Engineering the Policy-making Life Cycle

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Report on the policy instruments considered and their likely effectiveness

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ABSTRACT

This deliverable describes the results of the integrated social simulator and incentive design component, when used to simulate the four policy instruments considered for incentivising photovoltaic (PV) solar panel adoption by households in Emilia-Romagna. The analysis focuses on: (a) the effect of regional budget, budget distribution and, regional objectives, on the energy produced in the region, costs to regional government, and the number of households installing PV; and (b) the effectiveness of the two regional instruments (grants and interest-rate support) in delivering regional objectives.

The ePolicy Consortium consists of the following partners: University of Bologna; PPA Energy; University College Cork, National University of Ireland, Cork; University of Surrey; INESC Porto, Instituto de Engenharia de Sistemas e Computadores do Porto, Fraunhofer – Gesellschaft zur Foerderung der Angewandten Forschung E.V.; Regione Emila-Romagna; ASTER – Società Consortile per Azioni; Università degli Studi di Ferrara.

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1 Executive Summary

This deliverable describes the results of the integrated social simulator and incentive design component of the ePolicy decision support system, when used to simulate the effectiveness of the four policy instruments (interest-rate support, grants, feed-in tariffs, and tax benefits) considered for incentivising photovoltaic (PV) solar panel adoption by households in the case study region of Emilia-Romagna. The analysis is based on two approaches: first, on the effect of regional policies on household PV adoption, and specifically the effect of (i) regional budget (in euro), (ii) budget distribution (i.e., even, ramp-up, ramp-down, first come first served) and, (iii) regional objectives (i.e., max participation, max energy, min cost), on (a) the energy produced in the region, (b) costs to regional government, and (c) the number of households installing PV. Secondly, it is focused on exploring the effectiveness of each regional policy instrument configuration (i.e., interest-rate support only, grant only, or both) in delivering regional objectives (i.e., max participation, max energy, or min cost).

As regional budget increases, the simulation results show gains in energy produced begin to level off, suggesting diminishing returns to increasing budgets at high levels. This is explained by the potential for regional funding to be received by households that also receive national support, and furthermore, would have installed PV without regional support. The simulation also identifies a similar effect caused by a 'first come first served' budget distribution policy, in which households that would have installed anyway, receive regional support ahead of households that are slower to apply for funding.

The most effective policy instrument configurations (i.e., grants only, interest support only, or both) for maximising energy appear to be grants only, or both grants and interest support together, with interest-only marginally less effective. For minimising costs, the three policy configurations appear equally effective. Finally, for maximising participation, the grants only, or both grants and interest support, configurations appear most effective.

Before the analysis was conducted, the first complete prototype of the social simulator (D4.1 [3]) was further developed based on continued analysis of the data collected during the survey and interviews described in D4.2 [2], and has improved the realism of agent's behaviour in the model. This process has also coincided with, and been significantly affected by, the integration of the social simulator with the incentive design component developed in WP5 which optimises the decision-making of the regional government with respect to the allocation of regional policy instruments (the incentive design component, and the integration with the social simulator are described in D5.3 [5]). The integrated tool (i.e., integrated social simulator and incentive design) is referred to as the integrated model, or model, from here onwards.

Since the first prototype (D4.1 [3]) another round of verification has taken place, in which the integrated model has been tested to check that the implementation is working as designed. The integrated model has also been through further validation, primarily using the data collected and presented in D2.1 [1] on the regional energy plan, containing estimates of minimum and maximum power to be provided by PV in the region, and the estimated cost of this power per megawatt (MW) produced.

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2 Introduction

The ePolicy project uses the Emilia-Romagna region in Italy as its case study. Deliverables D2.1 [1] and D2.2 [7] describe the energy plan, and the policy instruments used within it. Whilst the aim of the project overall is to support decision-makers by providing a multi-disciplinary decision support system (and its results), the specific role of the social simulator and incentive design is to simulate the behaviour of households and the regional government with respect to policy instruments. For households, it is their reaction to these incentive policy instruments that is modelled; for the regional government, it is their decision on how to allocate their funds under the instruments that is modelled.

The high-level research question that is being addressed with the integrated model is:

> *What are the effects of different policy instruments on photovoltaic system diffusion in the Emilia-Romagna region?*

Taken in conjunction with T4.4 (from the DOW), this deliverable thus aims to:

1. identify the most effective policy instruments for the case study of Emilia-Romagna, given regional objectives (T4.4), and
2. explore the effect of (i) regional budget size (in euro), (ii) regional budget distribution (i.e., even, ramp-up, ramp-down, first come first served), and, (iii) objective (i.e., max participation, max energy, min cost), on (a) the energy (kWh) produced by households with PV systems, (b) the cost of these systems, in total, and by policy instrument, and (c) the number of households that have adopted PV systems.

It is important to note that this deliverable and D5.4 [6] share some of their contents because of the integrated nature of the social simulator and incentive design component (described in both deliverables and D5.3 [5]). In particular, the experimental setup and evaluation of results is shared in these deliverables. It is important to note that as the two components were originally developed separately, they are still treated as separate in evaluation and contingency planning as set out in D9.2.

The deliverable is structured as follows. In Section 3, the updates to the simulator since the first prototype (D4.1 [3]) are described, as well as the integration with the incentive design component (D5.3 [5]). The policy instruments that are represented in the model are described in Section 4. In Section 5, the verification and validation process for the integrated model is outlined. Section 6 details the experimental design used to produce results for our analysis. Finally in Section 7, the results are presented and discussed in detail, before the conclusion in Section 8.

3 Updates to the Simulator

Since the first complete prototype of the social simulator (D4.1 [3]), further development has been conducted. This has been based on further analysis of the data collected during the survey and interviews described in D4.2 [2], and has improved the realism of agent's behaviour in the model. This process has also coincided with, and been significantly affected by, the integration of the social simulator with the incentive design component developed in

WP5 which optimises the decision-making of the regional government with respect to the allocation of the regional policy instruments; grant and interest-rate support (the incentive design component, and the integration with the social simulator is described in D5.3 [5]).

3.1 The Agent Decision Process

Figure 1 presents the first prototype decision process.

