UCL ENERGY INSTITUTE

energy saving trust

City Energy Demand Simulation (CEDS)

Feasibility Study

Technology Strategy Board – SBRI Future Cities

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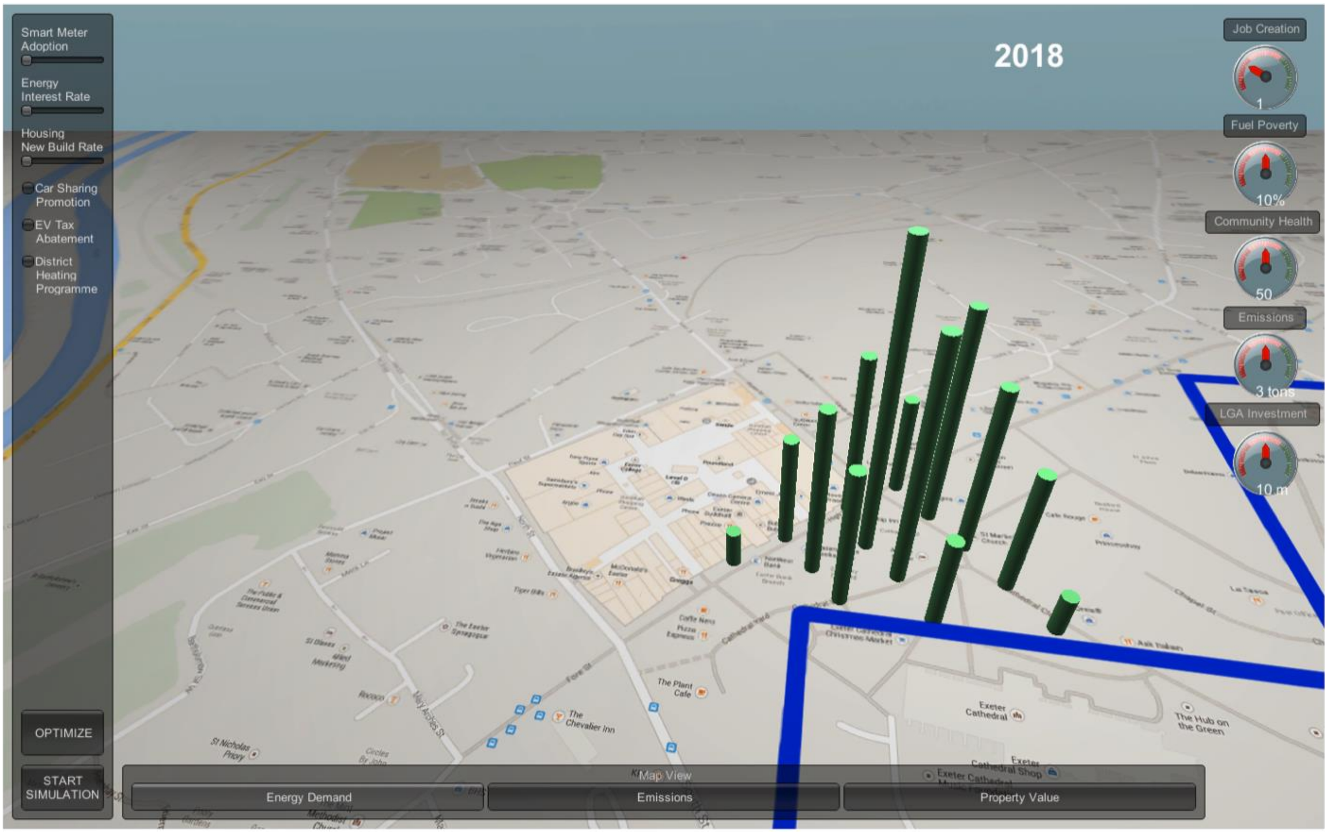

1. City Energy Demand Simulation – *Feasibility summary*

As part of the Future Cities programme we set out to explore the best way to create a City Energy Demand Simulation tool (CEDS). Our investigation explored the premise that by optimising a city's energy architecture it is possible to maximise economic, social and environmental, i.e. sustainable value in a city.

Our approach is to develop a computer model that enables city stakeholders to collaborate and decide on energy projects that best meet their cities unique visions and objectives. The aim is that this model delivers effective information to decision makers to take energy infrastructure projects beyond the drawing board and into construction, from domestic retrofit schemes to district heating networks.

We have been delighted to work with representatives from five metropolitan regions: **Birmingham, Cardiff, Coventry, Exeter** and **Haringey** and we thank them for their expert and candid input.

We conducted a series of interviews to understand what issues are at play in creating (or destroying) economic, environmental and social value through city energy planning. These findings, combined with desk reviews and the team's experience of successfully modelling national and regional energy systems enabled us to create a robust model and data framework. Further they enabled us to design a user interface which brings evidence and value to officer and member decision making processes.

A fundamental learning from our engagement with cities is that there is a need for the model to operate in a 'collaboration' mode whereby all the necessary stakeholders use the model together to test and fine-tune policy and investment solutions. This is made possible through engagement sessions and an intuitive and clear graphical user interface. This it is felt will better facilitate consensus building around strategic energy infrastructure investments. It is for this reason we have developed a more appropriate name for this tool, Stakeholder interactive City Energy Demand Simulation SiCEDS.

Additionally from the interviews, we took away the need that SiCEDS must contain a business case generator which is seen as essential for dealing with the risks associated with the new technology development pathways necessary to radically improve a cities control of its energy infrastructure.

SiCEDS itself is an agent-based model which will enable the holistic design of a city's future energy architecture. It will contain a full data management system to overlay nationally available datasets and those the Energy Saving Trust and UCLs Energy Institute can provide with locally available data. The model contains a series of calculation modules and configured assumptions which address fuel poverty, emissions, energy and installation costs, job creation, health impacts, policy interventions and a city's existing infrastructure. This connects to the SiCEDS visualisation user interface which offers a series of lenses to deliver appropriate access and functions to stakeholders including planners, city leaders, investors, developers and citizens.

CEDS will enable cities to develop a strong 'pipeline' of energy infrastructure projects that are investable, have consensus agreement and stakeholders in place to deliver. SiCEDS will help to build capacity and human capital to unlock potential and make possible localised energy systems that import greater levels of energy autonomy, economic activity and societal benefits that will help to achieve strategic city objectives.

Our work has shown that building a Stakeholder interactive City Energy Demand Simulation would be a valuable addition to a city's energy architecture planning capability because it would:

- Enable effective collaboration to ensure discussion leads to action
- Provide the means for a holistic view comprising economic, environmental and social aspects of alternative options
- Create the clear business case which is imperative to creating the necessary funding for city energy infrastructure implementation
- Provided the means to zoom in and out of areas of a city
- Meet the requirements as specified by the cities interviewed
- Quantify and measure outcomes to support decision makers

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2. Executive Summary

The CEDS project team set out to demonstrate how a city energy demand model could support city authorities and stakeholders to optimise their energy systems. Further we wanted to demonstrate that by doing so participants can maximise economic, social and environmental, i.e. sustainable value for the city and enable stakeholders to choose energy projects that best meet their unique visions and objectives.

This report demonstrates how we have investigated city requirements and researched existing modelling approaches. It goes on to show how we have detailed a clear modelling framework, explored the best options for a visual user interface and investigated the data assets necessary to drive such a tool. The contents page above gives details of the location of these sections.

This report is the result of a project team with a strong set of competencies, experience and knowledge gained from successfully modelling national and regional energy systems and buildings combined with first class input from a diverse range of senior city representatives. As a result this report highlights some exciting and fundamental learnings that strengthen the case for a Stakeholder interactive City Energy Demand Simulation (CEDS) tool.

A key learning includes the need for the tool to operate in a ‘collaboration’ mode whereby all the necessary stakeholders interface with the model to test and fine-tune policy and investment solutions. This it is felt will facilitate consensus building around strategic energy infrastructure investments. Additionally we are clear that a fun and accessible user interface will be more effective than spreadsheet outputs and that a business case generator is essential for taking projects beyond the drawing board and into construction.

3. Learning from CEDS

3.1 What do City authorities require from a CEDS tool?

How do cities derive value from their energy infrastructure?

We interviewed eight city representatives (details of interviewees shown in table 1 below) spanning five cities.

Each interview lasted between 45 and 90 minutes and was facilitated by a number of trigger questions designed to let respondents put on the table the issues they considered important in determining how the management of a cities energy architecture created (or destroyed) value.

Table 1

City	Interviewee(s)	Further feedback session
Birmingham	**Raj Mack, Sandy Taylor**	
Cardiff	**Dylan Owen**	
Haringey	**Jessica Sherlock, John Mathers, Sadhbh Ni Hogain**	**Natalie Butler**
Coventry	**John Kyffin-Hughes**	
Exeter	**John Rigby**	**Howard Smith**

Each interview was transcribed into bullet points. We collected 237 bullet points in all.

These were then sorted into issue areas. Each issue became a cluster shown in the value map diagram (figure 1) below and the topics brought up by interviewees within each of these areas were shown as hexagons within the clusters (figure 2 shows one of these). The Value Map was then fed back to two cities represented by Howard Smith (Exeter) and Natalie Butler (Haringey). Their comments were then incorporated into the final report on this module.

Figure 1: City energy infrastructure value map

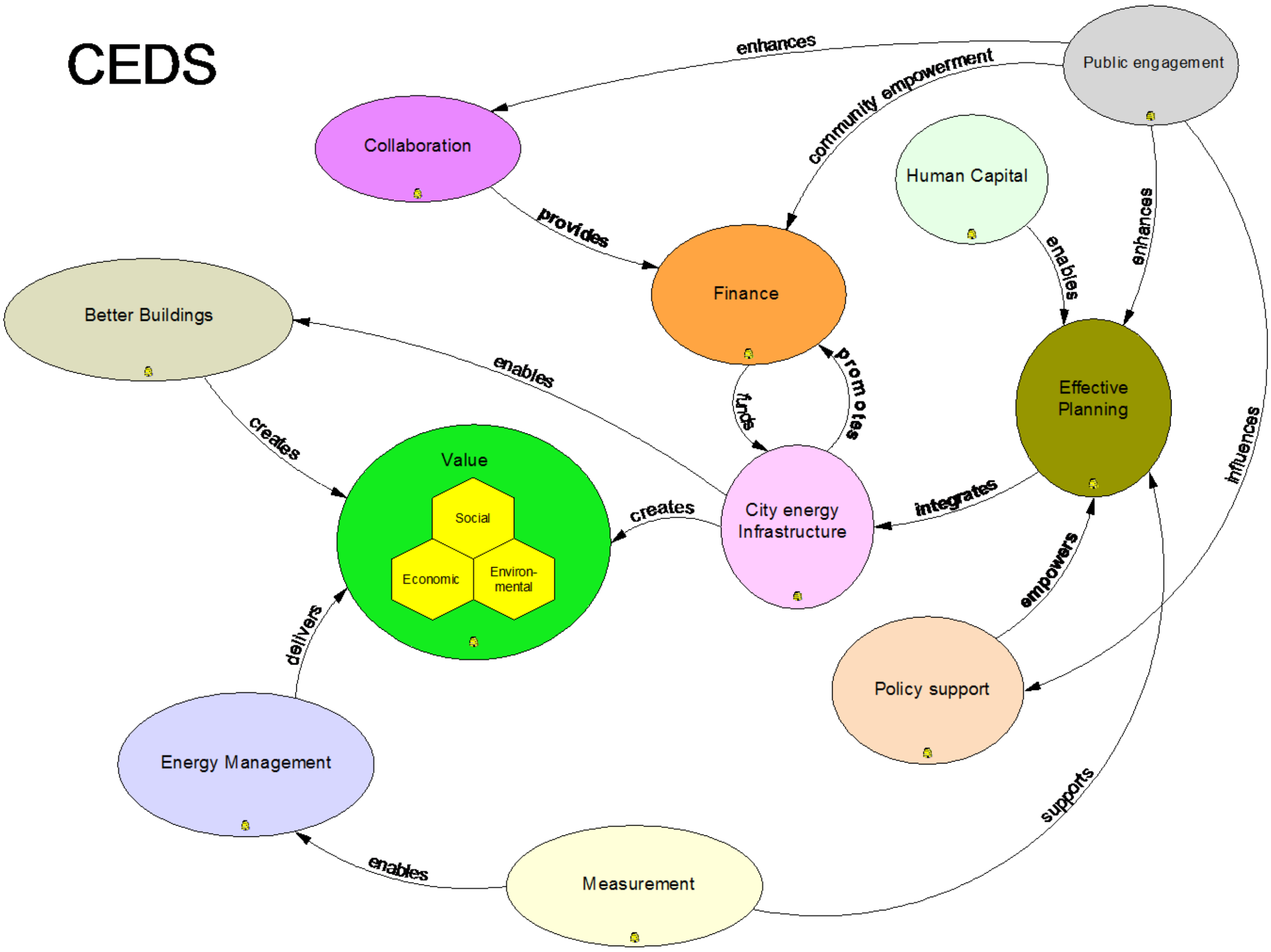
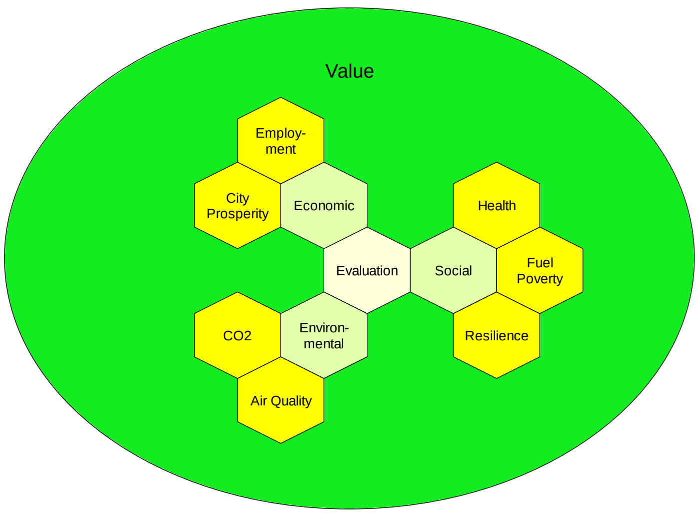


