SAMSET – Supporting Sub-Saharan African Municipalities with Sustainable Energy Transitions

Energy futures modelling for African cities – selecting a modelling tool for the SAMSET project

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1. Introduction

Urbanisation is occurring fastest in developing countries, with the least developed countries expected to have the highest population growth rates between 2010 and 2050 (Madlener and Sunak, 2011). Cities in these countries are going to increasingly be important sites of energy demand and associated emissions. Much of the literature about sustainable urban energy transitions has to date focussed on developed country contexts; as the current sources of greatest emissions, this makes sense. In looking forward, however, if the energy demand and emissions of developing country cities increase to that equivalent of many western cities today, we may be unable to avoid catastrophic climate change. Transitioning energy infrastructures and associated urban systems is a long-term process. In the absence of forward planning, developing country cities run risks of infrastructural and urban planning lock-in to systems that are unsustainable (Olazabal and Pascual, 2013).

The energy systems of developing countries and notions of sustainability or energy transitions are distinct from those of developed countries in many ways (Bhattacharyya and Timilsina, 2010b). These urban contexts experience significant levels of poverty and a lack of access to modern energy services, and a portion of their energy system is often dominated by informal activities. Any energy interventions will need to align with other pressing developmental objectives. Many African cities are experiencing rapid growth and changes in lifestyles as incomes rise, so that their energy systems will see rising demand profiles – in many cases significantly so. The focus may therefore be less about energy conservation and reduction, as it is in many developed country contexts, but rather about using energy more efficiently and decoupling economic activity from emissions. Bhattacharyya and Timilsina (2010b) refer to the relative steady state of many developed countries' energy sectors in comparison to the various demand and supply transitions occurring in rapidly growing developing countries.

The SAMSET project aims to support six African cities in three countries – Ghana, Uganda and South Africa – with sustainable energy transitions. One of the first steps in this project is to develop an evidence base of their energy systems to support scenario-based planning exercises to explore the impacts of different sustainable energy interventions. There are various established modelling platforms available that are useful for different purposes. Selecting an appropriate software tool must conform to the objectives and scope, as well as the context of the study. The tool for this project must be well suited to a developing country context and its associated socio-economic and technical characteristics. It must be able to model an energy system at a sub-regional city scale, as opposed to national scale. An objective of this project is to pass the models developed over to partner academic institutions, and possibly municipalities, that in all cases have no previous experience in energy modelling, building capacity and expertise, so that maintenance, development and improvement of the models can continue and yield benefits into the future. The software should therefore be accessible and not overly technical in application. This document, prepared by the Energy Research Centre at the University of Cape Town, explains some of the considerations in selecting an appropriate modelling tool for the SAMSET project.

2. Urban energy systems in developing countries

Energy models were historically designed to cater to the scope and characteristics of the developed and industrialised world (Bhattacharyya et al. 2010b; Ruijven et al., 2008). However, developing countries have a number of distinct characteristics. Many cities in Africa and other developing countries are challenging previous conceptualisations (based on western or developed country experiences) of economic development trajectories, sociology and theories about urban geography (Bhattacharyya and Timilsina, 2010b;

Urban et al., 2007; Myers, 2011). This study is therefore mindful of the tendency to rely on models of 'developed country' cities to guide how we theorise and make forecasts for those in developing countries. Urban et al. (2007) point out, for example, how the classical paradigm of economic development that posits that countries transition from agricultural based economies to industrialisation to a service-based economy does not hold true for many developing countries. This theory is based on empirical observations of historical trends of developed countries, but many developing countries have not experienced major industrialisation prior to the growth and expansion of service-based sectors. Ghana is such an example. The country has seen sustained economic growth over the last 16 years (averaging 5% per year) with relatively little structural change. The most significant shift in sectorial composition has been the growth of the services sector, whereas the industrial sector has grown minimally in comparison (Republic of Ghana, 2010).

