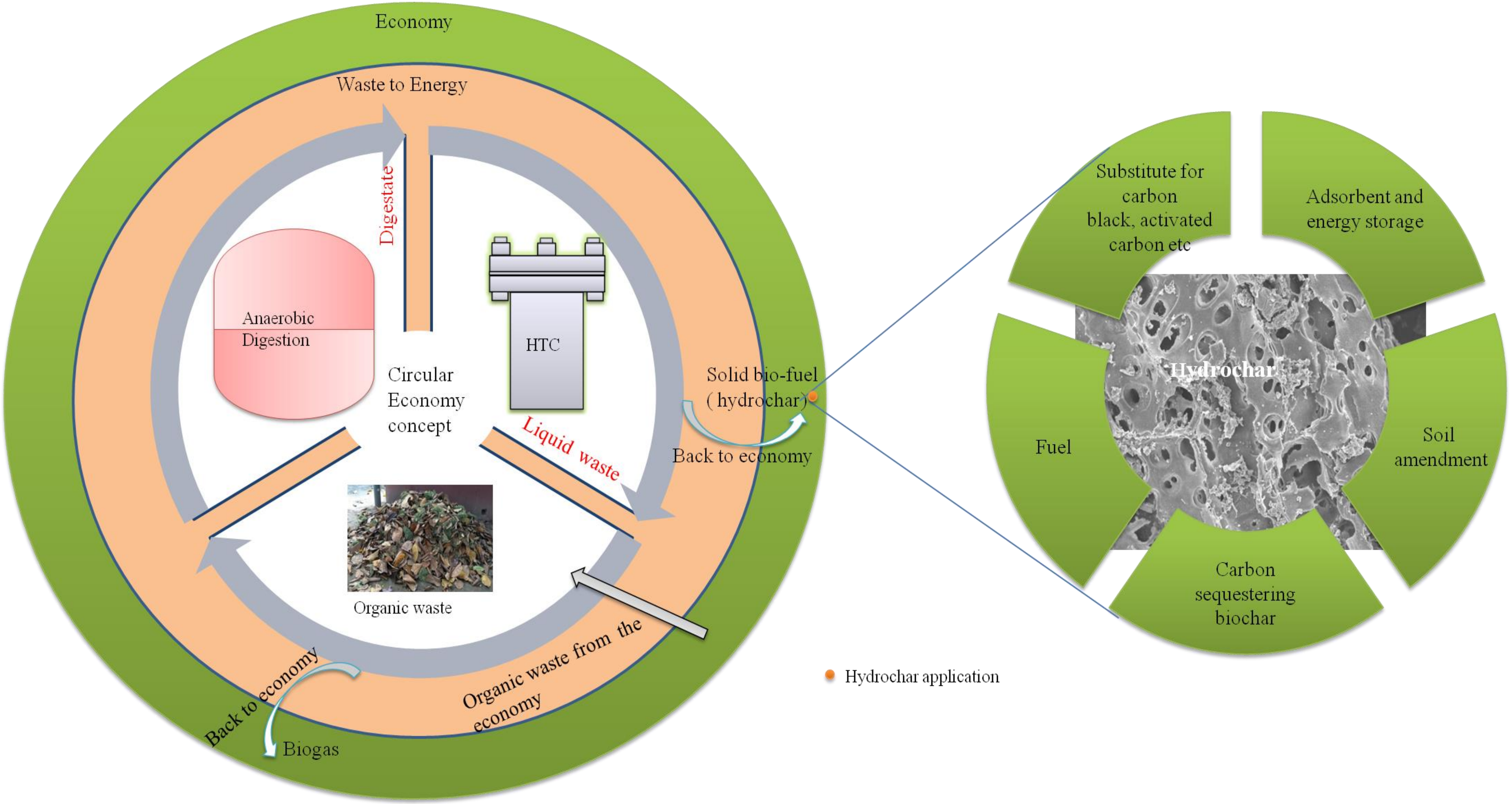
# Pelletization using self design pelletiser



