PROJECTS IDEATION

Green Hydrogen for Development in Nepal

"Towards a Clean and Prosperous Economy Contributing to Carbon Neutral and Energy Independent Nepal"

Prepared By

GREEN HYDROGEN LAB

CONSCIOUS ENERGY
For Energy Transition and Green Growth
A Spin-off from KATHMANDU UNIVERSITY

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EnergizeNepal
Hydro Himalaya

Message from the Team Leader

Energy has been a fundamental element for the evolution of humans and humanity. There has always been a search for cheaper sources energy for the industrial revolutions and economic prosperity. This has eventually made the current development unsustainable from the climate change perspective. The depletion of the environment has been continuous and has arrived at an irrecoverable point if a dramatic interventions are not made. With the lessons learned from the force of climate calamities, the society is getting more mature and is identifying itself as one of the components of nature. This has induced an urge and sense of responsibility to sustain the future developments with minimum damage to the climate eco-system.

In 2022, Nepal spend over 380 billion NPR on imports of fossil fuels. The figure makes up about 13 percent of the country's GDP. There has been a liner increase of coal contributing to the primary energy from 7% in 2019 to 9 % in 2021. The industrial, transport, commercial, and agricultural, sectors are dominated by coal and diesel as the main source of energy. Nepal has struggled for more than 110 years to achieve less than 5% of the economic feasible capacity of hydropower potential. However, it has been projected that over 25 billion NPR equivalent electricity in the country will be spilled in the monsoon season of 2023.

It is high time for energy transition in Nepal with proper use of its immense hydropower and abundant solar energy sources to strategically replace fossil fuels in both commercial and residential sectors. Green hydrogen can play a vital role as an energy carrier and could be one of the promising links in energy transition for Nepal. This will have a significant impact on the energy mix of the country and energy export alternatives. This transition process demands strong political and social commitments, high-level knowledge transfers from university to the industry, and willingness from the commercial and business sectors to diversify their income with green energy.

This Project Ideation Document is prepared by Green Hydrogen Lab, Kathmandu University, Nepal in collaboration with Conscious Energy, a spin-off company by Kathmandu University established for the purpose of inducing commercialization possibility of Green Hydrogen in Nepal. This document explores different areas of application of green hydrogen in Nepal to be further investigated thoroughly by the serious developers. The projects at different stages of studies by the joint team of Green Hydrogen Lab and Conscious Energy have been compiled and presented for the purpose of knowledge dissemination for business incubation. The room for improvement is kept open through the comments and suggestions from the readers of this document.

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Executive Summary

Green hydrogen has the capability to decarbonize the hard-to-abate sectors by replacing fossil fuels in heating applications as well as industrial feedstocks. Steel, cement, and transportation are the sectors in which hydrogen has huge potential by acting as a fuel and also as an energy carrier. Hydrogen produced using electricity from renewable electricity can be used in various commercial and industrial sectors where direct electrification is not feasible which in turn helps the country to achieve energy independence.

Out of all the applications of green hydrogen in Nepal, hard-to-abate fuels as the coal and diesel are the sectors where green hydrogen can play a vital role to achieve the decarbonization goals. In steel industries, green hydrogen can be directly used for the reduction process replacing the coal which is currently being used. In cement industries, hydrogen can be used for high-temperature heating applications to produce clinker. Transportation especially heavy-duty vehicles are the sector where green hydrogen can be utilized to reduce imported diesel consumption. Existing heavy-duty trucks can be retrofitted into fuel cell trucks to not only reduce diesel consumption but also to reduce emissions.

Green hydrogen also has the potential for seasonal energy storage and power backup applications owing to its high energy density of 140 MJ/kg. The surplus electricity from hydropower can be utilized to produce green hydrogen which can be stored to balance the load that gets deficits during the dry season. To provide continuous power in the service sectors such as hospitals, fuel cell-based combined heat and power systems can be utilized to tackle the problem of power disruptions due to unreliable grids.

