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07 of September of 2018.

Natasha Catunda Master Thesis Proposal
Autumn Semester 2018

Title: Common goal-setting for Community-Scale Solar PV: Is it possible to optimise PV self-consumption by promoting sustainable community behaviour?

Date: From 24.09.2018 to 22.03.2019.

"Citizens are an important co-producer. If they are treated as unimportant or irrelevant, they reduce their efforts substantially."

Elinor Ostrom.

1. Introduction

Decentralised energy generation from photovoltaic (PV) systems is projected to be an important energy generation system in urban areas, helping to meet Swiss Energy Strategy and 2000-Watt-Society goals. Individual household PV installations can be done but community-scale PV implementation is more desirable because of the possibility of matching different load profiles with the generation pattern. This brings advantages such as minimisation of storage needs and network instabilities arising from energy generation arrangements which are outside of the control of centralised grid operators.

The hypothesis is that common goal-setting for the implementation of community-scale PV system is key goal for the maintenance of sustainable consumption behaviour over long periods of time. The involvement of the community in a approach like this is important to avoid community resistance but a special focus should be given to the the way the process of decision-making and the social networks are organised since the possibilities of the project are crucially shaped by them [7].

Bagliani argues that completely disconnected projects from the socio-economic and environmental local context may even generate negative impacts [1]. So, besides the technical aspects inherent to the implemented system, structuring correctly those organisational aspects is very important for the success of a community project.

One of the issues is that, while the technical aspects of how to implement photovoltaic systems at community scale are being more explored, societal considerations can hardly be found, even though this is crucial for further renewables deployment (7). The lack of attention given to the individual users shows a gap in user acceptance and usability of community-scale PV systems. Concerning the later one, the master thesis plans to explore how to promote sustainable behaviours with the communities considering the PV system constraints and test the impact of common goal-setting. The thesis will be part of a bigger project for the location of Bezirk Einsiedeln, called the IMG Stiftung Phase 2 (see appendix I) - that aims to apply the Citizen Design Science approach on the implementation on the system.

2. Research Objectives

The main objective is to test behavioural load shifting based on common-goal setting for PV implementation at community scale.

The specific objectives of the research would be:

- Identification of the barriers and potentialities associated with load shifting at the community;
- Design of proper strategies to address barriers and benefits;
- Execution of a 2 part challenge for community engagement of a simulated PV implementation scenario at the Einsedeln area.

3. Research Methodology

A simulated PV implementation scenario will be applied on a real community using an approach from the five points of Community-base Social Marketing [4]. This approach aims to promote specific desirable sustainable behaviours within a community and it is determined by the steps below:

- Selection of the behaviour to be promoted;
- Identification of the barriers and benefits associated with the selected behaviour;
- Design of a strategy to address barriers and benefits;
- Piloting a strategy with a small segment of a community;
- Evaluating the impact of the program once it has been implemented broadly.

This approach will be used as a base for fostering behavioural load shifting (or any other important selected goal, if applied) on a interactive platform where people can actively participate in selecting (ideally designing) desirable scenarios and common goals.

Considering that the PV systems is not going to be really implemented, the research will focus on the engagement at the platform and testing the potential for behaviour change, based in the development of PV scenarios and assessment through surveys.

The surveys are going to be held either for identification of barriers and benefits as of evaluating the impact of the project using user feedback.

It is important that platform that can communicate clearly and efficiently with the user. To test the common goal-setting, the community should be strategically guided to set desirable goals, e.g. higher rates of self-consumption, considering the PV system constraints.

The research is divided in 3 main tasks, according to table 1. More measures to reach the main research goal and to interact with the community available at appendix II (tables 3 and 4). A web developer will be hired for developing the platform necessary for executing the master thesis, the scope of work can be seeing at appendix III.

Table 1 - Research structure.

