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Behavioral and Technological Changes Regarding Lighting Consumptions: A MARKAL Case Study

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ABSTRACT

The present study aims at assessing the joint impact of awareness campaigns and technology choice, on end-use energy consumption behaviour. Actions to achieve energy savings through the use of more energy efficient end-use technology are included. A new MARKAL framework, the Socio-MARKAL, was recently proposed by the authors. As opposed to the traditional MARKAL framework based on technical and economic considerations, the Socio-MARKAL concept integrates technological, economic and behavioural contributions to the environment. This study takes into consideration, technological improvements on the demand side by consumers as well as behavioural changes minimizing carbon dioxide emissions and encouraging rational use of energy. The study presented in this paper, "Lighting Consumptions Habits in Geneva Households", was conducted from September to December 2009. *Based on the statistical analysis of this survey, we have determined coefficients to feed the database of the Socio-MARKAL model* (*an IEA/ANSWER database is available for testing purposes*).

Keywords: *Demand Side Management, Energy and Environmental Planning, MARKAL, Sociological Surveys, Sustainable Development*

1. Introduction

The original MARKAL model is a multi-period linear programming formulation of a reference energy system (RES). The constraints of the model describe all energy flows, production of electricity and centralized heat, industrial processes, consumption by end-use technologies and lastly energy services. The objective function in the linear programming model is the discounted sum, over the time horizon considered (usually between 30 and 45 years), of investment, operating and maintenance costs of all technologies, plus the cost of energy imports. The model also accounts for emissions of atmospheric pollutants (NO_x, SO_2 and CO_2) and is currently used in many countries and regions around the world for the assessment of energy pollution abatement policies. As the existing literature shows [1-4], the MARKAL family of models and similar energy optimization models to a certain extent are appropriate to answer questions such as: how do technologies and policies affect the environmental impacts of energy use (*i.e.*, GHG and emissions of other pollutants)? How do actions on the demand-side affect the supply-side and vice versa? How to model the dynamics of technology (e.g., the switch from one technology to another)?

However, among the existing MARKAL models, the social/sociological aspect of energy use on the demand-side is not taken into account. In particular, none of the above mentioned models takes into account the contribution of end use consumers' behavioural change as a reliable resource for energy efficiency, energy savings, and emissions reductions. Saving energy requires a change in the behavior of consumers, either to improve the energy efficiency of their technology (e.g., technology switch), or to improve the way they use energy with non-efficient technologies (e.g., better use of a less efficient technology). As such, information can be an important driver, as it can positively influence people's behavior towards energy and the environment [5]. Do we know enough about factors that can affect the behavior of energy consumers? Is it reasonable to integrate behavioral and techno-economic parameters? How behavioral parameters and data can be obtained?

Such considerations are accounted for in the Socio-MARKAL concept developed at HEG [6]. Behavioural contributions are modeled through virtual technologies built from sociological surveys, in order to capture the perception of the population in terms of attitudes and behaviors regarding energy consumption. These sociological and intangible technologies are therefore combined with traditional and tangible technologies. As a result of this combination, it will be possible to model the actual behavior of consumers as well as economically rational technology choices. These days, environmental/behavioral campaigns are becoming increasingly sophisticated, going far beyond standard information-only programs. Consequently, it is essential to define a clear and systematic protocol for socio-technological evaluations based on the Socio-MARKAL concept.

2. Protocol for the Socio-MARKAL

The Socio-MARKAL concept is based upon the introduction of a virtual technology built from sociological surveys. The purpose of such a concept is to capture consumers' perceptions towards their energy consumption trends, with an emphasis on their attitudes and behaviours. To this end, the virtual, *i.e.*, "sociological" technologies are associated with tangible technologies, allowing planners or analysts to model, analyse and assess the actual behaviour of consumers as well as technology choices which are economically rational. A detailed presentation of the Socio-MARKAL concept can be found in Fragnière *et al.* [6].

Below, we present a method for collecting social data in the context of the Socio-MARKAL project.

1) Hypothesis generation: qualitative research to identify potentials of behavioral change regarding energy consumption, handled through empirical methods (semi structured interviews, observations, social experiments). The energy-saving benefits (without a reduction in performance) as well as the essential character of behavioral change must be clearly explained. If the interviewees or respondents express interest in the campaigns, the awareness program must be designed so as to remove all the barriers – e.g. lack of information and motivation, cost of changing the technology, as well as its installation.

