Engineering the Policy-making Life Cycle

Seventh Framework Programme – Grant Agreement 288147

The first complete version of the agent-based model

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Authors of this document:

Tina Balke[1], Nigel Gilbert[1],

[1]: Centre for Research in Social Simulation, University of Surrey
email: {t.balke,n.gilbert}@surrey.ac.uk

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1 Introduction

This deliverable introduces the social simulator of the ePolicy project. The social simulation focuses on the simulation of the impact of different policy instruments on the adoption of photovoltaic panels at a household level. It is placed logically after the planning-step on the regional level (also referred to as global level in the project). Once planning goals have been determined, through optimisation (e.g. with respect to minimum costs, maximum CO_2-reduction, minimum disruption,...) and decisions on how to allocate the budget to policy instruments in order to achieve these goals at the level of the region have been made, it is then necessary to apply the policy instruments.

However, what is an optimal policy at the regional level may not be locally or individually optimal. Thus some (incentive) mechanism is needed to enforce the policy – one cannot assume that individual agents will adopt the desired behaviours of their own accord. These potential policy instruments could reach from fiscal incentives, via tax incentives and different tariffs to legislation for example. All options have disadvantages, and which is best is not clear and will vary from case to case. In order to be able to assess effects of the different policy instruments on individual households better, a multi-level agent-based model has been developed that allows policymakers to explore the consequences of different types of policy instrument and thus enable them to make better choices.

In the social simulation so-called (software) agents represent the main actors, the individual households. They are given behavioural rules modelling their likely individual responses to policy instruments (including the effect of influences from other actors, e.g. as a result of collective actions, imitation etc.). The overall response to the simulated policy instruments will be measured to inform policymakers.

This document is supporting Deliverable 4.1 of the ePolicy project, which is the just described simulator that was developed using Netlogo[1]. The simulator can be found on `http://epolicy-project.eu/sites/default/files/public/epolicy_simulation.zip`. The deliverable starts with the research question the social simulator helps to answer (Sec. 1.1). Afterwards the social simulator is being described. Particular focus thereby is given to the general components of the simulator (Sections 2.1 and 2.2) for which the visual interface (in- and output) and their execution is described.

1.1 Research Question

As mentioned before, the main research question the social simulator is answering is as follows:

> What are the effects of different policy instruments on the photovoltaic system diffusion (individual level) in the Emilia Romagna region with respect to the CO_2 emission and the costs involved w.r.t. the policy instruments.

Looking at this research question, the social simulator has two main foci: (i) It focuses in particular on photovoltaic panels as technology, and (ii) it focuses on attitudes of individual households only.

[1] `http://ccl.northwestern.edu/netlogo/`

Reasons for this focus and explanations how the model can be extended (e.g. to incorporate other stakeholders such as companies and policy makers on various levels) have been given in Deliverable 4.2. The policy instruments modelled in the simulator were chosen in agreement with regional politicians in the Emilia Romagna region:

1. investment grants
2. contributions to interest rates for loans individuals have to take in order to finance a photovoltaic system
3. feed-in-tariffs, and
4. tax deductions on the photovoltaic investment.

Whereas the first of these two options are regional policy instruments, the latter two are being used on a national level. These national incentives were included in the simulator to analyze to what extent the national incentives influence the regional incentives[2]. In the simulator itself, the users such as policy makers can decide themselves which (set of) incentives they want to analyze.

1.2 Agent-based Modelling with Netlogo

The modelling technique used to develop the social simulator for the ePolicy project is agent-based modelling. An agent-based model (ABM) "is a computational method that enables a researcher to create, analyse, and experiment with models composed of agents that interact within an environment [1]."

There are several important elements in this description. Firstly, the model is composed of autonomous and heterogeneous agents. That is, there are many simulated individuals with different properties and decision making rules. In ePolicy for example, properties include geographic location, photovoltaic and policy instrument knowledge as well as housing and financial situation, and rules include photovoltaic prevalence at which the individual will consider gathering information about photovoltaic because they might install panels.

Secondly, these agents interact within an environment. That is, the individuals are able to perceive the situation in which they find themselves, take that situation into account in their decisions and take actions that affect the environment. Continuing the example, the individuals are able to perceive the photovoltaic prevalence in their location, which allows them to check their perception of photovoltaic and the respective policy instruments.

Finally, ABM is a computational method that simulates interactions over time. Simulations allow 'what if' questions to be tested quickly, cheaply and without the ethical problems of setting up experiments. Provided the key interactions are properly represented in the model, the simulation can explore the consequences of different actions. For ePolicy, different policy instruments (see above) were implemented that can be tested as separate runs of the simulation model with the results of the simulation indicating the reaction of individual households to the different policy instruments.

