Integrated Resource Planning Training for Decision Makers

Day 2, Session 4 Malawi case study

9 March 2021

ECONOMIC
CONSULTING
ASSOCIATES

www.eca-uk.com

Contents

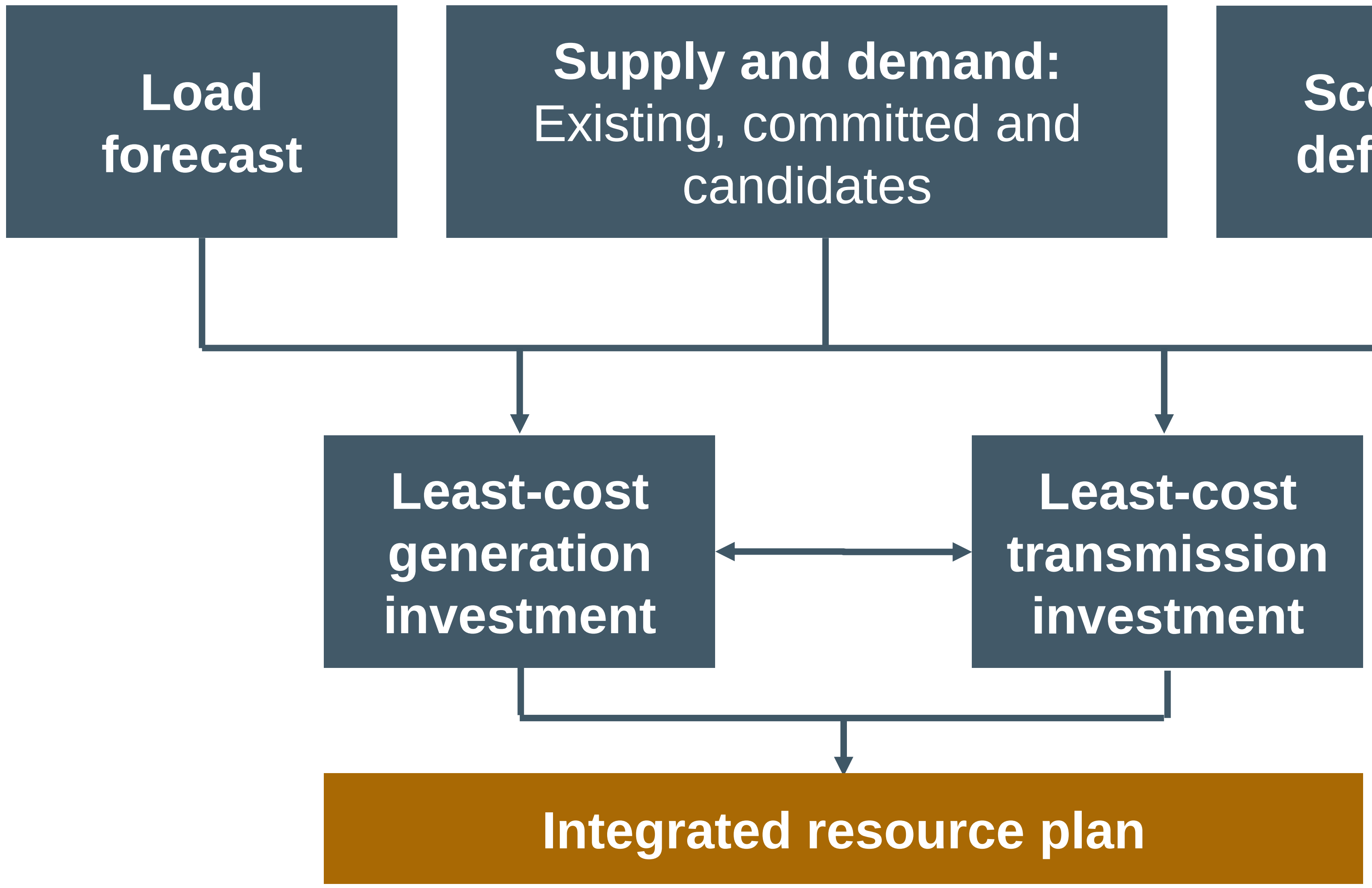
What is an Integrated Resource Plan (IRP) – what is its purpose?

- It is a **short-term investment plan, set against a long-term background**
- An IRP shows the least-cost investment needed to meet load growth
- An IRP needs to be updated periodically – the Ministry is not trying to identify an investment plan that remains correct for the next 20 years
- Why then do we consider investments over a 20-year period?
  - Because investment decisions today needs **some idea** of what will happen in the long term
  - The long-term plan is therefore more indicative
  - The investment plan over the next 5 years is the main focus of the IRP

Who will use the IRP and for what purpose?

