ETH zürich

An Analysis Of Individual And Community Solar PV Adoption Levels Under Current Regulations Using Agent-based Modelling

Master Thesis Mid-term Presentation

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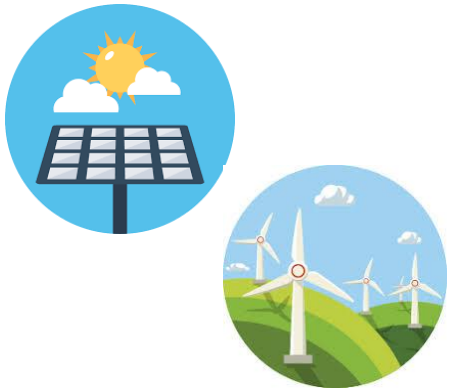
A / S Architecture and Building Systems

SusTec

Agenda

- Introduction and Motivation
- Methodology Overview
- Communities – “Plots” – in Alt-Wiedikon
- Agent-based Modelling and Decision Making
- CEA v SFOE data
- Next steps
- Discussion: inputs and feedback

Introduction



2017: 1.4 TWh

2020: 4.4 TWh

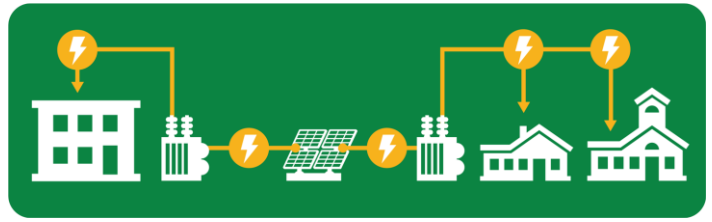
2035: 11.4 TWh

Zurich

Great case for community solar

Complementary building types closely packed together

Alt-Wiedikon: high resolution CEA data

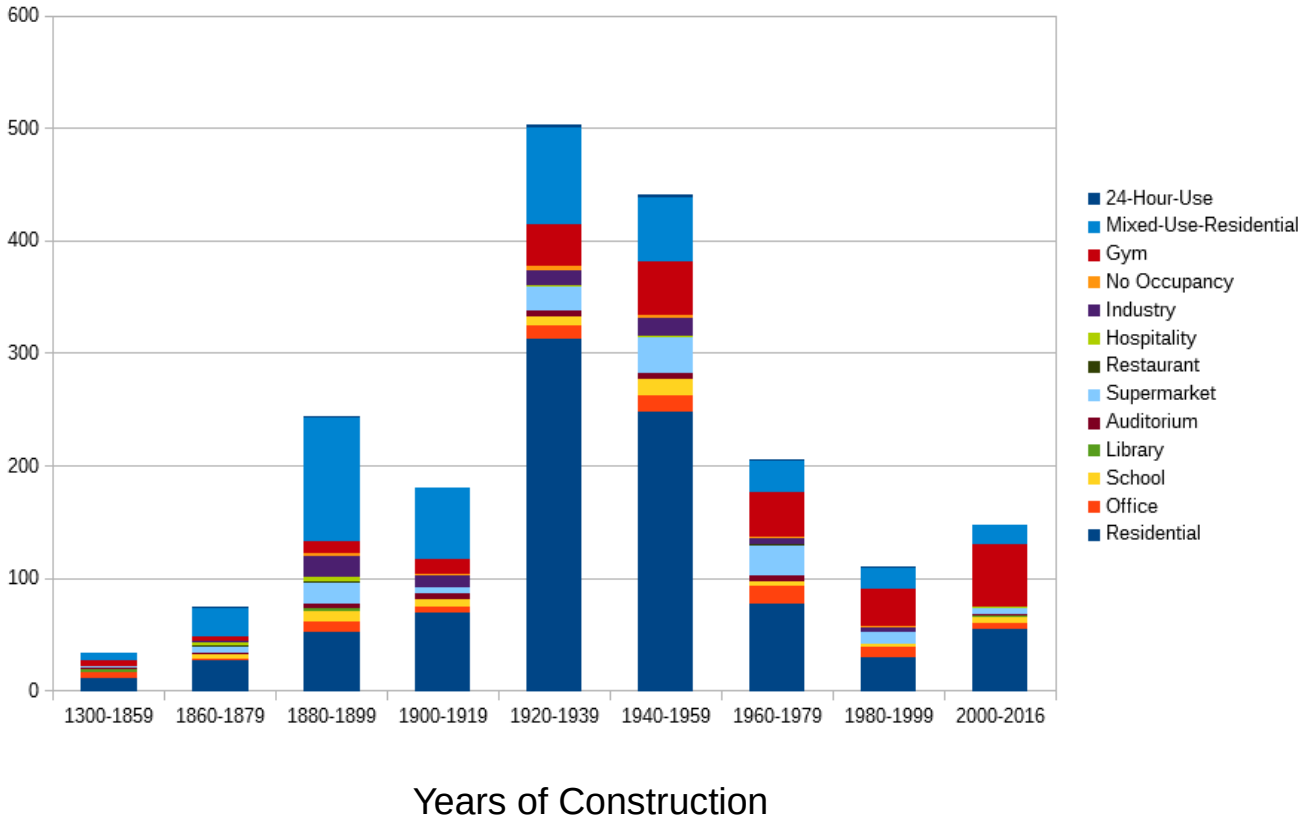


Community Scale PV systems

- Larger = reduced price/kW
- complementary load profiles
- Financial benefits/products