2) Hypothesis testing: survey research to test and measure hypotheses generated during the first phase (questionnaire, rank and sample statistical analyses).

3) Behavioral change scenario process: construction of long-term scenarios including behavioral change, in particular expert-built scenarios from the collected data.

4) Design: transformation of the Socio-MARKAL (abbreviated SOMARKAL in **Figure 1**) data and scenarios to feed the MARKAL data base.

The survey questionnaire is elaborated with the express purpose of assessing the potential contribution of behavioral change in end-use energy consumption pattern, and thereby in climate change mitigation. The methodology is structured as presented in **Figure 1**.

3. The Survey Research

The questionnaire can be constructed based on the consideration that climate change is due to greater energy use by humans. In line with this, two approaches apparently inclusive can be used [7]: 1) improving the efficiency of end-uses of energy and 2) not using or conserving energy. For Rudin, the proponents of the first approach seem to denigrate the overall notion of sufficient and limited energy use.

The main focus of this paper is on lighting technologies. Our survey is based upon the analysis of a sample (probabilistic) made up of 393 valid questionnaires addressed to the populations living along Lake Geneva. This research has been conducted by the laboratory of market research (LEM, Laboratoire d'Études de Marché) of Geneva Haute École de Gestion, whose objectives are to develop locally-based survey research in Economics and Business Administration and to train students to marketing survey techniques. The study presented in this paper, "Lighting Consumptions Habits in Geneva Households", was conducted from September to December 2009. In the questionnaire, we also included questions based on Contingent Valuation Methods (hypothetical scenarios) to assess the individuals' possible behaviors in specific contexts. Relationships between classes as well as relationships between variables have been investigated and analyzed in depth. Then, research hypotheses were verified on the basis of non-parametric statistical tests before being introduced in the Socio-MARKAL database. This survey questionnaire has been elaborated with the express purpose of assessing the potential contribution of behavioral change in end-use energy consumption pattern, and thereby in climate change mitigation.

The survey questionnaire was distributed to a random sample of people, equally distributed between men (52%) and women (48%). These individuals are aged between

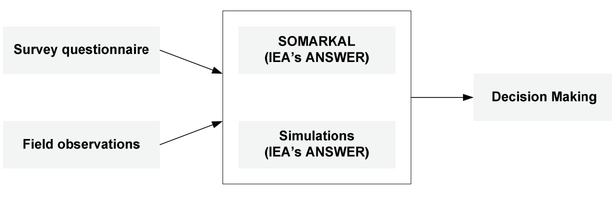

Figure 1. Outline of the methodology.

15 and 75 years old, with a mean of about 38 years old. They have the following occupations: employees (39%), students (31%), high-level executives (12%), independents and retirees, as well as housewives and unemployed (4% respectively). As for the ownership, 31% of the respondents own their house while 66% are tenants. Additionally, 68% live in apartments, while 32% live in a house. In this short paper, we just focus on some descriptive statistics. In particular, we present the results related to the question "What proportion of low consumption bulbs do you have at home".

Table 1 below indicates that, firstly, the great majority of the respondents (58.84%) have a proportion of low consumption light bulbs ranging between 25% and 75%. Secondly, the lowest response rates are on the extremes, namely those who have only low consumption bulbs (8.04%), and those who have none (14.83%).

The first observation shows that 58.84% of the population can potentially switch technology or change their consumption behavior through better use of incandescent bulbs. The corresponding maximum of incandescent light ranges from 25% to 75% of the bulbs.

However, 20% of the respondents responded "I don't know", which seems to indicate that they have no information about the technology (incandescent or not) they have been using for lighting.

Among other results provided, it is interesting to mention the following elements: 82.3% of the respondents indicates that they have been taught by their parents to switch off the lights when leaving a room; the respondents had also to give the most important peculiarities (2 choices) associated to a light bulb and it appears that "lighting intensity" is the most important one (26.8%), followed by "consumption" (22.0%), "lifetime" (20.2%), "purchase price" (10.6%). Summing up, economic parameters (lifetime, price and consumption) represent 52.8%, while parameters related to comfort (light intensity, color and ambiance) represent 40.3%. Ecological parameters (origin, manufacturing, and disposal) are of least concerns to the respondents (6.9%). The other questions have been designed in order to provide social data to these so-called virtual technologies in MARKAL.