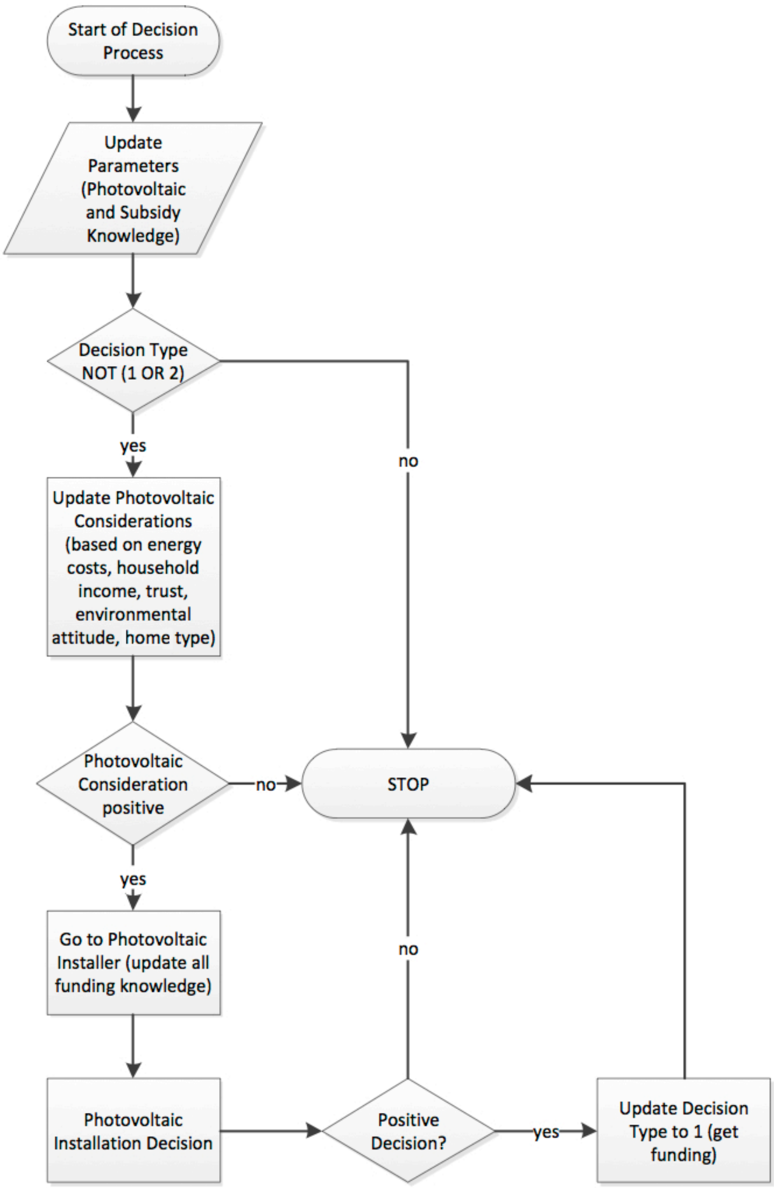

Figure 1: The General Agent Decision Making Process

In this original process, the agents (representing a household) began by updating their beliefs and awareness of PV (which may have changed owing to perceiving neighbouring agents installing PV). Next, if they hadn't already installed, or were not aware of PV (i.e., decision types 1 and 2), they considered installing PV. This step is a relatively simple process where an agent considers its attributes and makes a decision about whether it would like to consider in detail whether to install PV. The relation between attributes and the decision to consider were based on the findings from our survey with Italian households. If they decided to consider in detail, agents would then make a much more complicated calculation regarding the costs of installing, and other factors (e.g., trust in future). This detailed decision represented the interaction of agents with a PV installer. If the calculation suggested an agent was ready to install PV, this would happen, and support from the various policy instruments would be automatic (i.e., there was no selection, or limit, on the number of agents that could get support). A more detailed description of this process can be found in D4.1 [3].

Figure 2 presents the updated decision process.

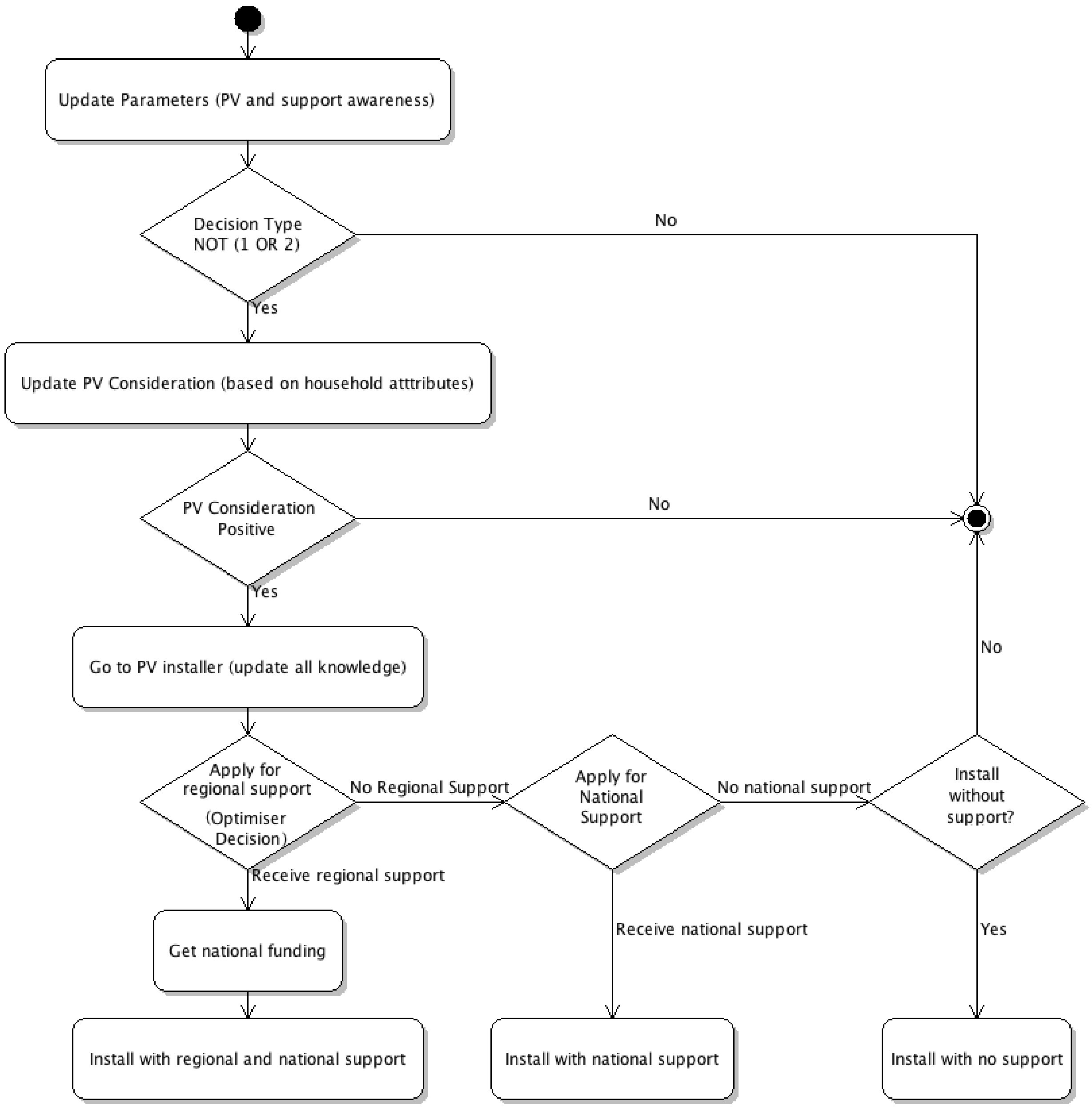

Figure 2: The Updated General Agent Decision Making Process

In this updated process, the first three stages of, (i) updating beliefs/awareness, (ii) making a basic consideration decision, and (iii) updating knowledge by visiting a PV installer are the same. However, beyond this the decision process has been changed significantly. Once an agent has received the updated information from the PV installer, they first apply for regional funding (grant and/or interest-rate support). This is where the incentive design (named optimiser in the figure) comes in. With a list of all the agents that have applied for funding it decides which should be allocated support. This decision is an optimisation problem defined by the agents' bid elements (energy produced, and amount of support requested in euro), and the objective function being used - minimise costs, maximise participation or maximise energy. More detail on this process can be found in D5.3 [5]; a brief summary is located in Section 3.2 below. If an agent is successful in getting regional support, they then also apply, and automatically receive national support (feed-in-tarrifs and tax benefits). If an agent is not successful in applying for regional support, they next consider applying for national support alone, in this situation the application is not automatic but dependent on the cost calculations conducted previously. Finally, if the agent has not received either regional or national support, there is still a small chance they will install without any support if their income is high enough.

3.2 Integration with the Incentive Design

The technical implementation of the social simulator and incentive design is described in D5.3 [5], but is also described in Figure 3. Note that this diagram only represents the interaction between the two components, not all of the activities of the integrated model.