Main Tasks	What?	How?
1. Identification of barriers and benefits	Community-scale focused survey.	Application either by the platform or on weekend campaigns at the location.
2. Simulated Scenarios and interaction	PV design	Elaboration of 4 types of parametric design. Tools: Grashopper™ (GH)[2] - plugin for Rhinoceros® [5] - and BIM software Archicad [3].
	Energy generation	Weather file based solar radiation simulation on Ladybug [6] and system efficiency assumptions.
	Consumption profile	Get from user feedback at the platform.
	Cost assessment	Based on which type of PV technology was chosen.
	Voting interaction	At the platform with WebGL interactive geometry embedded at the website.
	Goal setting	Evaluate and show to the community actions that can impact on the improvement of self-consumption.
3. Project Assessment	User Feedback	Survey at the platform. Analysis of user interaction analytics at the website.

Table 2 - Timetable of the research plan.

Wk	1	2	3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Task	September			October					November				December				January					February				M
a.																										
b.																										
c.																										
d.																										
e.																										
f.																										
g																										

4. Research Plan

The research is structured according to the steps below and the timetable (table 2) above.

a. **Literature review** will focus on: Community-scale PV systems; Common goal-setting; Survey for community energy systems; Gamification and User Engagement on platforms; Household engagement consumption profile; Any other literature necessary to develop specific tasks.

b. **Survey**: Literature review; Survey Development; Survey application through platform or through weekend campaigns.

c. **Data collection** of the surveys.

d. Data analysis and **assessment** of the study case.

e. **Scenarios development**:

f. Voting interaction and goal-setting.

g. **Report** and presentation of the findings.

5. Research Contribution

This is an effort to gather little explored aspects of collective user interaction of PV installations on a community scale, helping the study field about the transition to renewables energies. Which social aspects were still a barrier even after application of common goal-setting in a community base social marketing approach? Which barriers were bridged?

A broader impact this thesis could bring is a possible framework for real world application in different locations worldwide with the further use of the platform.

6. Final considerations

Mid-Term presentation: Can be done at end of week 13 showing the scenarios execution and how is going the tool development.

Code: If a code is being produced, it will be handed electronically via GitHub or any convenient means.

Final Report: The final report will be handed in one week before the end of the Thesis (01.03.2019).

Final presentation: At the end of the project the work should be presented to the chair during a group meeting or equivalent.

Duration of the Thesis: From 10 of September of 2018 to 08 of March of 2019.

7. References

[1] Bagliani, M., Dansero, E., & Puttilli, M. (2010). **Territory and energy sustainability: the challenge of renewable energy sources.** Journal Of Environmental Planning And Management, 53(4), 457-472. doi: 10.1080/09640561003694336.

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[7] Wolsink, Maarten. **The Research Agenda On Social Acceptance Of Distributed Generation In Smart Grids: Renewable As Common Pool Resources**. Renewable And Sustainable Energy Reviews, vol 16, no. 1, 2012, pp. 822-835. Elsevier BV, doi:10.1016/j.rser.2011.09.006.

Appendix I

Proposal: IMG Stiftung Phase 2

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

Date: 12 March 2018

Das Viadukt über den Sihlsee in Bezirk Einsiedeln ist Europas längste Seebrücke und ein Beispiel eleganter Ingenieurskunst des frühen 20. Jahrhunderts. Es verbindet Tausende von Einwohnern auf beiden Seiten des einzigartigen Sees, der für Energieerzeugung, Energiespeicherung und richtungsweisenden naturnahen Erholungsraum steht. Seine weitere Existenz war nach dem Ende der Konzession ernsthaft in Frage gestellt. Phase 1 des IMG-geförderten Projekts "Eine ganzheitliche Sicht auf die Auswirkungen der Entfernung von Verbindungen, eine beispielhafte Studie in Einsiedeln" half, eine wissenschaftliche und rationale Grundlage für die Wirkung des Viaduktes zu schaffen und trug zu dessen höchstwahrscheinlichem Überleben bei. Sie hatte somit eine sehr positive wissenschaftliche und praktische Wirkung bereits vor dem Ende der Phase 1. Aufbauend auf diesem Erfolg zielt Phase 2 darauf ab, Szenarien mit dem neuartigen Citizen Design Science Ansatz zu entwerfen und so das langfristige lokale, regionale und nationale Potenzial des Viaduktes und seiner Region aufzuzeigen.

