Energy Visualization – Why, What & How?

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Abstract

This text explores the field of energy visualization, regarding motivation, content and concepts in an academic and non-academic context. Besides the general challenges and demands on visualization of this resource, we discuss the issues of scale and areas of application within current research. Drawing from examples of geographic methods that are aiming to capture human use of resources, every day life and issues of communication between planners, researchers and individuals, there is great potential for future development of visualization tools both for analysis, participatory approaches as well as science communication.

Introduction

Within the concept of climate visualization, energy is one of the central resources that links to climate policy, individual consumption, mitigation options and is thus of interest in several thematic contexts. We aim with this text to explore the field of energy visualization and potential areas of application. We argue that this is a new field that shows great potential for the representation and analysis of linkages between the various scales of energy production and consumption. Energy visualization opens up for inter- and trans-disciplinary research and research communication with planners, users and other stakeholders.

Why energy visualization?

The simple response to this question is similar to other areas of climate visualization: *because we can feature the invisible*. Similar to greenhouse gas emissions, flows of resources, future temperature scenarios and the potential impact of policies, the analysis and communication of the use of energy resources on different scales – from the individual household to the global frame – is a methodological and pedagogical challenge. Whether we focus on quantity, systems or energy sources, energy visualization can be a tool that can be adapted to the needs and demands of a large number of stakeholders.

One of the key challenges of energy visualization is the complexity of issues, areas and fields of stakeholder interest, that has to be integrated to fulfil a sustainability perspective. Many of these issues are hard to grasp within current research. Global current and future energy use (e.g. peak oil, renewable energy, biofuels) is strongly debated in the media over the last years and has thus become a challenge for science communication. Accordingly, the complexity of this field demands new approaches and tools, which visualization can provide.

Visualization can function as a tool for science communication, the analysis of large data sets as well as a platform for decision making and participatory processes (fig 1). As means of visualization lead us back to the usage of images, maps, film, etc., several applications on visualizing energy use in households or simply with focus on everyday life have been developed over the last decade.

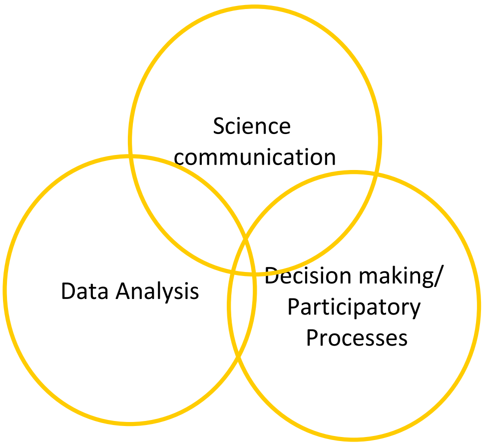

Figure 1. Three research approaches to visualizations.

What's been done?

Visualization is a wide term, and comprises various forms of visual representation of data but also on qualitative information, knowledge, ideas and concepts etc. The tradition within the academic field of geography has included cartography but also more abstract spatial representations in form of maps, overlying for instance topographic information with socio-economic, health, people's movements etc in order to use a visual tool for analysis and communication of geographic data. Some recent research has focused on the pedagogic and communicative implications of technology-integrated science teaching (Hennessy et al. 2007) and landscape visualization in order to increase awareness of climate change (Sheppard 2005).

The fact that energy flows are invisible to the human eye has engaged researchers in developing methods for "seeing the unseen" (McGormick et al. 1987). The McGormick study acknowledge the importance of developing this field of research in 1987. Mainly disciplines in science and engineering recognized the call the subsequent ten years. Before 1999 social sciences or interdisciplinary research did not develop visualization to any great extent. Consequently, no central core in social science or interdisciplinary visualization could be discovered and it was impossible to define key research areas (Orford et al. 1999). Since science visualizations often were attached with problems of for example lack of contextualization or scaling there should be a great potential for linkages to interdisciplinary research (Tufte 1997).

The most promising area for visualization was considered to be geography, since spatial data use within the discipline and integration of ideas from other disciplines gives geography a leading position in visualization research (Orford et al. 1999). Other than geography visualization in social sciences and interdisciplinary research was predicted a slow growth mainly due to its transdisciplinary character and problems with finding ways to publish.

In the area of data analysis, time geography is a branch of geography which could benefit particularly from the development of visualization techniques. For examples, researcher can easily move from aggregated data to detailed information in specific data points (Orford et al. 1999). Visualization techniques developed at Linköping University use data from time diaries in a visual activity-analysis tool called VISUAL-Time PAcTS (Vrotsou et al. 2009). This application can be used to visualize, analyze and compare activity patterns on different levels, from the individual to the population. New and unexpected patterns in everyday lives of Swedish households have been discovered using this tool and it has also provided rich knowledge about activity patterns in different groups of the population. For example, VISUAL-Time PAcTS has shown how division of labor between men and women differ concerning the activity "go to day care centre with child". Women leave the child in the mornings and men do the pick-up in the afternoons. Activity patterns have also proved to be useful to describe energy use on individual and household levels (Widén et al. 2009).

