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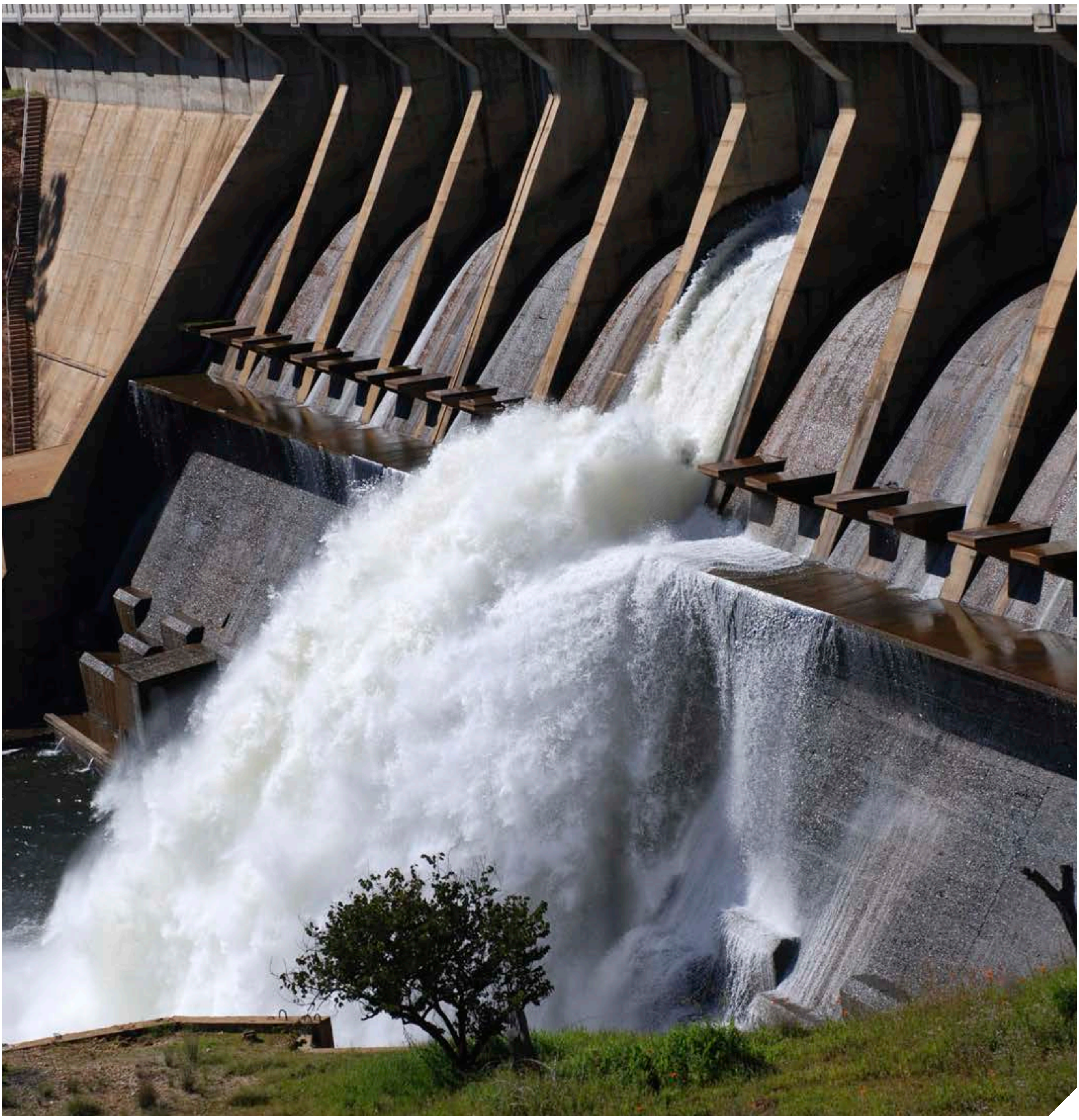
ANDREW BULLOCK, STEPHAN HÜLSMANN

WORKING PAPER - No. 4



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# Table of Contents

## Strategic Opportunities for Hydropower within the Water-Energy-Food Nexus in Mozambique

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## ABSTRACT

It is increasingly acknowledged that the close interlinkage of water and energy requires adopting a Nexus Approach to sustainable resources management. Hydropower dams that also provide water services are among the most obvious showcases of this water-energy nexus. Using the case of Mozambique, a country which is characterized by i) still considerable development challenges, ii) high importance of hydropower for energy production, with iii) large unexploited capacities for hydropower and iv) in general low storage capacities for water, we here explore strategic opportunities for hydropower development within the water-energy-food nexus. The analysis is based on a detailed survey of the state of the art of the energy sector in Mozambique and the policy context at national and international levels. We propose four areas for strategic expansion in the hydropower sector and analyse the current development and respective potential of the main river basins of Mozambique.

The paper clearly demonstrates that future hydropower development must be nexus-oriented, thus considering the strong inter-relations with other water uses, its strategic positioning among other renewable energy sources as well as environmental and socio-economic dimensions and governance. Five key integrators of management are identified, namely scale, the water-energy-food nexus, finance, governance and institutions and mitigating social and environmental detriment. Each of these integrators, besides impact as the ultimate integrator, interacts differently with the proposed four areas for strategic expansion in the hydropower sector, requiring a differentiated approach.

## List of Acronyms

| | |
|---|---|
| AfDB | African Development Bank |
| AMCOW | African Ministers' Council on Water |
| ARA | Administração Regional de Aguas (Regional Administration of Water) |
| ARA-Centro | Administração Regional de Aguas de Centro (Regional Administration of Water- Central Region) |
| ARA-Norte | Administração Regional de Aguas de Norte (Regional Administration of Water - North) |
| AU | African Union |
| BRIC | Brazil, Russia, India, China |
| CAADP | Comprehensive African Agricultural Development Plan |
| CapEx | Capital Expenditures |
| CENELEC | Conselho Nacional da Electricidade (National Electricity Council) |
| CESUL | Project of Regional Development of Energy Transport between the Centre and the South of Mozambique |
| COSOP | Country Strategic Opportunities Programme |
| CPS | World Bank Country Partnership Strategy |
| CSP | Country Strategy Paper |
| CWRAS | Country Water Resources Assistance Strategy |
| DNA | Direcção Nacional de Águas (National Directorate of Water) |
| DPO | Climate Change Development Policy Operation |
| DRR | Disaster Risk Reduction |
| EdM | Electricidade de Moçambique (Energy Company of Mozambique) |
| EIA | Environmental Impact Assessment |
| ESKOM | South African electricity public utility, ESCOM : Electricity Supply Commission |
| FAPA | Fund for African Private Sector Assistance |
| FiTs | Feed in Tariffs |
| FUNAE | Fund for Rural Electrification |
| GDP | Gross Domestic Product |
| GHG | GreenHouse Gases |
| GiZ | German Gesellschaft für Internationale Zusammenarbeit (German Society for International Cooperation) |
| HCB | Hidroelectrica de Cahora Bassa (Company operating the Cahora Bassa hydropower plant) |
| IFAD | International Fund for Agricultural Development |
| IFPRI | International Food Policy Research Institute |
| IIMA | Interim IncoMaputo Agreement (Tripartite Interim Agreement on Water Sharing of the Maputo and Incomati Rivers) |
| IPP | Independent Power Producers |
| IRENA | International Renewable Energy Agency |
| IRP | Integrated Resource Plan |
| IWRM | Integrated Water Resources Management |
| IWRM&D | Integrated Water Resources Management and Development |
| KSM | Kwaedza Sumukai Manica (NGO in Manica province of Mozambique) |
| LEC | Lesotho Electricity Company |
| MAR | Mean annual runoff |
| MINAG | Ministério da Agricultura e Segurança Alimentar (Ministry of Agriculture and Food Security) |
| MoE | Ministry of Energy |
| MOPH | Ministério das Obras Públicas e Habitação (Ministry of Public Works and Housing) |

| | |
|---|---|
| MoTraCo | Companhia De Transmissao De Moçambique Sarl (Mozambique Transmission Company) |
| Mozal | Mozambique aluminium smelter Project |
| MSIOA | Multi-Sector Investment Opportunities Assessment |
| NGO | Non-Governmental Organization |
| NORAD | Norwegian Agency for Development Cooperation |
| PARP | Poverty Reduction Action Plan |
| PARPA | Action Plan for the Production of Absolute Poverty |
| PAT | Pumps-as-Turbines |
| PEDSA | Plano Estratégico para o Desenvolvimento do Sector da Agricultura (Strategic Plan for the Agriculture Sector Development) |
| PIDA | Program for Infrastructure Development in Africa |
| PPAs | Power Purchase Agreements |
| PPP | Public–Private Partnership |
| PROCANA | Sugarcane Production irrigation Project |
| PROIRRI | Sustainable Irrigation Development |
| PRONASAR | National Water Supply and Rural Sanitation Program |
| PRSPs | Poverty Reduction Strategy Papers |
| PSAA | Small Water Supply Systems programme |
| PV | Photovoltaics |
| RE | Renewable Energy |
| REA | Rural Electrification Agency |
| REFIT | Renewable Energy Feed In Tariffs |
| REIPPPP | Renewable Energy Independent Power Producer Procurement Programme |
| RERA | Regional Electricity Regulator Association |
| RISDP | Regional Indicative Strategic Development Plan |
| RPP | Regional Position Paper |
| RSA | Republic of South Africa |
| RSAP | Regional Strategic Action Plan |
| RSWIDP | Regional Strategic Water Infrastructure Development Programme |
| RWR | Regional Water Resources Planning and Management |
| RWSSP | Regional Water Supply and Sanitation Programme |
| SADC | Southern Africa Development Community |
| SAPP | Southern Africa Power Pool |
| SE4ALL | Sustainable Energy for All |
| SPP | Species pluralis (Species Plural) |
| SWECO | Swedish consulting company |
| UEM | Eduardo Mondlane University |
| UNECA | United Nations Economic Commission for Africa |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UNISDR | United Nations International Strategy for Disaster Reduction |
| UNU-Flores | United Nation University- Institute for Integrated Management of Material Fluxes and of Resources |
| US | United States |
| USD | United States Dollar |
| WEF | Water, Energy and Food |
| ZACPLAN | Zambezi River System Action Plan |
| ZACPRO | Zambezi Action Plan Project |
| ZAMCOM | Zambezi Watercourse Commission |

# 1. Introduction

## 1.1 Background: The Nexus Approach

Under conditions of limited resources and increasing demand for water, energy and food, the need for sustainable use and management of basic resources is more and more acknowledged. Given the strong interrelations between resources, sustainable management solutions require integrated management strategies. Such an approach has been coined a Nexus Approach, emphasizing in particular the nexus of water, energy and food security (WEF nexus) (Hoff 2011; Finley and Seiber 2014). The Nexus Approach emphasizes the potential for unlocking synergies. By striving to apply an unbiased view of interrelated resources (instead of only looking at, for example, water or soil) and consider different uses and users, it also provides a framework for minimizing and balancing trade-offs.

Within the WEF nexus, the link between water and energy has received particular attention (Spang et al. 2014; Howells and Rogner 2014; Gilron 2014). This 'node' of the WEF nexus is based on the fact that energy is required for providing water services (treatment, distribution etc.), while all forms of energy production require water. Hydropower dams that also provide water services are among the most obvious showcases of this water-energy nexus. In particular in energy systems with an increasing share of renewable energy, hydropower plays a special role due to its capacity to store energy at variable time horizons (Hülsmann, Harby, and Taylor 2015).

### 1.1.1 The Position of UNU-FLORES

The United Nations University Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES) looks at the WEF nexus from a resources perspective ("UNU-FLORES Institute for Integrated Management of Material Fluxes and of Resources" 2015). It thus strives to advance a Nexus Approach to the sustainable management of water, soil and waste. Together with partners such as the International Hydropower Association, UNU-FLORES has identified multi-purpose reservoirs as a promising example of applying a Nexus Approach to resource management. At several events and in a recent publication, the specific opportunities of multi-purpose reservoirs as showcases of the Nexus Approach (from whatever perspective) have been highlighted (Hülsmann, Harby, and Taylor 2015). Given the current boom in hydropower dam construction (Zarfl et al. 2015), promoting the sustainable development of these new systems and integrated management strategies for their operation is an urgent task and could make a large impact on sustainable hydropower development worldwide.

UNU-FLORES, which was founded in late 2012 in Dresden, Germany, has from the very beginning established close links to the Eduardo Mondlane University (UEM) in Maputo and the Government of Mozambique. This cooperation has been aimed at establishing a close partnership in research, teaching, advanced training, capacity development and dissemination of knowledge in the area of sustainable use and integrated management of environmental resources.

Ultimately, a sustained presence of UNU-FLORES in Maputo, in close cooperation with UEM and other partners in the region (Hülsmann and Ardakanian 2013), is supposed to act as regional hub for integrated resources management.

This paper has arisen from joint institutional interests in exploring further the potential and advantages of hydropower and is based on UEM's strong expertise in renewable energy in Mozambique (Hammar et al. 2012; Spalding-Fecher et al. 2014a; Yamba et al. 2011). It follows up on a seminar at 2014 Stockholm World Water Week (Hülsmann, Harby, and Taylor 2015), which included a case study on hydropower and renewable energy in Mozambique by the Renewable Energy Physics Group at UEM (Prof. Cuamba). Accordingly, this paper has been commissioned by UNU-FLORES as a contribution to their continually strengthening partnership with Mozambique.

The entry point for the UNU-FLORES perspective behind this study is that among the renewable energy alternatives, hydropower represents the highest potential in Mozambique (for example, four times higher than wind energy sources and less variable), with opportunities of storage capacity balancing the intermittency of other renewables, and offering synergies with other uses of water, including irrigation, water supply and flood protection. Hydropower therefore provides a showcase of the Nexus Approach and can be considered an essential tool for sustainable development. The latter point will be followed up in another seminar during World Water Week in 2015 ("Water Storage and Hydropower as Drivers for Sustainable Development | World Water Week" 2015).

### 1.2 Purpose of Paper

This paper aims to provide substantive evidence on the strategic opportunities of hydropower within the water-energy-food nexus for sustainable development. Using the case of Mozambique, a country with particularly high hydropower potential, we draw the evidence from a comprehensive situational analysis of hydropower development, with emphasis on integrating factors within the nexus between water, energy and food.

The intended use of this paper is to provide a foundation for initiatives and activities to translate the key findings into action. For that reason, an accompanying element of the paper has been the identification of key experts with experience in the field – forming the basis for a network of expertise that can potentially enable the progress of the process.

There have already been substantive analyses of the Mozambique energy sector, within which hydropower has been prominent (Chambal 2010; Cuamba et al. 2013). However, there has not yet been any substantive stocktaking of the evidence as relates directly to the water-energy-food nexus. So, given the wide range of experiences and outlooks that the different stakeholders bring to the process, a principal value of this paper lies in its collection and analysis of relevant policies, their status and emerging opportunities.

The energy sector has long recognised the major differences between on-grid and off-grid hydropower. However, dialogues around water and hydropower have tended to focus on different categories of hydropower according to size and have not addressed other important differences among hydropower strategies. This paper introduces for the first time a framework of four areas for strategic expansion that appear to best categorise the hydropower sector within Mozambique. Those four strategic directions offer a better frame for integrated management than any single interface between water and hydropower could otherwise achieve.

Because this paper is envisioned as a catalyst of future action, the forward-looking contents in Section 6 are necessarily illustrative and intended for uptake by others, rather than being prescriptive. Nonetheless, they are informed by a very thorough diagnostic.

### 1.3 Case for Integrated Management Solutions within Renewable Energy in Mozambique

While substantive reviews of the potentials of renewable energy in Mozambique have been conducted (Mahumane et al. 2012; International Renewable Energy Agency (IRENA) 2012), there has not, to date, been a substantive consolidated analysis within the context of the energy and water nexus. A case study presented during a seminar at Stockholm World Water Week in 2014 on the role of hydropower in Mozambique (Case study by B. C. Cuamba in Hülsmann, Harby, and Taylor 2015) started off and set the frame by reminding that Mozambique (see map in Fig. 1), one of the fastest growing economies in Sub-Saharan Africa still faces enormous development challenges (UNDP 2014). The case study recognised that amongst the potential renewable energy sources hydropower plays a special role with on- and off grid potential with generation and transmission at various scales, including large dams such as Cahora Bassa serving on-grid electricity for export, medium scale local grids serving communities and villages and small-scale through off-grid solutions serving individual farms. Yet, any future case for integrated management solutions within the energy-water nexus would require a fuller understanding of those strategic domains and their own distinctive and different interfaces with water management (and agriculture, for example). The case study also assessed that hydropower is seen to face some major challenges, including reduced availability of water as a result of climate change (drawing on a recent regional assessment, Fant, Gebretsadik, and Strzepek 2013) and a general expectation of increasing drought incidences (Gan, Ito, and Hülsmann 2013), increasing water demand from other sectors (Spalding-Fecher et al. 2014b), current low storage capacities and challenges in the implementation of IWRM and transboundary issues.

Accordingly, it has been recommended that Mozambique fosters Integrated Water Resource Management (IWRM), promotes regional and international collaboration and enhances research and capacity development on water and energy issues, on climate change impacts and on socioeconomic issues related to water use (Cuamba in Hülsmann, Harby, and Taylor 2015). These suggestions are revisited in Section 6 in light of the substantive, consolidated analysis provided below. It is also considered that there are distinctively

different areas for strategic expansion within the hydropower domain, each in unique relation to the water agenda, such that an all-embracing, unifying theme such as IWRM (or 'water and hydropower') may not be the most effective entry point to advance a Nexus Approach with a focus on hydropower development in Mozambique.


Figure 1: Political and Administrative Map of Mozambique (United Nations (UN) 2004)

# 2. Survey of the Energy Sector in Mozambique

## 2.1 State of Mozambique Energy Sector

At present Mozambique possesses an installed national total electricity capacity of about 2,400 MW. More than 95% is generated from hydropower, and 90% is of hydropower capacity is produced at the 2,075 MW Cahora Bassa Hydroelectric facility located in the Zambezi Basin, Tete Province (African Development Bank (AfDB) 2011b).

