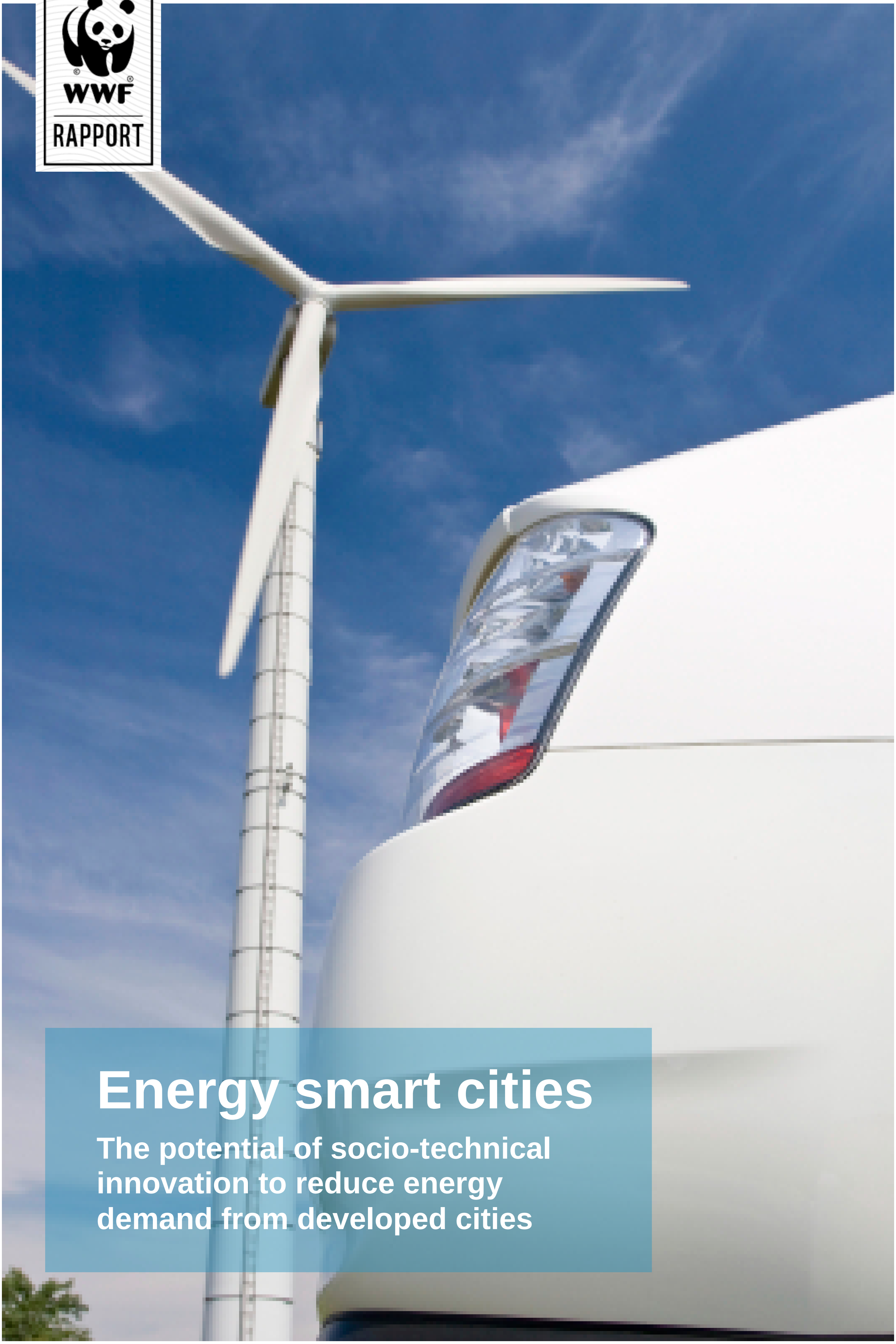
WWF

RAPPORT



Energy smart cities

The potential of socio-technical innovation to reduce energy demand from developed cities

The potential of socio-technical innovation to reduce energy demand from developed cities

Project Report

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1. Introduction

WWF has identified *urban transformation* as one of the central components in the work to promote a *One Planet Future*, where everyone can live a good life within the capacity of the planet.

WWF challenge now is to better define *urban transformation* and to identify the strategies required to deliver on its ambition. One clear goal for WWF is a radical reduction of energy demand in urban environments obtained while increasing quality of life.

To start addressing this challenge, WWF commissioned Climate innovators (Marco Buttazzoni and Andreas Follér) the study titled: *The potential of socio-technical innovation to reduce energy demand from developed cities.* Aim of the study is to further develop a WWF's vision for an *energy smart city*, identifying and quantifying opportunities for radical energy reduction in buildings, transportation and consumption, focusing on Swedish cities as case studies, while drawing conclusions that are relevant for a broader set of cities in developed countries.

In response to WWF's requirements this study addresses the following questions:

1. How does an *energy smart city* – i.e. a city where citizens' enjoy a very high quality of life, while using a minimum amount of energy– look like?

2. If we take Swedish cities as case study, can we estimate their future energy needs, assuming different energy use trajectories, including an 'energy smart trajectory'?

3. Given the fact that this study is an initial attempt to address these questions, what future activities should we undertake to improve our analyses?

This report summarizes the results of the study:

Section 2 discusses the project activities undertaken, between October 2010 and February 2011, to gather relevant information and develop and validate the answers to the study questions.

Section 3 illustrates the background analysis undertaken and discusses the key conclusions reached on question 1. This section describes the key characteristics of an energy smart city and compares such city with alternative cities (scenarios) which could unfold in the future, depending on the decision we take today.

Section 4 describes the excel model that was created to estimate the energy requirements of 5 Swedish cities (Stockholm, Göteborg, Malmö, Lund, Växjö) depending on different development trajectories chosen, including an energy smart trajectory. The section illustrates the main results of the analysis, highlighting key factors driving energy use and discussing the strengths and weaknesses of the approach undertaken.

Section 5 builds on section 4 and focuses on how to further improve quantification models currently used to assess energy requirements in cities. In particular this section discusses the strengths and weaknesses of the REAP model and proposes a number of improvements that would enable the model to better address the urban transformation questions the WWF is posing.

Finally, section 6 concludes the report with a brief summary of the main results of the study, and a reflection on the steps that could help WWF further develop its vision for urban transformation and a one planet future.

The study was conceived as an internal project within WWF, with the aim of gaining insight on how to create an energy smart city, while building a background of data and analyses, which can support WWF's strategy development and decisions on this topic. This report reflects this premise and assumes that its readers are WWF executives interested in the topic. While some of the parts of the report may be relevant (and close to ready) for external publication, the report is not written with an external audience in mind.

2. Project description

The project was undertaken between October 15th, 2010 and February 28th, 2011. The Gantt chart below illustrates the main project activities.

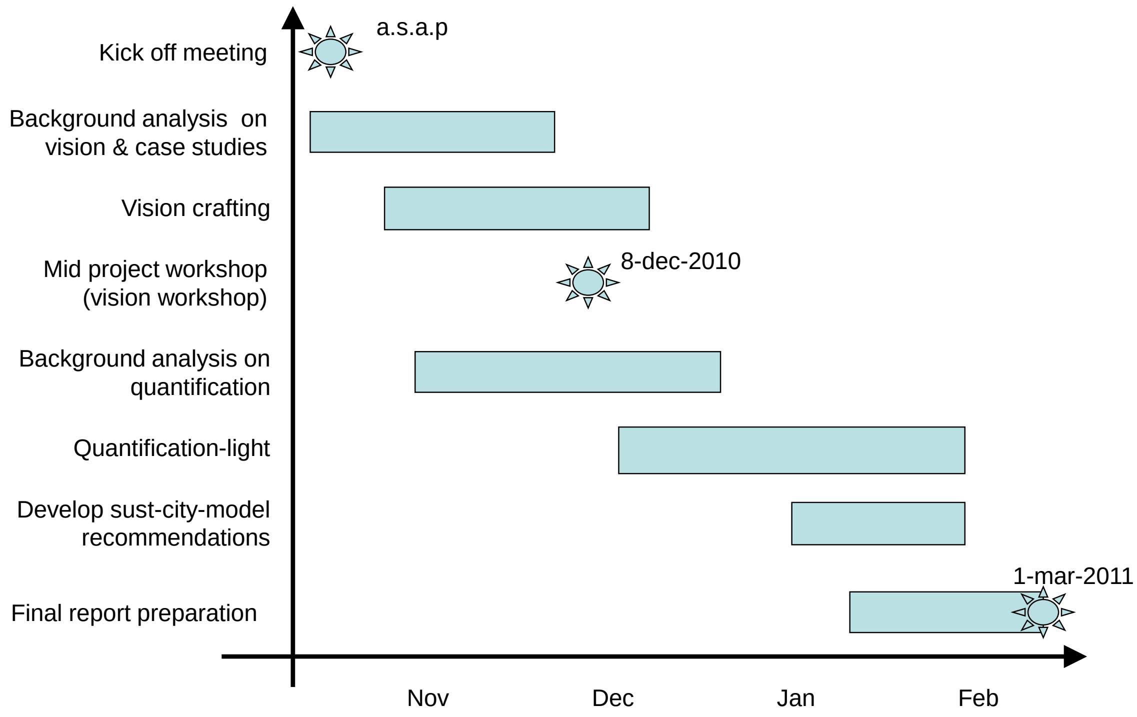

Figure 1: Project Activities

The first part of the project was devoted to the development of a vision for an energy smart city. After an initial kick-off meeting with the WWF's project manager, project activities included an extensive background analysis of existing literature on: energy systems, energy efficiency – including rebound effect problems - sustainability & urban planning, collaborative consumption and the economics and psychology of well-being. Secondary research was coupled with ten interviews with WWF experts (which became part of the extended *WWF Project Team*), six interviews with external specialists and on-going interaction with executives from the five case-study cities. The results of the background research were synthesized in a "Vision development package", which was distributed among the WWF project group and discussed during the 'mid project workshop' organized on December 8th, 2010. During the workshop we collected valuable feedback and comments that were incorporated into successive revisions of the three tools we used to analyze options, explore opportunities and develop the vision:

- The brainstorming mind maps
- The scenarios framework and
- The scenario table

This work greatly enhanced our understanding of the existing thinking about energy use in cities, providing insight on the strengths and limitations of such thinking and on the type of transformations required to truly achieve an energy smart city. The insight gained with these activities was also critical to inform the design of the quantification tool we developed during the second half of the project.

The quantification process included a number of interconnected work-stream, which, by and large, proceeded in parallel. The first work-stream entailed the collection of data about the target cities we selected for the analysis. Primary data sources were Statistics Sweden, the Swedish Energy Agency, the municipalities and the REAP model. These sources provided current and historical data about the cities and enabled the establishment of a *year 0* baseline. A broad array of additional sources was used to evaluate and estimate future parameter affecting energy use. Building on this broad set of data sources, we developed an excel based calculation tool, which was designed to: (1) provide an initial assessment of energy use trajectories, assuming different development scenarios (2) identify critical variables, and sensitivities, driving energy use and (3) highlight areas were current data or modeling tools are lacking. As the draft excel calculations took shape, we distributed them among the WWF's project team, and provided copies to the energy and environmental experts in the target cities. The feedback received was used to further develop and improve the excel model and to identify areas where more sophisticated modeling solutions are need. The insights gained with the construction of the excel model and with the feedback received from experts, provided a valid benchmark for the third quantification work stream: the analysis of the structure and logic of the REAP tool with the assessment of its areas of strength and weakness and the identification of opportunities for improvement.

The main results of the various project activities are summarized in the sections below.

3. Vision crafting

Several studies and initiatives have analyzed energy demand and supply and associated technologies, at various degree of geographic aggregation, including the urban level.

Although such studies have provided a number of insights on how urban environments can tackle their 'energy addiction', such insights seems to only provide part of the answers needed to create a fully-fledged energy smart city. Many such studies merely focus on technology deployment (weatherization, more efficient appliances, etc.) as a means to achieve energy savings, but fail to consider how behavior can affect energy use and the impact – or lack thereof – of energy saving technologies. Most studies that consider the role of both technology and behavior in delivering energy savings define *energy systems* narrowly and do not consider how, for example, consumption decisions, broadly defined (including food, durables, leisure etc.), can dramatically affect energy requirements. Finally, even if consumption variables are considered, when analyzing energy use, energy-scenarios builders typically make the assumption that production (GDP) continues on a path of exponential growth, implicitly postulating that recent (in historical terms) economic trends can be repeated in the future and, perhaps most importantly, that GDP is the only variable relevant to measure the well-being of a society (or a city).

In looking at sustainable urban environments WWF wants to go beyond narrowly defined approaches and to consider, instead, how urban environments can be (re)designed to meet human needs, create well-being (as opposite to mere GDP), and improve the natural environment in which we live. WWF believes that obtaining such goals will both require smart technologies, and smarter ways to use (or not use) technologies, thus demanding that social/cultural/behavioral components go hand in hand with technological change/deployment.

The vision crafting work module was therefore designed to build on insights coming from tradition energy analysis and to also explore opportunities for more radical energy reduction strategies, built around transformational changes in life-style and behavior, building on the premise that urban environments should maximize well-being (as opposite to mere production/consumption).

Thus, the first step of the vision crafting module was to undertake background analysis (secondary research and primary interviews) to explore the different issues identified by WWF, build insight about current and projected developments, frame vision/scenario crafting work and identify useful parameters to undertake quantitative analysis.

The table below summarizes some of the key insights provided by the background research. Additional information can be found in the power point document that was presented during the December 8th workshop. References for additional reading are available in the project web site: https://sites.google.com/a/wwf.panda.org/project-energy-smart-cities/home.

Background topic	Insights provided to the project
Energy systems analysis	Analysis of energy technologies and systems Estimates of current energy uses, and efficiencies in various energy systems, including in buildings , transportation and industry Projections and scenarios for future energy supply and demand
Change behavior and energy use	Identification of behavioral changes that lead to energy savings (at zero or very little cost). Quantifications of how such changes can affect energy use (e.g. through comparison of different households). Insight on the steps (and strategies) that lead to change behavior and actual energy savings.
Green-ICT analysis	Analysis of innovative, ICT based, strategies to reduce energy use (e.g. teleworking, energy monitoring systems, smart public transportation systems, etc.)
Urban design – sustainable cities	Analysis of existing case studies from progressive and innovative cities Discussion and definition(s) of sustainable city concept Examples of new urban concepts, with illustrations of innovative ways of living, producing, designing, and reflections on possible implications for socialization, living tempo and the environment
Collaborative consumption – sharing economy	Analysis of how social networks can enable new forms of consumption and production which are based on collaboration, could cause significant cultural shifts (more emphasis on community and less on possession) and affect the environment (from owning to using, requiring less products to deliver similar benefits/services)
Rebound effect literature	Highlight the strong risk that the initial positive impacts of energy savings (or any other strategy that improves efficiency) will likely be reduced, if not reversed due to: (1) increases in energy use and/or consumption, in response to the lower costs of (more efficient) energy and energy-containing products and (2) the additional consumption generated by the higher disposable income made available by lower energy expenditures and increased efficiencies
Well-being & behavioral economics	Insights on what is associated to people's well-being (e.g. strong family relationships, community of friends, good health, financial security, pleasant environments, rewarding jobs) and lack thereof (e.g. dysfunctional families; commuting, especially when done by car or public transportation; unrewarding jobs; unemployment; household chores) More sophisticated approaches (especially when compared with neoclassical economics) for the analysis of consumption decisions, labor supply, transportation demand and the benefits produced by healthy and pleasant environments and other 'intangibles'.

Table 1: Key insights from background research

The project team reflected on the results of the background analysis and created a number of Mindmaps to brainstorm on key variables and their interconnections, and to start visualize and assess options for scenario building. In particular, the *Well-Being* Mindmap was used to explore factors affecting human's well-being and their connection to energy use, while the *Smart city living* Mindmap provided a first visualization of what an energy smart city may include. Both Mind maps are provided below.

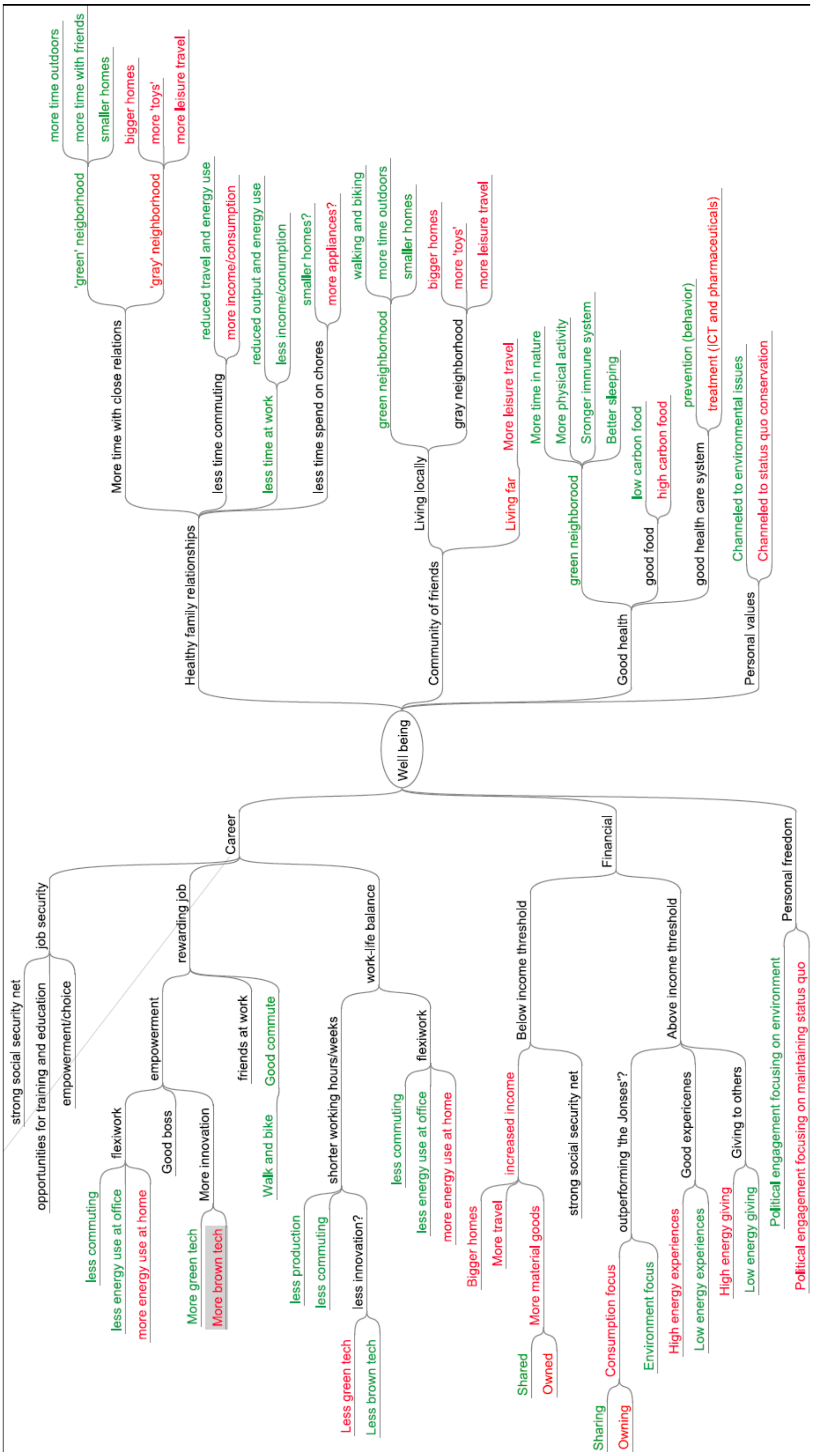

Figure 2: Well-Being Mindmap (text in green font: lower energy use; text in red font = higher energy use)

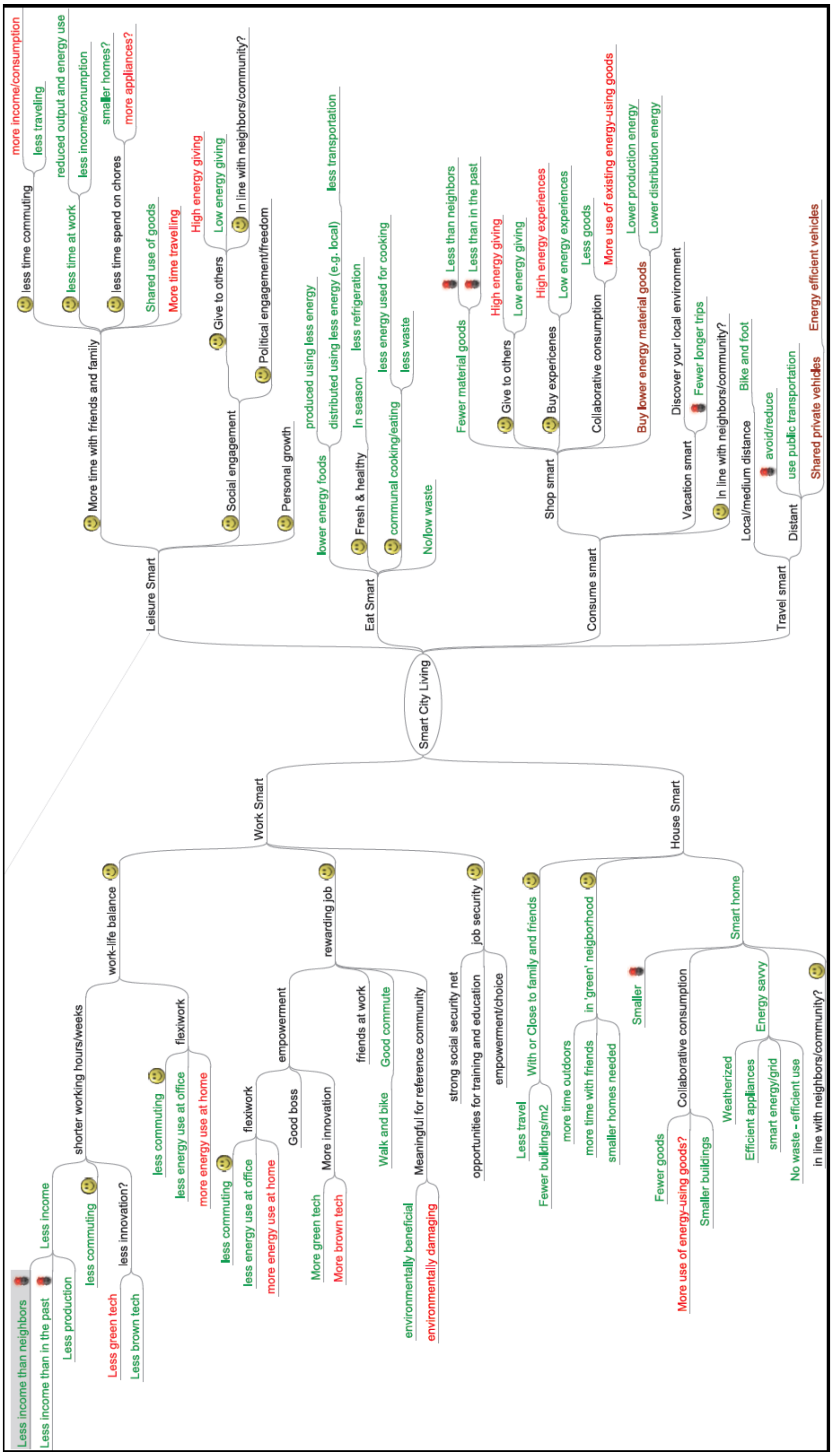

Figure 3: Smart city living Mindmap (text in green font = lower energy use; text in red font = higher energy use; traffic light = negative impact on well-being; smiley face = positive impact on well-being)

Background analysis and Mindmaps provided several insights and ideas to build upon. The next step of the vision crafting work focused on organizing these insights and ideas and on articulating a framework to categorize and compare future scenarios.

Two variables appear to be critical in determining the trajectories of socio-economic systems and of energy systems within them:

1. The prevalent attitude towards technological development, and in particular towards the role of clean technology as possible source of solutions. A low-tech attitude would not focus on technology as a critical tool to address societal, environmental or energy problems and may even view new technologies as sources of problems rather than solutions. At the other extreme a high-tech attitude would emphasize the development of new technologies as central to achieve any societal, energy or environmental goal.
2. The prevalent attitude about consumption and social life. At one extreme, cultures (and consequently policies, institutions and behaviors) can focus on the individual, and define him/her as a consumer, emphasizing and promoting individual consumption as main societal goal. On the other hand, the focus could be on broader well-being objectives, viewing people as members of communities, and communities as providers of numerous tangible and intangible benefits to their members.

Using these two variables as critical factors to differentiate possible future scenarios, four future cities were defined, as illustrated below.

