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Long-Term Joint EU-AU Research and Innovation Partnership on Renewable Energy

Innovation Outlook on RE technologies

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Summary

This Innovation Outlook has synthesized lessons from the LEAP-RE portfolio to highlight how renewable energy innovations can move beyond pilot stages toward sustained deployment and impact in African and European contexts.

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Executive Summary

Accelerating Africa's energy transition is not primarily a matter of deploying individual renewable technologies, but of building integrated innovation ecosystems capable of aligning technology development with policy frameworks, financing mechanisms, skills, and societal needs. Evidence from the LEAP-RE portfolio (31 projects funded between 2021 and 2025) demonstrates that renewable and sustainable energy innovation delivers the greatest and most durable impact when it simultaneously addresses technical performance, affordability, social acceptance, environmental sustainability, and institutional readiness.

Across a diverse set of thematic priorities – including geothermal energy, modern cooking technologies, bioenergy, green hydrogen, energy system optimisation, productive uses of energy,

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smart stand-alone systems, and the circular management of renewable components – a consistent insight emerges: technology-first approaches are insufficient. Technical maturity alone does not guarantee adoption, scalability, or socio-economic benefit. Innovation becomes transformative only when it is embedded in local contexts, linked to livelihoods and value chains, and supported by data-driven planning tools, appropriate business models, and enabling policy and regulatory environments.

The LEAP-RE experience challenges the widely held assumption that energy transitions follow a linear pathway from technology development to deployment and impact. Geothermal mapping confirms vast subsurface potential, yet also highlights persistent barriers related to investment risk, regulatory uncertainty, and limited integration into national energy planning. Modern cooking projects demonstrate that efficient appliances alone do not drive uptake; adoption is shaped by cooking practices, affordability, gender roles, grid reliability, and trust in technologies and service providers. Mini-grid optimisation shows that governance structures, system architecture, and demand evolution are as decisive as generation capacity. Similarly, bioenergy and green hydrogen initiatives underline that feedstock logistics, standards, skills, and value chains must mature in parallel with conversion technologies. Circularity-focused projects further demonstrate that sustainability cannot be retrofitted at end-of-life, but must be embedded from the earliest stages of technology design and system planning.

Several structural challenges consistently shape renewable energy innovation outcomes across the portfolio. Fragmented, inaccessible or outdated data-covering resources, demand, infrastructure and socio-economic conditions – continue to limit effective planning and increase investment risk.

LEAP-RE initiatives such as the Geothermal Atlas for Africa, energy system optimisation tools and Energy Village mapping illustrate how open, interoperable data platforms can reduce uncertainty and support evidence-based decision-making. Affordability and market readiness remain critical barriers, particularly for modern cooking solutions, decentralised systems and productive uses of energy, where high upfront costs, immature business models and limited access to finance constrain adoption despite favourable lifecycle economics. Social acceptance and behavioural factors also play a decisive role, underscoring the importance of user-centred design, participatory approaches and co-creation. Finally, many projects highlight persistent gaps in skills, institutional capacity and regulatory readiness, alongside emerging sustainability challenges linked to waste streams, critical materials and lifecycle impacts.

In response to these challenges, the LEAP-RE portfolio reveals several innovation pathways with high potential for scale and impact. These include the translation of resource assessments into decision-ready planning and investment tools; the development of user-centred and livelihood-oriented energy services that link access to health, income generation, food security and local value chains; the diversification of energy vectors and applications to enhance system resilience and reduce import dependence; and the use of digitalisation and open innovation to lower entry barriers, foster entrepreneurship and strengthen local innovation ecosystems.

LEAP-RE projects reposition renewable energy not merely as a supply-side intervention, but as a development enabler supporting agriculture, food systems, health, entrepreneurship, industrialisation and climate resilience.

This Innovation Outlook synthesises these cross-cutting lessons to inform future AU–EU research, innovation and policy cooperation. It calls for a shift towards systemic, context-sensitive innovation approaches that align R&I, policy and investment with shared objectives under AU Agenda 2063, the EU Global Gateway and Mission 300, thereby supporting inclusive, resilient and sustainable energy transitions across Africa and Europe.

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Beyond informing policy and research priorities, the lessons from LEAP-RE provide a concrete basis to identify which innovations can credibly transition from pilots to investable ventures. Across thematic priorities, the most promising opportunities are those combining (i) validated user demand, (ii) replicable delivery and maintenance models, and (iii) an enabling regulatory pathway. This Outlook therefore supports the next step of the AU–EU innovation pipeline: transforming selected research outputs into market-driven ventures through structured readiness assessments, business model development, and investor-oriented evidence generation.

1. Context and Introduction

The Long-Term Joint EU-AU Research and Innovation Partnership on Renewable Energy (LEAP-RE) is a six-year collaborative initiative that has brought together 85 partners committed to implementing an Africa-Europe joint research and innovation program addressing key renewable energy challenges. As this program approaches its conclusion in 2026, it is essential to assess the progress, achievements, and lessons learned from its 31 constituent projects. These projects represent the collaborative heart of the LEAP-RE initiative, demonstrating practical applications of Africa-Europe cooperation in renewable energy development.

Accelerating the transition towards sustainable, affordable and reliable energy systems is a defining challenge of our time. In Africa and Europe alike, energy systems must respond simultaneously to climate imperatives, socio-economic development needs, population growth, and increasing pressure on natural resources. Innovation plays a central role in this transition – not only through technological advances, but also through new approaches to system design, governance, value chains and end-use applications.

This Innovation Outlook builds on its shared ambition to strengthen cooperation between Africa and Europe in the field of renewable energy research and innovation. Grounded in LEAP-RE's seven thematic priorities, this Outlook explores how ongoing research and innovation activities contribute to addressing critical energy challenges, while opening pathways for scalable, inclusive and environmentally responsible solutions.

Rather than presenting innovation as a linear or purely technical process, this Outlook adopts a systemic perspective. It examines how renewable energy technologies interact with social needs, local contexts, environmental constraints and economic opportunities.

By synthesising lessons from ongoing projects and positioning them within broader innovation trajectories, this Innovation Outlook aims to:

- Highlight key challenges and opportunities across LEAP-RE thematic priorities;
- Identify gaps where further research, demonstration or policy support is needed;
- Support stakeholders – including policymakers, researchers, practitioners and investors – in shaping coherent, forward-looking energy strategies.
- Ultimately, this document seeks to contribute to a shared vision of an energy transition that is sustainable, inclusive and adapted to local realities, while reinforcing long-term Africa–Europe cooperation.

This outlook can also be used by:

- Policymakers: identify enabling measures that reduce investment risk and accelerate adoption (data availability, standards, tariffs, licensing, circularity frameworks).
- Investors and DFIs: identify innovation segments where risk can be mitigated through decision tools, demand aggregation, and proven service models.
- Incubators and the LEAP-Energy Startup Studio: select ventures based on readiness signals (technical maturity, validated demand, replicability) and design targeted support packages (business model, partnerships, regulatory strategy, investment readiness).