It is important to recognise, however, that the results of a simulation run will not be suitable for forecasting. For example, it would not be appropriate to claim that a particular policy

[2]The national and regional incentives are not exclusive, but can be combined by households.

instrument implementation would lead to 20% adoption of photovoltaic. The model is a simplified representation of the key relationships that exist in the real world. That simplification is what makes the model useful – knowledge about the real world can be captured and its consequences can be understood – but the model will not be detailed enough to support specific claims. In the terminology of [2], the model is a mediator "used primarily to establish the capability of the conceptual model to represent the system and to then gain some insight into the system's characteristics and behaviours" so as to understand potential implications of different scenarios.

The ABM for the ePolicy project is developed in NetLogo [3], a specialist ABM development tool with its own programming language. NetLogo is available open source and has a wide popularity. One reason for this popularity is its integrated user interface which allows users of the model to interact with it easily.

The NetLogo model developed for ePolicy allows users to input different policy instruments (and the funding they give) and also to manipulate other parameters that are relevant for planning such as the region to be considered and the threshold of photovoltaic adoption that one wants to reach.

A NetLogo model has three layers (see Figure 1) that can be accessed by clicking on the respective tabs in the simulation environment.

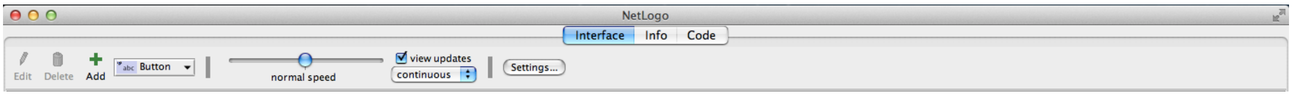

Figure 1: The NetLogo Layers

The 'Code' layer sets out agent properties, interaction rules and data. The 'Interface' layer provides tools to allow the user to manipulate key model parameters and run the model, and reports of results including charts and other information to monitor the simulation during the run. The 'Info' layer is to allow accessible documentation to be packaged with the model. In addition, a so-called BehaviorSpace tool in NetLogo provides scenario management capabilities, so that results from multiple simulation runs can be exported for analysis.

The main user group of the ePolicy social simulator component are policy makers who are envisioned to have access to the interface layer of the simulator only. Reasons for this are their lack of modelling skills to change the code layer as well as the attempt to avoid conflicts of changing the simulation to produce desired results. This document will briefly outline the components of the interface layer in the following sections. A detailed description of the rules encoded in the code layer can be found in Deliverable 4.2.

2 The Social Simulator

Recalling the requirement specifications of the social simulator from previous deliverables (in particular Deliverable 2.3), two main directions for requirements were defined (both for functional and non-functional requirements):

1. The realistic representation of the decision behaviour of households in the Social Simulator, and

2. the usefulness and ease of usage of the social simulator for its stakeholders (in particular policy makers) for answering the before mentioned policy question.

The realistic representation of household decision making is discussed in Deliverable 4.1, which is why it is not addressed in this Deliverable. Instead we focus on the second aspect, the usefulness and ease of usage for users.

For better understanding what is considered "useful and easy to use" for the potential users of the social simulator, we designed a questionnaire which was given to representatives of potential user groups (including the regional policy makers, as well as photovoltaic companies interested in the reaction of households to different incentives fostering the uptake of photovoltaic panels). This questionnaire can be found in Appendix A.

Besides the obvious requirement that the social simulator must allow to analyze the update of photovoltaic by individual households based on different policy instruments, the main result of the questionnaire was that users want to be able to look at individual sub-regions (e.g. their electoral region) of the Emilia Romagna region and want to be able to look at both regional as well as national policy instruments. For these policy instruments they want to be able to specify funding levels. With respect to the output, in particular adoption rates, the resulting energy production from photovoltaic and the costs associated with the adoption (per policy instrument) were of interest to the users. Furthermore the speed of the simulation was mentioned as one attribute that can influence the utilization of the simulator.

2.1 Main Simulation

2.1.1 The Simulation Interface

Based on the above described user requirements, the social simulator shown in Figure 2 was developed. Once NetLogo is installed[3] the social simulation can be started by executing the file *ePolicy_simulation.nlogo*.

The social simulator interface consists of four areas, which will now be explained in more detail.

Starting at the top left, as show in Figure 3, the first area is comprised of two buttons labelled *setup simulation* and *run simulation* as well as several sliders and a drop-down menu for specifying parameters of the simulation.

As indicated by their labels, the first of the purple buttons sets up the simulation with all specified parameters and the different decision entities, whereas the second one can be used to run it. Running the simulation without setting it up beforehand it not possible, thus it is strictly necessary to press the setup button before running the simulation. The parameters that can be specified by the user for the setup include the region to be simulated (via the drop-down menu; as this is a proof-of-concept prototype currently only the Emilia Romgna and the Bologna region are available), the initial percentage of people having photovoltaic (initial-percentage-of-PV-users slider), the average interest rate for credits in percent (credit-

[3]Details on how to obtain and install NetLogo on different operating systems can be found on the NetLogo website `http://ccl.northwestern.edu/netlogo/`. The systems requirements are detailed on `http://ccl.northwestern.edu/netlogo/requirements.html`.

