Green Energy

Biomass to Hydrogen

Innovative Technological Options

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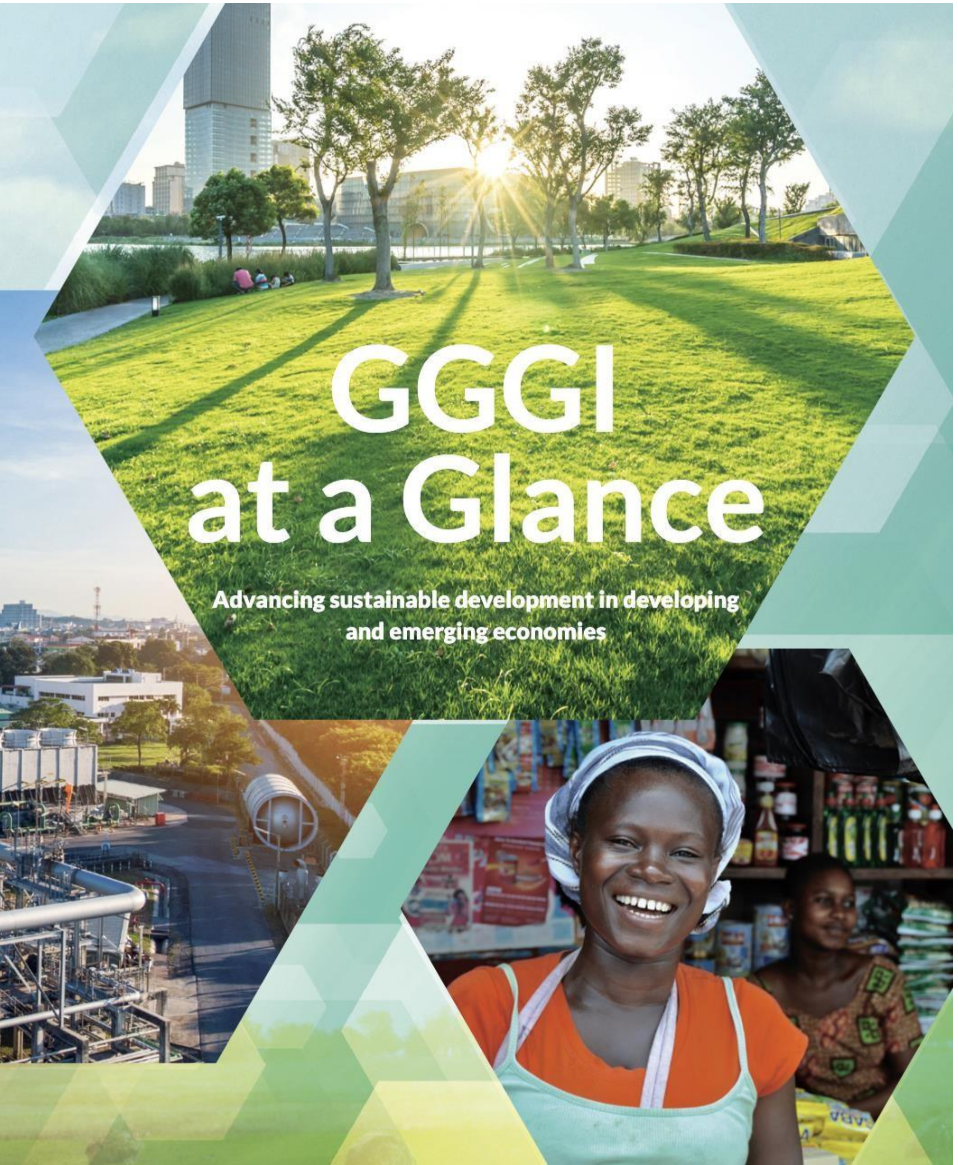
GGGI

Agenda

- About GGGI
- Overview of Green Hydrogen
- Hydrogen Production Processes
  - Thermochemical
  - Biological
  - Other upcoming processes
- Challenges & Way forward

Introduction



The **Global Green Growth Institute (GGGI)** is **a treaty-based international organization** focused on supporting developing and emerging economies **to achieve sustainable, inclusive economic growth.**

Our Vision

A **LOW-CARBON**, **RESILIENT WORLD** OF **STRONG**, **INCLUSIVE**, AND **SUSTAINABLE GROWTH**

Our Mission

GGGI SUPPORTS ITS **MEMBERS** IN THE **TRANSFORMATION** OF **THEIR ECONOMIES** TO A **GREEN GROWTH** ECONOMIC MODEL.