Abstract
The Viadukt across the Sihlsee in Bezirk Einsiedeln is Europe's longest bridge across a lake and an exemplary piece of elegant engineering. It connects thousands of citizens on both sides of the unique lake that stands for energy production, energy generation, and citizen recreation. Its further existence was questioned and threatened by the end of the concession. Phase 1 of the IMG supported project "A holistic view on the impacts of removing links, an exemplary study in Einsiedeln" helped to build a rational and scientific basis for the impact of the Viadukt and contributed to its most likely survival. It thus had a very positive scientific and practical impact even before the end of Phase 1. Building on this success, Phase 2 aims at designing scenarios with the novel Citizen Design Science approach and showing the long-term local, regional and national potential of the Viadukt and its region.

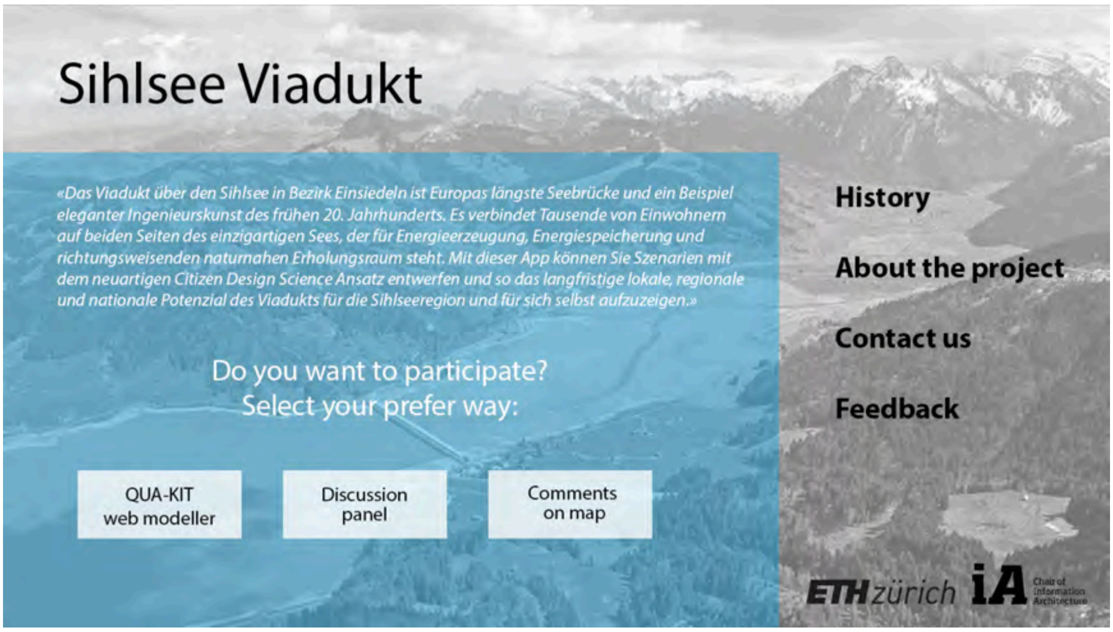

Figure 1: Citizen Design Science App Mock-up

Project Summary
The project around the Sihlsee Viadukt conducted by the *Chair of Information Architecture* at ETH Zurich, aims to (i) bring knowledge based on analysis and simulation, to the discussions regarding the existence of the Sihlsee Viadukt, (ii) engage the citizens and different stakeholders into the design process through Citizen Design Science, coordinated through a custom *Citizen Design Science App* as shown in Figure 1 below, and (iii) demonstrate the value of such tools and techniques through a citizen-designed community scale photovoltaic (PV) installation at the Viadukt. The first phase of the project (items (i) and part of (ii)) is on-going work at the Chair of Information Architecture, supported by phase 1 of the IMG Stiftung. We would like to expand the scope of work to include future development scenarios of the Sihlsee Viadukt into the *Citizen Design Science App* with the focus on a community driven 'Eigenverbrauch' PV installation. This incorporates items (ii) and (iii) discussed above.