Alt-Wiedikon Buildings Distribution

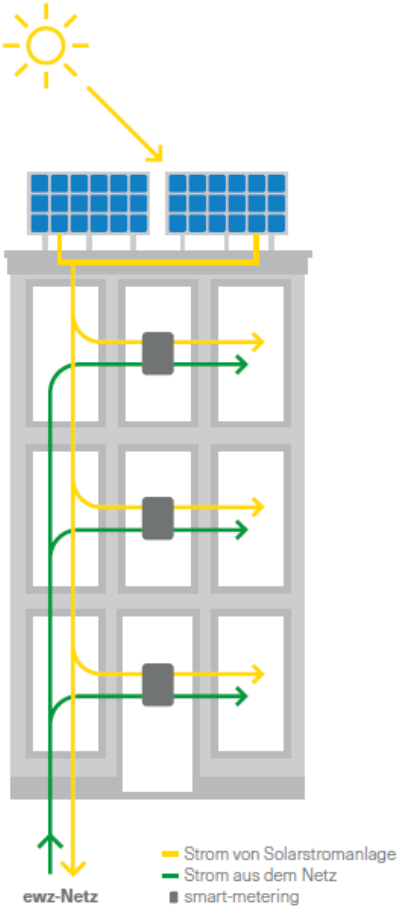
FIGURE 1.1: Building types of the whole district as in the statistics of the City of Zurich



Years of Construction

Regulations

- Energy Act (EnG 2018):
  - Mandatory for EWZ: FiT = 7.91Rp./kWh in Zurich
  - Only one-time subsidy from government: up to 30% of PV system costs
- Zusammenschulss für Eigenverbrauch (ZEV) Formation
  - Article 17, EnG 2018: Incentivizes self consumption communities
  - multiple consumers → single customer
  - Building owner/Tenants → form ZEV, share system costs and electricity in premises



Need for Solar Adoption + Policy Incentives = Ingredients for a Research Question!

- Switzerland needs to increase renewable energy generation by 10 TWh by 2035. Community Solar PV Systems have important advantages over Individual PV systems.
- Problem Statement:
  - *Newly introduced regulations incentivize self-consumption and favour Community Solar PV, but their effectiveness remains unknown and un-researched.*
- Research Questions
  - *Will the adoption of community scale solar PV outpace individually owned solar in the Swiss urban context, given current regulations?*
  - *What elements of the current regulation have greater impact on adoption levels?*
    - *Level of subsidies*
    - *Size of allowed communities*

State-of-the-Art

- Agent-based models have been used to model solar PV adoption
  - Individual, heterogenous agents making decisions
  - Account for irrational human behaviour and how peers/society drive decision making
  - *Rai, Douglas (2016):* "Interaction of heterogeneous agents at the micro-level produces macro outcomes" i.e. Emergent behaviour
- *Icek Ajzen's Theory of Planned Behaviour (1991)* commonly used as the base for decision making
- Existing research focuses on individual level PV adoption
  - Ex-Post: Palm (2017): Surveys of PV adopters –
    - Active peer effects as a final confirmation from trustworthy sources → Passive peers unimportant
  - Ex-Ante: Rai, Robinson (2015): Empirical approach to ABM with Relative Agreement algorithms and Small World Networks –
    - Effect of change in rebate levels on adoption scales with installed base → greater adoption later in the model
- No existing research on adoption of community PV systems! ☺

Methodology Overview

Other Inputs
- Peer effects, environmental attitudes, agent locations
- Prices – PV and Electricity

Building Data, Geometry, etc.