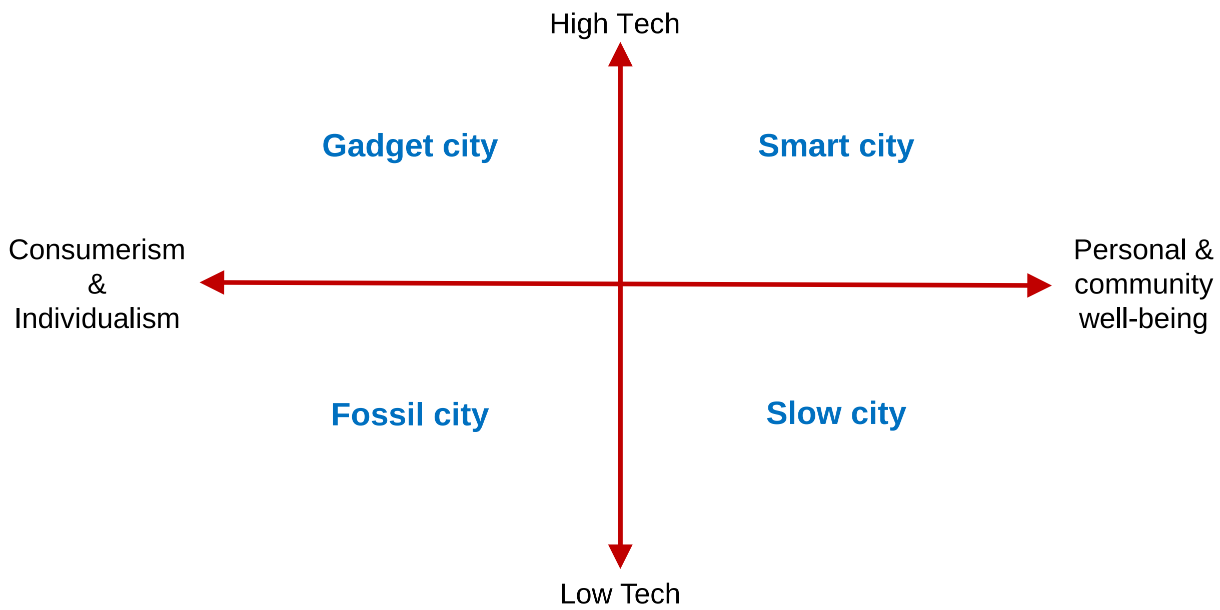

Figure 4: Building scenarios. High vs. low tech and consumerism/individualism vs. community well-being.

Gadget city: Compared to today (year 0) new, more efficient, energy systems are rolled out in housing, transportation and production processes. ICT systems are extensively used to improve efficiency. Like today, long working hours/weeks are common and personal and social lives are subordinate to work-life. The relentless pursuit of increased material consumption remains a central 'function' of the citizen-consumer. The size of the average household keeps decreasing, while dwellings become larger. 'Single use' neighborhoods, shopping malls and long commutes remain prevalent. The city experiences low levels of participation in political processes and voluntary work.	**Smart city:** Compared to today (year 0) new, more efficient, energy systems are rolled out in housing, transportation and production. Citizens allocate less time to paid work and more time to their personal and social life, participating more actively in political processes and donating voluntary work. More activities take place locally as mixed use neighborhoods, endowed with abundant green spaces and culturally thriving, are prevalent. Citizens are aware of energy/climate issues while material consumption is less central in their lives. New technologies enable more and more workers to work from home or locally. Technology also facilitates collaborative consumption, which satisfy people's needs with a more efficient use natural resources and manufactured products, reducing negative environmental impacts.
Fossil city: Compared to today (year 0) limited roll out of new, more efficient, energy systems takes place. People's knowledge about energy consumption and ability/willingness to reduce energy use is low. The work-life balance is skewed towards paid work. The relentless pursuit of increased material consumption remains a central 'function' of the citizen-consumer. The size of the average household keeps decreasing, while dwellings become larger. . 'Single use' neighborhood, shopping malls and long commutes remain prevalent. The city experiences low levels of participation in political processes and voluntary work.	**Slow city:** Compared to today (year 0) limited roll out of new, more efficient, energy systems takes place. Citizens' awareness about energy consumption and willingness to reduce energy use is high. The balance between work-time and personal/social time is readdressed, with more time allocated to personal and social life and more activities taking place locally, thanks to the prevalence of mixed use neighborhoods, endowed with abundant green spaces and culturally thriving. Material consumption is less central in people's lives, while the increased focus on family and friendships leads to larger-size 'households'. The city enjoys high levels of participation in political processes and voluntary work/activities.

Table 2: Definitions of Fossil, Gadget, Slow and Smart cities

During the December workshop and through follow up telephone and email conversations, more specific characteristics of different scenarios were identified and discussed, as illustrated in the table below. The scenario characteristics, expressed below in qualitative terms, provided reference and specifications for the construction of the quantification model, which was required to simulate different cities and their energy footprints, assess the role of different variables, and identify critical areas where change (e.g. driven by policies) can significantly affect the final energy consumption.

Descriptors	Fossil city	Slow city	Gadget city	Smart city
Live				**Smart living**
People want to live in smaller building integrated in local community and environment		xxx		xxx
Mixed use and more dense green neighborhoods		xxx		xxx
Extended-household, behond direct relatives		xxx		xxx
Rapid take up or Energy Efficiency technologies (weatherization, efficient appliences, efficient heating and cooling systems)			xxx	xxx
Move				**Smart moving**
Prevalent travel mode if foot and bike (+ public transport)		xxx		xxx
Fast adoption of high efficiency transport technologies			xxx	xxx
Work				**Smart work**
Working-life balance		xxx		xxx
Work life is subortinated to socialization and family life		xxx		xxx
More work locally		xxx		xxx
More telework		xxx		xxx
Leisure				**Smart leisure**
Time spent with family and friends is central in people's lives		xxx		xxx
Preferred meeting Places are parks and other public places (rather than the mall)		xxx		xxx
Walking biking locally, in pleasant environment, for socialization and recreation is part of daily life (less need for longer exotic vacations)		xxx		xxx
Eat				**Smart eating**
Higher market share for foods with lower energy content food (LCA)		xx		xxx
Lower food waste		xxx		xxx
Shop				**Smart shopping**
Community centric society, lower need/want for material consumption		xxx		xxx
Prevalence of Services over products whenever possible		xxx		xxx
Preference for products/services with lower energy content		xx		xxx
The prevalent shopping experience involves walk to local stores (or 'tool-libraries')		xxx		xxx
Cross cutting enablers/background drivers				**Cross cutting**
Citizens behave in the most energy efficient way		xxx		xxx
High level of sharing and communal use (cooking together, gardening, socialising)		xxx		xxx
Urban planning promotes Support community living, walking, biking and local laisure		xxx		xxx
High level of implementation of "climate solver" solutions			xxx	xxx
High level of synergies between different policies to achive energy savings (holistic approach: infrastructure, working hours, education, technology incentives)				xxx
Higher cost of energy (or taxes on energy)		ooo		ooo
Public influence/participation is high		xxx		xxx
Higher productivity gains			ooo	ooo

Table 3: Scenarios characteristics

4. Quantification light – The Excel-based calculation model

The 'quantification light' work component focused on developing an Excel based calculation tool able to simulate Fossil, Gadget, Slow and Smart city scenarios and to provide an initial assessment of energy use trajectories, at different points in the future.

4.1. Excel tool structure

The structure of the excel model is illustrated by the picture below

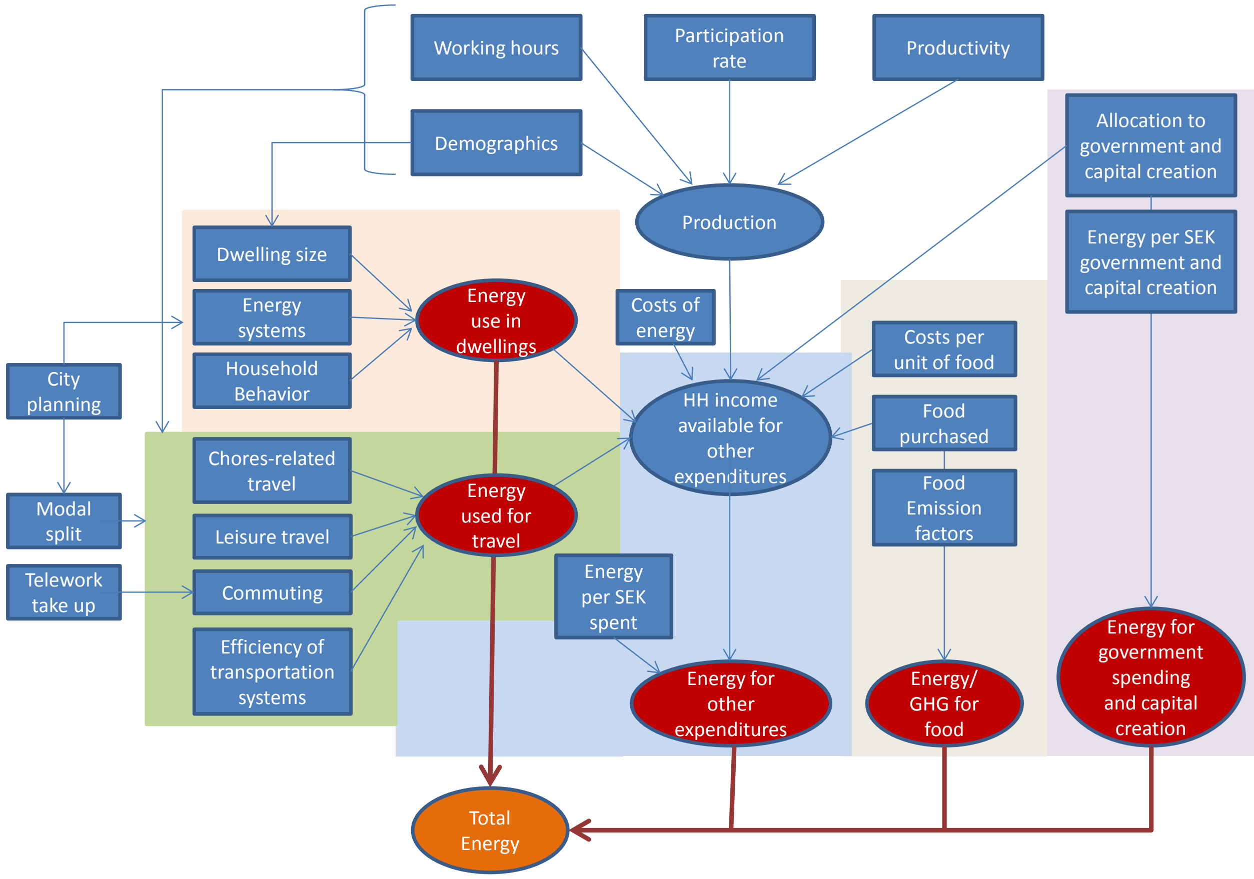

Figure 5: Excel tool - structure of calculations

Top level inputs in the excel model include demographics (population and working age population), employment rate, working hours and productivity assumptions, which, together, enable production/GDP estimates. The production/GDP estimate provides an overall 'budget' for the city, which is invested (capital formation), allocated to government expenditures, or allocated to households. Households' available income, in turn, is used for energy purchases (for dwellings and transportation), food consumption and other expenditures. Historical data from Statistics Sweden are used to allocate a share of GDP to investment, government expenditures and households. Energy costs are calculated bottom up, from energy consumption estimates (see below). Food consumption (SEK/person/year) is a model input extracted from the REAP tool. Other expenditures (SEK) are calculated as residual (Production/GDP minus investment minus government expenditures minus energy expenditures for buildings and transportation minus food expenditures). Energy consumption is calculated for each component. For dwellings and transportation, it is estimated bottom up using data such as: number of dwellings, dwelling size, dwelling efficiency (e.g. kwh/m2), electricity consumption per household/dwelling, km travelled per person, market share of different modes of transportation, efficiency of transportation technology etc. For investment, government, food and other expenditures energy consumption is estimated using energy/expenditure parameters (kwh/SEK). For capital formation and government expenditures the energy/expenditure (kWh/SEK) factors are calculated from the REAP tool. For food and other expenditures, the factors are derived from data received from the University of Göteborg, in turn based on an input-output analysis from Statistics Sweden's Environmental Accounts for 2005[1].

The assumptions used for the different scenarios are transparently visible in the model and are based on various sources, e.g.:

- Energy technology assumptions are based on energy systems analyses, such as the Ecofys Energy Scenario (2010)[2]
- Estimates of change behavior impact on energy use build on research such as Jean Paul Zimmermann End-use metering campaign in 400 households in Sweden. Assessment of the potential electricity savings[3]
- Teleworking take up and impact estimates rely work such as the report Ecofys/WWF/Connecore report From workplace to anyplace, assessing the opportunities to reduce GHG emissions with virtual meetings and telecommuting[4]
- Collaborative consumption literature, such as Rachel Botsman and Roo Rogers' What's mine is yours: the rise of collaborative consumption informed expenditure assumptions[5]

For any given city, and future year, the Excel model enables users to estimate and compare energy consumption (and other parameters such as production, disposable income, leisure time) for the four scenarios and with the current (year 0) situation[6].

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[1] Data available from http://www.mir.scb.se

[2] Yvonne Deng, Stijn Cornelissen, Sebastian Klaus (2010) *The Ecofys Energy Scenario*, in WWF the energy report, part 2, http://www.ecofys.com/com/publications/documents/part_2_energy_report.pdf

[3] Zimmermann Jean Paul (2009) *End-use metering campaign in 400 households in Sweden. Assessment of the potential electricity savings* Swedish Energy Agency, http://www.enertech.fr/pdf/54/consommations%20usages%20electrodomestiques%20en%20Suede_2009.pdf

[4] Buttazzoni Marco, Rossi Andrea, Pamlin Dennis, Pahlman Suzanne (2009) *From workplace to anyplace, assessing the opportunities to reduce GHG emissions with virtual meetings and telecommuting* http://www.worldwildlife.org/who/media/press/2009/WWFBinaryitem11939.pdf

[5] Botsman Rachel and Rogers Roo (2010) *What's mine is yours: the rise of collaborative consumption* Harper Collins

[6] Further details on the data and assumptions used, and the model calculations, are available in Appendix 1

4.2. Excel tool results

The main excel simulation results are reported below. Each section focuses on a specific city and discusses the following model results:

- Projections for the total energy consumption in different scenarios, between year 0 and year 40
- Projected changes (Index value) of key demographic, economic and energy intensity variables, under different scenarios. Variables projected include: population, income per person, energy per person, energy per unit of GDP and total energy use
- Year 30 snap shot for the four scenarios, with (1) a breakdown of energy use by usage type (2) a graph showing what makes up the changes in energy use between year 30 and year 0
- Time-use graph showing changes over time of two well-being related variables. For each city two out of four possible time uses (working, doing chores, commuting, leisure time) are reported.
- A table summarizing, for year 30, projected changes in nine well-being-related-variables. The table is color coded with green cells highlighting positive impacts on well-being and red cells highlighting negative impacts on well-being

4.2.1. Model simulation – Växjö

A highlighted in Figure 6, the model project increased energy consumption in both Fossil and Gadget City scenarios, with higher increases in Fossil, where energy use growth is only moderately mitigated by technology developments. In the Slow city scenario, energy consumption is stabilized but no significant reductions in energy use are achieved. Only in the Smart city scenario the projected total energy consumption declines.

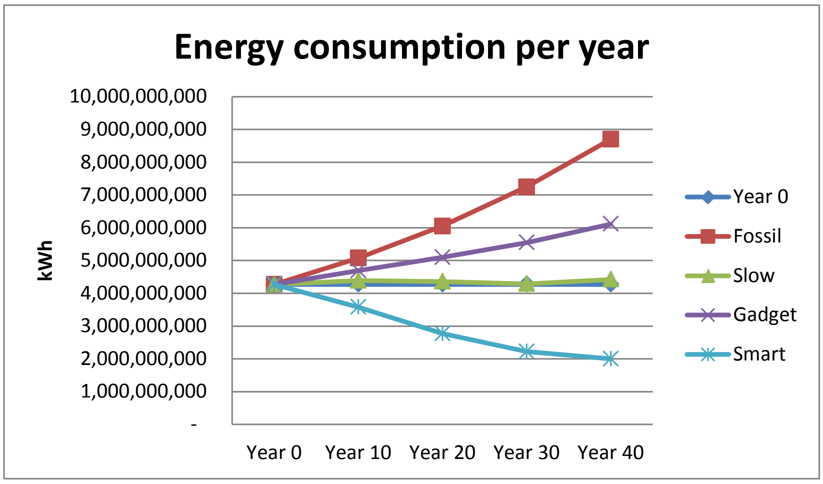


Figure 6: Total energy consumption over time for the four scenarios- Växjö

The analysis of key economic and energy use indicators, reported below for the different scenarios, provide additional insight on the changes affecting overall energy use.

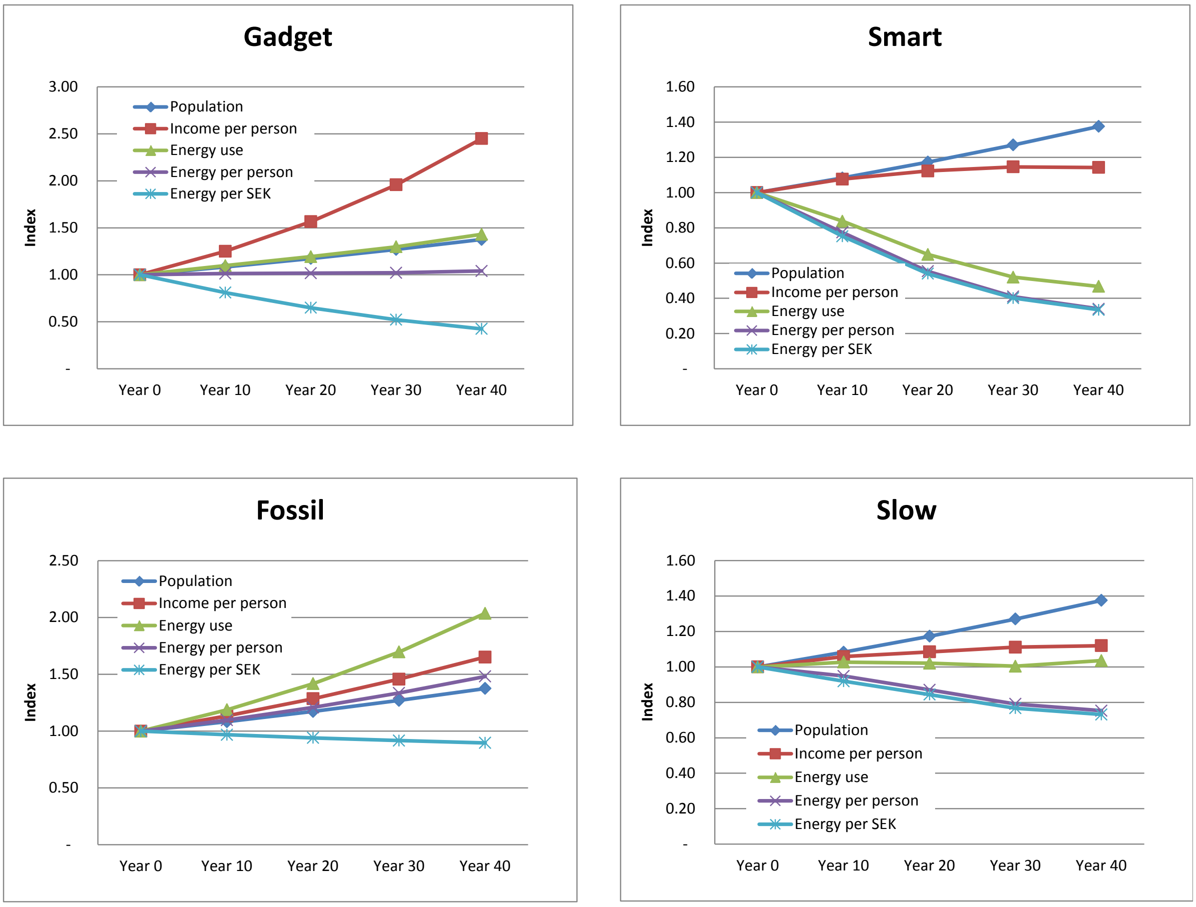
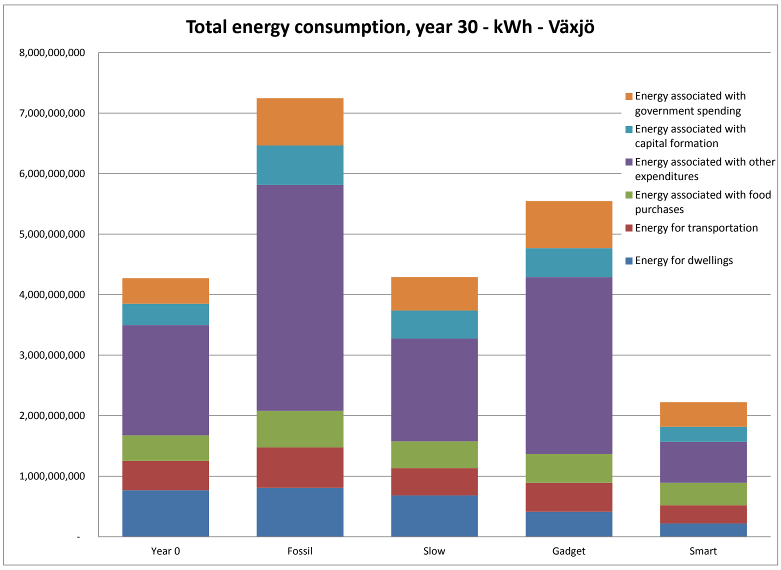


Figure 7: Projected changes over time (index value) in population, income per person, energy use per person, energy use per unit of GDP and total energy use – four scenarios, year 0 to year 40 - Växjö

Whereas the energy intensity of the economy (kWh/SEK) decreasese in all scenario, with significantly higher declines in Gadget and Smart, this efficiency increase is counterbalanced by increases in population and income per capita. This effect is particularly high in Gadget, leading to a stable level of energy uses per person and an increase in overall energy use (due to population increase). In the Slow City scenario the slower rate of technological improvement (kWh/SEK) is partially counterbalanced by a more moderate rate of income growth, leading to an overall decline in energy use per person and a stable value for total energy use. By combining a faster decline in the energy intensity with more moderate income growth rates (compared to Gadget), the Smart City scenario is projected to achieve significant declines in energy use per person and overall energy use.

The analysis of the energy use breakdown for different scenarios and of the changes in energy use vs. Year 0 (done for year 30 below) highlight the critical role played by ’other expenditures’ in driving energy use and changes in energy use. In the model, if energy efficiency improvements ’free up’ income, the additional income created is allocate to ’other expenditures’. The energy impact of other expenditures, can therefore be interpreted as the impact of rebound effects. As highlighted in the figures below, the rebound effects appear particularly strong in both Fossil and Gadget scenarios. In particular, in Gadget city scenarios, the rebound effect is projected to be strong enough to completely counterbalance the energy savings achieved (thanks to technological improvements) in dwelligs and transportation.



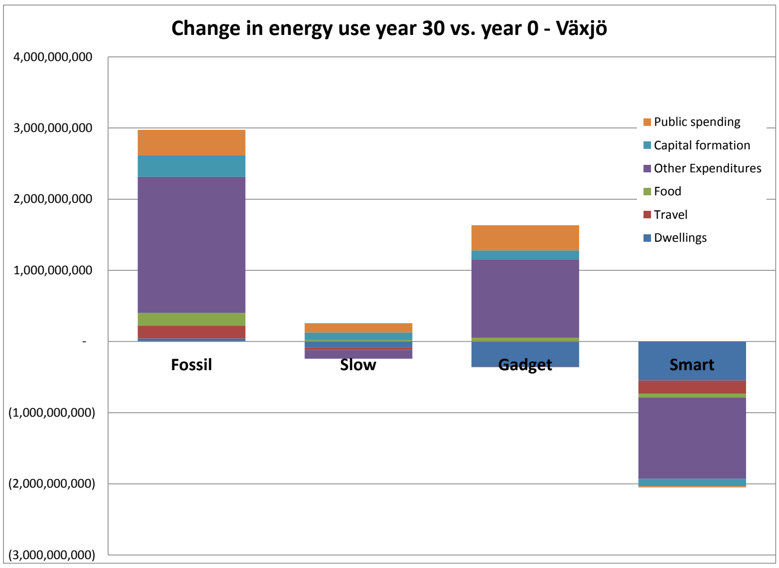
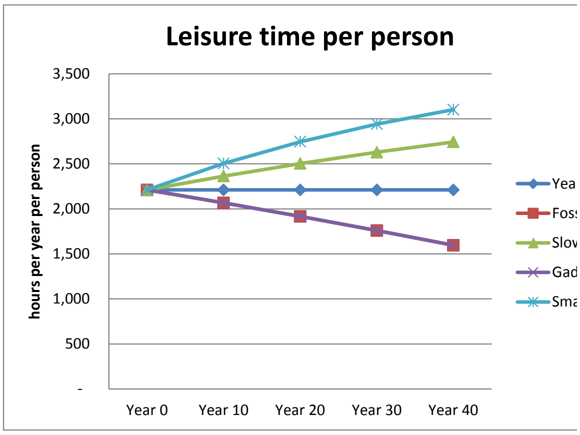


Figure 8: Year 30 breakdown of energy use and change in energy use vs. year 0. Four scenarios – Växjö

The time-use projections highlight that with both Fossil and Gadget scenarios, average leisure time will decline while average commiting time will increase, which should result in a decline in well-being. Conversely with Slow and Smart scenarios, leisure time increases and commuting time decreases, which should generate increases in the level of well being.



