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Federal Department of the Environment, Transport,

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Swiss Federal Office of Energy SFOE

Energy Research and Cleantech Division

Final report dated 30 November 2023

InnoNet-Energy

Diffusion of innovations in the energy landscape: The role of supply and demand-side network effects for integrated energy management systems

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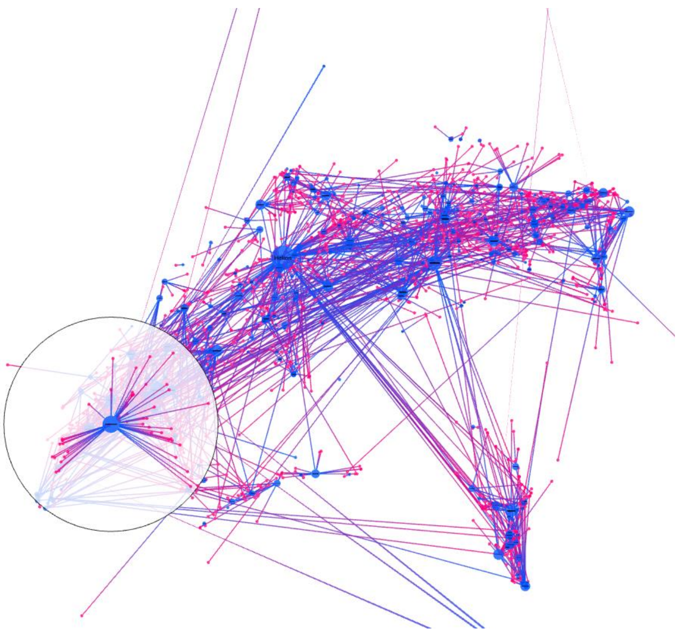

Source: © Serra Coch, 2023

Date: 30 November 2023

Location: Lausanne

Publisher:

Swiss Federal Office of Energy SFOE
Energy Research and Cleantech
CH-3003 Bern
www.bfe.admin.ch

Subsidy recipients:

École Polytechnique Fédérale de Lausanne (EPFL)
Laboratory on Human-Environment Relations of Urban Systems (HERUS)
Bâtiment GR, Station 2, CH-1015 Lausanne
https://www.epfl.ch/labs/herus

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SFOE contract number: SI/502112-01

The authors bear the entire responsibility for the content of this report and for the conclusions drawn therefrom.

Zusammenfassung

Das Hauptziel des Projekts ist es, die Informationsnetzwerke von Akteur:innen auf der Angebots- und Nachfrageseite von EMS zu verstehen, die PV und EV integrieren, wobei der Schwerpunkt auf sozialen und räumlichen Näheeffekten und ihrer Rolle für die Verbreitung von Energietechnologien im Schweizer Wohngebäudesektor liegt. In diesem Projekt verfolgten wir einen gemischten Methodenansatz, der eine qualitative Phase umfasste, in der 36 leitfadengestützte Interviews mit Akteur:innen auf der Angebotsseite von EMS (d.h. Energieversorgungsunternehmen, Energietechnologieanbietern, Hochschulen, Beratungsunternehmen und Interessenvertretungen) sowie mit Akteur:innen auf der Nachfrageseite im Wohngebäudesektor (d.h. Haus- und Wohnungseigentümer:innen, institutionelle Eigentümer, Ingenieure und Architekten) geführt wurden. Die Erkenntnisse aus den Interviews dienten als Grundlage für die Gestaltung zweier groß angelegter quantitativer Umfragen bei Technologie-anwender:innen und wichtigen Akteur:innen auf der Angebotsseite (Organisationen). Die Umfragen lieferten Daten von rund 5'000 Technologieanwender:innen im Schweizer Wohngebäudesektor sowie von 160 Organisationen, die mit den untersuchten Energietechnologien arbeiten. Auf der Grundlage unserer Ergebnisse können wir Empfehlungen und auch Vorschläge für die Gestaltung wirksamer Informations- und Marketingkampagnen zur Unterstützung der Verbreitung von Energietechnologien, insbesondere von EMS, ableiten.

Zur Förderung von EMS in Wohngebäuden sind nicht nur finanzielle Anreize, sondern auch die Unterstützung der Co-Adoption von Technologien oder Technologiebündeln von entscheidender Bedeutung. Geeignete Ansätze hierfür sind die Koordinierung on Technologieanbietern, technische Standards für die Systemintegration bei EMS, sowie die Nutzung von günstigen Momenten wie Gebäudesanierungen oder wenn PV oder andere Verbrauchertechnologien gekauft und registriert werden. In Bezug auf PV und EMS sehen wir ein erhebliches ungenutztes Potenzial in Mehrfamilienhäusern, wobei institutionelle Investor:innen eine große Hebelwirkung haben.

Unsere Ergebnisse zeigen, dass Veranstaltungen und Verbände eine Vermittlerrolle einnehmen und eine ideale Plattform sind, um nicht nur die Akteur:innen auf der Angebotsseite zu stärken und zu koordinieren, sondern auch um bessere Formen der technischen Systemintegration zu diskutieren. Informationen werden wirkungsvoll unter derzeitig aktiven Akteur:innen der Angebotsseite verbreitet und gleichzeitig entstehen Verbindungen zu Akteur:innen, die im Austausch mit Technologieanwender:innen stehen und deren spezifische Bedürfnisse und Herausforderungen kennen. Die engen Verbindungen, die wir im gegenwärtigen Akteursnetzwerk auf der Angebotsseite gefunden haben, implizieren, dass Informationen von bestimmten Akteur:innen - z.B. Anbieter:innen von EMS, Verbände und öffentliche Behördern - schnell verbreitet werden können und als sogenannte Change Agents agieren.

Für die weitere Verbreitung der Technologien scheint es effizienter zu sein, zunächst diejenigen anzusprechen, die über ähnlich günstige bauliche Bedingungen und soziodemografische Merkmale verfügen wie Technologieanwender:innen die schon installiert haben, da sie eher bereit sind die Technologie zu übernehmen. Alternativ könnten bestehende Vertrauensbeziehungen zwischen Fachleuten und potenziellen Technologieanwender:innen genutzt werden, wie z. B. der/die örtliche Architekt:in, Heizungsinstallateur:in, Elektriker:in oder Kfz-Techniker:in für EV, um eine Verbindung zu Energietechnologieanbietern, Energieversorgungsunternehmen oder anderen Energiedienstleistern herzustellen. Der Informationsaustausch von Technologieanwender:innen mit Fachleuten und persönlichen Kontakten scheint einem bestimmten Muster zu folgen und drei Elemente zu enthalten, die

sich gegenseitig positiv beeinflussen: Vertrauen in die Person die sie ansprechen, Häufigkeit der Interaktion und räumliche Nähe. Informationskampagnen könnten sich diese Erkenntnisse zunutze machen und Elemente wie die Einladung von Technologieanwender:innen und ihren Freunden und Bekannten zu Veranstaltungen, die Auswahl von Orten in der Nähe ihres Wohnorts oder in ihren Aktivitätsbereichen und die Schaffung der Grundlage für mehrere persönliche Interaktionen zur Vertrauensbildung beinhalten.

Résumé

L'objectif principal du projet est de comprendre les réseaux d'information des acteur·rice·s de l'offre et de la demande de systèmes de gestion de l'énergie (SGE) intégrant le photovoltaïque et les véhicules électriques en Suisse, en se concentrant particulièrement sur les effets de proximité sociale et spatiale et leur rôle dans la diffusion des technologies énergétiques dans le secteur des bâtiments résidentiels. Dans ce projet, nous avons appliqué une approche mixte comprenant une phase qualitative au cours de laquelle 36 entretiens guidés ont été menés avec des acteur·rice·s de l'offre de SGE (entreprises de distribution d'énergie, fournisseur·euse·s de technologies énergétiques, universités, bureaux de conseil et des associations), ainsi qu'avec des acteur·rice·s de la demande dans le secteur des bâtiments résidentiels (propriétaires de maisons et de propriété par étage, propriétaires institutionnel·le·s, ingénieur·e·s et architectes). Les résultats des entretiens ont été essentiels pour concevoir deux enquêtes quantitatives à grande échelle auprès des adoptant·e·s de technologies et des principaux acteur·rice·s du côté de l'offre (organisations). Ces enquêtes ont permis de recueillir des données auprès d'environ 5'000 utilisateurs·trices de technologies dans le secteur résidentiel en Suisse, ainsi que de 160 organisations qui travaillent avec les technologies énergétiques étudiées. Sur la base de nos résultats, nous pouvons formuler plusieurs recommandations ainsi que des suggestions pour concevoir des campagnes d'information ou de marketing efficaces soutenant la diffusion des technologies énergétiques, en particulier des SGE.

Pour encourager les SGE dans les bâtiments résidentiels, il est essentiel non seulement de sensibiliser à leur rentabilité sur le long-terme, mais aussi de promouvoir la co-adoption des technologies par des offres groupées de technologies. La coordination des fournisseurs de technologies énergétiques est nécessaire, ainsi que des normes et des protocoles techniques pour l'intégration des systèmes, et une meilleure utilisation de fenêtres d'opportunités telles que les rénovations de bâtiments ou les moments où le PV ou d'autres technologies à disposition des consommateurs sont achetés ou enregistrés. En ce qui concerne le photovoltaïque et les SGE, nous constatons qu'il existe un potentiel inexploité important dans les logements collectifs, avec des investisseur·se·s institutionnel·le·s disposant d'un important levier.

Nos conclusions révèlent que les manifestations et les associations semblent être une plateforme idéale non seulement pour renforcer et coordonner les acteur·rice·s de l'offre, mais aussi pour discuter de meilleures formes d'intégration des systèmes technologiques. Ils sont efficaces pour diffuser des informations dans le paysage actuel des acteur·rice·s de l'offre et, en même temps, pour établir des liens avec les acteur·rice·s de l'offre en contact direct avec les utilisateur·trice·s de technologies, ce qui permet d'en savoir plus sur leurs besoins spécifiques et les défis auxquels ils sont confronté·e·s. Outre, les liens étroits que nous avons trouvés dans le réseau actuel des acteur·rice·s de l'offre impliquent que l'information pourrait être diffusée rapidement par certains acteur·rice·s - par exemple, les fournisseurs

de SGE, les associations et les autorités publiques - qui pourraient agir en tant qu'agent·e·s de changement.

Lorsque l'on s'adresse à des adoptant·e·s potentiel·le·s, il semble prometteur de cibler d'abord celleux qui ont des conditions de construction favorables et des caractéristiques sociodémographiques similaires à celles des adoptant·e·s, car ils pourraient être plus enclin·e·s à adopter la technologie. Il est également possible d'utiliser les relations de confiance existantes entre les professionnel·le·s et les adoptant·e·s potentiel·le·s de technologies, comme l'architecte, le·la plombier·ère, l'électricien·ne ou le·la technicien·ne automobile local·e pour les VE, afin d'établir un lien avec les fournisseur·e·s de technologies énergétiques, les entités de services énergétiques ou d'autres sociétés de services énergétiques. Les échanges d'informations des adoptant·e·s de la technologie avec des professionnel·le·s et des contacts personnel·le·s semblent suivre un modèle particulier et contenir trois éléments qui s'influencent positivement les uns les autres: la confiance dans la personne à laquelle ils s'adressent, la fréquence de l'interaction et la proximité spatiale. Les campagnes d'information pourraient profiter de ces résultats en invitant les adoptant·e·s des technologies et leurs ami·e·s et connaissances à des événements, en choisissant des lieux proches de leur domicile ou de leur environnement, et en préparant le terrain pour plusieurs interactions en face-à-face afin d'instaurer la confiance.

Summary

The main goal of the project is to understand information networks of actors on the supply and demand-side of EMS integrating PV and EV in Switzerland, particularly focusing on social and spatial proximity effects and its role in the diffusion of energy technologies in the residential building sector. In this project, we followed a mixed-methods approach that included a qualitative phase where 36 guided interviews were conducted with actors on the supply-side of EMS (i.e., energy utility entities, energy technology providers, academia, consultancy companies, and advocacies), as well as with demand-side actors in the residential building sector (i.e., home and condominium owners, institutional owners, engineers, and architects). The insights of the interviews were key to designing and supporting the results of two large-scale quantitative surveys for technology adopters and key supply-side actors, i.e., organizations. The surveys provided data from around 5'000 technology adopters (PV and EV) in the Swiss residential building sector as well as 160 organizations that work with the energy technologies of study. Based on our findings, we can derive several recommendations as well as suggestions to design effective information or marketing campaigns supporting the diffusion of energy technologies, particularly EMS.

To foster EMS in residential buildings, not only raising awareness about its long-term profitability, but also advocating for technology co-adoption through technology bundles are found to be key. Suitable approaches for that are the coordination of energy technology providers, technical standards and protocols for system integration, as well as using windows of opportunities, such as building refurbishments or moments where PV or other large consumer technologies are purchased or registered. For PV and EMS, we find a significant untapped potential in multi-family housing with institutional investors having a high leverage.

Our findings reveal that events and associations have a brokerage role and seem to be an ideal platform to not only strengthen and coordinate supply-side actors but also to discuss better forms of technological

system integration. They are effective in spreading information among the current supply-side actors' landscape, and at the same time in connecting to those supply-side actors in direct contact with the technology users, providing ground to learn about their specific needs and challenges they are confronted with. Additionally, the tight connections we found in the current supply-side actor network imply that information could be spread rapidly by certain actors - e.g., EMS providers, associations, and public authorities - who could act as change agents.

When approaching potential adopters, it seems promising to first target those with favorable building conditions, i.e., house owners, and socio-demographic characteristics similar to adopters, as they might be more prone to adopt. Alternatively, existing trust relationships between professionals and potential technology adopters could be fostered, such as the local architect, plumber, electrician, or car technician for EV, to establish a link to energy technology providers, energy utility entities, or other energy service companies. Technology adopters' information exchanges with professionals and their personal contacts seem to follow a particular pattern and contain three elements that positively affect each other: (i) trust in the person they reach out to, (ii) frequency of interaction, and (iii) spatial proximity. Information campaigns could make use of these findings, including elements such as inviting technology adopters and their friends and acquaintances to events choosing places close to their homes or within their activity spaces, and setting the ground for several face-to-face interactions to build trust.

Main findings

- EMS are not (yet) perceived as financially attractive, which is one of the main barriers we identified, together with the complexity of the supply-side actors' landscape and the lack of technical standards. Public authorities could support the diffusion of EMS by raising awareness about its long-term profitability, enabling technology providers to generate synergies to support technology users throughout the implementation process, and by steering the process to harmonize technical standards and protocols.
- The technology co-adoption rate in Switzerland is high with 65% of the technology adopters in our sample using more than one energy technology, which reveals a promising potential for EMS in the residential building sector. To further foster EMS, promoting technology bundles are key while windows of opportunities are crucial and need to be used, such as building refurbishments or moments where PV or other consumer technologies (e.g., HP, EV) are purchased and registered.
- Events and associations have a high brokerage potential as they connect not only actors from different fields, i.e., technology providers, energy utility entities, associations, and academia, but also actors working with different technologies (EMS, PV and EV). They could be used to improve coordination among supply-side actors and to discuss a harmonization of technological standards and protocols, which we found to be among the most relevant barriers to the diffusion of EMS.
- Technology adopters' information exchanges with professionals and personal contacts seem to follow a particular pattern and contain three elements that positively affect each other: (i) trust in the person they reach out to, (ii) frequency of interaction, and (iii) spatial proximity. Information campaigns should therefore include elements such as inviting technology adopters and their friends and acquaintances to events, choosing places close to their homes or within their activity spaces, and setting the ground for several face-to-face interactions to build trust.

Contents

Abbreviations

EMS	Energy management system(s)
PV	Photovoltaic system(s)
EV	Electric vehicle(s)
HP	Heat pump(s)

1 Introduction

1.1 Background information and current situation

The ongoing sustainability transition towards low-carbon solutions is key to tackling the current challenges tied to climate change. The energy transition has a central role in enabling a systemic change towards more sustainable ways of living. With the Energy Strategy 2050, the Federal Council of Switzerland is pushing more than ever to reduce its carbon footprint and explore ambitious energy-based strategies by improving energy efficiency, increasing renewable energies, phasing out nuclear energy, and developing the electricity grid (SFOE, 2020). Besides the use of renewable sources to generate energy, a central aspect to tackle the energy challenge is the efficient management of available energy.

Energy management systems (EMS) are key to addressing these needs. They aid in balancing the supply and the demand, to effectively align production and consumption in time and space. With the widespread electricity production from photovoltaics (PV) and increased electricity consumption from electrical vehicles (EV), EMS are becoming crucial. However, although innovative technological solutions are available, a broad uptake of these innovations is still missing in the Swiss context (Tagliapietra, 2019). The most important challenge is therefore to bridge this gap and take energy technologies to the final users. As such, there is a need to address the energy transition from a social perspective, considering the role of information and proximity effects, including supply and demand actors, and analyzing their interrelations while also integrating the geographic context.

1.2 Purpose and objectives of the project

Access to information and its reliability has been identified as having a significant effect on the diffusion of innovations (Rogers, 2003; Rai et al., 2015). In line with that, proximity and peer effects were found to be key to enabling the information exchange (Rai et al., 2015; Palm, 2017; Bernards et al., 2018; Mundaca & Samahita, 2020; Noll et al., 2014). Therefore, there is an interest in investigating how information circulates, how it affects the adoption of energy technologies, and which role proximity effects play in different geographic contexts. The focus of the InnoNet-Energy project is on analyzing the gap between energy technologies and their implementation through understanding the information networks of actors that connect the supply and demand-side.

The main goal of the project is to understand the information networks of actors on the supply and demand-side of EMS integrating PV and EV in Switzerland, particularly focusing on social and spatial proximity effects and their role in the diffusion of energy technologies.

To reach this goal, we have several objectives:

- **ACTORS:** Identify and characterize supply actors key for the diffusion of EMS integrating PV and EV and demand actors that are adopting these technologies.

- **TECHNOLOGY ADOPTION:** Investigate the drivers and barriers decisive for technology (co-)adoption and analyze the role of the information exchange in the adoption decision.

- **INFORMATION EXCHANGE:** Understand from whom and how supply and demand-side actors get information and to whom and how they spread the information.

- **INFORMATION NETWORKS:** Identify through which actors or information networks the supply and the demand-side actors are connected.

- **PROXMITY EFFECTS:** Explore how the social and spatial context affects the construction of these networks and the information exchange.

Throughout these objectives, we dissect the different dimensions that link the supply of the technology and the adoption by the user, accounting for the key actors, how they are connected, the information circulating among them, the impact of the geographic context, and how all this influences the investment decision.

2 Description of facility

The project takes four regions of Switzerland as case studies, bounded by their respective canton's boundaries and representative for the three official languages in the country: Solothurn and St. Gallen, Vaud and Ticino. Within the four case study areas, several regional partners in the field were identified and are providing continuous support throughout the project to tap into the local expert knowledge. The regional partners are Yverdon-les-Bains Énergies, Aare Energie AG, Weesen, and Energietal Toggenburg, besides our project partners Energie Zukunft Schweiz and Protoscar (Figure 1).

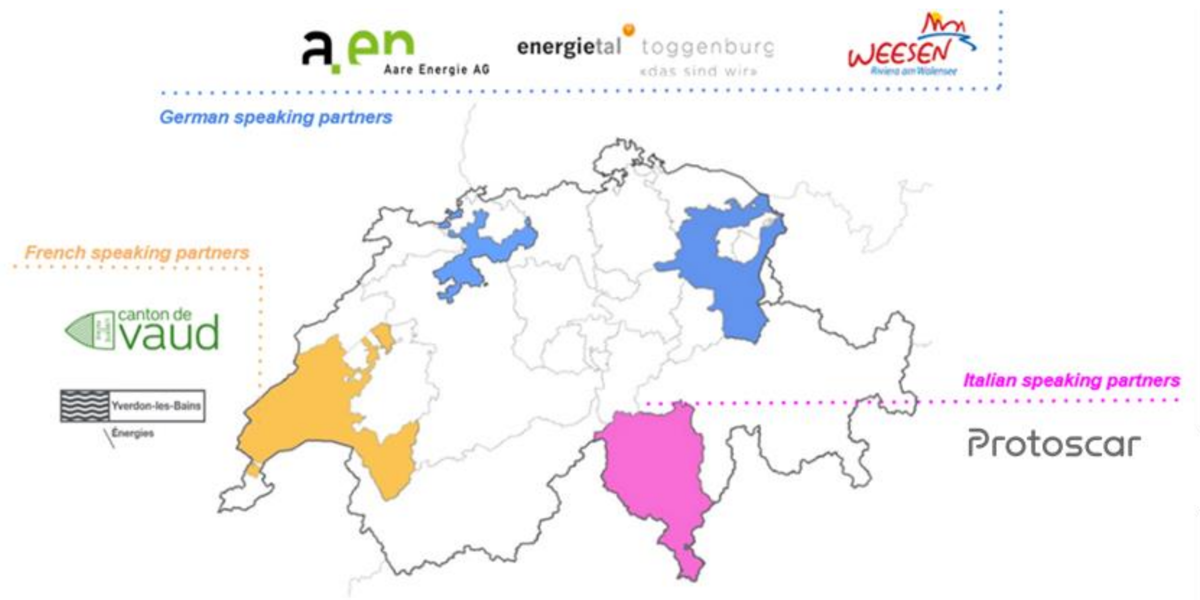


Figure 1: Study regions and partners of the project.