Green hydrogen can be utilized to produce several derivatives such as ammonia, urea, and green methane. Green ammonia which is ammonia produced from green hydrogen is not only an essential industrial feedstock to produce urea but also can be used as a useful energy carrier for long-term storage and also for long-distance energy transportation. Green urea can be a vital commodity in the case of Nepal to resolve the issue of shortage of fertilizer during the peak harvesting season. Green Methane, also known as Synthetic Natural Gas, produced using carbon dioxide captured from industries, and green hydrogen, can be a flexible fuel for high-temperature industrial heating applications. Green methane can also be produced from the anaerobic digestion of organic wastes. The raw biogas can be reacted with green hydrogen to increase the methane content significantly which has the application in clean cooking as well as in industrial heating applications. Green Hydrogen lab has completed the pre-feasibility analysis for these green hydrogen-based derivatives for industrial applications. Now pilot scale testing of these technologies is essential to explore the commercialization potential.

On the long run green hydrogen and its derivatives as Green Ammonia can be exportable commodity from Nepal. This will eventually contribute to the carbonization of the region with the renewable electricity of the country meeting the need of every rising global demand of clean energy to achieve the climate goals.

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HYDROGEN

Introduction

Hydrogen is the first and most basic of all the elements in the universe. Almost 90% of all the atoms in the universe are hydrogen atoms, hence it is the most abundant chemical substance in the universe. On Earth, it's rarely found in pure form. Instead, it is found in combinations such as water, methane, and biomass. Not only as a primary energy source, Hydrogen can also act as an energy carrier (like electricity), meaning it can store and deliver energy in an easily usable form. Hydrogen can be used as an energy storage system as it has the advantage of having the highest energy density i.e., 140 MJ/kg which is almost more than thrice the energy density of other fossil fuels. The stored hydrogen can be used to generate energy with little to no carbon emissions

Table 1: Properties of Hydrogen

Property	Hydrogen	Comparison
Density (gaseous)	0.089 kg/m^3(0°C, 1 bar)	1/10 of natural gas
Density (liquid)	70.79 kg/m^3(-253°C, 1 bar)	1/6 of natural gas
Boiling point	-252.76°C (1 bar	90°C below LNG
Energy per unit of mass (LHV)	120.1 MJ/kg	3x that of gasoline
Energy density (ambient cond., LHV)	0.01 MJ/L	1/3 of natural gas
Specific energy (liquefied, LHV)	8.5 MJ/L	1/3 of LNG
Flame velocity	346 cm/s	8x methane
Ignition range	4–77% in air by volume	6x wider than methane
Auto-ignition temperature	585°C	220°C for gasoline
Ignition energy	0.02 MJ	1/10 of methane

Hydrogen is found in a compound state, typically in the form of water and hydrocarbons, and must be synthesized from raw materials with the help of an external source. Since Hydrogen is a flexible vector, it can be produced from several energy sources including petroleum products, renewables, and nuclear using a wide range of technologies like steam reforming, gasification, electrolysis, pyrolysis, water splitting, and others.

Global hydrogen production today is dominated by the use of fossil fuels. Green hydrogen – that is, hydrogen produced from water and electricity – plays only a minor role. With declining costs for renewable power (in particular solar PV, wind and hydropower), interest is now growing in water electrolysis for hydrogen production and in the scope for further conversion of that hydrogen into hydrogen-based fuels or feedstocks, such as synthetic hydrocarbons and ammonia, which are more compatible than hydrogen with existing infrastructure.

