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# Calling for Nexus Thinking in Africa's Energy Planning

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**Summary**

The simultaneous achievement of the sustainable development goals (SDGs) is, to say the least, challenging. In a situation of increasing and multiple demands over limited resources, pursuing each goal separately could lead to increased competition. The situation in Africa is particularly problematic, as the continent lags behind all others in terms of quality and quantity of infrastructure and counts the highest shares of population living in poverty and without access to food, safe water, and energy. At the same time, natural resources are under increasing pressure from population growth, environmental degradation, and climate change.

Given the entity of the challenge, finding synergies and strengthening coordination across sectors will be crucial and the energy sector has an important role to play. As recognized in the Agenda 2030, the energy sector holds the key to many aspects of development, however no energy solution (albeit green or synergetic) should be casually labelled as a nexus solution. This could be deceiving also because of the ambiguities that surround the concept of nexus.

In order to give concrete insights to policy makers, this paper proposes a pragmatic approach to the nexus that allows on one hand to detect areas where cooperation needs to be strengthened, on the other to explore the nexus potential of energy solutions. This is in line with a view of the nexus as a way of thinking, which can apply both at the level of policy making and in the actual implementation of projects.

We will give three concrete examples to improve energy access at different levels: multipurpose hydropower for large-scale electricity production, solar pumps for irrigation in farms, and efficient cookstoves in households. These can catalyse much needed action in other areas (notably water supply, agriculture, and forestry) but realizing their potential requires stronger cooperation and coordination across sectors. Moreover, their successful implementation requires an honest and thorough assessment of the local context in terms of constraints as well as opportunities.

**Keywords**: Africa, Energy Access, Nexus Approach, Resource Security, Environmental Sustainability, Water Management, Agriculture, SDGs

**JEL Classification**: O13, O55, Q49

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# 1 Nexus

## 1.1 An ambiguous concept, a brand, or a way of thinking?

The concept of *nexus* associated to natural resources has quite a fluid definition in research (Endo et al., 2015). It usually refers to the challenges of achieving water, energy and food security simultaneously (the *water-food-energy nexus*), however there are plenty of examples where this perfect triangle gets twisted to adapt to different research questions. For instance, when the focus is agriculture *food* goes to the centre of *water*, *land* and *energy* (CGIAR Research Program on Water, Land and Ecosystems, 2014); *climate* gains prominence when considering future *water*, *energy*, and *land use* planning options (Howells et al., 2013); the explicit addition of *ecosystems* is used to stimulate an environmentally sensible transboundary dialogue (UNECE, 2015); and so on. A nexus approach can be applied at different geographical scales, although necessarily (due to intrinsic differences between the various resource systems) an analysis of the nexus requires to some extent to move across-scales (Hoff, 2011).

Overall, the nexus refers to the complexity of natural resource management when uses are multiple, resources are scarce, and cross-sectoral dependencies and impacts can no longer be ignored. At this point, we become aware of trade-offs and start looking for synergetic solutions to reduce inter-sectoral tensions.

The debate over the novelty of the nexus concept is an open one. While some see it as a new label for an old problem (e.g. (Allouche et al., 2014)), arguing that efforts in" re-inventing the wheel" only distract from the actual decision making process, others point out that there are interlinkages across sectors that cannot be captured without adopting a multi-centric (nexus) approach. As pressures on resources increase both globally and locally, a new framework is needed to inform strategic decisions (e.g. (Bazilian et al., 2011)). Regardless of its novelty, the real ambition of nexus research is to help policy makers taking more informed (i.e. better) decisions when it comes to resource management.

The background paper to the 2011 Bonn Nexus Conference, commonly considered a sort of nexus manifesto, called for the adoption of a new approach that "*integrates management and governance [of resources] across sectors and scales"*, as opposed to conventional 'silo-thinking', with the aim of jointly improving water, energy, and food security. According to Hoff, by means of a "*coordinated and harmonized nexus knowledge-base*" the scientific community could assist policy makers in this increasingly complex decision making process by providing unbiased evidence on the nexus. This turned out to be a critical point of discussion, making at least two conceptual issues emerge fairly soon within the newly established nexus community.

The first concerns the sphere of policy. The nexus exists where there are trade-offs, and by definition trade-offs arise where different interests overlap. This poses the question of what makes a *good decision* from a nexus perspective, a question which possible answers (resource efficiency, social justice, environmental conservation, etc.) typically unveil deep differences in perspectives, interests, and even philosophies. The second pertains to science: as long as a universally agreed definition of nexus is lacking, no scientific statement can be made. Since the current trend seems to be that of diverging, rather than converging perspectives on the matter, *scientific evidence* and *nexus* remain notions that can be only be associated with caution.

In time, there has been a tendency to use the nexus as a brand for a number of technological innovations. Quoting Allouche et al., "*Genetically modified crops, transgenic technologies, automation of agriculture or micro-irrigation technologies […] These solutions rely heavily on a simplistic availability assumption, namely* *that increased food supply will automatically reduce hunger or that increased supply of water will improve general access to water".* (Allouche et al., 2015) In other words, nexus challenges are as political as technical, and innovation alone fails to address the deeper issues of poverty, inequality, and uneven access to resources. Stirling et al. make a similar remark in the context of the Sustainable Development Goals (SDGs). Many SDG targets will only be achieved if current socio-economic trends are inversed (e.g. meat consumption) and yet too often nexus-related research seems to point at solutions that require technological innovations rather than broad societal change (Stirling and others, 2015).

Although it would be possible to come to an agreement on a generalized definition of the nexus, it may not necessarily be useful. The concept is so deeply contextual - not only in terms of resource characteristics, but also when in comes to society, governance mechanisms, and political landscape – that a simple definition of the nexus may fail to capture its most important features at a given place and time. Moreover, since nexus research usually tackles complex societal issues it would be irresponsible to suggest that these can be solved with scientific precision, as this would shift the burden of justification from the policy making process to the research community, with important consequences on accountability (Stirling and others, 2015).

Given these premises, it is clear that nexus challenges can be framed in very different ways and, as a result, different solutions can be put forward to address them. Critical nexus thinking requires a careful consideration of contextual conditions. Stirling at al. suggests that a researcher who investigates solutions to complex problems should be guided by two concepts: reflection and reflexivity. The first leads to account for margins of error, uncertainty, and ambiguity, while the second to consider that different perspectives could lead to different solutions (Figure 1).

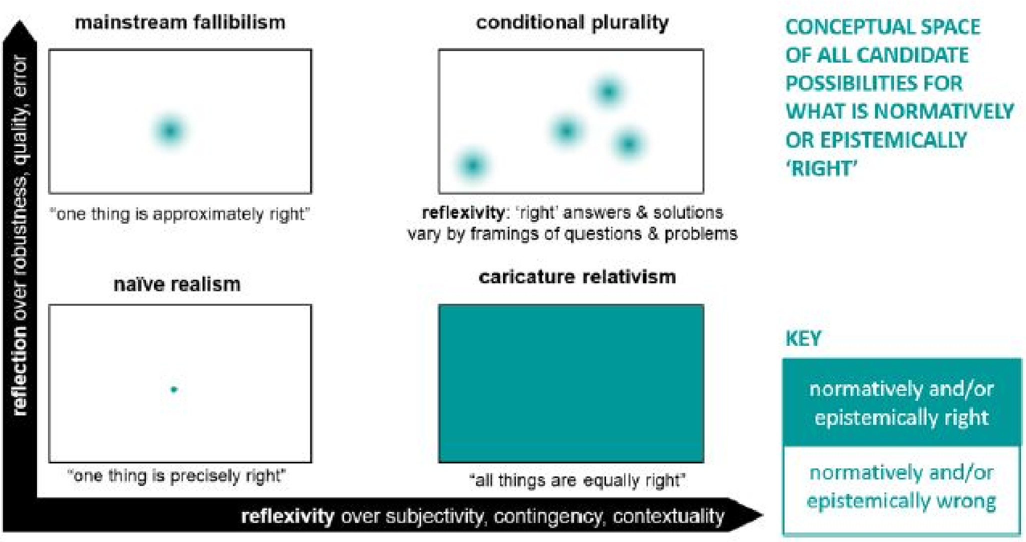


**Figure 1 Reflection and reflexivity in understanding nexus-related interactions and implications. Source: Stirling et al., 2015**

Ultimately, the nexus approach should help finding common ground for different stakeholders to cooperate. It is worth recalling here the three simple guiding principles as stated by Hoff, which constitute a non-controversial starting point for this quest (Hoff, 2011):

- investing to sustain ecosystem services

- creating more with less
- accelerating access, integrating the poorest

The spirit motivating this paper is that despite the fact that nexus research has so far delivered ambiguous results, the undisputable existence of multiple interests on common and increasingly scarce resources justifies a holistic approach to the problem. Our idea is that nexus research should help broadening the perspective of policy makers (Stirling and others, 2015), and that a nexus approach can be used to facilitate dialogue across sectors and stakeholders (de Strasser et al., 2016; Johnson and Karlberg, 2017).

