

Energy Access, Climate Change and Water Use: Synergies and Trade-offs

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Abstract

Clean and affordable energy is central to the 2030 Agenda for Sustainable Development and in particular to climate change mitigation. On the one hand, SDG 7 calls for ensuring universal access by 2030. On the other hand, SDG 13 invites to take urgent action to combat climate change and its impacts. Energy production and use account for around two thirds of global greenhouse gas emissions and sustainable energy systems are essential in achieving a low-carbon economy and reducing emissions. In order to mitigate the risk of climate change, it is crucial to reduce energy consumption (Target 7.3) and improve the mix of energy sources in favour of renewables (Target 7.2), or in favour of less carbon-intensive fossil fuels. Nevertheless, universal access to energy (Target 7.1) could limit the options for achieving climate mitigation strategies since energy access can be achieved through both renewable and traditional energy generation systems.

Indeed, should universal access to energy be achieved by 2030 final energy consumption would increase by 7% (IEA, 2011). Sub-Saharan Africa (SSA), the region with one of the highest energy poverty rates, would contribute to the global share of electricity-related CO₂ emissions by only 0.7% by 2030. Moreover, since global energy consumption is projected to grow by one third by 2035 (IEA 2013) this would lead to an increase in the global water use. Sub-Saharan Africa (SSA) is subject to extreme climate variability and it is the region with the highest water stress level, which implies increased water scarcity and serious consequences on energy security and supply. All types of energy generation consume water either through their process of accessing the raw materials or operating and maintaining the power plants. However renewable energies, especially wind and solar, have the lowest water footprint. Therefore, the move towards clean and sustainable energy not only would contribute to climate change mitigation but could also reduce water consumption (biofuels excluded).

Understanding the interlinkages between water, energy and climate plays a crucial role in delivering sustainable outcome and assisting communities in their collective efforts to

implement the SDGs. The analysis investigates interlinkages among the Goals with a focus on SDG 7, SDG 6 and SDG 13 starting from the perspective of universal access to energy (Target 7.1). Results show that although access to energy may seemingly counteract climate change mitigation, providing universal access to energy is expected to have a small impact on global CO2 emissions. Results also show that if developing nations may overcome technological lock-ins and develop their energy infrastructure based on sustainable and off-grid energy systems, this counter-effect would be minimal compared to the benefits in terms of emissions reduction, water saving, social inclusion and economic development.

List of Contents

| | |
|---|----|
| 1. Introduction..... | 3 |
| 2. Water Energy Climate Nexus..... | 4 |
| 2.1 Water Energy Nexus | 4 |
| 2.1.1 RES and water footprint | 5 |
| 2.2 Climate Energy Nexus..... | 6 |
| 2.2.1 Climate Change Impact on RES Generation | 7 |
| 3. Energy Access and Climate Change Mitigation: Synergies and Trade-offs? | 7 |
| 3.1 Energy Access and Growth | 7 |
| 3.2 Energy Access and GHG Emissions | 9 |
| 4. Energy Access and Climate Change Mitigation in Sub-Saharan Africa..... | 10 |
| 5. Technological innovation, water saving and energy efficiency..... | 13 |
| 6. Conclusions..... | 13 |
| References..... | 14 |

1. Introduction

The Water-Energy-Food and Climate nexus (WEF nexus) addresses the interrelated nature of our global natural resource systems. The nexus is a key topic in the 2030 Agenda for Sustainable Development launched in 2015 and setting 17 Sustainable Development Goals (SDGs). The 2030 Agenda touches on multiple Goals, namely SDG 6 (Ensure availability and sustainable management of water and sanitation for all); SDG 7 (Ensure access to affordable, reliable, sustainable and modern energy for all); SDG 2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture); SDG 13 (Take urgent action to combat climate change and its impacts). It aims to tackle simultaneously different issues, such as food and water security, the connection between global warming and water scarcity, and between climate change and food production, as well as energy security, and the connection between energy production and water and land use. For the purpose of this work, which is aimed at analyzing the interlinkages between energy and water and the impact of climate change, the food nexus is outside the scope of this analysis and will not be investigated.

Global projections indicate that demand for freshwater and energy will increase significantly over the next decades under the pressure of population growth and mobility, economic development, international trade, urbanization, cultural and technological changes, and climate change.¹ Climate change will exacerbate the pressures and risks associated with variations in the availability and distribution of water resources, and consequently of energy supply. Global energy consumption is projected to grow by one third, with the demand for electricity having the lion's share with a 70 percent increase by 2035². By 2050, global water demand is projected to increase by 55 percent, driven mainly by growing urbanization in developing countries.

The issue of water security gained a growing attention after the Johannesburg conference which marked the tenth anniversary after the Rio Conference in 2002³. "Water is essential not only for survival but also for the bare necessities of life. It is also a necessity for the realization of each individual's potential"⁴ Lack of access to basic service such as water leads to hunger and poverty and is a demonstration of inequality. "Without planetary stewardship for water resilience, it is difficult to see how the world could eradicate poverty and hunger, two of the emerging Sustainable Development Goals to replace the MDGs"⁵.

Alike the integrated water resources management (IWRM), the WEF nexus approach considers the different dimensions of water, energy (and food) on the same level playing field and recognizes the interdependencies of different resource uses. Water management impact possibilities for energy security and food security, "particularly within an era of globalization under the overarching context of climate change"⁶.