Background
The tools developed for Citizen Design Science (Mueller, Lu, Chirkin, Klein, & Schmitt, 2018) have a strong potential to help a community coordinate complex layers of information and opinions to support important community-level decisions. For example, the ongoing debate to keep or remove the Sihlsee Viadukt, which connects Einsiedeln and Willerzell, is a long-standing topic of concern for the members of these communities. First, it is important to analyze and understand the range of consequences if the bridge is removed. For this, we have developed tools to analyze short-term and long-term traffic scenarios, economic development and the change in living and working quality with, and without the bridge. Citizens can explore what will happen to the 2700+ daily commuters who cross the bridge if it is removed; the new route would increase their average commuting time, costs and associated CO2 emissions. They can also explore how this might affect local business potential on both sides of the bridge; commuters might decrease their visits to the neighboring areas if it becomes less accessible, causing potential long-term segregation. The living and working quality might also change as a result of the impact on rent and transportation time. The closing of the Viadukt could also gradually cause unwanted suburban sprawl into the pre-alpine valley of Euthal.

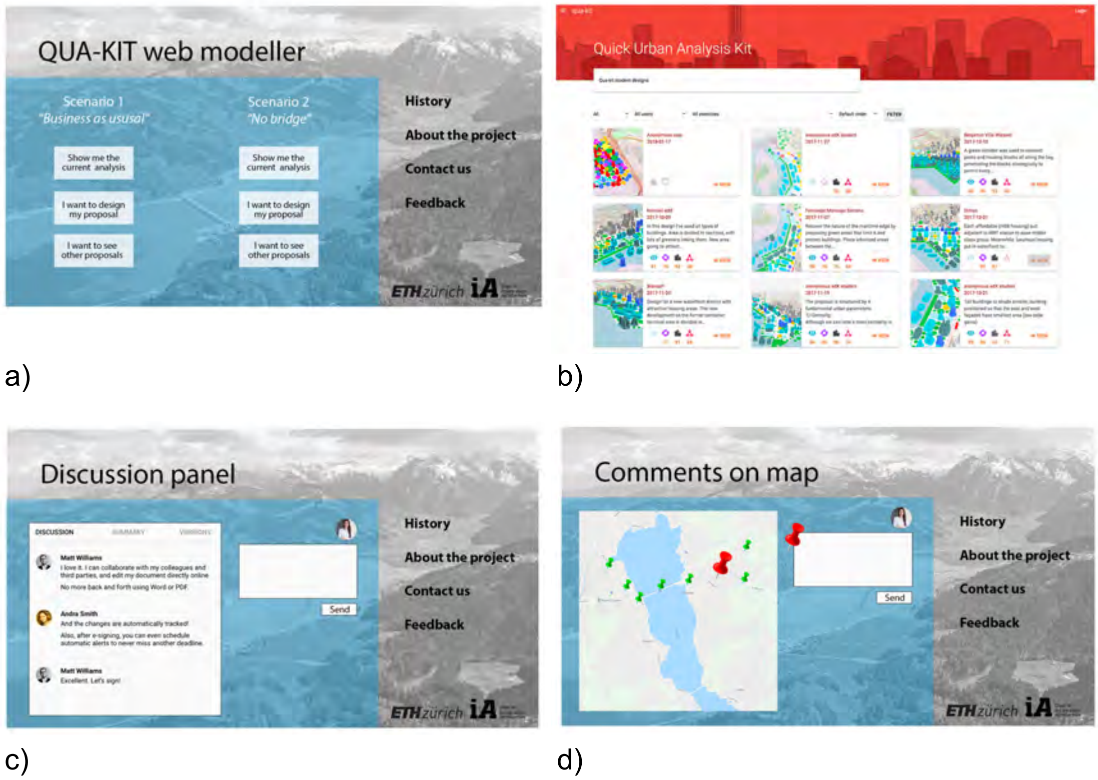

Figure 2: Citizen Design Science platform for citizen engagement

These scenarios will be incorporated into the *Citizen Design Science App* where the platform also allows citizens to start discussions, raise questions and document other important items to be explored or analyzed. The Citizen Design Science App developed for the Sihlsee Viadukt project utilizes qua-kit, Quick Urban Analysis Kit (Chirkin, 2018), a custom made tool developed at the Chair of Information Architecture, where citizens can directly contribute their design ideas and vote on other proposals. Figure 2 illustrates the proposed application and the connection to qua-kit.

Proposed work