### 1.2 A network of linkages behind the SDGs

This paper focuses on the nexus dynamics at play around technical solutions to improve energy access in Africa. Improving access at different levels is the essence of the first target of SDG 7: "*By 2030, ensure universal access to affordable, reliable and modern energy services"*. It seems therefore important to spend a few words on the relation between the nexus concept and the SDGs, a much-discussed topic.

The simultaneous achievement of the sustainable development goals (SDGs) is, to say the least, challenging. In a situation of increasing and multiple demands over limited resources, pursuing each goal and aiming at its relative targets separately would lead to increased competition and unintended consequences. The entity of this challenge is apparent when considering the targets of SDGs 2 "*Zero Hunger*", 6 "*Clean water and Sanitation*" and 7 "*Affordable and clean energy*", all requiring an increased usage of limited water and land resources (Mohtar, 2016).

Dealing with the SDGs as separate elements - just like the Millennium Development Goals before them – truly poses a methodological question: if interlinkages between goals are not addressed, how can we even make sure that the sum of their separate implementation is sustainable (ICSU and ISSC, 2015)? Considering the strong link between livelihoods and the environment, one could even wonder if their separate implementation would actually lead to development.

Win-win solutions can be hard to find considering that some SDG targets are mutually constraining, and others are even mutually cancelling, meaning that reaching one makes it impossible to reach the other (Nilsson et al., 2016), bringing us back to the political nature of nexus trade-offs. The framework proposed by Nilsson et al. aims at supporting the analysis of interrelations between various SDG targets. According to this, they relate to each other on a scale of seven, going from *indivisible* (inextricably linked to the achievement of another goal) to *cancelling* (makes it impossible to reach another goal).

So how does the SDG 7 related to the others? In general terms, energy is crucial for achieving all the SDGs, from access to water and food to education, reduced inequalities and so on (UNDESA, n.d.; UNECE, 2017). Some studies dig deeper into this question, looking at each specific target of the SDG 7. For example Alloisio et al. used the above mentioned framework from Nillson et al., concluding that reaching the targets of SDG 7 will enable, reinforce or even be inextricably linked (this is the case, notably, of the targets of SDG 13 (*Climate action*)) to the other SDG targets. (Alloisio et al., upcoming).

The limitations of this approach is that it takes a purely global perspective to interlinkages. While this is coherent with the concept of SDGs, it is less so with the concept of nexus, which manifests itself at local scale and requires an understanding of dynamics linking trends and policies at different scales: global, regional, national, sub-national, and local.

# 2 Africa

## 2.1 The energy challenge

It is common language to differentiate between North Africa and Sub-Saharan Africa, a rough distinction that is as geographically convenient as arbitrary (when the countries of Sahel have to be assigned to either one of the two groups), if not misleading. As it strips away a few countries from the rest of continent and squeezes all others in the same group, it deepens north-south differences and wipes out the others at the same time (Amrani, 2015; Haldevang, 2016). Yet, when talking about energy access this divide becomes remarkably neat.

By assigning 48 countries to Sub-Saharan Africa (i.e. the whole continent excluding Morocco, Algeria, Tunisia, Libya, Egypt, plus Djibouti), the World Bank calculates that electricity access in this region is the lowest in the world (32%), a stark difference with the almost universal access of North Africa. The picture is only minimally nuanced: Seychelles (99%) and South Africa (86%) have a much higher access than Djibouti (47%), whereas Morocco stands at around 90% like Cabo Verde and Gabon (World Bank, n.d.). The situation is similar for clean cooking facilities: in Sub-Saharan Africa, 80% rely on traditional use of biomass, in contrast with North Africa where most households do have access to modern cooking (IEA, 2014)(Guerrero-Lemus and Shephard, 2017).

Low access to modern energy has profound social and environmental implications. Indoor air pollution caused by the inefficient use of solid biomass for cooking kills around 600 thousand people every year, and as population increases this number follows (Africa Progress Panel, 2015) (outdoor pollution is quickly approaching a comparable number (Roy, 2016)). In terms of industry, almost 40% of the firms identify electricity (accessibility high costs, shortages etc.) as a major constraint to their business (World Bank, n.d.). Even the agricultural sector uses little amounts of energy if compared to other continents, and while there are very different views on how the sector should develop, there is little disagreement on the fact that low energy access holds productivity back (FAO, 1995).

In the future, electricity demand is expected to increase, if not boom. This is a result of very high population growth rates, urbanization, industrialization and expansion of the middle class, and even climate change. Big cities and related industrial areas will remain the largest share of the electricity consumption, explaining the commitment of many countries to develop large projects for power production (e.g. mega-dams) as well as national and international grids (power pools[1]). At the same time however, decentralised production will play an exceptionally central role in Africa, because grid-based electricity will only reach rural households in proximity of transmission lines, where their extension is economically viable. The remaining rural population, which is expected to increase as much as its urban counterpart, will have to rely on (or rather, start universal electrification from) off-grid and mini-grids options (IEA, 2014).

Biomass deserves a special mention. In terms of primary energy mix, bioenergy holds the largest share with 70-80% of the total (apart from South Africa where coal dominates). Fuelwood outweighs every other fuel in rural households and holds a significant share also in cities, where charcoal (often a product of wood processing) and fossil fuel based options (e.g. kerosene and LPG) are more accessible. Only in South Africa electricity is widely used for cooking. Overall, the demand for wood and charcoal will most likely keep on increasing, exerting significant pressure on forest resources (IEA, 2014).

[1] There are five regional power pools in Africa at different stage of development: South, West, East, Central and North

This race against time to power the African continent will unfold in different ways due to an uneven distribution of energy resources, both fossil and renewable (IEA, 2014; IRENA, 2015a). Relatively few countries can count on proven, significant, and exploitable fossil fuels (coal, oil and gas) [2], however exploration is ongoing in many countries and recent discoveries in East Africa are encouraging big expectations of growth in the oil and gas sector. Hydropower plays a key role in several countries, especially in Central Africa, and despite the uncertainties brought by climate change, hydropower generation will most likely increase exploiting at least some of the 90% of capacity that is still untapped. Some nuclear power is produced in South Africa, however uranium extraction mostly serves for export (with the overall continent contributing to around 20% of total production) (IEA, 2014).

The remaining resource base is constituted by non-hydro renewables. While their current contribution to the total energy mix stands at less than 2%, their potential is massive. Solar potential is great across the continent and prices of photovoltaic panels are dropping much quicker than expected (Bloomberg New Energy Finance, 2017), resulting in higher bankability of small installations as well as large solar farms. Although more unevenly distributed than solar, wind power has a huge potential too. Mostly available in the East, West and South, it shows an interesting complementarity with the hydropower potential of Central Africa. Geothermal potential is concentrated in the East and South, with Kenya leading the way of technology development. Finally, modern forms of bioenergy include the product of biomass residues treatment (e.g. biogas, pellets) and liquid biofuels (i.e. bioethanol and biodiesel) however their theoretical potential is often restricted by high costs and competition with food, respectively (IRENA, 2015a).

