



Our Energy

ETH zürich

IMG Stiftung Phase 2: The Our Energy Challenge

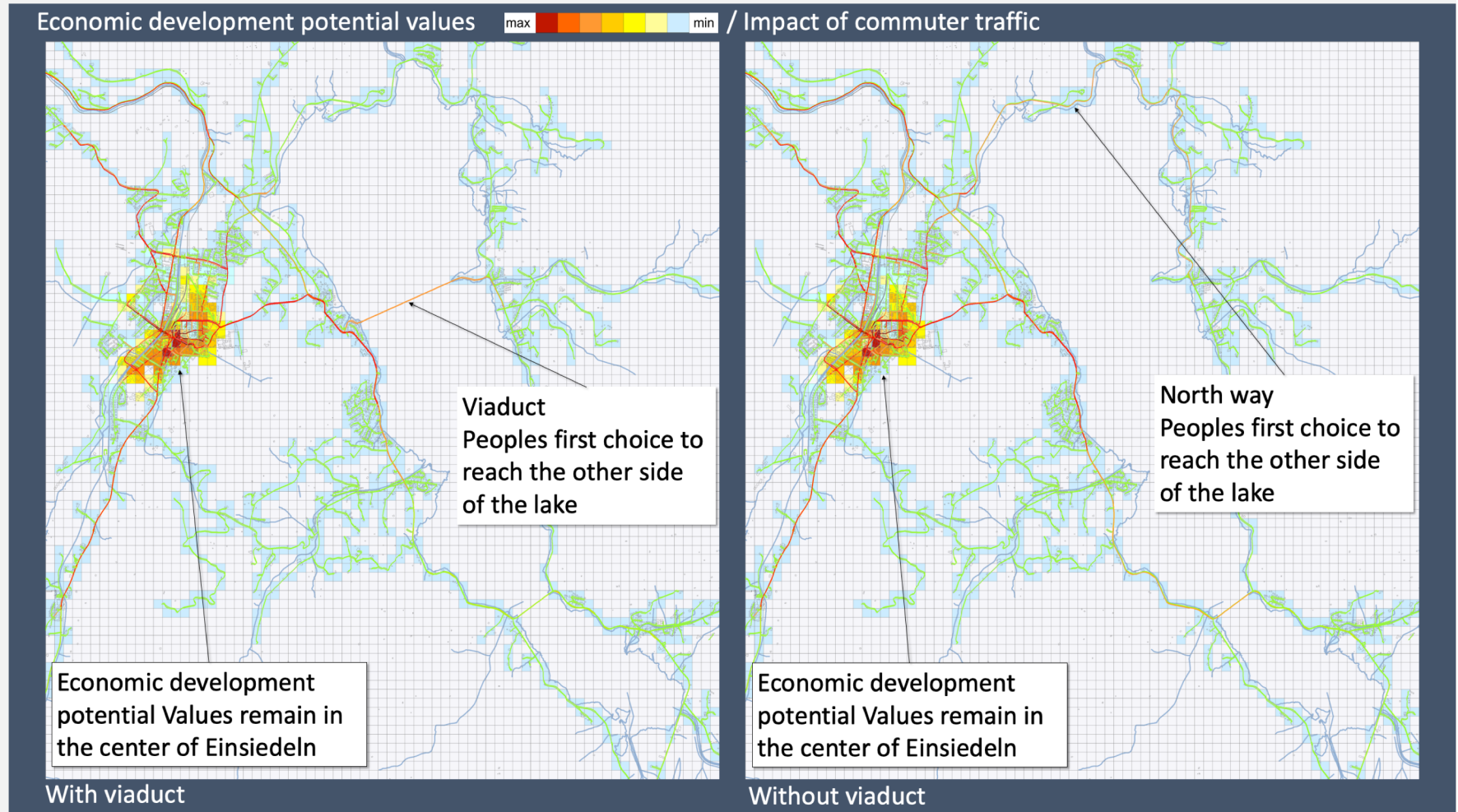
An exemplary case for Citizen Design Science applied to
Community-Scale Solar PV at the Einsiedeln – Willerzell Viadukt



Prof. Dr. Gerhard Schmitt
Danielle Griego, Natasha Catunda, David Dal Busco
Denise Weber, Torsten Häffner

Previous project in Einsiedeln

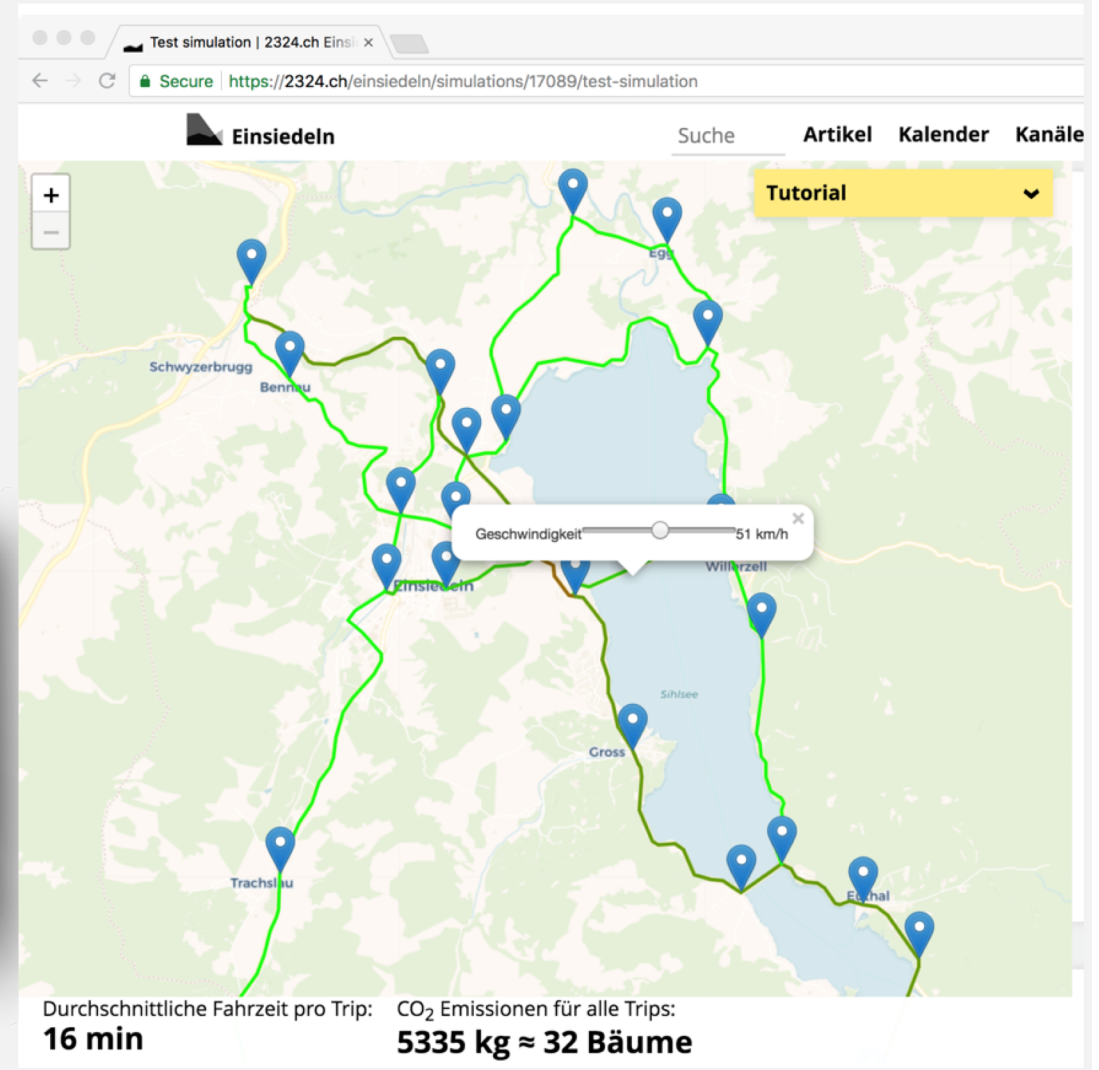
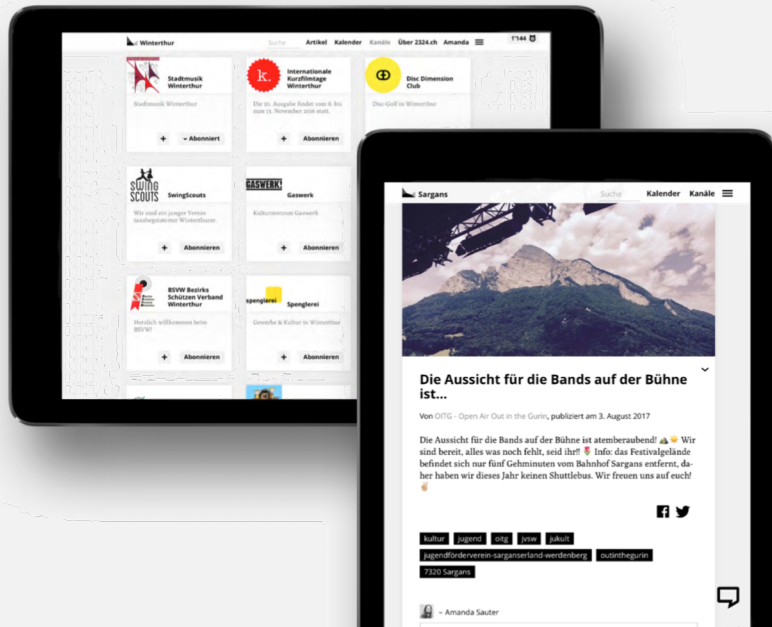
Impact analysis of
bridge removal



Previous project in Einsiedeln

Citizen Design Science app

- ↳ Engagement platform
- ↳ Traffic simulator
- ↳ CO₂ estimator



Current project in Einsiedeln: Our Energy



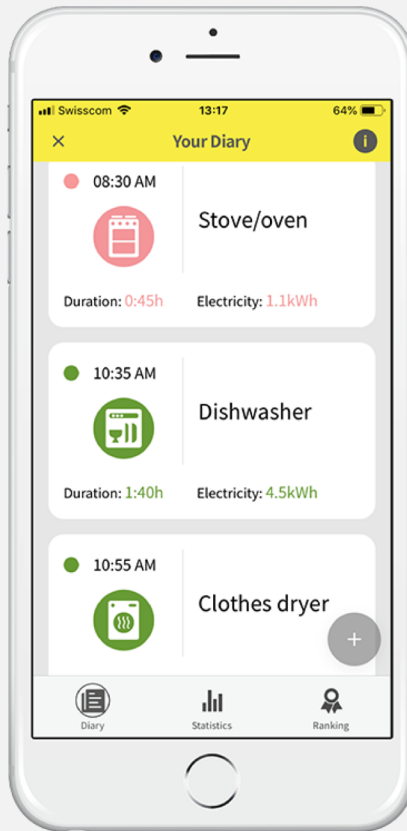
Chair of Information Architecture (iA)

Our Energy Project, Einsiedeln 2019, Banner by Edgar Kälin

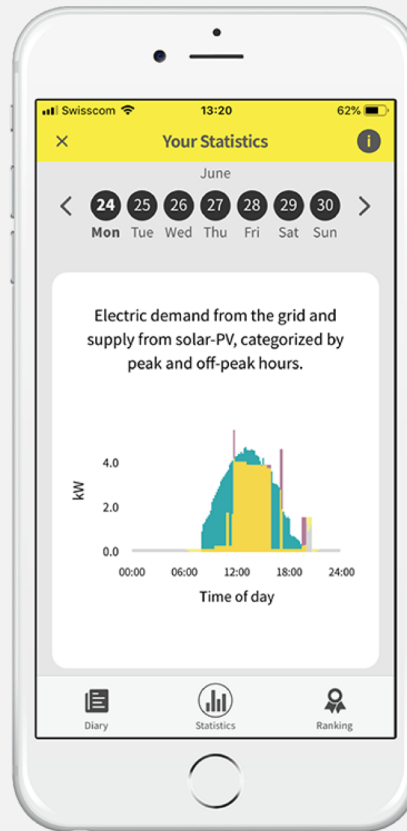


Our Energy
ETH zürich

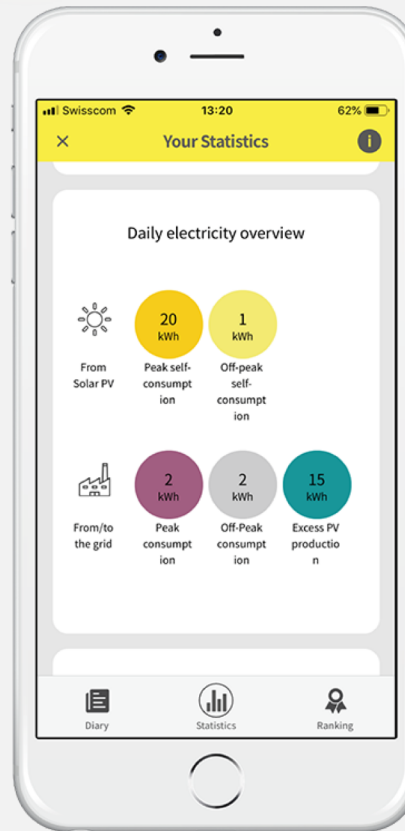
Simulation app to experience solar electricity:



