PRE-LEAP-RE

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Technological and innovation thematic pathways

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Summary

D2.1presents the technological and innovation thematic pathways identified by the project partners and led by task leaders 2.1

Approval

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PREparing for a Long-Term EU-AU Research and Innovation Partnership on Renewable Energy

Technological and Innovation Thematic Pathways

Deliverable D2.1

Lead Beneficiary: CEA

March/2019

New submission following EC Comments

All PRE LEAP RE partners

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About PRE-LEAP-RE

PRE-LEAP-RE – Preparing for a long-term EU-AU research and innovation partnership on renewable energy – is promoting an effective pathway for empowering local research. This pathway could be achieved by fostering EU-AU joint cooperation while creating the condition to transform research into effective innovation, tailored to the specific needs, the capacity and the aspiration of the African people and society which may be different from region to region.

Led by CEA, it gathers 17 partners across Africa and Europe jointly committed to strengthening the overall framework for cooperation in the field of science, technology and innovation (STI). During 14 months, the participants will identify and formulate a strategic Joint Research and Innovation (R&I) Programme for renewable energy technology and establish the organizational principles for its implementation within a forthcoming Joint Programme by bringing together national funding agencies of EU member states, African states and other key EU-AU actors involved in energy research.

For more information visit: www.leap-re.eu

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Executive Summary

This deliverable lists the pathways identified as a result of the work implemented in T2.1. The formulation of pathways started during a physical meeting where 13 pathways were identified. Contributing authors worked on the content development. Further to the 1st Workshop in which those 13 pathways were presented and discussed with the stakeholders, authors revised them taking into consideration comments received. This led to 6 pathways that are further described in these deliverables.

Keywords

Renewable energy, EU-Africa collaboration, methodology, research, innovation, capacity building, Europe, Africa, RIA, challenges, KPIs

1 Pathway 1: Evaluation of priority joint research and innovation actions for next step development of renewable energy

PRELIMINARY DESCRIPTION OF PATHWAYS		PRE-LEAP-RE
Topic Number	Pathway 1	

Title	Evaluation of priority joint research and innovation actions for next step development of renewable energy		
Type of action*	*Study*	**Expected period***	Year 1
Indicative budget (M€)*		**Expected duration (years)***	

**To be specified later on*

Specific challenges:

Africa is a wide continent with a large variety of renewable energy sources and energy development needs from one region to another. As the driving role of energy for nation development is no longer disputed, Africa will need more and more energy for its own development. But instead of falling into the steps of developed countries the continent should find its own way through a well-balanced Energy transition. That energy transition for Africa means, on the one hand moving away from traditional use toward modern use of energy, and on the other hand reducing its fast growing use of fossil fuel, and improve its use of RE instead. Up to now, most of the recent deployments of Renewable Energy Sources (RES) in Africa were achieved using pre-existing technologies initially devoted to developing countries environment. It is now clear that innovative solutions specifically designed for African use are needed for a wider deployment of RES thanks to a technical and economical optimisation of the different solutions.

In this regard, a frank North/South collaboration is necessary to adapt existing solutions to local contexts. It goes hand in hand with research/innovation to be implemented in the partner countries in the North as well as in the South.

In order to identify the priority Research and Innovation Actions (RIA) and technological roadmaps, a clear mapping of present R and D initiatives in both European and African continents have to be done technology per technology and application per application. For now, a meta-analysis of existing initiatives has been done in the frame of this Pre-LEAP-RE and led to results to be used by this pathway.

In this regards a few rules are to be taken into consideration: (i) projects for RIA must comply with national policies for RE development; (ii) compliance with the need of local population is also essential; (iii) Efficiency and reliability are key points; (iv) projects must tend to replace fossil fuel or conventional energy solutions; (v) projects must target the objective of Access to Energy for all in a short term.

Scope:

Technological development and efficiency

RE have the particularity of being usable both as decentralized energy source (stand alone, hybrid, mini-grids power systems) or centralized (power connected to the national grids or not). This characteristic is their strength but must be valued and amplified, particularly in the case of Africa where all levels of demand exist and are sometimes difficult to meet by conventional systems.

- The main objective of this topic is to achieved a fine tuning mapping of the RES Research and Innovation Actions devoted to design technological solutions suitable for different African regions (RES atlas, climate conditions…) including the quantification of the maturity level (TRL, production cost…) for different RES (solar, geothermal, wind, biomass…) and applications (urban, rural, agricultural, desalinisation, domestic, industrial…)
- To achieve the previous objective, the project will have to identify
  - ✓ The present and future energy uses for different African regions with a sufficient level of details (applications, geographical size…) and quantification of the technological and economical requirements (performances, durability, LCOE…)
  - ✓ The priority regions for RES synergies based on a RES atlas
  - ✓ Synergies between energy sector and other sectors (e.g. energy and agriculture/forestry/ waste management)
  - ✓ the technological solution consistent with both available RES and final uses and avoidance of decisions inconsistent with the reality of the field

Methodological Approach

- The following points will have to be addressed in a proposal:
  - ✓ Mapping of renewable energy sources in different African regions, present and future needs and possible technological solution (African RES atlas). The needs will have to be technically and economically quantified: definition of the main KPIs (Key Performance Indicators) and to take into account the local specificities (climate, RES accessibility…)
  - ✓ Assessment of RE potential by zone, country and region in order to help for the sizing of engineering of systems
  - ✓ Mapping of the present RIA initiatives in Europe and Africa aiming to develop innovative solutions specifically or partially devoted to African needs (as an example: low cost and high durability PV cells devoted to African climate).
  - ✓ Analysis of the technological solutions versus RES: identification, when relevant, of present achievements or on-going actions (As complete as possible SoA) in terms of performances, durability, LCOE… versus futures expectations (KPIs) in order to estimate the gap between present situation and future needs
  - ✓ Define RIA roadmaps on key technologies to fill the gap between present solution and future optimised solutions.
  - ✓ Analyse final uses versus technological solutions: definition of priorities for African regions with different levels of prioritization (critical, highly priority, middle priority).
  - ✓ Stakeholder network mapping to identify relevant actors, decision makers, investors and beneficiaries

