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Second Prototype of incentive policy mechanism

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ABSTRACT

This report describes the second version of a testbed for formulating and exploring complex policy design problems motivated by the case-studies settings provided by the consortium, specifically the allocation of grants to citizens in the Emilia-Romagna region of Italy to incentivize the installation of photovoltaic systems.

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1 Introduction

This report describes the second version of a testbed for formulating and exploring complex policy design problems motivated by the case-studies settings provided by the consortium. Specifically, we consider auction design for promoting renewable energy production, and in particular solar photovoltaics (PV) panel installations in Emilia-Romagna region.

The prototype is based on and extends the prototype presented in Deliverable 5.2 [2]. The main changes are as follows.

- The incentive design was integrated with the social simulator component (Deliverable 4.1 [1]). Instead of relying on historical data to determine optimal policies, the results of the social simulation are used.
- The proprietary backend solver CPLEX has been replaced with the Open Source solver `lpsolve`¹.

2 Integration with the social simulator component

The social simulator is a multi-level agent-based model that allows policy-makers to explore the consequences of different types of policy instruments. The agents in the simulation represent the main actors. The agents have 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.). It allows us to directly evaluate the effect that policy decision will have on the population, the number of PV installations, and the added PV capacity.

The social simulator is implemented in the NetLogo framework², which, like this prototype, is Java-based. It provides an API that allows simulations to be set up, controlled, and run from within other programs. The incentive design prototype is thus able to use it transparently – the user does not need to take any additional steps in order to use the social simulation.

The interaction between the incentive design and the social simulator happens as follows.

1. The incentive design initialises the simulation using the parameters provided by the user.
2. The incentive design runs the simulation for one time step. The simulation produces a list of bids.
3. The incentive design retrieves the list of bids for funding from the simulation.
4. The incentive design builds an optimisation model based on the bids and the parameters specified by the user.
5. The incentive design solves the optimisation problem. The solution determines the allocation of funds to bids.
6. The incentive design informs the simulator of the funding decisions. The simulator finishes the time step by evaluating the effect of those decisions.
7. The incentive design loops back to 2 unless the planning horizon has been reached.

¹<http://lpsolve.sourceforge.net/>

²<http://ccl.northwestern.edu/netlogo/>

The main change compared to how the problem is solved in the previous version of the prototype of the incentive design is that instead of solving a single optimisation problem that determines the allocation of incentive funds to bids, a series of such problems are solved – one for each time step. This change has important ramifications for how the optimisation problems are set up. In particular, the overall budget available for incentives has to be distributed in time up to the planning horizon. In the previous version of the incentive design prototype, the entire budget was dispensed at once if the optimal solution required this.

The decision of how the total incentive budget should be spread across the time steps is one that cannot be made purely from an optimisation point of view alone. For an optimal solution, it may be necessary to allocate the entire budget for a 5-year plan in the first year. In practice, this is undesirable from the point of view of a policy maker because the incentive programme would then only be effective for one year, causing resentment in citizens who want to put in bids after that.

For this reason, the distribution of the budget across time is a decision left to the user of the prototype, who can choose from among four pre-specified options.

First come, first served. The entire budget is available at every time step. It may be allocated completely during the first time step.

Even distribution. The budget is split evenly across all time steps for the entire planning horizon. Unspent parts of the budget are carried over to the next time step.

Ramp up. The budget is split in such a way that the first time step has a small budget, which increases linearly for the subsequent time steps and reaches its maximum at the time step immediately before the end of the planning horizon.

Ramp down. The budget is split in such a way that the first time step has a large budget, which decreases linearly for the subsequent time steps and reaches its minimum at the time step immediately before the end of the planning horizon.

If the entire budget for a time step is not spent at that time step, the remainder is carried over to the next time step.

This repeated interaction with the social simulator allows the incentive design to not only make optimal decisions based on the current state of the world, but also to judge the effect of those decisions in the future. This allows us to compare the expected outcome of a funding decision with the actual outcome as computed by the simulator. In practice, the nature of the simulation means that there is a large amount of uncertainty associated with the outcome. As a simulation is non-deterministic, different runs with the same parameters will give different results. This limits our ability to compare expected with actual outcomes.

