D5.3

Replication potential analysis

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Document History

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Draft	2022-11-28	Paper will be updated. The access to the simulation model is currently limited due to the unavailability of an essential person for the simulation work. After the person will be back in office, the report can be finalized.
Final	2023-02-03	Final corrections.

TABLE OF CONTENTS

1. INTRODUCTION

This deliverable develops ideas about the replication potential in several countries. Due to learnings and subsequent changes of the consortium throughout the project, the replication potential analysis contains solely the work undertaken by the simulation modelling team responsible for D1.3 and D1.4. The simulation model used for the replication analysis was developed in WP1 and is detailed in D1.3 and D1.4 respectively.

1.1. INTENDED AUDIENCE

The intended audience of the report are members of the CIRCUSOL consortium, scholars, business consultants, and the general interested public. The envisioned purpose of the report towards this audience is to show how the potential for 2nd use of PV modules and systems can be applied to several countries in Europe.

1.2. REPORT OUTLINE

The report is structured in the following way. **Chapter 1** provides the introduction and the logic of the replication potential analysis. **Chapter 2** executed the analysis and demonstrates by means of the policy simulation developed in WP1, D1.4, the replication potential in other three selected countries. **Chapter 3** provides background information on the interactive workshops that have been held with various stakeholders from organizational market segments in Switzerland as a concrete attempt to further use and enhance the results created in CIRCUSOL.

2. REPLICATION POTENTIAL ANALYSIS

2.1. REPLICATION IN SWITZERLAND

2.1.1. BACKGROUND

One low-carbon electricity generation technology that is expected to significantly contribute to Switzerland's energy targets is solar photovoltaic. As explained throughout this project, solar PV has relatively low environmental impact compared to other electricity generation technologies and it is cost-competitive to fossil fuels in terms of levelized cost of electricity (LCOE) (Lonergan & Sansavini, 2022).

By the end of 2020, Switzerland had installed 493 MW of new solar PV capacity, reaching a total PV installed capacity of about 3 GW and generating about 2500 GWh of electricity per year (Bundesamt für Energie BFE, 2021). With very little ground-mounted utility-scale PV, due to the country's constraints on available land, rooftop PV installations are most common in Switzerland in the different market segments, including residential, commercial, and industrial. Besides buildings, the growth in photovoltaics is also expected to happen in alpine regions where irradiation is high, especially in winter months.

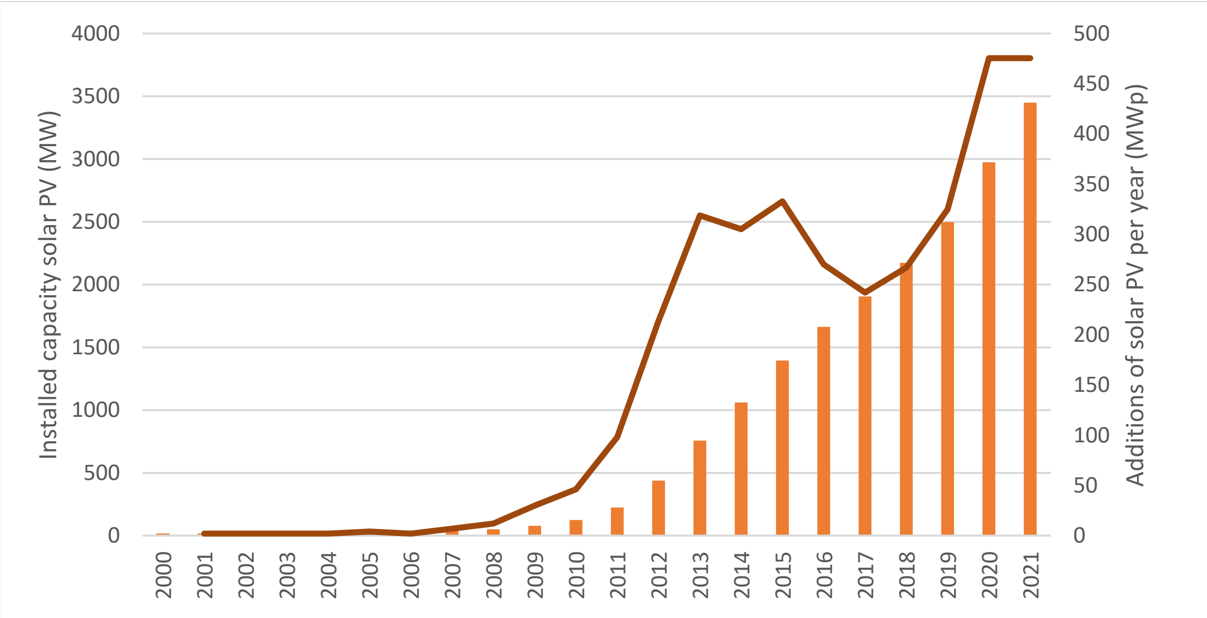

Figure 1 Development of solar PV in Switzerland: Yearly and cumulative installations

Table 1 Development of solar PV in Switzerland: Yearly and cumulative installations

Year	Installed solar PV capacity (MW)	Additions of solar PV (calculated by the author)
2000	16	
2001	18	2
2002	20	2
2003	22	2
2004	24	2
2005	28	4
2006	30	2
2007	37	7
2008	49	12
2009	79	30
2010	125	46
2011	223	98
2012	437	214
2013	756	319
2014	1061	305
2015	1394	333
2016	1664	270
2017	1906	242
2018	2173	267
2019	2498	325
2020	2973	475
2021	3449	475

Source: IRENA (2022), IRENASTAT Online Data Query Tool, Renewable energy statistics 2022, International Renewable Energy Agency (IRENA), Abu Dhabi. URL: https://pxweb.irena.org/pxweb/en/IRENASTAT/IRENASTAT__Power%20Capacity%20and%20Generation/RE-ELECGEN_2022_cycle2.px/

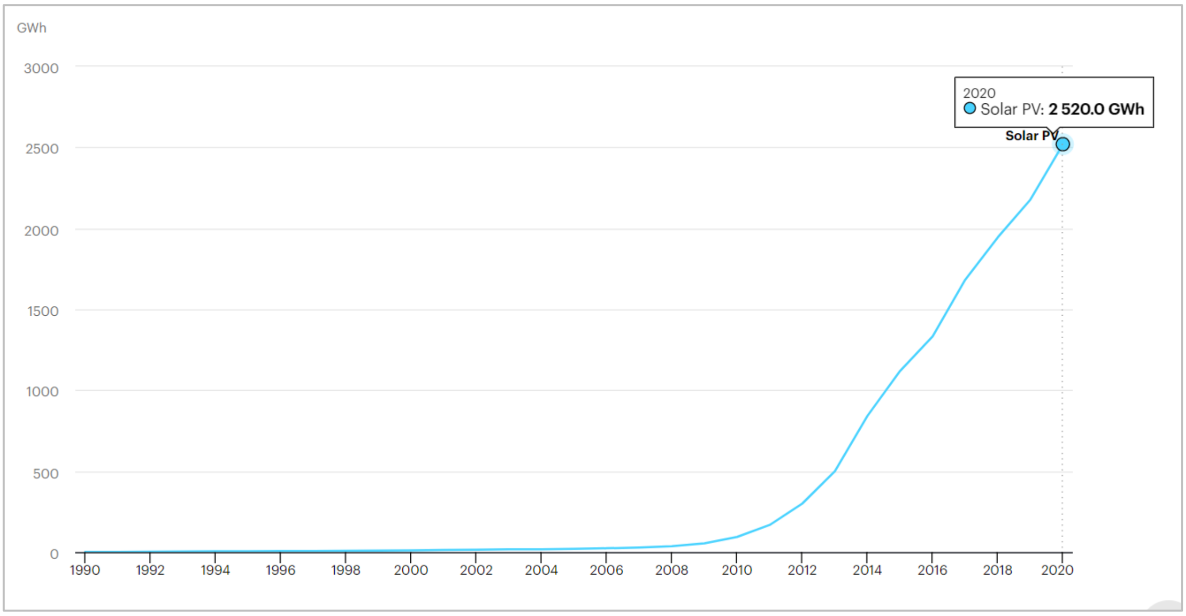

Figure 2 Solar PV electricity generation in Switzerland (1990-2020)

Source: IEA (2020)

The Swiss government has encouraged investment in PV and wind projects with a feed-in-tariffs (FITs) mechanism (for installations above 50 MW) and capital subsidy schemes (for installations less than 100 kW) (SFOE, 2012). The effect of FITs on the electricity system has been an increase of solar installed capacity from 79 MW in 2009 to 3 GW in 2020 and an increase of wind installed capacity from 18 MW to 87 MW over the same period (Martínez-Jaramillo, van Ackere, & Larsen, 2020). Furthermore, latest statistics from Swissolar, the Swiss Solar Energy Professionals Association, show that residential batteries linked to PV systems are becoming increasingly popular. According to its figures, the number of battery storage systems sold in 2020 grew by 65% with around 15% of residential PV systems being coupled with battery storage. In total, storage systems with a capacity of 28,400 kWh had been installed in Switzerland by the end of 2020 (Bundesamt für Energie BFE, 2021).

Solar PV production is expected to significantly contribute to filling the production gap left by the closure of nuclear stations, which are scheduled to be phased out by 2050. The potential for additional electricity generation from solar PV is, in fact, the largest among all renewables, with estimates from the Swiss Federal Office of Energy placing the maximum generation potential at 67 TWh (for reference, Switzerland's annual electricity consumption is consistently on the order of 60 TWh) (Bundesamt für Energie BFE, 2019; Lonergan & Sansavini, 2022). Since PV faces less societal opposition than other RES (Bauer et al., 2017), realizing its potential is feasible, but will depend on government incentives and appropriate regulation to make it less expensive. Spatial planning, as well as new building construction regulation are also important factors required to double the installed PV capacity every decade from now until 2050. Most importantly, if hydrogen becomes prevalent, the increase will have to be even faster, and the challenges much greater (see Section 3).

Finally, based on the forecasted penetration of renewable energies, including solar, it is expected Switzerland's electricity supply will shift from demand-following to weather-driven, which stresses the need for balancing the system at different timescales (i.e., daily, weekly and seasonal). The need for flexibility would demand market opening, which includes a wide range of option for centralized storage (including new solutions based on hydrogen and e-fuels), for flexible consumers (offering their installed capacities through aggregators) with decentralized storages and smart demand technologies, and for electricity producers integrated via peer-to-peer trading[1]

2.2. REPLICATION IN ITALY

2.2.1. BACKGROUND

Until 2005, unattractive incentive programs coupled with both economic and political instability prevented the expansion of photovoltaic energy in Italy. The boom of PV installations in Italy responds to the introduction of the Energy Bill ("Conto Energia"), a feed-in scheme implemented by the government in 2005 aimed at providing incentives over a period of 20 years for electricity generated and self-consumed. In 2007, this program was expanded and incentives were given out to prosumers delivering energy to the network as well (Bianco, Cascetta, & Nardini, 2021). Growth in the Italian PV industry was further facilitated by the 20-20-20 directive enacted by the European Union in 2007. The third version of "Conto Energia" took place in 2010 with the introduction of specific tariffs for concentrating and innovative integrated PV plants. Additional amendments to this bill took place until its 5h version, which was introduced in 2012.

In 2011 Italy saw an explosion in PV installed capacity, which went from 3.5 GW to 12.8 GW (a massive 9 GW of power added). This boom responded to the awareness of the market about the benefits of the PV incentives, which had an effect on the development of solar parks. By the end of the solar boom in 2011, Italy was only second in the world, after Germany, when it came to installed capacity. Whereas the increasing trend continued in 2012, the following years evidenced a smoother growth pattern, due to the cessation of the governmental subsidy scheme in July 2013. In 2022, however, Italy made its largest addition to solar generation since 2012, with about 3 GW of new capacity.

