ICLEI Local Governments for Sustainability

100% RENEWABLES CITIES & REGIONS ROADMAP

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IKI INTERNATIONAL CLIMATE INITIATIVE

solutionsgateway Climate, Energy, and Finance Solutions

100% RENEWABLES SOLUTIONS PACKAGE

Local strategies for green hydrogen

This solution is part of a package of solutions meant to guide local and regional governments in implementing a local renewable energy transition by providing guidance on mechanisms, applications or technologies that can help accelerate their climate and energy action.

It was produced as part of the 100% Renewables Cities and Regions Roadmap project, which supports nine cities and regions across Argentina, Indonesia and Kenya to develop bankable renewable energy projects and in-depth local strategy and action plans to achieve one hundred percent renewable energy. The 100% Renewables Cities and Regions Roadmap project is implemented by ICLEI – Local Governments for Sustainability and funded through the International Climate Initiative (IKI), which is implemented by the Federal Ministry for Economic Affairs and Climate Action (BMWK) in close cooperation with the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) and the Federal Foreign Office (AA).

DISCLAIMER

All cities are unique. The Solutions Gateway has been developed as an advanced knowledge catalogue to provide an overview of possible Low Emissions Development Solutions. The Solutions and Packages it contains provide guidance on general conditions, which may not correspond to the existing conditions in your city or jurisdiction. The consultation and use of the Solutions Gateway does not waive the need for the Local Government to assess the feasibility of a Solution or Package in the local context in its city or jurisdiction, prior to implementation. Please note that the impacts, benefits and co-benefits indicated are generally valid but may not materialize in particular circumstances.

ABOUT SOLUTIONS GATEWAY

Solutions Gateway is an online resource platform for Local Governments where they will be able to find possible Low Emissions Development (LED) Solutions for their cities.

In the context of the Solutions Gateway, Solutions are processes, or groups of actions, which Local Governments can implement to deliver climate change mitigation results and enhance local sustainable development. Taking an integrated approach, and focusing on Local Governments usual responsibilities and roles, Solutions include core actions as well as enabling and multiplying actions essential to maximize their effectiveness and efficiency. These include policy, regulatory, governance, capacity building, awareness raising, stakeholder engagement, etc.

ABOUT ICLEI – LOCAL GOVERNMENTS FOR SUSTAINABILITY

ICLEI – Local Governments for Sustainability is a global network working with more than 2,500 local and regional governments committed to sustainable urban development. Active in 125+ countries, ICLEI influences sustainability policy and drives local action for low emission, nature-based, equitable, resilient and circular development. ICLEI's Members and team of experts work together through peer exchange, partnerships and capacity building to create systemic change for urban sustainability.

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1. INTRODUCTION

Green hydrogen refers to hydrogen gas produced through a process called electrolysis, using renewable energy sources such as wind, solar, or hydroelectric power. It's called "green" because the energy used in its production comes from sustainable and clean sources, resulting in minimal or no greenhouse gas emissions. The process of creating green hydrogen involves splitting water molecules (H2O) into hydrogen (H2) and oxygen (O2) through electrolysis. During electrolysis, an electric current passes through water, causing the water molecules to dissociate into their constituent elements: hydrogen and oxygen. The hydrogen produced in this way can be stored and used as a clean energy carrier in various sectors, such as transportation, industry, and power generation.

The key advantage of green hydrogen lies in its potential as a versatile and clean energy carrier. It can be used in fuel cells to generate electricity or as a feedstock in industries like manufacturing, refining, and transportation. Additionally, when green hydrogen is utilized in fuel cells, the only by-product is water vapor, making it a zero-emission energy source. The widespread adoption of green hydrogen is seen as a promising solution for reducing carbon emissions and transitioning toward a more sustainable energy economy.

Implementing local green hydrogen solutions requires an enabling framework at the national and local levels. Local governments can undertake a number of measures, in collaboration with industry and the national government, to enable the adoption and use of green hydrogen.

1.1 RELEVANCE

Green hydrogen local strategies contribute to reducing greenhouse gas emissions and improving air quality, as the electricity required for this process is sourced from renewable energy, making the overall production cycle emission-free.