# Framework development using socio-economic context



# Application of hydrochar



# Recent Publication addressing Hydrothermal carbonization of organic waste

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

## Hydrothermal carbonization of yard waste for solid bio-fuel production: Study on combustion kinetic, energy properties, grindability and flowability of hydrochar

Hari Bhakta Sharma, Sagarika Panigrahi, Brajesh K. Dubey *

*Environmental Engineering and Management, Department of Civil Engineering, Indian Institute of Technology Kharagpur, Kharagpur 721302, West Bengal, India*

A R T I C L E I N F O

*Article history:*
Received 24 November 2018
Revised 19 April 2019
Accepted 27 April 2019
Available online 4 May 2019

*Keywords:*
Yard waste
Hydrothermal carbonization
Hydrochar
Flowability
Combustion behavior

A B S T R A C T

Yard waste is either dumped or is being openly burned to get rid of it, instead of using it as a valuable renewable energy source. In this study, hydrothermal carbonization of yard waste was conducted to valorize it as a solid bio fuel, using a batch reactor. The effect of process parameter on yield, energy and physicochemical properties of the valorized solid bio fuel (hydrochar) was examined in this study by varying reaction temperature (160–200 °C for 2 h) and reaction time (2–24 h at 200 °C). The calorific value of hydrochar was within a range of 17.72–24.59 MJ/kg as compared to 15.37 MJ/kg for untreated yard waste. Hydrochar mass yield decreased from 78.6% at operating temperature – time of 160 °C – 2 h to 45.6% at 200 °C –24 h. The plot of atomic ratios (H/C and O/C) demonstrates improvement in the coalification process which was mainly governed by decarboxylation and dehydration reactions. The grindability of the prepared hydrochar was comparable to that of coal. Hydrochar produced at lower reaction condition (160–200 °C at 2 h) have better flowability as compared to that produced at higher reaction condition (4–24 h at 200 °C). The reaction time longer than 12 h has a minimal effect on the yield, energy and physicochemical properties of hydrochar. Increasing reaction time and temperature improved the ignition and burnt temperature of hydrochar. All reaction condition has an energy ratio (energy output to energy input) of more than one making HTC process a net energy producer.



Science of the Total Environment 690 (2019) 261–276

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Review

## Valorisation of food waste via hydrothermal carbonisation and techno-economic feasibility assessment

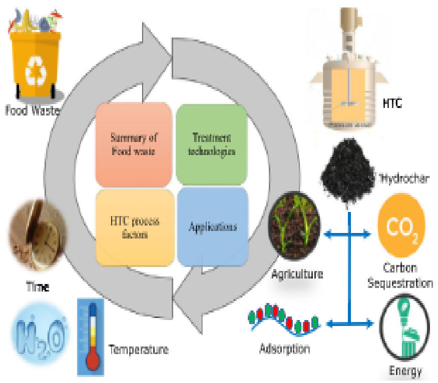
Najam Ul Saqib [a], Hari Bhakta Sharma [b], Saeid Baroutian [c], Brajesh Dubey [b], Ajit K. Sarmah [a,*]

[a] *Department of Civil & Environmental Engineering, Faculty of Engineering, The University of Auckland, Private Bag 92019, Auckland 1142, New Zealand*
[b] *Department of Civil Engineering, Indian Institute of Technology - Kharagpur, Kharagpur, West Bengal 721302, India*
[c] *Department of Chemical & Materials Engineering, Faculty of Engineering, The University of Auckland, 1010, New Zealand*

H I G H L I G H T S

- Thermal treatments like incineration and pyrolysis are not favourable for food waste.
- Hydrothermal carbonisation (HTC) is an effective treatment for conversion of food waste into energy.
- HTC is highly dependent on process parameters (i.e. temperature, time and pressure).
- HTC is highly dependent on fluctuating cost of equipment, labour, and transportation.