The questionnaire includes questions on Contingent Valuation Methods (hypothetical scenarios) to assess individuals' attitudes and behaviors towards more efficient end-use technologies (*i.e.*, incandescent light bulbs vs. low consumption bulbs) (see for example [8-11]).

Based on this recent survey, we have determined an environmental and energy planning scenario that simultaneously takes into account technological as well as sociological aspects.

4. Modeling the Bulb Demand Devices in Socio-MARKAL

The representative parameters of the Socio-MARKAL have been designed so as to keep the traditional MARKAL formalism. This will ease the use of MARKAL platforms such as ANSWER. ANSWER [12] is the data base management system of the MARKAL-TIMES models generators developed by IEA-ETSAP, the International Energy Agency Implementing Agreement for a Program of Energy Technology Systems Analysis.

As mentioned on the previous sections, energy conservation may require the introduction/adoption of measures aimed at promoting rational use of energy. These measures include: 1) a better use and management of existing equipments or technologies and/or 2) technology switch. In this study, we assume that people/consumers who are willing to adopt one or more of these measures are driven by the desire to change their energy consumption behaviour. This willingness could be explained by many factors, such as their sensitivity to marketing/ awareness campaigns, training, their education, the quality of information they have been receiving, as opposed to the assumption of perfect economic rationality generally used in the traditional MARKAL family of models.

Behavioural change in Socio-MARKAL requires introducing virtual technologies, whose purpose is to trigger

Table 1. Summary statistics showing the proportion of low consumption vs. incandescent light bulbs.

Proportion of low consumption bulbs [%]	N, number of respondents	Percentage [%]	Percentage without "does not know" [%]	Cumulative percentage [%]
0	43	14.83	17.13	17.13
25	76	24.44	30.28	47.41
50	55	17.68	21.91	69.32
75	52	16.72	20.72	90.04
100	25	08.04	9.96	100.00
Does not know	60	19.29	-	-
Total	311	100.00	-	-

Note:
Number of questionnaires missing or not filled by the respondents. N = 82; Percentage: 20.87% in a total of 393 questionnaires

behavioural change among energy consumers. For the bulb demand devices section of the Socio-MARKAL model, we ended up with the following representation, using structures defined by MARKAL, as outlined in **Figure 2**.

We've got four demand devices. Parameters RLD1 and RLD4 represent the real and tangible lighting technologies, receiving electric power as input, and generating residential lighting.

Parameters RLD2 and RLD3 represent the virtual technologies.

As opposed to the real technologies, virtual technologies receive inputs that are intangible, leading to energy savings or technology switch. These devices are presented below:

- RLD1, "existing incandescent bulbs"
- RLD4, "existing low consumption bulbs
- RLD2, "moderate use of incandescent bulbs", and
- RLD3, "switch to low consumption bulbs"
- MRKRP2 and MRKRP3 are marketing/awareness campaigns which have the effect of changing the behaviour of energy consumers. MRKRP2 and MRKRP3 are respectively supposed to trigger the "Moderate use of incandescent light bulbs", and the behaviour towards low consumption bulbs, *i.e.* "Technology Switch towards low consumption bulbs".

5. Transforming Sociological Data into MARKAL Parameters: An Example

In this section, we show how the statistics obtained from the survey research are transformed to feed the bulb demand devices section of the Socio-MARKAL model. In this short paper, we will concentrate on a single case. Note that due to the qualitative nature of the data, we will be using a narrative scheme to make the case.

We have two sets of data for the residual capacities for incandescent bulbs RLD1 and low consumption bulbs RLD4. One data set comes from MARKAL data points that are obtained from statistics of observed actual contexts. The second data set about the number of bulbs and their split comes from the survey and it is not exact because it corresponds to elements of perceptions. The qualitative scale is defined over: zero, 1/4, 1/2, 3/4, all bulbs, and "do not know".

Residual capacity of behaviour change in favour of electricity savings RLD2 and for technology switch RLD3 is zero at the beginning of the optimisation. Then, we have the evolution of the environment that corresponds to Socio-MARKAL scenarios. For instance, there are people who will never change their behaviour and will only use incandescent bulbs RLD1 as long as they can buy them. Then, another case concerns people who are not aware of the advantages of low consumption bulbs and consequently might change their behaviour spontaneously as they get or receive more information.