The paper is organized as follows: section 2 that analyses the WEF nexus from a two-fold perspective, first the interaction between water and energy, with an in-depth analysis of the water renewables interlinkage, and second the interaction between climate change and energy with an in-depth analysis of climate change impact on renewables; section 3 investigates the synergies and trade-offs existing between energy access and climate change mitigation, with a first paragraph on the relation between energy access and growth, and a second one on the interaction between energy access and GHG emissions; section 4 analyses the interaction of energy access and climate change mitigation in Sub-Saharan Africa; section

¹ Hoff, 2011

² IEA, 2013

³ Schmidt, 2017

⁴ Henri and Tubiana, 2018: p. 35

⁵ Rockstrom *et al.*, 2014: p. 165

⁶ Swatuk and Cash 2018: p. 2

5 proposes some concrete solutions to energy access, energy and water security and to climate change mitigation challenges; section 6 concludes.

2. Water Energy Climate Nexus

Improving access to water is not trivial. Water is not homogeneously available and the variation in its distribution does not fully explain water scarcity. Shocks associated with water are usually attributed to either scarcity or abundance of water. Climate change exacerbates the magnitude and frequency of such shocks and makes them more unpredictable. Extreme events such as El Nino can impact on both the quantity and quality of available water in a given region and time, further increasing the negative impacts of natural disasters⁷. Since climate change adds uncertainty to existing supplies of freshwater, given their interlinkage energy security will inevitably be impacted by water availability, resulting in mutual vulnerability.⁸

2.1 Water Energy Nexus

Water and energy are closely interdependent, as they are major consumers of one another, and choices made in one domain have direct or indirect consequences on the other. Energy is required for the extraction, treatment and distribution of water, and electricity accounts for an estimated 5-30 percent of the total operating cost of water and wastewater utilities. On the other hand, water is required to produce, transport and use nearly all forms of energy. Freshwater withdrawals for energy production accounted in 2010 for 15 percent of the world's total water use and are expected to increase by 20 percent through 2035⁹.

The power sector's dependence on water creates vulnerabilities and risks that are exacerbated by extreme weather events induced by climate change. Severe droughts or elevated temperatures may lead to diminishing the performance of thermal power plants - which are high water intensive - or can even hinder the capacity of the power sector to achieve sufficient cooling, thus leading to power outages. Therefore, water constraints are among the most important factors for deciding where to build power plants and what specific cooling system to opt for. Cooling systems without the use of water exist, such as air cooling, but at present these are prohibitively expensive. Conversely, climate change can also benefit electricity production in certain areas exposed to an increase in precipitations.

Unlike the water sector, the energy sector can switch to other resources. Water resources required in power generation can be substituted, e.g. by solar and wind energy. The latter not only have a very low carbon footprint, but also consume little water. Nevertheless, wind and solar energy have the important disadvantage of being intermittent and thus needing base load systems such as thermal power or hydropower. Conversely, although other Renewable Energy Sources (RES) such as concentrated solar power reduces the carbon footprint, it has a large water footprint. Among RES a special focus is reserved to geothermal energy power plants, which have the dual advantage of producing base load and clean energy and of having a low water footprint (see a more in-depth analysis of RES and water use in the next paragraph).

As for fossil fuel-based energy, thermal power plants use large quantities of water because of cooling systems that are responsible for around 50 percent of total freshwater withdrawal. In

⁷ Anand, 2007

⁸ Pittock *et al.*, 2015

⁹ IEA, 2013

the upstream sector, extraction and production of unconventional energy sources are much more water intensive than conventional oil and gas. Both the hydraulic fracturing technique (better known as fracking) for shale gas extraction, and open-pit mining or in situ drilling techniques for tar sand extraction require a barrel of water for each barrel of gas and oil produced.

In the field of climate change mitigation, Carbon Capture and Sequestration (CCS) systems are very important in any national decarbonization pathway. Nevertheless, implementing CCS in an existing power station will have some effect on its water consumption, requiring additional water for cooling. Estimates show that with the addition of a CCS system, the increase in water consumption per megawatt of electrical output can be as high as 90 percent.

Having treated water consumption issues in energy production, we will now make one example of energy need for water production. Desalination of salt water and pumping of freshwater supplies over long distances may contribute to reducing water scarcity, but in the process it will increase energy use. Desalinated seawater is very high energy intensive compared to clean water from locally produced surface water and from reclaimed wastewater. Moreover, the two most common techniques for desalination have both an important although different water footprint. Indeed, if reverse osmosis plants consume 4-6 kWh to desalinate one cubic metre of treated water, the multistage flash technique consumes much more, up to 21-58 kWh per cubic metre.

In brief, water and energy are closely interlinked, and the use of each resource has an impact on the use of the other. Therefore, interaction between energy and water can be considered as bidirectional, meaning that both A impacts B and B impacts A. This is evident from Target 6.4, which calls for substantially increase water-use efficiency across all sectors, and with Targets 7.1 and 7.2 calling for universal access to affordable, reliable and modern energy services and the substantial increase of the share of renewable energy in the global energy mix, respectively. Against this background, a well-balanced natural resources management should take this interaction into account when tackling the issues of energy and water scarcity.

2.1.1 RES and water footprint

This paragraph investigates how a shift towards renewable electricity could positively impact the electricity generation dependence on water resources. If translated into a research question: how can renewable energy improve the reliability of our electricity system while not burdening our water resources?