Energy Scenarios (and link with Policy)

- A proposal will have to address the following points:
  - ✓ Identification of future RIA pathways for RES development in Africa
  - ✓ Prioritization of future actions (RIA, IA, capacity building)
  - ✓ Definition of technological roadmaps with quantified objectives (KPIs)
  - ✓ Definition of associated business models including new policies, incentives, international collaborations, future Europe Africa join programmes
  - ✓ Prioritization of access to affordable energy for the poorest population.
  - ✓ Identification and mapping of major European and African RE research centres with their specificities and synergies.

Expected outputs, outcomes and impacts:

A proposal will have to deliver:

- Definition of the key KPIs for future development of RES and applications in Africa for different dates (2025, 2030, 2040…) based on the RE Potential per region/country
- A precise mapping of the State of the Art of the RES components and systems specifically devoted to African needs from both European and African initiatives
- Detailed Research and Innovation agenda including prioritization and RE roadmap in each region/country if it exists
- Identification of key Research and innovation actors to be involved in future RIA from both Europe and Africa
- Identification of the potential role for different stakeholders including international partnerships with a special focus on joint Europe/Africa future initiatives.
- Support to private sector and engineers by defining key parameters for quick assessment of RE project along with the mapping of resources.
- Delineation of zones of profitability limits of RE projects by type of RES

References:

Bertani R. (2016) - Geothermal power generation in the world 2010-2014 update report. Geothermics, 60, 31-43.

ICEIDA (2012) - The geothermal exploration project. Sub-project of the geothermal compact in East Africa. Project Document ICE23066-1301, 30 p.

IRENA (2013) - L'Afrique et les énergies renouvelables : La voie vers la croissance durable. IRENA document, 34 p.

Lund J.W. & Boyd T. (2015) - Direct Utilization of geothermal energy 2015 worldwide review. Proceedings World Geothermal Congress 2015, Melbourne, Australia, 19-25 April 2015, 31 p.

Omenda P. (2018) - Geothermal Outlook in East Africa: Perspectives for geothermal development. IGA Oral presentation, 37 p.

Pathway 2: End-of-life and second-life management and environmental impact of RE components

PRELIMINARY DESCRIPTION OF PATHWAYS		PRE-LEAP-RE
Topic Number	Pathway 2	

Title	End-of-life and second-life management and environmental impact of RE components		
Type of action*	R&I	**Expected period***	Year 1
Indicative budget (M€)*		**Expected duration (years)***	

**To be specified later on*

Specific challenges:

End-of-life (EoL) components (batteries for electric cars, solar panels from large PV plants…) used in Renewable Energy (RE) production or storage present a new environmental challenge, but also an unprecedented opportunity to create value and pursue new economic avenues.

More energy systems will get decommissioned at the end of life or when out of specifications (OoS) for their initial field of use as RE technology is mainstreamed. To contextualize this, volume of decommissioned solar PV panels will increase as the global solar PV market increases thus large amounts of annual EoL PV components are anticipated. The International Renewable Energy Agency (IRENA) estimates that there will be a surge in solar panel disposal in the early 2030s, and that by 2050, there will be 60 to 78 million cumulative tons of photovoltaic panel waste globally [1].

The rise of electric vehicles and increase in adoption of storage systems will also lead to a large amount of EoL/OoS batteries. There will also be a yearly increase in decommissioned wind turbine blades.

In some cases, these components may still have enough performances to be used in “second life” applications. At the same time, new energy paradigms are emerging in both Africa and Europe where “second life” components could be an appropriate solution for example the substitution of lead-acid batteries by second-life Li-ion batteries. In this regard, RE EoL/OoS components and its supply chains require research, development, innovation and capacity support. Materials that enable RE should be recycled or reused to prevent a scenario where the envisaged clean energy future becomes anything but clean.

In Africa, off-grid solar products are revolutionizing the quality of life. Current EoL component volumes from this sector are small in proportion to the quantity and environmental impact of the total e-waste stream. However, due to a rapid sector growth, there is a need to develop the end-of-life management of off-grid solar products without delay.

In Africa and most developing countries, EoL components collection is done very effectively by informal collectors who purchase the components from consumers. The informal collectors then re-sell it to other informal sector players such as local repair shops. Informal sector EoL component streams do not usually incur costs associated with proper treatment and disposal of hazardous e-waste due to the use of rudimentary methods. These rudimentary methods tend to be unsafe and environmentally unfriendly. There is need to regularize this sector and ensure that EoL RE components collected enters the formal system.

Scope:

Technological development and efficiency

The second life performance and durability of components from primary uses should be evaluated. This should cover for example the automotive Li-ion batteries, the PV panels from large solar plants, the decommissioned wind turbine blades… The R&I should target test and demonstration activities on EoL/OoS components with still some performances. The recycling of out-of-operation components won't be considered for second life use.

The way that these components could answer specific present and future needs for African and European countries should be analysed. This should cover test and demonstration activities on applications.

In parallel, processes development to repair, reuse, repurpose and recycling of EoL/OoS components from out-of-operation components had to be envisaged. This should cover the recovery processes of high-added-value materials possibly targeting a circular economy.

R&I actions should integrate recycling and repair routes in the component design particularly targeting a circular economy in the African environment.