CEA Model
Alt-Wiedikon, Zurich
(Sabine Python)

CEA
Output
Data
Processing

ABM for
Building Owners
[Individual/Community Adoption]

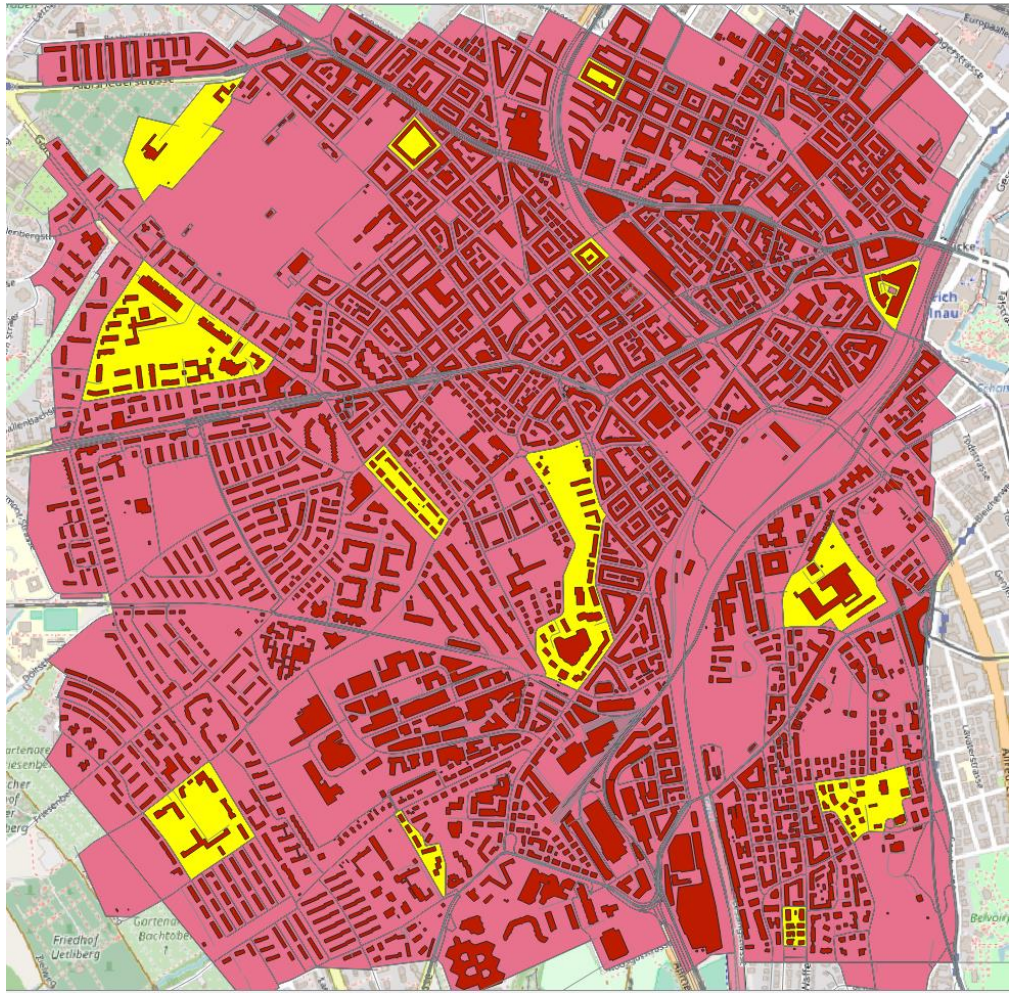
Parameters
- Agent Categories based on building type and ownership
- Time: Yearly time steps until 2035
- Small-world Network: Which agents interact

Results
Visualisation
Excel + GIS

- Adoption levels Individual v Community

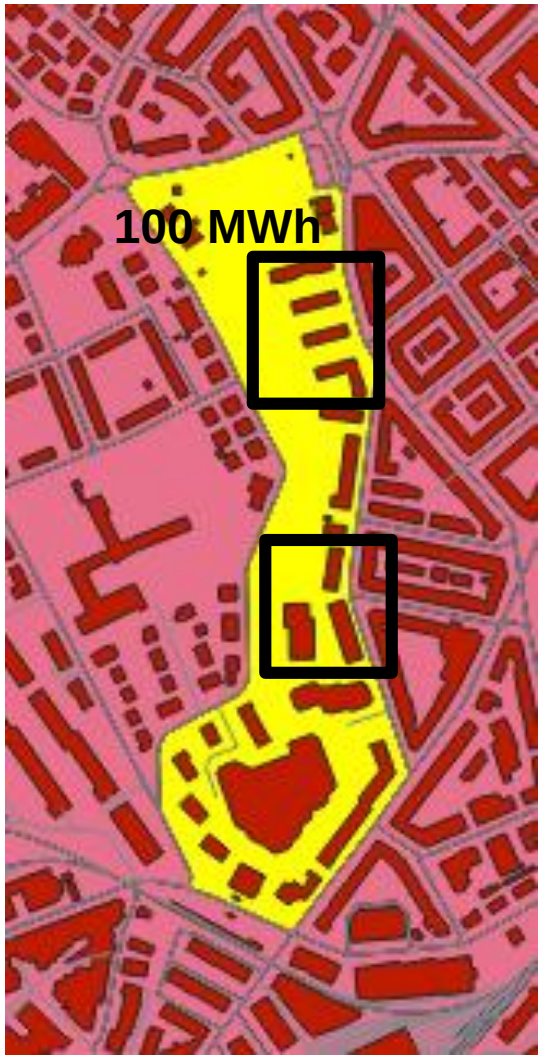
Communities based on Strict ZEV regulations – “Plots”

- Make “Plots” very strictly according to regulations
- Plots aren’t perfect
- Different types of plots formed:
  - Single/Multiple buildings
  - Small/Large areas
  - Different Building types



Zooming into a Plot

- All could potentially form a SINGLE community
- Or can form multiple SUB-communities
- 100 MWh Demand self-imposed limit – threshold for wholesale electricity market participation – *discussion later*
- → Buildings which can actually form a ZEV are further classified into sub-plots



What does our ABM do?