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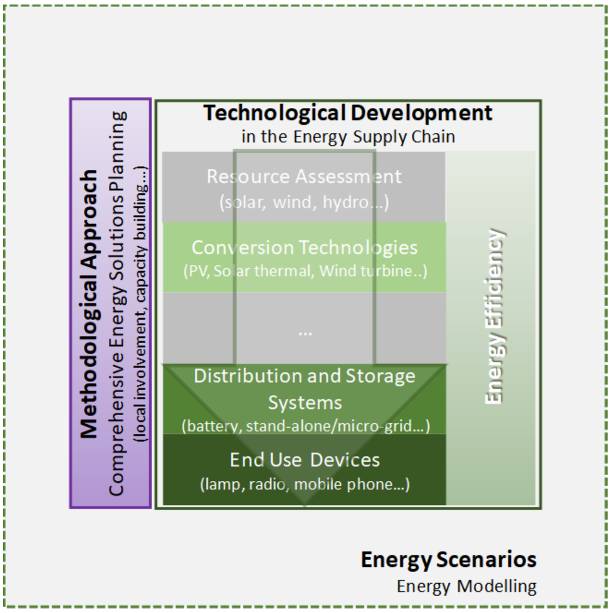
2. Multi-annual roadmaps

The Horizon 2020 project, Preparing for a Long-Term Joint EU-AU Research and Innovation Partnership on Renewable Energy (PRE-LEAP-RE), undertook an ecosystem analysis to highlight the gaps, trends, and potential opportunities for bi-regional collaboration in the renewable energy sector.

The analysis was based on information provided by PRE-LEAP-RE consortium members and relevant international literature and studies. An *Initiatives & Network Matrix* was built with 89 selected initiatives, which allowed for analysis resulting in the recommendation of a multidisciplinary framework for an R&I agenda, with the following three key components.

1. Technological development needs to be deepened at all points along the energy supply chain, including conversion technologies and end use devices. Resource assessment is still crucial for some sources, while distribution is an important area for research and innovation when dealing with integration of renewables via smart hybrid mini grid, either in their off-grid configuration, or when considering their long-term integration within the national grid. This is one of the most attractive areas of research, where leapfrogging can be done by leveraging innovation with the digital revolution that is currently taking place in Africa and allowing integration of sources and additional storage opportunities.
2. Technological development cannot stand alone. A comprehensive methodological approach is needed, able to address the different phases of the energy supply chain by taking into account societal needs, market evaluation, business models for long-term sustainability, and solution deployment as well as the long-term impact on society. As underlined by the CCSE Roadmap, such an approach is essential for guaranteeing the long-term social, economic, and environmental sustainability of technology.
3. Renewed attention to energy scenarios and policy is vital for understanding the contexts in which technologies and energy solutions will be developed, helping to minimize unforeseeable consequences. there is a clear need for supporting further research and capacity building on energy scenario analysis, including modelling approaches and tools that support policy and decision makers to build a long-term plan at national and regional levels.

Figure 1 Schematic representation of the PRE-LEAP-RE multidisciplinary framework for an R&I agenda



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Such a multidisciplinary approach encourages the development of scenarios that are appropriate to logical contexts and can be further utilized to support policy makers. Moreover, this approach requires the development of capacity building activities to increase local empowerment and ownership.
With this basis, and in consultation with stakeholders, PRE-LEAP-RE developed a set of 6 Multi-Annual Roadmaps (MARs) for research and innovation, representing the main topics related to renewable energies development and described in terms of social challenges, research scope, and expected output, outcome, and impact. A seventh roadmap has been added when LEAP-SE COFUND has been funded. These MARs serve as the basis for the LEAP-RE Joint Calls 2021 and 2022, for upcoming calls for projects, and for the 8 projects undertaken in Pillar 2.

#	Multiannual Roadmaps (MARs)
1	**Mapping joint research and innovation actions and resources for future RES development** – Consolidation of detailed map of R&I initiatives, sources in Europe and Africa per technology, application etc. type with the aim to support the RE industry to prioritize and contextualize target areas of RES deployment
2	**End-of-life and second-life management and environmental impact of RE components** - Map the component value chain, identification of key stakeholders & successful business models promote replicability scenarios of operational models and standard operating procedures in concerned regions
3	**Smart stand-alone systems (SAS)** - Promote the development of RE-SAS demonstrator(s) considering the diversity of potential local RE sources and the local effective environment
4	**Smart grid (different scale) for off- grid application** - Development of new tools for optimizing capacity in planning/ and dispatching strategies based on people's needs with the aim to reduce the energy dependence on fossil fuel and increasing the share of RES use
5	**Processes and appliances for productive uses (PRODUSE)** – Improvement and Promotion of wider us of PRODUSE appliances for Cold chain and thermal tools and equipment's (healthcare and agriculture - livestock, fisheries and farming)
6	**Innovative solutions for priority domestic uses (clean cooking and cold chain)** - Improving, managing and maintaining solar photovoltaic systems, cookstoves and cold chain components for food cooking and food storage. Supporting interactions with policymaking to foster fast market uptake considering the macro socio-economic and gender impacts
7	**Green Hydrogen** was not specifically addressed in LEAP-RE roadmaps. However Green Hydrogen is identified at global level as an important option for sustainable energy systems and several African countries are developing a national strategy on Green Hydrogen.

These roadmaps not only structure AU–EU research and innovation priorities, but also provide a foundation for downstream activities under future LEAP-Energy activities. In this context, the Outlook supports the translation of roadmap priorities into venture pipelines, market intelligence, and investment mobilisation actions.

3. Overall Analysis: innovation pathways for Sustainable Energy systems in Africa

From resource assessment to deployable energy systems

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A recurring innovation pattern across LEAP-RE is the transition from resource mapping to actionable decision-support tools.
In geothermal energy, the Geothermal Atlas for Africa (GAA) represents a major step change. By integrating geological, geophysical, geochemical, and socio-economic data into open, interoperable platforms, the Atlas transforms fragmented datasets into investment-ready intelligence. The use of scenario-based modelling and technology-specific indicators such as LCOE and CO_2 impacts enables policymakers and developers to identify where, how, and for which end-uses geothermal resources can be sustainably deployed. It is in this spirit that the data has been used to feed into the Africa Knowledge Platform developed by the JRC.
Similar logics apply to energy system optimisation projects, where open-source models (e.g. MicroGridsPy) translate resource availability and demand projections into cost-optimal hybrid mini-grid designs. These tools allow planners to explore trade-offs between renewable penetration, storage capacity, backup generation, and system architecture, moving beyond static design rules toward adaptive planning frameworks.

Digitalisation, open innovation and capacity building

Innovation in LEAP-RE is also strongly driven by digital tools and human capital development.
Open data platforms, interactive atlases, and optimisation models increase transparency and reduce entry barriers for new actors. At the same time, initiatives such as the Open Innovation Ideathon organized within SETaDiSMA project, demonstrate the role of entrepreneurship and youth engagement in translating technical solutions into scalable business models.
Capacity building – through PhD and Master's training, institutional partnerships, and skills development – emerges as a foundational pillar, ensuring that innovation is locally owned, maintained and evolved.

Transitioning from pilots to scalable impact

The LEAP-RE projects analysed collectively demonstrate that Africa's energy transition is not constrained by a lack of ideas or technologies, but by the challenge of scaling context-appropriate solutions. LEAP-RE's portfolio shows how coordinated research, innovation, and capacity development can bridge the gap between pilots and systemic transformation.
This Innovation Outlook highlights pathways toward integrated, inclusive and sustainable energy systems, positioning innovation as a driver not only of decarbonisation, but also of socio-economic development across the African continent.

User-centred innovation and social acceptance

Across multiple thematic areas, projects demonstrate that technical feasibility does not guarantee adoption. This is particularly evident in modern cooking technologies, where extensive fieldwork in Kenya, Rwanda and Mozambique reveals the complexity of household energy transitions. Innovations in electric and solar cooking were not limited to appliance design, but extended to:

- Longitudinal cooking diary studies capturing real-time behavioural change,
- Iterative prototyping of cookers adapted to local power constraints,
- Policy and regulatory analyses identifying barriers to market uptake,
- Capacity assessments addressing repair, installation and user training needs.