R&I actions should integrate development of processes for treatment requirements definition of collected RE EoL/OoS.

Methodological Approach

The approach should be based on the definition and testing of rules for information and reporting requirements on collected RE EoL components and integration of tags in the component design to keep information for recycling at EoL/OoS.

This will need:

- A sector mapping and categorization of generated and short term available EoL/OoS components including performance, durability and cost;
- To identify how these components could match with new energy systems in Africa;
- To identify the technological solutions integrating second life components;
- To identify the different stakeholders of the value chain both from Europe and Africa including collection and transportation (consider informal and formal sector);
- To help the awareness creation on RE e-Waste targeting individuals, households and organizations

This may be supported by the introduction of incentives for RE EoL component management activities.

The R&I actions should include the evaluation of the business models for different components and associated value chains.

Energy Scenarios (and link with Policy)

The R&I actions will be based on the identification of RE related gaps in existing EoL/OsS component management legislation. They should contribute to the creation of policies and enforcement of legislative provisions, the harmonization of the energy access and EoL component management policies, the deployment scenarios of second life components, the identification of the value chain privileging local stakeholders, the definition of associated business models including business model development for RE systems inclusive of end of life management.

In that field R&I activities on second-life of OoS Li batteries from electrical vehicles has be initiated few years ago in Europe at the Lab scale. The pathway targets to extend the R&I actions to different RE components and to take into account the specific environments in Africa. This should open the road for demonstration in various relevant environments.

Expected outputs, outcomes and impacts:

This pathway will allow:

- **Output**: To provide routes for EoL/OoS components recycling taking care of a local limited and controlled environmental impact through the management of the effective EoL component stage; To develop comprehensive models for EoL/OoS components management;
- **Outcome**: The creation of jobs and incentives towards RE production and uses through EoL/OoS components management; The dissemination of the acquired knowledge in particular among the African community to support a sustainable EoL/OoS components management;
- **Impact**: To promote environmental and ecological sustainability of renewable energy systems; To identify a second life components with a benefit for African countries: lower cost; higher reliability, less environmental impact….; To identify the key stakeholders; To identify the most promising business models
- **Related KPIs**:
  - Collection of the EoL/OoS components: at least *75 % of EoL/OoS components*
  - Prolonged life of EoL/OoS components: at least *30 % more life-time use*
  - Reduction of the cost of the energy production through the use of suitable EoL/OoS components: at least *30 % cost reduction*
  - Improvement of the stability of the energy production through the use of suitable storage components in the energy production systems: at least *30 % stability improvement*
  - …

References:

[1] IRENA and IEA-PVPS (2016), "End-of-Life Management: Solar Photovoltaic Panels," International Renewable Energy Agency and International Energy Agency Photovoltaic Power Systems

2 Pathway 3: Smart stand-alone systems

PRELIMINARY DESCRIPTION OF PATHWAYS		PRE-LEAP-RE
Topic Number	Pathway 3	

Title	Smart stand-alone systems		
Type of action*	RIA	**Expected period***	Year 2
Indicative budget (M€)*		**Expected duration (years)***	

**To be specified later on*

Specific challenges:

Energy has always played an important role in human and economic development and in society's well-being. As there are a lot of off-grid areas in Africa, renewable energies are worth to be integrated in the global energy mix through versatile stand-alone systems.

The rural isolated communities represent more than 45 % of the African population. They are the first and obvious ones which needs should be covered [1]. The environment of these communities may be very different from one geographical area to the other in particular from the point of view of the kind of the available RE sources. In addition, in the vast landscape of the Sahel, steppes and open areas, nomads, tuaregs and shepherds have rarely access to electricity. Nomads are characterized by moving from one place to another in search of pasture and water, setting up tents and nurturing livestock. The severe climatic disasters and conflicts added migration and refugees in many African regions [2]. It is essential to deal with these humanitarian crises brought by forced displacement and to empower refugees to reach their full potential as active members of society.

The Renewable Energy and technology can provide a unique opportunity in enabling these communities with new facilities without interfering with their way of life or being left behind. The utilization of the renewable energies can also be a good opportunity to fight the desertification and dryness in the Sahel and keep communities alive by encouraging younger people to stay on their traditional lands. Access to energy, in particular electricity, is then a fundamental component to fix these populations, and guarantee economic and social development. Specific needs concern cooking, clothes washing, studying, walking safely (by night), connecting fridges and fans, phones charging, refrigeration (store food and medication), lighting, communications, and water pumping.

RE stand-alone systems (RE-SAS) are mandatory **to ease the access to energy in all its forms** (electricity for lighting, domestic appliances and pumping, heat for cooking, potable water…) **from local renewable sources and for local use of population and economy**.

Scope:

Technological development and efficiency

The work must target the design, prototyping and test of stand-alone systems that fulfil at least two of the following specifications.

The design and operation of the RE-SAS systems may target the a**gility and flexibility of the energy production system regards the kind of the potential local RE sources and the specific usages**. This may include solutions targeting the design of **a modular platform independent from the kind of the ER source**.

In the RE-SAS systems, the **management of the production stability regards the use of RE sources** may consider different **storage solutions including Power-To-X energy conversion** and **hybrid technology systems**.

Solutions targeting **suitable internal architecture of the RE-SAS system** for the different specific uses **based on X-to-X conversion** for example may be investigated.

Solutions targeting **cost effectiveness of the production of the RE-SAS system** based on avoiding long distance material transport and using local resources and staff may be studied.

Solutions targeting **portable solar home systems with easy installation and transportation** may be investigated through the integration of **lightweight photovoltaic components** such us OPV and thin film PV solar modules. This could include the use of new materials such as quantum dots and nanostructures, using low-cost polymer materials. Also relevance of passive solar energy production through design may be evaluated.