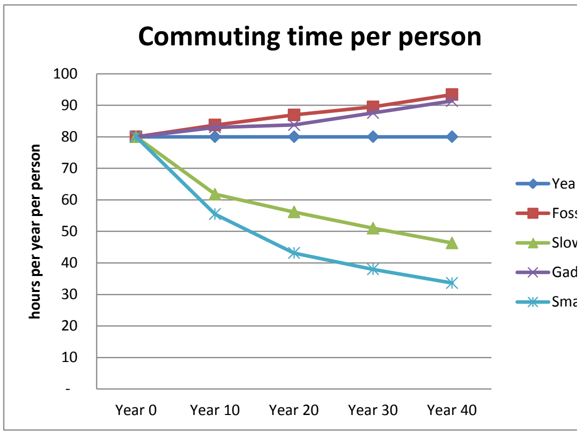


Figure 9: Time use analysis, leisure time and commuting time, year 0 to year 40, four scenarios - Växjö

A more complete picture of variables affecting well-being is provided in the table below, where per cent changes between year 0 and year 30 are reported. Green cells indicate changes with a positive well-being impact, while red cells highligh negative developments.

Variables	Units	Fossil	Slow	Gadget	Smart
Income per person vs. year 0	%	65.2 %	12.0 %	145.0 %	14.2 %
Unemployed people vs. year 0	%	38 %	-23 %	38 %	-23 %
% change in energy use vs. year 0	%	103.7 %	3.5 %	43.1 %	-53.2 %
% change in energy used per person vs. year 0	%	48.1 %	-24.7 %	4.0 %	-66.0 %
% change in energy use per SEK vs. year 0	%	-10.3 %	-26.9 %	-57.5 %	-66.6 %
Change in work time vs. year 0	h/person/ year	176	(533)	176	(892)
Change in chores & shopping time vs. year 0	h/person/ year	438	-	438	-
Change in average time spent commuting per person - ex. walking and biking	h/person/ year	13	(34)	11	(46)
Change in leisure time vs. year 0	h/person/ year	(614)	533	(614)	892

Table 4: Year 30, variables affecting well-being four scenarios – Växjö

The table highlights that in the model projections, Gadget outperforms Fossil and Smart outperforms Slow. Even if they deliver lower levels of economic growth, both Slow and Smart increase the level of well-being through a variety of different variables. In other words, the higher economic growth acheived in Fossil and Gadget, comes at a price. The model cannot produce a synthetic value to synthesise the overall well-being impact of all these variables, but a tool such as Table 4, should help decision makers.

4.2.2. Model simulation – Malmö

Projected energy consumption

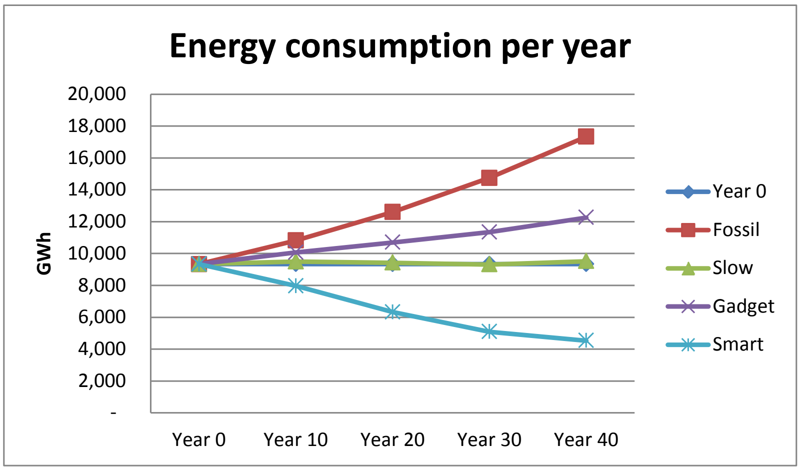


Figure 10: Total energy consumption over time for the four scenarios- Malmö

Key economic and energy use indicators.

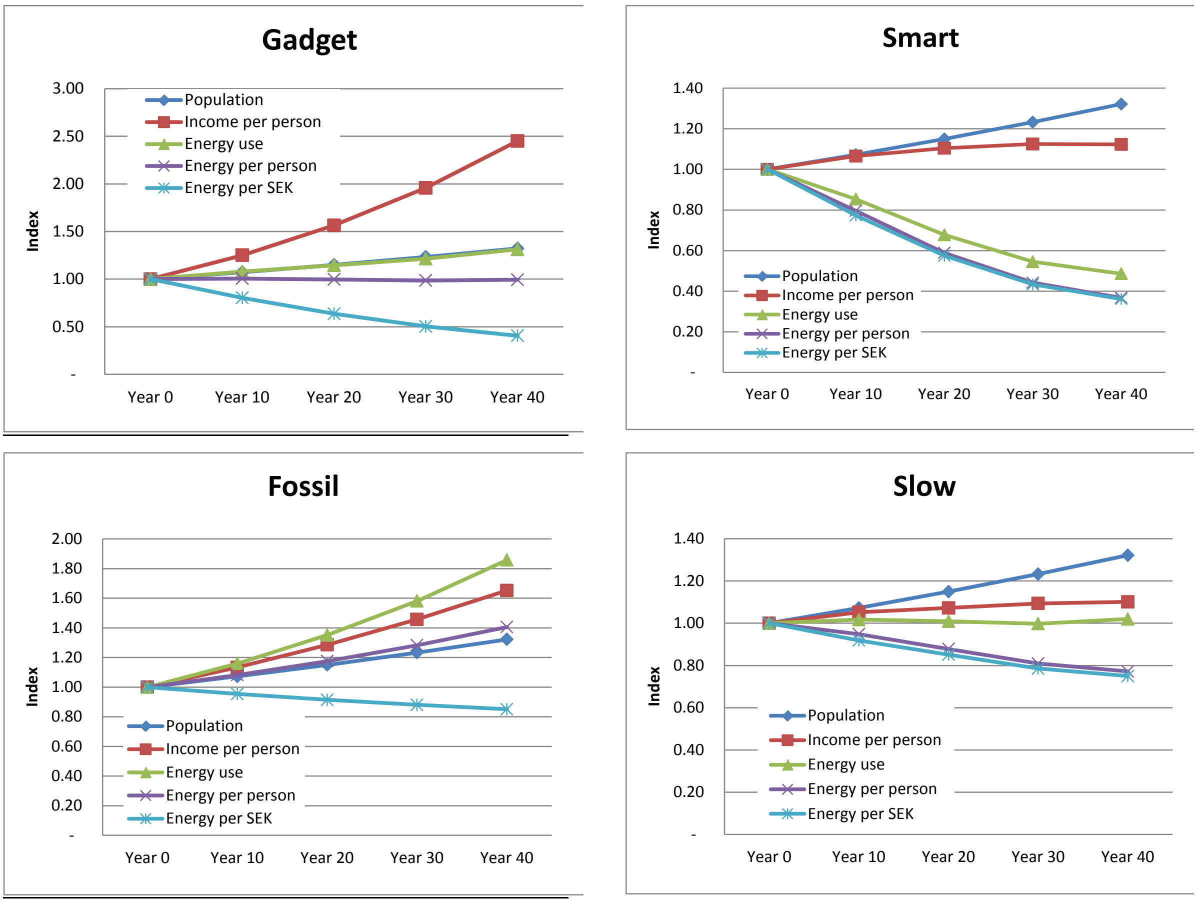
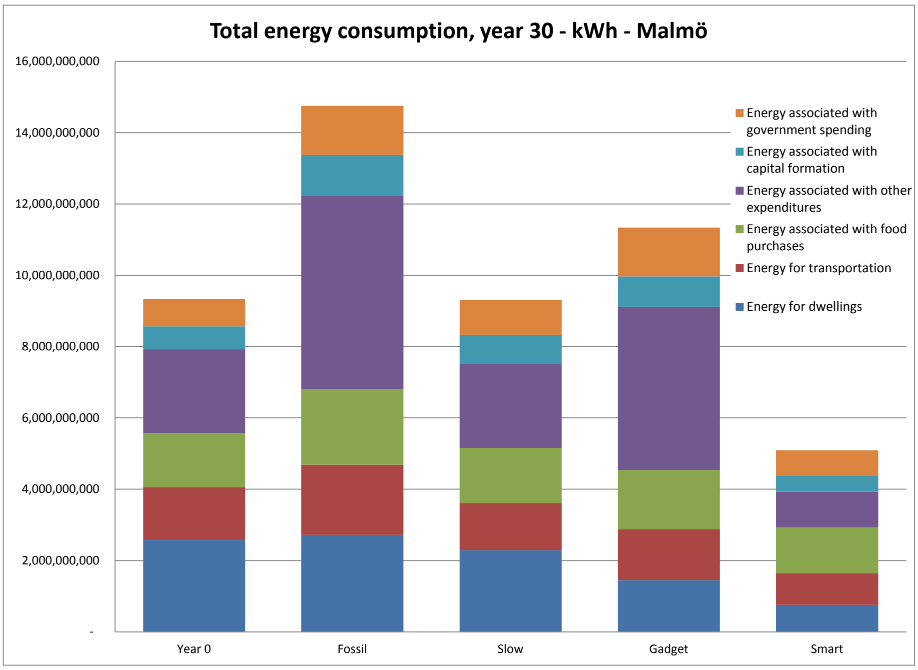


Figure 11: Projected changes over time (index value) in population, income per person, energy use per person, energy use per unit of GDP and total energy use – four scenarios, year 0 to year 40 – Malmö

Energy breakdown and changes in energy requirements (year 30).



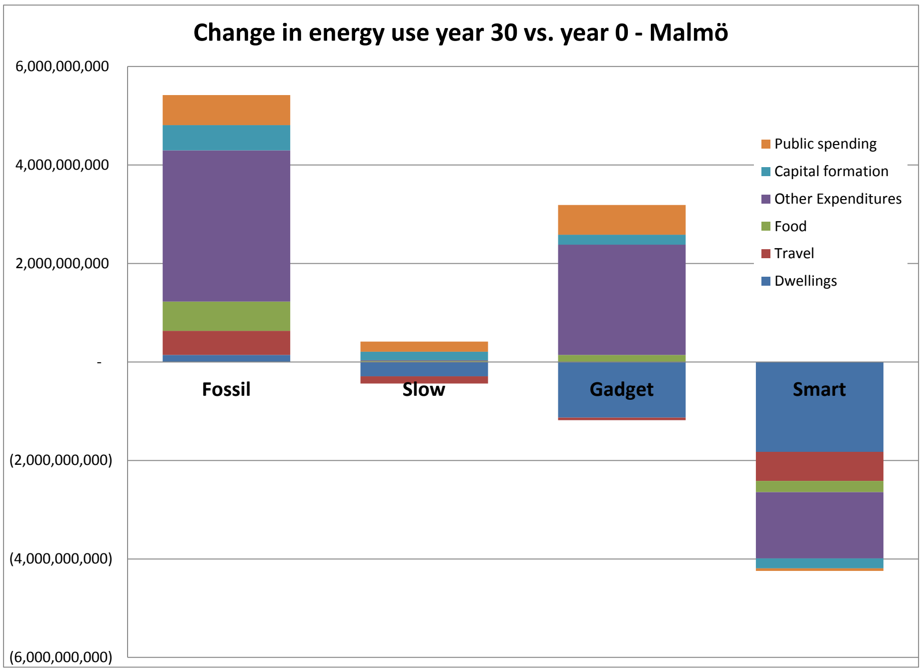
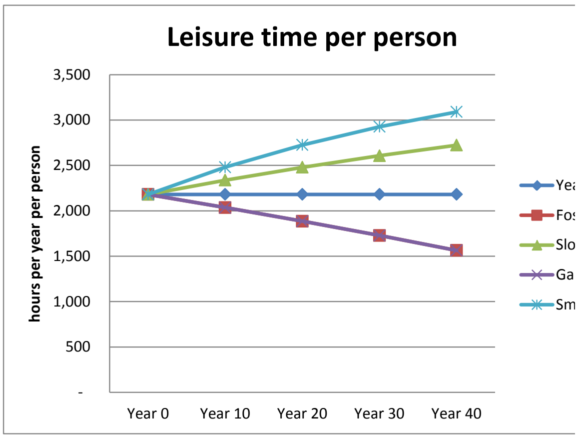


Figure 12: Year 30 breakdown of energy use and change in energy use vs. year 0. Four scenarios - Malmö

Time use changes associated with Well-being



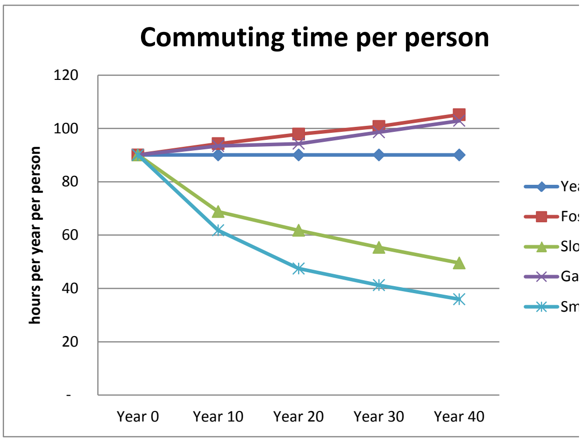


Figure 13: Time use analysis, leisure time and commuting time, year 0 to year 40, four scenarios - Malmö

Summary of well-being-realated-variables (for year 30) – changes vs. year 0. Green cells indicate changes with a positive well-being impact, while red cells highligh negative developments.

Variables	Units	Fossil	Slow	Gadget	Smart
Income per person vs. year 0	%	45.7 %	9.4 %	95.8 %	12.5 %
Unemployed people vs. year 0	%	23 %	-31 %	23 %	-31 %
% change in energy use vs. year 0	%	58.1 %	-0.3 %	21.5 %	-45.5 %
% change in energy useper person vs. year 0	%	28.2 %	-19.1 %	-1.4 %	-55.8 %
% change in energy use per SEK vs. year 0	%	-12.0 %	-21.5 %	-49.7 %	-56.7 %
Change in work time vs. year 0	h/person/year	133	(427)	133	(745)
Change in chores & shopping time vs. year 0	h/person/year	320	-	320	-
Change in average time spent commuting per person - ex. walking and biking	h/person/year	11	(35)	9	(49)
Change in leisure time vs. year 0	h/person/year	(453)	427	(453)	745

Table 5: Year 30, variables affecting well-being four scenarios – Malmö

4.2.3. Model simulation – Lund

Projected changes in energy consumption.

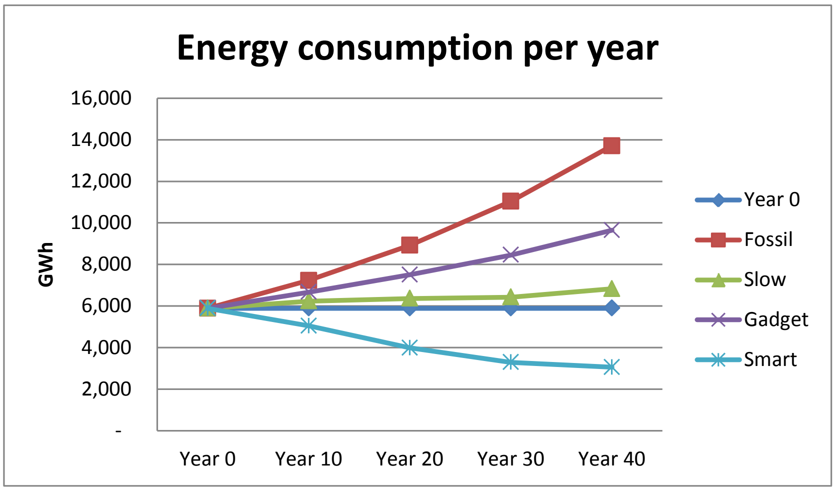


Figure 14: Total energy consumption over time for the four scenarios- Lund

Key economic and energy use indicators

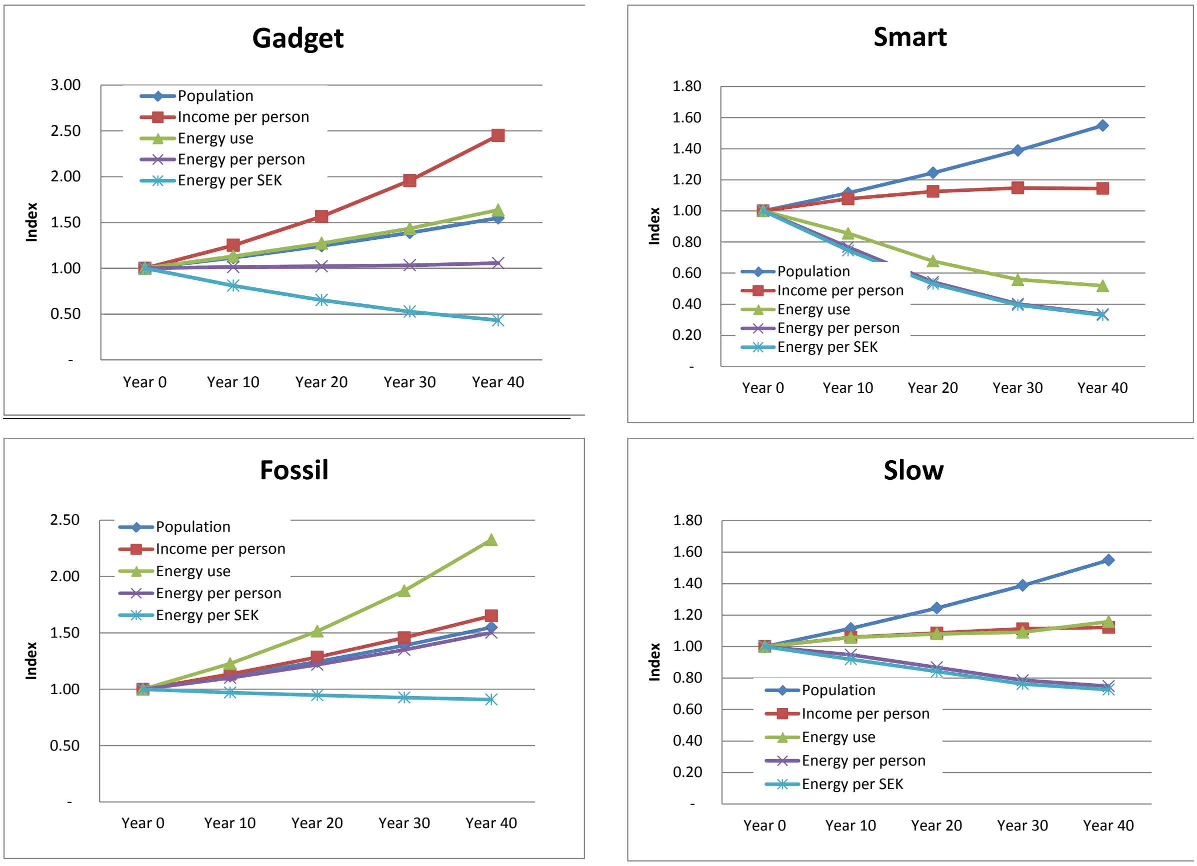
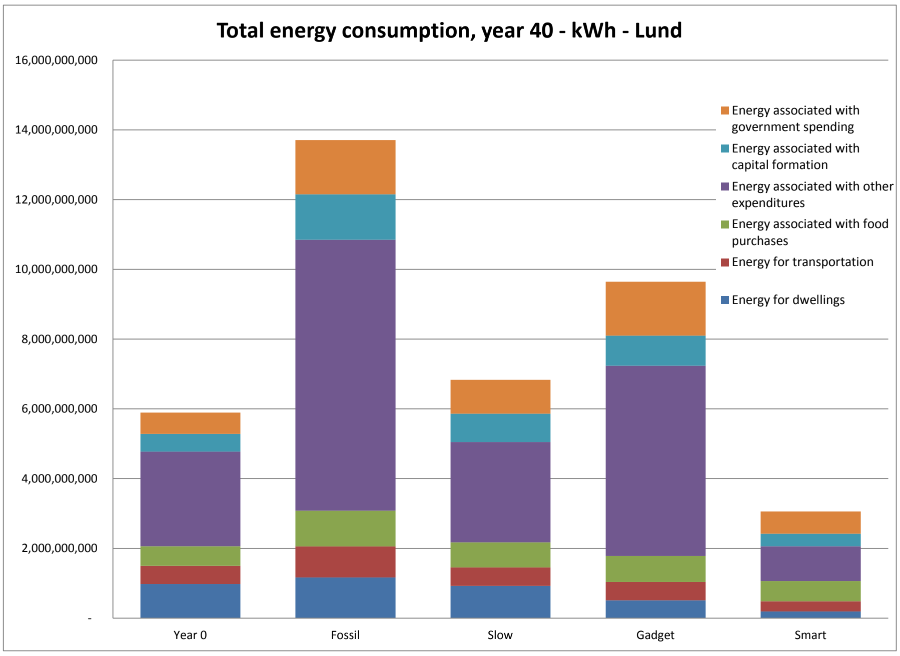


Figure 15: Projected changes over time (index value) in population, income per person, energy use per person, energy use per unit of GDP and total energy use – four scenarios, year 0 to year 40 - Lund

Energy breakdown and changes in energy requirements (year 30).



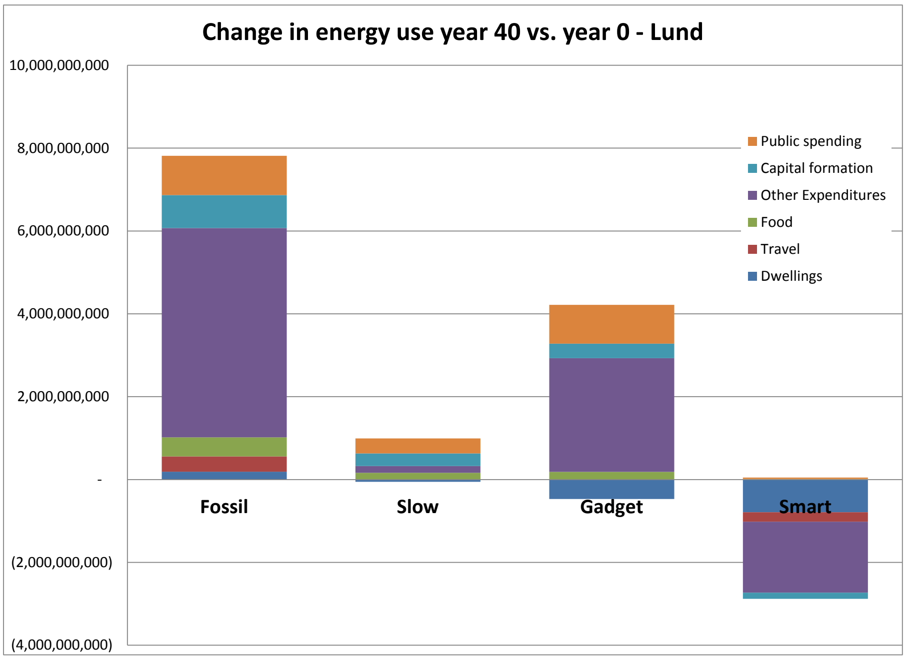
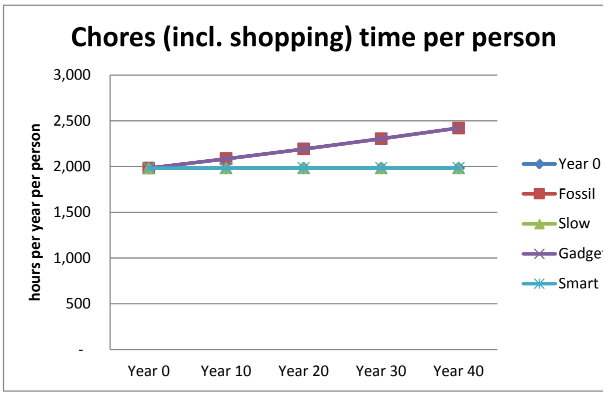


Figure 16: Year 30 breakdown of energy use and change in energy use vs. year 0. Four scenarios - Lund

Time use changes associated with Well-being (chores and commuting)



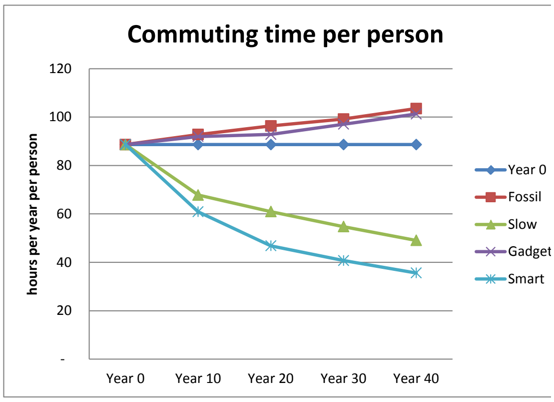


Figure 17: Time use analysis, chores time and commuting time, year 0 to year 40, four scenarios - Lund

Summary of well-being-related-variables (for year 30) – changes vs. year 0. Green cells indicate changes with a positive well-being impact, while red cells highligh negative developments.