Although Switzerland is advancing towards PV and EV implementation, it is still far from guaranteeing a significant share of low-carbon energy technologies which it aims for. To reach the long-term climate and energy of net-zero greenhouse gas emissions by 2050, Switzerland envisions a total PV energy production of 34 TWh and 3.6 billion battery-powered cars (SFOE, 2020). EMS are key to balancing and effectively aligning the production and consumption of energy. EMS manage and visualize the energy production and consumption in a building and enable the automatic control of several appliances, such as PV, EV charging stations, heating systems, energy batteries, or other household appliances. Additionally, EMS relieve power grids during demand time by shifting the usage periods of non-essential appliances to an off-peak time. This prevents an overload of the house network connection and stabilizes the grid as a whole. For instance, an EMS can switch on the heating and cooling system throughout the day precisely when PV is producing solar power and, therefore, increase the self-consumption rate and the profitability of the system. Alternatively, the load of EV charging stations can be reduced when there is a consumption peak, i.e., dynamic load management (see Figure 2).

There is not a uniform definition of EMS and the products available in the market vary depending on their objective. Some are grid-oriented, providing services that benefit the grid while others are marketoriented, expanding their services for the customers. We can also find cases in which both objectives are sought, looking at benefiting particular customers with products that also increase grid stability. In terms of spatial scale, there is a range from those controlling the energy flows within a building, and others focusing on the integration of several buildings within a neighborhood. In this project, a special focus is set on EMS integrating PV and EV in the residential sector. Therefore, we focus on EMS installed in residential buildings, be it single-family houses or multi-family buildings, looking especially at those that integrate PV panels and EV charging stations.

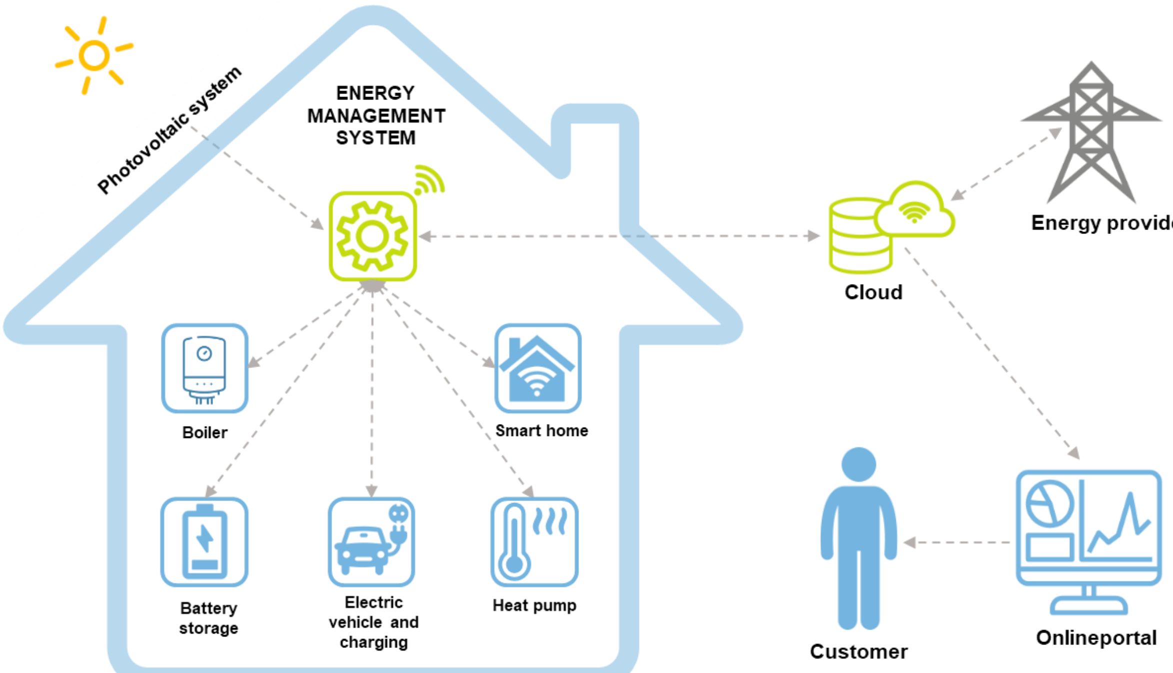


Figure 2: Exemplary illustration of EMS (Energie Zukunft Schweiz).

3 Procedures and methodology

The project is structured in five work packages (WPs) applying a mixed-methods approach. First, a qualitative analysis was conducted with semi-structured expert interviews to understand and conceptualize the technology adoption process and the information networks of supply-side actors and technology users (WP1). Second, a large-scale supply and demand-side survey was designed and released to obtain quantitative data for analysis (WP2). In WP3 a spatial network analysis was performed to investigate the role of social and spatial proximity effects in the diffusion of energy technologies. WP4 and WP5 contain the dissemination of the project findings and the management of the project.

3.1 Data collection

3.1.1 Semi-structured expert interviews

A kick-off workshop with our regional partners acted as a departure point to obtain key insights on the region and its relevant actors for the diffusion of EMS integrating PV and EV. During the workshop, we identified actors that contribute to the knowledge transfer of the considered technologies. We identified and categorized 70 actors in terms of their field (i.e., energy utility entity, energy technology supply, consulting, academia, advocacy, public administration), the technology they work with (i.e., PV, EV, EMS), and their location. By balancing the relevance and diversity of actors for each of the case study regions, we selected 17 organizations we approached for an expert interview. In each case study region, we interviewed at least one energy utility entity, academic institution, and technology provider as well as one organization specialized in advocacy or consulting (Figure 3).

Based on the insights of the expert interviews on the supply-side, we selected the residential sector to be the main focus of our analysis on the demand-side. The sector was chosen due to its significance for the energy transition and replicability, as well as the possibility of developing standardized solutions and their scalability, particularly in relation to the installation of PV and EV charging stations. We interviewed 19 demand-side actors in the residential sector, i.e., two single-family house owners and four private individual multi-family house owners with rented apartments (individual decision), one condominium owner, and two house-owners of single-family houses in an auto consumption community (collective decision), eight institutional owners (authoritative decision), as well as one engineer and one architect (decision influencer). We did not consider tenants as a target group as they do not have sufficient decision-making authority when it comes to technology implementation. Eleven interviews were conducted in the German-speaking region, six in the French-speaking region, and three in the Italian region.

The expert interviews served as a basis to conceptualize the technology adoption process and the information networks of supply-side actors and technology users. The insights gained were the backbone for designing the large-scale surveys conducted in this project. The expert interviews with actors on the supply-side mainly focused on the identification of key supply and demand-side actors in the diffusion of EMS integrating PV and EV, and those that connect them. In addition, and also at the center of interviews with demand-side actors, were the driving and hindering factors for the diffusion of the technology, the information sources and channels used, and the role of social and spatial proximity when exchanging information.

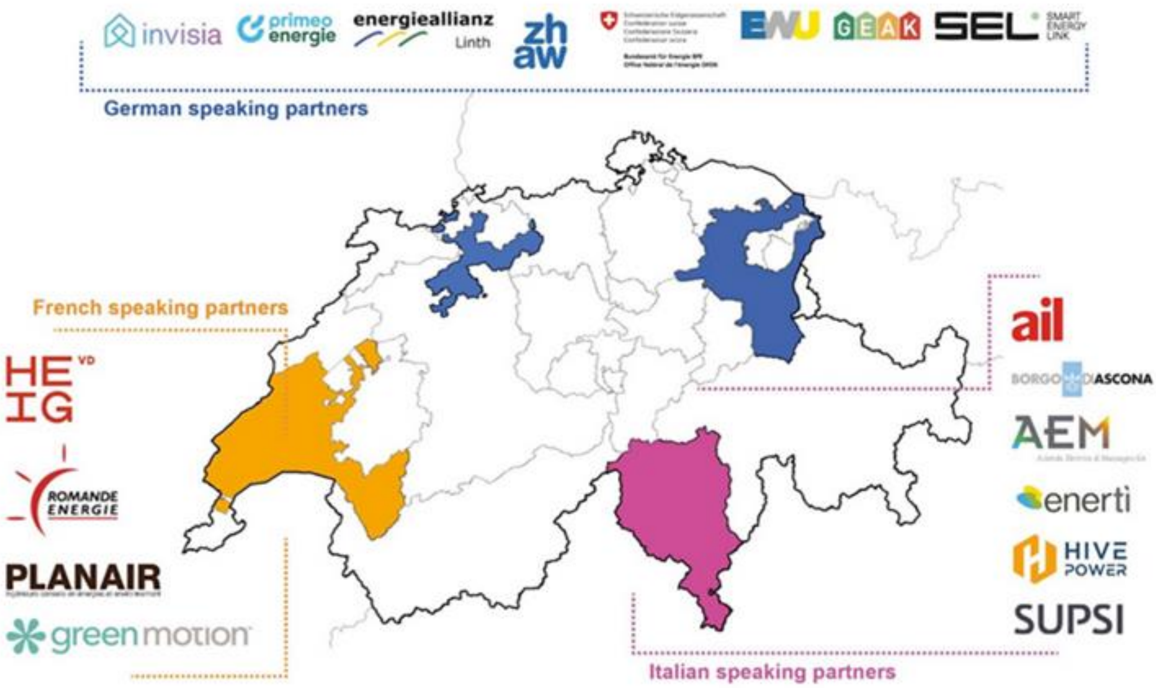


Figure 3: Supply-side interview partners.

3.1.2 Technology adopter survey

To reach our target sample of EMS adopters in the residential building sector, we relied on a technology co-adoption perspective. A dataset recording the adoption of EMS does not exist in Switzerland, however, data on PV and EV adopters is available. Two entities, the Swiss Federal Office of Energy (SFOE) and the Federal Road Office (FEDRO), provided us with contact information. In June 2022, we distributed an online survey to 20'000 private PV owners and 15'000 private EV owners. We contacted them via email and post and shared with them a link to the survey. The survey was implemented into a map-based survey platform (Maptionnaire www.maptionnaire.com) and made available in four different languages (German, French, Italian, and English).

For the PV sample, we received the contact information through the Swiss system for guarantees of origin operated by Pronovo AG, which contains all electricity production plants with a capacity greater than 30 kVA, as well as small plants with a capacity greater than 2 kWp that are voluntarily registered for the certification of the method of production and source of electricity. In addition, it contains all installations that are subsidized by a feed-in tariff, one-time payment, additional cost financing, or an investment contribution. We approached the owners of the 10'000 most recent PV installations in the four case study cantons and the 5'000 most recent PV installations in Zürich, Bern, Basel, and Valais and the 5,000 most recent PV installations in the rest of Switzerland (installations between 2019 and 2021). For the EV sample, we approached the owners of the 10'000 most recent EV registrations in the case study cantons and the 5'000 most recent registrations in Zürich, Bern, Basel, and Valais (installations between 2020 and 2022).

The online survey was structured into two main parts (Figure 4). The first part of the survey aimed to understand the personal background of the respondent, i.e., socio-demographic and household data, building characteristics, personal sphere (i.e., home, work, leisure location), as well as general attitudes towards energy-conscious behavior. The second part focused on the technology specifics and their adoption process including the drivers for adoption, information sources used, as well as details about the most important information exchange with a professional and person in their personal network. The respondents filled in the survey related to either EMS, PV, or EV. In case they had EMS, they answered the survey questions related to EMS (EMS respondent group). If not, we asked them if they had PV, EV, or both. In case they had both, we used the first technology they adopted to filter them into the PV or EV respondent group.

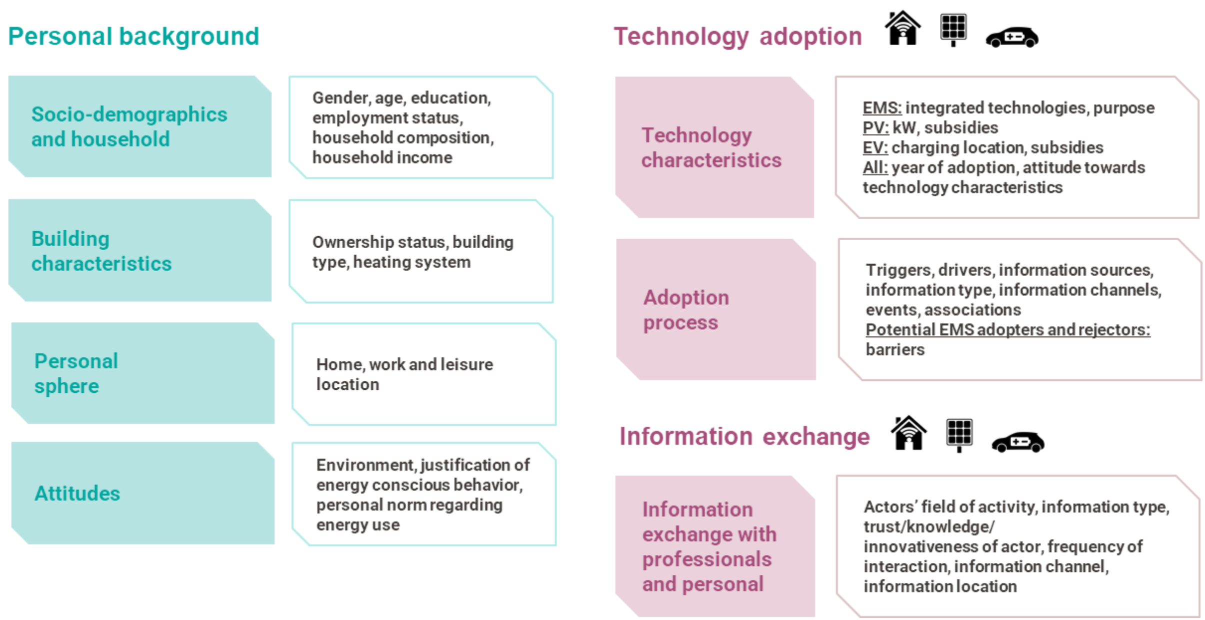


Figure 4: Technology adopter survey structure.

3.1.3 Supply-side actor's survey

To identify key actors relevant to the diffusion of EMS integrating PV and EV, we went through several steps. In the kick-off workshop with our project partners as well as regional partners, we collected a first list of organizations they found relevant to the diffusion of EMS. This list was complemented by the actors mentioned in the 36 guided interviews we conducted in WP1. Based on this preliminary list of actors, we conducted desktop research collecting all their partners mentioned on their websites. Once we had the results of the technology adopters survey, we expanded this list with the actors mentioned as information sources for the respondents' decision-making process of the technology they were referring to. Finally, the actors went through a validation process that categorized and assessed the supply actors considering their field of activity (according to the Swiss general classification of economic activities, NOGA codes), their link to the residential building sector as well as their location. Overall, we identified 928 organizations, which were contacted in January 2023 via post and invited to fill in the map-based online survey, also made available in four languages.

The online survey was structured into two main parts (Figure 5). The first part of the survey contained questions about the general characteristics of the organization (sector, number of employees, location, etc.) and questions related to the technologies they work with. The second part focused on the information exchange of organizations related to the technology, as well as their perspective on the drivers and barriers to adopting the technologies. Also, for the supply-side survey, we filtered the organizations into three main respondent groups. If the respondents work with EMS, they responded to the survey questions related to EMS. If they do not work with EMS, they responded to the survey related to PV or EV, depending on which technology the person who filled in the survey has more professional experience in.

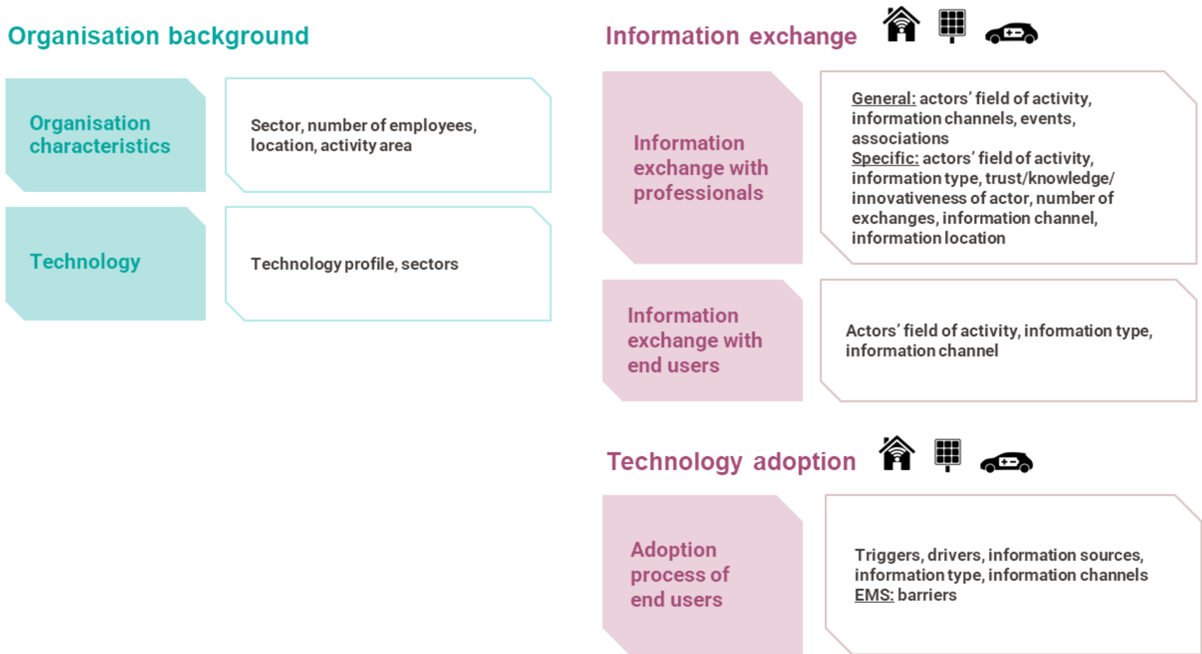


Figure 5: Supply-side actor's survey structure.

3.2 Data analysis

The data we collected from both surveys were used to analyze the drivers and barriers to energy technology adoption in the Swiss residential building sector and to investigate the information networks between supply and demand-side actors. Firstly, we created technology profiles for PV adopters, EV adopters, and technology co-adopters who have PV, EV, and EMS installed in their homes. These profiles contain their socio-demographic, household, and building characteristics. Secondly, we analyzed the technology co-adoption patterns looking at the technology combinations and the order in which these technologies were implemented. Thirdly, we analyzed the perceived drivers and barriers for PV, EV, and EMS adoption as well as the information sources and channels used in the decision-making process. Thereby, the main objective was to identify the mismatches between the perception of technology users and supply-side actors. We assessed the data descriptively and conducted bivariate statistical analysis to test for significant differences between groups, i.e., Chi-square tests for categorical and Kruskal Wallis tests for continuous variables with $p < 0.05$. Finally, we conducted a network analysis.

The last step consisted in looking at the information networks and proximity effects. The core of the network analysis was to investigate social and spatial proximity effects in the diffusion of energy technologies. To do that, we analyzed the most relevant information exchange of technology users with a professional and with someone in the personal network when deciding to adopt EMS, PV or EV. Social proximity is operationalized as the level of trust in that person and the frequency of interactions. Spatial proximity is operationalized as the distance between the location where this information exchange happened and the "regular location" of the technology user. The "regular location" refers to the actual home of the technology users but also to the place where they work, where they spend their leisure time, their commute route, and their activity space, i.e., the area where they conduct their regular weekly activities. The distances between information exchange locations and the regular locations were studied with a buffer-based approach. We looked, for each user, if the location where they exchanged information fell within a radius of 500m around the home location, 250m around the work location, 150m around leisure locations, 100m around their commute route, or within the polygon of the activity space. The buffer distances were based on prior research on activity spaces that found these thresholds to be the most representative of individuals' regular movement in space (Laatikainen et al. 2018; Orford and Leigh 2013; Arentze and Timmermans, 2002).

To analyze the information network between supply-side actors, we applied a reference-based and affiliations-based network approach. Within the reference-based approach, the network was created with the links the supply-side actors referred to in the survey when asked about the professional from another organization with whom they collaborate the most. We examined the relationships between the actors looking at the strength of the links and at centrality indicators. To measure centrality, we counted the number of direct connections an actor has, which is the number of times an actor is mentioned by another actor, i.e., degree centrality. In addition, we calculated how often an actor lies on the shortest path between other pairs of actors, i.e., betweenness centrality. For the network analysis, we used the software Tulip and the centrality algorithms included. We also examined the geographic distribution of the supply-side actors in the network. To do that, we geocoded the addresses available on the supply-side actor's website using the plug-in MMQGIS available in QGiS. We used the SNoMaN social network mapping and analysis nexus web-based platform to visualize the network and measure the distances between actors. To evaluate if supply-side actors clustered in the network also cluster in space, we used the network community algorithm.

With the affiliations-based approach, the links in the network were created with the events, supply-side actors attended, and the associations they used to exchange information about the energy technologies (for a list of events and associations we considered, please see Appendix Figure A1 and Figure A2). The data we collected allowed us to create a bi-partite network that connects the actors directly to the events and associations they mention they use to exchange information. In this way, we can evaluate (i) which events and associations are the ones used more often to exchange information, i.e., degree centrality, (ii) which ones have a brokerage role and therefore are in a strategic position to diffuse information among actors, i.e., betweenness centrality, and (iii) if they connect diverse or similar actors in terms of their activity field (e.g. academia, association, technology provider etc.) or technologies that the supply-side actors mostly work with.

4 Results and discussion

4.1 Technology demand and supply-side sample

Survey respondents of demand survey

The survey was completed and submitted by 4,847 respondents, which corresponds to a response rate of 12%. Table 1 shows by canton how many respondents referred to PV, EV, and EMS when answering the survey questions, as well as the sample size for the network analysis. About 40% of the respondents indicate that they have an EMS installed in their home (N = 2'105). About 30% of the respondents answered the survey related to PV, as they have only PV installed or installed PV before EV (N = 1'378). Another 30% responded to the survey related to EV (N = 1'365). For the network analysis, the sample size decreases, as not all respondents answered the question about their home location (N = 2'726).