These insights highlight the necessity of user-centred design, where innovation is shaped by everyday practices, affordability, reliability, and trust, rather than purely by efficiency metrics.
A similar emphasis on social embedding is visible in Energy Village concepts and productive use applications, where energy systems are explicitly linked to livelihoods, income generation, and local value chains. Here, energy innovation becomes a lever for territorial development, not just electrification.

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Diversification of energy vectors and end-uses
LEAP-RE projects illustrate the importance of diversifying both energy carriers and applications to strengthen resilience and economic impact.

- Bioenergy projects explore pathways to valorise agricultural residues and organic waste through biogas, biofuels and thermal applications, contributing to circular economy objectives while reducing dependence on imported fuels.
- Green hydrogen initiatives focus on early-stage ecosystem building, addressing not only production technologies but also standards, skills, and cross-sector integration for future industrial and mobility uses.
- Productive use technologies target agriculture and food value chains, enabling energy-powered irrigation, processing, cooling, and storage to increase productivity and create off-farm employment.

This diversification reduces systemic risks and aligns energy deployment with broader development priorities, including food security, industrialisation, and climate resilience.

Sustainability beyond deployment: circularity and lifecycle thinking
A notable cross-cutting innovation dimension concerns the end-of-life and second-life management of renewable energy components. Projects addressing recycling, reuse and environmental impacts of PV panels, batteries and electronic components recognise that sustainability does not end at installation. By developing:

- Second-life applications for energy storage,
- Recycling pathways adapted to African contexts,
- Environmental impact assessment frameworks,
- LEAP-RE contributes to avoiding future waste streams and building local circular value chains around renewable technologies.

This lifecycle perspective is essential for ensuring that the energy transition remains environmentally and socially sustainable over the long term.

Innovation Outlook: key systemic insights
Across thematic priorities, several common innovation insights emerge:

1. Energy innovation is systemic, requiring the integration of technology, policy, finance, and social acceptance.
2. Data-driven decision tools are critical to move from potential to implementation.
3. User-centred and livelihood-oriented approaches significantly increase adoption and impact.
4. Hybrid and diversified energy systems enhance resilience and cost-effectiveness.
5. Lifecycle and circularity considerations must be embedded early in technology deployment.
6. Capacity building and entrepreneurship are essential to sustain innovation beyond project lifetimes.

4. Geothermal energy as a strategic pillar of Africa’s renewable transition

Geothermal energy represents a largely untapped yet highly strategic renewable energy resource for Africa. With its ability to provide stable, low-carbon power, heat and cooling, geothermal energy can play a critical role in strengthening energy security, supporting productive uses, and enabling long-term decarbonisation pathways. However, its development has historically been constrained by fragmented data, high upfront exploration risks, and limited integration of socio-economic considerations into planning processes.

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Within the LEAP-RE framework, geothermal research and innovation activities have focused on reducing uncertainty, strengthening the knowledge base, and supporting informed decision-making for policymakers, investors and local stakeholders. The Geothermal Atlas for Africa (GAA), the Geothermal Village and the Energy Village concept together illustrate how technological, environmental and social dimensions can be combined to accelerate geothermal deployment.

A cornerstone of LEAP-RE's geothermal activities is the development of the Geothermal Atlas for Africa (GAA), which aims to provide an open, harmonised and scientifically robust platform for assessing geothermal potential at the continental scale. Extensive efforts were dedicated to collecting, processing and quality-controlling a wide range of datasets from both open sources and project partners. These activities resulted in the integration of diverse data types, including heat flow measurements, basin geometries, porosity and permeability indicators, well and seismic data, crustal and lithospheric models, fault systems, surface temperature datasets and volcanic information. The consolidation of these datasets enabled the creation of geothermal energy indicators and the identification of areas with promising geothermal conditions across Africa.
Beyond data aggregation, a significant innovation lies in the development of modelling frameworks that translate subsurface characteristics into actionable energy insights. By combining temperature-depth distributions, reservoir properties and sediment thickness models, geothermal potential maps were produced to delineate areas suitable for different technological applications. The Atlas does not limit its scope to resource availability but extends the analysis to the energy systems level. Multiple geothermal exploitation scenarios were developed – ranging from conservative (Basecase) to high-potential (Up-upside) assumptions – allowing stakeholders to explore different development trajectories. The assessment covers a wide spectrum of geothermal applications:

- Power generation, including flash steam and binary cycle (ORC) plants;
- Heat production, through high-temperature heat pumps for industrial uses and direct-use systems for residential heating;
- Cooling production, using absorption refrigeration systems for cold chains and air conditioning.

Each technology pathway was evaluated using key performance indicators such as levelised cost of energy and climate change impact, enabling a multi-criteria comparison of options. This approach supports evidence-based decisions by identifying not only where geothermal energy is available, but also which technologies are most sustainable and cost-effective in specific contexts. An interactive, open-access map viewer further enhances the impact of the Atlas by making these insights accessible to a broad range of users, from researchers and planners to public authorities and private developers.
Recognising that geothermal development is not purely a technical endeavour, LEAP-RE activities also place strong emphasis on social, economic and institutional factors. A dedicated socio-economic analysis was conducted for eight African countries, combining national-level data with case studies of renewable energy development.
This work highlights key drivers and barriers influencing geothermal deployment, including regulatory frameworks, community engagement practices, financing conditions, and cultural perceptions. By documenting good practices and lessons learned from existing projects, the analysis contributes to a more nuanced understanding of how geothermal energy can be embedded in local development strategies.
Complementing large-scale resource assessment, the Energy Village concept explores how renewable energy – including geothermal where locally available – can support energy self-sufficiency in small towns and rural regions. By mapping energy demand, local renewable resources and socio-economic conditions, the concept demonstrates how integrated energy systems can deliver tangible benefits at the community level.

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Activities carried out across multiple African countries focused on developing sustainable action plans, business models and implementation roadmaps for both on-grid and off-grid villages. These efforts highlight the importance of coupling technical solutions with policy alignment, financing mechanisms and local capacity building to ensure long-term viability.

Taken together, these geothermal-focused activities illustrate a shift from fragmented exploration towards coordinated, data-driven and socially informed innovation pathways. By reducing geological uncertainty, integrating techno-economic and environmental assessments, and embedding socio-economic considerations from the outset, LEAP-RE contributes to lowering investment risks and supporting scalable geothermal development.
Looking ahead, the geothermal innovation outlook points to several priorities:

- Continued expansion and updating of open-access geothermal datasets;
- Stronger links between resource assessment and national energy planning;
- Enhanced support for direct-use applications in industry, agriculture and cooling;
- Increased focus on capacity building and local stakeholder engagement.

By aligning scientific excellence with practical deployment needs, geothermal energy can become a key enabler of Africa's sustainable and resilient energy future.

Lastly and from a scale-up perspective, the main opportunity for geothermal innovation lies less in standalone technologies than in service-based models that reduce exploration and development risks for public and private actors. Decision-support tools, subsurface data services, and project development platforms can significantly improve bankability by lowering upfront uncertainty and clarifying permitting and licensing pathways. The key challenge for market uptake remains risk concentration at early project stages, requiring evidence on resource validation, regulatory clarity, and replicability across contexts. These characteristics position geothermal-related innovations as strong candidates for venture building focused on de-risking services, public–private partnerships, and investment-ready project structuring under the LEAP-Energy Startup Studio.