The energy systems of developing country cities are also distinct from developed countries in important ways. Some of their key characteristics are highlighted in Table 1. One key feature is the existence of various networks of markets and actors that co-exist within a continuum of formal to informal within the overall energy system. Nissing and von Blotnitz (2010) distinguish, in the context of South African cities, the formal networked system of central actors, formal activities and business practices, but also the more decentralised, informal systems comprising many actors and small and often under-regulated practices. There is also a great deal of interaction between the two. The informal interacts with and is dependent on the formal in many ways; for example through electricity theft amongst poor households who do not have access to their own connections, or the movement of appliances from wealthier households that discard ageing and inefficient appliances that make their way to homes of poor households. In Ghana, the recycling of appliances and cars happens across borders, and the country is a major destination for second hand appliances from richer countries (Addo, n.d.). Another feature is the supply-constrained picture of many African cities. All three countries experience a supply constrained electricity sector. The consumption data in a supply-constrained system does not capture the unmet demand and may not provide an accurate or complete picture (Bhattacharyya and Timilsina, 2010b). Without trying to downplay the tremendous diversity in developing countries, Table 1 tries to draw out specific features and their implications for sustainable energy and modelling energy systems.

Table 1: Characteristics of energy systems

Sources: Bhattacharyya and Timilsina (2010b); GEA (2012); Ruijven et al. (2008); Urban et al. (2007)

Some characteristics of urban energy systems in developing countries	*Implications for modelling energy systems and sustainable energy transitions*
Non-technical losses in electricity sectors	Meter data does not reflect city consumption.
Under-pricing of electricity tariffs (below long term marginal costs of production)	Base load stations may not have predictable availability due to poor maintenance. Low financial viability of utilities makes financing of new infrastructure difficult. This may affect reliability of assumptions in demand forecasting.
Informal economy and markets	Many unregulated transactions that are difficult to capture – data difficulties. Such markets also often tend to work –sub-optimally in terms of information and transaction costs, meaning that neoclassical assumptions of rational choice may not hold true.

Some characteristics of urban energy systems in developing countries	*Implications for modelling energy systems and sustainable energy transitions*
Existence of many poor quality and/or second hand end-user technologies (appliances, cars etc) with poor efficiencies	In the absence of survey data, the assumption of data from other markets may be highly inaccurate.
Built environment – informal housing	Impacts on thermal properties of buildings.
Poverty and inequality	A very wide range of income driven consumer behaviours may exist, requiring extensive dis-aggregation to achieve a structurally sound model.
Households without access to safe and modern energy services	Difficulties in tracking energy use and large suppressed demand. There is also a large focus on transitioning consumers to safe and modern energy services. However such energy transitions often cannot be explained with optimising and rational choice theory (for example responding to prices). In reality such transitions are much more complex and often require specific policy interventions.
'Suppressed demand'	Basing analysis on consumption data only reflects 'satisfied demand'. Extrapolating consumption patterns into the future might therefore be problematic.
High reliance on biomass and traditional fuels	Difficulty in acquiring reliable data about consumption, efficiencies, technologies etc. Point of use combustion with poor quality or no appliances has significant impacts on local air pollution.
Urban form and low densities – many cities have 'urban sprawl' –	Implications for the transport demand sector. The viability of certain public transport investments is affected by population densities. High cost of expanding electricity distribution infrastructure. Lower density single family dwellings generally have poorer thermal performance than high density dwellings.
Own generation through diesel and gasoline generators to compensate for unreliable supply.	Difficult to track and assess fuel consumption which confounds both residential energy demand estimates and the calibration of transport demand.

3. Selecting a modelling tool

3.1 Overview of model types

Energy models have historically taken two distinct approaches, top-down or bottom-up (Bhattacharrya and Timilsina, 2010a; UNEP, 1995). Top-down models, based on economic theory, use macro-scale aggregated economic data such as consumption, incomes, prices and factor costs to model demand and supply sectors. Bottom-up models, on the other hand, focus on a more technological and engineering perspective in representing the energy system. Data inputs are collected from consumers about equipment and appliances used for different sectors.

