Optimising the economic efficiency of monetary incentives for renewable energy investment

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Problem Description

- Government policy: increase renewable energy production.
- Limited budgets.
- Lack of information regarding willingness of population to share costs.
- Instrument to support policy: grant aid.
- **Primary challenge: who should get what level of grant aid.**
- Secondary challenge: how to split a budget among competing technologies.

Game Theory

- A formal way to analyze interaction among rational agents who behave strategically.
- Economic modelling tool.
- People behave in a **selfish** manner that maximizes their own utility.

Game Theory

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- Solution concept: Nash equilibrium
- Outcome is stable (no agent has an incentive to *unilaterally* deviate)

Inverse Game Theory

- game of *private* information
- center chooses the payoff structure
- agent's "type" $\theta \in \Theta$
- outcome o consists of an allocation and payoff $o(\theta) = \{x(\theta), p(\theta)\},\ x \in X, p \in P$

Designing An Economic Game

- Inverse Game Theory
- Design rules
- selfish actions lead to socially desirable outcome

Designing An Economic Game

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Allocation Scheme

Who gets what.

Payment Scheme

What they pay to the Center in exchange.

Solar Grant Problem

- Altruistic central planner.
- Finite budget b to subsidize renewable energy micro generation.
- Set of self-interested agents I (seeking subsidies).
- Private information held by agent i[1]
- Common knowledge: price to acquire and install r
  - Pitch of roof p_i
  - Orientation o_i
  - Latitude l_i
  - **Value of cashflow stream** v_i

[1] Smart phone applications available for this purpose (e.g. Pitch Gauge).

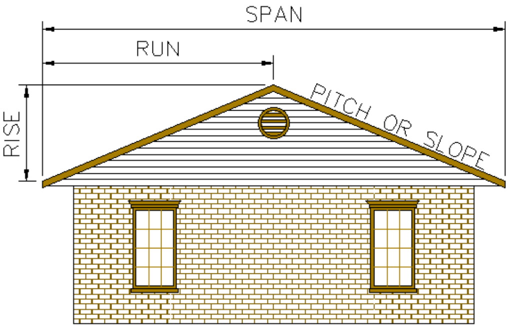

Figure: Roof pitch.

Figure: Orientation.

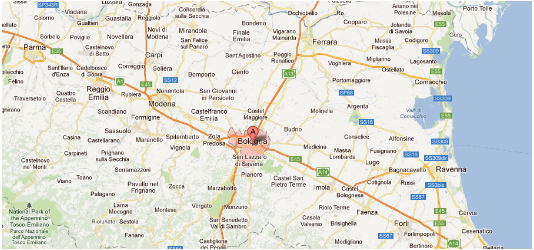

Figure: Latitude

Smart Phone: $\langle \mathbf{p},\mathbf{o},\mathbf{l},\mathrm{v} \rangle$

Figure: Data Capture

Cost

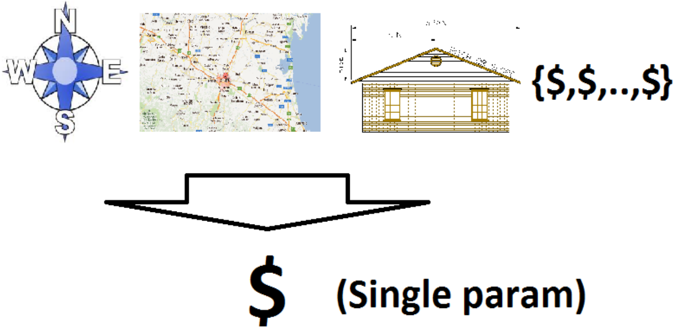

Figure: Maximum Cost an agent is willing to pay

Goal of Center

- **Minimize maximum cost for any agent**
- Incentivise truthful revelation of private data
- Allocate grants to those best placed to generate solar energy cost effectively
- Respect budgetary constraints.

Problem and Rationale

- Makespan minimization problem ($Q||C_{max}$)
- NP-complete
- allocate device acquisition and hosting responsibility (jobs) across houses (machines)
- private cost associated with acceptance of that job.
- inconvenience is bounded as tightly as possible.

Greedy Allocation Algorithm

1. order the devices from most expensive to cheapest
2. Greedily assign each to the household that minimizes the max cost imposition.
3. A 2-approximation that is **non-monotone**.
4. Leads to strategic manipulability

Non-monotone Allocation Failure Example

- 3 devices $\{d_1, d_2, d_3\}$ and 2 house-owners $\{h_1, h_2\}$
- power of each device: ϕ_1=10W, $\phi_2 = \phi_3 = 9 + \epsilon$W.
- price for each device: \$60 (common to all).
- Each house-owner has private value of \$5/W and $(5 - \epsilon)$\$/W, resp.
- greedy algorithm $d_1 \rightarrow h_1$, $d_2 \rightarrow h_2$ and $d_3 \rightarrow h_3$
- Cost $c_1 = 60 - (10 \times 5) = \$50$,
  $c_2 = 2 \times (60 - (45 - 4\epsilon - \epsilon^2)) \approx \$30$.
- Note: if v_2 increases to $5 + \epsilon$, he loses the second device.

Solution

- Complete search to ensure optimality
- Intractable: potentially large problem instances
- Compromise: approximation scheme with guarantees of monotonicity.

Approach: Monotone Algorithm

1. Random 3-approximation [Kovacs 2005]
2. Randomized rounding of partial allocations
3. Implementable within a truthful mechanism (critical payment scheme).

Payment Scheme

- Critical payments
- The minimum cost declaration to be awarded that item.
- Implementable within a truthful mechanism.

Future Work

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- Empirical study of expected outcomes using simulations
- Pilot Subsidy Auction
- Emilia Romagna region of Italy