- Three or more entities need to use the IRP
- Malawi has adopted **a single-buyer model**. Power Market Ltd holds the single-buyer licence (at the time it was ESCOM). The single buyer purchases electricity from EGENCO and from IPPs and sells to consumers (via distribution). ESCOM clearly had an interest in the IRP.
- ESCOM is regulated by **MERA** and MERA concerned to ensure that ESCOM's electricity purchases are least-cost
- The **Ministry** has an interest to ensure that its energy security, social and environmental policies are reflected in investment decisions
- There were no expectations of bilateral contracts involving IPPs selling directly to large consumers

The general approach



Strong emphasis on stakeholder engagement

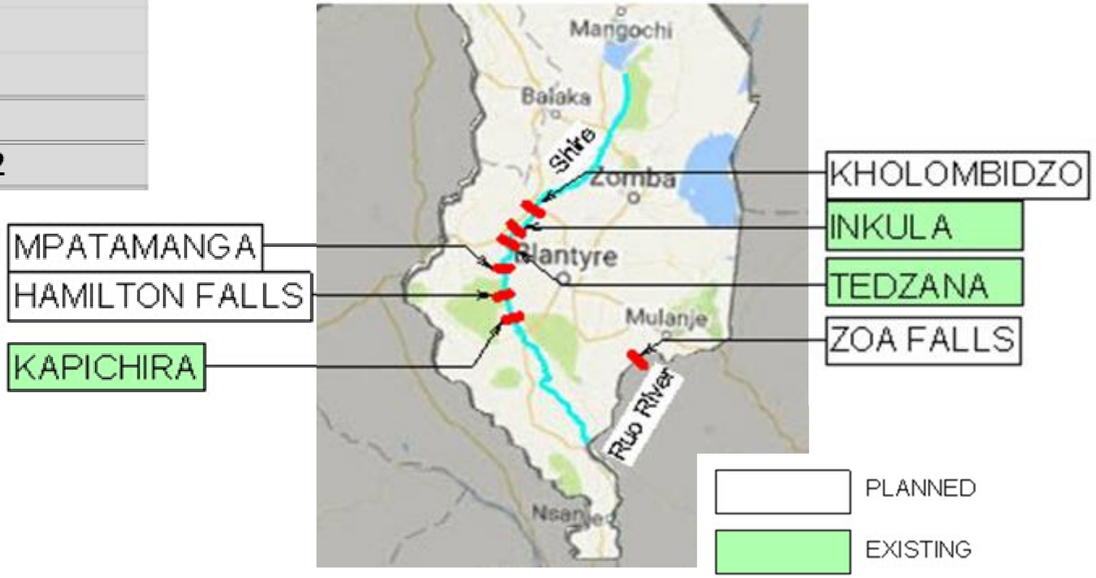
Resource assessment / Supply-side and demand-side

Resource assessment

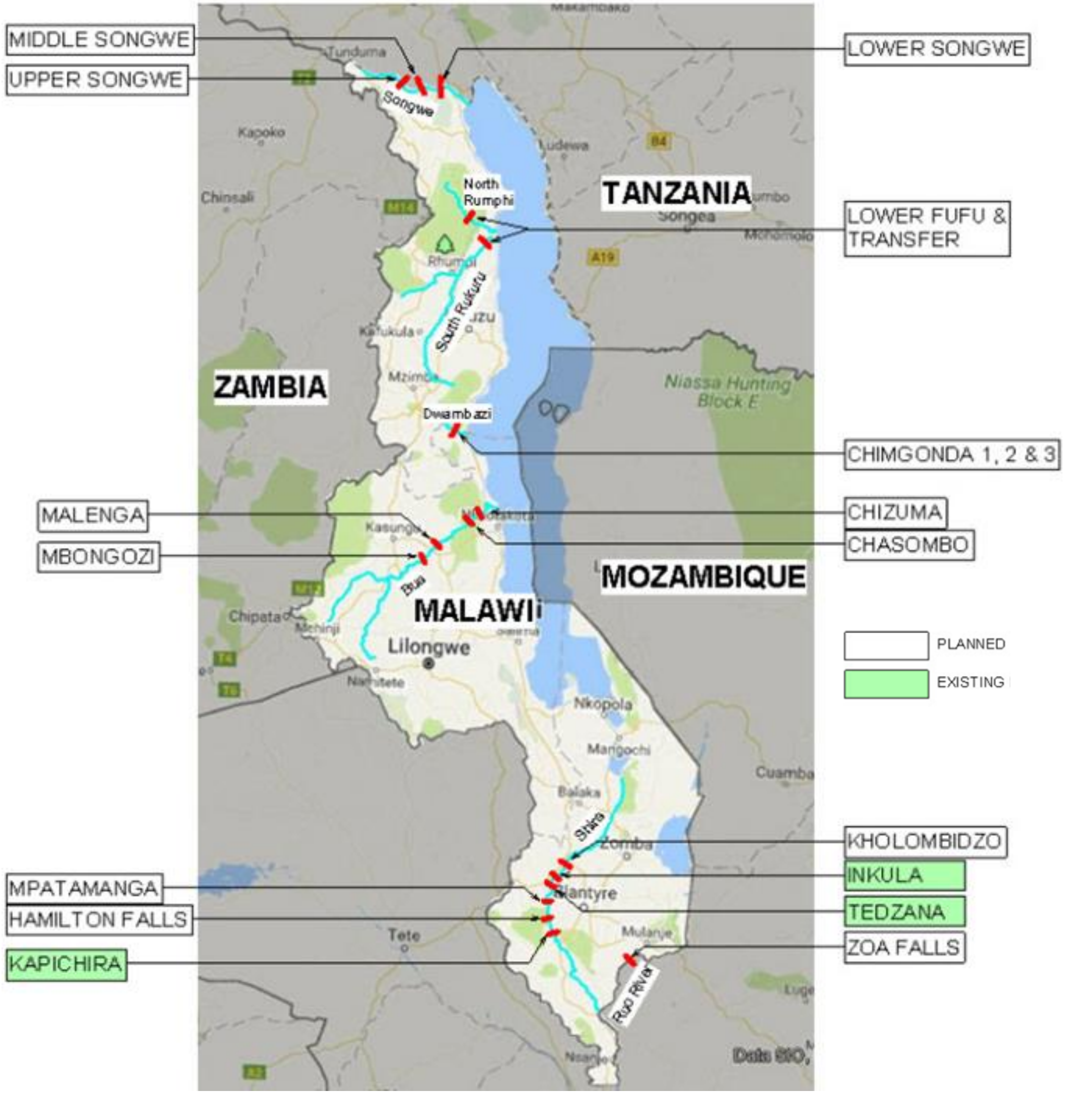
- Study based on extensive collection of data from studies, reports, public sources of information etc.
- Kick-off Meeting on Generation
- Interim Stakeholder Meeting
- Information extracted from various studies covering:
    - Hydropower
    - Coal fired power plants
    - Diesel/HFO
    - Renewables
        - Solar
        - Wind
        - Biomass