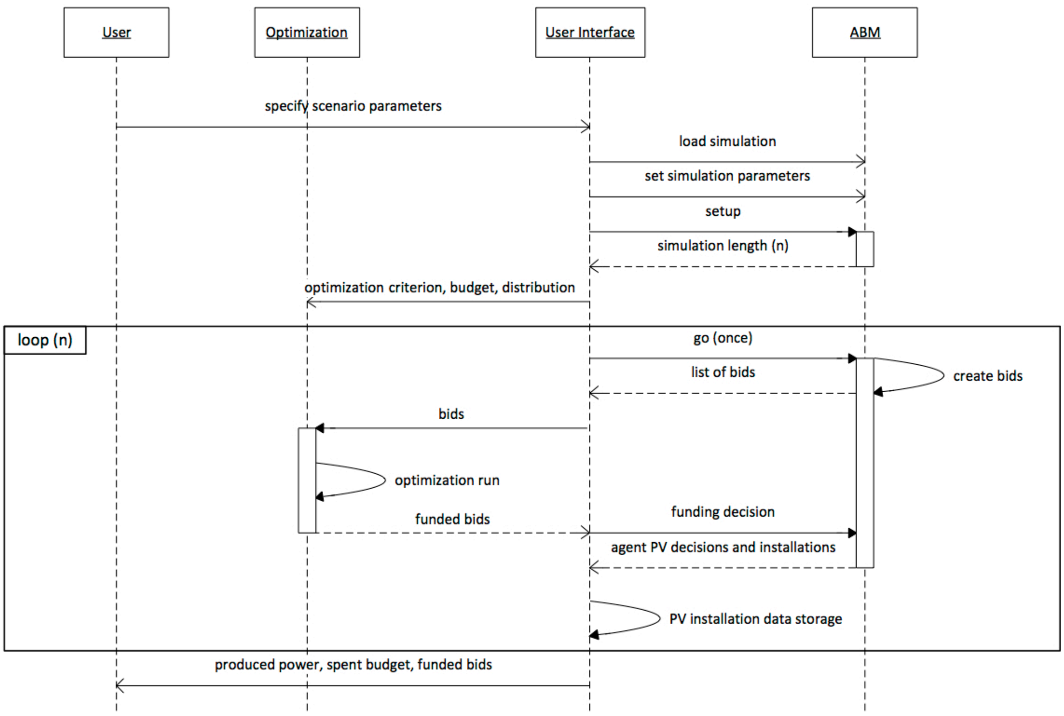

Figure 3: Integration of simulator with Incentive Design

First, the incentive design (made up of the Optimization and User Interface elements in Figure 3) initialises the simulation using the parameters provided by the user (i.e., target energy, budget, policy instruments etc). Second, the incentive design runs the simulation for one time step. The simulation produces a list of agents making bids for support under the regional policy instruments. The incentive design then retrieves the list of bids for funding from the simulation. The incentive design builds an optimisation model based on the bids and the parameters specified by the user. Next, the incentive design solves the optimisation problem. The solution determines the allocation of funds to bids (i.e., which agents receive support). Then the incentive design informs the simulator of the funding decisions. The simulator finishes the time step by asking those agents that have received regional support to install PV. The incentive design loops back to the second step unless the planning horizon has been reached.

A fuller discussion of the integration of these two components is presented in [4].

4 The Policy Instruments

At this stage, it is important to recap the policy instruments that are being simulated. These were chosen on the basis of interactions with policymakers in the Emilia-Romagna region. There are two regional, and two national level policy instruments included:

1. Regional: (simulated on and off)
   (a) *Grants*: This type of policy instrument is already running in Emilia-Romagna and represents the application of a household to have a proportion of the installation cost of their PV system paid for by the regional government. Households do not always request the entire cost. Past data from the region was used to implement the agent's behaviour in requesting a proportion of their PV installation cost (i.e., agents request support using a 'distribution of proportion requested' taken from past data).
   (b) *Interest rate support*: This type of policy instrument does not currently exist in the region, but our policy maker partners felt it was the most relevant for them in terms of potential future instruments, so asked for it to be included. This type of instrument offers support to households in the form of payments to cover the cost of interest on loans they take out to cover PV installation costs.
2. National: (simulated as on)
   (c) *Feed-in Tariffs (FIT)*: This type of policy instrument is already running in Italy. Any energy that the PV system produces that the household does not require can be sold back to the national grid at an agreed price.
   (d) *Tax benefits*: This type of policy instrument is already running in Italy. It represents the reduction in income tax, in proportion to the cost of a household's PV system, that one person in the household can claim.

Households can apply for as many of the support schemes as they wish. They can receive a grant towards a proportion of the installation cost, and interest-rate support for a loan to pay the remaining cost. They could then also sell energy back to the grid under a FIT agreement, and apply for a reduction in income tax, under the tax benefits scheme. As described above, in the simulation, households are very likely to behave in this way. This is because the interviews with PV installers highlighted the fact that once a household considers PV they tend to visit a PV installer and become well-informed about their options, and thus apply for everything they are eligible for.

5 Verification and Validation

There is varying use of the terms verification and validation across the social and computer sciences. Here, verification refers to ensuring that the model is implemented in such a way that it is doing what we intend. This is to ask 'is the model correct?' rather than, 'is this the correct model?', which is addressed here by validation in Section 5.2.

5.1 Verification

Once the updates to the simulator and integration with the incentive design were complete, another full iteration of verification was conducted. This was done in several ways:

1. Iterative modular code development: building each section of code in turn, and testing between each section.
2. Corner and extreme value tests: where parameter values are set to zero, or extreme values, to ensure the model is able to deal (i.e., not crash or report errors) with these parameter values and report 'reasonable' results.
3. Local sensitivity analysis: changing one input variable at a time and checking effects make sense.
4. Observation - running the model whilst monitoring a multitude of parameters and outputs that would typically not be monitored/visible as key outputs in analysis.
5. Code checking - having a second researcher, with extensive knowledge of the project and model, check the code.

5.2 Validation

We split validation into two parts here: first micro-validation which refers to the validation of the rules of the agents and other micro-level parameters in the model, and second macro-validation which refers to the validation of the outputs of the model against observed real-world data and projections (from regional policy makers).

5.2.1 Micro-validation

As was discussed in D4.2 [2], the rules of the agents in the simulator are based on the data gathered during the household survey and interviews with PV installers and apartment caretakers. Basing the rules on this data, rather than on theory alone, lends the rules a reasonable level of validation in itself. Beyond this (and the verification process described above), the checking of 'reasonable' outcomes for individual agents, in relation to the household survey data, was used to further validate the rules of the agents.

5.2.2 Macro-validation

The key task in macro-level validation is comparing the results of the model to real-world observed outcomes. This is difficult in the absence of a large amount of data on the system being modelled. Suitable PV adoption data is not available for Emilia-Romagna because of two key factors. First, the lack of time under which the proposed energy plan has been running (i.e., previous household adoption data is under significantly different policy scenarios). Secondly, the integrated tool has two components that make it different from reality. The model includes a policy instrument - interest-rate support - that does not currently exist, but has been requested to be modelled by our policy partners; and, the integrated model uses optimisation in the behaviour of the regional government in allocating funding. This represents an idealised representation of regional government behaviour, rather than one based on past or observed behaviour. Thus, whilst we would still expect the integrated model to produce results that are theoretically feasible, and reasonable in a qualitative sense, no formal quantitative macro-validation and calibration is possible. This is not a problem when we consider the purpose of the integrated model. Owing to the non-deterministic nature of the model, it is important not to attempt to use its results to make point predictions about real world outcomes under different scenarios. Rather, the value of the model is in identifying potential dynamics that are not intuitive or tractable. Under this use, this qualitative macro-validation is adequate.

During D2.1 [1] and D2.2 [7] data was collected on the regional government's energy planning, with estimates of its own that were considered reasonable for the Emilia-Romagna region. These were used as the key data source in the qualitative macro-validation of the integrated model. First, the region's estimates suggested that between 400 MW and 1240 MW installed capacity was a realistic range for household PV. Secondly, the region's estimates suggested that a cost of approximately €3,500,000 per MW capacity was realistic. Table 1 outlines the results of the model against these validation criteria.