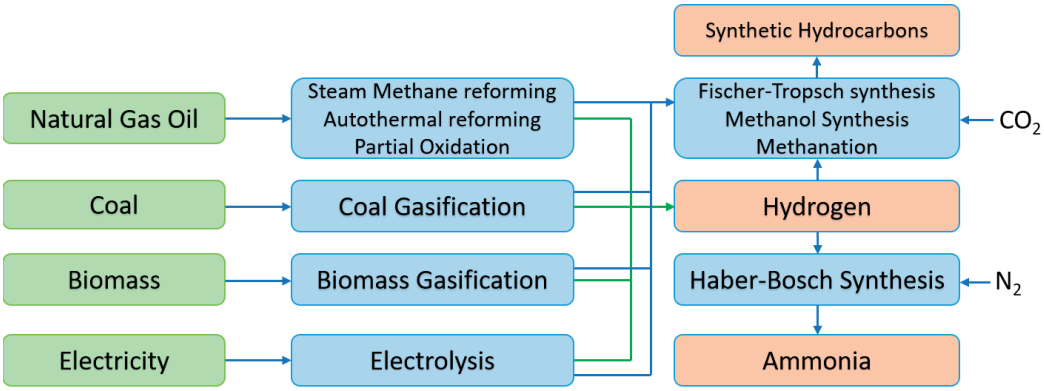


Figure 1: Production of hydrogen and hydrogen-based products

Transition to Green Hydrogen

Climate change is one of the most pressing issues that threaten the lives and livelihoods of billions of people. Presently, there is a broad international scientific consensus that greenhouse emissions from human activity such as fossil fuel use and deforestation, are the key element of climate change. At the end of 2015, the Paris Agreement was signed with a pledge to curb greenhouse gas (GHG) emissions to minimize the rise in the temperature and strengthen the capability to deal with climate risk. The energy sector is a major contributor to GHG emissions, which accounts for two-thirds of the global emission. For the reasonable likelihood to stay below 1.5°C of global warming, the net anthropogenic GHG emission should decline by around 45% by 2030, from 2010, reaching carbon neutrality by 2050. As a result, several countries have published their plan and policies to reduce GHGs emissions and achieve net-zero emissions.

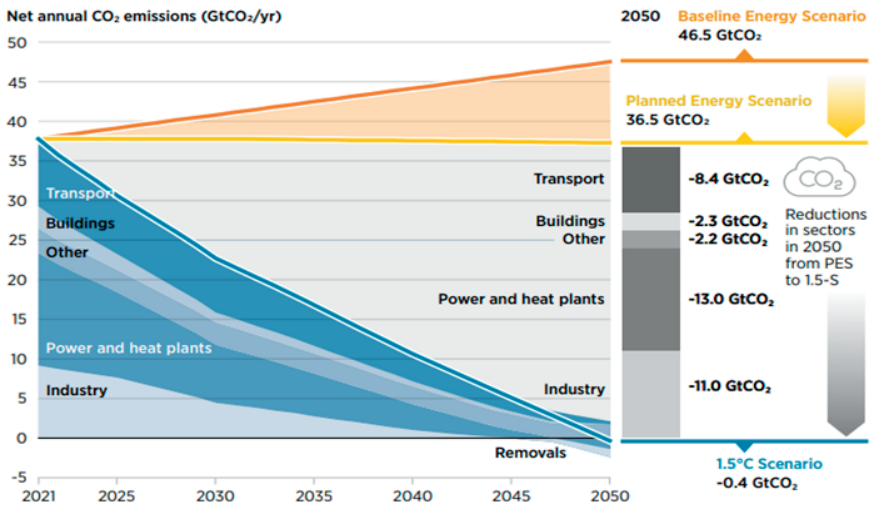
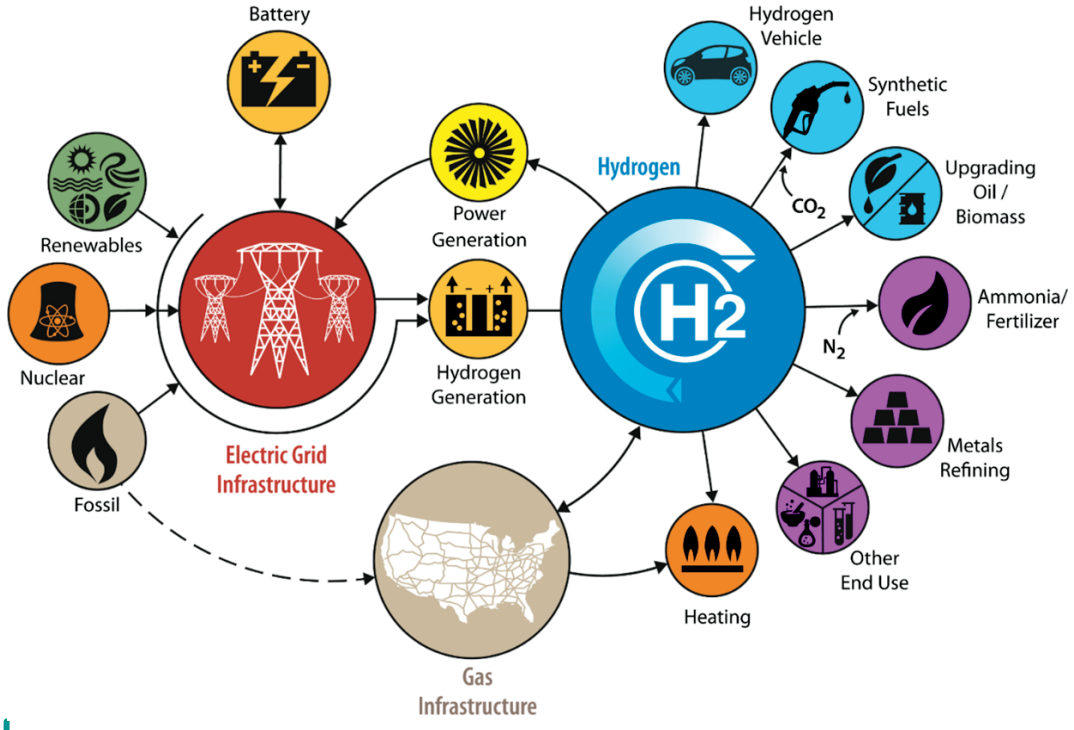