Table 1: Sample size by technology and canton for demand survey (sample size for spatial network).

	PV respondent group	EV respondent group	EMS respondent group	Total
St. Gallen	262 (150)	194 (110)	359 (212)	815 (472)
Solothurn	105 (52)	123 (67)	198 (107)	427 (226)
Vaud	408 (221)	348 (180)	477 (255)	1'235 (656)
Ticino	139 (84)	205 (98)	239 (138)	583 (320)
Other cantons	464 (276)	495 (253)	832 (523)	1'787 (1'052)
Total	**1'378** (783)	**1'365** (708)	**2'105** (1'235)	**4'847** (2'726)

Survey respondents of the supply survey

For the supply-side survey, we identified 928 organizations to be key for the diffusion of EMS in Switzerland. Table 2 shows that 60%, the majority of the organizations we approached, are energy technology providers, mainly providing installation and engineering services. Associations, energy and e-mobility service companies, and energy utility entities rank second with 9% respectively, followed by public and non-profit organizations (7%).

157 organizations responded to the supply-side survey, which corresponds to a response rate of 17%. 37% of the respondents state that their organization is working with EMS (N = 58) and therefore referred to EMS when answering the survey questions. 49% of the respondents state that they have the most professional experience in PV and therefore filled in the survey related to PV (N = 77). 14% fill in the survey related to EV (N = 22). Table 2 shows that the majority of the respondents in our sample are energy technology providers (36%), followed by energy or e-mobility service companies (18%), energy utility entities (15%), construction sector (12%), public and non-profit organizations (9%) and associations (6%). Compared to the organizations we approached, we have a significantly lower share of energy technology providers, more energy and e-mobility service companies as well as energy utility entities in the sample. Also, a higher share of organizations from the construction sector answered the survey (12%).

Table 2: Sample size by field of activity for the supply survey.

	Contacted organizations (N = 928)	Supply sample (N = 157)
Energy technology provider (electrical and electronic industries, photovoltaics, heat pumps, energy management systems, electric vehicles, information and communications technologies...)	60%	36%
Energy or e-mobility service company (consulting...)	9%	18%
Energy utility entity (energy production, distribution and supply)	9%	15%
Construction sector (engineering, architecture, real estate...)	2%	12%
Public and non-profit organization (public federal, cantonal or municipal authorities, platforms, community services...)	7%	9%
Association	9%	6%
Academia (universities, research institutions, teaching centers...)	2%	2%
Other	2%	1%
Total	**100%**	**100%**

The organizations in the sample are mostly located in the German-speaking cantons of Switzerland (56%), 33% are located in the French-speaking part and 11% in Ticino. 20% of the organizations are small-sized with 1-9 employees, 40% are medium-sized employing 10-49 people, while the remaining ones are rather large organizations with 50-250 (20%) and >250 employees (20%). The organization size of energy technology providers as well as energy and mobility service companies are spread from small to large over the sample, while energy utility entities tend to have more employees.

Across the sample, 71% of the organizations state that they work with EMS. Most of the organizations also work with PV (93%), EV charging stations (81%), battery storage (73%), and heat pumps (57%), while only 29% work with EV. Related to EMS, the majority of the organizations state that they work with the residential sector (89%) as well as the industrial and production sectors (71%). They are less active in the office sector (55%) as well as the retail and service sectors (41%). For PV, the ranking of the sectors is the same as for the EMS technology, although they are less active in the industrial and production sector. For EV, 100% of the organizations are active in the residential sector. They are also mostly active in the office sector (82%) as well as the retail and service sectors (82%) and least active in the industrial and production sectors (68%).

4.2 Technology adopter profiles

Based on our demand-side sample, we formed three technology adopter groups (Table 3), described their socio-demographic, household and building characteristics, and compared them to the Swiss population and the Swiss residential building stock (Table 4).

Table 3: Technology adopter profiles.

	Technology profiles
Co-adopters with PV, EV, and EMS (and EV charging station)	1'076
Adopters with PV without EV and EMS	631
Adopters with EV without PV and EMS	802
Total	**2'509**

All technology co-adopters have their PV integrated into their EMS, while 83% make use of dynamic load management for charging their EV. Almost 90% of the ones who use a heat pump (HP) as their main heating system manage it with their EMS, whereas about 65% of the battery storage systems are integrated.[1] About 20% integrate other household appliances, such as washing machines or dishwashers. When we asked about the main purpose of their EMS, the majority wants to optimize the share of energy self-consumption (86%) and visualize energy flows (72%). Less important is the load management for EV charging, the billing of energy applicable for buildings with multiple owners or tenants, and the management of auto-consumption communities. The PV installations of the PV adopters group have an installed capacity of 5-10 kWp (45%), and 27% have 10-20 kWp. Only 19% are below 5 kWp and 9% are above 20 kWp. The EV owners mostly charge their car at home. When asked how often they charge their car at home, at work, or in public spaces on a scale from never (0%) to always (100%), we get a mean value of 80% for home, 31% for work, and 29% for public spaces.

When distributing the survey, we asked the person who was mostly responsible for the technology adoption decision in the household, to fill in the survey. The socio-demographics, therefore, refer to the person who mostly feels responsible for the decision to adopt the technology. The results show that energy technology adopters are on average 56 years old, being, thus, significantly older than the Swiss average. They are mostly male and highly educated, with 88% of them having a secondary or tertiary education level, compared to 52% in the Swiss population. Technology adopters are mostly employed or retired, with 70% of them having a monthly budget above CHF 7'000, which is significantly higher than the Swiss average. The results also show that most technology adopters live in a couple with children (54%), they live in single-family housing (70%) with a clear majority owning their home (86%). The high share of house ownership is the most outstanding when compared to Swiss standards. About 20% of them also renovated their house when implementing the technology, and 20% are part of an auto-consumption community.

When looking at the differences between the three technology profiles, we observe that PV adopters are significantly older than the other two groups. PV adopters tend to have lower education and income levels and more are retired. EV adopters, in contrast, hold the highest employment rate and have slightly higher education levels than the other groups. The majority of PV adopters and technology co-adopters with PV, EV, and EMS live in single-family housing (about 80%), they own their house, while this clearly distinguishes them from EV adopters, with a higher share of tenants (38%) and multi-family housing (54%). In addition, they are rather members of auto-consumption communities and renovated their houses when compared to EV adopters.

[1] 57% of technology co-adopters have heat pumps; 62% have a battery storage.

Table 4: Socio-demographics, household and building characteristics of technology adopter groups compared to the Swiss population and the Swiss residential building stock (opendata.swiss).

		CH	**Total** (N = 2'509)	**PV + EV + EMS adopters** (N = 1'076)	**PV adopters** (N = 631)	**EV adopters** (N = 802)
Socio-demographic characteristics						
Gender (*)	Male	50%	81%	80%	84%	83%
	Female	50%	13%	10%	16%	17%
	Other	-	5%	10%	0%	1%
Age (*)	Mean	43	56	56	61	50
Education (*)	Primary level	48%	12%	13%	13%	12%
	Secondary level	27%	42%	40%	49%	37%
	Tertiary level	25%	46%	47%	37%	51%
Employment (*)	Employed	59%	72%	74%	56%	82%
	Retired	23%	25%	22%	41%	15%
	Others	18%	3%	4%	3%	3%
Household characteristics						
Region (*)	German	68%	54%	61%	48%	50%
	French	26%	34%	30%	41%	35%
	Italian	6%	12%	9%	11%	15%
Monthly household income (*)	Above CHF 13,000	4%	26%	33%	11%	27%
	CHF 9,001 -13,001	8%	27%	28%	22%	29%
	CHF 7,001 - 9,000	12%	18%	16%	22%	17%
	CHF 5,001 - 7,000	27%	13%	8%	22%	13%
	Up to CHF 5,000	49%	5%	3%	10%	4%
	Others	-	12%	12%	13%	10%
Household composition (*)	Couple with children	34%	54%	61%	49%	48%
	Couple without children	27%	34%	33%	37%	33%
	Single	36%	9%	4%	9%	15%
	Other	3%	3%	2%	5%	3%
Building characteristics						
Ownership (*)	Owner	36%	86%	98%	100%	62%
	Tenant	58%	13%	2%	0%	38%
	Other	6%	1%	0%	0%	2%
Building type (*)	Multi-family	28%	29%	17%	15%	54%
	Single-family	57%	70%	82%	83%	44%
	Other	15%	2%	1%	2%	2%
Renovation with technology adoption (*)		-	19%	25%	24%	8%
Part of auto-consumption community (*)		-	21%	31%	27%	4%

(*) Significant differences among technology adopter groups (Chi-square and Kruskal-Wallis test; Sig. p < 0.05).

Key takeaways

The findings show that compared to the Swiss average population, energy technology adopters are highly educated, have a higher income level, and tend to live in a partnership with children. We observe that technology co-adopters and PV adopters mostly own their homes and live in single-family housing. The employment rate and income level of EV adopters are even higher. However, with a mean age of 50, they are younger than the average age of technology adopters in our sample, and they are also tenants living in multi-family housing. Our results suggest that there is a significant untapped potential in multi-family housing. This does not imply that there is no further potential for single-family buildings, especially considering the Swiss energy goals until 2050, however, it needs particular attention. Thereby, institutional investors (e.g., insurances, banks) have a high leverage and are key for energy technology diffusion in the multi-family housing sector.

4.3 Technology co-adoption patterns

Technology co-adoption refers to the situation in which users adopt more than one energy technology, either at the same time (technology bundle) or within a short or longer period. As we had the possibility to directly approach PV and EV adopters, our technology user sample is well suited to analyze the technology co-adoption patterns in the Swiss residential building sector. In order to do so, we analyzed which energy technologies the households apply, and in which sequence these technologies were installed and purchased. For the analysis, we consider the technologies PV, EV, EMS, and HP. For the technology co-adoption analysis, we are more restrictive with the definition of EMS adopters. We only consider as EMS adopters those who have PV integrated and two consumption technologies, such as HP, EV charging stations, hot water boilers, battery storage, or household appliances. For HP, we only consider the ones that are installed as main heating systems.

The diffusion of EMS is taking off

The analysis shows that 76% of the respondents in our sample have PV installed, 67% have EV, 45% have HP and 16% have EMS in their building. Table 5 presents the technology combinations of our sample showing that 65% of the respondents are technology co-adopters, i.e., they use more than one technology, while 35% only use either PV or EV. 16% of the technology adopters in our sample manage their energy production and consumption with an EMS that integrates their PV and at least two consumption technologies.

Table 5: Technology co-adoption patterns of PV and EV adopters.

	Technology co-adoption patterns (N = 4'847)
HP_PV_EV_EMS	10%
PV_EV_EMS	6%
HP_PV_EV	13%
PV_EV	14%
PV_HP	16%
HP_EV	6%
PV	16%
EV	18%
Total	**100%**

Technology bundles are key with PV as a trigger for technology co-adoption

Figure 6 shows the installation or purchase year for PV, EV, EMS, and HP of our sample. It shows that most of the PV installations were adopted between 2019 and 2021 and most EV purchases took place between 2020 and 2022. This is due to our sample selection, as we approached the most recent 20'000 PV adopters starting from December 2021 and the most recent 15'000 EV adopters starting from March 2022. For analyzing the sequence of technology adoption and to avoid any biases due to our sample selection, we selected the households that adopted PV or/and EV in 2021. Therefore, we analyzed which technologies were adopted before and after the PV installation or/and EV purchase for Swiss 1'483 households.

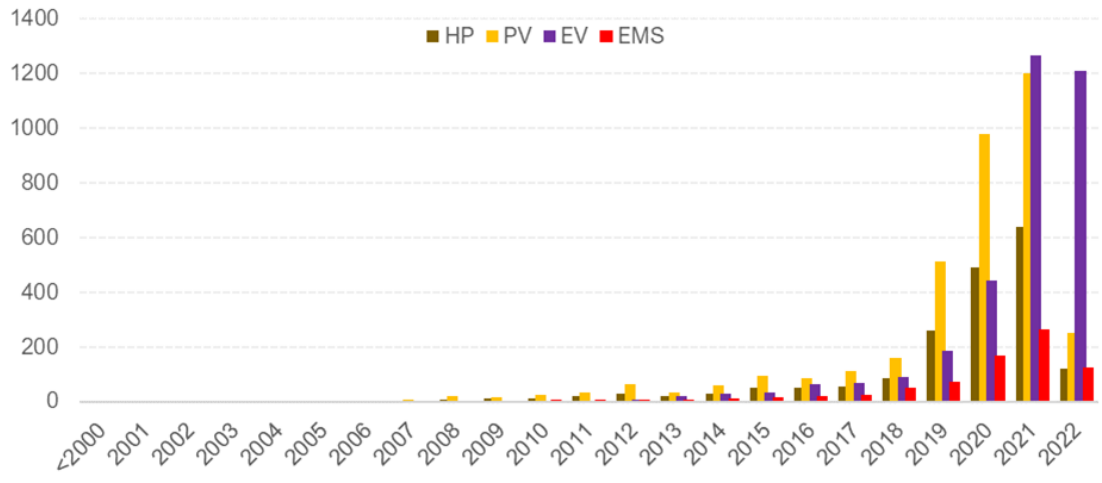


Figure 6: Installation year of energy technologies.

The ranking of the technologies by adoption year resulted in 62 different combinations of what we call technology co-adoption pathways. These pathways give us not only more insights regarding the relevance of certain technologies that might function as triggers to co-adopt other technologies but also highlight to what extent technologies are installed as bundles, i.e., are installed at the same time. Table 6 shows the most common pathways (representing 82% of all combinations). Overall, our results show that 88% of the cases contain technology bundles where a technology is adopted at the same time together with one or more other technologies.

Table 6: Technology co-adoption pathways of PV and EV adopters.

Technology co-adoption pathways (N = 1'483)					
4-tech		**3-tech**		**2-tech**	
HP>**PV**=**EMS**>**EV**	4%	**HP**>**PV**>**EV**	7%	**PV**>**EV**	15%
HP>**PV**=**EV**=**EM**S	3%	**HP**=**PV**>**EV**	3%	**HP**>**PV**	14%
HP=**PV**=**EMS**>**EV**	2%	**HP**>**PV**=**EV**	3%	**HP**=**PV**	6%
HP>**EV**>**PV**=**EMS**	2%	**PV**=**EMS**>**EV**	3%	**HP**>**EV**	5%
… (26)	7%	**PV**=**EV**=**EMS**	2%	**EV**>**PV**	5%
		HP>**EV**>**PV**	2%	**PV**=**EV**	5%
		EV>**PV**=**EMS**	2%	*... (3)*	2%
		... (16)	7%		
Total (x-tech)	**18%**		**29%**		**52%**
Total					**100%**

techA **>** *techB: techA adopted* ***before*** *techB*
techA **=** *techB: techA adopted* ***at the same time*** *as techB (technology bundle)*

When analyzing the technology pathways in more detail, our results show that PV and EV are adopted at the same time in 21% of the cases, PV is adopted before EV in 40% and EV is adopted before PV in 13% of the cases (Table 7). We observe that 38% of our technology users installed HP before PV, 34% adopted HP before EV, while 22% bundled their HP with the installation of PV or EV purchase. For technology pathways including EMS, we find EMS-PV bundles in almost 70% of the cases, and only in 15% of the cases EMS is installed afterward. EMS is least bundled with HP (3%) but rather installed after HP (45%).

Table 7: Technology combinations of PV and EV adopters.

	=HP (1)	=PV (1)	=EV (1)	=EMS (2)
HP (1)		17%	5%	3%
PV (1)			21%	69%
EV (1)				32%
EMS (2)				

	>HP (1)	>PV (1)	>EV (1)	>EMS (2)
HP (1)		38%	34%	45%
PV (1)	5%		40%	15%
EV (1)	4%	13%		19%
EMS (2)	5%	17%	32%	

techA **>** *techB: techA adopted* ***before*** *techB*
techA **=** *techB: techA adopted* ***at the same time*** *as techB*

(1) Based on N=1'483 (all technology pathways)
(2) Based on N = 392 (technology pathways with EMS)

Key takeaways

The technology co-adoption rate in the Swiss residential building sector is high - 65% of the PV and EV adopters in our sample apply more than one low-carbon energy technology. This is due to our sample selection, as we only approached PV and EV adopters in the first place. However, among these, it seems that the diffusion of EMS is taking off as 16% effectively manage their energy production and consumption in their building, having PV and two other consumption technologies integrated into their management system. We could argue that 16% of PV and EV adopters in Switzerland are highly engaged in the energy transition, not only by adopting certain low-carbon energy technologies, but by managing their energy production and consumption and relieving power grids, which is essential for a transition towards renewable energy. The share of highly engaged technology adopters also corresponds with the innovators and early adopters' group, which we observe in the diffusion of innovation studies (Rogers, 2003).

The high co-adoption rate reveals that there is a high potential for EMS in residential buildings, as 50% of our sample have either two or three energy technologies installed. For further diffusion of EMS, it seems to be promising that technology providers and energy utilities raise awareness among customers who already have energy technologies installed, or once they get in touch with their customers, i.e., whenever PV installations or other consumer technologies such as HP and charging stations are registered. They could for instance inform about the advantages of EMS when confirming registration.

Although we cannot argue that there is a causal link between the adoption of two or more technologies, however, due to our sample size and the analysis of almost 1'500 technology co-adoption pathways, we can observe the main patterns and get insights about the relevance of certain technologies that trigger technology bundling or co-adoption. First, our findings reveal the importance of technology bundles. It seems that there is already awareness among energy technology users, and/or that supply-side actors promote technology bundles, as we observe a high share of technologies implemented at the same time. Although long-term planning is necessary and energy technologies are not or cannot necessarily be implemented at the same time (e.g., heat pump and EV), households should be informed about the potential synergies whenever one of the technologies is installed.

Second, we found that PV is the most relevant trigger technology for EMS. EV-EMS bundles are implemented in only half as many cases, however, EV purchases still seem to be a trigger to install EMS. PV also seems to be a trigger for EV adoption, rather than the other way around. One may think that this is because PV has a longer history than EV, however, we analyzed the technology co-adoption pathways of PV and EV adopters who both implemented or purchased the technology in 2021, which means that this cannot only explained by that. On the other side, our results show that HP is mostly installed before PV and EV (and therefore EMS), which can also be explained by our sample selection, since we observe HP adoption only one year after PV and EV adoptions take place (technology user survey conducted in 2022). Therefore, how far PV and EV adoption triggers HP adoption cannot be derived from our results.

4.4 Perceived drivers and barriers to technology adoption

Technology adoption perceived as an opportunity rather than a crisis

Often, a specific trigger or spark event makes people start considering the adoption of a new technology . This can either be perceived as a problem or as an opportunity. According to Mintzberg (1976), a problem or crisis can be evoked by multiple stimuli initiating a certain degree of pressure of action. Opportunity situations tend to be also triggered by a stimulus but are characterized by an idea and by being voluntary rather than an unintended pressure. Our results show that the adoption of the studied energy technologies is clearly perceived as an opportunity situation. For each of the technologies we studied, i.e., PV, EV, and EMS, about 75% of the respondents state that they took advantage of an opportunity and optimized their situation by implementing the technology. Preventing possible future crises was a trigger for about 22% of them, while only 2-3% stated that they followed the recommendations from others (social norm and opportunity situation).

Perceived characteristics of technologies

According to Rogers' diffusion of innovation theory (2003), not only the characteristics of the adopters, but the perceived characteristics of innovations influence the adoption decision. Rogers states that the "individuals' perception of these characteristics predicts the rate of adoption of innovations". Rogers describes the innovation-diffusion process as an uncertainty reduction process and proposes attributes of innovations that can help to decrease uncertainty about the innovation, i.e., relative advantage, compatibility, complexity, trialability, and observability. Figure 7 shows the statements we used to operationalize some of these characteristics and how far the respondents agreed or disagreed with these statements for each of the technologies. The results show that the respondents rather agree that the technologies contribute to promoting renewable energy and that they have a positive image, they rather disagree with the statement that they are complicated to use, especially for EV. On the other side, there is a low agreement that the technology brings a good economic return.

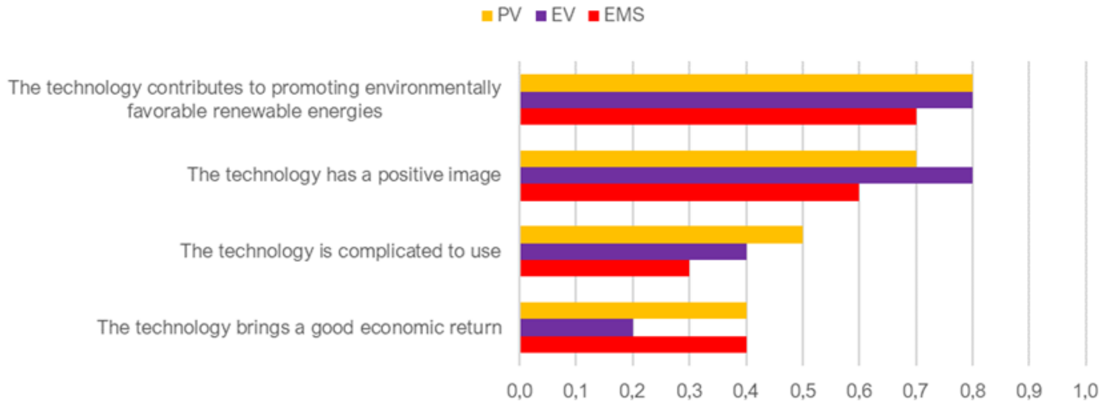


Figure 7: Perceived characteristics of technologies (fully disagree (0) to fully agree (1)).