Figure 2: key value drivers



At the highest level the value cluster highlighted seven key aspects of value which drive Economic, Environmental and Social Value. These are shown in figure 2 and the three drivers of value are exemplified by the two quotes below.

> “by covering environmental, social and economic - that covers all the sins I could think of”
>
> “Recognising the links across social, economic and environmental objectives and the more that you can link those up the more effective approaches you can develop.”

Figure 1 shows the 10 issues that drive the creation or destruction of value.

These are summarised below and each is illustrated by one or two quotes from the city interviewees.

1. Collaboration

> *“For me it’s the stakeholders working collaboratively with big commitment (that brings success).”*
>
> *“So collaborative working, a commitment to doing stuff on the ground, and getting political sign-up retained (are the keys to success)”*

A major learning point for the study team was the crucial importance of effective collaboration between the multiplicity of stakeholders involved in the energy architecture planning process. We learnt that our primary focus should not be on the algorithms which determine the value performance of the energy infrastructure but should be on enabling the diverse group of stakeholders to collaborate effectively.

That means any CEDS tool needs to both meet the needs of diverse stakeholders and to be accessible to a diverse range of stakeholders in disparate locations. That said the interviews also clearly defined the functional areas which need to be handled appropriately by a CEDS tool. Given the importance of effective collaboration we have decided that it would be more appropriate to call the model SiCEDS – “Stakeholder interactive City Energy Demand Simulation”

2. Policy Support

> *“On several different levels there would be changes in policy and legislation that would make all of this much easier, whereas sometimes it feels like you are working against policy and legislation to try and achieve what you need to do in the area”*
>
> *“It is important that the politicians are committed to the agenda. And I am very heartened that despite what is going on nationally at the local level both the labour and tory authorities, within the constraints set by national government, seem to be committed to the low carbon agenda - but we need to keep reminding them of how important it is and what it delivers”*

Whilst concerns were expressed regarding national government support for the green agenda there was a universal recognition of the need to engage with politicians at both national and regional levels. Indeed, this could be seen as another aspect of the importance of effective multiple stakeholder engagement.

3. Public Engagement

"I think citizens are looking increasing to the council to do something, and there is a lot of community action/ involvement going on who want to be more energy efficient and generate more of their own energy within the community, which they can control in a co-operative way, so they are looking at the council to do more on that front"

"Functionality is key – is it easy to engage with, easily connects with popular consciousness"

The public were highlighted as one of the stakeholders that SiCEDS would need to engage with effectively. Public support is so often a lynch-pin in moving a project forward. Where community ownership of assets is part of the mix this can have a direct bearing on Finance. Understanding community requirements enhances effective planning. And with the public being voters represents a lever for ensuring that Policy support is forthcoming.

4. Effective Planning

"The planning system is not in favour of actually integrated approaches on energy"

The city planner is herself/himself a key stakeholder. There is a clear desire to have the integrated vision, which a SiCEDS tool could bring, of what the consequences are of various energy architecture options.

5. Finance

"Money will follow proven track record, and therefore you need to have a credible offer, then you get something in the pot, and then your proven track record gets you more money"

The investment community was also identified as an important stakeholder again underpinning the need for a platform that can communicate and interact with a broad range of stakeholders. It was a clear view that this tool must offer a 'business-case generator' enabling projects of technologies and their associated risks to be presented and funded effectively.

6. City Energy Infrastructure

"A greater proportion of energy generated from renewables and de-centralised energy"

"Looking at energy required for a community and look at optimising the energy efficiency and energy generation within that community"

The consequence of effective collaboration, and its consequent delivery of funding, can enable cities to start to control their self-sufficiency. There was a clear desire to generate more energy within city boundaries and import less to boost local economic activity.

7. Better Buildings

"Developers out at Sky Park have bought wholly into the Low Carbon concept. The developer he sees this as part of his brand image to distinguish his site from others in the city, and he also sees the economic development benefit because that helps him with the investment message"

"If I was energy supremo I would say you have to invest in the retrofit of the leakiest stock which is where the fuel poor tend to be"

Developers were identified as an important stakeholder constituency to achieve highly performing new homes. Retrofit of the housing stock was also seen as integral to tackling fuel poverty.

8. Measurement

"To have a city wide data portal for all energy and data resources across the city, so water, gas etc that data could be sat on, analysed for where the issues are, what type of systems link together and how does one set of data then influence the water mark. How do they then combine their plans? So having that city portal and open data system that enables all data and be public facing "

"At the moment the way the utilities are positioned its information flow is one way only, or the information that is provided is to enable the utility to make decisions based on the value that the utilities place on that information. And the priority is to turn that around and ask is there a two way process where information on consumption, how can that be delivered to an individual and then be scalable across a city, so the city can start planning how to use its information"

Data access and availability, both for individual building stock performance and more broadly were seen as key to the successful deployment of a SiCEDS tool. It is clear there is a need to 'open-up' the current flow of energy demand data to enable more coherent, locally strategic decisions to be made.

9. Energy Management

"From an operational side, public buildings in particular the fragmentation and lack of monitoring system enables us to have visibility of some of the energy consumption in the city. But the data that comes in is measured in different ways. There is no standard comparable information. We cannot aggregate information the way that we want to"

"What are the management systems that we need to have in place, what are the monitoring tools that should enable us to have the visibility we need to understand what the consumption is?"

The focus here was on the need for good data to understand energy use and to plan energy infrastructure.

10. Human Capital

"My second fear is that local government is being absolutely hammered by people who don't really understand what the impact is. They think you can cut resources by 25% and it will have no impact"

> *"A lot of these issues are extremely complex and for a borough being relatively small organisation to up-skill and has limited resources to tackle these issues, it makes sense to work across boroughs to share learning and pool expertise"*

Lack of human resources is a concern in the city planning community, although effective collaboration with other organisations was cited as a potential mitigating action to manage this risk. Energy planning issues are extremely complex so effective pooling of skills and expertise is invaluable yet again highlighting the importance of creating a platform that can link multiple stakeholders in effective dialogue.

Looking at the full Value Map as shown in Figure 1 at the beginning of this section of the report the clusters do not exist in isolation – they are linked to each other and to the creation and destruction of value. The arrows between each cluster represent these relationships and an arrow between two entities means that more of the entity at the tail of an arrow creates more of the entity at the point of the arrow.

So for example more "Collaboration" causes more "Finance" to be made available which in turn enables more "City Energy Infrastructure" to be built which in itself creates economic and environmental value (lower emissions), but also in turn creates "Better buildings" which in turn creates economic, environmental and potentially social value (through reductions in fuel poverty).

An interesting feedback loop is shown in the "Finance" area where more "Finance" enables more "City energy Infrastructure" which itself creates more "Finance" availability through a demonstration of the value creation of the investment.

A full description of the linkages can be found in the Value Map report.

What does this mean for the design of a SiCEDS tool?

The discussions which formed the basis of the Value Map clearly indicated that a SiCEDS tool would be extremely valuable to cities. As is clear from the preceding section the tool needs to be a platform which enables effective dialogue between multiple stakeholders.

In addition there were also numerous learning points regarding the functionality required for such a tool. These are summarised in table 2:

Table 2 - Implications for a SiCEDS tool
Address trade-off between environmental, social, & economic outcomes
Health is an important issue
Appropriate view for each stakeholder
Access for each stakeholder
Needs to create a business case

City energy imports and production
Heat supply and demand
Effectively demonstrate benefits to government
Integrated view of a city
Handle complete range of technologies and innovations
Look at the future (scenarios)
Consistent and city-wide data access
A public view

3.2 What can be learnt from alternative city and energy modelling approaches?

In parallel with the Value Mapping work, we conducted a desk study into existing city and energy modelling tools to understand their strengths and weaknesses.

A summary of models used in energy-environmental planning is provided in table 3 below. A critical evaluation of these models has been completed. Some of the main aspects that are missing in the existing models are described before an outline of how the SiCEDS tool fills these gaps to meet the needs of city planners.

Due to their complexities, comprehensive models are increasingly needed for cities to capture key functions and to help urban planners to develop integral city plans for future transformation of energy flows. So far, different models have attempted to predict how city energy flows might change over time. Significant advances have been seen for energy demand predictions for buildings (residential, commercial and industrial) as distinct categories and to estimate the energy demand. In addition, significant efforts have looked at the energy supply side, where various models can be used to interrogate the evolution of renewables with GIS technologies for example. Also, there is a variety of modelling techniques to simulate energy consumption, distribution and production.

However, these models have different strengths, weaknesses and applicability. Various models can be classified in different ways, on different temporal and spatial dimensions, by application focus and simulation approach (bottom-up or top-down). Bottom-up models are based on the data to investigate the energy usage in urban and regional level, they need extensive databases of empirical data to support the description of each user.

Recently the tendency has been to develop integrated models, more holistic models of the city system. Such examples are: LT-Urban - assessing the potential of renewable energy in cities; SUNtool - Sustainable Urban Neighbourhood Modelling Tool – a computer tool to support urban planners and building designers to develop a 3D model of an urban neighbourhood using a simple sketching tool and SymCity a synthetic tool that integrates different urban modelling approaches, including the layout of a city, it's socioeconomic structure, activities, energy carriers and technologies which facilitates the integrated modelling of urban energy systems across issues that related to the energy supply and demand. All these models focus on urban energy system and have one goal, to help city planners to evaluate future alternative scenarios.

From our review, it is evident that already there is a wide range of urban energy models and that they are quite diverse in terms of scales (spatial and temporal), energy side focus, analysis variables and the methodological approaches that are used for simulation. However, the existing integrated models only address some specific parts of the whole urban energy system and there are still several challenges that haven't been addressed. For example the integration of the urban layout models with the socioeconomic structure of the city to evaluate energy performance.

Despite the diversity of approaches found in the literature, there are a number of common challenges which we identified such as spatial variables, specific data intensity, availability and credibility of data, policy relevancy and integrated multi-layer models. In the development of integrated models, one of the major challenges we identified is the interaction and dynamics between different spatial scales and capturing these dynamics in macro and micro levels. Also we observed that current integrated models are strictly constrained to one spatial scale such as building, neighbourhood, district or city. In reality, energy consumption depends on different variables at different spatial scales which need to be taken into account in optimising a cities energy infrastructure.