Variables	Units	Fossil	Slow	Gadget	Smart
Income per person vs. year 0	%	65.2 %	12.2 %	145.0 %	14.4 %
Unemployed people vs. year 0	%	55 %	-13 %	55 %	-13 %
% change in energy use vs. year 0	%	132.6 %	15.9 %	63.7 %	-48.1 %
% change in energy useper person vs. year 0	%	50.2 %	-25.2 %	5.7 %	-66.5 %
% change in energy use per SEK vs. year 0	%	-9.1 %	-27.3 %	-56.9 %	-67.0 %
Change in work time vs. year 0	h/person/year	179	(543)	179	(908)
Change in chores & shopping time vs. year 0	h/person/year	438	-	438	-
Change in average time spent commuting per person - ex. walking and biking	h/person/year	15	(40)	13	(53)
Change in leisure time vs. year 0	h/person/year	(617)	543	(617)	908

Table 6: Year 30, variables affecting well-being four scenarios – Lund

4.2.4. Model simulation – Göteborg

Projected changes in energy consumption

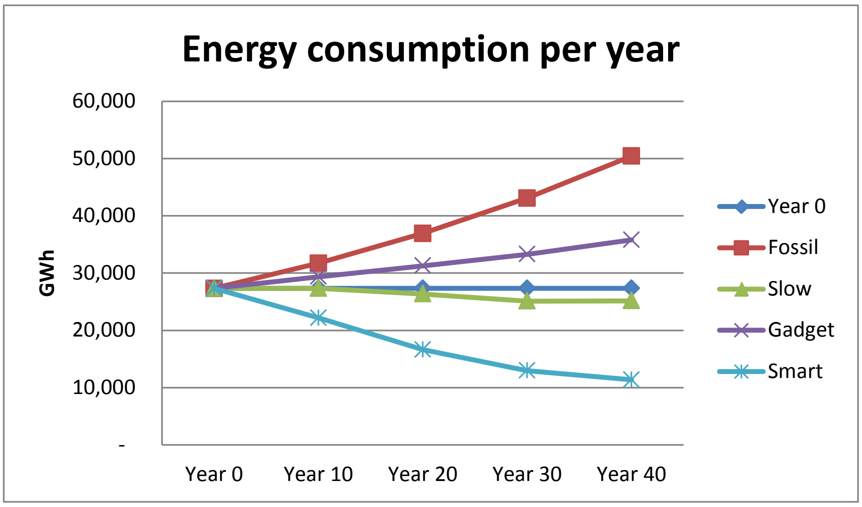


Figure 18: Total energy consumption over time for the four scenarios- Göteborg

Key economic and energy use indicators

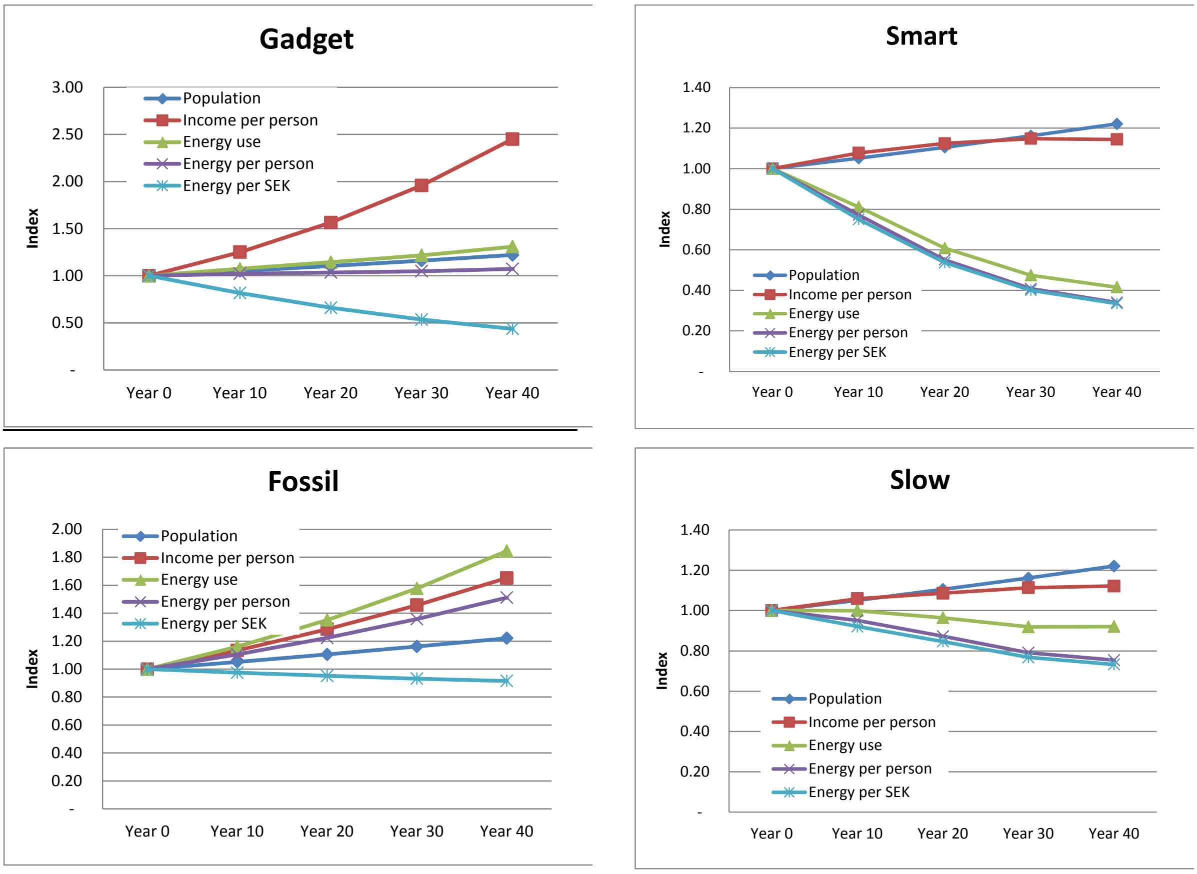


Figure 19: Projected changes over time (index value) in population, income per person, energy use per person, energy use per unit of GDP and total energy use – four scenarios, year 0 to year 40 - Göteborg

Energy breakdown and changes in energy requirements (year 30).

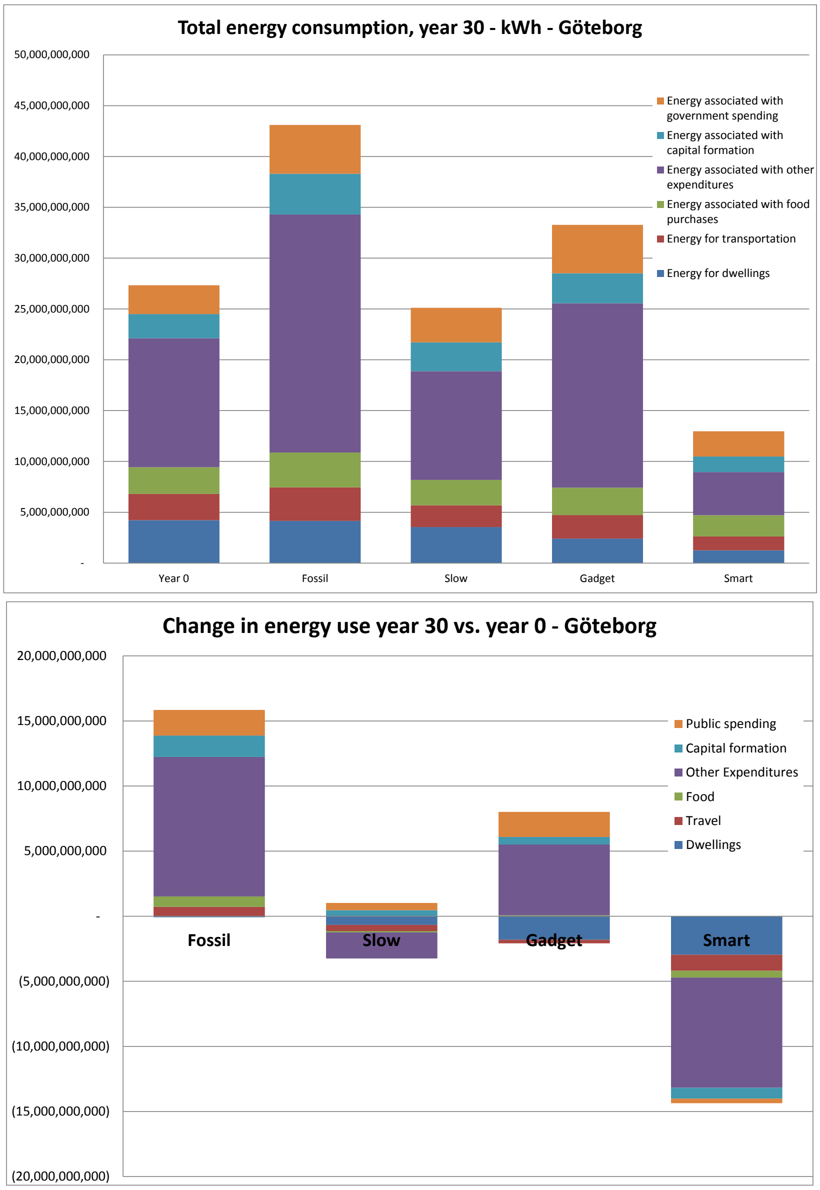
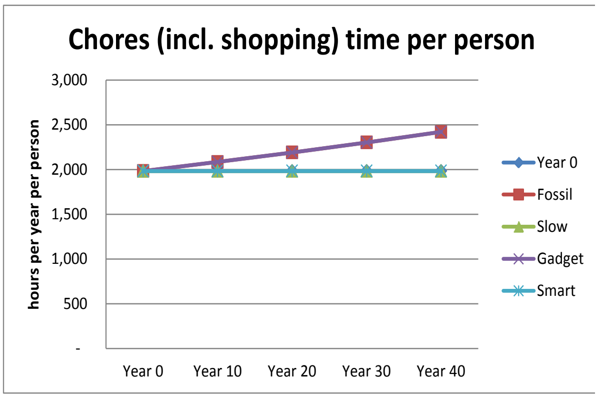


Figure 20: Year 30 breakdown of energy use and change in energy use vs. year 0. Four scenarios - Göteborg

Time use changes associated with Well-being.



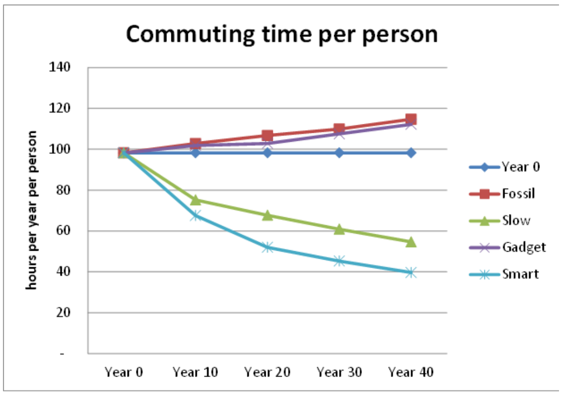


Figure 21: Time use analysis, Chore time and commuting time, year 0 to year 40, four scenarios - Göteborg

Summary of well-being-realated-variables (for year 30) – changes vs. year 0. Green cells indicate changes with a positive well-being impact, while red cells highligh negative developments.

Variables	Units	Fossil	Slow	Gadget	Smart
Income per person vs. year 0	%	45.7 %	11.3 %	95.8 %	14.8 %
Unemployed people vs. year 0	%	16 %	-35 %	16 %	-35 %
% change in energy use vs. year 0	%	57.7 %	-8.1 %	21.7 %	-52.5 %
% change in energy useper person vs. year 0	%	35.8 %	-20.9 %	4.8 %	-59.1 %
% change in energy use per SEK vs. year 0	%	-6.8 %	-23.2 %	-46.5 %	-60.0 %
Change in work time vs. year 0	h/person/year	133	(427)	133	(745)
Change in chores & shopping time vs. year 0	h/person/year	320	-	320	-
Change in average time spent commuting per person - ex. walking and biking	h/person/year	12	(37)	9	(53)
Change in leisure time vs. year 0	h/person/year	(453)	427	(453)	745

Table 7: Year 30, variables affecting well-being four scenarios – Göteborg

4.2.5. Model simulation – Stockholm

Projected changes in energy consumption

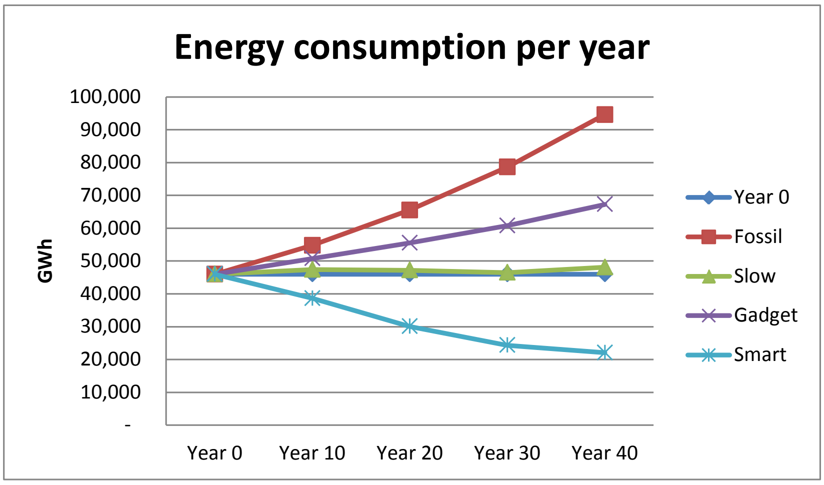


Figure 22: Total energy consumption over time for the four scenarios- Stockholm

Key economic and energy use indicators

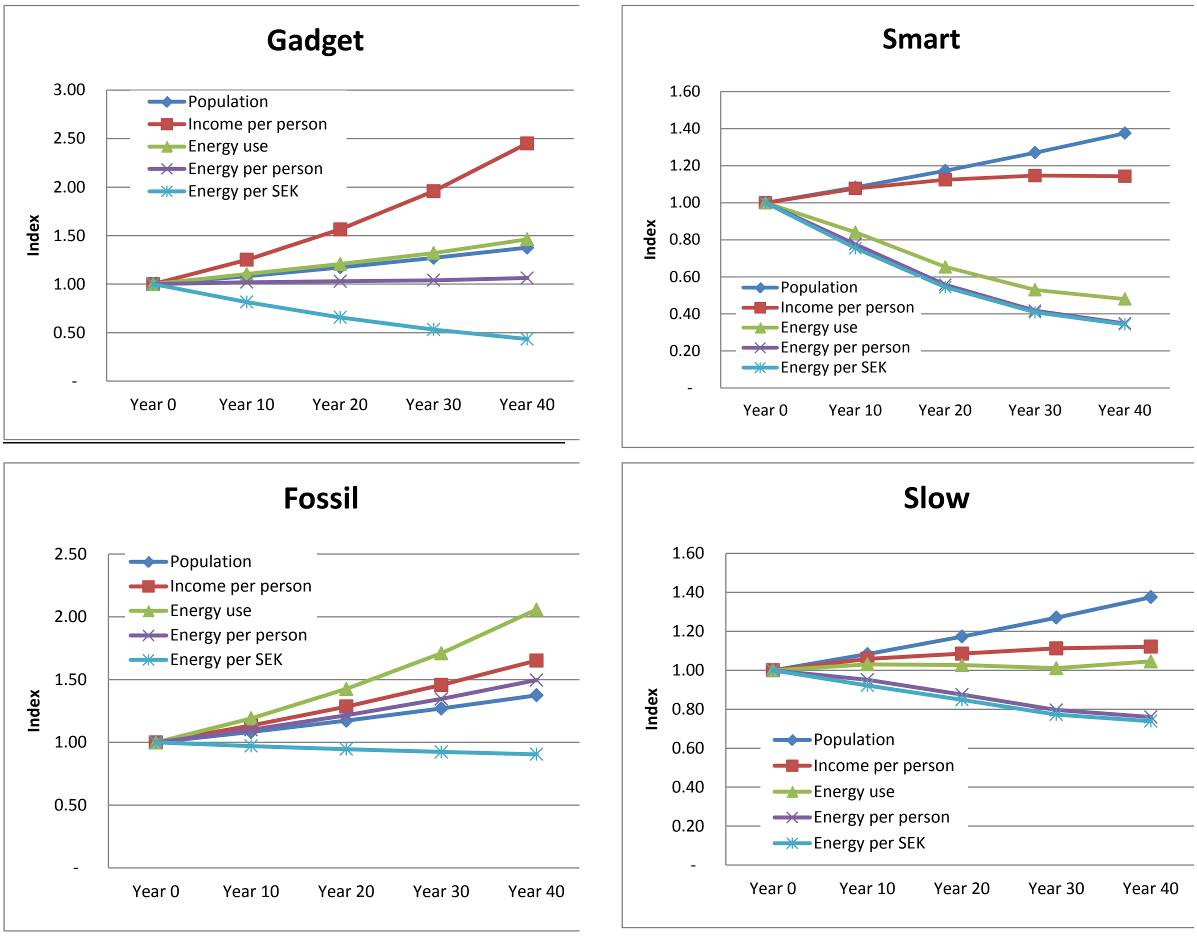
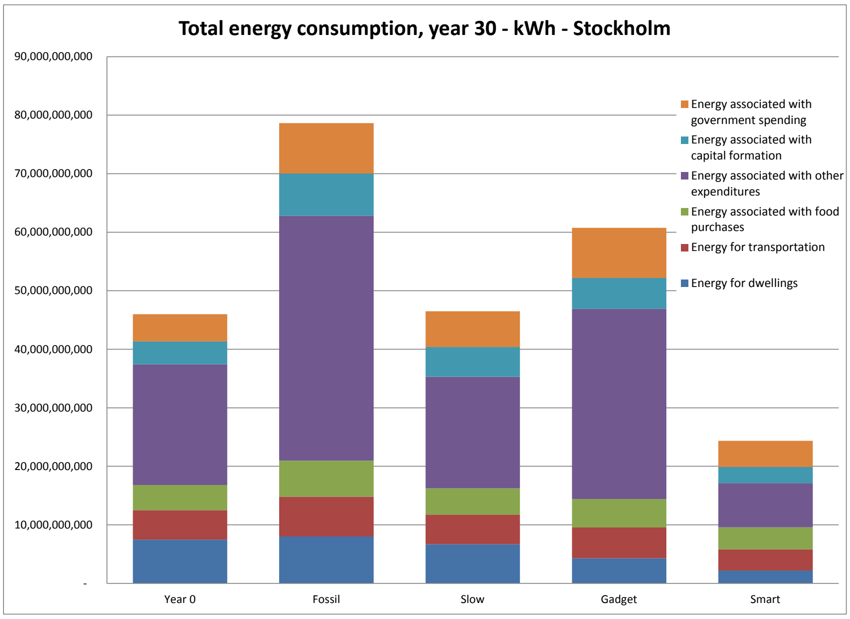


Figure 23: Projected changes over time (index value) in population, income per person, energy use per person, energy use per unit of GDP and total energy use – four scenarios, year 0 to year 40 - Stockholm

Energy breakdown and changes in energy requirements (year 30).



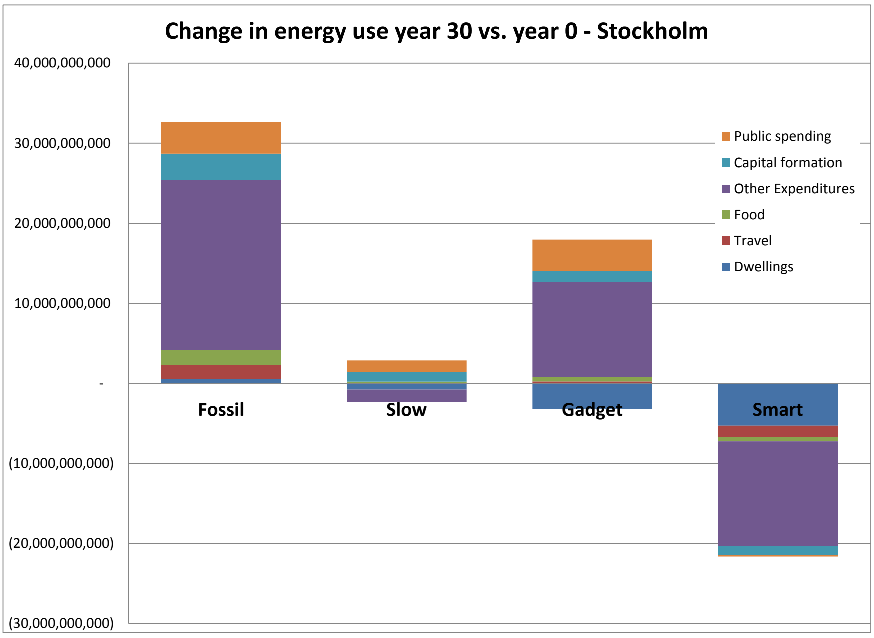


Figure 24: Year 30 breakdown of energy use and change in energy use vs. year 0. Four scenarios - Stockholm

Time use changes associated with Well-being (work time and commuting time)

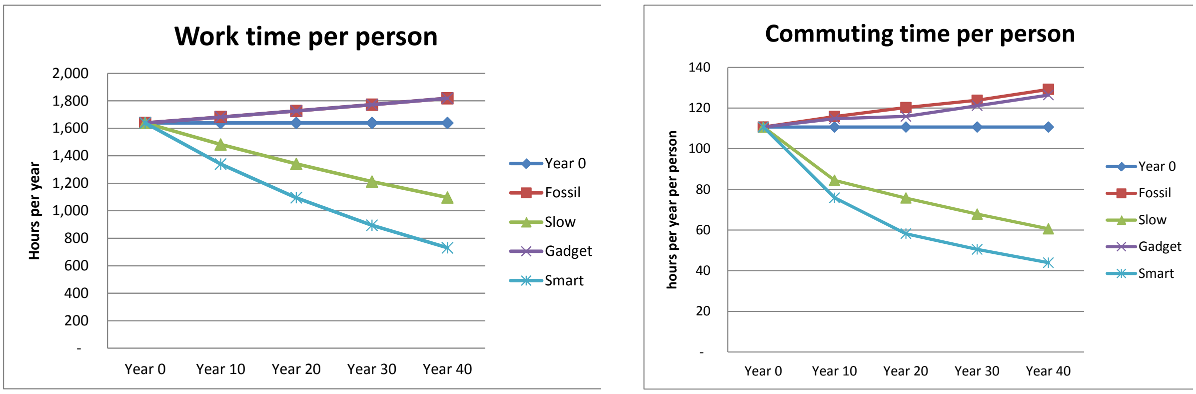


Figure 25: Time use analysis, work time and commuting time, year 0 to year 40, four scenarios - Stockholm

Summary of well-being-related-variables (for year 30) – changes vs. year 0. Green cells indicate changes with a positive well-being impact, while red cells highligh negative developments.

Variables	Units	Fossil	Slow	Gadget	Smart
Income per person vs. year 0	%	45.7 %	11.2 %	95.8 %	14.7 %
Unemployed people vs. year 0	%	27 %	-28 %	27 %	-28 %
% change in energy use vs. year 0	%	71.0 %	1.1 %	32.1 %	-47.1 %
% change in energy use per person vs. year 0	%	34.6 %	-20.4 %	4.0 %	-58.3 %
	%	-7.6 %	-22.7 %	-46.9 %	-59.2 %
Change in work time vs. year 0	h/person/year	133	(427)	133	(745)
Change in chores & shopping time vs. year 0	h/person/year	320	-	320	-
Change in average time spent commuting per person - ex. walking and biking	h/person/year	13	(43)	10	(60)
Change in leisure time vs. year 0	h/person/year	(453)	427	(453)	745

Table 8: Year 30, variables affecting well-being four scenarios – Stockholm

4.1.6. Model simulation – sensitivity analysis

The scenarios simulated by the model buid on a variety of data and assumptions. Whereas each input plays a role in the final energy consumption estimate, the impacts of some of the inputs is clearly stronger than others. For some of the assumptions used in the model, the table below summarizes the sensitivity of the energy consumption estimate, using the model run *Malmö 2030* as reference – changes higher thatn 3 % are highlighted in bold.