Responsibilities for the supply of electricity lie among five major national players:

1. *Hidroelectrica de Cahora Bassa (HCB)* manage and operate Cahora Bassa hydropower stations and associated networks transmitting power into the national grid and the Southern African Power Pool (SAPP). HCB thus represents the biggest supplier in terms of capacity.

2. The privatised national utility *Electricidade de Moçambique (EdM)* has a generation capacity of approx. 400 MW, around 109 MW of which is hydropower and 300 MW is thermal capacity. EdM is not only a supplier, but involved in all parts of the electricity supply chain (e.g. transmission and distribution).

3. The third major supplier, *MoTraCo*, imports power exclusively to Mozal aluminium smelter based in Maputo.

4. The *Fund for Rural Electrification (FUNAE)* is responsible for the rural electrification strategy, with functions of project finance, promoting private sector engagement in rural energy services, and project management.

5. An energy regulator, *Conselho Nacional da Electricidade (CENELEC)*, was established after opening the energy sector to competition and new entrants (International Renewable Energy Agency (IRENA) 2012).

The national transmission system is weakly developed (Chambal 2010), as can be seen in Fig. 2. EdM transmission covers three regions – northern, central and southern – comprising 220 and 110 kV lines. Long distances between generation and load centres mean high transmission and distribution losses, estimated at 25%. Mozambique has transmission capacity into SADC of nearly 2,000 MW.

The current electricity consumption of 1,300 MW is dominated by large industrial projects and low per capita use (Branco 2012). Consumption was increased substantially due to several industrial 'mega projects', among them notably the aluminium smelter in Maputo (Mozal), which uses 900 MW. The remaining domestic consumption is around 400 MW. With low grid access, EdM has 2.4 million domestic consumers. Domestic consumption (78 kWh per capita) is very low.

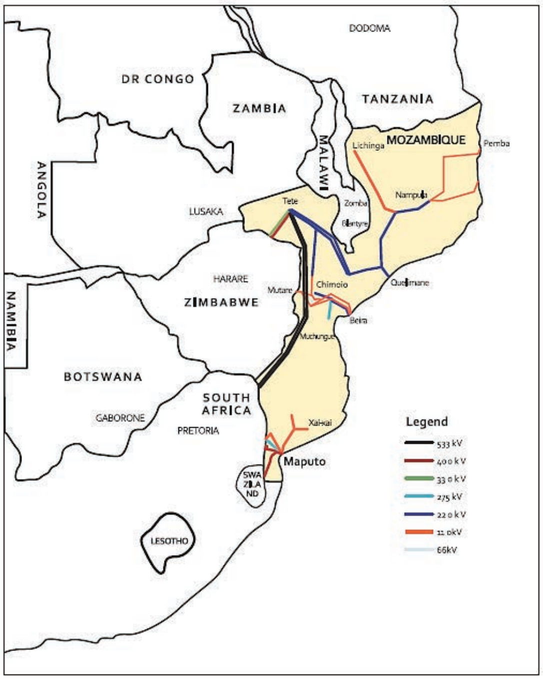


Figure 2: Mozambique Electricity Grid by EDM (International Renewable Energy Agency (IRENA) 2012)

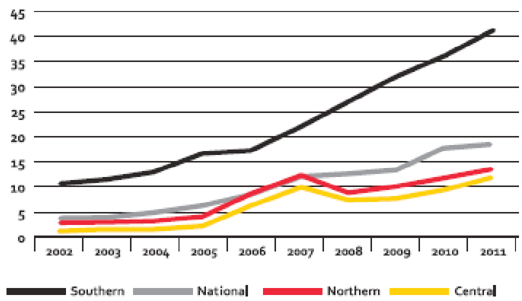


Figure 3: Evolution of National Electricity Access through EDM (2011), (International Renewable Energy Agency (IRENA) 2012)

Access to the electricity grid reached 21% of households by 2011, which is one of the lowest electrification rates in SADC (Cuamba et al. 2013). Electrification access is estimated at 26% in urban areas (mostly Maputo and provincial capitals) and 5% in rural and peri-urban areas (see fig. 3). Over half of Mozambique's 128 districts have lacked 24-hour-a-day access to electricity. In 2011, 11% of the population accessed intermittent off-grid technologies, such as solar power (African Development Bank (AfDB) 2011b).

80 percent of citizens, mostly rural and peri-urban, rely on primary biomass (including wood fuel) to meet house-hold energy needs (Cuamba et al. 2013). Kerosene is the main lighting fuel, including in rural institutions operating at night (e.g., health centres).

Mozambique is a net exporter of electricity to a 4,000 MW energy-deficit SADC. Around 73% of HCB's generated 2,075 MW is exported to SAPP – bringing important foreign revenue – the other 300 MW constituting Mozambique's 'entitlement' (Chambal 2010). MoTraCo accounts for 100% of imports (900 MW for the aluminium smelter).

Given the low electrification rate in rural areas, access by agriculture is minimal (Mahumane et al. 2012). Despite the high economic and social importance of agriculture and the benefits for the sector from electricity use, agricultural electricity consumption is less than 0.4% of EdM's distribution. Access to cultivation areas is difficult for EdM, and not profitable in a subsistence-dominated sector.

An erratic electricity supply causes nation-wide economic set-backs (World Bank 2007). Even where there is access, outages and oscillations mean electricity has been rated the most serious infrastructure problem for manufacturing.

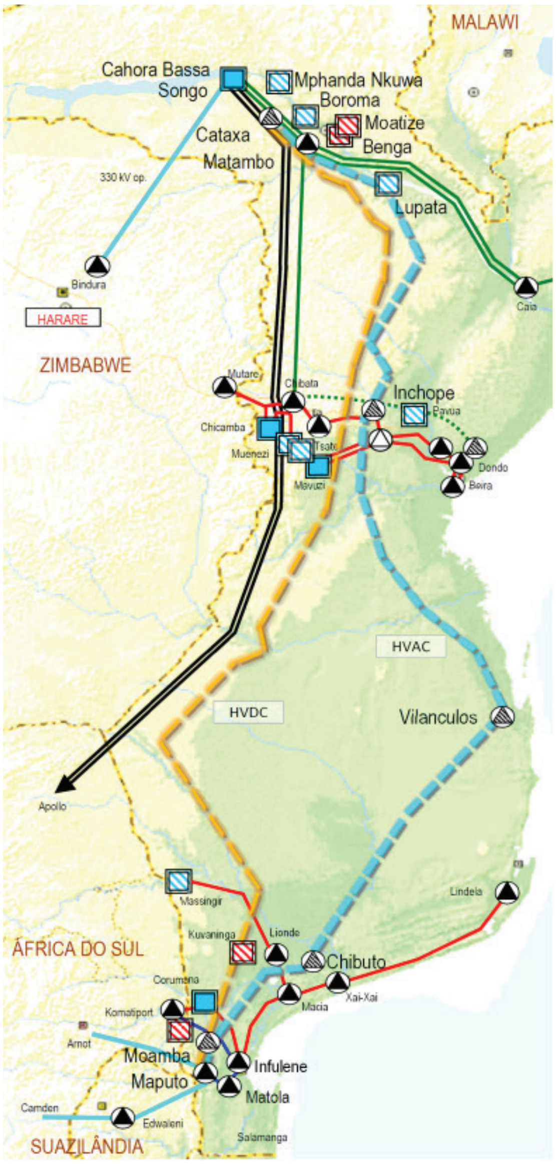


Figure 4: Mozambique Regional Transmission Backbone Project – CESUL (Ministry of Energy, Directorate of Studies and Planning, n.d.). Projected main lines are marked in yellow and blue.

## 2.2 Rising Demand – Nationally, in South Africa and Regionally

Mozambique is estimated to have a total energy need of 5.4 Gwh and an electricity demand close to 900 MW by 2020 – based on a projected yearly growth of 7% and the Government's objectives with regard to electrification(Chambal 2010). To meet this demand, future large-scale generation projects are planned in the Tete Province, which is distant from the main power demand centres in Mozambique and SADC. The capability to transport the generated power is a prerequisite for the viability of these projects. Therefore, the Mozambique Government has developed the Regional Transmission Backbone Project (CESUL, see Fig. 4), enabling relatively low-cost power generation to meet rapidly growing domestic and industrial needs, as well as export.

The export of electricity is expected to increase considerably, particularly to South Africa. South Africa's public electricity utility, Eskom, faces major supply-side challenges and has identified Mozambique as a key strategic supplier (Mahumane et al. 2012). Eskom will have to increase that nation's generation capacity to approximately 100–120,000 MW. To this end, the South African Department of Energy has launched a base load programme envisaged in the 2010 Integrated Resource Plan (IRP), including, among others, a 2,609 MW Hydropower Base Load Programme. One scenario in the IRP has been to make available 2,600 MW of power from Mozambique, including a 2,135 MW from new hydropower projects and opportunities among non-renewable sources.

Another regional development influencing electricity demand in Mozambique was the commitment of SADC Governments to regional cooperation through SAPP to enhance market scale and competition. The SAPP regional market is

facing a shortage of energy at around 2,000 MW p.a. (Chambal 2010). A Regional Electricity Regulator Association (RERA) has been established and is already in operation (Ministry of Energy, Directorate of Studies and Planning, n.d.).

## 2.3 Opportunities for Renewable Energy

This section provides an overview of renewable energy (RE) potential in Mozambique; key figures are given in Table 1. Sub-sections summarise the development of separate RE resources and the REFIT programme. Hydropower is dealt with only superficially, being subject to substantive analysis in subsequent sections.

Table 1: Key renewable energy sources available (Sources: (Chambal 2010) and (Caixote 2014))

| Resource | Potential | 'Priority' | Availability | Comments |
|---|---|---|---|---|
| Wind | 4.5 GW | 1.1 GW | Encouraging wind resources along Niassa coast<br><br>Tests at four sites show >6 m/s wind speed in some areas | Higher masts may reveal greater re-sources<br><br>Resources mapping needed |
| Solar | 23 TW | 597 MW | High: 4.5-7 kWh/$m^2$/day<br><br>Average insolation of 5.2 kWh/$m^2$/day means 1.49 m Gwh of annual radiation on Mozam-bique's land surfaces | Estimated 1 MW of off-grid PV systems installed<br><br>FUNAE study on PV potential under way |
| Biomass/ Cogeneration | 2.0 GW | 128 MW | 100 s of MW from various fuel sources; potential bagasse of 433,000 tons (dry weight) | 5 sugar plantations in Maputo and Sofala |
| Hydropower | 18 GW | 5.4 GW | > 1,000 MW for small (<10 MW) plants | 60 potential small projects |
| Geothermal | 0.1 GW | | Possible resources, but no studies yet<br><br>Conservative estimates of 25 MW in Tete, Manica and Niassa Provinces | No realistic plans yet |
| Tidal | | | Ample resources, but no studies completed yet | No realistic plans yet |

### 2.3.1 Wind Power

Wind power in Mozambique is in its early stages (International Renewable Energy Agency (IRENA) 2012). FUNAE has promoted feasibility where there are substantial resources, namely for water pumping in coastal areas, interior highlands and the vicinity of water bodies. Resources are considerable in such areas, with average speeds of 6-7 m/s. During 2014, GIZ was considering supporting Mozambique's first wind farm, up to 30 MW (Caixote 2014). To assess wider potential and costs, better understand wind resources, and inform policies, the Mozambican Government has conducted a mapping project to produce a Wind Energy Resources atlas, backed by installation of four wind speed measurement stations throughout the country.

### 2.3.2 Solar Power

Receiving considerable sunshine, with annual average solar radiation at 5.2 kWh/ $m^2$/d, Mozambique has significant solar power potential (International Renewable Energy Agency (IRENA) 2012). At 1.49 million GWh, this is several multiples of total national consumption, but is a highly diurnal source with seasonal variability. Ubiquitous solar energy is a potential key resource for a highly dispersed, off-grid rural population.

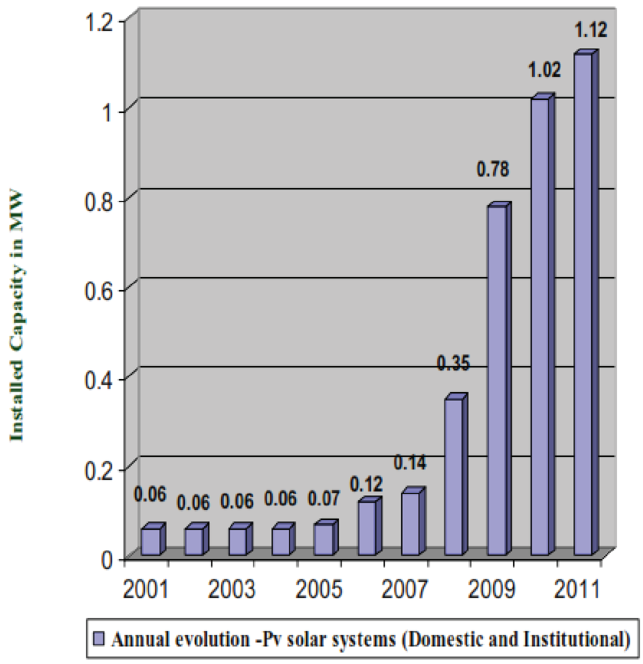


Figure 5: Annual evolution of photovoltaic systems installed, adapted from FUNAE, 2012 (Cuamba et al. 2013)

With comparatively low progress on mini-hydro and wind energy, levels of off-grid rural electrification accomplished so far have mainly been through solar photovoltaic (PV) systems. To date, around 1.0 MW of solar PV has been installed (Fig. 5), most by FUNAE, supplying around two million people – comprising a very substantial majority of that 11% of the population accessing energy through off-grid solutions.

The majority of PV systems installed by FUNAE have been decentralised mini-grids (International Renewable Energy Agency (IRENA) 2012), mostly serving the public sector institutions prioritised under rural electrification (e.g., health centres, schools, public buildings, police stations, etc.), as well as pumping to provide potable and

agricultural water. Early local community involvement and created 'Management Committees' (representatives from communities and local authorities to perform services) have been important success factors.

PV equipment prices are high in Mozambique (International Renewable Energy Agency (IRENA) 2012), with no tax exemption or reduced duty on imports. Active commercial markets have not yet developed and private sector activity is low. Reportedly, FUNAE has plans for a manufacturing plant in Maputo, with production capacity of 5 MWp p.a. and PV modules ranging from 1.0 to 150 Wp.

While FUNAE's policy allows a social programme alongside market-based projects (Chambal 2010), PV expansion has fallen mostly under a well-funded programme-based social provision to targeted communities, backed by development partners, providing low cost electricity or equipment, and charging nominal fees. International companies have featured significantly in solar deployment. Given FUNAE's small size and modest budget and the huge size of the off-grid population of the country, the impact of its work has been relatively small. Beyond public sector institutions, there have not, to-date, been a significant number of commercial rural electrification projects. There are concerns that the well-funded social approach may be undermining commercial approaches (International Renewable Energy Agency (IRENA) 2012).

### 2.3.3 Biomass

Wood, charcoal and agricultural waste currently are the dominant source of energy in Mozambique. 'Modern' biomass for decentralised electricity generation is less widespread than other technologies. Five sugar companies have an installed generation capacity of 60 MW for bagasse (International Renewable Energy Agency (IRENA) 2012). A grid feed-in mechanism may incentivise producers to invest in technology.

### 2.3.4 Biofuels

Mozambique is endowed with potential for expanded biofuel production (International Renewable Energy Agency (IRENA) 2012). Resource mapping and zoning studies have identified conditions for sustainable biofuels production. The Mozambique Government has reportedly received 17 biofuel-related proposals in nine out of ten provinces, including five bioethanol and twelve biodiesel projects. The Government has set aside more than USD 700 million to fund biofuel research, production and promotion, and has allocated 3.5 million ha of land for biofuels. A National Biofuels Strategy has reportedly been under preparation (UNIDO and ICSHP 2013).

### 2.3.5 Hydropower

Mozambique has one of the highest hydroelectric potentials in Africa (Chambal 2010), amounting to 12,500 MW of which 2,200 MW have been developed. The largest potential is on the Zambezi River, where to-date only Cahora Bassa South Bank has been developed, with potential schemes including Cahora Bassa

North and Mphanda Nkuwa, among others. Small hydropower potential has been estimated at 190 MW (Chambal 2010), with sites among the mountainous terrain and perennial rivers of Manica, Tete and Niassa. Despite ample resources and numerous sites, only a handful of small hydropower projects have been completed (International Renewable Energy Agency (IRENA) 2012). Chapter 4 and 5 go into further detail on this topic.

### 2.3.6 REFIT Programme

In line with Mozambique's efforts on renewables, and supported by GIZ, advances have been made under the Renewable Energy Feed In Tariffs (REFIT) programme (Caixote 2014), (Gray 2011), within four RE resource sub-sectors namely: hydro, wind, biomass and solar. REFIT has targeted opportunities with Power Purchase Agreements (PPAs) of 20 years, with a proposed maximum generation capacity of 10 MW, (up to 150 to 250 MW in a contracting process up to 3 years), and a range of Feed-In Tariffs that would vary according to capacity under consideration. The programme aspires to mobilize investors with investment incentives stemming, inter alia, from feed-in tariffs.

A recent study (Cuamba et al. 2013) has explored investment incentives in respect to renewable energy in Mozambique. While the vast majority of incentives are not targeted specifically at renewable energy, many are broad enough in scope and coverage to have an impact on the sector, for example Rapid Development Zones. That study concluded that so far investment incentives had failed to attract a diverse range of small-scale and medium-size projects incorporating a wide range of renewable energy technologies. With work required to create a legislative environment that could attract investors for a wider range of systems, hydropower offers significant potential if incentives based on feed-in tariffs can be advanced.

### 2.3.7 Non-renewable energy sources

It is worth mentioning that besides its great potentials in renewable energies Mozambique has extensive potential non-renewable energy resources (gas, coal and oil) (Mahumane et al. 2012). The country has large sedimentary basins of gas, potentially 3.5 trillion cubic feet, with Pande gas already used industrially and exported to South Africa. Three large coal deposits within Tete – at Moatize-Minjova, Senangoe and Mucanha-Vuzi – have total reserves of three billion tons. Explorations suggest oil reserves in quantities that do not justify economic exploitation.