Our Position

A **TRUSTED ADVISOR** & **DEVELOPMENT PARTNER** EMBEDED IN MEMBER & PARTNER GOVERNMENTS

Our Thematic Areas

- Sustainable Energy
- Sustainable Landscapes
- Green Cities

How we work

As of 2021, GGGI has 41 Members and delivers programs for more than 30 Members and partners – in Africa, Asia, Caribbean, Europe, Latin America, Middle East and Pacific

- GGGI has a unique in-country presence and prominent role as a neutral, trusted advisor and strategic development partner embedded in Member and partner governments.

- **GGGI's operating model focuses on**
  - **Energy technologies which need support to transition to bankable and viable business models.**
  - **Support partner members in range of technical and commercial aspects through targeted Technical Assistance (TA) support.**
  - **Leverage global relationships to enable partner members to increase access to green finance, technical knowhow etc.**

Net Zero Commitment: Government of India

Net Zero commitment	1	2	3	4	5
	India will reach its non-fossil energy capacity to 500GW by 2030	India will meet 50 percent of it energy requirements from renewable energy by 2030	India will reduce the total projected carbon emissions by 1Bn tons from now onwards till 2030	By 2030, India will reduce the carbon intensity of its economy by less than 45 percent	Achieve Net Zero by 2070

Evolving Green Hydrogen Framework in India

India made a broader pledge to reach net zero by 2070, Green Hydrogen will play a key role to meeting this

Policy framework

- India launched the National Hydrogen Mission (NHM) on 15th Aug 2021 with an aim to cut down carbon emissions and increase the use of renewable sources of energy.
- The draft rules on "Electricity (promoting renewable energy through Green Energy Open Access) Rules, 2021" issued by MOP focusses on Green Hydrogen as means to meet the Renewable Purchase Obligation for obligated agencies which includes large energy intensive industries.

Creating Demand

- It is expected that GOI will mandate hard to abate industries like fertilizers, petrochemical, Iron and Steel etc to meet part of the energy requirement from Green Hydrogen.
- Progressive targets are planned to be stipulated with an expected initial target to replace atleast 10% of the energy demand met from fossil fuels with Green hydrogen by 2030.

Supporting manufacturing

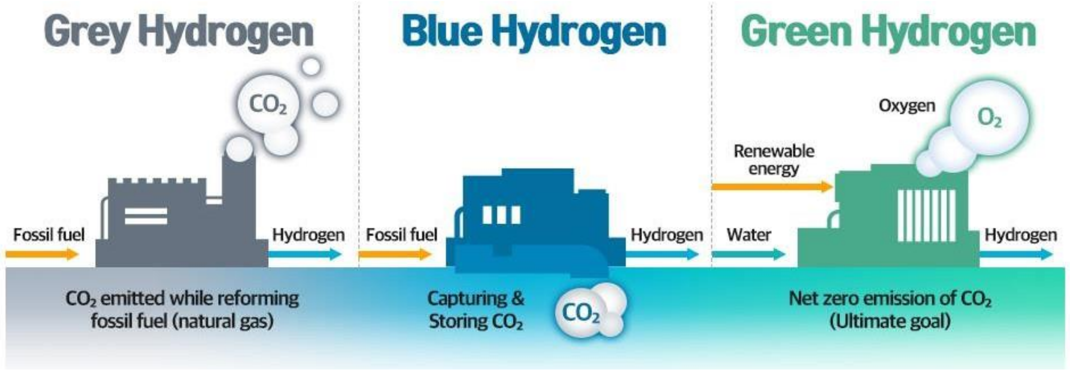
- To build scale and reduce cost of green hydrogen production in India, local manufacturing of electrolysers is critical.
- The government plans to extend the Performance Linked Incentive (PLI) scheme to electrolyser manufacturing locally in India.

Green Hydrogen – The Sunrise sector

Hydrogen has multiple end-uses (due to inherent chemical characteristics, harmony with other fuel, and as energy carriers) makes it a strong contender of the clean energy transition

What is Green Hydrogen

Classification of hydrogen is based on feedstock and process to reduce CO_2 emissions



Why Green Hydrogen?

