ENERGYSCAPE – Recommendations for a Landscape Strategy for Renewable Energy Systems

Report

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Summary

Within the scope of the NRP 70 project «ENERGYSCAPE», social preferences for landscape development with a combination of different infrastructures of renewable energy systems are systematically investigated in an online panel survey and a laboratory experiment. The preferences for the investigated landscape scenarios can be explained by the landscape and the perception of its structure, by physiological reactions to the scenarios as well as by connotations to the landscape and to renewable energy infrastructures. The results provide the basis for recommendations that can help to promote a socially accepted landscape development with renewable energy systems.

Zusammenfassung

Im Rahmen des NFP 70-Projekts «ENERGYSCAPE» werden gesellschaftliche Präferenzen für eine Landschaftsentwicklung mit einer Kombination verschiedener Infrastrukturen erneuerbarer Energiesysteme mit einer Online-Panel-Befragung und einem Laborexperiment systematisch untersucht. Welche der untersuchten Landschaftsszenarien bevorzugt werden, erklärt sich durch die Landschaft und die Wahrnehmung ihrer Struktur, durch physiologische Reaktionen auf die Szenarien sowie durch Bedeutungszuweisungen zur Landschaft und zu erneuerbaren Energieinfrastrukturen. Die Ergebnisse liefern die Basis für Empfehlungen die helfen können, eine gesellschaftlich akzeptierte Landschaftsentwicklung mit erneuerbaren Energiesystemen zu fördern.

Résumée

Dans le cadre du projet «ENERGYSCAPE» du PNR 70, les préférences sociales en matière d'aménagement paysager combinant différentes infrastructures de systèmes d'énergies renouvelables sont systématiquement analysées par une enquête par Internet et une étude de laboratoire. Le choix des scénarios paysagers étudiés s'explique par le paysage et la perception de sa structure, par les réactions physiologiques aux scénarios et par l'attribution de sens au paysage et aux infrastructures d'énergies renouvelables. Les résultats de ces recherches servent de base à des recommandations qui peuvent aider à promouvoir un aménagement paysager socialement acceptée avec des systèmes d'énergie renouvelable.

Contents

List of abbreviations

NRP	National Research Programme
nSCR	Number of Skin Conductance Responses
RES	Renewable Energy Systems
RPG	Raumplanungsgesetz
RPV	Raumplanungsverordnung
UVPV	Verordnung über die Umweltverträglichkeitsprüfung

1 Introduction

One of the strategic pillars of the Swiss Federal Council to offset the loss in electricity production from nuclear energy is to noticeably increase the use of renewable energy systems (BFE 2018a). Massive expansion of the new infrastructures has impacts on our landscapes and the services they provide – a main factor influencing social acceptance of the new renewable energy systems. Successful implementation of these new technologies in a landscape, however, requires strong social acceptance (Wolsink 2012). In Switzerland, renewable energy systems are generally supported, but public conflicts at the local level are increasing the closer the process gets to implementation (Hübner et al. 2013).

Hence, the sustainable use of renewable energy resources can only be achieved if its spatial dimensions are taken into consideration (Stoeglehner et al. 2011). The European Union has defined various guidelines for integrating specific renewable energy infrastructures into the landscapes. Examples are the development of wind parks in accordance with the EU nature legislation (EU 2011), the Maritime Spatial Planning (European Commission 2008), or the guidelines for environmental impact assessments (EU 2012). All these instruments, however, address only a single renewable energy infrastructure. In Switzerland, an environmental impact assessment at the cantonal level, which includes a landscape impact assessment, comes into action when planned wind energy infrastructures or photovoltaic systems that are not building-integrated produce more than 5 MW (UVPV, 2016, Anhang 21 Erzeugung von Energie). Further, Art. 18a Abs. 1 of the RPG and Art. 32a Abs. 1 RPV describe which solar energy projects need to be reported. At the Federal level, there exist sectoral plans for transmission lines and wind parks (ARE 2019). However, comparable to Europe, the spatial coordination of tasks is linked to a single energy system. There are no instruments allowing the planning of a mix of renewable energy systems and assess their landscape effects and public acceptance in Switzerland. Yet, the diversity of Swiss landscapes with their services calls for spatially explicit guidelines and strategies to plan and coordinate the landscape changes coming along with the development of the required infrastructures needed to reach the energy turnaround.

2 Context

2.1 Background

A huge amount of literature exists trying to explain people's perception and evaluation of large-scale renewable energy technologies (e.g. Apostol et al. 2017). Several factors have been identified, which influence people's evaluations of renewable energy projects and the social acceptance of renewable energy infrastructures. These factors include age, gender, income, education, socio-psychological factors, such as knowledge and experience concerning particular technologies, as well as environmental and political beliefs, and procedural aspects of the planning and implementation phase (e.g., Clayton et al. 2015; Devine-Wright 2007, 2011; Cohen et al. 2014; Huijts et al. 2012; Zoellner et al. 2008). One important aspect that influences the evaluation of renewable energy projects (existing or planned), however, is the perceived landscape impact of renewable energy infrastructures (Wolsink 2007a, 2007b; Cohen et al. 2014; Wüstenhagen et al. 2007; Strazzera et al. 2012; Ek and Persson 2014; Torres-Sibille et al. 2009a, 2009b; Molina-Ruiz et al. 2011; Lennon and Scott 2015; Graham et al. 2009; Devine-Wright & Howes 2010; Scognamiglio 2016; Manyoky et al. 2016). Several authors show that judgments of renewable energy systems such as wind turbines or ground-mounted photovoltaic systems not only depend on the infrastructure itself, but also on the evaluation of the surrounding landscape (Bishop 2011; Strazzera et al. 2012; Molnarova et al. 2012; Wolsink 2007a; Spiess et al. 2015; Michel et al. 2015; Manyoky 2015).

In addition, not only the physical change of the landscape per se – provoking immediate affective responses – is important, but also the cognitive sense-making process of the place change and symbolic meanings attached to the installations (Batel and Devine-Wright 2015; Devine-Wright 2011; Devine-Wright and Howes 2010; McLachlan 2010). There is some empirical evidence of the link between sense of place and affective responses (Syme et al. 2000; Woolcock 1998; Eisenhauer et al. 2000), but the last stages of psychological responses of humans when confronted with a change in place (including acceptance and acting with place change), are still poorly understood.

We are well aware that landscape impacts are only one out of many drivers governing social acceptance of renewable energy. Issues such as trust, procedural justice and community benefit funds play an equally important role. These aspects are, however treated in other NRP 70/71 projects (e.g., Acceptance of renewable energy. Prof. Isabelle Stadelmann-Steffen, Universität Bern; Exploring ways towards societal consensus. Prof. Dr. Patricia Holm, Universität Basel; Collective financing of renewable energy, Dr. Irmi Seidl, FE Wirtschafts- und Sozialwissenschaften, WSL, Birmensdorf; see also https://nfp-energie.ch/de/projects).

2.2 Motivation of the Project

In order to successfully implement the solutions developed in the scope of the NRP 70 "Energy Turnaround" and NRP 71 "Managing Energy Consumption" and secure the energy turnaround, we need to foster acceptance of the mix of renewable energy systems and infrastructures in specific landscapes. While we know that perceptual impacts caused by renewable energy systems on a specific landscape type are one of the most important factors in explaining opposition or support for such infrastructures (Wolsink 2007a, 2007b; Jones and Eiser 2010), knowledge about the judgment of landscape effects of a mix of such infrastructures in various landscape contexts is missing. This project focused, thus, on the perceived landscape effects of a mix of renewable energy systems.

Thereby, not only the cognitive but also the affective responses to the landscapes with renewable energy systems should be investigated. The affective responses shall be taken into account because it is known that purely objective landscape measures fall short due to a strong emotion related to landscape values and because landscape perception is both cognitively and affectively influenced (Ulrich 1986; Maehr et al. 2015). Therefore, cognitive data (e.g., explicit preferences) and affective data (e.g., physiological reactions) should be analysed in order to assess proposed landscape changes more comprehensively (Ulrich 1986; Daniel 2001; Devine-Wright 2005; Singh et al. 2008; Maehr et al. 2015; Yu et al. 2017).