Life-cycle analysis is used to quantify the full impact of renewable energy technologies on water resources. While the water used to operate power plants presents vulnerability to constraints in local water supplies, water withdrawn for equipment manufacturing can present direct and indirect impacts, depending both on water availability and on the manufacturing locations. “For wind and photovoltaic power, the largest component of life-cycle water withdrawal and consumption is for the manufacturing and construction of power facilities, where the manufacturing facilities are often in a different water basin from the power facility. For geothermal and concentrated solar power, cooling dominates the life-cycle water use, and most of the water withdrawn and consumed is in the same water basin where the production facility is located. Unlike electricity generated by fossil fuels, renewable technologies have few upstream water impacts”.¹⁰

¹⁰ Pittock *et al.*, 2015: p. 70

In the case of intermittent renewable energies, wind and solar energy, the use of water is negligible. In wind generation water is mainly used to wash the turbines blades, conversely wind power has been used - especially in the United States - to provide energy for near-surface groundwater extraction for agriculture use. In photovoltaic solar power (PV) water is used in a small amount to manufacture modules, and almost no water is consumed for PV electricity generation, as opposed to most concentrated solar power (CSP) technologies that use a thermal cycle and thus require cooling water. Water withdrawals and consumption in CSP plants whether power towers, linear fresnel or parabolic troughs – can be relevant and reach 1,000 or more gallons per megawatt-hour, whereas Dish Stirling technology uses water only for required periodic cleaning.¹¹

The water requirements of geothermal power plants vary depending on technology and local conditions. At the hottest geothermal resources, it is possible to directly pull steam through the turbine into a condenser where the steam is condensed into water. In ‘flash’ geothermal plants, very hot water is depressurized into steam, which can then be used to drive the turbine. If the water from the geothermal resources is not hot enough for direct or flash designs, a more complex process called binary generation is used.¹² In particular, geothermal binary cycle power plants utilize a closed loop system allowing for the re-injection of water back into the geothermal reservoir.

Hydroelectric energy uses the energy of water moving from higher to lower elevations to generate electricity. Hydropower encompasses dam projects with reservoirs, run-of-river and in-stream projects and therefore it has a large water footprint. However, unlike geothermal energy which can have an impact on the quality of water and on the safety of drinking water, as the superheated water dissolves solids underground and brings them to the surface, hydroelectric energy does not have an impact on the quality of water. Moreover, hydropower is becoming an important source for energy storage and could contribute to balance electricity systems that have large amounts of variable RE generation¹³. As of 2017 up to 118,596 MW of pure pumped storage capacity is available globally¹⁴. In brief, geothermal and hydropower have the characteristics that could improve the reliability of the electricity system while not burdening water resources.

2.2 Climate Energy Nexus

The energy sector is the largest contributor to global Greenhouse Gas (GHG) emissions, representing roughly two-thirds of all anthropogenic GHG. Within the energy sector, electricity generation is the largest single sector emitting fossil fuel CO₂ at present and in baseline scenarios of the future. The electricity sector plays, therefore, a major role in mitigation scenarios with deep cuts of GHG emissions. A variety of climate change mitigation options exist in the electricity sector, including renewable energy generation. The lifecycle GHG emissions normalized per unit of electrical output (g CO₂eq/kWh) from technologies powered by RE sources are less than from those powered by fossil fuel-based resources.¹⁵

Conversely, climate energy nexus can be explained (see paragraph 2.2.1) by the impact of climate change on energy generation, on the reliability of the energy system and in general on the efficiency of the generation systems as a whole.

¹¹ *Idem*

¹² *Idem*

¹³ IPCC, 2012

¹⁴ IRENA, 2018

¹⁵ IPCC, 2012

2.2.1 Climate Change Impact on RES Generation

Geothermal energy is not dependent on climate conditions and climate change is not expected to have a significant impact on the resource potential. However, on a local level some effect of climate change on rainfall distribution may have a long-term impact on geothermal potential. With its natural thermal storage capacity, geothermal energy is suitable for supplying base-load electricity and thus useful for the electricity system stability in presence of intermittent renewable resources (wind and solar).

Hydropower is highly dependent on the volume, variability and seasonal distribution of the runoff and, therefore, is vulnerable to climate change effects. A shift in winter precipitation from snow to rain due to increased air temperature may lead to a temporal shift in peak flow and winter conditions in many continental and mountain regions.¹⁶ As glaciers retreat due to warming, river flows would be expected to increase in the short term but decline once the glaciers disappear.¹⁷ On the other hand, in Sub-Saharan Africa droughts have caused a reduced hydropower production (e.g., in Ghana and Kenya).

3. Energy Access and Climate Change Mitigation: Synergies and Trade-offs?

Access to energy is key for socio-economic development and growth. [Decoupling of global energy-related emissions and economic growth](#) is therefore pivotal, especially in developing countries. Despite energy is responsible for two third of GHG emissions globally, and CO2 emissions from the energy sector have risen over the past century to ever higher levels, providing universal access to energy is expected to have a small impact on global CO2 emissions.