Present Electric Generation Capacity - Hydropower Plants

NAME	PHASE (Commissioned)	HEAD m	DISCHARGE m3/s	INSTALLED CAPACITY MW
NKULA	Nkula A (1966)	50	60	24
	Nkula B I (1980)	50	130	60
	Nkula B II (1986)	50	45	20
	Nkula B III (1992)	50	45	20
	Total		**280**	**124**
TEDZANI	Tedzani I (1973)	37	60	20
	Tedzani II (1977)	37	60	20
	Tedzani III (1995)	37	160	52.7
	Total		**280**	**92.7**
KAPICHIRA	Kapichira I (2000)	54	135	64
	Kapichira II (2012)	54	135	64
	Total		**270**	**128**
WOVWE	Mini Hydro			**4.5**
	Total Installed Capacity			**349.2**

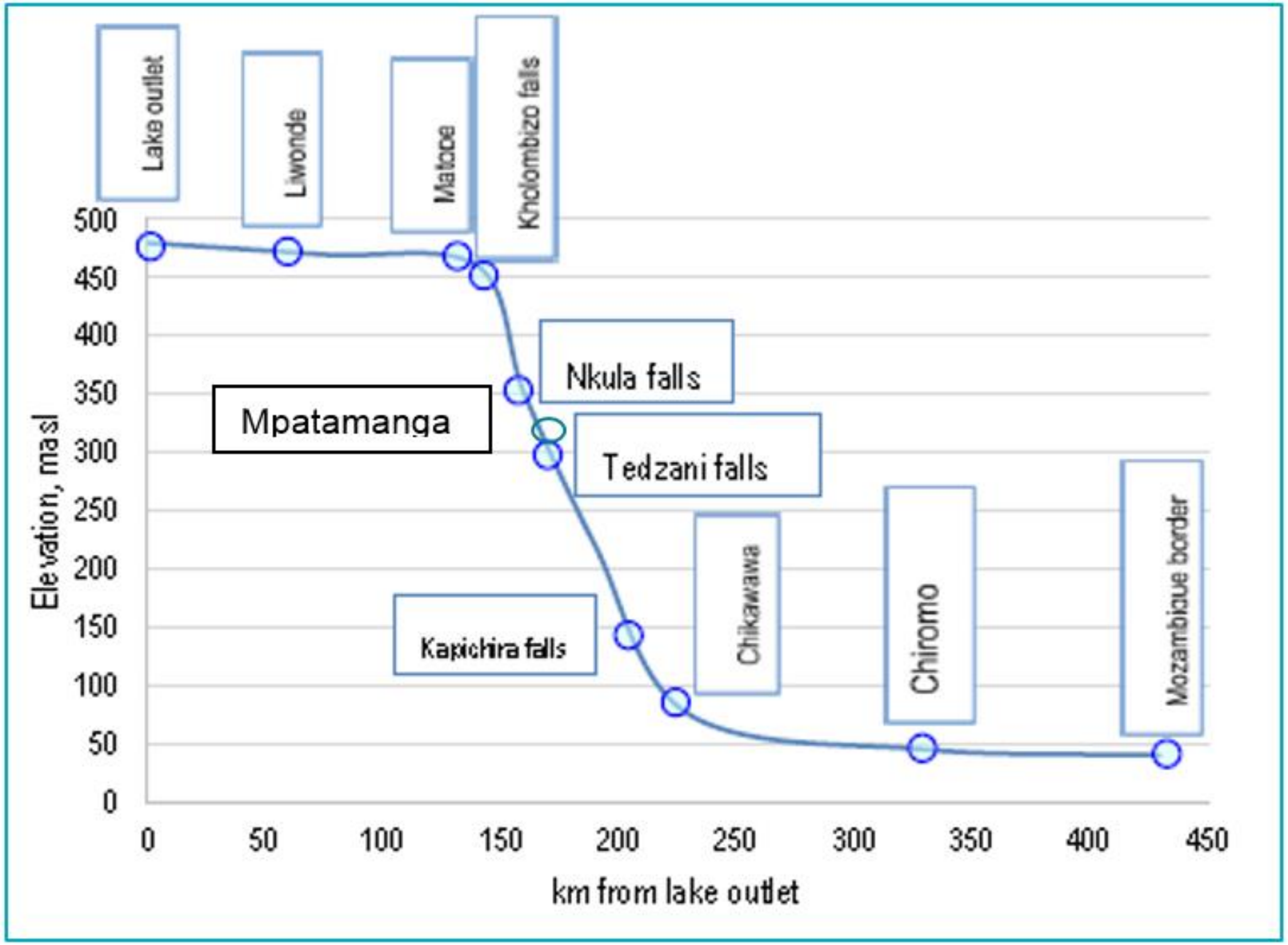


Hydropower Candidate Projects



Project name	Capacity MW	Generation GWH/y	CAPEX mill. USD
			Plan
Lower Fufu High Fufu	132 169	647 1008	350 455
Lower Songwe	90	343	261
Mpatamanga Shire R.	300	1740	522
Kholombidzo Shire R	213.2	1212	511.5
Chimgonda 1,2 &3 Dwambazi R.	(1) 10-12 (2)25-30 (3)14-16	n.a.	n.a.
Chizuma Bua R.	40	200	158
Chasombo Bua R.	40	231	389
Malenga Bua R.	63	242	570
Mbongozi Bua R.	41	261	182
Middle Songwe	80		
Upper Songwe	14		
Zoa Falls, Ruo R.	23	110.8	115
Hamilton Falls. Shire R. 1)	96	555	200
Kapichira Ext.	112	647	139

Shire River Projects



- Optimisation in IRP based on conservative estimate of 230 m^3/s at Liwonde
- Impact of dry and wet scenario tested

Thermal Power Plants - Generic Coal-fired Projects

Generic Coal-fired Plant	
Type	Mine-mouth, pulverised fuel, FGD, forced draught wet cooling
Capacity (sent out)	273 MW (2 x 137 MW)
Fuel	Coal fields in Northern Malawi
Efficiency (net, HHV)	36.3%
Overnight capital cost	USD 844 million (~USD 2,814/kW)