Technology adopters are driven by their positive attitude toward energy-conscious behavior

To identify the drivers for technology adoption, we asked the respondents to assess a set of statements related to their decision to adopt a specific technology. The statements were designed based on the general conceptualization of investment behaviors derived from the theory of planned behavior (Ajzen, 1991) and can be categorized into (i) respondents' attitude towards the adoption behavior and technology; (ii) perceived behavioral control which is the perceived ease or difficulty to use the technology; (iii) perceived contextual factors; and (iv) social norm, i.e., social influence from experts and personal network through recommendations (active) and influence through seeing the technology being implemented (passive). Figure 8 shows the results related to the EMS, PV, and EV technology and to what extent the respondents agree or disagree with the given statements.

For EMS and PV, the results show that they mostly have a positive attitude regarding energy-conscious behavior. They want to optimize their energy self-consumption, promote renewable energy, be energy independent and they like to use innovative technologies. The perceived behavioral control factors rank second, i.e., they feel capable of applying the technology and have sufficient information about it. The agreement is lower when it comes to favorable contextual factors such as their building characteristics, their financial situation, and the support by professionals, while the benefit from the regulatory framework ranks lowest. The (dis-)agreement with favorable contextual factors is approximately at the same level as the factors related to the attitude towards economic aspects of the technology, i.e., the expectation of electricity costs to increase in the future and the financial attractiveness of the technology. The statements related to the respondents' social norm rank lowest, i.e., recommendations from professionals, the personal network and neighbors, and the influence from seeing the technology being implemented around them receive disagreement.

For EV, we observe a slightly different picture. EV respondents also have a very positive attitude regarding energy-conscious behavior, however, mostly want to promote renewable energy and use innovative technologies. They have about the same agreement levels for perceived behavioral control factors, attitude regarding economic aspects of EV, and favorable contextual factors, while the benefit from the regulatory framework and the support by professionals during the decision and implementation phase rank even lower compared to EMS and PV. This is also the case for social influence, especially for recommendations from neighbors and professionals.

Through the survey, we identified a group of potential EMS adopters who consider implementing an EMS in the near future (about 30% of respondents who have not yet implemented EMS). They also assessed the statements presented above (see Figure 8, values for potential EMS adopters are in brackets). Overall, we obtained similar results with regard to the rank of the factors, however, the factors related to social norm receive a lower level of disagreement compared to the ones who already adopted EMS. This is true, especially for recommendations from personal networks and professionals.

DRIVERS demand-side How much do you agree with the following statements? *Fully disagree (0) to fully agree (1)*	**EMS** *N = 1'076* *(N = 746)*	**PV** *N = 1'378*	**EV** *N = 1'365*
Attitude			
I believe the technology is financially attractive for me	**0.5** *(0.5)*	0.5	0.6
I expect my electricity or fuel costs to increase in the future	**0.6** *(0.6)*	0.5	0.5
I want to promote environmentally friendly renewable energies	**0.9** *(0.8)*	0.9	0.8
I want to become more energy independent	**0.8** *(0.8)*	0.7	0.5
I want to optimize my energy (self-)consumption	**0.9** *(0.8)*	0.8	0.6
I like using a new or innovative technology	**0.7** *(0.7)*	0.7	0.8
Perceived behavioral control			
I feel capable of applying the technology appropriately	**0.7** *(0.7)*	0.7	0.7
I have access to sufficient information on the technology	**0.7** *(0.6)*	0.7	0.7
Perceived context			
I benefit from regulatory framework conditions	**0.4** *(0.5)*	0.5	0.3
I have favorable infrastructural framework conditions	**0.6** *(0.6)*	0.6	0.5
I have a favorable financial situation	**0.6** *(0.6)*	0.6	0.6
I am supported by a professional during the decision or implementation phase	**0.6** *(0.6)*	0.6	0.3
Social norm			
Someone from my personal network recommends it to me	**0.3** *(0.5)*	0.3	0.3
A neighbor recommends it to me	**0.1** *(0.3)*	0.1	0.1
A professional recommends it to me	**0.3** *(0.5)*	0.3	0.2
I see an increasing number of people implementing the technology around places I spend time for work or leisure activities	**0.3** *(0.4)*	0.3	0.3
I see an increasing number of people implementing the technology around my home or in my neighborhood	**0.2** *(-)*	0.3	0.3

Figure 8: Perceived drivers for technology adopters (potential EMS adopters).

Mismatches between technology adopters' and supply-side actors' perception of drivers

One of the objectives of conducting a survey with technology users and a survey with actors on the supply-side key for the diffusion of these technologies was to identify the mismatches between the two. Therefore, we asked the organizations to assess the statements based on their experiences and their exchange with technology adopters. Figure 9 shows the differences for each of the statements.

Overall and across all technologies, we can make three relevant observations when focusing on the mismatches. First, the organizations rate social influence, i.e., the recommendations from others but also seeing the technology being implemented around them, much higher than the technology adopters. Second, the technology adopters rate the perceived behavioral control factors higher than the organizations. This shows that users feel more capable of applying the technology and rather perceive to have sufficient information about the technology than the organizations think they have. Third, the opposite is true for professional support. Organizations rate the professional support when implementing the technology higher than the technology users. For EMS and PV specifically, the willingness to promote environmentally friendly renewable energies is rated higher by technology adopters, whereas the organizations have higher ratings when it comes to the financial attractiveness of these and the expectations that electricity costs will increase in the future.

DRIVERS demand versus supply-side *How much do you agree with the following statements?* *Fully disagree (0) to fully agree (1)*	**EMS** *N = 1'076* *N = 55*	**PV** *N = 1'378* *N = 60*	**EV** *N = 1,365* *N = 22*
Attitude			
I believe the technology is financially attractive for me	-0.1	-0.2	0.0
I expect my electricity or fuel costs to increase in the future	-0.1	-0.2	0.0
I want to promote environmentally friendly renewable energies	0.1	0.2	0.0
I want to become more energy independent	0.0	0.0	0.0
I want to optimize my energy (self-)consumption	0.0	0.0	-0.1
I like using a new or innovative technology	0.2	0.2	0.1
Perceived behavioral control			
I feel capable of applying the technology appropriately	0.2	0.1	0.2
I have access to sufficient information on the technology	0.2	0.1	0.1
Perceived context			
I benefit from regulatory framework conditions	0.0	-0.1	-0.1
I have favorable infrastructural framework conditions	0.1	0.1	-0.1
I have a favorable financial situation	0.1	0.0	-0.1
I am supported by a professional during the decision or implementation phase	-0.2	-0.1	-0.3
Social norm			
Someone from the personal network recommends it to me	-0.2	-0.1	-0.3
A neighbor recommends it to me	(-)	(-)	(-)
A professional recommends it to me	-0.3	-0.4	-0.5
I see an increasing number of people implementing the technology around places I spend time for work or leisure activities	-0.4	-0.4	-0.4
I see an increasing number of people implementing the technology around my home or in my neighborhood	(-)	(-)	(-)

Figure 9: Perceived drivers for technology adoption comparing demand and supply-side *(positive values indicate that technology adopters rate higher than organizations, negative values indicate that organizations rate higher than technology adopters).*

Lack of financial attractiveness, standards, and complexity of actors' landscape as main barriers to the diffusion of EMS

Through the survey, we identified a group of EMS rejectors who stated in the survey that they had considered implementing EMS but decided not to do so (about 5% of respondents who have not yet implemented EMS). They were asked about the factors that prevented them from adopting EMS. Figure 10 shows that the highest rated barrier by EMS rejectors is the lack of financial attractiveness, while the lack of favorable contextual factors ranks second, i.e., conditions of the building infrastructure as well as the lack of financial means to implement EMS. On the supply-side, the organizations also perceive the lack of financial attractiveness as the highest barrier to adoption, together with the hesitation to use a new technology and the disagreement with the condominium owners. The lack of perceived behavioral control factors also ranks second, however are - in absolute terms - rated higher by organizations than by technology adopters. This is also true for the lack of professional support and the social norm factors. The mismatches between organizations' and technology adopters' perception of barriers therefore follow the same pattern as we could observe for the drivers.

BARRIERS *How much do you agree with the following statements?* *Fully disagree (0) to fully agree (1)*	**EMS reject** *N = 99*	**EMS supply** *N = 55*	**EMS compare**
Attitude			
I believe the technology is financially not attractive for me	0.6	0.5	0.1
I tend to hesitate using a new or innovative technology	0.2	0.5	-0.3
Perceived behavioral control			
I do not feel capable of applying the technology appropriately	0.2	0.4	-0.2
I do not have access to sufficient information on the technology	0.2	0.4	-0.2
Perceived context			
The present regulatory framework conditions hinder me	0.2	0.3	-0.1
I have unfavorable infrastructural framework conditions	0.4	0.4	0.0
I do not have the financial means	0.3	0.4	-0.1
No agreement can be found among the condominium owners	0.1	0.5	-0.4
I lack support from professionals that spearhead the implementation	0.1	0.3	-0.2
Social norm			
Someone from my personal network discouraged me	0.1	0.3	-0.2
A neighbor discouraged me	0.0	(-)	(-)
A professional discouraged me	0.2	0.2	0.0

Figure 10: Perceived barriers for technology adoption comparing demand and supply-side.

These findings are in line with the findings from the interviews we conducted with supply-side actors working with EMS as well as technology users who mention that the lack of financial viability is a barrier to EMS diffusion. Some statements that support this aspect are for example: (i) *"We need to find a financial model that benefits the end-user, that gives him reasons to make the investment, but that also supports companies wishing to carry out pilot projects and experiments."*; (ii) *"If we put EMS in an existing house, well, rewiring, the neighbor, etc., it is going to get expensive very quickly. I think that the financial aspect is really an obstacle."*; (iii) *"I think the obstacles are financial because everything that has to do with batteries is still an extremely expensive technology for the moment."*

Less prominent in the surveys, but dominant in the supply-side interviews, was the current regulatory framework as a barrier for the diffusion of EMS. One interviewee for example states: *"The EMS can manage and optimize your flows but if your billing does not correlate with that optimization, it is useless. We need a regulatory framework that correlates the technical reality with the billing reality. If the costs do not change when you invest in an EMS, why should you invest? The price should depend on the effective consumption."* According to the supply-side actors we interviewed, a supportive regulatory framework should be implemented which includes (i) technical standards for products the companies produce; (ii) regulations in the construction sector to meet certain standards in terms of energy consumption, PV installations, and charging stations; and (ii) effective investment strategies that focus on the highest impacts, e.g., to incentivize real estate companies to install EV charging stations in residential and office buildings, instead of focusing on the installation of public charging stations.

Another relevant barrier we identified through our supply and demand-side interviews is the complexity of the actors' landscape and the lack of coordination among those. The most prominent aspects mentioned were (i) the complexity of actors in the field who have different interests and lack understanding; (ii) the different products and systems on the market and the lack of compatibility; and (iii) the need for a coordinating actor that accompanies the end-users on the decision process and implementation. We selected two statements from technology users that support these findings: (i) *"The decision-making process is extremely long and complex because nobody helps you."*; (ii) *"Finding the right person is the most important and the most difficult (...) This person needs to have the knowledge, have a general perspective, be able to give advice and be objective, not have interests. The heating installer only knows his part, he doesn't have the whole picture, and he cannot give you advice about the investment and the returns, he also has private interests in it. There is a missing link on the chain from the theory to the implementation, a person that can bridge the gap from theory to practice, answer the questions from people, and allow them to get into action."*

Key takeaways

The results imply that technology adopters as well as potential adopters hold an innovative spirit motivated to engage in the energy transition through their energy-conscious behavior, while sufficient information and knowledge seem to be key. Besides promoting renewable energies – the ones who implement EMS – particularly want to optimize their energy self-consumption, be independent, and use an innovative technology. Technology adopters perceive their situation mostly as an opportunity situation, which implies that a positive framing might be crucial to motivate potential adopters and should be preferred over a negative one, such as the climate or energy crisis. Raising awareness about energy-conscious behavior as well as innovative and efficient solutions to contribute to the energy transition, together with sufficient information to make the technologies more approachable, seems to be important.

Overall, we find that technology adopters have the characteristics of so-called "innovators and early adopters", who are interested in new ideas and who are willing to take risks (Rogers, 2003). They implement the technology although they perceive it as not (yet) financially viable and take this decision independently from their social environment. However, to reach the "early and late majority", we need to create incentives. It is argued that people typically need to see evidence that the innovation or technology works before they are willing to adopt it. They need information and want to see or hear about success stories and thus are more influenced by their social network (Rogers, 2003). This is also confirmed by our results, which reveal that social influence is a driver for technology adoption as not only organizations but also potential technology adopters rate social influence higher than the ones who already adopted the technologies. Our results therefore suggest that demonstrating the feasibility, advantages, and limits of technology implementation through success stories and best-practice examples is key. In addition, awareness about the long-term profitability of implementing energy technologies seems to be important, as they are rather not perceived as financially attractive although this is usually the case in the long-term. The results from the interviews reveal that coordination among technology providers and a supportive regulatory framework through technical standards ensuring technology integration hold the potential to foster EMS. Again, institutional investors are mentioned to be a key target group to foster EMS in the multi-family housing sector.

4.5 The role of information in technology adoption

Energy technology providers are key and information sources are expected to be more multifaceted than they actually are

Figure 11 shows the information sources of technology adopters that were useful for them in the decision-making process. Overall, professional information sources are more often used in the decision-making process than information exchanged with the personal network. The results show that they mostly rely on energy technology providers. Depending on the technology, about 60-80% of the respondents state that the information from technology suppliers and installers was useful for them. Also, they rely on energy or e-mobility service companies, energy utility entities, as well as public and non-profit organizations. Private funding companies and insurances, the construction sector, academia, and associations play a less important role. For EV, we observe that tendentially less information is exchanged with others when compared to PV and EMS. Regarding information from the personal network, technology adopters mostly exchange with persons living in their household (30%), followed by work or study colleagues, friends, and acquaintances. EV adopters tend to exchange much less with their neighbors than EMS and PV adopters, although the exchange with neighbors is on a low level in absolute terms.

When asking the supply-side actors which professional information sources the technology users mention as being useful for their decision, we see the following differences (Figure 12). Overall and across all technologies, we observe that supply-side actors generally expect a higher degree of information exchange and a more multifaceted information pool, i.e., more information from a different set of actors. This is especially the case for EV. In contrast – for PV – the supply-side actors expect the energy technology providers to be more important.

INFORMATION SOURCES demand
Multiple choice

	EMS N = 1'076	PV N = 1'378	EV N = 1'365
Professional			
Energy technology providers	79%	73%	58%
Energy or e-mobility service companies	36%	23%	25%
Energy utility companies	27%	23%	17%
Construction sector	17%	17%	6%
Public and non-profit organizations	22%	26%	14%
Associations	8%	9%	7%
Academia	13%	9%	11%
Private funding companies or insurances	5%	3%	3%
Personal network			
Persons living in my household	30%	33%	31%
Other family members or relatives	18%	19%	17%
Friends	20%	20%	25%
Neighbors	11%	12%	6%
Work or study colleagues	28%	19%	25%
Acquaintances	22%	25%	18%

Figure 11: Professional and personal information sources.

INFORMATION SOURCES demand versus supply-side
Multiple choice

	EMS N = 1'076 N = 55	PV N = 1'378 N = 60	EV N = 1'365 N = 22
Professional			
Energy technology providers	1%	20%	-28%
Energy or e-mobility service companies	-37%	-14%	-38%
Energy utility companies	-24%	-14%	-46%
Construction sector	-9%	-18%	-12%
Public and non-profit organizations	-3%	-5%	-31%
Associations	-20%	-13%	-29%
Academia	-8%	-4%	-7%
Private funding companies or insurances	-1%	-3%	-1%

Figure 12: Professional information sources comparing demand and supply-side *(positive values indicate that technology adopters rate them higher than organizations, negative values indicate that organizations rate them higher than technology adopters).*

Mismatch of information channels, especially related to the internet and social media

In both surveys, we asked about the information channels and platforms they use. On the demand-side, we asked about the channels that were useful for technology adopters to inform themselves in the decision-making process. On the supply-side, we asked about the channels supply-side actors use to exchange information or promote their services with potential technology users. Our results show that internet websites with information about the technology (66-78%) as well as subsidies and legal regulations (36-51%) are key and among the most frequently used channels. This is also true for personal face-to-face contact (42-56%) and media such as TV, newspapers, magazines, or radio (27-38%). One interviewee states: *"Interpersonal human relations are the most important thing, seeing each other face-to-face."* Other channels like events, social media, personal contact through email or phone, and exchanges with communities are less important (Figure 13). The results show that EV adopters use significantly less personal face-to-face contact and fewer internet websites with information about subsidies and legal regulations, they inform themselves less at events, however, use significantly more social media channels.

Figure 14 demonstrates the mismatches between the demand and supply-side. It shows that the internet as well as media are more frequently mentioned by technology adopters than by supply-side actors. The opposite is true for social media and events. For EV in particular, interpersonal face-to-face contact is mentioned more often by organizations.

INFORMATION CHANNELS demand
Multiple choice

Channels	EMS *N = 1'076*	PV *N = 1'378*	EV *N = 1'365*
Media	27%	34%	38%
Internet websites - information on technology	78%	66%	77%
Internet websites - information subsidies and regulations	51%	47%	36%
Mailings	5%	5%	3%
Digital newsletter	8%	7%	8%
Events	14%	14%	6%
Social media	10%	5%	22%
Interpersonal face-to-face contact	53%	56%	42%
Interpersonal digital contact (f.e. phone, email)	19%	12%	11%
Communities or projects related to the technology	15%	12%	9%

Figure 13: Information channels for technology adopters.

INFORMATION CHANNELS demand versus supply-side
Multiple choice

Channels	EMS *N = 1'076* *N = 55*	PV *N = 1'378* *N = 60*	EV *N = 1'365* *N = 22*
Media	11%	18%	16%
Internet websites - information on technology	32%	35%	18%
Internet websites - information subsidies and regulations	23%	21%	-9%
Mailings	-10%	-9%	-19%
Digital newsletter	-10%	-2%	-28%
Events	-26%	-8%	-39%
Social media	-26%	-15%	-41%
Interpersonal face-to-face contact	-15%	8%	-39%
Interpersonal digital contact (f.e. phone, email)	-46%	-29%	-57%
Communities or projects related to the technology	-13%	3%	-27%

Figure 14: Information channels comparing demand and supply-side *(positive values indicate that technology adopters rate them higher than organizations, negative values indicate that organizations rate them higher than technology adopters).*

Information about general characteristics and functionality of the technology are key

Figure 15 shows which type of information is the most relevant when deciding to adopt a technology (EMS, PV or EV). Knowing about the general characteristics and functionality of the technology (62-73%) appears to be the most important across all technologies. Also, information about financial support and investment possibilities, information about benefits and risks of implementing the technology, as well as specific ways to implement, use, or maintain the technology are useful for them. However, we observe significant differences, mostly related to EV. Information about financial support and investment strategies is significantly less important than for EMS and PV. In contrast, the success or failure stories of others who adopted EV are more relevant. For EMS, we observe that specific ways to implement the technology are more important than for PV and EV.

Figure 16 shows results for the differences between demand and supply. Overall, the results show that demand and supply are in line regarding the general characteristics and functionality of the technology. However, information about specific ways to implement the technology is more frequently exchanged by supply-side actors than they are useful for technology adopters. For EMS, this is also the case for information about the benefits and risks of implementing the technology as well as the success or failure stories of someone who adopted the EMS. In contrast, for EMS and PV, information about financial support is more frequently mentioned by technology adopters than by organizations who responded to the survey.

INFORMATION TYPE demand
Multiple choice

Type	EMS N = 1'076	PV N = 1'378	EV N = 1'365
General characteristics and functionality of the technology	66%	62%	73%
Specific ways to implement, use or maintain the technology	39%	26%	28%
Financial aid	46%	53%	21%
Investment possibilities	30%	32%	9%
Benefits and risks of implementing the technology	39%	32%	43%
Success and failure story of someone who adopted the technology	18%	17%	27%

Figure 15: Type of information for technology adopters.

INFORMATION TYPE
Multiple choice

Type	EMS N = 1'076 N = 55	PV N = 1'378 N = 60	EV N = 1'365 N = 22
General characteristics and functionality of the technology	-5%	7%	-13%
Specific ways to implement, use or maintain the technology	-34%	-18%	-31%
Financial aid	21%	7%	-47%
Investment possibilities	17%	4%	-13%
Benefits and risks of implementing the technology	-24%	-16%	-20%
Success and failure story of someone who adopted the technology	-23%	1%	-13%

Figure 16: Type of information comparing demand and supply-side *(positive values indicate that technology adopters rate higher than organizations, negative values indicate that organizations rate higher than technology adopters).*

Key takeaways

A better understanding of the key actors who spread information about energy technologies and the information platforms used is highly important, as effective information strategies can be seen as highways for energy technology diffusion. The ones who provide and install the technologies, energy service companies as well as energy suppliers are the most relevant, while the information exchange with the personal network should not be underestimated. These results highlight that certain professionals are key for transferring information and should get training about the integration and synergies with other technologies.

Technology adopters particularly rely on the internet and interpersonal face-to-face exchanges and are mostly interested in the general characteristics and functionality of the technology, as well as information on financial support. Although basic technical information is relevant for all technologies, specific ways to implement the technology seem to be rather important for EMS. Regarding the internet and social media, we observe a mismatch. While the internet is used more by technology users than by supply-side actors, the opposite is true for social media. For EV specifically, the decision-making process seems to be more private and less informed by professionals. EV adopters use less personal face-to-face contact and internet websites, however, use more social media channels. The findings suggest that supply-side actors, especially technology providers and energy utilities, should put efforts into their online presence and provide information on their websites, rather than using their resources for social media (except EV). Their websites could be used as an entry point for face-to-face exchanges which are key (even though less than supply-side actors perceive).