5. Modern cooking technologies as a driver of clean energy access and socio-economic transformation

Access to clean, affordable and modern cooking solutions remains a critical challenge across many African countries. Traditional cooking practices, often reliant on biomass and fossil fuels, are associated with adverse health impacts, environmental degradation and significant time burdens – particularly for women. At the same time, the rapid expansion of electricity access, including through grid extension and mini-grids, opens new opportunities for electric cooking (e-cooking) and solar-powered cooking technologies.
Within LEAP-RE, research and innovation activities on modern cooking technologies adopt a systemic perspective, recognising that successful adoption depends not only on technology performance, but also on user behaviour, business models, policy frameworks, value chains and local capacity. By combining social science research, technology development and market and policy analysis, these activities aim to support scalable pathways towards clean cooking transitions.
A core contribution of LEAP-RE activities in this area is the development and application of a common, cross-country methodology to study the adoption of modern cooking technologies in

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diverse contexts. Kenya, Rwanda and Mozambique were selected to represent different energy access configurations and use cases:

- Kenya, focusing on newly electrified households and the emergence of e-cooking in on-grid contexts;
- Rwanda, examining electric cooking adoption in households supplied by mini-grids;
- Mozambique, exploring cooking practices from a business and productive-use perspective.

Using a harmonised approach adapted to local contexts, a multi-stage data collection process was implemented, combining pre-screening surveys, detailed household surveys, baseline and exit cooking diary studies, and pilot deployments of electric pressure cookers equipped with real-time energy metering. This methodology enabled a granular understanding of cooking event profiles, fuel switching behaviour, user preferences and constraints before and after exposure to electric cooking technologies.

By grounding innovation in real-life cooking practices, these activities generate robust evidence on how, when and why households and businesses adopt modern cooking solutions, and which factors most strongly influence sustained use.

Beyond adoption studies, LEAP-RE projects also address the technical adaptation of cooking appliances to African energy contexts, particularly where grid capacity is limited or where systems rely on solar photovoltaics and batteries. Significant innovation efforts were dedicated to the design and testing of improved electric cookers suitable for standalone and solar-powered operation. Laboratory-based cooking tests examined energy efficiency, thermal performance, current and voltage behaviour, and component durability under realistic operating conditions. Particular attention was given to reducing inrush currents, improving compatibility with photovoltaic systems, and enhancing safety and reliability. The exploration of positive temperature coefficient (PTC) heating elements represents a notable innovation pathway. These self-regulating components demonstrated potential for lower steady-state current consumption compared to conventional resistive elements, making them more suitable for constrained energy systems. Ongoing design considerations – such as hotplate geometry, insulation and custom component manufacturing – highlight the iterative nature of appliance innovation and the need to align technical design with manufacturability and cost constraints.

However, technological innovation alone is insufficient to trigger large-scale transitions in cooking practices. LEAP-RE activities therefore place strong emphasis on market readiness, policy alignment and capacity development. Market and policy analyses conducted in Kenya, Rwanda and Mozambique assessed the regulatory, legislative and institutional environments shaping clean cooking and e-cooking uptake. These analyses identified legal and financial barriers, gaps in existing policy frameworks, and opportunities for incentives and private sector engagement. Engagement with policymakers and key stakeholders further strengthened the relevance of the findings and supported the formulation of actionable recommendations.

In parallel, efforts to map electric cooking value chains provide insights into stakeholder roles, distribution channels, after-sales services and marketing strategies. Understanding how cookers are positioned within local supply chains is essential for designing viable business models and ensuring long-term adoption beyond pilot phases.

A recurring insight across projects is the importance of human and institutional capacity to support the deployment and maintenance of modern cooking technologies. Repair technicians, installers, energy planners and entrepreneurs all play critical roles in sustaining clean cooking ecosystems. Capacity needs assessments and engagement with training institutions aim to identify skills gaps and inform curriculum development for the electric cooking sector. By anticipating future workforce requirements, these activities contribute to creating enabling conditions for scaling modern cooking solutions while fostering local ownership and economic opportunities.

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Taken together, LEAP-RE activities on modern cooking technologies demonstrate how integrated innovation approaches can address one of the most persistent energy access challenges. By combining user-centred research, appliance innovation, policy analysis and capacity development, these projects move beyond isolated pilots towards replicable and scalable solutions. Looking forward, the innovation outlook highlights several priorities:

- Strengthening the evidence base on long-term adoption and behavioural change;
- Further adapting cooking technologies to low-power and solar-based systems;
- Aligning clean cooking strategies with electrification and mini-grid expansion plans;
- Enhancing policy coherence, financing mechanisms and private sector participation.

Modern cooking technologies thus emerge not only as a health and environmental intervention, but as a cornerstone of inclusive energy transitions, linking household well-being, productive uses and sustainable energy systems.

Lastly, scaling clean cooking solutions depends primarily on the viability of integrated delivery and financing models rather than on incremental technological advances. PAYGo, leasing, and bundled appliance–fuel services have demonstrated strong potential, provided that affordability constraints, last-mile distribution, and fuel supply reliability are addressed. For market uptake, investability hinges on sustained user adoption, willingness to pay, and evidence that operational models can function at scale. This makes clean cooking a priority area for Startup Studio support focused on user-centred business models, go-to-market strategies, and alignment with results-based and blended finance mechanisms.

6. Bioenergy: advancing sustainable biomass pathways for climate-resilient development

Bioenergy – derived from organic materials such as agricultural residues, forestry by-products and dedicated energy crops – presents a versatile and scalable renewable energy source that can contribute to climate mitigation, rural economic development and energy access. In Africa and Europe alike, sustainably integrated bioenergy systems can support not only power generation but also heat provision, industrial processes and transport fuels. However, realising this potential requires overcoming technical, environmental and socio-economic challenges associated with feedstock availability, conversion efficiency, supply chain organisation and governance.

Within the LEAP-RE agenda, bioenergy research has emphasised systemic innovation that moves beyond single technologies to encompass resource mapping, sustainable feedstock development, advanced conversion pathways and community engagement. Projects such as Vil2Bio, PyroBioFuel and BIOTHEREP illustrate how scientific advances, participatory methodologies and environmental assessment can work in concert to strengthen bioenergy innovation landscapes.

The Vil2Bio project focuses on unlocking the potential of agricultural residues and other biomass resources that are abundant yet underutilised in many African and European contexts. By developing methodologies for mapping biomass availability and evaluating value chains for bioenergy feedstocks, Vil2Bio contributes to evidence-based planning and investment decisions.

By combining quantitative mapping with stakeholder engagement, Vil2Bio advances a replicable approach to bioresource assessment. This facilitates the design of bioenergy systems that are both economically viable and environmentally responsible, while laying the groundwork for scaling biomass utilisation across rural and peri-urban landscapes.

While resource assessment is foundational, transforming biomass into usable energy carriers requires technological innovation. The PyroBioFuel project addresses this by advancing pyrolysis-

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based conversion pathways that produce biofuels and bio-based chemicals with improved energy density and lower emissions profiles compared to traditional combustion or inefficient cookstoves. Pyrolysis – the thermal decomposition of biomass in the absence of oxygen – yields a suite of products, including bio-oils, syngas and char. The project's comparative analyses provide critical evidence for stakeholders – from small enterprises to policy makers – on the cost-competitiveness and climate performance of pyrolysis-derived biofuels. By elevating bioenergy conversion technologies beyond traditional biomass burning, PyroBioFuel strengthens the case for integrated renewable portfolios that include bio-based liquid fuels and chemical intermediates.

Finally, organic waste streams – from crop residues to food processing by-products – represent both a challenge and an opportunity. Left unmanaged, organic wastes contribute to environmental degradation and greenhouse gas emissions. Properly valorised, they can become feedstocks for decentralised bioenergy systems that support local livelihoods, reduce waste and increase energy access. The BIOTHEREP project explores innovative waste repurposing pathways, including anaerobic digestion and composting, to produce biogas, biofertilisers and other value-added products. The project's focus on closed-loop systems illustrates how bioenergy can be embedded within circular bioeconomies, supporting both environmental objectives (by reducing waste and methane emissions) and socio-economic goals (by creating jobs and strengthening food-energy linkages).