Table 3. Summary of Energy and City models

Model name	Origin	Type of model	Other information
BALANCE	IAEA, US-DOE[1]	Energy supply and energy system model	A model for the simulation of energy
CO2DB	IIASA[2]	Energy information system	CO_2 database
DEAM	UCL[3], UK	Dynamic model, energy demand and supply	A dynamic techno-economic energy model
DYNEMO	UCL[4], UK	Energy demand and supply, all sectors	A dynamic energy model, with optimisation
DECPAC/DECADES	IAEA[5]	Energy information system	Database and technology chain analysis
EEP	Welsh School of Architecture, Cardiff[6]	Case study: The Energy and Environmental Prediction (EEP) Model	A computer based model that provides an auditing tool for quantifying energy used and associated emissions for cities; predicts the effects of future planning decisions from a whole city level down to a more local level.
EFOM-ENV	EU[7]	Energy supply and energy system model	Energy Flow Optimisation model
EM	World Bank, GTZ[8]	Model for life-cycle assessment of power systems	Environmental Manual: a simulation model
ENERPLAN	UNDTCD[9]	Modular planning instrument	It couples a macro-economic model with a simulation model of energy sectors
ENPEP	IAEA, US-DOE	Modular planning instrument	Energy and Power Evaluation Program
ETA-MACRO	EPRI[10]	Energy-economic model	Energy Technology Assessment, a dynamic model which couples the macro-economic MACRO with the aggregated energy system model ETA
GEM-E3, E3ME	EU	Energy-economic model	Computable General Equilibrium Model for studying economic-energy-environment interactions
GLOBAL 2100, GREEN, 12RT	**OECD[11]**	Energy-economic model	Dynamic models based on energy technology assessment with 5 world regions
HOVA	PROFU[12]	Model for the analysis of energy conservation potential	An Excel-based with database model

LEAP	SEI-Boston[13]	Modular planning instrument	Long-Range Energ Alternatives Planning, a simulation model with environmental database
MADE	IKE[14]	Model for the analysis of energy demand	Model for the Analysis of Energy Demand, a module of the ENPEP planning tool
MARKAL	ETSAP[15], IEA	Energy supply and energy system model	MARKet Allocation model with a user support system
MARKAL-MACRO	BNL[16]	Energy-economic model	Linked models for energy-economy analysis
MEDEE	IEJE[17]	Model for the analysis of energy demand	Modele d'Evaluation de la Demand En Energie, a bottom-up model
MESAP	IER[18]	Modular planning instrument	Modular Energy System Analysis and Planning
MESSAGE	IIASA	Energy supply and energy system model	Optimisation Model for Energy Supply Systems and Their General Environmental Impact
MIDAS	EU	Energy supply and energy system model	A modular simulation model
MODEST	IKP[19]	Energy system optimization model	Minimization of capital and operation costs of energy supply and demand side management
PLANET	IER	Energy supply and energy system model	Long-term energy system simulation
POLES	EU	Energy supply and energy system model	Prospective Outlook on Long-term Energy Systems, a simulation model
SAFIRE	EU	Technology assessment model	Strategic Assessment Framework for the Implementation of Rational Energy, a simulation model for heat and power supply at the local and regional level for European countries
SESAM	Aal-U[20]	Modular Planning instrument	The Sustainable Energy systems Analysis Model for energy systems planning at local and regional scale
SynCity	Imperial College[21]	An integrated tool kit for urban energy systems modeling	**Modelling** of urban ***energy*** systems across energy carriers and technologies used to facilitate city and its activities
TEESE	TERI[22]	Modular planning instrument	TERI Energy Economy Simulation and Evaluation model
TIMES	ETSAP[23], IEA	Energy supply and energy system model	The Integrated MARKAL-EFOM System, an optimization model that produces least-cost solutions. It is intended to replace MARKAL which has its origin in the late 1970 and no longer meets modern requirements and possibilities of up-to-date software engineering
WASP	IAEA, US-DOE	Electricity supply model	Wien Automatic System Planning, an optimization model

As a result of both the value mapping exercise and this desk based study we have a clear view of the critical features of SiCEDS which will add value to a city planning authority. These essential functions (listed in Table 4) combined within a SiCEDS tool fills the gaps identified and will deliver the unique functionality for city planners to optimise their energy infrastructure.

Table 4: Essential functionality for SiCEDS
Ability to enable multiple stakeholders to access the system
Built in effective collaboration support processes
Spatial freedom – ability to zoom in and out of regions of the city
Fuel poverty impact calculator
Emissions impact calculator
Health and employment impact (user set) evaluation parameters

3.3 What is the best functional design for a SiCEDS tool?

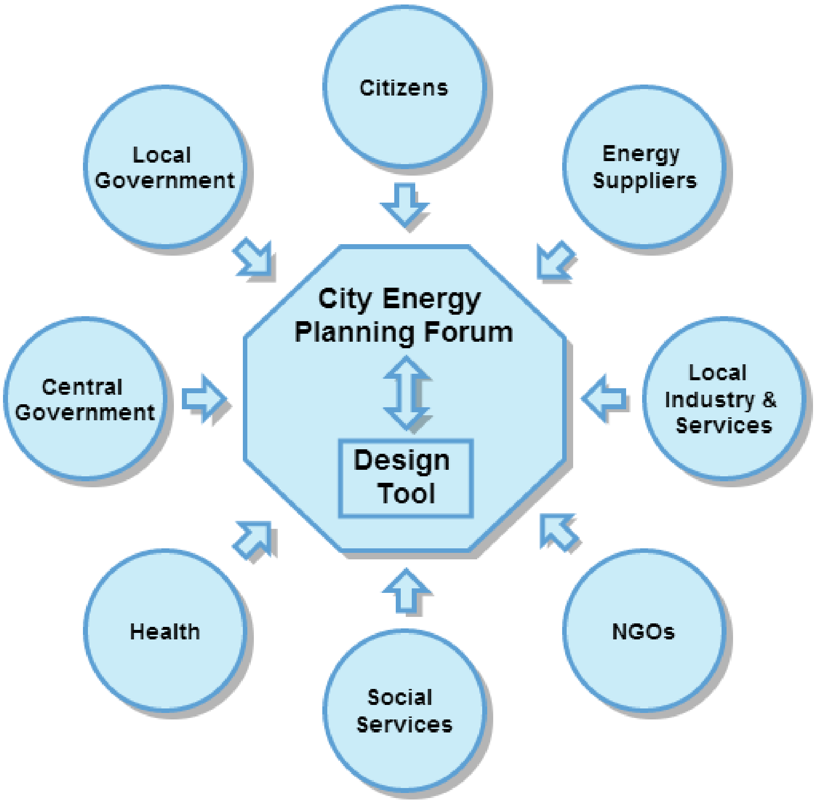
We built on the findings from the value mapping exercise, the literature review and the teams experience in delivering similar modelling products to outline the optimal specification for an effective SiCEDS tool.

Stakeholder collaboration function

We have learnt that energy infrastructure interventions require a complex interaction between numerous key stakeholders. This functionality will enable a facilitated ‘stakeholder forum session’ to take place allowing a range of policies and technical solutions to be properly debated and refined based on clear cost benefit information. From the review it has been shown that we need to integrate into the model the multiple players in an integrated whole energy system model. A typical scenario of this functionality is set out below. The outputs of these sessions can then be used to trigger detailed design studies e.g. for district heating solutions in particular areas, inform strategic plans and enable viable ‘projects’ to be defined and presented for funding.

There would be an overall energy design process for a planning forum comprised of stakeholders, supported by SiCEDS software models and data. The design of SiCEDS would take account of existing planning processes to maximise and ease utility for stakeholders (Figure 3). The process would have as an aim the defining and initiating of the practical implementation of policies.

Figure 3: stakeholder collaboration approach for SiCEDS



A proposed outline process for the planning forum:

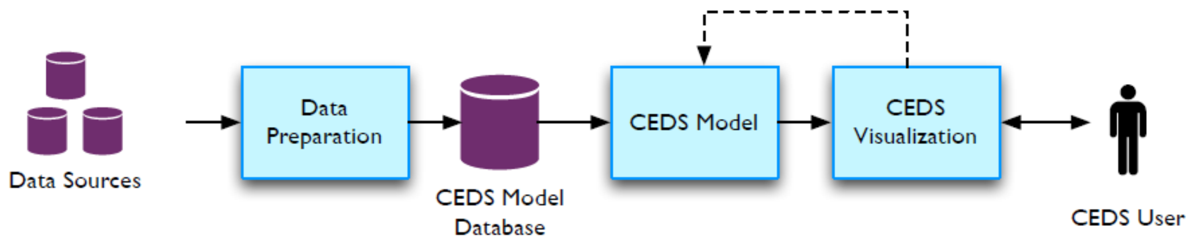
1. The forum decides on energy planning objectives for a selected city; such as reducing energy service costs in a borough with low incomes, or reducing the city's energy import costs and carbon and air pollutant emissions.
2. With the aid of SiCEDS, data for the urban area is selected including social (demography, income, etc.) and economic data (industry) and the infrastructure (building stocks, energy supply, etc.) would be collected.
3. The forum explores different policies, such as programmes of insulation or local public heat supply, to meet objectives.
    a. policies will be defined, such as programmes of insulation or local public heat supply
    b. SiCEDS will include some optimisation to aid the design of programmes to meet objectives (e.g. energy, emission, poverty) at low cost.
4. For current and future years, SiCEDS calculates the impact of programmes and will produce reporting in terms of tables, charts and maps to assess:
    a. energy flows, the capital and running costs of the system for different consumers and suppliers, and the effects on emissions.
    b. the impact on fuel poverty.
    c. direct employment in installation of efficiency packages or supply systems
5. The forum can assess the results of their policies and iteratively adjust policies to produce better results and test the robustness of plans.
6. The forum can use the information to help take plans to implementation by providing cost profiles, returns on investment and benefits (societal, economic and environment). This can be used to negotiate with government and other funding bodies, energy suppliers, industry and so on.

In addition to information about particular cities, SiCEDS will include contextual information, for example scenarios for the national context that impact on cities - population, households, energy prices, carbon limits and so forth.

SiCEDS computational framework

This section outlines the proposed technical solutions that ensure SiCEDS will deliver accurate information for evidence based decision making. The overall model architecture will function as in figure 4 below.

Figure 4. Model architecture



The SiCEDS model

SiCEDS will be embedded with a set of agents, representing objects and populations at an elemental level such as building archetypes and a set of assumptions, for example the cost per unit of energy or of a solar pv installation. This is a powerful way of enabling the user(s) to draw a geographical boundary around a cluster of these agents and test what happens with a given set of policies over time.

In addition, this model will be divided into the following calculation modules:

i. Energy demands in domestic and non-domestic buildings, industry

ii. On-site and public energy supplies

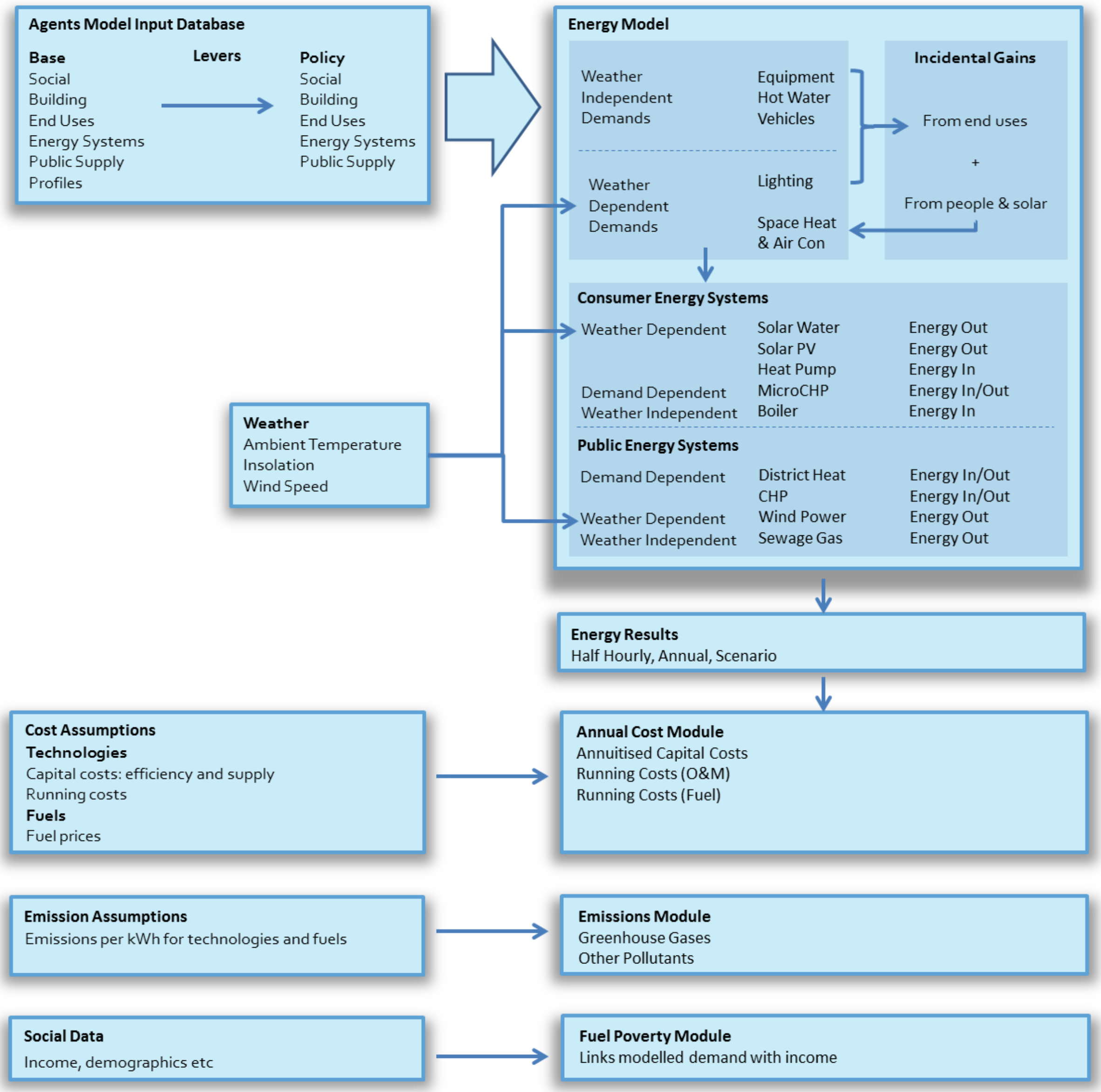
iii. Emissions from demand and supply

iv. The capital and running costs of energy efficiency and public and private supply

v. The impact on consumers of energy costs, in particular on fuel poverty and CO_2

Figure 5 provides a diagram of the specific agents, assumptions and modules that will be needed to deliver the key calculations and outputs required by the end users.

Figure 5: Schematic of the calculation modules within SiCEDS



Modules

The following section presents the detailed calculations deemed necessary for each module within SiCEDS.

Energy cost module

The total cost (TC) is the capital costs (CC) of technologies plus variable costs (VC). TC = CC + VC

The total cost will be calculated over the project or technology lifetimes.

Initially the costs will be restricted to energy related technologies (e.g. insulation, energy supply). Variable costs will include O&M (operation and maintenance) and fuel costs. Technology capital costs can be annuitised with appropriate discount rates and accounting lifetimes. Then the annual cost can be calculated for each agent (and then the impact on fuel poverty) and this may be used to find the total costs of a programme, or the costs to individuals.

The capital cost is annuitised since the investment provides a sustained capacity increase for a number of years. Annuitised costs represent an even level of annual expenditure spread over a period of time that is equivalent to a capital investment.

Emissions module

Emissions of carbon dioxide and other air pollutants will be calculated using indices in g/kWh and energy flows in kWh. These indices will apply to technologies in the urban area modelled (e.g. gas boilers) and to energy imported from outside the area (e.g. gCO_2/kWh electricity).

Fuel poverty module

There are two approaches to calculating fuel poverty as detailed here, and we propose to enable the model to calculate both to ensure all stakeholders using the model can align the outputs to their existing reporting processes.

The 1991 and 1996 English House Condition Survey Energy Reports adopted the 10% of income threshold for fuel expenditure required to achieve a satisfactory heating regime. Household income was not normalised. However, standards mentioned that when comparing incomes of households of different sizes (number of people) income should be normalised – adjusted for household size and composition. For example, the *United Nations Expert Group on Household Income Measurement (Canberra Group)* recommended “that income should be adjusted to take account of household size, using equivalence scales”. The only income related definition of poverty in the World that does not normalise income is the UK Fuel Poverty Measure.

The recent definition of Fuel Poverty (according to DECC, 19th September 2013) based on the Low Income High Costs (LIHC) approach a household is said to be in fuel poverty if:

- they have required fuel costs that are above average (the national median level)
- were they to spend that amount they would be left with a residual income below the official poverty line

Also, statistics are available for 10% definition. Under this, a household is said to be fuel poor if it needs to spend more than 10% of its income on fuel to maintain a satisfactory heating regime (usually 21 degrees for the main living area, and 18 degrees for other occupied rooms). The drivers behind fuel poverty are: the energy efficiency of the property (and therefore, the energy required to heat and power the home); the cost of energy; household income.

The cost of energy can be calculated by combining the fuel requirements of the household with corresponding fuel prices, which covers four areas of fuel consumption: space heating, water heating, lights and appliances; cooking.

The Fuel Poverty Ratio is defined as:

$$fuel\ poverty\ ratio = \frac{fuel\ cost\ (usage\ X\ price)}{income}$$

If this ratio > 0.1 then the household is Fuel Poor

The fuel poverty ratio shows that fuel poverty can be considered to be an interaction of three main factors:

i. the energy efficiency of the dwelling (affecting the numerator)
ii. the cost of energy (effecting the numerator); and
iii. household income (affecting the denominator).

Health module

Energy policies mainly impact on physical through personal exposure to pollution and to low or high temperatures. Mental and social health is also affected by adequacy of heating; for example, children may not have a comfortable, quiet place to study.

People may have inadequate heating (or cooling) in their buildings and may therefore be subject to unhealthy temperatures. The health impact of low or high temperatures depends partly on the health and age of individuals, the length of time exposed to extreme temperature and their adaptations such as clothing. A common cause of inadequate heating in the UK is fuel poverty – an inability to pay for the fuels needed for warmth. Under-heating may have secondary impacts such increased mould growth which can impact on health.

Energy demand and supply has direct impacts on the environment. Perhaps most important in cities is that the combustion of fuels in buildings, processes and transport gives rise to a number of air pollutants (particulates, nitrogen oxides, carbon monoxide, etc.) which, when breathed in, either outdoors or indoors, directly affect human health. To estimate health impact it is necessary to estimate pollution emission from all sectors and technologies, calculate the concentrations in the air inside and outside buildings at different places, the exposure times of people, their age and activity and so on. This is complex.

SiCEDS will provide some data which may be used in the estimation of the health impact including social data such as fuel poverty, and physical information about buildings (energy efficiency, heating type, air tightness) and the emission of pollutants from certain energy technologies. However, these data can only be one input into the complex process of calculating health impacts using a range of atmospheric, building and health impact models.

The operation of calculation modules as a whole

Figure 6: example calculation for an agent

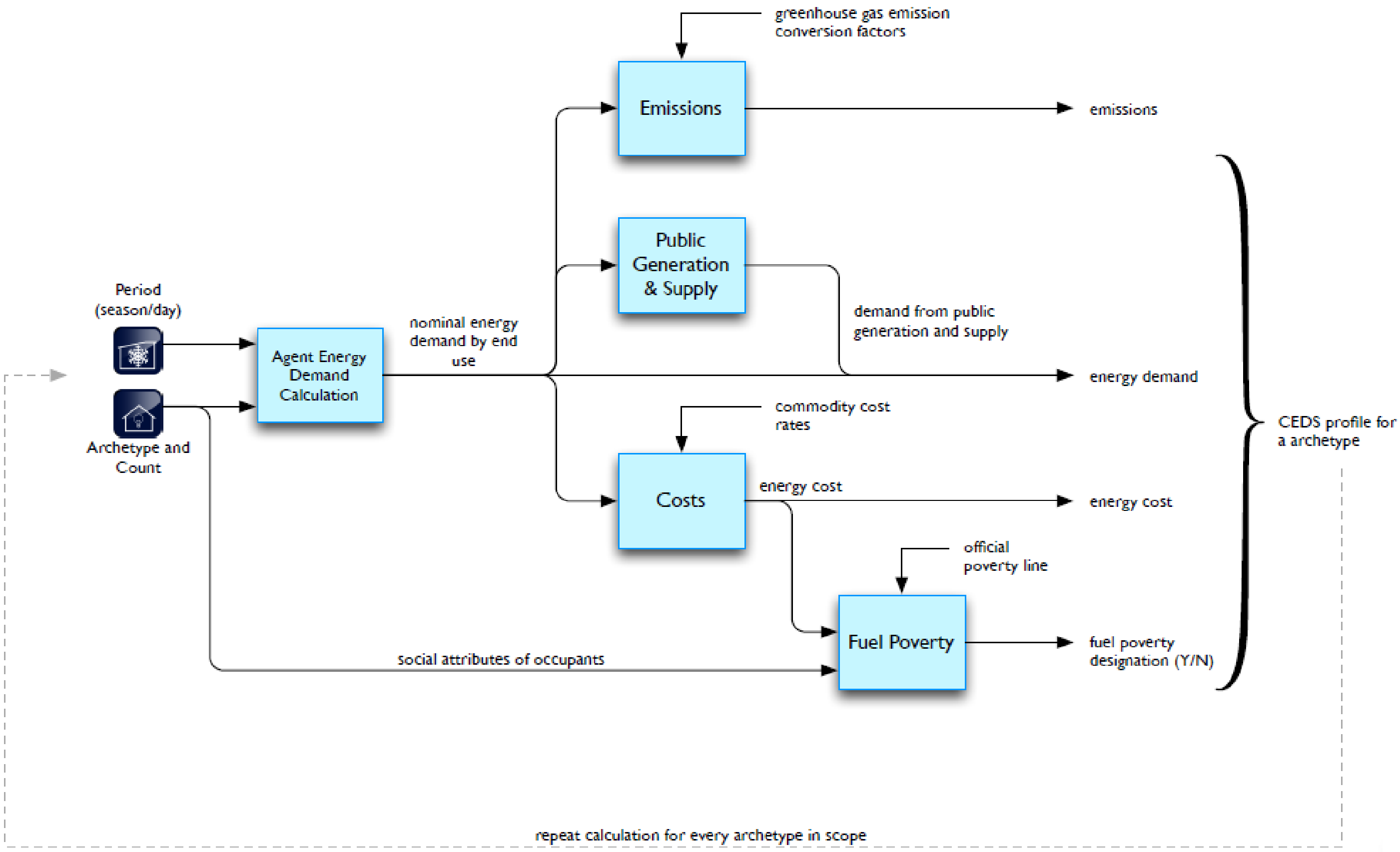


Figure 6 demonstrates how the calculation modules work together to deliver an iterative result for a given agent. In this case a building archetype will have been selected geographically and given a count e.g. 55 ‘pre-1900s terraced homes’. Dependent on what policy intervention is being tested, the parameters of these homes will be combined with related assumptions of the calculation modules, iterated over a period of time and deliver a new result. This result then represents a new level of performance and associated value (economic, social and environmental) to the city.

It is through the aggregation of results from the complete set of agents within a given area that will present a policy outcome to the user to support decision making. The real power of SiCEDS as an agent based model that is able to handle multiple policy objectives will become evident in the user interface section that follows. Likewise a further, more detailed demonstration of this approach to generating policy based results is illustrated in figure 15 in the Data section.

3.4 What will the user interface need to do?

The design of the user interface for the SiCEDS model is vital, as it is insufficient to generate numerical solutions from the model, rather, we must also explain those solutions to a wide audience in non-complex, non-mathematical ways. Graphical user interfaces (GUIs) do just that, representing the "last mile" of the model to the user. SiCEDS is unique as a project, in that there is a large and diverse group of users/stakeholders, and each must be respected in the design of the interfaces.

Moreover, SiCEDS leadership has expressed a keen interest in collaboration with the model – groups of stakeholders diving deeply into a policy question to examine the inherent trade-offs and their meanings. We have taken the collaboration goal specifically into account in the design of the interfaces you will see here.

There is a "science" behind the proper generation of GUIs that is too often ignored (and why we see so many confusing and badly formed interfaces everywhere from ATM machines to online stores). Our intention is to use the best science in GUI design, coming from thinkers like Edward Tufte[1] and Stephen Few[2], to create a series of effective user interfaces on top of the SiCEDS model. Design principles guide our use of colour, font, shape, and scale to communicate key ideas, provide emphasis or focus, and set context.