This massive stock of renewables coupled with a relatively low dependency on fossil fuels justifies and motivates a vision of a low-carbon development for Africa. But while there is no doubt on the availability of renewables, the extent and speed at which they will be exploited is unknown as it will depend on how investments, policies, and regulations will unfold. While large-scale infrastructure needs to be pushed by the countries and foreign investments, entrepreneurs and NGOs are playing a key role in the deployment of energy solutions at small scale, especially in rural areas. Moreover, counting on empowered local governments can be crucial, as these oversee the actual implementation of national plans (e.g. ensuring the capillary penetration of clean cookstoves (see section 3.3)) and can ensure an enabling environment for local initiatives to thrive (SAMSET, 2017).

### 2.2 Resources, environment, and climate change

For a long time now in Africa the poor have been both "*victims and perpetrators of environmental damage*" (Hope, 2007). Already in 1990, a report on development in Africa defined a nexus between population growth, agricultural stagnation and environmental degradation and explained how they combine into a vicious circle that is threatening African development (McNamara, 1990). It is interesting to point out that these considerations were made without even taking into account the effects of climate change, which would later be recognized as being one of the major threats to development in the continent (Hope, 2009).

Water access is at the centre of development in Africa. Even more than for energy, improving water access is needed to ensure basic human needs. Despite some improvement, 319 million people in Sub-Saharan Africa still lack access to drinking water and 695 million do not have basic sanitation facilities (WHO, 2015). Water scarcity can be natural or economic, the latter meaning that even where resources available to supply local needs, their access is limited. As a whole, Africa accounts for 9.2% of the world's internal

[2] Excluding North Africa, major producers and exporters are Nigeria (oil and gas), South Africa (coal), and Angola (oil), while emerging markets are Mozambique, Tanzania, and Equatorial Guinea.

renewable freshwater resources, Central Africa being the richest part (4.4%) and North Africa the poorest (0.1%) (FAO, 2005). While in the North (Sahara and Sahel) and the Southern tip of the continent water is physically scarce and river basins (including fossil groundwater aquifers) are often critically exploited, scarcity in the rest of the continent is mostly economic (Figure 2) (Unesco, 2012). This largely due to a generalized lack of storage and distribution infrastructure (Foster and Briceño-Garmendia, 2010).

Rain fed agriculture accounts for around 95% of farmed land in Sub-Saharan Africa, which makes large shares of populations exposed to rainfall variations and highly vulnerable to droughts (IWMI, n.d.). About 80% of land theoretically suitable for agricultural production has serious problems of soil fertility or other limitations that compromise its productivity (Africa Progress Panel, 2015), and at the same time despite some progress 217 million people remain undernourished in the continent[3] (FAO, 2015). Investments in the agricultural sector constitute less than 1% of total commercial lending and for a great part they benefit large-scale farms (Ekekwe, 2017). One of the key factors discouraging investments is precisely the high weather variability combined to high exposure to climatic stress, which keeps agricultural productivity low even when rains are abundant (Grey, 2002)

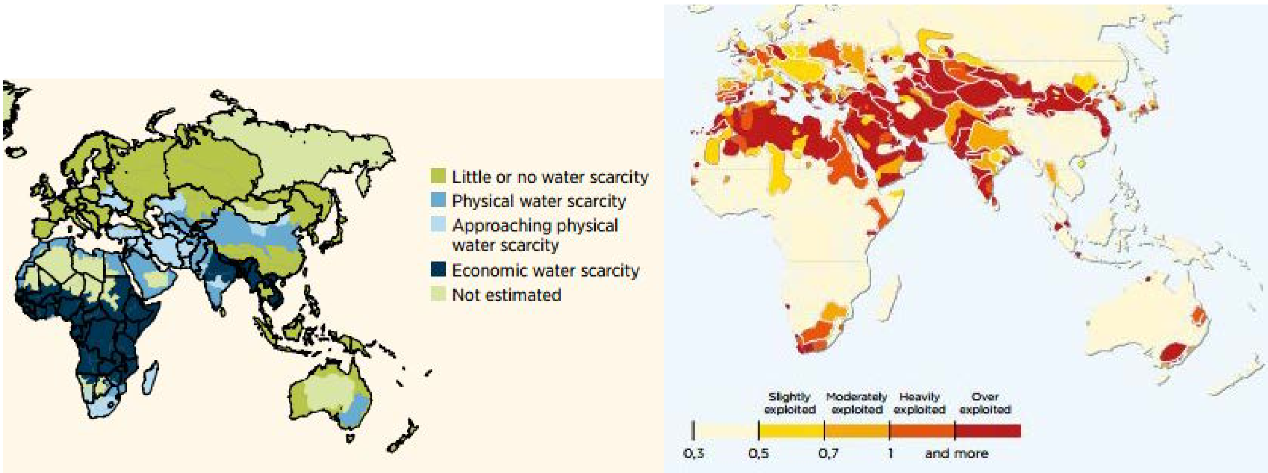


**Figure 2 Physical and economic water scarcity (left) and Water Stress Indicator (WSI) in major basins (right). Source: UNESCO, 2012**

The impact of climate change in Africa is felt across sectors, triggering dynamics that are difficult to predict and resulting in severely compromised development prospects (Conway et al., 2015) (Serdeczny et al., 2016). What is worse, climate change acts an accelerator for above mentioned vicious circle of poverty and environmental degradation (Africa Progress Panel, 2015).

The IPCC states with high confidence that Africa will be hit particularly hard by climate change due to a combination of high exposure and low adaptive capacity. Temperature increase will likely exceed 2 degrees, with significant impact on local ecosystems and water stress as well as, indirectly, on health and livelihoods. The projections for precipitations are more uncertain, however an overall reduction is expected in the North and South regions, while extreme events such as droughts and floods are more or less likely to intensify depending on the region. Notably, an increased frequency of such events has already been observed during the past 30-60 years in East Africa. Adaptation efforts, on the other hand, are hampered by a number of factors among which lack of infrastructure and weak governance (Niang et al., 2014).

[3] While this number reflects an improvement in relative terms, it also reveals an overall increase in absolute numbers (in '90-'91 this number stood at 175 million).

Among all, climate change will shake the African energy system at its core because this fully rests on two natural resources - freshwater and wood - that are shrinking quickly not only due to increasing demands, but also to natural causes: reduced rainfalls, higher temperatures, and desertification. New energy investments will have to respond to such increased uncertainty, vulnerability, and social pressure (Ebinger and Vergara, 2011).

Looking at greenhouse gas emissions, it is interesting to note that although Africa only contributes to 2% of global energy sector related emissions (IEA, 2014), emissions from land use change are not negligible and outweigh those from fossil fuels. Despite the presence of vast tropical forests, Africa is only a small carbon sink and may turn into a net carbon source precisely because of CH4 and NO2 emissions from logging, charcoal production, and agriculture (Valentini et al., 2014).

## 3 The nexus potential of energy policies and investments

Low access to modern energy is only one aspect of poverty. With water and food insecurity threatening entire populations, African governments and international financing institutions face significant tradeoffs when it comes to budget allocation. Investments gaps are huge when it comes to infrastructure development and investors easily shy away from unfriendly business environments and fragile states (Foster and Briceño-Garmendia, 2010). Similarly, budget limitations can influence choices at household level, a key issue for demand-side interventions on water and energy access. Maximising the impact of energy investments in Africa is therefore more than reasonable, it is necessary, and the need to economize investments automatically translates into a search for synergies with non-energy sectors.

Opportunities exist at different scales. At the level of national and regional policy making, for instance, energy system planning could be more coherent with other sectoral strategies, and climate action would be more effective as a consequence (Howells et al., 2013). In particular, spatial planning allows to deliver larger benefits from otherwise scattered infrastructure (Foster and Briceño-Garmendia, 2010), while at the same time the maximisation of their positive impact on society and the environment passes through an inclusive and participatory design of energy delivery models (markets, policy frameworks , regulation etc.) (Bellanca and Garside, 2012). Energy investments can therefore catalyse much needed action in other sectors (e.g. water supply, agriculture, and forestry), but how to make the best of this *nexus potential* of energy solutions?