The work outlined in this proposal for phase 2 of the IMG Stiftung will explore the scenarios beyond “Business as Usual” and “No Bridge” shown in Figure 2 (a). It will also include “Future Developments” scenarios, which will focus on electricity generation from photovoltaic (PV) systems. This will be explored as a community scale installation along the Viadukt in Einsiedeln. An initial parametric analysis of the PV system at the Viadukt indicates enough electricity to supply over 140 residents per year when considering the 2000-Watt Society (17520 kWh/person/year). However, this system goes beyond pure energy production; it would also serve as an for Einsiedeln’s commitment to the future Energy Transition, the Swiss Energiewende 2050 (Schweizeriche Eidgenossenschaft, 2018).

The citizens will have the opportunity to collectively design the PV system, and it would be physically present to the entire community. Furthermore, within the scope of this proposal, citizens will have the opportunity to evaluate how they might also collectively *use* the on-site electricity generation with other community members. Utilities in Switzerland are increasingly interested in optimizing hours of ‘self-consumption’ or Eigenverbrauch from decentralized renewable energy systems rather than directly sending the electricity to the grid (Der Verband Unabhängiger Energieerzeuger (VESE), 2018).

This is proposed as ‘Eigenverbrauchsgemeinschaften’, which have many benefits, however this requires great coordination between multiple users. This type of information sharing has not yet been tested at the community scale. Therefore, this research provides a unique opportunity for the citizens of Einsiedeln to test the shared mechanisms of the theoretical output from a customized community scale PV system.

This system will serve as the fourth typology for community scale PV system as part of the PhD research project by Danielle Griego titled “Implementing Community-Scale PV Systems as a Sustainable and Governable Urban Common” (Griego, 2018). The basis of this work builds upon literature from social science that shared commodities, transparent monitoring, mutual agreements and community-developed commitments have the greatest potential to create lasting sustainable behavior (McKenzie-Mohr, 2011).