3.1 Energy Access and Growth

Energy is an input to support the delivery of fundamental services such as health, education and other social services.¹⁸ The lack of modern and clean energy services negatively affects agricultural and economic productivity, and other opportunities for income generation.¹⁹ The link between energy availability and development is summarized in Figure 1, which reports the relationship between the Human Development Index (HDI) and the energy access (indicated by per capita electricity consumption). The relationship is not linear: at low levels of HDI, a little increase in energy availability results in a significant growth in development, which is why energy availability is fundamental especially in developing countries. "Variations in modern energy consumption across countries partly explain the wide variations in human development, even among developing countries"²⁰. Also, variations exist within countries, with a significant disparity in terms of access to electricity between rural and urban populations.²¹

¹⁶ Stickler and Alfredsen, 2009

¹⁷ IPCC, 2008

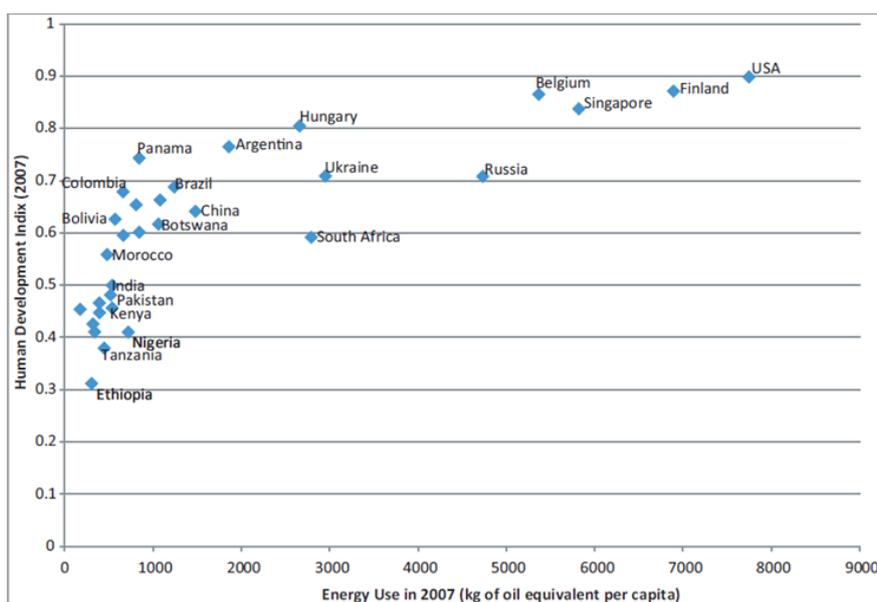
¹⁸ Bonan *et al.*, 2016

¹⁹ Alloisio *et al.*, 2017: pp. 4-7

²⁰ UNDP, 2007: p. 3

²¹ IEA, 2010

Figure 1: Correlation between the HDI and electricity consumption per capita



Source: Karekezi et al., 2012

According to IEA, 1.18 billion people (16 percent of the global population) lack access to electricity, and 2.74 billion (40 percent of the global population) rely on traditional cooking methods based on the use of biomass (IEA 2016). However, the geographical distribution of energy poors is uneven. People without access to electricity are mostly based in Africa (53 percent) and developing Asia (43 percent). Similarly, those still relying on traditional cookstoves and fuels are concentrated mostly in developing Asia (68 percent) and Africa (29 percent).

Energy poverty is defined as lack, scarcity or difficulty in accessing modern energy services by households, in particular it refers to the access to electricity and to modern and clean cooking facilities. In the 2030 Agenda for Sustainable Development, SDG 7.1 indicators to evaluate access to energy are two: the first one is access to electricity, the second one is referred to the use of solid fuels for households (i.e. heating and cooking).²²

Electricity is considered as the most valuable form of energy and the most suitable in the pathway towards the decarbonisation of the energy system. It is clean, it can be converted in to other forms of energy, and it can be delivered over long distances. As already mentioned, access to electricity is an important indicator of development of a country. An analysis covering 26 African countries finds that poor-quality electricity supply infrastructures have strong negative effect on firm's productivity, especially in lower income African countries such as Eritrea, Ethiopia, Mali, Senegal, Uganda and Zambia.²³ Another example of positive correlation between energy access and growth is the positive interaction of energy access with SDG 4 on Education for all, because access to energy allows students to study overnight and to have access to internet and online-education.

The second indicator is relevant because populations which have no or low access to modern forms of energies generally use solid fuels (biomass or charcoal) for heating and cooking.

²² Karekezi *et al.*, 2012

²³ Escribano *et al.* 2009

These fuels are very inefficient from an energy standpoint and, above all, have a negative impact on health, as the untreated emissions are responsible for serious respiratory diseases (Martin *et al.*, 2011). Conversely, this does not happen in developed countries where gas or electricity is generally used for cooking purposes, while the use of solid fuels for heating purposes is limited to few complementary biomass-based appliances. In brief, ensuring access to modern energy carriers could not only improve energy efficiency and thus have positive impact on the mitigation of climate change (SDG 13), but also could have important co-benefits on human health. In this framework energy access (SDG 7.1) is closely interlinked with SDG 3 calling for ensuring healthy lives and promote wellbeing for all at all ages.

3.2 Energy Access and GHG Emissions

The energy access goal (SDG7.1) is closely interlinked with other SDGs including climate change mitigation (SDG13). This is acknowledged by the other two targets of SDG7 including targets on renewable energy (SDG 7.2) and energy efficiency (and 7.3). Strategies to mitigate climate change should not limit the ability of least developed countries to meet their basic energy needs for development but rather support access to cleaner energy sources.