The prototype of the social simulator we had available for the implementation of this prototype considers the non-deterministic effects in the simulation, such as interaction between agents, only in a limited fashion. This means that the results for the same set of simulation parameters are identical across several runs. There is no randomization between different runs.

Adjusting the allocation strategy for incentives between different time steps can be used for fine-tuning the model. Based on results from preliminary experiments, any such changes will

only have a minor effect on the simulation, and no significant effect in the current version of the simulation prototype. For this reason, we decided to leave the implementation of a reactive allocation strategy for future versions of the incentive design.

3 A revised incentive design prototype

We now present the revised incentive design prototype and describe its usage. It is available for download at <http://4c.ucc.ie/~larsko/downloads/pver-0.2.zip>.

The software can be run as follows. Extract the deliverable file `pver-0.2.zip` to a location of your choice. Inside the extracted folder, run the following command.

```
LD_LIBRARY_PATH=lib java -Djava.library.path=lib -jar pver-0.2.jar
```

This will start the application. These instructions and the libraries included with the deliverable assume that the software will be run on 64 Bit Linux. Other platforms are supported as well, but the user will need to download the respective `lpsolve` libraries for their platform and adjust the command to be run accordingly. To do this, the libraries for the respective platform have to be downloaded from the project's website and placed in the `lib` directory of the extracted deliverable software.

The initial screen of the application is shown in Figure 1. Nothing is shown by default. To show the configuration parameters for the current scenario, select `Scenario` from the `Window` menu. The parameters that can be set by the user are as follows (Figure 2).

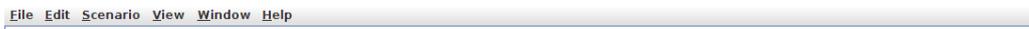


Figure 1: Initial screen.

TotalBudget Specifies the total budget available for incentives.

TargetEnergy Specifies the target PV energy capacity.

ObjectiveFunction Specifies the objective function for the optimisation problem.

BudgetDistribution Specifies the distribution of the total budget across the time steps.

GrantIncentives Specifies whether or not to offer grants as incentive.

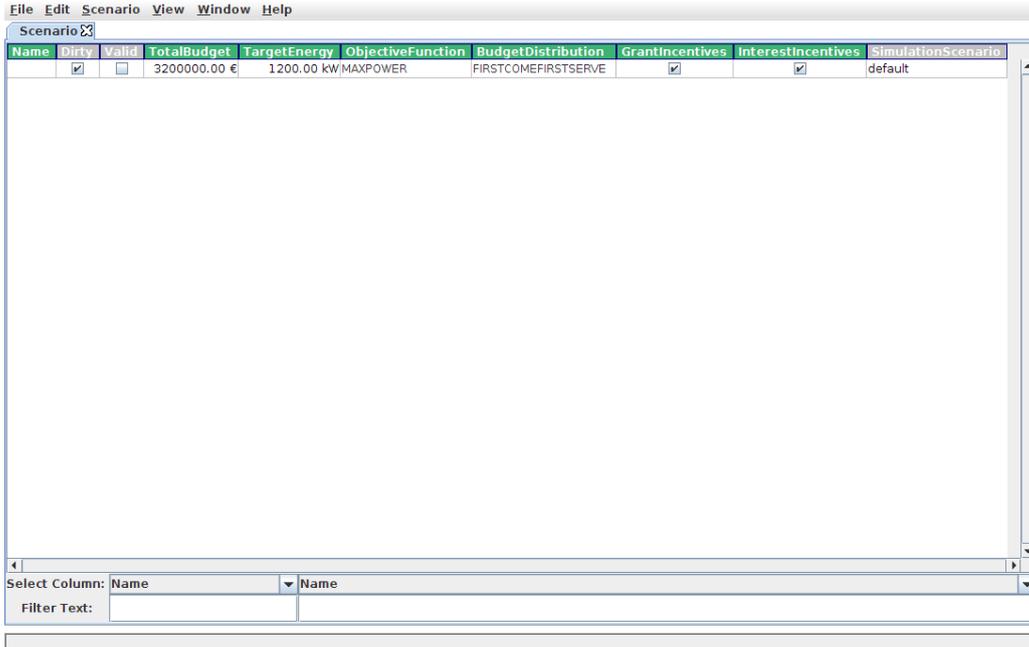


Figure 2: Scenario configuration screen.