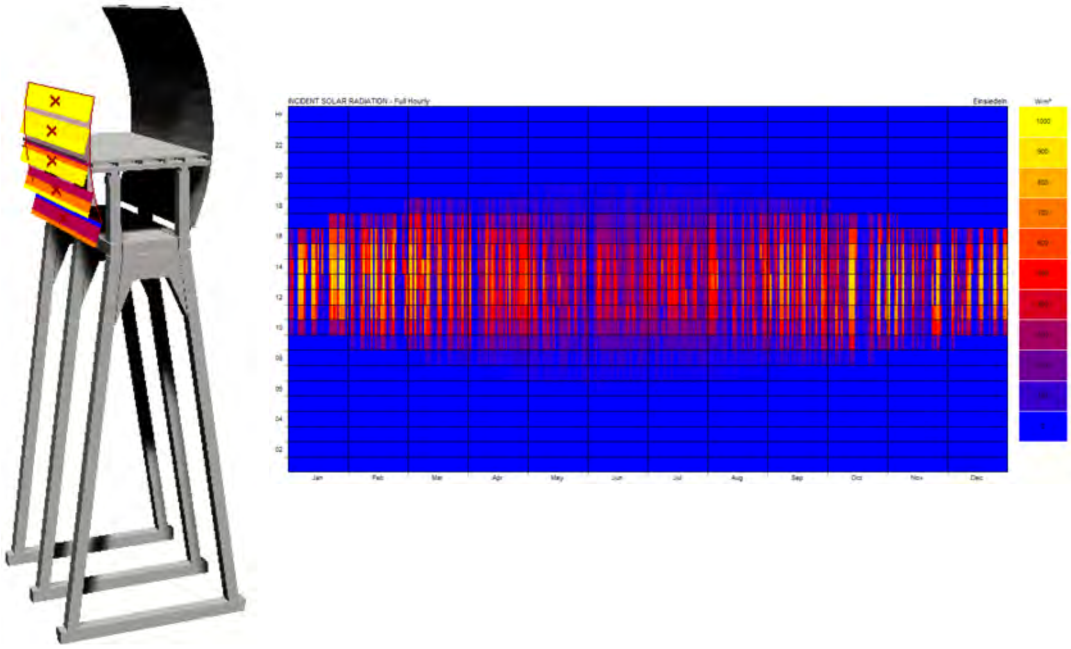

Figure 3: Energy production analysis at the Sihlsee Viadukt

Scope of Work
The scope of work for this proposal, Phase 2 of the project around the Sihlsee Viadukt includes three work packages outlined below. Although each work package is described as a single activity, each is dependent on the other to realize the final project goal: to explore the utility of Citizen Design Science for Community-Scale Solar PV applications to optimize Eigenverbrauch.

Work package 1: Connection to the Citizen Design Science App
Citizens will have an opportunity to actively design a system, which they would like to see installed at the bridge via the *Citizen Design Science App* under “Future Developments”. Citizen could also view other design proposals and vote if they choose not to contribute a unique idea. For example, they can view the existing PV system designs created by the *Chair of Information Architecture* as shown in Figure 3, (and further reported in Appendix I). It could also include the novel light-weight and flexible photovoltaic systems such as the Adaptive Solar Facade, designed by researchers from the professorship of Arno Schlüter at ETH Zürich (Schlueter, et al., 2018).

Work package 2: Weather station installation and data collection

Since this PV system is not yet installed at the Viadukt, we will install a local weather station to collect instantaneous weather data, including incident solar irradiation (kWh/m^2), air temperature (°C), and wind speed (m/h). This step is particularly important to simulate the instantaneous on-site energy generation potential for various system designs. Additional consideration for wind energy generation potential can also be included in the calculations based on the wind speed/direction measurements.

Work package 3: Data analysis and simulation
The real-time energy production potential will be calculated and displayed on the *Citizen Design Science App* for each of the PV system design options provided from citizens in work package 1, using the instantaneous weather data gathered from work package 2. The App users will also have the opportunity to "join" the proposed 'Eigenverbrauchsgemeinschaften' to see what it means to share electricity generated with this community-scale PV system. For this, each user will provide an energy consumption profile (options integrated into the app). The analysis will include the calculations for instantaneous and historic values of self-consumption along with pricing signals to show the value of 'time of use' energy utilization.

Project Timeline
The timeline for the proposed future work for Part 2 of the IMG Stiftung is outlined below for each of the three work packages. This also includes a section for reporting, which allows time for writing and presenting the results and findings to the IMG Stiftung, to the public, and also to select scientific journal(s) such as Energy, Sustainability and Society.

	Aug 18	Sep	Oct	Nov	Dec	Jan 19	Feb	Mar	Apr	May	Jun	Jul	Aug
WP 1													
WP 2													
WP 3													
Reporting													

Expected Outcomes
The project around the Sihlsee Viadukt serves as an exemplary case study for *Citizen Design Science* to facilitate a real and on-going community discussion. In particular, the proposed work in Phase 2 of the IMG Stiftung will explore development scenarios for an iconic citizen-designed community-scale solar PV system along the Sihlsee Viadukt. This research also aims to explore and address the new challenges of 'self-consumption' for PV systems at a community-scale and the Citizen Design Science App developed in Phase 1 of the project provides a perfect platform to engage the community around this topic.