[1] STEM Scenarios (sccer-jasm.ch)

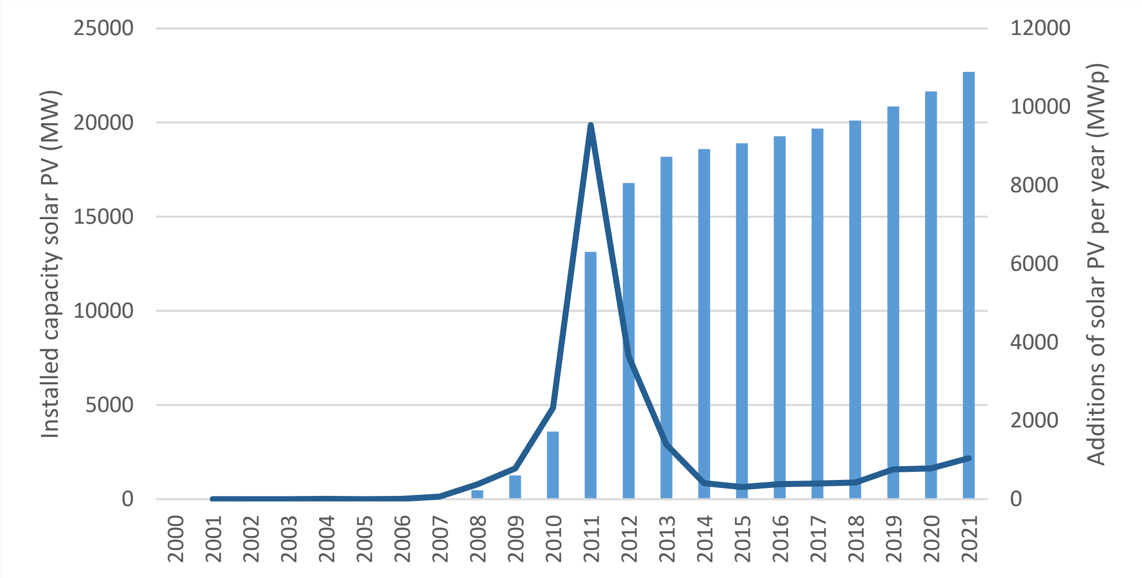

Figure 3 Development of solar PV in Italy: Yearly and cumulative installations

Table 2 Development of solar PV in Italy: Yearly and cumulative installations

Year	Installed solar PV capacity (MW)	Additions of solar PV (calculated by the author)
2000	19	
2001	20	1
2002	22	2
2003	26	4
2004	31	5
2005	34	3
2006	45	11
2007	110	65
2008	483	373
2009	1264	781
2010	3592	2328
2011	13131	9539
2012	16785	3654
2013	18185	1400
2014	18594	409
2015	18901	307
2016	19283	382
2017	19682	399
2018	20108	425
2019	20865	758
2020	21650	785
2021	22692	1042

Source: IRENA (2022), IRENASTAT Online Data Query Tool, Renewable energy statistics 2022, International Renewable Energy Agency (IRENA), Abu Dhabi. URL: https://pxweb.irena.org/pxweb/en/IRENASTAT/IRENASTAT__Power%20Capacity%20and%20Generation/RE-ELECGEN_2022_cycle2.px/

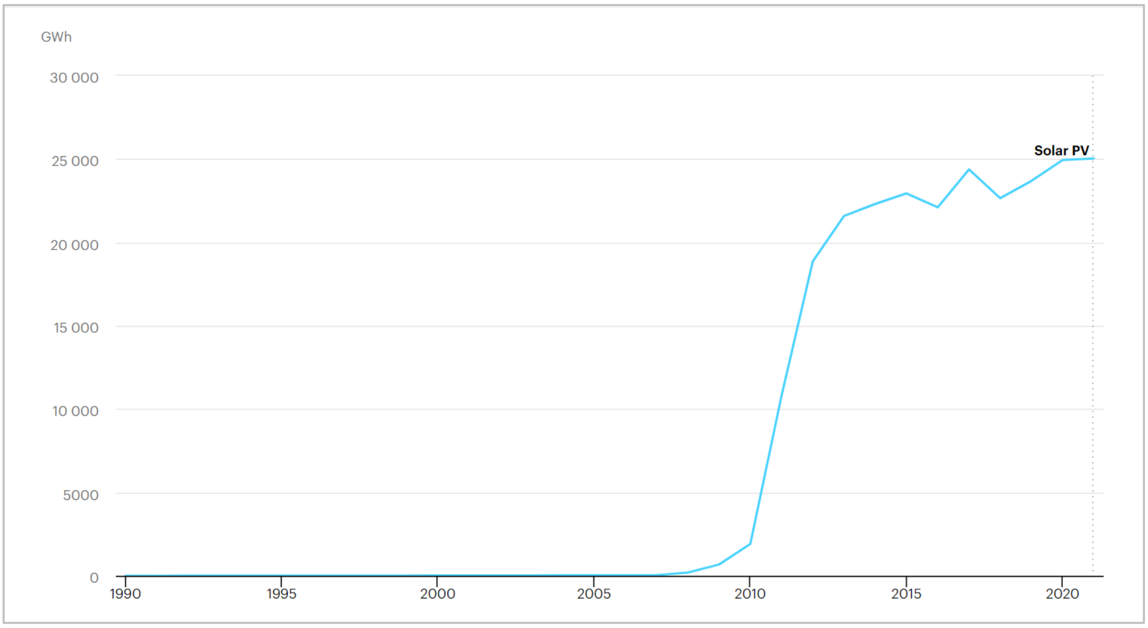

Figure 4 Solar PV electricity generation in Italy

Source: IEA (2020)

2.3. REPLICATION IN THE UK

2.3.1. BACKGROUND

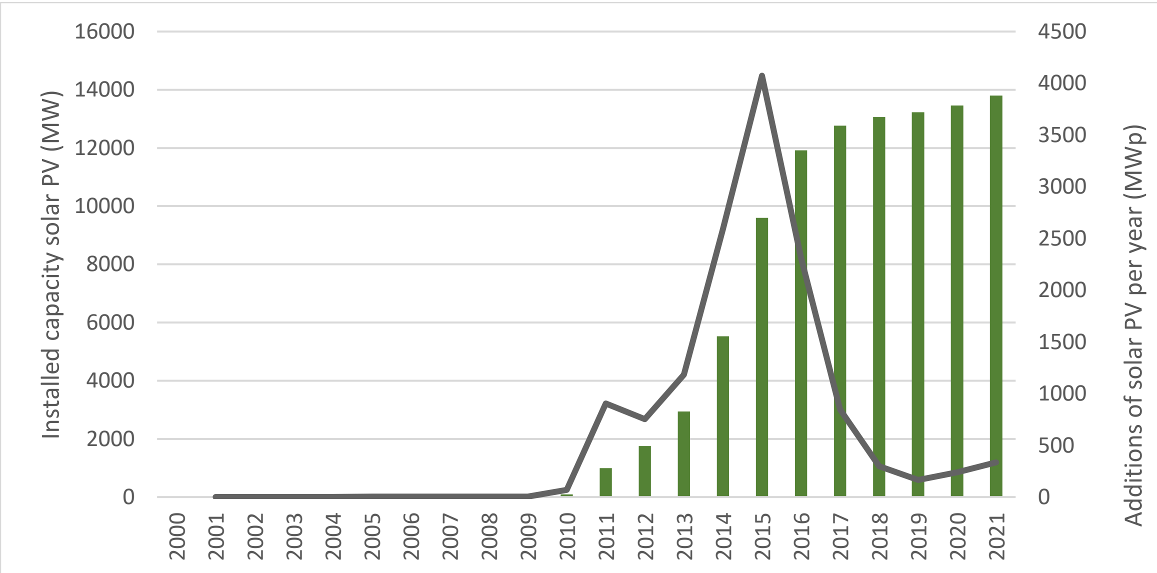

Figure 5 Development of solar PV in the UK: Yearly and cumulative installations

Table 3 Development of solar PV in the UK: Yearly and cumulative installations

Year	Installed solar PV capacity (MW)	Additions of solar PV (calculated by the author)
2000	2	
2001	3	1
2002	4	1
2003	6	2
2004	8	2
2005	11	3
2006	14	3
2007	18	4
2008	23	5
2009	27	4
2010	95	68
2011	1000	905
2012	1754	754
2013	2937	1183
2014	5528	2591
2015	9601	4073
2016	11914	2313
2017	12760	846
2018	13059	299
2019	13224	165
2020	13462	238
2021	13799	337

Source: IRENA (2022), IRENASTAT Online Data Query Tool, Renewable energy statistics 2022, International Renewable Energy Agency (IRENA), Abu Dhabi. URL: https://pxweb.irena.org/pxweb/en/IRENASTAT/IRENASTAT__Power%20Capacity%20and%20Generation/RE-ELECGEN_2022_cycle2.px/

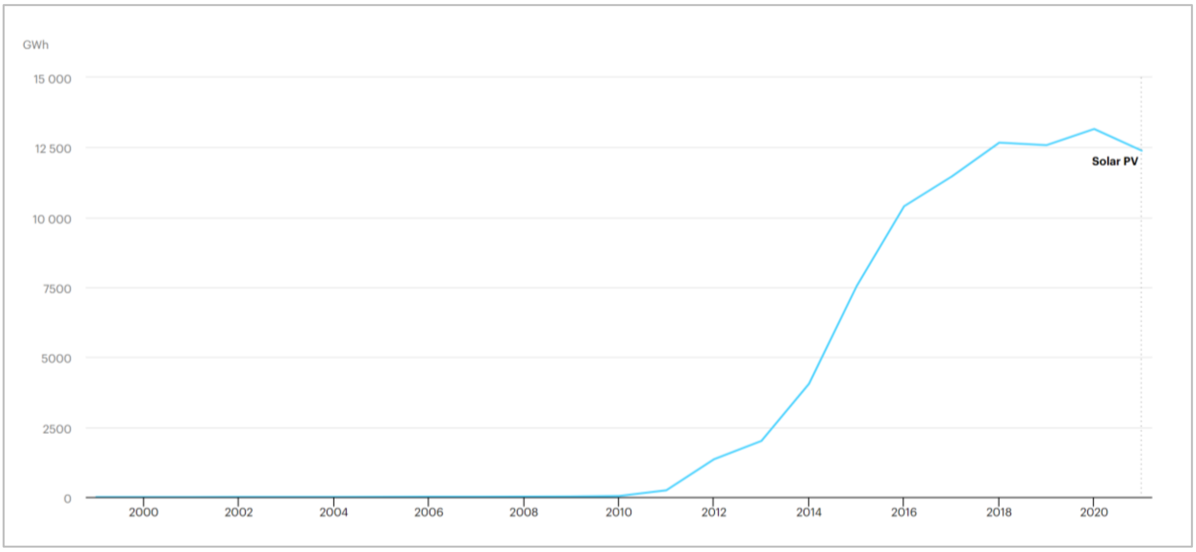

Figure 6 Solar PV electricity generation in the UK

Source: IEA (2020)

Driven by a dramatic decrease in the price of PV systems and key subsidy mechanisms, the UK has witnessed rapid growth in photovoltaic development during the last decade, going from 26 MW at the end of 2009 to almost 13 GW at the end of 2008 (i.e., 500% increase). The boom in installation was late, however, compared to other European countries. The introduction of a feed-in-tariff (FiT) subsidy in April 2010 (when installed capacity started to peak) was maintained until the end of March 2019 when it was withdrawn. Since January 2020, the government has offered "Smart Export Guarantees", which allows prosumers to be financially rewarded for sending excess energy to the national grid. The key segments driving current growth are coming from residential, large commercial rooftops and ground-mount sites. The residential segment is seeing strong growth nowadays, with the sector fully recovered from the reset that occurred at the start of 2019, when FiTs ended. New builds form the basis of this market recovery. Currently around 6% of the generated electricity in the UK comes from solar.

3. A NOTE ON MODEL PARAMETERS – GLOBAL HORIZONTAL IRRADIATION

A key parameter to update in the model for each country location, is the amount of solar irradiation. Global horizontal irradiation is the most important parameter for calculating the energy yield and performance of flat-plate PV. It refers to the amount of heat radiation received by a PV surface horizontal to the ground. The images below display the yearly totals of sunshine hours per region per selected country. Table x shows a country average of minimum and maximum values for the amount of peak sunshine hours per day (kWh/m2), which is the measure taken as input by the simulation model.