In the area of decision-making and participatory processes, and data analyses, another research field, partly inspired by the time-geographic approach, is called exploratory visualization (Kraak 2008). Visualizations are used as tools for interaction, to capture dynamics in data, and to generate new knowledge without the preconceptions and constraints of former analytical frameworks (Keller & Keller 1992). For example, the space-time-prism (Hägerstrand 1982) and later developed to a space-time-cube (Andrienko et al. 2003, Kraak 2003, Kapler & Wright 2004, Anundi et al. 2006) show potential to visualize information to users. Visualization tools like CommonGis and Geotime are able to generate time-space-cubes (see figure 2).

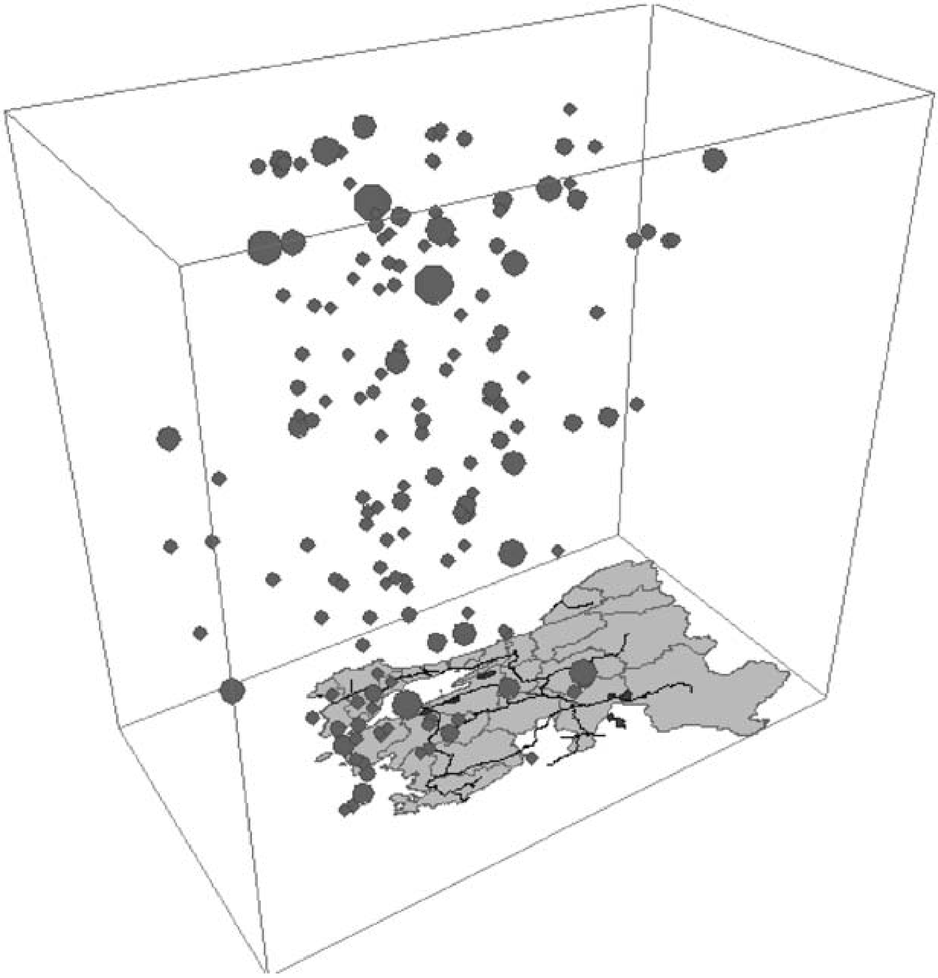

Figure 2. The principles of Space Time Cubes. The geographical map in the plane is completed with vertical axes symbolizing time. The spots are activities and are placed according to appearance, from bottom to top and their relative size might show the magnitude of an activity, for example energy use (Andrienko et al. 2003).

From the perspective of communicating science to laymen, smart metering and advanced visualization has been recognized by the European Commission as promising tools for energy awareness and behavioral changes (Commission of the European Communities 2008). According to the Commission real-time-feedback in Finnish households reduced energy consumption by 7 % and in commercial building the potential is probably 10 %. A Swedish anthology "Visualization of energy use" explores the different available option of smart metering (Pyrko 2008). Results from several minor research project show how visualization has the potential to change energy behavior, especially if combined with price signals. But behavioral change is very complex and feedback mechanisms provided by for example available smart meters has to be flexible to suit different users. Experiments with visualizing energy through different household appliances has shown how difficult it is to have long term effects on behavior since people get used to it and eventually ignore the signals (c f Löfström 2008). This knowledge will be taken into account in our future work on energy visualization.