Top-down models may be less suited to the SAMSET project context for several reasons. Top-down models, for example econometric models, aim to establish the economic relationships between variables, and may often be used for demand forecasting. Because of their reliance on historical patterns, their suitability to developing country contexts where economies may be undergoing, or aiming at, structural changes may be more limited (Urban et al., 2007; ESMAP, 2012). Another limitation from the SAMSET project perspective is that, because they capture aggregate demand, they do not allow for a more detailed characterisation of demand sectors and so have less scope to represent the diversity typical of this sector in developing countries. By contrast, bottom-up models take a more disaggregated approach with a specific focus on end-users and technology. This enables a greater characterisation of consumption behaviour and technology choices by different income categories, for example in the household sector, and is one of the reasons they are regarded as better suited to developing country contexts (Urban, 2007; Bhatacharyya and Timilsina, 2010b). Bottom-up models can be used to evaluate efficiency impacts of different scenarios, but offer more limited detail on feedback such as how a change in prices may affect uptake of a technology than a top-down model might provide (ESMAP, 2012). Accounting models such as LEAP describe the outcomes of hypothetical policy decisions, about a change in technology for example, defined 'outside' the model.

Models can broadly be categorised as either optimisation or simulation. Optimisation models use linear programming to determine the lowest-cost technology choices along the energy chain to meet the demand for energy services, subject to given constraints; for example, a cap on CO_2 emissions (UNEP, 1995). They are useful from a supply-side planning perspective and may often be used for national energy planning which traditionally is interested in questions around least-cost investment decisions (GEA, 2012; UNEP, 1995). In contrast, the focus on the energy system at a city level is likely to be more demand-side-oriented and interested in questions around the quantification of impacts from different scenarios. Supply-side decisions (in general) tend to be outside of a city's sphere of influence, and the interventions at city level tend to be more on demand management, focussing on energy efficiency, influencing the structure of the urban form and density, and public transport (GEA, 2012). This characteristic may increasingly be changing, however, as we see growth of distributed generation options and smart grids.

In an African context, where national electricity supply may be unreliable, there is also a higher incidence of auto-generation by commercial, industrial and household consumers, primarily using diesel- and gasoline-fuelled generators. Bottom-up optimisation models such as the IEA's MARKAL-TIMES platform allow for very detailed representation of the demand side with reasonably quick solution times, but the model building requires the development of fairly high technical proficiency and these models may not be easy to disseminate or establish as a living project within a municipality. Implicit in optimisation models are assumptions around rational choice, competition, and markets in perfect equilibrium (Bhattacharyya and Timilsinab, 2010b; ESMAP, 2012). This theoretical underpinning could arguably be suited to developed countries where adequate infrastructure means access and availability are not an issue, consumers have access to information and choice, there may be tight regulation on monopolistic practices etc. In developing countries, however, energy choices may be constrained by limited availability or accessibility and poor information flows which impact consumer choice. Optimisation models tend to assume that energy is the only factor in technology choice, whereas in reality, especially in poorer market segments, there may be more complex behavioural and preference factors (Ruijven et al., 2008).

Simulation models are end-use-orientated (for example cooking, heating and transport demands) and go into detail about specific technologies such as types of cooking stoves or types of furnaces used in industry. One of their advantages is that, unlike optimisation models, this data does not necessarily need to be detailed to create the model. Simulation models are more flexible in their data requirements and can still yield valuable insights even with sparser inputs (Bhattacharyya and Timilsina, 2010a). In terms of scenario analysis, top-down or optimisation models may be more useful for understanding impacts of economic instruments. However, the scenarios constructed for the SAMSET project may be interested in types of policy interventions other than price-based ones, for example. Simulation models may be more useful in that they can be used to structure more complex scenarios based on different policy interventions, and do not make projections based on historical demand and supply, but since these models are not self-optimising they will not identify the optimal solution. Instead, multiple scenarios must be run and then the preferred outcomes chosen (ESMAP, 2012). Capturing informal activities remains an outstanding issue for all model types, and requires a higher reliance on assumptions or extrapolations based on use of sparse survey data, whose representivity may not be assured.