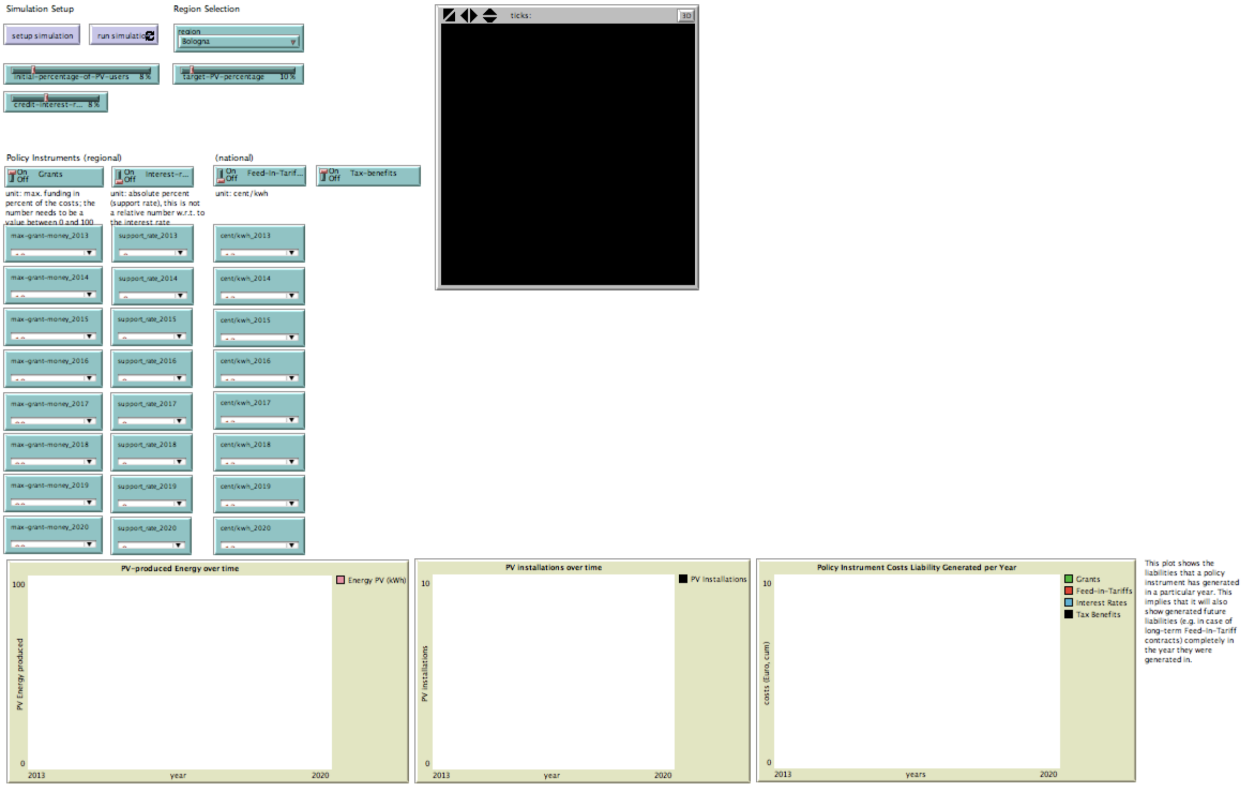

Figure 2: The Social Simulation Interface

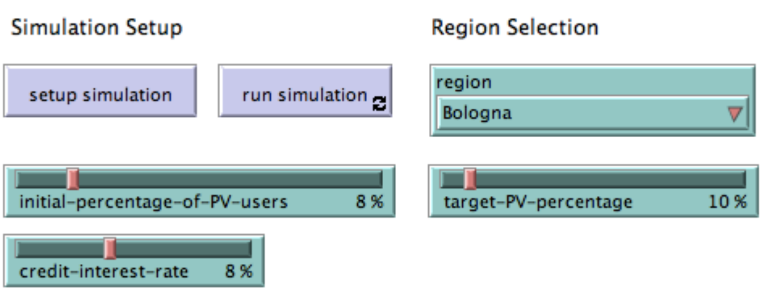

Figure 3: Simulation Input Parameters

interest-rate slider) as well as the target percentage of people who should have photovoltaic (target-PV-percentage slider).