- Building owners of different types
- DECISIONS:
  - Solar NO
  - Solar YES
    - Individual
    - Community
      - What size of community? With who?
- Individual PV on building – no problems
  - Size of system known – prices known
  - 2 choices only – “Ja” oder “Nein”

- Community PV in a plot – lots of problems!
  - PV System Size ←→ Costs ←→ Members of ZEV
  - Keep Community PV Size varying
    - Avoids Bias
  - Hence use combinatorics – each subplot (100 MWh) will decide out of many options after buildings get an idea to adopt/not adopt solar

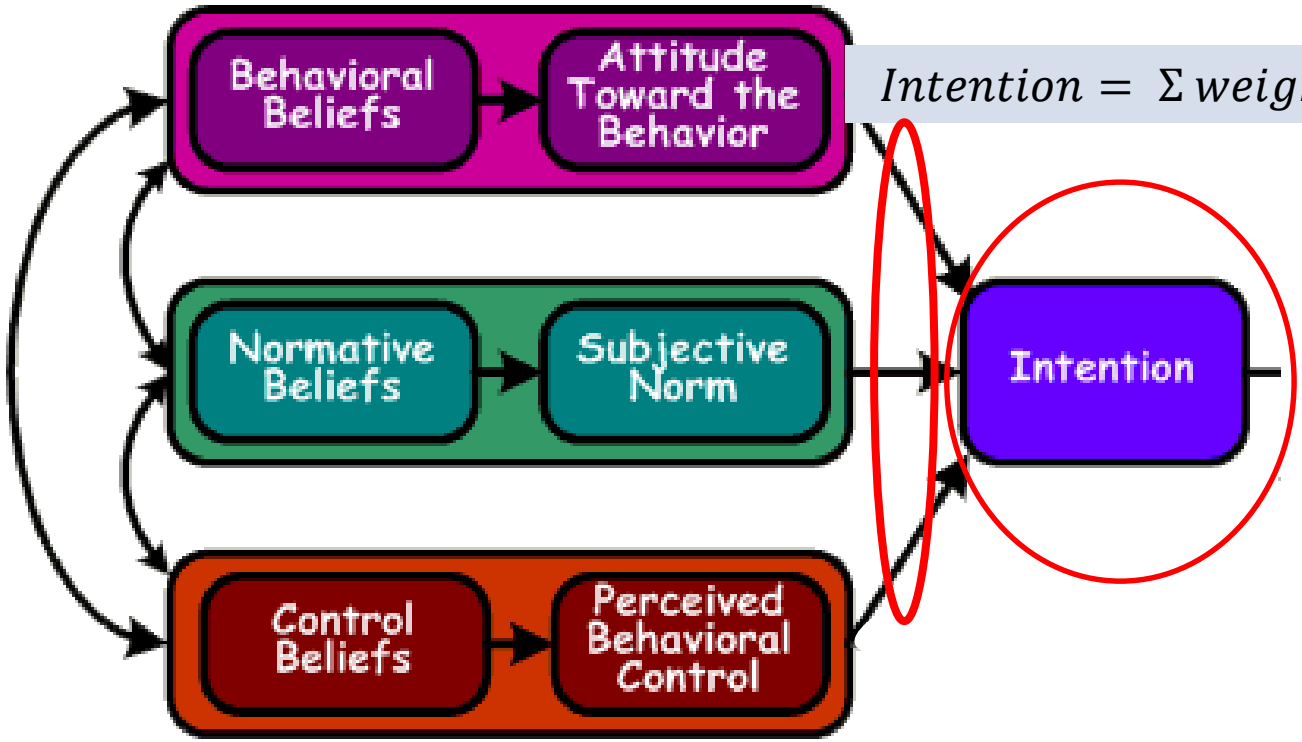
Use of Theory of Planned Behaviour for decision making
Stage I – Idea Generation

Variables

Environmental attitudes/beliefs
Range = [0,1]
w/ MINERGIE = high EA ~1
w/o MINERGIE = low EA ~0

Small-world Network (Closest people – Friends, Family): in-plot/out-plot
Range = [0,1]
Ratio: $\frac{\#people\ in\ SWN\ with\ Solar}{Total\ \#people\ in\ SWN}$