3.2 Selecting a model for the SAMSET project

The study objectives and questions, data availability and quality, capacity of users of the model and the country-specific context are all need to be considered when selecting a model (ESMAP, 2012). The SAMSET project aims to model the energy system of African cities and answer questions about the energy and emissions impacts of different technology interventions. In terms of users, this project aims to provide a tool that ultimately will be used by relevant in-country stakeholders whether they are officials within local municipalities or partners such as local universities. Models need to be maintained and updated. Attention was therefore given to the ease of use and skills levels required of various models, as well as cost and accessibility to the software. Software that is either freely or easily available enhances opportunities for collaborative work with other institutes or organisations, beyond the study partners as well. Increasing the size of the research community using the software can enhance the development and quality of local research (Howells et al., 2011). Flexibility in data inputs was another key consideration in the selection process. Modelling is highly data-intensive, and the data limitations in developing countries are a real limitation. Some models are more flexible than others in working with data on a more limited scale, and can be more gradually populated over time.

A comparative assessment of different modelling software against project specific criteria is illustrated in Table 2. It was decided that the Stockholm Environment Institute's LEAP software tool would be most useful to create city models in terms of the project objectives and for many of the considerations for a developing country context, such as data constraints and ease of learning. Also, there is extensive experience with the software amongst the partners of the project (namely; Sustainable Energy Africa and the Energy Research Centre). LEAP is a simulation accounting tool, but also allows for optimisation through the use of a link to another platform, OSeMOSYS. It also allows for easy porting of data in and out of the software to other databases for analysis – such as the use of Microsoft Excel based models. LEAP has also been used for city-level energy modelling in several cities across South Africa, including the City of Cape Town, Buffalo city, and the municipality of eThekwini. In these cities, LEAP was used to create or compliment state of energy reports and future energy scenarios – detailing the energy picture of the cities and giving information about possible energy futures and their associated implications on resources (City of Cape Town, 2005; Ethekwini Municipality, 2008; Buffalo City Municipality, 2008; Palmer Development Group, 2007). Some of these reports are part of an ongoing series or collection of work in South African cities, where LEAP plays an integral part of the research. Research using LEAP for the city of Cape Town, by Sustainable Energy Africa (SEA) has been ongoing for many years. Of the South African cities that have been the subject of LEAP studies, only Ethekwini Municipality has attempted to maintain and use a LEAP model themselves but lack of human resources has in general prevented such models getting the attention necessary for them to remain useful and relevant (Borchers, 2014). The academic partner institutions in this project are therefore the more likely custodians of future city LEAP models for Ghana and Uganda.

Several studies (UNEP, 1995; Winkler et al., 2005; SEA, 2007) have used LEAP as a tool for city-level modelling of impacts of different scenarios on energy, economic and environmental indicators. These reports and studies have an underlying tone of improving policy recommendations around suitable energy interventions. Phdungslip (2009) investigated the energy needs and emissions of Bangkok with the goal of identifying the implications of different policy scenarios on the energy mix of the city. Bose (1997) utilised LEAP to create a model of Delhi's urban transport system. The model was used to estimate the energy consumption of transport and associated emissions. LEAP was also used to investigate scenarios that would lead to a reduction in energy requirements and emissions of the city. LEAP was utilised by the Energy Research Centre and Sustainable Energy Africa to create an energy model of the city of Cape Town in South Africa and to support the Cape Town Energy and Climate Action Plan (SEA, 2010). The model showed that, at current trends, the city will consume four times as much energy by 2050. An optimal energy future scenario was modelled, which combined an intervention within each sector – transport, industry, household and commercial. The optimal energy scenario cost was only slightly above the business-as-usual scenario but had a significant energy reduction by 2050.

In addition to LEAP, strong consideration is also given to the World Bank's Tool for Rapid Assessment of City Energy (TRACE) model and the Municipal Services Financial Model (MSFM) developed by South African specialist urban development consultants PDG. The TRACE tool provides for benchmarking of city energy-intensity performance against a global cities database. TRACE is easy to use, with an intuitive interface and, while not a rigorous scientific tool, may prove useful to establish relative performance from an efficiency or sustainability perspective and demonstrate the range of effect of interventions in an accessible way. The MSFM may prove useful to this project at a later stage for evaluating the long-term financial viability of interventions in the context of the total burden of service delivery on a city. The MSFM is a city infrastructure investment tool that that compares the projected demand for all municipal services and associated investment requirements, against projected revenue streams. This includes energy, water, sanitation, etc, and aims to identify financing requirements and mediate shortfalls. This financial model has a ten-year timeline and can support the municipal managers responsible for the practical implementation of infrastructure changes that may arise after considerations of the results from the LEAP modelling.