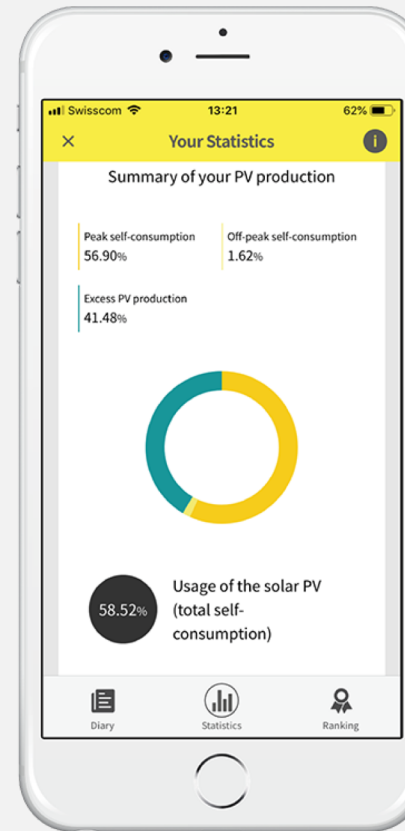
Appliances diary



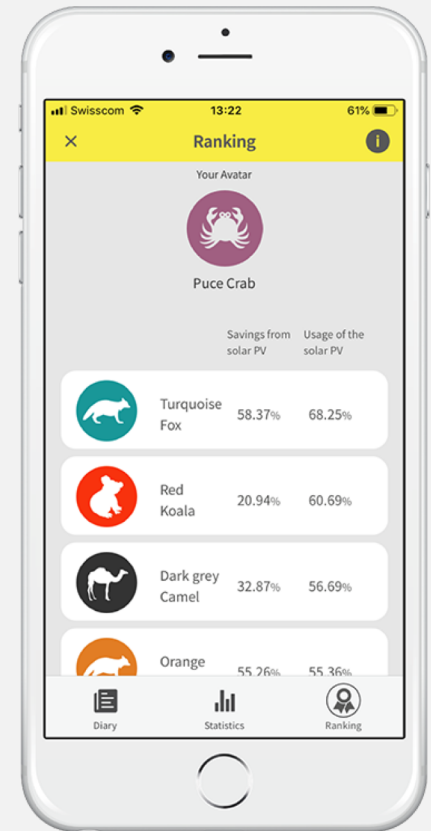
Statistics graph



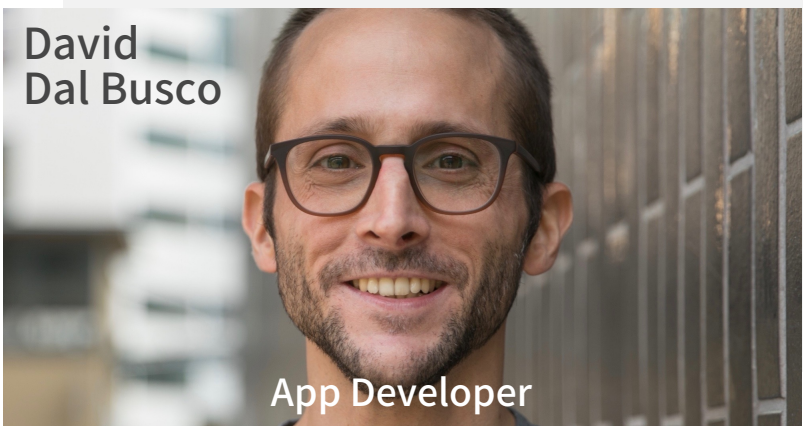
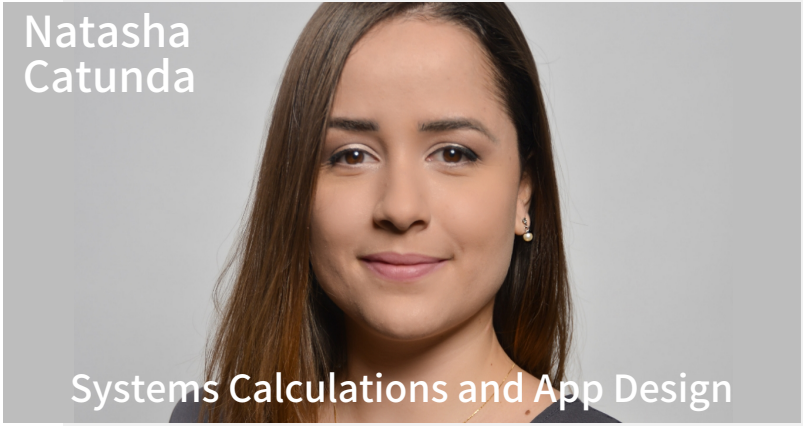
Statistics legend



Self-consumption visualization



Ranking

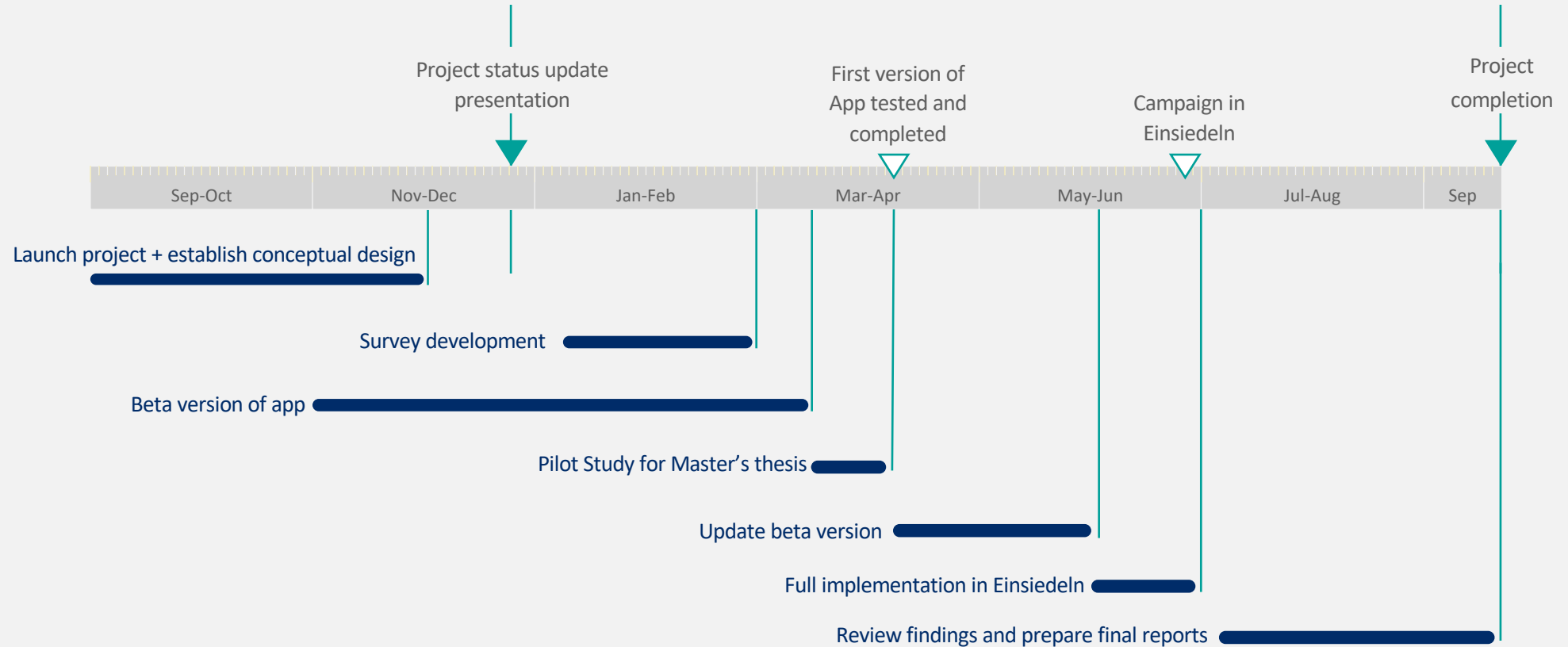


Team Our Energy

IMG Stiftung Phase 2
The Our Energy Challenge



Planned and executed timeline



Motivation



Citizens of Willerzell and Einsiedeln want to keep the Viadukt



What future developments can be incorporated into the community around the bridge? Solar Photovoltaics (PV)?



Help contribute to the 2000 Watt-society and Energy Strategy 2050 goals.



Focus on solutions that address both increasing renewable energy supply and energy conservation through self consumption or “Eigenverbrauch”



PV is the most promising renewable energy source in CH

Einsiedeln demographics

Total population: 15,550

Number households: 6,565

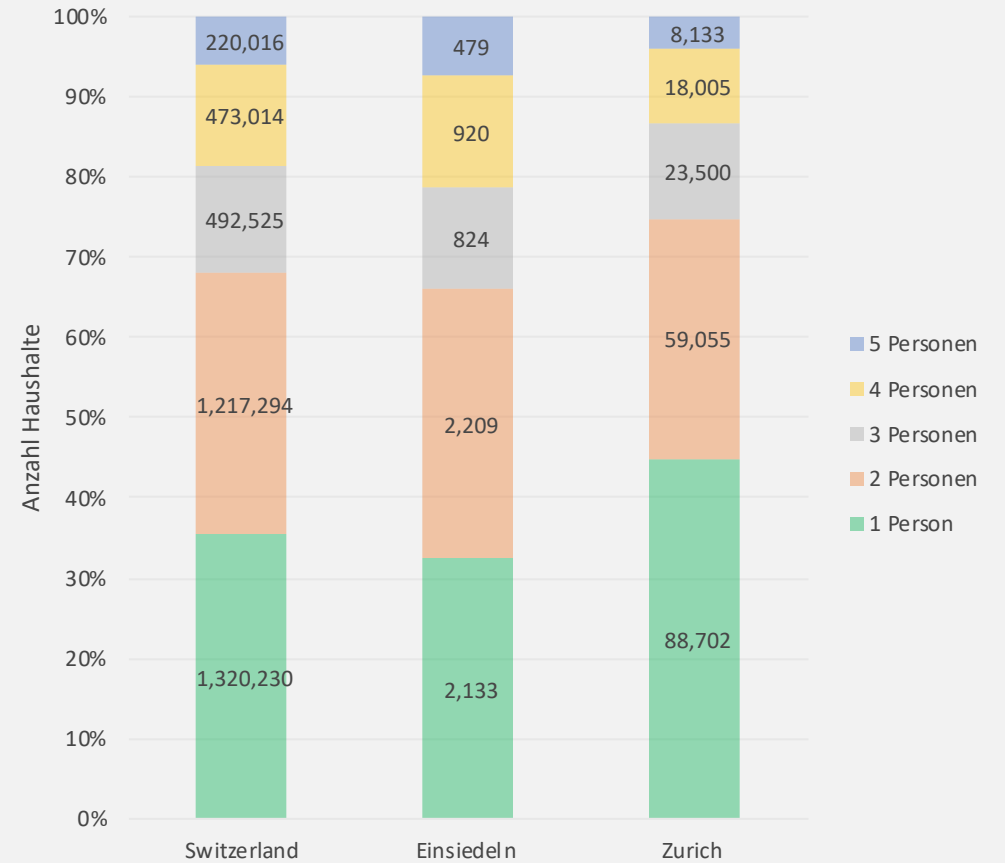
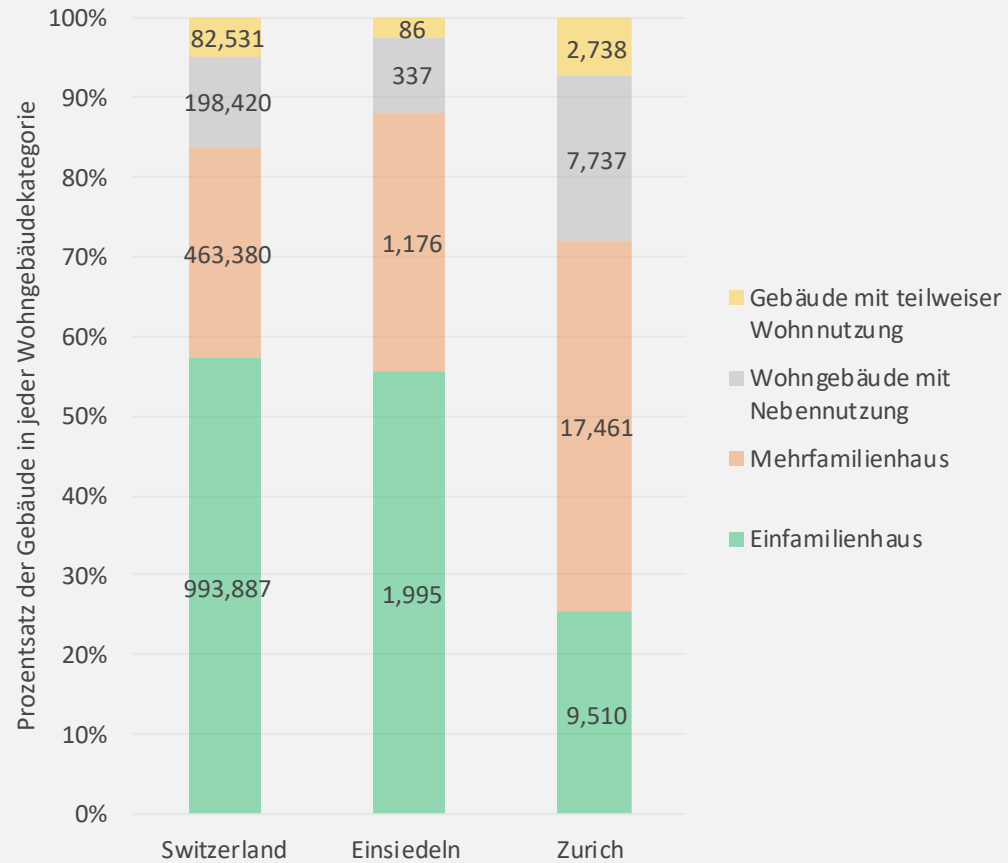
Average residence: 114 m²