The fluidity of the nexus concept allows us to take a pragmatic approach to the question. Without aiming at the development of an improved nexus framework, we propose to start from generic considerations of interlinkages between the energy, water and food/land elements of the nexus. We chose three areas where broad cooperation is needed between the energy sector and the other policy areas. On this basis, we put forward three promising renewable energy solutions and we analyse their nexus potential. In our logic, even though technological innovation cannot address, alone, the most pressing social challenges of the nexus (see section 1.1), it offers a base to multiply benefits across sectors and to activate partnerships between public, private, and non-governmental organizations (Sarni, 2015).

Thinking in terms of natural resources, energy immediately stands out as a *product* of their use, just like food. Another common feature with food is that the process of producing, transporting, and using energy has always an *impact* on the environment, and in turn on society. However, unlike food, energy is also a valuable *input* to the nexus. Apart from  energy supply (to households, industry, services), a very basic scheme of the energy resources flow in the nexus would reveal the following key interlinkages with water and food/land[4]:

- Energy input to water (supply and treatment)
- Energy input to food (agri-food supply chain and irrigation)
- Water input to energy (production of electricity)
- Land input to energy (bioenergy, including biomass)

Glancing at this list, it is easy to spot three of the major development challenges for Africa that emerged in section 2, namely: increasing water access, modernizing food production, and reducing the use of biomass.

There are many ways in which energy solutions could contribute to address the above[5], however let us just pick three: multi-purpose hydropower for large scale electricity production, solar pumps for irrigation in farms, and efficient cookstoves for rural households. These solutions are different in terms of energy type (electricity versus biomass), scale of production (centralised versus decentralised), and direct beneficiary (final user, farmer, utility), however they are all renewable[6], which makes them interesting from a sustainability perspective. Also, and most importantly, they are available and applicable in many parts of the continent. It is important to keep in mind that these are only examples which selection has been made with the purpose of illustration, i.e. without a comparative evaluation of other options available.

### 3.1 Multipurpose hydropower

As mentioned in section 2, there is huge hydropower potential still unexploited in the African continent. From an energy perspective, hydropower is a low-carbon technology that offers the opportunity to produce electricity in large quantities and in a dispatchable manner (i.e. electricity production can be initiated and ceased quickly on demand). This makes it particularly attractive in many parts of Africa as it allows to increase baseload generation capacity (hence supporting industrial development with a steady supply) while at the same time balancing the variability of an increasing share of variable renewables (EDF and WWC, 2015) (IRENA, 2012). Moreover, as of today hydropower constitutes the cheapest option for electricity production on large scale in Africa (IRENA, 2015a).

Hydropower plants can be multipurpose as long as they have storage capacity (i.e. they are not run-of-river type), going from small to very large installations (mega dams). The services that they can provide are: domestic water supply, flood and drought management, irrigation, navigation, fisheries/aquaculture, environmental services, recreation, and of course hydropower production (EDF and WWC, 2015). These uses are typically competing with each other. Even though the process of hydropower production in itself does not consume water, it needs large flows at given times. Hence, operating a dam with the single purpose of maximising energy production can translate into severe disruptions of water supply and environmental water requirements, both in the dam area and downstream. A multi-purpose dam, in response, is supposed to balance these different needs.

Water infrastructure in Africa is needed beyond energy production. Higher levels of water storage and irrigation could significantly improve agricultural productivity and resilience to climate change. As part of the initiative "Nexus Dialogue on Water Infrastructure Solutions", the Infrastructure Consortium for Africa

[4] A similar list can be found in (Bazilian et al., 2011)

[5] IRENA's report "Renewable Energy in the Water, Energy & Food Nexus" offer a number of insights on this matter (IRENA, 2015b)

[6] Although it should be noted that the appropriateness of considering large hydropower a renewable source is strongly debated

(ICA) and the International Union for Conservation of Nature (IUCN) point out that without more investments in water infrastructure (both natural and engineered), political choices in the nexus domain[7] remain limited (ICA et al., 2015).

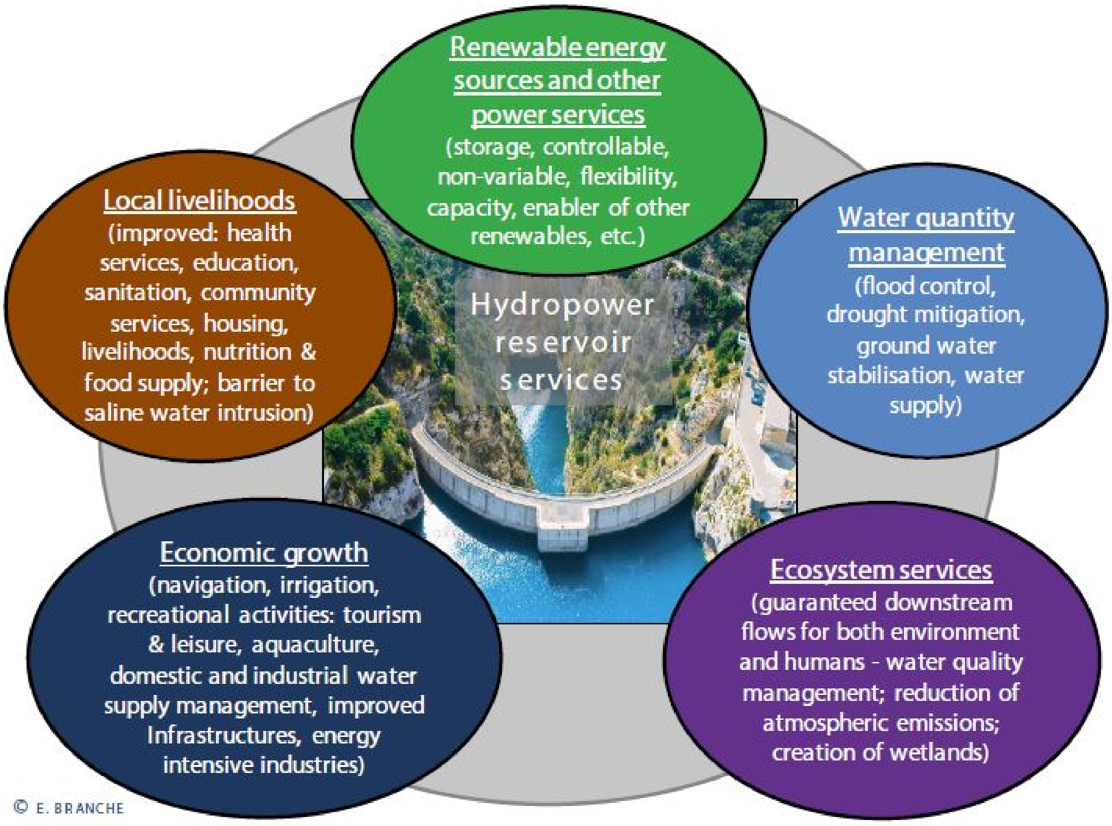


**Figure 3 Benefits of a multipurpose dam. Source: EDF and WWC, 2015**

Building large dams is not straightforward. Dams are infrastructures which construction and operation have a major social and environmental impact, and this is particularly true in Africa where large shares of population rely on the direct use of natural resources for their livelihoods (McCartney, 2007). During the 90s, these concerns caused development institutions to reduce substantially financial support for large hydropower in Africa (McCartney, 2007), a trend that has partially reversed as a result of higher commitment towards energy security (e.g. Ethiopia) and increased foreign investment (e.g. China). Altogether high costs, impacts, and risks make large dams much less bankable then smaller solutions.