Table 2: Reviewing energy models for SAMSET project

Sources: Barney (1995); Bhattacharyya and Timilsina (2010a); IIASA (2014); Mirakyan and De Guio (2013); Pachauri et al. (2012); Ruijven et al. (2008); Walsh (2008); World Bank (2014)

Name	*Model type*	*Description, time scales and data type*	*Model components*	*Cost*	*Applicability to SAMSET project*
TRACE – Tool for Rapid Assessment of City Energy	Bench-marking tool. Not specifically a model	This is a tool used for energy efficiency gauging or comparisons to other cities. Allows analysts to discern areas of concern such as poor transport energy efficiency. Also allows for energy saving assessments and testing of recommendations or policy measures.	Passenger transport, municipal buildings, water and waste water, public lighting, solid waste, power and heat.	Free.	Allows the analyst to compare the energy performance of a city to other cities. This could be useful in gauging how far along a city is compared to other cities with similar histories and energy related problems. Could be useful in analysing how well a policy that has been implemented in other cities can apply to the city being analysed. This could be a useful tool during the formation of a framework of knowledge transfer from one city to another. A draw back with TRACE is in context of this project, it would not be useful on its own and another model would still be needed.

Name	*Model type*	*Description, time scales and data type*	*Model components*	*Cost*	*Applicability to SAMSET project*
LEAP – Long range energy Alternatives Planning	Bottom-up, accounting, simulation	A fully developed accounting model. Can model city scale models or national scale. Very flexible and customisable to the project. There is also an optimisation ability when used with OSeMOSYS (a free open source optimisation system) which allows for a wider potential for future development in this project.	Energy demand, GHG emissions, resource constraints	Free.	The project team has experience with this tool. Considered well suited to developing country context. An extensive range of learning material and support is easily available online. It is flexible in data requirements. Characterisation of the energy system can be as detailed or rough as required,depending on data availability
MSFM – Municipal services financial model	Accounting , financial	These models are designed for financial accounting and projecting, can be useful in understanding financial impact of city-wide measures or project implementations. Can be used for projecting number of consumers for a service, determining investment plans for services. Period is short-to-mid-term. The data needs are flexible.	Public services, housing, water services, electricity, roads, solid waste.	Free – needs own devel-opment.	This type of model may prove useful in future stages of this study when considering the financial implications of different investment options. This model be custom tailored, and is designed to be of use to cities with scarce modelling skills.
HEAT – Harmonized Emissions Analysis Tool	Simulation	This model can be used to measure and quantify progress against emissions targets through preparing baseline inventories and tracking commitments as well as Inform policy decisions and preparing action plans.	Pollution and environment orientated model – GHG emissions, air pollutants and volatile organic compounds.	Re-quires organi-sation mem-bership	This project has a specific focus on sustainable energy interventions and therefore tracking of emissions and prioritising actions for implementation may be of interest. However this model does not cover all the data of interest to this project, eg costs.

Name	*Model type*	*Description, time scales and data type*	*Model components*	*Cost*	*Applicability to SAMSET project*
Threshold 21 (T21) – System dynamics model	Simulation	Reaching a target goal. MDG orientated. Poverty reduction strategies using economic modelling are a focus of the model; it is also used for monitoring progress towards MDGs or other national goals.	Economy, health, education, nutrition, demography, agriculture, energy and environment.	Comm-ercial but there are donors – UNEP, UNDP, CIDA.	Poverty reduction strategies are the focus, and rural sectors are a major player, thus the model could be useful for evaluating strategies for energy transitions.
EnergyPLAN	Simulation	Integrated energy systems and analysis. Model is created to help design planning strategies for energy, based on economic analyses of the outcomes of different system investments. Could be said to be operation optimisation based – where it's the operation of the system as a whole which is optimised and not the cost of the system.	Energy demands, RE sources, capacities, costs, aggregates technologies and sectors rather than individually. Hourly detail. Focus is placed on energy planning in relation to technology, geography, economic and institutional conditions	Free.	Fair amount of support and project study cases. Strategy design is the focus, which would be in line with main goal of the project – sustainable energy transitions.
MESSAGE – Model for Energy Supply Strategy Alternatives and their General Environmental impact	Optimis-ation	A full-fledged optimisation model which can model a national or regional energy system.	Able to implement with perhaps some difficulty but not impossible – the rural/urban divide, traditional biofuels and structural economic change.	Free.	MESSAGE is a powerful optimisation tool which could be useful for developing energy transition pathways. While criteria such as electrification and traditional fuels use can still be implemented through exogenous modelling of the inputs.