Average number of people per household: 2.3

Swiss Cantonal Statistics: Schweizerischer Städteverband (2017)

Einsiedeln demographics

Swiss Cantonal Statistics: Schweizerischer Städteverband (2017)



Outline phase 2



Objectives



Method



Primary project outcomes:

- ✓ Pilot study and evaluation (Master thesis)
- ✓ Final version of 'Our Energy'
- ✓ Our Energy campaign in Einsiedeln
- ✓ Full Implementation results



Conclusions and Future work



Additional outcomes:

- ✓ CISBAT paper + poster
- ✓ Energy Informatics - App Demo
- ✓ Book (Torsten)



Objectives

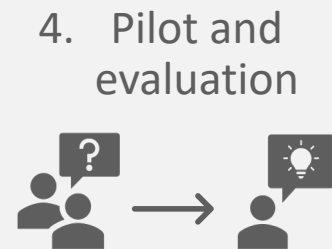
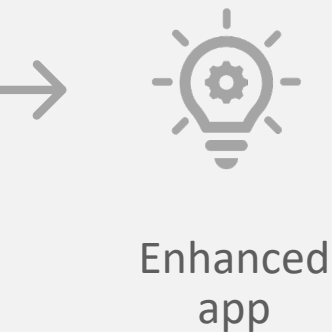
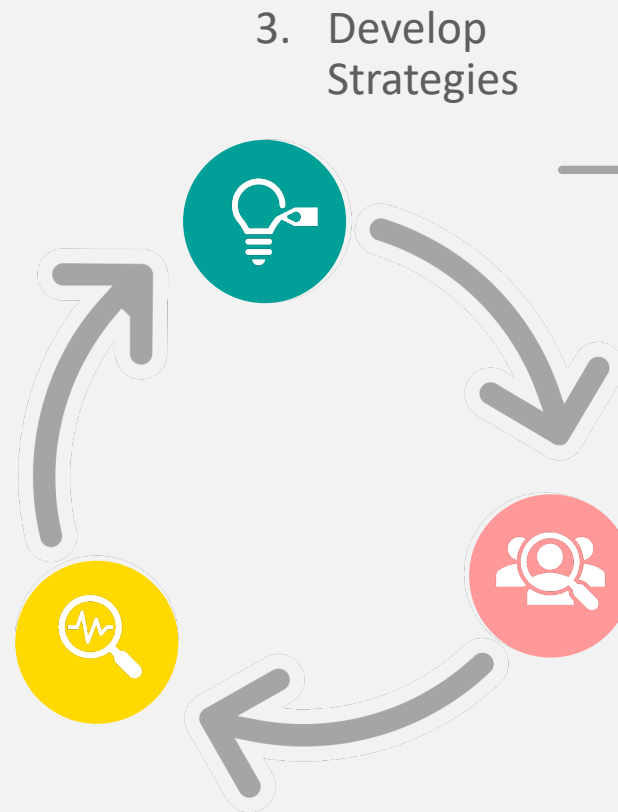
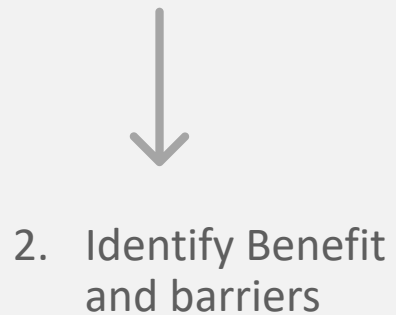
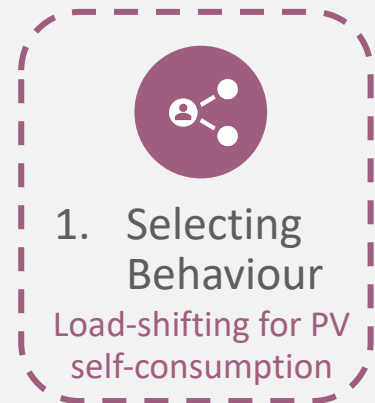
Evaluate if the **community context** positively influences the desired behavior of **load-shifting** to maximize self-consumption of a **shared solar PV system**.

1. Develop an energy information platform with both individual and aggregate energy performance data for a community PV system located in Einsiedeln, Switzerland.
2. Test if households achieve higher levels of self-consumption when they are connected to a community scale PV system compared to an individual rooftop PV system. (Pilot study)
3. Test if participants load-shift at the household level to increase their self-consumption compared to an established baseline. (Full implementation)
4. Evaluate if other criteria may also influence the levels of participation such as "energy literacy", sense of community, environmental awareness or interest to invest in renewable energy technology



Method

5-step community-based social marketing approach





Method

5 step community-based social marketing



1. Select Behaviour

- Focus on load-shifting for self-consumption of solar electricity production
- Categorize appliances to facilitate load-shifting



2. Identify Benefit and barriers

- Most people do not have access to solar PV at home
- Most people do not receive regular energy consumption information

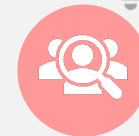


3. Develop Strategies

- Simulate 'what it would be like to have electricity from solar PV'
- Appealing app to show how to load shift using an 'energy diary'
- Community activities require direct contact with the people



Enhanced app



4. Pilot and evaluation

- Test usability of the strategy (APP) with team members
- First pilot study with ETH students
- Focus group with representatives from Einsiedeln



5. Full implementation

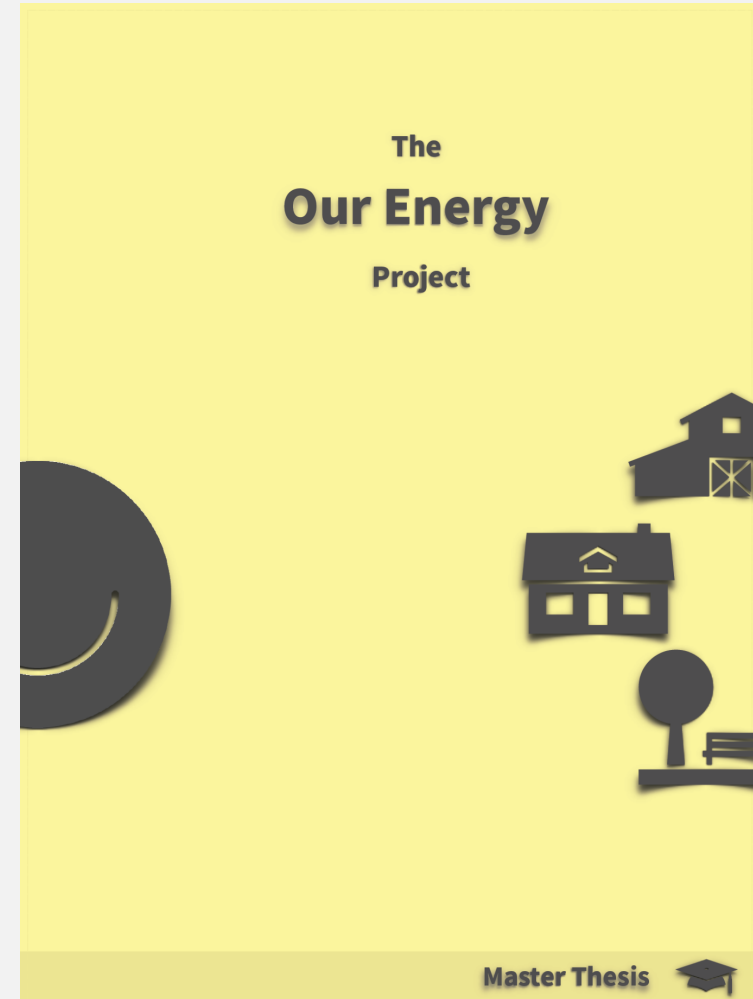
- Outcomes from the pilot study to improve the full implementation
- Marketing campaign in Einsiedeln on 22-23 June
- Full study 23 June- 7 July



Primary project outcomes

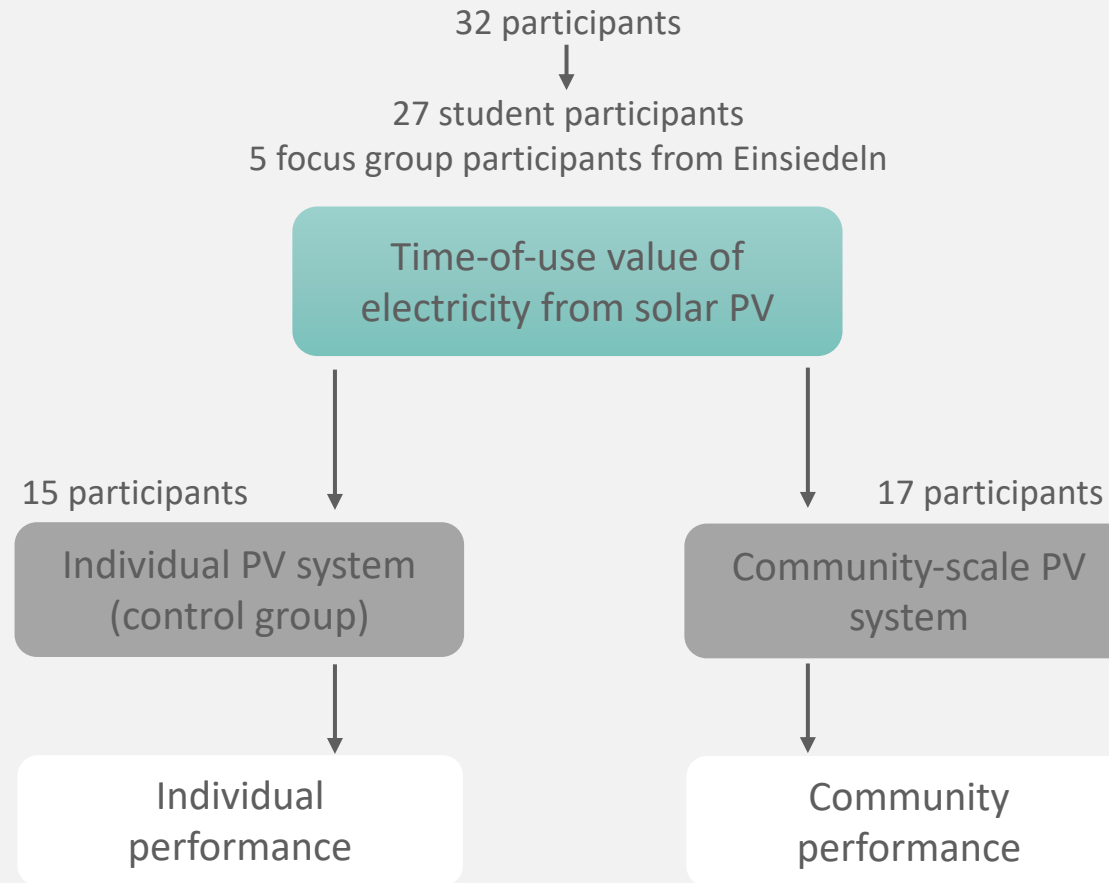
1. Pilot study and evaluation
2. Final version of 'Our Energy'
3. 'Our Energy' campaign
4. Full Implementation

- a. Experimental Set-up
- b. Summary of findings
- c. Design improvements

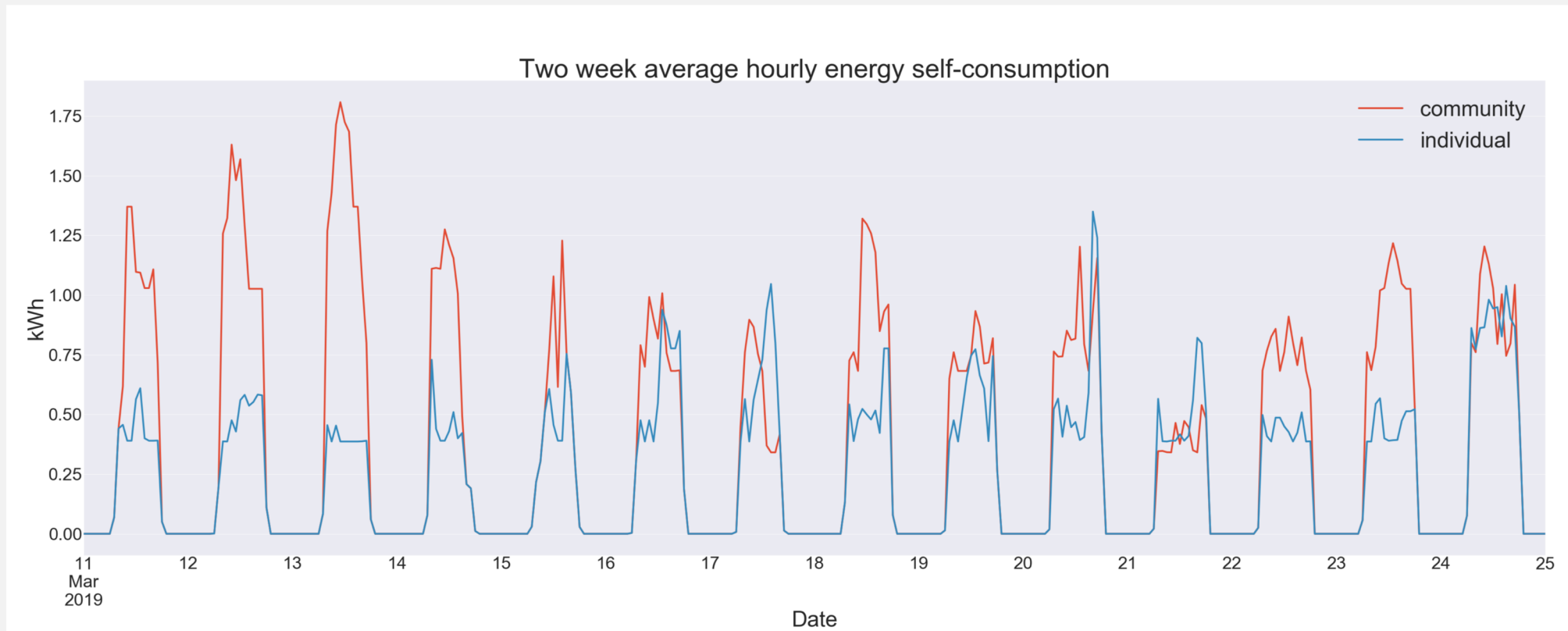


Experimental set-up

Two-week study: 11-25 March 2019

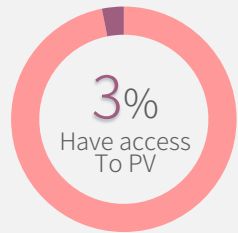


Summary of findings

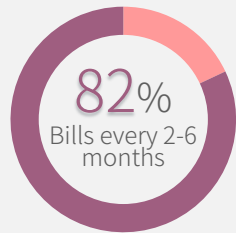


Summary of findings

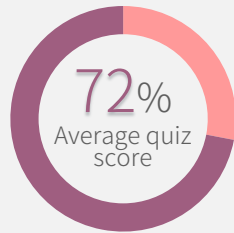
Pre-participation survey results:



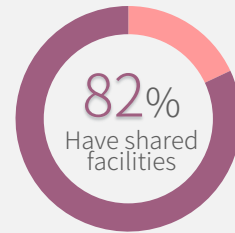
Access to PV



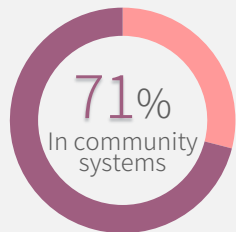
Access to electricity data



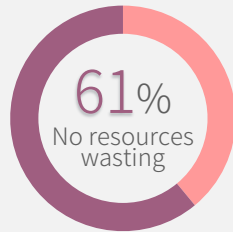
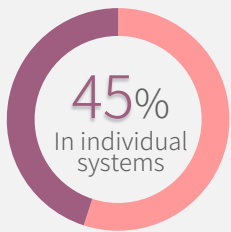
Energy literacy



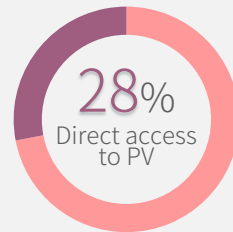
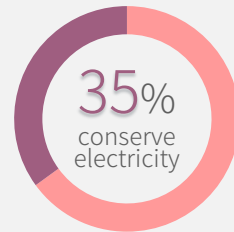
Shared facilities



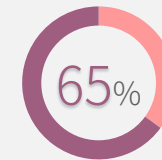
Likelihood to invest in PV



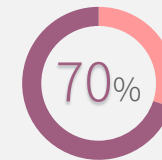
Environmental awareness



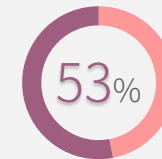
Post-participation survey results:



Household electricity consumption



Time-of-use of electricity



Load-shifting

Reported learning effects

Summary of findings

What worked:



Visual representation and ease of use of the app



Knowledge about personal use of electricity



Raised awareness and experience with the time-of-use of electricity



Sense of other people participation with the ranking function

What did not work:



Initial point scheme was too simplistic



Not enough knowledge on how to shift appliances

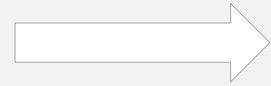
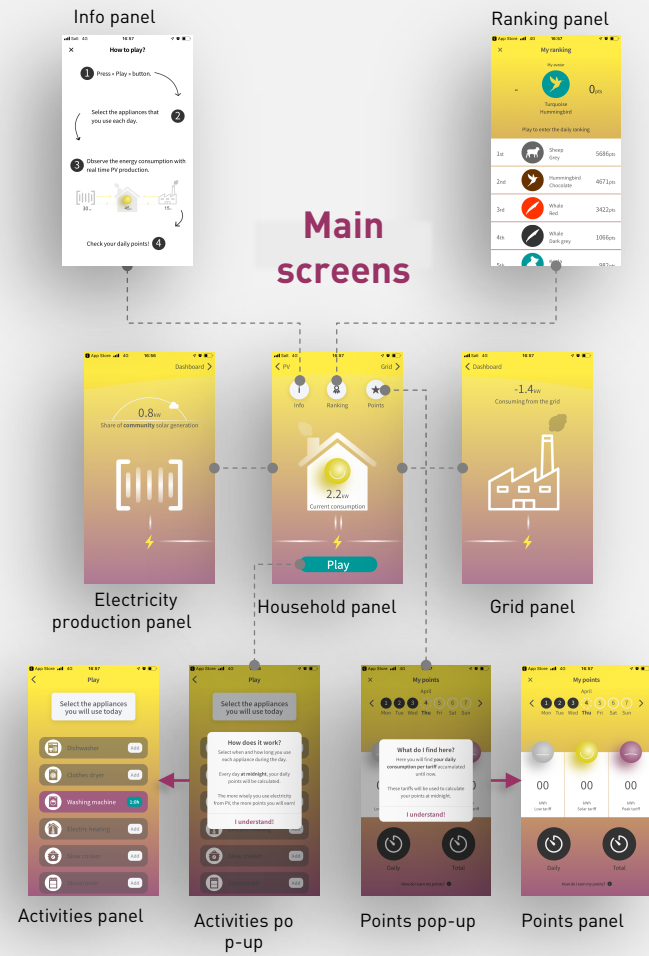


Version without the ranking was not as interesting

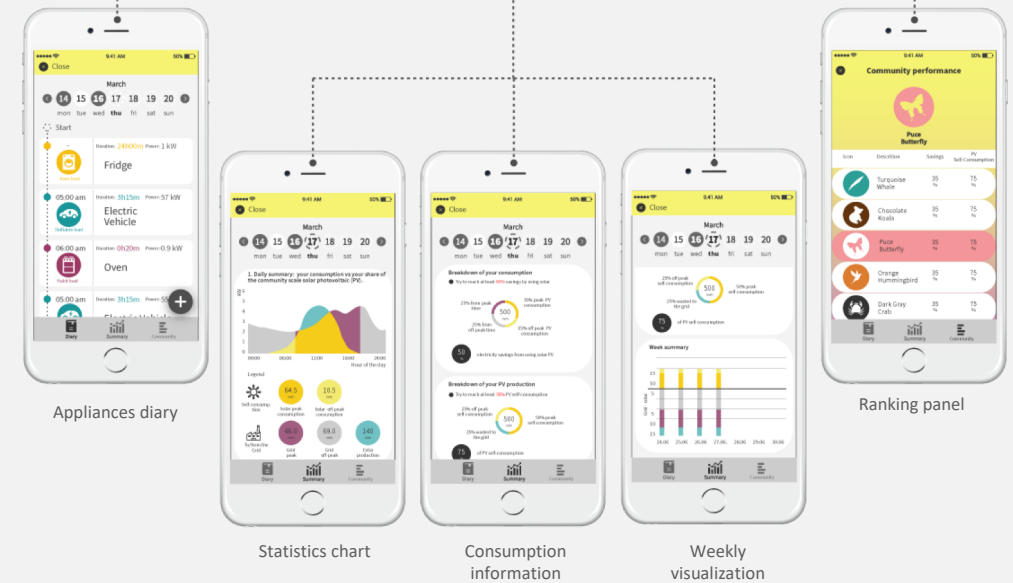


List of appliances not representative and no possibility of adding multiple entries

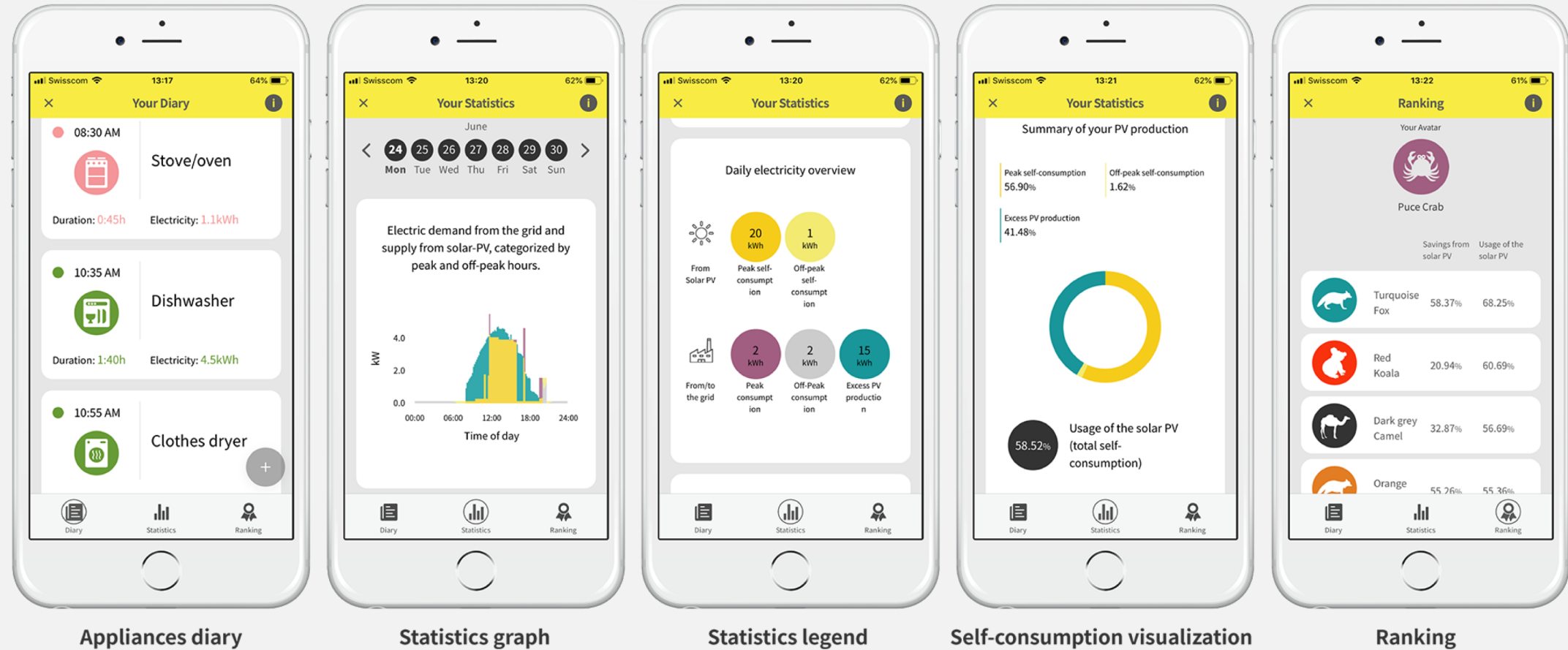
Design improvements



Electricity production panel Household panel Electricity production panel



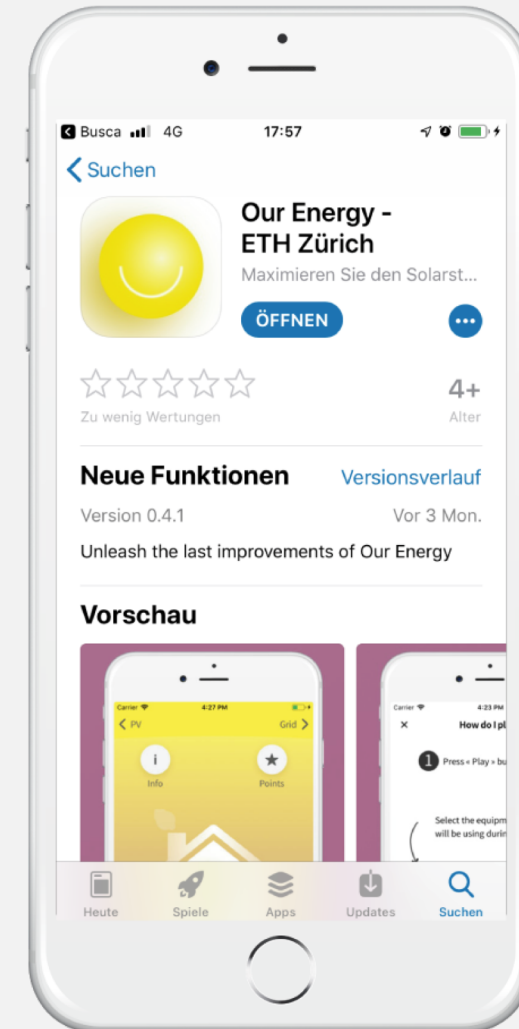
Design improvements



Available on Apple store and Google Play

Current features:

- Solar information available only for Einsiedeln
- Appliances are based on typical Swiss and European power ratings
- Lighting, heating and cooling calculations are for a typical Swiss residence (size, number of people, typology)



Two-day Campaign 22-23 June 2019

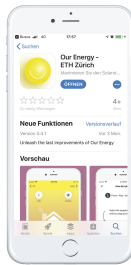
Wollen Sie erfahren wie es wäre,
zu Hause Strom aus Solar-PV zu haben?