It is clear that especially in a situation of water scarcity (be it of natural or economic nature) dams *need* to be multipurpose. However, most hydropower dams that are constructed in Africa are not (ICA et al., 2015), which gives a sense of how disconnected the energy sector can remain from the others, even in a situation where there is a clear common interest: building water infrastructure. Of course, multi-purpose solutions do not come without challenges. Sharing infrastructure means competing over the use of one single, common resource. Hence, it is precisely on the realization of a balance between different uses in the long term that lies the success or failure of a project. The potential benefits are many (Figure 3) but of course

[7] For ICA, the nexus is "*[…] a process for allocating and using resources to ensure water, energy and food security for an ever-growing population at a time of climate change, land use transformation, economic diversification and the need to make development pay*".

their realization need to pass through a delicate process of stakeholder engagement most importantly at community level (EDF and WWC, 2015).

The impact of dams can easily spread across the borders. Africa is the continent with the largest number of shared river basins (over 60) and every nation in sub-Saharan Africa shares at least one basin with its neighbours (Grey, 2002). The building of large hydropower can causes friction among riparian countries (Yale E360, 2017). However, it is often pointed out how these projects can present an opportunity for increased cooperation (AfDB, 2013), in particular for catalysing regional energy integration and share the cost of investment (IEA, 2014).

The uncertainty brought by climate change in Africa future poses questions on the extent to which new power capacity will be matched by water availability. A drier climate may result in over-sizing, a wetter climate in under-sizing, and both mean an economic loss in the long term. On top of that, in some cases dams will face increased runoff and siltation brought by land degradation (HELIO International, 2007). Due to the low confidence of climate projections, planning water infrastructure against a fixed scenario involves a considerable risk, hence a safer option is to go for robust planning across a range of possible climate futures (Cervigni et al., 2015).

While the hydropower sector needs to adapt to climate change, the broader energy system needs to diversify. Rainfall levels have a significant impact on the economic performance of Sub-Saharan African economies (in contrast, for instance, with North African ones), which mostly reflects a high share of GDP coming from rain fed agriculture, but also means that many countries' energy systems heavily depend on hydropower (Barrios Cobos et al., 2008). Indeed, various African countries are already experiencing severe power disruption as a result of low water levels in reservoirs (e.g. in the south (Bloomberg, 2016) and east (Reuters, 2017)).

### 3.2 Solar pumps for irrigation

Irrigation is key for rural development and its improvement and expansion can significantly increase agricultural revenues. For water collection, small farmers often rely on buckets - a labour intensive option - or diesel pumps - an expensive one. Using photovoltaic modules to pump water is an attractive option for farmers who see the benefits of improved productivity, reduced spending on fuel as well as for governments who see the decoupling of agricultural growth from energy subsidies (IRENA, 2016).

Technological and financial innovations are reshaping the agricultural sector and solar irrigation is just one of many solutions that can make the African agricultural sector climate-smarter. There are multiple opportunities to modernise the sector using renewable energies and this is something that more and more entrepreneurs are exploring (Figure 4). Precision farming is becoming possible as digital tools become affordable and accessible (Ekekwe, 2017). In particular, solar powered irrigation can be easily enhanced with drip irrigation and monitoring systems for water consumption, and further combined with fertigation for a more efficient application of nutrients.

The concept of solar pumps is not new, however their deployment among small farmers has been constrained for a long time due to the high costs of photovoltaic panels. Now that their price is dropping, they are becoming affordable and competitive with respect to diesel pumps, but of course there are other costs associated to import, transportation, installation, and maintenance that still need to be covered. As for solar lighting, innovative financing for solar pumps can be designed around on pay-as-you go schemes that are more affordable for farmers and less risky for investors, such as banks and microcredits (Powering Agriculture, n.d.).

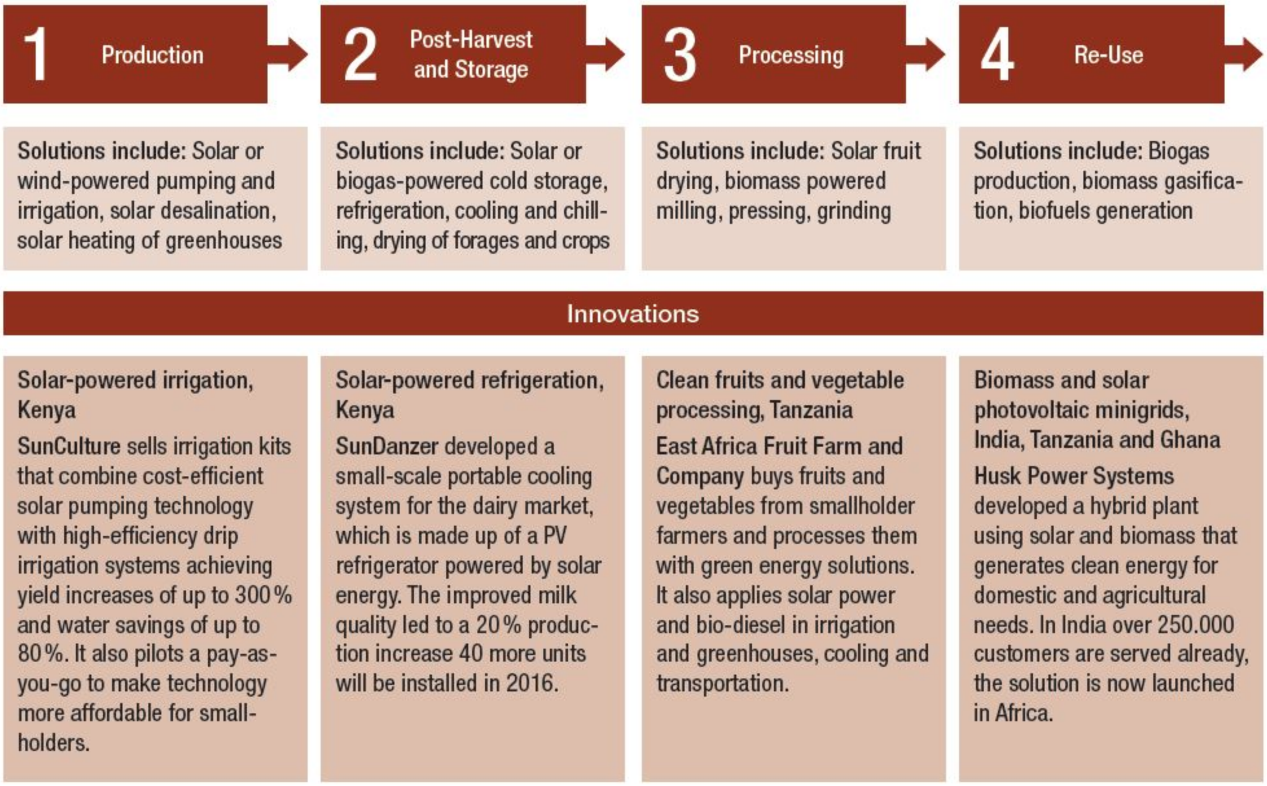


**Figure 4 Opportunities for clean energy technologies along the agricultural value chain. Source: SEED, 2016**

From an environmental perspective, there is a concern that free electricity could drive higher water consumption rates, leading to unsustainable withdrawals of water resources. This problem has occurred in the past (an infamous example is given by the water crisis in Punjab (Columbia Water Center, n.d.)), making it clear that such policies need to be coupled with the appropriate regulation as well as complementary policies. As an example, the opportunity of using solar panels to produce extra-electricity and sell it to the grid could provide an incentive for income diversification, reducing the dependence of farmers on crops and in turn water demand (IRENA, 2016).

Groundwater is key for food security resource in many part of Africa, however its current and future availability is often difficult to quantify with precision, largely because there is limited information on groundwater overall (MacDonald et al., 2012). Moreover, there is uncertainty on future uses and environmental requirements (Pavelic et al., 2013) as well as on the impact of climate change (e.g. modelling by the African Progress Panel predicts that while West Africa will experience heavy decreases in groundwater recharge rates, higher rainfalls could increase groundwater reserves in the Horn of Africa (Africa Progress Panel, 2015)). Notwithstanding regional trends, the widespread adoption of cheap irrigation at local level can create hotspots of groundwater depletion, which suggests that advancing regulation and awareness on this issue independently from projections can be a strategic move.