To that end we conducted a formal workshop in GUI principles in London on February 4, 2014. Our interactions with the SiCEDS stakeholders led us to identify five distinct classes of users of the SiCEDS model:

1. **Observer**. Users who wish to *view* the geo-centred information generated by the SiCEDS model, perhaps with particular emphasis on their own city or town.
2. **Questioner**. Users seeking answers to a specific query phrase, such as "what is the carbon output of postcode ____?"
3. **Analyst**. Users who wish to conduct policy experiments with the model, such as "what is the impact of a new carbon containment programme?" or "what is the optimal location for a new district heating plant?"
4. **Gamer**. Users who take part in the model expressed as a game-like immersive learning environment for role playing. Users (or teams of users) "compete" by making a range of policy decisions over time whilst a scorecard displays a basket of metrics on outcome.
5. **Admin**. These are users who set up and maintain the model by uploading new data or settings.

It will be our intention to build interfaces tailored to each user class whilst taking advantage of common componentry available to each. It will also be critical for the user interface to adapt outputs for different user types as planners, financiers and the public will have different expectations of the data.

[1] www.edwardtufte.com

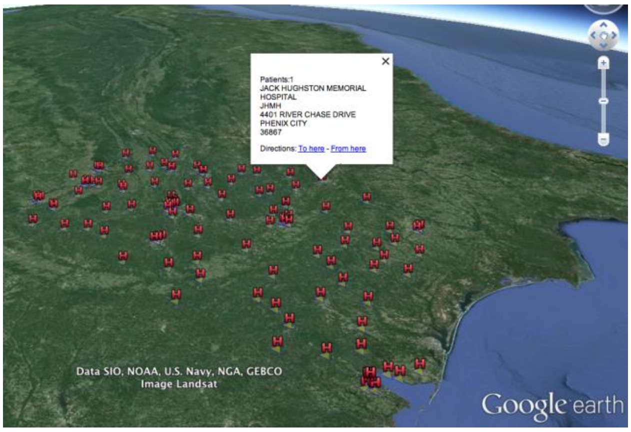
[2] www.perceptualedge.com

The Observer Interface

Observers wish to browse a map for geo-contextual information. They are often in interested in a particular region, and will zoom and pan the map until the region of interest comes in to view. The Observer expects the interface to be “zoom aware” whereby certain details become available (and others fade away) as we change the zoom, such as minor roads that only appear when we are “close in”.

Our experience suggests that a custom tailored instance of Google Earth is the best choice for Observer class interfaces[3]. They can be built in two forms (not mutually exclusive). In the first form, the underlying data in Google Earth, called a Keyhole Markup Language (KML) file is extended to include custom regions and place marks. These appear as polygons and landmark icons on the map as shown in the figure. This is an example of an Observer display we built for the US Centers for Disease Control where each placemark is a particular type of emergency care facility.

Figure 7. Google Earth as Observer interface



Notice that by clicking on one of the placemarks an information bubble is displayed above it. Google Earth uses HTML rendering for infromation bubbles, so any text, graphs, charts, images, or even referencable web pages may be included here.

Figure 8. Google Earth tour

The second form of the Observer interface is the tour. In a tour, Google Earth itself (as configured in the KML) smoothly navigates the user from one location to another whilst providing information bubbles at key places along the timeline. Tours can also be voice narrated. We would expect to construct one or more of these tours for each of the pilot sites in the SiCEDS study, as in “A Tour of the Energy Aspects of Exeter”. The figure at left shows a similar tour we constructed for the Port of Blythe in marketing property as part of the BEREZ redevelopment zone.

Both of these Observer interface forms can be accessed from a browser over the web.

[3] At this time we do not believe that the “Professional” version of Google Earth will be required for users of the Observer interface. Rather, the freely available version should suit just fine.

The Questioner Interface

Questioners seek answers to specific questions, posed in the form of a query. Here are some examples of Questioner queries:

1. How much electricity is consumed in Postcode ___?
2. What is the carbon footprint of city ___?
3. How many heat pumps are there in ___?

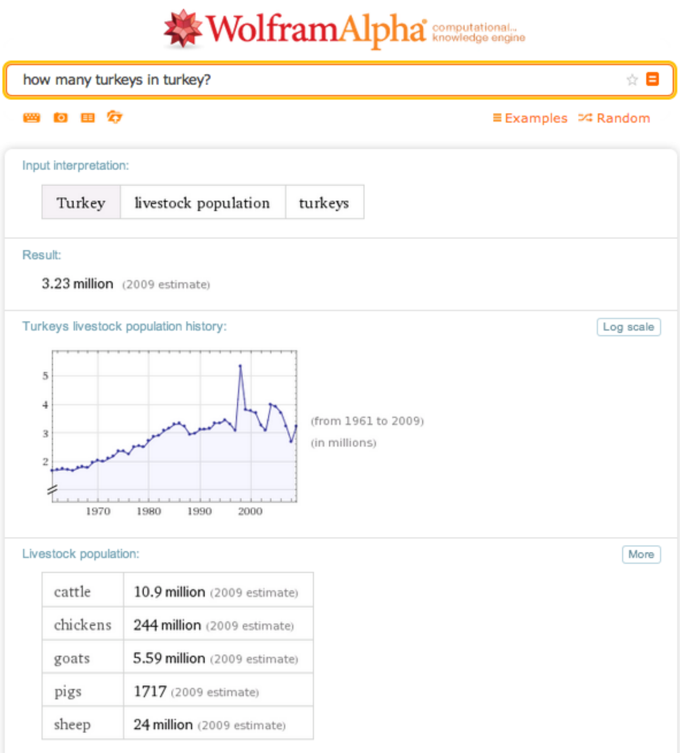
Please understand that these are examples for illustration and the range of information to be maintained by the SiCEDS project has yet to be determined. However, for whatever extent the information becomes, it is our remit to provide an interface to Questioner queries and the repository of information.

The modern way to create Questioner interfaces is to curate the data – wrap the data in a meaningful semantic expression that can be easily mapped to a range of queries. In other words, determine the *meaning* of the Questioner's original intent and search the knowledge accordingly. This is the definition of the word *curation*.

Note that this is decidedly different from "keyword searching" in the same manner that web-based search engines operate.

Our plan for the Questioner interface is to take the data that is used for and also generated by the SiCEDS model and apply it to a curation process so that it may be accessed by stakeholders through a knowledge engine like Wolfram Alpha.

Figure 9. Data curation



The Analyst Interface

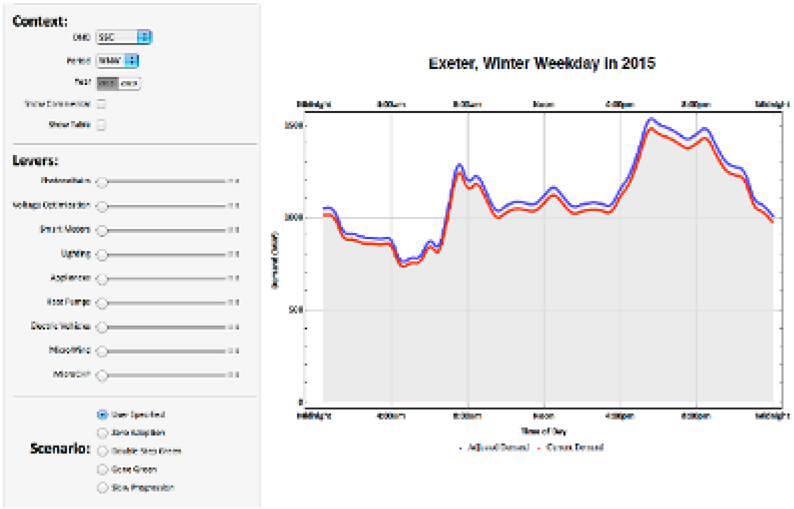
With the analyst interface, we introduce a degree of interactivity into the user interface design. The GUI is separated into two panels, the left hand side (LHS) holding the controls over the simulation model – sliders, check boxes, dropdown menus, etc., while the right hand side (RHS) shows the outcome of the simulation run given those parameters set on the left hand side.

This interface is structured to provide the user with a "laboratory" of sorts for conducting policy experiments. Typically at the start of a session with the model the user will set a context - in this case that means the selection of one of several pilot sites via a dropdown menu, and a particular year.

From here, the user has access to a range of standard GUI controls: sliders, check boxes, radio buttons, and input fields each representing a parameter guiding the calculations the simulation will perform. Finally a "RUN" button causes the RHS visualization to appear, showing the implications of settings chosen by the user.

The workshop participants made recommendations as to what controls should be part of the Analyst interface:

Figure 10. Planner analysis interface screenshot



1. Energy generation mix
2. Building efficiency
3. Appliance efficiency
4. Smart meter adoption
5. Renewable heating centers
6. Cost of energy finance
7. Conservation extent

The workshop also brainstormed candidates for *experiments* using the model:

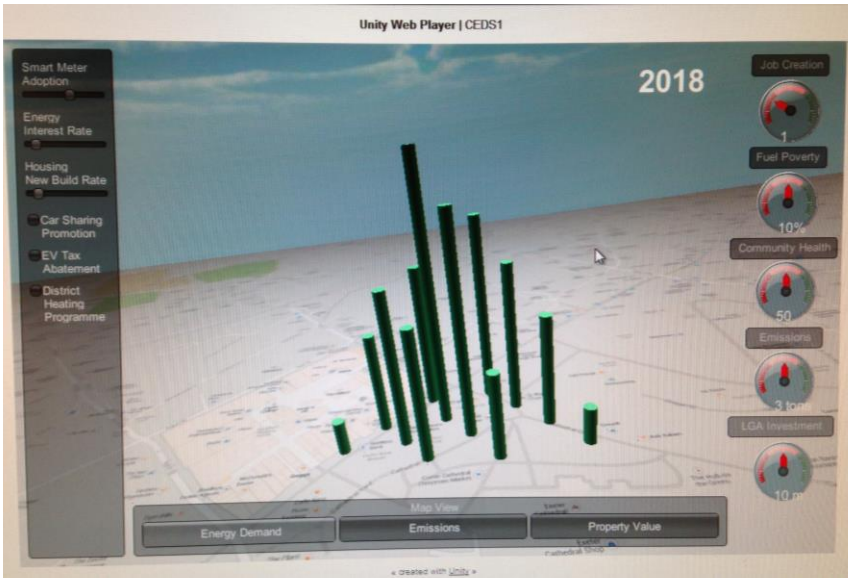
1. Transport infrastructure rebuilds
2. Car sharing and bike promotion schemes
3. Electric vehicle impact
4. Changes to energy-related regulations
5. Resilience to natural and man-made disasters
6. Property development plans
7. New energy infrastructure (such as district heating or wind turbines)

The RHS contains the visualization of the context and control settings on the LHS. Its purpose is to show "at a glance" what is happening with key outcome dimensions such as fuel poverty and emissions. Because the information is strongly geo-centric – ie it matters where emissions occur and not just some average level – we expect the RHS to show all outcomes on a map in 3D (which allows for panning and zooming). We will make use of a GUI concept here called Data Adjacency, which the interweaving of a real scene (a map) with a fictional data element (like a bar that grows in the Z direction with its value). In this way users can instantly spot patterns in the outcome data far better than standard charts on a plain white background. We will also structure the elements for key thresholds should cause a change in the interface to draw attention to that element (ex. emissions crossing an upper threshold make the bar turn red).