Testen Sie die Our Energy App vom 23. Juni – 6. Juli 2019!

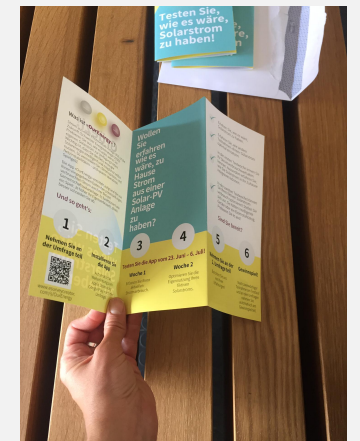
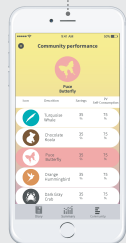
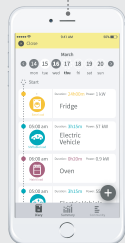
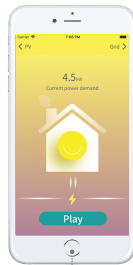
1
Umfrage



2
Installieren der App



3
Los geht's



- a. Updated experimental Set-up
- b. Participation summary
- c. Summary of findings
- d. Novelty



Updated Experimental set-up

Two-week study: 23 June- 7 July 2019

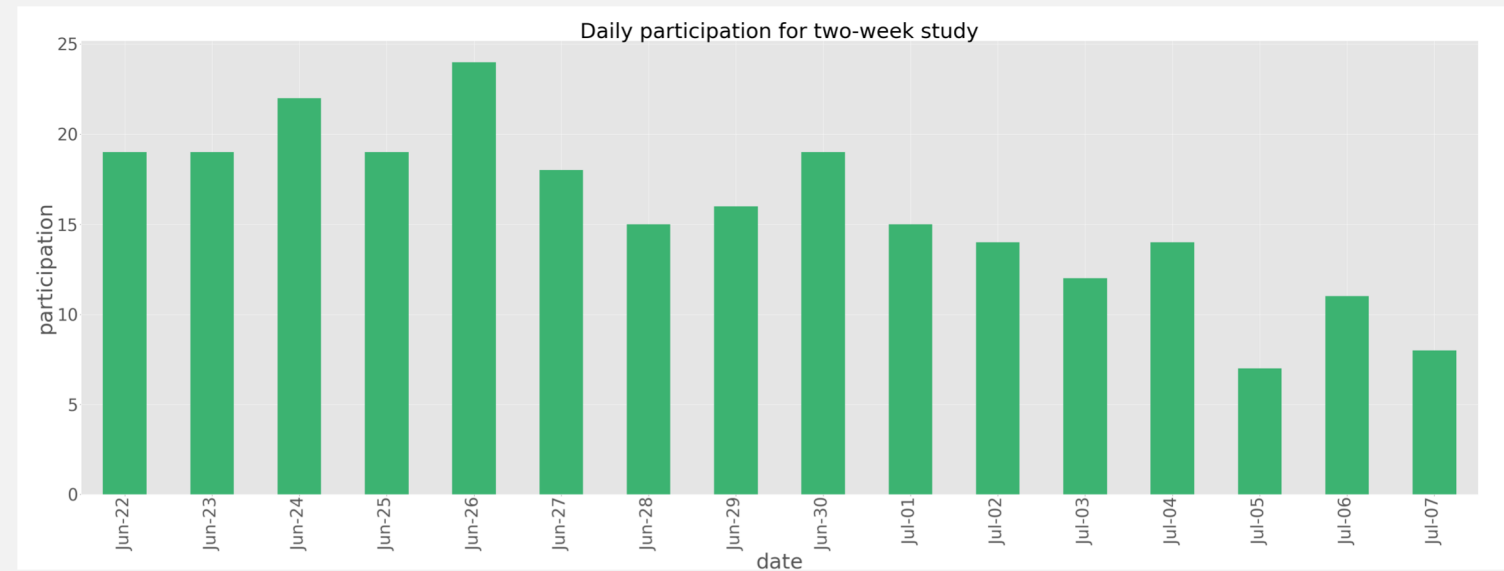
Week 1 objective: Baseline actual energy consumption

Week 2 objective: to increase self-consumption (compared to week 1 baseline)

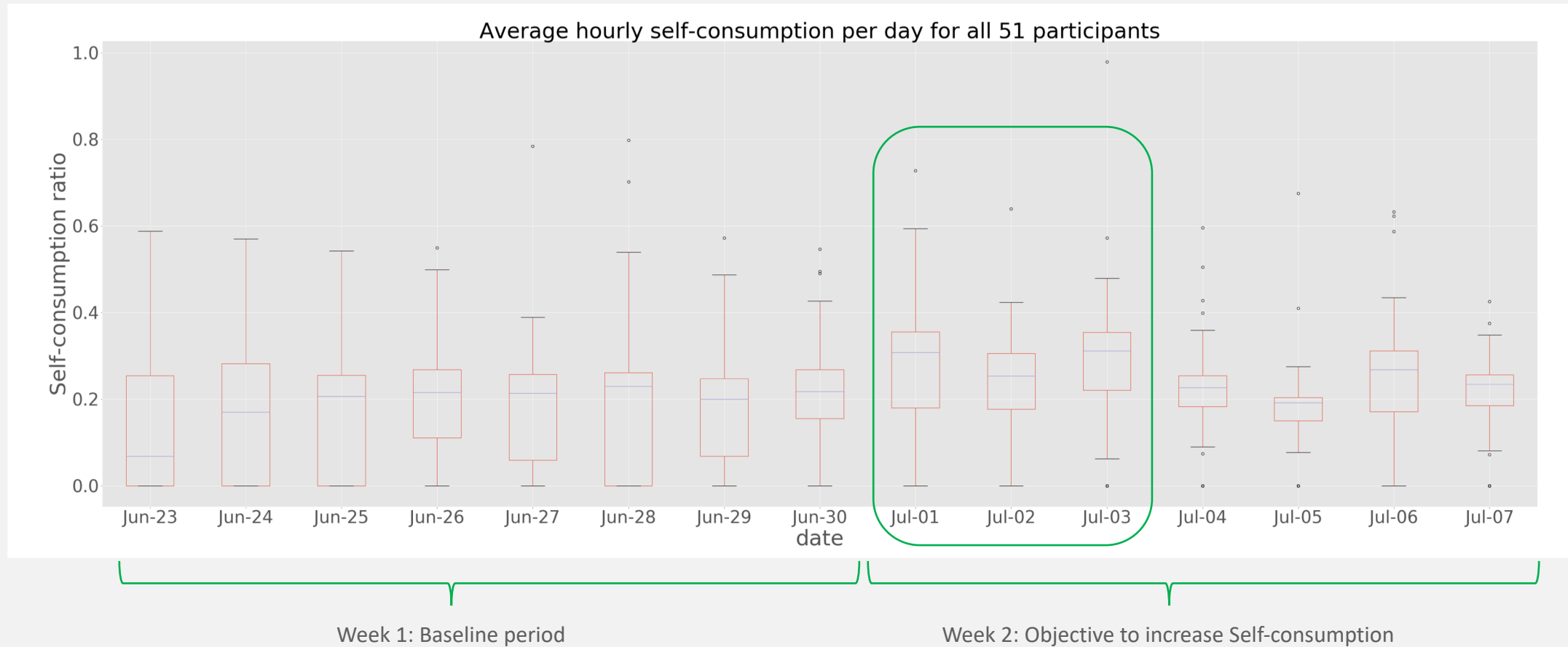


Participation summary

- **61** pre-survey's
- **24** post-participation survey's completed
- **87** App downloads
- **51** App users (with appliance data input for 1 or more days)

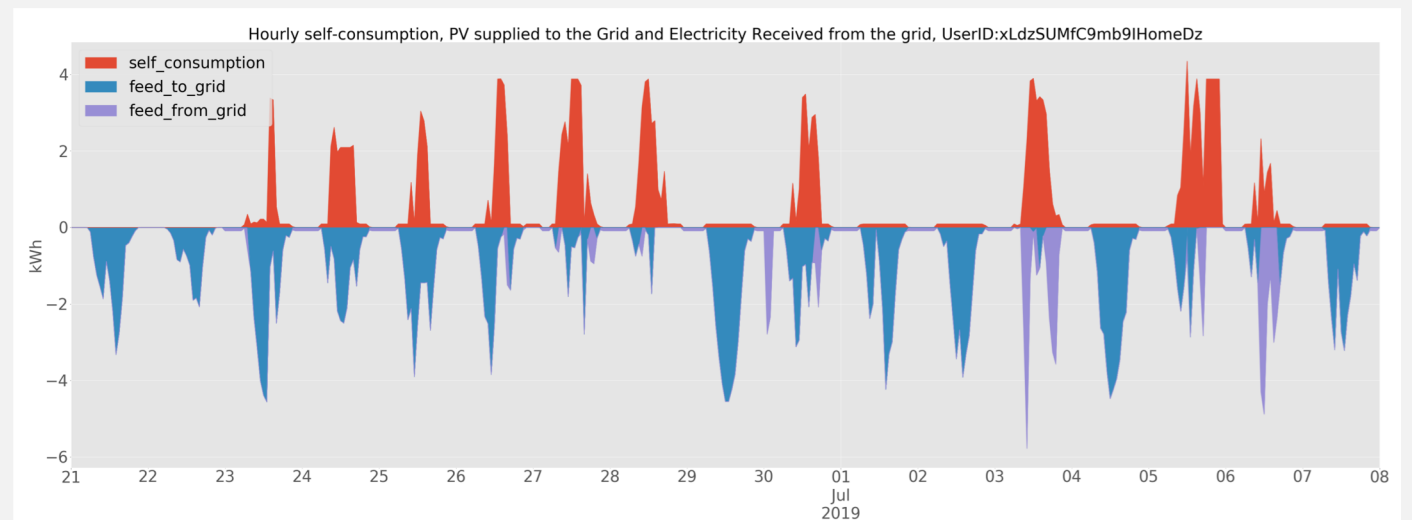
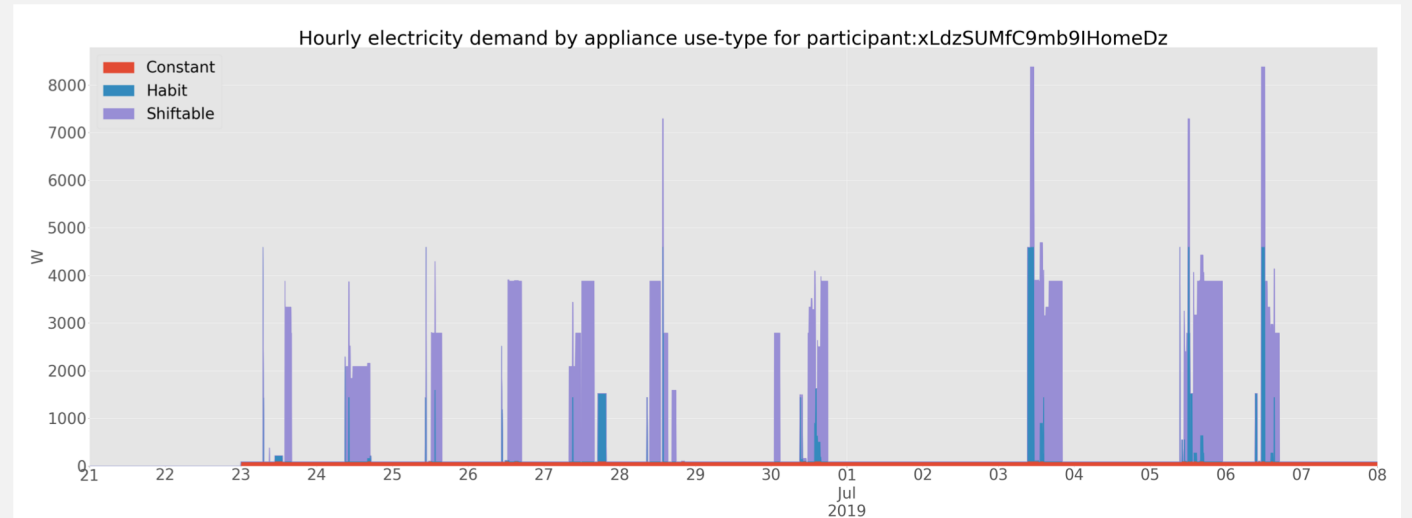


Summary of findings



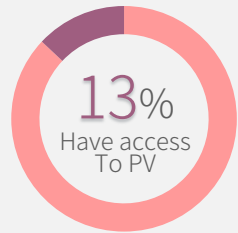
Summary of findings

Example of an individual participant

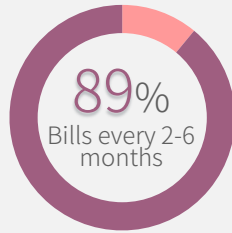


Summary of findings

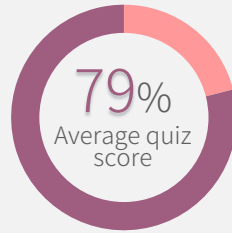
Pre-participation survey results:



Access to PV



Access to electricity data



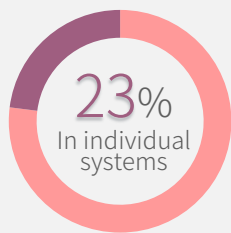
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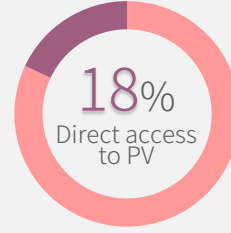
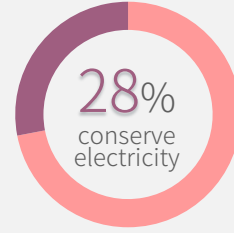
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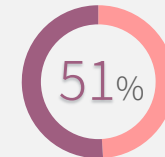
Likelihood to invest in PV