Deploying irrigation in a sustainable way that benefits the poor is particularly challenging in Africa because of deeper issues of land tenure that remain largely unsolved (World bank, 2013). A lack of land ownership discourages the adoption of a long-term, sustainable approach to agriculture among tenant farmers (Xie et al., 2014) and at the same time the deployment of new technologies can end up benefiting the owners of large farms (who can make economy of scale) more than smallholders, thereby deepening inequality. Notably this is one of the key message from a study on the effects of large scale deployment of drip irrigation in Morocco that also pointed at how up-scaling water-efficient irrigation can actually result in higher overall withdrawals (Jobbins et al., 2015).

### 3.3 Efficient cookstoves

Switching from fuelwood is a complex challenge that, as of today, remains far from resolved. If it is true that modern alternatives to wood are often simply unavailable, even when they are they may not be affordable or applicable. The adoption of alternative cooking options needs to pass a test of "customer satisfaction" and overcome a generalised lack of awareness of the negative effects of fuelwood on health and environment, obstacles that caused several programs to fail even when cookstoves were subsidized by the government (Global Alliance for Clean Cookstoves, 2011).

Within the realm of petroleum based fuels, highly flammable ones (e.g. kerosene) can turn out to be a dangerous option in rural households. While there are safer solutions (e.g. LPG), the high cost of fuel (at least compared to wood) means that these need to be backed by heavy subsidies, which can be a realistic option for a few countries only. This motivates the interest in other, cleaner, alternatives.

*Clean cookstove* is a loose definition that indicates lower direct (indoor) and indirect (greenhouse gas) emissions as compared to the baseline of many developing countries: wood burnt in an open fire or inside a rudimentary cookstove. Theoretically available *clean* options range from electric cookstoves (which in turn can be cleaner or dirtier depending on the source of electricity) to cookstoves based on a clean fuel (e.g. biogas, solar), to traditional cookstoves (using wood and charcoal) which design is modified to improve efficiency[8] (Differ Group, 2012).

While the latter option is often the dirtiest, in many contexts it is also the most applicable, at least at present. Efficient cookstoves encounter less resistance than cleaner options because their use does not involve any fuel switch and does not significantly alter the habitual cooking process. For users, the appeal of this option lies in reduced fuel use and reduced cooking time more than in the health and environmental benefits brought by a more efficient combustion process (Differ Group, 2012).

In principle, higher efficiency brings to lower wood consumption, reduced forest degradation[9], and in turn to lower emissions as well as improved preservation of vital ecosystem services related to forests (e.g. biodiversity). The integration of water and land management in the framework of adaptation-mitigation response to climate change can strongly increase resilience (Niang et al., 2014). As forests are natural water buffers, they are essential for the water cycle, on which functioning depends the quantity and quality of water that reaches all users (including hydropower). As such, managing forests can be key to mitigate problems of water scarcity and global warming (Ellison et al., 2017).

When it comes to deforestation, it is clear that the uptake of efficient cookstoves can only contribute to a certain extent. In order to start seeing results it is necessary to modernise the whole wood energy value

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[8] The account of emissions would need to be made on a case by case basis. For instance, biogas burning can be associated with significant emissions, while emissions from wood and charcoal can be reduced substantially when the resource is sustainably managed.

[9] Logging causes forest degradation, in contrast with deforestation that is driven mostly by the expansion of agricultural and urban areas. However, when degradation becomes overexploitation, it can cause deforestation.

chain, taking action beyond the demand side. This includes supporting the creation of a functioning woodfuel market, investing in sustainable forest management and, crucially, addressing problems of land tenure and land use (Figure 5). In other words, biomass production should be integrated into a broader picture of bioeconomy, where both sustainable production and use of biomass are properly rewarded (IRENA et al., 2017).

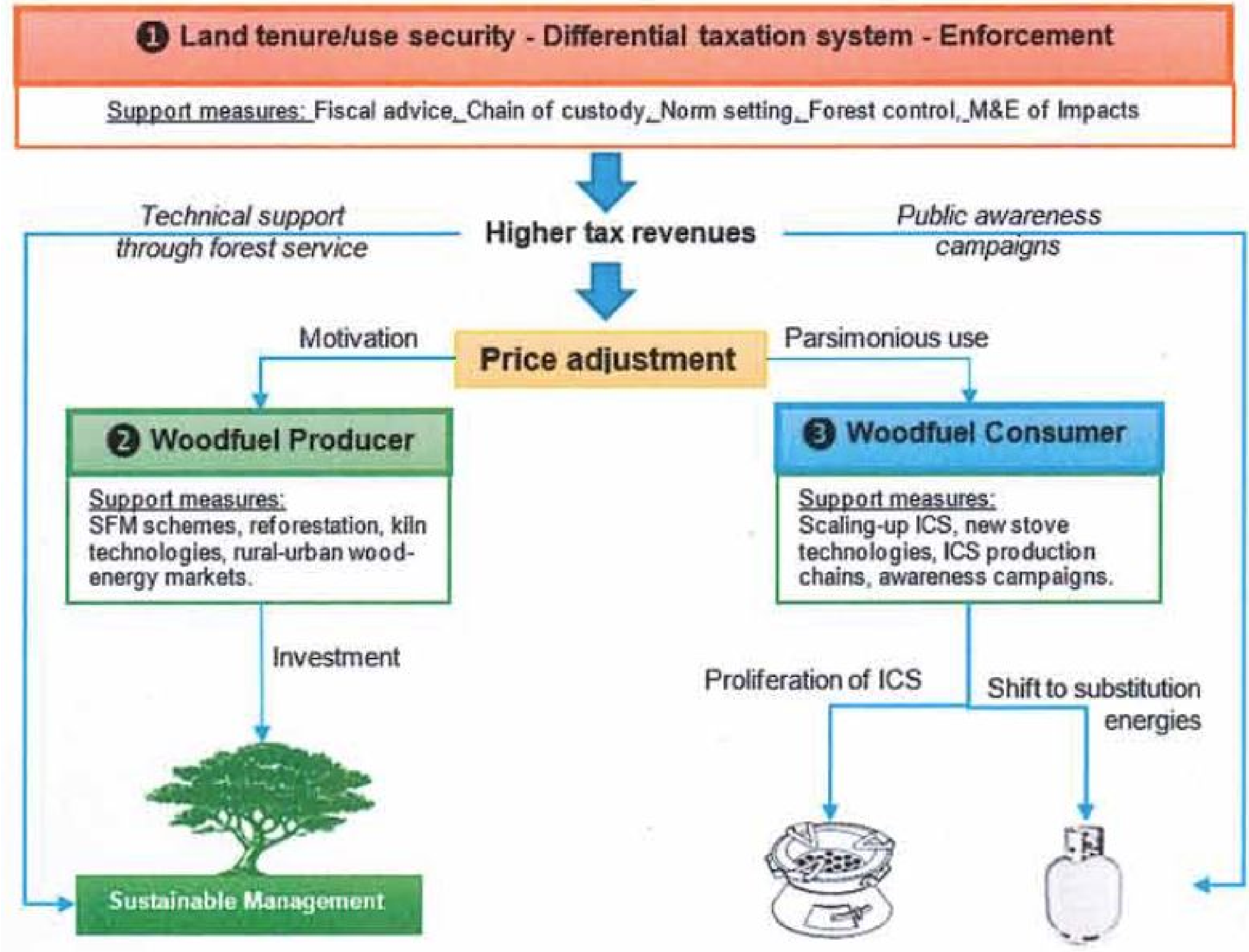


**Figure 5 Measures and their impact structure of wood energy value chain development. Source: GIZ, 2014**

Governments tend to give low priority to wood energy policies as compared, for instance, to electrification. Still, wood and charcoal consumption keep on increasing (see section 2.2) and the real picture is likely to be worse than that pictured by official data because a large part of the sector is informal and therefore excluded from official accounts (GIZ, 2014). If it's true that switching to electricity would bring higher benefits because it is (in principle) the cleanest option, it is also unlikely that this will happen overnight. Even where available, electricity may remain an expensive and impractical option for a long time, while cleaner cookstoves, and efficient ones in particular, can act as a transitory solution (Differ Group, 2012).