InterestIncentives Specifies whether or not to offer interest payments as incentive.

SimulationScenario Specifies the scenario for the social simulator.

The objective functions currently supported are the same as in [2] with the exception of partial funding. In the context of the current setup of the social simulator, it is not supported to fund only part of what an agent is asking for. Adding support for this may be part of future deliverables. The three supported objective functions are as follows.

- maximise power production
- minimise expenditure while achieving the power target set by the user
- maximise participation, i.e. the number of funded proposals

The optimisation problem that is solved depends on the objective function. With n bids, c_i the cost of bid i , p_i the power produced by bid i , b the budget and t the power target, the optimisation problems are defined as follows. To maximise the power, we use

$$\begin{aligned}
 x^* &= \operatorname{argmax}_x \sum_{j=1}^n p_j x_j \\
 \text{s.t.} \quad &\sum_{j=1}^n c_j x_j \leq b \\
 &x_j \in \{0, 1\}
 \end{aligned}$$

Similarly, to minimise expenditure, we use

$$\begin{aligned}
x^* &= \operatorname{argmin}_x \sum_{j=1}^n c_j x_j \\
\text{s.t.} \quad &\sum_{j=1}^n p_j x_j \geq t \\
&\sum_{j=1}^n c_j x_j \leq b \\
&x_j \in \{0, 1\}
\end{aligned}$$

Finally, to maximise participation, we use

$$\begin{aligned}
x^* &= \operatorname{argmax}_x \sum_{j=1}^n x_j \\
\text{s.t.} \quad &\sum_{j=1}^n c_j x_j \leq b \\
&x_j \in \{0, 1\}
\end{aligned}$$

The models are described in detail in [2]. The x_i in the solutions tell us whether a particular bid was funded or not.

At each step of the simulation, the respective optimisation problem is modelled and solved. The bids generated at a particular time step are only valid for that step. While we find the optimal solution at each step, we can no longer compute a globally optimal solution because of the interaction with the social simulator – funded bids in time step i affect the bids in time step $i + 1$.

The split into several time steps causes another complication. The optimisation problem to minimise expenditure will be infeasible in the first time steps because the bids may not amount to enough power to satisfy the target. This would result in no bids being funded even though enough bids may be generated in subsequent time steps to reach the power target. It is clearly desirable to fund bids until the power target is reached.

The solution implemented here is to solve two optimisation problems at each time step if the objective is to minimise the expenditure. The first problem is as described. If it has no solution, the optimisation problem to maximise the power is solved instead. The rationale behind this decision is that the power target should be achieved as quickly as possible.

The budget distributions that can be selected are first come first served, even, ramp up, and ramp down, as described in Section 2.

There are currently only Boolean controls for whether grant and interest payment incentives are used. There is no control over the level of incentive.

The list of possible values for the scenario for the social simulator depends on the scenarios that the simulator is shipped with. A scenario determines the background information such as population and solar power generation model. In addition, parameters such as the feed-in tariff set at the national level and the interest rate for bank loans are defined in a scenario. At the moment, only a single scenario is available for the Emilia-Romagna region and the value in the user interface cannot be changed. This scenario has, in addition to the regional incentives, national incentives (i.e. feed-in tariffs) enabled and also reflects the current reality in its other parameters.

3.1 Running the incentive design

After setting the parameters of the scenario, it is run by selecting Run . . . in the Scenario menu. There are no further options to set after this and the incentive design is started by clicking Run (Figure 3). Running the incentive design takes a few minutes. Note that this increased runtime compared to the previous version of the prototype is not because of the changed optimisation solver, but because the simulation component takes a relatively long time to set up the simulation and run the time steps.