GHG emission Reduction Drivers – by 2030

Through 2030 current RE tech will drive GHG reductions

GHG emission Reduction Drivers –beyond 2030

Beyond 2030 tech like battery, electrolysers will drive GHG reductions

Where to use Green Hydrogen?

Industries which are hard to abate

Heavy Transport

Petrochemical Industry
For desulfurization and Hydrocracking process

Fertilizer Industry
For Ammonia to produce Urea and Ammonium nitrate

Fuel cells for transport sector

Chemical Industry
For production of Methanol and Hydrochloric Acid

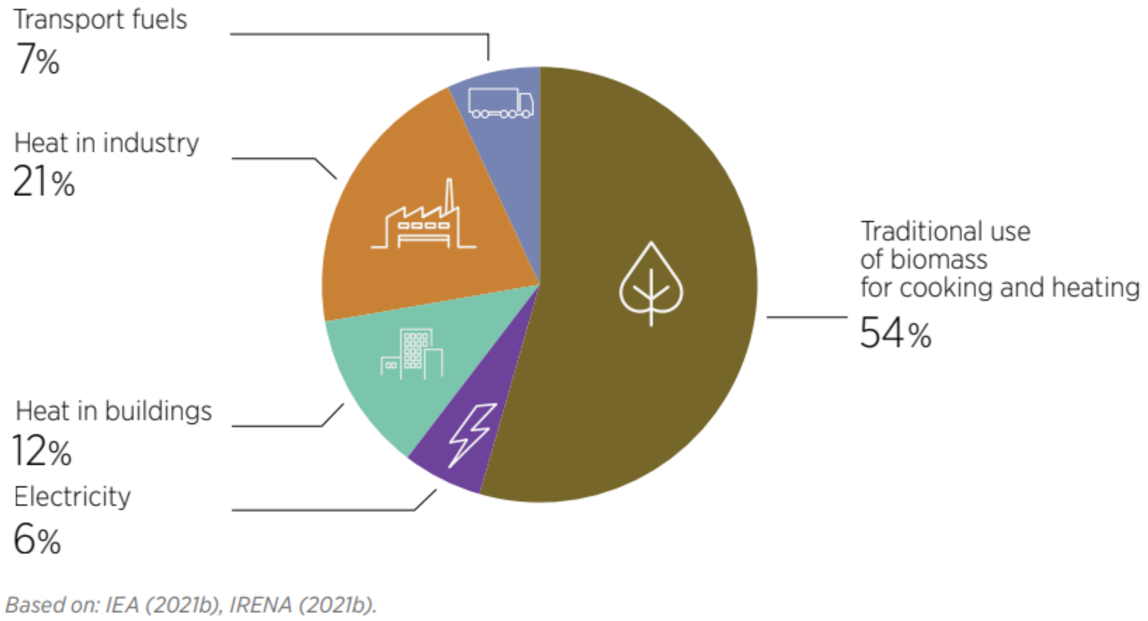
Steel industry
To replace coking coal in blast furnace

What is driving the transition to Green Hydrogen?

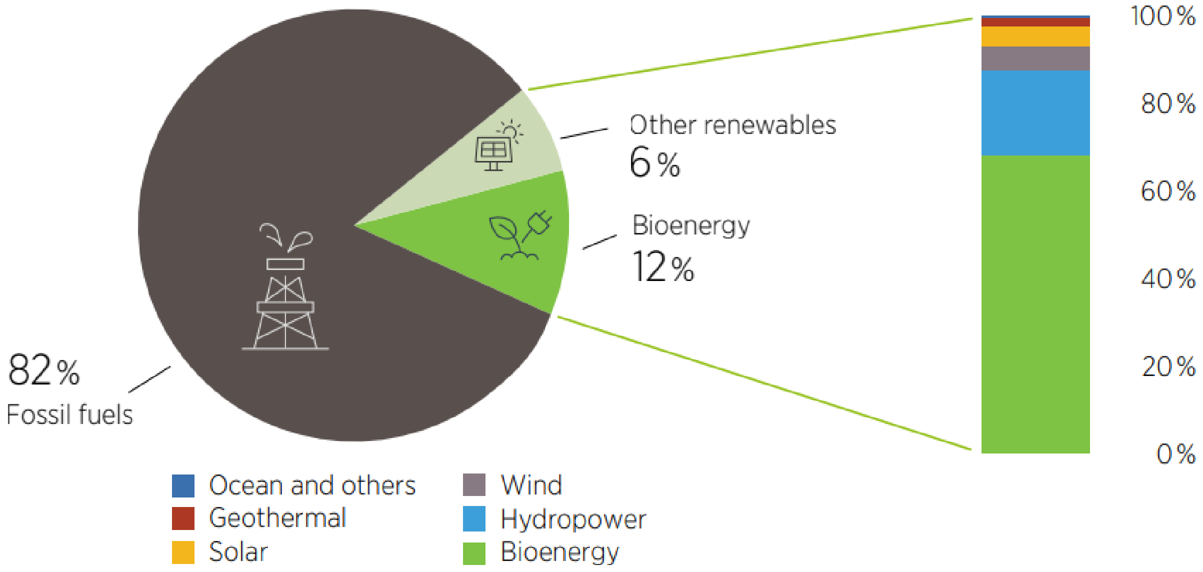
- Decreased cost of RE generation
- Decarbonise hard to abate industries like steel, refinery, chemical
- Flexibility of storage to be used as required
- Use in heavy transport - truck, train, ships