2.3 Goals

The overarching research goal of the project was to understand landscape-related public judgments of renewable energy developments in Swiss landscapes and their influence on the acceptability of the related infrastructures. These insights provide the basis for the formulation of recommendations for a prioritization of renewable energy systems (RES) in the Swiss landscapes, which are thought to support the realization of the "Energy Strategy 2050" (BFE 2018a) for Switzerland.

The following research questions were addressed:

1. Do the physiological responses to landscape changes with a mix of renewable energy systems correlate with public preferences for the respective scenarios?
2. In how far are judgments of the renewable energy systems dependent on the landscape context?
3. How are different infrastructures for producing renewable energy systems and their respective landscape changes judged by the Swiss public?

4. What further variables have an influence on the preferences for landscape developments with renewable energy systems?
5. What is the judgment of the public regarding specific (single) installations and infrastructure types compared with the comprehensive judgment of the whole mix of energy infrastructures (including transmission lines) within a certain landscape?

3 Approach and Methodology

The project focused on assessing public judgements stimulated by a mix of renewable energy systems (RES) within different landscapes of Switzerland. Figure 1 gives an overview of the project workflow. The public judgements were gathered in a preference study comprising (1) a physiological laboratory experiment and (2) a Swiss-representative online panel survey. The results served for evaluating a spatial prioritization for the development of RES. On this basis, recommendations for developing the landscape with a mix of RES were derived in strong collaboration with a group of experts.

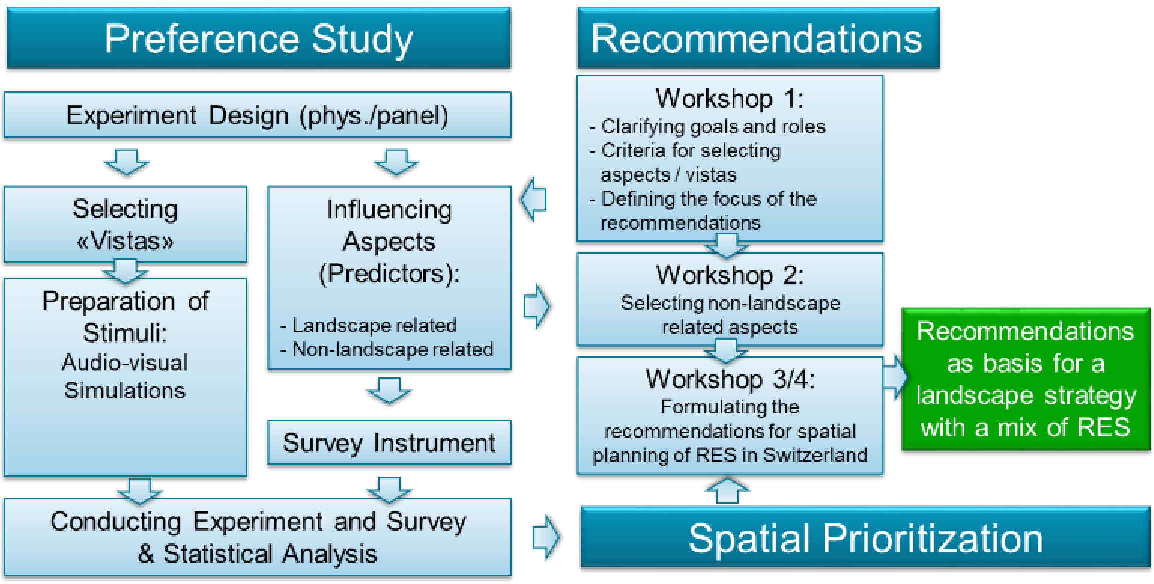

Figure 1: Overview of the project workflow.

3.1 Preference Study

3.1.1 Concept

Various aspects influence the social acceptance of landscape changes through a mix of renewable energy infrastructures (Figure 2). Landscape related factors such as knowledge and values about the environment and the landscape, as well as landscape services such as the provision of habitats for animals and plants or cultural heritage including landscape aesthetics, influence acceptance (Wolsink 2007b; Hastik et al. 2015; Tabi & Wüstenhagen 2015; Kienast et al. 2017). But also aspects that are not landscape-related have an influence. For example, the perception of and opinion on renewable energy systems can have an impact on the people's acceptance of landscape developments with these systems (Devine-Wright 2007; van der Horst 2007), as well as the assessment of individual or societal costs and benefits or attitudes to politics and climate change (Bronfman et al. 2012; Hübner et al. 2013; Cohen et al. 2014; Stadelmann-Steffen et al. 2018).

However, the perceived impacts on landscape appearance and related services are identified as one of the major reasons for public opposition towards RE projects within the scientific literature (Scognamiglio 2016; Torres-Sibille et al. 2009). This circumstance is concisely summarized by Scognamiglio (2016, 629): "*Landscape is the spatial and cultural medium through which the perception of the energy generation by RES happens, and the social acceptance of RES passes therefore also through the acceptance of a certain modified landscape*". Hence, in this project, we systematically measure public preferences for a range of landscape scenarios with renewable energy systems and take these preferences as proxy for approximating social acceptance.

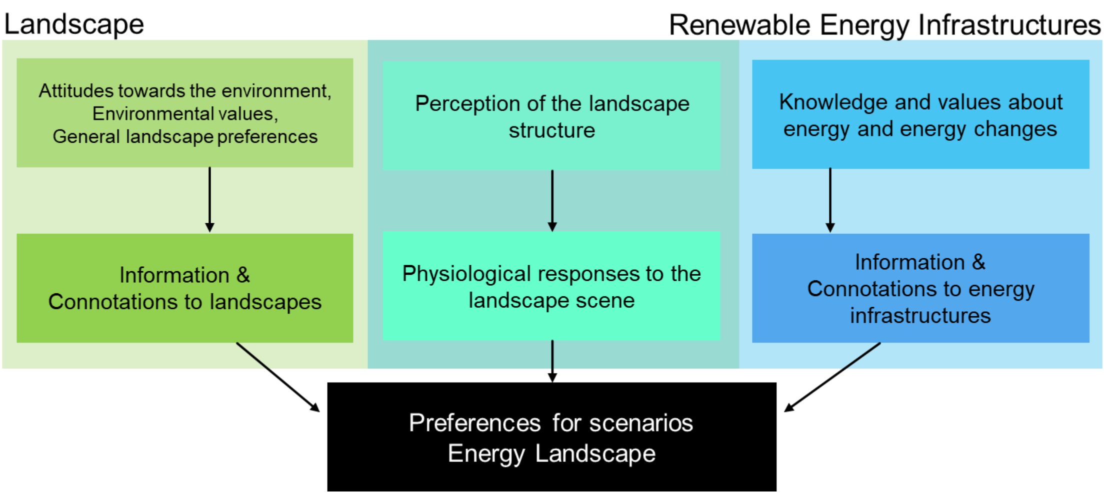

Figure 2: Simplified conceptual model of the influences of different aspects on the preferences for landscape developments with renewable energy systems.

A preference study was designed to systematically examine how the Swiss population perceives and evaluates the mix of renewable energy systems in different landscapes. The focus was on identifying those aspects that are particularly relevant for the preference statements. Therefore, preferences were measured in two ways: With a laboratory experiment and with an online panel survey representative throughout Switzerland. These two approaches are complementary and enable the respective strengths to be used and the weaknesses of the individual methods to be reduced.