# 3. Policy Context for Hydropower Development in Mozambique

This section explores the policies at national, regional and international level which do have an impact on the RE development and on hydropower in particular. With water being a crucial factor for sustainable development, and given its importance for various sectors, many policies come into play.

## 3.1 Mozambique Development Policies

With water and energy being crucial factors for economic development, development of respective infrastructure is largely shaped by development policies. The 2003 'Agenda 2025' (National Development Vision) (Government of Mozambique 2003), captured the 'Nation's Vision and Strategies' to boosting national wealth through rural development by 2025, backed by a 'Declaration of Commitment' from the highest political level (Government of Mozambique 2003). With regard to the energy sector, Agenda 2025 aims to increase availability of electricity for household consumption from high production capacity and grid expansion – challenged by high costs of required investments but backed by new forms of partnership and national capacities. Concerning the water sector, Agenda 2025 recognised that the country is importing more than it exported, with minimal use of irrigation systems, inoperative irrigation systems and a lack of national programmes to store surface water for irrigation, flood control and other purposes. The National Development Vision projected that access to drinking water and sanitation services would increase significantly – to 70%. Agenda 2025 foresaw more dams and weirs for storing water, more secure national interests among shared watercourses, economic and social justice in pricing and expansion of small water systems to most of the population that were managed by communities and not the State.

The **Poverty Reduction Action Plan 2011–2014 (PARP)** (Government of Mozambique 2007)(Government of Mozambique 2011), is the third of Mozambique's medium-term (five-year) strategy of the Mozambique Government. It aims at achieving inclusive economic growth and reducing poverty and vulnerabilities. The 2011–2014 period was set to achieve expansion of access to energy at the lowest possible cost, broadening the geographic coverage of supply infrastructure and services. The Plan also included a renewable energy objective that emphasized increasing capacity to use new and renewable energy sources, developing the necessary technologies and their installation in health centres and schools. Growth in the electricity and water sectors would be a result of a new Rural Electrification project and a new National Water Supply and Rural Sanitation Program (PRONASAR) that aims to increase water provision and Small Water Supply Systems (PSAA). PARP's emphasis on boosting water provision – accompanied by intentions to make "better use" of water for agricultural purposes – were matched by objectives to boost agricultural production, to expand water infrastructure in areas with productive potential, to build and rehabilitate systems and to expand access to electricity – prioritizing areas with agricultural and fisheries

potential. While progress has been made on the expansion of rural water sources and on rehabilitation of some irrigation systems, adverse meteorological conditions held back substantive progress (notably unduly heavy rainfall in southern regions), with the Mozambique Government supporting motor pumps among other factors of production.

## 3.2 National Energy Policies

Complementing national development strategies, the national government adopted certain policies that set the framework for the energy and renewable energy sectors("REN21: Renewable Energy Policy Network," n.d.). The following policies were the most influential:

- *Energy Policy (1998)* on providing energy to households and productive sectors, with aims to build capacity and improve management within the sector, increasing exports and efficiency.

- *Energy Sector Strategy (2000)* for implementing the 1998 Policy, including the Mozambique Government action plans, programmes, projects and investments. It provides guidance for operators, financial institutions and investors and outlines strategies for private sector, competitive markets and regulation.

- *Energy Reform and Access Project (2003–2011)*, to accelerate commercially viable uses of electricity for economic growth and social services, in un-served and under-serviced areas, and increasing access to modern energy – thereby supporting the Strategy through investments.

- *Electricity Master Plan for Development of the National Grid (2005–2019)* focusing on Grid Supply Expansion in the short-to-medium term over an ongoing period of 15 years.

The intention to adopt a Policy for Renewable Energy and Master Plan for Off-Grid Energy Phase II has been expressed (UNIDO and ICSHP 2013).

## 3.3 National Agricultural Policies

Mozambique's **PEDSA** *(Plano Estratégico para o Desenvolvimento do Sector da Agricultura [Strategic Plan for the Agriculture Sector Development])* was prepared in 2010 by the Ministry of Agriculture (Government of Mozambique 2010), and constitutes the national agricultural agenda under the Comprehensive Africa Agriculture Development Program (CAADP) agenda. PEDSA has the general objective to contribute to food security and livelihood of agricultural producers in a sustainable way. PEDSA aims to boost production and productivity (of agriculture and fisheries) while generating output surpluses to be marketed on a regional level. It promotes implementation strategies that emphasize a sustainable use of natural resources.

Agricultural productivity has been very low in Mozambique due to under-practised irrigation, limited market access, poor post-harvest infrastructure, poor availability of credit and insurance mechanisms and vulnerability to climate change. About 97% of production comes from 3.2 million subsistence farms averaging 1.2 hectares. Use of water in agriculture has been guided by the Irrigation Strategy and Irrigation Programme, both prepared in close collaboration between the Ministry of Public Works and Housing (MOPH) and the Ministry of Agriculture (MINAG). Intended to reverse low infrastructure development and access to irrigation, the **National Irrigation Strategy**, was approved by the Mozambique Government for the period 2011–2019. Its budget amounts to USD 645 million, aiming to double total irrigated land in Sofala, Manica and Zambézia from 66,000 to 113,000 ha by 2019. Lack of access to electricity has created a fossil fuel dependency for irrigation, as a result rising prices made the cost of irrigated production unsustainable. Even irrigation operators that had access to electricity, considered prices charged by concession companies to be excessive. PEDSA strove to implement long-term improvements in water management through an integrated national water management policy. This policy would include legal instruments and a strategy for the use of water in agricultural and other sectors and for mitigating risks stemming from climate change.

Based on projections of the International Food Policy Research Institute (IFPRI), under an accelerated agricultural growth scenario, or 'CAADP scenario', the central and northern regions are prioritized under PEDSA due to a superior agricultural potential, while agriculture in the southern region is not a priority under PEDSA (Mogues, Benin, and Woldeyohannes 2012). Thus, agricultural growth and hydropower growth are projected in the same northern and central regions, while the southern region is not targeted for either (although there may some agricultural and energy growth in that region).

### 3.4 Regional Water Policies

The Southern African Development Community (SADC) framework on water constitutes a coherent suite of policies strategies and plans that have been set in place over the preceding 15 years. In this section the most important of these will be outlined.

The 2001 **Regional Indicative Strategic Development Plan** (RISDP) (Southern African Development Community (SADC) 2003a),(Southern African Development Community (SADC) 2003b), a 15-year regional integration development framework, set the priorities, policies and strategies for achieving the long-term goals of SADC. It has guided SADC Member States and Institutions, regional stakeholders and international cooperating partners in deepening integration to turn the Community's vision into a reality. Within RISDP, the overall energy-related goal was to ensure sufficient, reliable, least-cost energy services that would assist economic efficiency and poverty eradication, whilst ensuring the use of energy resources would be environmentally sustainable. The **1996 SADC Protocol on Energy** provides the general legal and policy framework for cooperation. It was operationalised through the **SADC Energy Cooperation Policy and Strategy**

and the **SADC Energy Sector Action Plan**. Within RISDP, the main priority for the water sector was to achieve sustainable and integrated utilization and management of water resources and contribute to the overall SADC objective of an integrated regional economy on the basis of balance, equity and mutual benefit for all Member States. In addition, RISDP sets out policies and in other areas, as well as setting out sustainable financing, implementation, coordination and monitoring and evaluation mechanisms.

In collaboration with Global Water Partnership, the **"Southern African Vision for Water, Life and the Environment in the 21st Century"** (Southern African Development Community (SADC) 2009) formed the basis of the Africa Vision on water and shaped the global water vision adopted at the 2nd World Water Forum. It includes a 'sub-vision' on energy security. The 1998 **SADC Protocol on Shared Watercourse Systems** provides the legal and policy framework for cooperation. The Protocol aimed at promoting and facilitating sustainable, equitable and reasonable utilization of the shared watercourses through agreements and institutions, harmonization and monitoring of legislation and policies, research technology development, information exchange, capacity building, and appropriate technologies. Lacking a long-term policy and strategy at the time of ratification, the Protocol was initially operationalised by a **Regional Strategic Action Plan (RSAP)** 1999–2004 (Southern African Development Community (SADC), n.d.) for IWRM & Development in SADC. It laid out seven priorities, the institutional basis for infrastructure projects and other development initiatives, and implementation of 31 projects.

The successor **RSAP II** was structured around four strategic areas (Practical Action, n.d.). Progress under RSAP II was in four principal areas, including firstly development and approval of the Regional Water Policy, Regional Water Strategy and Regional Awareness and Communication; second, completion of integrated planning studies at basin level, and basin strategies and databases; third, completion of IWRM demonstration projects in 5 SADC countries and fourth, the establishment and strengthening of several River Basin Organisations. **RSAP III** (2011-2015) (Southern African Development Community (SADC) 2011) was again anchored in the SADC vision and the Southern African Vision on Water, Life and Environment.. It framed interventions within three strategic areas, namely: i) water governance, ii) infrastructure development and iii) water management. Each of these are aligned with the three strategic objectives of capacity development, climate change adaptation and social development.

The **2005 SADC Regional Water Policy** (Southern African Development Community (SADC) 2005) provided a framework for sustainable, integrated and coordinated development, utilization, protection and control of national and transboundary water resources in the SADC region. The aim of which was the promotion of socioeconomic development, regional integration and improvement of the quality of life of all people in the region. On 'water for energy development', the Regional Water Policy set out three policy priorities for Member States, namely hydropower for regional benefits, water-efficient technologies on coal-fired power stations and small hydropower for economic and social outcomes.

Under alternative sources of water, the Policy acknowledges that as technologies improve and costs diminish, solar energy desalinating seawater could provide an important source of water for certain locations in SADC at a future stage. The Policy also set out guidelines and targets on dam development and management, particularly on shifting from single- to multi-purpose dams to maximise a wider set of benefits, stakeholder engagement, and negotiation of operating rules for transboundary watercourses and dams. Responsibility for implementation of the Regional Water Policy, Strategy and Protocols lies with the SADC Secretariat, in close cooperation with other sectors, such as health, energy, agriculture, trade, tourism and environment. Inter-sectoral coordination at SADC level would be an important building block for Integrated Water Resources Management and Development (IWRM&D).

While the Regional Water Policy dealt with the 'what' on regional water issues, the 2006 **SADC Regional Water Strategy** (Southern African Development Community (SADC) 2006) under the supervisory responsibility of the SADC Secretariat added the 'how'. It was supported by the detailed strategic five-year RSAP plans, with implementation responsibility lying with Member States through RSAP projects and through national policy and strategy. Under the Strategy, and in light of the prevailing urgency for increased electricity generation, 'water for energy development' would be better addressed by the Energy sector in the region (Southern African Development Community (SADC) 2006) and was therefore covered in the Strategy only in as much as it relates to water. The Strategy summarised challenges facing the regional energy sector. These issues topped the agenda during the 2005 SADC Council of Ministers meeting and were subject of a 2006 AMCOW (African Ministers' Council on Water) hydropower meeting. Accordingly, a strategic objective was set 'to promote the development of water resources for environmentally sustainable and socio-economically viable hydropower generation plants and improve grid inter-connectivity between sources and demand centres, and improve electricity service delivery especially to rural communities' (Southern African Development Community (SADC) 2006). This objective was accompanied by four sub-strategies, namely 4.4(a) on cooperative development, 4.4(b) on regional grid interconnectivity, 4.4(c) on affordable services to off-grid communities and 4.4(d) on water-use efficiency by thermal power stations. Under the Regional Water Strategy, 4.4(a) was to be handled under RSAP I under the portfolio of 'RWR 4: Support for Strategic and Integrated Water Resources Planning'. Strategic Areas (b), (c) and (d) would be handled by SADC Energy Unit and by SAPP.

In 2010 SADC launched its **Regional Water Infrastructure Programme** (Southern African Development Community (SADC) 2010) with three components, namely the Regional Water Supply and Sanitation Programme (RWSSP), the Community Livelihood and IWRM Demonstration Programme, and the Regional Strategic Water Infrastructure Development Programme (RSWIDP). It also included ten 'Macro Strategic' Water Infrastructure Projects, these principally being dams of regional significance, such as Batoka Gorge on the Zambezi in Zambia, and the Moamba-Major and the Large Bue Maria Dams in Mozambique.

## 3.5 A Pan-African Political Framework on Water

On a pan-African level the overarching objective is attaining the **Africa Water Vision** (UN Water/Africa et al. 2000) by 2025, with its strong roots in, and origin from, the Southern Africa Water Vision. The Africa Water Vision, prepared by United Nations Economic Commission for Africa, the African Union (AU) and the African Development Bank (AfDB) in 2001, envisages a continent by 2025 with sufficient water for food and energy security. It noted at the time of preparation the continent's huge hydropower potential (1.4 m GWh p.a.), ongoing efforts to create regional power pools and that small-scale hydropower potential for supplying rural areas had hardly been exploited. The Vision recognized that ensuring (food and) energy security called for a range of actions involving socioeconomic development policies, and that water could also be a limiting factor in the success of such measures.

With the Vision taking some years to gain traction as a political commitment, the 2008 **Africa Regional Position Paper (RPP)** (African Union (AU), African Ministers' Council on Water (AMCOW), and African Developement Bank(AfDB) 2009) was influential in framing an agenda for implementation of the Vision on a Pan-African level. That RPP talks extensively on water and energy and on a wide range of issues at the interface of the two, including newly emerging issues around scales of intervention, regional financing and cost recovery. In response, the RPP noted a suite of factors significant to the enabling environment. This came with a delivery agenda focused at the time on construction and advanced planning stages of over 130 dams across the continent (not all of which are within the energy sector), steps to retrofit the existing installed capacity, and implementation of a number of small hydropower installations.

The RPP was a key step in building political commitments from the 2008 'Declaration of the Ministerial Conference on Water for Agriculture and Energy in Africa' into the 2008 **Sharm-el-Sheikh Commitments by African Heads of State and Governments** (African Union (AU) 2008). On energy, the Sharm-el-Sheikh commitments stress under-utilization and uneven sharing of water resources, a growing challenge of food and energy securities, thus setting commitments to rectify, inter alia, the infrastructure gap to accelerate attainment of the African Water Vision. The Sharm-el-Sheikh commitments now underpin AMCOW's purpose. African States, including Mozambique, have committed to the **AMCOW Work Program** (Taal 2013), which responded to the Ministers' collective recognition that actions on water for growth must be elevated. This document also addressed the water-energy-food nexus. Annual reporting to Heads of State under the AU has now been instigated, based on a pan-African monitoring and evaluation framework (African Union(AU) and African Ministers' Council on Water (AMCOW) 2013).

## 3.6 International Partnerships

A number of international projects, initiatives and partnerships are currently ongoing with strong relations and potential (direct and indirect) impacts on hydropower development in Mozambique. The following section refers to some major initiatives launched by international organizations and donors.

The **Sustainable Energy for All** initiative (SE4ALL) is a multi-stakeholder partnership between governments, private sector and civil society. Mozambique is one of more than 85 governments that joined the initiative, fostering rapid assessments, scale up actions in priority areas, strategic reforms where needed and spuring new investments and financial support.

The continent-wide AU **Program for Infrastructure Development in Africa** (PIDA) targets four infrastructure sectors including energy and water. The Program supports developing water storage and hydropower infrastructure, targeting 20,000 $hm^3$ of new water storage capacity by 2040 ("Program Infrastructure Development for Africa (PIDA) | African Union" 2015).

The major **Comprehensive African Agricultural Development Plan** (CAADP), under the auspices of the African Union, is, in the case of Mozambique, linked to the national Strategic Plan for Agricultural Development (PEDSA) (Mogues, Benin, and Woldeyohannes 2012). New irrigation schemes are planned, requiring water storage infrastructure and potentially implying trade-offs with hydropower (Spalding-Fecher et al. 2014b).

The **World Bank Country Partnership Strategy** (CPS) (2012-2015) (World Bank 2012a) provided support to the Mozambique Government to develop one of the region's largest hydroelectric generation and transmission projects, in partnership with the private sector and donors. The CPS also included support for water resources planning and capacity building. The focus is a long-term strategy to assist the government in prioritizing infrastructure investments, including key power transmission investments, to unlock the country's water resources and hydropower potential, in conjunction with Spatial Development Planning.

In 2007, the World Bank's **'Mozambique Country Water Resources Assistance Strategy (CWRAS): Making Water Work for Sustainable Growth and Poverty Reduction'** began to assist the Mozambique Government in prioritizing water resources interventions. This was achieved by analysing Mozambique's changing socioeconomic circumstances and possible World Bank engagement over the subsequent 3–5 years. An Implementation, Completion and Results Report of the 'Energy Access and Reform Project' was released in 2012. It highlighted, among other things, the risk of overstating private sector participation (World Bank 2012b).

The World Bank-funded **Sustainable Irrigation Development (PROIRRI)**, awarded in 2013, aims to increase marketed production (horticulture and rice), enhance farm productivity in new or rehabilitated irrigation schemes in Manica, Sofala and Zambezia, and progress climate adaptation.

In late 2014, the World Bank approved USD 50 million to support climate change-related reforms agreed on by the Mozambique Government and the Bank under the **Climate Change Development Policy Operation** (DPO) (World Bank 2012a). Policy actions aim to reduce the country's vulnerability to climate risks (in particular floods, affecting water supply, agriculture and electricity generation), in support of the Government's National Climate Change Adaptation and Mitigation Strategy.

The African Development Bank **Country Strategy Paper (CSP) 2011–2015** (African Development Bank (AfDB) 2011b) prioritised the CESUL transmission backbone, Xai-Xai irrigation scheme and potential transport projects linked to Development Corridors. Concerning capacity development, bilateral Trust Funds and the **Fund for African Private Sector Assistance (FAPA)** is supposed to support studies and technical assistance, including on energy and water.

The 2011 International Fund for Agricultural Development (IFAD) **Country Strategic Opportunities Programme (COSOP)** (IFAD 2011) sets out opportunities in the rural sector, namely smallholder agriculture and artisanal fisheries, backed by new community structures and rural finance.

