IRENA
International Renewable Energy Agency

GREEN HYDROGEN

A GUIDE TO **POLICY MAKING**

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ABOUT IRENA

The International Renewable Energy Agency (IRENA) serves as the principal platform for international co-operation, a centre of excellence, a repository of policy, technology, resource and financial knowledge, and a driver of action on the ground to advance the transformation of the global energy system. An intergovernmental organisation established in 2011, IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

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INTRODUCTION

The world is facing the major challenge of climate change. In 2015 the global community committed to taking action to keep global temperature rise this century well below 2°C above pre-industrial levels. A growing number of countries are pledging to reach net-zero carbon dioxide (CO_2) emissions by mid-century with the goal of limiting temperature rise to 1.5°C. Achieving the deep or full decarbonisation of economies will require concerted and wide-ranging action across all economic sectors.

We have barely begun such emission reductions. It has been estimated that 8.8% less CO_2 was emitted in the first six months of 2020 than in the same period in 2019, following the COVID-19 pandemic and the consequent lockdowns (Liu *et al.*, 2020). But for continued long-term reduction, the need for structural and transformational changes in our global energy production, consumption and underlying socio-economic systems cannot be understated.

Dramatic emission reductions are both technologically feasible and economically affordable. IRENA's Global Renewables Outlook report offers a perspective for reaching net-zero emissions in the 2050-2060 timeframe. The Deeper Decarbonisation Perspective suggests possibilities for accelerated action to bring down CO_2 emissions while bringing an economic payback of between USD 1.5 and USD 5 for every USD 1 spent on the energy transition (IRENA, 2020a).

The energy transformation requires a major shift in electricity generation from fossil fuels to renewable sources like solar and wind, greater energy efficiency and the widespread electrification of energy uses from cars to heating and cooling in buildings. Still, not all sectors or industries can easily make the switch from fossil fuels to electricity. Hard-to-electrify (and therefore hard-to-abate) sectors include steel, cement, chemicals, long-haul road transport, maritime shipping and aviation (IRENA, 2020b).

Green hydrogen an provide a link between growing and sustainable renewable electricity generation and the hard-to-electrify sectors (IRENA, 2018). Hydrogen in general is a suitable energy carrier for applications remote from electricity grids or that require a high energy density, and it can serve as a feedstock for chemical reactions to produce a range of synthetic fuels and feedstocks.

Additional benefits of green hydrogen include: the potential for additional system flexibility and storage, which support further deployment of variable renewable energy (VRE); contribution to energy security; reduced air pollution; and other socio-economic benefits such as economic growth and job creation, and industrial competitiveness.

Nevertheless, green hydrogen will have to overcome several barriers to fulfil its full potential. Chief among those barriers is cost.

Overcoming the barriers and transitioning green hydrogen from a niche player to a widespread energy carrier will require dedicated policy in each of the stages of technology readiness, market penetration and market growth. **An integrated policy approach is needed to overcome the initial resistance and reach a minimum threshold for market penetration, resting on four central pillars: building national hydrogen strategies, identifying policy priorities, establishing a governance system and enabling policies, and creating a system for guarantee of origin for green hydrogen.**

ABOUT THIS GUIDE

This publication is the first of a series of briefs that aim to guide policy makers in the design and implementation of policy to support green hydrogen as one of the feasible methods of decarbonising the energy sector.

This guide is composed of three chapters. The first focuses on the status and drivers of green hydrogen and the barriers it faces. The second chapter explores the pillars of national policy making to support hydrogen, and the third presents the main policy recommendations in different segments of the green hydrogen value chain.

The forthcoming brief is due to be published and will address the supply side, covering electrolysis and infrastructure. The following briefs will first explore specific policies for different uses of green hydrogen in the hard-to-abate sectors, including industrial applications and long-haul transport (aviation, maritime shipping). Selected policy recommendations for these uses are presented here in the third chapter. Future briefs will explore niche applications for hydrogen, such as power generation and heating, and land transport.

Each of the policy briefs will present relevant case studies to highlight previous experiences and provide potential starting points for governments, exploring policies to support greater use of green hydrogen. They will also offer policy recommendations, which can be adapted and tailored for specific countries depending on their context and priorities beyond the energy system, such as economic development objectives.

Some of the necessary policy tools already exist in energy sector and only need to be expanded in scope. However, in other cases dedicated attention might be needed.

IRENA'S WORK ON **GREEN HYDROGEN** AND HARD TO ABATE SECTORS.

This report is part of IRENA's ongoing programme of work to provide its members countries and the wider community with expert analytical insights into the potential options, enabling conditions and policies that could deliver the deep decarbonisation of economies.

IRENA's annual Global Renewable Outlook provides detailed global and regional roadmaps for emission reductions alongside assessment of the socioeconomic implications. The 2020 edition includes Deep Decarbonisation Perspectives detailing options for achieving net-zero or zero emissions.

The 2021 edition will include further detailed analysis of a pathway consistent with a 1.5-degree goal.

Building on its technical and socio-economic assessment IRENA is analysing specific facets of that pathway including the policy and financial frameworks needed. One particular focus is on the potential of green hydrogen.

Recent and upcoming publications include:

- "Hydrogen: A renewable energy perspective" (2019);
- "Reaching zero with renewables" (2020) and its supporting briefs on industry and transport;
- "Green hydrogen cost reduction: Scaling up electrolysers to meet the 1.5°C climate goal" (forthcoming);
- "Renewable energy policies in a time of transition: Heating and cooling" (forthcoming)
- and the subsequent briefs to this report.

These reports complement IRENA's work on renewables-based electrification, biofuels and synthetic fuels and all the options for specific hard-to-abate sectors

This analytical work is supported by IRENA's initiatives to convene experts and stakeholders, including IRENA Innovation Weeks, IRENA Policy Days and Policy Talks, and the IRENA Collaborative Platform on Green Hydrogen. These bring together a broad range of member countries and other stakeholders to exchange knowledge and experience.