In the laboratory experiment, the unconscious, spontaneous reactions on different scenarios of landscape developments with a mix of renewable energy systems were measured with skin conductance response under controlled conditions. Skin conductance response is a valid indicator for the state of arousal or attention (Critchely 2002; Bradley et al. 2007). In the context of this study, measured skin conductance assesses the strength of an affective response to landscape changes caused by renewable energy systems. In addition, cognitive aspects of landscape assessment were queried in order to gain a better understanding of the perception of energy landscapes in combination with physiological measurements. However, in this experiment, only a total of 105 subjects at ETH Zurich and 35 subjects in Lucerne could participate and the focus was on comparatively few aspects. But in return, due to the controlled conditions, the laboratory experiment provides a high measuring validity.

The online panel survey, on the other hand, was representative of Switzerland. The participants (n = 1065) completed an online questionnaire, whereby survey effects could not be avoided. Therefore, many scenarios and non-landscape-related aspects were combined in order to get generalizable statements, which aspects have a strong effect on the social acceptance. In particular, the role of the associative and emotional assignments of meaning to places (connotations) or the opinions and meanings assigned to (renewable) energy systems were examined.

As a common basis for both approaches, 3D visualizations of seven landscapes with a mix of renewable energy systems were used. However, the laboratory experiment focused on a set of 14 scenarios, while the online panel survey used considerably more scenarios. Overall, the results of the two approaches are complementary and help gaining a deeper insight into the preferences of the public regarding the investigated scenarios.

In the following sections, the preparation of the stimuli, the identification of further non-landscape related influencing factors, the design of the laboratory experiment and the online panel survey respectively are briefly described.

3.1.2 Selecting “Vistas”

As stimuli for the preference study, audio-visual landscape simulations had to be prepared, which illustrate the current situation as well as possible scenarios of a mix of RES in these landscapes. First, the «Vistas», i.e., the specific locations in different landscape types for which these scenarios are generated, had to be defined. This was done in four steps (Figure 3).

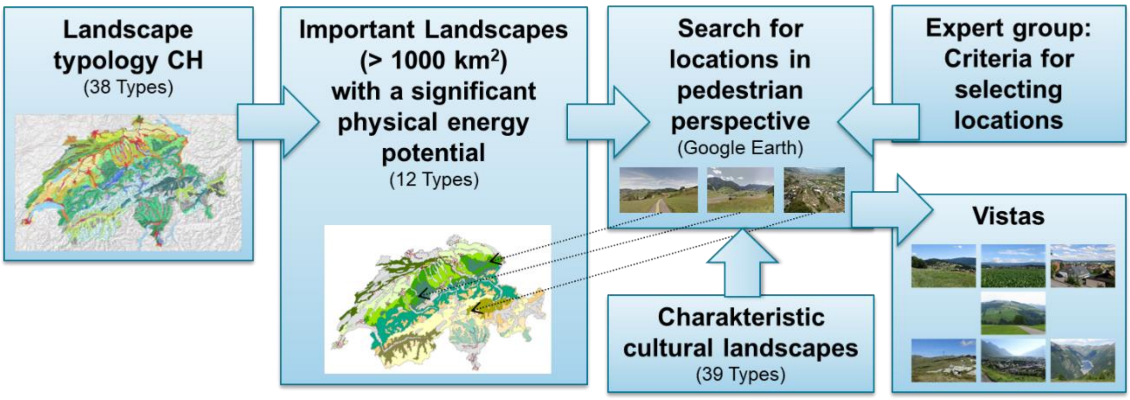

Figure 3: Approach for the selection of «Vistas».

First, with an analysis of the energy potential of the important landscapes (> 1000 km^2) in Switzerland (Segura Morán et al. 2014, Kienast et al. 2017) the most relevant landscape types for renewable energy production were identified for the study. Second, possible locations in these landscapes types were selected in deskwork. Esri ArcMap, Google Earth and Google Street View were used to check if suitable perspectives that show the potential RES from a pedestrian perspective are available.

Third, the selection of possible locations for «Vistas» was presented and discussed in the first Expert Group Workshop (May 8, 2017). The participants of the Expert Group represent different actors in the scope of landscape development with RES: representatives of authorities (BAFU, BFE, ARE), energy providers (EKZ, SBB, Swissgrid), consultants (Meteotest, Laserdata GmbH, Swissolar, Swiss Eole), associations and foundations (BPUK, KBNL, Stiftung Landschaftsschutz Schweiz, VLP-ASPAN, Binding-Stiftung, Greina Stiftung), and science (WSL, ZHAW).

In the fourth step, the experts' feedback gathered in the workshop on the full selection of locations, and per e-mail on the subsequent set of locations resulting from the discussion, informed the final decision on the locations for «Vistas» (Figure 4).

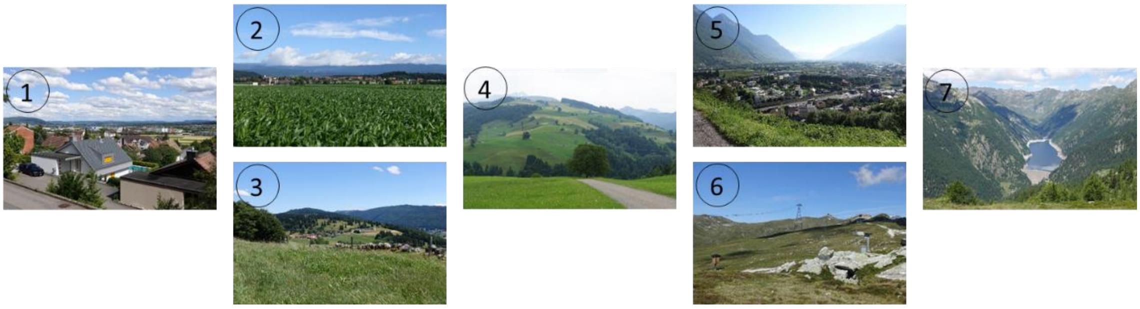

Figure 4: Vistas in seven characteristic landscapes of Switzerland: (1) Urbanized Plateau, (2) Agricultural Plateau, (3) Jura, (4) Pre-Alps, (5) Urbanized Alpine Areas, (6) Touristic Alpine Areas, (7) Further Alpine Areas.

The vistas are representative for all greater geographical areas of Switzerland (Jura, Central Plateau, Prealps, Alps, and Southern Alps) and show a typical landscape structure. Furthermore, the vistas comprise locations with different settlement densities. Locations with low to high percentage of living, working, and industrial land use, as well as infrastructure for transportation and energy were selected. In particular, also locations in a peripheral valley and a location in the high mountains were included to investigate public preferences for the mix of renewable energy systems in landscapes with low intensities of use. One alpine location contains tourism infrastructure (ski lifts) so that the combination of renewable energy systems with these infrastructures could be explored. Overall, these vistas illustrate seven different Swiss character landscapes.

3.1.3 Preparation of Stimuli

Visualization of the Vistas of the Character Landscapes

The visualization of the vistas (Figure 5) was based on LiDAR (Light Detection and Ranging) data in order to represent the individual, characteristic shape and colour of the landscape elements. Therefore, we collected cantonal Airborne Laser Scanning (ALS) data and scanned the landscape at the specific locations with a Terrestrial Laser Scanner (RIEGL VZ 1000). The latter was necessary because the airborne laser scans do not provide sufficient data from pedestrian perspective. Implementing RiSCAN Pro (RIEGL), the point cloud data was then post-processed and colorized with photos taken simultaneously with the scans. In case of the ALS data we used the software LIS Pro 3D (Laserdata GmbH) for their colorization with orthophotos.