Bioenergy Share

Bioenergy currently contributes the largest share (two-thirds) of renewables utilization worldwide, when including the traditional use of biomass.



Share of global bioenergy consumption by end use, 2020



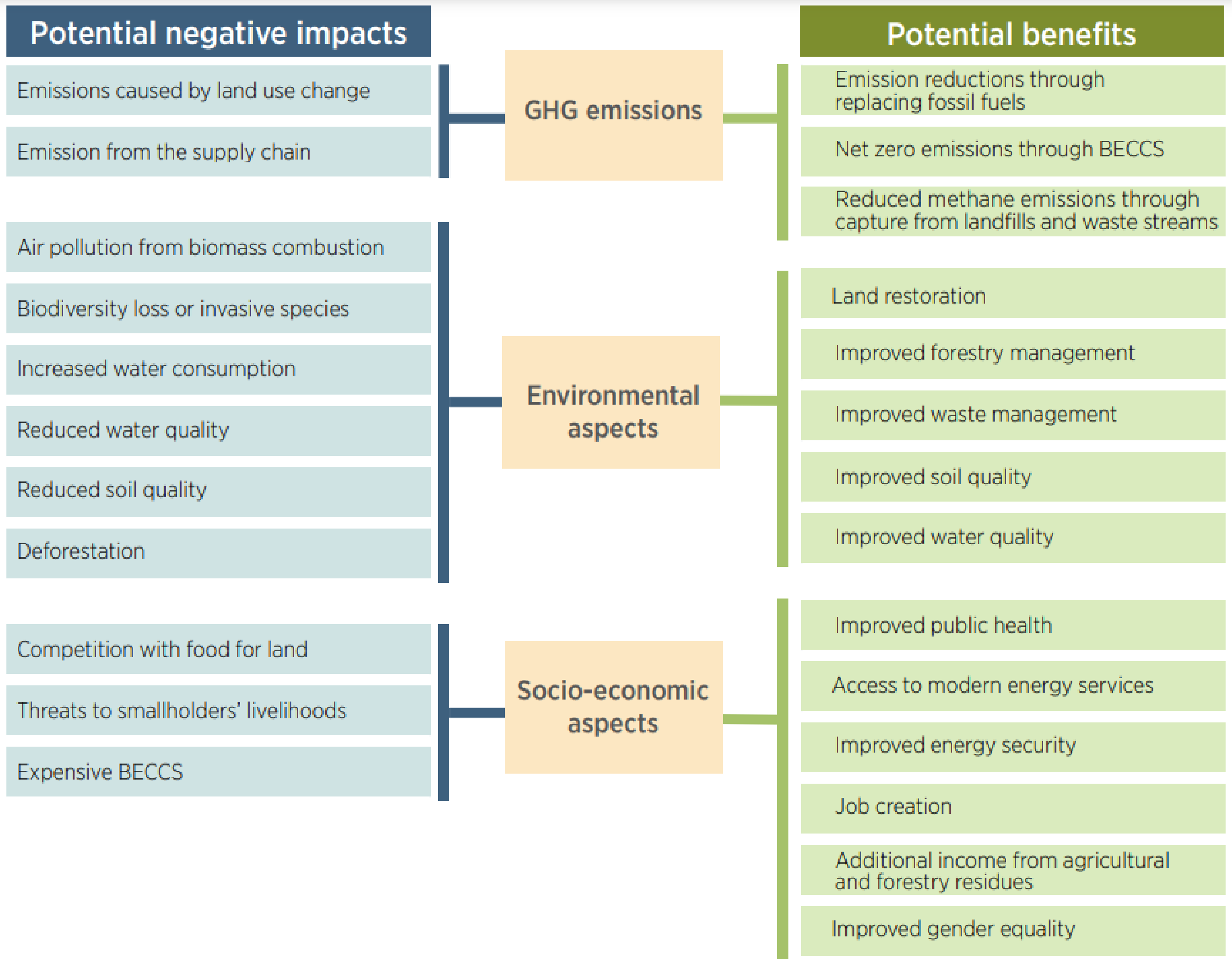
Share of bioenergy and other renewables in global total final energy consumption, 2020