# 4. Strategic Areas for Expansion in the Hydropower Sector

## 4.1 Survey of the Hydropower Sector

As summarised in Section 2, the following section outlines currently installed and potential hydropower capacity in Mozambique, within the contexts of current and future demand based on figures given in (Mahumane et al. 2012; International Renewable Energy Agency (IRENA) 2012; Chambal 2010).

The currently installed total electricity capacity is approximately 2,400 MW. Nearly all of that total, >95%, is generated from hydropower. Ninety per cent of the total installed capacity is from the Cahora Bassa Hydroelectric facility, which at 2,075 MW is the primary electricity source for both Mozambique and Southern Africa as a whole. EdM has an installed capacity of around 400 MW, of which 109 MW are from five (three of which are major) hydropower plants they own and operate.

The total hydropower potential of Mozambique has been estimated as 12–13,000 MW, producing around 60–65,000 GWh/y of energy. Around 70% of this potential (10,000 MW, 45,000 GWh/y) is concentrated in the Zambezi basin, mostly on the main Zambezi River. Accordingly, potential for medium-sized and large plants has been assessed as very high in the central (Sofala, Manica and Zambézia provinces) and northern (Nampula, Cabo Delgado and Niassa provinces) regions. The south (Maputo, Gaza and Inhambane provinces) has been assessed as relatively poor in hydro-resources for energy generation. The potential for small-scale hydropower projects has been estimated at around 1,000 MW, and at 190 MW for plants < 15 MW, with sites in the mountainous terrain and on the perennial rivers of Manica, Tete and Niassa provinces. However, despite this potential, only

a handful of small- and micro-hydropower projects have been completed. Rural electrification has so far been primarily through PV installations under social provision.

Total national electricity consumption is 1,300 MW, with the aluminium smelter plant in Maputo (Mozal) consuming 60% at 900 MW, and total energy consumed (by all other sectors) being about 400 MW. Around 70% of Cahora Bassa's capacity of 2,075 MW, except for Mozambique's entitlement of around 300 MW, is committed to supplying other SADC nations through the SAPP. For various reasons such as lack of grid access, distribution networks and affordability, Mozambique has one of the lowest rates of access to electricity in the world. As stated earlier, by 2020, the country will have a total energy demand (excluding Mozal) of close to 900 MW. EdM has a long-term strategy for exploiting large hydropower opportunities and has identified transmission infrastructure gaps that need to be addressed, as well as also supposedly having identified bilateral and multi-lateral funding opportunities for its hydropower projects. Those opportunities depend upon grid expansion, and the planned CESUL centre-south interconnection will enable the development of further large hydropower projects. Furthermore, both South Africa and the wider SADC region are also looking for opportunities in Mozambique's underdeveloped hydropower potential, given their prevalent energy-deficit situations and pressures on coal-fired thermal plants.

But Mozambique faces challenges that are common to the energy sector across Sub-Saharan Africa, exacerbated by the country's dominance in the regional hydropower domain (KPMG 2014). Those are, namely, underdeveloped infrastructure, ageing assets and major transmission challenges, with a cost recovery that does not support operation and maintenance or new investments. New transmission lines are not only needed within each country, but also to connect regions across borders to secure energy supply and to realise economies of scale. Country-specific plans to increase the capacity of transmission lines are now mostly coupled with the development plans of the whole energy sector, and this is increasingly the case in Mozambique.

## 4.2 Four Areas for Strategic Expansion in the Hydropower Sector

Different categories of hydropower development (Practical Action, n.d.) for analytical purposes have commonly been based on scheme size. Size is a key categoriser, but is neither the only nor over-riding determinant of variation within the hydropower sector. While in other countries, renewable energy may be limited to schemes that are small and off-grid that is not the case for Mozambique, with large-scale hydropower already in place (Cahora Bassa) or projected. Therefore it is not advantageous to apply a single, simple differentiation based on size. Instead, a more useful framework can be evolved from the four main strategic thrusts within the Mozambique hydropower sector (below). Rather than size alone, these thrusts are differentiated by factors such as strategic development, grid connectivity and markets. Each has different political economies and different roles and responsibilities for institutions. Each will interface differently with water.

a. *Strategic grid expansion based primarily on new large and medium hydropower schemes.* This are of expansion is characterized by a massively unsatisfied load demand that drives an expansion of transmission infrastructure within Mozambique and into South Africa and SADC through the SAPP. Whereby, only the new transmission infrastructure (primarily into and out of Tete) has the technical means to evacuate, and the economic case to justify, new large and medium hydropower installations, mostly on the Zambezi, for example at Mphanda Nkuwa ("Mphanda Nkuwa Hydropower Project - Project Brief" 2013). The new hydropower schemes enabling grid expansion will be major infrastructure projects of high national and regional importance. Arguably this thrust has two different strands of political economy, namely of the national grid expansion driven by national development goals and by EdM, but also of regional grid expansion led by South Africa and by SAPP. Although their goals may be common, sequencing may differentiate the two strands – for example the extent to which the first major new hydropower scheme will boost closing of national, South African or regional gaps (Chambal 2010). How such infrastructure will be financed and decisions on benefits are both important interfaces for energy and water.

b. *Localised mini-grids in off-grid population centres.* This strategic area of expansion will be driven mostly by urban centres and secondary rural towns (including District capitals) that will remain off the main national grid system for the foreseeable future, and that are currently either not supplied or have dilapidated generation and distribution systems. Mini-grids are the responsibility of the MoE through provincial directorates and/or donor-specific initiatives. They are characterised by local distribution networks with multiple consumers. So far, developments in electricity generation in these areas have principally been PV installations under social provision, targeting public institutions and dependent on significant financial and technical support from development partners. The country has received an estimated USD 330 million in funding for renewable energy (REN21 2015, 21). There have been few hydropower-based mini-grids, despite a significantly underdeveloped capacity in northern and central regions.

c. *Off-grid small hydropower plants, servicing (mainly) individual enterprises.* Mozambique is witnessing a growth in pico and micro-hydropower schemes that are created to service individual enterprises (rather than the general localised distribution network) in off-grid situations. Enterprises may be social (for example, where responsibility for electricity access or energy services to institutional facilities falls to individual ministries for providing essential services, such as health or education) or they may be commercial (set-up and operated under market conditions).

d. *REFIT-financed, grid connected small hydropower plants.* A fourth area of expansion, as yet largely undeveloped in Mozambique, is the opportunity for hydropower plants (of different sizes, but typically small) to be economically viable for the supply of renewable energy into the grid network, financed by REFIT tariffs under Power Purchase Agreements (PPA) by Independent Power Producers (IPPs).

The current state of affairs and opportunities within each of these strategic areas of expansion are summarised in the subsequent sections.

### 4.2.1 Strategic grid expansion based on large/medium hydropower schemes

This thrust is driven by expanding transmission/distribution networks to meet unsatisfied demand in Mozambique and in South Africa and SADC through SAPP, fed by new generation of major significance within Mozambique. This modifies the strategic energy direction of Mozambique of the past 50 years, when external influences dominated the value chain of Cahora Bassa. With demand so high, networked coverage so low, and CESUL transmission underway, this thrust holds major prospects given Mozambique's undeveloped hydropower potential and inadequate storage capacity - upon which other water using sectors facing growing demand will also depend (World Bank 2007).

There are six Mozambique hydropower generation plants currently supplying the grid, namely Cahora Bassa, and five EdM plants, namely Mavuzi, Chicamba, Corumana, Cuamba and Lichinga (Branco 2012). With infrastructure in place for decades, maintenance has been needed, with regular financing of operation and maintenance constrained by low cost recovery. Within recent years the two largest EdM plants - the 52 MW run-of-river plant at Mavuzi and the 38.4 MW plant at Chicamba Real, both on the Revue River in Manica - have undergone rehabilitation under joint ventures with Norwegian and French companies. During rehabilitation that has prolonged lifetimes by 30 years and increased installed capacity to a combined 86 MW, opportunity has been taken to build a water supply programme at the multi-purpose Chicamba Dam. Unlike Chicamba, some of the older facilities were established as single-purpose infrastructure, discarding multiple-use opportunities, which now offer some scope for recovery, particularly at the dominantly single-purpose Cahora Bassa, given that HCB is now under a new ownership model (Chambal 2010). Rehabilitation of the EdM-owned Massingir is also adding a new 25-40 MW hydropower facility, widening its multi-purpose functionality. It is unclear whether there is over cost recovery for operation and maintenance from the HCB-exported energy to its customers who can afford to pay tariffs, but do so to other (resource-stressed) national utilities.

This area of expansion hinges on installing new generation capacity. That capacity will be linked to the new CESUL Backbone for evacuation and to wider distribution networks connecting customers. That new capacity has been assessed as least cost within the region (Ministry of Energy, Directorate of Studies and Planning, n.d.), and viable amid other non-hydropower solutions to the energy mix (CCS-Africa, n.d.; Ministry of Energy, Directorate of Studies and Planning, n.d.). One proposal has been enlargement of the Cahora Bassa spillway (Chambal 2010) that would both increase capacity and facilitate restoration of downstream flows from HCB. But in conjunction with market demand (World Bank 2007) and major improvements to the transmission and distribution network, the country has planned a number of new medium- and large-scale hydro power generation projects, with a pipeline (Branco 2012) of more than 4,000 MW. These new power schemes can structure the emerging national grid in ways that allow power sharing between several production centers and create conditions for smaller generation in other central and northern basins. The pipeline includes the following planned hydropower projects (EDM, published by IRENA (International Renewable Energy Agency (IRENA) 2012). The status of currently planned hydropower projects in Mozambique is summarized in Table 2.

Table 2: Planned hydropower schemes in Mozambique according to IRENA (International Renewable Energy Agency (IRENA) 2012)

| Project name | Location | Size | Status (as of 2010) |
|---|---|---|---|
| Mphanda Nkuwa | Tete | 1,500 - 2,500 MW | Commercial agreements |
| Cahora Bassa North Bank | Tete | 850 - 1,245 MW | Pre-Feasibility |
| Lupata | Sofala | 600-650 MW | Feasibility |
| Boroma | Tete | 200-400 MW | Feasibility |
| Lurio | Cabo Delgado | 120 MW | Feasibility |
| Ruo | Zambezia | 100 MW | - |
| Mavuzi 2&3 | Manica | 60 MW | Conceptual |
| Malema | Nampula | 60 MW | Pre-Feasibility |
| Massingir | Gaza | 25 - 40 MW | Pre-Feasibility |
| Majawa | | 25 MW | |

Although not associated with hydropower, recent rehabilitation of Nacala Dam (Millennium Challenge Account-Mozambique (MCA-Mozambique) and National Directorate of Water (DNA) 2010) has highlighted environmental and social responses to medium- to large-size dams in Mozambique.

### 4.2.2 Localised mini-grids in off-grid population centres

The EdM grid currently reaches 20% of the population, over half those having access being in and around Maputo, with all provincial capitals and most urban centres connected, giving access of 26% in urban areas and 5% in rural areas. People not on the grid are mainly those living in peri-urban areas, District capitals and rural areas. These, especially rural population centres, rely upon mini-grids independent of the main grid, typically powered by diesel or gas generators, of which many generation and distribution systems are dilapidated. The large majority are state-owned and operated by district administrations, municipalities or other government institutions. These centres are typified by low-demand, with very little electricity used for economic purposes, very few large customers and with most consumers being domestic only. The lacking economies of scale and economic customers has the consequence that electricity development, connection and operation costs per customer are higher than in larger centres, and revenues rarely cover costs. With uniform tariffs throughout the country, there is implicit cross-subsidy of consumers in these low-demand centres by larger cities and towns. Yet, rural households without access to electricity reportedly spend around USD 50 p.a. (from annual incomes of USD 300 p.a.) on substitute products (kerosene and batteries) (Public. Private Infrastructure Advisory Facility (PPIAF) 2003).

Amid such contexts, public sector institutions in such centres have witnessed a growth of PV-based decentralised mini-grids. As discussed elsewhere, public buildings been targets of rural electrification projects, and the majority of PV

systems installed by FUNAE have been decentralised mini-grids (International Renewable Energy Agency (IRENA) 2012), mostly serving public sector institutions (health centres, schools and police stations), as well as water pumping systems to provide potable water for community and (in some cases for agricultural purposes), and backed by Management Committees that provide support services. As discussed, this social approach has provided very low cost electricity or equipment, and the charging of nominal fees, but has relied upon external financing and international companies for deployment. Concerns have been raised over whether a 'well-funded social approach' and 'market-based initiatives' can coexist effectively, mainly in respect of PV, but probably of greater relevance to hydropower which might support wider commercial opportunity. FUNAE has been exploring possibilities for market-based off-grid energy based on micro-financing among poor rural communities (International Renewable Energy Agency (IRENA) 2012), allied with training, marketing and other promotional activities.

One example of a mini-grid micro hydropower serving a small community distant from the national grid is the Honde scheme, in Bárue District, Manica, electrifying a 200 household village (Chambal 2010). With little consolidation to-date of wider evidence from Mozambique, assessments (Mujere 2013) reveal the impact of mini-hydro (20-30 kW range) on rural livelihoods in Eastern Zimbabwe, with beneficiaries numbering around 1,000 to 6,000 per scheme providing (some for the first time) poor rural communities with relatively affordable, easy-to-maintain, and long-term sources of power. Benefits have been economic, social and environmental, specifically to income generating activities, agriculture, education, health, entertainment, environment, and community capacity. Notwithstanding these beneficial impacts, there are reportedly outstanding issues around more wattage demand for cooking, environmental flow requirements, conflicts and coping with climate.

Alongside Government, a small number of NGOs and bi-lateral donors are active in the micro-hydropower field. Practical Action and their Mozambican counterpart Kwaedza Sumukai Manica (KSM) have been developing village electrification projects following what they called the ‘generator model’. This model is built around a private entrepreneur generating electricity for the community, while the local transmission and distribution infrastructure will be owned by the community. GIZ has also worked with local entrepreneurs to extend their business from milling to local electricity distribution and has upgraded three systems, supporting local production of turbines. GIZ is currently assisting local education institutes in Chimoio, Manica province, to set up a local hydropower training and knowledge centre.

The potential of, and constraints on, hydropower development to service mini-grid distribution systems in district capitals and peri-urban centres - as a possible complement to the well-funded PV social programme of FUNAE and development partners - and rural communities would prove valuable focus for discussion. That potential should be in the context of the extent to which a critical mass of peri-urban areas, district capitals and other secondary towns and communities (with social need and productive opportunities) will continue to remain off-grid for the

foreseeable future, while also lying in areas with hydropower generation potential and specific sites. In such cases, the merits of hydropower-based mini-grids over and above PV-based solutions need to be set out, under both social and market-based financing, considering both CapEx and operation and maintenance.

### 4.2.3 Off-grid small hydropower servicing (mainly) individual enterprises

A substantial number of independent off-grid independent systems are already operational - notably in both microand pico-size("African Hydropower Database - Hydro Stations in Mozambique" 2015) (<10 kW) categories. Such operational schemes are presumed to be in remote areas, but as this thrust advances, there may be viability even in places where electricity is available from the grid, if they can produce electricity at lower cost and more reliably than that provided by the national utility. While the technology may be small hydropower, such a thrust is distinct from micro-grids as the customer-base is dominantly an individual enterprise, and presumably commercially motivated given that the operator is also the customer. The thrust can be associated with social or market-based financing models, themselves depending on the principal consumer and the rationale for initial investment in installation. Whether the operational schemes are serving commercial or social purposes is not known, as at this stage, such information is not yet available in any distilled format across a wide number of schemes. While it has been reported that micro-hydro schemes are well-established in the tea-producing areas of Zambézia, again there is little consolidated evidence of existing installations, but a case for rehabilitation and new plants to foster the tea industry (International Renewable Energy Agency (IRENA) 2012).

With Mozambique being such large country with a widely dispersed, mostly rural, population, so even with grid extension plans, it is likely that large areas of the country (and notably the most remote) will not be reached by the electricity grid in the medium-term. Accordingly, there is a strong and growing thrust for off-grid, independent generation and supply solutions for isolated rural communities, in the country's as yet unexploited hydropower potential, given the potential for even micro-hydro to transform communities. The scale of these off-grid systems range from pico-scale lighting systems for individual buildings to more substantial systems for clinics, schools, complementing the thrust on community-level mini-grids.

As described by Practical Action (Practical Action, n.d.), the best geographical areas for small hydropower exploit steep, perennial rivers. Low-head turbines offer small-scale exploitation where there is sufficient flow but low head. General national assessments of small hydropower potential have identified projects totalling 190 MW (Chambal 2010), with very high potential in northern and central parts (mountainous terrain and perennial rivers), and notably in the tea producing Districts in Zambézia, with detailed assessments having been conducted in Manica, Niassa and Tete. Regarding specific sites with potential, the Policy for Renewable Energy and Master Plan for Off-Grid Electrification provides a list of 60 identified hydropower locations. The Department of Energy estimates that over 60 potential micro- and mini-hydropower projects with a potential of up

to 1,000 MW exist (UNIDO and ICSHP 2013). Assessments of the suitability of potential sites are based on the hydrology of the site, but this region does not yet have regionalised flow regime data for estimation at sites without historic data (Macaringue 2009).

With major costs in site preparation and capital costs of equipment, Practical Action (Practical Action, n.d.) have set out recent technical innovations in micro-hydro that now offer considerable financial benefits.

### 4.2.4 REFIT-financed, independent grid-connected small hydropower

The fourth strategic area of expansion is driven by prospects for the setting up by independent producers of hydropower projects along an expanding grid network, including but not limited to proximity to load centres. The district-level grid extension being carried out by EdM provides such an opportunity. Furthermore, reforms in the energy sector have created the necessary enabling environment for private investments in the sector, as were foreseen by the 1997 Electricity Act granting concessions for private energy production, distribution and sales. Under such arrangements, the private sector - typically Independent Power Producers (IPPs) can operate their own generating systems, supplying full production to the grid. Alternates may be available whereby producers providing electricity to surrounding communities may sell any energy surplus to the state power utility while buying energy from the utility when it is required.