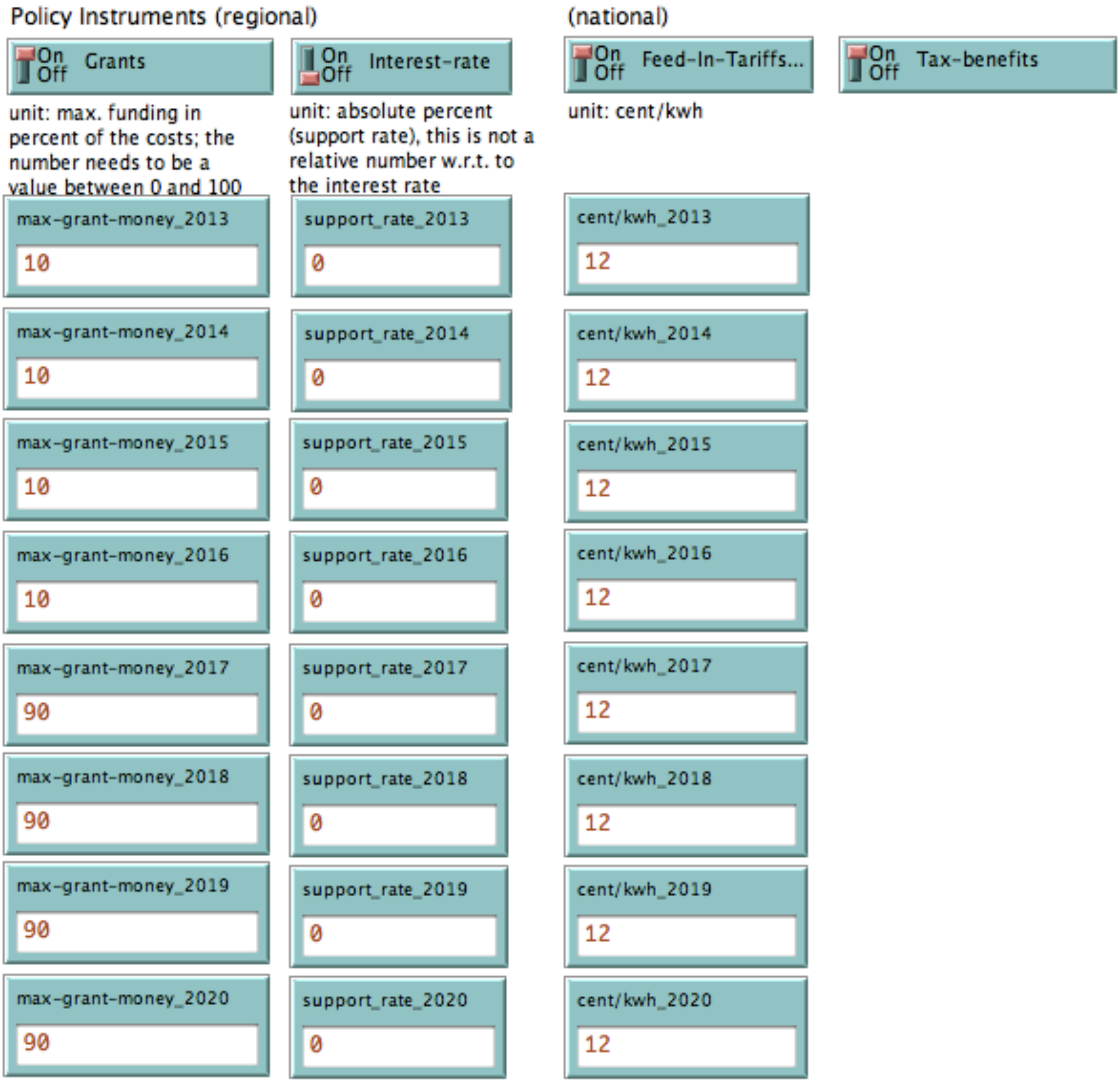

Figure 4: Specifying Policy Instruments

In addition to these parameters, the users can specify which policy instruments should be available to the households being simulated. We thereby distinguish two regional and two national policy instruments all shown in Figure 4:

1. investment grants
2. contributions to interest rates for loans individuals have to take in order to finance a photovoltaic
3. feed-in-tariffs, and
4. tax deductions on the photovoltaic investment.

For each of these instruments, using the on-off-switches, the user can specify whether the instrument shall be considered (on) or not (off position of the switch). Furthermore, for each instrument the user can specify the size of the support by the policy instrument.

- For the investments grant this size is a percentage (number between 0 and 100) of the installation cost investment for the photovoltaic panels.
- For interest rate contributions the number refers to the percentage of the interest rate the region covers (e.g. if the interest rate is 8% and the specified interest rate constribution 2%, the region covers 2% of the interest rate costs and the household has to cover 6%). As a result, the interest rate support should always be smaller or equal to the average interest rate for credits.
- On the national level, for the feed-in-tariffs, the user can specify how many cents the state pays per kwh of photovoltaic generated electricity the households contribute to the energy network (this does exclude any energy that was self-consumed).
- For the tax deduction policy instrument, no further specifications can be made. Instead, if the switch is turned on, the national tax deduction rate (for costs associated with the installation of photovoltaic) of 55% is used. The reason for this design choice is that the main users of the simulator are regional policy makers who do not have any influence on the national tax deduction scheme.