The selection and test of the **RE components suitable to the RE-SAS system and its environment** may be conducted through **durability and reliability** technical studies for the different African environmental stresses.

Methodological Approach

The approach should be built on the identification of the complete range of local possible energy usages and existing RE-SAS systems in Africa in order:

- To develop a standardised versatile architecture, simple and adapted taking into account the lack of local infrastructure and qualified workforce;
- To integrate a management and control system, simple, flexible and adapted based on expert laws, wireless, without internet, limited forecasting, possibility of load shifting or shedding for example;
- To develop a design tool, integrating all possible RE sources, components and uses;
- To provide trainings dedicated to the installation, operation and maintenance of the autonomous system.

Specific R&I actions should identified:

- For the evaluation of organic and/or thin film PV modules for nomad use;
- For the test of the production stability of lightweight energy production systems in specific environmental use;
- For the assessment of the efficiency and stability of suitable components for the energy production system operation and its environment;
- To support the design of the lightweight energy production systems for specific use in terms, for instance, of size of PV modules and their configuration in panels or rolls.

The R&I actions should include the evaluation of the business models for stand-alone systems exploitation.

Energy Scenarios (and link with Policy)

The R&I actions will be based on the identification of RE related gaps in existing RE-SAS system management legislation. They should contribute to the creation of policies and enforcement of legislative provisions, the local energy market development, the deployment scenarios of stand-alone systems, the identification of the value chain privileging local stakeholders, the harmonization of the energy access and the definition of associated business models.

RE-SAS systems are already demonstrated but for dedicated uses such as water pumping and they are mainly based on energy production from solar or wind sources. The R&I actions of the pathway aims to the design and test of an adaptive system integrating existing components taking into account the specific environments in Africa. This should open the road for demonstration in various relevant environments and various uses.

Expected outputs, outcomes and impacts:

- **Output**: To provide routes for RE-SAS demonstrator(s) to be developed taking care of the diversity of the potential local RE sources and the local effective environment; To develop tools for RE-SAS design;
- **Outcome**: The development of reliable stand-alone system architecture that can be easily and widely deployed in off-grid African rural and remote areas; The creation of jobs towards RE production and uses through RE-SAS systems installation, management and maintenance; The dissemination of the acquired knowledge in particular among the African community to develop a sustainable RE-SAS systems deployment;
- **Impact**: To promote environmental and ecological sustainability of renewable energy systems; To increase the share of renewables; To give access to affordable energies to the largest number of beneficiaries and to maximise the socio-economic impact; To identify the key stakeholders; To identify the most promising business models.
- **Related KPIs**:
  - Range of average size of targeted communities: *100 to 10 000 people*
  - Range of energy production power of RE-SAS systems: *10 kW-1 MW to be justified by the targeted community kind and size*
  - Limitation of the energy production cost: *less than 5 % of the community resources*
  - Reduction of the weight of the components for portable use: *weight reduction by a factor of 10 compared to components in stationary use*
  - …

References:

[1] *Chapter 5 and Chapter 6 in "Africa-EU RenewableEnergy Research and Innovation Symposium 2018 (RERIS 2018)", Edited by Moeketsi Mpholo, Tonny Kukeera and Dirk Steuerwald, Springer Proceedings in Energy (https://doi.org/10.1007/978-3-319-93438-9)*

[2] *https://reliefweb.int/report/jordan/azraq-refugee-camp-continues-embrace-clean-energy*

3 Pathway 4: Smart grid (different scale) for off grid application

PRELIMINARY DESCRIPTION OF PATHWAYS		PRE-LEAP-RE
Topic Number	Pathway 4	

Title	*Smart grid (different scale) for off grid application*		
Type of action*	*RIA / Study*	**Expected period***	
Indicative budget (M€)*		**Expected duration (years)***	

**To be specified later on*

Specific challenges:

Currently, in Africa more than 600 Million people, 80% of which living in rural areas, do not have access to electricity. In addition to small stand-alone systems for individual households and extensions of the national grid, there is a growing need for **small-to-medium scale Distributed Generation (DG)** solutions capable of integrating a diverse **mix of Renewable Energy Sources (RES)** for supply to **small and medium sized communities**.

Energy demand in sub-Saharan Africa has grown by more than 50% over the last 20 years, but accounts for only 4% of the world total, despite including 13% of the global population.

- At the light of the above consideration, many governments are working for removing regulatory and political barriers that are preventing foreign investment in domestic energy supply but the current inadequate energy infrastructure is still a strong limiting factor. Indeed, the power sector is not adequate, nor reliable in the majority of the African countries.
- From the production side, severe and frequent power shortages are threatening the development of the agriculture and industrial sector and thus the consolidation of the socio-economic development in line with the growing trend in GDP within the region, including provision of modern services for education and health care.
- For the transmission and distribution side, the losses in poorly maintained networks are often twice the world average and contribute to increase the overall primary energy used in the country, reducing efficiency of transformation.
- Despite this poor service, electricity tariffs are, in many cases, among the highest in the world and to complete the paradox, for the poor quality and quantity of the supply, the increasing private use of back-up oil-fuelled generators has induced consequences on the electricity price for the final user and the impact for the local environment. For this reason, the attraction of renewable systems versus conventional sources has risen the attention toward mini- and off-grid power systems especially where financing is available to contribute to cover upfront expense, thus assuring cost effectiveness of the solution. Indeed it is worth to recall that energy affordability is a critical issue especially in low income countries and while electricity price are high, oil products are still subsidised in many oil-producing countries.

The increase of attention from governments to a regulated penetration of REs into the national grid will help overcoming the dichotomy between centralized and decentralized electrification, using hybrid solution coping different renewable energies sources with conventional sources thus combining a bottom up and top down approach.