Finally, there are people who would not change their behaviour without an information campaign; however with an exposure to information, they will start saving energy and/or switch technology. In order to measure this part of behavioural change, we have asked the following questions in the survey:

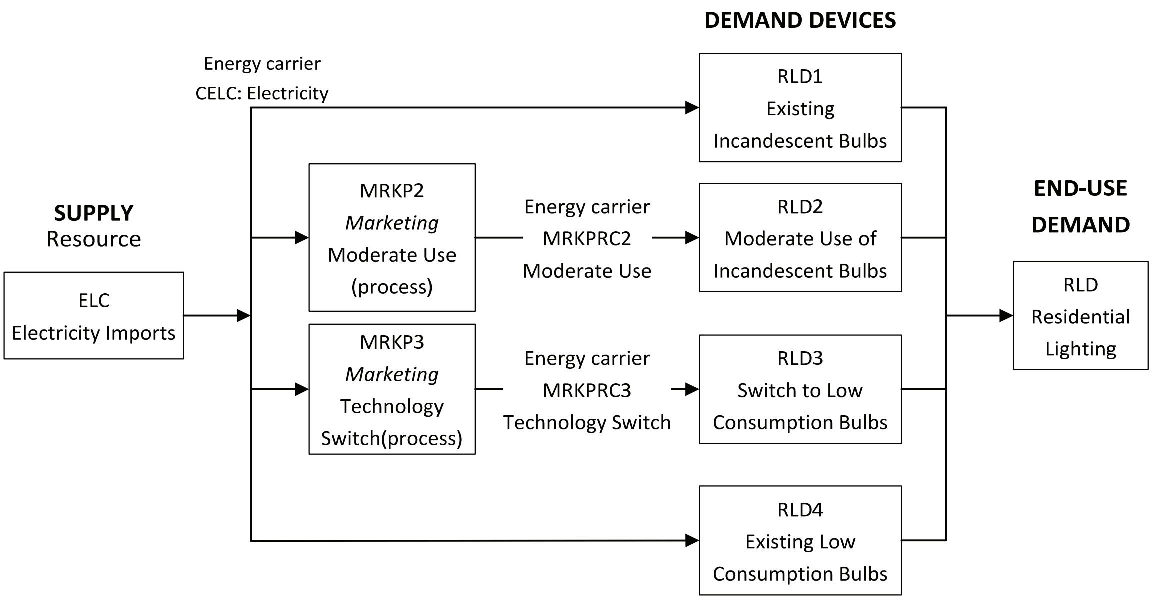

Figure 2. Structure of the reference energy system (RES).

- Question 10: "Did you know that low consumption bulbs may consume up to 5 times less energy than the incandescent ones?" (possible answers: Yes, No).
- Question 11: "Did you know that low consumption bulbs have a lifetime up to 10 times superior to the incandescent bulbs?" (possible answers: Yes, No).
- Question 12: "If you were better informed about the economic advantages of the low consumption bulbs, would you be ready to abandon completely the incandescent bulbs?" (possible answers: Yes, No).

Thanks to these questions, we can identify the part of consumers who were not informed about the energy consumption and lifetime of the technology. But once they got this complement of information, they claim to be ready to undertake technology switch. People who know about the advantages of low consumption bulbs and despite that, are not willing to change, influence the decrease of RLD1 to a steady incompressible level. For people who did not know about the advantages of low consumption bulbs and are then informed, there will be some of them switching to low consumption bulbs. We have then added one more question formulated as hypothetical scenarios:

- Question 13: "Did you know that if a household changes half of of incandescent bulbs for low consumption ones, about 200 CHF per year can be saved?" (possible answers Yes, No).
- Question 14: "Based on this information, would you change at least half of your bulbs?" (possible answers: Yes, No, I did it already).

This question enables us to identify the part of people who are well informed but will not change, those who were not informed but did the change and finally those who would do the technology switch thanks to the information.

In order to assess the drivers of energy savings, we have asked about the reasons why people turn the lights on when they enter into a room. If this is due to their poor eyesight or irrational fear of obscurity, they will probably not change their behaviour. However people who say it is just a habit, or if they do so for comfort, aesthetics, or do not know, they could possibly make the effort to change their behaviour. Likewise, people who say they leave light on when watching TV, could switch it off. But those who do have already done this or who leave only a small spot to reduce contrast and eyestrain, cannot make further savings. This is typically the kind of hypotheses we need to set up in order to get a proxy of the parameters that will be entered into the model.