Location/connection	Coal fields in Northern Malawi 400 kV to central/southern Malawi
Status	No specific proposals
Earliest date	36 – 60 months construction, October 2020?
Information source	MCC Malawi Pase II – Final IRP report Vol 2 for North Rukuru

Renewables

- Integration of intermittent renewables like solar PV and wind power plants may cause problems as regards frequency control and regulation – in particular on small, islanded systems
- To avoid excessive frequency deviations, the size of individual projects and the overall installed capacity will have to be limited
  - Previous studies have indicated a limit of 70 MW for solar PV on the existing system
- Once interconnected to SAPP/EAPP, higher levels of integration can be technically feasible as interconnections would stabilise the frequency in view of intermittency from solar PV plants and wind farms
- For the purpose of the IRP, the base case assumes that total installed capacity for intermittent renewables should be limited to 10 % of the peak demand in each year
  - Sensitivity studies on higher/lower levels of integration

Demand-side measures

Demand-side measures and their potential impacts	
COMMITTED	
Time-of-use tariffs	0 (ToU tariffs existed since 2009)
Information dissemination	Not included as candidate in this IRP
Subsidised LED promotion	40 MW (early morning and evening)
Minimum efficient lighting	10 MW (early morning and evening)
Off-peak water pumping	Unknown
Off-peak irrigation	Already incentivised through tariffs
CANDIDATE	
Solar water heating	14 MW (throughout the day and evening)
Other	0 (err on conservative)