Name	*Model type*	*Description, time scales and data type*	*Model components*	*Cost*	*Applicability to SAMSET project*
Energy-ENACT – Energy Access Tool	Optimis-ation (MESSAGE-Access)	The primary aims of the Energy-ENACT tool are to provide policy advice and visualise costs and benefits that each policy or a combination of policies could bring. Timescale to 2030. Data is available from global source but not customisable.	Energy and emissions, Energy access, population health, and socio-economic benefits.	Free.	Subsidies are covered- which can play an important part in energy transitions. Traditional fuels have a focus in the tool. Tool has characterisation for households with different income levels which is a major component of the project.

LEAP was utilised in a study of GHG mitigation options for the city of Tehran in Iran. Abbaspour et al. (2013) found that the building regulation known as Note 19 had a large impact on the GHG emissions of the household sector – a total reduction of 20% by 2036 relative to a 'current trends' reference scenario. Other mitigation options were explored, such as population migration out of the city area, and energy-efficient appliance use through labelling of devices. Lin et al. (2010) developed a LEAP-based energy model for the city of Xiamen in China, to try to understand the impact of several GHG abatement and energy consumption reduction interventions and policies. The authors found that the industrial sector had the largest energy saving potential, followed by commercial and then transport sectors. They also found that their clean energy substitution measure of replacing many fuels used in the household, industry and transport sectors with gas had the largest impact. Other measures of reducing energy consumption throughout the city were simulated using LEAP, included a combined heat and power intervention where many CHP plants are built to improve overall energy efficiency and building energy intensity reductions.

The GHG abatement potential for various biofuel supplementations for fuel use, as well as various combinations of hybrid vehicles and fuel cell vehicles in the transport sector of the Mexico City Metropolitan area, was studied by Manzini (2005). The author assessed each scenario using LEAP to determine the total GHG emissions arising from the fuel use in the transportation sector. The planning implications of model outputs such as the required capacity and costs of ethanol production could be assessed from the results. Shabbir and Ahmad (2010) used a LEAP model of the transportation sectors for the cities of Islamabad and Rawalpindi to understand the GHG emissions and pollutants trends and to assess possible scenarios involving abatement of emissions. The cities have a three to four times higher growth rate than other cities of Pakistan. Their research showed that emissions and pollutants (particulate matter) can be reduced by a shift to public transport and using natural gas for fuel substitution.

4. Modelling an urban energy system – data and assumptions

4.1 Defining system boundaries

Delineating the system boundary for modelling can be complex at an urban scale. The system boundary includes firstly geography – whether the greater metropolitan area is to be included or a more localised core urban area. Secondly, the boundary of the energy system must be defined in terms of including embodied and/or upstream energy (GEA, 2012). Urban energy systems are not discrete, and have a great deal of interaction outside of their official boundaries. Upstream energy refers to the primary or secondary energy linked to final energy demand, or the energy used in getting the final energy to the city and final consumer. This could, for example, be the road, rail or pipeline transport required to transport liquid fuels, or the transmission losses in the electrical grid from power station to point of demand. Embodied energy refers to that energy used in the manufacture of goods and services. This would need to consider both goods produced elsewhere but consumed within the city boundary, as well as goods manufactured in the city but consumed elsewhere.

The decision on whether to include these aspects depends on both the purpose of the model and data availability. For the SAMSET project it is suggested that embodied energy not be included. Although consumption- rather than production-based metrics of energy usage arguably give a more accurate picture of a city's footprint, this exercise is very data-intensive, requiring for example, extensive economic data. Consumption-based accounting studies of urban energy systems are limited (GEA, 2012). Given the data scarcity often associated with developing countries, this type of data may be harder to obtain at a city level than at national level. National-level consumption-accounting exercises can draw on import and export customs data. At the city region, however, it is much more complex to track goods entering and leaving the geographic area of interest. Interrogating embodied energy could be kept in mind for future phases.