4.6 Networks and proximity

4.6.1 Demand-side interactions are driven by socio-spatial proximity

Technology adopters exchange information with those socially close to them

Technology adopters' most important personal interaction to exchange information is with those living in the same household (Figure 17). Outside of the household, they mostly exchange with friends, followed by colleagues, family, acquaintances, and, in the last position, with neighbors. The distributions for the three technologies show similar patterns except in the case of neighbors, in which EV shows lower values. They compensate those with higher values in exchanges with friends and "others". The values of others tend to refer to "nobody" or someone working in the professional sector, like an architect, car seller, energy technology provider, or consultant.

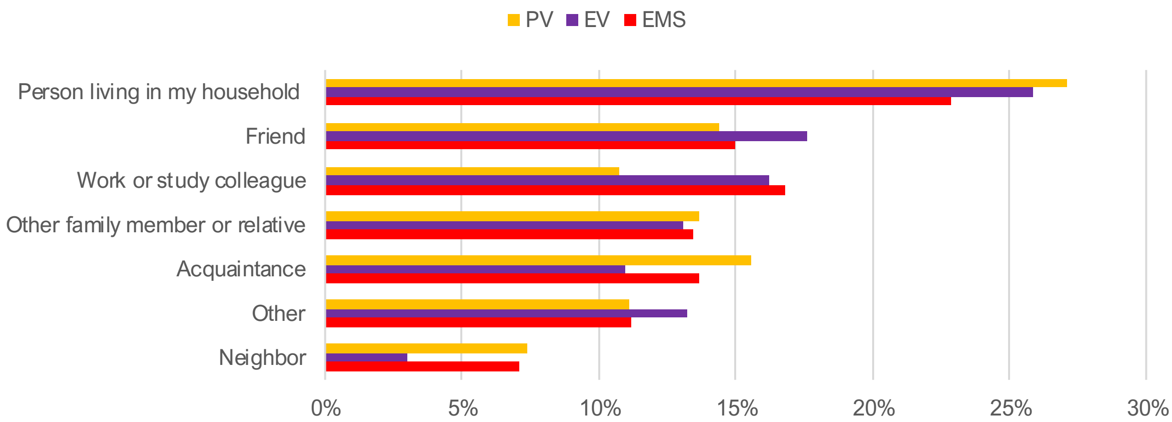


Figure 17: Most relevant personal interaction during the decision process to adopt the technology.

In general, the most relevant personal exchanges occurred at home. Even if this number decreases when interactions with their partner are excluded, it is still much higher than in any of the other locations (Figure 18). Outside the household, they exchange mostly at their work location or the home or office of the other person. Some differences exist between the different technologies being adopted. For EMS and PV, an important share of exchanges occurs at home, with these values being lower for EV. Home is the prime location for most PV respondents, with 35% of them exchanging there compared to 17% of

EMS and EV. EV respondents have an important share of exchanges in office locations (32%) and have higher values than EMS and PV in locations that are not homes.

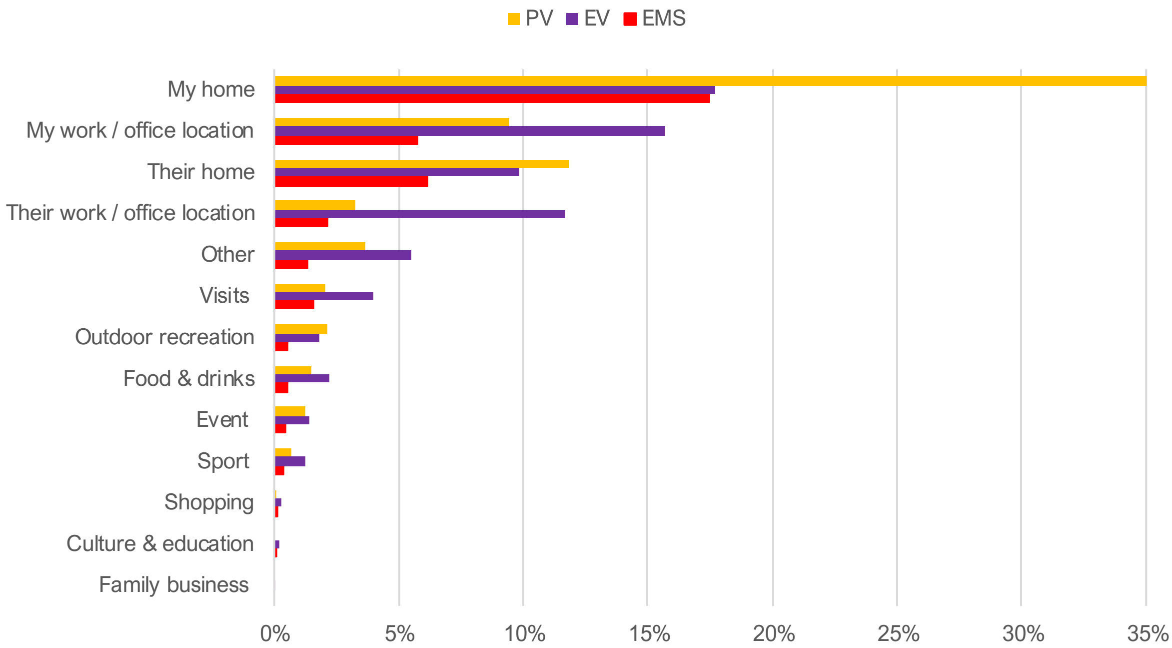
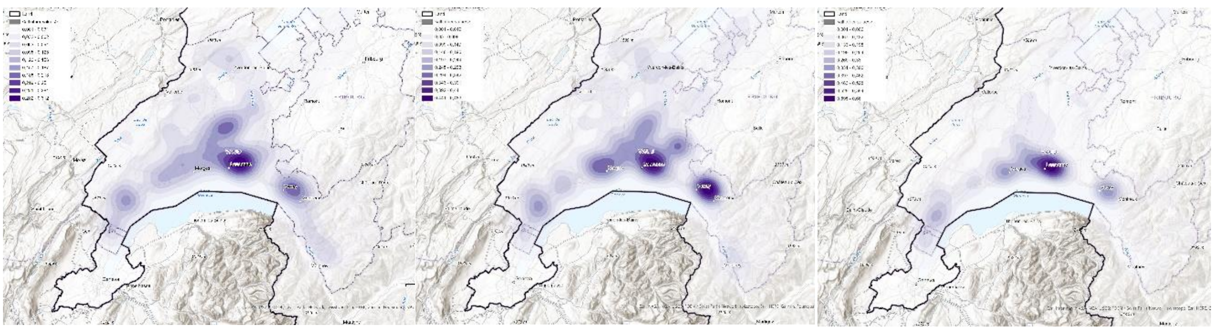


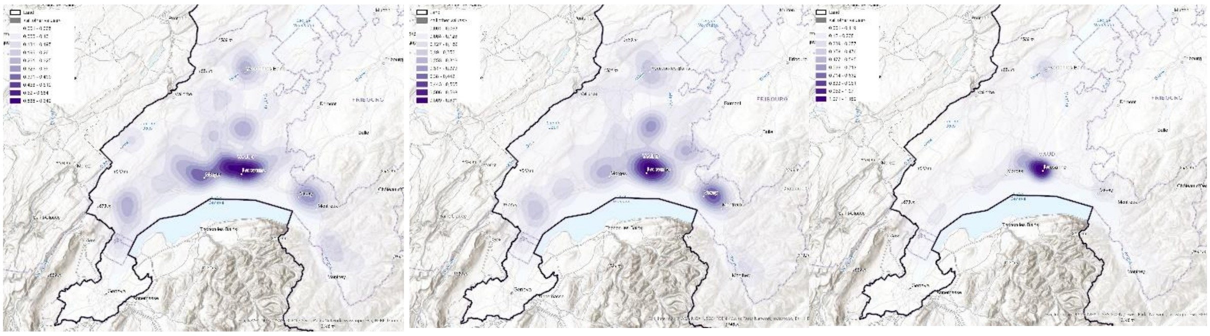
Figure 18: Place of most relevant personal interaction during the decision process to adopt the technology, excluding those that interacted with their partner or other person living in their household.

When not exchanging at home, they exchange in urban areas

The geographic distribution of personal information exchanges shows similar patterns in all case study regions. Compared with the home locations of technology adopters, information exchanges seem to be more concentrated in urban areas (Figure 19 for the case study region Vaud; see Appendix Figure A3 for other case study regions). This indicates that, when technology adopters exchange outside of their homes, they do so more in urban areas than in their home locations.



Vaud: EMS home location　　Vaud: PV home location　　Vaud: EV home location



Vaud: EMS information exchange location Vaud: PV information exchange location Vaud: EV information exchange location

Figure 19: Kernel density map of home locations and information exchange locations within the canton of Vaud.

Key takeaways

Although proximity effects, also called neighborhood effects, have traditionally been understood as social influence from neighbors through visual cues or interactions, our results indicate that technology adopters value exchanges with people with whom they have a close relationship. They are mostly partners but, outside of the household, also friends, colleagues, and family. EV users are the ones exchanging the least with neighbors, indicating the different characteristics of the technology. It may be possible that technologies more connected to the building infrastructure, such as PV and EMS, spur more interest in understanding how neighbors - people who may have similar conditions - have decided to address them.

The results regarding the place where the information exchanges occur show that the home location is very relevant for EMS, and most importantly for PV, while the office is very important for EV. This reveals a divide between technologies that are more tied to the building infrastructure (PV, EMS) and those that are more independent (EV). Previous results have shown that PV respondents own their homes and most live in single-family housing. These necessary conditions to adopt PV may also be reflected in their geographic distribution in the suburbs (Figure 19), which may also influence the location of social encounters. That is, people living in suburban areas tend to meet more often in each other's homes than in public locations.

Although most interpersonal exchanges when adopting technologies occur in private locations, for EV, the working environment also seems to be important. When designing marketing campaigns, it is therefore relevant to follow different approaches to increase adoption. Campaigns focusing on PV and EMS should be envisioned as a household-related decision, that is, people may be open to considering it when they are already in the process of renovating or refurbishing their homes. For EV, the timing may be more connected to other types of life events and less affected by changes in the household.

4.6.2 Demand-supply-side interactions are local

Technology providers are the most relevant information source for technology adopters

Energy technology providers are, by far, the supply-side actor that is most often mentioned by technology adopters when asked about the most important information exchange with a professional that helped them make the decision (Table 8). They are often mentioned with the specific name of the provider (2116 times) but also generally, stated as "supplier" or "provider" (329 times).

The number is not only significant in absolute terms but also when compared to the number of technology providers we contacted (440%). The other two supply-side actors that are overrepresented are energy utility entities (350%) and the construction sector (333%). It is interesting to mention that, in the latter, the supply-side actors were mentioned more often in general terms, such as "architect" or "engineer" than by the name of the organization. This implies that, for the demand-side users, a specific professional may be more relevant than the organization they belong to. In other words, it is more important that they exchanged with an architect than which company the architect works in.

There is a large range between the number of times a specific supply actor is mentioned. One supply-side actor was mentioned more than 150 times, 70 actors were mentioned 10 times or more, 10 actors were mentioned 30 times, and 38 actors were only mentioned once (Appendix Figure A4, Table A1). The top ten actors include seven energy technology providers, two energy utility entities, and one energy and e-mobility service company.

Table 8: Number of times supply-side actors were mentioned by demand-side actors when asked *"If you think about the most relevant information exchange with a professional that helped you make your decision… Would you please give us the specific name of the company or institution of this professional?"*

	Times mentioned	**Contacted organizations**	**Times mentioned by contacted organizations**
Energy technology providers	2'116 (+329)	555	381% (440%)
Energy utility entity	293	84	350%
Energy or e-mobility service company	52	83	63%
Association	31	82	38%
Construction sector	23 (+37)	18	128% (333%)
Academia	14	21	67%
Public and non-profit entity	8	63	13%
Total	**2'537** (2'903)	**906**	**280%** (320%)

Technology adopters mostly exchange information with supply-side actors around them

Spatial distance matters for the exchanges between technology adopters and the professionals they exchange with (Figure 20). In general, they exchange more information with local suppliers, particularly within the same linguistic region (Appendix Figures A5 and Figure A6). We can also see more links between the Italian and German region than between the Italian and French region. Some supply-side actors do not follow these local patterns and provide services throughout Switzerland. These seem to have a high degree centrality - many demand-side actors mention them - and seem to be located in the Swiss-German region.

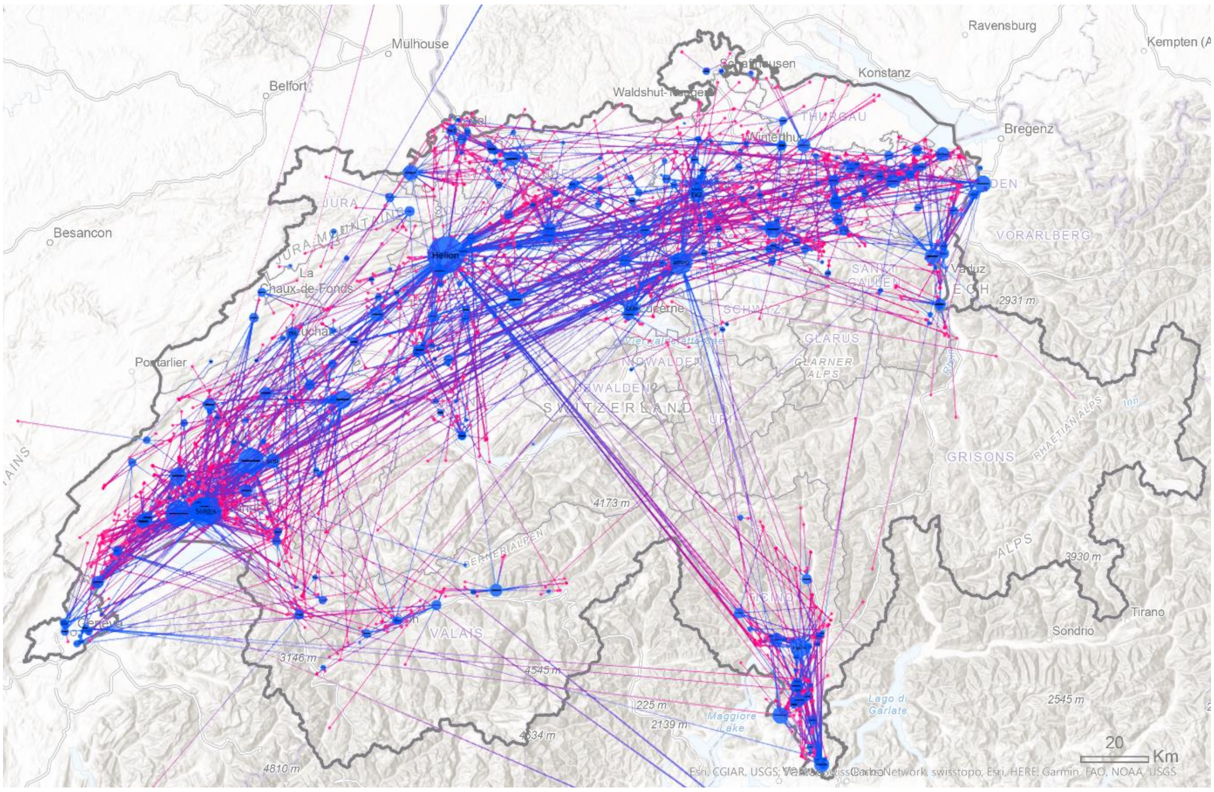


Figure 20: Supply-demand-side network with geographic location. Self-referenced home location coordinates for demand-side actors and main organization coordinates obtained with desktop research for supply-side actors. Supply-side actors are in blue and demand-side actors are in pink. Size of the nodes by degree centrality (number of times the supply-side actor has been mentioned).

Key takeaways

The results highlight the key role that energy technology providers, energy utility entities, and the construction sector play in connecting supply and demand-side actors. They are in line with our interview results, represented by for example: *"Clearly, the architects right now in Ticino are very important influencers. (...) In my opinion, the ones who are already well established, in the sense that they are also quite far ahead, are typically the electrical installers and the plumbers."* Some of the interview partners warn about the danger of not having them involved in the energy transition *"Heating installers and architects act as an "innovation brake" because they are afraid of competition and the technology."*

Local supply-side actors can become key change agents to drive and direct the diffusion of energy technologies. Being close to potential adopters, both spatially and socially, gives them a leverage to convince them to adopt that more distant actors do not have. The results of the interviews also support this, with one demand-side actor stating: *"Yes, we favor spatial proximity. This generally means a faster intervention, with fewer issues. We are not going to search for a provider on the other side of Switzerland unless we cannot find him around here."*

4.6.3 Trust and socio-spatial proximity are key in exchanges with personal contacts and professionals

Most relevant personal and professional information exchanges take place around the home and within personal activity space

When analyzing in more detail the geographic location where the information exchange with a personal contact occurred (Figure 21, Appendix Table A2), we can see that a great majority exchange within the area where they conduct their regular weekly activities (activity space). Although the differences between technologies are rather small - 73% for EMS, 70% for PV, and 65% for EV - it is important to point out that, for EV, between 5-8% fewer exchanges occur within this area. Within their activity space, they mostly exchange around their home (53%), followed by their work (19%), the area where they spend their leisure activities (5%), and the least around their commute route (2%). When looking at how many exchanges occur within 500m of the home location, the differences between technologies are larger, with 59% for PV, 57% for EMS, and 42% for EV. Additionally, we can see that a great majority of the exchanges around the commute route are located either at the beginning or the end of the journey, that is, next to the home location and/or the work location (Appendix Table A2). While we do not have data on the mode of transportation used, which limits some of the interpretation of the results, there is extensive literature pointing out that this is the part of the trip in which travelers have more "adherence", i.e., higher contact with the surrounding context (Curis, 2020).

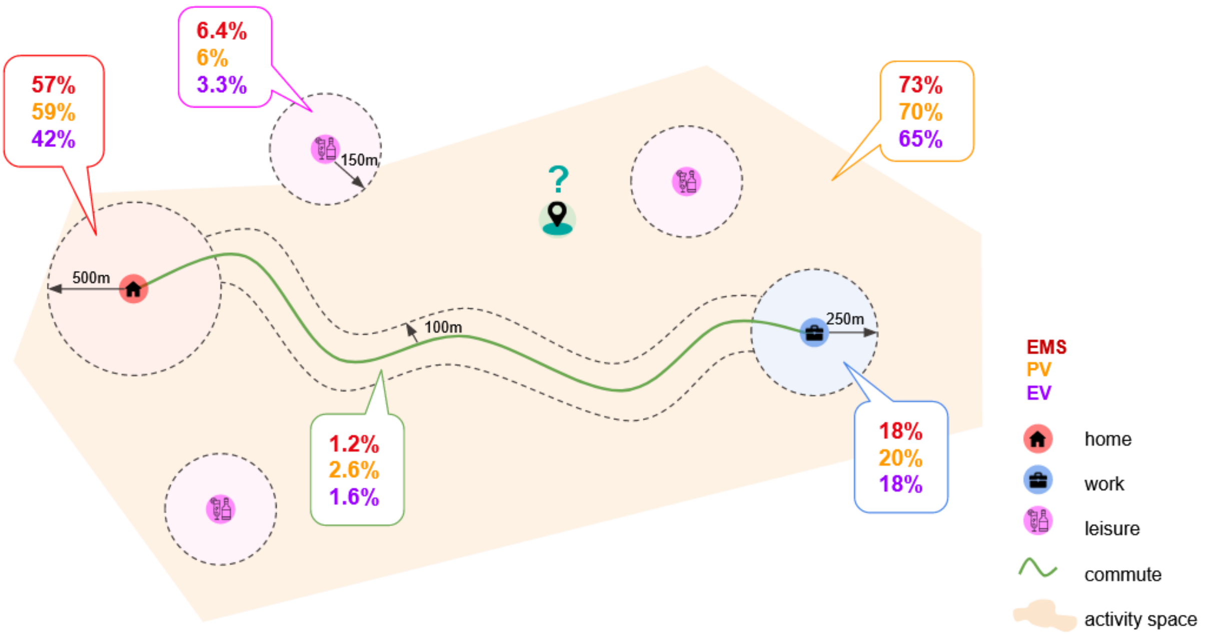


Figure 21: Information exchanges with personal contacts that fall within 500m from home, 250m from work, 150m from leisure locations, 100m from the commute route, or within the activity space (the area where demand-side actors conduct most of their regular weekly activities).

For exchanges with professionals, we observe similar patterns (Figure 22, Appendix Table A3). Overall, 70% of the technology adopters exchange within their activity space, 53% of them exchange around their home location, 15% at work, and 1.8% around the commute route. However, when looking at the different technologies, we can spot some differences between personal and professional exchanges. For EMS and PV, more information exchanges occur around home with professionals (64% and 66%) than with personal contacts (57% and 59%). For EV, this pattern is reversed. While 42% exchanged with personal contacts at home, only 22% exchange with professionals in the same location. This is also mirrored in the activity spaces, where the information exchanges for EMS and PV account for 73% and 70% for personal and 75% and 76% for professional exchanges, while for EV it is the opposite with 65% for personal and only 56% for professional exchanges. In contrast, while the exchanges around work are around the same level for EMS and PV, in the case of EV, it is 18% for personal and 7.7% for professional exchanges.