The existing literature provides a contradictory picture on the implications of energy poverty alleviation on energy consumption and associated future GHG emissions. Most international organizations estimate this effect as moderate. The International Energy Agency (IEA, 2013) estimates that achieving universal energy access by 2030 would increase electricity consumption by 2.5 percent and fossil fuels use by 0.8 percent.²⁴ A less moderate picture is the one suggested by Chakravarty and Tavoni (2013) that assess an overall increase in global final energy consumption by about 7 percent.²⁵ The bulk of this 7 percent addition would happen in Africa that would need to double final household energy consumption with respect to the case without a poverty alleviation policy.²⁶

The additional energy consumption can be translated into increased CO₂ emissions. The cumulative emissions due to energy poverty eradication has been estimated to be in the range of 44 to 183 GtCO₂, corresponding to a limited induced temperature change of below 0.13°C.²⁷ This range depends on the carbon intensity of the energy mix. As already observed, RES are less carbon intensive with respect to fossil-fuel energy sources. A different argument can be raised for the use of biomass for cooking which has severe negative effects on health due to household air pollution. In this case, the access to fossil fuel sources would displace large quantity of traditional biomass for cooking with important benefits on health and only small effects on CO₂ emissions. Current technologies that use traditional biomass are associated with significant emissions of non-CO₂ Kyoto gases (e.g. CH₄, N₂O) and aerosols (e.g. BC, OC) due to incomplete combustion. On the access to electricity and emissions, Pachauri *et al.* (2013) estimate that to achieve total rural electrification alone will increase GHG emissions by about 2 - 4 percent over the baseline in 2030.²⁸

²⁴ Universal electricity access according to IEA projections assumes a basic level of electricity for every person gaining access.

²⁵ According to Chakravarty and Tavoni, 2013: p. S71. The alleviation policy allows for a higher threshold of consumption compared to IEA (2013) and encompasses both basic and productive uses.

²⁶ Chakravarty and Tavoni: S71

²⁷ Chakravarty and Tavoni: S72

²⁸ Pachauri *et al.*: p. 5

Global energy-related CO₂ emissions stood at 32.1 Gt in 2015, having remained essentially flat since 2013²⁹ (Figure 2). The IEA preliminary data suggest that electricity generated by renewables played a critical role, having accounted for around 90 percent of new electricity generation in 2015. In parallel, the global economy continued to grow by more than 3 percent, offering further evidence that the link between economic growth and emissions growth is weakening.

Figure 2: Global energy-related CO₂ emissions



Sources: IEA, March 2016 (based on data from WEO 2013 for ys 2013-2015 and from IEA 2015 for ys 1975-2012)

Decoupling of global emissions and economic growth is key especially in developing countries in their path towards energy access and sustainable development. The decline in CO₂ emissions in the two major emitters (US and China) was offset by increasing emissions in most other Asian developing economies and the Middle East. According to Calvin *et al.* (2016), African emissions could account for between 5 and 20 percent of global emissions, and Sub-Saharan Africa would contribute with between 4 and 10 percent of world emissions by 2100.³⁰

4. Energy Access and Climate Change Mitigation in Sub-Saharan Africa

Sub-Saharan Africa (SSA) is the region with energy consumption per capita among the lowest in the world and the greatest concentration of energy poverty.³¹ Of 1.2 billion people without access to electricity in 2013 globally, more than half live in SSA³², which has around 65 percent of the population lacking access to electricity and about 80 percent without access to clean

²⁹ IEA, preliminary date for 2015, issued in March 2016 (<https://www.iea.org/newsroom/news/2016/march/decoupling-of-global-emissions-and-economic-growth-confirmed.html>)

³⁰ Calvin *et al.*, 2013: p.1

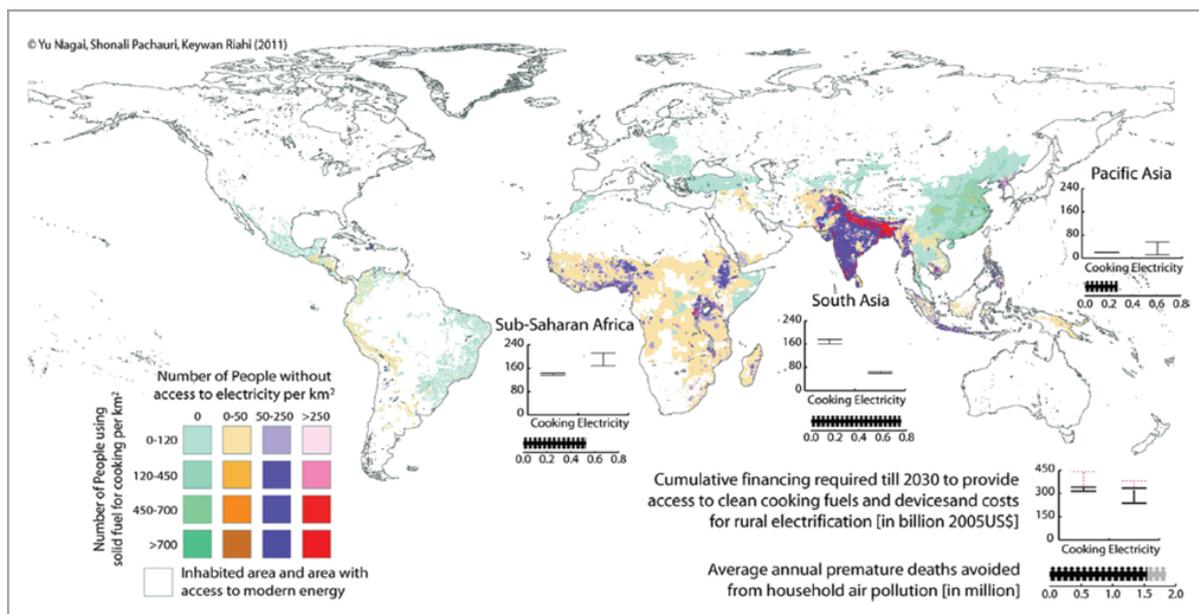
³¹ South Africa is the exception in the region as it is responsible for more than 40 percent of the power generation capacity - but only a quarter of the population (IEA, 2014).