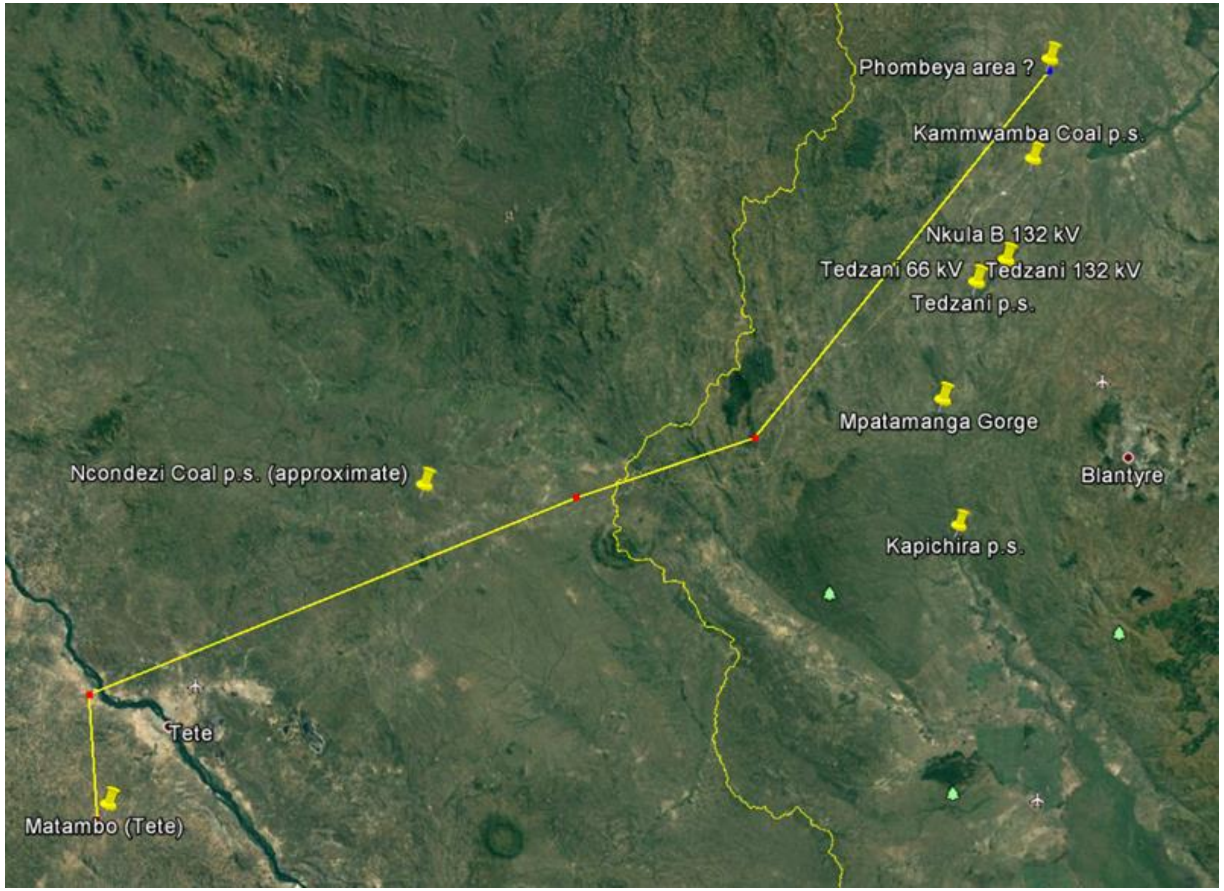
Solar water heaters (SWH)

Solar water heaters (SWH)	
Description	Programme of solar water heaters
Cost (excluding electricity)	Cost incurred by users or subsidised by GoM, but still an economic cost. SWH may eventually replace existing electrical hot water heaters **Assume: $ 9.5 million (14,000 SWH)**
Impact	**Assume 14 MW coincident**
Status	Under consideration
Earliest date	Impact gradual – assume 2021 for full effect
Information source	ECA calculations and estimates based on SWH program for Jordan; Household Survey; ICF-Core IRP study

Imports

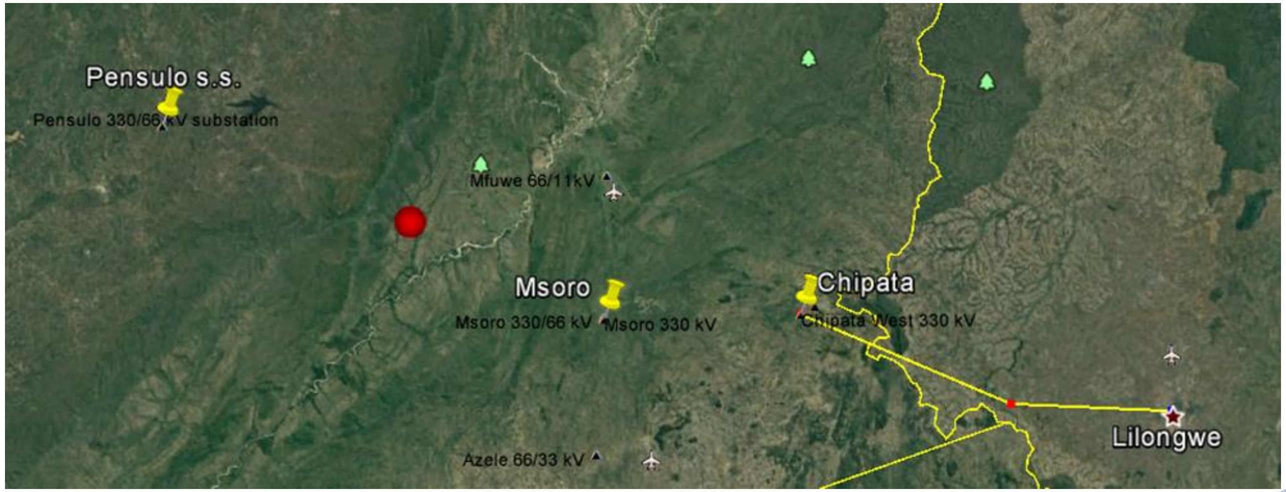
Interconnectors for import and export
Options and technical transfer limits