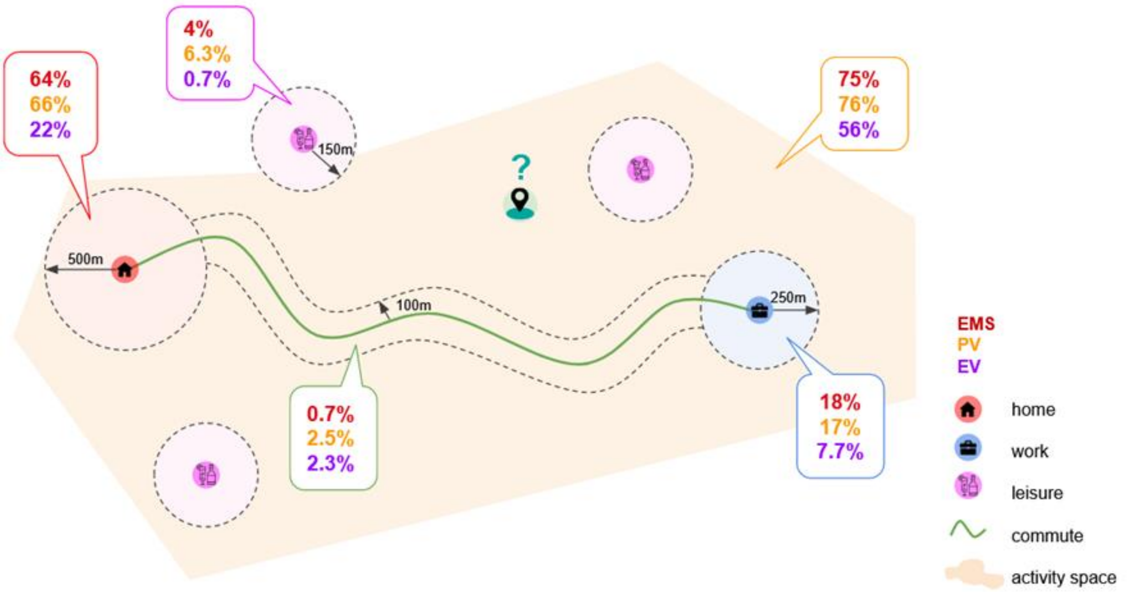


Figure 22: Information exchanges with professionals that fall within 500m from home, 250m from work, 150m from leisure locations, 100m from the commute route, or within the activity space (the area where demand-side actors conduct most of their regular weekly activities).

Trust in personal and professional networks correlates with frequency of interaction and spatial proximity

When examining the personal information exchanges that were relevant for the technology adopters, we observe a connection between the person they exchange with, the trust they have in that person, and the frequency of interaction (Figure 23). First, we observe that information exchanges with people that can be considered to be “socially closer" have higher average values for trust, such as "partner or person living in my household”, "other family member or relative" and "friend”, while "neighbor" and "acquaintance" have lower values (left figure). The option "others" is the one displaying the largest range, which is explained by the different types of relationships it may include. Second, we identify a relationship between trust and frequency of interaction (right figure). Our data shows that the more often they exchange with someone in their personal network, the higher they rate their trust in that person. Similar patterns can be identified regarding the relationship between spatial distance and frequency of interaction (Appendix Figure A7). Overall, the results imply that people tend to exchange more often with those who live closer to them. For the ones who exchange more than six times, we observe the strongest spatial distance effect.

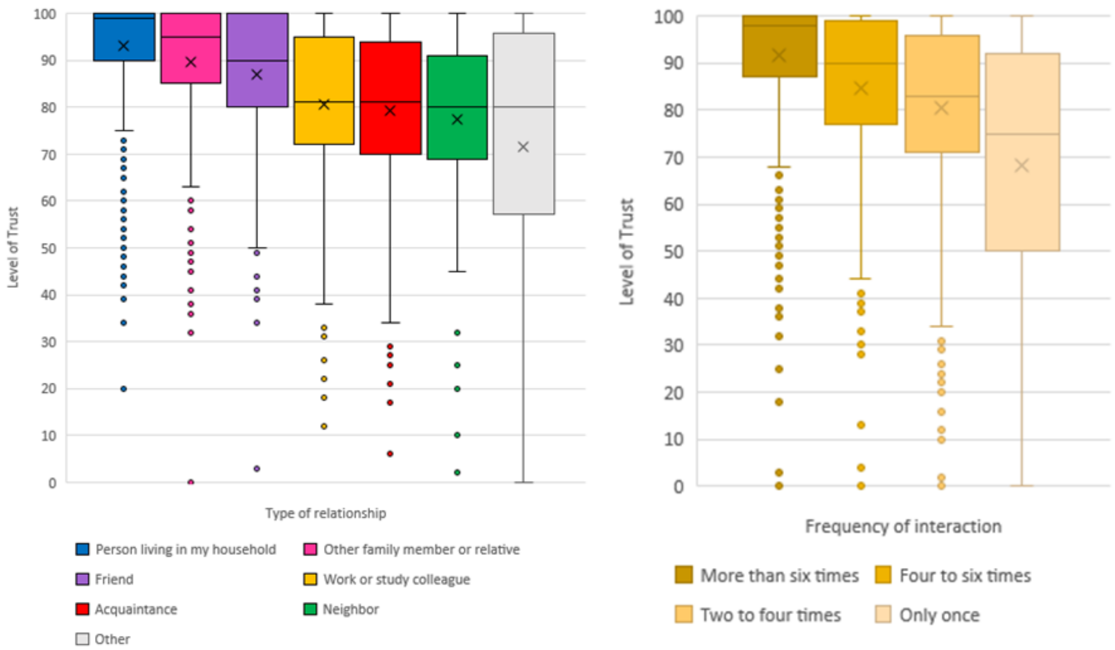


Figure 23: Rated trust by personal contacts (left) and by frequency of interaction (right).

The frequency of interaction also plays a relevant role in building trust when exchanging with professionals (Figure 24, right). In general, demand-side actors trust more those professionals with whom they exchange more often. The average trust value for one-time exchanges is 65%, while it increases to 78% for 2-4 times, and to 85% for more than 6-time exchanges. Additionally, we observe that the range in the trust level is higher for one-time exchanges and tends to decrease with the frequency of interaction. This suggests that more frequent interactions within the personal network not only increase trust but also reduce the demand-side actors' disparities of trust.

When looking at professional exchanges (Figure 24, left), we see that associations have the highest average trust value and, together with actors from academia, have the highest upper trust values. All organizations that could be described as companies providing goods or services - energy technology providers, energy utility entities, energy and e-mobility service companies, and the construction sector - show similar average values and ranges. Public and non-profit entities show the lowest average trust value and ranges. The category "others" is the one with the largest ranges in trust, as it may represent many different types of supply-side actors and trust levels.

When looking at the level of trust by technology (Figure 25), we can see a clear pattern for EV with lower levels and ranges in trust when compared to EMS and PV. This is in line with the frequency of interactions. For EV, the frequencies are lower than for the other two technologies.

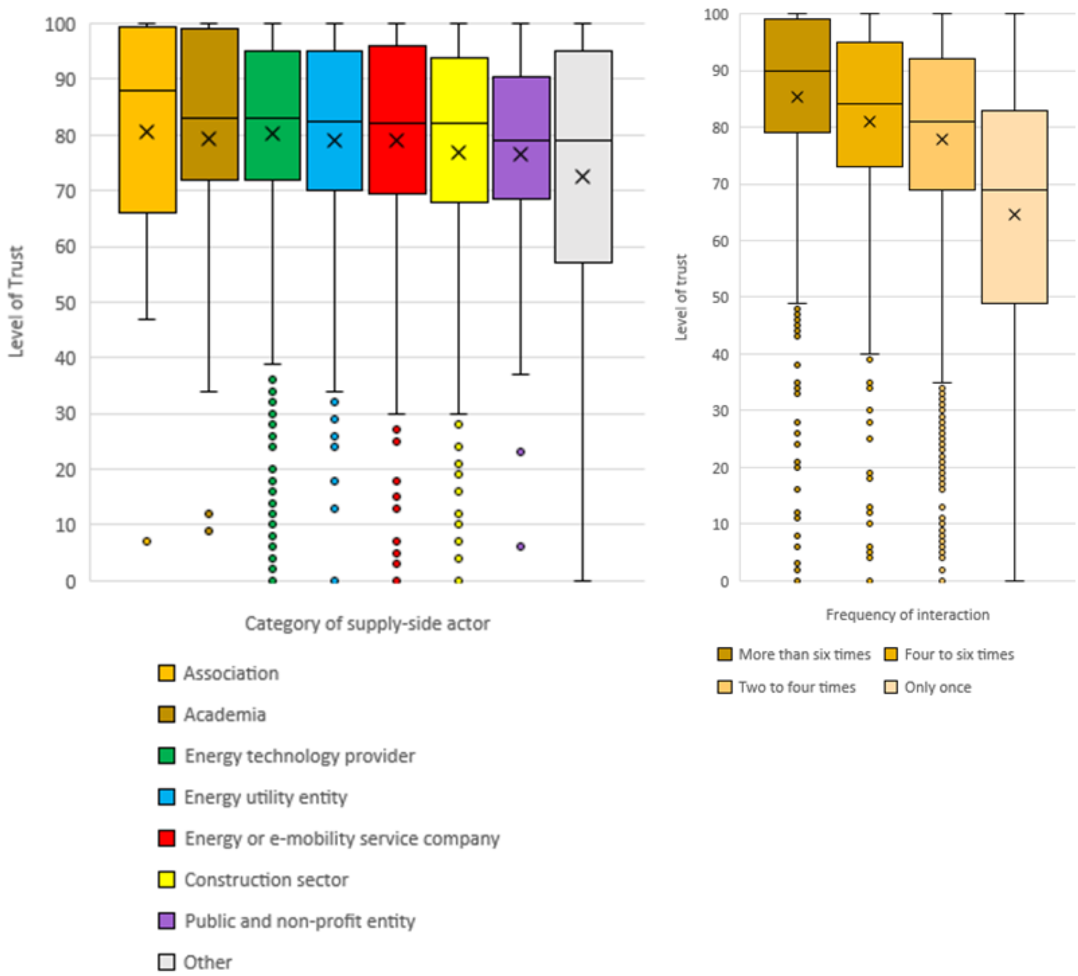
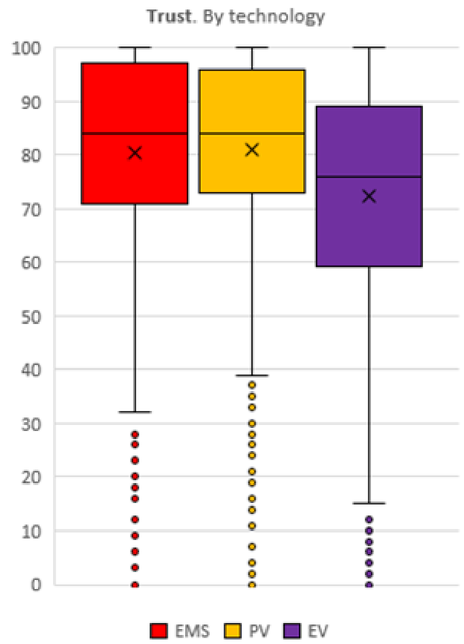


Figure 24: Rated trust by professionals (left) and by frequency of interaction (right).



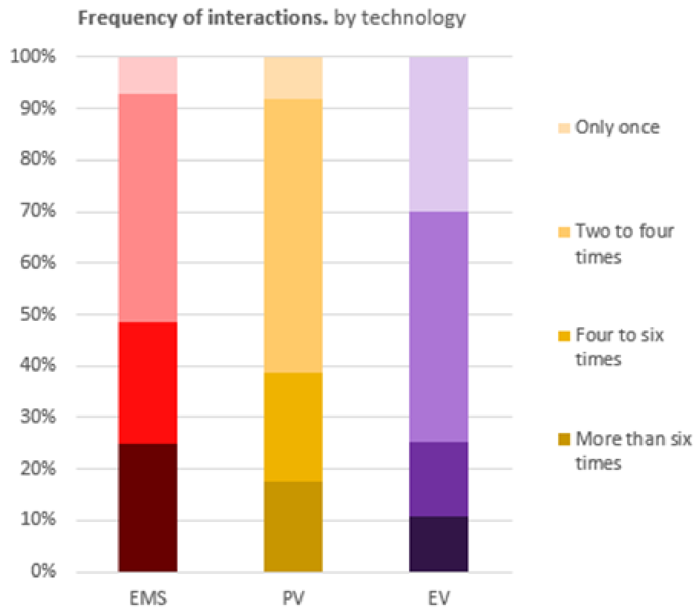


Figure 25: Rated trust for professionals by technology (left) and frequency of interaction with professionals by technology (right).

Key takeaways

Most technology adopters exchange information about the technology around the area where they conduct their regular weekly activities, the activity space, both with personal and professional contacts. Regarding personal contacts, we showed that they exchange the least with their neighbors and rather with friends and colleagues. However, they interact with those in locations within their activity space. Thus, the combination of spatial and social proximity seems key for the decision to adopt energy technologies. For professional exchanges, we observe some differences between EMS, PV, and EV. For technologies that are more closely connected to the building infrastructure (PV and EMS), information exchanges tend to occur at home. On the other hand, exchanges regarding EV seem to be less linked to the home location and to take place in less frequent locations within their activity space. Another interesting finding is the importance of the first and last meters of the commute route. Most of the exchanges take place in that area, pointing at the relevance of this specific zone. These results reveal the importance of potential adopters' activity space and, especially, the area around their home location for information exchange. Besides, they reinforce the importance of local supply-side actors and their leverage through informing and supporting potential technology adopters around them. While EMS and PV adopters may need more tailored, continued, local support, EV adopters may rather seek a one-time exchange.

For personal and professional information exchanges, we observed a relationship between the person they exchange with, the trust in that person, and the frequency of interaction. We find that they trust not only those socially close to them but also those with whom they interact more. Besides that, we find a relationship between spatial proximity and frequency of interaction, that is, interactions occurring close to their home location seem to be repeated more often. For professional information exchanges with supply-side actors, our findings suggest that increasing the frequency of interaction may be a promising way to achieve more trustful relationships and a higher influence on technology adoption decisions, which is a key insight for designing information campaigns.

These findings are supported by our interview results, with one interviewee mentioning the connection of locality with social proximity: *"Yes, it was very important that the energy utility entity was local. There was even the syndic on that evening. The proximity of the energy utility to the people has been important for the general decision of the community. I could imagine that if the same presentation had taken place with strangers, the dynamics would have been very different. Also, there is a cultural part. "Latins" need this kind of close relations a bit, need to be more involved, a bit more personal. The local and regional question is important for the people.".* Another interviewee explained: *"Yes, (…) location played a role; (…) looks after customers and I have a coffee with them every few months. Personal contact is still better than a computer. I also meet (…) on a regular basis; they also organized two events for our tenants and explained the EMS."* Finally, a third one highlights the importance of cultural proximity: "*Personal exchange is important and it's easier if you are closer, but cultural proximity is even more important.".*

Overall, our findings reveal a combination of factors that positively affect each other: trust in the person with whom technology adopters exchange when deciding on a technology (social proximity), the frequency of interaction, and spatial proximity. These three elements can act as an accelerating triad. Spatial proximity facilitates the frequency of interaction, which increases trust. For the personal network, their compounded effect may be key to increasing the role of social influence in adoption which is in line with previous analysis in the French-speaking region of Switzerland. Both social and spatial proximity were found to be relevant for the decision to install PV panels and information exchanges tied to the technology (Serra-Coch et al., 2023). For exchanges with professionals, being spatially close may lead to more visits to their office and vice versa. On top of that, if both conduct their daily activities within the same geographic area, they might have more chances to exchange outside of the purely professional relationship, which contributes to the development of trust influencing the adoption decision. In this case, spatial proximity influences social proximity by means of frequency of interactions. On the other side, if there is a relationship of trust already established, they might be willing to travel longer distances to interact with that person, increasing, de facto, the spatial proximity. In this case, social proximity - or trust - influences spatial proximity by means of travel.

4.6.4 Communication between supply-side actors is top-down and not geographically bounded; events and associations can be key connectors

Strong information network between technology providers and service companies

When we asked the organizations with whom they exchanged information the most or collaborated the most regarding EMS, PV, or EV, energy technology providers were mentioned most often (Table 9). However, when weighing the results by the number of organizations we contacted, we see that the construction sector and academia gain importance. When weighing the results by the number of respondents, academia and associations stand out. This shows that these supply-side actors might have been underrepresented in the first place or less frequent in their presence in relation to how important they are considered by other supply-side actors.

Table 9: Number of times supply-side actors mention other supply-side actors when asked: *"Think about the professional from another organization that you exchanged information the most and/or that you collaborated with the most regarding EMS/PV/EV. How would you classify the organization this person belongs to?".*

	Times mentioned	**Organizations contacted**	**Supply sample**	**Times mentioned by contacted organizations**	**Times mentioned by supply sample**
Construction sector	7	18	19	39%	37%
Academia	5	21	3	24%	167%
Public and non-profit entity	10	63	14	16%	71%
Association	13	82	10	16%	130%
Energy or e-mobility service companies	9	83	28	11%	32%
Energy utility entity	9	84	24	11%	38%
Energy technology provider	41	555	56	7%	73%
Total	**94**	**906**	**154**	**10%**	**61%**

The network visualization among supply-side actors shows that energy technology providers are mostly mentioned by energy or e-mobility service companies (Figure 26), followed by the construction sector. They are mentioned far less by energy utility entities, barely mentioned by associations, and not mentioned at all by academia and public and non-profit entities. Energy technology providers, yet, mention very often not only energy and e-mobility service companies but also associations as well as public and non-profit entities.

These results suggest not only a strong collaboration and synergy between energy technology providers and energy service companies but also an asymmetric "top-down" circulation of information flows, where energy technology providers obtain information from public entities (federal, cantonal or municipal authorities), while these seem to not see energy technology providers as sources of information and collaborators. Additionally, the network allows us to see that, although energy technology providers are mentioned more often and have a higher degree centrality, academic actors seem to have higher betweenness centrality, i.e., they are in more strategic positions to rapidly connect actors. Lastly, when specifically looking at which actors were mentioned the most, Solar Manager is at the top, with 7 mentions, followed by Swiss eMobility and the SFOE, with 4 mentions each, and Swisssolar, with 3 mentions (Appendix Table A4).

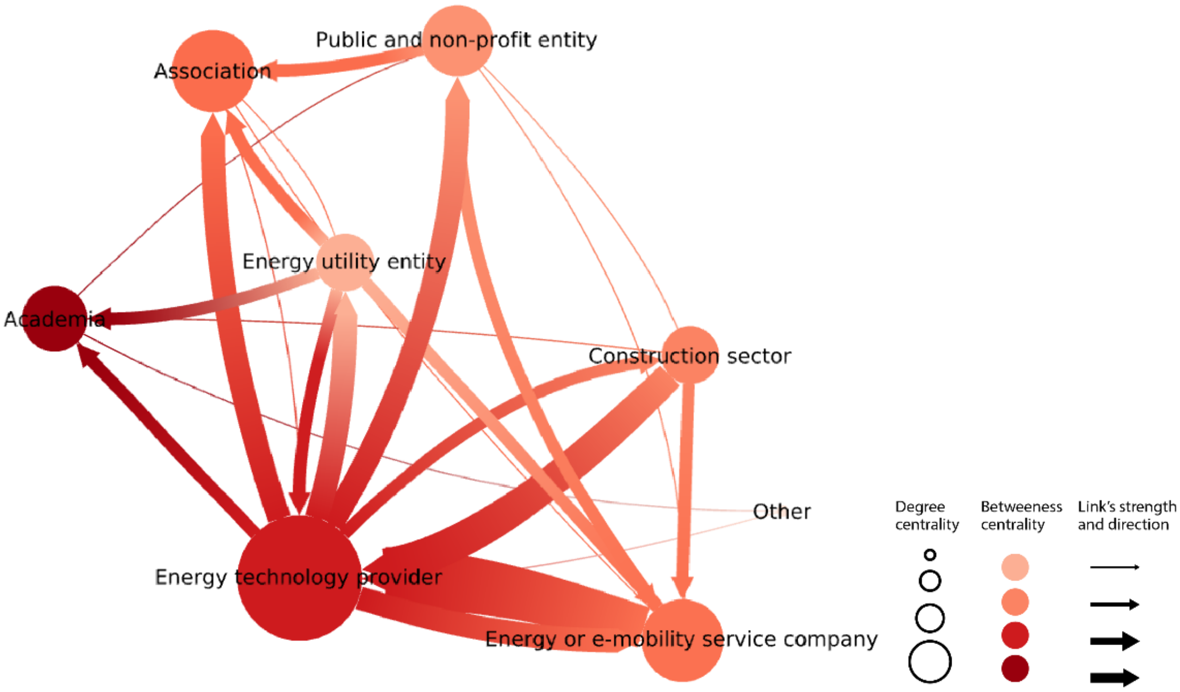


Figure 26: Network of supply-side actors when asked *"Think about the professional from another organization that you exchanged information the most and/or that you collaborated with the most regarding EMS/PV/EV. How would you classify the organization this person belongs to?".* The node size shows degree centrality (number of mentions) and the color shows betweenness centrality (brokerage role). The thickness of the links shows the number of mentions and the arrows point to the actors they collaborate with. Force-directed layout with curved edges for visualization purposes.

The information network of supply-side actors does not show spatial patterns

When looking at the geographic distribution of the supply-side actors and the supply-side respondents that referenced them, we cannot see any spatial pattern, that is, connected actors do not seem to be geographically close (Figure 27). The distances between paired actors range between 0 to 500 km, with the majority of them concentrated on a 0-200 km range.