What?

Concepts and Content

Sustainable resource use comprises an environmental, social and economic dimension which in turn demands a strongly integrated and interdisciplinary approach. To be able to present and explain linkages between fields with a wide variety of academic tradition, data collection, analysis etc, there is a need for common representations. To step beyond the traditional forms of science communication and to enter forms of explanatory models that can show the direct interaction between fields of knowledge is thus possible by means of visualization.

The visualization we focus on in recent studies is focused on energy use, climate change and global resource flows for data analysis, pedagogic and communication purposes. The tools that could be applied within this field can be divided into two categories:

1) Soft-ware that handles large quantities of data which can in form of mappings, flows, charts, and most importantly interactive solutions provide forms of presentation or interactive workshops that could be applied in higher education or other fori.

2) Visualization tools that can be used in everyday-life, in households, by consumers or as means for classroom teaching. Examples for this can be illuminated cables that increase their light-intensity depending on current energy use in the households or interfaces that provide data on a household's individual energy consumption as well as in relation to neighbours.

The general field of energy use and energy resources intertwines natural science, social science, economy on a local to global level. Every single action that we undertake as individuals on this planet, may it be which milk we choose for our breakfast, if we turn out the light when leaving home, which mode of transport we choose during our day or how we choose to vote in the next election has an impact on the global system, on flows of resources, people in remote countries. How these connections can be communicated is a challenge that can be met through visualization.

Energy visualization is a tool for communication, feed back to consumers, planners, stakeholders as well as for pedagogic purposes directed to students as well as the general public. A significant effort can be directed towards the sustainable use of resources, both through representation of complex data sets and through scaling of use-related data and scenarios. As such, it enables us to create storylines that are adapted to local households, to planners, housing companies, students or the general public.

In our current study we explore the potential of energy visualization as a communicative tool. In dialogue with representatives of the housing company we defined a number of visualization efforts that would contribute to their general mission of a) communicating changes in energy consumption on a household/neighbourhood scale b) 'translating' the effect of what changes would imply on a larger (national) scale. Applications for such local energy communication could involve:

- An energy visualization that shows the individual and regional/national energy use
  - for selected energy sources
  - for selected energy demanding activities
- That enables us
  - to zoom in on the potential effects for e.g. land use

- to see who is consuming what and which countries (in terms of consumption) use area elsewhere (e.g. energy footprints/carbon footprints)
- to change single parameters (for instance if biomass for biofuel production is produced in one or the other country) and their effects for global resource flows

As such it could be an interface that communicates on an individual level, through experimenting and understanding as well as 'asking the questions' to test different hypotheses can be made in a vast number of ways.

How?

Scales & Planned Applications

Energy use implies resource flows on a number of scales. In terms of communication efforts, this means a translation from the individual user to larger entities (e.g. neighbourhoods, cities, regions) to the national and finally global scale. The strength of scaling up (and down) energy use is to be able to visualize the impact individual choices and minor changes in consumption, be it through behavioural changes or technique, can have on the larger scale. As such, it is a communicative tool to enhance understanding (and potentially create commitment) for local changes.

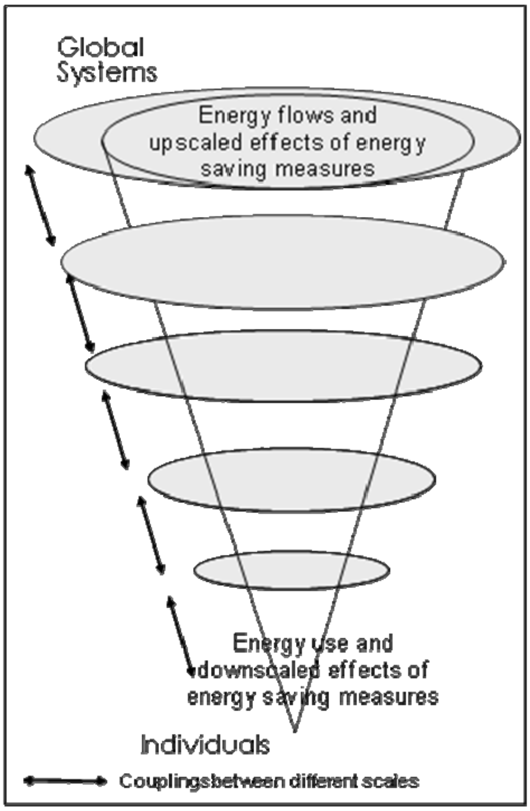

Figure 3. Schematic figure to approach energy visualization from an interdisciplinary perspective.