For instance, in **Table 1**, related to Question 7 "What proportion of low consumption bulbs do you have at home", we had roughly 20% who wouldn't know about the number of low consumption bulbs they originally had. Based on cross table analyses involving different questions of the questionnaire, and referring to the above hypotheses, we propose a new presentation for the proportion of low consumption bulbs in **Table 2** above. This table is now usable to determine the RESID of RLD 1.

6. Preparing the Data for Socio-MARKAL

This section aims at determining the parameters for all the demand technologies (*i.e.*, RLD1, RLD2, RLD3, RLD4) presented in **Figure 2**. More descriptive details about these technologies can be found in the appendix, in **Table 5**. We start with RLD3, which corresponds to "Switch to low consumption bulbs".

6.1. The Case of RLD3

Our evaluation is based on the cross-analysis of questions 13 and 14. The respondents (3.9% of the sample and 15.3% of people who answered "Yes" to question 13) were already informed about the economic advantage of choosing low consumption bulbs and are not willing to change. These respondents represent an incompressible ratio that enters into the efficiency coefficient of the MARKAL model. To this figure, it is necessary to add 14.4% of the sample (*i.e.*, 19.2% of people who answered "No" to question 14). These latter persons did not have the information before and were informed during the survey. Still, they indicate that they won't change their behavior.

On the other hand, 9% of the sample and 35.7% of the people answering "Yes" to question 13 were already informed about the economic advantages of switching to low consumption bulbs. Moreover, they indicate that they are willing to make a technology switch soon, but did not do it yet. We believe that for these respondents, this new exposition to information represents a reminder. Likewise, 44.2% of the sample (*i.e.*, 59.1% of all people for whom the information is new) claim that they are willing to undertake the technology switch in order to replace half of their incandescent light bulbs by low-consumption bulbs.

Finally, people who have announced that they already made the change before the survey, are deducted from

Table 2. Descriptive statistics showing the proportion of low consumption light bulbs.

Proportion of low consumption bulbs [%]	N, number of respondents	Percentage [%]
0	53	17.04
25	96	30.87
50	65	20.90
75	72	23.15
100	25	08.04
Total	311	100.00

the final ratio that is inputted in MARKAL (53.2% of the people who answered "Yes" to question 14).

6.2. The Case of RLD2

Here we explore and analyze the answers in question 15, "Your electricity consumption would likely change for the following reasons" (respondents can make up to 2 choices among six options). The results (normalised) are presented on the table below.

In order to determine the parameters for RLD2, we have considered three different aspects. Firstly, we have decided to evaluate the direct impact of an advertising campaign (*i.e.*, "An information campaign on the media or advertising") as our main explanatory parameter for RLD2. Secondly, the indirect effect can be represented by both "The opinion of a relative" and "A request from our children". Thirdly, economic criteria include the income modification (*i.e.*, "A change in your income"), and "Electricity price increases". The former and the latter are excluded because these parameters (effects) are in fact characterized by their economic rationality, which is compatible with the standard MARKAL formulation.

Our evaluation shows that 37.5% of all respondents (24.7% of the normalized total, as shown in **Table 3** above) declare that an awareness campaign can influence their electricity consumption. Based on this information, we can set the *efficiency of the awareness campaign* to 24.7%. Setting the efficiency as composed of both the direct and indirect effects, we get 27.5+37.5+11.1 = 76% of all replies (*i.e.*, 50.2% of the normalized total). However this figure represents the declared likeliness of the respondents influenced directly by an information campaign or indirectly through a third-party person (*i.e.*, relatives and parents).

6.3. Determining Investment Costs for MRKP2 and MRKP3

The following table corresponds to the results provided for question 16, "What kind of information means would likely change your behaviour". These results, presented in **Table 4** below, are associated with percentages that have been normalised. In this table, we have included a new column titled "Cost per individual". These estimates represent calculations based on the results of question 16 and hypotheses related to marketing costs (obtained through a discussion with a marketing expert operating in the Geneva region). In the case of articles from newspapers, we consider the cost to be zero because it is an independent editorial initiative.

6.4. Inputting the DM Tables of MARKAL

We have implemented a MARKAL model using ANSWER, the IEA platform. Consequently this kind of simulation will be directly available to ANSWER users and we hope that it will enable them to develop their own Socio MARKAL scenarios (the IEA/ANSWER mdb file of the case study presented in this paper is available by contacting the authors).