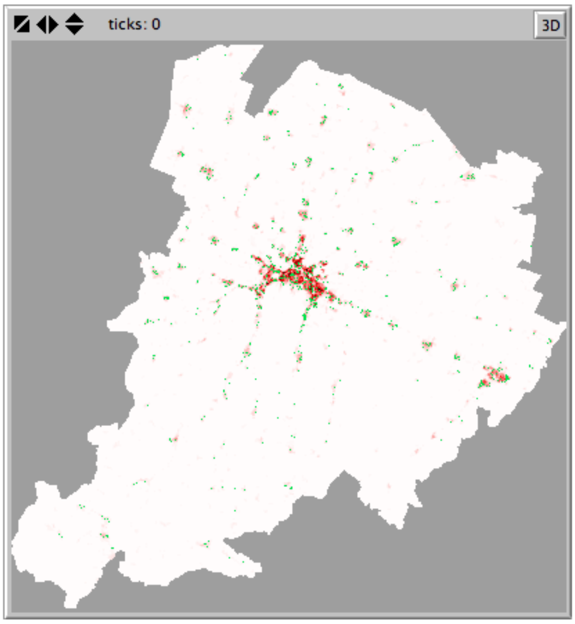

Figure 5: Geographic Representation of Photovoltaic Adoption

On the top right hand side of the simulation interface a third area can be seen, which shows the geographic representation (in form of a map) of the photovoltaic adoption. Before setup this map is black. However, once the region the user is interested has been defined in the setup process (and this setup process has been completed), it changes to a map showing the selected region. In the map, for easier orientation, different red-shades are used to reflect population densities (with darker red-shades representing higher population densities and lighter shades lower densities). The example map shown in Figure 5 displays the map of the Bologna region. Furthermore, in each area where the previously specified target photovoltaic threshold is met, a green dot is shown to indicate this success.

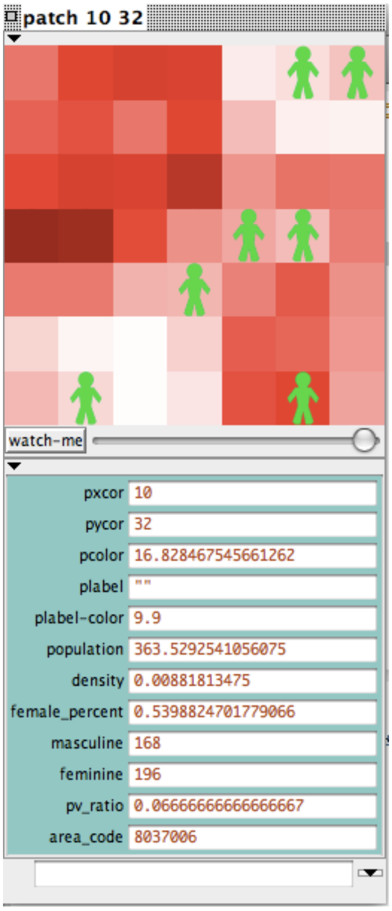

Figure 6: A Patch Display in NetLogo

By right-clicking on the map, users also have the chance to analyze the spots (so-called patches in NetLogo terminology) more closely. Figure 6 shows the display which is shown for a selected patch in more detail.

2.1.2 Running the Social Simulation

The social simulation can be run by clicking on *run simulation* after the setup of the simulation is completed. A message announcing this setup completion is displayed at the end of the setup process. When the simulation is running, the area at the bottom of the simulator interface shows the results of the simulation in form of three plots (Figures 7–9). The screen show the liabilities the policy instruments have generated in a particular (per instrument)[4], the total number of photovoltaic installations over time, and the energy produced by these photovoltaic panels in terms of kwh.

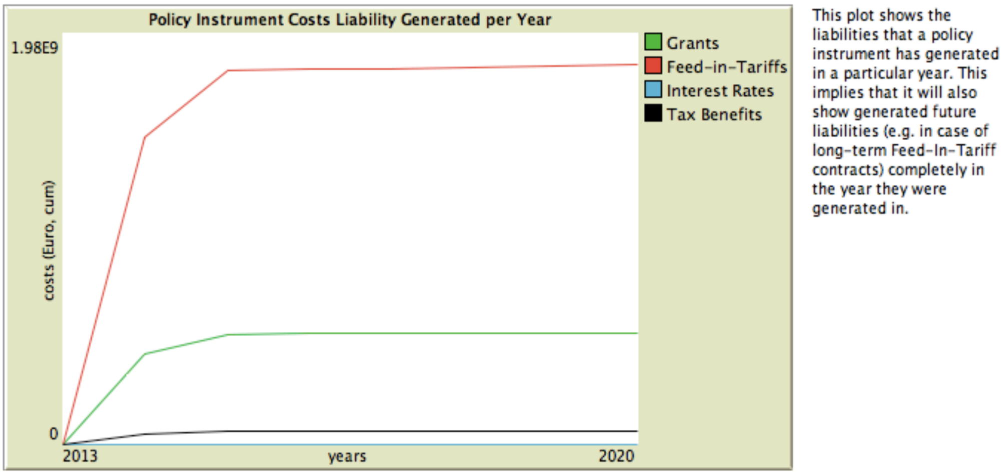

Figure 7: Output 1: Costs per Policy Instrument

2.2 Map Generator

Profiling the performance of the simulation, a disproportionately large amount of the complete time needed to run the social simulation was used in setting up the GIS-based map information. This is why this step has been decoupled from the actual simulation and the GIS-based maps can be loaded by a separate program which converts them from the GIS format (with its long loading times) to a NetLogo specific format which is faster to load. The program does not need to be called in order to run the main simulation, as all maps (Bologna and Emilia Romagna) the user can select in the main simulation have already been recoded. The program is only needed if new maps should be added to the main social simulator. The map generator tool (Figure 10) which converts the GIS information into the NetLogo-specific format can be started by executing the file *generate_gis.nlogo*.