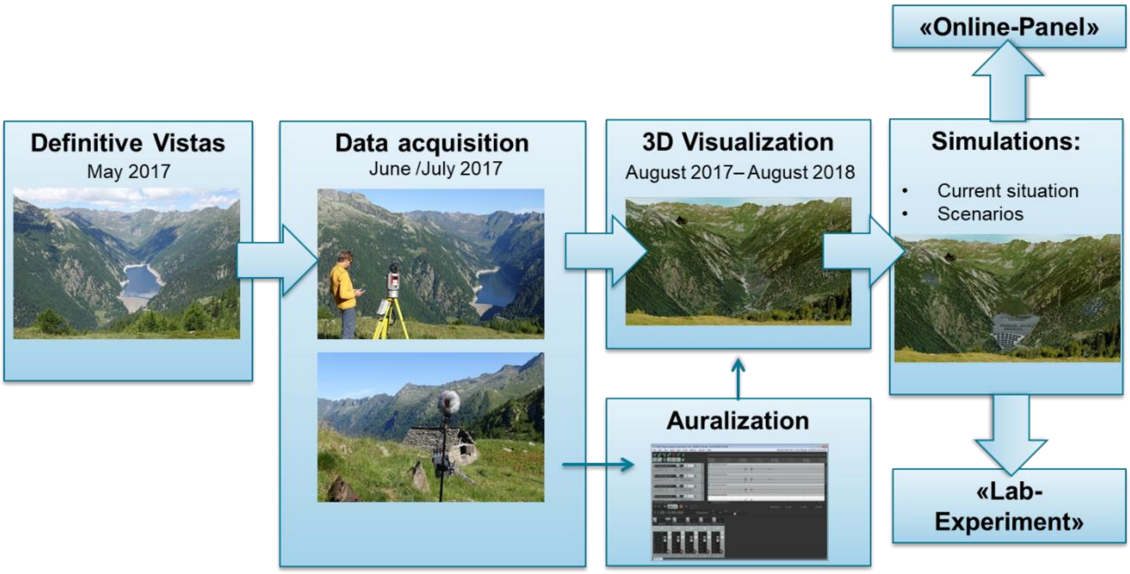

Figure 5: Workflow of the preparation of audio-visual stimuli.

For further editing of the atmosphere and the sky, the point cloud data was imported into the 3D modelling and rendering application Cinema 4D (MAXON). In the basic 3D models significant landscape objects discovering the specific location, e.g., well-known mountain formations, were removed and characteristic built landscape objects, such as typical stables or urban settlement patterns, were added in some scenes. Then, further fine-tuning of the scene settings (colours, lightning, focal depth etc.) was done in order to produce a consistent visual appearance. This resulted in renderings of the current situation of all seven vistas.

Development of the RES scenarios

As a next step, scenarios were developed for the seven vistas that illustrate different intensities of a mix of renewable energy systems at these locations. Thereby, it was aimed at a comparable visual impact of the energy infrastructure between the landscapes. This means that the visual impact of wind energy and PV infrastructures was first defined in the maximum scenario "HIGH". Based on this, a minimum scenario "LOW" and a scenario "MEDIUM" with an impact between the minimum and maximum scenario were derived (Table 1). This systematic variation allows differences in perception and preferences to be attributed to either the character landscape or the visual impact of the energy infrastructure.

Scenarios	**# Wind Turbines (3,5 MW)**	**Mean Area of Photovoltaic Panels [m²]**
HIGH	10 (15*)	18000
MEDIUM	6	9000
LOW	3	4500

Table 1: Characteristics of the scenarios «Wind» and «Photovoltaic (PV)». (*For the online panel survey, where more scenarios could be analyzed than in the laboratory experiment, in addition, a more extreme wind scenario for the “Jura” landscape with 15 wind turbines was created.)

The wind turbines and PV panels were placed in the virtual environments in two steps. First, an initial scenario was designed for the seven vistas. Then, the scenario was altered manually based on iterative calculations of the visual impact of the infrastructures for each scenario level. A separate approach was applied for wind energy (Brahms and Peters 2012; Torkler and Zeidler 2013) and for PV systems (Torres-Sibille et al. 2009). In several iterations, the placement of the wind turbines and PV panels was adjusted based on the results in the individual landscape scenes of the vistas until the total ratio of the changed pixels for each scenario level was comparable between the landscapes.

Regarding wind energy, the maximum and minimum number of wind turbines was determined in collaboration with wind energy experts. At a minimum, three wind turbines should be placed, as some cantons also specify this as a threshold value for wind parks (e.g. Kanton Bern, Amt für Gemeinden und Raumordnung 2018). Ten wind turbines were determined as the maximum, as this number was considered realistic for larger wind parks in Switzerland. Additionally, ten turbines can also be plausibly placed in all vistas, although some character landscapes have a generally lower topographical potential for the use of wind energy. No extreme scenarios were generated, but a focus was placed on the sizes of wind parks in Switzerland discussed today. However, to not underestimate the possible landscape developments with wind energy systems in the “Jura” landscape, we included an additional maximum scenario with 15 wind turbines in the online panel survey, where more scenarios could be investigated than in the laboratory experiment. In the middle scenario, the number was set at six wind turbines. This corresponds to a doubling of the minimum scenario and could be generated in all vistas from the maximum scenario by omitting turbines (note: for seven turbines in the "Jura" landscape scene, a turbine in the middle ground would have had to be added).

A different approach was adopted with regard to the placement of PV systems in the vistas. The decisive factor was that the PV systems were visible in the 3D visualizations. For this reason, the roofs (and facades) facing the viewer were fitted with solar panels for the maximum scenario. The actual orientation of the roofs was not always taken into account in the placement. However, care was taken to ensure that the overall orientation of the PV systems in the scenes seemed plausible. In addition, PV systems were placed on open spaces. For their placement, the GIS data by Segura Morán et al. (2014) of the spatial potentials for ground-mounted PV systems on agricultural land as well as on scrublands were used, or plausible areas (e.g. steeper slopes with meadows) were searched for in the respective landscape scene. For the minimum scenario, it was decided that there should be no ground-mounted PV systems. In the scenarios for the landscapes "Touristic Alpine Areas" and "Further Alpine Areas", however, it could not be avoided, as the PV scenarios here consist primarily of ground-mounted installations.

The models of the wind turbines in the scenarios have a hub height of 117 m and a rotor blade length of 60 m. Wind turbines of this size (e.g. Vestas V126, 3.5 MW) are well suited for the in an international context rather weak to moderate wind conditions in Switzerland. In the case of PV systems, a mix of rooftop-mounted systems with racks and fully integrated systems was visualised, as these forms can be seen in practice. Beyond the year 2050, it is likely that the majority of fully integrated systems will not attract visual attention. In order to include PV systems in this study, however, they had to be clearly visible. This also means that with regard to landscape aesthetics, the scenarios have lagged behind what is technologically possible today. They represent a point in time with the currently existing technology, which shapes the landscape. Illustrations of the 3D landscape visualizations are shown in Figure 6, presenting the low and the high scenario with a mix of wind and photovoltaic systems. Please note that for the online panel study further 3D visualizations of scenarios with different combinations of the intensity of the respective renewable energy infrastructures were prepared. Only for the online panel survey, scenarios of the seven landscapes including power lines (four pylons placed in the middle ground of the view) were generated.

Audio-Visual Simulation

For the laboratory experiment, the visual representations of the landscapes with the HIGH and the LOW scenario were coupled with environmental sounds. It has been shown that environmental sound increases the vividness and experimental authenticity of the simulated landscapes and intensifies the study participants' immersion into the virtual landscape scenes (Lindquist et al. 2016, Wissen Hayek et al. 2016). To develop consistent sound ambiences for the vistas, we recorded sounds with a sound-field microphone (4-channel, first-order ambisonics microphone) at the specific locations in the landscapes where the point cloud data was collected (June – July 2017). Recordings of about 20 minutes were carried out at different specific moments of the day (morning, midday, afternoon) while taking notes of the sound events. These recordings and listening protocols served as basis for identifying soundmarks. Soundmarks (in analogy to landmarks) are defined as sounds reflecting natural (e.g., streaming water, natural wind traps) or cultural characteristics (e.g., distinctive bells, sounds of traditional activities), and are often the sounds first noticed (Kang 2007: 45, 98). If the quality of the descriptive recording was not sufficient to isolate these identified sounds, another recording was conducted in a more isolated manner, e.g., recording the sounds of cow bells, of typical birds, or of haymaking. We processed and arranged the sounds for each landscape type utilizing the digital audio workstation REAPER (https://www.reaper.fm). Overall, rather ordinary sounds were integrated into the mix to present a real-sounding ambience. Finally, the perceived consistency of the sound ambiences with the landscapes was tested and based on the results a fine-tuning of the sounds has been done (Wissen Hayek et al. 2018).