1 GREEN HYDROGEN: STATUS, DRIVERS AND BARRIERS

H

Hydrogen 1.01

Henry Cavendish discovered the element in **1766**

Most abundant chemical structure in the universe

The first industrial water electrolyser was developed in **1888**

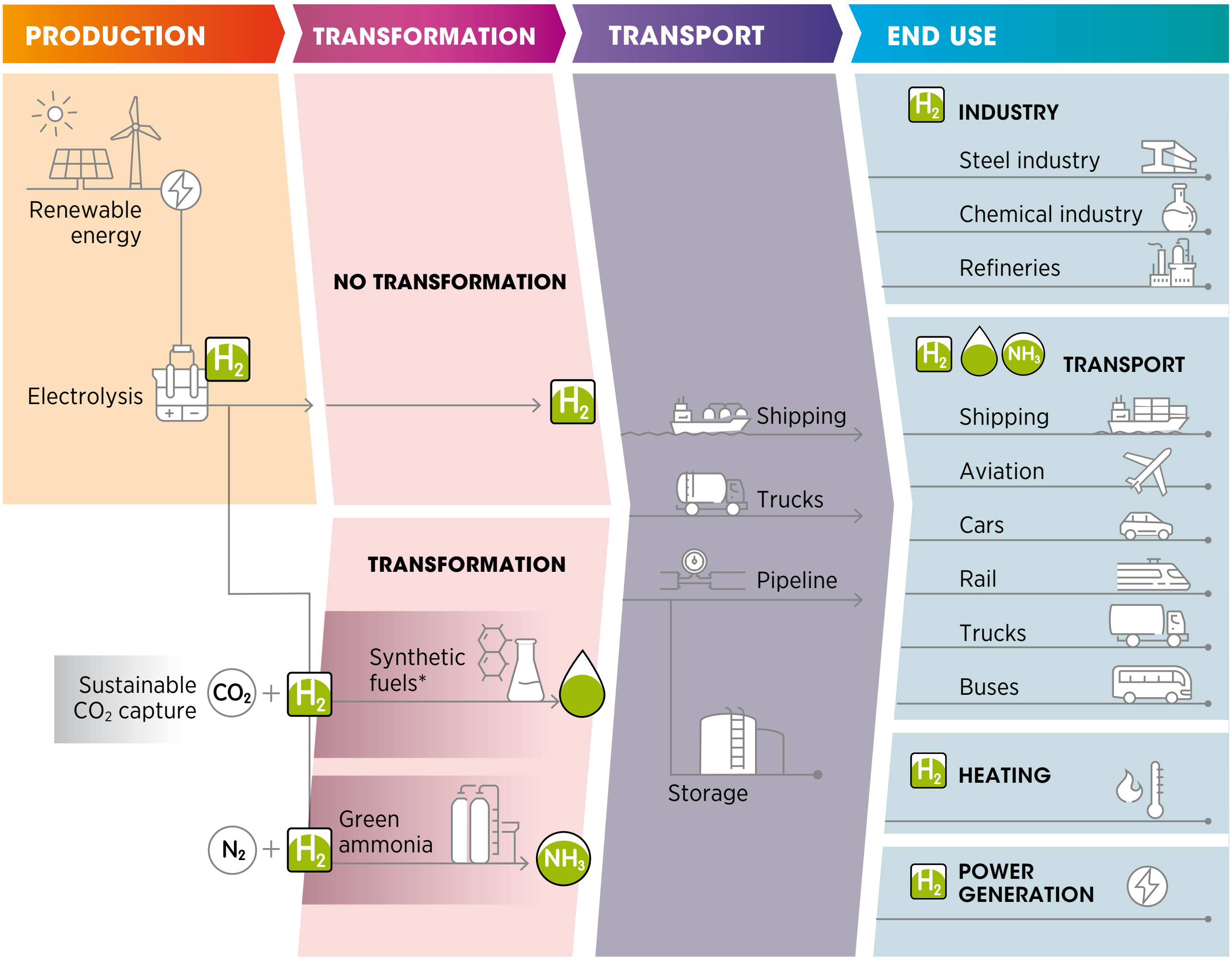
Hydrogen means "Creator (-gen) of water (hydro-)": its combustion releases only water

H_2 O H_2O

Green hydrogen is an energy carrier that can be used in many different applications (Figure 1.1). However, its actual use is still very limited. Each year around 120 million tonnes of hydrogen are produced globally, of which two-thirds are pure hydrogen and one-third is in a mixture with other gases (IRENA, 2019a). Hydrogen output is mostly used for crude oil refining and for ammonia and methanol synthesis, which together represent almost 75% of the combined pure and mixed hydrogen demand.

Today's hydrogen production is mostly based on natural gas and coal, which together account for 95% of production. Electrolysis produces around 5% of global hydrogen, as a by-product from chlorine production. Currently, there is no significant hydrogen production from renewable sources: green hydrogen has been limited to demonstration projects (IRENA, 2019a).

FIGURE 1.1 Green hydrogen production, conversion and end uses across the energy system



Source: IRENA.

** The term synthetic fuels refers here to a range of hydrogen-based fuels produced through chemical processes with a carbon source (CO and CO_2 captured from emission streams, biogenic sources or directly from the air). They include methanol, jet fuels, methane and other hydrocarbons. The main advantage of these fuels is that they can be used to replace their fossil fuel-based counterparts and in many cases be used as direct replacements – that is, as drop-in fuels. Synthetic fuels produce carbon emissions when combusted, but if their production process consumes the same amount of CO_2, in principle it allows them to have net-zero carbon emissions.*