³² IEA, 2014

cooking fuels. The bulk of energy poors live in rural areas where only 14 percent have access to electricity, against 63 percent in urban areas.³³

Figure 3 illustrates the proportion of people without electricity and using solid fuels for cooking. The figure shows that, among developing countries SSA has the highest proportion of its population having a combination of low access to electricity and reliance on solid fuels while the absolute largest number of the people with limited access live in Asia. According to projections by IEA (2010), the population without electricity will continue to rise in SSA, unlike in other regions of the developing world (e.g., MENA region and Latin America), which are projected to significantly increase access to electricity.

Figure 3: Proportion of population without access to electricity and using solid fuels.



Source: Karekezi *et al.*, 2012 (based on data from UNDP and WHO, 2009)

If we exclude South Africa, in SSA region the total installed generation capacity is around 40 GW in 2012. Bazilian *et al.* (2012) estimate that providing moderate access to both households and businesses in SSA (excluding South Africa) would require an installed capacity of around 374 GW by 2030. A lower estimate is the one by Pachauri *et al.* (2013) that argue that an additional 20 GW of installed capacity in SSA by 2030 is needed to provide basic electricity access although limited to households.³⁴ Against this background, and despite the projection on population growth, SSA is deemed responsible for a small share in global electricity-related emissions: 0.7 percent in 2030³⁵. This is mainly due to fuel switch, the use of more efficient coal and gas-powered powered plants and the decrease in carbon intensity, especially in western and central Africa. Conversely, in southern Africa (excluding South Africa) the growing use of coal increases the carbon intensity in SSA region³⁶ According to Calvin *et al.* (2016) - in two of the analyzed scenarios³⁷ - SSA results the African region with the largest rates of energy intensity reduction and of carbon intensity increase.³⁸

³³ IEA, 2010

³⁴ Pachauri *et al.*, 2013

³⁵ Dagnachew, 2018: p. 363; IEA, 2011

³⁶ Dagnachew, 2018: p. 363

³⁷ See the REMIND and WITCH models

³⁸ Calvin *et al.*, 2016: p. 114-115

Moreover, SSA is one of the regions mostly vulnerable to the impacts of climate change and this has important consequences on its economic growth and the rate of energy access. As observed, climate change poses threats to water availability and energy security due to the water-energy and climate nexus. The magnitude of these impacts varies at different levels of warming, corresponding to 2°C and 4°C above pre-industrial levels. Overall, projections of impacts of climate change on water resources in SSA are associated with large uncertainties.³⁹ According to Serdeczny *et al.* (2017), “East Africa is at higher risk of flooding and concurrent health impacts and infrastructure damages. West Africa is projected to experience severe impacts on food production, including through declines in oceanic productivity, with severe risks for food security and negative repercussions for human health and employment. South Africa sees the strongest decrease in precipitation with concurrent risks of drought”.⁴⁰

If we consider both the major impacts of climate change on SSA and the need to achieve energy access whilst mitigating climate change, renewable energies seem the most suitable sources to achieve a sustainable and modern energy access (SDG 7.1). Another possible trade-off after that between energy access and climate mitigation (SDG 13) is the one between climate policy and energy prices. Indeed, climate policies can negatively impact energy access by increasing energy prices. Climate mitigation policies are projected to result in higher electricity prices in all SSA with higher increases in regions with large shares of fossil fuels in their electricity mix.⁴¹ Within SSA mitigation policy will increase electricity price by 40 percent in southern Africa, due to natural gas dependency (especially in Angola, Mozambique and Tanzania). In western and central Africa price is projected to increase by 35 percent by 2030 due to the dominance of fossil fuel in the energy mix. Eastern Africa has the highest share of generation from RES and therefore the lowest price increase.

Against this background and because of the lower carbon intensity of RES, low carbon electricity generation should be further exploited in SSA. This could give a contribution to the achievement of SDG 7.1 with considerable climate co-benefits (SDG 13) and water consumption advantages (SDG 6). Natural gas is among the less carbon intensive fossil fuel sources and is largely available in SSA. The renewable-gas paradigm should therefore be encouraged. Such a paradigm would cut by half SSA utilization of coal in electricity production and would represent a significant step to ensure a sustainable energy access in SSA.⁴² Alike IEA 2010 projections, under the IEA New Policies Scenario around 70 percent of the population in SSA will have access to electricity in 2040, while this rate raises to 83 percent under the African Century Scenario. However, IEA projections in SSA are not in line with SDG 7.1 target of universal energy access, and more investment in technological innovation is needed.⁴³ According to Pachaury *et al.* (2013) USD 19 – 40 billion⁴⁴ investment per year will need to occur in SSA.