Table 4 Solar irradiation measures for Italy, Switzerland and the UK

Variable	Italy	Switzerland	UK
Peak sunshine hours per day (KWh/m2)	3.93 (Min: 2.92, Max: 4.93)	3.24 (Min: 2.61, Max: 3.87)	2.59 (Min: 2.1, Max: 3.07)
Specific photvoltaic power output (kWh/kWp)	3.61 (Min: 2.67, Max: 4.54)	3.23 (Min: 2.31, Max: 4.15)	2.51 (Min: 1.94, Max: 3.08)

Source: Global Solar Atlas (https://globalsolaratlas.info/map?c=8.581021,-42.363281,2&r=ITA)

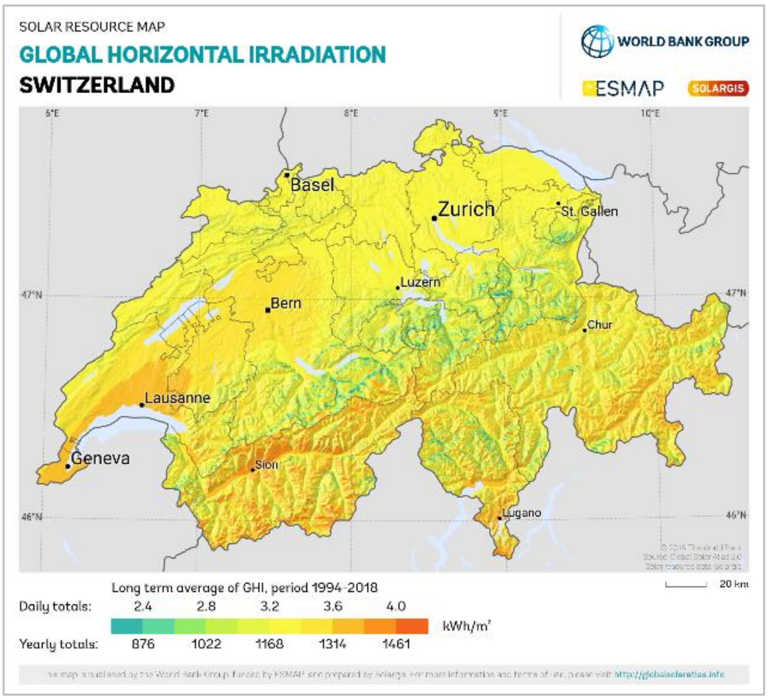

Figure 7 Switzerland's global horizontal irradiation (by region)

Source: Global Solar Atlas (https://globalsolaratlas.info/download/switzerland)

Figure 8 Italy's global horizontal irradiation (by region)

Source: Global Solar Atlas (https://globalsolaratlas.info/download/italy)

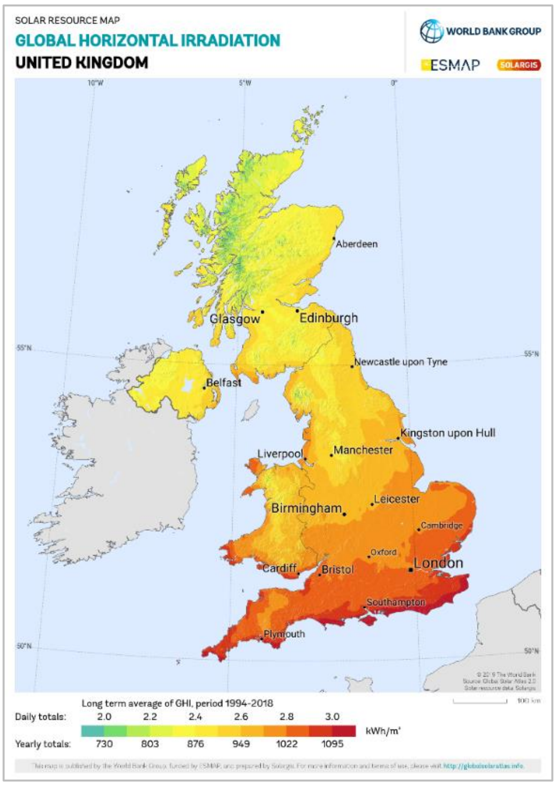

Figure 9 UK's global horizontal irradiation (by region)

Source: Global Solar Atlas (https://globalsolaratlas.info/download/united-kingdom)

4. RESULTS

4.1. RESULTS 1 (SWITZERLAND)

Although the production of solar power in Switzerland is higher than some Mediterranean countries, it is still below the European average. Expensive land costs and authorisation permits cause most PV systems to be located mostly on rooftops. More recently, the residential and commercial segments have performed strongly as a result of recent improvements in Switzerland's rebate scheme for PV installations coupled by an awareness and preoccupation on climate issues.

To study Switzerland's solar PV landscape, we propose three scenarios. The first (i.e., modest growth) mirrors the estimates proposed by Fraunhofer ISE (2015) for the long-term PV market growth. Based on experts' estimates, a realistic development of PV installations assumed a compound annual growth rate (CAGR) of 14% in the period of 2020-2030, 8% from 2030-2040, and 4% from 2040 onwards (these same assumptions are used for the other two country cases). Scenario 2 uses scenario 1 as a point of departure and adds 0.05% to the specified time cohorts. Scenario 3 does the same but in reference to scenario 2. The percentage addition for each scenario is proposed by the authors and is lower than the additions made to Italy and UK's growth rates where expansion is expected to be higher.

Table 5 Scenarios for model testing (Switzerland)

	Scenario 1	**Scenario 2**	**Scenario 3**
Growth rate	**Modest growth**	**Medium growth (+0.05)**	**High growth (+0.05)**
2020-2030	0.14	0.19	0.24
2030-2040	0.08	0.13	0.18
2040-2060	0.04	0.09	0.14

Most model parameter values remained as described in D1.3, except for the installation rate, the solar irradiation value detailed in the previous section and the assumed growth rates. PV system prices (i.e., modules and BOS components) were assumed to have experienced the same cost decrease as in the base model for Germany. These assumptions hold true for the other two country cases in this report. The table below shows simulation results for selected variables, including installed capacity and PV collected eligible for reuse and recycling. Results suggest that a constant growth rate in installations will not be enough to

reach Switzerland's climate targets. In order to replace the nuclear power that will be no longer available, and to cover the additional electricity demand for the electrification of transport and heating, the annual growth must be increased as done in Scenario 1, for instance. With the proposed growth rates of 14%, 8% and 4%, Switzerland reaches around 68 GW of installed capacity by 2050. This goes in accordance with Switzerland's national energy plan "Energy Strategy 2050", where the Swiss Ministry of Energy is targeting an installed solar PV capacity of 37.5 GW in 2050. This suggests that during this period a yearly installation rate of less than 1.8 GW/year would suffice to reach the government target. The question remains though as to how this will be achieved in the presence of slow market take up rates. The Swiss Solar Association has proposed the support for PV installations on other type of roofs (e.g., agricultural facilities) and building facades (integrated photovoltaics)

Table 6 Results of key output variables by scenario (Switzerland)

	Scenario 1		Scenario 2		Scenario 3	
Output variables	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
PV installed capacity (GW)	11.3	68.0	13.8	183.0	17.1	499.0
Electricity produced (TWh)	11.3	68.3	13.9	184.0	17.2	501.0
Installation rate (GW/year)	1.8	5.6	2.7	21.7	4.1	79.2
Potential for PV reuse ('000 tonnes)	0.2	0.7	0.2	2.0	2.8	5.2
Potential for PV recycle ('000 tonnes)	11.9	106.0	11.9	180.0	12.0	306.0
Cummulative PV reused ('000 tonnes)	0.2	2.1	2.5	3.8	0.3	7.0

Similar to the case of Germany, model results show limited potential for PV reuse (both in terms of volume and financially speaking). Besides having curtailed age cohorts (i.e., as explained in D1.3, this refers to the age cohorts of disposed PV that are suitable for reuse, repair or refurbishment) and installation trajectories (i.e., the shape and peak of the installation rate) as limiting factors for the collection of "potential PV for reuse", one must take into account other factors that curtail PV reuse: (i) actual collection targets and quotas, (ii) fraction of modules that can be economically repaired, (ii) actual market uptake of used modules. For CIRCUSOL this is of great importance since, as the simulation shows, recycling still will play a big role for the PV industry and continues to be a crucial activity that must be further developed, also in Switzerland.

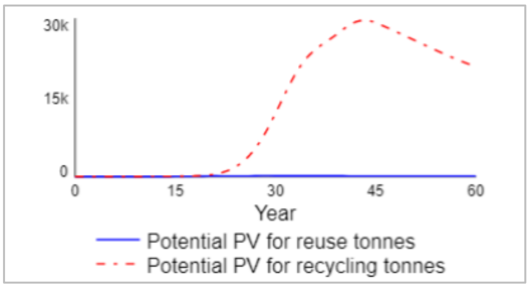

Figure 10 Tons of PV eligible for reuse and recycling in Switzerland (Scenario 1)

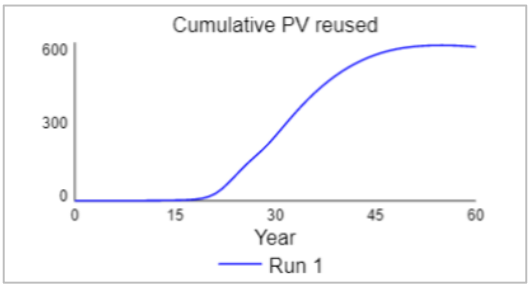

Figure 11 Cumulative PV reused in Switzerland (Scenario 1)

Graphs below show results when a constant growth rate in installations is assumed. Financially speaking, LCOE results show 2nd life PV is not economically attractive when compared to new PV. In some cases, however, the willingness to pay could be high for 2nd life PV even when it is not profitable. As explained in D1.3, examples include customers driven by environmental concerns, such as in the case of the cohousing projects, or very specific market segments (e.g., hospitals, schools) for whom the influence of aesthetics and space requirements is not that strong. Other CIRCUSOL deliverables have provided empirical evidence for this.

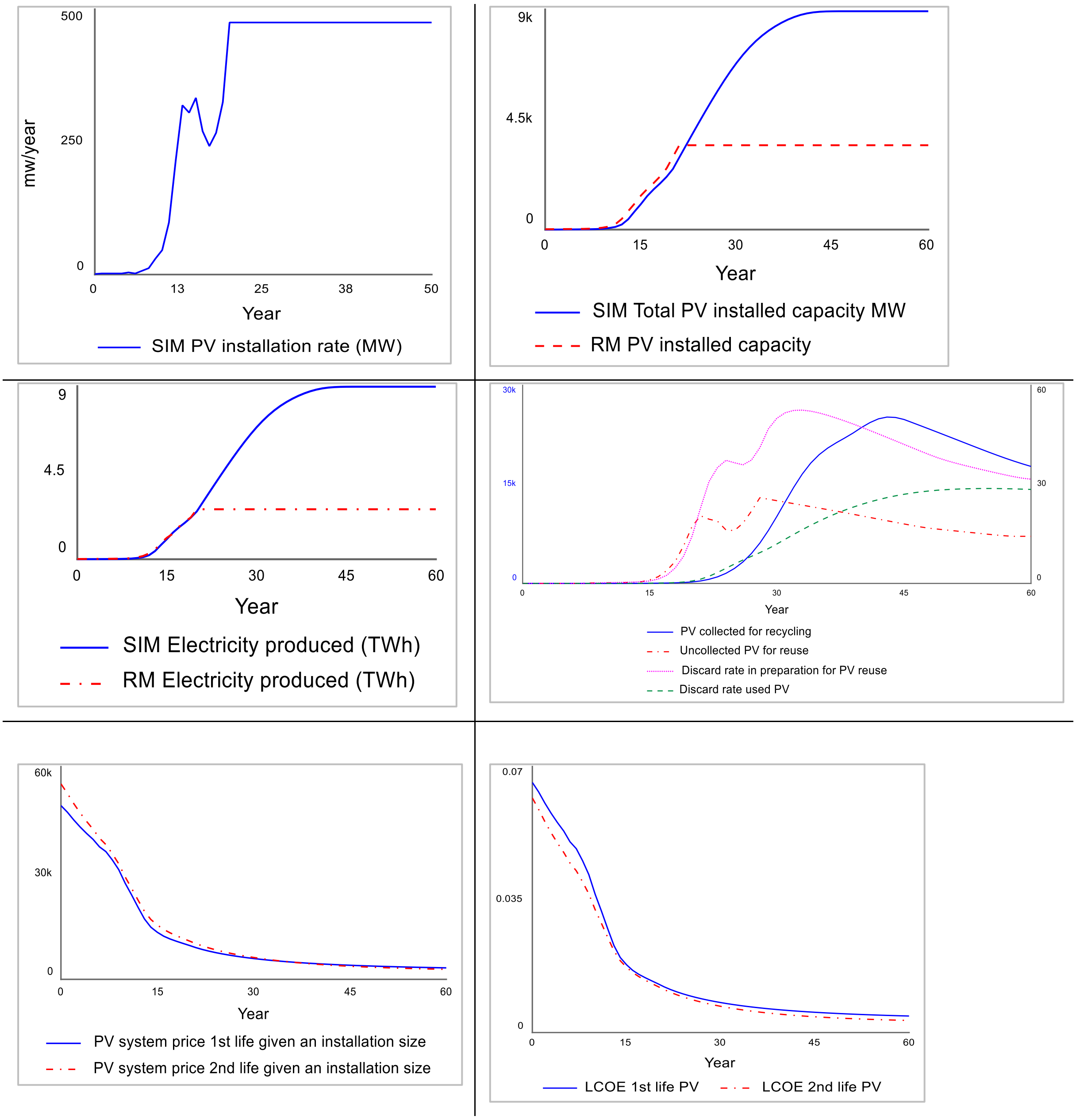

Figure 12 Key model results with constant growth rate in installations (Switzerland)