Hydrogen from biomass- Advantages

Advantages

- Biomass is eco-friendly Sustainable energy forms and support rural ecosystem.
- Independence from oil imports.
- Net product remains within the country.
- Stable pricing level
- Improved CO2 balance by around 30%.
- Potential to replace conventional fossil fuels without releasing GHGs.

Potential aspects related to bioenergy sustainability



Note: BECCS = bioenergy with carbon capture and storage; GHG = greenhouse gas.

Major Hydrogen Production Processes

Thermochemical Process

- Natural gas reforming (also called steam methane reforming or SMR)
- Biomass gasification
- Biomass-derived liquid reforming
- Solar thermochemical hydrogen (STCH)

Electrolytic Process

- Electrolysis

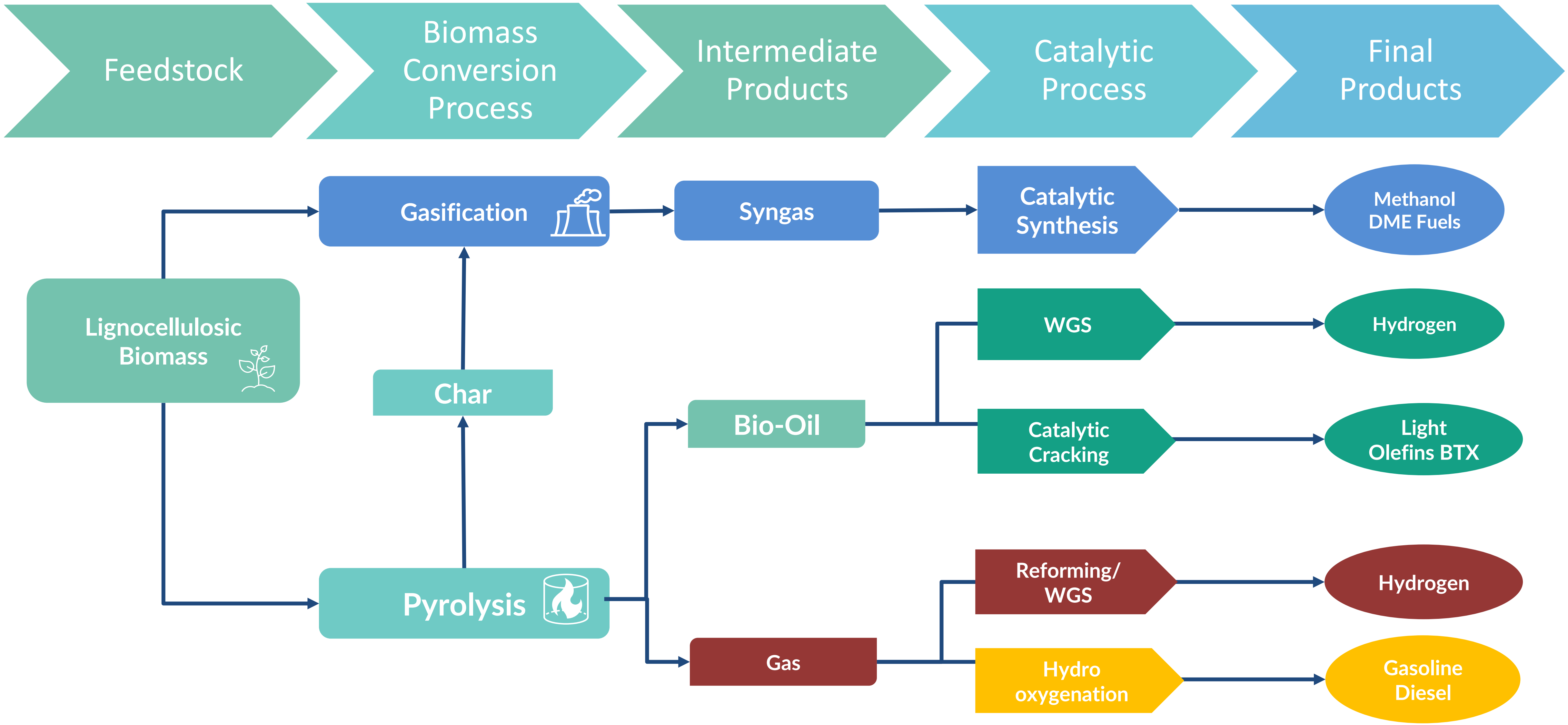
Direct Solar Water Splitting Processes

- Photoelectrochemical (PEC)
- Photobiological

Biological Processes

- Microbial biomass conversion
- Photobiological

Hydrogen Production Processes from Biomass



Processes

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Biological Processes

- Microbes - Bacteria and Microalgae can produce hydrogen through biological reactions, using sunlight or organic matter.
- These technology pathways are in the research and development stage, with pilot demonstrations occurring, but in the long term have the potential for sustainable, low-carbon hydrogen production.
- Two major processes are:
    - **Microbial biomass conversion**
    - **Photobiological**

Processes

Microbial biomass conversion	**Ability of microorganisms to consume and digest biomass and release hydrogen** **Fermentation-based systems:** • microorganisms, such as bacteria, break down organic matter to produce hydrogen. • The organic matter can be refined sugars, raw biomass sources such as agro residues, and even wastewater. • Because no light is required, these methods are sometimes called "dark fermentation" methods. **Direct hydrogen fermentation:** • Microbes produce the hydrogen themselves. • Microbes can break down complex molecules through many different pathways, and the byproducts of some of the pathways can be combined by enzymes to produce hydrogen. **Microbial electrolysis cells (MECs)** • MECs harness the energy and protons produced by microbes breaking down organic matter, combined with an additional small electric current, to produce hydrogen. • This technology is very new, and researchers are working on improving many aspects of the system, from finding lower-cost materials to identifying the most effective type of microbes to use.