Such solutions may contribute to increased reliability of the power supply, reducing energy poverty, dependence on storage and fossil backup systems. Hybrid and Smart RES Grids have a role in addressing the many *technological challenges* that may come from the integration of different RE technologies, distribution and storage system which needs to be integrated and optimized according to different and evolving demand scenarios and other boundary conditions (weather condition, adverse climate temperature, seasonality…). They can play a role within the *environmental challenges* since they contribute to reduced local air pollution and GHGs emission. If properly designed, they can also reduce energy-water-food competition by reducing reliance on traditional biomass and wise water management. Furthermore, Smart and Hybrid grid can respond to the local *socio-economic challenge* since they can be scaled-up with the growing demand, tailored to match productive uses in either agriculture or rural industries and support community service delivery in education and health. With the deployment of appropriate business models, improved energy affordability may be achieved for local people and job opportunities associated with manufacturing, installation and maintenance.

Scope:

Technological development and efficiency

The specific technological aspect of the research (what is the pathways topic?) has to be investigated under components and system point of view. So, under this pathway it may be crucial to carry out ***technological research*** *responding to some specific questions:*

- Hybrid generation system: integration of different RE technologies into smart grids and mini-grids (wind turbines, solar PV panels, bioenergy systems…) and the and the mix optimization through specific components (smart inverter, battery recharge controller…) and interconnecting solutions. Mix of resources and related technologies is a solution to increase the reliability of RE and overall the oscillatory resource availability. *How can we improve the interconnection among different technologies? How can we optimize the technology mix?*
- Distribution system: local grid distribution and related components are necessary to ensure a stable and reliable system. To improve the state-of-the-art of components and to adapt them to specific operating conditions. *How can we improve performance and decrease cost of current distribution solutions?*
- Dispatching and Management system: smart metering for customer interaction and remote monitoring for system optimization (smart metering devices, cloud-connected controller…) to maximize the system performance, improve the remote control and decrease the maintenance and failure of the system. *How can we improve the reliability of the system? How can we optimize the system production?*
- Cross-cutting themes: efficiency improvement at both component and system level for real operating conditions is necessary to apply the current technology in specific contexts without compromising the expected performance of the system. Storage system integration and optimization (battery technology coupling, compressed air energy storage…) is necessary to increase the capability to store energy at short-middle term and compensate the oscillatory generation based on resource availability. *How can we improve the efficiency at real operating conditions? How can we integrate and improve storage solutions in smart hybrid generation systems?*
- Development of specific methods and tools for resources evaluation, energy management and monitoring of mini-grid
- Development of strategies for selection, sizing and management of batteries in mini-grid

Methodological Approach

The specific technological aspect of the research (what is the pathways topic?) need to be complemented with a Comprehensive approach to the research (how the research is carried out?).

*So, under this pathway it may be crucial to carry out **complementary research** responding to some specific research questions:*

- Resource assessment (resource availability and reliability of the source): methods for remote monitoring: how can we better forecast/assess the local resources?
- Needs Analysis: how will be energy be used by the people? What are they real needs? How can researcher work with local civil society to assess this element?
- Demand side management: how can we optimize energy demand and peaks reduction…
- Monitoring different case studies and past projects to identify criteria for successful electrification – best and bad practise (what are the component that can make a mini-grid project successful?)
- Market Analysis, Delivery and Management: business model and payment schemes to increase long term sustainability of the mini-grid (who will pay the tariffs and how? What if the tariffs are not affordable? Who will manage the grid in the long term?)
- Environmental Impact analysis: GHGs and local pollution evaluation as well as impact on water and eventually food, including also LCA and LCC evaluations
- Social and Economic impact (inclusive growth, job creation, Income generating activities, reduced reliance on traditional biomass and social acceptance): how can we measure and evaluate it in a quantitative-qualitative but scientifically sound way?

Energy Scenarios (and link with Policy)

To understand the long term impact of the pathway is also crucial to realise the placement of the technology within the national strategies. In order to go in this direction the research need to respond to some further issues:

- Energy Modelling at country level to see the interaction among the specific pathways and the country strategy: how can the contribution coming from mini-grid support the national policy in the decarbonization strategy increasing access to energy?
- Regulatory Frameworks: how can they impact on the dissemination/implementation of mini-grid in the country? Wat are the best options?
- Enabling policies: how can specific and dedicated policies impact on the dissemination of mini grid? (de-risking policies, business support, incentives, priorities on renewables….)

Smart-grid systems are already demonstrated in relevant environment and complete in their complex, but for specific components, system configurations and applications development and validation are still necessary. The R&I actions of the pathway aims to the development, validation, demonstration and system proof of adaptive systems integrating existing and new components and system solutions taking into account the specific environments in Africa.

Expected outputs, outcomes and impacts:

This pathway will be mainly focus on

- **USERS**: “single community based users” (hospital, schools, industry….) or multiple users (villages and communities)
- **SIZE** from tents to hundreds of kW, assuming off-grid situations

Moreover the pathway wish to obtain

As OUTPUT

- Innovative solutions for mini-grid based on Res will be within a shared data base

- Optimised capacity and dispatching strategies based on people needs will be set up
- Energy dependence on fossil fuel will be reduced
- Share of Res in rural electrification will increase
- New open-source code will be delivered and made available to the researchers world wide

(examples of) related "output" KPI (target values will be set in future call): *number of Technologies within the database, affordability of the electricity to the people, share of RES as total Energy produced by the minigrid, number of open-source tools delivered by the programme*