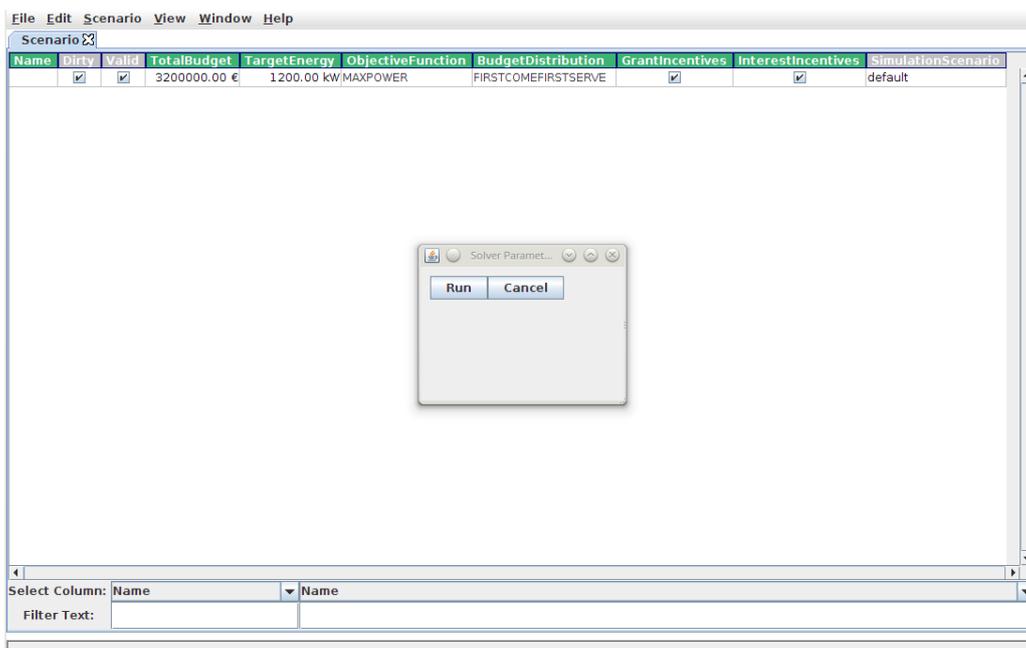


Figure 3: Running a simulation.

After the run finishes, a summary of the funded bids can be seen by selecting AllocationSummary in the Window menu (Figure 4). It shows the total amount of money requested by individual bids, the total power produced by the funded bids, the total amount of money allocated to bids, and the number of bids that have been funded. More details on the bids and allocated funds can be found in the Bid (Figure 5) and Allocation (Figure 6) entries in the Window menu. The Allocation window shows the subset of the Bids that were funded. For each bid, the agent that made it and the time step of the simulation during which it was made is presented.

Compared to the previous version, the revised version offers less functionality in some re-

Name	Requested	Power	Allocated	FundedProjects
	2580499162.26 €	7125.00 kW	3199996.67 €	825

Figure 4: Allocation summary screen.

spects. There are two main reasons for this. First, the integration with the social simulator makes some options present in the previous version obsolete, as the respective functionality is provided by the simulator. Second, the functionality offered for visualising and comparing several runs with different parameters has not been implemented to the extent present in the previous version. This is because this functionality will be provided in the deliverables of WP 7. Work on the integration of the incentive design into the visualisation framework has started and we will focus our efforts on that instead of providing our own implementation for the same purpose.

4 Experimental evaluation

To demonstrate the effectiveness of the implementation, we evaluate the incentive design by comparing the allocations of incentives to bids across a range of different scenarios. Note that the outputs themselves are not necessarily realistic, as the version of the social simulator available to us has not been calibrated and tuned.

Table 1 presents a comparison of the key outputs that the different incentive design mechanisms implemented in the prototype achieve on the data of the 2004 Emilia-Romagna region auction, assuming a budget of 3,200,000 Euro and a target power of 1,200 kW. All scenarios use the first come, first served budget distribution and have both grant and interest payment incentives enabled. The table clearly shows the significant impact of the different optimisation objectives.

Table 2 shows the same comparison for the different budget distribution strategies. All scenarios optimise for power output and have both incentive instruments (grants and interest payments) enabled. Again the data highlights the difference between these distribution strategies, which are not as significant as the differences between the optimisation objectives.