Character Landscape	Scenario LOW	Scenario HIGH
Urbanized Plateau		
Agricultural Plateau		
Jura		
Pre-Alps		
Urbanized Alpine Areas		
Touristic Alpine Areas		
Further Alpine Areas		

Figure 6: 3D point cloud visualizations of the seven character landscapes with the low and the high scenario with renewable energy systems respectively.

3.1.4 Identification of Influencing Aspects

Accompanied by the development of the 3D visualization of the landscape development scenarios, the research additionally focused on landscape and non-landscape related aspects with a possible influence on preferences for landscape developments with RES. A well-known concept for landscape related aspects is given by the Ecosystem Services, which indicate that landscapes are providing services to humans (Haines-Young et al. 2010). One of those services, landscape aesthetics, is already covered by the 3D visualisation. However, aspects with no direct relation to landscapes but a relation to renewable energies (e.g., trust, fairness, efficiency, participation etc.) or the peoples' environmental and renewable energy related knowledge and values (e.g., personal importance of the energy turnaround) had also to be taken into account.

Besides literature analyses, several approaches were applied to collect information about the non-landscape related aspects and to evaluate their importance legitimating to include them in our investigations. In the first Expert Group Workshop a brainstorming session was conducted on criteria that the experts regard important in the context of landscape development with RES in the different landscapes in Switzerland. This resulted in an extended list of criteria such as the contribution to climate protection, protection of areas, incentives and taxes or fees, economic factors, energy production in terms of the amount and the time of production, etc. In addition, reports of NRP 70 / 71 projects were screened for relevant aspects influencing public preferences for RES. Further, about 50 scientific research papers and studies were analysed regarding aspects of social acceptance. This led to an identification of about 70 relevant aspects potentially contributing to social acceptance. In order to ensure that no important aspects were overlooked and to identify the importance of those aspects, a robust selection approach was required. Therefore, the second Expert Group Workshop was conducted in January 2018, where 17 experts from 16 institutions participated. With the help of the workshop participants, another 115 relevant items were developed. Hence, in total 184 relevant aspects were identified.

After normalisation and comparison of both datasets, the aspects were aggregated to a total of 26 main categories. These built the basis for the further development of the study design of both, a post-questionnaire for the laboratory experiment and for the Swiss-representative online panel survey, but with different level of detail. The post-questionnaire of the laboratory experiment predominantly focused on opinions on the environment and renewable energies, trust and fairness, perception of the landscape in their living environment, the personal concernment regarding renewable energies, and socio-demographics. The online panel survey contained further item groups addressing socio-demographic information, place attachment, landscape aesthetics, landscape connotations, the environmental knowledge and -values, knowledge and values about energy issues, and human-place related aspects.

3.1.5 Laboratory Experiment: Design

The laboratory experiment was carried out in July and August 2018 both at ETH Zurich and at the Laboratorium Luzern (www.laboratorium-luzern.com). At Luzern, the experimental conditions were not perfect for a controlled experiment, because noise from a railway line affected a lot of the sessions. The results are therefore based on the ETH Zurich sample, where a total of 105 participants (19-47 years old (Ø 23.5; SD 4.4), 53 % male, 47 % female, 70.5 % with a university degree, 26 % with some graduate studies, 3.5 % other) took part. These participants were recruited by the University Registration Center for Study Participants (www.uast.uzh.ch) and received 30 CHF for compensation after completing the experiment. Participants were purposefully excluded if they were above 40 years old because of known changes in EDA (Boucsein 2012). All participants were fluent German speakers with normal or corrected-to-normal vision and had no acute or chronic, physical or mental, disorders. The vast majority of the study participants were resident in the character landscape "Urbanized plateau", which is characterised by settlements and infrastructures.

The scenarios examined in the experiment were the mix of the minimum (LOW) and the maximum (HIGH) scenarios of wind energy and PV systems (Table 1) for all seven character landscapes (Figure 6). After applying and calibrating the electrodes for measuring skin conductance, three pairs (MAX / MAX, MIN / MIN and MIN / MAX or MAX / MIN) were shown to each participant (Figure 7). To avoid familiarization effects, one participant saw a landscape type only once (between subject design). While observing the six landscapes, the change in skin conductance was measured in the first part of the experiment. In addition, the study participants were asked which energy landscape of the pairs shown they liked better. The participants then chose the respective landscape by pressing a button.

In the second part, the participants assessed their perception of the landscape image of the scenarios shown in relation to four basic qualities of the landscape. These qualities concerning the visual landscape structure were based on central concepts of the information processing theory: legibility, mystery, coherence, and complexity (Bourassa 1991; Kaplan & Kaplan 1989; Kienast et al. 2013, 2015). The perceived Legibility indicates how well the landscape allows for orientation. Mystery refers to the degree of further information expectations given by the landscape. Coherence is fostered by clear structures and recurring patterns so that the variety of information results in a coherent picture. Complexity is determined by the perceived variety of different landscape elements and the visual richness (Kienast et al. 2013). These indicators are also included in the Swiss Landscape Monitoring Program LABES (abbreviation for German "Landschaftsbeobachtung Schweiz"). Finally, the participants answered questions on attitudes towards climate change, environment, renewable energies and other socio-demographic aspects of the post-questionnaire.

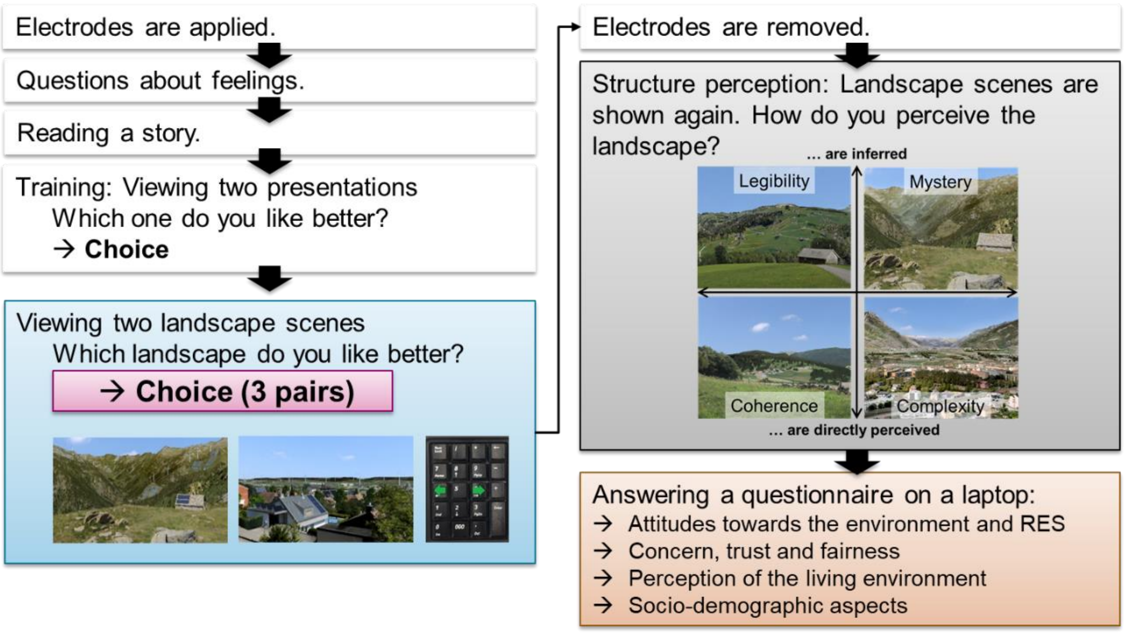

Figure 7: Procedure of the laboratory experiment.