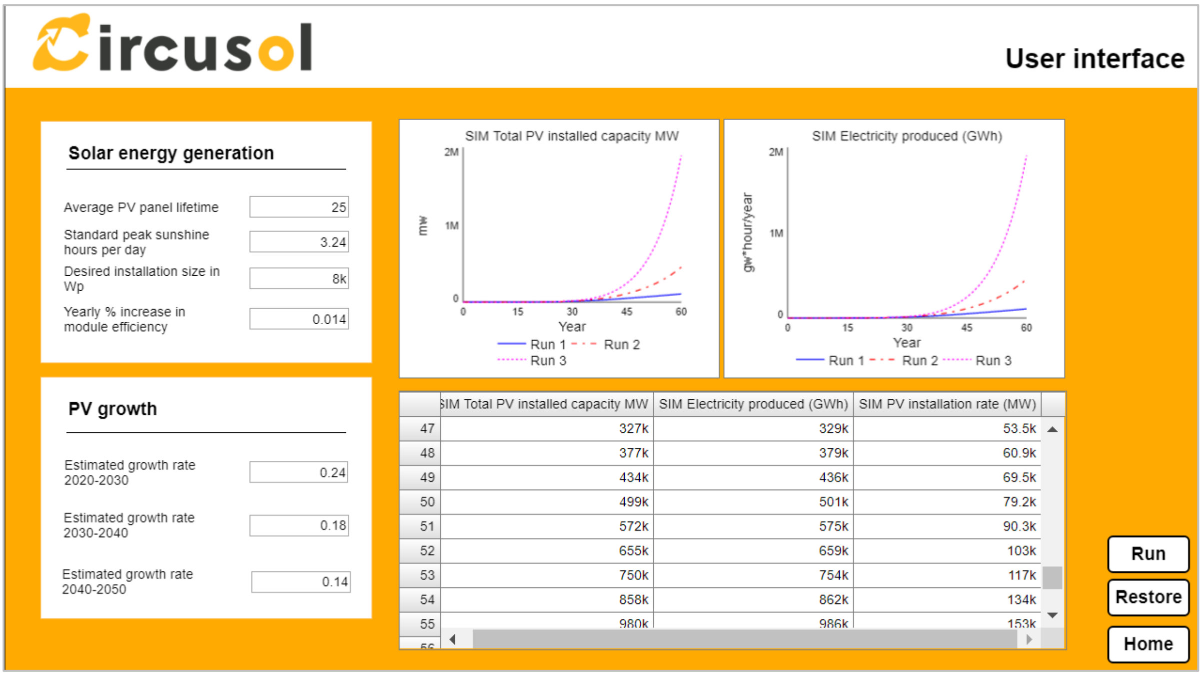

Figure 13 Model results for selected variables 1. [Run 1 (Scenario 1), Run 2 (Scenario 2), Run 3 (Scenario 3)].

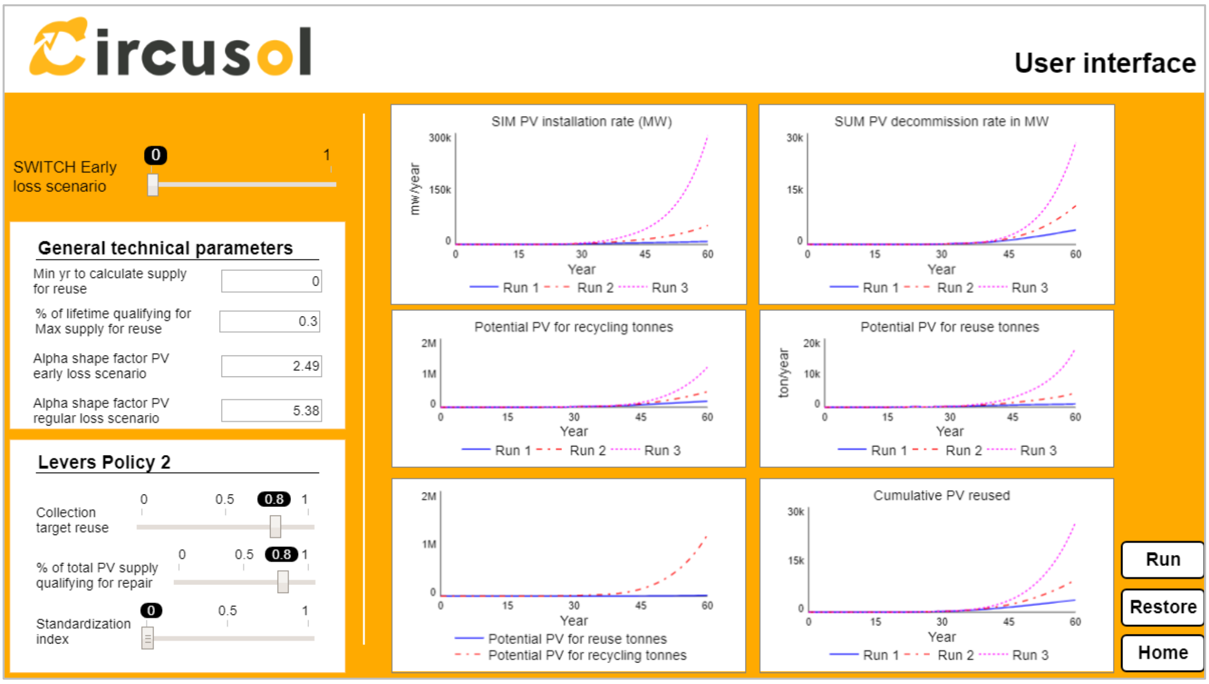

Figure 14 Model results for selected variables 2. [Run 1 (Scenario 1), Run 2 (Scenario 2), Run 3 (Scenario 3)].

4.1.1. FURTHER DEVELOPMENT WORKSHOPS

BUAS organized five focus groups in Switzerland and Belgium in cooperation with VITO. The aim was to evaluate the replication potential of the demonstration projects in the respective countries. Based on the experiences in the demonstration projects, the focus was on companies, public institutions, and social organizations, since private customers turned out not to be a suitable target group for second-hand PV modules in a PSS sales model (see, in particular, the BKW demonstrator). The selection of target countries for the evaluation of the extension potential of the ideas generated in the CIRCUSOL project was primarily based on the following two criteria: (1)

Proximity of research institutions and (2) knowledge of the market (especially regulatory circumstances). This to be able to deliver timely results before CIRCUOSL ends.

Since social organizations are less common in Switzerland, it was only possible to find participants for the focus groups with companies and public institutions in Switzerland. In Belgium, on the other hand, all three focus groups could be conducted. All focus groups were conducted in the respective national language and accompanied by the respective researchers involved (Swiss researchers for focus groups in Belgium and vice versa).

Through the intensive examination of the topic, contacts could be made in Switzerland for follow-up projects that go beyond CIRCUSOL. The researchers in Switzerland found that there is a high interest in the business model of reuse of PV systems, which are currently in progress be realized on the exchange of information via a data platform. Further clarifications with the solar industry association Swissolar and the collection network SENS confirmed this interest, and a follow-up project can now be realized. The project receives financial and non-material support from the Swiss Federal Office of Energy and the Federal Office for the Environment. In Belgium, comparable projects have not been able to build on the findings, mainly because the regulatory environment is changing significantly. The following sections detail the data gathering focus groups which manifest the potential to replicate or extend the insights gained by CIRCUSOL on a national level. The annex shows more details on the workshops conducted in Switzerland.

4.2. RESULTS 2 (ITALY)

Despite a deacceleration in the PV installation rate after 2011-2012, following cuts in government subsidies, Italy is expected to see its installed base of PV installations grow in the upcoming decades. Factors such as supportive government policies and efforts to meet power demand from renewable energy sources look forward to driving market growth in the future. Such growth is furthermore fueled by further cuts in systems prices as installed capacity increases.

To study Italy's PV landscape, three scenarios were developed. The first (i.e., modest growth) mirrors the estimates described in Fraunhofer ISE (2015) for the long-term growth of PV market development. Based on experts' estimates, a realistic development of PV installations assumed a compound annual growth rate (CAGR) of 14% in the period of 2020-2030, 8% from 2030-2040, and 4% from 2040 onwards. Scenario 2 uses scenario 1 as a point of departure and adds 0.08% to the specified time cohorts. Scenario 3 does the same but in reference to scenario 2.

Table 7 Scenarios for model testing (Italy)

	Scenario 1	**Scenario 2**	**Scenario 3**
Growth rate	**Modest growth**	**Medium growth (+0.08)**	**High growth (+0.08)**
2020-2030	0.14	0.22	0.30
2030-2040	0.08	0.16	0.24
2040-2060	0.04	0.12	0.20

The table below shows model results for selected output variables including installed capacity, electricity produced, installation rate and tonnes of potential PV available for reuse and recycling ("in preparation for reuse" and “in preparation for recycling”). The years 2030 and 2050 were selected as reference. Results suggest that in the modest and medium growth scenarios (1 and 2), Italy does not reach its intended 50 GW of PV installed capacity by 2030.

This is achieved only in the aggressive growth scenario (Italy’s National Integrated Plan for Climate and Energy aims for 50 GW of solar by 2030). Finally, just as in the results obtained in the base model, even when the installation rate increases, the number of tonnes available for PV reuse do not increase dramatically. Furthermore, they are only a small percentage of the volume available for recycling.

Table 8 Results of key output variables by scenario (Italy)

	Scenario 1		Scenario 2		Scenario 3	
Output variables	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
PV installed capacity (GW)	28	112	35	552	46	2720
Electricity produced (TWh)	34	137	43	673	56	3320
Installation rate (GW/year)	3	9	6	79	11	576
Potential for PV reuse ('000 tonnes)	0.30	1.19	0.36	6	0.43	26
Potential for PV recycle ('000 tonnes)	184	175	184	409	184	956
Cummulative PV reused ('000 tonnes)	2	4	2	10	2	26

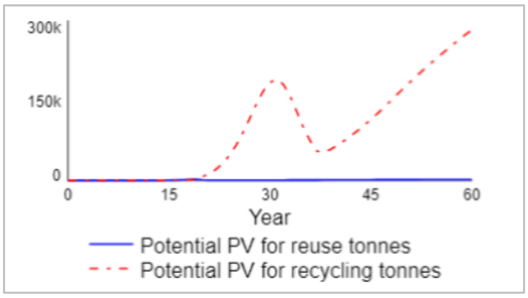

Figure 15 Tons of PV eligible for reuse and recycling in Italy (Scenario 1)

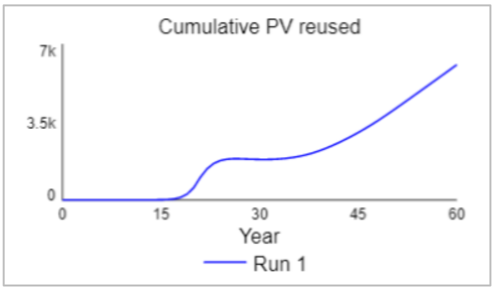

Figure 16 Cumulative PV reused in Italy (Scenario 1)

Output graphs below show similar value for a scenario where the installation rate is kept constant at around 1000 MW/year. This is to check the effect on selected model variables even when growth does not take place. Again, mirroring the results of Germany’s model, LCEO (levelized cost of electricity) results suggest second-life PV is not financially attractive to buyers. It is still more attractive to get new PV modules with higher efficiency, longer lifetime, lower costs and less space requirements. This is especially true in the case of countries, such as Italy, where government incentives to deploy PV are expected to make installations even more attractive.