The workshop participants made several recommendations for elements to be included in the visualization:

1. CO_2 emissions
2. Total LGA investment
3. Jobs created
4. Energy demand
5. Health
6. Fuel poverty
7. Social connection density
8. Resilience

Figure 11. Stakeholder interactive collaboration interface screenshot

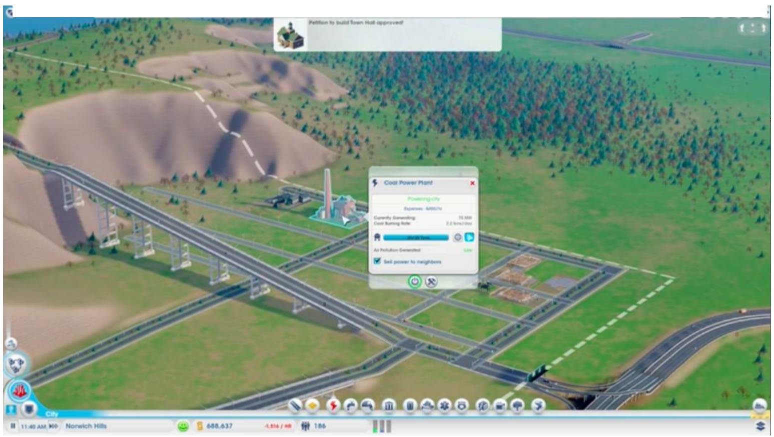


The Stakeholder Interactive Collaboration Interface

The enthusiasm for a Management Flight Simulator experience with the SiCEDS model was made clear in the February 4 workshop. Again, the objective of SiCEDS is not only to generate solutions to complex city energy issues, but also to communicate the merit, the consequences, and *unintended* consequences of policy actions. Most energy policies involve trade-offs in some sense.

The idea behind the gamer interface is to create a game-like environment where participants can experience energy policy in an “up close and personal” way. The game in this case treats the user as an all-powerful policy czar capable of making a wide range of decisions, from energy mix to pricing to taxation. Once a set of decisions are made (with a similar control panel as that described in the Analyst interface), a button is clicked to advance to the next year where the implication of those polices is now seen. The user is then presented with the next round of policy decisions, and so on across several cycles of the game. All the while a “scorecard” of critical metrics displays how well (or poorly) the user is doing in managing energy policy.

Figure 12. SimCity was the inspiration behind much of our initial thinking on the gamer interface.



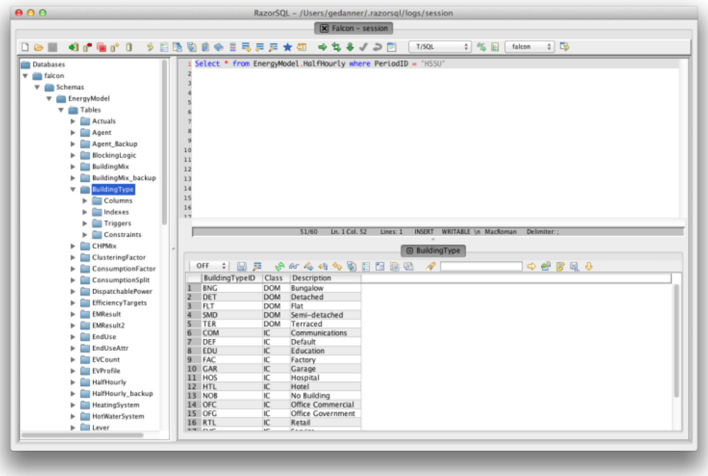
We have seen a wide spectrum of formats for the uses of these simulation-based games. From the simple, informal end where individual users play the game in solitude, to formal offsite events with competitive teams of users, prizes for the winners (and losers) and official debriefs. In each case the objective is the same – move energy policy from its rather dry form (text on pages) to one where the stakeholders can better appreciate the subtle nuances of energy policy over time.

The GUI structure of the gamer interface consists of two primary parts. First, the Heads Up Display (or HUD) which can be thought of a metrics displayed on a sheet of glass covering the interface, and second the scene itself which is a 3D view of the pilot site, similar to what was described in the Analyst interface. Buttons on the HUD can alter the scene by showing data layers imposed on the map, for example, a set of bars showing emissions levels at various parts of the site.

After the user starts the game (the simulation run), they are prompted to make decisions at frequent intervals. For example, the user may be confronted with a gap between electricity supply and demand which may be closed in a variety of ways, each with inherent tradeoffs. This decision may in turn prompt other implications later on, which require a new set of decisions, and so on. There will be a sufficient number of branches in the decision tree along with a careful dose of randomness so that no one play of the game is ever exactly the same.

We expect the gamer interface to be deployed over the web in the same manner that other common MMORPG games are deployed[4].

The Admin Interface



The admin interface will be used by "superusers" who are charged with maintaining the underlying data for the SiCEDS model. Energy profile information, building attributes, weather – all of these aspects of the model are represented in a normalized database that is tightly integrated with the model's logic. The admin interface allows these superusers to update the data as will be required periodically. This particular interface does not require bespoke design as the others, but rather can be accomplished through commonly available 3rd party tools for such functions. One popular data administration tool is called Razor, as shown in the figure above.

[4] Massively multiplayer online role-playing game

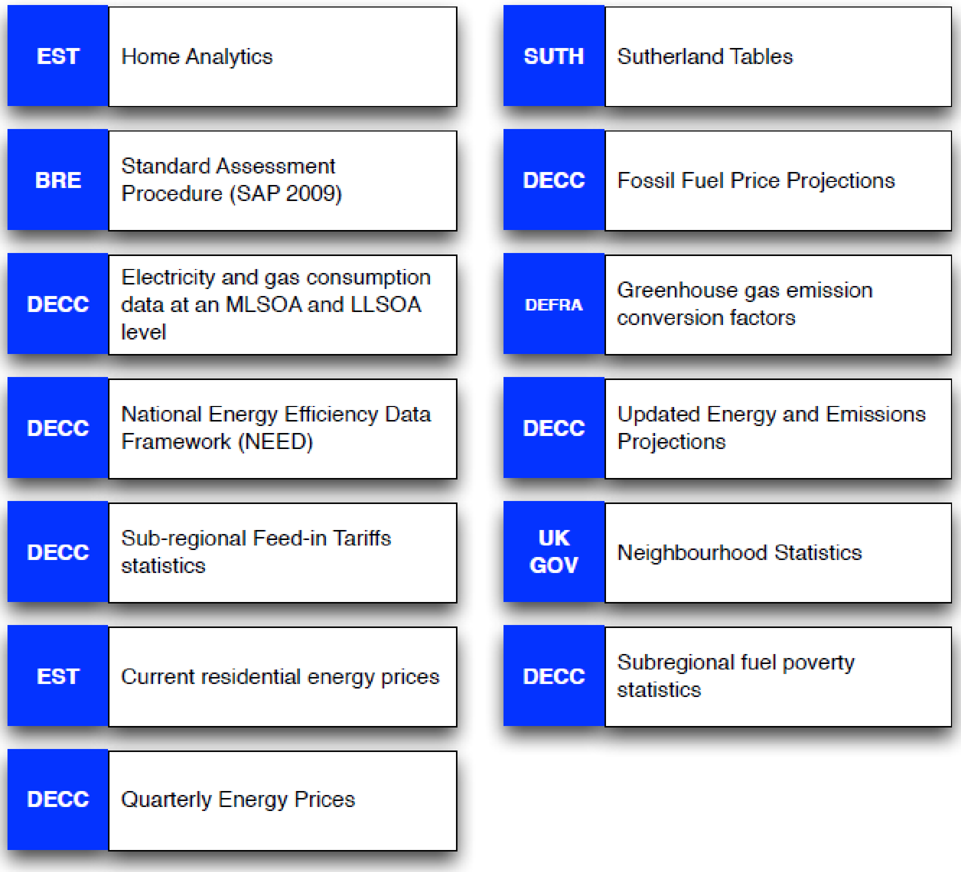
3.5 What are the ideal data arrangements for a SiCEDS tool to be effective?

So far we have made the case that both a great user interface which enables collaborative decision making and an accurate model computational structure are both necessary components of a SiCEDS tool. A clear additional requisite is the availability of quality data with which to drive the tool, and to enable policies to be applied to an accurate representation of a particular city. This section presents our analysis of the best data arrangements to support SiCEDS development and delivery.

For effective planning it is necessary to collate social, economic and physical data about the city's inhabitants, their activities and the infrastructure – buildings, energy supply etc. – that supports them. The characteristics of both domestic and non-domestic buildings have a large impact on the quantity of energy consumed. The energy demands of a building depend on its use by occupants, built form, the thermal performance of the construction, and the type of heating system and appliances installed. The SiCEDS tool will therefore require data obtained from a wide range of sources to inform the energy modelling. In addition, planning requires knowledge of the city's meteorology.

To inform this critical element of the feasibility study we followed up with key Local Authority contacts responsible for stock data and planning tools within the organisations outlined in table 1. As a result Figure 14 presents our initial conclusions of the data sources available for accessible raw data.

Figure 14. Raw data inputs for SiCEDS



Data protection

The bulk of the data which would be used within the SiCEDS tool would not be considered personal data. The only data which falls into this category is the EAC or AQ data (annual estimates of electricity and gas demand). These estimates are linked to meter point access numbers (MPANs) or meter point reference numbers (MRPNs) respectively which are in turn linked to customer names and addresses in a connectivity database which is maintained by the suppliers or DNOs.

The customer names would not be necessary for the purposes of matching Home Analytics to the domestic MPANs and MPRNs but the address would be necessary. Customer names would be used in the non-domestic components of CEDS where the company name can help identify the nature of the business.

The Energy Saving Trust has managed the Homes Energy Efficiency Database (HEED) for many years. The data contained within HEED was defined by Information Commissioner's Office as personal data and accordingly the Energy Saving Trust has all of the procedures in place to handle large quantities of personal data in a secure and effective way. Furthermore the EST/UCL team has already worked with Western Power Distribution's connectivity and EAC database in a previous project.

HEED is an address-level database and the ICO ruled that being able to access the data at such a granular level could result in a data breach so as a result access to HEED is only accessible down to Lower Super Output Area (LSOA). This led to the Energy Saving Trust developing the Home Analytics package which uses interpolation algorithms to produce synthetic data which are not personal data and Home Analytics can therefore be accessed at address level.

Data hierarchy

We quickly came to the conclusion that a data hierarchy will best describe the availability, cost and risk for accessing the necessary data sources. We propose to create a tool which can make use of three levels of data:

- ***Level 1: Universal and free*** – databases which are collated at a national level which are available at no cost. Level 1 data will enable a broad overview of energy supply and demand within the city.
- ***Level 2: Universal and paid for / restricted*** – databases which are collated at a national level which are available at a cost or are otherwise not widely available. Level 2 data will enable the user to explore future energy scenarios.
- ***Level 3: Local*** – databases which are collated at a local level which may be available at no cost or at a cost. Level 3 data will enable the investigation of projects which are specific to the city such as CHP systems connected to district heating networks.

The main reason for adopting this tiered approach to the data is to make the SiCEDS tool available to cities with varying levels of funding available for city energy planning.

By developing a tool which can generate outputs based purely on freely available universal databases (Level 1) it will be possible to keep costs down while providing useful outputs which can help guide a city in its energy planning. Universal databases which are collated at a national level have the advantage that a single database structure applies to all cities in the country, albeit with different levels of detail.

For cities which have funding available to dig deeper into their energy options the Level 2 data sources will provide a lot more depth and resolution. As for Level 1, the data sources used in Level 2 are universal but will have a charge attached for their use or are not publicly available. Level 2 data sources will have more in depth information about the nature of the housing stock, demographics and business activities will allow the city to compare the impacts of different energy programmes and enable the selection of activities that provide optimum outcomes in terms of cost effectiveness, fuel poverty reduction, and CO_2 emissions abatement.

Finally for those cities which have their own data sources which could be incorporated into SiCEDS there is Level 3. This can involve some considerable effort in translating databases into a structure which can be incorporated into SiCEDS but has the potential to add significant value to the city. Where appropriate we have divided the following sections on data sources into the different levels to illustrate the range of sources which will be used by the tool.

Data requirements and sources

Demographic Characteristics

The demographic make-up of a city is a key input into the SiCEDS tool. Demographics have a strong impact on energy demand, both in terms of the quantity of energy consumed and the shape of energy usage over the course of a day. It is therefore important that good quality demographic data is sourced for use in this tool.

Level 1

The ONS Neighbourhood Statistics website also contains demographic data derived from the 2011 census data down to the Lower Layer Super Output Area (LLSOA) level which will be used to build up a picture of the demographic make-up of the city at a granular level. This data includes:

- Adult Lifestage
- Household Composition
- Household Type
- Living Arrangements
- Lone Parent Households with Dependent Children
- Occupation
- Population

Level 2

The Energy Saving Trusts Home Analytics tool also provides information on the characteristics of the household. This data ultimately comes from Experian's market segmentation and gives information which can be used to make broad inferences about the likelihood of occupants being in or out during the daytime, whether occupants are on benefits etc. This information can be used by the model to calculate household energy demand profiles as well as informing the fuel poverty module.