3.1.6 Online Panel Survey: Design

Based on literature reviews and the expert input from the workshop(s) (see Section 3.1.4) a survey concept was developed (Figure 8). The survey concept consists of two parts. The first part represents conceptual item modules (0-9), whereas the second part includes a choice experiment (modules 10-11).

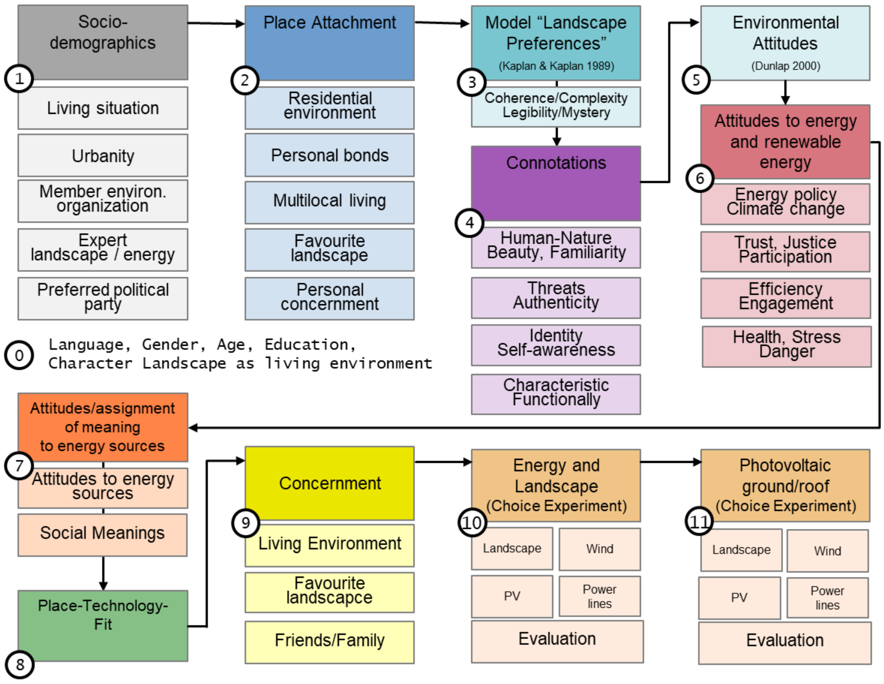

Figure 8: Survey design (modules).

In the first part of the survey (see Figure 8, module 1-9), multiple concepts have been implemented such as:

- how people are attached to landscapes of living/recreation (Lewicka 2011; Bonaiuto et al. 2003; Bonaiuto et al. 1999; Ströbele und Hunziker 2015; Kienast et al. 2013),
- how people process landscapes (information processing theory by Kaplan und Kaplan 1989),
- what meanings people assign to landscapes (Rodewald 2001; Meier und Bucher 2010; Stremlow und Sidler 2002),
- environmental attitudes of people (Dunlap und Van Liere 2008; Hawcroft und Milfont 2010; Díaz et al. 2017),
- attitudes and meanings people assign to energy and renewable energy attitudes (Ntanos et al. 2018; Devine-Wright und Batel 2017; Devine-Wright und Batel 2013; Heras-Saizarbitoria et al. 2011; Wolsink 2000),
- personal affectedness of the development of renewable energy systems (Hunziker et al. 2001; Bontadina et al. 2001), and
- socio-demographics.

In addition to the mentioned literature references, a significant contribution to these concepts was also made during project workshops and during internal development processes. The survey was set up with Sawtooth software (Sawtooth 2017).

In the second part of the survey, a choice experiment (CE) was applied. The original CE is based on a multi-nominal logit model (MNL). A MNL model is a regression model which is used to predict the probabilities of discrete outcomes based on a set of independent variables (Olschewski 2013). These independent variables are called attributes, which include "Landscape" (LS), "Wind" (W), "Photovoltaics" (PV) and "Overhead Powerlines" (PL). The attributes "Wind" and "Photovoltaics" have four numerical levels (absence, minimum, medium, maximum number of infrastructures), whereas the attribute "Overhead powerlines" consists of two numerical levels (absence, presence) (see Figure 9). The attribute "Landscape" consists of the seven Vistas of the Swiss character landscapes (see Section 3.1.2). To take into account that the landscapes were defined earlier in the project, the attribute has been developed as a nominal variable using dummy variables.

Figure 9: Structural development of choice alternatives from attribute levels.

All four attributes and their respective levels have been combined to unlabelled alternatives (choice card) where two alternatives are shown per choice decision (choice set). The way the attribute levels are arranged is determined by the "design" of the CE. Huber and Zwerina (1996) show four principle ways to achieve an efficient CE: orthogonality, level balance, minimal overlap and utility balance. Given the situation that it is not possible to satisfy all principles, the short-cut method has been chosen which ensures minimal overlap (Sawtooth 2017, p.16). This means that each option is built by choosing attribute levels least frequently applied in previous options to keep the alternatives in any task as different from each other as possible (Olschewski et al. 2012).

For this study in total 224 theoretical alternatives were available. The model design was calculated with NGENE (v.1.2.0) a leading software regarding the experimental design of stated choice experiments. This led to a design where each respondent had to select one out of two options from 15 successive choice sets (Figure 10). The underlying question each subject had to answer was "If these were your only options, which one would you prefer to choose?" To add realism in choice situation, Louviere et al. (2000, pp.13–36) suggest to include a "no choice" option, to which in the following study is referred to as "None: I cannot choose."

The survey was implemented as a national representative online panel survey, operated by panel provider BILENDI GmbH. A pre-test with 116 respondents was conducted in October/November 2018 and was mainly used to estimate and verify the priors used in the design development. The main survey was online from late November 2018 until March 2019. A total of n = 1065 surveys were fully completed. 221 (20.75%) respondents failed quality criteria due to a minimum of total time, time spent in choice model per choice task and in total, percentage certainty and continuity in answers per module, which led to a total number of qualified respondents of n = 844. The median time for the completion of the survey was about 49 minutes.

The data was processed and evaluated in with IBM SPSS Statistics (V 25), R (https://www.r-project.org) and Lighthouse Studio (v.9.5.3, Sawtooth Software).