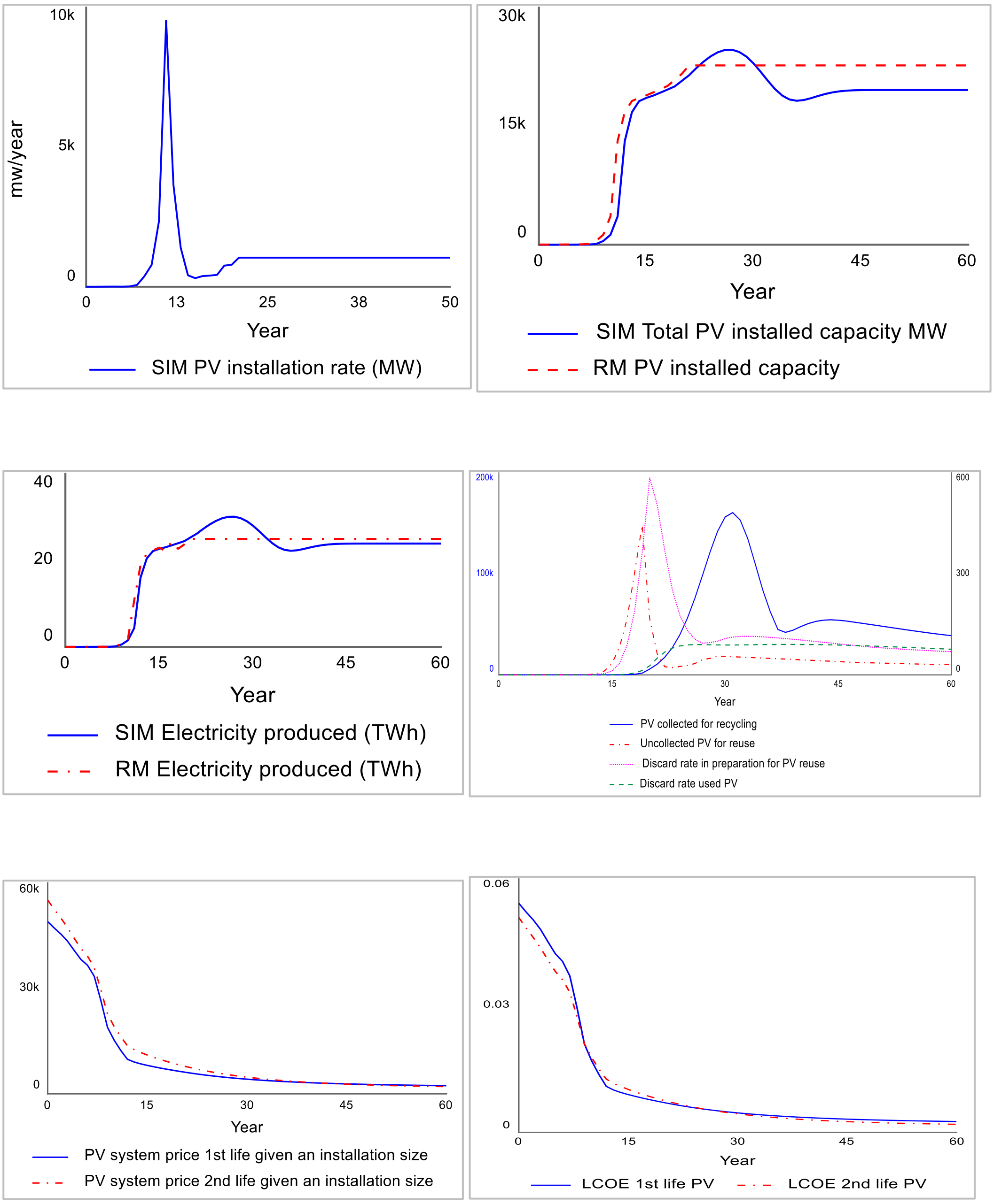

Figure 17 Key model results with constant growth rate in installations (Italy)

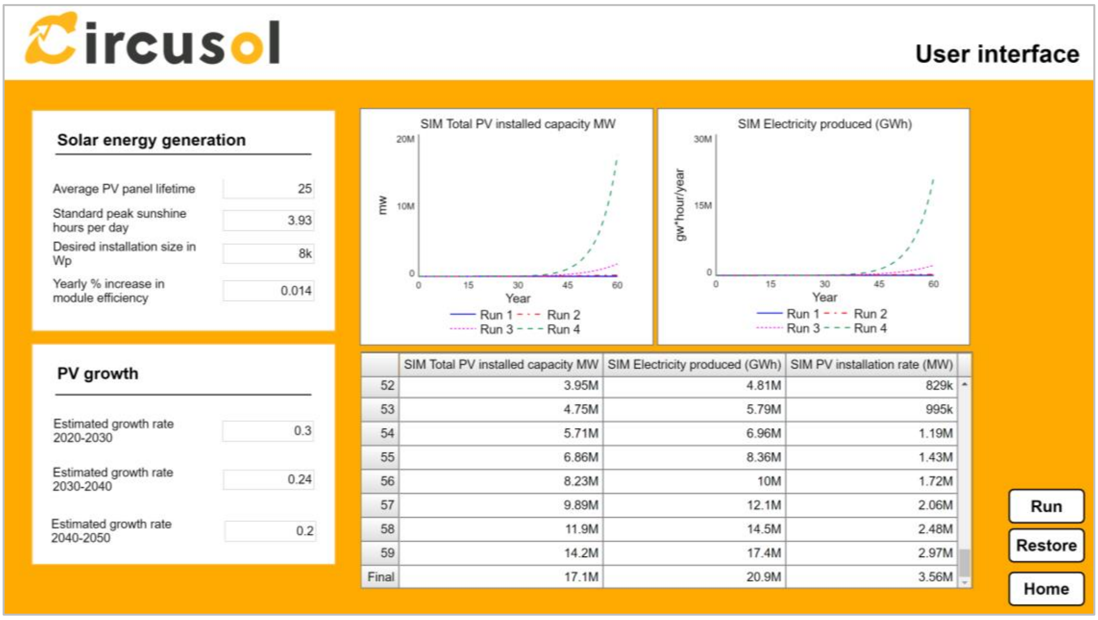

Figure 18 Model results for selected variables 1. [Run 1 (constant growth in PV installations), Run 2 (Scenario 1), Run 3 (Scenario 2), Run 4 (Scenario 3)].

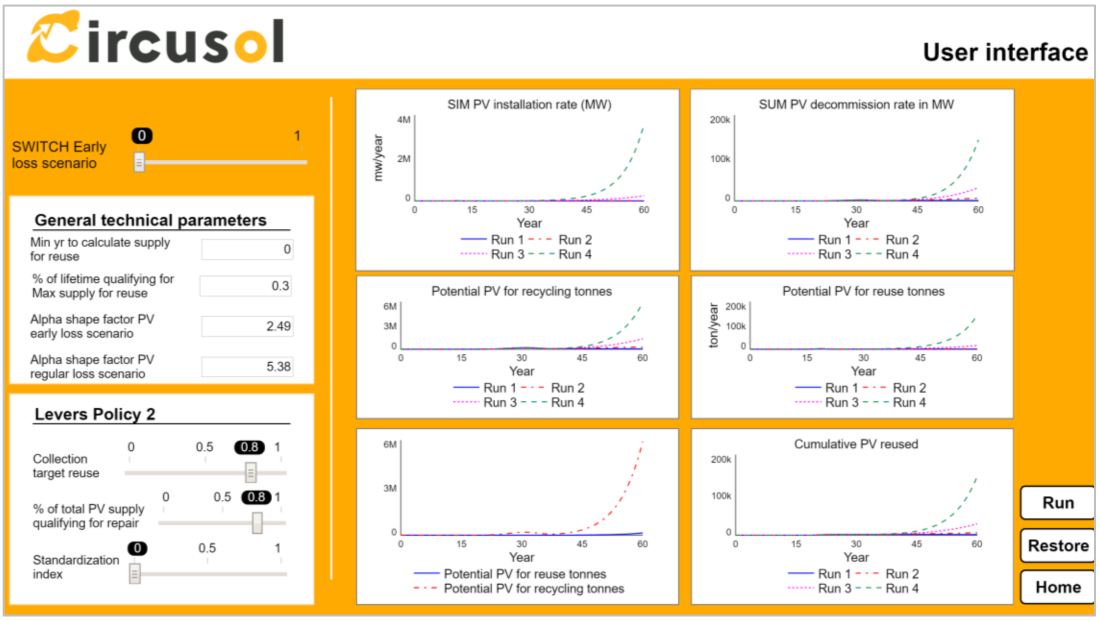

Figure 19 Model results for selected variables 2. [Run 1 (constant growth in PV installations), Run 2 (Scenario 1), Run 3 (Scenario 2), Run 4 (Scenario 3)].

4.3. RESULTS 3 (UNITED KINGDOM)

From 11 MW of installed capacity in 2011 to around 13000 MW in 2021, the UK has seen an explosion in installations during the past few years. After a "solar stagnation when the FIT scheme was taken down by the government, rising numbers in installations during 2021 and 2021 show the potential that is yet to be tapped in the UK market.

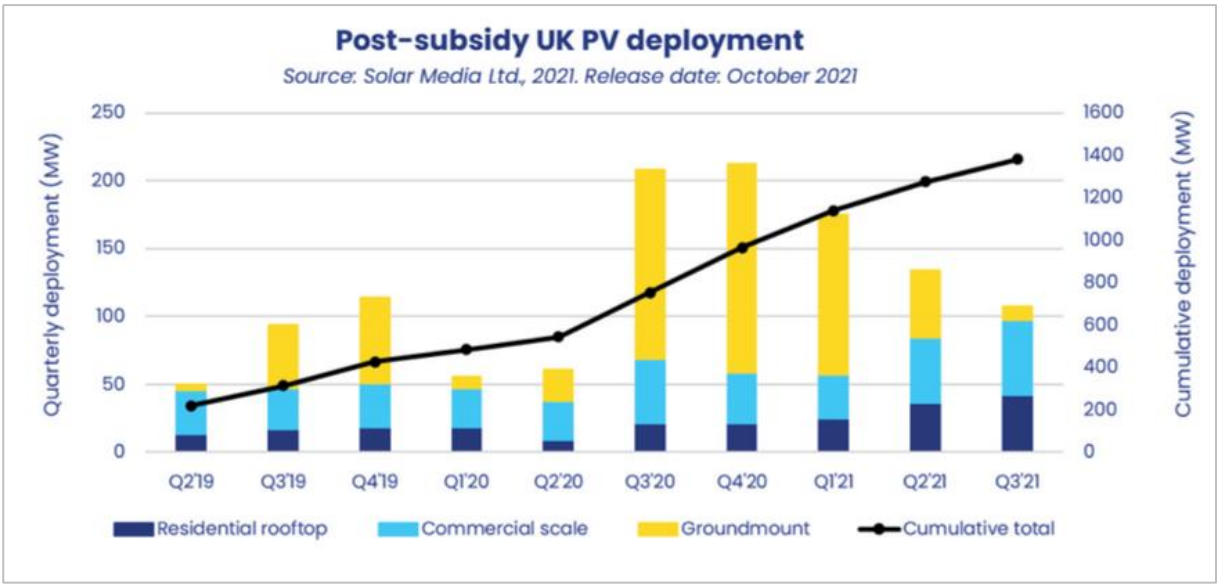

Figure 20 Post-subsidy UK PV deployment

Source: Solar Energy UK (2022)

Model testing for the UK case resembles the past two country cases, where modest, medium and high growth scenarios are introduced. As in the case of Italy, the growth addition from Scenario 2 and Scenario 3 are set to 0.08 percentual points departing from Scenario 1 and Scenario 2, respectively.

Table 9 Scenarios for model testing (UK)

	Scenario 1	**Scenario 2**	**Scenario 3**
Growth rate	**Modest growth**	**Medium growth (+0.08)**	**High growth (+0.08)**
2020-2030	0.14	0.22	0.30
2030-2040	0.08	0.16	0.24
2040-2060	0.04	0.12	0.20

Results show that not even in the forecasted high growth scenario will the UK able to reach 40 GW of cumulative deployment by the start of 2030 to keep up with net-zero climate policy proposed by the government. As in the previous sections, we see volumes of second-life PV being only a minimum fraction of the PV volume available for recycling (no more than 2% every year).

Table 10 Results of key output variables by scenario (UK)

	Scenario 1		Scenario 2		Scenario 3	
Output variables	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
PV installed capacity (GW)	15.7	34.1	17.9	167.0	21.3	825.0
Electricity produced (TWh)	12.6	27.4	14.4	135.0	17.1	663.0
Installation rate (GW/year)	0.9	2.8	1.7	23.8	3.3	175.0
Potential for PV reuse ('000 tonnes)	0.1	0.4	0.1	1.8	1.3	8.0
Potential for PV recycle ('000 tonnes)	68.8	52.9	68.8	124.0	68.8	290.0
Cummulative PV reused ('000 tonnes)	1.2	1.5	1.2	3.2	1.2	8.0

Pictures below show model results for selected model variables.