Economic Attractiveness:
Range = [0,1]
Payback Period Ratio = $\frac{PP\_bldgtype - PP\_bldgtype\_PV}{PP\_bldgtype}$



$$Intention = \Sigma\, weight * var > threshold$$

IDEA Generation
Do I want solar?
Yes/No

Icek Ajzen, 'Constructing a TPB Questionnaire: Conceptual and Methodological Considerations', 2002

Use of Theory of Planned Behaviour for decision making
Stage II – Choice

Environmental attitudes/beliefs
Range = [0,1]
w/ MINERGIE = high EA ~1
w/o MINERGIE = low EA ~0

Small-world Network (Closest people – Friends, Family): in-plot/out-plot
Range = [0,1]
Ratio: $\frac{\#people\ in\ SWN\ with\ Solar}{Total\ \#people\ in\ SWN}$

Economic Attractiveness:
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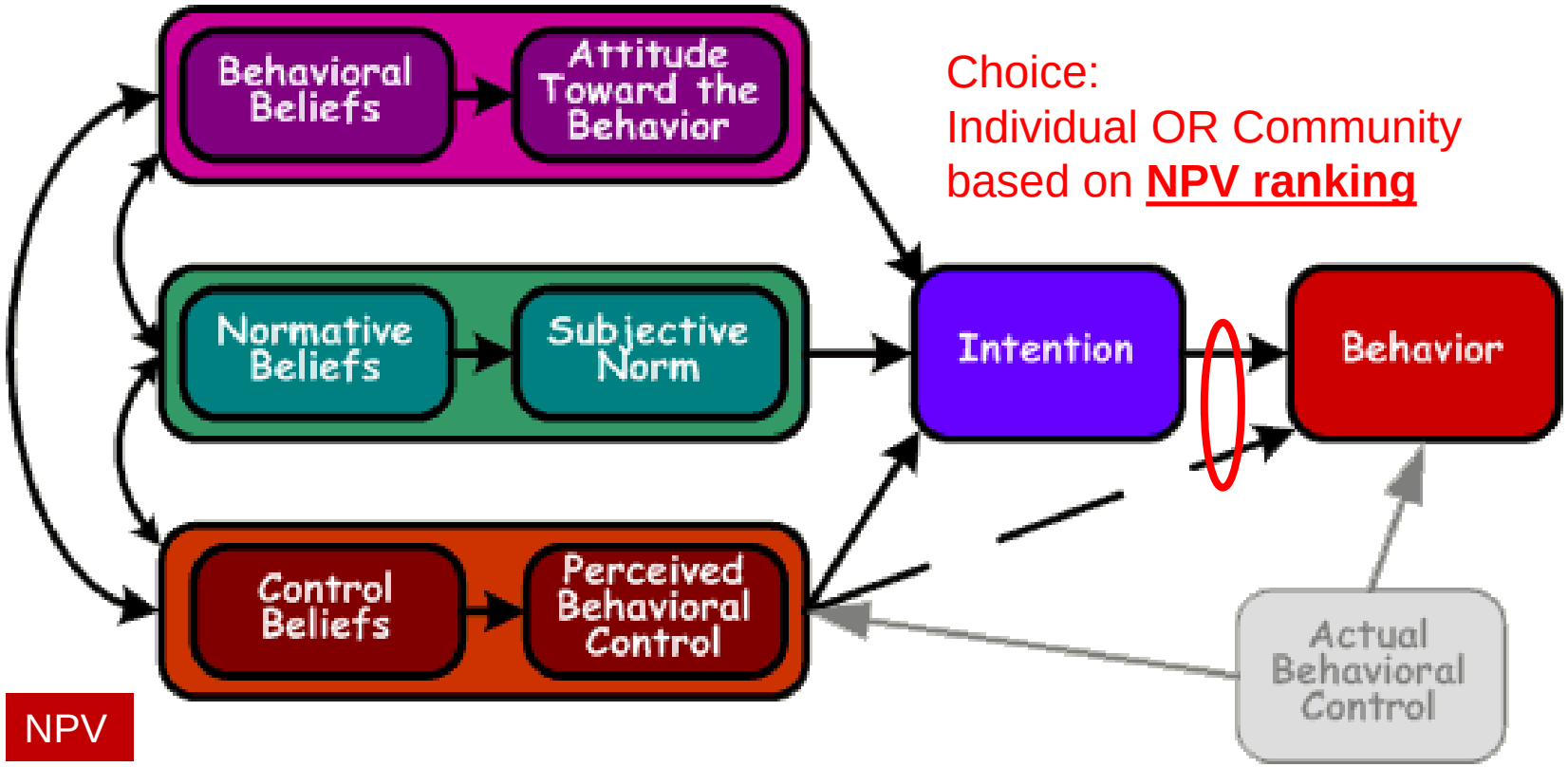
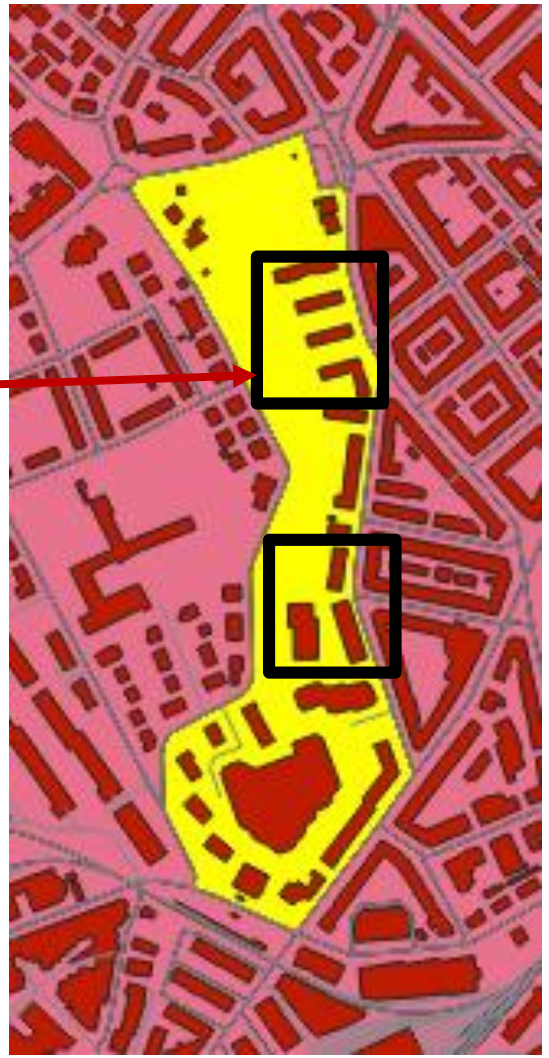