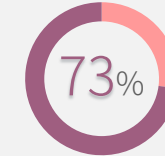
Environmental awareness



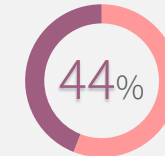
Post-participation survey results:



Household electricity consumption



Time-of-use of electricity

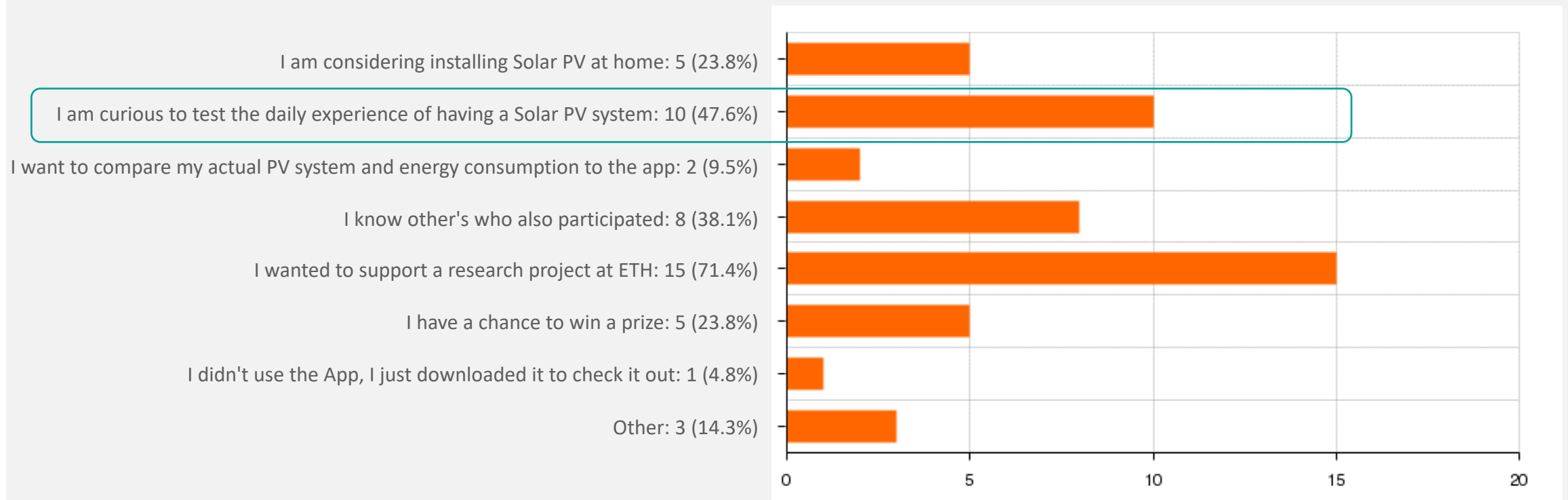


Load-shifting

Reported learning effects

Novelty: Testability of solar PV systems was not previously available

Reasons for participating in the two-week study





Conclusions and future work



For research?

- Adapt the app for case study areas that already have Solar PV systems
- Study the effects of community for behaviour of users who already have solar PV
- Simulate how users can share/sell the excess electricity from their system to neighbors in their community
- Study the preferences of different user categories
- Include energy storage scenarios



For market?

- Automatic input of data / connection with real electricity consumption
- Possibility to remotely control appliances using the app
- Provide PV sizing options for the users to choose & test anytime
- Include weather forecasting to inform users when and what to shift
- Share control of a household between the same household users

Additional outcomes

1. CISBAT paper + poster

2. Energy Informatics - App demo

3. Book (Torsten)

Additional outcomes

- Published paper in Energy Procedia conference proceedings
- Theme: Human and building interaction



Chair of Information Architecture

A / S

Architecture and Building Systems

Pilot study of 'Our Energy', an app designed to facilitate self-consumption of community solar photovoltaic systems

Danielle Griego^{1,2}, Natasha Catunda¹, Gerhard Schmitt¹
¹Chair of Information Architecture, ETH Zurich. ²Chair of Architecture and Building Systems, ETH Zurich.

1 Objective

Evaluate if the community context positively influences the desired behavior of load-shifting to maximize self-consumption of a shared solar PV system.

However, solar PV and metering infrastructure was not available to our case study participants.

We therefore developed a Mobile application (Fig. 1) to provide testability of this complex task.

2 Methodology

Community based social marketing approach [1].

1. Select Behaviour
2. Identify Benefits and Barriers
3. Develop Strategies
4. Pilot and Evaluation
5. Full Implementation

Data collection
 32 users in a two-week pilot study.
 - 17 community users
 - 15 individual users

3 Pilot Study Results

Data Analysis

Table 1. Overall community & individual energy self-consumption (SC) and amount of days participated (DP)

	Individual	Community
SC	9.85 kWh	12.3 kWh
DP	6.8 days	7.4 days

Graph 1. Two week average hourly electricity self-consumption

Pre-Participation Survey results

- Access to PV: only 1 out of 32 have access to solar;
- Access to electricity data: 92% receive energy bills every 2-6 months;
- Energy literacy: 72% average 'score' to energy quiz;
- Environmental awareness: rate as very important or important;
 - 61% to not waste resources;
 - 35% to conserve electricity;
 - 29% to have direct access to renewable energy;
- Shared facilities: 92% have and use shared facilities;
- Likelihood to invest: 71% in a community system, 45% in an individual rooftop system (not mutually exclusive).

Post-Participation Survey results

- Reported learning effects about the following topics:
 - 65% - household electricity consumption;
 - 70% - time-of-use of electricity;
 - 53% - load-shifting;
- The frequency of participation and average daily self-consumption values indicate a slight increased participation and self-consumption values from users of the community-version of the app. However, the large distribution of results and do not indicate a strong generalizable trend.
- Qualitative feedback indicates that participants did not fully understand the context of community without a physical point of connection.
- In the full study, we only keep the community version of the app and focus on the learning effect of load-shifting for all participants. All participants are given the same tasks to 1) develop a baseline energy consumption profile during the first week and 2) improve their self-consumption compared during the second week.
- Future work includes developing a clear concept of community, and testing the set up with place-based communities where participants have a pre-established connection.

Application Improvements

- Updated the demand side response user interface to improve the learning effect of load-shifting:
 - Appliances are categorized as shiftable, habit & constant;
 - Appliances can be added multiple times per day (previous limitation);
 - Added hourly, daily and weekly statistics (Fig. 1);
- Updated objective to "experienced what it is like to have direct access to electricity from solar PV";
- New objective is explicitly stated in the introduction of the app.

4 Conclusions

Appliances diary

Statistics graph

Statistics legend

Self-consumption visualization

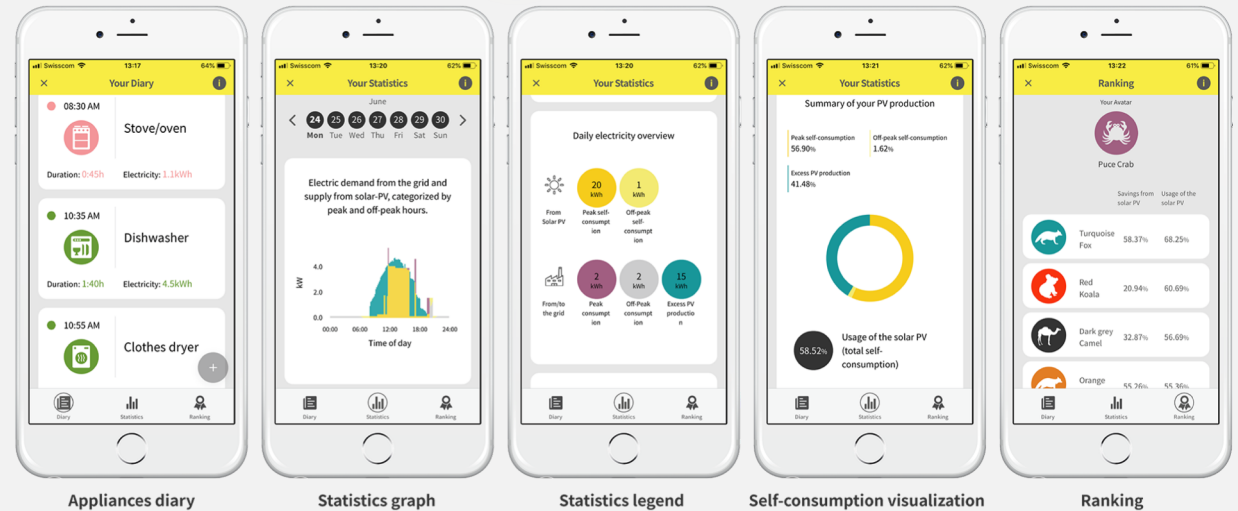
Ranking

Additional outcomes

- Demo presentation of the App
- Information and communication technologies in the energy domain the German-Austrian-Swiss region and its neighboring countries (DACH+)



Simulation app to experience solar electricity:



Additional outcomes

Die Demokratisierung der Schweizer Stromversorgung: Die Sihlseeeregion als Pionier und Beispielgeber

Kapitel:

1. Alpen-Traum
2. Grossrisiken in der Stromversorgung
3. Vorteil Senegal
4. Risikofaktor Energiewende
5. Blackout – Was ist zu tun?
6. Bürgerkraftwerke
7. Braunes Gold – Exzessive Holz- und Torfgewinnung
8. Blaues Glück – Der Sihlsee
9. Bürgerlicher Widerstand gegen Konzessionäre + Politik – Vorstellung der diversen Initiativen und Energie-Projekte
10. „OurEnergy“ – ein ETH-Projekt als Innovationstreiber:
 - Masterarbeit Natasha: Soziologische Aspekte künftiger Energiepolitik
 - Pilot-Study Danielle: «Pilot study of ‘Our Energy’, an app designed to facilitate self consumption of community solar photovoltaic systems »
11. Die Dezentralisierung der Stromproduktion und der zelluläre Ansatz („Energiezellen“, Microgrids, dezentrale Balancegruppen, etc.) zur Erhöhung der Versorgungssicherheit
12. Prognosen zur künftigen Stromversorgung

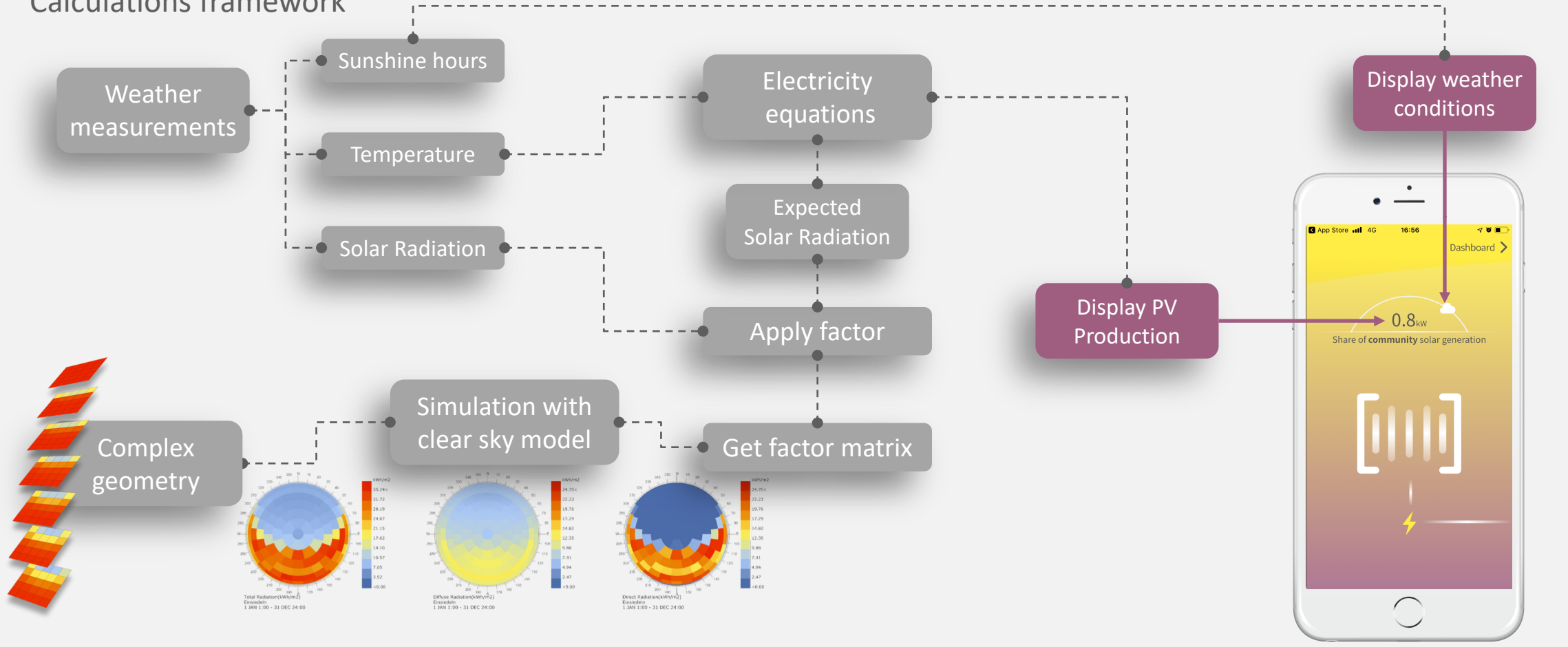
Thank you for your
attention!



