Towards a 2kW City – the case of Zürich

Urs Wilke[1,*], Maria Papadopoulou[1], Darren Robinson[1]

[1] *EPFL, Lausanne, Switzerland*
** Corresponding author. Tel: +41 693 4545, Fax: +41 693 2722, E-mail:urs.wilke@epfl.ch*

Abstract: In 2004 the Council of the Federal Polytechnics of Switzerland proposed that the country's per capita primary energy demand should be reduced by a factor of three from its current average of around 6kW to 2kW – the current global average – by 2150. During the past six years the semantics of this proposition have been much debated, but the concept has won overall favour, with several cities voicing their support. Indeed in November 2009 the inhabitants of the city of Zürich voted in favour of applying the 2kW city concept to their city, but targeting the year 2050. Thus, the city of Zürich is now committed to understanding which strategies should be employed and when, to achieve 2kW city status. But the city is not naïve, it fully appreciates that this target is ambitious and will only be realised through commitment and a multiplicity of transition strategies; some of which have already been implemented. But to understand, which are the most promising future strategies will require some form of predictive model. In this paper we describe one such model, which is currently under development, and the strategies that may be tested by it as well as outlining the already implemented strategies.

Keywords: *Urban sustainability, Environmental politics, Micro-simulation*

1. Introduction

In 2009, the total end energy use in Switzerland amounted to about 878 PJ [1] of which 55.1% are covered by petroleum products and 23.6% by electricity. Approximately 55.8% (*cf. Fig. 1*) of Switzerland's overall electricity conversion comes from hydropower, which forms the main part (96.5%) of electricity produced by renewables [2; 3]. Nuclear power plants account for 39.3% of domestic conversion and conventional thermal energy/other renewable energy plants for approximately 5% (*Fig. 1*). And while hydropower has been, historically, Switzerland's longest-serving and most important source of renewable energy, other renewables including solar, wood, biomass, wind, geothermal and ambient heat are starting to play an increasingly important role in Switzerland's energy supply [1; 2]. Private households, industry, services and the transportation sector account for almost 29, 19, 16 and 35% of Switzerland's energy use, respectively (*Fig. 1*).

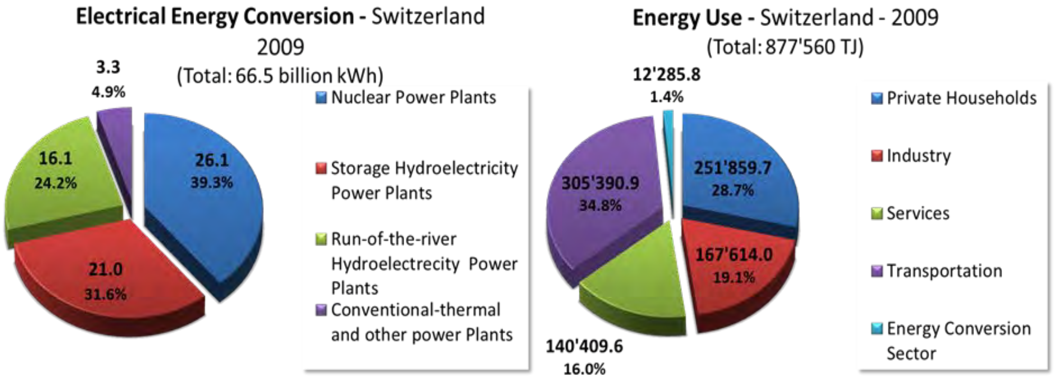

Fig. 1. Electricity conversion (left) and total energy use (right) by sector in Switzerland for 2009 [1; 2]

Ten years ago, the Swiss Federal Institute of Technology (ETH) in Zürich developed the vision of a "2000-Watt Society" which represents Switzerland's approach to tackling climate change and the upcoming conflict of resources. It is based on the idea that the Swiss citizens limit their energy use to the global average value of 2000 watts by the year 2150. Should other developed countries follow suit, this would enable the per capita energy demands of developing countries to increase, to meet their inhabitants' aspirations for improved living standards, without further increasing the global average. Furthermore, renewable energies should be used to satisfy at least 75% of these 2000 Watts, so that on an annual basis only one tonne of carbon dioxide equivalent is emitted per capita and year. The use of nuclear energy should also be completely phased out [4]. The implications of this approach are summarised in Fig. 2.