Reportedly, numerous sites for small hydro need only 5-10 km of grid extension to allow them to feed into the grid, and should be prioritised for development in EdM's master plan for grid extension, and for backing by developing partners. Arguably, planning for grid extension should take such generation sources into account. Indeed, the financial rationale for this thrust can stem from the improved transmission efficiency gained from such feed-ins. A technical study assessing the impact of distributed small hydropower generation on distribution losses would give impetus.

A key factor in this thrust is a tariff sufficiently attractive to the entry of the private sector, allowing returns on investments for IPPs. An average hydropower tariff would not be helpful. A higher and more attractive feed-in tariff for small hydro, compared to the lower average tariff for large hydro, would be offset by the reduction in grid losses if the development of small hydro projects near load centres were prioritised. Such F-iTs would give clarity to developers and incentivise IPPs. Mozambique does not currently have a Grid Code, and it has been reported that the Ministry of Energy (MoE) has been looking into the possibility of introducing one (International Renewable Energy Agency (IRENA) 2012). There is international experience for formulating feed-in tariffs from which Mozambique could benefit. These experiences can include those of a Zimbabwe IPP enterprise in grid-based small hydropower, namely Nyangani Renewable Energy (NRE, n.d.).

### 4.3 Status of Small Hydropower in Southern Africa - Barriers and Constraints

Within this context of four strategic thrusts, of which three embrace a category of small schemes, a recent overview (Klunne 2013) of small hydropower in five countries in Southern Africa has drawn a number of specific conclusions. Grid-connected small hydropower is mostly build and operated by either national utilities or IPPs. Only the Lesotho utility LEC is operating small hydropower for off-grid electrification, and only after private sector operation did not succeed. Sustainable financing and business models are required to facilitate deployment of off-grid small hydropower, including in Mozambique. The local situation in Mozambique has been assessed as favourable to small hydropower (UNIDO and ICSHP 2013). Main barriers are the lack of a framework to support IPPs, uncertainty of revenue streams and lack of finance for economically sustainable projects. A simpler process for EIA could be developed for small run-of-river hydro plants. A further study (Ahlborg and Hammar 2014) has compared drivers and barriers to rural electrification in Tanzania and Mozambique, concluding that the two countries face similar challenges with low population densities, weak customer bases, large distances and inadequate infrastructure, Yet, in Mozambique domestic actors regard social demand as the important driver for RE, while this view is less pronounced among external actors who rather regard the (lack of) economic demand as a barrier. At the national level, both countries rely on external funding, but low institutional capacity, quality and economically unviable plans hinder efficient funding. There is political recognition that grid extension needs to be complemented by off-grid solutions, but responsible agencies are yet to become fully operational.

# 5. River Basin Context for Hydropower in Mozambique

The following sections review the key characteristics of the main river basins of Mozambique, from North to South. We refer to watershed management plans and strategies of the respective river commissions, which are often transboundary in nature. Highlighting existing and planned hydropower schemes, we also refer to other major water uses and potential conflicts. Totally, there are 13 main river basins in Mozambique, national and transboundary. (Fig. 6)

### 5.1 Rovuma

A 2008 Rovuma Basin Issues Paper by the Governments of Mozambique and Tanzania (Kivugo and Chutumia 2008) targeted sustainable development and equitable utilisation of common water resources. The Basin has an area 152,200 km$^2$, 65% in Mozambique (Lucheringo, Likonde and Lugenda sub-basins), 34% in Tanzania, and 0.3% is in Malawi. The River defines the Mozambique-Tanzania border for 650 km from the coast, so is shared on a basis different to Mozambique's downstream position in all other shared basins. Mean annual runoff (MAR) is 15 km$^3$. Population is 3.2 m, of which one million in Mozambique, covering (all or part of) Niassa and Cabo Delgado provinces, and nine Districts. Administratively, decentralized basin

management lies with ARA-Norte in Mozambique and the Ruvuma Basin Office in Tanzania (formed in 1974), acting together under a Joint Water Commission. The basin has, along with the Buzi and Save, been a focus for potential Shared Watercourse Support, for example, by the African Development Bank (African Development Bank (AfDB) 2005).

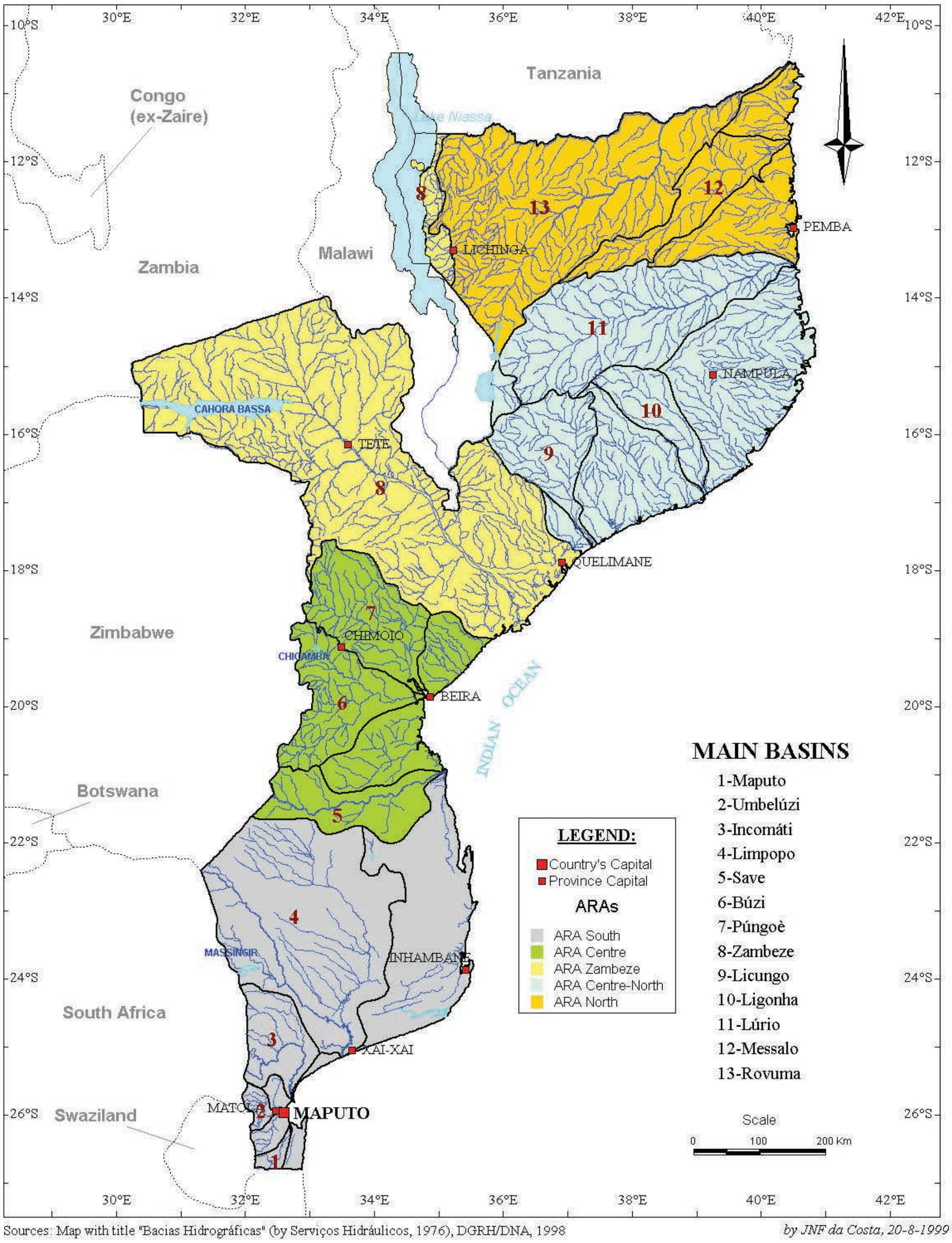


Figure 6: Main river basins of Mozambique by DNA(World Bank 2005)

Basin development and infrastructure is minimal with 'irrigation and hydropower potential, but largely undeveloped' (African Development Bank (AfDB) 2005). The smallest of EdM's hydro plants - the 0.75 MW Lichinga installation - is located within the headwaters, and connected to the northern region transmission system. With an historic specific assessment conducted on the Tanzanian side (Danish International Developement Agency (DANIDA) 1982), the Issues Paper implies (multi-purpose) hydropower potential, and a pre-feasibility has been conducted for a 2 MW plant at Mbahu (Kivugo and Chutumia 2008). The Basin contains extensive protected areas, but without electricity access, may suffer fuelwood destruction. Most households are rely on subsistence agriculture, although the Issues Paper foresaw some new and rehabilitated small irrigation schemes as Early Investment projects, typically targeting 2-6,000 people. An increase in irrigated area in the Lichinga Basin to 10,520 ha by 2015 had been projected, with agricultural water demand static through efficiencies from rehabilitation (World Bank 2007). Development pressures stem from future Mtwara and Rovuma Development Corridors (Kivugo and Chutumia 2008). Major energy developments are now driven by offshore Rovuma Basin Liquid Natural Gas.

### 5.2 Lurio, Messalo, Licongha, and Licungo

Collectively covering 125,000 km$^2$, the four basins all lie entirely within Mozambique, in Capo Delgado, Nampula and (northern) Zambezia. With Government receiving external finance for National Water Resources Development, DNA tendered the Lurio Basin Strategic Plan in 2013 (National Directorate of Water (DNA) 2013) to orientate potential use and to guide several water-related investment.

EdM has assessed detailed hydropower potential on the Lurio at three sites, totalling close to 200 MW (World Bank 2007). New Lurio capacity - possibly 65 MW - had been studied from 2007 (feasibility and EIA) as a response to rising industrial demand from the Nacala Special Economic Area in Nampula(“Lurio River, in Mozambique, May Have Hydroelectric Facility in the Future | Macauhub English” 2011), aiming to reduce dependence on Cahora Bassa. With feasibility studies completed, Ministry of Energy has reportedly been seeking USD 480m of investment for 120 MW on the Lurio to respond to northern energy demand (Ministry of Energy, Directorate of Studies and Planning, n.d.). An increase in irrigation in the Ligonha basin to 7,500 ha by 2015 had been projected with a 10% rise in agricultural water demand. No irrigation development is projected in the Messalo Basin.

The Lurio is the target of a 24,000 ha Sustainable Forestry investment (2014-2018) (African Development Bank (AfDB) 2011a) based on Climate Funds, for which an environmental safeguard assessment (African Development Bank (AfDB) 2014) advised of the risk of runoff reduction from the reforestation, to be mitigated by limiting reforestation to not more than 20% of any individual sub-basin, thereby limiting forestry in the Lurio three sub-basin to 5,500 ha, and with advice to plant Acacia spp rather than Eucalyptus spp.. Further recommendations governing reforestation were to avoid plantation in the riparian zones of rivers or lakes and not to develop wetlands, around which a buffer (no-plant) zone must be established, on the basis that forestry in these areas would use up to three times as much water as forests in non-riparian zones.

## 5.3 Zambezi

Mozambique territory represents 140,000 km$^2$ of the 1.4 m km$^2$ basin that is shared with seven other SADC Member States, namely Angola, Namibia, Botswana, Zambia, Zimbabwe, Malawi and Tanzania (Fig. 7). The Zambezi has been the subject of extensive assessment and diagnosis over the years, initially under the auspices of ZAMCOM, including the intensive ZACPLAN and its component ZACPRO studies of the 1990s and 2000. More recently, three studies provide the basis for diagnosis in this Discussion Paper, namely a 2007 Rapid Assessment (Southern African Development Community (SADC-WD) and Zambezi River Authority 2007), a 2008 IWRM Strategy and Implementation Plan (Southern African Development Community (SADC-WD) and Zambezi River Authority 2008) and a 2010 Multi-Sector Investment Opportunities Assessment (MSIOA) (World Bank 2010), also informed by the 2007 World Bank Water Resources Country Assistance Strategy (World Bank 2007) and an earlier assessment of the role of water in the Mozambique economy (World Bank 2005).


Figure 7: Zambezi river basin (GRID-Arendal 2013)

The Rapid Assessment presented key summary statistics, quantified the basin's overall modest water use, emphasised the nearly 5,000 MW of installed large hydropower generation, stressed the dominance of Cahora Bassa and Kariba upon storage and regulating capacity, revealed that the combined evaporative losses make energy by far the largest water consumer within the basin (more than ten times the use by the under-developed agricultural sector) and emphasised the single-purpose operations of the mainstream and Kafue hydropower plants.

Looking forward, on total future water demand the Rapid Assessment projected water use could be increased to 41% if plans by riparian states for hydropower development and irrigation were implemented by 2025, bringing use into the critical zone, but envisaging major (but not fullest) scope for both hydropower and irrigation development, even with a major (four fold) increase in managed flood releases. On forward projections of hydropower, some 40 schemes with a total potential of close to 13,500 MW have been identified and partly studied to pre-feasibility level, including maximising different multi-purpose objectives, and framed within three scenarios of likely development. On controlled flood releases, revised operating rules could improve conventional operations at Cahora Bassa, and while re-creating historical floods in full would lead to substantial reduction in hydropower, significant artificial flood releases could benefit the Lower Zambezi without significant reduction in electricity generation or reliability. Even benefits of large flood level changes (over 10,000 $m^3/s$) to farming, fisheries, control of invasive species, natural vegetation, groundwater and Zambezi Delta wetland restoration could be attained with a 7% reduction in power generation, if in conjunction with Kariba. The Assessment projects benefits and issues for three Sub-Basins, namely Zambezi Delta (agricultural development and controlled floods), Tete (major hydropower development with some displacement, and need for upstream soil and water conservation) and Shire/Lake Malawi (smallholder agricultural and forest productivity).

The 2008 Basin IWRM Strategy and Implementation Plan was to develop a feasible package of major hydropower sites (taking into account multiple functions in coordination with SAPP) and to identify and promote options for small scale hydropower development. On hydropower, even with high demand, development to 2025 does not correspond to the envisaged full hydropower potential, and the SAPP power expansion plan foresees Cahora Bassa North (600 MW) and Mphanda Nkuwa (2,400 MW) as part of a wide basin-wide energy expansion to 53% (6,616 MW) of potential, with a 160 MW Boroma being implemented in stages as part of an economically attractive ultimate development. The SAPP Power Expansion Plan also envisages 24 MW of small hydro per year (2006–2025) especially in upper catchments and in the Shire River/Lake Malawi/Nyasa/Niassa sub-basins, including funding under the Carbon Credit scheme. On irrigation, while a number of states have ambitious plans for expanding irrigation representing a three-fold increase to 467,385 ha by 2025, a more modest (50%) expansion of irrigated agriculture was assessed as more likely, if synchronised regionally and with existing water uses, given the prima facie ample water resources in the Basin. The Plan also carried forward the Rapid Assessment recommendations on multi-purpose benefits from improved operating rules and controlled flood releases, and proposed more than a dozen short-term actions (including numerous plans, studies and network activity).

To stimulate the basin's economies, and accommodating other sector demands, the World Bank Multi-Sector Investment Opportunities Analysis (2010) analysed different development paths for conjunctive development of hydropower and irrigation under 12 different scenarios. Principal findings were that

- basin-wide cooperation over existing hydropower facilities could increase firm energy generation by 7%, (worth USD 585 million over a 30-year period without new infrastructure),

- the SAPP generation plan requiring an investment of USD 10.7 billion over 15 years would meet all or most of the estimated 48,000 GWh/year demand of the riparian countries,

- coordinated operation of hydropower could provide an additional 23% generation,

- All proposed national irrigation would equipped area by 184%, costing USD 2.5 billion, but would reduce hydropower generation by up to 21%. If developed alongside SAPP plans, generation reduction would be 8% for firm energy and 4% for average energy. Cooperative irrigation development could increase firm energy generation by 2% (valued at USD 140 m) but would introduce complexities associated with food security and self-sufficiency,

- Basin transfers would not majorly affect current productive use, but may affect tourism and the environment, especially during periods of low flow,

- Benefits to fisheries, agriculture, environmental uses and better flood protection from restored flooding in the Lower Zambezi could be assured by modified reservoir operating guidelines at Cahora Bassa Dam. Depending on scenario selected, these changes could cause significant reduction in hydropower production (between 3% and 33% for Cahora Bassa and between 4% and 34% for Mphanda Nkuwa).

Overall, under Scenario 8 (which assumes full cooperation of riparian countries), a reasonable balance between hydropower and irrigation investment could result in firm energy generation of some 30,000 GWh/year and 774,000 hectares of irrigated land, while providing a level of flood protection and part restoration of natural floods in the Lower Zambezi.

The World Bank Water Resources Country Assistance Strategy (World Bank 2007) concluded hydropower development on the Zambezi River should be an investment priority in water resources development, being highly economically and commercially viable, and some of the investments could be provided by the private sector. With Mozambique having regained some significant independent control, there would now be greater possibility of approaching the Mphanda Nkuwa development from a more multi-purpose perspective, and an opportunity to ensure environmental and social considerations under the operational regime of Cahora Bassa and the proposed new developments, whilst still achieving major growth objectives.

A World Bank assessment (World Bank 2005) of water in the national economy assessed that the proposed package of investments (having multiple objectives to improve flood protection, reduce the impact of droughts through expanded irrigation and increase hydropower production) would reduce by 75% the year-on-

year costs to the economy of water shocks (1.1% of GDP), and further additional economic benefits including improved water supply for urban and industrial consumption, improved rural supply and other increased agricultural output.

## 5.4 Buzi

The Basin area is 27,700 km$^2$ of which 24,500 (88%) is in Mozambique and 3,200 (12%) in Zimbabwe. Built in 1968 on the Revué tributary with an installed capacity of 38.4 MW, the EdM Chicamba Dam is currently undergoing rehabilitation for hydropower generation. Its multi-purpose functions are hydropower and flood control, supply for domestic water use and irrigation. Main activities in the Buzi catchment are bananas, beans, vegetables, forestry and tea growing. The upper catchment in Zimbabwe is heavily utilized - the lower basin in Mozambique is not as utilized as the Save basin. The Buzi is prone to flooding, and was hit severely in 2000–2001. Gauging stations are regularly out of order and flow data generally unreliable. Major environmental threats are on the Revué, being erosion (a consequence of artisanal gold mining, inadequate farming practices and deforestation) and flow alterations by Chicamba Dam. Environmental flow requirements at 57% of Buzi total flow are needed to maintain a largely natural condition (Lagerblad 2010). Maintaining the Revué in its present ecological state requires an environmental flow of 23-37% of MAR. It cannot be concluded that environmental requirements would reduce hydropower production in the Buzi Basin (Nicolin 2011).