Processes

Photo-biological

Photolytic biological systems

- Microorganisms—such as green microalgae or cyanobacteria—use sunlight to split water into oxygen and hydrogen ions.
- The hydrogen ions can be combined through direct or indirect routes and released as hydrogen gas.
- Challenges for this pathway include low rates of hydrogen production and the fact that splitting water also produces oxygen, which quickly inhibits the hydrogen production reaction and can be a safety issue when mixed with hydrogen in certain concentrations. Researchers are working to develop methods to allow the microbes to produce hydrogen for longer periods of time and to increase the rate of hydrogen production.

Photo-fermentative hydrogen production

- Some photosynthetic microbes use sunlight as the driver to break down organic matter, releasing hydrogen.
- Some of the major challenges of this pathway include a very low hydrogen production rate and low solar-to-hydrogen efficiency, making it a commercially unviable pathway for hydrogen production at this time.

Processes

Biomass-Derived Liquid Reforming

- Liquids derived from biomass resources—including ethanol and bio-oils—can be reformed to produce hydrogen in a process similar to natural gas reforming.
- Biomass-derived liquids can be transported more easily than their biomass feedstocks, allowing for semi-central production or possibly distributed hydrogen production at fueling stations.
- Biomass-derived liquid reforming is a mid-term technology pathway

Processes: Biomass Gasification

Biomass gasification is a mature technology pathway that uses a controlled process involving heat, steam, and oxygen to convert biomass to hydrogen and other products, without combustion.

Gasification is a process that converts organic or fossil-based carbonaceous materials at high temperatures (>700°C), without combustion, with a controlled amount of oxygen and/or steam into carbon monoxide, hydrogen, and carbon dioxide. The carbon monoxide then reacts with water to form carbon dioxide and more hydrogen via a water-gas shift reaction. Adsorbers or special membranes can separate the hydrogen from this gas stream.