Not only can citizens provide ideas for the new Viadukt PV system design, but they can also learn about the benefits of 'Eigenverbrauchsgemeinschaften' using interactive tools which can show how to work collectively to shift individual energy activities to peak hours of production. This is particularly valuable to test such interactions in a hypothetical case where citizens can experiment and provide feedback. As this is an emerging topic, something of this scale has not yet been performed. The findings of the energy analysis can also inform real project installations such as the ongoing projects of G3E Genossenschaft Erneuerbare Energien Einsiedeln, further advancing the solutions to meet the goals of the Swiss Energiewende 2050.

Finally, this single project can also potentially inspire citizens to develop additional ideas for other “Future Development” projects for the Sihlsee Viadukt or other community related activities.

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Chirkin, A. (7. March 2018). Quick Urban Analysis Kit. Von qua-kit: https://qua-kit.ethz.ch/ abgerufen

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Schlueter, A., Nagy, Z., Svetozarevic, B., Jayathissa, P., Lydon, G., Begle, M., & Hofer, J. (25. February 2018). Adaptive Solar Facade (ASF). Von Chair of Architecture and Building systems ETH Zurich: http://www.systems.arch.ethz.ch/research/active-and-adaptive-components/asf-adaptive-solar-facade.html abgerufen

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Appendix II

Table 3 - Community-base Social Marketing approach

Strategies	Description	Action	Further considerations/comments
Selection of the behavior to be promoted		Foster behavioural electrical load shifting to better match with energy generation patterns from the shared solar PV system.	Test common goal setting for community-scale PV implementation. As we believe it is the best way to maintain sustainable consumption behaviour over long periods of time.
Identification of the barriers and benefits associated with the selected behavior	Barriers that impede people from engaging in the activity must first be identified along with what would motivate them to act. Begin by identifying these barriers and benefits using a combination of literature reviews, observations, focus groups and survey research.	Literature review and survey implementation - see how to do on the website	Consider doing the survey campaigns by using this tool here: https://www.hotjar.com/tour (free up to 2000 pageviews/day) and analysing user behaviour and it they are drooping the form somewhere, or just a regular survey monkey.
Design of a strategy to address barriers and benefits	By utilizing behavior-change tools - frequently involve direct personal contact. Personal contact is emphasized because social science research indicates that we are most likely to change our behavior in response to direct appeals from others.	Based on the survey results design the “campaigns” - design competition, user’s consumption profile data.	Site visits and a close contact chanel at the platform with us answering direct could be good to them to have the feeling of being close. Webchat and user forum available. Check for gamification strategies to attract users to participate in campaigns.
Piloting a strategy with a small segment of a community		Presentation of design scenarios at the website - sliders and graphs responding to different steps of the sliders and voting platform (I guess we could do with the survey tool).	Try the website with a group of enthusiasts before, i.e. test with ETH students.

Strategies	Description	Action	Further considerations/comments
Broadly implementation		Implement the design scenarios at community level.	
Evaluation of the impact of the program once it has been implemented broadly.		User feedback/survey at the very end.	

Table 4 - Communication skills to be met with the platform

Strategies	Description	Action
Use Captivating Information	Presenteting the information in a vivid way is more likely to be remembered later - like the cracks the size of a soccer ball.	Presentation of diagrams and graphs and energy consumption comparisons.
Know Your Audience		At the first survey.
Frame your message	Messages which emphasize losses which occur as a result of inaction are often more persuasive than messages that emphasize savings as a result of taking action.	Take this care when presenting information for users at the platform.
Consider the Use of Threatening Messages Carefully -	Threatening messages need to be coupled with concrete and empowering information on what can be done to address a threat such as climate change. Failing to couple threatening information with empowering suggestions may well lead your target audience to avoid an issue as they feel helpless to address it.	Suggest actions that can actually be done by the community.
Decide on a One-Sided versus Two-Sided Message	If you are presenting your communication to an audience that has little comprehension of the issue you will be most persuasive if you present just one side. However if you are communicating with an audience that is aware of both sides of the issue then you need to present both sides in order to be perceived as credible.	For community communication use one-sided approach, i.e. show loses and suggests tackling actions, weighing costs/benefits for shared solar resources.
Make your Message Specific		Set only one goal to the community, i.e. load shifting for improving self-consumption for shared solar resources.