Choice:
Individual OR Community
based on **NPV ranking**

Choice based on NPV Ranking

- After clearing Stage I: Only subplot considered
- A, B, C, D
- 11 possible communities
  - ABCD
  - ABC
  - BCD
  - …
  - Which community is formed?



Who prefers what? Let's rank preferences:

- Lower the sum of NPV rankings, more preferred the community
- Other criteria, like self-sufficiency of communities formed, can also be ranked and weighted together

Combinations	Ranking A	Ranking B	Ranking C	Ranking D	SUM	Overall Rank	Comments
ABCD	1	1	2	1	5	1	C compromises
ABC	2	3	3	-	8	3	
CDA	3	-	4	4	11	4	
ABD	4	4	-	3	11	4	
BCD	-	2	1	2	5	2	
AB	5	5	-	-	10	6	3 member ZEV prioritized over 2 member
BC	-	6	5	-	11	7	

Base Case ABM

- Base Case: Adoption under current regulations until 2035
  To what degree do current regulations lead to the Energy Strategy 2050 goals?
- Assumptions:
  - PV size = Max. roof area available
  - Community formation = strict ZEV + max. 100 MWh demand/year
  - Policy = Current regulations
- Variables changing with time:
  - Falling PV prices (projections), peer effects

- Expected Results
  - Community > Individual adoption
  - Adoption increases towards the end of simulation period as peer effects increase and PV prices decrease

Interesting Scenarios – change Base Case Assumptions

a) Reduced PV sizes
- Maybe demands are not high enough for larger PV systems
- Can show us optimum size levels in terms of technical and economic aspects