It is proposed that upstream energy is also excluded from this analysis, as the project scope is aiming at looking at sustainable energy interventions within the scope of the cities' governance. Measuring upstream energy is typically more useful at a national level when considering regional development decisions, and infrastructure investments – for example, whether to invest in rail links, or where to locate a power station. This depends on political structure within countries, whether cities wish to promote certain interests, or whether regulatory framework exists for utilities at a municipal scale for example.

4.2 Data inputs into a LEAP model

The LEAP model requires the construction of a reference scenario and then data inputs to inform demand forecasts under different scenarios of sustainability interventions. In general, there are three modelling approaches to forecasting. The first is trend forecasting of final energy, and these forecasts are reliable for a period ranging from a few months to a few years. The second type, econometric forecasting, is also based on final energy and estimates are reliable for one- to ten-year timeframes. The third type is end-use forecasting, which is based on useful energy and estimates are reliable for ten- to 30-year projections (IEA, 1984; UNEP, 1995). LEAP, a bottom-up model, can be used for end-use forecasting if the demand side is sufficiently disaggregated, and the various drivers (like population) are available. Table 3 describes the types of data and typical sources for populating a LEAP model. Data availability for the smaller cities in this project will undoubtedly remain a challenge. This should not be used to argue against modelling at all, instead it is anticipated that the modelling process can itself initiate processes of identifying and addressing data gaps incrementally over time.

Table 3: Data inputs for LEAP
Source: UNEP (1995)

Data categories	*Types of data*	*Common sources*
Macroeconomic variables		
Sectoral driving variables	GNP, gross output value, physical production , population, household size, transportation requirements, agricultural irrigated area.	National statistics and plans; macroeconomic studies.
Energy demand		
Sector and subsector total	Fuel use by sector/subsector.	National energy statistics; national energy balance, energy sector yearbooks.
End-use and technology characteristic by sector/subsector	Energy consumption breakdown by end-use and device: energy intensity, efficiency, vintage, etc.	Domestic relevant studies, surveys, audits; expert judgments, industry association data, government licensing data.
Energy supply		
Characteristics of energy supply, transport, and conversion facilities	Capital and O&M costs, performance (efficiency, unit intensity, capacity factors, etc).	National energy statistics, sector-specific plans, industry association data, utilities and public companies.

Energy prices	Prices for imported/exported fuel.	Relevant international studies.
Energy resources	Estimated, proven recoverable reserves of fossil fuels.	Relevant domestic studies.
Emissions factors		
Air pollutant emission factor	Pollutant emissions per unit fuel consumed, produced, transported.	IPCC, US EPA, EU CORINAIR, relevant domestic studies.

5. Conclusion

Apart from South Africa, there remain still relatively few studies at this stage for modelling energy futures for urban energy systems in African cities (GEA, 2012). This project will make a substantial contribution to engaging with the methodological challenges associated. An assessment of appropriate modelling tools has considered the study objectives and questions, data availability and quality, capacity of users of the model and the country-specific context. It is recommended that LEAP, a bottom-up accounting model, be used. This platform has several advantages for this study, some of which include the flexibility of data inputs, easy accessibility of the software and as a simulation model it is capable of constructing the types of scenarios relevant to the project objectives.

In the context of city and urban energy use within developing nations, LEAP has been used to model the energy consumption and the emissions of the transport sector for Mexico city, Delhi, Islamabad and Rawalpindi as well as the industry, household and commercial sectors energy consumption in Xiamen in China, Bangkok, Tehran, and Cape Town (Manzini, 2006; Bose, 1996; Shabbir, Lin et al, 2010; Phdungslip, 2009; Abberspour et al, 2013; SEA, 2010). In all of these studies, various energy consumption reduction strategies were studied, ranging from biofuel and hybrid car use (Manzini) to more energy efficient buildings in Tehran (Abberspour et al.) or shifting fuel use in industry and homes to natural gas (Lin et al, 2010), or a combined effect of energy reduction strategies (SEA, 2010).

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