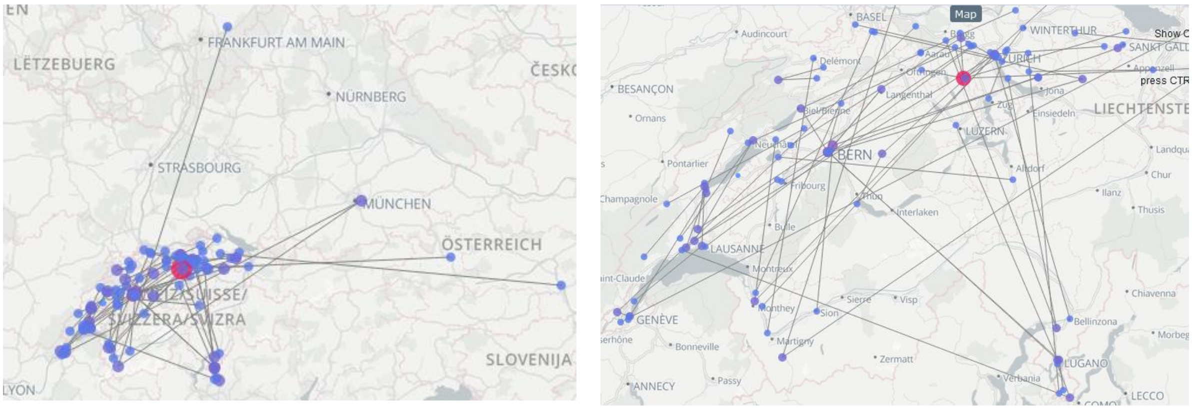


Figure 27: Distribution of reference network in the geographic space using the coordinates of the main location of each supply-side actor and the software SnoMaN. The size and color of the nodes represent their degree centrality.

Events and associations have a brokerage role and connect actors from different fields

A few events seem to be key for the exchange of information within the supply-side sectors of EMS, PV, and EV: Powertage is mentioned most often (19 times), followed by AEE congress (13), Innovationsforum Energie (11) and Smart Energy Party (10) (Appendix Table A5). They are not only mentioned more often, with a higher degree centrality, but also have higher betweenness centrality (100, 326, 240, 218) and therefore have strategic positions to spread information in the network. It is interesting to observe that they seem to connect different types of actors (Figure 28, left). For instance, the AEE congress is a reference for energy utility entities, energy technology providers, one association, and one public and non-profit entity. Powertage connects not only energy technology providers and energy utility entities but also energy and e-mobility service companies as well as associations. In terms of technologies, we see the same pattern, as supply-side actors primarily working with different technologies seem to attend the same events (Figure 28, right).

Overall, associations are mentioned more often than events and seem to be even more important for the exchange of information within the supply-side sectors of EMS, PV, and EV (Appendix Table A6). Swissolar is mentioned 70 times and Electro is mentioned more than 50 times. They are followed by VSEAES (35), Mobility and EIT (24), VESE (23), eMobile, SIA and Energie-cluster (21), Swisscleantech (20) and others below 20. They all show high betweenness centralities (140-2179), being able to rapidly connect actors in the network. As with the events, associations connect various types of supply-side actors in the energy landscape and technologies these actors primarily work with (Figure 29).

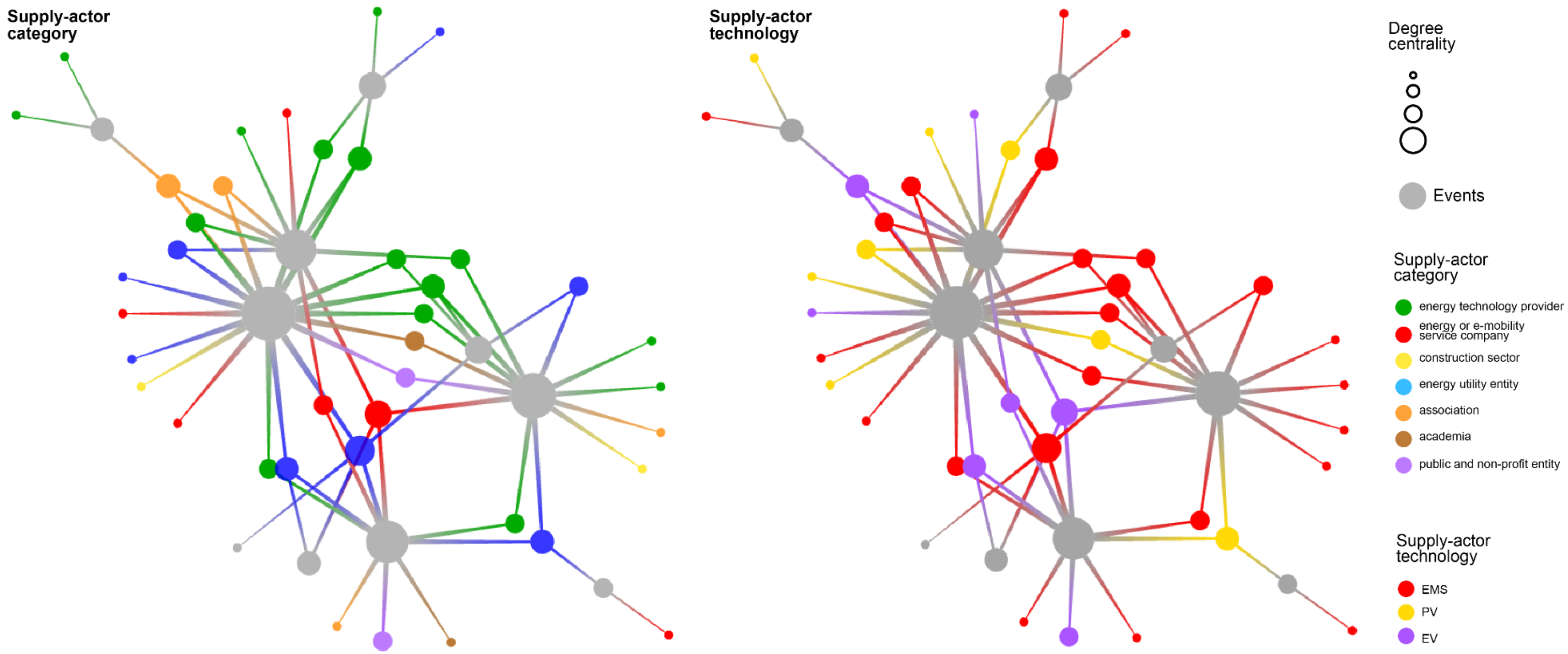


Figure 28: Network of events mentioned by supply-side respondents for information exchange. On the left, the size of the nodes represents degree centrality, and the colors of the nodes show the type of actors, using grey to display the events and several colors for the supply-side respondents. On the right, the size of the nodes represents degree centrality, and the colors of supply-side respondents show the technology the respondent works with among **EMS**, **PV**, and **EV**. Generated with the software Tulip. The layout is the force-directed FM^3 (OGDF) algorithm.

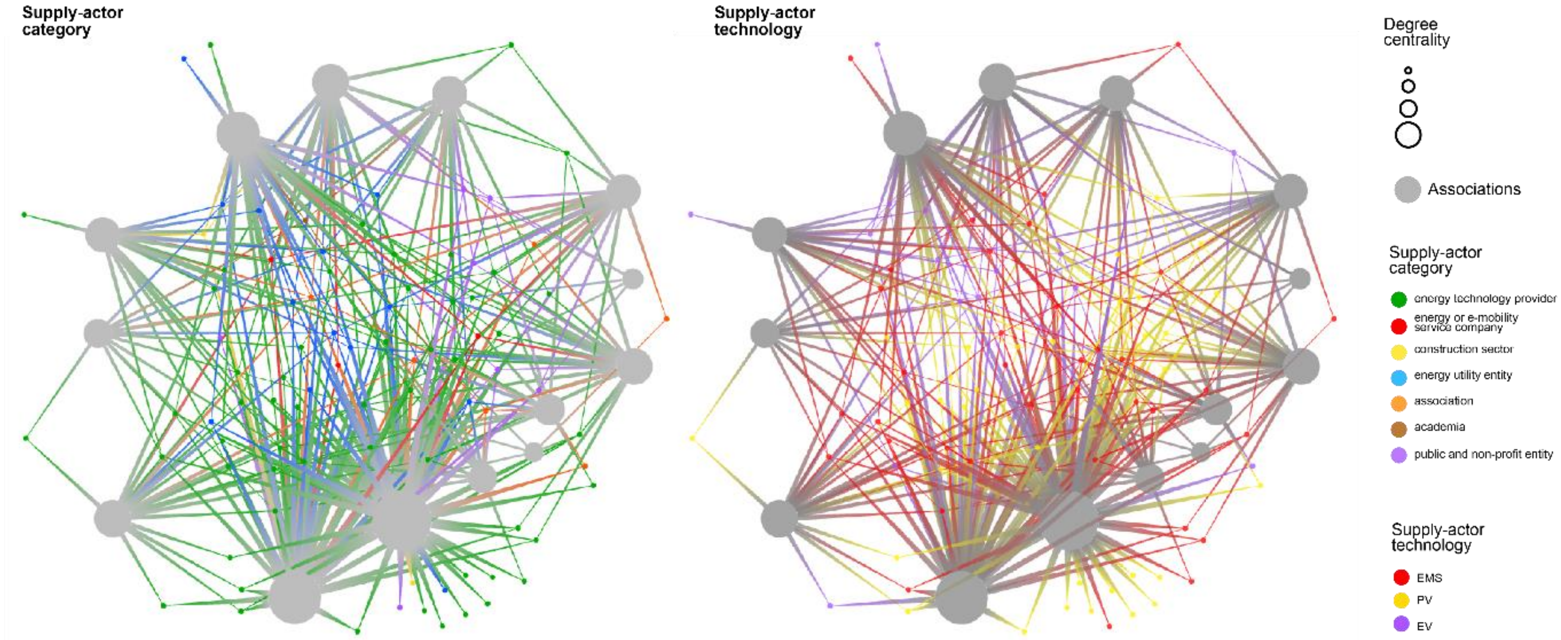


Figure 29: Network of associations mentioned by supply-side respondents for information exchange. On the left, the size of the nodes represents degree centrality, and the colors show the type of actors. On the right, the size of the nodes represents degree centrality, and the colors of supply-side respondents show the technology the respondent works with among **EMS**, **PV**, and **EV**. Generated with the software Tulip. The layout is the fast multipole embedder (OGDF) algorithm.

Key takeaways

In absolute terms, energy technology providers are the ones referred to the most as sources of information. However, when weighted by the number of organizations we contacted, those belonging to the construction sector have the highest percentage of references. When weighted by the number of survey respondents, academic actors gain importance. On that line, energy technology providers have a high degree centrality, while academic organizations seem to have a high brokerage role. Further, our results show an asymmetrical top-down circulation of information flows where public and non-profit entities are active in sharing information for technology providers, however they do not seem to actively collect information on the providers' experiences and needs. Being more active in that regard and more involved in the implementation process may improve the collaboration of actors that is perceived as lacking.

The analysis of the events and associations supply-side actors use to inform themselves about EMS, PV, and EV shows that both can be key channels to inform a diverse set of actors efficiently. Some events seem to have a central role in diffusing information, being a reference for several supply-side actors, connecting actors from different fields, and having brokerage potential (Powertage, AEE Congress, Innovationsforum Energie, Smart Energy Party). Particularly, associations show a very extensive reach. The diffusion potential of associations seems to be more homogeneous but rather high in all cases, pointing out that associations, although they have a lower connecting power than events, may be a better way to diffuse unidirectional information. Swissolar, Electro, and VSEAES can be mentioned as the most important in terms of being a reference for information but also brokerage potential. Nevertheless, to interpret the results, we should consider that the surveys were conducted shortly after the Covid-19 epidemic. This could potentially have reduced the perceived relative importance of events for supply-side actors, which may have gotten higher numbers in another period.

In any case, and both for events and associations, it is important to highlight their capacity to connect different types of actors and those working on different technologies. The lack of coordination between actors and the lack of technological system integration are among the main barriers to the diffusion of EMS mentioned by supply-side actors during the interviews. The results regarding events and associations show how those could be used as a platform to improve coordination and to discuss better forms of integration among systems. In addition, these spaces could be used to actively discuss co-adoption dynamics and leverage them through business strategies, for instance, in the form of bundles. One supply-side interview partner states: *"In general, discussions stop at the moment we make offers, so those who manage to get by, in my opinion, at the beginning, are those offering a bundle. They'll tell you: "I'm offering you everything, I'm equipping you entirely key in hand (...) everything is included." (...) Thus, we need to do the packaging. Basically, that's the future".* From the demand-side perspective, interview partners also explain how this helped them in the process: *"The advantage for me was that everything was implemented as an overall/entire system with the coordination of the energy advisor."*

5 Conclusions

The main goal of the InnoNet-Energy project was to better understand adoption decisions of EMS integrated with PV and EV in the Swiss residential building sector with a special emphasis on analyzing the information networks of relevant demand and supply-side actors. The core of the project was to analyze social and spatial proximity effects and their role in the diffusion of energy technologies, in particular EMS which effectively align energy production and consumption. They enable automatic control of several appliances in a building, such as PV, EV charging stations, and heating systems, and are therefore key for the efficient management of renewable energy and a sustainable transition towards low-carbon solutions.

In this project, we followed a mixed-methods approach that included a qualitative phase where 36 guided interviews were conducted with actors on the supply-side of EMS (i.e., energy utility entities, energy technology providers, academia, consultancy companies, and advocacies), as well as with demand-side actors in the residential building sector (i.e., home and condominium owners, institutional owners, engineers, and architects). The insights of the interviews were key to designing and supporting the results of two large-scale quantitative surveys for technology adopters and key supply-side actors, i.e., organizations. Through the surveys, we obtained data from around 5'000 technology adopters in the Swiss residential building sector as well as 160 organizations that work with the energy technologies of study.

The richness of the data collected in this project, allowed us to answer the following questions which were at the center of our analysis:

- **ACTORS:** Who are the key supply-side and demand-side actors for the diffusion of EMS integrating PV and EV and how are they characterized?
- **TECHNOLOGY ADOPTION:** What are the technology (co-)adoption patterns in Switzerland? What are the drivers and barriers decisive for technology adoption as well as the information sources and channels used in the decision-making process?
- **INFORMATION EXCHANGE:** Which role does information exchange with professionals and the personal network play for technology adopters and how does this contrast with the perceptions and information exchange patterns of supply-side actors?
- **INFORMATION NETWORKS AND PROXIMITY EFFECTS:** Through which actors or information networks are supply and demand-side actors connected to each other? What are the key actors and pathways for information to spread?

For the demand-side, we selected the residential sector to be the main focus of our analysis, not only due to its significance for the energy transition but especially the scalability of standardized solutions for the implementation of EMS. We specifically focused on private individuals but also considered institutional actors relevant to the diffusion of EMS. On the supply-side, we identified around 930 organizations to be key for the diffusion of EMS in Switzerland. They are mostly energy technology providers, associations, energy and e-mobility service companies, and energy utility entities, in that order.

Compared to the Swiss average population, we found that energy technology adopters (EMS, PV, and/or EV) are highly educated, have a higher income level, mostly live in single-family housing, and own their home. This shows that there might be a significant untapped potential in multi-family housing. The technology co-adoption rate of PV and EV adopters in Switzerland is high, and the diffusion of EMS is taking off. Already 16% of the respondents in our sample have EMS installed, balance their energy consumption and production and are highly engaged in the energy transition, while 30% who have not yet implemented EMS consider doing so. The co-adoption analysis shows that 50% in our sample have either two or three energy technologies installed and are therefore potential adopters for EMS.

Energy technology adopters hold an innovative spirit and want to engage in the energy transition, they perceive to have enough information and knowledge, and feel capable of applying the technology. Overall, they perceive their contextual factors as being favorable to adopting the energy technology, however, do neither agree nor disagree when it comes to the financial attractiveness of the technology and the benefit from the current regulatory framework. Technology adopters perceive the influence from their social network and their environment as not very relevant, while this distinguishes them from potential adopters and supply-side actors who perceive the social influence to be higher.

The ones who provide and install the technologies, energy service companies as well as energy suppliers, are the most relevant information sources for technology adopters, while the information exchange with the personal network also plays a significant role. The internet and interpersonal face-to-face exchanges are the channels mostly used, while the general characteristics and functionality of the technology, as well as information on financial support, is the information considered most useful for them. Regarding the internet and social media, we observe a mismatch between the demand and supply-side. While the internet is used more by technology users than by supply-side actors, the opposite is true for social media.

Energy technology adopters do not particularly exchange information about the technology with neighbors during their decision-making process. They mostly exchange with their partners and, outside of the household, with friends and family members, and less with acquaintances and colleagues, revealing the importance of social proximity. However, when looking at the location of the exchanges, we realize that they occur close to their home and within their weekly activity space. This implies that not only social proximity, but also spatial proximity plays a role in information exchange and there seems to be a relationship between them. Our results suggest that trust increases by the frequency of interaction, which at the same time increases by spatial proximity, and vice versa.

When looking at the most important exchange that energy technology adopters had with professionals in the decision-making process, energy technology providers appear to be the most frequent contact, followed by energy utility entities and actors in the construction sector. Spatial proximity seems to be key, as the professionals they reach out to tend to be close to them. As shown before for the exchanges with the personal network, three elements - spatial proximity, trust, and frequency of interaction - seem to act as an accelerating triad for the diffusion of energy technologies.

The analysis of the supply-side actors' network shows that energy technology providers and the construction sector have important roles in diffusing information, with academia acting as an intermediary. The spatial proximity of supply-side actors seems to be less relevant. However, events and associations show a promising potential to connect different actors and rapidly diffuse information. Supply-side actors from different fields seem to be closely connected, i.e., they exchange information, collaborate, attend the same events, and are members of the same associations. Therefore, the supply-side network has a high heterophilic potential that can be leveraged for the diffusion of information. In other words, different types of actors are tightly connected, which can open the door to rapidly diffuse information among the system.

6 Recommendations

For a successful energy transition towards renewable energy, we need to foster technology co-adoption as well as EMS, allowing to integrate production and consumption technologies in the Swiss residential building sector. Through the findings in this project, we can derive several recommendations as well as suggestions to design effective information or marketing campaigns supporting the diffusion of energy technologies.

Foster EMS in residential buildings by raising awareness about innovative energy solutions and long-term profitability, coordination of technology providers, and technical standards

Energy technology adopters hold an innovative spirit and want to engage in the energy transition. They are mostly driven by their positive attitude towards renewable energies, energy independence and optimizing energy self-consumption. However, energy technologies are not (yet) perceived as financially attractive. Besides that, the complexity of actors' landscape and the lack of technical standards for system integration were identified as the main barriers for the diffusion of EMS. To further fostering the diffusion of EMS, we suggest three different approaches. First, demonstrating its feasibility through best-practice examples and raising awareness about its long-term profitability. Second, enable technology providers identifying and generating synergies between technologies in order to support technology users from the initial stage of contemplating the technology to its implementation. And finally, steering the process to harmonize technical standards and protocols for securing system compatibility and interoperability. In their role of providing information and guidance as well as developing regulations, public authorities play a key role for each of these approaches, as well as associations and technology providers themselves when it comes to raising awareness about the long-term profitability of EMS, strengthening the collaboration among technology providers, and the generation of synergies and integration of energy technologies.

Promote technology co-adoption through bundles and by using windows of opportunities

To foster energy technology co-adoption and the diffusion of EMS, technology bundles are highly relevant. Bundles can be offered whenever PV installations or other large consumer technologies are purchased or registered, which highlights the essential role of energy utility companies and energy technology providers. They both have financial incentives to promote technology bundles, while energy utility companies gain grid stability whenever EMS are in the bundle. PV seems to be the most promising and accessible technology to trigger the co-adoption of other technologies, i.e., not only EV and HP but especially EMS, and is therefore key, while building renovations and refurbishments create a promising window of opportunity to inform about low-carbon energy technology solutions. For PV and EMS, we find a significant untapped potential in multi-family housing. The focus should therefore be set on institutional investors who have a high leverage in the multi-family housing sector. Associations such as the Swiss homeowner association play a key role to mobilize institutional investors.

Strengthen and coordinate the network of supply-side actors through events and associations

Our findings reveal that events and associations could be used as a platform to improve coordination among supply-side actors and to discuss the harmonization of technical standard and protocols which we found to be among the most relevant barriers to the diffusion of EMS. This platform can also be utilized to collect data on specific needs and issues experienced by those supply-side actors in direct contact with the technology users and the implementation process. Having a tight actor-network that not only links different types of actors, but also different technologies can be used as leverage to rapidly diffuse new information. This approach aligns with innovations' research, which highlights the importance of tight information networks and the diversity of connected actors to spur innovation in society (Grannovetters, 1973; Rogers, 2003).

Therefore, it is important to exploit the events and associations interface potential. Based on the network analysis, public authorities seem to have a good connection with associations. The interviews also highlighted their role as a reference for both supply and demand-side actors. Thus, they could take an active role in leveraging those interfaces by directly contacting the organizers of the most important events and influencing the general direction and, potentially, agendas. They could also support associations with the insights collected from supply-side actors when setting-up information campaigns. Additionally, they could partner with associations and use their membership pool to launch a matching platform, i.e., finding supply-side actors' pairs that would benefit through collaboration.

Leverage supply-side actors as change agents

With energy technology providers representing the great majority of the actors involved in the sector, one of the priorities for the diffusion of energy technologies is to understand their needs and challenges when selling and implementing them. By learning from the specific experiences of energy technology providers, the different challenges faced by single- and multi-family housing owners as well as co-owners of apartment buildings could be identified in more detail, and regulatory frameworks can be adapted to these needs. Thus, it is important to foster bi-directional flows in the network, i.e., not only energy technology providers being informed by associations, academia or public authorities about new political directions, subsidy schemes or research updates, but also them actively collecting experiences from energy technology providers to understand the specific challenges they face when selling and implementing the technology. Associations could organize events in which energy technology providers are encouraged to share success stories and challenges they face. Academic actors can organize exchanges, in which both researchers and providers are invited, and the latter are encouraged to share their specific needs.