The following snapshot, exhibited in **Figure 3** below, presents an example of this kind of Socio-MARKAL

Table 3. Distribution of responses to question 15, "Your electricity consumption would likely change for the following reasons" (respondents can choose among up to 2 options).

	Proportion of respondents (N = 311)
Option 1. The opinion of a relative, a friend or a neighboor	18.20
Option 2. A request from your children	7.27
Option 3. An information campaign on the media or advertising	24.74
Option 4. A change in your income	12.53
Option 5. Significant electricity price increase	30.71
Option 6. Nothing would change my behaviour	6.62
Total	100.00
Aggregates	
Information (options 1 to 3): 50.13%	
Economic conditions (options 4 & 5): 43.25%	

Table 4. Distribution of responses to question 16, "What kind of information would likely help changing your behavior".

Means	Percentage [%]	Cost [CHF] per individual
A Web page filled with useful information	10.50	5.00
A Web page with an energy savings calculator	17.60	5.83
Articles from newspapers/TV reports	19.40	0.00
Leaflets from utilities or green organisations	14.50	0.03
Doorstep awareness campaigning	2.40	20.00
Selling points with information (e.g. posters)	12.30	20.00
Advertisement on TV and radio	14.20	1.00
Advertisement campaigns on public transports	9.10	0.25
Total	100	