Strategies	Description	Action
Make Your Message Easy to Remember	One of the simplest ways to remove the burden that a sustainable activity can place upon memory is through the use of prompts. Remember unless we make it easy for people to remember how when and what to do it is unlikely that a program will be very successful.	Put prompts/notifications at the website/ app. Make a lot of visual guides/steps for users to follow.
Provide Personal or Community Goals	Providing targets for a household or a community to reach can be effective in reducing energy and water use and in increasing waste reduction.	Try to set goals after the results of the simulation. I.e. storage management strategies: one for maximizing self-consumption and the other to reduce net load variance.
Emphasize Personal Contact	Research on persuasion demonstrates that the major influence upon our attitudes and behavior is not the media but rather our contact with other people.	Community user forum, webchat, means of interaction in person.
Model Sustainable Behavior	Whether the contact is made personally or through the media one of the more effective methods for increasing adoption of a sustainable behavior is to model the behavior we wish others to adopt. Modeling involves demonstrating a desired behavior. Modeling can occur in person or through television or internet-based instructional videos. For example studies have documented significant reductions in energy use in response to a broadcast that demonstrated simple energy efficient actions and mentioned the financial benefits to be gained from carrying them out.	The scenarios for voting will be build here, but we should show what is the behaviour necessary for getting most of it. Provide an example.
Community Block Leaders	People (leaders) from the community that implements the actions.	Give points at the platform to engage people to become block leaders. Make their energy savings public as example to others. Check similarities with the "bike to work" app and "energy challenge" app.
Provide Feedback	To be fully effective information about the impact of newly adopted activities needs to be presented as well. Households that received daily feedback on electricity consumption lowered energy use by 11% compared to physically identical households that did not receive feedback.24	Feedback information to users by showing self-consumption graphs. Remainders for seeing washing machines during a sunny day.

Appendix III

Follow below the web developer scope of work for realising the project:

Mobile Cross-Platform App for a Community-Scale Solar PV Project

Develop an interactive web/mobile application for a community-scale solar PV project, with a full stack developer to manage the client and server-side development. The app will host a 2-part community challenge where the main features are:

- Users can make individual profiles/teams
- First challenge:
  - users can vote on three to five 3D design scenarios which can be explored through a 3D viewer (using WegGL for example);
  - Users can view the instantaneous (calculated) energy production from the winning PV system on an updating time-series plot. Real-time weather data will be used for these calculations.
- Second challenge:
  - Users from each team can vote on a self-consumption goal, for the 1-week challenge;
  - Users can provide the best estimate of their daily energy consumption habits through an interactive 24-hour time series plot;
  - Users can view the collective instantaneous and historic self-consumption (energy consumption/energy production) on a time-series plot
- Forum for comments, feedback and questions.

Primary tasks and responsibilities:

- Responsible for the development of a new Mobile App (usable on both iOS and Android, thus probably using React Native, Ionic, Phonegap, Cordova or similar), all the way from start to deployment and putting it in the respective App Stores.
- Responsible for server side to store user data and process analytics data, along with a simple page with links to download the app from the respective stores.
- Embed WebGL widget which is generated from Rhino/Grasshopper (potentially making it interactive, thus WebGL knowledge is a plus).
- Implement user-interaction analytics (to obtain the frequency, duration and repeated user device id's for example).

Prerequisites:

- Demonstrated experience in mobile cross-platform app development
- Expertise in JavaScript, css, html, web APIs, WebGL, PHP, .Net, etc.
- A background and/or interests in renewable energy technologies is a plus.