- Mozambique
  - 400 kV Phombeya – Matambo (Tete)
  - Tete likely to become a regional generation hub
  - Existing plant at Cahora Bassa and DC and AC links provide significant capacity for power exchange with other SAPP countries as well as Mozambique
  - Existing 220 kV system between Songo and Matambo may limit trade until new power plants are built and grid reinforced



Interconnectors for import and export
Options and technical transfer limits

- Zambia
  - 400 kV from Nkhoma/Lilongwe to Chipata (330 kV substation)
  - Limited capacity for import
    - Even with grid reinforcement in Zambia
  - Interconnection could provide higher capacity for export
    - But may require additional investments on grid in Malawi to support such export
  - Risk of large part of Zambia being islanded on supply from Malawi
    - Requires a system protection scheme



Interconnectors for import and export
Options and technical transfer limits

Transfer limits:

- First interconnection:
  - To avoid unacceptable frequency drop following loss of import:
    - Limit import to ~10 % of peak demand, or
    - Implement system protection scheme that sheds load to limit frequency drop
    - In a long-term perspective, load shedding following loss of import should not be accepted
    - IRP assumes that import is limited to 10 % of peak demand as long as there is only one interconnection
  - An interconnection to Mozambique seen as the most viable option in the preparation of the IRP

Interconnectors for import and export
Options and technical transfer limits

Transfer limits:

- Second interconnection:
  - Substantial increase in export and import capacity may be achieved
  - However, some operational challenges may arise if connecting to two different countries:
    - Significantly different transfer limits on the interconnections would mean that the import/export limits could still be relatively low as operation would have to account for an outage of one of the two lines
    - Inter-area power oscillations may cause severe voltage variations

      - Need for dynamic voltage control (SVC)
    - Malawi may experience high levels of wheeling – particularly following outages in neighbouring systems
    - Parallel path flows may cause additional losses on the system and possibly limit export/import capacity
  - For the purpose of the IRP, the second interconnection is also assumed to be a link from Tete/Matambo in Mozambique
    - Operationally, robust solution
    - Access to the regional market may favour connecting to two different countries

Scenarios analysed

Scenarios

- **Constrained** (Base case) scenario:
  - Required level of internal generation capacity >= 100% of peak demand
  - Average hydrological conditions
  - Two cross-border lines given as candidates
- **Unconstrained** scenario:
  - Without constraint on the level of installed generation capacity
- **Diversification** scenario:
  - Diversification of resources by forcing new builds away from the Shire river
  - Kholombidzo, Mpatamanga and Hamilton Falls projects can be built only after Songwe, Fufu and Pamodzi
- **Isolation** scenario:
  - Self-sufficient scenario with no interconnectors

Sensitivity analyses

- **Demand** (according to load forecast scenarios):
  - high demand
  - low demand
- **External market price:**
  - high average price of $60/MWh
  - low average price of $30/MWh
- **Hydrology of Shire river:**
  - high flow of Shire river (corresponds to mean annual flow at Liwonde of 388 m3/s)
  - low flow (mean annual flow of 160 m3/s)
- **RES integration:**
  - 50% higher RES integration
  - 50% lower RES integration
- **Discount rate:**
  - 6%

Approach; Investment plan under alternative scenarios

Approach and assumptions

- PLEXOS@ Integrated energy model
- Minimization of net present value (NPV) of the total costs of the system over a long-term planning horizon
- Costs include build cost for new generating capacities (and interconnectors), fuel costs and variable O&M costs, fixed O&M costs, value of unserved energy and cost of capacity shortage in the scenarios where the required capacity margin is defined
- **Optimal expansion plan represents the least-cost investment plan that meets the system demand and obeys technical constraints with given set of candidate projects**
- A 20 year planning horizon observed: 2017-2036
- The end-year effect treated with the assumption that the last year of the horizon is repeated an infinite number of times