## 5.5 Pungwe

The Basin covers 31,151 km$^2$, of which 29,690 km$^2$ (95.3%) is in Mozambique. A Basin Monograph was issued jointly by Governments of Mozambique and Zimbabwe in 2006 (Government of the Republic of Mozambique, Government of the Republic of Zimbabwe, and Swedish International Development Cooperation Agency (Sida) 2004; Swedish International Development Cooperation Agency (Sida) and Cap-Net 2008; Government of the Republic of Mozambique and Government of the Republic of Zimbabwe 2006), building on prior IWRM work. Regarding decentralised governance, the basin is governed by the Pungwe Sub-Catchment Council in Zimbabwe and by ARA-Centro in Mozambique (established in 1998). The Monograph ascribes the Basin three parts, being an upper part in Zimbabwe (with intensive agriculture in Mutasa Communal Land, Nyanga National Park and inter-basin transfer to Mutare). The sparsely populated middle section has hitherto been underdeveloped, but recent years have witnessed increased investments in large-scale commercial farming, particularly in Manica. In the floodplain, there are major natural resource, economic and social interests comprising the Gorongosa National Park, the large Mafambissa irrigated sugar cane irrigation estate and other agricultural potential, Beira/Dondo City water supply, a proposed Bue Maria dam (to supply Beira), and estuarine prawn farming and fishing, with issues of saline intrusion. Flooding is frequent in the lower Basin, and even if new storage were to mitigate impacts, flood forecasting and protection systems are needed (Ron Cadribo, UNISDR DRR Advisor, AUC 2012). With hydropower potential, and present hydraulic infrastructure that support a fraction of the Basin's agricultural potential, the Monograph identifies numerous dam sites.

## 5.6 Save

Basin Area is 110,420 km$^2$ of which 84,500 (79%) are in Zimbabwe and 23,620 (21%) in Mozambique. Basin population is 3.3 million, of which 300,000 in Mozambique. There is no Basin study, but the Save, along with the Buzi and Rovuma basins, has been targeted for potential support under shared watercourse interests (African Development Bank (AfDB) 2005). The hinterland is a mix of large scale (7,400 ha), small (20,000 ha) and subsistence farmers. In Zimbabwe, the Basin suffers erosion and siltation from poor agricultural management practices and fuel wood deforestation. Existing water storage in Zimbabwe is 2,734 Mm$^3$ in 13 dams, primarily for irrigation and urban water supplies, the largest being Lake Mutirikwe within the Runde sub-basin. Potential irrigable area in Zimbabwe is 335,000 ha, most in the lower reaches of the Save, Runde and Mutirikwe sub-basins, and 220,000 ha in Mozambique. The largest dam in Zimbabwe, the Tokwe-Mukorsi, has recently been completed, and is due for commissioning later in 2015, further boosting areas under irrigation, and with an installed hydropower capacity of 12 MW. Reportedly(Bango 2013), seven hydropower plants along the Save in Zimbabwe are at an advanced stage, the largest at 30 MW, supported by Indian support to planning . With significant small hydropower potential, the NGO Practical Action have reportedly recently installed three mini-hydropower systems in Zimbabwe. As in the Limpopo, principal IWRM concerns have been around community engagement, with a focus on local conflict reduction among different water users within the Save (Chifamba 2013).

## 5.7 Limpopo

The Basin area is 79,800 km$^2$ in Mozambique, part of the 408,000 km$^2$ shared with Botswana, South Africa and Zimbabwe (Fig. 8). Agreement on the Limpopo Water Resource Commission was ratified in 2011 (Sitoe 2012). A River Basin Plan (2011-2015) has been mooted, but not yet conducted. A 2010 Joint Basin Study (BIGCON Consortium 2010) was commissioned to quantify the present and future water balance in each of the four states, and to plan development and management options. The Report reveals irrigation as the largest consumer (50%) of total water use of 4,730 Mm$^3$/a, of which total 2/3 is used in South Africa, 30% in Zimbabwe, 6% in Mozambique and 2% in Botswana. In Mozambique, almost all of Limpopo water demand is for irrigation, as urban and industrial demand are quite small and rural water supply is dispersed and use water from local aquifers. Present irrigation is concentrated in two areas, Chokwè (22,000 ha) and Xai-Xai (4,000, potentially up to 9,000 ha), with a further 30,000 ha proposed by the PROCANA irrigation project (BIGCON Consortium 2010). Developments in Mozambique irrigation could increase the water demand for irrigation to about 1,200 Mm$^3$/a in the future from the present 270 Mm$^3$/a, but water productivity is low, particularly at Chokwè. Livestock is quite important in Gaza Province, with a 2007 inventory of 400,000 cattle requiring 7 Mm$^3$/a. Two cities, Chokwè and Xai-Xai, have low water demand, around 4 Mm$^3$/a, as do other towns, like Chibuto. Industrial water use is small and mostly part of urban water supply systems. There is a major mining project to extract heavy mineral sand in the Chibuto area to extract heavy mineral sands, which would abstract water from the Limpopo River, but is currently on hold.

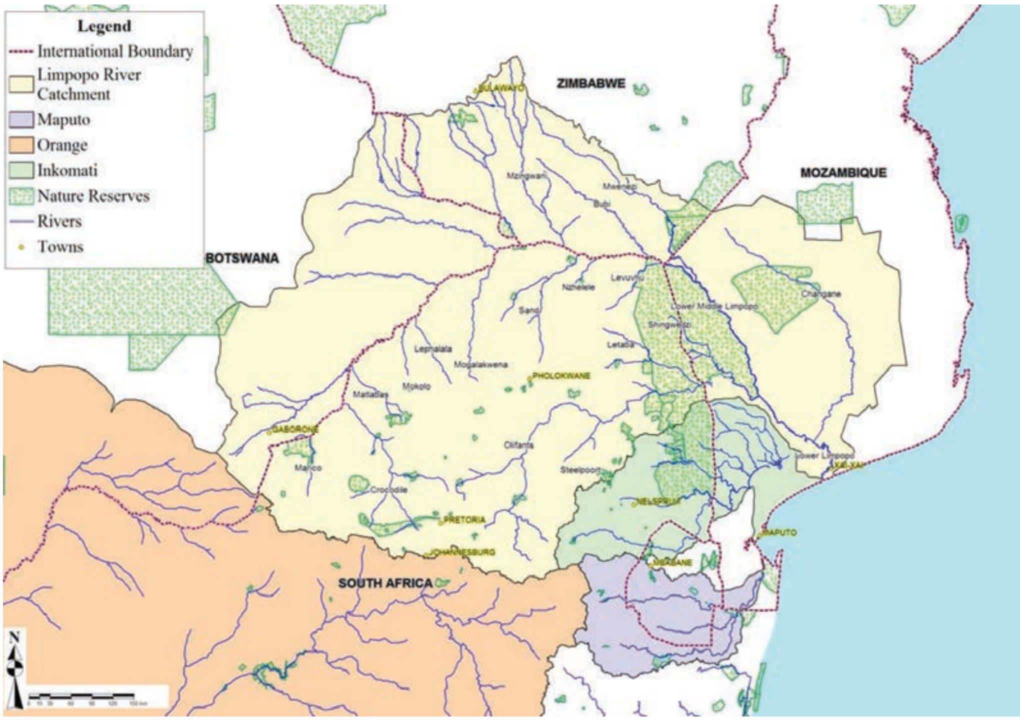


Figure 8: Limpopo river basin(BIGCON Consortium 2010)

The Basin has extensive dam storage as the basis for the present intensive use of its water resources. Botswana has a number of large dams totalling 355 Mm$^3$. Zimbabwe has 21 large or medium dams within the Mzingwane basin, with extensive storage in South Africa. There is one large dam in the Basin within Mozambique, Massingir Dam on the Elephants River, having the largest storage capacity in the basin at 2,800 Mm$^3$. Previously a single purpose dam for irrigation, installation of a 28 MW power station has been proposed as part of rehabilitation following a serious accident in 2008. Mozambique's Macarretane Dam, capacity 4 Mm$^3$, is also on the Limpopo. Within all countries, there are many small dams (in most cases below 1 Mm$^3$). There are several interbasin transfers into the basin from the Vaal, Usutu, Incomati and Gwaai/Shangani, as well as transfers between Limpopo's own sub-basins (Mabiza 2007). In none of the above dam situations does the Basin study discuss actual, or potential for, hydropower generation. Assessment of the key issues around IWRM in the Limpopo in 2007 focused ostensibly on stakeholder engagement, and questioned the local relevance of 'international IWRM' (Mabiza 2007), while efforts on flood impact reduction have focused on building local resilience within transboundary frameworks, including (but not limited to) the Limpopo (Ron Cadribo, UNISDR DRR Advisor,AUC 2012).

### 5.8 Incomati and Maputo

Principal development interests within the basins are irrigation, including sugar cane and citrus fruits, with some plans for biofuel production (Marx 2012). Reportedly, water consumption in South Africa and Swaziland increased rapidly in the 1990s and up to 2006, water resources in these two countries now fully (if not over-) utilised. Corumana Dam, on the Sabie River inside Mozambique, serves to guarantee a secure inflow to irrigation schemes and hydropower generation - this is EdM's third largest hydropower facility with an installed capacity of 16.6 MW. The Maguga dam in Swaziland is the only major dam used for significant hydropower generation, with other power from run-of-river schemes. With the majority of farmers in South Africa and Swaziland using electricity powered pumps, most electricity comes via international and national grids.

Institutionally, the bilateral Komati Basin Treaty between Swaziland and South Africa dealt only with the management of certain reaches of the Komati River. An Interim IncoMaputo Water Use Agreement (IIMA) has provided agreement on water-related management of the whole Incomati Basin, developing from an earlier "Tripartite Permanent Technical Committee" into a fully fledged River Basin Organisation. Given the area's water shortage, prime drivers of storage development (Corumana) are meeting water needs of Great Maputo and irrigation opportunities.

## 6. Integrated Management – Opportunities, Challenges and the Way Forward

This Chapter provides an evidence-based foundation from which recommendations on next steps are drawn. Those next steps are intended to set in course a process that will advance the issue of integrated management of energy and water in Mozambique. The result of which will be an approach that tackles the most prominent challenges and opportunities amid the current situation.

### 6.1 Assessment of Initial Position: Opportunities

In the case of Mozambique, it is particularly evident that there are large unlocked potentials for further development of hydropower, and these potentials may even be enhanced when developed in the context of the water - energy - food security nexus. The analysis provided so far clearly illustrated that hydropower in Mozambique has the highest potential among renewable energy sources. It can also play an important role in balancing the intermittency of supply by other renewables. Furthermore, hydropower offers synergies with other water users (including agriculture and flood control as examples). Finally, within the hydropower system there is the opportunity to develop different grid and off-grid supply of different size categories. Taking a closer look at these opportunities, evidence provided in this paper allows a somewhat elaborated and slightly shifted position on some of them, as outlined below.

With respect to **hydropower potential**, it seems important to note that several other energy sources have potential that well exceed future demand projected for Mozambique– individually and collectively. Rather than hydropower, as postulated, it is the potential of solar power that has been assessed as the highest among renewables. Nonetheless, hydropower potential is extensive. Exploiting the potential of Mozambique's hydropower has been embedded in national policies for decades. Yet, despite that potential, there have been no major new hydropower dams built in decades. Furthermore, with many district capitals and over 2 million households supported by PV systems, hydropower is not yet being exploited at an equivalent rate to other renewables under rural electrification. Trends in uptake and exploitation appear to be far more significant than the size of latent potential. Government, donors and delivery agents appear to have developed successful models for implementing PV but have not yet done so for hydropower.

Concerning **hydropower's potential to balance intermittency** of other renewable energy sources, the existing plants– backed by intra- and inter-year carry-over storage – largely do yield consistent electricity supply, with some further load-balancing also provided by the grid. Run-off-river schemes could yield an improved constancy of supply compared with PV, (except when river flow falls below critical levels, especially seasonally). So, indeed, hydropower does – in principle – offer prospects of greater constancy of supply to off-grid communities, especially among the more or less perennial streams in the remote upland areas of central and northern Mozambique. However, despite what would appear to have been a major advantage from exploiting hydropower compared with other renewables, it is very clear from the very wide uptake under rural electrification of solar PV with its characteristically diurnal supply that intermittency has not been a principal barrier to new-entrant electricity access. Intermittent PV has proven by far to be the more attractive renewable option than the constancy of hydropower.

With respect to **synergies with other water uses**, the massive deficit of water (and energy) storage in Mozambique has been a detriment to agricultural production, urban water supply and flood protection. So indeed, there are opportunities for synergies. However, much of the existing infrastructure has been either multi-purpose at the time of construction (e.g. Chicamba and Corumana) or during rehabilitation opportunities for different users have been widened (for example at Mavuzi and Massingir). The major exception has been Cahora Bassa, which has been dominantly single-purpose. Multi-purpose objectives have been embedded in national and regional policy for more than ten years – under the first national Poverty Reduction Plan and most explicitly under the 2005 SADC Regional Policy (shifting from single-purpose dams to maximise a wider set of benefits) – a policy that has been highly influential for any new major storage constructed (as they have been for example at Tokwe-Mukorsi on the Save in Zimbabwe). The likelihood of new storage seizing those multi-purpose opportunities increases as new energy capacity will lighten the major dependence upon the existing 'sweated assets'. There is major potential for expanding both hydropower and irrigation within the Zambezi, and the extent of development by both the energy and agricultural sectors can be extended even further through multi-purpose schemes. But at the

higher ends (in terms of capacity) of Zambezi development projections, then the projected demands of both sectors become incompatible with each other. At those levels, opportunities for further irrigation development and further energy development will be traded off against each other. However, such development scenarios are not yet planned. Should they be, then decisions concerning those trade-offs will benefit from a nexus (integrated) approach and use of appropriate tools and models to that end (Spalding-Fecher et al. 2014b). While opportunities within the Zambezi are synergetic, the narrative appears to suggest that for small hydropower, the relationship is becoming mutually dependent such that only the commercial and economic demands of (and financial returns from) agricultural development can unlock small hydropower development in remote communities.

Finally, concerning **on- and off-grid potentials**, evidence in this paper fully supports the notion of different categories of hydropower, but not on the proposition based on size alone. This paper has demonstrated that there are four distinctive strategic thrusts within the hydropower sector. A tendency to associate small hydropower only with off-grid solutions negates the very real opportunity of IPP hydropower generators to be incentivised by feed-in tariffs or to support mini-grid distribution systems in some rural district centres, or peri-urban areas.

In essence, while the opening opportunities have provided useful entry point for study, the consolidated evidence base has yielded only partial support of determining how to move forward solely on basis of these opportunities.

### 6.2 Assessment of Initial Position: Challenges

When considering the principal challenges for hydropower development we had initially identified the following:

- reduced availability of water as a result of climate change
- increasing water demand from other sectors
- current low storage capacities
- challenges in the implementation of IWRM and transboundary issues

Reviewing these challenges our analysis suggests an even more nuanced position: While there are clearly **climate risks** (that have, for example, recently justified a USD 50 million policy support operation), projections that climate change will reduce availability of water and jeopardise Mozambique's hydropower sector have not emerged with the same prominence from the evidence base as ascribed initially. It is clear that the southern basins of the Incomati and Maputo (possibly the Limpopo also) are effectively closed to any further development due to extensive demand already in place – but these are, however, not areas with any major undeveloped hydropower potential. Progressively further north, basins are assessed as possessing undeveloped potential. While climate risks may or may not moderate that potential to some degree depending on interpretation of data, climate risks do not eradicate that potential. The fact that the Zambezi is being considered for potential increases in its water use for energy by a factor of three – given that it is already ten times bigger than any other sector – suggests

climate risks are not dominant in central and northern regions where hydropower prospects are greatest. A large part of assessing whether or not climate risk is prominent appears to hinge on the association climate and irrigation. Agricultural water use is massively underdeveloped in the Zambezi and other central and northern basins, and there are many economic and social drivers of a major expansion. If that major expansion were to be solely attributed to overcoming future climate risk, then indeed the prominence of the impacts of climate change upon water availability could be multiplied many-fold. An alternate framing is that agricultural development is a major pillar of poverty-reduction and, as part of that development, a significant expansion of water use can be accommodated by Mozambique's central and northern water bodies. Notwithstanding, climate change may modify amounts of river flow. That alternate framing does not include abstraction of water for agricultural use as a direct response to climate change. Climate change is expected to cause a 6% change in irrigation water demand in Mozambique by 2050 (Fant, Gebretsadik, and Strzepek 2013). At the same time, the National Irrigation Strategy projects a doubling of total irrigated land in Sofala, Manica and Zambézia from 66,000 to 113,000 ha by 2019 – a different scale of increase upon national irrigation water demand than the 6% directly attributable to climate change.

**Increasing water demand from other sectors** may jeopardise hydropower development, based on conclusions from recent studies (Spalding-Fecher et al. 2014a; Yamba et al. 2011). What clearly emerges is the fact that future projections of numerous water demands (including urban and industrial water demands, at forecast rates of growth, and even under the more intense scenarios) must be accommodated alongside hydropower. Issues around water demand potentially jeopardising hydropower relate – on a large scale – to irrigation alone. But even in the Zambezi, where major hydropower opportunities exist, there is an assessed potential to meet at least half of national projected irrigation demand (perhaps up to 774,000 ha, of which 200,000 ha at least by 2025). That potential is in addition to more than 6,000 MW of new hydropower and to partial restoration of natural floods. Elsewhere, assessments of environmental flow requirements at around 30-50% of MAR in the Buzi are not yet implying that sustaining high-status ecological conditions would constrain a substantial level of hydropower production. That said, in dam situations where high flow releases are not of mutual benefit to hydropower and ecology, and where wet season storage is to be maximised by dam operators, the possibility of meeting environmental flow requirements could be more detrimental to water use (as at Nacala Dam).