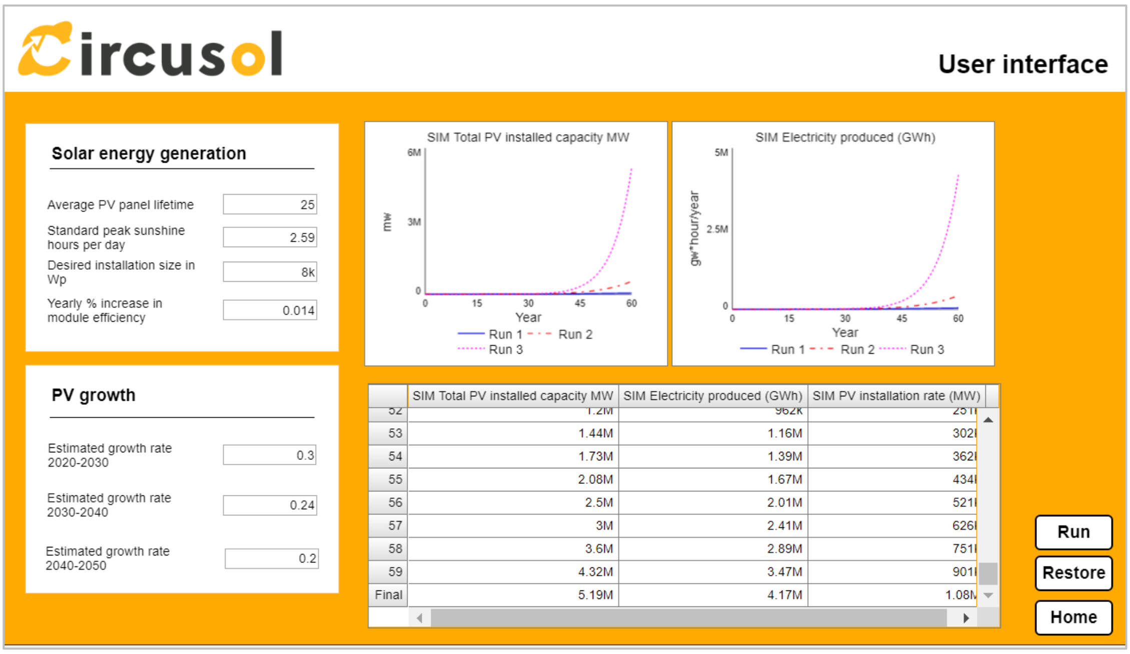

Figure 21 Model results for selected variables 1. [Run 1 (constant growth in PV installations), Run 2 (Scenario 1), Run 3 (Scenario 2), Run 4 (Scenario 3)].

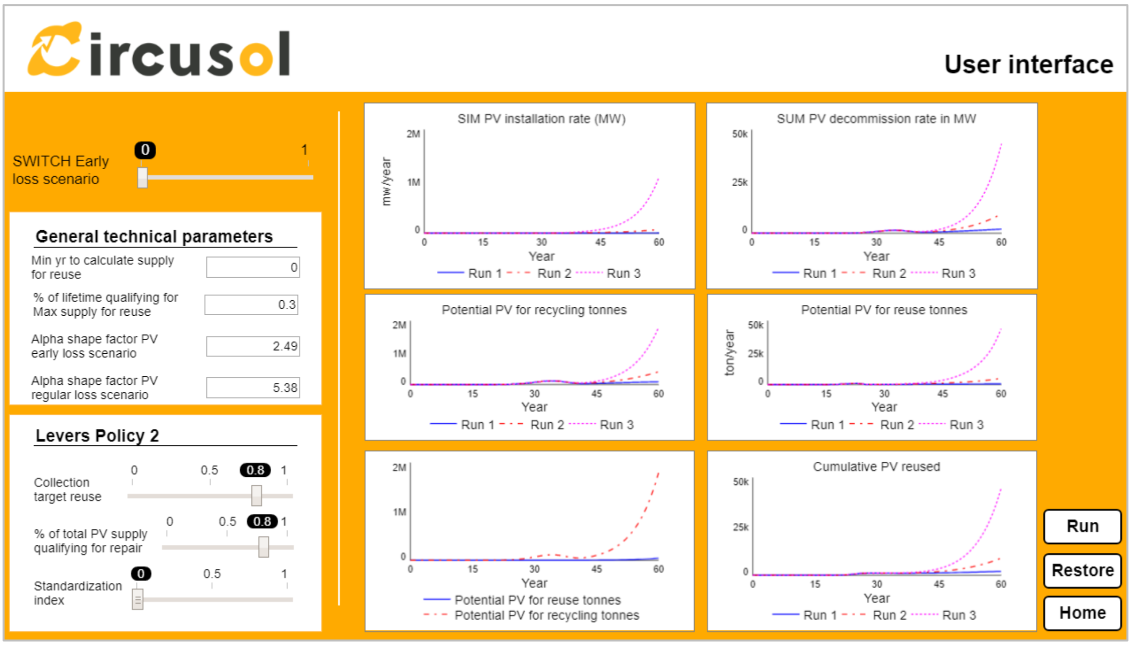

Figure 22 Model results for selected variables 2. [Run 1 (constant growth in PV installations), Run 2 (Scenario 1), Run 3 (Scenario 2), Run 4 (Scenario 3)].

5. CONCLUSION

The System Dynamics model structure developed for Task 1.3 and explained in detail in its corresponding report (D1.3) has been used to examine selected variables in the three selected country cases. As evidenced in this report, an end to FIT schemes all over Europe during the past years (perhaps with the introduction of new government subsidy mechanisms afterwards) has caused the deacceleration of yearly PV installation rates after a peak during the period from 2010 to 2015. This is often referred to as a “solar coaster” featuring peaks and troughs created by government feed-in-tariffs through which prosumers received payments for energy fed into the grid.

In spite of the slow-down, continuing fall in the cost of panels and other BOS components, coupled with supporting technologies such as household batteries for residential energy storage, are expected to compensate for curtailed subsidy support and the decreasing installation rate. Furthermore, A deeper understanding on climate change issues and its consequences, as well as rocketing gas and fuel prices worldwide, are becoming the motivators for residential, commercial, and industry electricity users to consider a switch to solar photovoltaics.

Overall, a higher level of policy ambition is still needed to achieve the different climate targets proposed by the three countries under study. In none of the cases will business-as-usual, low or moderate-ambition growth scenarios generate the MW of installed capacity needed to reach net-zero commitments. Bigger policy changes are needed that can support investment in and uptake of solar PV in larger numbers. Regarding reuse and recycling, two topics central to the CIRCUSOL project, results from the main model applied to Germany also applied to the country cases outlined in this report.

Policy wise, supporting eco-design, addressing premature defects on PV panels (to support the expected big volumes of recycling) and establishing targets for the recovery of critical raw materials at end-of-life are decisions worth taking a look at. In the reuse realm, simulation results, as well as more qualitative studies developed by other CIRCUSOL partners, have evidenced the extent to which second-life panels can be catered to niche applications in different industry sectors. This is also supported by the low volumes expected to reach the “in preparation for recycle” stream, which is affected by a number of variables including age cohorts of suitable panels, fractions of “suitable for repair/refurbish” panels, collection percentages and market uptake. All overall, when looking at particular country locations, other types of studies are need to define to which applications will second-life panels be suitable.

6. ACKNOWLEDGEMENTS

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8. ANNEX ABOUT DEVELOPMENT WORKSHOPS

8.1. WORKSHOP ABOUT DATABASE REQUIREMENTS

Date: 06/04/2022

Location: Online – Microsoft Teams

Duration: 2u30

Means of information sharing and input gathering: PowerPoint presentation, discussion questions, Miro boards

Moderators: Roger Nyffenegger and Ässia Boukhatmi (BUAS)

Participants:

Participant ID	Professional position	Stakeholder type
1	Owner and Chairman of the Board	Building material manufacturer and trade
2	Building Asset Manager	Insurance company
3	Head of Climate Strategy	Retail and wholesale company
4	COO	Chocolate Manufacturer
5	Head of Environment and Energy	Provider for industrial and business parks
6	Project Manager Energy Efficiency & Climate Protection Projects	Retail company and association of cooperatives
7	Architect & Business Unit Manager	Real estate company
8	Head of operations	Company for conveyor technology

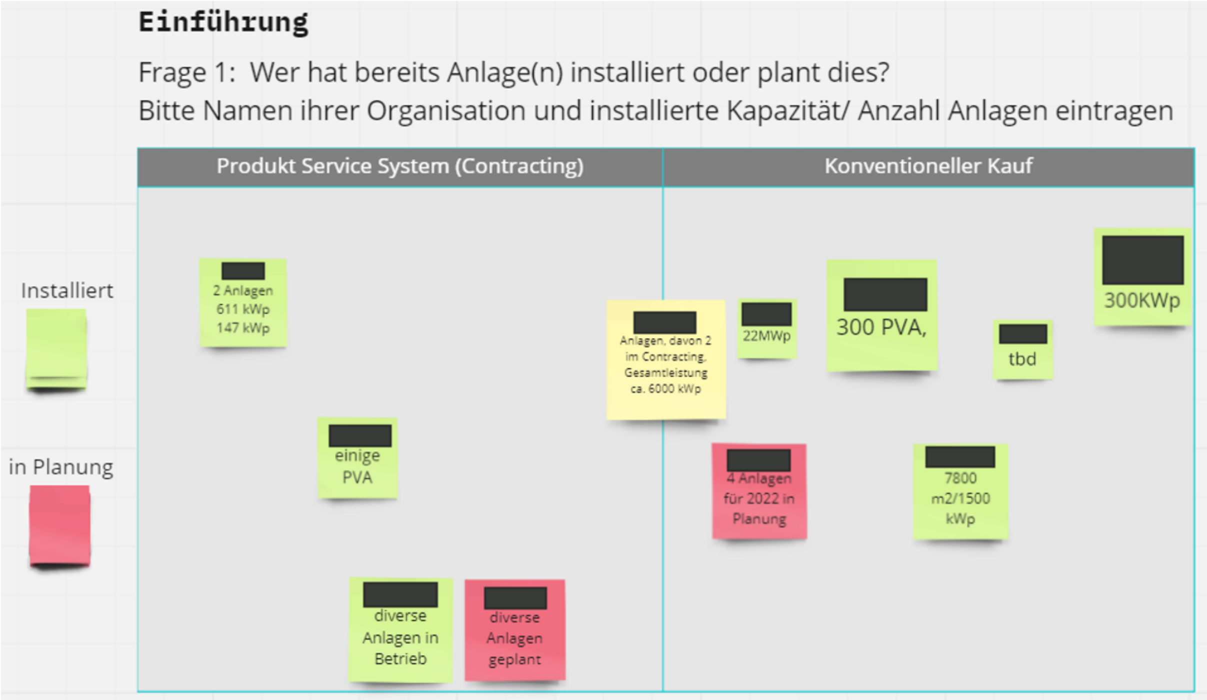
Discussion questions

1. Introduction: Who has already installed system(s) or is planning to do so?
2. Please evaluate the advantages and disadvantages of PSS models (or contracting) compared to conventional purchase of PV systems (under consideration of economic, technological, ecological, and legal aspects).
3. How do you evaluate the different end-of-life options? What enablers and barriers do you see with regard to the different end-of-life options?
4. Assessment of advantages and disadvantages, incentives, and barriers to the release of information on installed equipment.