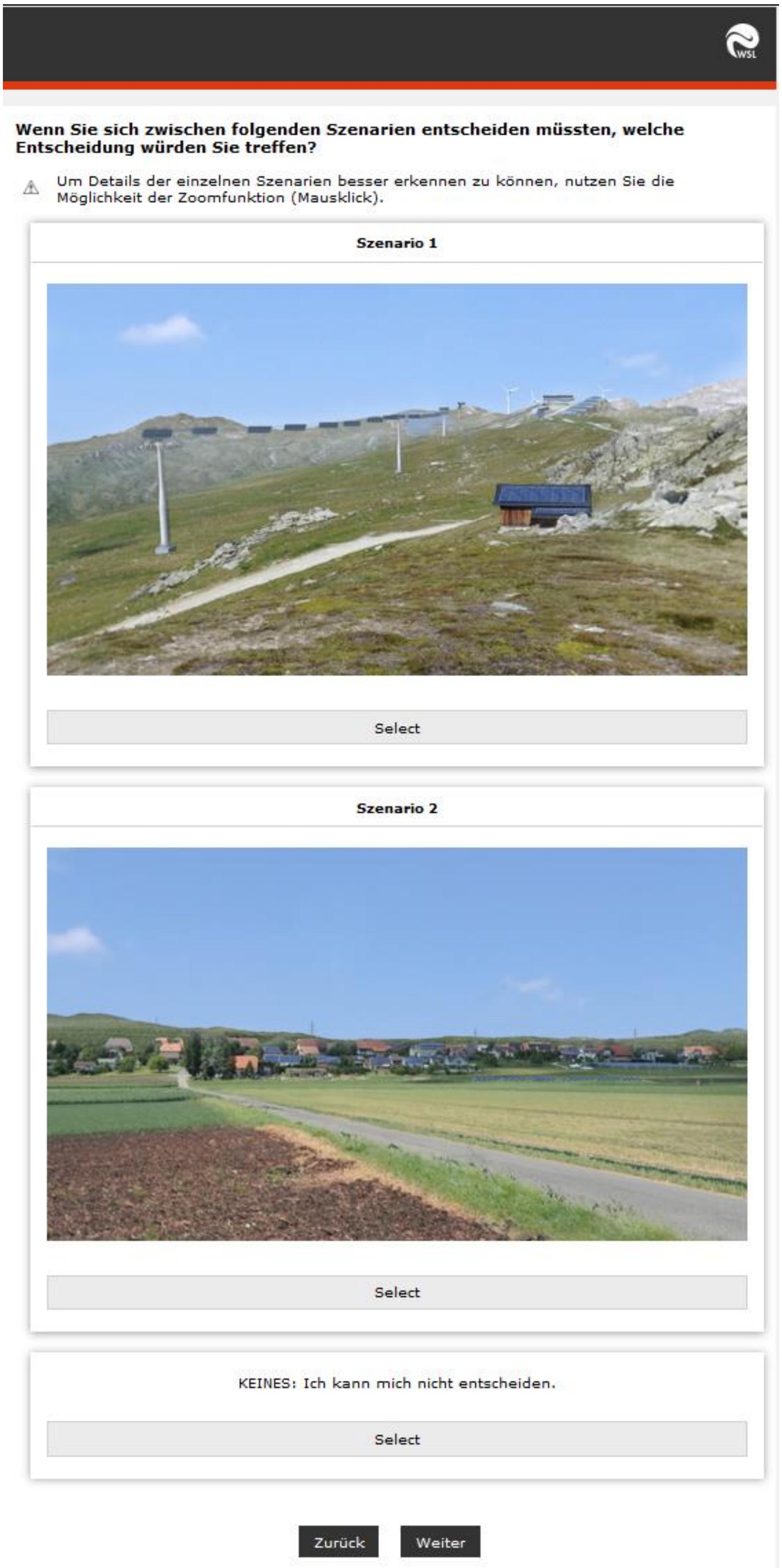

Figure 10: Exemplary choice situation for each subject (choice task).

3.2 Development of Recommendations

The recommendations were developed in strong collaboration with the group of experts collaborating from the outset on with the project team. In addition to the workshop for selecting vistas (first Expert Group Workshop, see Section 3.1.2) and the workshop for identifying further influencing aspects (second Expert Group Workshop, see Section 3.1.4) two further workshops were organized. In the third Expert Group Workshop (January 16, 2019) initial results of the preference survey were presented and first conclusions drawn from these results were discussed. It was defined that the recommendations shall be drawn from the conclusions, which should stay close to the results. Further, the expert group called for the possibility to collaboratively reviewing and revising the draft recommendations. Therefore, a fourth Expert Group Workshop was organized (September 18, 2019).

4 Results

In this section, the most important results of the preference study are summarized. First, the physiological responses on the low and the high scenario with a mix of wind energy and photovoltaic systems are provided, which were measured in the laboratory experiment. Second, the results from the laboratory experiment and the online panel survey are given regarding the participants' stated preferences, which scenarios they preferred compared to the other ones. Third, the stated preferences (laboratory experiment and online panel survey) are compared with the physiological response and correlations between both patterns are discovered. Finally, the results are presented of how the study participants perceived the landscape structure in order to get a deeper understanding of the perception and evaluation of the landscape scenarios.

4.1 Physiological Responses to the LOW and the HIGH Scenarios

An important finding is that the amount of infrastructures elicits physiological responses. Landscape scenarios with high amounts of renewable energy infrastructures evoke higher attention than scenarios with only few do. This effect is strongly significant in the landscapes “Further Alpine Areas” and “Jura”. In the landscape “Urbanized Plateau” we cannot see any differences in the number of skin conductance responses (nSCR) between LOW and HIGH scenarios. This result indicates that skin conductance response is more sensitive to the visual impact of higher amounts of renewable energy systems in near natural landscapes compared to urban scenes.

4.2 Preferences for the Landscape Scenarios with Renewable Energy Systems (RES)

The preferences for the landscape scenarios were determined in two ways:
1) Stated preference in the online panel survey (choice experiment, "What picture do you opt for?")
2) Stated preference in the laboratory experiment (choice, "What picture do you like better?")

The results show that the preferences for infrastructures for a renewable energy supply strongly depends on the type of landscape, the combination of energy production facilities and the already existing use of a landscape: The more natural a landscape looks, the greater the rejection of energy infrastructures. Nevertheless, the results of the online panel survey show that a small number of solar and wind energy infrastructures are clearly preferred in the Plateau shaped by settlements and infrastructures as well as in Alpine landscapes, where facilities for touristic use such as ski lifts characterise the landscape. In contrast, the people do last prefer the renewable energy infrastructures in the “Further Alpine Areas”. Also in the landscapes “Jura” and “Pre-Alps” these developments are rather little preferred. The “Agricultural Plateau” as well as the “Urbanized Alpine Areas” range on the medium ranks.

In the laboratory experiment, compared with the other landscapes, the landscape “Further Alpine Areas” with the LOW scenario was liked best. This means, that participants rated the “Further Alpine Areas” with just a small amount of renewable energy systems as the most beautiful, whereas participants did not like the landscape “Urbanized Plateau”. This coincides with the findings of the landscape observation programme (LABES; Kienast et al. 2013: 54), where the visual landscape of the central alpine regions was rated by the people living there as most beautiful, whereas the urbanized regions of the Plateau (and Ticino) were rated least positively. Generally, people rate landscapes with a LOW amount of renewable energy systems as more beautiful compared to the landscapes with a HIGH amount of these infrastructures. In near natural landscapes this difference is much bigger compared to urbanized areas.

Concerning the energy production facilities, the pure use of solar energy on roofs and facades is more preferred than the scenarios with wind energy systems or combinations of wind and PV systems. However, in all landscapes, a combination with few wind turbines and PV panels is preferred to a scenario with a high number of these infrastructures. A scenario with a minimum amount of wind turbines and a minimum amount of PV infrastructures is better preferred than this wind energy scenario without PV. Scenarios with wind turbines are preferred less the more wind turbines are visible.

Power lines are least preferred in comparison to PV (best preferred) and wind energy infrastructures. Looking only at scenarios with power lines, in all landscapes the power lines are more preferred in combination with a minimum or medium amount of PV than power lines only. In the landscapes "Urbanized Plateau", "Agricultural Plateau", "Jura", and "Touristic Alpine Areas", a scenario with power lines combined with a minimum amount of both PV and wind turbines is still equally or even slightly better preferred than the scenarios with power lines only.

4.3 Comparison of the Arousal Response with the Stated Preferences for the LOW and the HIGH Scenarios

We compared the arousal response with the stated preference of the participants of the laboratory experiment, and the stated preferences of the online panel survey for the LOW and HIGH scenarios. Concerning near-natural landscapes, particularly the "Further Alpine Areas", and concerning "pre-stressed" areas such as the "Urbanized Plateau" the patterns of the stated preferences (laboratory experiment) are similar to the ones identified for the arousal responses. For the landscape "Further Alpine Areas", all three measures provide significant results. The stated preferences (online panel survey and laboratory experiment) are here higher for the LOW scenario than for the HIGH scenario. Additionally, this landscape seems to be more sensitive to the visual impact of renewable energy systems than the other landscapes regarding the arousal, which is increasing with the amount of renewable energy infrastructure. A higher amount of renewable energy systems clearly attracts more attention and, therefore, leads to an effect not only cognitively, but also affectively.

4.4 Impact of the Scenarios on the View of the Landscape

The results of the participants' landscape perception measured with the indicators for the quality of the landscape structure reveal specific visual aesthetic aspects as factors influencing people's preference decisions. In particular, the perceived coherence has a major effect on the preferences in several landscapes, especially the near-natural ones.