Policy choices: Scenarios

- **Concerned about extended periods of low flow on the Shire River?**
  - Force an increase in diversification by advancing non-Shire hydro (Fufu and Songwe), bring forward Pamodzi coal, and delay Mpatamanga and Hamilton Falls - this will cost an additional $121 million in PV terms (+1.8%)
- **Happy to accept full optimisation and greater dependency on imports?**
  - Postpone Lower Fufu, Hamilton Falls, Kholombidzo, Pamodzi and generic coal – this will save
  - $9 million in PV terms (-13%)
- **Unwilling to interconnect with Mozambique?**
  - This will cost an extra $194 million in PV terms (+3%)
  - And no insurance against delays in power plant construction or low flows on the Shire River

Policy considerations: Sensitivities

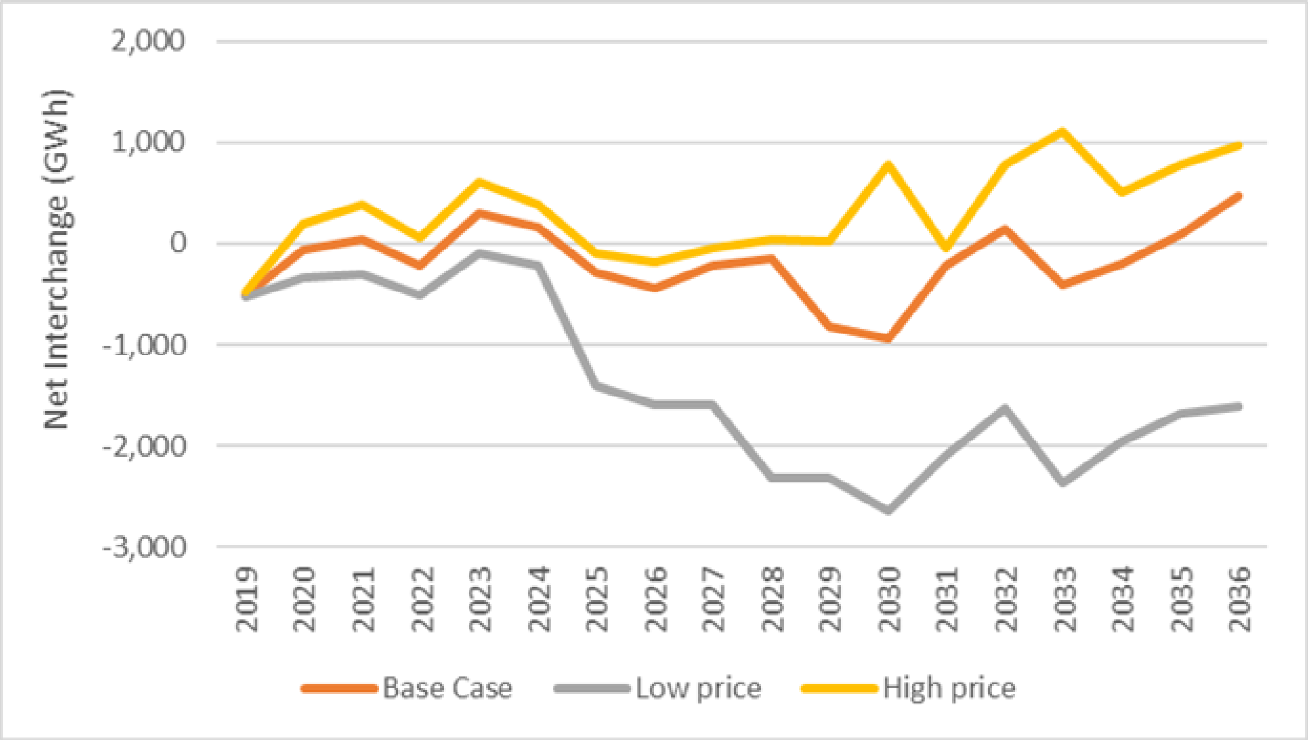
- **What are the cost implications of choosing renewable energy?**
  - If renewable energy (solar, wind and biomass) are cut by half, the present value costs would fall be $45 Million (0.7%) or equivalent to $0.0005 per kWh
  - If renewable energy (solar, wind and biomass) are increased by 50%, the present value costs would increase by $50 Million (0.7%) or equivalent to $0.0006 per kWh
- **What are the environmental consequences of the options selected by PLEXOS?**
  - Social and environmental mitigation measures are assumed to be included in capital costs (including resettlement costs and compensation where appropriate)
  - The costs and benefits of other environmental and social externalities (CO_2, air quality, etc.) have not been quantified – hydro selected early in programme, issues relate more to coal later

How robust are the conclusions: Sensitivities (fatal flaw analysis)