By selecting a region and choosing the *Generate Map* option, the desired map in the NetLogo format is generated. This map then needs to be saved using the *Save Map* option. When

[4]"Liability generated" that in a given year, also generated future liabilities will be shown. In terms of feed-in-tariffs this means that all costs/liabilities resulting from the long-term (e.g. 30 year) feed-in-tariff contracts are completely in the year they were generated in.

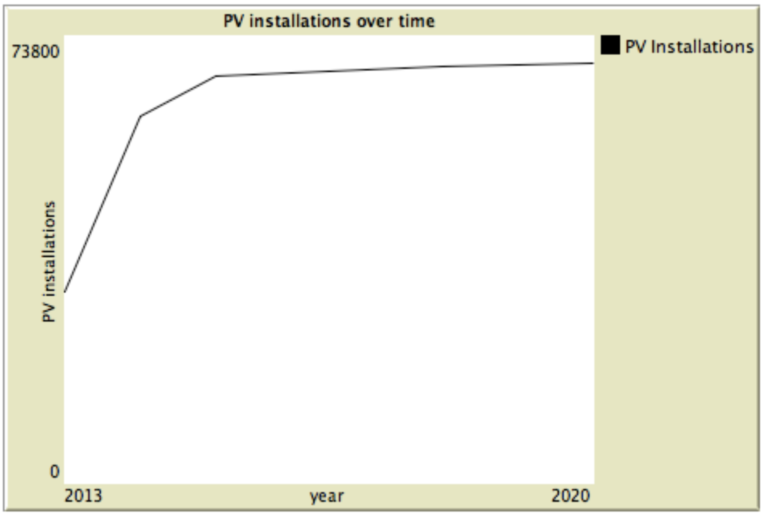

Figure 8: Output 2: Number of Households with Photovoltaic Panels

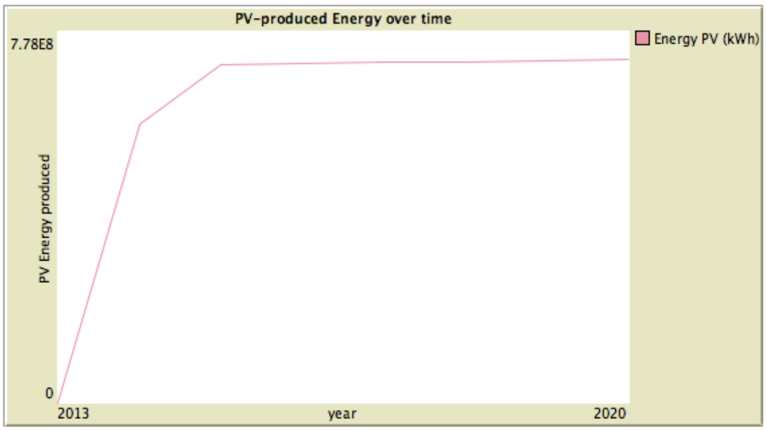

Figure 9: Output 3: Energy produced by Photovoltaic Panels

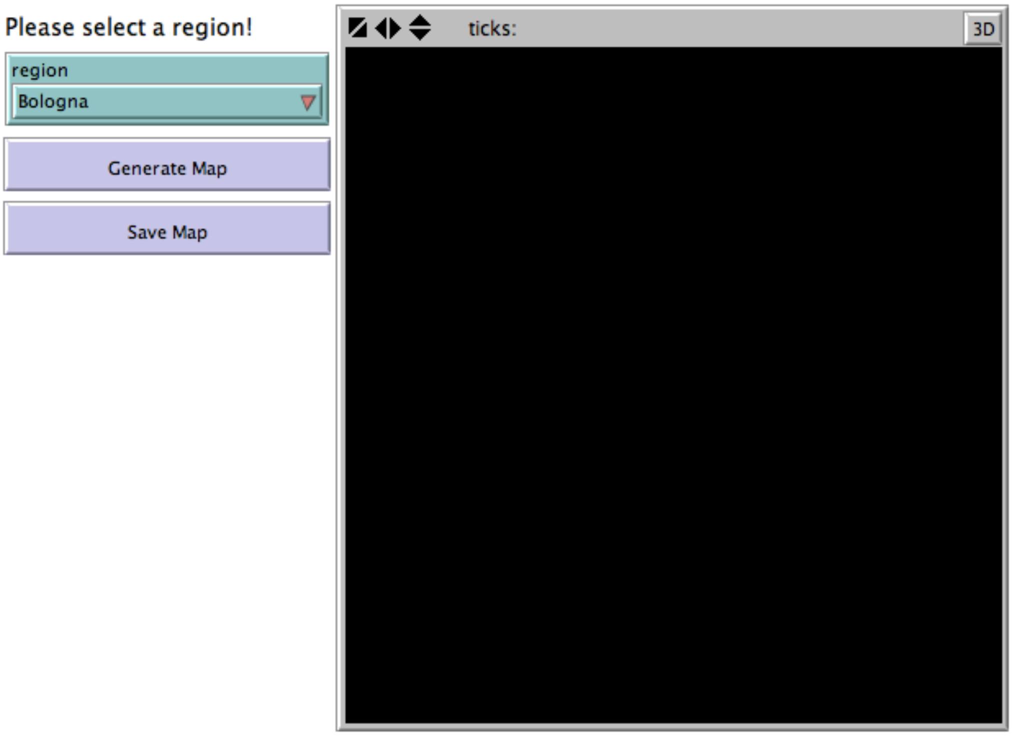

Figure 10: The Map Generator Tool Interface

selecting this option a dialog (Figure 11) is displayed which allows to specify the name of the new file. The file is automatically saved in the csv-format[5].

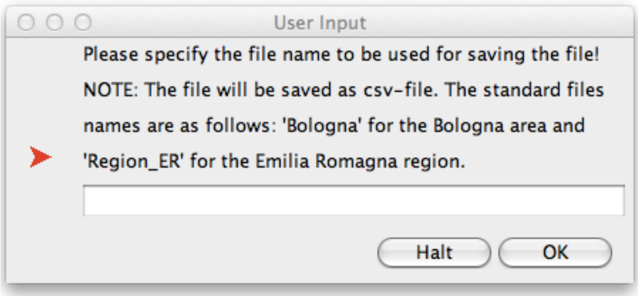

Figure 11: Dialog Box for Saving Maps

[5]Standard file names should be used for the already existing files, as the main simulation will be checking for these files names. The standard files names are as follows: 'Bologna' for the Bologna are and 'Region_ER' for the Emilia Romagna region.

References

[1] Mohamed Abdou, Lynne Hamill, and Nigel Gilbert. Designing and building an agent-based models. In Alison J. Heppenstall, Andrew T. Crooks, Linda M. See, and Michael Batty, editors, *Agent-Based Models of Geographical Systems*, pages 141–165. Springer, 2012.

[2] Brian Heath, Raymond Hill, and Frank Ciarallo. A survey of agent-based modeling practices (January 1998 to July 2008). *Journal of Artificial Societies and Social Simulation*, 12(4):9, 2009.

[3] Uri Wilensky. Netlogo. `http://ccl.northwestern.edu/netlogo/`, 1999. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

A Interface Questionnaire

The following questionnaire, designed by the Fraunhofer Institute for Computer Graphics Research and the University of Surrey, was used in order to acquire knowledge about the visual needs and requirements of policy makers with respect to the social simulator. In the questionnaire we used te term "policy maker" in a wider sense referring to elected representatives, the officials that support them and various levels of management in other kind of organisations including private industry and commerce. This is why, the questionnaire has been completed by this wider group of policy makers and the answers have been incorporated into the interface design of the social simulation prototype.