Level 3

Councils maintain databases of benefit claimants which could be fed into the fuel poverty module of the SiCEDS tool. There are clear data protection issues associated with using information such as this and care will need to be taken to ensure that information is suitably cleansed to avoid the identification of individuals, a process which the Energy Saving Trust is very familiar with through its HEED and Home Analytics work.

Electricity and Gas Consumption

In cities, liquid and solid fuels constitute a small fraction of energy delivered to non-transport domestic and non-domestic sectors and so the focus is on gas and electricity. The ideal source of energy consumption data would be to obtain the Estimated Annual Consumption (EAC) of electricity consumption and Annual Quantity (AQ) of gas consumption for each meter point within the city. This data is held by the city's Distribution Network Operator (DNO) and also by DECC (who use it to calculate sub-regional energy demand statistics using this data).

However should this data prove to be inaccessible it will be necessary to source electricity and gas consumption data from other sources.

Level 1

The electricity demand component of the model makes use of a value for the EAC (estimated annual consumption) of electricity for the agent. Gas demand is calculated by the model however having the EAC for gas demand at the household level would be very useful from the point of view of calibrating the model outputs.

DECC's Electricity and gas consumption data at an MLSOA and LLSOA level[1] gives average gas and electricity consumption at the level of Middle / Lower Layer Super Output Area (and Intermediate Geography Zone in Scotland). The average MLSOA represents an area covering around 3,000 domestic meters or 260 non-domestic meters. The average LLSOA represents an area covering around 700 domestic meters (non-domestic consumption is not given at the LLSOA level). Data for 2011 and 2010 are available (data for 2012 should be available at the end of March 2014).

DECC's National Energy Efficiency Data Framework (NEED)[2] gives average annual domestic electricity (both standard credit and Economy 7) and gas consumption by dwelling age, size and type in each local authority. Mean, median and quartile demand are given. These can be used to allocate the MLSOA / LLSOA demand data amongst each agent.

Level 2

As referred to above, the ideal data sources would be the EAC and AQ data which is used by National Grid, the Distribution Network Operators and DECC in their operations and our initial focus would be on obtaining this data.

Level 3

Some councils have undertaken research in collaboration with their local Distribution Network Operator which may mean that they hold EAC or AQ data at address level which could be included in the SiCEDS model.

In addition to this, in some cases local councils may have energy consumption data for specific buildings, in particular public buildings. Many of these larger buildings will be large consumers and would have a significant impact on energy demand so incorporating this data into the model would help improve the outputs.

Energy consumption and Costs

Energy costs will be derived by taking the energy flows calculated by the model and multiplying them by estimates of fuel costs.

Level 1

EST publishes current residential energy prices[3] which are derived from DECC's Quarterly Energy Prices[4] publication (gas and electricity) and the Sutherland Tables[5] (oil and LPG).

In order to calculate future energy costs it will be necessary to use forecasts for energy prices. DECC publishes annual Fossil Fuel Price Projections[6] however it should be noted that these are forecasts of the wholesale prices of energy. A significant proportion of both domestic and I&C energy prices are made up of other costs such as environmental levies, distribution charges etc, some of which are expected to increase significantly in the coming decades so this should be considered when forecasting future energy prices.

Finally the Energy Saving Trust's Home Economics[7] research looks into the cost effectiveness and the direct employment potential of adopting low carbon measures in the UK housing stock. This will be supplemented by UCL's resources for the Industrial & Commercial sector.

Domestic Building Characteristics

The energy demands of a building depend on its built form, the thermal performance of the construction, and the type of heating system and appliances installed. The SiCEDS tool will therefore require data obtained from a wide range of sources to inform the energy modelling.

Level 1

The main Level 1 sources for residential dwelling characteristics will include the Office of National Statistics Neighbourhood Statistics[8] and the national housing surveys. The Neighbourhood Statistics website has data at local authority level and lower including:

- Accommodation Type
- Central Heating
- Dwelling Stock
- Dwellings, Household Spaces and Accommodation Type
- Household Size
- Household Spaces
- Local Authority Dwelling Stock by Size, Age and Type
- Lowest Floor Level
- Number of Bedrooms
- Number of Rooms
- Social Rented Housing: Demand and Supply
- Tenure
- Vacant Dwellings

The national housing surveys have data on the energy performance of residential buildings in the different devolved nations of the UK. This includes data on:

- Stock of dwelling type by size and age
- Penetration of different heating systems
- Mix of wall types
- Level of insulation

Between these sources it will be possible to build up a basic picture of the housing stock within a city with enough data to start generating outputs.

Level 2

The Energy Saving Trust's Home Analytics[9] service will provide data covering the building characteristics of homes within the city. This includes the house type, age, number of bedrooms and footprint.

This data will allow us to assign each property to an archetype which will have representative building characteristics such as levels of insulation, associated element U-values etc derived from BRE's Standard Assessment Procedure (SAP 2009)[10] default values, associated with it. These building characteristics will be used to calculate the specific heat loss coefficient for each dwelling archetype.

Level 3

Conversations with the local authorities involved in the value mapping exercise has revealed that some hold the Energy Performance Certificate (EPC) data for owner occupied and private and social rented homes. There is potential for this data to be uploaded to the Energy Saving Trust's Home Analytics package to produce an even more detailed and robust picture of the energy performance of homes within the city. The Energy Saving Trust already maintains the EPC register for Scotland and has developed the functionality to feed EPC data into Home Analytics in Scotland and this could be deployed for cities within the rest of the UK.

Fuel Poverty

There are two fuel poverty metrics which may be included in the model. The first is the existing 10% ratio indicator whereby a household was considered to be in fuel poverty if energy bills represented 10% or more of total household income.

The second is a new indicator described in the 2012 Hills Review (Getting the measure of fuel poverty)[11] and has two criteria which define whether a household is in fuel poverty or not. Firstly they must "have required fuel costs that are above the median level" and secondly "were they to spend that amount they would be left with a residual income below the official poverty line."

Level 1

The fuel poverty module will need to combine modelled annual energy demand with the energy costs module outputs in order to calculate annual energy bills for each agent. This can then be assessed against estimates of household income using the household characteristics data in Home Analytics as well as taking into account the likelihood that a household is receiving benefits. One potential source for the benefits data is the Neighbourhood Statistics[12] website which breaks down census data into Lower Layer Super Output Area including:

- Adults not in Employment and Dependent Children and Persons with Long-Term Health Problem or Disability

- Benefits Data: Summary Statistics
- Child Benefit Statistics
- Housing Benefit/Council Tax Benefit Claimants
- Income Support Claimants
- Pension Credit Claimants

DECC also publishes sub-regional fuel poverty statistics[13] (currently based on the 10% ratio indicator) at the level of LLSOA which could be used to validate the outputs of the model. It should be noted that there is considerable lag in the publication of fuel poverty statistics with the 2011 data being published in August 2013.

Non-Domestic Data

Overview

The stationary commercial and public non-domestic sectors are highly variegated in terms of size and function – including schools, hospitals, offices, shops, factories, garages, mobile phone masts, water supply and so on. Currently there are no publicly available (free or commercial) comprehensive databases of agents in these sectors covering socioeconomic aspects (e.g. employees), activity (e.g. economic output, number of pupils) and the buildings or other infrastructure they utilise. This lack of data is partly due to heterogeneity (which means high costs to collect data), partly because of commercial sensitivities and partly because these sectors have lower political priority and use less energy than the domestic sector.

Due to the diversity and complexity, various data will be combined with data processing to estimate building characteristics and energy demands and will form the base from which a richer database will be generated providing information about the basis for energy demands for heat, electricity and gas.

Level 1

Data on the energy performance of public buildings can be readily obtained from the Display Energy Certificate database[14]. This database contains information on the type of public building, annual gas and electricity demand.

The Valuation Office Agency (VOA) data for 1.8 million industrial and commercial premises gives information such as:

- The Ordnance Survey Address database
- Electronic Property Information Mapping Service (e-PIMS)
- Energy Performance Certificates for industrial and commercial buildings

There are publicly available data and listings on some public sub-sectors such as education (schools, colleges), hospitals and so on.

There are also regional data such as the number of hereditaments (approximately properties) including DCLG (2005a) Table 2.1: Number of hereditaments by region and age for each bulk class, DCLG (2005b) Table 2.2: Total floorspace by region and age for each bulk class and DCLG (2010c) P401 Commercial and industrial property: summary statistics1 England and Wales, 1st April, 1998-2008.

Level 2

There is a business database of 2.2 million enterprises (UKMD) which describes the nature of the business activities (which defines the type of building and energy demand profiles used by the model) and the number of employees in the business (which informs estimates of the size of building). This includes private and some public.

Level 3

Councils may also capture data about the range of businesses which are found within their area (for example as part of their business rates collection) which could produce better matches and greater resolution than the Level 2 databases.

The VOA data could be very useful to bridge between the business database and estimating building characteristics as floor area is a key determinant. Conversely, the business database might serve as some check on the VOA.

Technology

Planning energy futures in part concerns the implementation of energy efficiency and energy supply technologies and so data are required on the performance and costs of these. The performance of technologies will include energy efficiency, availabilities and air pollution emissions.

For level 1, there are many studies and databases from DECC, the Energy Saving Trust and elsewhere to draw on.

For level 2, there are commercial databases.

Greenhouse Gas and Air Quality Emission Factors

Level 1

Emissions will be derived by taking the energy flows calculated by the model and multiplying them by standard emission factors. Defra/DECC publish greenhouse gas emission conversion factors[15] for the basket of greenhouse gases and the majority of energy sources found in the UK.

In most cases these factors will be constant however electricity emission factors will change over time. DECC publishes Updated Energy and Emissions Projections[16] annually which describes forecasts of the grid mix out to 2030 which could be used to derive an estimate of future grid electricity emission factors.

Generation Data

Renewable Energy Generation

The rapid growth in renewable energy systems installed within cities since the introduction of the Feed in Tariff in 2010 means that renewable energy now contributes a small (but significant) contribution to city energy supplies. The SiCEDS tool will include functionality to produce generation profiles for all of the main types of terrestrial renewable generation which exist today (wind, solar photovoltaic, solar thermal, heat pumps, biomass, anaerobic digestion and energy from waste). Data sources which map the locations of these technologies will therefore be needed.

Level 1

DECC's Sub-regional Feed-in Tariffs statistics[17] give the quarterly cumulative installed capacity in kW for PV, wind, hydro, AD and MicroCHP by Local Authority, Parliamentary Constituency, and Local Enterprise Partnership areas. Installations under the Feed In Tariff form the bulk of the UK installed base of microgeneration.

DECC's RESTATS website[18] contains data on larger scale renewable energy installations which are already operational, are being constructed or have been consented. For existing installations it also has performance statistics.

Level 2

Ofgem maintains a detailed register of installations which have occurred under the Feed in Tariff (and which will start to occur under the Renewable Heat Incentive). This data is not currently publicly available due to data protection issues but it would be productive to investigate whether this data could be released for the purposes of inclusion into the SiCEDS tool as the improved spatial resolution of this data would improve the outputs of the tool compared to the Level 1 data.

Fossil Fuel Generation

In addition to renewable installations it is common to find fossil fuel generation within the boundaries of cities. This can be in the form of backup diesel generators found in hospitals which can sometimes be called upon in order to provide Short Term Operating Reserve (STOR) services or combined heat and power plants which distribute waste heat to nearby residential, industrial or commercial centres.

Level 1

Our investigation has not revealed any energy generation data available in sufficient detail at this level.

Level 2

Platts produces the World Electric Powerplants database[19] which gives information about generators as small as 200kW including their technology. Additionally it may be possible to partner with both the relevant DNO and the National Grid whose interests will be aligned and who can provide further data covering sub 200kW generation assets.

Level 3

Where fossil fuel generation is found in public buildings such as hospitals, it may be possible to integrate half hourly generation data into the SiCEDS tool, improving the outputs of the model.

Environmental Data

Conservation Areas

Level 1

Conservation Areas restrict the deployment of certain low carbon measures (such as double glazing, solar thermal and photovoltaic panels and external solid wall insulation) and it will therefore be necessary to include a conservation area layer within the tool. English Heritage collates local authority conservation area GIS data and publishes it on the Environment Agency's DataShare website[20].