Once produced, green hydrogen can be stored and used in various sectors. Its potential lies in its versatility as a clean energy carrier that can be used in sectors that are hard to decarbonize, such as heavy industry or long-haul transportation, offering a promising pathway towards reducing carbon emissions and achieving sustainable energy systems.

Local strategies for green hydrogen can help to ensure that hydrogen projects are developed in a way that is tailored to the specific needs and resources of a particular city or region. By focusing on local needs and resources, these strategies can also help to create jobs and economic opportunities in the area. Additionally, as hydrogen is not confined by borders, local strategies can also help to ensure that hydrogen production aligns with the country's or region's energy security goals.

1.2 SDGs ADDRESSED

- **SDG 7:** Ensure access to affordable, reliable, sustainable and modern energy
- **SDG 9:** Build resilient infrastructure, promote sustainable industrialization and foster innovation
- **SDG 11:** Make cities inclusive, safe, resilient and sustainable
- **SDG 13:** Take urgent action to combat climate change and its impacts
- **SDG 17:** Revitalize the global partnership for sustainable development

1.3 MAIN IMPACTS

- Reduction of dependency on fossil fuels in hard to decarbonize sectors such as heavy transport, industry, and commercial.
- Improvements in system integration of renewable energy and enabling sector coupling.
- Achievement of renewable energy targets more quickly through enablers such as green hydrogen.
- Attraction of investments and opening of new market segments and sectors, providing new opportunities for innovation.
- Improvement of air quality and the reduction of pollutants in the city with improved health benefits if used on a significant scale in the displacement of fossil fuels.
- Generation of local, green jobs in a high-tech sector.

1.4 BENEFITS

- Reduce local dependency on fossil fuels, especially in hard-to-decarbonize sectors
- A pioneering city can act as a hub for hydrogen innovation and attract innovation
- In the transport sector, green hydrogen can help decarbonize heavy transport such as buses and trucks where direct electrification is not so viable
- In the industry and commercial sector, green hydrogen helps promote the use of synthetic fuels and moving away from fossil fuels in processes where high heat is required
- Professional training and technical qualification to build a qualified workforce for a future-oriented industry
- Overall, it contributes to improving a region's energy security by diversifying its sources of energy
- Minimal environmental effects from combustion of hydrogen, compared to fossil fuels, resulting in the mitigation of GHG emissions and improvements in local air quality due to the increased use of renewable energy in various forms

1.5 SUGGESTED INDICATORS FOR MONITORING RESULTS

- Percentage of heavy-duty vehicles using green hydrogen [% of total]
- Number of RE-based electrolysis plants [number]
- Volume of green hydrogen produced [MWh/year]
- Number of jobs generated or industries created [number/year]
- GHG emissions [tCO_{2e}/year]
- Number of hydrogen refueling stations added [number/year]

1.6 TYPICAL LOCAL GOVERNMENT ROLES

- **Policy Development:** Local governments can create policies, regulations, and incentives to encourage the adoption and production of green hydrogen. This might involve setting targets for renewable energy use, establishing emission reduction goals, or offering financial incentives for businesses and residents to invest in green hydrogen technologies.
- **Education and Awareness:** Educating the community about the benefits of green hydrogen and its role in decarbonizing energy systems. This can involve awareness campaigns, workshops, educational programs in schools, and outreach events to engage residents, businesses, and stakeholders.
- **Support for Research and Development:** Encouraging research, development, and innovation in green hydrogen technologies by providing funding, grants, or partnerships with local research institutions and industries. This can accelerate technological advancements and make green hydrogen more accessible and cost-effective.
- **Economic Development:** Supporting economic growth by attracting investments in green hydrogen projects, creating job opportunities in the renewable energy sector, and fostering a conducive environment for green technology businesses to thrive.
- **Infrastructure Development:** Investing in infrastructure for green hydrogen production, storage, and distribution. This includes establishing hydrogen refueling stations, storage facilities, and supporting the integration of hydrogen into existing energy systems.
- **Partnerships and Collaboration:** Facilitating partnerships between public and private sectors, academic institutions, and local industries to create a collaborative environment that promotes the growth of green hydrogen initiatives. These partnerships can help share knowledge, resources, and expertise to drive innovation and adoption.
- **Demonstration Projects:** Implementing pilot projects or demonstration initiatives to showcase the viability and effectiveness of green hydrogen technologies. These projects can serve as models for larger-scale implementation and encourage further investment.
- **Regulatory Support:** Working with state or national governments to advocate for supportive policies, standards, and regulations that promote the use and development of green hydrogen technologies.