At the local level, efficient cookstoves can grow to create a considerable market and trigger social development. It is becoming clear that local manufacturers are able to respond much better to the users' needs than governments and humanitarian agencies. Customized solutions can compete in price with mass-produced ones and perform better (Differ Group, 2012). Moreover, their local production triggers the creation of a market for local businesses, from manufacture to distribution, customer support, and so on. This adds to the already significant market of biomass (wood and charcoal), which in Africa employs tensto-hundreds thousands of people (World Bank et al., 2011). Given the economic weight of the sector, developing a sustainable wood and charcoal value chain holds a tremendous potential for rural employment (GIZ, 2014). Women groups can lead the way to the adoption of improved cooking facilities because they are the first to see the benefits on their own health and security as well as on the household economy. Women can also play a key role in the creation of markets for alternative fuels (e.g. biogas and agricultural waste), as well as capacity building and environmental awareness in forestry (GIZ, 2014; UNEP and UNDP, 2017).

### 3.4 Nexus solutions?

Now let us discuss the nexus potential of the energy solutions just illustrated. To some extent, a *nexus map* (Figure 6) allows us to visualize what inter-sectoral links need to be established between the energy and the water and agricultural sectors in order to make a particular energy solution environmentally sustainable, at least in principle. However its applicability and actual impact, as we will see, can only be evaluated by broadening up this scheme and focusing specifically on the local conditions where the solution is implemented.

Figure 6 simply shows how solutions relate to the water and land/food spheres of the nexus[10]. Going back to the basic principles of a nexus approach (i.e. investing to sustain ecosystem services, creating more with less, accelerating access and integrating the poorest), it is clear that there are a number of elements to consider, and only some of them can be pictured in this (basic) nexus map. Still, this scheme is useful to visualize areas where cooperation is needed.

Two of the solutions we described (multipurpose hydropower and solar pumps) are inherently cross-sectoral. A multipurpose dam, by definition, serves various water users, and – at least in Africa where the agricultural sector is so vulnerable - providing water for irrigation can be considered the minimum requirement for a hydropower dam to be called multipurpose. Similarly, at a smaller scale, solar pumps allow farmers to access water using clean energy. In contrast, the third solution (efficient cookstoves) only serves the purpose of improving energy access (as its contribution to reducing wood consumption, we have seen, is only potential). These elements are represented by in Figure 6 by solid lines.

Then there are further elements that go beyond the mere design of each energy solution, which establishment depends on the effectiveness of cross sectoral cooperation and environmental regulation. Hence they are represented by dashed lines. Namely, a multipurpose hydropower dam *can* ensure a balance of various water uses, safeguard ecosystems and be resilient to climate change; the implementation of solar pumps *can* go hand on hand with appropriate regulation on water abstraction, integrate sustainable soil management, and stimulate a broader energization of rural areas; the deployment of efficient cookstoves *can* be part of a modern value chain for bioenergy that ensures sustainable wood production and forest conservation (in turn a vital element of integrated water resource management at the level of watershed).

This means that putting in place renewable energy solutions aimed at increasing access to energy (as well as to water, for two of our examples) cannot ensure, alone, that this will happen in a sustainable way. It is necessary to put in place appropriate regulatory frameworks and mechanisms for intersectoral cooperation and value chain integration. In this logic, the nexus potential can be harnessed as much by appropriately

[10] Note the choice of including a "land/food" element, which allows to include both the 'security' aspect of food and the 'resource' nature of land.

designing energy solutions as by properly coordinating with other players (particularly in the case of cookstoves, their potential lies entirely *beyond* their design).

This type of insight is useful for policy makers to map areas where water- land/food-energy intersectoral linkages should be strengthened in order to deploy energy solutions on large scales without depleting resource stocks. The examples point at the need to increase cross-sectoral cooperation in two ways: vertically along value chains and horizontally among stakeholders (and relative institutions), considering environmental needs and climate constraints.

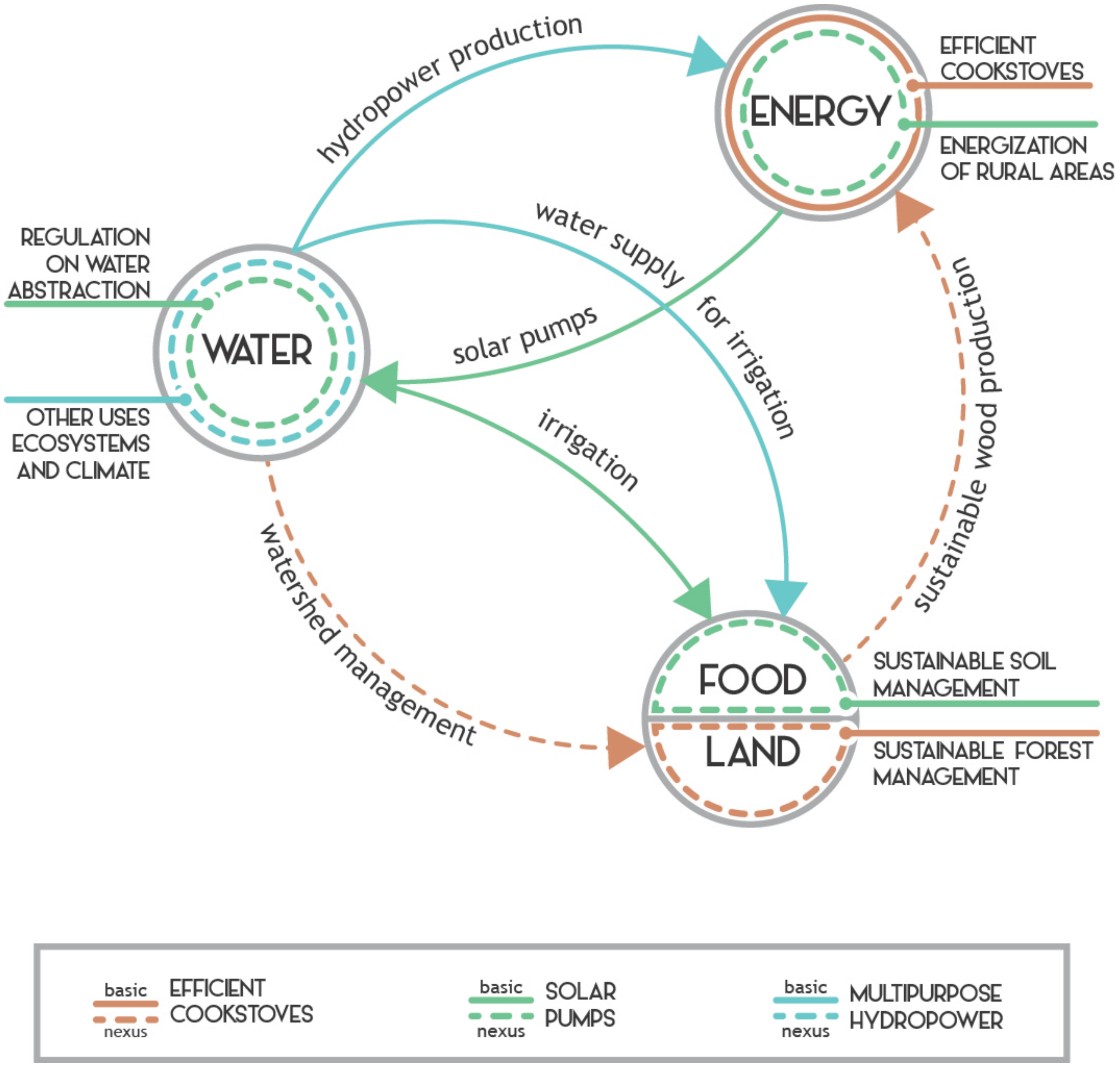


Figure 6 Position of the three examples of energy solutions in the nexus framework

Notably, failing to tackle the environmental sustainability issues of energy solutions not only impacts other sectors that rely on the same water and land resources, but also undermines the long-term usability of the energy solutions themselves. So if water becomes scarce agricultural supply may be given priority over hydropower production; if groundwater levels drop too much or agricultural soil is degraded, irrigation becomes challenging or less effective; if forests get depleted, efficient cookstoves start lacking fuel and become useless.