	Regional Government Estimate	*Model Outputs*
Minimum PV capacity	400MW	454MW
Maxiumim PV capacity	1240MW	800MW
Cost (per MW)	€3.5m	€2.5m - €3.3m

Table 1: Model validation versus region's estimates

The table shows that the model reproduces these ranges well, under both high and low budget/energy scenarios. This was felt sufficient validation here, considering the availablity of data and purpose of the analysis.

6 Experiments

To produce useful results from the model, a set of scenarios needed to be defined and run, with repeats of each scenario. Repeats are needed as the simulator is non-deterministic so produces results with a significant level of variation. Using averages of these repeats gives a more reliable output form the model than one run alone. All of the results presented in this deliverable are based on averages over multiple runs of the integrated model.

6.1 Scenarios

In total there were 1200 scenarios used to generate the results presented below. This high number was the result of the interaction of the key input parameters and their various levels needed to address the aims of the analysis described above. These were:

- Grants: on and off
- Interest rate support: on and off
- National instruments: both fixed as on
- Budget Distribution: first come first served, ramp-up, ramp-down, and even
- Objective: Max energy, Max participation, and min cost
- Regional Budget: €1,000,000, €10,000,000, €100,000,000, €1,000,000,000, and €10,000,000,000
- Target energy: 11,628,000,000 kWh, 23,256,000,000 kWh, 34,884,000,000 kWh, 46,512,000,000 kWh, 58,140,000,000 kWh, which are equivalent to 1,000 ktoe, 2,000 ktoe, 3,000 ktoe, 4,000 ktoe, and 5,000 ktoe.

Using the number of values for each input, this gives, 2*2*4*3*5*5 = 1200 scenarios. The regional budget and target energy levels were chosen on the basis of reasonable potential values for the regional government, plus an additional 'buffer' into relatively high figures. Thus the integrated model covers a wide range of scenarios, some of which are clearly unlikely to ever occur. This 'wide' approach was used so to make sure as many potential scenarios were covered as possible. Given time and computational constraints this left the potential for the scenarios to have gaps in-between, which may be worthy of further exploration. When this was the case, exploration was carried out on a subset of scenarios, or identified for further work.

6.2 Repeats

The second decision in setting up the experiments was to decide how many repeats of each scenario was required to generate a reliable average output. To do this, one scenario was run fifty times, and then averages and standard deviations taken of the outputs over, 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50 of these repeats. The aim was to explore the relationship between the the size of the standard deviation and the number of repeats used to generate it, and thus be able to choose the smallest number of repeats, that gave an acceptable standard deviation, relative to that of 50 repeats. This process found that 5 repeats gave an acceptable standard deviation of 3.5% of the absolute value (i.e., for a total energy of 600m kWh, the standard deviation over 5 runs was 21m kWh), so this was used.

7 Results

To recap, the aims of the analysis were to:

1. identify the most effective policy instruments for the case study of Emilia-Romagna, given regional objectives (T4.4), and
2. explore the effect of (i) regional budget size (in euro), (ii) regional budget distribution (i.e., even, ramp-up, ramp-down, first come first served), and, (iii) objective (i.e., max participation, max energy, min cost), on (a) the energy (kWh) produced by households

with PV systems, (b) the cost of these systems, in total, and by policy instrument, and (c) the number of households that have adopted PV systems.

7.1 Regional Budget

The regional budget represents the budget the regional government has to spend on implementing the two policy instruments of grants and interest-rate support. In the scenarios run it was set at five different levels: €1,000,000, €10,000,000, €100,000,000, €1,000,000,000, and €10,000,000,000.

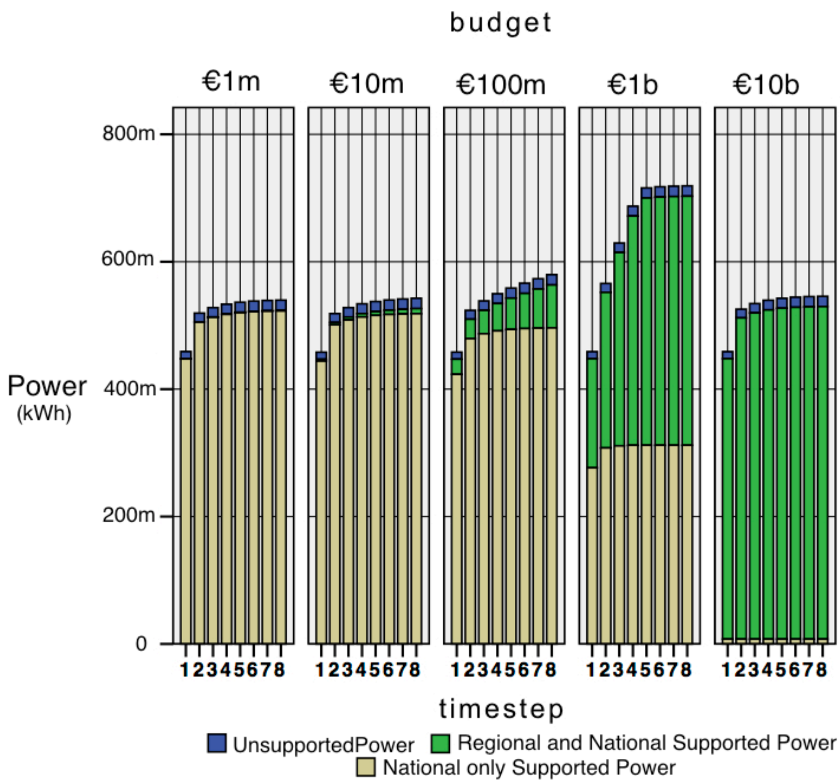

Figure 4: Energy produced at different Regional Budget levels

Figure 4 plots the energy produced by households with PV systems (in each year), against the regional budgets in euro. These are displayed on each timestep (i.e., year) through the simulation. All runs of the simulation with both regional instruments on were used to generate this graph. Three support 'types' are shown, (i) unsupported households, (ii) households receiving national and regional support together, and (iii) households receiving only national support. At the low budgets of €1m and €10m the energy produced by households supported by both regional and national support is barely visible in comparison to those supported by national schemes alone, and those without any support. At the €100m budget we see a more significant amount of energy from those supported by regional and national schemes (approx 100m kWh by the end of the simulation period). In the next budget level of €1billion we see a big jump in the energy produced by those with regional/national support, however there is clearly some displacement of energy produced by those solely supported by national schemes. This is even clearer at the final budget level of €10billion, where we see another increase in the energy produced under region/national support (from approx 400m kWh to 500m kWh), but a drop in the total energy produced, owing to a large drop (nearly to zero) in the energy produced under national schemes only.

This macro-behaviour was deemed worthy of further inspection owing to its counter-intuitive nature. This was done using more budget levels around the figure of €1billion. Figure 5 shows the results of the further experiments run, with a finer-grained increase in budget levels. Notice, for simplicity the bars now show the final outcome of the model, not the year by year results. Here, we can see that as the regional budget increases, the increases in total energy begin to reduce and flatten, before a relatively sharp reduction in energy post €2billion.