The issue and challenge of **low storage capacities** is generally valid, but should be seen in the context of demand for storage considering all water uses. This was discussed extensively under opportunities above.

While the **implementation of integrated management plans** is still a challenge, IWRM is at least principally acknowledged as a desirable strategy and partially implemented. Strategic Basin Plans have been pursued under IWRM paradigms, and the translation of SADC policies on water were through IWRM-based RSAPs. It is, however, increasingly acknowledged that sustainable management of

resources requires an even broader perspective, more explicitly – and in equal terms – considering interrelated resources and sectors, thus a Nexus Approach. Such an approach would have to consider hydropower within the context of other (renewable) energy sources and the respective resources, for example, soils for biomass production. Fostering the development and implementation of such a Nexus Approach requires research and capacity development addressing also the socioeconomic aspects of the WEF nexus. Moreover, the Nexus Approach calls for regional and international cooperation. This is particularly true in Mozambique with mostly transboundary river basins and the need for regional coordination of energy supply and demand.

## 6.3 Advancing a Nexus Approach: The Way Forward

There are, in the authors' views, several further arguments supporting the plea to extend the scope of integrated management from IWRM towards a Nexus Approach: IWRM has been an underpinning premise of the SADC policy and of Basin plans for over a decade. It has enabled many diverse facets of water management to achieve progress across the region – especially on community-level engagement, as highlighted in the cases of the Save and Limpopo. But with the original framing at the Rio+20 UN Conference on Sustainable Development not as IWRM but as IWRM&D, the development dimension – and hence the interface with energy – had been given strong emphasis. The evidence consolidated in this paper confirms that management of water and energy has several integrators that are common to IWRM, for example, scale, different demands, governance, finance and social and environmental impacts. However, when one looks at the general positioning of hydropower in relation to IWRM internationally, for example by NORAD (Ibrekk 2007), one finds an adoption of several a priori positions on those integrators that are not reflected in the current Mozambique situation. Therefore, while integrated management is a clear way forward, a concern must be raised over importing preconceived notions into the Mozambique energy-water nexus that may be unsubstantiated, sometimes contradictory and anyway are certainly more nuanced. This does not undermine the case for integrated management - rather, it absolutely creates the case for it, but under an evolved outlook. This evolved outlook, to our understanding, is covered in the concept of the Nexus Approach, confirming earlier conclusions (Schreier, Kurian and Ardakanian 2014). A major contribution by this paper is thus to provide evidence that there is indeed a need to advance a Nexus Approach.

In the context of integrated management, the importance of partnerships (at various levels: between sectors, governance bodies and on an international scale) cannot be over-emphasized. Because without partnership, and without dialogue, it is evident that a large body of evidence can be assembled, but in a way that has lacked the essential inter-comparison and consolidation. Consequently, partnership is key to unlocking policy.

So, in conclusion, while follow-up action is most certainly needed on integrated management, that response needs to be defined differently and to be more nuanced to the Mozambique situation. It needs to go beyond IWRM towards a Nexus Approach.

## 6.4 Evidence on Integrators of Management

In support of a Nexus Approach, our analysis highlights the importance of certain key integrators of management. Five such integrators emerge with prominence, namely i) scales of relevance for implementation, ii) the water-energy-food nexus, iii) finance, iv) governance and institutions and v) mitigating social and environmental detriment. Each of these integrators is discussed in further detail below.

For each of these integrators it seems important to avoid generalisations that can be assumed to apply across the whole hydropower sector. This is because the four different strategic thrusts of hydropower can sit at alternate (and even contradictory) ends of the spectrum. So, a priori assumptions may apply to some parts of the hydropower sector, but not across all. To put it simply, for large grid-based hydropower, several factors of political economy extend the drivers of demand well beyond basin confines, incompatibility issues at upper ends of the development scenarios mean both hydropower and irrigation cannot be developed to their fullest maximum potential and governance is primarily executed by the state (in fact, by several states under SAPP). In addition, drivers of demand for small, independent off-grid hydropower plants lie mostly within individual sub-basins, such schemes virtually require agriculture to drive the commercial case for economic viability, and governance is executed by local communities. So, there can be divergent positions on these five integrators across the four different classes within the hydropower sector. For these reasons, a water-energy-food construct around the four strategic thrusts is likely to prove a more fruitful way forward than a simple and over-generalised 'water and hydropower' framing.

i. Scales of relevance for implementation

   There has clearly been an emphasis by the Government of Mozambique on understanding strategic issues in each of Mozambique's river basins. It is appropriate that in assessing these issues hydropower figured most prominently in basin analyses of the Zambezi (where 70% of the nation's hydropower potential lies). Clearly, the hydrological and environmental viability of individual schemes has to be assessed along such basin lines. But complementing that basin scale, and with a consequence that has yet to be recognized, our analysis revealed drivers at other scales of relevance that are highly significant.

   It seems important to highlight that the water-energy nexus is characterized by a major imbalance of spatial scales in the case of hydropower. Few (if any) medium- to large-schemes have been, or will be, justified by demand for electricity within their own basin, either solely or significantly. Instead, it is the transfer of power out of basins (by the new north-south interconnecting transmission backbone, CESUL) that is running across (and uniting) more than seven separate basins, which provides the economic justification for new hydropower.

   With weaknesses in transmission efficiency over such long distances, there is also a strong economic case emerging for hydropower in certain locations because it reduces transmission losses within the national grid. Hydropower schemes that were planned on a river basin basis alone would miss such opportunities.

Clearly, Mozambique hydropower has the potential of being a key component within South Africa's Integrated Resource Plan. As such, the future demand for Mozambique hydropower is also driven by a client-base in South Africa, many of whom do not even reside in a river basin flowing into or shared with Mozambique. In fact, the population constituting that part of regional demand may be of a similar size to the entire population of all the river basins that Mozambique shares with its neighbouring states. In other terms, the number of potential South African customers of Mozambique electricity living outside of any shared basin is not greatly less than the entire population of the Zambezi, Limpopo, Save, Rovuma, Maputo and Incomati combined – across all of the SADC countries. Thus, there is a major disconnect between the boundaries of river basins and the those of regional energy markets. IWRM has succeeded in extending notions of water allocations towards benefit sharing, but to-date that notion of benefit-sharing has tended to be confined only to the sharing of benefits within basins. Yet, Mozambique energy is a prime example of the case for extending notions of benefit sharing beyond river basins. Drivers of the demand for national hydropower are also stemming from external influences beyond South Africa, for example from the Mtwara Development Corridor aiming to connect the inland nations of Malawi and Zambia to the coastal port in Tanzania (Kivugo and Chutumia 2008).

There are major benefits from regional, multi-country cooperation, including across river basins. Given the high regional demand for power (SAPP), the coordinated operation of hydropower has been quantified at an additional 23% of generation. While the pursuit of irrigation development under separate national strategies would reduce energy production in the Zambezi (by around 20%), cooperative irrigation development could increase firm energy development by 2%, valued at USD 140 million.

While hydropower potential is low in southern Mozambique, water demand pressures are high, especially for reliable urban supply to Maputo. Being already heavily allocated to agriculture, opportunities exist in the south to move away from water dependent agriculture and promote commercial agriculture into other regions. Regions with higher water availability and lower water costs (where for example the demand may be more for supplementary rather than full irrigation), and where hydropower potential are at their highest should be targeted, creating more opportunities for multi-purpose storage in northern and central regions.

It can be summarized that any focus on the basin scale alone (even under transboundary conditions) will overlook important opportunities and challenges of energy demand and supply. These insights require taking a regional perspective.

ii. The Water-Energy-Food Nexus

This is a crucial integrator, given recent high-level policy shifts towards 'nexus thinking'. It is particularly the drives to improve both the underdeveloped hydropower sector and the underdeveloped agricultural sector (with the same water resources) that make this integrator so crucial. As discussed above, the extensive evidence on this particular integrator outlined in this paper cover a range of inter-relationships including incompatibilities, mutualities and even dependencies.

Within the Zambezi Basin, where the greatest hydropower potential lies, scenarios of the fullest possible development of both hydropower and irrigation are incompatible with each other. But there are certainly compatibilities at major levels of development (below the highest levels at which incompatibilities kick-in). Feasible projections of 30,000 GWh/yr of hydropower in conjunction with 774,000 hectares of irrigated land have been projected, as well as a level of flood protection and part restoration of natural flood plains in the Lower Zambezi.

Use of distributed electricity by agriculture is very low, with perhaps as few as 55 clients drawing power under agro tariffs. Grid-based electricity is seen as expensive by farmers, while reportedly EdM view access to cultivation areas to be difficult and non-profitable. In this light, while many South African and Swazi farmers access grid-based electricity, a lack of access to electricity among Mozambique farmers has created a dependence on increasingly expensive fossil fuels, pushing up production cost margins.

Although the numbers are small, where farmers do have access to electricity, major benefits have been imparted, especially to value-chains and post-production. Mini hydro-enabled horticulture is enabling farmers to spread the timing of production, bringing fresh produce to town markets throughout the year, and also through refrigeration and mechanical milling. Opportunities are being explored in some cases for irrigation scheme canals to act as conveyance infrastructure for hydro schemes and PAT (Pumps-as-Turbines) opportunities are being explored.

While some areas of machamba farming may be at risk from reservoir flooding, opportunities for recession farming or reservoir-based aquaculture do not yet appear to have gained traction. In the case of the former, this may possibly be because of the characteristically steep volume to area relationships in gorge locations.

One of the greatest areas of synergy between the water and energy sector lies in the use of reservoirs for multi-purpose objectives. Clearly, Cahora Bassa remains the one major opportunity for introducing revised operating rules, based on studies already conducted. Otherwise, it seems that much of Mozambique's installed hydropower capability has been retrofitted with some multi-purpose functionality during major rehabilitation, if such functionality wasn't already in place originally. Certainly, multi-purpose objectives are firmly embedded in national and regional policy.

What seems to be crucial, if narratives from energy-sector experts are correct, is a synergy that is yet to be taken advantage of at any significant level, namely that of an economic (principally agricultural) demand stimulating capital investment

into the small off-grid hydropower sector. However, this review has provided clear evidence that those stimuli have not yet infiltrated a renewables sector that is dominated by a well-funded (but heavily subsidised) social model for solar PV.

Arguably, such nexus-related issues can only be framed meaningfully in line with the four strategic thrusts of hydropower within Mozambique. A simplistic, single interface between water and hydropower would risk being too generalised to be of value to that framing. At the same time, the opportunity is there for the Mozambique Government, SADC and others to reframe hydropower impacts as the relevance of nexus-oriented and IWRM approaches evolve.

iii. Financing hydropower

Financing of hydropower certainly can be a strong driver for integration. Development of the regional hydropower sector according to the generation plan of SAPP has been estimated at USD 10.7 billion over 15 years, with an overall indicative financial balance (on a continental scale) of 2/3 to generation (retrofitting as well as new capital) and 1/3 to transmission.

There are some major distinctive features within the African hydropower financing sector. Namely, the mismatch on economies of scale between national utilities and investment costs (a feature to which Mozambique is no exception) and the 'near-monopoly' purchasing role of ESKOM. Consequently, depending on the cost-sharing agreements that will be set in place, there is a potential situation of host countries (such as Mozambique) facing a disproportionate cost (especially of operation and maintenance cost), while utilities (in neighbouring countries) derive the income from energy tariffs but with minimal reimbursement to the generator.

A range of potential financing mechanisms were noted in this review, including the state – backed by different partnerships, including with the SAPP Power Pool nations, the BRIC nations, the European Union (collectively or individual Member States). Consideration was also given to Partial Risk Guarantee funds (for small hydropower), Government equity stakes, microfinance and carbon credit schemes. As yet, there are few demand-intensive industries driving possible PPP mechanisms, large private investors view returns as low from a single hydropower tariff, and there is generally a lack of framework support for IPPs to enter the market with any reasonable prospect of cost-recovery under PPAs to cover debt and capital repayments.

Hydropower revenues have often provided the primary financial revenues from multi-purpose river regulation and water storage investments. Other benefits may be considered as public and private goods (e.g., irrigation) and less readily monetized benefits (e.g., flood and drought management), being less quantifiable as financial revenues alongside energy. While both national and regional policies have set firm objectives on multi-purpose use, there does not yet seem to be clarity on the multi-origin financing mix (for both CapEx and recurrent operations), and this is a topic that will

certainly warrant further attention. It touches on a number of issues, for example, while afforestation in South Africa requires an abstraction permit, it is probable that the 5% of Zambezi water evaporated from Cahora Bassa has not to-date been treated as consumptive abstraction, as it is subject to water user fees, and these costs are recovered by passing them on to electricity consumers through tariffs. A further major issue is that water pricing in the Mozambique agricultural sector has historically been at very low rates, and at those levels would offer little viable return to capital.

Energy tariffs seem key to unlocking hydropower potential, both the tariffs paid by consumers for using electricity and the tariffs paid to suppliers feeding electricity into the grid. Operators (large and small) rely upon cost recovery from consumers – indeed, one main driver of institutional reform within the energy sector stemmed from the low cost recovery and unpaid invoices associated with the national utility. Currently, there is national uniform pricing (with implicit cross-subsidy from urban consumers to the more expensive mini-grid consumers) and a hierarchy of different tariffs for different users. Despite major developmental needs from electricity within Mozambique, the ability-to-pay of a substantial client base in South Africa may lead to future generation capacity from Mozambique being purchased across national borders given the seemingly weaker (but still growing) ability-to-pay on the national side. Some Mozambique irrigators have contended that grid electricity tariffs renders their own irrigation unviable compared with the majority of South African and Swazi farmers drawing electricity from the grid - which ironically may be electricity generated in, but not available within, Mozambique.

Current practise of subsidized rural electrification implies a potential risk for economically sustainable solutions including hydropower. The rural electrification program in Mozambique has been dominated by the solar PV technology, with installations that have prioritised social institutions. This expansion has been heavily financed (effectively subsidised) by Mozambique's development partners, perhaps by as much as 60% external finance, meaning reduced costs of equipment and prices charged to customers. This has created a potentially significant risk that a Mozambique public familiar with such subsidised tariffs in one sector supported by one renewable technology might not be amenable to market-based and commercial rates in the agricultural sector and small hydropower. Electricity tariffs for renewable sources based on subsidised solar energy (with subsidised equipment costs and subsidised charges to customers) may be unrealistically low for off-line mini-grids based on hydropower that need to operate on commercial lines. In principle, water user charges should be passed on to electricity consumers. While water user charges may be a comparatively minor component of total costs of energy generation, they may be significant in marginal economic cases. A risk has been cited that water agencies may view small-hydro in particular as 'budget-balancers' given the high volumes passing through turbines, even though run-of-river schemes are non-consumptive. The principle of water charges needs to be sustained, but not in a way that burdens non-consumptive users.

Feed-in tariffs are crucial to revenue streams, to repaying capital finance based on loans and to the economic viability of schemes. A case has been made that Feed-in tariffs should not be based on a single class of hydropower, given that economies of scale mean the relatively low unit cost tariffs paid to large hydropower generators cannot stimulate any reasonable returns on investment by IPPs. Yet, higher rates could be justified where hydropower reduces grid losses. A case has been made that while solar PV has been the technology of choice for social institutions, it is a framework for Feed-In Tariffs that will be key to unlocking the small hydropower sector, running alongside the CESUL backbone and short grid extensions that link the main backbone to hydropower generation sources. A further (off-grid) narrative is that developers and users will develop a financial case for self-investment (CapEx investment and operation and maintenance financial flows) when backed by viable small-scale economic (mostly agricultural production and post-production) enterprises. A third case, yet to gain any real momentum, is that small hydropower generators could, in some central and northern regions, generate electricity at a lower cost and more reliably than EdM, even where they are on the grid.

iv. Governance and institutions

Governance and institutional arrangements within the Mozambique energy sector are certainly also very important integrators for hydropower development. These levels of institutional capacity development have transformed in recent years, for example HCB ownership and EdM privatisation. A process of institutional reform and capacity development is still underway – not least in respect of the functionality of FUNAE.

What is clear is that there are different energy institutions, and that particular institutions have distinctive roles that are each closely associated with distinctive segments of the hydropower sector. SAPP and HCB are directly associated with regional markets, EdM with grid-based electricity and FUNAE functions within the renewables sector, driving rural electrification. Energy sector institutions are increasingly mature and increasingly differentiated from one another in their roles and responsibilities.

The situation is a different one in the water sector. Water management has clearly been decentralised within the last 15–20 years, during which time the ARA regions alongside DNA (nationally) have gained in progressive strength, and River Basin Organisations (RBOs) have been established to varying degrees in line with regional SADC Policies. Yet, while SADC policy is strongly oriented towards both management and development aspects, the financial backers of a number of the region's RBOs are more oriented towards management. As a result, development responsibilities continue to reside within national governments and not with the RBOs. Consequently, the evolution of RBOs has been uneven among basins, and they have been allocated different levels of functional responsibility or reside within the Mozambique Government entirely.

Local Management Committees have gained traction as key partners (alongside Local Administrations) in respect of solar mini-grids, indicating a potentially significant mechanism if hydropower were to be similarly socially-oriented. In Zimbabwe, IPPs have engaged local communities more informally, given incentives of local environmental protection to scheme sustainability.

v. Mitigating social and environmental detriment

With impact assessments increasingly embedded within policies, it can reasonably be assumed that environmental impact assessments have been conducted at the feasibility stages of newly-proposed schemes. In the case of Cahora Bassa, opportunities to introduce improved downstream environmental and productive conditions through modified operating rules have been studied intensively, with recommendations emanating from key development partners.

Intensive social and environmental impact assessments have been conducted at Nacala Dam in Nampula Province, addressing a wide range of environmental and social dimensions with recommendations on associated mitigation measures. Although Nacala Dam is not a hydropower scheme, the process has set benchmarks for water storage schemes.