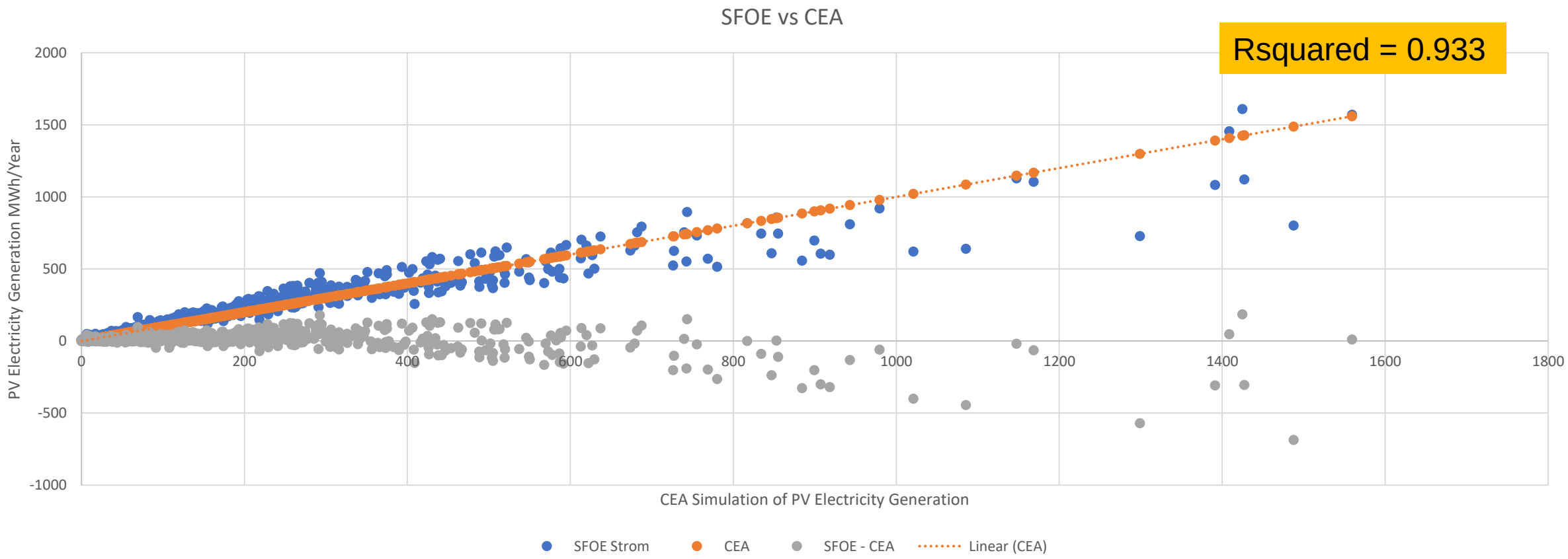
b) Relaxed ZEV regulations
- Bigger Plots/Subplots
- No 100 MWh demand criteria
- Can show if better and larger communities can be formed at possibly lower costs

c) Changing Subsidies and FiTs
- Prolong availability after 2030,Increase/Decrease/Special ZEV credit
- Gives an idea of the importance of the level and type of subsidies

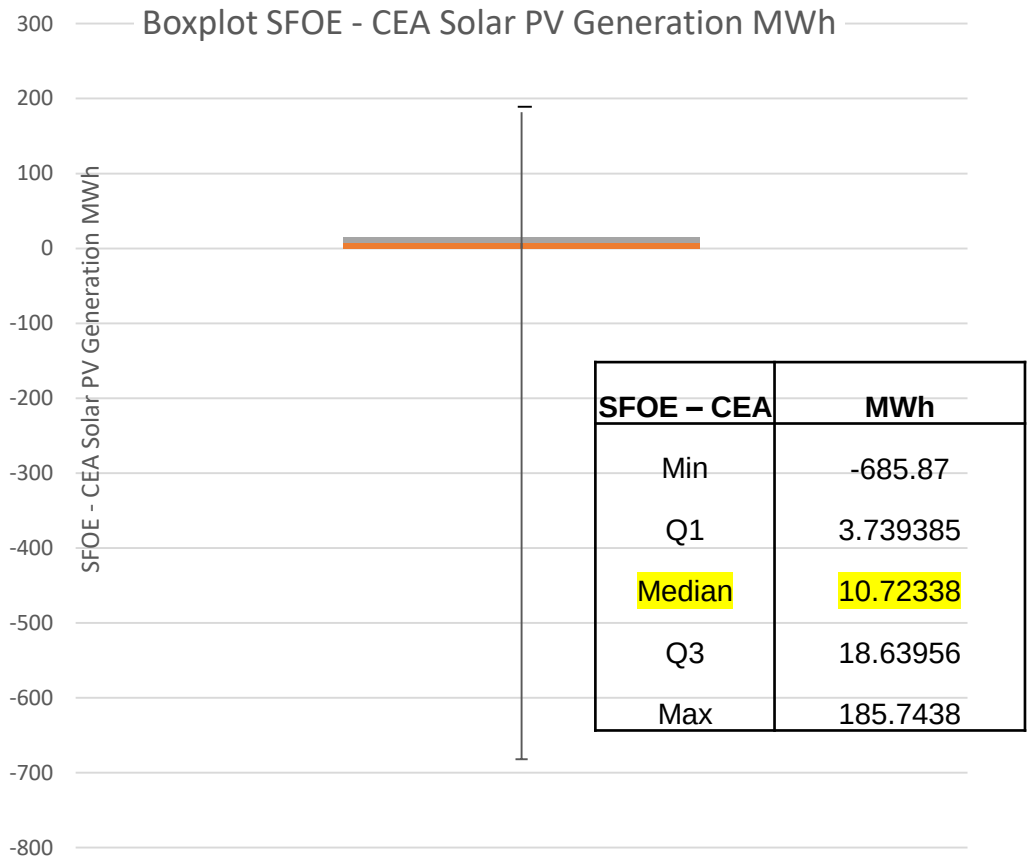
SFOE v CEA Data
Fits well but magnitude of difference is high!