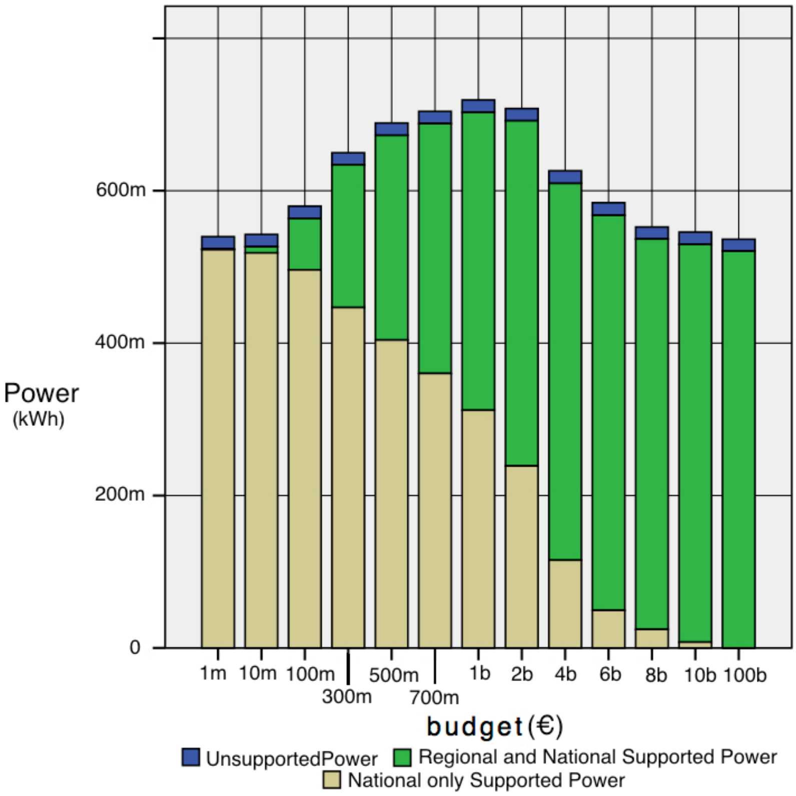

Figure 5: Energy produced at different Regional Budget levels - further exploration

This behaviour is broken down further in Figure 6 and Figure 7, which focus on just the energy generated by regionally and national supported households, and national only supported households respectively. These figures also present the 95% confidence intervals for each budget level. In these figures, the rise and leveling-off of regional and nationally supported households is clearer; as is the decrease in national only supported energy.

The appearance in the results of this apparent 'sweet-spot' of regional funding is important, and also counter-intuitive. At this stage the mechanism behind this dynamic is unclear, and thus requires continued investigation in further work. Once this has been done, we will be in a much better position to make assertions about the potential policy implications of this result.

Figure 8 displays the costs to the region generated by the two regional policy instruments.

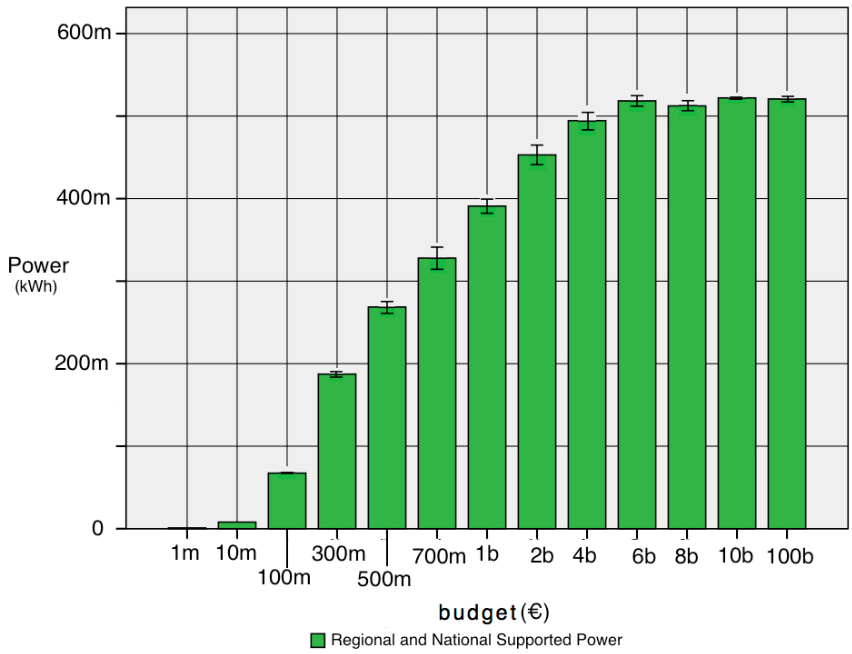

Figure 6: Energy produced at different Regional Budget levels - Regional and Nationally Supported

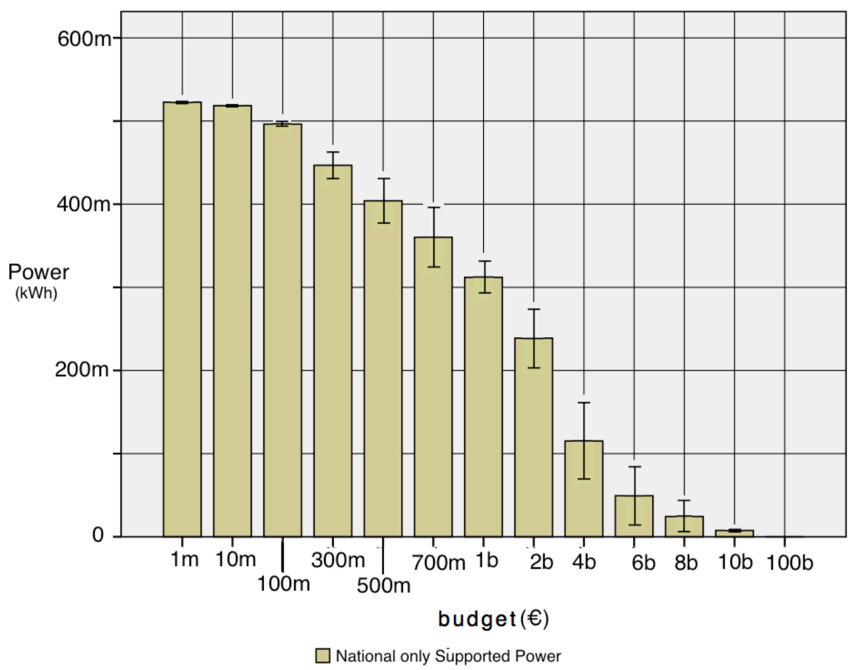

Figure 7: Energy produced at different Regional Budget levels - National Only Supported

Again, at the two lower budget levels, there is only a very small cost. However, as the budget increases so does the cost created by supporting more households. However, unlike the energy produced, which dips in the last budget level, the costs continue to grow.

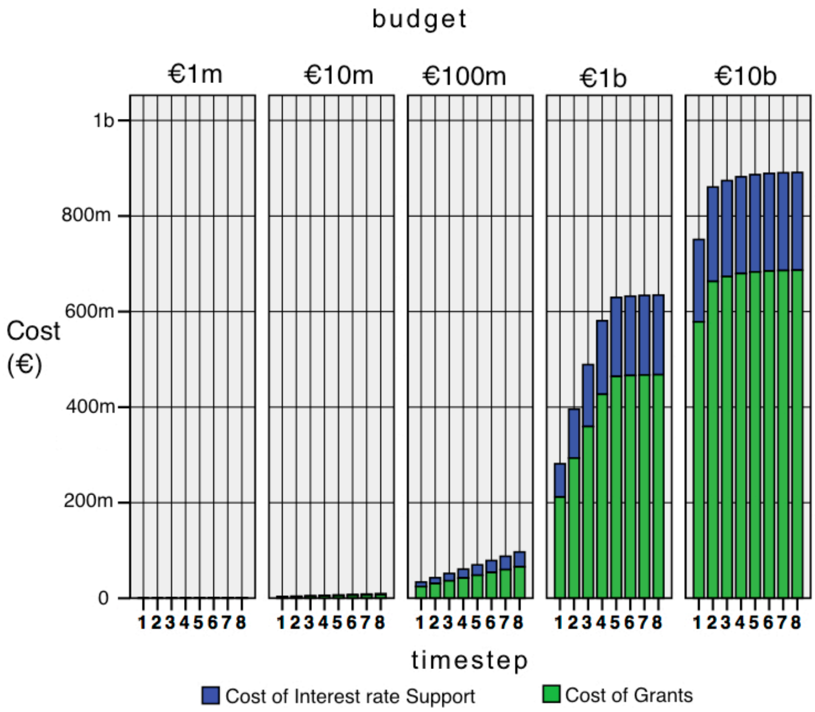

Figure 8: Cost of policy instruments produced at different Regional Budget levels

Finally, Figure 9 shows the effect of regional budget on the participation rate (i.e., number of households with PV) in the region. This follows a similar pattern to costs, with an ever increasing participation rate as budget increases. The key difference would appear to be that the levelling-off of the participation appears stronger than that for cost. The final budget level (of €10b) only increases participation by approx 30%, whereas the costs increase by approx 45%.