³⁹ Serdeczny *et al.*, 2017: p. 1591

⁴⁰ *Idem*: p. 1596

⁴¹ Dagnachew *et al.*: p. 363

⁴² The paradigm would consist in: i) a decrease of coal from 53% to 24% of the mix; ii) an increase of gas from 9% to 25%; iii) an increase of renewables (excluding hydro) from 2% to 16%. Alloisio *et al.*, 2017, p: 11-15

⁴³ This estimation rises to more than USD 2 trillion between 2014 and 2040 in the African Century Scenario, which has a focus on energy alleviation vs. a lower cumulative total investment of around USD 1.2 trillion between 2014 and 2040 as projected in the New Policies Scenario. IEA 2014: p 222

⁴⁴ In 2005 USD

5. Technological innovation, water saving and energy efficiency

Decision makers in developing countries are examining efficient, environmentally sound, climate-friendly energy options that reduce the climate risk profile of their energy industries and deliver substantial development benefits. There are no blueprint solutions, nevertheless a number of areas of opportunity for sustainably improving water, energy and climate change mitigation exist. These include opportunities for improving water use efficiency in the energy sector, such as for example:

- 1) Increasing the use of renewable energies for electricity production, e.g. geothermal energy which is unaffected by climate variability and has a limited water footprint.⁴⁵
- 2) Shifting from fossil fuels to renewable energy, e.g. photovoltaic for water desalination.⁴⁶
- 3) Enhancing off-grid systems (e.g. mini-grids based on hydro, solar, and wind) mostly stand-alone systems (based on solar) in remote and low-density settlements would play an important role in reaching the poorest and isolated populations (the so-called “last-mile” challenge).
- 4) Switching from kerosene to electric lighting that could reduce related climate impacts due to avoided black carbon emissions.
- 5) Increasing resource productivity, e.g. water productivity in ethanol production has increased by 30 percent over the past decade.
- 6) Developing multi-use reservoirs, which could increase the total water use efficiency of hydropower as compared to traditional dams for power generation only.
- 7) Reducing freshwater demand in energy production by using marginal water, e.g. brackish water.

6. Conclusions

The increase in emissions from providing universal access to electricity is negligible relative to global emissions, and it barely influences global climate change. Moreover, climate mitigation policy could offset the projected increase, due to efficiency improvements and a shift to low-carbon energy sources.⁴⁷ Furthermore, RES generation technologies based on off-grid systems are becoming increasingly competitive with fossil fuel-based energy systems. This provides an opportunity for developing countries, and in particular SSA - one of the regions with the highest rate of energy poors - to achieve energy access, decarbonize the electricity system and avoid fossil fuel lock-in over the long term.⁴⁸

The exacerbation of climate change with negative consequences on energy security and water availability can provide new opportunities for overcoming lock-in and facilitating integrated resource planning in SSA. A comprehensive integrated resource planning based on the WEF nexus would help in managing trade-offs and could maximize co-benefits among multiple sectors, guaranteeing a sustainable use of natural resources and contribute to diminishing costs. Technological innovation is needed for increasing resource productivity, and investments that lock development into non-sustainable pathways must be strictly avoided. Ad-hoc solutions for sustainably and affordably improving water, energy and climate change mitigation exist in SSA region.

A coherent mitigation policy based on national resource endowments, and an adaptation strategy that balances the risk of inaction with the risk of adapting to climate change in the wrong way, together with careful consideration of all interrelated aspects of the WEF nexus, are pivotal for any suitable energy and climate policy in SSA and all the developing world.⁴⁹

⁴⁵ See case study on the role of geothermal energy in Kenya. UNESCO 2014: p. 16

⁴⁶ See case study on desalination in the Gulf Cooperation Countries. UNESCO 2014: p. 147.

⁴⁷ Dagnachew, 2018: p. 365

⁴⁸ *Idem*

⁴⁹ Cervigni G. *et al.*, 2015

References

Alloisio, Isabella, Jacopo Bonan, Carlo Carraro, Marinella Davide, Manfred Hafner, Simone Tagliapietra, Massimo Tavoni., “Energy Poverty Alleviation and its Consequences on Climate Change Mitigation and African Economic Development”. Policy Brief 2/2017, Milan, FEEM, https://www.feem.it/m/publications_pages/2-feem-energy-poverty-alleviation-low1.pdf

Anand, P.B.. “Scarcity, Entitlements and the Economics of Water in Developing Countries”. Northampton: Edward Elgar, 2007 (ISBN 978 1 843767688)

Bazilian, Morgan, Patrick Nussbaumer, Hans-Holger Rogner, Abeeku Brew-Hammond, Vivien Foster, Shonali Pachauri, Eric Williams, *et al.*. “Energy access scenarios to 2030 for the power sector in sub-Saharan Africa”, *Utilities Policies*, Vol. 20 (1) (March 2012): 1-16 <https://doi.org/10.1016/j.jup.2011.11.002>

Bonan, Jacopo, Stefano Pareglio, Massimo Tavoni. “Access to modern energy: a review of barriers, drivers and impacts”. FEEM Working Paper 2016.068, Milan: FEEM, 2016

Bosello, Francesco, Marinella Davide, Isabella Alloisio. “Economic Implications of EU Mitigation Policies: Domestic and International Effects”. FEEM Working Paper 2016.034, Milan: FEEM, 2016

Calvin, Katherine, Shonali Pachauri, Enrica De Cian, Ioanna Mouratiadou. “The effect of African growth on future global energy, emissions, and regional development”. *Climatic Change* 136 (2016): 109–125 DOI 10.1007/s10584-013-0964-4

Chakravarty Shoibal and Tavoni Massimo. “Energy poverty alleviation and climate change mitigation: Is there a trade off?”. *Energy Economics* 40 (1) (2013): S67–S73

Cervigni Guido, *et al.* (Eds). “Enhancing the Climate Resilience of Africa’s Infrastructure. The Power and Water Sectors”. Washington: World Bank & AFD, 2015