The combined contributions of VIL2BIO, PyroBioFuel and BIOTHEREP demonstrate a maturing bioenergy innovation landscape that aligns technical capability with sustainability and local relevance. Several cross-cutting insights emerge:

1. Integrated resource and value chain planning: effective bioenergy deployment depends on understanding the spatial and temporal dynamics of biomass availability and aligning them with conversion technologies and market opportunities. Mapping tools and sustainability metrics – as advanced by Vil2Bio – provide essential foundations for investment planning and resource governance;
2. Technological pathways beyond heat generation: moving bioenergy beyond traditional heat applications towards higher-value fuels and chemicals expands economic opportunities and aligns with decarbonisation goals. PyroBioFuel's work underscores the importance of adaptable conversion technologies that match local feedstocks with market needs;
3. Circularity and co-production models: BIOTHEREP exemplifies how bioenergy can be integrated into broader circular economy frameworks, linking waste reduction with energy generation and agricultural productivity. These co-production models not only enhance resource efficiency but also diversify income streams for communities.
4. Enabling policy and institutional support: realising the potential of bioenergy requires supportive policy environments that incentivise sustainable biomass utilisation, internalise environmental benefits, and promote equitable value sharing. Policies should also address data gaps, facilitate finance access, and ensure standards for environmental protection and social inclusion.

In the next phase of innovation, scaling bioenergy will hinge on:

- Strengthening multi-stakeholder partnerships that link research institutions, enterprises, communities and policymakers;
- Developing financing mechanisms that de-risk bioenergy investments;
- Embedding bioenergy deployment within national energy strategies that prioritise emissions reduction and equitable access.

To conclude, in bioenergy, scaling opportunities are closely linked to the ability to structure reliable value chains around feedstock availability, processing, and end-use markets. Service-oriented and waste-to-energy models show the greatest potential where they address both energy access and waste management challenges. However, market uptake remains constrained by feedstock variability, regulatory complexity, and operational risks. Demonstrating stable

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supply chains, environmental compliance, and economic viability is therefore critical for investability. These features make bioenergy well suited for venture building approaches that combine value chain integration, regulatory alignment, and partnerships with local authorities and agro-industrial actors.

7. Green hydrogen as an emerging pillar of the renewable energy transition

Green hydrogen – hydrogen produced via water electrolysis powered exclusively by renewable energy sources – is gaining global attention as a zero-carbon energy carrier with applications spanning industrial decarbonisation, energy storage, transport and feedstocks for chemical processes. In Africa, abundant solar and wind resources offer unique opportunities to produce green hydrogen competitively and to support sustainable economic development. However, realising this potential requires technological optimisation, infrastructure planning, cost reduction, and supportive policy frameworks that connect hydrogen production with end-use markets.

Within the LEAP-RE framework, the D3T4H2S and HyAfrica projects explore critical aspects of green hydrogen innovation, including system integration, techno-economic assessment, market readiness, and pathways for uptake in African and European cooperation contexts. These initiatives contribute to shaping evidence-based strategies that can accelerate the deployment of green hydrogen solutions aligned with climate, development and energy access goals.

The D3T4H2S project focuses on the systemic aspects of green hydrogen production and utilisation, advancing methodologies to assess and optimise hydrogen systems at multiple scales. By embedding green hydrogen within broader energy systems modelling, D3T4H2S advances a holistic view that moves beyond hydrogen production alone to consider integration, flexibility and economic viability in real operating contexts.

The HyAfrica project translates modelling insights into contextualised pathways for green hydrogen in African settings, focusing on region-specific resources, markets and institutional landscapes. HyAfrica explores how green hydrogen can contribute to both local development and export-oriented value chains, recognising the continent's potential as a hydrogen producer for domestic use and international markets. HyAfrica's approach emphasises contextual relevance, recognising that hydrogen adoption pathways must be tailored to local energy needs, infrastructure conditions and socio-economic priorities.

Beyond production, green hydrogen innovation must address storage, transportation and conversion into usable forms. Projects within LEAP-RE address several elements of this continuum:

- Energy storage and grid flexibility, where green hydrogen can act as a long-duration storage medium that balances variable renewable generation and supports grid stability.
- Industrial decarbonisation, with hydrogen and derivative fuels (such as ammonia or synthetic methane) providing low-carbon alternatives for sectors where electrification is challenging.
- Clean mobility applications, where hydrogen fuel cells can support zero-emission transport in heavy duty, maritime and off-grid contexts.

By linking production with end-use pathways, LEAP-RE's hydrogen portfolio contributes to shaping a value chain perspective on hydrogen innovation – one that recognises interdependencies between supply, conversion technologies, storage solutions and markets. Green hydrogen represents a promising but complex innovation frontier. The work of D3T4H2S, HyAfrica and other associated activities within LEAP-RE points towards several strategic priorities:

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1. Reducing production costs through technological learning: continued innovation in electrolyser design, materials and system integration – informed by real operational data – is essential to reduce levelised cost of hydrogen and improve system durability and efficiency.
2. Strengthening policy frameworks and market signals: supportive policies, including incentives, standards, procurement frameworks and blended finance mechanisms, can lower barriers to early hydrogen projects and attract private investment.
3. Aligning infrastructure development with local and regional needs: hydrogen infrastructure – from production facilities to storage and distribution networks – must be planned in coordination with national energy systems, industrial clusters and export strategies.
4. Building human and institutional capacity: technical skills, regulatory expertise and business competencies are critical to sustain hydrogen innovation ecosystems and to enable knowledge transfer between Europe and Africa.

Green hydrogen's potential lies not merely in its carbon-free production pathway, but in its ability to function as a flexible energy vector, connecting renewable energy supply with hard-to-decarbonise sectors, storage needs and international partnerships. The joint research efforts under LEAP-RE highlight the importance of systemic planning, multi-stakeholder collaboration and evidence-based policy making in advancing this transition.
As renewable energy systems expand across Africa and Europe, green hydrogen emerges as a strategic complement – not a standalone solution – capable of strengthening energy system resilience, enabling industrial transformation, and fostering sustainable development trajectories aligned with climate goals.

In conclusion, for green hydrogen, the primary scaling challenge lies not in technological feasibility but in system-level integration, cost reduction, and demand aggregation. Innovations that support project development, optimise system design, or facilitate connections between producers and off-takers offer the clearest pathways to market uptake. Investability depends on credible cost trajectories, long-term demand signals, and regulatory frameworks that enable deployment. As such, green hydrogen-related innovations align with Startup Studio activities centred on market positioning, stakeholder coordination, and preparation of bankable projects rather than early-stage technology development.

8. End-of-Life and second-life management of renewable energy components: towards circular, low-impact energy systems

The rapid scaling of renewable energy technologies – from solar photovoltaics and wind turbines to batteries and power electronics – has brought significant progress in decarbonising energy systems. However, accelerating deployment also raises pressing questions about the end-of-life (EoL) management, circularity and environmental impacts of key components. Without appropriate strategies for reuse, recycling and waste management, the environmental benefits of renewable energy can be undermined by resource depletion, hazardous waste streams and unplanned disposal. Within the LEAP-RE thematic priorities, projects such as SIREVIVAL, RESTART and RCLIB address these challenges by developing frameworks, tools and demonstrators to support sustainable lifecycle practices. These efforts span materials recovery, second-life battery utilisation, and circular business models – contributing to a more holistic vision of renewable energy innovation that integrates product life extension, waste reduction and value

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recovery. The SIREVIVAL project advances understanding of the full lifecycle impacts of renewable energy components, with a focus on enabling evidence-based strategies for material recovery and reuse. Through robust data integration and modelling, SIREVIVAL contributes to decision support tools that can guide manufacturers, policymakers and recycling enterprises toward circular pathways that reduce environmental burdens and resource dependencies.