As OUTCOME

- Researcher capacity will be strengthened with "holistic" and multidisciplinary thinking and their behaviour will change since the will be more and more aware of people needs.
- Research will be valorised as instrumental to the creation of native and local innovation
- Technologies design will be so more people-driven and this should increase efficiency
- Local people and civil society will feel more engaged in the research-innovation process understanding that the knowledge triangle is leading to effective solutions for their needs
- Private players will benefit from new (but open and free) instrument for supporting the creation of sustainable business at local level

(example of related "outcome" KPI (target values will be set in future call): *number of publications, researches approached with holistic views, number of joint cooperation among research ground with different background, Number of innovations reaching a certain TRL, Number of awareness and dissemination campaign, private players engagement for sustainable business solutions*

As IMPACT

- Energy access in rural areas and electrification integration through REs
- Improving living conditions and social inclusive growth in the local context
- Improving economic development and promoting job creation in local context

(example of) related "impact" KPI (target values will be set in future call): *number of people electrified by the whole programme, number of productive activities associated to the electrifications, % increase in income and job creation within the target communities*

References:

IRENA (2016), Innovation Outlook: Renewable Mini-grids, International Renewable Energy Agency, Abu Dhabi.

IEA (2017), *Energy Access Outlook 2017: From Poverty to Prosperity*, IEA, Paris, https://doi.org/10.1787/9789264285569-en

Trotter P.A., McManus M.C., Maconachie R. (2017). Electricity planning and implementation in sub-Saharan Africa: A systematic review, *Renewable and Sustainable Energy Reviews*, 74, pp. 1189-1209

Moner-Girona M., et al. (2018). Electrification of Sub-Saharan Africa through PV/hybrid mini-grids: Reducing the gap between current business models and on-site experience, *Renewable and Sustainable Energy Reviews*, 91, pp. 1148-1161

UN Fundation, Microgrids for Rural Electrification: A critical review of best practices based on seven case studies https://rael.berkeley.edu/wp-content/uploads/2015/04/MicrogridsReportEDS.pdf

4 Pathway 5: Processes and appliances for productive uses

PRELIMINARY DESCRIPTION OF PATHWAYS		PRE-LEAP-RE
Topic Number	Pathway 5	

Title	Processes and appliances for productive uses		
Type of action*	*RIA / Study*	**Expected period***	
Indicative budget (M€)*		**Expected duration (years)***	

Specific challenges:

According to the 2017 State of Food and Agriculture report by the UN's Food and Agriculture Organisation, the key to achieving Sustainable Development Goals in Africa is transforming rural communities and promoting agriculture. In addition to this, approximately 60% of Africans derive their income from agriculture and agricultural processes. It is therefore important to prioritize boosting small-scale farmers' productivity and incomes in the agricultural production stage and creating off-farm employment in expanding segments of food supply and value chains.

Food supply and value chains segments involve processes such as harvesting, drying, cooling, transportation and retail. These processes require variations of cold chain technology, thermal and electrical power. The demand is met differently by different industries and countries in Africa. An example of such is industries where thermal power demand is met through biomass while cold chain energy needs are met through grid supply supplemented by diesel generators in cases of blackouts. Technologies like combined heat and power systems (cogeneration) can help improve fuel use efficiency while improving pollution control.

In order to transform rural communities, access to lighting systems alone is not enough to empower them economically. To do this, it's important to support technological innovations and solutions such as productive use (PRODUSE) appliances in agriculture as a way of improving rural livelihoods. These appliances can be used to improve the productivity and/or efficiency in agriculture and other Income Generating Activities (IGAs) such as rural industrial processes and to improve healthcare systems delivery.

PRODUSE appliances are relatively new in bottom of the pyramid markets which are mostly found in rural communities since system costs are as sensitive as the need for the appliances. Their uptake and utilization of emerging renewable energy (RE) can easily be slowed or curtailed by quality assurance concerns, energy efficiency gaps, lack of consumer financing and policy interventions. It is therefore prudent to implement well researched and informed interventions to avoid slowing adoption or having unforeseen negative impacts.

RE sources are such as solar PV are abundant on the continent. With proper capacity building efforts, off grid communities can install and maintain these systems. This can create employment and grow small and medium enterprises within communities. However, to achieve this, the following challenges should be addressed:

- The cost of energy should be low for bottom of the pyramid consumers
- The power provided should be reliable to prevent loss of trust in technology
- Technologies used should account for cultural interactions
- Appliances availed should be of good quality
- System operation and maintenance capacity should exist locally

Scope:

Technological development and efficiency

- Assessment of existing business models and social impact of existing PRODUSE appliances
- Assessment of PRODUSE processes in agricultural industries that can use RE systems to improve process efficiency, increase financial savings and reduce energy costs
- Market research to identify current gaps and energy cost related issues PRODUSE processes and appliances, both at industrial and household level
- Market research on energy needs in food supply and value chains and agro processing. SMEs and rural households should be the focus of such.
- Research on adsorption refrigeration and combined heat and power systems in cogeneration processes as an alternative for other cold generation technologies
- Development of RE cooling and drying processes for food transformation and preservation.

Methodological Approach

- Pilot project based on gaps identified in market research on PRODUSE processes and appliances, both at industrial and household level.
- Feasibility study and/or pilot on the use of geothermal and energy efficient use of biomass in thermal processes
- Promoting the local manufacturing of AC and DC PRODUSE appliances, market accessibility of these appliances and access to financing
- Technical assistance to MSMEs on the use of PRODUSE appliances, field testing and case studies on uptake of and reliability of existing PRODUSE appliances

Energy Scenarios (and link with Policy)

- Deepen the link between energy and economic activities (growing demand, growing supply)
- Promote trade in productive use appliances by financial modelling Projects must be consistent with national energy policy
- Projects must be consistent with national energy policy
- Quality assurance framework to ensure reliability and energy efficiency in the appliances
- Promotion of RE mini-grids that take up PRODUSE appliances
- Reduction of GHG emissions through energy substitutions from conventional to RE.