The rated landscape coherence differs strongly dependent on the amount of renewable energy infrastructure (LOW / HIGH) in the landscapes. Perceived coherence *increases* in almost every landscape, with just a small amount of renewable energy infrastructure (LOW scenario). With a high amount of renewables (HIGH scenario), coherence *decreases* drastically. This holds for all character landscapes except the following two: In the "Urbanized Plateau", where the perceived coherence changes just marginally with both scenarios. Further, in the "Further Alpine Areas" coherence is perceived lower with both scenarios compared to this landscape without renewable energy systems.

The results show that the landscape changes can be measured with these landscape structure indicators. Thereby, the participants of the laboratory experiment rated the whole landscape including the mix of renewable energy systems.

5 Discussion of results

5.1 Answers on the Research Questions

In this section, the results of the preference study are briefly discussed with regard to the five research questions (see Section 2.3). Based on the results, the people's stated preferences for renewable energy infrastructures in the seven character landscapes is explained regarding the physiological responses to the landscapes, the landscape structural measures, as well as the connotations to the landscape. Hence, the preferences for the scenarios are treated as an indicator for acceptance solely from a landscape perspective.

1. Do the physiological responses to landscape changes with a mix of renewable energy systems correlate with public preferences for the respective scenarios?

Overall, the arousal response on a scenario with a combination of many wind turbines and photovoltaic systems (scenario HIGH) is higher than on a scenario with only few of these infrastructures (scenario LOW). Furthermore, in the landscape "Urbanized Plateau", which is already "pre-stressed" with other infrastructures, adding a large amount of renewable energy systems seems not to affect the arousal response on these landscapes in the same way as it does in near-natural landscapes such as "Jura" and "Further Alpine Areas".

There is no direct link between the arousal response and a positive or negative perception (Critchley 2002). However, the combined analysis of arousal responses and stated preferences helps to better understand landscape perception processes. The comparison of the arousal response with the stated preferences of the online panel survey showed that in the near-natural landscape "Further Alpine Areas" the preferences for the LOW and the HIGH scenario differ significantly and so does also the arousal response. People do not regard infrastructures of renewable energy systems as fitting into this landscape and the more of them are visible, the more aroused they are. Moreover, regarding all seven character landscapes, the landscape "Further Alpine Areas" was liked best and was least preferred for developments with renewable energy scenarios compared to the other landscapes. This means, we did find meaningful correlations between the physiological responses and the public preferences.

2. In how far are judgments of the renewable energy systems dependent on the landscape context?

The results demonstrate clearly that the participants' preference judgments of the renewable energy systems are depending on the respective landscape context because the gradients between the LOW and the HIGH scenarios differ between the landscapes. Moreover, the judgments reveal a ranking of the landscapes with respect to such developments, suggesting that people weigh their choices according to the landscape context (see Section 4.2). The people seem to want to protect the near-natural landscapes ("Further Alpine Areas") and therefore show higher preferences for landscape developments with renewable energy systems in "pre-stressed areas" ("Urbanized Plateau").

In addition, the amount of renewable energy infrastructures affects the perceived landscape structure, notably the perceived coherence (see Section 4.4), which in turn effects the visual landscape preference. From a landscape aesthetics point of view, the integration of a combination of renewable energy infrastructures can have positive effects on the perceived coherence. However, this effect may become negative in case of too many renewable energy infrastructures.

3. How are different infrastructures for producing renewable energy systems and their respective landscape changes judged by the Swiss public?

The people prefer developments with renewable energy systems in the “Urbanized Plateau” best, followed by the “Touristic Alpine Area”. These landscapes contain already other infrastructures and it seems that this is fostering the acceptance of adding further infrastructure to the landscape view (see also Lienert et al 2017 and Batel et al. 2015).

Developments with renewable energy systems in the landscapes “Agricultural Plateau”, “Jura” and “Pre-Alps” are not as much preferred as such developments in the “Urbanized Plateau” or the “Touristic Alpine Areas” are. Apparently, the people want to protect these agriculturally shaped landscapes. The alpine areas seem to trigger this protection effect, too, so that developments with renewable energy systems in these areas are less preferred than in the “Urbanized Plateau”. As the “Further Alpine Areas” are least preferred for such developments, it may be the Alps that further the refusal.

4. What further variables have an influence on the preferences for landscape developments with renewable energy systems?

This question will be answered with further results of the online panel survey. However, the data analysis requires a new model, which still needs to be further developed.

5. What is the judgment of the public regarding specific (single) installations and infrastructure types compared with the comprehensive judgment of the whole mix of energy infrastructures (including transmission lines) within a certain landscape?

Overall, the public prefers a landscape development scenario with renewable energy infrastructures more than a scenario without any of these. However, the public has also clear preferences for the different infrastructure types and their preferred amount. Landscape developments with PV on roofs and facades are clearly preferred over developments with wind turbines and developments with power lines are least preferred. Lienert et al. (2017) explain the people’s low acceptance of power lines with deeply rooted negative affective connotations.

But also the combination of the infrastructure types matters. A combination of high amounts of all infrastructures is clearly less preferred than the scenarios with combinations of low amounts. The public seems to generally agree with moderate landscape developments with renewable energy systems. Thereby, the preferences for such developments differ between the landscapes as discussed for research question 3.

5.2 Recommendations

Due to further time required for the analysis of the preference study’s results and the demand of the expert group to take part actively in the formulation (see Section 3.2), the recommendations could not be integrated into this report. The final recommendations will be made available in the project report for the NRP 70 in form of a web page. This format is thought to communicate the results to a broad target group, so that politicians and the general public are also addressed. Furthermore, there will be a brochure (PDF) addressed particularly to practitioners, i.e., the spatial, landscape and renewable energy infrastructure planners at all three planning levels, companies and consultants of the renewable energy industry, as well as of the landscape protection and development area. This product, funded as a follow-up project also by the BFE, will be made available in the end of 2019 on the NRP 70 web page of the ENERGYSCAPE project and the BFE web page.

6 Conclusions

The goal of the project ENERGYSCAPE was to better understand landscape-related social preferences, and hence, the public acceptability of renewable energy developments in Swiss landscapes. Therefore, a preference study consisting of a laboratory experiment and an online panel survey was conducted. The landscapes considered comprise the “Urbanized” and the “Agricultural Plateau”, the “Jura”, the “Pre-Alps”, the “Urbanized Alpine Areas”, the “Touristic Alpine Areas”, and the “Further Alpine Areas”. Altogether, these seven landscapes represent major character landscapes.

A combined analysis of the results of the online panel survey and the laboratory experiment gives, from a landscape perspective, concrete insights into preferences for landscape developments in Switzerland with different combinations and amounts of infrastructures of wind energy and photovoltaic systems as well as power lines. In this context, the Swiss people prefer placing infrastructures of renewable energies into “pre-stressed” landscapes over placing them into more natural looking landscapes. Moreover, overall they prefer developments with a rather moderate amount of renewable energy infrastructures with a clear preference for PV on roofs and facades. But also combinations of low amounts of both PV and wind turbines are preferred scenarios.

Further, the arousal response to landscape scenarios with renewable energy systems is related to the amount of renewable energy systems and the scenic quality. Therefore, this aspect should be further investigated to get a deeper understanding of the relationships between the visual characteristics and physiological responses. Also the perceived coherence is strongly related to the amount of renewable energy infrastructures in a landscape scene, and hence, possible effects on this aspect need to be taken into account seriously. Thereby it has to be noted that adding a low amount of renewable energy infrastructures can also increase the perceived coherence of a landscape. Except the rather natural, remote alpine areas, which are more sensitive to changes with renewable energy systems concerning the perceived coherence.

For developing a landscape strategy with renewable energies, taking into account both, landscape and non-landscape-related influencing factors is necessary. The results of the project predominantly make landscape related aspects explicit. Furthermore, the analysis of the connotations to landscape and (renewable) energy will provide further insights into the people’s attitudes regarding the fit of the renewable energy infrastructures into specific places. Together, these results provide a valuable basis for practical suggestions to steer the landscape development with renewable energy systems towards socially accepted directions.

7 Publications [within the project]

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