Name	Power	RequestedForGrant	RequestedForInterest
agent 82234 @ step 0	150.00 kW	87000.00 €	20931.50 €
agent 26427 @ step 0	300.00 kW	210000.00 €	29902.14 €
agent 72658 @ step 0	150.00 kW	93000.00 €	18938.02 €
agent 42749 @ step 0	450.00 kW	265500.00 €	61299.39 €
agent 95084 @ step 0	375.00 kW	243750.00 €	43607.29 €
agent 3979 @ step 0	375.00 kW	187500.00 €	62296.13 €
agent 34516 @ step 0	225.00 kW	168750.00 €	18688.84 €
agent 622 @ step 0	300.00 kW	225000.00 €	24918.45 €
agent 76022 @ step 0	300.00 kW	141000.00 €	52827.12 €
agent 110169 @ step 0	450.00 kW	270000.00 €	129498.22 €
agent 57888 @ step 0	450.00 kW	175005.00 €	91366.00 €
agent 114241 @ step 0	375.00 kW	187500.00 €	62296.13 €
agent 26883 @ step 0	300.00 kW	199410.00 €	33420.63 €
agent 68277 @ step 0	150.00 kW	112500.00 €	12459.23 €
agent 118860 @ step 0	450.00 kW	270000.00 €	59804.28 €
agent 58991 @ step 0	375.00 kW	150000.00 €	74755.36 €
agent 10284 @ step 0	150.00 kW	75000.00 €	24918.45 €
agent 55150 @ step 0	375.00 kW	180000.00 €	64787.97 €
agent 103908 @ step 0	450.00 kW	265455.00 €	61314.34 €
agent 101680 @ step 0	225.00 kW	85500.00 €	46348.32 €
agent 33125 @ step 0	150.00 kW	105000.00 €	14951.07 €
agent 61375 @ step 0	375.00 kW	262500.00 €	37377.68 €
agent 121916 @ step 0	300.00 kW	159000.00 €	46846.69 €
agent 128184 @ step 0	150.00 kW	75000.00 €	24918.45 €
agent 106763 @ step 0	450.00 kW	216000.00 €	77745.57 €
agent 1043 @ step 0	300.00 kW	180000.00 €	39869.52 €
agent 67977 @ step 0	375.00 kW	187500.00 €	62296.13 €

Figure 5: Bid screen.

	Total power (kW)	Total allocated funds (Euro)	Total funded bids
maximize power	7125	3,199,996.67	825
minimize expenditure	1200	466,252.50	125
maximize participation	6300	3,198,519.88	12050

Table 1: Comparison of key outputs for different optimisation objectives. Both incentive instruments are enabled and first come, first served budget distribution is used. The output that is optimized in a particular scenario is shown in **bold**.

5 Conclusion

We have developed a tool that supports policy-makers to, given an incentive budget and a target power output, determine the distribution of these incentives to interested parties. The constructed design aims to achieve at least the target power production while remaining within budget. In addition, a number of different objectives to be optimised are available.

To evaluate specific incentive designs, we run a social simulation that considers the specific factors affecting the target population and region. As optimisation targets and budget distributions are subject to policy decisions, the incentive design does provide not only a single solution, but rather allows the policy maker to explore and adapt different scenarios.

The interaction between the incentive design and the social simulator is an iterative process. Decisions made by the incentive design affect the course of the simulation. This allows to not only make decisions as in the previous version of the incentive design prototype, but also evaluate their effects.

This novel integration of social simulation and optimisation technology provides a more realistic means of evaluating policy decisions than approaches that use only one of those tech-