ePolicy – Engineering the policy making life-cycle
Requirements Analysis

Introduction

The ePolicy project (www.epolicy-project.eu) is a joint research project funded by the European Commission with the goal to support policy makers in their decision process.

It has two objectives:

> (i) To facilitate the policy making process by providing tools that can help policy makers to analyze the impact of specific policy incentives (for example investments grants, feed-in-tariffs, interest rate subsidies and others) and
>
> (ii) To apply the thereby gained knowledge to the case study of the regional energy plan of the Emilia Romagna region in Italy.

Whilst the policy making process is frequently considered within the public sector it is equally applicable to other kinds of organisations, including private industry and commerce. Thus the term policy maker should be interpreted widely including elected representatives, the officials that support them, and various levels of management in other entities.

Modelling techniques are often used to gain insights into possible policy effects. It is useful to consider the alternative nature of such models. The dictionary definition of a model describes them as graphical, mathematical, symbolic, physical, or verbal representations of a concept, phenomenon, relationship, structure, system, or an aspect of the real world. Essentially, they seek to simplify a complex reality in order to facilitate understanding, aid in decision making, and to explain, control, and predict events on the basis of past observations.

Since the inter-relationships within these models are usually too numerous and complex to be comprehended in their entirety, a model often contains only those features that are of primary importance to the model maker's purpose. As the policy issues under consideration become broader and the complexity further increases then more than one model may be needed to gain a comprehensive understanding and to apply different techniques, where appropriate, to varying aspects of the particular issue under consideration. Thus, the nature of such models may be significantly different which increases the challenge of presenting all the available data to decision makers in a useful and accessible way.