Variable changed	Year 0	Fossil	Slow	Gadget	Smart
Population growth per year is 0.8% and not 0.7 %	0.0 %	2.9 %	2.7 %	2.8 %	2.6 %
Productivity increase reduced by 20 % (0.8 % and 1.6 % p.a. vs. 1 % and 2 %)	0.0 %	-4.2 %	-3.4 %	-8.1 %	-5.6 %
Dwelling refurbishing and rebuilding rates reduced by 20 %	0.0 %	0.2 %	0.7 %	2.0 %	6.1 %
M2 per person increase by 20 %	0.0 %	0.7 %	0.7 %	0.4 %	0.0 %
Energy intensity in dwellings increases by 20 %	0.0 %	1.2 %	1.4 %	1.8 %	1.9 %
The speed of switches between travel modes increases by 20 %	0.0 %	0.0 %	-0.6 %	0.0 %	-0.6 %
Rate of technological improvement in transportation increases by 20 %	0.0 %	0.0 %	0.0 %	-1.0 %	-1.3 %
Rate of change in work time is 20 % faster	0.0 %	1.0 %	-3.5 %	1.0 %	-5.9 %
100 % response of leisure travel to income changes (rather than 50 %)	0.0 %	0.7 %	0.0 %	1.5 %	0.0 %
Average energy intensity of food is 20 % higher	3.3 %	2.9 %	3.3 %	2.9 %	5.1 %
Low energy food baskets can deliver 8 % energy savings rather than 4 %	0.0 %	0.0 %	-0.7 %	0.0 %	-1.1 %
Reduction in food waste is halved	0.0 %	0.0 %	0.6 %	0.0 %	2.2 %
Average energy intensity of other expenditures is 20 % higher	5.0 %	7.3 %	5.1 %	8.1 %	3.9 %
Technology improvements in industry are 20 % higher	0.0 %	0.0 %	0.0 %	-4.7 %	-2.3 %
The energy impact of collaborative consumption is reduced by 20 %	0.0 %	0.0 %	2.5 %	0.0 %	4.7 %
The potential impact of switching to low energy consumption baskets is doubled	0.0 %	0.0 %	-2.0 %	0.0 %	-2.2 %
The energy intensity of capital formation is 20 % higher	1.4 %	1.6 %	1.8 %	1.5 %	1.7 %
Technology improvements in capital formation are 20 % higher	0.0 %	0.0 %	0.0 %	-0.9 %	-1.0 %
The energy intensity of public expenditures is 20 % higher	1.6 %	1.9 %	2.1 %	2.4 %	2.8 %
Energy savings in public expenditures are 20 % higher	0.0 %	0.0 %	0.0 %	-0.7 %	-0.8 %

Table 9: Sensitivity analysis changes in energy consumption deriving from changes in selected variables –Malmö 2030 projections used

Significantly the sensitivity analysis highlights that several of the variables with the highest impact on energy consumption are not variables on which traditional energy models focus. For the Smart City scenario for example, the variables with the highest impact include: changes in productivity, changes in the real estate market (rate of refurbishment and rebuildings), changes in labor supply (changes in work time), average energy intensity of food consumption and average energy impact of collaborative consumption. This highlights the relevance of WWF's desire to take a broader approach when looking at 'energy smart cities'.

4.3. Excel tool discussion

The structure of the excel tool enables several interesting analysis that shed light on how future energy use trajectories could unfold. In particular, the tool enables the exploration of some energy- drivers, and decisions about such drivers, which are rarely (if ever) analyzed together. Examples of novel model components include:

- The explicit inclusion of a labor supply component in the analysis, in the form of choices about the allocation of time between paid work and personal time. These choices affecting overall production (measured quantitatively in the tool) and well-being levels (measured indirectly in through ‘work time’ and ‘leisure time’)
- The adoption of a consumer perspective, when assessing of the energy demands of a city, so that also energy (and emissions) ‘imported’ through purchases of products and services, from outside the boundaries of a city, are included. This approach provides a more complete picture of the energy impact of a city and is similar to the approach followed in REAP tool
- The explicit analysis of collaborative consumption impacts, which may affect housing and consumption choices, enabling a reduction in the infrastructure and products required to deliver a given service/benefit
- The tracking of income changes (and household budgets), resulting from productivity improvements and energy savings, which enable the quantification of the additional economic resources made available for consumption, and the resulting increase in energy use (rebound effects)
- The monitoring/simulation of ‘soft’ (from a traditional economist’s perspective) well-being indicators, such as leisure time, commuting time or level of employment/unemployment

As the Excel tool tries novel calculation approaches of complex and interacting systems to project future energy use trajectories, it also suffer a number of limitations. The table below lists some of the areas where improvements are possible; discussing how such improvements could be obtained.

Areas of improvement	Possible improvement
The calculations of the various interactions and feedbacks, occurring within a socio-economic system in response to technological, behavioral, cultural, infrastructural and financial changes are mostly treated as independent variables, as the model does not deploy a full input-output matrix for the economy and instead used life cycle estimates (e.g. for indicators such as kWh/SEK spent on product x).	New model design, built around economy-wide input-output matrixes. Such models are typically highly complex, but solutions already considered (REAP) include a input-output matrix at its core
Some of life cycle variables used as inputs, were estimated using a relatively limited and aggregated set of data. E.g. this is the case for the energy intensity parameter (kWh/SEK) for capital formation and public expenditure, which were calculated from REAP numbers. Due to the uncertainty of these parameters and the fact that they are used at a high level of aggregation, they significantly contribute to the uncertainty of the end-results	Further analyze these variables, ideally in conjunction with SEI's REAP team, to refine the estimates and, if appropriate and possible, undertake calculations at a lower level of aggregation (e.g. individual investment categories instead that 'capital formation' as a whole)
The inputs necessary for the calculations include some variables that are not typically monitored by the cities or by Statistics Sweden. For such inputs, estimates had to be made, often using data coming from multiple sources. This adds a layer of uncertainty to the inputs both because of the additional calculation step and because of possible reconciliation problems with data coming from different sources	Work with municipalities (and with Statistics Sweden and the Energy Agency) to collect relevant input data, or improve the current estimates
Food's energy intensity parameters are currently based on energy content per unit of expenditures (kWh/SEK). This indicator is somewhat distorted as high-value foods tend to have lower energy intensity values, regardless of their caloric or nutritional content.	Revise food calculations to include the calories and nutrition values provided by different foods so that projection can be made in which 'nourishment needs (calories and nutrients) are provided at minimum energy costs'
The impact of collaborative consumption is based on assumptions on 'number people that could share product x, while receiving product x's services in an amount equal to the one received, if they owned product x'. We have found no academic literature on this topic and the publications focusing on collaborative consumption offer only limited and anecdotal examples (perhaps selected based on availability and to support the collaborative consumption case, rather than assessing the potential collaborative consumption impact). Given significance of collaborative consumption in the model, the uncertainty associated to this parameters reverberates on overall model results.	Wait for more rigorous research on collaborative consumption to become available – monitor and engage the field. Undertake more research on collaborative consumption and its potential impacts on energy use and the environment (the scope of such project is likely to be significant)
The excel model does not include an estimate for the overall level of well-being achieved in different scenarios. A number of variables, which are correlated to well-being, are projected, but other variables that may be of relevance (e.g. amount of green space, level of social cohesion, cultural scene, etc.) are not estimated quantitatively.	Monitor the field of well-being economics for additional insights, and development, on indicators. Explore opportunities to produce additional indicators/proxies for well-being. Explore ways to synthesize different well-being indicators into one, or a smaller number of, higher level indicators(s).

Table 10: Excel tool - limitations and possible improvements

Overall the Excel tool provides a good starting point for the analysis of the complex dynamics the WWF wants to explore, as it extends the scope of traditional energy models and enables users to simulate the energy impacts of drivers, which are rarely included in energy models (e.g. choices associated to work-life balance or collaborative consumption). The use of the model, and the reflection on its strengths and weaknesses, highlights several areas where improvements are possible, and where more detailed and sophisticated modeling approaches could improve on the tool's results.

5. Recommendation for REAP implementation and development

This section focuses on the 'wish list' of functionalities (and data) that would enable a better modeling of the urban transformations the WWF wants to study (and achieve). In particular, the section focuses on the REAP model, as this model is currently used, or considered for use, by a number of Swedish municipalities and by WWF. After quickly summarizing the main characteristics of the REAP tool the section illustrates specific functionalities/modules that could be added to REAP, discussing the opportunities and challenges that adding such functionalities/modules may bring.

Note: This section is based on our understanding of the REAP tool, which we developed during the project by 'playing' with the tool. We also exchanged occasional emails with SEI (REAP's developers), but we were not able to organize direct person-to-person conversations with SEI, prior to the redaction of this report. Our understanding of the working of the REAP tool may not be fully accurate at times, and we would have wanted to discuss our ideas and proposals with the model developers to obtain their feedback and to refine our ideas. Despite our inability to do so, we believe that the comments below provide relevant ideas for the improvement of the REAP tool.

5.1. REAP characteristics

REAP has at least four characteristics that make it a good starting point for the type of analysis and explorations the WWF wants to undertake:

- REAP is designed with a focus on urban/regional level analysis, and has already been populated with Swedish data.
- REAP looks at energy and emissions from a consumption perspective, also including the 'imported' impacts associated with the production of goods and services used in a city but produced elsewhere. This is highly valuable for the analysis of Swedish cities (and of many other cities in western countries), which import a high proportion of high-energy goods and services from abroad.
- REAP calculates impacts using input-output matrixes (Leontief), which are able to simulate how the impact of a specific change (e.g. switching demand from good A to good B) ripples through the various sectors of the economy associated (directly or indirectly) with the change. Being able to undertake analyses with this level of complexity/sophistication provides a significant advantage when assessing multiple changes of interconnected variables, where multiple feedbacks are presents, which are the essence of the transformative solutions WWF wants to analyze.
- Scenario analysis is central to REAP's design and interface

Some of the key inputs for a REAP simulation are:

- Parameters open to the end-user manipulation (for scenario calculation)
    - Population
    - Expenditures for final demand (SEK/person/year)
    - Transportation parameters such as demand (km/person/year) for different modes of transportation, occupancy rates and changes in efficiency (index) parameters
    - Households' domestic energy consumption parameters such as electricity or

liquids fuel use per person per year
    - Energy mix parameters
- Parameters not available for the end-user manipulation – managed by the modelers
    - Input output matrixes
    - Import and export data
    - Associated environmental impact parameters (it is not fully clear how these parameters are derived and how they are coupled with input-output matrixes and import-export data)

As it currently stands, REAP would be able to simulate some of the components of the scenarios developed in this project such as change behavior leading to lower expenditures in high-energy goods and services. A number of critical simulations, however, would not be feasible with REAP or would be hard to implement e.g. changes in energy consumption due to changes in working hours or the take up of collaborative consumption.

5.2. Possible REAP improvements

We believe that the following functionalities/modules would be required for REAP to simulate the scenarios developed in this project:

1. A production module to calculate labor supply (supplied hours = active population * employment rate * hours worked per employee) and production (SEK production = supplied hours * SEK produced per hour). This is critical to simulate changes in work-life balance and resulting impacts on production, disposable income and environmental impact. REAP already includes population data, and it should be relatively straightforward to add the additional variables required for this module. A possible complication is that the Leontief tables may not have any explicit link with labor supply, but this may not be an issue since the main impact should go through 'final demand' which is a model input (scenario variables) for REAP.
2. Currently REAP's assumptions for energy use in dwellings are based on 'energy use per person' (SEK/person/year) assumptions. Such assumptions are inputs to the model and are not explicitly linked to assumption on the energy performance of (new and old) buildings. It may be possible to overlay the calculations used in the Excel tool onto REAP, so that assumptions on the energy performance of new and refurbished buildings, and the ratio or renewal and rebuilding become key drivers for the analysis.
3. For goods services and food, the current scenario variables in REAP are SEK/Person/year, and these variables drive production and import demands, which result in different energy requirement and associated emissions. Currently the model requires users to enter separate inputs for each expenditure category considered. As there are about 70 categories, manually changing each individual category to run a simulation is cumbersome. The usability would be improved if end-users were able to change all factors at once, and/or to link such change with the module described in 1 above, to incorporate different assumptions on productivity or labor supply. End users would also benefit if they were able to create groups of goods and services and to rapidly change assumptions at group level, e.g. to reflect switches from high-energy categories to low energy ones.
4. If a 'calorie based' module is created for food (and this can be done within REAP or in a separate model) such module could simulate and identify food consumption baskets that provide similar benefits (in terms of nourishment and food quality) while requiring less energy or generating less GHG emissions. Such food-expenditures basked could then be applied within REAP to simulate the impact on energy consumption. The low-energy-food-basket will likely lead to changes in the overall basket devoted to food purchases and such changes should also be reflected within REAP (and can be used to make an adjustment in 'other expenditures' if the same approach used in the Excel tool is followed).
5. Collaborative consumptions breaks historical relationships between expenditures and energy/ environmental impacts, as they reduce the amount of goods needed to deliver the same service (e.g. with car-sharing 10 customers may share a vehicle rather than owning a vehicle each, even though other variables, such as km travelled per person, may be unchanged). It would be relevant to integrated this type of impact into REAP. A possible approach is to create new (with collaborative consumption) expenditure categories and map them onto the current (no collaborative consumption) REAP's

expenditure categories. Take up in collaborative consumption could then be modeled by changing the relative weight of current expenditure categories. For example, car sharing may lead to 10 people using 1 car, rather than those 10 people owning 10 cars, while their km travelled per year, and expenditure on car use, may remain the same (or decrease). To provide their services, however, car sharing companies will also run more extensive ICT systems to manage their fleets and members, invoice customers, handle customer care, etc. Thus to deliver the same benefit to a car users with car sharing, less cars will be produced but more extensive demands will be placed on sectors such as ICT. If car sharing is assumed to be cheaper that car ownership, additional income will become available for other expenditures. Similar dynamics seem to apply to all expenditure categories subject to collaborative consumption: a decrease in demand for the product that is shared coupled with an increase in demand for customer relations and ICT systems and, possibly, an increase in disposable income, which could be used for other expenditures.

6. With technological change, the variables included in the Leontief tables are affected, especially when inputs and outputs are expressed in quantities/energy (but the same is likely to hold if the tables are in SEK). E.g. if to produce 1 ton of paper new processes enable the use of ½ the energy and ½ the materials used with old processes, the relevant matrix cells for input energy and materials can be reduced by ½, while paper output remain unchanged. To simulate technological change (especially in industry/expenditures) it is therefore important to modify input-output parameters included in the matrixes. Currently the REAP tool does not enable these changes and it appears that current licensing restrictions preclude this option [in a recent email exchange SEI pointed out that *"…you cannot adjust the Leontief Inverse Matrix (structure of the economy), total production or Direct Impact Multipliers because these are based on GTAP data and the GTAP license prohibits disclosure of these data"*]. If licensing restrictions cannot be overcome, REAP's ability to model technological changes, and their effects as they ripple through the whole economy, will be significantly limited. This is an area where further discussions with SEI will be needed to explore possible solutions.
7. Currently REAP can be used to simulate individual cities, regions or Sweden as a whole. The available choices seem to be pre-determined. It would be relevant for end-users to be able to select and combine municipalities of their own choosing, independent from geographic proximity. E.g. one could envision a split in metropolitan municipalities, suburban municipalities, large cities, commuter municipalities, sparsely populated municipalities, etc. It is not fully clear if end users already have this level of control with REAP. It looks like they don't but that it may be an easy functionality to add.
8. For some variables, such households energy demand (on a per person basis) or transportation variables, REAP seems to be using the same assumption for all municipalities in Sweden. This is an oversimplification which limit the insight provided by REAP. It would be relevant to consider other drivers for some of the energy requirements, such as dwelling size, dwelling performance, type of urban environment (e.g. dense and mixed use vs. sprawled and segregated), availability of public transport infrastructure etc.

6. Conclusions and next steps

The goal of this study was to better understand how cities can become smart energy users, i.e. delivering a high quality of life to their citizens, while using a minimum amount of energy. The background analysis undertaken at the beginning of the project identified several factors that drive energy use in cities and, building on this analysis, the project team articulated and described four alternative scenarios for evaluation. The excel model used to simulate and assess the scenarios (using five Swedish cities as case study) provided insights and how 'energy smart' could be achieved and highlighted areas where further analysis and modeling work is required.

The study ambition was to take a broader approach in assessing potential energy savings in urban environments, considering opportunities for technological development, urban design and cultural and behavioral change. Moreover, the scenarios developed for the project, explicitly included well-being creation (as opposite to mere GDP enhancement) as a primary goal for cities and the quantification model tracked a number of well-being indicators alongside energy indicators.

The most important results of the study can be summarized as follows:

- Broadening the analysis beyond traditional energy system variables provides a more complete, and likely accurate, depiction of how and why cities consume energy. Moreover a broader approach provides better information on the actual benefits (well-being) generated by the energy used.
- The explicit inclusion of productivity and employment indicators in the modeling sheds light on how these economic variables affect energy consumption:
  - Growth in (labor) productivity tend to increase energy use as it enhances wealth and (in business as usual situations) this results in higher consumption, which, in turn, drives energy use up
  - Choices pertaining work-life balance (time spent working vs. socializing or leisurely) determine how productivity gains are allocated. Choices that take advantage of productivity gains to free up time for socialization and other interpersonal activities, rather than increasing production and consumption endlessly, lead to reductions in energy use
  - Both variables affect energy use significantly, especially in the long run
- Explicitly tracking the GDP produced in a city, and its allocation, provides a complete representation of the city and reduces the risk of overlooking important rebound effects, which may significantly reduce the energy reduction achieved by individual energy saving measures: In current economic systems, which are geared towards stimulating higher and higher consumption levels, income 'freed up' by initial energy savings, is directed towards additional consumption, which is associated with additional energy use, thus limiting or reversing initial energy savings.
- New forms of socialization and consumptions, such as collaborative consumption, can play a critical contribution in the effort to reduce energy consumption, while improving the level of well-being enjoyed by citizens.

- In order to deliver significant energy savings, a combination of both technological and behavioral strategies are likely to be required
    - Even with optimistic technological improvement scenarios, total energy use typically increases, due to rebound effects
    - Conversely, behavioral changes alone, seem able to stop the growth in energy consumption, but unable to deliver significant reductions in energy use, unless drastic reduction in consumption are assumed (which would likely lead to a decrease in well-being)
    - The combination of technological and social innovation can deliver increases in well-being, while reducing energy requirements
- A combination of quantitative and qualitative analysis can be used to simulate and assess indicators of well-being, and their interactions with energy consumption, as illustrated by the scenarios and calculations undertaken in this study .

This study was one of the first WWF-Sweden studies on energy smart cities, and its goal was to provide a basis upon which additional work can be built. There are therefore several possible follow-up activities to this study.

The scenarios developed in the study, including their description and characteristics, could be further refined or improved to increase clarity and communication effectiveness or to facilitate additional quantitative analyses. Internal (WWF) and external (cities, other NGOs, businesses) partners could be invited to comment and contribute to this **scenario crafting**.

A number of the **calculations** used in the quantification model could be revised and made more accurate or granular to better capture differences between and within cities and to better differentiate technologies or behaviors (or policies, if the model is extended to explicitly assess policy choices). Of course, to implement more sophisticated calculations, better and more granular **data** would be needed. The quantification approaches used in this study, and the level of aggregation utilized, reflect the data available when the quantification model was built. An ongoing program, directly engaging cities and other expert organizations, should be able to broaden and deepen data collection efforts, enabling the construction of more sophisticated quantification models. Such models could be built around **REAP**, along the lines depicted in section 5, or could simply result in extensions and revisions of the current **Excel** tool, depending on the time and resources available to refine the existing tools.

The study developed an approach to analyze energy use in cities, identified a number of factors that can affect energy consumption (see table 3, above) and 'translated' the ideas developed during the project into the inputs and algorithms of the quantification model (see also Appendix for further details). This report discusses the results of the study in a format that is designed for well informed and interested readers, who, by and large, have participated or followed the project and know its context. The **communication** of (some of the) results of the study to a broader audience outside WWF Sweden seems a logical next step. To successfully achieve this, WWF Sweden will have to develop an appropriate communication strategy, articulating communication goals, identifying desired target audiences, setting priorities, articulating key messages, selecting communication channels, (when needed) creating needed communication teams, etc.

Although this study pursued several goals – crafting energy visions and scenarios, identifying drivers for energy consumption, modeling future scenarios and energy uses, identify opportunities to further improve quantification –policy and strategy analysis was outside the scope of this study. A critical follow up to this study is therefore the identification and analysis of the **policies and strategies** required to build an energy smart city. The scenarios and tool built with this project indicate a path for the future, highlighting milestones and barrier that need overcoming. These provide a valid starting point for policy and strategy development, which will likely entail addressing questions such as: What are the specific changes needed to create an energy smart city (goals)? How can such changes be achieved (options)? Who is best positioned to achieve such changes – local government vs. national government vs. other actors (roles)? What are the areas where local governments (or actor x) can make the biggest difference (priorities)? Out of the available options, what are the specific policies and strategies that should be implemented to achieve the desired goals (policies)? What should be done by whom and when to achieve the desired goals (planning)? How should we measure progress (evaluation)?

In summary this study can be seen as a building block for a broader Smart City Program that WWF Sweden can build, alone or in collaboration with other WWF offices or organizations. Such program could positively catalyze the work of local governments and other organizations, both in Sweden and internationally, to help deliver the urban transformation needed to achieve goals of a *One Planet Future*, where everyone can live a good life within the capacity of the planet.

The authors of this report hope that readers will find their study (and this report) relevant and interesting. For question or comments on the report or the study please contact:

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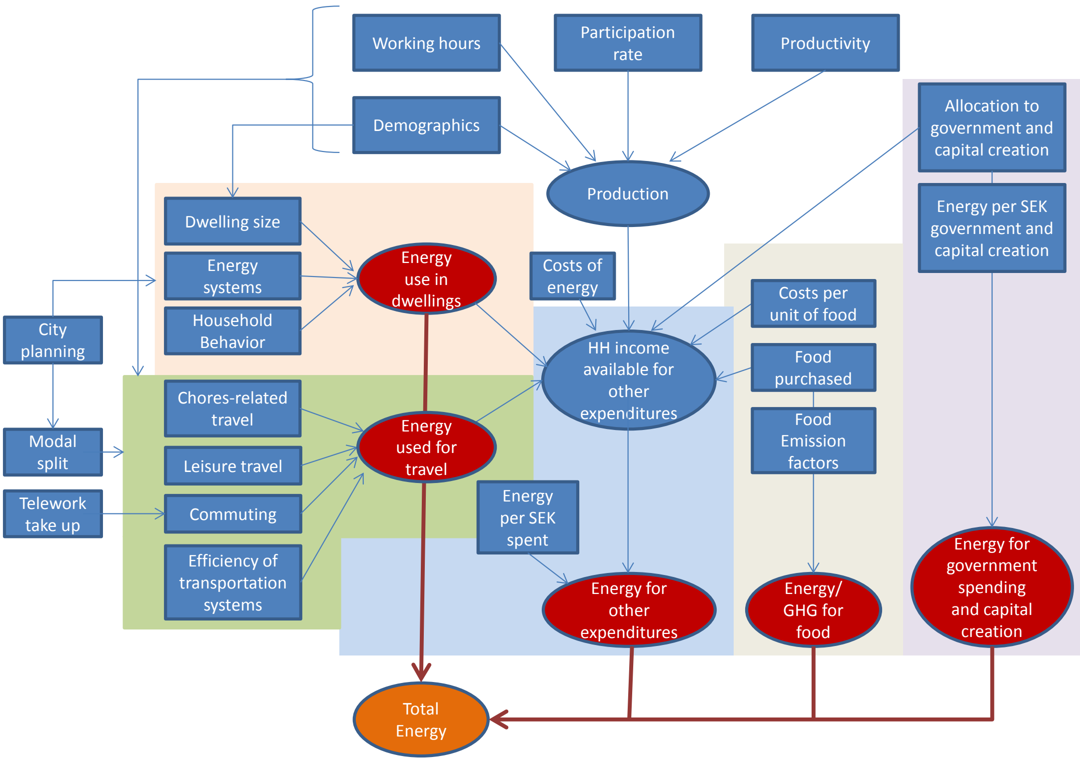
7. Appendix

This appendix provides a description and comment on the main components of the Excel-based calculation tool. The description focuses on the 'calculations' sheet in the file 'calculations v0x'. The remaining sheets and graphs in the file should be self-explanatory. For some of the inputs/assumptions, additional comments are provided with details on the background calculations undertaken to inform the choice of input/assumption made.

The calculation steps included in the model are based on the approach illustrated by the picture below:



The color coding convention adopted in the file is the following:

Color coding cells	
Inputs with city level data	
Inputs/city used in the calculations	
Calculations	
Assumptions used in future scenarios calculations	

The top half of the sheet is devoted to inputs and assumptions about year 0 and the four scenarios analyzed, the bottom part of the sheet includes the results of the calculations and includes the tables used to create graphs.

7.1. Inputs

The first input entered in the sheet is the information about the **time horizon** of the analysis, i.e. the number of future years projected in the analysis. To enable comparisons, all scenarios refer to the same future year (25 years in the example below). There are no restrictions in the time horizon one can use, but, given the characteristics of some of the data and algorithms used for the calculations, results are likely to be more stable with projections of 40 year of less.