We should note at this stage, that in the high budget scenarios (€1b and €10b), not all of the regional budget was spent. In these scenarios, it would appear that there simply was not enough households applying for regional support for all of the budget to be spent.

7.2 Regional Budget Distribution

The regional budget distribution represents the strategy of the regional government in how to spend their budget over time. In the scenarios run it was set at four different levels: first come first served, ramp-up, ramp-down, and even. First come first served is a strategy in which the budget is spent as quickly as is possible given bids from households. Ramp-up and ramp-down represent strategies in which the funding is either loaded to the beginning or end of the funding period. Finally, even represents a strategy in which the regional government aims to keep funding even over the time period.

The effect of budget distribution on energy generated is shown in Figure 10. Here we see that first come first served appears to have the highest energy generated by regional/national

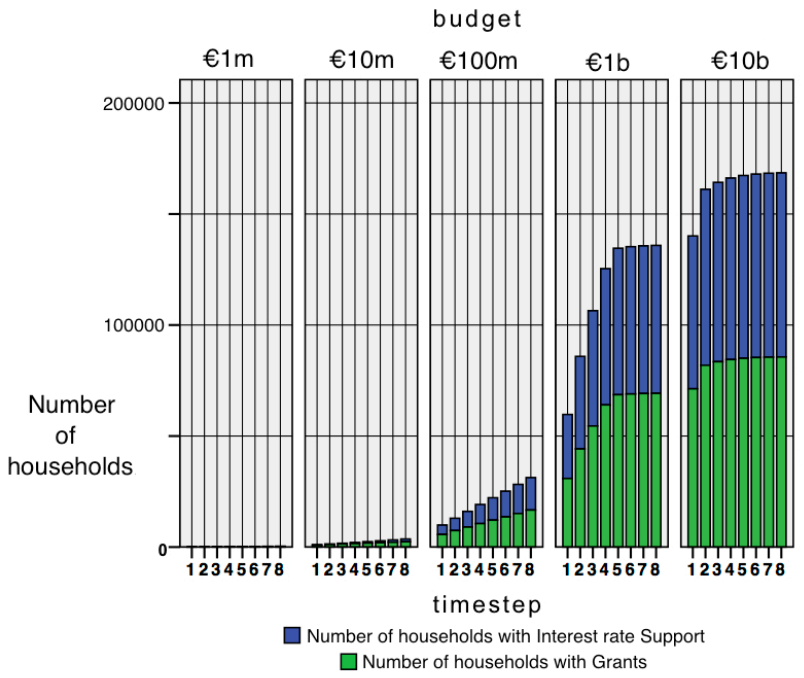

Figure 9: Participation at different Regional Budget levels

only, with ramp-up and ramp-down showing the lowest. There appears a subtle, but expected, difference in the rate of increase between ramp-up, even, and ramp-down; ramp-up shows relatively bigger changes through time, whereas ramp-down sees a stronger levelling-off in energy. There is an equally expected slow rise in the energy under first come first served. These patterns are expected in the sense that it is intuitive to think that a ramp-up strategy would increase energy through the simulation, whereas ramp-down and even strategies may not see such large increases, as funding levels-off.

However, Figure 10 also highlights an important dynamic. When energy produced by national-only supported households is included, we see that the overall energy produced is much lower under first come first served.

Figure 11 shows the effect of budget distribution, on cost to the region under the two regional policy instruments. It is quite clear here that first come first served gives a much higher cost to the region, however when compared to the figures including national-only supported households, there is no difference in the overall costs. Thus, the extra cost is bore by the region.

Finally, Figure 12 shows a similar pattern for participation, but a less pronounced one. This suggests that the extra cost of first come first served, is again not delivering in terms of participation.

7.3 Regional Objective

The regional objective represents a decision to be made by the regional government as to the main aim behind its policy decisions. Three options were simulated: maximise participation, maximise energy, and minimise cost. This variable gave the least clear differences seen