Figure 2: Projected trends in global CO_2 emission under three scenarios, 2020-2050

Nepal is one of the minimal contributors, about 0.027 percent of the global GHG emission but is most vulnerable to the consequence of GHG. Due to climate change, the country has experienced a change in precipitation, shrinking of ice, and increment in the frequency of extreme weather conditions such as floods, landslides, droughts, and other water-induced disasters resulting in loss of life and damage to socio-economic aspects. The transition to a green hydrogen-energy economy would represent the ultimate step on the path away from carbon-based fossil energy. Presently, the industrial use of hydrogen (pure hydrogen and hydrogen-based fuel) is already a major global business with a global demand of around 115 million metric tons in 2018. For the past few decades, industrial application of hydrogen is dominated by the use of hydrogen as a chemical feedstock in the chemical industries, oil refineries, and steel industries. Today, governments around the world are committed to net-zero emissions by 2050. Since green hydrogen can generate zero-emission at the point of end-use and can be produced from renewable energy, it has the potential to be used as fuel for power and transportation to achieve the decarbonization goals.



Prospective of Green Hydrogen in Nepal

Nepal has ample potential for renewable resources including hydropower and solar. The resources can produce green hydrogen sustainably and cost-effectively. Green Hydrogen can channel renewable energy sources to decarbonize the high-heat energy

applications in the industrial and transportation sectors. One kilogram of hydrogen can produce about three times more energy than the same of petrol without carbon emission as long as it is produced from renewable energy. The energy cost for hydrogen production varies from US$ 5.91 to US$ 12.75 depending upon the production period and tariff rates. In contrast, Nepal has a competitive advantage over other nations as surplus energy, having the risk of being spilled, can be utilized for green hydrogen thus reducing the energy cost. If the surplus electricity is provided at a discounted rate, the cost of production for 1 kg of hydrogen would come down significantly to US$ 1.17- US$ 2.55 for different time-of-day tariff rates. The policy-based interventions to promote renewables as the primary supply of energy can push green hydrogen to overtake fossil fuels both technically and economically in Nepal.