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Energie BFE



Median difference = 10 MWh = approx. 3 households' yearly demand! CEA underestimates.

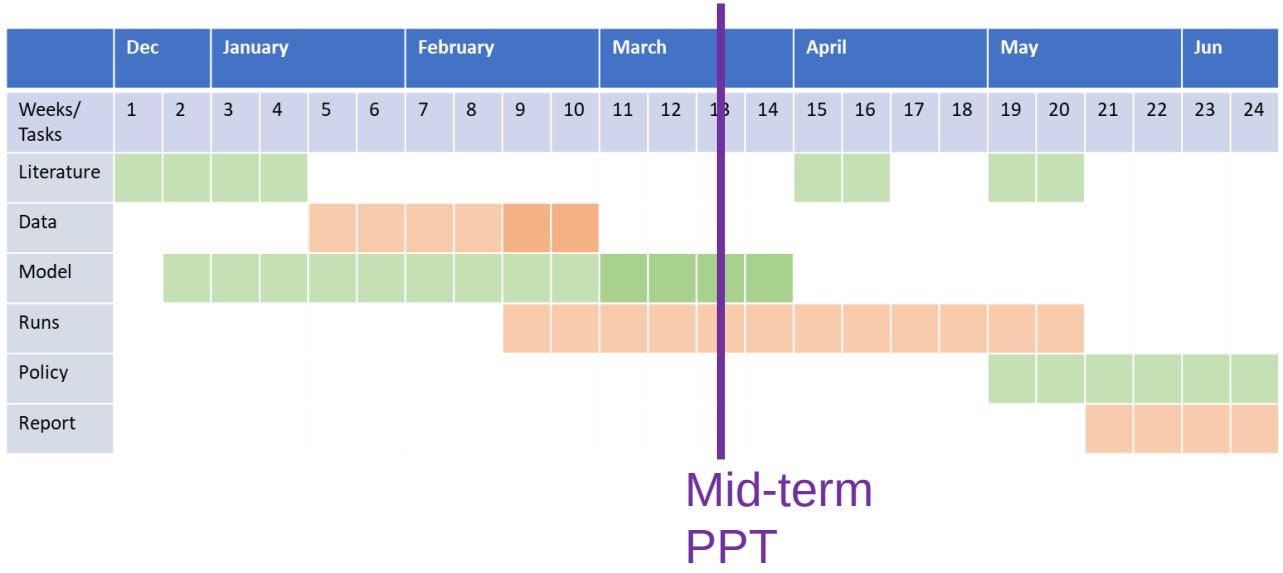


SFOE – CEA	MWh
Min	-685.87
Q1	3.739385
Median	10.72338
Q3	18.63956
Max	185.7438

Still use CE
Hourly data
important fo
and SS calc

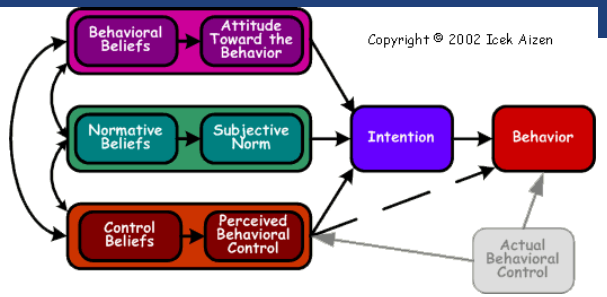
Next Steps

- March: ABM model architecture
- April: ABM Runs
- May: ABM results analysis
- June: Final Presentation
- September: CISBAT Conference Poster Presentation!



Thank You! Time for questions and discussion! ☺

Discussion: inputs and feedback



- 100 MWh self-imposed limit
  - ~25-30 households ~ 4-5 typical residential buildings
  - Dsregard this limit and consider PV comparison with wholesale prices? NPV changes!
- NPV not considered in Stage I
  - TPB becomes complex with various options (else had to fix community size, unrealistic)
  - But, any other way than PP ratios to develop economic attractiveness?
- Does considering NPV ranking in Stage II make sense?
  - Conflict resolution:
    - Based on technical criteria, like greater self-sufficiency?
    - Based on best NPV situation for all buildings concerned?
    - Based on inclusion – include as many buildings in community system?
  - Include feedback to Stage I to model it as persuasion from peers?
- Any thoughts on the decision making process?
- What scenarios do you like? – reduced PV, relaxed regulations, changing subsidies, Others?

Back-up Slides

My case: So. Many. Variables!

Environmental attitudes/beliefs
Technical aspects
Economics
Past opinions

Cost effectiveness
No. of installations in neighbourhood
Feedback based on peer decisions
What Peers Say
- General Social Image of PV
- Small-world Network (Closest people – Friends, Family)

Does agent feel confident enough to do it?
Money/Economic Attractiveness
Time
Skills
Support and Persuasion