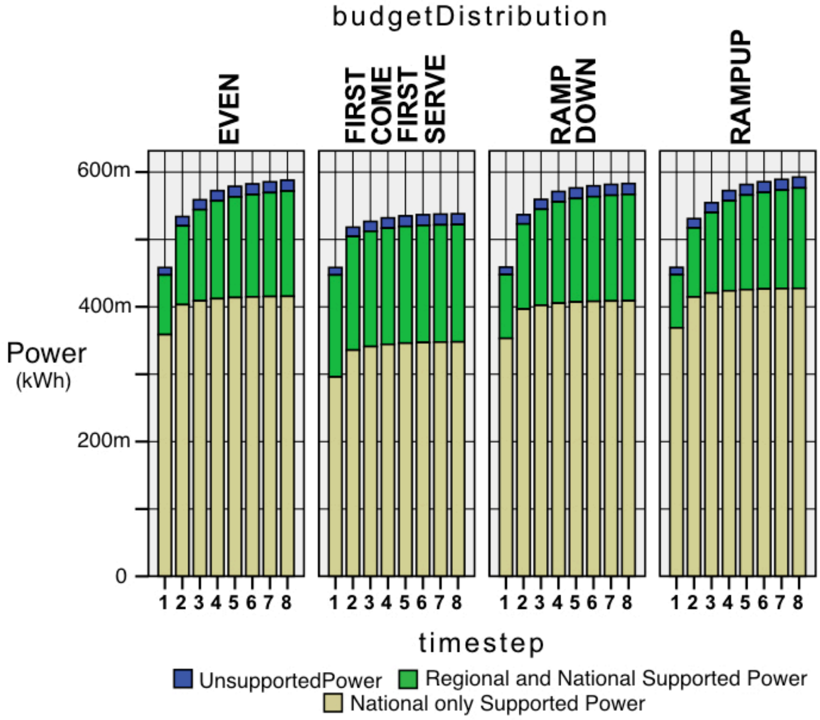

Figure 10: Energy produced at different budget distributions

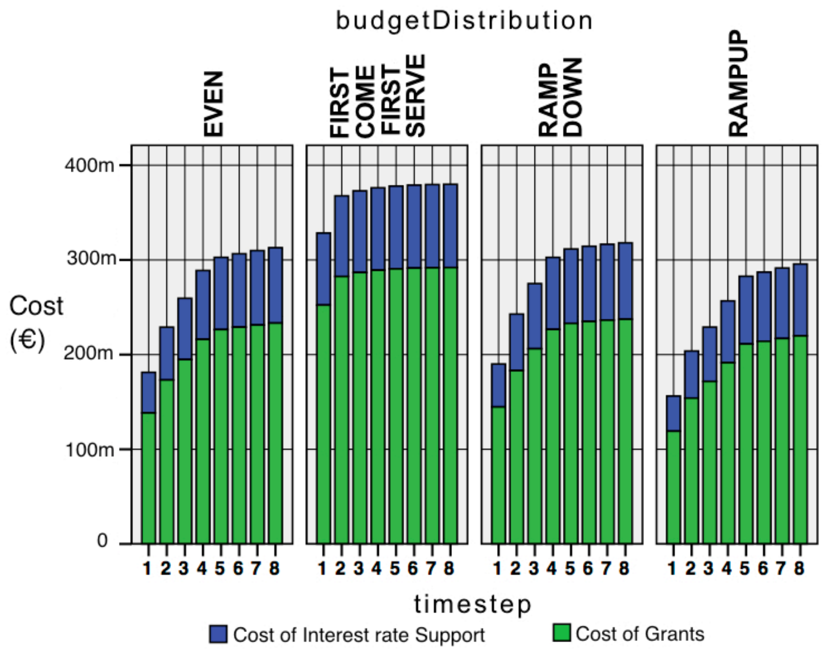

Figure 11: Cost of policy instruments at different budget distributions

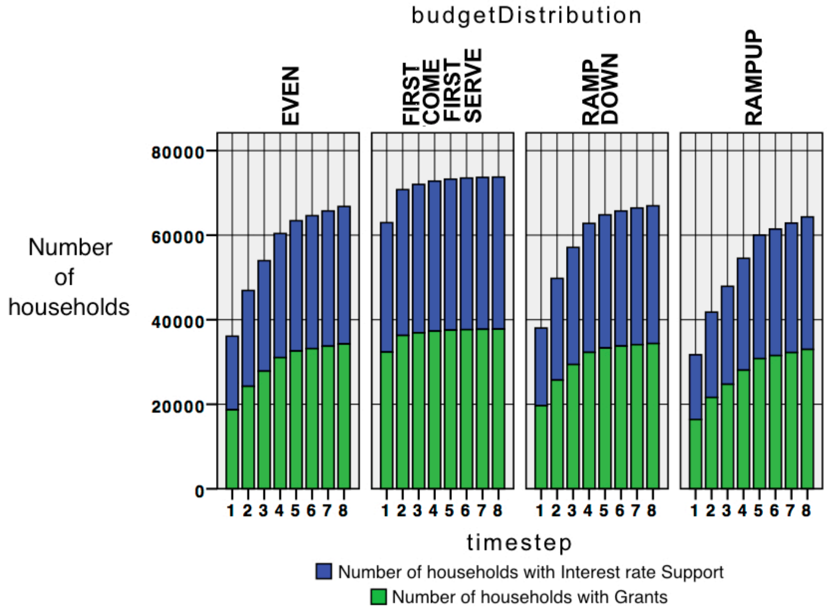

Figure 12: Participation at different budget distributions

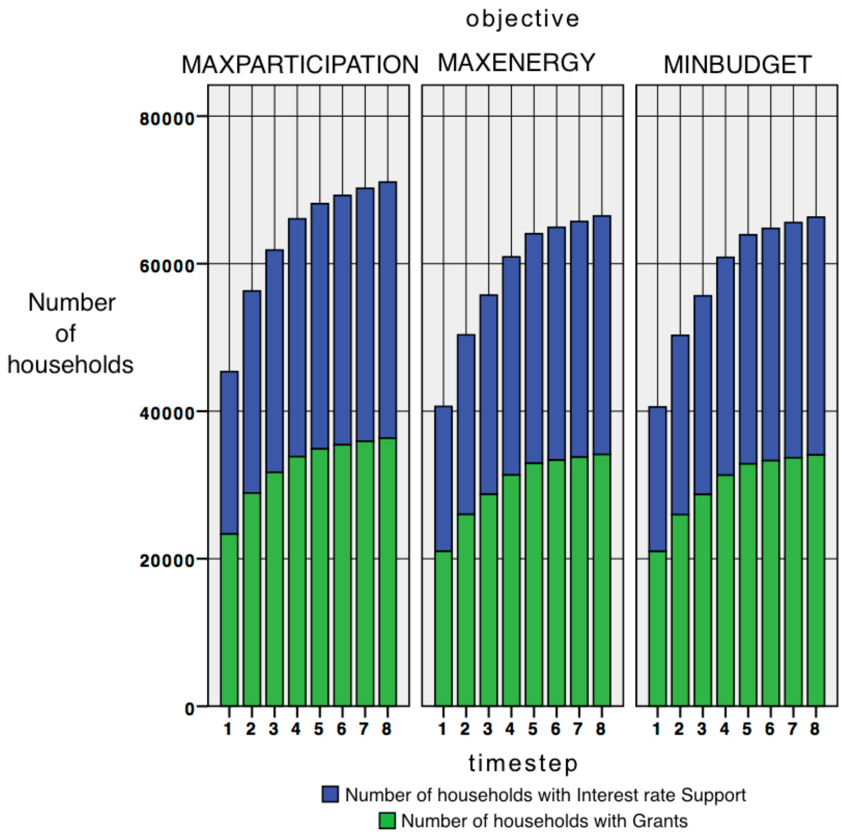

Figure 13: Participation under different objectives

between outputs from different scenarios. Figure 13 shows the participation rate under the three different objectives. Here, we can see that the max participation objective does indeed show a higher rate of participation for regional/national supported households. However, the same graphs for cost and energy showed only very small, if any, difference between the objectives.

7.4 Regional Policy Instruments

This section presents and compares the results of the model between the scenarios with the regional policy instruments turned on and off, with respect to the regional objective. This allows us to consider which regional policy instrument(s) (interest-rate support or grants) are most effective in reaching the regional objectives of max participation, max energy, or min cost.

Figure 14 shows the energy produced under regional support. Under grants only, the objectives of max energy and min cost deliver marginally more energy than max participation, but this difference is small. Under interest-rate support only, there is no apparent difference in the energy outcome under the three objectives. Finally, for the scenarios in which both policy instruments were on, we see that again max energy and min cost did give a marginally higher level of energy, compared to max participation. However, when both policy instruments are used, we get a counter-intuitive result showing that regionally supported energy is actually lower, than when either of the two instruments are used alone. This difference is in-fact made up by national-support only household energy, meaning overall energy produced remains the same but more comes from national-only supported households.

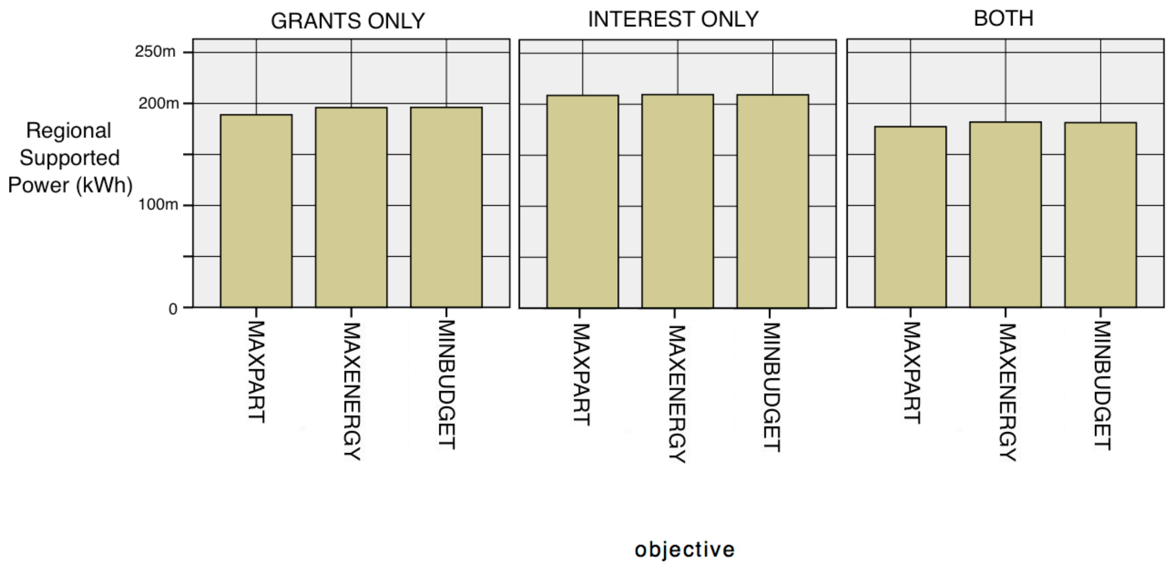

Figure 14: Energy produced under different policy instruments and objectives

These results appear to show that the grants policy instrument is marginally more effective in delivering the objective of max energy, but only by a small margin.