The TRL starting level (TRL 4) is the laboratory research level. All technologies involved here have been proved and tested at lab level at least. The end TRL (TRL 8) is the demonstration on site level or the proof that it is reliable even on field.

All the RE technologies involved in this pathway should be only systems to be tested for efficiency on site. After demonstration (TRL 8) they should be adopted by end users for their own businesses.

Expected outputs, outcomes and impacts:

This pathway will allow:

- **Output**: Comprehensive models for PRODUSE appliances
- **Outcome**: Understanding opportunities for PRODUSE appliances, improved understanding on best opportunities for adaption of existing technologies to address specific challenges, supportive policies for establishing conversion technologies. Reduction of post-harvest

losses especially in SMEs and informal sector. Energy efficiency and energy transition/substitution in areas where is could be difficult. • **Impact**: Improved socio-economic development of the off-grid communities; Creation of jobs and improved energy access; Reduced GHGs, local pollution and deforestation. Research for appliances making will be done through various lab partnerships (Africa and Europe).

References:

https://www.powerforall.org/resources/fact-sheets/fact-sheet-global-grid-appliance-market

https://www.giz.de/fachexpertise/downloads/giz-eueipdf-en-productive-use-manual.pdf

http://www.factore.com/2017/10/09/the-problem-with-productive-use-appliances/

5 Pathway 6: Innovative solutions for priority domestic uses (clean cooking and cold chain)

PRELIMINARY DESCRIPTION OF AGENDAS PATHWAYS		PRE-LEAP-RE
Topic Number	Pathway 6	

Title	*Innovative solutions for priority domestic uses (clean cooking and cold chain)*		
Type of action*	*RIA / Study*	**Expected period***	
Indicative budget (M€)*		**Expected duration (years)***	

**To be specified later on*

Specific challenges:

Nowadays, about 2.7 billion people still have no access to clean cooking. This figure includes one third of the world's population, 50% of which is living in developing countries.

Among them, 2.5 billion people still rely on traditional solid biomass, while the others mostly on kerosene and coal.

In Africa, 700 million people still lack access to clean cooking mechanisms. Currently, the traditional devices used are fuelled by firewood or charcoal and have very low efficiency.

The utilization of traditional biomass poses numerous *environmental challenges*. Traditional biomass utilization is in fact a recognized contributor to deforestation and land degradation. Even if agriculture and timber industry are known as the major drivers of large scale deforestation, firewood collection and charcoal making for domestic uses can have significant impacts on local ecosystems, especially in densely populated areas.

Biomass burning in traditional cookstoves has also been found to be responsible for about 20% of global black carbon emissions, which makes it the second largest contributor to global warming, after carbon dioxide. Indoor cooking with traditional devices causes respiratory illness, which contribute to prematurely death of millions of people due to associated diseases, including respiratory infections, chronic obstructive pulmonary disease, lung cancer, cardiovascular disease and eye irritation.

The problem mainly affects female and children. In addition, illness due to respiratory infections has been identified as one of the most common cause of absenteeism from school in some countries in sub-Saharan Africa.

The time used by female in gathering fuel is another *social challenge* associated with traditional cooking.

Three are the complementary actions generally proposed to overcome the challenges associated with the utilization to traditional cooking systems: (i) decrease the fuel needed to prepare a determinate meal; (ii) promote sustainable biomass harvesting and collection; (iii) provide alternative solutions for both traditional fuels and cooking technologies.

Referring to such actions, *technological challenges* associated with this topic may be divided into two categories: improving the design of existing stoves, or developing new, more efficient designs; or increasing the opportunity for fuel switching.

Appropriate solutions in both categories also contribute to the *environmental challenge*: the utilization of more efficient stoves, or the switch from traditional biomass to other fuels (such as LPG) guarantee a reduction of fuel consumption, and therefore allow to mitigate the pressure on biomass resources and the overall ecosystem.

Another way to address the environmental challenge, is working on the sustainability of the overall biomass supply chain, from tree plantation, to efficient conversion of biomass into fuels (charcoal, briquettes, pellets ,…), and also considering the transformation of biomass residuals into biogas, ethanol, or other fuels.

However, numerous *socio-economic challenges* must also be addressed: improved cooking solutions or modern fuels are often too costly, and it is observed that cooking technologies that require a strong modification of traditional practices are often characterized by low levels of acceptance.

Moreover, in some contexts LPG or other modern fuels may not be easily available due to logistic constraints. On the other side, the promotion of efficient stoves represents also an opportunity for the local economy, especially if based on local manufactory.

Along with clean cooking topic food and drugs preservation is one of the most common issues at domestic and community level in Africa. As example, in Sub-Saharan Africa nearly 40% of food perishes before it can reach a consumer, while the lack of effective refrigeration means limits the possibility to distribute vaccines in rural and remote areas. In this topic the cold chain can play a crucial role in reducing food waste, improving public health, and enabling African communities, especially in rural areas, to participate in national and international trade as producers and consumers.

The *technological challenges* are mainly based on the energy vector, with the use of heat in place of electricity to generate low temperatures in the domestic and communitarian systems, or the use of static and compact technologies with higher reliability compared to traditional systems, and the coupling of refrigeration units with off-grid electric power systems. Moreover, the development of movable autonomous systems is another important element. The need for compact and fully reliable systems avoiding the break of the cold chain for medicine and food preservation with reasonable costs also represent the main *socio-economic challenge*.