- **Would a higher or lower demand projection change the fundamental investment planning sequence?**
  - **Low forecast**: Investments could be delayed but the only changes in the sequence are that peaking diesels are not selected until later
  - **High forecast**: Investments bought forward. More significant impact is that Pamodzi (120 MW) and generic coal (300 MW) would be required much earlier in 2021 and 2026. And Mbongozi HPP (41 MW) is selected as part of least-cost plan and Lower Songwe brought forward. Other HPPs cannot be brought forward
- **Does the 10% discount rate impact on the investment plan?**
  - A 6% discount rate has a minor impact on the investment plan (advance Hamilton Falls by one year, delay Lower Songwe by one year, no need for peaking diesel plant)

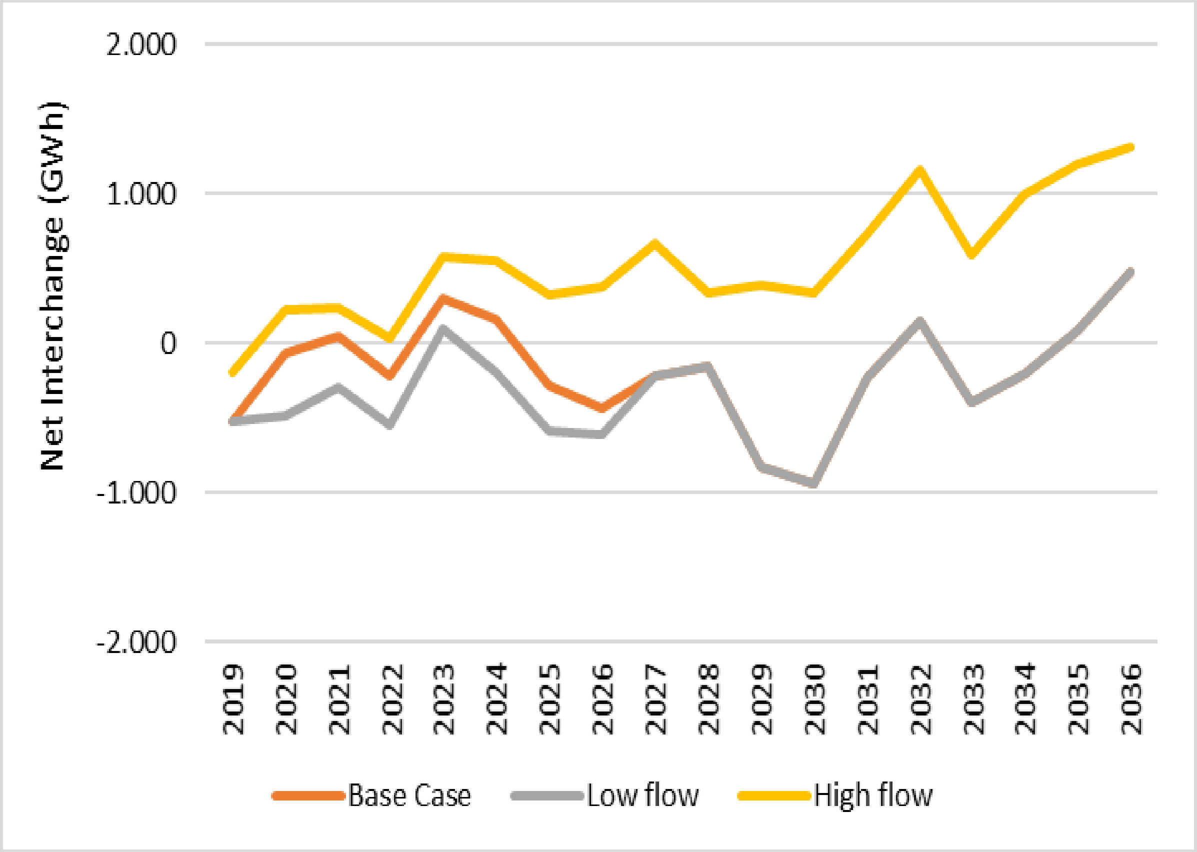
Fatal flaw analysis: SAPP market prices/ power availability

- **What if the prices in the regional market are higher ($60/MWh) or lower ($30/MWh) than assumed?**
  - **Lower prices**: The second interconnector is built in 2025, some re-scheduling of Fufu and Kholombidzo later
  - **Higher prices**: Brings forward some coal plant but only later in the programme – no impact on immediate investment decisions
  - Impacts on the amount traded:



Fatal flaw analysis: Low flow on the Shire River

- **What if there is a continuation of low flows on the Shire River?**
  - No impact on the least-cost investment plan (in the constrained scenario) – but it does impact on the amount of power imported:



Conclusions

- The proposed investment plan is:
  - Least-cost, subject to constraints
  - Robust to low flows on the Shire River (with one interconnector)
  - Flexible to alternative load growth scenarios
  - With proper safeguards, environmentally and socially positive until the late 2020s (Malawi will need to assess the impact of coal-fired plant before decisions are finally made on coal)
  - Robust to alternative assumptions regarding SAPP pool prices and discount rates
  - Potentially at risk from financing constraints that could delay the generation projects – would a second interconnector be good value insurance?

Paul Lewington, paul.lewington@eca-uk.com