Name	Bid	Value	Power	RequestedForGrant	RequestedForInterest
agent 41971 @ step 0	agent 41971 @ step 0	165000.00 €	375.00 kW	165000.00 €	0.00 €
agent 10906 @ step 0	agent 10906 @ step 0	72000.00 €	150.00 kW	72000.00 €	0.00 €
agent 24243 @ step 0	agent 24243 @ step 0	74970.00 €	150.00 kW	74970.00 €	0.00 €
agent 12233 @ step 0	agent 12233 @ step 0	66855.00 €	150.00 kW	66855.00 €	0.00 €
agent 91248 @ step 0	agent 91248 @ step 0	73500.00 €	150.00 kW	73500.00 €	0.00 €
agent 52017 @ step 0	agent 52017 @ step 0	85500.00 €	225.00 kW	85500.00 €	0.00 €
agent 82125 @ step 0	agent 82125 @ step 0	70500.00 €	150.00 kW	70500.00 €	0.00 €
agent 64125 @ step 0	agent 64125 @ step 0	72000.00 €	150.00 kW	72000.00 €	0.00 €
agent 50745 @ step 0	agent 50745 @ step 0	148152.75 €	300.00 kW	72600.00 €	75552.75 €
agent 133504 @ step 0	agent 133504 @ step 0	101250.00 €	225.00 kW	101250.00 €	0.00 €
agent 13446 @ step 0	agent 13446 @ step 0	62160.00 €	150.00 kW	62160.00 €	0.00 €
agent 3536 @ step 0	agent 3536 @ step 0	168750.00 €	375.00 kW	168750.00 €	0.00 €
agent 2166 @ step 0	agent 2166 @ step 0	185190.93 €	375.00 kW	90750.00 €	94440.93 €
agent 2500 @ step 0	agent 2500 @ step 0	70500.00 €	150.00 kW	70500.00 €	0.00 €
agent 103209 @ step 0	agent 103209 @ step 0	96750.00 €	225.00 kW	96750.00 €	0.00 €
agent 29168 @ step 0	agent 29168 @ step 0	73485.00 €	150.00 kW	73485.00 €	0.00 €
agent 85007 @ step 0	agent 85007 @ step 0	59835.00 €	150.00 kW	59835.00 €	0.00 €
agent 25231 @ step 0	agent 25231 @ step 0	74076.37 €	150.00 kW	36300.00 €	37776.37 €
agent 120911 @ step 0	agent 120911 @ step 0	74076.37 €	150.00 kW	36300.00 €	37776.37 €
agent 128964 @ step 0	agent 128964 @ step 0	120000.00 €	300.00 kW	120000.00 €	0.00 €
agent 102286 @ step 0	agent 102286 @ step 0	135270.00 €	300.00 kW	135270.00 €	0.00 €
agent 40761 @ step 0	agent 40761 @ step 0	67500.00 €	150.00 kW	67500.00 €	0.00 €
agent 93896 @ step 0	agent 93896 @ step 0	157462.50 €	375.00 kW	157462.50 €	0.00 €
agent 49802 @ step 0	agent 49802 @ step 0	73500.00 €	150.00 kW	73500.00 €	0.00 €
agent 84634 @ step 0	agent 84634 @ step 0	153337.50 €	375.00 kW	153337.50 €	0.00 €
agent 34915 @ step 0	agent 34915 @ step 0	101250.00 €	225.00 kW	101250.00 €	0.00 €
agent 64232 @ step 0	agent 64232 @ step 0	92002.50 €	225.00 kW	92002.50 €	0.00 €

Figure 6: Allocation screen.

	Total power (kW)	Total allocated funds (Euro)	Total funded bids
first come first served	7125	3,199,996.67	825
even	6975	3,189,418.50	825
ramp up	6900	3,196,969.01	800
ramp down	6375	2,781,642.06	775

Table 2: Comparison of key outputs for different budget distribution strategies. Both incentive instruments are enabled and the optimisation objective is to maximise the power capacity.

nologies. The present version of the prototype provides a solid base to comprehensively explore different incentive design mechanisms and their practical ramifications.

The experimental evaluation presented here is limited to the scenarios that are feasible with the version of the social simulator available for this prototype. We plan to extend this evaluation in the future when more sophisticated versions of the simulator become available.

5.1 Future work

There are several avenues for future work. We have started to explore the evaluation of incentive mechanisms through an econometric approach. This builds a macro model that considers the economy and population as a whole instead of simulating individual agents. As such, the outputs are not as fine-grained as for this approach, but it allows to take global considerations into account.

In addition, there are additional scenarios that policy makers may want to consider. These will be provided with future versions of this software. We will also integrate future versions

of the social simulator, along with the changes that may be necessary to realise this.

Being able to configure the incentive design to their liking is one of the aspects of major importance for policy makers. We plan to extend the prototype to offer even more flexibility, for example with respect to how the budget is distributed across time steps.

As adding more options increases the burden on the user, we also plan to provide automatic means for determining the best value for a particular option. The user could, for example, have the budget distribution and whether to use grants or not determined automatically and only specify the values for the remaining parameters.

References

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