		Year 0	Fossil	Slow	Gadget	Smart
Simulation time horizon - years from year 0		0	25	25	25	25

The **demographic and labor supply** data entered in the model are illustrated in the table below (which refers to Malmö simulation version 08).

Demographic and labour supply data		Year 0	Fossil	Slow	Gadget	Smart
Population	#	297,948	354,713	354,713	354,713	354,713
Population growth rate per annum	%	0.70%	0.7%	0.7%	0.7%	0.7%
% working age population (14-64)	%	64.20%	64.2%	64.2%	64.2%	64.2%
Participation rate	%	80.40%	80.4%	80.4%	80.4%	80.4%
Employed rate	%	92.90%	92.9%	96.0%	92.9%	96.0%
Unemployment rate	%	7.10%	7.1%	4.0%	7.1%	4.0%
Employed people	n.	142,872	170,092	175,768	170,092	175,768
Unemployed people	n.	10,919	13,000	7,324	13,000	7,324

Historical (year 0) population data are based on Statistics Sweden (2010) data, whereas the assumption on population growth rate is based on the average growth of the last 30 years (assumed to be the same in all scenarios). Assumptions on working age population and participation rates are based on the Swedish average for the 2005-2010 period. The 2005-2010 average is also used for the employment/unemployment assumption for the Fossil and Gadget scenarios, whereas for the Slow and Smart scenarios lower unemployment assumptions are used. The rationale for such choice is that scenarios that focus on well-being, value meaningful employment as a source of well-being while trying to minimize unemployment. Moreover, average working hours per employee (see below) are lower in the Slow and Smart scenarios and this should contribute to a reduction in the unemployment rate.

Critical economic parameters in the calculations are **productivity and income allocation** inputs, highlighted in the table below.

Productivity parameters		Year 0	Fossil	Slow	Gadget	Smart
Productivity per hour	SEK/h	201				
Increase in productivity per annum	% change per year		1.0%	1.0%	2.0%	2.0%
Income allocation parameters (starting point)						
Gross Capital formation as % of GDP	% of GDP	18%	18%	18%	18%	18%
Household consumption as % of GDP	% of GDP	48%	48%	48%	48%	48%
Government consumption as % of GDP	% of GDP	26%	26%	26%	26%	26%
Import as % of GDP	% of GDP	42%	42%	42%	42%	42%
Export as % of GDP	% of GDP	50%	50%	50%	50%	50%

Year 0 productivity data are based on city level data, when available and national average data when city level are not available. There is a degree of uncertainty about this data as various sources were used for the city-level parameters typically used to make this estimate (GDP, employment, hours worked per employee). This data should be discussed and double checked with city level executives and, if uncertainties are deemed too high, country level data may be preferred. Productivity assumptions reflect the notion that Gadget and Smart scenarios are more technology focused then Fossil and Slow.

These assumptions are based on Swedish historical data where productivity growth was about 1.97 % per annum in the 1994-2005 period and 0.4 % per annum in the 2005-2010 period. Income allocation assumptions are similar for all cities and scenarios and are based on the Swedish average for the 1993 – 2009 period. The data was estimates using Swedish national accounts data. The excel model treats these parameters as exogenous inputs and does not include ways to link income allocation to other model variables. This is a simplification of reality, as it is evident if one thinks, for example, at the rate of refurbishing and rebuilding of dwellings. The scenarios we developed make different assumptions about dwelling refurbishment or rebuilding rates (see below). In the real world these differences are reflected in different rates of gross capital formation, which also include real estate investment. The simpler approach used in the excel model could therefore be improved, and an input output tool such as REAP should be able to provide useful options to make this improvement.

The model aims at calculating bottom up the energy used for dwellings and transportation systems, and keeps track of the income impact of the energy savings achieved, so that resulting changes in other expenditures can be estimated and their energy impact assessed. For this reason the model necessitates **energy-price parameters**, which can link the two variables. The relevant parameters are listed below.

Energy content and prices		Year 0	Fossil	Slow	Gadget	Smart
Price per unit of heating energy	SEK/kWh	0.7500	0.7500	0.7500	0.7500	0.7500
Price per unit of electricity	SEK/kWh	1.4801	1.4801	1.4801	1.4801	1.4801
Price per unit of private vehicles fuels	SEK/kWh	1.1200	1.1200	1.1200	1.1200	1.1200
Price per unit of public transportation energy - road	SEK/kWh	1.0500	1.0500	1.0500	1.0500	1.0500
Price per unit of public transportation energy - rail	SEK/kWh	1.4801	1.4801	1.4801	1.4801	1.4801
Price per unit of public transportation energy - water	SEK/kWh	1.0500	1.0500	1.0500	1.0500	1.0500
Price per unit of air travel energy	SEK/kWh	1.1200	1.1200	1.1200	1.1200	1.1200

Historical (year 0) assumptions are based the Energy Markets publication of the Swedish Energy Agency (heating energy and private vehicle fuels) or are own elaborations from the REAP model. Price levels are assumed to be similar in different cities and stay constant over time. These assumptions would benefit from an independent assessment, and form the use of additional sources to validate existing data.

Dwelling related data and assumptions are reported below. Legacy dwelling data refer to the current stock of buildings in a given city. Typically the data are based on elaborations of Statistics Sweden data (e.g. on number of dwelling per type per city) and publications, such as the housing survey[7], which mostly includes national level data, with occasional city-level data.

[7] Bostads- och byggnadsstatistiskårsbok 2010

Legacy dwellings		Year 0	Fossil	Slow	Gadget	Smart
Average m2 per dwelling	m2	84.7				
Average m2 per person	m2/person	42.5				
Dwelling cost per m2 (rent or mortgages)	SEK/m2	945	0			
Average people per dwelling	people	2.0				
Number of dwellings	n.	149,502				
Average heating use per legacy dwelling	kwh/m2	157.3				
Electricity use per dwelling	kwh/dwelling/year	3,930				
m2 for all dwellings	m2	12,662,790				
Heating energy	kwh	1,991,856,867				
Electricity use	kwh	587,541,496				
Improved energy systems in buildings						
Retrofits of existing dwellings per year	% of year 0 dwellings	0.60%	0.60%	0.60%	1.50%	1.50%
New dwellings per year	% of year 0 dwellings	0.60%				
Demolished dwellings per year (most will be rebuilt)	% of year 0 dwellings	0.60%	0.60%	0.60%	1.50%	1.5%
Average m2 per person in new dwelling	m2/person	47.1	55	36	55	36
Average people per dwelling in new dwelling	people	2	2	11	2	11
Average size of new dwellings	m2	94	110	389	110	389
Heating use after retrofit	kwh/m2	110	110	110	40	40
Heating use new buildings	kwh/m2	90	90	90	20	20
Electricity use after retrofit	kwh/dwelling	3,930	3,930	3,000	5,000	3,000
Electricity use new buildings	kwh/dwelling	3,930	3,930	10,800	6,000	10,800
Check - electricity in new buildings	*kwh/person*	*1,972*	*1,972*	*1,000*	*3,011*	*1,000*
Pure behavior al change - energy focus @ home						
Reduction in heating use if energy savvy	% kwh		6%	6%	8%	8%
Reduction in electricity use if energy savvy	% kwh		6%	6%	8%	8%
Take up energy savvy per year	% dwellings	0%	0%	4%	0%	4%

For dwelling retrofit and demolition the assumption for Fossil and Slow are based on historical data for Sweden, whereas for Gadget and Smart it is assumed a faster pace of dwelling renewal. Assumptions on average m2 per person and people per dwellings reflect the notion that Fossil and Gadget cities will continue with current trends (more space per person few people per household) whereas Slow and Smart cities will promote bigger households and more communal living. There is significant uncertainty about the potential developments in Slow and Smart city and, by and large, they will depend on the policies and the cultural transformations that policy makers (and players such as WWF) will be able to instill in society. This is an area where WWF's thinking (and model tinkering) is particularly important. The assumptions on heating requirements after retrofit/rebuilding are based on the Ecofys' Energy vision document, which indicate a 60 % energy reduction after retrofit and a zero energy requirement for new buildings. Ecofys' document assumes that electricity consumption will increase due to increased used in appliances and other energy-requiring technologies in buildings. The excel model uses a similar assumption for Gadget city. For Slow and Smart cities, on the other hand, we assume that also electricity consumption is reduced (when per person values are considered) thanks to larger share of communal activities in the household.

The background analysis informing the model assumptions is reported below. Average consumption data by type of household and appliance are based on Zimmerman (2009). The rational for total energy consumption in co-housing is based on the assumption that economies of scale become possible with larger households (e.g. a family formed by 3 people and living alone needs one fridge but an extended household, formed by 4 families will likely need 1 or 2 larger, and more efficient, fridges). Per person calculation simply follow from the energy and household composition (number of people per dwelling) assumptions.

	one family houses	one family houses - per person	multiple family houses	multiple family houses - per person	Co-housing	Co-housing per person
Average people per dwelling	2.7		1.6		10.8	
	kwh/year total	*kwh/year per person*	*kwh/year total*	*kwh/year per person*	*kwh/year total*	*kwh/year per person*
Cold appliances	818	303	633	396	1636	151
washing/drying	525	194	296	185	1575	146
cooking	402	149	320	200	804	74
lighting	1021	378	574	359	2042	189
audiovisual site	455	169	311	194	910	84
computer site	374	139	434	271	1122	104
total	3,595	1,331	2,568	1,605	8,089	749
weight	45%		55%			
weighted total consumption					3,019	1,475
Delta co-housing versus weighted total					168%	**-49%**

The background calculations above, and the resulting parameters used in the scenarios, are based on limited background data. This is an area where additional research will be very useful, to assess the potential savings, understanding what 'household configurations' are more conducive to such savings and explore the policies that may enable the desired changes.

The assumptions on 'pure behavioral change – energy focus @ home' are based on the observation that today, even in dwellings where technologies and demographics are alike, there is a significant variance in energy consumption. The assumptions on % reductions are based on analysis of energy use in Swedish households[8].

For **transportation** the staring (**year 0**) assumptions are reported below.

Travel - year 0					
	km/person/year	kwh/km passenger	% commuting	% chores	% leisure
Walking	311.0	0.000			
Cycling	276.0	0.000			
Private vehicles	5,715.0	0.574	33%	33%	33%
Public transport - road	747.0	0.310	60%	30%	10%
Public transport - rail	1,201.0	0.148	60%	30%	10%
Public transport - water	128.0	1.812	33%	33%	33%
Air travel	2,072.0	0.515	0%	0%	100%

Transportation demand data (km/person/year per mode of transportation) are derived from our own analysis, using data from RES 2005–2006 Den nationella resvaneundersökningen. There is a degree of uncertainty about these factors, for example because regional level data, rather than city level data (which were not available) were used for the estimate. The highest uncertainty in the transportation data, however, resides in the parameters used to split total km travelled between commuting, leisure and

[8] Jean Paul Zimmermann (2009) End-use metering campaign in 400 households in Sweden Assessment of the potential electricity savings

chores related travel[9]. Better data on these parameters were not found and follow up will be required to gather additional information on these variables.

The characteristics of a city, and in particular the prevalence of mixed used neighborhoods, the availability of walk/bike paths and public transportation options can significantly affect how much and how citizens move around the city. In Fossil and Gadget scenarios, where current trends in city development are maintained, single use neighborhoods and persistent sprawl are likely to lead to an overall increase in km travelled per year. In Slow and Smart scenarios, where walk and bike friendly neighborhoods, and public transportation options, are more prevalent, overall traveling will not increase as much and **mode of transportation shifts are likely.** These dynamics are reflected in the model assumptions, and summarized in the table below. The assumptions below are applied to all cities as insufficient city-level data was available to differentiate assumptions.

Travel smart city (enabled by mixed neighborhood, infrastructure and policy)		Year 0	Fossil	Slow	Gadget	Smart
% change in average km travelled per year -private vehicles and public transport	% added per year	0.0%	0.5%	0.0%	0.5%	0.0%
% of private vehicle travel switched to bikes and walk per year from year 0	% added per year	0%	0%	0.5%	0%	0.5%
% of private vehicle travel switched to public transport per year	% added per year	0%	0%	0.5%	0%	0.5%
% of public transport road switched to bike and walk per year	% added per year	0%	0%	0.5%	0%	0.5%
% of public transport train switched to bike and walk per year	% added per year	0%	0%	0.5%	0%	0.5%
% of public transport water switched to bike and walk per year	% added per year	0%	0%	0.5%	0%	0.5%

Changes in transportation technology are an additional source of efficiencies in the transportation sector. The table below illustrates the assumptions made in the model: Gadget and Smart are assumed to be the scenarios where technological improvements take place and the pace of improvement is based on the trajectories suggested by Ecofys. It should be noted that individual cities have a limited leverage as far as influencing the rate of technological development in the transportation sector. The assumptions used below, therefore, assume that new vehicle technologies will be available and that cities will benefit (and drive) the adoption of new technologies. If WWF wants to take a more conservative stand and focus on variables that cities can affect more directly and effectively, more conservative assumptions may be required for both Gadget and Smart city.

Improved vehicle technology		Year 0	Fossil	Slow	Gadget	Smart
private vehicles average life time	years	8.7	8.7	8.7	8.7	8.7
public transport - road - vehicles average life time	years	8.7	8.7	8.7	8.7	8.7
public transport - rail - vehicles average life time	years	8.7	8.7	8.7	8.7	8.7
public transport - water - vehicles average life time	years	8.7	8.7	8.7	8.7	8.7
air travel - vehicles average life time	years	8.7	8.7	8.7	8.7	8.7
private vehicles efficiency increase per year %	%	0%	0%	0%	1.5%	1.5%
Public transport road - vehicles efficiency increase per year %	%	0%	0%	0%	1.15%	1.15%
Public transport train - vehicles efficiency increase per year %	%	0%	0%	0%	0.60%	0.60%
Public transport water - vehicles efficiency increase per year %	%	0%	0%	0%	1.00%	1.00%
Air travel - vehicles efficiency increase per year %	%	0%	0%	0%	1.00%	1.00%

Work-related decisions, and time allocation decisions in general, can have a significant impact both on income generation and on travel requirements. The table below summarizes the assumptions used in the model in terms of time allocated to work and telework take up. Change in working hours assumptions for Fossil and Slow cities assume that future trends will continue the 1994- 2009 trends, when working hours increased by about 0.26 % per annum. Assumptions on Slow and Smart cities presuppose that productivity improvements will be converted into additional free time rather than additional production. It is assumed that only 50 % of the working hours will result in a reduction of working days, and commuting requirements. As in Fossil and

[9] Following the approach used in REAP, the travel data included in this table do not include work-related travel as the energy used for work related travel (and the associated GHG emissions) are included in the emission factor of individual products (kwh/SEK) for which travel was required. The assumption made on air travel (100% air travel for leisure) reflects this allocation approach.

Gadget cities levels of consumption are projected to grow, we assume that time allocated to shopping/chores will also grow in these two scenarios. For teleworking the model includes assumption on maximum % of workers that could telework[10], the % of days they telework and the rate of take up of telework. The Smart city scenario assumes the highest take up as both technological and cultural systems are in place to favor telework (and its rapid take up). In slow city total take up is assumed below Smart city, due to slower technological adoption. In Fossil and Gadget city cultural barriers (such as high-control work environments) are the factors slowing the adoption of telework. The assumptions on the maximum penetration of telework in Smart cities, and consequently in the other scenarios, could be revised and improved with a granular analysis of Swedish employment figures per sector and job function to assess the % of knowledge workers over the total workforce (today and in the future).

Time allocation - Smart work (less work)		Year 0	Fossil	Slow	Gadget	Smart
Work time per worker	h / year	1,639				
Sleep time per year per person	h/year	2,957				
Chores & shopping time per year per person	h / year	1,983				
Change in work time per year	% per year		0.26%	-1%	0.26%	-2.0%
% resulting in less working (commuting) days	% of total		0%	50%	0%	50%
Change in sleep time per year	% per year		0%	0%	0%	0%
Change in chores & shopping time per year	% per year		0.5%	0%	0.5%	0%
Smart work - telework						
max teleworking	%		30%	50%	40%	60%
% teleworking days	%		30%	60%	30%	80%
increase teleworking per year as % of year 0	%	0%	1%	5%	2%	5%

The variables above drive the amount of time devoted to work and commuting. Empirical research has highlighted that, on average, commuting time and work time are among (if not the) least liked daily activities. The model includes therefore assumptions on 'average speed' for different commuting options (see tables below[11]), which is used to estimate the total commuting time 'wasted' every year in different scenarios.

	average happiness	average hours a day
Having Sex	4.7	0.2
Socialising	4	2.3
Relaxing	3.9	2.2
Praying/worshipping/meditating	3.8	0.4
Eating	3.8	2.2

[10] Assumptions based on the Ecofys/WWF/Connecore report *From workplace to anyplace, assessing the opportunities to reduce GHG emissions with virtual meetings and telecommuting*, available at the following web address http://www.worldwildlife.org/who/media/press/2009/WWFBinaryitem11939.pdfhttp://www.worldwildlife.org/who/media/press/2009/WWFBinaryitem11939.pdf

[11] Study based on 900 working women in texas from Kahneman et al 2004 A survey method for characterizing daily life experience: the day reconstruction method (DRM) Science, mentioned by Layard happiness - page 15

Exercising	3.8	0.2
Watching TV	3.6	2.2
Shopping	3.2	0.4
Preparing food	3.2	1.1
Talking on the phone	3.1	1.1
Talking care of my children	3	2.5
Computer/email/internet	3	1.1
Housework	3	1.9
Working	2.7	6.9
Commuting	2.6	1.6

Average commuting speed						
Walking	km/h	12	12	12	12	12
Cycling	km/h	25	25	25	25	25
Private vehicles	km/h	30	30	30	30	30
Public transport - road	km/h	20	20	20	20	20
Public transport - rail	km/h	35	35	35	35	35
Public transport - water	km/h	30	30	30	30	30

For transportation related emission calculations, the final set of assumptions in the model focus on **changes in leisure and chores related travel**. For leisure travel it is assumed that in Fossil and Gadget cities changes in leisure time and available income result in changes in leisure travel, whereas chores related travel does not change, except for Slow and Smart cities where a slow decline takes place, in response to changing attitudes resulting in less emphasis on consumptions.

Leisure travel		Year 0	Fossil	Slow	Gadget	Smart
% increase in leisure time resulting in % increase in leisure travel - private veh	%	100%	100%	0%	100%	0%
% increase in leisure time resulting in % increase in leisure travel - publ. transp	%	100%	100%	0%	100%	0%
% increase in leisure time resulting in % increase in leisure travel - publ. transp	%	100%	100%	0%	100%	0%
% increase in leisure time resulting in % increase in leisure travel - publ. transp	%	100%	100%	0%	100%	0%
% increase in leisure time resulting in % increase in leisure travel - air travel	%	100%	100%	0%	100%	0%
% increase in income resulting % increase in leisure travel - private vehicles	%	50%	50%	0%	50%	0%
% increase in income resulting in % increase in leisure travel - publ. transp. Ro	%	50%	50%	0%	50%	0%
% increase income resulting in % increase in leisure travel - publ. transp. Rail	%	50%	50%	0%	50%	0%
% increase in income resulting in % increase in leisure travel - publ. transp. Wa	%	50%	50%	0%	50%	0%
% increase in income resulting in % increase in leisure travel - air travel	%	50%	50%	0%	50%	0%
Chores related travel						
change in chores-related travel per year - private vehicles	% per year	0%	0%	-0.5%	0%	-0.6%
change in chores-related travel per year -public transport, road	% per year	0%	0%	0%	0%	0%
change in chores-related travel per year -public transport, rail	% per year	0%	0%	0%	0%	0%
change in chores-related travel per year -public transport, water	% per year	0%	0%	0%	0%	0%
change in chores-related travel per year -air travel	% per year	0%	0%	0%	0%	0%

Energy associated to **eating** is calculated from average expenditures data, using REAP as a source, and average energy content per unit of expenditure (kWh/SEK), using data from the University of Gothenburg, based on an input-output analysis from Statistics Sweden's Environmental Accounts for 2005[12]. These initial parameters are adjusted, over time, to reflect changes in technology, food preference, and food waste. Energy use in agricultural is assumed to decline in Gadget and Smart scenarios, remain stable in Slow scenarios and increase (follow historical trends) in Fossil scenarios. These assumptions deserve further investigation to assess their validity. The assumptions on the impact of switching to low-energy food baskets were based on the data provided by the University of Gothenburg and our own simulations of the energy requirements of different food baskets. The available data only included energy intensity parameters (kWh/SEK) for 15 food categories[13]. The differences in energy intensity between different categories is not very large and the estimated benefit of switching diets to lower energy staples, only shows a relatively modest (4 %) reduction in energy requirements. More accurate and meaningful analysis would be possible if a more granular breakdown of food categories was available and if, in addition to the energy intensity parameter, indicators were also available for caloric and nutritional values of different foods and food categories (per SEK spent). With these additional parameters and granularity the available food choices, and their impacts on energy use, could be better assessed and it would be possible to identify food consumption baskets that preserve caloric and nutritional values while delivering larger energy savings[14].

Eating		Year 0	Fossil	Slow	Gadget	Smart
Average food expenditures per person benchmark	SEK/person/year	21,648	21,648	21,648	21,648	21,648
Average energy content per SEK spent on food	kwh/SEK	0.2360				
Change in energy content per unit of expenditure due to technological change	% per year		0.4%	0.0%	-0.4%	-0.4%
Potential savings due switch to a lower energy basked of foods	%	4.0%	4.0%	4.0%	4.0%	4.0%
Take up of low energy food (per year)	% added per year	0.0%	0.0%	4.0%	0.0%	4.0%
Potential savings due to waste reduction	%	10.0%	10.0%	10.0%	10.0%	10.0%
Take up of waste reduction behaviors (per year)	% added per year	0.0%	0.0%	4.0%	0.0%	4.0%

In the tool **'other expenditures'** (SEK) are calculated as a residual, once public expenditures, investments, household energy and food expenditures are subtracted from gross income. An average energy intensity factor (kWh/SEK) is used to estimate the energy associated with the products and services included in 'other expenditures'. Such factor is derived from the data provided by the University of Gothenburg, and in particular from the relative expenditures (SEK/1000 SEK) and energy intensity (kWh/SEK) for 80 categories of products, which were assumed to be included in 'other expenditures'.

Other expenditures		Year 0	Fossil	Slow	Gadget	Smart
Average energy associated to other expenditures	kwh/SEK	0.1950				
change in energy content per unit of expenditure due to technological change	% per year	0%	0%	0%	-2%	-2%
Potential impact of collaborative consumption on energy consumption	% of kWh/SEK	-60%	-60%	-45%	-60%	-60%
Take up of collaborative consumption per year	% added per year	0%	0%	3%	0%	4%
Income effect of collaborative consumption (% SEK / % energy saving)	% SEK / % energy savi	50%	50%	50%	50%	50%
Potential impact of switching consumption towards low-energy-content products	% of kWh/SEK	-10%	-10%	-8%	-10%	-10%
Take up of low energy consumption per year	% added per year	0%	0%	3%	0%	4%

Four dynamics were modeled by the tool to construct the scenarios for other expenditures:

[12] Data available from http://www.mir.scb.se

[13] The categories are; Milk, cheese eggs; fruit; vegetables; fish, seafood; meat; oils, fats; sugar, jam, etc.; coffee, tea, cocoa; bread, cereals; salt, spices, etc.; mineral water, soft drinks, juices; light beer; beer; wine; spirits

[14] We understand that gathering the relevant data, and ensuring it is of sufficient good quality, may be challenging and time consuming. We are aware the SEI intended to run a REAP simulation for 'higher take up of organic food', but decided to abandon this scenario because of the data collection difficulties encountered. Given the importance of food, both as driver for energy consumption and as main connection between our everyday lives and nature, we believe that this area should be farther explored by WWF

1. Technological progress. I.e. increases in energy efficiency in the production sector. The assumptions for this variable are based on the estimates proposed by Ecofys (2 % energy efficiency increase on average)
2. The impact and take up of collaborative consumption. I.e. modes of consumptions based on collaboration enable multiple consumers to share individual products, significantly reducing the number of products required to deliver the same level of service/benefit to end users. Background calculations were undertake to model this impact, using the assumption listed in the table below, and calculating the resulting changes in terms of % reduction in energy intensity (kWh/SEK) for 'other expenditures' (calculated as weighted average of expenditure on different products post-collaborative consumption)

Collaborative consumption indicators

(average multiplier of people sharing an item vs. baseline)

Clothing and footwear	10.0	assumes ICT based services designed to facilitate exchanges on a regular basis
Housing	1.5	driven by ratio between average m2/person
Furnishing & household goods	4.0	e.g. assuming extended households of 12 people (vs 2 today and allowing for non perfect economies of scale). Sharing occurs within household for the most part
Health	1.0	Except for therapeutic equipment, health products and services are person- and pathology dependent, with little opportunities for collaborative consumption
Transport	10.0	number of people sharing one vehicle, assuming that ICT technologies enable extensive sharing
Communication	2.0	assumes many devices, such as telephones by also PCs are used extensively and so are less amenable for sharing
Recreation equipment	10.0	number of people sharing recreational equipment within and outside households (enabled by ICT)

3. The potential income effect of collaborative consumption, reflecting the fact that with efficient collaborative consumption, the cost of the similar services will decline (e.g. the cost of using a car is smaller with car sharing than with a car owning). The cost reduction *frees up* income which can be used for additional consumption. The model assumes that each 1 % reduction in the energy intensity (kWh/SEK) enabled by collaborative consumption will result in a 0.5 % increase in the disposable income, and that such income is also used for 'other expenditures' and this will increase energy use).
4. The impact that may result from change preferences in consumers, leading to a decrease in market share for high-energy-content products/services and an increase in market share for low-energy-content products/services. For the Slow and Smart scenarios the assumption made was that the expenditures for the top 20 high-energy-content categories are reduced by 20 %, while the expenditures for the top 20 low-energy-content categories are increased by 25 % (these changes keep the overall expenditure unchanged).