Scope:

Technological development and efficiency

The specific technological aspect of the research (what is the pathways topic?) has to be investigated under components and system point of view. So, under this pathway it may be crucial to carry out ***technological research*** *responding to some specific questions:*

- Fuel switching: from traditional biomass to modern/advanced technologies and applications (e.g. anaerobic digestion, gasification, improved efficiency combustion, micro CHP). *How can we support a switch from traditional to modern fuels in different contexts?*
- Production of fuel from waste and residues. *How can we improve the transformation process of biomass clean fuels?*
- Efficiency and combustion chamber improvement for ICS (Improved Cook Stoves), advanced rocket stoves, Improved Charcoal Stoves. *Which are the most important parameters influencing combustion in improved stoves?*
- Design of advanced cooking stoves**:** forced-draft stoves, micro-Gasifiers. *Which innovative elements (electric fan, combustive agent controllers …) can be added to existing stoves to enhance their performances?*
- Additional devices complementary to cook stoves (pot-skirt, pressure cooker). *How can we improve complementary devices, or develop add-ons, to contribute to the goal of better cooking systems?*

- Small scale/domestic biogas. *Which technology and materials can be introduced to obtain reliable and cost-effective small biogas systems?*
- Clean liquid and solid biofuels. *How can we improve the transformation process of liquid and solid biofuels?*
- Use of geothermal surface activity for cooking, baking purpose (example Iceland). *How can we start developing appropriate technologies based on geothermal energy for cooking?*
- Design of solar cookers. *How can we promote local manufacturing, appropriate use and local acceptability?*
- Design and development of a sorption refrigeration platform for research, feasibility demonstration and showcase. *How can we improve systems other than compression refrigerators for effective cold chains?*
- Development of a model of high temperature solar heat generator using Fresnel CSP. *Can we effectively use solar technologies as a heat source for sorption refrigeration units?*
- Development of a hybrid system to compare the performances of power compressor and sorption refrigeration units. *Which are the main advantages and disadvantages of sorption platforms compared to traditional refrigerators in different operative contexts?*
- Increase of the life span of sorption units based on the reduction of moving parts. *How can we improve the reliability of sorption refrigeration units?*
- Testing of low-cost, innovative materials for refrigeration units (e.g. insulating materials). *How can we effectively reduce the cost of refrigeration units?*

Methodological Approach

The specific technological aspect of the research (what is the pathways topic?) need to be complemented with a Comprehensive approach to the research (how the research is carried out?).

So, under this pathway it may be crucial to carry out **complementary research** *responding to some specific research questions:*

- Sustainability of Biomass Supply Chain (including new and fast way to grow trees): how can we grant the sustainability of the supply chain of biomass?
- Assessment of energy demand and social features of cooking (target groups – energy, resource, technology, and knowledge access match…): how can the link between cooking and cultural habits influence the choice of technologies?
- Local manufacturing for traditional and improved cook stoves: how can the availability of a local market influence the spreading of specific cooking technologies?
- Bottom of Pyramid Business model (microfinance & payment scheme): how the definition of appropriate business model lead to a change in local habit and influence technological design?
- Environmental Impact Analysis: how can we grant standards of quality and performance by relaying on lab test or field campaigns?
- Wider sustainability assessment (social and economic): how can we assess any social impact?
- Influence of extreme conditions: can we reach reasonable COPs and maintain an adequate temperature inside refrigeration units in extreme environment conditions? Which is the effect of dust on such systems?
- Cost-effectiveness of cold chain systems: how can we demonstrate the cost-effectiveness of refrigeration units such as sorption systems under various scenarios of functioning?

Energy Scenarios (and link with Policy)

To understand the long term impact of the pathway is also crucial to realise the placement of the technology within the national strategies. In order to go in this direction the research need to respond to some further issues:

- Modelling for Integrating Power sector and Cooking: how can we model and which kind of benefit may be obtained when planning integrated heat and electricity?
- Enabling policy promoting clean cooking: how can policies support the scale up of modern cooking solutions?
- Market analysis and penetration by driving huge social and environmental benefits: what are the social research that are needed to be able to engage the local community in the process of technological change?
- Energy saving: how can we improve more and more the overall energy systems?
- Low-cost solutions for remote locations: can we develop low-cost systems that can be effective in remote and rural areas?

Expected outputs, outcomes and impacts:

The pathways will allow to :

As OUTPUT

- Development of innovative design of cooking devices
- Development of new appropriate modern cooking systems
- Use of local and low-cost materials for stoves construction
- Technical improvements of fuel processing or production technologies
- Improvement of existing and innovative technologies for cold chains, including refrigeration units based on solar or biomass resources

As OUTCOME

- Provide researchers with capabilities for lab and field testing of cookstoves
- Promotion of the utilization of modern fuels
- Promotion of sustainable fuel supply chains
- Preservation of medicines and vaccines in remote areas
- Promotion of effective and low-cost food preservation
- Promotion of efficient air conditioning
- Reduction of GHG emissions due to lower power consumption form the grid or diesel generators

As IMPACT

- reducing GHGs, local pollution, land degradation and deforestation
- improving health and social conditions of local stakeholders as well as Job creation
- Reducing the drudgery for woman and increase their social power (woman empowerment)
- Reducing demand for unclean sources of energy
- Strengthening food security
- Strengthening people's health and public healthcare

References:

IEA (2017), *Energy Access Outlook 2017: From Poverty to Prosperity*, IEA, Paris, https://doi.org/10.1787/9789264285569-en

Africa Clean Cooking Energy Solutions Initiative, ESMAP: https://www.esmap.org/node/71157

H. Clemens, R. Bailis, A. Nyambane, V. Ndung'u (2018). Africa Biogas Partnership Program: A review of clean cooking implementation through market development in East Africa,Energy for Sustainable Development,46, pp. 23-31, doi.org/10.1016/j.esd.2018.05.012.