Figure 1: Puertollano green hydrogen plant. Source*: Iberdrola*

2. INTEGRATED SOLUTION OVERVIEW

	Enabler Actions	Required Actions	Multiplier Actions
Policy	• Establish ambitious renewable energy targets or goals within the region, including specific benchmarks for green hydrogen production and utilization. • Develop and implement public procurement policies that prioritize the use of green hydrogen in public transportation fleets, government facilities, or other public-sector operations, to drive up demand and market opportunities for green hydrogen. • Evaluate and map gaps in legislation, energy-related legal frameworks, and successful case studies • Develop local content focused policies to ensure local stakeholders benefit from green hydrogen projects through jobs, market for local supply chains, etc.	• Create policies, regulations, and incentives to support and encourage the adoption and production of green hydrogen. • Develop local green hydrogen strategies and roadmaps • Develop supportive regulatory frameworks that facilitate the deployment of green hydrogen technologies. This can include streamlining permitting processes, establishing safety standards, or ensuring fair market access for hydrogen-related projects. • Develop policy reforms and instruments to direct Investment in infrastructure for green hydrogen production, storage, and distribution.	• Integrate green hydrogen strategies into broader climate action plans or sustainability initiatives to ensure alignment with long-term environmental goals. • Provide sufficient information on costs, development plans, supply-chain issues, and grid considerations • Prepare market demand reports for green hydrogen • Highlight the importance of political will from leaders to attract more investments and engagement with the private sector
Stakeholders and Awareness	• Engage the community and other stakeholders and involve them in promoting citizens' awareness. Thus involve civil society, NGOs, and the youth community in green hydrogen promotion • Involve research organizations in the innovation and continuous development of green hydrogen • Collaborate with and engage other levels of government to ensure vertical integration.	• Identify and engage local stakeholders and develop a communication strategy for involvement and awareness • Launch educational campaigns to raise awareness among citizens, businesses, and policymakers about the benefits and potential of green hydrogen. This can increase public support and engagement in green hydrogen projects.	• Foster partnerships between the local government and national government, private industries, research institutions, and other stakeholders to collaborate on research, development, and implementation of green hydrogen initiatives. • Share findings and benefits transparently with citizens, highlighting accomplishments and progress made.

	Enabler Actions	Required Actions	Multiplier Actions
Governance	• Form collaborative committees to plan green hydrogen programs, involving the central and local government, utilities, sponsors, and international organizations • Examine the legislation and regulations governing green hydrogen, particularly those involving private sector investment	• Establishing mechanisms to monitor progress towards green hydrogen goals, collecting data, and reporting on the impact of policies and initiatives to ensure accountability and refine strategies as needed. • Outline how the project's financial savings will be dispersed, define the legal framework, and define the local support plan • Provide a professional technical advisor based in the city/local administration	• Create a dedicated department for institutional interactions • Ensure data delivery and integration.
Capacity Building	• Providing funding, grants, or support for research and development initiatives focused on advancing green hydrogen technologies, improving efficiency, and reducing costs. • Creating educational and training programs and initiatives to develop local capacity and ensure the availability of qualified local employees • Provide decision-makers with managerial concepts and evidence such as financial indicators, policy and technology performance, etc.	• Investing in research and development initiatives focused on advancing green hydrogen technologies, efficiency improvements, cost reductions, and scalability. This support can encourage innovation and accelerate the commercialization of hydrogen-related technologies. • Develop hydrogen infrastructure, including production facilities, storage solutions, distribution networks, and refueling stations. • Involve existing technicians and staff in inspection, installation, and maintenance to increase technical capacity	• Encourage research and study on this topic • Strengthen linkages green hydrogen industry players and universities and research institutions • Incorporate training and information on green hydrogen into vocational high school and university curriculum