Whereas collaborative consumption represents an extremely interesting trend, which may significantly affect how individuals and societies work, consume and interact, very little empirical evidence is available on the potential impacts on energy consumption and the environment. Qualitative descriptions of potential benefits have been provided by collaborative consumption advocates, but we were not able to locate any academic, rigorous or quantitative analysis of this interaction. All the assumptions discussed above should therefore be considered as initial approximations, and should be subject to further test and analysis.

The final set of input data and assumptions are about the energy content parameters for **capital formation and government spending**.

Government and investment related energy		Year 0	Fossil	Slow	Gadget	Smart
Energy intensity of capital formation	kwh/SEK	0.0742	0.0742	0.0742	0.0742	0.0742
% change in energy intensity per year	% change	0%	0%	0%	-2%	-2%
Energy intensity of Government spending	kwh/SEK	0.0619	0.0619	0.0619	0.0619	0.0619
% change in energy intensity per year	% change	0%	0%	0%	-1%	-1%

We did not have a direct measurements or estimates for these parameters. We therefore estimated them using capital formation and government spending (SEK) data from Statistics Sweden and the total energy (kWh) for capital formation and government spending estimated by the REAP tool. The limitation of this approach is that we were not able to assess the degree of consistency between Statistics Sweden and REAP data, and we did not have any insight on how REAP estimated the energy consumption for these two categories. For capital formation we assumed that changes in energy intensity per year will follow the same path followed by 'other expenditures'. This seems a reasonable assumption since both variables are driven by energy efficiency improvements in production processes. For government expenditures we assumed a more modest annual improvement. This is a significant uncertainty around this variable and a better estimate could be achieved by analyzing government expenditure (and associated energy consumption) at a higher level of granularity than the one used in the Excel tool.

7.2. Outputs and calculations

The first set of data provided in the output/calculation portion of the model is a summary of **timeline and demographic** data.

		Year 0	Fossil	Slow	Gadget	Smart
Timeline and demographic data						
Simulation time horizon - years from year 0		-	25	25	25	25
Population	#	297,948	354,713	354,713	354,713	354,713
Employed people	n.	142,872	170,092	175,768	170,092	175,768
Unemployed people	n.	10,919	13,000	7,324	13,000	7,324

The first actual calculations undertaken in the model are the estimates of **number and m2 of dwellings by type**. The calculations are based on the assumptions made on the rate or dwelling refurbishing and rebuilding and on the assumptions on population growth (coupled with the assumptions on m2 per person in different scenarios).

		Year 0	Fossil	Slow	Gadget	Smart
Dwelling numbers						
Number of dwellings demolished	# dwellings	-	22,425	22,425	56,063	56,063
Number of dwellings rebuilt after demolition	# dwellings		22,425	4,138	56,063	10,345
New dwellings to accommodate population growth	# dwellings	-	28,483	5,256	28,483	5,256
Retroffitted dwellings	# dwellings		22,425	22,425	56,063	56,063
Legacy dwellings	# dwellings	149,502	104,651	104,651	37,375	37,375
Number of dwellings	# dwellings	149,502	177,985	136,471	177,985	109,040
m2 in demolished dwellings	m2		1,899,419	1,899,419	4,748,546	4,748,546
m2 in rebuilt dwellings (after demolition)	m2		2,458,071	1,608,919	6,145,178	-
m2 in dwellings accommodating population growth	m2		3,122,081	2,043,544	3,122,081	-
m2 in new dwellings	m2		5,580,152	3,652,463	9,267,258	-
m2 for retrofitted dwelling	m2		1,899,419	1,899,419	4,748,546	4,748,546
m2 for legacy dwelling	m2	12,662,790	8,863,953	8,863,953	3,165,698	3,165,698
m2 for all dwelling	m2	12,662,790	16,343,523	14,415,835	17,181,502	7,914,244
average m2 per person	m2	42.5	46.1	40.6	48.4	22.3
Estimated costs of dwellings (rents/mortgages)	Mln SEK	-	-	-	-	-

Dwelling data (number and m2) are used in conjunction with the energy intensity assumptions (kwh/m2 and kwh/dwelling) to calculate the **energy consumptions after dwelling refurbishing and replacing** (see table below).

Refurbishing and replacing of dwellings		Year 0	Fossil	Slow	Gadget	Smart
Heating energy legacy dwellings	kwh	1,991,856,867	1,394,299,807	1,394,299,807	497,964,217	497,964,217
Heating energy new dwellings	kwh		502,213,678	328,721,680	185,345,169	-
Heating energy refurbished dwellings	kwh		208,936,035	208,936,035	189,941,850	189,941,850
Total Heating energy	kwh	1,991,856,867	2,105,449,520	1,931,957,522	873,251,236	687,906,067
Total expenditures in heating energy	Mln SEK	1,494	1,579	1,449	655	516
Delta vs. year 0			*6%*	*-8%*	*-55%*	*-65%*
electricity use legacy dwellings year	kwh	587,541,496	411,279,047	411,279,047	146,885,374	146,885,374
electricity use new dwellings year	kwh		88,131,224	44,692,200	336,378,719	111,730,500
electricity use refurbished dwellings year	kwh		88,131,224	67,275,744	280,315,599	168,189,360
total electricity use dwellings year	kwh	587,541,496	587,541,496	523,246,991	763,579,692	426,805,233
Expenditures in electricity	Mln SEK	870	870	774	1,130	632
Delta vs. year 0			*0%*	*-11%*	*30%*	*-27%*

As next step the model calculates the **energy savings associated to behavioral changes** (see below).

Behavioral change in dwellings		Year 0	Fossil	Slow	Gadget	Smart
Energy savvy dwellings year	%	0%	0%	100%	0%	100%
heating saved by energy savvy behavior year	kwh	-	-	115,917,451	-	55,032,485
heating net of savings due to savvy behavior	kwh	1,991,856,867	2,105,449,520	1,816,040,071	873,251,236	632,873,581
heating energy saved with change behavior	%	0%	0%	6%	0%	8%
heating expenditures saved	mln SEK	-	-	87	-	41
heating expenditures net of saving from energy savvy behavior	mln SEK	1,494	1,579	1,362	655	475
electricity saved by energy savvy behavior	kwh	-	-	31,394,819	-	34,144,419
electricity net of savings due to savvy behavior	kwh	587,541,496	587,541,496	491,852,171	763,579,692	392,660,815
electricity saved with energy savvy behavior	%	0.0%	0.0%	6.0%	0.0%	8.0%
electricity expenditures saved	mln SEK	-	-	46	-	51
electricity expenditures net of saving from energy savvy behavior	mln SEK	870	870	728	1,130	581

For each dwelling-related calculation, in addition to calculating energy savings and consumption, the model estimates the energy expenditures undertaken by households, so that their 'budget available for other consumption' can be adjusted.

For energy consumption associated to travel the first set of calculations focuses on the impact deriving from the **change in market share of different modes of transportation**, where Slow and Smart city scenarios experience a steady reduction in the market share of private vehicles in favor of public transportation, biking and walking. After estimating the changes in market share accumulated from year 0 to year x, the model revises the estimated km/person/year for different modes of transportation and calculates energy consumption (using the kWh/km parameter).

Smart travel -travel smart city (infrastructure and policy enabled)		Year 0	Fossil	Slow	Gadget	Smart
cumulative % of private vehicle travel switched to bikes and walk vs. year 0	%	0%	0%	13%	0%	13%
cumulative % of private vehicle travel switched to public transport vs year 0	%	0%	0%	13%	0%	13%
cumulative % of public transport road switched to bike and walk vs. year 0	%	0%	0%	13%	0%	13%
cumulative % of public transport train switched to bike and walk vs. year 0	%	0%	0%	13%	0%	13%
cumulative % of public transport water switched to bike and walk vs. year 0	%	0%	0%	13%	0%	13%
private vehicle travel switched to bike and walk	km/person/year	-	-	1,137.1	-	1,137.1
private vehicle travel switched to public transport	km/person/year	-	-	1,137.1	-	1,137.1
public transport road switched to bike and walk	km/person/year	-	-	76.4	-	76.4
public transport train switched to bike and walk	km/person/year	-	-	87.3	-	87.3
public transport water switched to bike and walk	km/person/year	-	-	12.8	-	12.8
Private vehicles	km/person/year	9,096.94	9,096.94	6,822.70	9,096.94	6,822.70
Public transport - road	km/person/year	610.83	610.83	1,026.47	610.83	1,026.47
Public transport - train	km/person/year	698.71	698.71	649.16	698.71	649.16
Public transport -water	km/person/year	102.24	102.24	95.79	102.24	95.79
Air travel	km/person/year	4,000.00	4,000.00	4,000.00	4,000.00	4,000.00
Total km private vehicles	km passenger	2,710,414,955	3,226,803,719	2,420,102,789	3,226,803,719	2,420,102,789
Total km public transport - road	km passenger	181,995,518	216,669,338	364,101,503	216,669,338	364,101,503
Total km public transport - train	km passenger	208,178,841	247,841,112	230,265,011	247,841,112	230,265,011
Total km public transport -water	km passenger	30,463,561	36,267,484	33,977,701	36,267,484	33,977,701
Total km air travel	km passenger	1,191,792,000	1,418,852,435	1,418,852,435	1,418,852,435	1,418,852,435
Energy use private vehicles	kwh	1,944,581,563	2,315,063,605	1,736,297,704	2,315,063,605	1,736,297,704
Energy use public transport - road	kwh	56,373,673	67,113,996	112,781,564	67,113,996	112,781,564
Energy use public transport - train	kwh	30,878,379	36,761,333	34,154,337	36,761,333	34,154,337
Energy use public transport -water	kwh	55,201,665	65,718,696	61,569,482	65,718,696	61,569,482
Energy use air travel	kwh	613,375,616	730,236,053	730,236,053	730,236,053	730,236,053
Total energy use	**kwh**	**2,700,410,896**	**3,214,893,684**	**2,675,039,140**	**3,214,893,684**	**2,675,039,140**
Energy use private vehicles delta vs. year 0	*%*	*0.0%*	*19.1%*	*-10.7%*	*19.1%*	*-10.7%*
Energy use public transport - road - delta vs. year 0	*%*	*0.0%*	*19.1%*	*100.1%*	*19.1%*	*100.1%*
Energy use public transport - train - delta vs. year 0	*%*	*0.0%*	*19.1%*	*10.6%*	*19.1%*	*10.6%*
Energy use public transport -water - delta vs. year 0	*%*	*0.0%*	*19.1%*	*11.5%*	*19.1%*	*11.5%*
Energy use air travel	*%*	*0.0%*	*19.1%*	*19.1%*	*19.1%*	*19.1%*
Total energy use - delta vs. year 0	*%*	*0.0%*	*19.1%*	*-0.9%*	*19.1%*	*-0.9%*

The second set of travel-related calculations builds on the first one and focuses on the **potential impact of new transportation technologies**. The top part of the calculations estimated the number of improvement years for each vehicle type, i.e. the model year of the average vehicle, starting from year 0. E.g. the table below projects year 25, the average life span of vehicles is assumed to be 8.7 years, thus the average car in circulation is model year 20.65 (=25-(8.7/2). Vehicle's model year drive the total rate of technological improvement embedded in vehicles (% added efficiency as compared to year 0). This value is used to revise the energy intensity parameter for vehicles (kwh/km) and the overall energy consumption estimate (kwh). Finally, the model estimates total fuels/energy costs, using energy unit costs (SEK/kWh).

Improved vehicles						
		Year 0	Fossil	Slow	Gadget	Smart
improvement-years, average private vehicle	years	0	20.65	20.65	20.65	20.65
improvement-years, average public transport vehicle, road	years	0	20.65	20.65	20.65	20.65
improvement-years, average public transport vehicle, rail	years	0	20.65	20.65	20.65	20.65
improvement-years, average public transport vehicle, water	years	0	20.65	20.65	20.65	20.65
improvement-years, average air travel vehicle	years	0	20.65	20.65	20.65	20.65
improved efficiency private vehicle	%	0%	0%	0%	31%	31%
improved efficiency public transport vehicle, road	%	0%	0%	0%	24%	24%
improved efficiency public transport vehicle, rail	%	0%	0%	0%	12%	12%
improved efficiency public transport vehicle, water	%	0%	0%	0%	21%	21%
improved efficiency air travel vehicle	%	0%	0%	0%	21%	21%
energy use average private vehicle	kwh/km passenger	0.574	0.574	0.574	0.396	0.396
energy use average public transport vehicle - road	kwh/km passenger	0.310	0.310	0.310	0.236	0.236
energy use average public transport vehicle - rail	kwh/km passenger	0.148	0.148	0.148	0.130	0.130
energy use average public transport vehicle - water	kwh/km passenger	1.812	1.812	1.812	1.438	1.438
energy use average air travel vehicle	kwh/km passenger	0.515	0.515	0.515	0.408	0.408
Energy used net of efficiency improvement - private vehiles	kWh	977,320,650	1,163,519,963	872,639,972	803,119,654	602,339,741
Energy used net of efficiency improvement - pub.transp. Road	kWh	68,940,864	82,075,490	100,059,155	62,584,613	76,297,607
Energy used net of efficiency improvement - pub.transp. Rail	kWh	53,076,391	63,188,515	58,132,064	55,359,458	50,929,501
Energy used net of efficiency improvement - pub.transp. Water	kWh	69,106,986	82,273,262	77,938,658	65,283,833	61,844,325
Energy used net of efficiency improvement - pub.transp. Air	kWh	317,728,569	378,262,275	378,262,275	300,151,116	300,151,116
Energy used net of efficiency improvement - total	kWh	**1,486,173,459**	**1,769,319,505**	**1,487,032,124**	**1,286,498,674**	**1,091,562,289**
Energy used net of efficiency improvement - delta vs. year 0	*%*		*19.1%*	*0.1%*	*-13.4%*	*-26.6%*
Energy costs - private vehicles	mln SEK	1,095	1,303	977	899	675
Energy costs - public transport, road	mln SEK	72	86	105	66	80
Energy costs - public transport, rail	mln SEK	79	94	86	82	75
Energy costs - public transport, water	mln SEK	73	86	82	69	65
Energy costs - air travel	mln SEK	356	424	424	336	336
total energy costs travel	mln SEK	1,674	1,993	1,674	1,452	1,231

As next step, the model splits km-travelled figures to differentiate between commuting, chores and leisure travel and undertakes separate simulations for each category. For **commuting** the model first focuses on the **potential impact of changed working hours**. As workers elect to work less hours (days) a week in Slow or Smart city scenarios, or more hours (days) a week in Fossil and Gadget city scenarios, commuting habits are also affected. The calculations below show the revised estimates for 'km commuting / person', reflecting changes in working hours. Km commuting / person are then used to calculate total km travelled for commuting, which form the basis to calculate the resulting aggregate energy requirement. Here too, the financial impact of commuting on households' income is assessed.

Smart work - less work		Year 0	Fossil	Slow	Gadget	Smart
average working hours per worker	hours	1,639	1,749	1,275	1,749	989
change in working hours vs. year 0	hours	-	109.93	(364.15)	109.93	(649.92)
change in work time vs. year 0	% per year	0%	7%	-22%	7%	-40%
change in commuting days	% per year	0%	0%	-11%	0%	-20%
Private vehicles commuting net of changing work habits	km commuting/perso	1,885.95	1,885.95	1,257.33	1,885.95	1,134.02
Public transport - road commuting, net of changing work habits	km commuting/perso	448.20	448.20	485.71	448.20	438.07
Public transport - train commuting, net of changing work habits	km commuting/perso	720.60	720.60	589.29	720.60	531.50
Public transport -water commuting, net of changing work habits	km commuting/perso	42.24	42.24	35.57	42.24	32.08
Air travel commuting, net of changing work habits	km commuting/perso	-	-	-	-	-
Total km private vehicles	km commuting	561,915,031	668,971,187	445,991,725	668,971,187	402,251,889
Total km public transport - road	km commuting	133,540,294	158,982,415	172,286,227	158,982,415	155,389,566
Total km public transport - train	km commuting	214,701,329	255,606,266	209,029,323	255,606,266	188,529,149
Total km public transport -water	km commuting	12,585,324	14,983,082	12,616,924	14,983,082	11,379,542
Total km air travel	km commuting	-	-	-	-	-
Energy use private vehicles	kwh	322,515,814	383,961,588	255,980,667	265,029,486	159,362,037
Energy use public transport - road	kwh	41,364,518	49,245,294	53,366,191	37,550,768	36,702,156
Energy use public transport - train	kwh	31,845,835	37,913,109	31,004,527	33,215,675	24,499,098
Energy use public transport -water	kwh	22,805,305	27,150,176	22,862,567	21,543,665	16,362,257
Energy use air travel	kwh	-	-	-	-	-
Total energy use	**kwh**	**418,531,473**	**498,270,167**	**363,213,952**	**357,339,593**	**236,925,549**
Energy use private vehicles delta vs. year 0	*%*	*0.0%*	*19.1%*	*-20.6%*	*-17.8%*	*-50.6%*
Energy use public transport - road - delta vs. year 0	*%*	*0.0%*	*19.1%*	*29.0%*	*-9.2%*	*-11.3%*
Energy use public transport - train - delta vs. year 0	*%*	*0.0%*	*19.1%*	*-2.6%*	*4.3%*	*-23.1%*
Energy use public transport -water - delta vs. year 0	*%*	*0.0%*	*19.1%*	*0.3%*	*-5.5%*	*-28.3%*
Energy use air travel	*%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
Total energy use - delta vs. year 0	*%*	*0.0%*	*19.1%*	*-13.2%*	*-14.6%*	*-43.4%*
Expenditures for private vehicles commuting net of changes in work habits	mln SEK	361	430	287	297	178
Expenditures for pub. Trans. Road commuting net of changes in work habits	mln SEK	43	52	56	39	39
Expenditures for pub. Trans. rail commuting net of changes in work habits	mln SEK	47	56	46	49	36
Expenditures for pub. Trans. water commuting net of changes in work habits	mln SEK	24	29	24	23	17
Expenditures for private vehicles commuting net of changes in work habits	mln SEK	-	-	-	-	-
Expenditures for commuting total	mln SEK	476	566	413	408	270

In addition to changing commuting habits, changing working hours affect production, and thus the **overall income** available in the city, which is equal: total amount of hours worked in a city * productivity per hour worked (see below). The output estimate is the basis to distribute the available income between different end uses (public spending, investments, energy expenditures, food expenditures, other expenditures).

Production impact of working hours						
Productivity per hour	SEK/h	201	258	258	330	330
Output per worker	SEK		450,819	328,616	576,729	326,160
Number of people working	n.	142,872	170,092	175,768	170,092	175,768
Total hours worked	h	234,167,284	297,478,436	224,077,560	297,478,436	173,848,278
Output total	Mln SEK	47,068	76,681	57,760	98,097	57,329

The second variable affecting commuting and modeled by the tool is **teleworking**. The relevant calculations are reported below. The teleworking module adjust the 'km commuting / person' variable to consider that teleworkers do not require to commute as often as 'office-bound' workers. The model then uses km commuting/ person to calculate total km commuted and (through kWh/km parameters) energy requirements. Finally (see the bottom of the table) the impact on disposable income is assessed.

Smart work - telework		Year 0	Fossil	Slow	Gadget	Smart
Teleworking take up (delta vs. year 0)	%	0%	25%	50%	40%	60%
% days teleworked per teleworker	%	0%	8%	30%	12%	48%
Reduction in commuting due to telwork	%	0.0%	1.9%	15.0%	4.8%	28.8%
Private vehicles commuting net of telework	km commuting/person/year	1,885.95	1,850.59	1,068.73	1,795.42	807.42
Public transport - road commuting, net of telework	km commuting/person/year	448.20	439.80	412.85	426.69	311.91
Public transport - train commuting, net of telework	km commuting/person/year	720.60	707.09	500.90	686.01	378.43
Public transport -water commuting, net of telework	km commuting/person/year	42.24	41.45	30.23	40.21	22.84
Air travel commuting, net of telework	km commuting/person/year	-	-	-	-	-
Total km private vehicles	km commuting	561,915,031	656,427,977	379,092,966	636,860,570	286,403,345
Total km public transport - road	km commuting	133,540,294	156,001,495	146,443,293	151,351,259	110,637,371
Total km public transport - train	km commuting	214,701,329	250,813,649	177,674,925	243,337,165	134,232,754
Total km public transport -water	km commuting	12,585,324	14,702,149	10,724,385	14,263,894	8,102,234
Total km air travel	km commuting	-	-	-	-	-
Energy use private vehicles	kwh	322,515,814	376,762,308	217,583,567	252,308,071	113,465,771
Energy use public transport - road	kwh	41,364,518	48,321,945	45,361,262	35,748,331	26,131,935
Energy use public transport - train	kwh	31,845,835	37,202,238	26,353,848	31,621,322	17,443,358
Energy use public transport -water	kwh	22,805,305	26,641,111	19,433,182	20,509,569	11,649,927
Energy use air travel	kwh	-	-	-	-	-
Total energy use	**kwh**	**418,531,473**	**488,927,601**	**308,731,859**	**340,187,293**	**168,690,991**
Energy use private vehicles delta vs. year 0	*%*	*0.0%*	*16.8%*	*-32.5%*	*-21.8%*	*-64.8%*
Energy use public transport - road - delta vs. year 0	*%*	*0.0%*	*16.8%*	*9.7%*	*-13.6%*	*-36.8%*
Energy use public transport - train - delta vs. year 0	*%*	*0.0%*	*16.8%*	*-17.2%*	*-0.7%*	*-45.2%*
Energy use public transport -water - delta vs. year 0	*%*	*0.0%*	*16.8%*	*-14.8%*	*-10.1%*	*-48.9%*
Energy use air travel	*%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
Total energy use - delta vs. year 0	*%*	*0.0%*	*16.8%*	*-26.2%*	*-18.7%*	*-59.7%*
Expenditures for private vehicles commuting net of telework impact	mln SEK	361	422	244	283	127
Expenditures for pub. Trans. Road commuting net of telework impact	mln SEK	43	51	48	38	27
Expenditures for pub. Trans. rail commuting net of telework impact	mln SEK	47	55	39	47	26
Expenditures for pub. Trans. water commuting net of telework impact	mln SEK	24	28	20	22	12
Expenditures for private vehicles commuting net of telework impact	mln SEK	-	-	-	-	-
Expenditures for commuting total net of telework impact	mln SEK	476	556	351	388	193

Together, decisions about work time and teleworking affect the total time devoted to commuting per year (see below) which will impact the total level of well-being in a city.

Time spent commuting		Year 0	Fossil	Slow	Gadget	Smart
Average per person for private vehicles commuting, net of telework	h/year/person	55	54	31	52	24
Average per person, for public transport - road commuting, net of telework	h/year/person	13	13	12	12	9
Average per person, for public transport - train commuting, net of telework	h/year/person	21	20	14	20	11
Average per person, for public transport - water commuting, net of telework	h/year/person	1	1	1	1	1
Average time spent commuting per person - ex. walking and biking	h/year/person	90	88	59	86	44
% change in average per person for private vehicles commuting, net of telework	*% change vs year 0*	*0%*	*-2%*	*-43%*	*-5%*	*-57%*
% change in average per person, for public transport - road commuting, net of telework	*% change vs year 0*	*0%*	*-2%*	*-8%*	*-5%*	*-30%*
% change in average per person, for public transport - train commuting, net of telework	*% change vs year 0*	*0%*	*-2%*	*-30%*	*-5%*	*-47%*
% change in average per person, for public transport - water commuting, net of telework	*% change vs year 0*	*0%*	*-2%*	*-28%*	*-5%*	*-46%*
% change in average time spent commuting per person - ex. walking and biking	*% change vs year 0*	*0%*	*-2%*	*-35%*	*-5%*	*-51%*
Total time spent for private vehicles commuting, net of telework	h/year/total	16,382,362	19,137,842	11,052,273	18,567,364	8,349,952
Total time spent for public transport - road commuting, net of telework	h/year/total	3,893,303	4,548,149	4,269,484	4,412,573	3,225,579
Total time spent for public transport - train commuting, net of telework	h/year/total	6,134,324	7,166,104	5,076,426	6,952,490	3,835,222
Total time spent for public transport - water commuting, net of telework	h/year/total	419,511	490,072	357,480	475,463	270,074
Total time spent commuting (excluded walking and biking)	h/year/total	26,829,500	31,342,166	20,755,663	30,407,890	15,680,827

For **leisure travel** the model uses the assumptions discussed in section 7.1 to estimate how changes in leisure time and available income will affect leisure travel in different scenarios. The model then uses the estimate % change in leisure travel to revise leisure travel figures (per person and total) and thereafter energy requirements and leisure travel expenditures estimates (see below).