By closely analysing the unexploited efficiency and substitution potentials in Switzerland, scientists of the Swiss Federal Institutes of Technology (ETH) and other institutions have shown that the vision of a 2000-watt society is indeed feasible. They concluded that a period of between 50 and 100 years would be needed for this to become a reality [4].

Following from this, the citizens of Zürich participated in a referendum in November 2009, with around three quarters voting in favour of committing to achieving the 2000 Watt society status, but by **2050** [4]. This follows from a long standing commitment in Zürich to reducing the city's energy use. Indeed in 2000 the city acquired the label "Energiestadt®", which has since become a Europe-wide initiative, the "European Energy Award®". Four years on, the city was recertified and obtained the label "Energiestadt® Gold" [5].

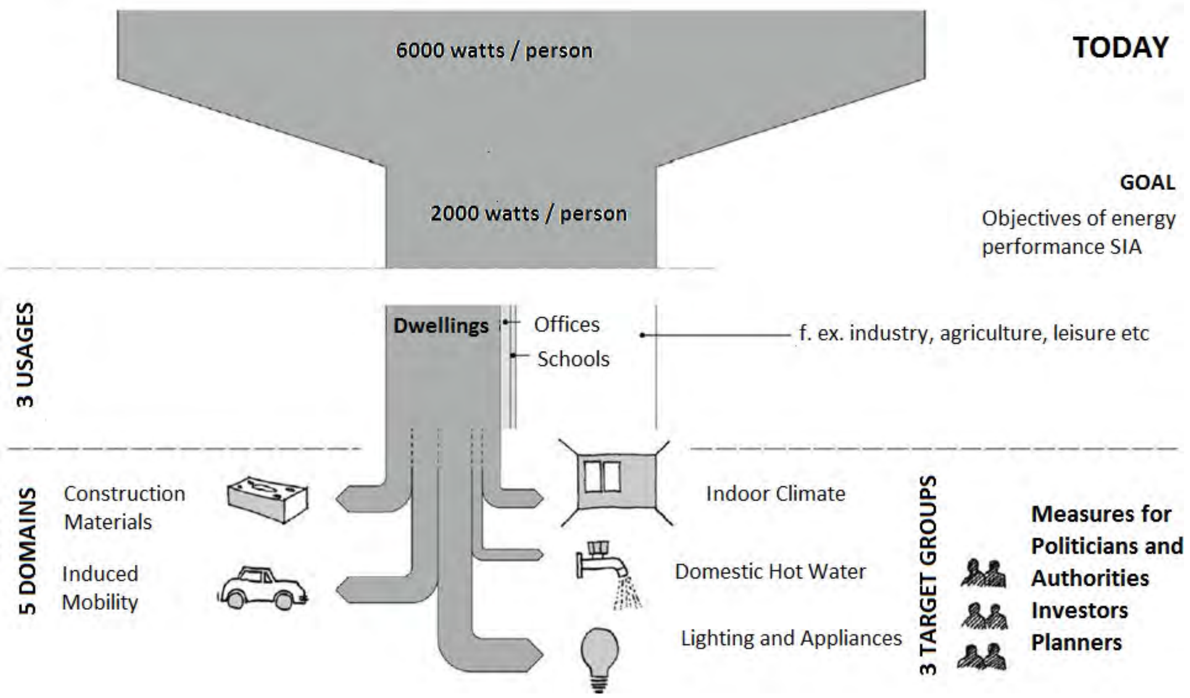

Fig. 2 The strategic plan to achieve a 2 kW-City-of-Zürich (original figure taken from [6])

2. 2 kW City of Zürich

2.1 Current energy breakdown: magnitude of improvements required

Private households and transportation are together responsible for around 60% of energy use in Zürich, with the remaining 40% being used by industry, commerce, services and retail sectors (economy and administration) (*Fig. 3*). Of these latter the non-industrial uses are dominant in Zürich. As such the city's efforts should be focussed upon transport, housing and other non-industrial building uses.