	Enabler Actions	Required Actions	Multiplier Actions
Technical	• Determine the number of required green hydrogen plants by mapping local potential and demand • Determine the renewable energy potential for green hydrogen production • Determine the availability of technologies and the cost of production, storage and transportation of green hydrogen • Establish the carbon footprint of the various technologies and resources • Determine the technical specifications and the availability of spare parts and a service value chain to ensure the project's long-term viability	• Determine the potential for RE in each unique hydrogen production or storage site • Determine hydrogen infrastructure needs from production, storage, transport to demand sectors (Value chain analysis). Eg. refueling stations, repurposing of natural gas distribution networks, etc... • Identify technological learning needs and associated costs • Ensure that technical standards & safety are met throughout the early stages of development • Develop a technical help program • Develop equipment testing centers for hydrogen applications	• Implement pilot and demonstration projects for green hydrogen and collect lessons learned • Implement programs for ongoing system improvements • Provide technical services for hydrogen production and storage in small community areas • Integrate plans for hydrogen with smart city development
Finance	• Offer financial incentives such as tax credits, rebates, subsidies, or grants to businesses, industries, or individuals investing in green hydrogen production, infrastructure, or utilization. • Establish strategic partnerships with potential funders • Evaluate initial financing sources • Map necessary technical feasibility studies to make the project financially viable	• Conduct assessments on financial indicators and investment payback scenarios to aid in decision-making • Create institutional and legal documents by researching various investment schemes • Choose a financing source and adhere to public procedure principles.	• Attract funding to enhance the system and operation as a whole • Provide incentives and subsidies for green hydrogen R&D, as well as for industries or transport that shift from fossil fuels to green hydrogen

3. WORKFLOW /PROCESS PHASES

3.1 PREPARATION

- Conduct a comprehensive assessment of local energy needs, existing infrastructure, and potential for renewable energy resources, especially solar, wind or hydropower, and further determine the potential for green hydrogen production.
- Conduct feasibility studies of potential green hydrogen production sites to ensure demand centers have access and transportation costs are not prohibitive and evaluate the feasibility of using existing networks e.g. gas pipelines to transport green hydrogen, etc.
- Collaborate with power producers and utilities to investigate the potential of green hydrogen for electrical system flexibility.
- Identify stakeholders, including local industries, research institutions, community groups, and potential partners interested in green hydrogen initiatives.
- Engage with stakeholders through workshops, forums, or consultations to gather input, raise awareness, and build support for green hydrogen initiatives. Also, improve collaboration between central and local governments to ensure a coordinated strategy across multiple levels of government.
- Develop a strategic plan outlining goals, targets, and timelines for green hydrogen implementation aligned with broader sustainability and climate action plans.
- Create or update policies and regulations to support the development and adoption of green hydrogen technologies, including safety standards, certification criteria for what qualifies as 'green' etc.
- Establish renewable energy targets and incentives to encourage investment in green hydrogen production and usage.
- Foster partnerships with local industries, academic institutions, and technology providers to leverage expertise, resources, and funding opportunities.
- Investigate appropriate business models to make green hydrogen production viable (e.g. only producing when renewable energy is in excess).
- Investigate appropriate business models to make green hydrogen production, transportation and use viable (e.g. only producing when renewable energy is in excess).

3.2 APPROVAL

- Streamline permitting and approval processes for green hydrogen infrastructure development
- Ensure the approval of the project by the responsible institutions
- Ensure clear criteria for certifying what qualifies as green hydrogen

3.3 PROCUREMENT

- Develop investment plans for green hydrogen, covering production facilities, storage systems, distribution networks, and refueling stations.
- Develop and implement public procurement policies that prioritize the use of green hydrogen in public transportation fleets, government facilities, or other public-sector operations, to drive up demand and market opportunities for green hydrogen.