Our Energy
ETH zürich

Pilot study and evaluation

Calculations framework



Pilot study and evaluation

Community x individual versions (PILOT)



Pilot study and evaluation

Survey learnings

Users were more interested in not wasting resources

There is a slightly more interest in sharing a PV system in a community

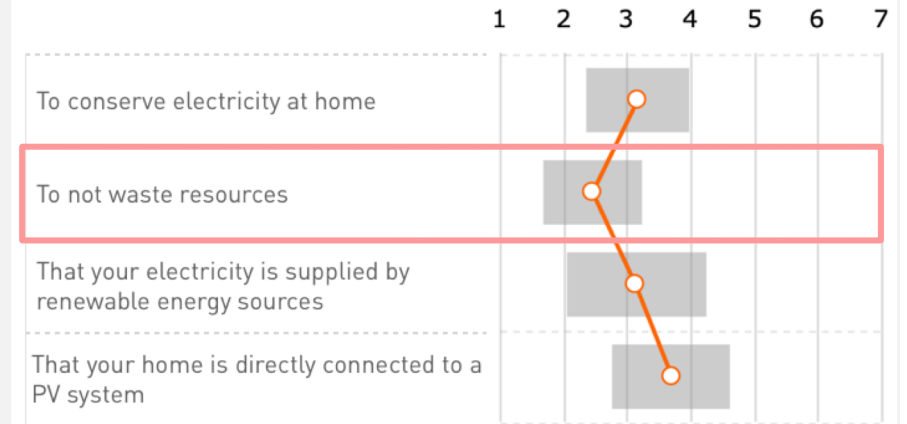


Figure 3.1 - Student's answers from the question of how important are each of these statements. Answers ranges from 1 (extremely important) to 7 (extremely unimportant). Orange circle shows the arithmetic average and the grey area shows the standard deviation.

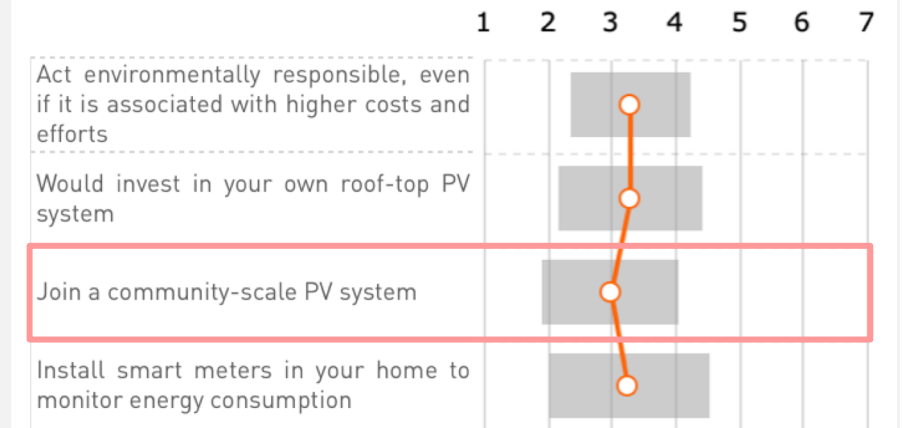
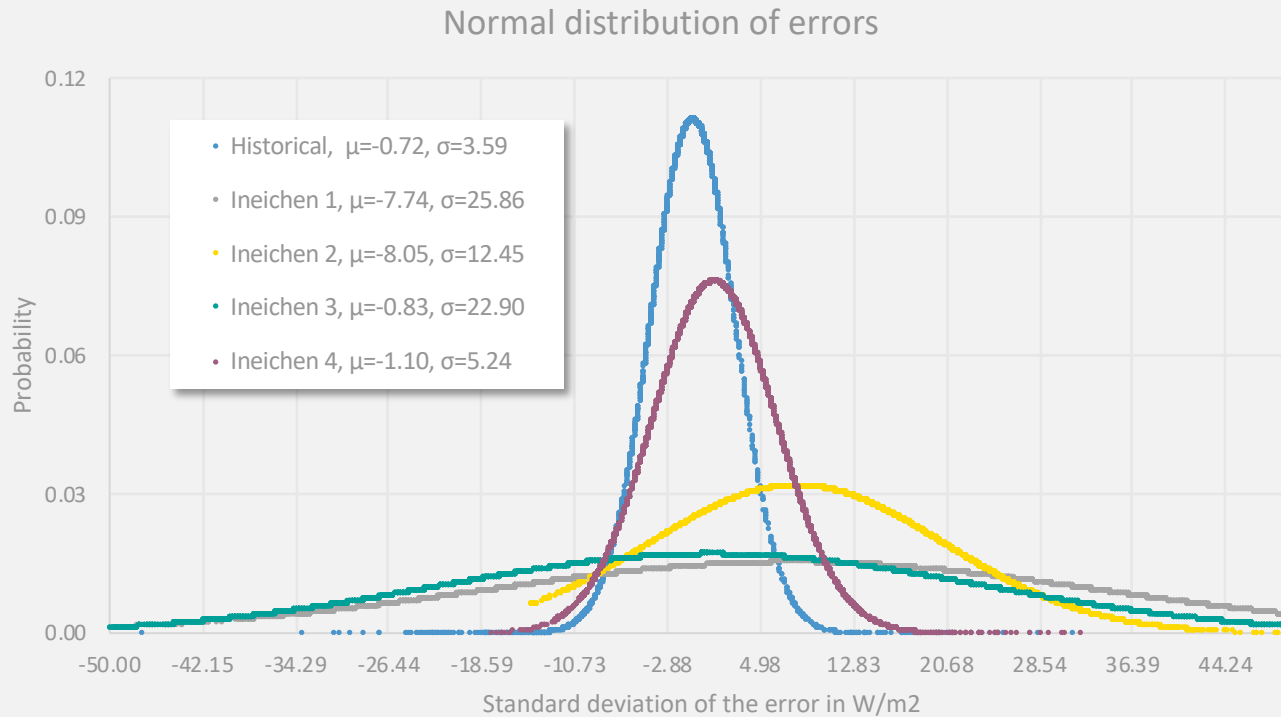


Figure 3.2 - Student's answers from the question of how likely are that users behave according to each of these statements. Answers ranges from 1 (extremely important) to 7 (extremely unimportant). Orange circle shows the arithmetic average and the grey area shows the standard deviation.

Pilot study and evaluation

Accuracy of clear sky weather file






The accuracy of output simulation values when compared with input values.

Weather file	Mean Absolute Error
Historical	0.6 %
Ineichen 1	11.9%
Ineichen 2	6.7%
Ineichen 3	7.6%
Ineichen 4	3.4%

Pilot study and evaluation

Cloud scheme

Classification of cloud cover from sunshine duration from [68] and adaptation for the Our Energy app.

Cloud classification from (REF)			Cloud scheme utilized in Our Energy app		
Code	Description	Sunshine Duration	Sunshine duration	Description	Icon
Type CC	Clear, cloudless	93-95%	8-10	Sunny	
Type QC	Quasi clear, non-homogeneous	70-95%			
Type CD	Cloudy, dynamic	40-75%	4-7	Partially cloudy	
Type CN	Cloudy, non-homogeneous	0-45%			
Type OQ	Overcast, quasi-homogeneous	0-20%	0-3	Cloudy	
Type OH	Overcast, homogeneous	0%			

Pilot study and evaluation

Enhance list of available appliances

Add multiple entries feature for appliances

Extra graphs

Something fun

Summary of set appliances

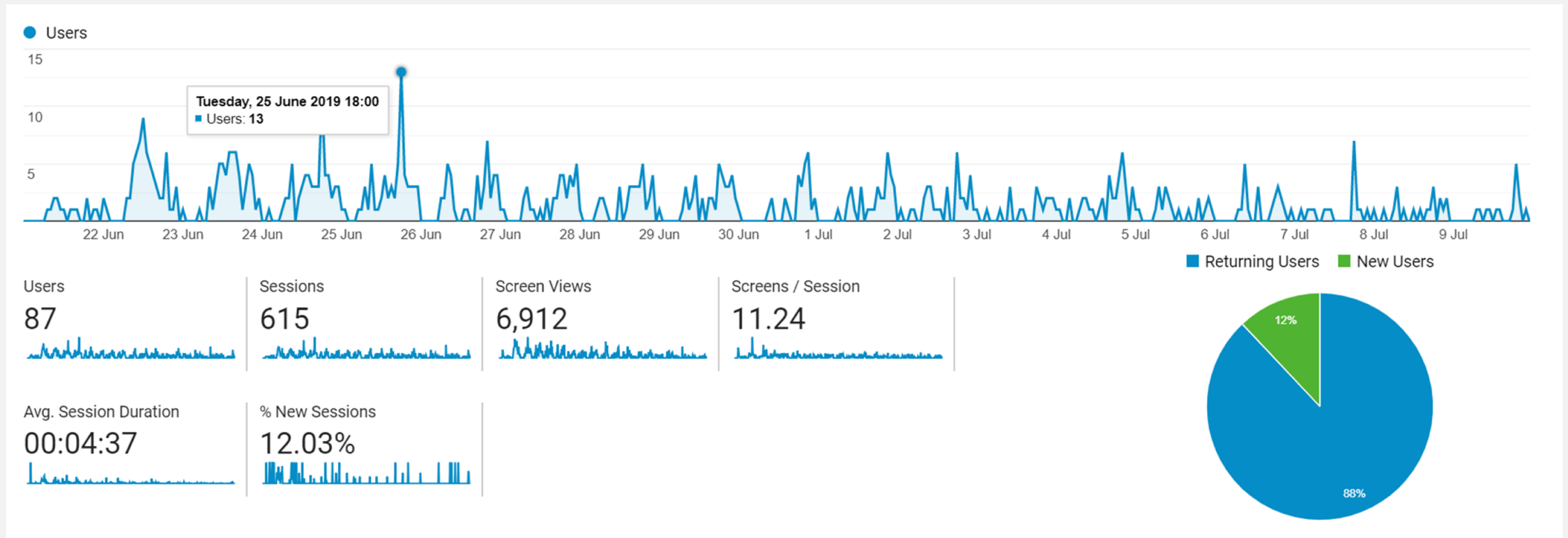
References

Table 3.2 - Students suggestions.

	Suggestion description	Applicability	Usefulness	Duplicate?
Appliances	Include additional devices or possibility to include own appliance. Add power rating description.	PA	PR	Yes
	Include appliances categories.	PA	PR	No
	Adjust appliances tag names visualization.	AP	PR	No
	Possibility of editing appliances' information after a day passed.	NA	ND	No
	Add a feature that make it possible to use the previous day as a template for the next day.	NA	DE	No
Points	Add something fun to show achievements (Ex. Hive growing).	PA	DE	No
	Show a summary of all the points in a graph.	PA	PR	Yes
Ranking	Add a time limit for the ranking. Restart ranking when time cross the time limit.	AP	PR	No
Notifications	Add reminders to enter the appliances according to ideal behavior.	PA	DE	Yes
	Add tips according to the time of the day.	PA	DE	Yes
	Add daily reminders.	AP	PR	No
PV screen	Add graphical representation of the daily incident solar radiation.	AP	PR	Yes
	Add information of where the data came from.	AP	PR	No
Others	Language picker within the app.	PA	DE	No
	Allow users to interact with other users in the community setting. Share and compare results also.	PA	PR	Yes
	Summary of the set up appliances.	AP	DE	Yes
	Possibility of choosing their own avatar.	NA	DE	No