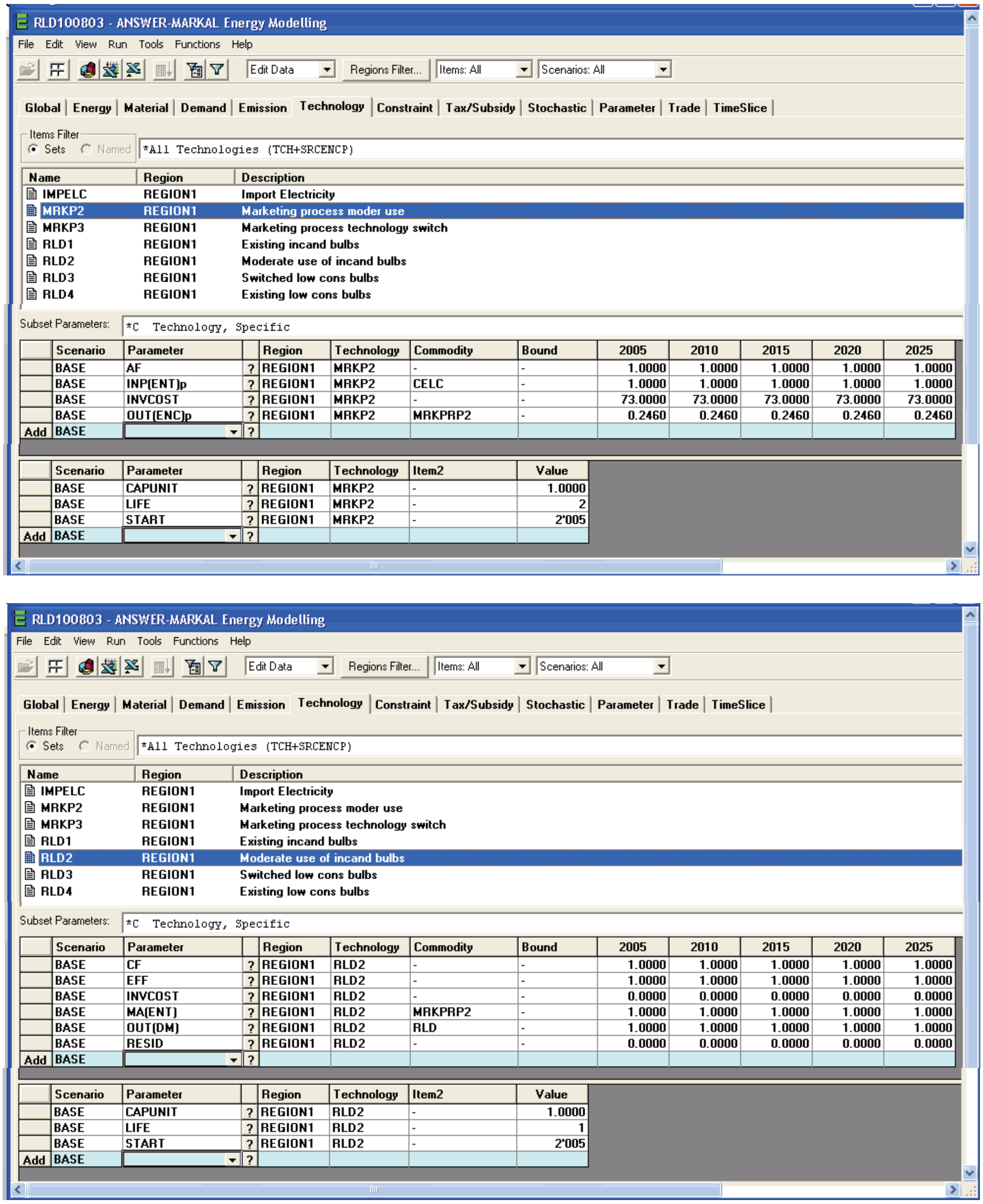

Figure 3. Example of Socio-MARKAL scenarisation developed in IEA's ANSWER.

scenarisation in IEA's ANSWER. We are aware that this kind of scenarisation is associated with uncertainties and that this kind of development is still in its infancy. However, it offers to policy makers a tool to test environmental policies that involve social change.

Recently, new regulations imposing low consumption bulbs have been enforced in the EU as well as in Switzerland. Consequently, this kind of scenario can be useful to understand alternate evolutions if this kind of regulations were not in place.

We have seen that it is particularly difficult to devise hypotheses regarding investment costs. We would like also to remind that it is possible to produce shadow prices from MARKAL, because it is based on convex optimization. So, it is always possible to determine what should be "the rational" cost of awareness campaigns.

7. Illustration

In this section, we will assess the Socio-MARKAL model with an illustration based on three scenarios. In this illustration, we consider an evaluation over a span of 20 years (*i.e.*, from 2005 to 2025) spread over 4 periods of 5 years.

7.1. Assumptions

A number of assumptions have been introduced, specifically regarding both the demand investments for residential lighting technologies.

The overall *demand* for light bulbs is expected to grow by about 50% over the evaluation period, *i.e.*, from 1442 hundreds units (144'200 bulbs) in 2005 to 2500 hundreds units (250'000 bulbs) in 2025. Residual capacity is split between RLD1 and RLD4, respectively for 80% and 20%.

*Investment cost*s for RLD1 are expected to rise by 40% over the evaluation period, *i.e.*, from 1 CHF/bulb in 2005 to 1.40 CHF/bulb in 2025. However, for low consumption bulbs (RLD4) whose costs are set to 10 CHF/bulb in 2005, we assume decreasing costs over the time periods of respectively, 7 CHF/bulb in 2010, 6 CHF/bulb in 2015, 5 CHF/bulb in 2020, and 4 CHF/bulb in 2025.

The *lifetime* of new light bulbs is set to 1 year for incandescent bulbs (RLD1) and 2 years for low consumption bulbs (RLD4).

The *energy carrier input,* (*i.e.* MA (ENT) in ANSWER), remains constant over the evaluation period. For RLD1 and RLD4, it is set to 0.0328 TJ/unit and 0.0065 TJ/unit respectively.

7.2. Scenarios and Results

We consider three scenarios.

Scenario 1: the first scenario (see **Figure 4**) is characterized by investment costs in marketing technologies which are so high that virtual technologies do not appear in the optimal solution. Here, we have a case of classical MARKAL competition between incandescent bulbs (RLD1) and low consumption bulbs (RLD4). Both technologies have bounds. In the case of incandescent bulbs, there is a constraint related to the proportion of people who claim they are not willing to undertake the technology switch, *i.e.*, from incandescent to low consumption bulbs. On the other hand, for low consumption bulbs, we have put a lower bound equal to the installed capacity on the first period, assuming that in the following periods, their penetration should never go below that value.

Scenario 2: the second scenario presented in **Figure 5**, is an example of a case when the cost of information campaigns in favour of technology switch is getting lower so

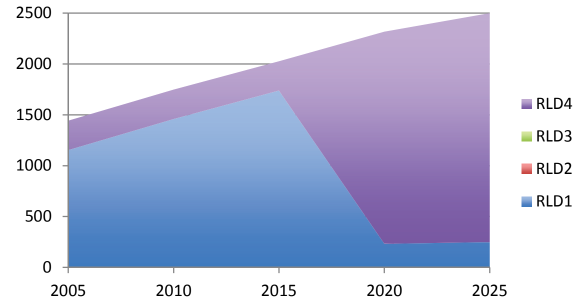

Figure 4. Outline of scenario 1, "Marketing technologies too costly".