- Develop technical specifications and guidelines (electrolysis, storage and transportation, safety, reliability, etc.) for the green hydrogen production industry
- Develop procurement methods according to the determined technical specifications

3.4 IMPLEMENTATION

- Implement pilot projects or demonstrations to showcase the feasibility and benefits of green hydrogen technologies in practical applications.
- Evaluate the performance, cost-effectiveness, and environmental impact of these projects to gather valuable data and insights.
- Scale up successful pilot projects and initiatives, considering lessons learned and best practices.
- Explore opportunities for further expansion of green hydrogen infrastructure and applications across various sectors.
- Foster a culture of continuous improvement by investing in research and development, seeking cost reductions, and enhancing efficiency in green hydrogen production and utilization.
- Collaborate with other local governments, regional bodies, and national agencies to share experiences, expertise, and resources for collective advancement in green hydrogen adoption.

3.5 MONITORING

- Establish monitoring mechanisms to track progress towards goals and targets set for green hydrogen adoption, as well as ensuring conformity with defined standards.
- Collect data on green hydrogen production and consumption, and track progress towards production targets and identify areas where more investment is needed. Also track the cost of green hydrogen production and efficiency of the production process, in order to identify opportunities for cost reduction.
- Regularly evaluate the effectiveness of policies and initiatives, adjusting strategies as needed based on collected data and feedback.
- Measuring the reduction of GHG emissions as a result of green hydrogen production and utilization.

4. REALITY-CHECK

This solution is applicable:

- Where the local government aims and commits to reducing carbon emissions and achieving sustainability targets, especially with sectors that are difficult to decarbonize, such as heavy industry, transportation, or heating.
- In regions where there are bold renewable energy plans, or increasingly high shares of variable renewable energy that need storage and flexibility options.
- Areas with significant industrial activity, particularly those reliant on fossil fuels, can benefit from green hydrogen as a clean energy alternative for processes such as manufacturing, refining, or chemical production.
- Localities with a focus on clean transportation, or cities with extensive public transport networks, can utilize green hydrogen as a fuel for buses, trucks, trains, or shipping.

4.1 REQUIRED PRE-CONDITIONS

- Access to abundant and cost-effective renewable energy sources such as solar, wind, or hydroelectric power is crucial for producing green hydrogen. Regions with ample renewable energy potential have a significant advantage.
- Adequate infrastructure is necessary for the production, storage, and distribution of green hydrogen.
- Supportive policies, incentives, and a conducive regulatory framework are essential for encouraging investment and fostering a favorable environment for green hydrogen development.
- Access to funding, grants, subsidies, or public-private partnerships can facilitate the upfront investment required for establishing green hydrogen infrastructure, making it economically feasible.
- Access to technical expertise, research institutions, and innovation hubs can accelerate advancements in green hydrogen technologies, improving efficiency and reducing costs.
- Economic viability of green hydrogen projects, ensuring the costs of production, distribution, and utilization of green hydrogen are competitive compared to conventional alternatives.

4.2 SUCCESS FACTORS

- Educating the public, businesses, and stakeholders about the benefits and potential applications of green hydrogen is crucial for garnering support and encouraging adoption.
- Integration of green hydrogen into existing energy systems and grid infrastructure is vital for balancing the grid and energy storage systems.
- Long-term vision and commitment from the local government are necessary for sustained efforts in developing, scaling up, and continuously improving green hydrogen initiatives.
- Building partnerships with key stakeholders including local industries, research institutions, utility companies, etc. is critical for collaboration and support.
- Documenting and applying lessons learned in continuous improvement of green hydrogen development and utilization.

Figure 2: Hydrogen buses in Aberdeen. Source: *Intelligent Transport*

4.3 FOLLOW-UP NEEDED AND/OR RECOMMENDED

- Consider the eventual increase of demand once the update of green hydrogen has already increased (e.g., more use of hydrogen vehicles and more industries shift to hydrogen).
- Consider the rebound effect on increasing green hydrogen demand which could stimulate the increasing supply of green hydrogen. In addition, encourage hydrogen production from greener sources and processes.
- Provide continuous training and capacity development to support existing and future green hydrogen projects.
- Ensure local content policies are effectively implemented to give priority to local suppliers and labor.
- Explore opportunities to scale up through collaboration with neighbouring regions or industries.