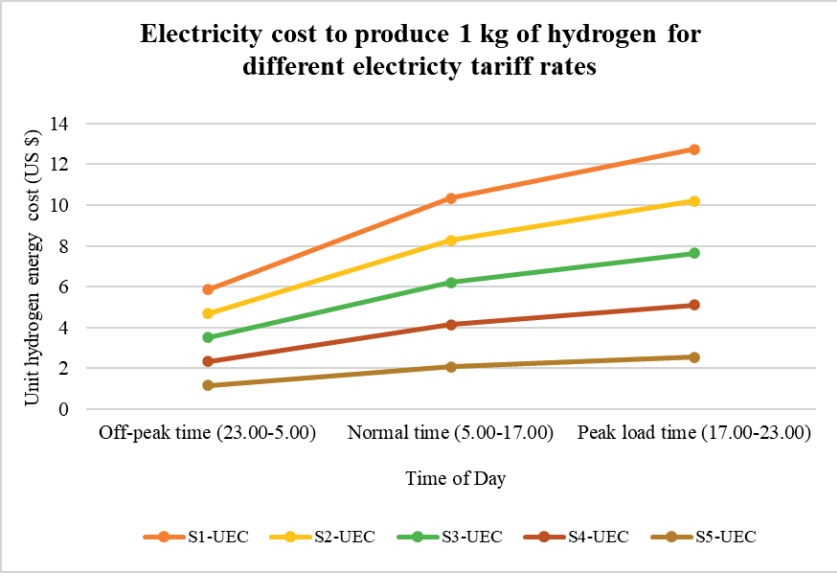


Figure 3: Potential hydrogen production from excess hydro energy in Nepal in 2019

Nepal relies on imports for all fossil fuels, consuming up to 10% of the country's GDP, and is one of the strong contributors to the trade deficit of around 13%. The production and use of green hydrogen to replace fossil fuels will enhance energy security and sustain the domestic energy sector. Nepal has huge hydropower potential, with over 20,000 MW in various stages of development. If proper planning is not done now, it is expected that 3,500 MW of production capacity will be unused during production peak periods over the next decade. It is evaluated that in 2028, 20% utilization of overflow power will create 8410 tons of green hydrogen and 336,384 tons if 100% of overflow power is utilized. To put it in Nepal's vitality setting, 336,384 tons of hydrogen will be sufficient to supplant 25% of the fossil fuel request for 2028. Additionally, 82,475 tons of hydrogen is sufficient to supply feedstock to the generation plant to meet the current request of 800,000 tons of urea. Moreover, it is critical to evaluate the potential application of hydrogen in other segments as well, which can contribute to a more secure and sustainable low-carbon economy.

Contributors of Green Hydrogen Project at KU

Title: Detailed Feasibility Study for Production of Urea Fertilizer
Funding Agency: Agriculture and Livestock Development Ministry, Bagmati Province

Title: Incubation of Synthetic Natural Gas Production Enterprise for Utilization in Cooking Sector
Funding Agency: NTIC under Korean International Cooperation Agency (KOICA)

Title: Pilot scale green ammonia production in Nepal for contribution to the domestic economy and better utilization of hydropower electricity.
Funding Agency: Nepal Electricity Authority (NEA)

Title: Technology Transfer and Local Adaptation for Developing NOC as Hydrogen Fuel Producing and Distribution Company
Funding Agency: Nepal Oil Corporation (NOC)

Title: Development of Green Hydrogen research Fund
Funding Agency: IPPAN Members and External Sources

Title: Piloting Green Hydrogen as a Fuel for Transportation and Clean Cooking Contributing to Carbon Neutral and Energy Independent Nepal
Funding Agency: Basket Fund (Dhulikhel Municipality, Rotary Club of Dhulikhel, and other Agencies)

Title: Green Hydrogen for Effective End-Use of Hydroelectricity
Funding Agency: NORHED-II

Title: Incubation of Nepal Hydrogen Initiative Program
Funding Agency: EnergizeNepal under Norwegian Embassy and NORAD

Title: Establish a foundation for the cooperation with Mechanical Engineering aspects of alternative energy including hydropower and green hydrogen
Funding Agency: JADE Consult

Title: Setting up a demonstrative facility for commercial application of Green hydrogen technologies in Nepal within Green Hydrogen Lab, DoME, KU"
Funding Agency: Alternative Renewable Energy Promotion Centre (AEPC)

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CONSCIOUS ENERGY

For Energy Transition and Green Growth

A Spin-off Company from KATHMANDU UNIVERSITY

Green Hydrogen

Renewable Energy

Intelligent Technologies

Vision:
Provide optimum solutions for energy and engineering challenges through knowledge-based professional services

Goals:

- Transform the knowledge and technology developed by university research for addressing the needs and challenges of society.
- Provide state of art solutions and best practices through design, engineering, and professional consultation services for business development in established and emerging energy technologies.
- Grow as a multi-national company contributing to the regional and global challenges in the energy transition.

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