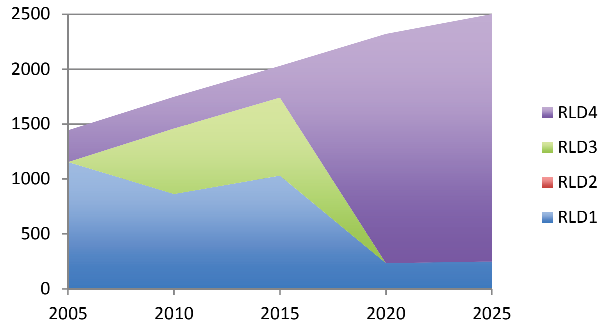

Figure 5. Scenario 2, "Marketing for technology switch becomes competitive".

that the campaigns are worth to be financed. In this case, and for two periods, the number of incandescent bulbs decreases, replaced by low consumption bulbs, which appear as the result of the campaign in favour of low consumption bulbs.

Scenario 3: the third scenario (**Figure 6**) shows that if the cost of marketing technologies is low, then the energy savings and technology switch may dominate the spontaneous purchase of real bulbs.

8. Conclusions

This study implements the Socio-MARKAL framework that would take into account consumers' technological

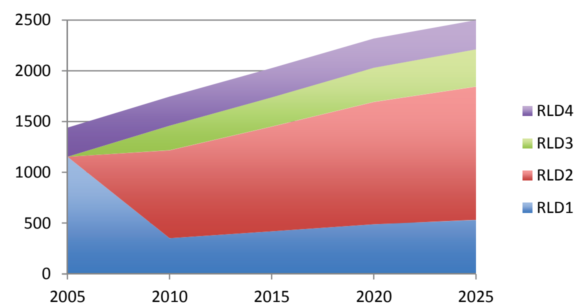

Figure 6. Scenario 3, "Both marketing technologies appearing in the optimal solution".

improvements and behavioral changes minimizing carbon dioxide emissions and encouraging rational use of energy. In this paper, we firstly present and discuss the results of a survey research related to attitudes and behaviors towards lighting consumption.

We show how to transform the sociological data into parameters for the MARKAL model. Secondly, we prove with this paper that, sociological data can be integrated in a model of technological choices such as MARKAL. The IEA's platform, ANSWER, has been used for that. Thirdly, our study shows that it is possible to develop environmental and energy planning scenarios that simultaneously take into account technological as well as sociological aspects. This study also shows that we have been able to move from an idea (*i.e.*, integration of behavioral aspects of energy consumption into a model of technological choices) to the concept proven (*i.e.*, the Socio-MARKAL).

We are currently working to extend the concept to the transportation sector. A new sociological survey about attitudes and behaviors regarding passengers is currently conducted in order to feed the Socio-MARKAL model with additional relevant data.

The conclusions drawn from one of our previous studies [10] show that the sociological/behavioural approach, *i.e.*, data collection through surveys and sociological experiments are powerful tools that can help people understand their (personal) energy use and for motivating their actions to reduce carbon emissions. This means that awareness campaigns can stimulate behaviour change to conserve energy. Consequently, both technological and behavioural contributions can be integrated into a single strategy. In turn, this is enough to justify an extension of the current MARKAL family of models, with the integration of data collected through surveys and/or awareness campaigns.

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Appendix

Table 5. Technologies and their description.

Parameters	Value	Units	Type
ELC	Energy imports	TJ	Resource
CELC	Energy carrier	TJ	Resource
MRKP2	Awareness campaign "Moderate use of incandescent light bulbs"	CHF/capacity unit	Process technology
MRKP3	Awareness campaign "Technology switch towards low consumption bulbs"	CHF/capacity unit	Process technology
MRKPRC2	Energy carrier MRKP2	TJ	Process
MRKPRC3	Energy carrier MRKP3	TJ	Process
RLD1	Existing Incandescent Bulbs	Hundreds of light bulbs	Demand device
RLD2	Moderate Use of Existing Incandescent Bulbs	Hundreds of light bulbs	Virtual demand device
RLD3	Technology Switch toward Low Consumption Bulbs	Hundreds of light bulbs	Virtual demand device
RLD4	Existing Low Consumption Bulbs (a mix of new technologies)	Hundreds of light bulbs	Demand device
RLD	End use residential lighting	Hundreds of light bulbs	Demand