Processes

Pyrolysis

- **Pyrolysis** is the gasification of biomass in the absence of oxygen.
- In general, biomass does not gasify as easily as coal, and it produces other hydrocarbon compounds in the gas mixture exiting the gasifier; this is especially true when no oxygen is used.
- As a result, typically an extra step must be taken to reform these hydrocarbons with a catalyst to yield a **clean syngas mixture of hydrogen, carbon monoxide, and carbon dioxide**.
- Then, just as in the gasification process for hydrogen production, a shift reaction step (with steam) converts the carbon monoxide to carbon dioxide.
- The hydrogen produced is then separated and purified.

Processes

Supercritical Water Gasification

- **Supercritical Water Gasification** is similar to the conventional gasification that uses water as the reaction medium to efficiently decompose biomass to hydrogen-rich syngas.
- Water reaches supercritical conditions at **374.12°C** and **221.2 bar** above its critical point, at which the distinct liquid and gas phases do not exit.
- The yields and composition of products from supercritical water gasification largely depend on the process parameters such as temperature, pressure, residence time, and feed concentration, biomass particle size, reactor configurations as well as reaction pathways and catalysis.
- These factors also determine the gasification efficiency, carbon conversion and heating value of the gas products.
- Biomass with high moisture content can be gasified without drying and hence reduces feedstock drying cost. High reaction rate, high H2 and low CO yields and low char and tar formation are other advantages of SCWG.

RDD&D Challenges & Way Forward...

- **Improving the rates and yields of hydrogen production** through-
  - Need extensive R&D and near commercial pilots.
  - Microbial strain improvements, reactor system optimization, and identifying feedstock sources and processing methods with the highest yields.
  - Developing systems that can be scaled up to commercially relevant sizes while maintaining the production rates and system efficiencies seen at the bench scale and minimizing the costs of the reactor components.
- **Photobiological hydrogen** - both photolytic and photo-fermentative through:
  - Improving the activity of the enzymes that produce the hydrogen, as well as the metabolic pathways needed for the reactions, to increase the hydrogen production rates.
  - Developing strains that can efficiently use the sunlight and other inputs to increase the hydrogen yields.
  - Developing strains and reactor configurations that can ultimately be used at large scales for commercial hydrogen production.
  - Photobiological Hydrogen Production need ways to make the microbes better at collecting and using energy to make more available for hydrogen production, and to change their normal biological pathways to increase the rate of hydrogen production.
- **Gasification-**
  - Replacing the cryogenic process currently used to separate oxygen from air when oxygen is used in the gasifier with new membrane technology.
  - Developing new membrane technologies to better separate and purify hydrogen from the gas stream produced (similar to coal gasification)

Barriers and Policy Support Required

Cross-cutting barriers to bioenergy deployment

Political and institutional barriers
- Policy uncertainty
- Weak institutional structures