G R A P H I C A L A B S T R A C T



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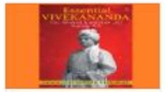

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Aug 1, 2019, 04.50PM IST by Jasleen Taneja

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*The new technology reaches the zero waste scale with this process. It can effectively manage mixed Municipal Solid Waste (MSW) with high moisture content. Read further to know more.*

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ETEnergyWorld | July 31, 2019, 13:58 IST

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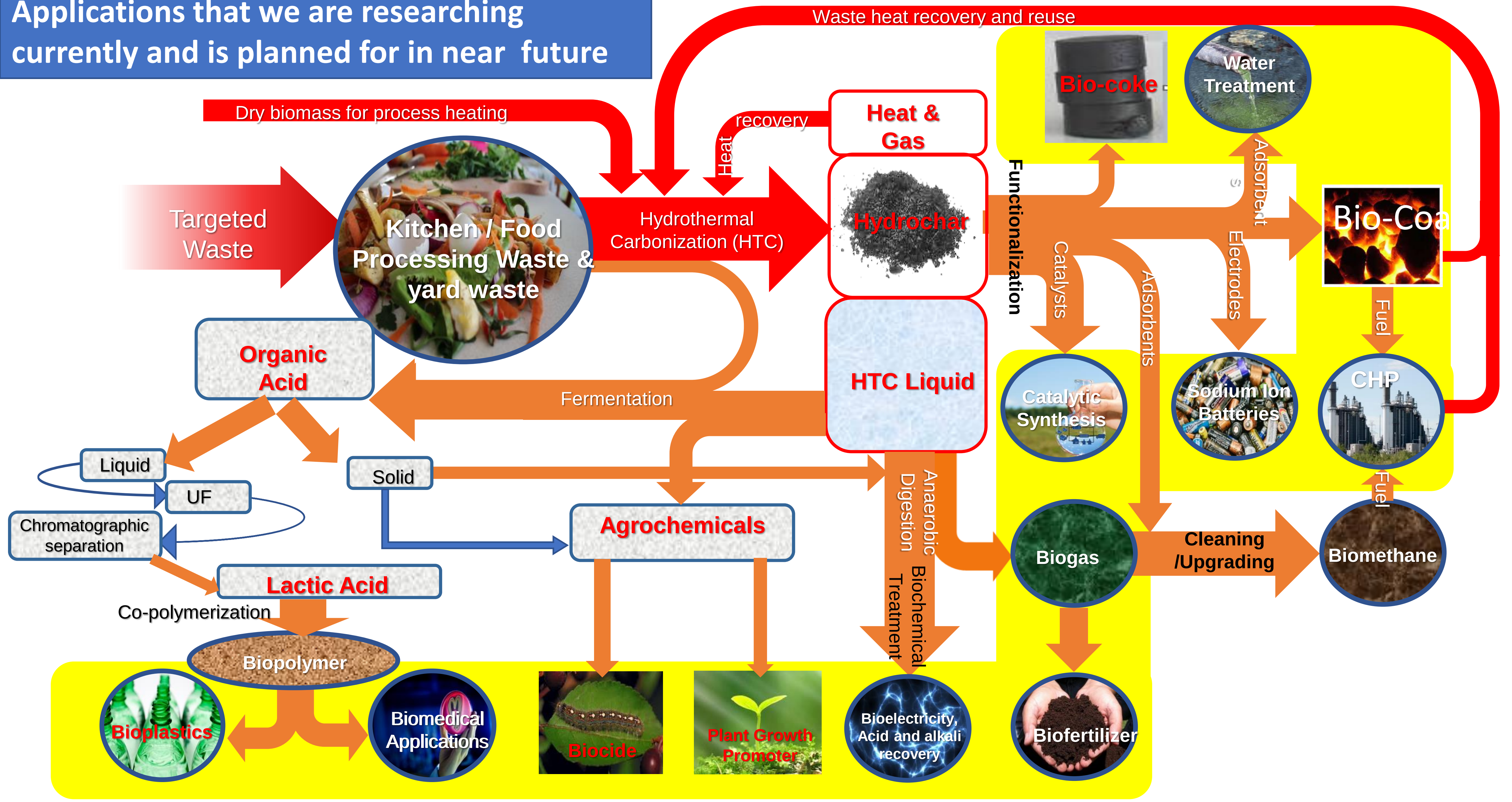
# Applications that we are researching currently and is planned for in near future



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# Thank you

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