Leisure travel		Year 0	Fossil	Slow	Gadget	Smart
Total time net of work time per worker	h/year/worker	7,121	7,011	7,485	7,011	7,771
Estimated sleep time	h/year/worker	2,957	2,957	2,957	2,957	2,957
Estimated chores time	h/year/worker	1,983	2,246	1,983	2,246	1,983
Leisure time remaining	h/year/worker	2,181	1,808	2,545	1,808	2,831
% change vs. year 0	*%*	*0%*	*-17%*	*17%*	*-17%*	*30%*
% increase in leisure travel - private vehicles	%	0%	-5%	0%	8%	0%
% increase in leisure travel - publ. transp. Road	%	0%	-5%	0%	8%	0%
% increase in leisure travel - publ. transp. Rail	%	0%	-5%	0%	8%	0%
% increase in leisure travel - publ. transp. Water	%	0%	-5%	0%	8%	0%
% increase in leisure travel - air travel	%	0%	-5%	0%	8%	0%
Private vehicles leisure travel	km leisure/person/year	1,885.95	1,798.93	1,414.46	2,034.67	1,414.46
Public transport - road leisure travel	km leisure/person/year	74.70	71.25	91.07	80.59	91.07
Public transport - rail, leisure travel	km leisure/person/year	120.10	114.56	110.49	129.57	110.49
Public transport -water, leisure travel	km leisure/person/year	42.24	40.29	40.01	45.57	40.01
Air travel leisure travel	km leisure/person/year	2,072.00	1,976.39	2,072.00	2,235.39	2,072.00
Total km private vehicles	km leisure travel	561,915,031	638,103,816	501,728,390	721,725,215	501,728,390
Total km public transport - road	km leisure travel	22,256,716	25,274,453	32,302,876	28,586,587	32,302,876
Total km public transport - train	km leisure travel	35,783,555	40,635,366	39,192,037	45,960,496	39,192,037
Total km public transport -water	km leisure travel	12,585,324	14,291,739	14,193,691	16,164,624	14,193,691
Total km air travel	km leisure travel	617,348,256	701,053,107	734,965,561	792,923,802	734,965,561
Energy use private vehicles	kwh	322,515,814	366,245,003	287,971,191	285,929,299	198,772,114
Energy use public transport - road	kwh	6,894,086	7,828,840	10,005,915	6,751,994	7,629,761
Energy use public transport - train	kwh	5,307,639	6,027,290	5,813,206	5,972,502	5,092,950
Energy use public transport -water	kwh	22,805,305	25,897,425	25,719,757	23,242,565	20,408,627
Energy use air travel	kwh	317,728,569	360,808,666	378,262,275	323,820,566	300,151,116
Total energy use	**kwh**	**675,251,414**	**766,807,224**	**707,772,345**	**645,716,925**	**532,054,568**
Energy use private vehicles delta vs. year 0	*%*	*0.0%*	*13.6%*	*-10.7%*	*-11.3%*	*-38.4%*
Energy use public transport - road - delta vs. year 0	*%*	*0.0%*	*13.6%*	*45.1%*	*-2.1%*	*10.7%*
Energy use public transport - train - delta vs. year 0	*%*	*0.0%*	*13.6%*	*9.5%*	*12.5%*	*-4.0%*
Energy use public transport -water - delta vs. year 0	*%*	*0.0%*	*13.6%*	*12.8%*	*1.9%*	*-10.5%*
Energy use air travel	*%*	*0.0%*	*13.6%*	*19.1%*	*1.9%*	*-5.5%*
Total energy use - delta vs. year 0	*%*	*0.0%*	*13.6%*	*4.8%*	*-4.4%*	*-21.2%*
Expenditures for leisure travel private vehicles	mln SEK	361	410	323	320	223
Expenditures for leisure travel pub. Trans. Road	mln SEK	7	8	11	7	8
Expenditures for leisure travel pub. Trans. Rail	mln SEK	8	9	9	9	8
Expenditures for leisure travel pub. Trans. water	mln SEK	24	27	27	24	21
Expenditures for leisure travel air	mln SEK	356	404	424	363	336
Expenditures for leisure travel total	mln SEK	756	859	792	723	596

The steps followed for **chores related travel** are similar to the ones used for leisure travel and are reported below.

Chores travel		Year 0	Fossil	Slow	Gadget	Smart
Private vehicles chores travel	km chores/person/year	1,885.95	1,885.95	1,247.87	1,885.95	1,216.89
Public transport - road, chores related travel	km chores/person/year	224.10	224.10	273.20	224.10	273.20
Public transport - rail, chores related travel	km chores/person/year	360.30	360.30	331.47	360.30	331.47
Public transport -water, chores related travel	km chores/person/year	42.24	42.24	40.01	42.24	40.01
Air travel leisure travel	km chores/person/year	-	-	-	-	-
Total km private vehicles	km chores travel	561,915,031	668,971,187	442,634,942	668,971,187	431,646,562
Total km public transport - road	km chores travel	66,770,147	79,491,208	96,908,627	79,491,208	96,908,627
Total km public transport - train	km chores travel	107,350,664	127,803,133	117,576,112	127,803,133	117,576,112
Total km public transport -water	km chores travel	12,585,324	14,983,082	14,193,691	14,983,082	14,193,691
Total km air travel	km chores travel	-	-	-	-	-
Energy use private vehicles	kwh	322,515,814	383,961,588	254,054,014	265,029,486	171,007,464
Energy use public transport - road	kwh	20,682,259	24,622,647	30,017,746	18,775,384	22,889,282
Energy use public transport - train	kwh	15,922,917	18,956,554	17,439,619	16,607,837	15,278,850
Energy use public transport -water	kwh	22,805,305	27,150,176	25,719,757	21,543,665	20,408,627
Energy use air travel	kwh	-	-	-	-	-
Total energy use	**kwh**	**381,926,296**	**454,690,965**	**327,231,137**	**321,956,372**	**229,584,224**
Energy use private vehicles delta vs. year 0	*%*	*0.0%*	*19.1%*	*-21.2%*	*-17.8%*	*-47.0%*
Energy use public transport - road - delta vs. year 0	*%*	*0.0%*	*19.1%*	*45.1%*	*-9.2%*	*10.7%*
Energy use public transport - train - delta vs. year 0	*%*	*0.0%*	*19.1%*	*9.5%*	*4.3%*	*-4.0%*
Energy use public transport -water - delta vs. year 0	*%*	*0.0%*	*19.1%*	*12.8%*	*-5.5%*	*-10.5%*
Energy use air travel	*%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
Total energy use - delta vs. year 0	*%*	*0.0%*	*19.1%*	*-14.3%*	*-15.7%*	*-39.9%*
Expenditures for chores-related travel private vehicles	mln SEK	361	430	285	297	192
Expenditures for chores-related travel pub. Trans. Road	mln SEK	22	26	32	20	24
Expenditures for chores-realated travel pub. Trans. Rail	mln SEK	24	28	26	25	23
Expenditures for chores-related travel pub. Trans. water	mln SEK	24	29	27	23	21
Expenditures for chores-related travel air	mln SEK	-	-	-	-	-
Expenditures for chores-related travel total	mln SEK	430	512	369	364	260

Next the tool includes **summary table for travel** related activities, associated energy requirements and income impacts. Elements of this table are used in the summary tables and graphs and in the disposable income calculations.

Summary travel		Year 0	Fossil	Slow	Gadget	Smart
Private vehicles travel per person	km/person/year	5,657.85	5,535.47	3,731.06	5,716.05	3,438.77
Public transport - road, travel per person	km/person/year	747.00	735.15	777.12	731.38	676.18
Public transport - rail, travel per person	km/person/year	1,201.00	1,181.95	942.86	1,175.88	820.38
Public transport -water, travel per person	km/person/year	126.72	123.98	110.26	128.02	102.87
Air travel per person	km/person/year	2,072.00	1,976.39	2,072.00	2,235.39	2,072.00
Total km private vehicles	km travel	1,685,745,092	1,963,502,981	1,323,456,299	2,027,556,972	1,219,778,298
Total km public transport - road	km travel	222,567,156	260,767,156	275,654,796	259,429,054	239,848,874
Total km public transport - train	km travel	357,835,548	419,252,148	334,443,074	417,100,795	291,000,903
Total km public transport -water	km travel	37,755,971	43,976,970	39,111,768	45,411,600	36,489,616
Total km air travel	km travel	617,348,256	701,053,107	734,965,561	792,923,802	734,965,561
Energy use private vehicles	kwh	967,547,443	1,126,968,898	759,608,771	803,266,855	483,245,349
Energy use public transport - road	kwh	68,940,864	80,773,431	85,384,924	61,275,708	56,650,978
Energy use public transport - train	kwh	53,076,391	62,186,082	49,606,674	54,201,662	37,815,158
Energy use public transport -water	kwh	68,415,916	79,688,712	70,872,696	65,295,799	52,467,182
Energy use air travel	kwh	317,728,569	360,808,666	378,262,275	323,820,566	300,151,116
Total energy use	**kwh**	**1,475,709,183**	**1,710,425,790**	**1,343,735,341**	**1,307,860,590**	**930,329,783**
Energy use private vehicles delta vs. year 0	*%*	*0.0%*	*16.5%*	*-21.5%*	*-17.0%*	*-50.1%*
Energy use public transport - road - delta vs. year 0	*%*	*0.0%*	*17.2%*	*23.9%*	*-11.1%*	*-17.8%*
Energy use public transport - train - delta vs. year 0	*%*	*0.0%*	*17.2%*	*-6.5%*	*2.1%*	*-28.8%*
Energy use public transport -water - delta vs. year 0	*%*	*0.0%*	*16.5%*	*3.6%*	*-4.6%*	*-23.3%*
Energy use air travel	*%*	*0.0%*	*13.6%*	*19.1%*	*1.9%*	*-5.5%*
Total energy use - delta vs. year 0	*%*	*0.0%*	*15.9%*	*-8.9%*	*-11.4%*	*-37.0%*
Expenditures for travel private vehicles	mln SEK	1,084	1,262	851	900	541
Expenditures for travel pub. Trans. Road	mln SEK	72	85	90	64	59
Expenditures for travel pub. Trans. Rail	mln SEK	79	92	73	80	56
Expenditures for travel pub. Trans. water	mln SEK	72	84	74	69	55
Expenditures for travel air	mln SEK	356	404	424	363	336
Expenditures travel total	mln SEK	1,662	1,927	1,512	1,475	1,048

The calculations **for eating-related energy**, reported below, start by reporting the average food expenditure assumptions, which are then multiplied by an energy intensity factor (in which the impact of technological progress is incorporated). The model then adjust the resulting energy consumption values (in kwh/person) to reflect reductions enabled by the take up of low-energy diets and by the reduction in food waste. Revised expenditure calculations are produced to adjust the income available for other expenditures.

Energy smart eating		Year 0	Fossil	Slow	Gadget	Smart
Average food expenditures per person (see assumptions)	SEK/person/year	21,648	21,648	21,648	21,648	21,648
Energy content per unit of expenditure year after technological change	kwh/SEK	0.2360	0.2608	0.2360	0.2135	0.2135
Food related energy per person per year, post technological change	kwh/person	5,109	5,645	5,109	4,622	4,622
% citizens opting for low energy food baskets	% of people	0%	0%	100%	0%	100%
% reduction in energy associated with food, thanks to low energy diets	% of kwh/SEK	0.0%	0.0%	4.0%	0.0%	4.0%
Food related energy per person per year, including impact of low energy diets	kwh/person	5,109	5,645	4,905	4,622	4,437
% citizens reducing food waste	% of people	0%	0%	100%	0%	100%
% reduction in energy associated with food, thanks to waste reduction	% of kwh/SEK	0.0%	0.0%	14.3%	0.0%	19.0%
Food related energy per person per year, post waste reduction	kwh/person	5,109	5,645	4,206	4,622	3,594
Total energy content in food consumed	kwh	1,522,194,880	2,002,395,409	1,491,806,113	1,639,420,952	1,274,813,732
Energy use associated to eating delta vs. year 0	*%*	*0.0%*	*31.5%*	*-2.0%*	*7.7%*	*-16.3%*
Average food expenditures per person	SEK/person/year	21,648	21,648	18,563	21,648	17,535
Total food expenditures	SEK	6,449,978,304	7,678,829,376	6,584,596,190	7,678,829,376	6,219,851,794

The calculation for **other expenditures** starts with the estimate of the gross disposable income available to households. The model then subtracts energy and food expenditures, using the values estimated within the model (and reported in the tables above). A net disposable income (SEK) is thus calculated and to this value the model applies an energy intensity factor (kWh/SEK) to calculate energy requirements (kWh). The energy intensity factor is corrected to take into account the impact of technological change and collaborative consumption. The income effect calculations estimate the impact of price reductions enabled by collaborative consumption, resulting in additional income and expenditures (and thus energy use). After estimating the energy requirements net of the impact of collaborative consumption, the model simulates potential changes in consumer behavior, leading to a switch to lower-energy-consumption baskets.

Energy aware expenditures		Year 0	Fossil	Slow	Gadget	Smart
% of total output allocated to household consumption	%	48%	48%	48%	48%	48%
Gross disposible income for household consumption	Mln SEK	22,503	36,661	27,615	46,900	27,408
Expenditures for dwelling (rents and mortgages)	Mln SEK	-	-	-	-	-
Expenditures in energy for dwellings	Mln SEK	2,364	2,449	2,090	1,785	1,056
Expenditures in energy for transportation	Mln SEK	1,662	1,927	1,512	1,475	1,048
Expenditures in food	Mln SEK	6,450	7,679	6,585	7,679	6,220
Available for other expenditures	Mln SEK	12,027	24,606	17,428	35,960	19,085
Available for other expenditures per person	SEK / person	40,366	69,369	49,133	101,378	53,803
Energy content per unit of expenditure considering impact of technological change	kwh/SEK	0.1950	0.1950	0.1950	0.1177	0.1177
% citizens engacing in collaborative consumption behavior	% people	0%	0%	75%	0%	100%
Energy impact of collaborative consumption	% kWh/SEK	0%	0%	-34%	0%	-60%
Energy content per unit of expenditure considering impact of collaborative consumption	kwh/SEK	0.1950	0.1950	0.1292	0.1177	0.0471
Income effect due to collaborative consumption	%	0%	0%	17%	0%	30%
Income effect due to collaborative consumption	MlnSEK	-	-	2,941	-	5,725
Income effect due to collaborative consumption	SEK/person	-	-	8,291	-	16,141
Income available for shopping including collaborative consumption in come effect	MlnSEK	12,027	24,606	20,369	35,960	24,810
Income available for shopping per person including collaborative consumption in come effect	SEK/person	40,366	69,369	57,425	101,378	69,944
Energy associated to shopping, including impact of collaborative consumption	kwh	2,345,257,433	4,798,206,328	2,631,459,146	4,231,637,352	1,167,823,235
% citizens further switching to lower energy consumption baskets	% people	0%	0%	75%	0%	100%
Energy impact of low energy consumption choices	% kWh/SEK	0%	0%	-6%	0%	-10%
Energy associated with shopping expenditures including impact of low energy consumption choi	kwh	2,345,257,433	4,798,206,328	2,473,571,597	4,231,637,352	1,051,040,911
Energy use associated to shopping delta vs. year 0	*%*	*0.0%*	*104.6%*	*5.5%*	*80.4%*	*-55.2%*

The last calculations module focuses on the **energy associated with capital formation and government expenditures**. Here energy intensity factors are estimated, taking into account the impact of technological progress, and the resulting energy aggregated energy requirements are calculated.

Energy associated to capital formation and government spending		Year 0	Fossil	Slow	Gadget	Smart
% output allocated to capital formation	%	18%	18%	18%	18%	18%
Energy intensity of capital formation	kWh/SEK	0.0742	0.0742	0.0742	0.0448	0.0448
Capital formation	SEK Mln	8,652	14,096	10,618	18,033	10,538
Energy associated to capital formation	kWh	642,351,334	1,046,492,802	788,277,485	807,900,891	472,142,387
Energy use associated to capital formation delta vs. year 0	*%*	*0.0%*	*62.9%*	*22.7%*	*25.8%*	*-26.5%*
% output allocated to government expenditures	%	26%	26%	26%	26%	26%
Energy intensity of government expenditures	kWh/SEK	0.0619	0.0619	0.0619	0.0482	0.0482
Government expenditures	SEK Mln	12,396	20,194	15,212	25,834	15,098
Energy associated to government expenditures	kWh	767,791,546	1,250,854,921	942,214,576	1,244,677,262	727,397,259
Energy use associated to government expenditures delta vs. year 0	*%*	*0.0%*	*62.9%*	*22.7%*	*62.1%*	*-5.3%*

The bottom part of the calculation sheet, includes a number of tables that have been created to summarize the results of the simulations, and create comparison graphs.

The first three graphs summarize key **energy consumption figures**: total energy consumption, change in energy consumption versus year 0 and % of energy consumption versus total energy requirements in year x (25 in the simulation reported below).

Total energy consumption, year 25 - kWh - Malmö		Year 0	Fossil	Slow	Gadget	Smart
Energy for dwellings	kwh	2,579,398,363	2,692,991,015	2,307,892,242	1,636,830,928	1,025,534,396
Energy for transportation	kwh	1,475,709,183	1,710,425,790	1,343,735,341	1,307,860,590	930,329,783
Energy associated with food purchases	kwh	1,522,194,880	2,002,395,409	1,491,806,113	1,639,420,952	1,274,813,732
Energy associated with shopping	kwh	2,345,257,433	4,798,206,328	2,473,571,597	4,231,637,352	1,051,040,911
Energy associated with capital formation	kwh	642,351,334	1,046,492,802	788,277,485	807,900,891	472,142,387
Energy associated with government spending	kwh	767,791,546	1,250,854,921	942,214,576	1,244,677,262	727,397,259
Total energy	kwh	9,332,702,738	13,501,366,265	9,347,497,354	10,868,327,976	5,481,258,469
Change in energy use year 25 vs. year 0 - Malmö						
Energy for dwellings - change vs. year 0	%	0.0%	4.4%	-10.5%	-36.5%	-60.2%
Energy for transportation - change vs. year 0	%	0.0%	15.9%	-8.9%	-11.4%	-37.0%
Energy associated with food purchases - change vs. year 0	%	0.0%	31.5%	-2.0%	7.7%	-16.3%
Energy associated with shopping - change vs. year 0	%	0.0%	104.6%	5.5%	80.4%	-55.2%
Energy associated with capital formation - change vs. year 0	%	0.0%	62.9%	22.7%	25.8%	-26.5%
Energy associated with government spending - change vs. year 0	%	0.0%	62.9%	22.7%	62.1%	-5.3%
Total energy - change vs year 0	%	0.0%	44.7%	0.2%	16.5%	-41.3%
% of total energy use, year 25 - Malmö						
Energy for dwellings as % of total energy	%	27.6%	20%	25%	15%	19%
Energy for transportation as % of total energy	%	16%	13%	14%	12%	17%
Energy associated with food purchases as % of total energy	%	16%	15%	16%	15%	23%
Energy associated with shopping as % of total energy	%	25%	36%	26%	39%	19%
Energy associated with capital formation as % of total energy	%	7%	8%	8%	7%	9%
Energy associated with government spending as % of total energy	%	8%	9%	10%	11%	13%
Total	%	100%	100%	100%	100%	100%

The next set of table focus on total **income and income per person**.

Income, year 25 - Mln SEK - Malmö						
Total GDP	Mln SEK	47,068	76,681	57,760	98,097	57,329
Expenditures in energy for dwellings	Mln SEK	2,364	2,449	2,090	1,785	1,056
Expeinditures for dwellings (rents and mortgages)	Mln SEK	-	-	-	-	-
Expenditures in energy for transportation	Mln SEK	1,662	1,927	1,512	1,475	1,048
Expenditures in food	Mln SEK	6,450	7,679	6,585	7,679	6,220
Other expenditures	Mln SEK	12,027	24,606	17,428	35,960	19,085
Income effect collaborative consumption	Mln SEK	-	-	2,941	-	5,725
Capital formation	Mln SEK	8,652	14,096	10,618	18,033	10,538
Public spending	Mln SEK	12,396	20,194	15,212	25,834	15,098
Total	Mln SEK	43,550	70,951	56,385	90,767	58,770
change versus year 0	*%*	*0.0%*	*62.9%*	*29.5%*	*108.4%*	*34.9%*
Income per person, year 25 - SEK - Malmö						
Total GDP	SEK/person	157,973	216,177	162,836	276,553	161,619
Expenditures in energy for dwellings	SEK/person	7,933	6,903	5,892	5,033	2,977
Expeinditures for dwellings (rents and mortgages)	SEK/person	-	-	-	-	-
Expenditures in energy for transportation	SEK/person	5,579	5,432	4,262	4,160	2,954
Expenditures in food	SEK/person	21,648	21,648	18,563	21,648	17,535
Other expenditures	SEK/person	40,366	69,369	49,133	101,378	53,803
Income effect collaborative consumption	SEK/person	-	-	8,291	-	16,141
Capital formation	SEK/person	29,039	39,738	29,933	50,837	29,709
Public spending	SEK/person	41,603	56,931	42,884	72,832	42,564
Total	SEK/person	146,168	200,023	158,960	255,887	165,683

Data summarizing **time allocation and changes in time allocation** (variables which affect well-being) in different scenarios constitute the next set of tables

Time allocation, year 25 - Malmö		Year 0	Fossil	Slow	Gadget	Smart
Work time	hours per year	1,639	1,749	1,275	1,749	989
Leisure time	hours per year	2,181	1,808	2,545	1,808	2,831
Sleep time	hours per year	2,957	2,957	2,957	2,957	2,957
Chores & shopping time	hours per year	1,983	2,246	1,983	2,246	1,983
Change in time allocation, year 25 - Malmö						
Change in work time vs. year 0	hours per year		110	(364)	110	(650)
Change in leisure time vs. year 0	hours per year		(373)	364	(373)	650
Change in sleep time vs. year 0	hours per year		-	-	-	-
Change in chores & shopping time vs. year 0	hours per year		263	-	263	-
% Change in time allocation, year 25 - Malmö						
Change in work time vs. year 0	%		7%	-22%	7%	-40%
Change in leisure time vs. year 0	%		-17%	17%	-17%	30%
Change in sleep time vs. year 0	%		0%	0%	0%	0%
Change in chores & shopping time vs. year 0	%		13%	0%	13%	0%

Finally the tables summarizing the amount **of time spent/wasted commuting** are reported

Time spent commuting per person, year 25 - Malmö		Year 0	Fossil	Slow	Gadget	Smart
Average per person for private vehicles commuting, net of telework	h/year/person	55	54	31	52	24
Average per person, for public transport - road commuting, net of telework	h/year/person	13	13	12	12	9
Average per person, for public transport - train commuting, net of telework	h/year/person	21	20	14	20	11
Average per person, for public transport - water commuting, net of telework	h/year/person	1	1	1	1	1
Average time spent commuting per person - ex. walking and biking	h/year/person	90	88	59	86	44
% change in time spent commuting per person, year 25 - Malmö						
% change in average per person for private vehicles commuting, net of telework	% change vs year 0	0%	-2%	-43%	-5%	-57%
% change in average per person, for public transport - road commuting, net of telework	% change vs year 0	0%	-2%	-8%	-5%	-30%
% change in average per person, for public transport - train commuting, net of telework	% change vs year 0	0%	-2%	-30%	-5%	-47%
% change in average per person, for public transport - water commuting, net of telework	% change vs year 0	0%	-2%	-28%	-5%	-46%
% change in average time spent commuting per person - ex. walking and biking	% change vs year 0	0%	-2%	-35%	-5%	-51%
Total time spent commuting for the city, year 25 - Malmö						
Total time spent for private vehicles commuting, net of telework	h/year/total	16,382,362	19,137,842	11,052,273	18,567,364	8,349,952
Total time spent for public transport - road commuting, net of telework	h/year/total	3,893,303	4,548,149	4,269,484	4,412,573	3,225,579
Total time spent for public transport - train commuting, net of telework	h/year/total	6,134,324	7,166,104	5,076,426	6,952,490	3,835,222
Total time spent for public transport - water commuting, net of telework	h/year/total	419,511	490,072	357,480	475,463	270,074
Total time spent commuting (excluded walking and biking)	h/year/total	26,829,500	31,342,166	20,755,663	30,407,890	15,680,827

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For additional bibliographic references, please refer to the project web site: References for additional reading are available in the project web site: https://sites.google.com/a/wwf.panda.org/project-energy-smart-cities/home.

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To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony and nature.

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