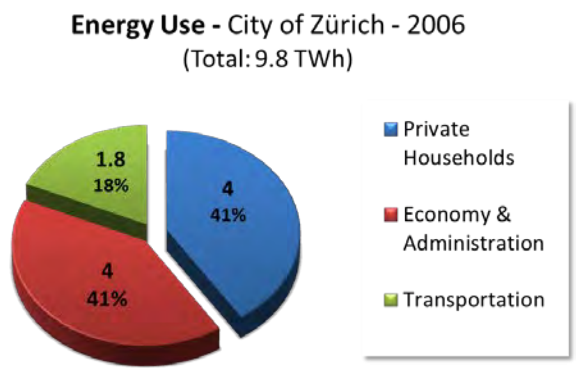

Fig. 3. Energy use by sector for the city of Zürich for the year 2006 [7]

The city has identified that, amongst the required improvements is reducing the energy use through better conservation and improving energy efficiency, while developing and exploiting innovative technical solutions. Thus, it is important to encourage the intelligent and efficient use of eco-friendly resources and materials, the utilization of waste heat and renewable energy, but also to promote social learning processes, new life styles and management concepts [8; 9].

Following from the above observations, the city is currently focusing on the following strategies to achieve its 2kW status:

- Building Sector: Implementation strategies regarding the use of better insulating construction methods and energy-efficient technologies. The target here is to demonstrate the feasibility by renovating and constructing "demonstration" buildings with low initial, running and maintenance costs, while ensuring a high quality of living [10].
- Mobility: Promotion of a more expansive and energy-efficient public transportation system whilst facilitating pedestrian and bike traffic. The city, in collaboration with the Canton of Zürich, has also proposed to launch a road pricing initiative to encourage the switch to more sustainable transport modes [10].

2.2 Initiatives under way since 2004

As part of its commitment to the European Energy Award the city has already established several initiatives which may be further reinforced during the coming years. And while Zürich promotes energy-efficient measures, companies and individuals can benefit from a vast variety of information and advice, including:

- Advising/educating/energy coaching: for eco-friendly lifestyle/behaviour in buildings and the induced mobility by various departments of the city to different actors (constructors, investors, operators and users) [11; 12; 13].
- Assessing existing buildings/construction projects: A methodology has been designed which makes use of the comprehensive international Life Cycle Inventory database "ecoinvent" [14]. This database contains indices relating to embodied energy and gaseous emissions (e.g. CO_2-equivalent) for a broad range of composite materials and their constituent parts [15].
- Environmental policy guidelines/regulations: Defining specific thresholds of energy use to assess the progress of energy savings in the building sector as well as its induced mobility [22]. The City Council also uses this document to formulate environmental policy

guidelines. For the construction sector, specific guidelines have been conducted regarding HVAC systems, electrical appliances and sanitary fittings [11].

- Financial Support:

  To promote and support the required transition strategies several incentive schemes have been established for energy-efficient investments. This includes subsidies provided to private citizens, firms as well as institutions, on a communal, cantonal and federal level:

  – Cantonal support program: Information and financial support (also for expertise of impartial consultants) of energy-efficient refurbishments [16].

  – Electricity Savings Fund of the City of Zurich: Subsidises investments for the efficient use of energy and the integration of renewables [17].

  – Subsidies from CO_2 tax on heating oil [18]: At the federal level, insulation improvement measures of the building envelope are subsidized for buildings which have been constructed before 2000. Furthermore, in the Canton of Zürich the use of renewable energy, modern building technology and the use of waste heat is supported [19].

  – Reduction of interest rates on credits for investments in energy-efficient measures: Environmental reductions up to 0.8% for new construction and renovation according to the MINERGIE® standard, investment in renewable energies, energetic refurbishments and other ecological projects [20].

  – Tax deductions: Investments in energy-saving renovation of old buildings can be partially deducted from tax [21].

3. A bottom-up model of urban energy flows

As noted above, the city of Zürich is very aware of the need for some rational basis to guide their decision making processes with respect to the choice and implementation of strategies for making the transition from the current per capita energy use of around 5kW to just 2kW within the next forty years. Ideally, this should be some form of model with which alternative hypotheses may be tested. Now, since the principle uses of energy within Zürich are to condition buildings, support the activities accommodated within buildings and to transport goods and people between buildings (see section 2.1), it follows that our decision making model should represent buildings and transport systems. Such a model may be spatially aggregated (or macroscopic), treating the city as an ensemble in which we model the stocks and flows of resources between compartments of this ensemble. Or we may have a spatially disaggregated model, in which we explicitly model individual buildings in their spatial context as well as individual transport journeys between these buildings. Or we may opt for some compromise between these two: for example grouping buildings into clusters and explicitly modelling an example from within each cluster and extrapolating to the remainder.