A key dimension of circular energy systems is the extension of component life through refurbishment, remanufacturing and second-use applications. The RESTART project focuses specifically on second-life strategies for key renewable energy components, including batteries and inverter systems. RESTART’s work illustrates how second-life pathways not only reduce waste and material demand, but also enhance energy access and resilience – particularly in off-grid and resource-constrained environments – by repurposing components that would otherwise be prematurely discarded. While second-life use can extend service life, eventual recycling remains essential to recover critical materials and close loop flows. The RCLIB’s research highlights that sustainable recycling is not simply a technical challenge, but also a systems challenge requiring coordination among producers, recyclers, regulators and financiers to achieve economies of scale and regulatory alignment.

The combined contributions of SIREVIVAL, RESTART and RCLIB illustrate how circular economy principles are increasingly central to renewable energy innovation. Rather than treating end-of-life as a problem to be managed at the end of project lifecycles, LEAP-RE projects integrate lifecycle thinking into early design, supply chain planning and policy formulation.

Several strategic insights emerge:

1. Lifecycle awareness from design to decommissioning: embedding lifecycle assessment and material flow considerations into technology design can reduce future waste, simplify recycling and support modular refurbishment;
2. Second-life markets as enablers of resilience: by validating second-use applications and establishing quality standards, refurbished components can provide cost-effective solutions for energy storage and access, particularly in developing and remote regions;
3. Policy and regulatory frameworks for circularity: standards, incentives and extended producer responsibility schemes can catalyse formal recycling sectors and attract investment in recovery infrastructure;
4. Cross-sector collaboration: achieving circularity requires collaboration among renewable energy developers, recycling industries, research institutions and policy makers to align commercial incentives with sustainability outcomes.

As renewable technologies proliferate, sustainability must be understood as encompassing not only climate mitigation and energy access, but also resource stewardship and waste prevention. The end-of-life and second-life management innovations advanced under LEAP-RE strengthen the foundations of a circular energy economy – one that protects environmental quality, fosters local economic opportunities, and reduces dependency on critical raw materials. By foregrounding lifecycle perspectives and actionable recovery pathways, these projects contribute to renewable energy systems that are not only clean in operation, but circular by design – supporting long-term resilience and equitable transitions in Africa, Europe and beyond.

In the end, circularity-related innovations demonstrate strong scaling potential where they address operational and regulatory barriers linked to second-life use, recycling, and material recovery. Service-based and circular supply chain models can create value by reducing costs, improving sustainability performance, and supporting local economic activity. However, market uptake depends on clear standards, safety assurances, and regulatory acceptance. Evidence on performance, quality, and compliance is therefore essential for investability. These characteristics position circular economy solutions as suitable candidates for Startup Studio support focused on standards alignment, partnership development, and replication strategies.

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9. Processes and appliances for productive uses: empowering agriculture and value chains with renewable energy

Energy is a foundational input for modernised agricultural systems: powering irrigation, processing, cooling and storage; enabling mechanisation and digital tools; and supporting transportation and value-added services. In many parts of Africa, however, small-scale farmers face persistent barriers – limited access to reliable and affordable energy, inefficient processing technologies, and weak linkages to value chains – that constrain productivity, incomes and opportunities for off-farm employment. Under the LEAP-RE framework, processes and appliances for productive uses address these challenges by developing and demonstrating renewable energy-driven solutions tailored to agricultural contexts. The portfolio of projects – including LEOPARD, MG-FARM, OPTIMG, RE4AFAGRI and SWITCH – illustrates how targeted innovation can enhance on-farm productivity, improve post-harvest handling, and stimulate local enterprise creation along food supply chains.

The LEOPARD project focuses on integrating renewable energy technologies into agricultural production and processing systems. Renewable energy solutions – such as solar-powered irrigation pumps, grain dryers and processing appliances – are evaluated not only for their technical performance, but also for their socio-economic impacts on farming households and enterprises. By linking renewable energy uptake with tangible improvements in productivity and farm incomes, LEOPARD demonstrates how energy can serve as a lever for inclusive rural development.

Moreover, mechanisation – even at a small scale – can dramatically increase agricultural efficiency and reduce labour burdens. The MG-FARM project explores how renewable energy, especially solar power, can support mechanised agricultural equipment suitable for small and medium-scale farms. This project highlights that renewable energy can be more than a power source – it can be a driver of technological adoption in agricultural workflows, enabling farmers to compete effectively in changing markets.

The OPTIMG project contributes to innovation in agricultural energy use by developing integrated modelling tools that help stakeholders understand and plan energy-driven productivity improvements. These tools combine agronomic, energy system and economic variables to simulate outcomes under different scenarios. By bridging technical modelling with real-world decision contexts, OPTIMG supports policymakers, extension services and farmers in crafting evidence-based strategies for productive energy use.

The RE4AFAGRI project addresses the broader food systems context by focusing on energy-enhanced agricultural value chains – moving beyond production to include storage, processing, transport and market linkages. Its work underscores that energy innovations must be embedded within ecosystems of actors and infrastructure to unlock their full potential. Through its holistic approach, RE4AFAGRI illustrates how renewable energy can simultaneously enhance food quality, expand market opportunities and create off-farm employment – especially for youth and women.

The SWITCH project explicitly links renewable energy innovation to the water–energy–food nexus, recognising that productivity depends on efficient interactions among these systems.

By integrating water management with energy and food systems, SWITCH contributes to resilient and resource-efficient agricultural practices that are sustainable in the face of climate variability and resource scarcity.

LEAP-RE's work on productive energy uses points to several innovation pathways:

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1. Context-specific appliance design and deployment: technologies must be adapted to crop types, farm scales and local environmental conditions. Renewable energy appliances that are modular, easy to maintain and cost-effective have higher adoption potential.
2. Integrating productivity with value-chain services: energy solutions are most impactful when they extend beyond single farm gates to include processing, storage and transport – creating economic opportunities along the value chain.
3. Decision support for strategic investments: tools that model energy-productivity-economic trade-offs help farmers, cooperatives and policymakers prioritise investments that yield measurable gains.
4. Enabling markets and enterprises: beyond technology provision, support for service delivery models, after-sales maintenance, financing mechanisms and skills training strengthen uptake and sustainability.

Renewable energy innovation for productive uses embodies a transition from energy as a cost centre to energy as an economic asset in agricultural systems. By prioritising solutions that increase productivity, create value-added opportunities and empower local entrepreneurs, LEAP-RE projects contribute to a holistic vision of rural transformation where energy supports livelihoods, food security and equitable growth.
As agricultural energy systems continue to evolve, future innovation will benefit from:

- Multi-stakeholder partnerships that connect researchers, private sector actors, farmer organisations and policymakers;
- Integrated planning that aligns infrastructure investments with agricultural calendars and market windows;
- Financing and policy frameworks that lower barriers for smallholders to adopt energy-driven tools and services.

Productive energy use thus emerges not only as a technological frontier, but as a cornerstone of inclusive, resilient and sustainable rural development.

To conclude, scaling productive use of energy solutions requires integrated approaches that link energy access directly to income generation and productivity gains. Equipment-as-a-service and bundled energy–equipment models offer promising pathways, particularly when they reduce upfront costs for users and align incentives across value chains. Demonstrating measurable economic benefits and sustained use is critical to attract investment. This makes productive use solutions well suited for venture building support that combines business model development, impact measurement, and replication across sectors and regions.