   Data/information to be released:

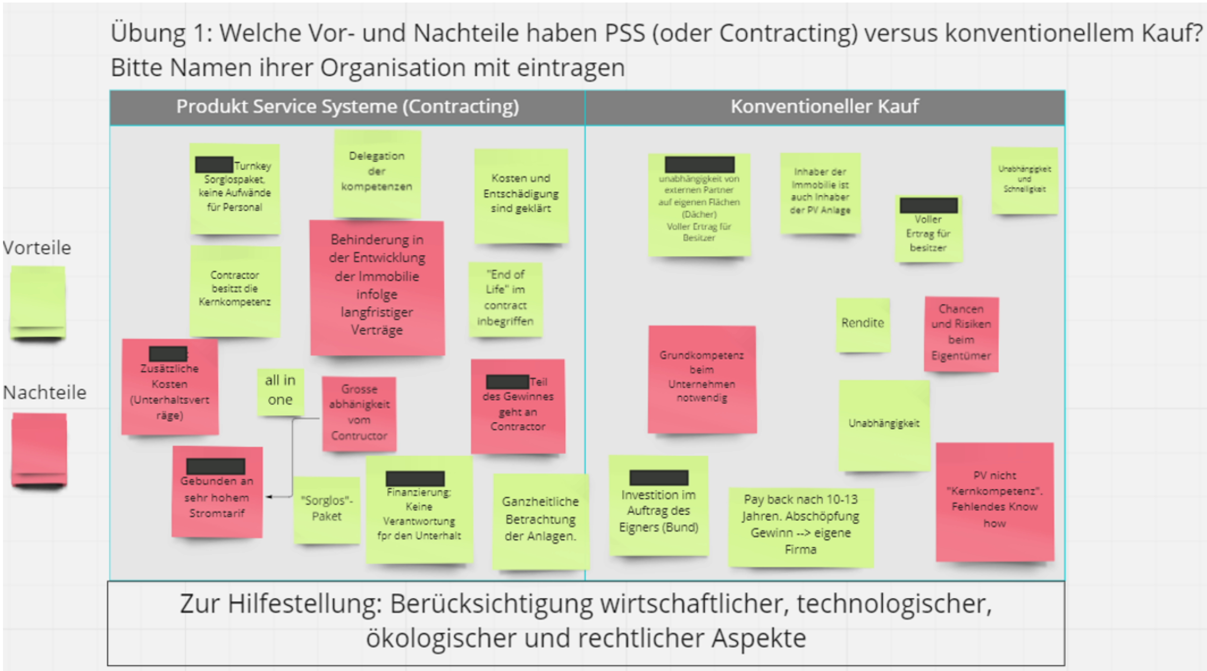
   - Location of the installation
   - Installation date
   - Production dates of the installation
   - Information on maintenance of the installation
   - General

Miro-board exercises



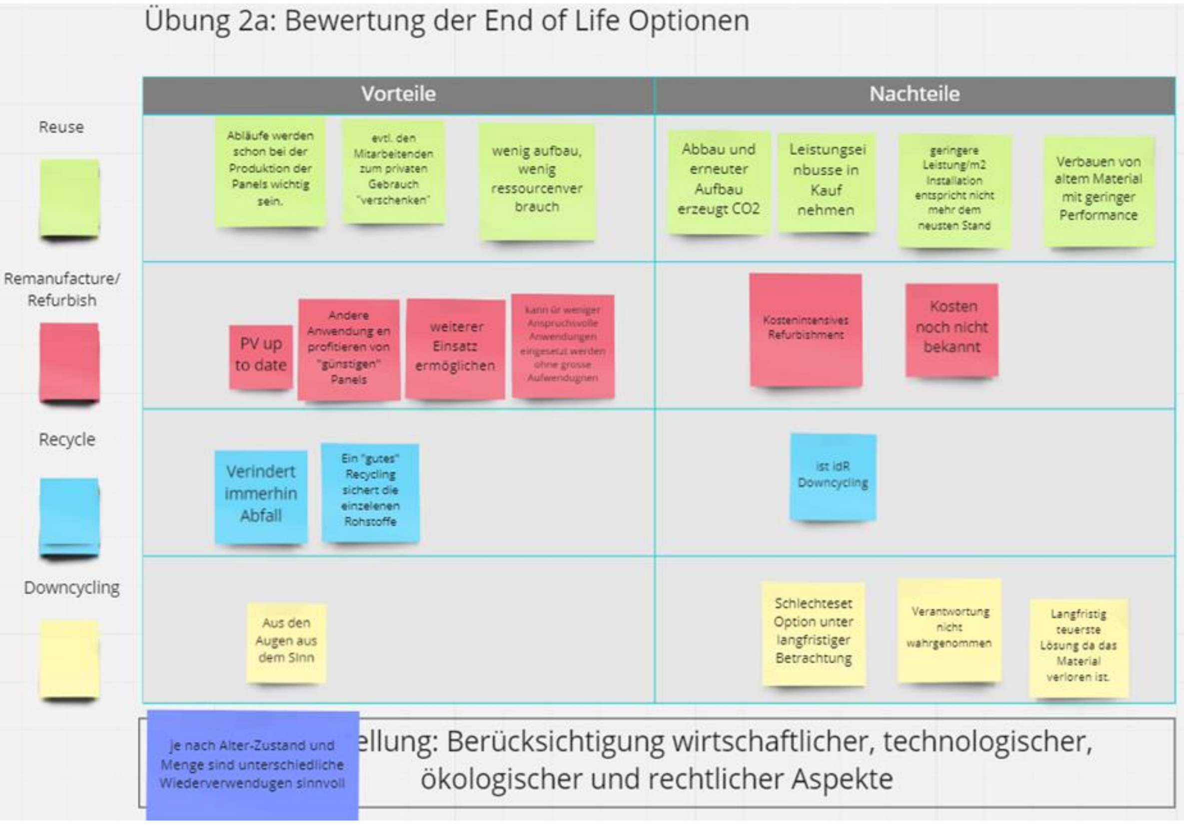
Note: company names have been anonymized

Exercise 1: Advantages and disadvantages of PSS vs PV purchase

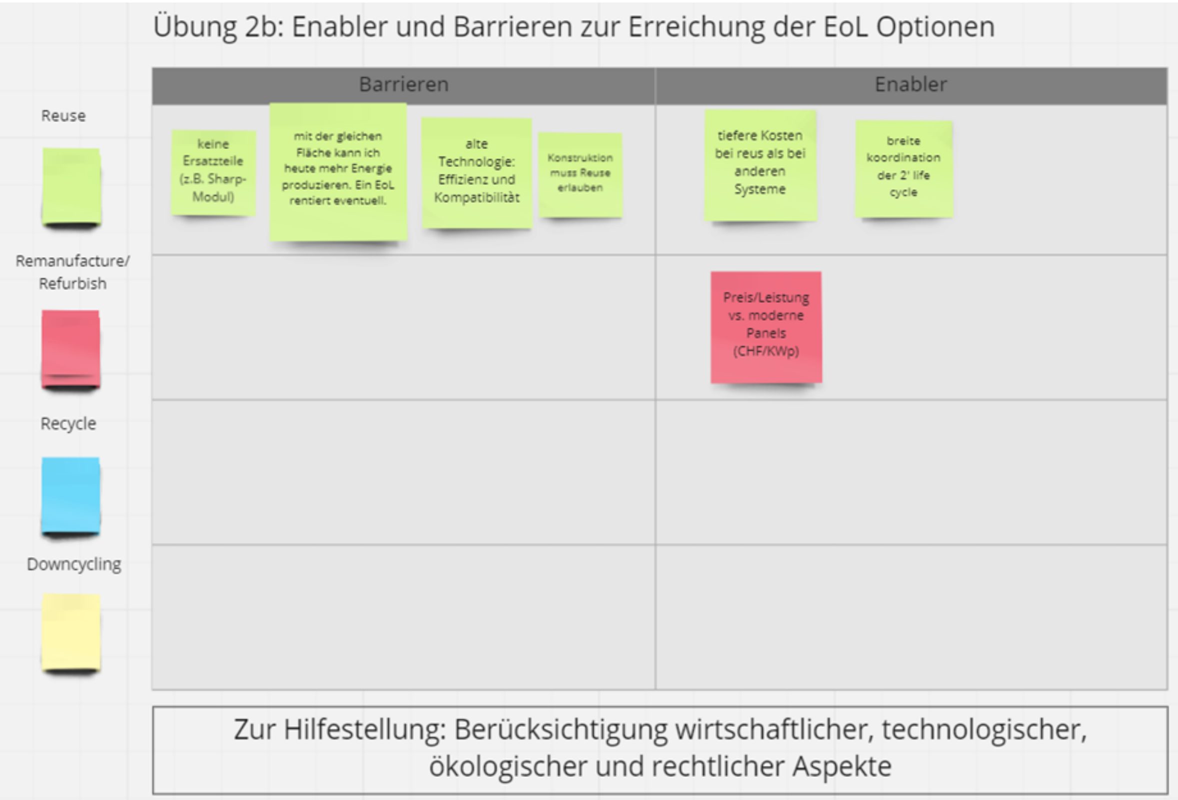


Note: company names have been anonymized

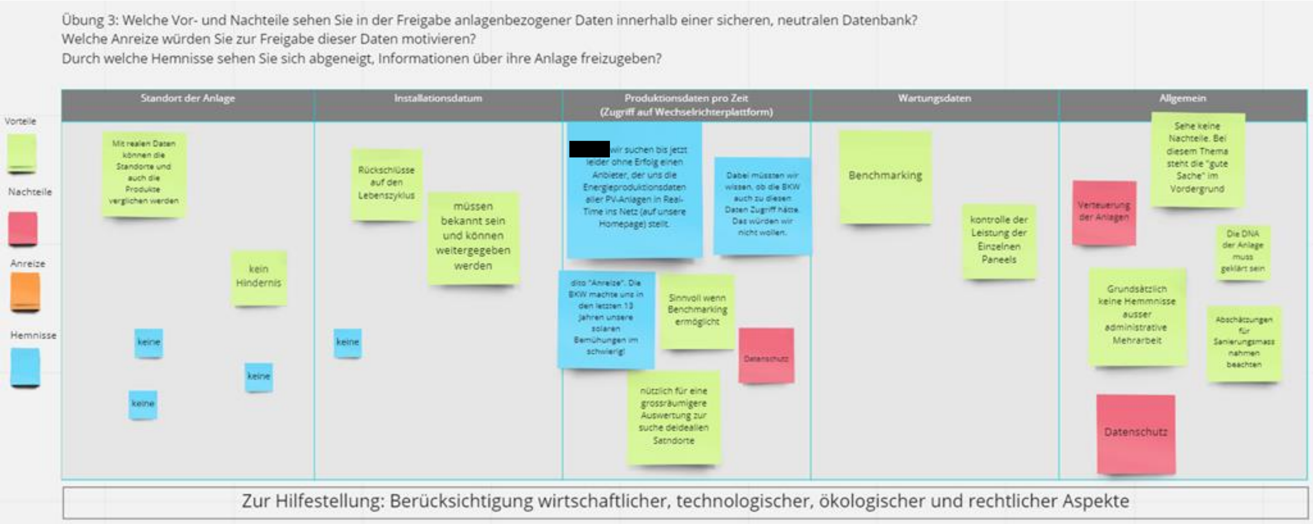
Exercise 2a: Evaluation of different End-of-Life options



Exercise 2b: Enabler and barriers of different End-of-Life options



Exercise 3: Advantages and disadvantages of data disclosure on a neutral data hub

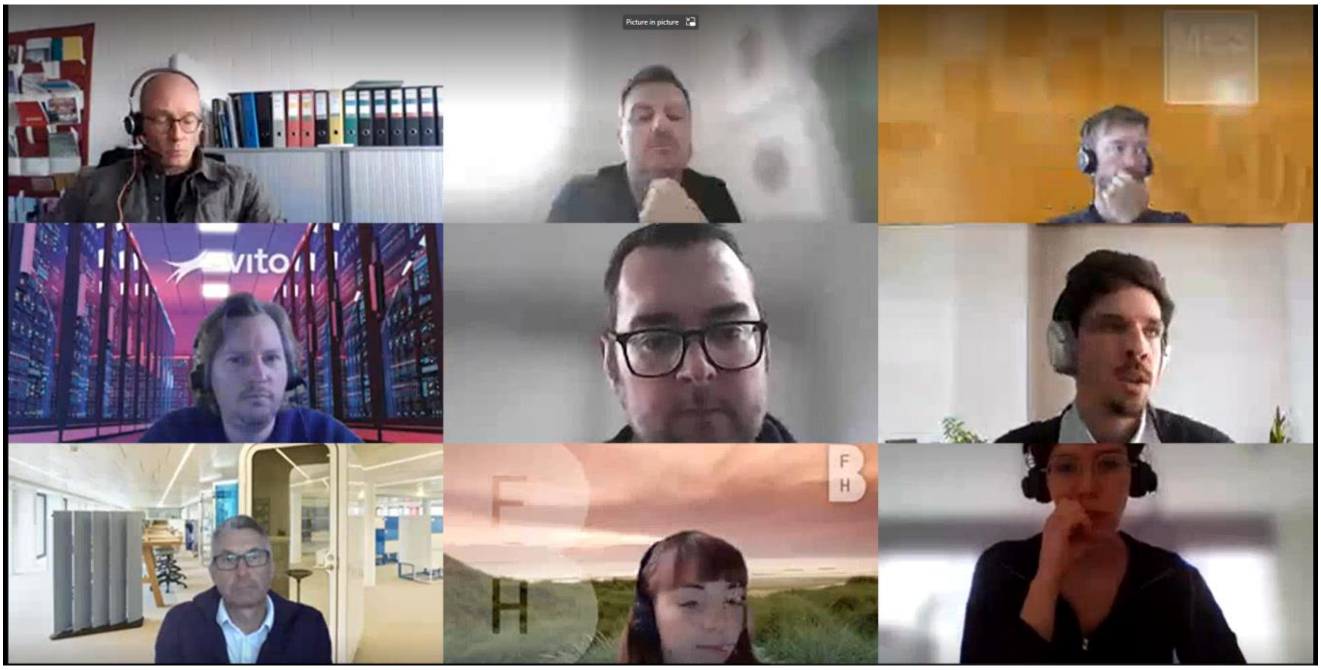


Note: company names have been anonymized

Demonstrators discussed

Cloverleaf

Screenshot participants



8.2. WORKSHOP ON PUBLIC AND SOCIAL INFRASTRUCTURE (CH)

Date: 13/04/2022

Location: Online – Microsoft Teams

Duration: 2u

Means of information sharing and input gathering: PowerPoint presentation, discussion questions, Miro boards