Dagnachew, Anteneh G., Paul L. Lucas, Andries F. Hof, Detlef P. van Vuuren. “Trade-offs and synergies between universal electricity access and climate change mitigation in Sub-Saharan Africa”. *Energy Policy* 114 (2018): 355-366 <https://doi.org/10.1016/j.enpol.2017.12.023>

Escribano, Alvaro, J.Luis Guasch, Jorge Pena. “Assessing the Impact of Infrastructure Constraints on Firm Productivity in Africa”. Working Paper 9, Africa Infrastructure Sector Diagnostic, Washington D.C: World Bank, 2009

FAO. The state of the world’s land and water resources for food and agriculture (SOLAW) – Managing systems at risk. Rome, Food and Agriculture Organization of the United Nations and London: Earthscan, 2011

Henri Claude and Laurence Tubiana. *Earth at Risk: Natural Capital and the Quest for Sustainability*. New York: Columbia University Press, 2018 ISBN 9780231162524

Holger Hoff. “Understanding the Nexus. Background Paper for the Bonn 2011 Conference: The Water, Energy and Food Security Nexus”. Stockholm: Stockholm Environment Institute (SEI), 2011.

International Energy Agency. “Energy Poverty – How to Make Modern Energy Access Universal? World Energy Outlook 2010”. OECD/IEA: Paris, 2010

- International Energy Agency. "World Energy Outlook 2011". OECD/IEA: Paris, 2011
- International Energy Agency. "World Energy Outlook 2013". OECD/IEA: Paris, 2013
- International Energy Agency. "Africa Energy Outlook. World Energy Outlook Special Report", IEA/OECD: Paris, 2014
- International Energy Agency. "CO2 Emissions from Fuel Combustion (2015)". OECD/IEA: Paris, 2015
- International Energy Agency. "World Energy Outlook 2016". IEA/OECD: Paris, 2016
- Intergovernmental Panel on Climate Change. "Climate Change and Water". Technical Paper VI. Bates B, Kundzewicz ZW, Wu S, Palutikof J (eds). IPCC, 2008
- IPCC. "Special Report of the IPCC on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change". O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, *et al.* (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA: 2012 (ISBN 978-1-107-02340-6)
- International Renewable Energy Agency. "Renewable Capacity Statistics 2018". IRENA, Abu Dhabi, 2018
- Karekezi, Stephan, Susan McDade, Brenda Boardman, John Kimani. "Energy, Poverty and Development". In *Global Energy Assessment (GEA) - Toward a Sustainable Future*. pp. 151-190. Cambridge and New York, Cambridge University Press, and the International Institute for Applied Systems Analysis, Laxenburg, 2012
- Martin, William J., Roger I. Glass, John M. Balbus, Francis S. Collins. "A Major Environmental Cause of Death". *Science* 334, Issue 6053 (October 2011): 180–181
doi: 10.1126/science.1213088
- Pittock, Jamie, Karen Hussey, and Stephen Dovers (Eds.). *Climate, Energy and Water: Managing Trade-offs, Seizing Opportunities*. Cambridge: Cambridge University Press, 2015.
doi: 10.1017/CBO9781139248792.
- Rockstrom J., M. Falkenmark, T. Allan, C. Folke, L. Gordon, A. Jägerskog, M. Kummu, M. Lannerstad, M. Meybeck, D. Molden *et al.* "The unfolding water drama in the Anthropocene: towards a resilience-based perspective on water for global sustainability". *Ecohydrology* 7 (2014): 1249–1261. doi: 10.1002/eco.1562
- Schmidt, Jeremy. *Water: Abundance, Scarcity, and Security in the Age of Humanity*. New York: New York University Press, 2017. ISBN: 978-1-4798-4642-9
- Serdeczny, Olivia, Sophie Adams, Florent Baarsch, Dim Coumou, Alexander Robinson, William Hare, Michiel Schaeffer, *et al.* "Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions". *Regional Environmental Change*. 17 (2017): 1585–1600. doi: 10.1007/s10113-015-0910-2.
- Stickler, Morten and Knut T. Alfredsen. "Anchor ice formation in streams: a field study. Hydrological Processes". Vol. 23, Issue 16 (30 July 2009) <https://doi.org/10.1002/hyp.7349>

Swatuk, Larry A. and Corinne Cash (Eds). *Water, Energy, Food and People Across the Global South. 'The Nexus' in an Era of Climate Change*, International Political Economy Series. London and New York: Palgrave MacMillan, 2018. ISBN 978-3-319-64023-5
<https://doi.org/10.1007/978-3-319-64024-2>

UNDESA. World Population Prospects, the 2012 Revision. New York, Population Division, United Nations Department of Economic and Social Affairs, UNDESA: New York, 2013

UNDP. "Access to Energy and Human Development". Amie Gaye. Human Development Report 2007/2008. Fighting climate change: Human solidarity in a divided world. Human Development Report Office occasional paper. UNDP 2007/25. UNDP: New York, 2007

UNDP. "UNDP Human Development Indicators Report 2009". United Nations Development Programme. UNDP: New York, 2009

UNESCO. "The United Nations World Water Development Report 2014. Facing the Challenges". WWDR 2014, Vol. 2, 2014

World Bank. "Beyond Scarcity. Water Security in the Middle East and North Africa". World Bank Group: Washington D.C., 2018. ISBN: 978-1-4648-1144-9

World Economic Forum. "Water Security: The Water-Food-Energy-Climate Nexus". The World Economic Forum Water Initiative. D. Waughray (Ed.). Washington D.C.: Island Press, 2011