As part of a project funded by the Swiss National Science Foundation, we have elected to develop a spatially explicit or micro-simulation program, which combines the modelling capabilities of two complementary tools: CitySim for buildings and MATSim for transportation.

CitySim [22] is a detailed simulation program for predicting the energy demands of buildings as well as the supply of energy to them, whether using building-embedded or district scale energy conversion systems. It takes as input a 3D description of the scene to be simulated, in which each building is attributed according to the thermal and optical properties of its construction, characteristics describing its occupants as well as the heating, ventilating and energy conversion systems. Either the buildings, or the district to which they belong, are then associated with characteristics describing their energy conversion systems. This scene description is parsed to an integrated dynamic model which simulates energy demands for heating, hot water, lighting, ventilating and cooling as well as for electrical appliances. These simulations account for the stochastic nature of occupants' presence and their interactions with the building envelope and its active systems as well as the effects of adjacent obstructions on surface radiation exchanges (accounting for occlusions to sun and sky as well as reflections from these occlusions). CitySim is thus a comprehensive and detailed program for simulating building-related energy flows at the urban scale.

In complement to CitySim, MATSim [23] simulates the sub-hourly transport of individual people within our urban scene. For this a geometric description of the scene is required, consisting primarily of the transport network nodes and the links between them as well as the locations of activities (work, home, education etc) located at or adjacent to these nodes / links. Using geo-coordinated census data a population of households may then be created. The members of this population are then associated with activity chains such as home-work-leisure-work-home and the locations and preferred timing of these activities. With this initialisation complete the scene may be simulated. Following from an initial shortest route finding algorithm, an optimisation algorithm is employed to optimise travellers travel plans: identifying departure times following each activity which maximise travellers utility, based on minimising travel time and maximising the time spent performing the required activities. With agents' daily travel plans chosen, their final journeys may be simulated and the associated fuel consumption calculated, using empirical performance data.

The means for coupling CitySim and MATSim is via the exchange of people. Upon launching a simulation a population of agents is generated, with each agent being associated with socio-economic characteristics, travel plans, building locations (e.g. residential and workplace) corresponding to these plans, environmental comfort preferences to be applied whilst within these buildings etc. MATSim is then launched to simulate agents' arrival and departure times at the geo-referenced buildings. These agent IDs and their arrival and departure times are then parsed to CitySim which simulates each buildings' energy demands as well as the supply of energy to them. Thus we have a comprehensive platform in which we are able to test a range of strategies, including:

- Inhabitants' investments in: building renovation measures, more efficient vehicles, public transport season tickets etc.
- Energy service company investments in distributed heating, cooling and power systems.
- Uptake of subsidies to encourage more widespread uptake of building-embedded renewable energy conversion systems.
- Changes in buildings' use to reduce transport energy demands and improve the match between energy demand and distributed energy supply system etc.

And of course the energy implications of the above measures.

Having now developed a first prototype of this coupled building-transport modelling platform we are currently in the process of testing this in conjunction with a district of the City. Our next step will then be to prepare and calibrate a whole city model and to test hypotheses for improving its energy performance; strategies that we will define in liaison with the City stakeholders.

4. Conclusions

Following from a longstanding commitment to reduce its use of energy and associated adverse environmental impacts, the citizens of the city of Zürich recently voted in favour of reducing its per capita primary energy use from its current level of more than 5kW to just 2kW within the next forty years. Other complementary commitments are to reduce per capita greenhouse emissions to below 1t CO_2 equivalent per Capita and to eliminate the use of electricity derived from nuclear sources. In pursuance of these objectives the city has already implemented a range of programs to contribute towards the required transformations, but so far these are relatively modest in their ambitions. The city understands that to achieve its ambitious objectives, will require serious commitment and a multiplicity of initiatives. To assist in this process the two Swiss Federal Institutes of Technology (Lausanne and Zürich) are collaborating in the development of a new urban energy modelling platform, integrating micro-simulation programs of buildings, distributed energy conversion and storage systems and transport systems.

A first prototype of this new modelling platform has been developed and is being applied to a sample district of the city. Following from this initial application a full scale city model will be prepared and a range of scenarios defined and tested, with the solicited contributions of key city stakeholders. It is also intended that a working model of the city will be handed over to the city, to support its continued updating and application to test future strategies.

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