Any individual policy maker could be using many models to help with policy and decision making. These could well be located on a mix of platforms including generic tools such Excel and much more specialist software.

The models that the ePolicy project has been considering have been computer models although generically such models could take other forms. However even though the main focus is such computer models the range of them is potentially very large. The simplest is probably a single worksheet in a spreadsheet product such as Microsoft Excel. However, whilst retaining Excel as the platform, large complex models can be developed which consist of many inter-connecting multi-worksheet work books. Hence the range of models in terms of scale and complexity can vary enormously even whilst using the same platform. Other models based on different programming languages can be used for more specialist tasks – for example ePolicy is using mathematical logic programs to support its work on optimisation and a program called Netlogo on social simulation. There are many other modelling tools including graphical and visualisation ones that could also be used.

Against this background, one aim of the ePolicy project is to provide a computational model to simulate citizens' adoption of photovoltaic programs and incentives. Solar photovoltaic systems, or solar panels, are used for generating electrical energy through solar radiation.

To enable an easy access to the complex simulation model a visual interface will be designed. The following questionnaire will be used to detect identify requirements for this visual interface. The questionnaire is structured into two parts: Part 1 will focus briefly on the general case. Part 2 afterwards ask questions with respect to the specific Emilia Romagna energy plan analysis.

Part 1

Please provide information on additional sheets if there is insufficient space.

Based on the description on the previous pages, please indicate whether you are using any models to help with policy and decision-making? If so, can you indicate the number and nature of the models that you are using?

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Which tasks are you addressing with these models? Please summarise the objective of the model, the information that is required to run it and the nature of the results. If you use many models please select those that you use most and those whose results are the most influential.

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Please consider a policy or decision that you have been involved with (for example, if you wanted to analyse the impact of a policy instrument or incentive such as investments grants, feed-in-tariffs, or interest rate subsidies). What results would you typically be interested in? Describe the information that you would like to be presented to you.

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What policy instrument settings would you want to be able to change when comparing different scenarios?

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Do you consider differences between geographic regions of relevance for a policy instrument analysis?

☐ Not at all

☐ Only for the input of the analysis

☐ Only for the results of the analysis

☐ Important for both

Part 2

The screenshot you are seeing in this part are taken from a simulation model, which attempts to model the adoption of photovoltaic panels by individual households in the Emilia Romagna region.

Input Parameters

In the simulation the following policy instruments can be selected. How do you judge their relevance for the question of supporting the uptake of photovoltaic in the Emilia Romagna region?

	Not relevant at all				Very relevant
Investment Grants	☐	☐	☐	☐	☐
Feed-In-Tariffs	☐	☐	☐	☐	☐
Interest Rate Subsidies	☐	☐	☐	☐	☐

Can you think of any other policy instruments that might be useful in this context? Which?

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Besides the selection of policy instruments the factors mentioned below could be provided as inputs for the simulating the PV uptake. How do you judge the relevance of these?

	Not relevant at all				Very relevant
Overall Budget	☐	☐	☐	☐	☐
Time frame	☐	☐	☐	☐	☐
Budget distribution over time	☐	☐	☐	☐	☐
Geographical region to be analyzed	☐	☐	☐	☐	☐

Can you think of any other input parameters that might be useful? Which?

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Output Parameters

The list below indicates the outputs from the simulation. How do you judge the relevance of these outputs?

	Not relevant at all				Very relevant
Number of households with PV installations at certain point in time	☐	☐	☐	☐	☐
Geographical distribution of PV installations	☐	☐	☐	☐	☐
Number of households with PV installations over time	☐	☐	☐	☐	☐
Spatial/Geographic distribution of PV installations over time	☐	☐	☐	☐	☐
Amount of energy produced	☐	☐	☐	☐	☐
Cost distribution over time	☐	☐	☐	☐	☐

Can you think of any other combinations of output information you would want to analyse? Which?

____

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On which granularity level would you like to view the information?

☐ Individual Household Level

☐ City/Town Level

☐ Provincial Level

☐ Regional Level

☐ National Level

☐ Other: ____

Can you specify use cases that exemplify a possible task that can be addressed via the simulation model? (Find an example below)

Description	**Stakeholder**	**Input**	**Output**
Analyse geographic distribution of PV panels after 1 year by the use of one incentive mechanism	*Policy Maker*	*Duration, Policy Instrument, Region*	*Geographic distribution of PV panels after the implementation of the incentive mechanism*

Do you have any comments, questions, ideas, suggestions etc.?

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Additional Information

Profession/Position: ____

Area of Expertise: ____

Experience in Years: ____

What is your role in the policy making process (multiple selection possible)?

- ☐ Decision Maker
- ☐ Policy Analyst
- ☐ Modeling Expert (e.g. mathematician, climate researcher)
- ☐ Domain Expert (e.g. in energy domain); please specify domain: _________________________
- ☐ Public Stakeholder
- ☐ Consultant in the Policy Domain
- ☐ Other: ____

Thank you very much for your support!

The ePolicy Project Team