However, do these solutions actually reach the poor? How do they sustain ecosystem services? When assessing the impact of nexus solutions it is important to go beyond resource efficiency, and unsurprisingly our very basic scheme of the water-land/food-energy nexus proves to be an insufficient framework[11]. Indeed, this scheme magnifies the three elements of water, land/food and energy and their (physical) interlinkages at the expense of other important elements (e.g. livelihoods, climate, health, biodiversity) and related interlinkages with energy (e.g. pollution, greenhouse gas emissions, impact on habitats).

The examples we gave indicate that the successful implementation of an energy solution depends on how well it adapts to the real needs of final beneficiaries and how it makes the best of the opportunities the local context has to offer. This, of course, requires passing from passive consultation to active participation. We see this in all examples: the most critical (and delicate) element in the decision making process of water allocation and compensation for multipurpose dams is an effective stakeholder engagement that puts forward the needs of local communities; the key driver to the deployment of solar pumps (and modern, clean technologies in general) is the development of appropriate business models that reflect the farmers' ability to pay and ambition to diversify their income; the uptake of a certain technology of cookstoves lies both in its attractiveness for users and the prospect of establishing, or improving, a local market of stoves and fuels.

It is ultimately this effectiveness at local level that allows us to step back and look at the big picture once again, accounting for the final benefits of energy solutions on a large scale. Improvements can be seen in terms of climate resilience, forest preservation, health and economy. About the latter, it can be noted that it is not only agriculture that benefits from the consideration of local needs and opportunities. For instance, energizing key productive sectors (such as, significantly for many African countries, mining) can accelerate the deployment of mini-grids, bringing about the multiple benefits of rural electrification.

When it comes to trade-offs, it is tricky to compare those brought by the construction of a dam to those brought by the introduction of a certain type of pump or cookstove. Dams are large projects that can affect entire communities at once, and there is no way of testing their appropriateness with pilot projects, for instance in rural households (cookstoves) or farmer groups (pumps). Still, trade-offs typically materialize across scales and this is true not only for large infrastructural projects, but also for the deployment of small solutions on a large scale: see for instance the risk of groundwater depletion when it comes to solar pumps or the missed opportunity to invest in cleaner solutions when it comes to efficient cookstoves.

## 4 Conclusions and recommendations

This paper argues that despite resting on a largely elusive definition, a *nexus* approach to sustainable development in Africa is necessary, particularly when it comes to water, energy, and food policies. Such an approach should be embedded in policy making as much as in the design of specific projects, in order to ensure coherence and coordination of action on one hand, and to exploit to the maximum the potential of each investment on the other. In order to give concrete recommendations for policy makers, we propose a pragmatic way of thinking about the nexus and to do so we go back to the basic principles of the nexus

[11] It is possible, of course, to improve and refine this picture in order to include other elements (e.g. economy, health, ecosystems). Notably, the framework proposed by (Biggs et al., 2015) which seeks to internalise the concept of environmental livelihoods in the water-food-energy nexus, is a good starting point.

approach as put forward in its original manifesto (increasing access, improve efficiency, benefiting the poor and preserving ecosystems).

First of all, it is important to identify critical challenges that the energy sector can contribute to solve by ensuring better policy coherence. Particularly in Africa, development challenges are complex and issues are compounded, which means that sustainable development goals should be thought of in a systemic way. In particular, improving and modernizing energy access can significantly contribute to improving access to water and sanitation, enhance food security and rural development, and advance climate mitigation and adaptation. This means that it is of outmost importance to streamline energy policies within the broader framework of the SDGs. The international community has an important role to play here. There are already a number of initiatives that encourage a nexus approach to energy policy development, notably the Sustainable Energy for All initiative (SE4A) that features the water-food-energy nexus in its list of "High Impact Opportunities" action areas. The SE4A is a well-established intergovernmental platform where policy makers can share their experiences and lessons learned.

Specifically when it comes to infrastructure development, dialogue needs to be improved among international organizations, governments and the private sector. International financing institutions are best positioned to take a lead on transboundary, regional, and continental coordination (e.g. through the African Development Bank's Programme for Infrastructure Development in Africa (PIDA)) as well as on knowledge development and capacity building in the area of water-energy integrated planning (e.g. along the lines of the World Bank's Thirsty Energy initiative that looks beyond hydropower to include thermal power production and the fossil fuel industry).

When looking at energy technologies, it is worth asking how they stands in relation to the bigger picture of the water-food-energy nexus and to map areas where cooperation can be activated. The options are many and of course renewable technology solutions make sense due to their vast potential available in the continent. In this paper, we only gave three examples: multipurpose hydropower, solar pumps, and efficient cookstoves, which have the potential to increase water access, modernize food production, and reduce the use of biomass respectively. As illustrated, realizing this potential means strengthening cooperation in different ways.

At national level, the first dimension where cooperation needs to be strengthened is horizontal, meaning across ministries and agencies. For instance, energy and agricultural ministries should work together to develop concrete plans to make the sector climate-smarter and more resilient, as well as to facilitate rural electrification developments linked to agri-food businesses. Similarly, environmental needs need to be better included in energy policy making. This is true not only for large infrastructure (e.g. ensuring ecological flows in the operation of hydropower) but also when it comes to upscaling solutions like small-scale solar pumps (e.g. putting in place mechanisms to avoid groundwater depletion).

Furthermore, coordination may need to be strengthened vertically along value chains. This is the case of bioenergy. Capillary interventions for improving cookstove efficiency on the demand side needs to be framed in a broader policy of modern woodfuel production and sustainable forest management. The attainable benefits go beyond a reduction forest degradation, including local job creation, stronger control over a largely informal sector, gender empowerment, improvement of health conditions, climate mitigation, and improved water management. As discussed, the way forward here is to generate stronger political commitment towards a largely neglected aspect of the clean energy transition (e.g. within the mandate of national Renewable Energy Agencies).

When it comes to the actual implementation of energy projects, social impact stands out as the most critical aspect of the nexus. Here the water-food-energy nexus framework falls too short of details, and it becomes necessary to think in terms of local constraints and opportunities. The applicability of particular solution is to be evaluated on a case by case basis and, at the same time, its particular design needs to be context specific - in line with an interpretation of the nexus that sees reflexion (i.e. the account of errors and uncertainties) and reflexivity (i.e. the account of different perspectives) as guiding principles in the quest for solutions to complex problems. Going back to our examples, investors can refer to guidelines that specifically target the final beneficiaries, such as: ECOWAS' "Guidelines for the development of water infrastructure in West Africa" (ECOWAS, 2012), GACC's "Conceptual framework to measure social impact" (Global Alliance for Clean Cookstoves, 2016)) and IWMI's "Framework for business model development for incentivizing adoption of solar pumps" (CGIAR and IWMI, 2017).

Special attention should be given to small entrepreneurs, demand-driven innovation, and customized solutions. In particular, local start-ups have a major role to play in the uptake of renewable solutions in agriculture, but governments need to be supportive. The development of appropriate information and communication technologies, increased access to finance, and targeted subsidies stand out as particularly important actions that need to be taken at national level.

Lastly, considerations on resource use efficiency and multiple benefits should not hide social challenges which are often at the root of environmental and resource-related problems. As partly illustrated in this paper, the poverty-environmental degradation link can only be broken with an improvement of socio-economic conditions that passes not only through sustainable development, but also social justice and inclusion. So for the poorest to benefit from technological innovation, not only governments need to put in place appropriate incentives (e.g. cross-subsidies, tax exemptions), they may also need embark on structural reforms (e.g. on land tenure).

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