Given the example of the local households, we include the use of energy through electricity, warm water and heating and see structures on household, building and neighbourhood level. Further, this consumption might be translated to a regional/national scale and compared to the energy implied in biomass (spatial) or other alternative energy sources. Indirect energy flows through the household (e.g. organic waste that is collected separately and will be reused for local biogas production) can be translated in a similar way to generate an understanding for the dimensions of individual energy use.

Results from these studies imply therefore all three areas of visualization (figure 1) and can be used in information visualization for analysis of abstract data, in visual representations through kml/kmz/wms/Arc GIS formats to be used in public communication and decision making (e.g. as part of the decision theatre of the Norrköping Visualization Centre-C) and as a basis to develop new interfaces for communication between researchers, planners, housing companies and the individual consumer.

The challenge of making sense of complex questions remains, and in an increasingly intertwined world of knowledge, the consequences of our actions need to be communicated in a most explicit way in order to facilitate sustainable changes.

References

Andrienko, Natalia, Andrienko, Gennady & Gatalsky, Peter (2003). Exploratory spatio-temporal visualization: an analytical review. Journal of Visual Languages and Computing 14(6), pp. 503–541.

Anundi, D., Björnstad, M., Gillberg H.,Haraldsson, J.,Mårtensson, I., Nordvall, M., Ståhl, J. (2006) Utvärdering av rymd-tidskuben: en teknik för översiktlig visualisering av spatial-temporal information

Commission of the European Communities (2008) *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Region: Addressing the challenge of energy efficiency through Information and Communication Technologies*. Brussels, 13.5.2008 COM (2008) 241 final.

Hennessy, S., Wishart, J., Whitelock, D., Deaney, R., Brawn, R., la Velle, L., McFarlane, A., Ruthven, K., Winterbottom, M. (2007). *Computers&Education* 48, pp. 137–152

Hägerstrand T., (1982) Diorama, path and project, *Tijdschrift voor Economische en Sociale Geografie*, Vol, No. pp. 323–339.

Kapler, Thomas & Wright, William (2004). GeoTime Information Visualization. IEEE Symposium on Information Visualization (InfoVis 2004). pp. 25–32

Keller P. R., Keller M. M. Visual Cues, Practical Data Visualization, IEEE Piscataway.

Kraak, M-J (2008) Exploratory Visualization. In Shekhar, Shashi. (2008). *Encyclopedia of GIS*. New York: Springer. 301–307.

Kraak, M. (2003). The Space-time Cube revisited from a geovisualization perspective. Proceedings of the 21st International Cartograhic Conference (ICC), ICA Durban s. 1988–1995.

Löfström, E., Palm J., Visualising Household Energy Use in the Interest of Developing Sustainable Energy Systems. Housing Studies, 23(6), pp. 935–940.

McGormick B. H:, and DeFanti, T. A. (1987) Visualization in Scientific Computing. *Computer Graphics* 21 (6 November).

Orford. S., Harris R., Dorling D., (1999) Information Visualization in the Social Sciences: A State-of-the-Art Review. *Social Science Computer Review* 1999: 17; pp. 289–304.

Pyrko J (ed.) (2008) *Visualisering av energianvändning* Institutionen för Energivetenskaper, Lunds universitet; Lunds tekniska högskola.

Sheppard, S R.J (2005). Landscape visualization and climate change: the potential for influencing perceptions and behaviour. *Environmental Science&Policy* pp, 637–654.

Tufte, E. R. (1997) Visual Explainations: Images and Quantities, Evidence and Narrative. Cheshire: Graphics Press.

Vrotsou K., Ellegård K. & Cooper M. (2009) Exploring Time Diaries Using Semi-Automated Activity Pattern Extraction. eIJTUR (electronic International Journal of Time Use research), vol 6, September 2009.

Widén, J., Lundh H., Vassileva, I., Dahlquist, E., Ellegård, K., Wäckelgård, E. (2009), Constructing load profiles for houshold electricity and hot water from time-use data – Modelling approach and validation. *Energy and Buildings* 41 (2009), pp. 753–768.

Biography

Tina-Simone S Neset is a postdoctoral researcher at the Centre for Climate Science and Policy Research/Department for Thematic Studies – Water and Environmental Studies. With a background in Geography her doctoral and postdoctoral research has been focused on human use of resources. She is currently the Head of Climate Visualization at CSPR and part of the WorldView project as well as a project co-operation on local and regional use of energy and energy visualization.

Wiktoria Glad is a postdoctoral research fellow at Tema Technology and Social Change at Linköping University. Her research has mainly focused on human use of energy in the built environment especially on the building and neighbourhood level, and includes a doctoral thesis on the first Swedish passive houses. Currently she is the project leader of research on innovative and collaborative energy efficient measures in the management of buildings.