4.4 BARRIERS

- Renewable energy data availability in the specific area
- Lack of regulation and stakeholders' responsibilities for a project or specific actions
- Unclear pricing or tariff schemes
- Missing or lack of relevant regulations and framework

4.5 RISKS

- Inadequate funds for the long-term operation of the system
- Lack of quality or poorly selected technology used for the project

5. CLIMATE CHANGE MITIGATION POTENTIAL

Green hydrogen, which is produced using renewable energy sources such as solar, wind, hydro, or geothermal power, can play a significant role in mitigating climate change. The Hydrogen Council's report highlights that hydrogen has the potential to reduce greenhouse gas emissions by 6 $GtCO_2$ per year by 2050, which is equivalent to around 20% of the total reduction needed to meet the Paris Agreement goals. When hydrogen is used as a fuel, it releases only water vapour as a by-product, unlike fossil fuels which release greenhouse gases that contribute to climate change. When green hydrogen is produced and consumed locally, it can have an even greater potential for climate change mitigation. This is because local strategies can help to ensure that hydrogen production is closely aligned with the specific energy needs and resources of a particular city or region. This can help to reduce the need for long-distance transportation of hydrogen and any associated greenhouse gas emissions. Furthermore, local strategies can also promote the integration of hydrogen production with other renewable energy sources, such as solar and wind power, which can help to increase the overall share of renewable energy in the local energy mix and reduce the dependence on fossil fuels.

6. FURTHER SCIENTIFIC AND TECHNOLOGICAL INSIGHTS

GREEN HYDROGEN CHARACTERISATION INITIATIVES: DEFINITIONS, STANDARDS, GUARANTEES OF ORIGIN, AND CHALLENGES

Abad, A.V., Dodds, P.E., (2020). Green hydrogen characterisation initiatives: Definitions, standards, guarantees of origin, and challenges. Energy Policy, 138, 111300. doi:10.1016/j.enpol.2020.111300

Abstract (retrieved from the article): "Hydrogen can be produced from many different renewable and non-renewable feedstocks and technological pathways, with widely varying greenhouse gas emissions. For hydrogen to have a role in future low-carbon energy systems, it is necessary to demonstrate that it has sufficiently low carbon emissions. This paper explores how green hydrogen has been defined, reviews nascent green hydrogen characterisation initiatives, and highlights the main challenges that standards and guarantee of origin schemes must overcome to develop a market for green hydrogen. Most existing green hydrogen initiatives are in Europe. In anticipation of a future market for green hydrogen, international standards are starting to be discussed by national and international standardization organizations and policy makers. A range of approaches have been taken to defining green hydrogen and guarantees of origin. These vary on whether green hydrogen must be produced from renewable energy, on the boundaries of the carbon accounting system, the emission thresholds at which hydrogen is considered green, and on which feedstocks and production technologies are included in the scheme. Decisions on these factors are often influenced by other national and international standards, and the legal framework in which the green hydrogen supply chain operates."

- Examples of existing applications of hydrogen at various deployment scales: https://www.enapter.com/applications

7. NATIONAL – SUBNATIONAL INTEGRATION IN THE CONTEXT OF THIS SOLUTION

7.1 BENEFITS TO LOCAL GOVERNMENT

- Reduce local government dependency on fossil fuel/internal combustion engine (ICE) vehicles
- Reduction of CO_2 emissions in industrial sector
- Generation of local and green jobs
- Provide additional income for local governments
- Pioneering cities can attract investments and advocate for more enabling frameworks at the national level

7.2 BENEFITS TO OTHER LEVELS OF GOVERNMENT

- Accelerate the achievement of national renewable energy targets
- Contribute to GHG emission reduction targets
- Improved policies and frameworks based on the experience of local governments

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