Moderators: Roger Nyffenegger and Ässia Boukhatmi (BUAS)

Participants:

Participant ID	Professional position	Stakeholder type
1	Deputy Head of Department for Municipal Buildings	Municipality Administration
2	Project Manager for Sustainable Development	City Administration
3	Head of Sustainability; Building Construction Office	Cantonal Administration
4	Senior Manager Business Development Mobility	Mobility Services
5	Head of Sustainability	Public transport association
6	Project Head Energy Management	Association for cantonal administration
7	President	Building cooperative
8	Sustainability consultant	Federal Office for Buildings and Logistics

Discussion questions

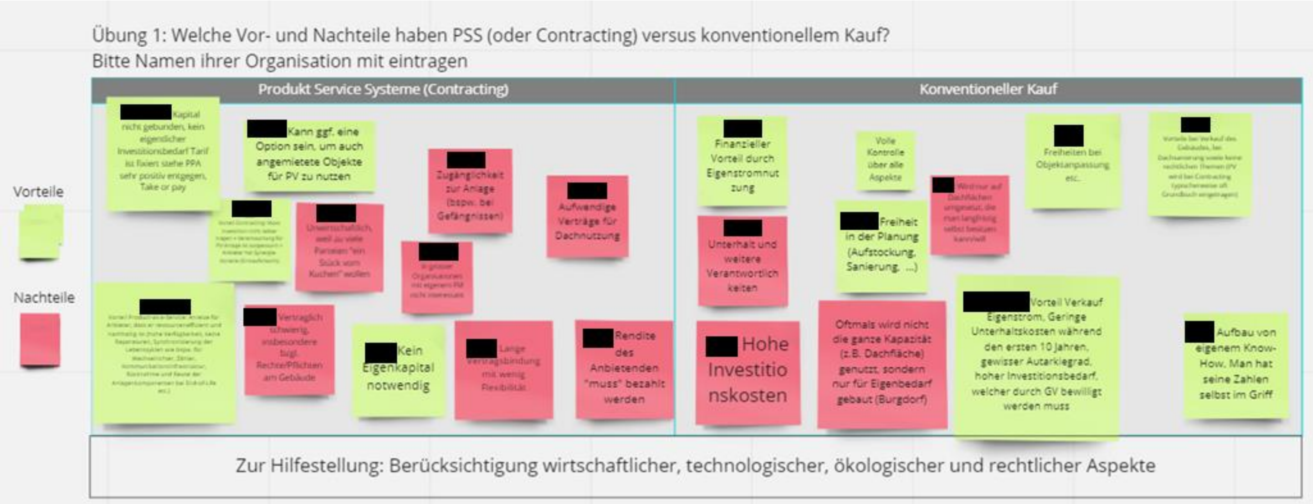
1. Introduction: Who has already installed system(s) or is planning to do so?
2. Please evaluate the advantages and disadvantages of PSS models (or contracting) compared to conventional purchase of PV systems (under consideration of economic, technological, ecological, and legal aspects).
3. How do you evaluate the different end-of-life options? What enablers and barriers do you see with regard to the different end-of-life options?
4. Assessment of advantages and disadvantages, incentives, and barriers to the release of information on installed equipment.

   Data/information to be released:

   - Location of the installation
   - Installation date
   - Production dates of the installation
   - Information on maintenance of the installation
   - General

Miro-board exercises

Exercise 1: Advantages and disadvantages of PSS vs PV purchase



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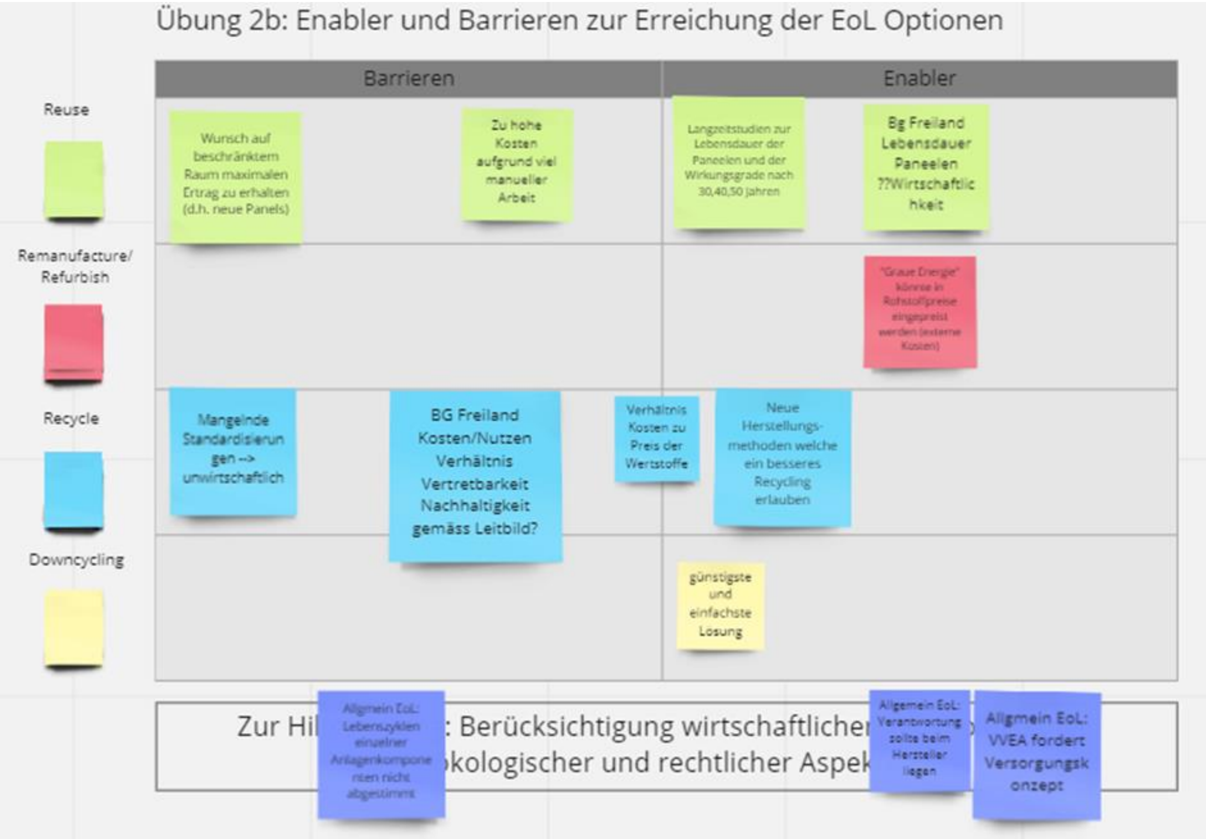
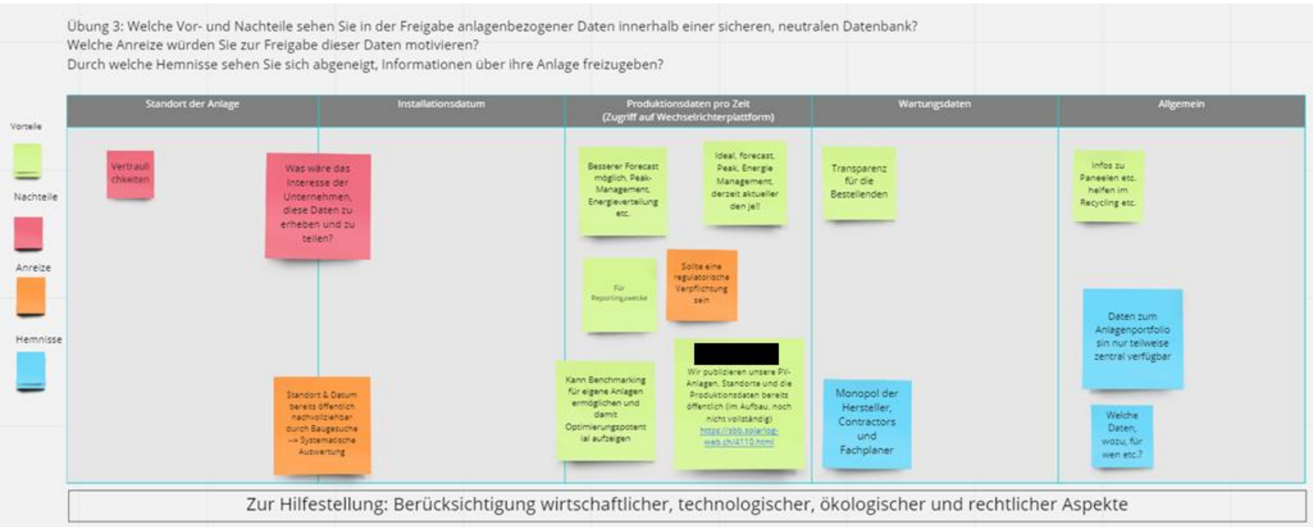
Exercise 2a: Evaluation of different End-of-Life options

Note: company names have been anonymized

Exercise 2b: Enabler and barriers of different End-of-Life options

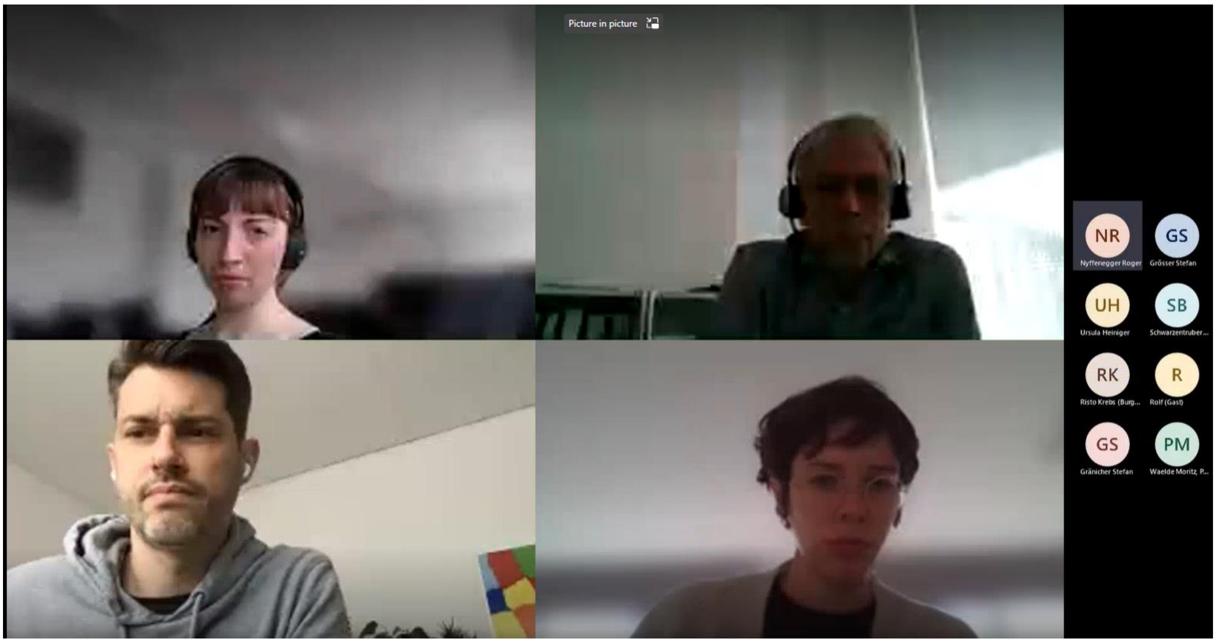


Exercise 3: Advantages and disadvantages of data disclosure on a neutral data hub



Note: company names have been anonymized

Screenshot participants


Picture in picture
NR
Nyffenegger Roger
GS
Grösser Stefan
UH
Ursula Heiniger
SB
Schwarzentruber...
RK
Risto Krebs (Burg...
R
Rolf (Gast)
GS
Gränicher Stefan
PM
Waelde Moritz, P...