10. Smart stand-alone systems to ease access to energy in all its forms

For millions of households and enterprises across Africa, reliance on centralised grids remains limited due to infrastructure gaps, costs and geographic barriers. In this context, smart stand-alone energy systems – decentralised renewable energy solutions that integrate generation, storage, control and end-use technologies – represent a promising pathway to ensure access to reliable, affordable and clean energy in both rural and peri-urban settings. These systems are integral not only for household electricity but also for productive uses, agricultural mechanisation, water pumping, cooking and community services.
LEAP-RE's portfolio of projects addressing smart stand-alone energy solutions – including MG-FARM, LEOPARD, PURAMS, and LEDSOL – highlights the interplay between decentralised

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system design, user needs, and socio-economic impact. By focusing on real-world deployments and context-adapted innovation, these activities underscore how stand-alone energy can transform livelihoods, strengthen local enterprises and advance multiple Sustainable Development Goals simultaneously.

While targeting productive energy uses in agriculture, as discussed in the previous section, the MG-FARM and LEOPARD projects also provide valuable insights into stand-alone energy system design. In many deployment locations, energy systems are inherently off-grid or hybridised with weak grid connections – requiring solutions that manage variable renewable generation and match energy supply with specific demand profiles.

These projects highlight the importance of tailored system design – recognising that stand-alone energy must align technical specifications with community needs, seasonal demand shifts, and maintenance capacities.

The PURAMS project deepens the knowledge around participatory planning and deployment of micro-renewable energy systems. PURAMS emphasises that technology solutions alone are insufficient – community engagement is essential to ensure uptake, relevance and long-term sustainability. By foregrounding community agency and local ownership, PURAMS demonstrates that smart stand-alone systems are as much social innovations as technological solutions.

Basic energy access – particularly for lighting and communication – remains a priority in off-grid contexts. The LEDSOL project addresses this need by developing and validating stand-alone LED lighting and energy management solutions that can substantially improve quality of life, education. The LEDSOL approach illustrates that even simple stand-alone systems – when well-designed and tailored to users – can yield transformative impacts on daily life and economic opportunity, especially in communities with limited access to grid power.

Collectively, the projects addressing smart stand-alone systems offer several strategic insights for innovation and deployment:

1. Integrated system design that matches end-use demand: stand-alone energy solutions must be planned based on actual demand profiles (e.g., seasonal irrigation needs, agricultural processing peaks, household load patterns), ensuring reliable performance and cost-effectiveness;
2. Hybridisation and modularity for resilience: combining multiple renewable sources (e.g., solar, wind, batteries) with smart controllers enhances system resilience and adaptability to weather variability, load changes and growth in demand;
3. Participatory governance for sustainability: community involvement in planning, governance and maintenance strengthens uptake, accountability and long-term system sustainability, turning users into stakeholders;
4. Affordable and scalable appliance ecosystems: stand-alone systems must be paired with energy-efficient appliances – from LED lighting to agricultural tools – that maximise the utility of available energy and expand productive opportunities.

Smart stand-alone energy systems embody a shift from energy access as a binary condition (on/off grid) to a nuanced understanding of energy quality, reliability and utility across multiple uses. By integrating technical innovation with participatory approaches and contextual adaptation, LEAP-RE projects contribute to a future where decentralised renewable energy systems are not stop-gaps but sustainable foundations for community resilience and economic development. Future innovation efforts should prioritise:

- Scalable business models that support local assembly, maintenance services and financing mechanisms for stand-alone solutions;
- Interoperability standards that allow modular upgrades and integration with emerging technologies (e.g., smart meters, IoT controllers);
- Policy frameworks that recognise and support decentralised renewable networks as legitimate contributors to national energy strategies.

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Smart stand-alone systems thus emerge as a cornerstone for inclusive energy transitions, enabling access in underserved areas while catalysing socio-economic transformation.

Lastly, smart standalone systems show high scaling potential when deployed through service-oriented delivery models that integrate installation, operation, and maintenance. While the underlying technologies are increasingly mature, market uptake is constrained by operational sustainability, user trust, and long-term service provision. Investability therefore depends on evidence of system reliability, cost-effective maintenance, and user satisfaction at scale. These conditions align smart standalone systems with Startup Studio activities focused on service design, operational partnerships, and scalable deployment models.

11. Energy System Optimization Achievements

LEAP-RE has demonstrated significant progress in optimizing mini-grid systems across Africa, focusing on efficient integration of renewable energy sources, storage, and hybrid configurations to provide reliable, cost-effective electricity. Projects such as EURICA, MIDINA, OASES, OPTIMG, and SETADISMA highlight both technical innovations and real-world case studies, illustrating the potential for optimized mini-grids to enhance energy access, support productive uses, and contribute to local socio-economic development.

Key achievements include:

- Integrated renewable generation: PV panels, wind turbines, and pico-hydro systems were selected and sized according to resource availability and modular scalability. Solar PV provides flexible, low-cost generation, while wind turbines and pico-hydro complement generation during low-sunlight periods.
- Storage and reliability: Lithium-ion batteries were implemented to store excess energy, balance intermittent generation, and ensure supply during peak loads. Diesel generators serve as backup power for critical demand periods.
- Inverters and system management: Power electronics manage energy flows between sources and loads, ensuring stable AC supply and optimal system efficiency.

LEAP-RE's work demonstrates that optimized mini-grids and Concentrated Solar Power (CSP) micro-plants, combined with digital and entrepreneurial engagement, can significantly advance energy access in African communities. Future priorities include:

- Scaling optimized configurations to additional mini-grid sites.
- Integrating digital monitoring and predictive maintenance for long-term reliability.
- Expanding local entrepreneurship models for mini-grid operation and appliance ecosystems.
- Further testing and deployment of medium-temperature CSP solutions using low-cost, locally compatible materials.

Optimized energy systems are not only technological achievements but also enablers of socio-economic development, resilience, and sustainable growth in off-grid and under-served regions.

In conclusion, optimisation and digital decision-support tools play a critical enabling role across energy value chains by improving planning, performance, and investment decisions. Their scaling potential lies in platform-based and data-as-a-service models that can be replicated across geographies and applications. However, uptake is often limited by data availability, interoperability, and institutional capacity. Demonstrating measurable performance gains, clear value propositions, and viable revenue models is essential for investability. These characteristics make digital optimisation tools strong candidates for Startup Studio support focused on product–market fit, pricing strategies, and partnerships with utilities and planners.

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12. Key policy insights from the LEAP-RE innovation portfolio

1. Energy innovation requires integrated policy frameworks, combining technology, regulation, finance and social considerations.
2. Decision-support tools improve planning quality and reduce investment risks.
3. User-centred policies are essential to ensure adoption and long-term impact.
4. Diversified energy systems enhance resilience and alignment with development goals.
5. Lifecycle and circular economy policies safeguard environmental sustainability.
6. Investment in skills and entrepreneurship strengthens local ownership of energy transitions.

The LEAP-RE Innovation Outlook demonstrates that Africa's energy transition is not constrained by a lack of technological solutions or research capacity, but by the need for coherent, enabling and forward-looking policy environments capable of scaling and replicating innovation. Across all thematic priorities, the evidence shows that isolated, technology-driven interventions are insufficient to deliver sustainable, inclusive and resilient energy systems. Instead, impact is achieved when innovation is embedded within integrated ecosystems that align policy, finance, skills, institutions and societal needs.

The portfolio confirms that energy transitions in Africa are fundamentally development and governance challenges, as much as technological ones. By linking renewable energy deployment to productive uses, modern cooking, agriculture, entrepreneurship and local value chains, LEAP-RE projects reposition energy systems as development enablers rather than stand-alone infrastructure investments. This systemic approach is essential to ensure that energy access translates into improved livelihoods, industrialisation, health outcomes and climate resilience.