With environmental impact assessments having been conducted for medium and larger schemes, there has been a proposition that new, simpler guidelines and assessments are needed for small hydropower schemes. It might also be considered to conduct a nationwide strategic environmental assessment of small hydropower schemes (focussing on the four central provinces with the greatest potential).

Estimated at around 30–50% of MAR in different rivers (composed of low flow, and flood flows), the need to set environmental flows that sustain currently good ecological conditions has not yet emerged as an obvious constraint to future abstraction or potential evaporative losses, especially where reservoirs are operating for hydropower. Such levels are likely to represent more of a constraint in urban water supply reservoirs that tend to optimise storage of wet season flows, rather than for reservoirs that continue releases for power generation. Widespread soil and water conservation measures in upstream Zimbabwe have been cited as an issue of sustainability in respect to sedimentation rates into Cahora Bassa, and efforts on local streambank protection have been mobilised to limit local sedimentation of turbines of small hydropower in the Eastern Highlands of Zimbabwe. The Lurio sub-catchment is currently subject to extensive afforestation under climate finance, with safeguards set to limit the extent of upstream afforestation to less than 20% in order to minimise stream flow reduction, along with guidance on species type and plantation areas. Sole attention to carbon offsetting through tree planting would undoubtedly risk being of some net detriment to hydropower generation.

It is clear that there have been substantial developments with regard to the integrated management of water and energy around Mozambique hydropower. The preceding section has indicated five areas at the heart of that integration.

But the narrative also has to avoid a simplistic interface, as it is self-evident that different segments of the hydropower sector have different interfaces between energy and water, even in respect to the same issue. Generalisation around a single 'hydropower' class would not be helpful. On some of the key integrating factors – such as finance or institutions – a large part of the major variation can be usefully accounted for by adopting the concept of there being four strategic areas of expansion within the hydropower sector. Those four strategic thrusts can each tell a different and more nuanced narrative of the interfaces between water and energy. In the case of Mozambique, what clearly needs to be avoided is the import of some of the dominant dimensions of IWRM that have been propagated with respect to hydropower, such as concerning water scarcity constraints on development, irreconcilability of hydropower and agricultural demand, hydropower as a non-consumptive renewable and the likely severity of climate change impacts.

### 6.5 Impact as the Ultimate Integrator

While there are key integrators within the nexus of water and energy, as discussed, it is the impact of hydropower on the livelihoods of citizens that appears to be the overarching and most important integrator within Mozambique. That is, the value of hydropower for economic and social outcomes seems the prime integrator, above and beyond the other five factors cited above. Yet, while the other five integrators can be backed by robust information, the evidence for impact of the contribution of hydropower to Mozambique's economic and social development is surprisingly weak.

Major gaps in the evidence suggest a major disconnect, which could be significantly improved by a new political narrative on impact. That disconnect appears to have three roots. First, that numerous different impacts on energy have resulted from past national or regional policies. Yet, those impacts have not yet been related directly to the contribution from hydropower. Second, as has been elaborated in Section 4, hydropower is not a single, unitary sector, and but rather reacts to four primary strategic thrusts. Not all of the economic and social impacts set out to be achieved in policies can be attained from certain thrusts within the hydropower sector. Therefore, a narrative that connects the high-level policy impacts achievable by each of the four main thrusts would represent a major advance. Third, there have been an array of rationales set for hydropower development, but these largely remain disconnected from their impacts.

It is anticipated that a strong impact-oriented narrative could be constructed, by combining current political direction with supportive evidence drawn from within this paper. Such a narrative would provide the essential, preceding framework for any further work on gap analysis or best practices. Because the narrative is primarily a developmental one, rather than a technocratic one, and also a narrative that relies upon the priorities of the Mozambique Government, such a review would need to stem from the Government. Without a focus on impact, it is clear that an otherwise fragmented evidence base can lead to significantly different positions and interests taking an undue prominence. Tools and support mechanisms risk being framed in a continuing fragmented manner, with low prospects of uptake.

A recent review of small hydropower in five southern African countries (Klunne 2013) concluded that within the Southern African region, off-grid hydropower for renewable energy is limited to those countries where there is an active support role for government institutions, and that Mozambique is challenged to find its own best implementation model. Central to taking stock of implementing renewable energy within Mozambique has been the existential difference between social and economic models. A key conclusion from this paper is that there is not 'one best implementation model', but that four different implementation models can be best pushed forward, each delivering different impacts, each backed by different rationales and each with their own distinctive niche within the water-energy-food nexus.

Impact is the crucial integrator, and the framework has to move on from simplification. Currently, hydropower outputs are typically expressed in MW (or GWh/yr) and irrigation development aspirations are typically expressed in hectares – both are missing the vital expressions of, and connections to, their crucial economic and social values.

Such an impact framework also seems very significant given the co-demands on an expanded hydropower generation – simply because power generation will not meet all demand for decades. Therefore, the next years will be a succession of incremental generation gains, with a succession of incremental impact gains. But there is a demand for those impact gains from within Mozambique, from within South Africa and from within Zimbabwe – perhaps even from different regions and Provinces within Mozambique. The pace of impact in different areas could become a source of potential tensions among those scales.

Further work is indeed needed, and the most fruitful area would seem to lie in a narrative that connects the four strategic thrusts within the hydropower sector with the more than 20 different stated impact aspirations, and the more than 20 different cited development rationales for hydropower (as assembled in the following table), reflecting main regional differences. To-date, those impact aspirations have been set for either the energy sector as a whole, or for hydropower as a whole. While projections for hydropower have been made for future installed capacity (in MW terms), those projections have not yet been connected to future economic and social impact. Pathways of poverty reduction through grid expansion and off-grid interventions will be very different and will need unpacking.

Such a narrative would be best promoted by the Government, particularly given DNA's role in reporting hydropower progress in line with attainment of the Africa Water Vision and the Agenda 2025. Much of the initial complexity could be overcome by this, given that a number of the impact aspirations and rationales listed in table 3 are particular to one of the four areas for strategic expansion. Once those thrusts have been better aligned with goals to achieve social and economic impact, with a trajectory of what is being targeted by 2025, then there can be a dialogue around each of the distinctive 'impact/implementation models'. These can be developed by a dialogue that begins to unlock the action

Table 3: Summary of four strategic thrusts, impact aspirations and development rationales – as the essential components for a new narrative on hydropower impact

| Four Areas for Strategic Expansion in the Hydropower Sector | Impact aspirations (as stated in national and regional policies) | Development rationales for hydropower |
|---|---|---|
| A. Strategic grid expansion based primarily on new large and medium hydropower schemes<br><br>B. Localised mini-grids in off-grid population centres<br><br>C. Off-grid small hydropower servicing (mainly) individual enterprises<br><br>D. REFIT-financed, independent grid-connected small hydropower | • Eradication of absolute poverty<br>• Inclusive economic growth<br>• Dependable energy in main regions, strengthening their economic growth.<br>• Electrification of Districts with economic potential.<br>• Cost saving in (cheaper) hydropower that allows investment resources to be channelled into productive activities, raising the pace of economic growth<br>• Overcome economy-wide detriment and attain economy wide value. (75% of current 1.1% of GDP shock can be mitigated by flood control under proposed schemes; that % does not include other, additional economic benefits)<br>• Reduction of regional imbalances<br>• Development of commercial sector<br>• Development corridor(s) eg Mtwara. Economic Areas with Accelerated Development - eg Special Economic Area of Nacala (industrial projects)<br>• Electrification targets and target dates. Target unserved and under-serviced areas<br>• Supply electricity to 60,000 new domestic customers<br>• Expansion of national grid (all Provincial capitals) | • Even with grid extension, large areas of the country will not be reached in the medium term/foreseeable future. Off-grid schemes create demand.<br>• Mozambique can recover (some) independent control of the Zambezi and power market.<br>• Small producers may produce power at lower cost than that provided by the national grid.<br>• Grid extension (CESUL) under combined planning with new generation.<br>• Attractive market for Zambezi power, opportunities for power sharing between several production centres and create conditions for incorporation of small production schemes on other central and northern rivers.<br>• Opportunity to reduce 25% distribution losses, given geographic proximity to load<br>• Small hydro (5-25MW) near load centres should be prioritised<br>• Hydropower needs complementary services and co-investments to better connect to economic potential. |

| | | |
|---|---|---|
| | • Rural electrification<br><br>• Electrification of areas isolated from national grid. Electrification of remote areas (stemming rural-urban migration)<br><br>• FUNAE social and economic programs.<br><br>• Prioritised health centres and schools.<br>    • Unsatisfied load demand and rising future demand i) nationally ii) in neighbouring RSA iii) within SADC<br>    • Coordinated operation of existing hydropower facilities to increase firm energy generation by 7%, (without new major infrastructure investment).<br>    • Coordination of future hydropower facilities to provide an additional 23% generation over uncoordinated (unilateral) operation.<br>    • Potential exports beyond SADC<br><br>• Reduce external dependencies.<br><br>• Comparative advantage in energy<br><br>• Areas with productive potential. Priority for areas with agriculture and fishery potential<br><br>• Reduction of greenhouse gases and carbon. Hydro-electricity importers avoid adverse consequences of developing domestic hydrocarbon or nuclear-based sources of power in their own countries. | • Mozambique has not yet found best implementation model for small hydropower uptake.<br><br>• Reduced dependence on Cahora Bassa (eg in Nampula)<br><br>• Maximizing hydropower sites in national interests, to avoid risk of undercapacity on the limited number of sites ...<br><br>• Constancy of supply (but some hydropower is intermittent)<br><br>• Carbon-free generation<br><br>• Mitigate environmental destruction - curb forest destruction for biomass<br><br>• Infrastructure assets .that are aging and inefficient. Maintenance and short-term alternatives expensive.<br><br>• Current low storage capacity (per capita) - floods and droughts<br><br>• Reducing (unit) costs ... including through innovation<br><br>• New low-head turbines (for small head but sufficient flow locations) |

agenda, the incentives and disincentives to action, and how the Mozambique Government and development partners can best support actions by different actors. There are many suggestions assembled within this paper on actions that could be taken to support particular facets of knowledge or process but within a Government-led impact framework that would greatly enhance uptake prospects.

### 6.6 Next Steps

It is evident that that past research and policies have focused mainly on on energy security within Mozambique, and despite hydropower being by far the largest primary source of energy generation, there has not yet been any previous substantive focus on the water-energy-food nexus. As a consequence, first attempts to assess that interface had perceived the main interface between these sectors from the generalised viewpoints of IWRM. These have been framed internationally around inter alia water scarcity, agriculture as the largest competing demand, equitable access by individuals to water, vulnerabilities to climate change and inter alia, the over-arching dominance of river basin scales.

This paper has sought to understand the water-energy-food nexus principally through the lenses of the energy and the agriculture sectors as they relate to water. It has looked primarily at the drivers of social and economic impact, as Mozambique seeks to attain progress under inter alia, its own Agenda 2025 and PARPA aspirations, the ambitions of SADC and of the African Union, including under the Africa Water Vision. There have been three overarching outcomes from this paper as a result of doing so: The first has been to ascertain that some international concepts of IWRM do not easily relate to the local circumstances within Mozambique, echoing the earlier findings of some others concerned with evolving IWRM, for example within the Limpopo. The second has been to identify four strategic areas of expansion within the hydropower sector, and that each connects differently to water. The third has been to confirm the lack of substantial progress on hydropower development, despite the immense potential.
Considering current governance arrangements, it is proposed that DNA should take a leading role in the next steps to be taken. The rationale for doing so is that DNA has lead responsibility for reporting progress to African Heads of States on national hydropower targets in line with Sharm-el-Sheikh commitments and the Africa Water Vision 2025.

In support of that process, the main initial follow-up to this paper should be a 10-year Outlook on Hydropower Impacts in Mozambique that is informed by wider energy scenario projections already conducted. The temporal range is suggested as it frames the timeline to 2025, being the date of attainment for the Mozambique Agenda 2025 and that of the Africa Water Vision. It is suggested that the Outlook be prepared by early- to mid-2016. Of two main objectives of the Outlook, the first would be to tackle the disconnect between hydropower projects and their social and economic impacts, framed around each of the four strategic thrusts. This could be achieved by projecting scaled hydropower development trajectories over the next ten years directly associated with the economic and social impacts that would derive from those trajectories. Those impacts should embrace the direct benefits of hydropower (within local, provincial, national and

regional scales) and also the multi-purpose benefits of increased water storage (to agriculture, flood reduction, carbon etc.). As such, the measurement of the outcomes of hydropower projects must move beyond MW and hectare terms.

The second objective, informed by the main five integrators between energy and water raised in this paper, would be to set out the operational support arrangements that the Mozambique Government envisages would be required (within its own institutions and among private sector, civil society and academia) in support of the delivery of impacts under integrated management over the next ten years. Operational support arrangements could embrace institutional roles, networks or particular tools and procedures.

It is recommended that the 10-Year Outlook on Hydropower Impacts in Mozambique should be a Joint Ministerial Dialogue Paper, led by DNA, and ideally signed off jointly by Ministers of Water, Energy and Agriculture, and ideally under the auspices of SADC. At discretion of the local authorities, the Outlooks could be positioned under the auspices of either SE4ALL or PIDA.

It is envisaged that the Outlook would serve a purpose similar to that of the AMCOW/AfDB Regional Position Paper into the 5th World Water Forum in respect of the Sharm-el-Sheikh commitments. Namely, to serve as an agenda that frames action to attain policy commitments, but remains non-binding. Thus it serves as an influencing agenda, around which the Government of Mozambique can orientate its support partners. Such an Outlook would, it is envisaged, be entirely compatible with other economic sector work that may be commissioned by the development IFIs.

It is recommended that UEM play a role in facilitating the Outlook, yet at the same time retain an independence from the Government's recommendations on needed support mechanisms, given that an established entity of UNU-FLORES in Maputo could constitute a key outcome among those mechanisms.
The process of preparation of the Outlook will be significant, and it is recommended that, following an initial framing of the Impact-Hydropower trajectories by Government, those trajectories be the foundation of dialogue with key stakeholders on potential support mechanisms. It is further recommended that the initial framing of the Impact-Hydropower trajectories involve four stages, initially between DNA and Ministry of Energy, second with the principal energy institutions, including EdM, HCB, FUNAE and SAPP, third with Ministry of Agriculture, fourth with the established River Basin Organisations and ARA regions and fifth with SADC Water and Energy Units.

Why this particular recommendation rather than any other? It is recognised that Government of Mozambique and stakeholders may frame a different response to this paper. The rationale for the above is that hydropower investments within SAPP are forecast to reach levels in excess of 10 billion USD, and investments in Mozambique irrigation to be around 2.5 billion USD. Accordingly, a minor investment in a Government-led Outlook that brings stakeholders towards a common agenda and that sets out required tools and support mechanisms under a government-internalised process appears a sensible and effective way forward.

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# ABOUT UNU-FLORES

## MISSION

*"Advancing the Nexus Approach to the sustainable management of environmental resources"*

In line with the general mission of UNU to foster sustainable development, UNU-FLORES aims to contribute to the resolution of pressing challenges to the sustainable use and integrated management of environmental resources, such as water, soil and waste. UNU-FLORES strives to advance the development of integrated management strategies that take into consideration the impact of global change on the sustainable use of the environmental resources. To this end, the Institute engages in research, teaching, advanced training, capacity development and dissemination of knowledge.

## VISION

UNU-FLORES acts at the forefront of initiatives promoting a Nexus Approach to the sustainable management of water, soil and waste. The Institute supports the overall mission of UNU as a think tank for the United Nations and its member states, in particular addressing the needs of developing countries and emerging economies. In this role, UNU-FLORES aspires to become an internationally recognized hub and intellectual focal point promoting integrated management strategies.

Additionally, UNU-FLORES engages in policy-relevant research, postgraduate education and capacity development in a broad sense. The Institute attracts high-calibre students for postgraduate study and research programmes in cooperation with other research institutions. Furthermore, UNU-FLORES builds the capacity of future leaders in the area of environmental resources management and develops innovative concepts for target- and region-specific knowledge transfer.

## ORGANIZATIONAL STRUCTURE

In developing its functional structure, UNU-FLORES has positioned itself well to consolidate the scientific foundation of the Nexus Approach. The institutional arrangement is a direct response to critical knowledge gaps relating to integrated management of the environmental resources water, soil and waste. The organization of UNU-FLORES into five academic units – three core scientific units (Water Resources Management (WRM), Waste Management (WM) and Soil and Land Use Management (SLM)) supported by two cross-cutting units (System Flux Analysis Considering Global Change Assessment (SFA) and Capacity Development and Governance (CDG)) – supports the think tank function of the Institute. All scientific units are supported by the operational support units, which consist of the Office of the Director, Finance and Administration, Communications and Advocacy, and Computing and ICT.

## OUR DEFINITION OF THE NEXUS APPROACH TO ENVIRONMENTAL RESOURCE MANAGEMENT

"The Nexus Approach to environmental resources' management examines the inter-relatedness and interdependencies of environmental resources and their transitions and fluxes across spatial scales and between compartments. Instead of just looking at individual components, the functioning, productivity and management of a complex system is taken into consideration."

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Institute for Integrated Management of Material Fluxes and of Resources

The United Nations University Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES) was established in Dresden, Germany in 2012 with the support of the Federal Ministry of Education and Research (BMBF) and the Ministry for Higher Education, Research and the Arts (SMWK) of the Free State of Saxony, Germany. As part of the United Nations University (UNU), the Institute helps build a bridge between the academic world and the United Nations. UNU encompasses 13 research and training institutes and programmes located in 12 countries around the world. UNU as a whole aims to develop sustainable solutions for pressing global problems of human survival and development.

UNU-FLORES develops strategies to resolve pressing challenges in the area of sustainable use and integrated management of environmental resources such as soil, water and waste. Focusing on the needs of the UN and its member states, particularly developing countries and emerging economies, the Institute engages in research, capacity development, advanced teaching and training as well as dissemination of knowledge. In all activities, UNU-FLORES advances a nexus approach to the sustainable management of environmental resources.

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ADVANCING A NEXUS APPROACH TO THE SUSTAINABLE MANAGEMENT OF ENVIRONMENTAL RESOURCES

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