Next, Figure 15 compares the costs to regional government, under the three objectives, and policy scenarios. Here, in all three policy instrument configurations (interest only, grant only, or both) we see no effect on the costs bore by the region between the objectives. However, interest only shows a clearly lower overall cost than grants only.

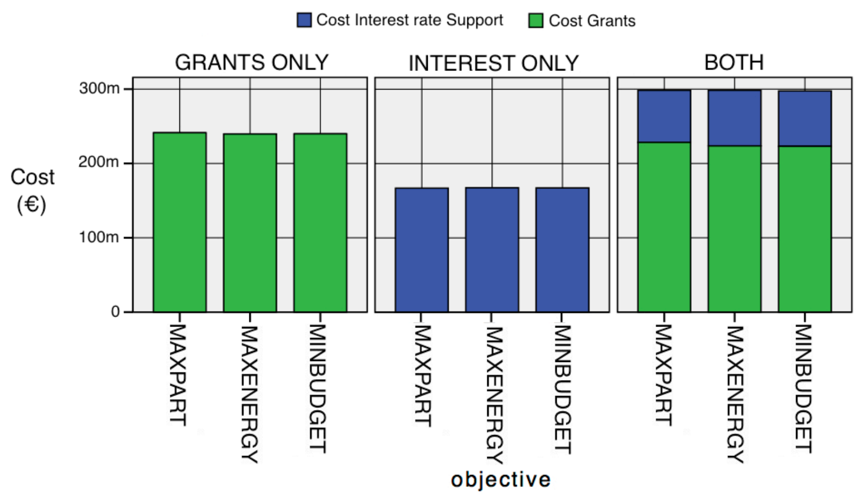

Figure 15: Costs under different policy instruments and objectives

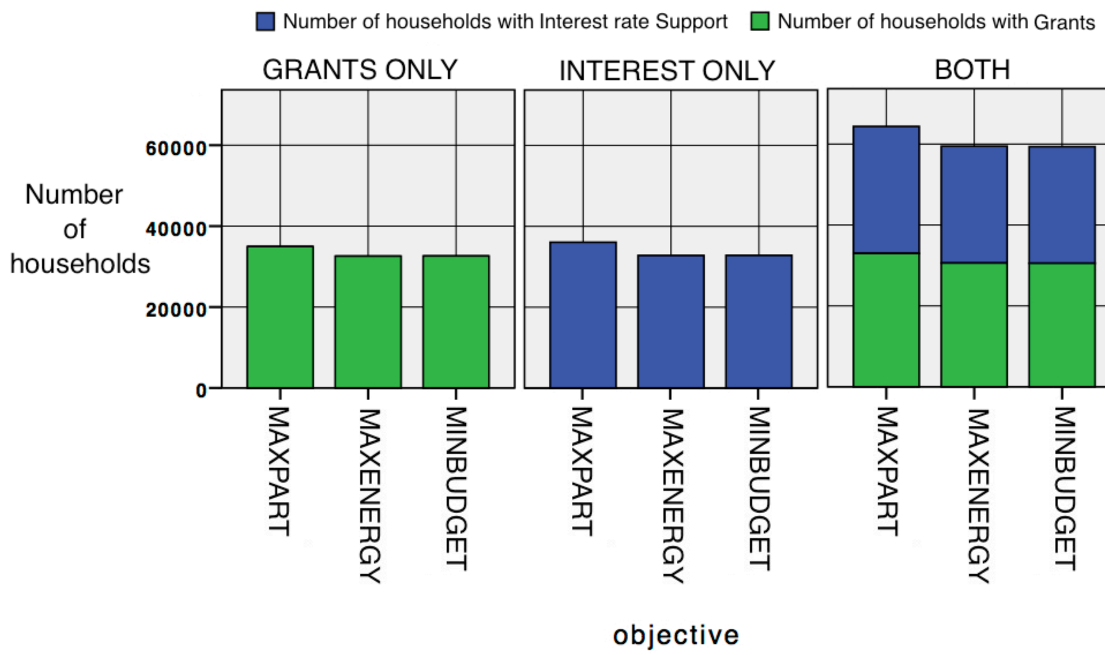

Figure 16: Participation under different policy instruments and objectives

This would appear to suggest that grants are typically more expensive than interest-rate support, which makes sense when we consider the likely differences in what a household may claim for each. However, the effectiveness of each policy instrument configuration appears equal with regard to the objective of minimising costs to the region.

Figure 16 shows the participation rates under the three policy configurations and objectives.

Here, we see a much clearer result, with max participation showing higher rates of participation in all three policy configurations. The scenarios in which both policy instruments are combined appears to show the most distinct effectiveness in maximising participation.

8 Conclusion

We have analysed the results of the integrated social simulator and incentive design component of the ePolicy decision-support system. The analysis was based on two approaches: first, on exploring the effect of regional budget, regional budget distribution, and regional objectives on the energy produced by PV in the region, cost to the regional government, and the level of participation amongst households. Second, on exploring the effectiveness of each policy instrument configuration (i.e., interest-rate support only, grant only, or both) in delivering the regional objectives (i.e., max participation, max energy, or min cost).

The results highlighted a potential 'sweet-spot' for regional budget between €500m and €2b, beyond which increases in budget do not generate extra energy, whilst still increasing the final cost to the region. The dynamic which creates this result is unclear at this stage, and requires further investigation. Thus, no firm policy implications can be drawn on this point.

For budget distribution, the results highlighted the poor performance of first come first served. Under this scenario it appears that households that might have decided to install with national support only, are more quickly given regional support as well, and so increase regional costs, without delivering overall increases in energy and participation. Giving away more of the budget quickly may also increase the chance of the less desirable bids in early time periods (in terms of size of installation to cost) are prioritised over more desirable, but later, bids.

The results have also shown that the regional objective has a much smaller effect on the results of the model. Optimising for maximum participation appears to increase participation, but optimising for maximum energy, and minimum cost, do not show any effect.

Finally, on effectiveness of policy instruments, the most effective policy instrument configurations for maximising energy appear to be grants only, or both, with interest-rate support only marginally less effective. For minimising costs, the three policy configurations appear equally effective. Finally, for maximising participation, the grants only, or both, configurations appear most effective.

Owing to the non-deterministic nature of the model, it is important not to attempt to use its results to make point predictions about real world outcomes under different scenarios. Rather, the value of the model is in identifying potential dynamics that are not intuitive or tractable. To this end, the model can be used to infer some policy implications for the regional government.

First, their appears to be a potential 'sweet-spot' for the budget level of the regional government, though the mechanism for this is not yet clear. One potential explanation may be that in effect the regional support schemes are rewarding households with regional support, that would have installed with national support only. Overcoming this issue could be a fruitful focus for the regional government. The survey of Italian households, carried out as part of this work, highlighted the patchy and poor knowledge of households with respect to support schemes. However, once a household makes enquiries with a PV installer, they are likely to become much better informed of the potential support they can claim. Thus the regional government will need to consider the way it implements support, and whether it wishes to support households that are also claiming support from the national government.

One way to limit this dynamic may be to avoid a first come first served policy for allocating support. In reality this kind of allocation system is simple to administer and so can be appealing. However, it is likely to maximise the 'displacing' effect of giving out support to households that would have installed without regional support.

Regional government may also wish to consider the fact that interest-rate support was found to be either equally, or least effective in reaching regional objectives (i.e., max participation, max energy, or min cost), whereas using both, or grants alone was found to be more effective overall. This suggests that the current policy of using grants, and not interest-rate support may be the better option.

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