These findings strongly align with shared AU–EU priorities.

The Innovation Outlook directly supports the ambitions of AU Agenda 2063, particularly its objectives on inclusive growth, structural transformation and improved quality of life. It also reinforces the goals of the EU Global Gateway, illustrating how energy innovation can reduce investment risk, strengthen institutional capacity and mobilise public and private finance through high-quality, sustainable infrastructure. Furthermore, LEAP-RE provides concrete, evidence-based pathways to advance Mission 300, demonstrating how optimised mini-grids, smart stand-alone systems and user-centred solutions can expand access to reliable and affordable electricity while ensuring long-term system viability, scalability and local ownership.

Looking ahead, the central policy challenge is to move from successful pilots to systemic impact. This requires coherent and predictable regulatory frameworks, sustained investment in human and institutional capacity, and continued support for open, data-driven planning and decision-support tools. Equally critical is the early integration of circular economy principles and lifecycle governance, ensuring that rapid deployment of renewable energy technologies does not create new environmental, material or social vulnerabilities.

LEAP-RE illustrates the strategic value of EU–Africa cooperation in research and innovation as a cornerstone of the clean energy transition. By combining European and African expertise, fostering open and inclusive innovation ecosystems, and prioritising capacity building and local ownership, the programme lays the foundation for resilient energy systems that deliver long-term socio-economic benefits.

In this context, this Innovation Outlook serves as a call to action for policymakers, development partners and investors. By aligning energy strategies with AU Agenda 2063, the EU Global Gateway and Mission 300, and by translating research and innovation into coordinated policy,

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investment and implementation, energy systems can become a powerful driver of inclusive growth, climate resilience and shared prosperity across Africa and Europe.

13. From Innovation Outlook to Market Uptake: Implications for the Startup Studio

13.1 What this Outlook delivers to the Startup Studio

This Innovation Outlook goes beyond a synthesis of research results and policy lessons. It provides a structured basis for downstream market-oriented activities, in particular for the design and operation of the LEAP-Energy Startup Studio.

First, the analysis identifies venture-ready thematic niches where innovation has progressed beyond proof-of-concept and where scaling challenges are primarily non-technical. These niches represent priority entry points for venture building.

Second, the Outlook highlights recurring de-risking needs across thematic areas, notably related to data availability and decision-support tools, regulatory and institutional frameworks, affordability and financing mechanisms, and local operational capacities. These recurring challenges can be translated into cross-cutting Startup Studio workstreams rather than addressed on a case-by-case basis.

Third, the document reveals recurrent business model archetypes emerging across the LEAP-RE portfolio, including service-based delivery models, PAYGo and leasing approaches, platform-based optimization and data services, and circular value chains. These archetypes provide a foundation for replicable venture design rather than isolated project-specific solutions.

13.2 From portfolio insights to venture selection

Building on insights from 31 LEAP-RE projects, this Outlook supports a structured transition from research portfolios to venture pipelines. Rather than selecting ventures solely based on technological maturity, the Startup Studio can use the thematic lessons presented in this document to identify opportunities where market uptake is realistic and scalable.

Key selection signals include:

- demonstrated relevance to user needs and local contexts,
- the presence of a viable delivery or service model,
- the potential to operate within, or actively shape, existing regulatory frameworks,
- and opportunities for replication across regions.

To operationalise this transition, Table 1 illustrates how thematic areas can be mapped to venture archetypes, critical de-risking evidence, likely first markets, and corresponding Startup Studio support packages.

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Table 1 Mapping thematic areas to venture building opportunities

Thematic area	***Typical venture archetypes***	***Key de-risking evidence required***	***Likely first markets / adopters***	***Startup Studio support focus***
Geothermal energy	Project development services; geothermal planning and data platforms; Energy-as-a-Service	Resource validation data; drilling risk reduction; permitting clarity	Public utilities; municipalities; industrial heat users	Business model structuring; partnerships; investor readiness
Clean cooking	PAYGo and leasing models; appliance-fuel service bundles; carbon-linked services	User adoption and sustained use; affordability; supply chain robustness	Low-income households; SMEs; local distributors	Go-to-market strategy; user testing; financing mechanisms
Bioenergy	Waste-to-energy services; biomass aggregation and processing ventures	Feedstock reliability; operational performance; environmental compliance	Agro-industries; municipalities; cooperatives	Value chain design; regulatory alignment; partnerships
Green hydrogen	Project development platforms; industrial off-taker-linked services	Cost curves; offtake agreements; regulatory frameworks	Industrial users; ports; utilities	Market positioning; stakeholder engagement; investment structuring
Circularity & second-life	Recycling and refurbishment services; circular supply chains	Quality standards; safety and performance data; regulatory approval	Utilities; mini-grid operators; public authorities	Standards alignment; partnerships; scaling strategy
Productive use of energy	Equipment-as-a-Service; bundled energy-equipment services	Productivity gains; income impacts; willingness to pay	SMEs; agri-value chains; local entrepreneurs	Business model design; impact metrics; replication
Smart standalone systems	Integrated service providers; platform-based operators	System reliability; O&M cost structures; user satisfaction	Rural households; remote communities	Service design; partnerships; operational scaling
Optimisation & digital tools	Data-as-a-Service; optimisation platforms; decision-support tools	Data quality; performance improvement; cost savings	Utilities; planners; project developers	Product-market fit; pricing models; scaling pathways

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13.3 Readiness criteria aligned with LEAP-RE

To ensure consistency between research outcomes, venture building, and investment mobilisation, the Startup Studio can apply a structured readiness lens aligned with LEAP-RE objectives.

This readiness assessment spans four complementary dimensions:

1. Technical maturity, including system reliability, performance under real-world conditions, and integration with existing infrastructure.
2. Market and user validation, including evidence of demand, affordability, adoption behaviour, and willingness to pay.
3. Social and institutional readiness, including alignment with local practices, capacity of delivery and maintenance ecosystems, and acceptance by communities and institutions.
4. Regulatory and implementation feasibility, including compliance with existing regulations, clarity of licensing and standards, and pathways for policy engagement where gaps remain.

Applying this multidimensional readiness approach ensures that Startup Studio activities focus on innovations that are not only technically sound, but deployable, investable, and scalable in real-world African and European contexts.

14. Conclusion

This Innovation Outlook has synthesized lessons from the LEAP-RE portfolio to highlight how renewable energy innovations can move beyond pilot stages toward sustained deployment and impact in African and European contexts. Across thematic areas, the analysis confirms that the primary barriers to scale are rarely technological alone, but instead lie in decision-making uncertainty, affordability, regulatory complexity, operational capacity, and the ability to translate innovation into viable delivery models.

The Outlook underscores the importance of system-level approaches that combine technical solutions with enabling frameworks, including decision-support tools, user-centered design, service-oriented business models, and circular value chains. These elements play a critical role in reducing investment risk, improving adoption, and enhancing the replicability of solutions across diverse geographies.

Importantly, the findings provide a direct bridge between research and market uptake. By identifying venture-ready niches, recurring de-risking needs, and common business model archetypes, the Outlook supports a structured transition from research portfolios to venture pipelines. This creates a foundation for targeted Startup Studio activities, investment mobilization, and policy engagement aligned with AU–EU energy and climate objectives.

Overall, this Outlook positions LEAP-RE outcomes not as isolated innovations, but as building blocks of an integrated innovation-to-market pathway. By aligning research insights, policy action, and venture building, LEAP-Energy can accelerate the deployment of scalable, investable, and impactful energy solutions that contribute meaningfully to sustainable development and energy transitions.

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