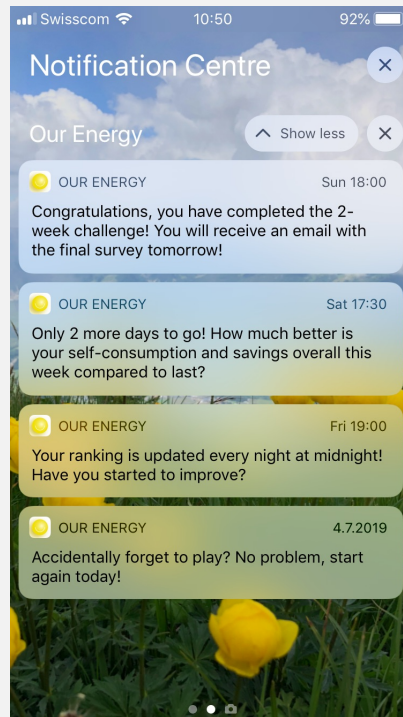
Full Implementation

Hourly overview for two-week study



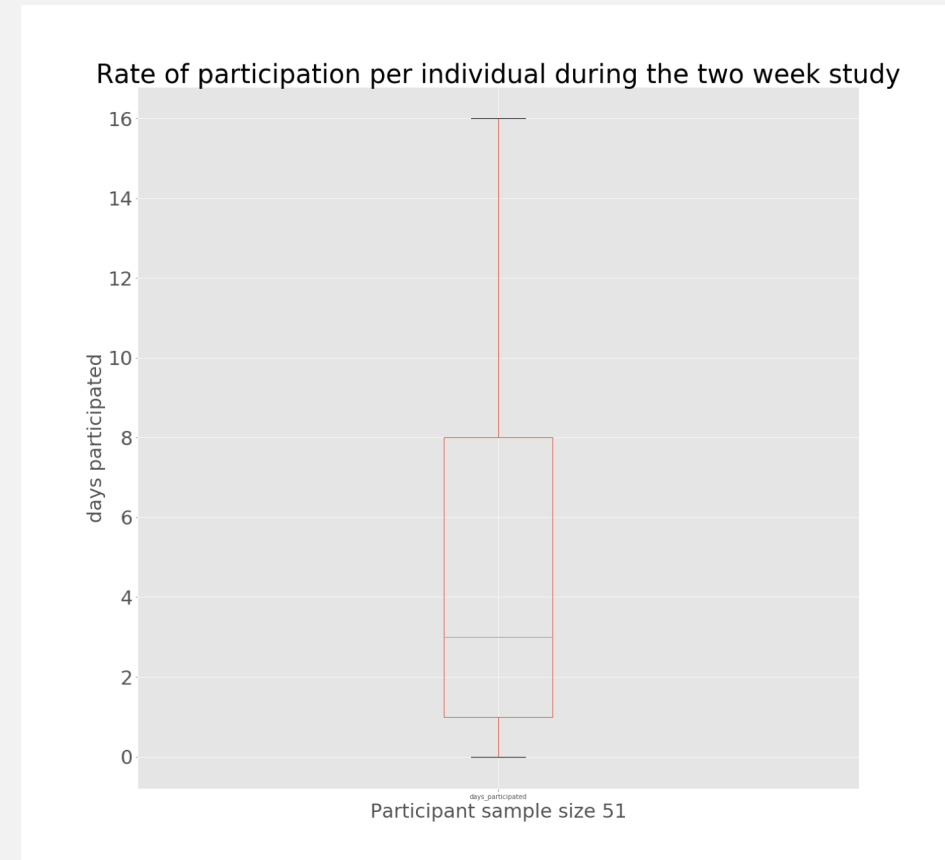
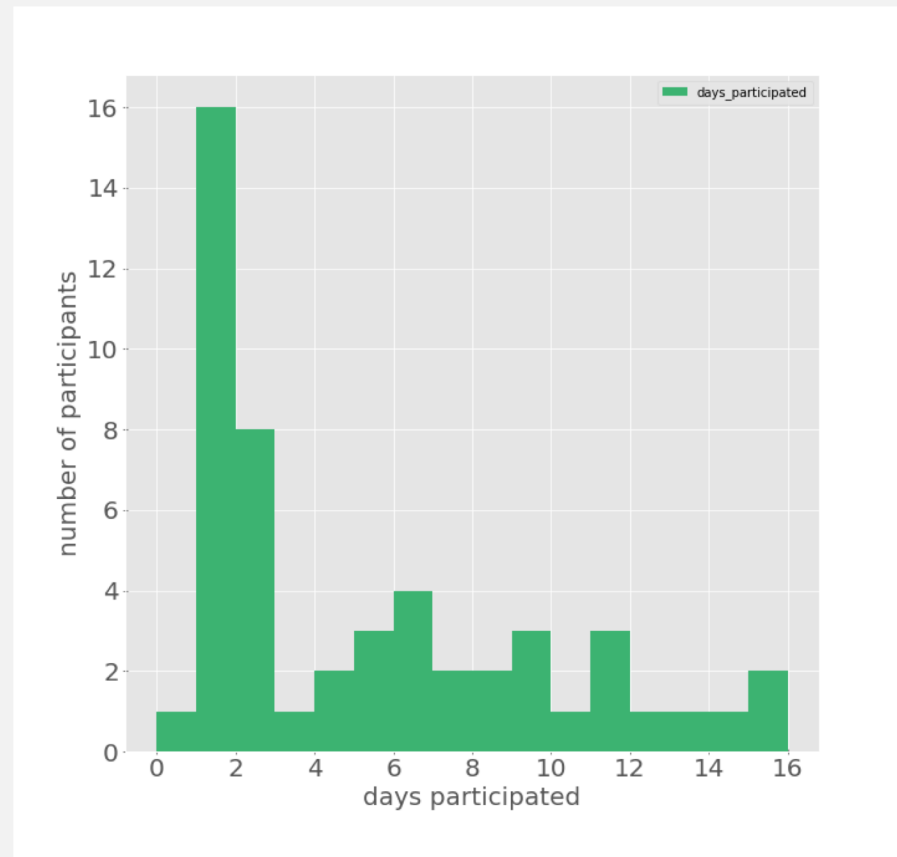
Full Implementation

Daily notifications



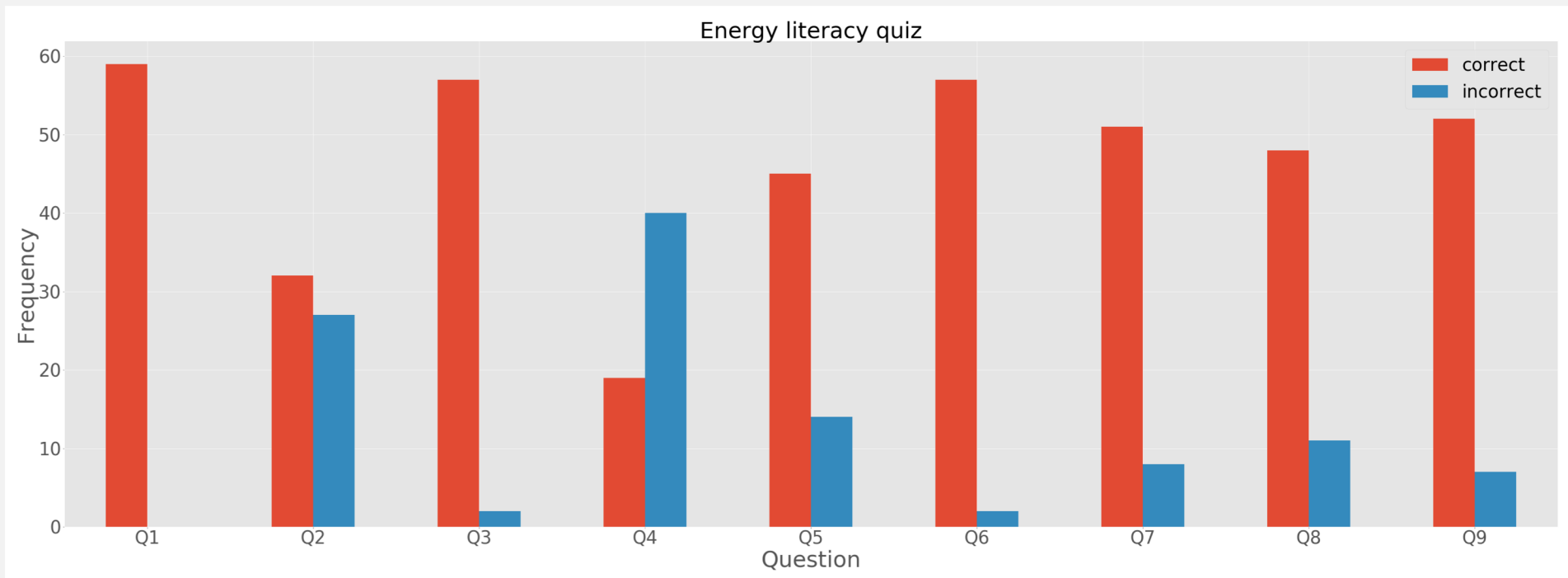
Date	English Notification	German Notification	Type
Mon 24-Jun-19	Welcome to Week-1! Add the appliances you actually use at home this week. Check your savings. Have fun!	Willkommen in Woche 1! Fügen Sie die Geräte hinzu, die Sie diese Woche zu Hause verwenden. Schauen Sie sich Ihre Ersparnisse an. Viel Spass!	Informative
Tues 25-Jun-19	It's not too late to participate, start logging your data today!	Es ist noch nicht zu spät, um teilzunehmen, beginnen Sie noch heute mit der Erfassung Ihrer Daten!	Reminder/ Incentive
Wed 26-Jun-19	Have you noticed that you cannot enter past data? Make sure to play each day!	Haben Sie bemerkt, dass Sie vergangene Daten nicht in Ihr Geräte-Tagebuch eintragen können? Versuchen Sie, jeden Tag zu spielen!	Informative/ Reminder
Thurs 27-Jun-19	Households with solar-PV typically have a self-consumption around 30%, what is yours so far?	Haushalte mit Solar-PV haben in der Regel einen Eigenverbrauch von rund 30%. Was ist Ihrer bisher?	Informative
Fri 28-Jun-19	Only 3 more days to record your actual appliance usage, keep it up!	Nur noch 3 Tage, um Ihren tatsächlichen Geräteverbrauch zu erfassen, weiter so!	Informative/ Incentive
Sat 29-Jun-19	Notice anything new or interesting while keeping a daily appliance diary?	Haben Sie bei der täglichen Gerätetagebuchführung etwas Neues oder Interessantes bemerkt?	Incentive
Sun 30-Jun-19	Today is the last day in week-1! Great job! What was your average self-consumption and savings from PV?	Heute ist der letzte Tag in Woche 1! Prima! Wie hoch war Ihr durchschnittlicher Eigenverbrauch und Ihre Einsparungen durch Solar-PV?	Informative / incentive
Mon 1-Jul-19	Today is the start of Week-2! Now try different options to maximize your electricity from solar PV.	Heute ist der Anfang der Woche 2! Probieren Sie nun verschiedene Möglichkeiten aus, um Ihren Strom aus der Solar-PV zu maximieren.	Informative
Tues 2-Jul-19	What is your goal this week? How much can you improve your self-consumption and savings from solar PV?	Was ist Ihr Ziel diese Woche? Wie viel können Sie Ihren Eigenverbrauch und Ihre Einsparungen durch Solar-PV verbessern?	Incentive
Wed 3-Jul-19	Have you tried matching your 'shiftable' appliances with available solar electricity this week?	Haben Sie diese Woche versucht, die 'flexibel' Geräte mit verfügbarem Solarstrom zu kombinieren?	Informative
Thurs 4-Jul-19	Accidentally forget to play? No problem, start again today!	Haben Sie versehentlich vergessen, zu spielen? Kein Problem, fangen Sie noch heute wieder an!	Reminder
Fri 5-Jul-19	Your ranking is updated every night at midnight! Have you started to improve?	Ihr Ranking wird jede Nacht um Mitternacht aktualisiert! Haben Sie angefangen, sich zu verbessern?	Reminder/ Informative
Sat 6-Jul-19	Only 2 more days to go! How much better is your self-consumption and savings overall this week compared to last?	Nur noch 2 Tage bis zum Ziel! Wie viel besser ist Ihr Eigenverbrauch und Ihre Einsparungen insgesamt diese Woche im Vergleich zur letzten?	Reminder
Sun 7-Jul-19	Congratulations, you have completed the 2-week challenge! You will receive an email with the final survey tomorrow!	Herzlichen Glückwunsch, Sie haben die 2-wöchige Testphase abgeschlossen! Sie erhalten morgen eine E-Mail mit der letzten Umfrage!	Informative

Participation summary

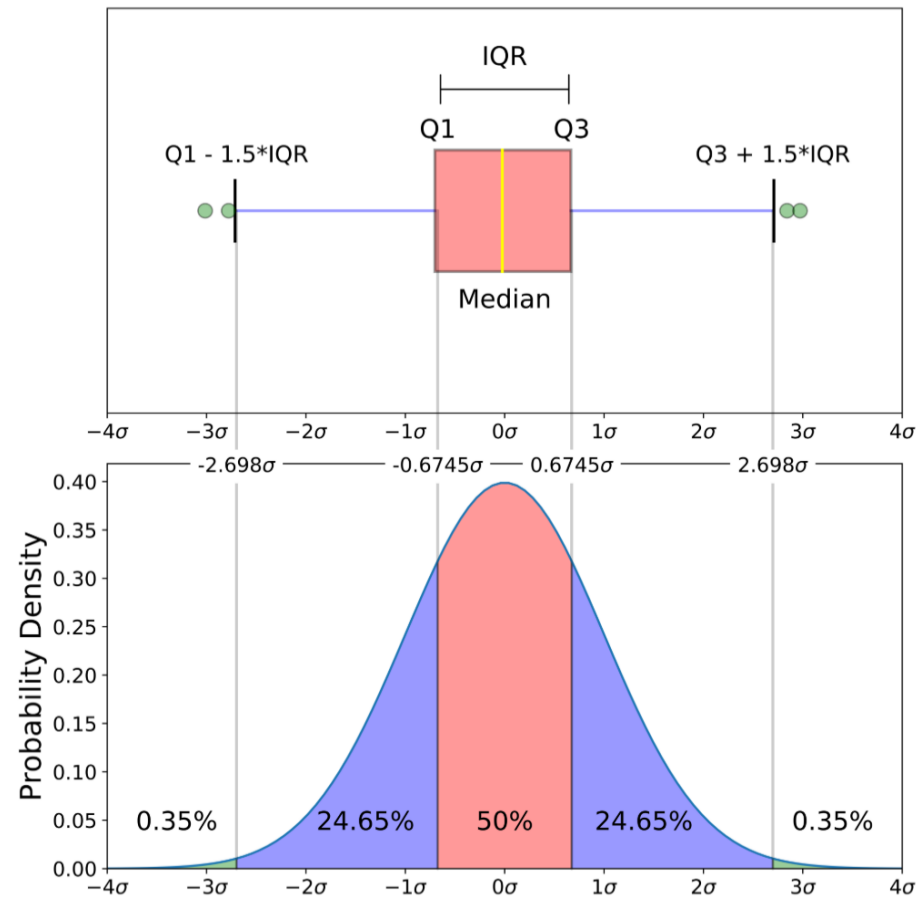


Full Implementation

Energy literacy quiz results: 79% correct



Boxplot on a Normal Distribution



Comparison of a boxplot of a nearly normal distribution and a probability density function (pdf) for a normal distribution