Meteorology

Weather data (covering ambient temperature, wind speed and insolation) will be used by the SiCEDS tool the model in the space heat demand and generation (in particular photovoltaics and wind) modules.

Level 1

Free historical weather data for 37 weather stations around the UK is provided by the Met Office[21], covering:

- Mean daily maximum temperature
- Mean daily minimum temperature
- Total sunshine duration

These data can be converted into synthetic half hourly weather data which can be used by the SiCEDS tool.

Level 2

The Met Office also supplies historical hourly weather data for many more weather stations around the country although this is a paid for service. The hourly data can be readily converted into half hourly data for use in the model.

Level 3

Cities may make use of weather data in existing models and tools and this could be incorporated into the SiCEDS model.

Greenhouse Gas and Air Quality Emission Factors

Level 1

Emissions will be derived by taking the energy flows calculated by the model and multiplying them by standard emission factors. Defra/DECC publish greenhouse gas emission conversion factors[22] for the basket of greenhouse gases and the majority of energy sources found in the UK.

In most cases these factors will be constant however electricity emission factors will change over time. DECC publishes Updated Energy and Emissions Projections[23] annually which describes forecasts of the grid mix out to 2030 which could be used to derive an estimate of future grid electricity emission factors.

Data Plan Documentation

This section describes the agents and what fields we need as an input to the model.

Agents

Model data input are of two kinds: those relating to agents (consumers and suppliers), and those relating to weather. Model data inputs define the technical characteristics of agents from which, in conjunction with weather, half hourly energy demands of production can be calculated

Data Preparation

These data and agents can be linked across various databases can be interlinked as shown in the diagram in Figure 15 below. There is a more detailed specification of data which can be found in appendix one. Together these demonstrate the complexities of how the computational tool will need to use data to build scenarios and enable the user(s) to try out policies or interrogate the performance of projects using levers.

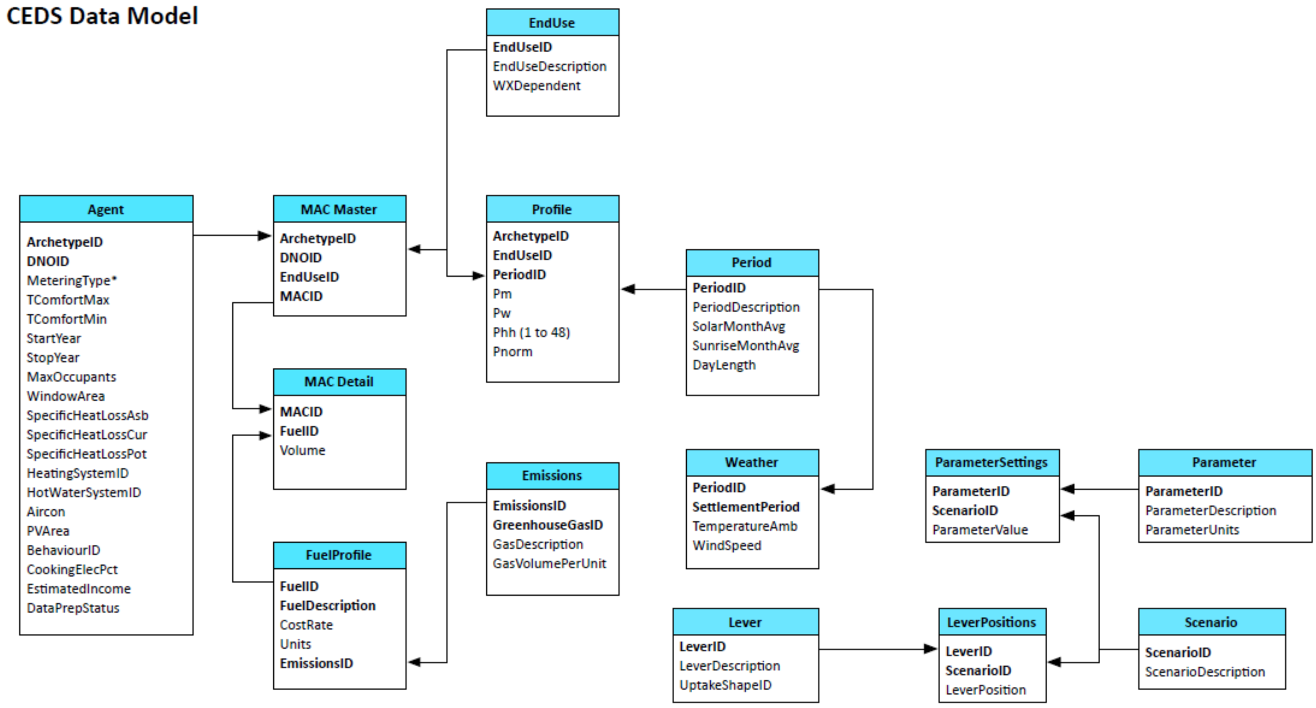


Figure 15. Schematic of how data flows within the SiCEDS model.

3.6 Conclusions and recommendations

Our work has shown that building a City Energy Demand Simulation would be a valuable addition to a city's energy architecture planning capability because it would:

- Enable effective collaboration (a missing element of other tools) to ensure discussion results in action
- Provide the means for a holistic view comprising economic, environmental and social aspects of alternative options
- Create the clear business case which is imperative to creating the necessary funding for city energy infrastructure implementation
- Provide the means to zoom in and out of areas of a city (again a missing element of other models)
- Meet the requirements as specified by the cities interviewed

A working prototype of this tool will be an invaluable activity for a city team to fast-track a number of energy infrastructure projects.

The tool will be used in two principal modes

1) A 'flight simulator' facilitation tool capable of engaging with large stakeholder groups simultaneously enabling participants to try numerous solutions and understand the implications
2) A planning office tool to support planning application assessment and strategic plan development

These conclusions give us a framework within which to develop SiCEDS as a phase two project within the Future Cities programme. We are finalising collaborations with two cities to ensure SiCEDS is universally applicable and not focussed on just one city's' data and planning processes. We will work closely alongside these two cities to develop a working prototype of SiCEDS, to validate it against existing and previous energy infrastructure projects and ultimately to launch it as an embedded service which supports strategic planning of energy infrastructure projects.

Throughout the phase one feasibility study we have explored possible business model configurations for SiCEDS which we will define as part of phase two development. They are as follows:

· Standard licencing to individual city authorities

· Web based subscription service to individual city authorities

· Web based subscription to all stakeholder participants

· Funded central authority providing access to all stakeholders with subscriptions varying from zero (general public) to positive such that ongoing development and delivery costs can be covered. E.g. C40, Cities Alliance.

The Energy Saving Trust and its partners have a broad network of European and Global contacts in the cities arena. In the longer term we would look to use the impacts resulting from the use of the live prototype to build a pipeline of interest to extent the use of SiCEDS to encourage much greater levels of city energy optimisation.

Appendix 1: Data specification

Table 5: Data specification

			Variable name	Description	Example
AGENT			Type	Type	Con
			Sec	Sector	Dom
			SubSec	Subsector	Ter
			SubSubSec	Subsubsubector	
			Name	Name	Terraced
			Agents_Num	No of agents	150
	Time		YrComm	Year start	2010
			YrDecomm	Year stop	
	Space		Location	Location	
			Address	Address	
			PostCode	Postcode	
			Lat	Latitude	
			Lon	Longitude	
	DNO		SubSt_ID	Substation ID	1
				MPAN	1
				Class profile	X
				Metered	
		kWh/a	Ele_Meter_kWhpa	EleAnnualMetered	
SOCIAL			People_N	Number of people	3
			Employ_N	Number of employees	
		oC	TComf_oC	Comfort temperature	20

			Pm	Month profile	Dom
			Pw	Weekday profile	Dom
			Powhh	Half hour profile	Dom
BUILDING		W/C	SpHLoss_WpC	Specific heat loss	303.9649
				Efficiency rating	0
			SpHLossRed_pc	Reduction %	0.5
			CondLoss_WpK	Conduction loss	202.6298
			VentLoss_WpK	Vent loss	101.3351
				Built form	Ter
		m2	Plan_m2	Plan area	50.71825
			Floors_N	Floors	2
		m2	Floor_m2	Floor area	101.4365
		m2	Wall_m2	Wall area	69.78849
			WallExt_pc	Wall external %	0.5
		W/m2/K	WallU_Wpm2pK	Wall U-value (base)	1
		%	Glaze_pc	Glazing % area	0.15
		m2	Glaze_m2	Glazing area	10.46827
		W/m2/K	GlazeU_Wpm2pK	Glazing U-value	3
			BldVol_m3	Building Volume	304.3095
		/h	ACHf_ph	Air change fresh	1
ENERGY SYSTEMS	Consumer		SpFuel	Space fuel	Gas
			SpFuelScen	Space fuel	Ele
			SpTech	Space technology	Boi

			SpTechScen	Space technology	HPa
			HWFuel	Water fuel	Gas
			HWFuelScen	Water fuel	
			HWTech	Water technology	Boi
			HWaTechScen	Water technology	
			AirCon	Air conditioning	
			AirConScen	Air conditioning	
		m2	SolarPV_m2	Solar PV	
		m2	SolarPVScen_m2	Solar PV	5
		m2	SolarHW_m2	Solar HW	4
			SolarHWScen_m2	Solar HW	
		kWth	CHPgas_kWth	CHPgas	
				Heat storage	
			PSupFuel	Input Fuel	
	Public		PSupTech	Technology	
			Output1	Output1	
			Output2	Output2	
			PSupCap_kW	Capacity	
		KWh/a	PSupAnn_GJpa	Annual supply	
End uses			TraTech	Transport tech	
		%	CookEle_pc	Cooking Elec %	0.5
		%	CookEleScen_pc	Cooking Elec %	
arranged in groups of 6			EUCode	End use type	ITC
		KWh/a	EU_GJpa	Annual use	3

			EURed_pcJpa	Reduction %	0.3
			Pm	Month profile	
			Pw	Weekday profile	
			Powhh	Half hour profile	
			EUCode	End use type	Lig
		KWh/a	EU_GJpa	Annual use	3
			EURed_pcJpa	Reduction %	0.3
			Pm	Month profile	
			Pw	Weekday profile	
			Powhh	Half hour profile	
			EUCode	End use type	Coo
		KWh/a	EU_GJpa	Annual use	6
			EURed_pcJpa	Reduction %	0.3
			Pm	Month profile	
			Pw	Weekday profile	
			Powhh	Half hour profile	Dom{Coo
			EUCode	End use type	HWa
		KWh/a	EU_GJpa	Annual use	3
			EURed_pcJpa	Reduction %	0.3
			Pm	Month profile	
			Pw	Weekday profile	
			Powhh	Half hour profile	
			EUCode	End use type	Ref
		KWh/a	EU_GJpa	Annual use	3

			EURed_pcJpa	Reduction %	0.3
			Pm	Month profile	Bas
			Pw	Weekday profile	Bas
			Powhh	Half hour profile	Bas

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[2]International Institute for Applied Systems Analysis, Laxenburg, Austria

[3]UCL Energy Institute http://www.ucl.ac.uk/energy-models/models/deam

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[5]International Atomic Energy Agency

[6]Welsh School of Architecture, Cardiff http://www.cardiff.ac.uk/archi/programmes/cost8/case/assessment/eep.html

[7]European Union

[8]Gesellschaft für Technische Zusammenarbeit mbH, Germany

[9]United Nations, Department of Technical Co-operation for Development

[10]Electric Power Research Institute, Palo Alto, California, USA

[11]Organization for Economic Co-operation and Development, Paris, France

[12]Projektinriktad Forskning och utveckling-PROFU, Göteborg, Sweden

[13]Stockholm Environment Institute-Boston, USA

[14]Institut für Kernenergetik und Energiesysteme, University of Stuttgart, Germany

[15]Energy Technology System Analysis Project

[16]Brookhaven National Laboratory

[17]Institut Economique et Juridique d'Energie, France

[18]Institut für Energiewirtschaft und Rationelle Energianwendung, University of Stuttgart, Germany

[19]IKP Energy System Institute of Technology, Linköping, Sweden

[20]Aalborg University, Denmark

[21]Imperial College, UK, https://workspace.imperial.ac.uk/urbanenergysystems/public/urs_keirstead2009.pdf

[22]Tata Energy Research Institute, India

[23]Energy Technology Systems Analysis Programme, Italy

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Computational framework

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Data arrangements

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