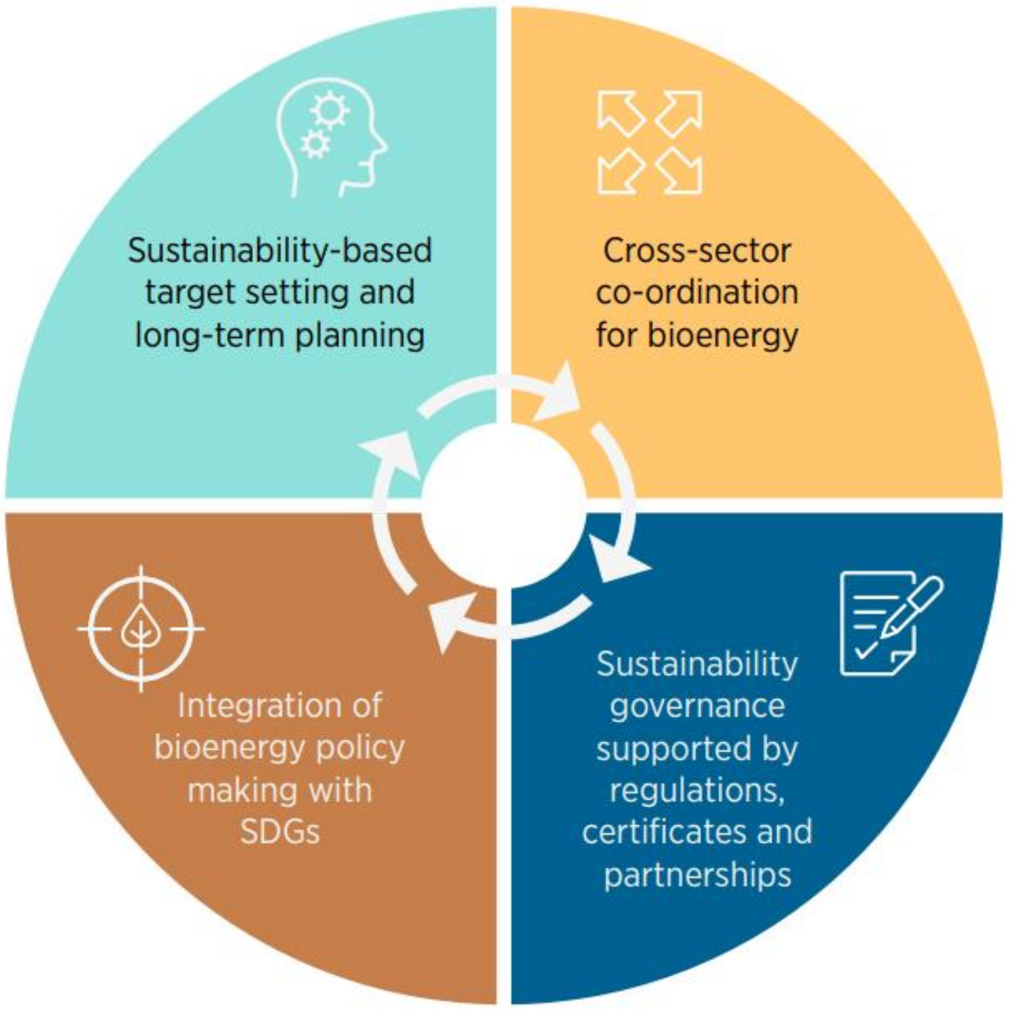
Financial and economic barriers
- Fossil fuel subsidies
- High cost
- Lack of access to affordable finance

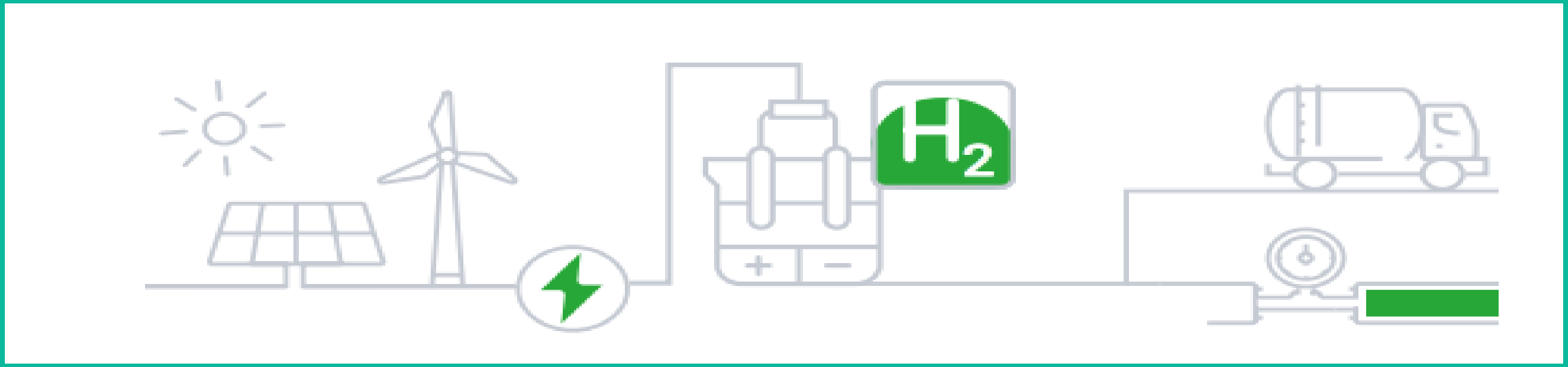
Technical and infrastructure-related barriers
- Low-level technology readiness
- Reliability of technologies
- Lack of infrastructure

Supply chain-related barriers
- Lack of stable feedstock
- Lack of qualified workers and skills
- Sustainability risks

Information and public awareness-related barriers
- Lack of reliable information
- Low public awareness

A policy framework for sustainable bioenergy development





Thank You

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