The tight connections we found among the supply-side actor network indicate that information could be spread rapidly by the concentration of some key actors. In particular, Solar Manager is the actor most mentioned in the network as a reference for information, followed by Swiss eMobility and the SFOE. These could be key for information campaigns, using their leverage and transforming them into change agents for the energy transition. Change agents are individuals or organizations that "provide a communication link between a resource system with some kind of expertise and a client system. The main role of a change agent is to facilitate the flow of innovations from a change agency to an audience of clients." (Rogers, 2003). The exchange is bi-directional, feedback from the clients also flows back to the agency, which adjusts its programs or interventions according to it.

Therefore, public authorities could also start campaigns with the goal of transforming key energy technology providers into change agents. To unlock this potential, we suggest engaging associations and academic actors (i) in the organization of training programs for professionals, (ii) providing technical, financial, and regulatory information material, including guidance on the subsidy scheme, (iii) generating information material that professionals can directly use to inform their clients, and (iv) to offer incentives for professionals to add these materials and support services to their current offerings.

Reach potential adopters through targeted approaches

The trust and impact of change agents - be it suppliers or actors from public authorities - might be higher when approaching a smaller targeted group of potential adopters with more interactions rather than one single time with a larger unspecified group. Based on the technology adopters' profiles and findings on proximity effects, it seems promising to first target potential adopters with favorable building conditions and socio-demographic characteristics similar to adopters, as they might be more prone to adopt. Thus, public authorities or associations could spearhead a study on identifying areas and profiles with high potential of adoption and share it with local energy technology providers. Besides, it might be effective to identify those individuals who are socially active and highly influential in their social circles or neighborhoods and include them in campaigns. Social media influencers from a specific region can be a first target to engage in the energy transition who are easy to identify. Additionally, regional surveys can be conducted to identify influential people in areas with high adoption potential. Finally, local actors in public positions, such as artists, actors or even café owners could be engaged to diffuse information.

An alternative approach would be to rely on those professionals who already have an established trust relationship with potential technology adopters through other services such as the local architect, plumber, electrician, or car technician for EV. Energy-related associations could focus on training these local professionals regarding energy technologies, offering them support to establish a link to other energy technology providers, energy utility entities, or energy service companies, and providing appropriate incentives to support this process, such as information material and brochures, but also direct showcases of the technology and its functionality. Particularly, architects and engineers should be the focus in areas characterized by an old building stock with high renovation potential. These professionals may be approached by residents to renovate their homes and it is important to take advantage of the opportunity window that these occasions generate. For this, engineers and architects should be familiarized with the technology, feel confident that they can successfully implement it during the renovation and have a clear idea on who to reach out for additional information. Providing them a trusted link within associations may be helpful for that.

Build trust to increase the effectiveness of information campaigns

Both for technology adopters' information exchanges with personal contacts and professionals, we can see a combination of elements that positively affect each other: trust in the person technology adopters reach out to, frequency of interaction, and spatial proximity. Their compounded effect seems to be key to increasing the role of social influence in technology adoption and provides valuable insights on how to design information campaigns.

As close social contacts are key when deciding on technologies, one promising approach could be to organize events with people who already adopted a technology, encourage them to bring family, friends, or acquaintances, and offer incentives for referring them to a supplier. These events could be organized by associations engaged in the energy transition in partnership with local actors, such as local energy utility entities, technology providers or municipal actors. With most technology adopters exchanging information at home, around their home, or within their activity space, these locations should be aimed at when organizing these events. While homes, due to their private nature, are more difficult to access through public campaigns, alternative locations within activity spaces may be an opportunity -

informative panels, exhibitions, talks - that may act as conversation starters or triggers for people. Other locations could be the first and last meters of main commute routes, where we found that most information exchanges occur on the way to or from work. Visual information or marketing campaigns, such as billboards, display panels or announcement boards, should be prioritized in public transportation nodes, public parking, or around private parking areas.

The relationship between frequency of interaction and trust points out that information or marketing campaigns should be organized with repetitions, for instance organizing several events in the same location or reaching out to the same people several times. It might be more effective to organize long-term campaigns and follow potential adopters from the beginning to the end of the adoption process. Thus, associations supporting the energy transition, municipal actors that want to update citizens of new subsidy schemes, energy utilities that may be promoting the use of smart-meters, or energy technology suppliers that want to showcase the technology, should organize several events or visits targeting the same people repeatedly to establish a more trustful relationship. For organizations working on a larger scale, with cantonal or even national reach, travel campaigns with frequent face-to-face interactions could be important to build trust. It is particularly crucial for those organizations that do not have a local reach to find alternatives ways of building trust with potential adopters.

Finally, it is important to account for the differences between the technologies. Our results reveal that not only trust but also the frequency of interaction is the lowest for EV and the highest for EMS, with PV in the middle. This implies that implementing a more complex technology such as EMS may require a stronger relationship with a professional than EV, a technology rather similar to the existing alternative. Niche technologies with higher complexity and low visibility may need more continuous support from supply-side actors in the decision and implementation process. Therefore, EMS providers should offer continuous support to potential adopters, specifically directing them in each step of the decision and implementation process, as well as offering a post-acquisition monitoring program to ease the adoption of less innovative people. Particularly, events where the technology and its functionality are showcased may help reluctant adopters to understand its less visible parts. EV providers, on the other hand, can continue to exploit the existing supply channels and even jump into more innovative options, such as online purchasing.

7 Outlook and next steps

The research conducted in this project provided us with rich insights concerning drivers and barriers to energy technology adoption, as well as the information networks of supply and demand-side actors. These findings have opened new exciting and promising avenues for research to support the transition to decarbonized energy systems. These avenues closely align with the expertise provided by the HERUS laboratory. The HERUS lab is currently leading an important research effort to identify, understand, and trigger positive tipping points towards sustainable futures, building on the question of how current systems can be transformed, and which leverage points need to be tackled to stimulate transformative change. Regarding the desired energy transition and basing ourselves on the results obtained, we see three main areas of research that could be pursued as a follow-up from the research performed.

Drivers and levers for adopting energy technologies. In the present study, we focused on adopters of energy technologies, their socio-economic and psychological characteristics, drivers, and perceived barriers. We identified clusters of adopters with different drivers and socio-economic characteristics. This understanding can provide a first lever for targeting specifically potential adopters. Thus, further research should base itself on first identifying potential adopters and second comparing them to adopters concerning socio-economic, psychological characteristics and perceived drivers and barriers. This would allow us to identify the factors driving adoption for specific socio-economic groups and simulate the dynamics of technology adoption. These models are essential as they will (i) identify tipping dynamics (e.g., where the acceleration of adoption occurs); (ii) support infrastructure providers to design spatially explicitly the grid; and (iii) allow for designing and (in silico) testing policy instruments.

Co-adoption dynamics. The results of this study provided relevant insights regarding the co-adoption dynamics of energy technologies. These insights suggest that we need to look into technology bundles rather than focusing on separate technologies. This systemic perspective will be essential if the energy transition is to be successful. Along these lines, further research should focus on understanding the specific configurations of co-adoption, including order, timelines, and bundles, which reinforce different energy transition pathways. Within each of these pathways configuration and coordination of actors becomes essential. Thus, understanding the connection between the desired pathways and the actors driving, opposing, and supporting the path is essential to designing the optimal policies.

Tipping dynamics in adoption pathways. Finally, a future research avenue would integrate the above two mentioned research areas and leverage them to understand and design tipping dynamics in the energy transition. A key question is when adoption processes contribute to surpassing the tipping point in different pathways and when do we reach a resilient future state. In addition to integrating adopters' characteristics and co-adoption dynamics, we would also integrate the dynamics of social proximity. Thereby we consider particularly interesting to unravel which triggers are required to release the potential of proximity effects and how they differ in socioeconomic clusters. In this way the key stakeholders can be identified and policy measures designed.

8 National and international cooperation

Please find below the cooperations we elaborated throughout the project.

Georgia Institute of Technology, School of City & Regional Planning. Prof. Clio Andris. Provided expertise on social networks and network analysis software developed in her lab to analyze the networks in this project.

University of Lausanne (UNIL), Institute of Geography and Sustainability. Prof. Céline Rozenblat. Provided expertise in network analysis.

École Polytechnique Fédérale de Lausanne (EPFL), Laboratory of Cryoshperic Sciences. Prof. Michael Lehning. SWEET-EDGE Enabling Decentralized renewable Generation in the Swiss cities, midlands, and the Alps.

University of Bern, Institute of Political Science. Prof. Isabelle Stadelmann-Steffen. SWEET-EDGE Enabling Decentralized renewable Generation in the Swiss cities, midlands, and the Alps.

ZHAW School of Management and Law, Institute of Innovation and Entrepreneurship. Dr. Yann Blumer. UNLOCK-PV Analyse des Potentials von gemeinschaftlich finanzierten PV-Anlagen zur Beschleunigung der Transformation des Schweizer Energiesystems.

University of Lausanne (UNIL), Swiss Graduate School of Public Administration (IDHEAP). Prof. Oliver Neumann. CLIMACT project: Can solar parties make photovoltaic socially contagious? The peer effects of community live demonstration events on residential photovoltaic adoption.

University of Basel, Psychology of Sustainability and Behavior Change. Dr. Mart van der Kam. SWEET-CoSi Co-Evolution and Coordinated Simulation of the Swiss Energy System and Swiss Society.

University of Geneva, Consumer Decision and Sustainable Behavior Lab. Dr. Maria Lagomarsino. Technology co-adoption.

9 Dissemination

We have actively communicated our findings via a plurality of channels, ranging from presentations at academic and industry-lead conferences to booklets and communication on general media channels. Please find below the dissemination activities divided by audience, i.e., scientific versus outreach activities.

Presentations at national and international scientific conferences and workshops.

Energy Geographies Postgraduate Forum Mid-Term Conference. Online, April 2021. Diffusion of Innovations in the Energy Landscape: The role of supply and demand side network effects for integrated energy management systems.

3rd International Conference on Energy Research and Social Science: Energy and Climate Transformations. Manchester, United Kingdom, June 2022. Diffusion of integrated energy management systems in Switzerland: A qualitative approach to uncover the role of supply and demand side information networks.

Urban Transitions Global Summit. Barcelona, Spain, November 2022. What is my neighborhood? The impact of boundary definition in the measurement of socioeconomic and environmental characteristics in urban systems.

3rd Swiss Social Science and Humanities Energy Research Workshop. Sion, Switzerland, June 2022. Technology co-adoption patterns in Switzerland.

12th International Conference on Geographic Information Science, Equitable Accessibility and Sustainable Mobility Workshop. Leeds, United Kingdom, September 2023. Understanding the relationship between activity spaces and commute routes.

7th European Conference on Behavior Change and Energy Efficiency: BEHAVE 23. Maastricht, The Netherlands, November 2023. Diffusion of energy technologies: The role of supply-side information networks.

Project presentations at national events.

Giornata dei Direttori e dei Quadri dirigenti delle aziende elettriche della Svizzera italiana. Gravesano (Ticino), Switzerland, October 2021.

Innovationsforum Energie. Zürich, Switzerland, June 2022. Energy management systems: New business models based on intelligent control.

Energie Cluster: Monitoring und Optimierung im Gebäudebestand. Dübendorf, Switzerland, June 2022.

Solar Update 2022: Energiemanagementsysteme: Digitales Werkzeug der Energieversorgung. Bern, Switzerland, November 2022.

Outreach activities to the non-scientific community.

InnoNet-Energy update. Booklet for regional project partners and interview partners. June 2021.

InnoNet-Energy update. Booklet for regional project partners and interview partners. February 2022.

Bulletin.ch. Türöffner auf dem Weg zum dezentralen Netz. May 2022.

Presentation and discussion of demand-side survey results with survey respondents. Drivers and barriers for the diffusion of energy management systems. Zürich, Switzerland, November 2022. 70 participants.

Presentation of demand-side survey results with survey respondents. Drivers and barriers for the diffusion of energy management systems. Lausanne, Switzerland, December 2022. 60 participants.

HABITAT magazine, opinion editorial. Energy is (not) sexy. September 2023. Also to be published in news portals Le Nouvelliste, ArcInfo, and La Côte; and EPFL news channels.

Podcast episode focusing on the energy transition in the series “Perspectives” of the Enterprise for Society (E4S), a joint center of UNIL-HEC, IMD and EPFL. November 2023.

10 Publications

Proximity effects in the diffusion of energy technologies: A conceptual framework to integrate social and spatial factors. Submitted to Energy Research and Social Science Journal, June 2023

Abstract: Proximity effects, the influence of close people on an individual's behavior, have been identified as relevant for the diffusion of energy technologies. Literature on proximity effects generally assumes that social interaction influences the decision to adopt a technology and that spatial proximity enables this interaction. However, studies tend to overlook the mechanisms underlying these effects and seldom examine how their social and spatial factors are related. Drawing on theories of diffusion of innovations relational space and structuration, we conceptualize proximity effects that integrate social and spatial factors by developing a Socio-Spatial Information Exchange framework (SSIE) that focuses on the information exchange situation. We apply it to the case of the diffusion of energy technologies in Switzerland and, through interviews, explore how socio-spatial contexts influence information exchanges that lead to the adoption of these technologies. The proposed framework contributes to proximity effects' research by conceptualizing social and spatial processes of individuals' information exchanges and contextualizing them in the larger system. This not only allows us to identify those exchanges that foster the diffusion of energy technologies but also to determine socio-technical structures enabling them. Gaining a better understanding of these processes can be key to promoting the role of individuals as active diffusers of energy technologies and unlocking their unique potential to contribute to the energy transition.

Photovoltaic panels diffusion in Switzerland: Developing tailored policies to increase adoption using clustering methods. Submitted to Energy Policy Journal. October 2023

Abstract: The adoption of photovoltaic panels (PV) by households is essential to meet the Swiss energy transition targets in the residential sector. PV adopters have been previously studied but few have focused on the relationship between their drivers to adopt, their personal characteristics, and their geographic context. Besides, most research has considered adopters as a homogeneous group, without delving into their differences. This study aims to understand how drivers differ among groups of PV adopters, and how these differences relate to their personal characteristics and to their geographic context. For this, we surveyed 1'300 Swiss PV adopters in 2022. We identified the statistically significant differences between PV adopters and the rest of the Swiss population. We used factor analysis and clustering methods to segment respondents based on their drivers to adopt PV. The results expose levers to implement tailored policies to increase PV adoption. First, house ownership seems to be an essential condition to adopt, which can be partly tackled by auto-consumption communities. Second, specific regions may significantly benefit from institutional support. Third, professionals can be key to increasing adoption, particularly during home renovations. Last, leveraging social influence is important to trickle-down adoption.

Work in progress:

Triggering technology co-adoption: The role of certain energy technologies to pave the ground for efficient energy management in Swiss residential buildings. Analysis of technology co-adoption decisions to identify the potential of certain technologies to serve as triggers or entry points for the adoption of multiple energy technologies and energy management systems.

Filling the gap: Differences in perceived drivers and barriers for the diffusion of EMS between supply and demand-side actors. Mixed-methods approach combining the survey and interview results to identify and analyze the gaps between supply and demand in terms of their perception, needs, and challenges.

Proximity effects for the diffusion of energy technologies: The role of socio-spatial proximity and trust. Geospatial analysis of demand-side information networks to better understand the relationships between trust, frequency of interaction, and spatial proximity.

Innovation-diffusion of energy technologies: The role and dynamics of supply-side information networks. In-depth analysis of supply-side information networks, in particular Energy technology providers and energy and e-mobility service companies, to reveal more specific patterns of information diffusion and understand how these networks are embedded in the socio-spatial context.

Innovation pathways for diffusion: Connecting supply and demand-side information networks. Geospatial analysis to understand how supply and demand-side information networks are connected, to identify promising information pathways, to analyze the roles of different types of actors in the network, and to investigate the role of frequency of interaction and trust.

11 References

Ajzen, I. (1991). The theory of planned behavior. Organizational Behavior and Human Decision Processes 50, 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Arentze T., Timmermans H., Modeling the Formation of Activity Agendas Using Reactive Agents. Environment and Planning B: Planning and Design. 10.1068/b12841

Bernards, R., Morren, J., Slootweg, H. (2018). Development and Implementation of statistical models for estimating diversified adoption of energy transition technologies. IEEE Transactions on Sustainable Energy 9(4), 1540–1554. https://doi.org/10.1109/TSTE.2018.2794579

Curis, G. (2020). Integrate the concept of adherence into the urban thinking. Master's thesis. Urban Sociology Laboratory (LASUR), EPFL.

Granovetter, M.S. (1973). The strength of weak ties. American Journal of Sociology 78, 1360–1380. https://doi.org/10.1086/225469

Laatikainen T., Hasanzadeh K., Kyttä M., (2018) Capturing exposure in environmental health research: challenges and opportunities of different activity space models. International Journal of Health Geographics. 10.1186/s12942-018-0149-5

Mintzberg, H., Raisinghani, D., Théorêt, A. (1976). The structure of "unstructured" decision processes. Administrative Science Quarterly 21, 246–275. https://doi.org/10.2307/2392045

Mundaca, L., Samahita, M. (2020). What drives home solar PV uptake? Subsidies, peer effects and visibility in Sweden. Energy Research & Social Science 60, 101319. https://doi.org/10.1016/j.erss.2019.101319

Noll, D., Dawes, C., Rai, V. (2014). Solar community organizations and active peer effects in the adoption of residential PV. Energy Policy 67, 330–343. https://doi.org/10.1016/j.enpol.2013.12.050

Orford S., Leigh C. (2013) The Relationship between Self-reported Definitions of Urban Neighborhood and Respondent Characteristics: A Study of Cardiff, UK. Urban Studies. 10.1177/0042098013499795

Palm, A. (2017). Peer effects in residential solar photovoltaics adoption: A mixed methods study of Swedish users. Energy Research & Social Science 26, 1–10. https://doi.org/10.1016/j.erss.2017.01.008

Rai, V., Reeves, C., Margolis, R. (2015). Overcoming barriers and uncertainties in the adoption of residential solar PV. Renewable Energy 89, 498–505. http://dx.doi. org/10.1016/j.renene.2015.11.080

Rogers, E. M. (2003). Diffusion of Innovations. Free Press, 5th edition

Serra-Coch, G., Wyss, R., Binder, C.R. (2023). Geographic network effects to engage people in the energy transition: The case of PV in Switzerland. Heliyon 9 (7), https://doi.org/10.1016/j.heliyon.2023.e17800

SFOE (2019). Energy perspectives 2050+

Tagliapietra S., Zachmann G., Edenhofer O., Glachant J.-M., Linares P., Loeschel A. (2019). The European Union energy transition: Key priorities for the next five years. Energy Policy 132, 950-4. https://doi.org/10.1016/j.enpol.2019.06.060

12 Appendix

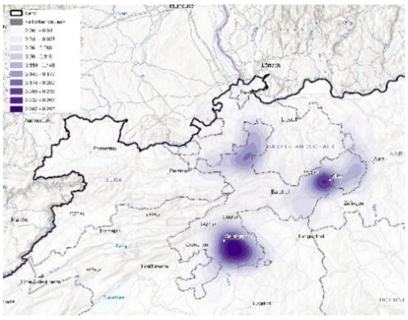
Figures

Name	Organizer	Website
AeeCongress - Aee Kongress (DE) - AeeCongres (FR)	AeeSuisse	https://aee-kongress.ch/de/#
Annual Conference SCCER SOE - Swiss Competence Center for Energy Research - Supply of Electricity	SCCER SOE	http://www.sccer-soe.ch/en/news/events/annual-conference-2020/
E-World Fair	Messe Essen / Con energy	https://www.e-world-essen.com/de/
Energy Startup Day	Zhaw School of Management and Law	https://www.energy-startup-day.ch/
Innovations Forum Mobility	Smart Energy	https://innovationsforum-mobility.ch/
Innovations Forum Energie	Lighthouse Institute AG	https://www.innovationsforum-energie.ch/
New Energy Investors Summit	ReMaP	https://investorsummit.ch/de
Powertage	Powertage	https://www.powertage.ch/
Smart Energy Party	energie360	https://smartenergyparty.ch/de/
Swiss Mobility Arena - Schweizer Mobilitäts Arena (DE) - L'Arène Suisse de la Mobilité (FR)	Mobilitätsakademie (TCS)	https://www.mobilitaetsarena.ch/de/
SwissPropTech Day	SwissPropTech	https://swissproptech.ch/
Stadwerkekongress (DE) - Congrès des services industriels (FR)	Swisspower AG	https://stadtwerkekongress.ch/fr/
Vertriebsleitertagung Energie	Lighthouse Institue AG	https://vertriebsleitertagung-energie.ch/
Swissbau	MCH Messe Schweiz	https://www.swissbau.ch/de-CH.aspx
Jahrestagung Verteilnetzforum	RePower	https://verteilnetzforum.ch/

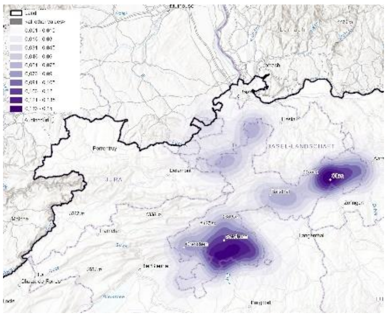
Figure A1: List of events in Switzerland relevant to the diffusion of EMS.

Name	Website
Aeesuisse	https://www.aeesuisse.ch/de/
CVI - Chambre Vadoise Immobiliere	https://cvi.ch/
Eco2Friendly	http://www.eco2friendly.ch/
EITswiss	https://www.eitswiss.ch/de/
Electrosuisse	https://www.electrosuisse.ch/de/
eMobile	https://www.e-mobile.ch/de/
EnAW - Energy Agency Swiss private sector (EN) - EnergieAgentur der Wirtschaft (DE) - Agence de l'Energie Pour l'economie-AEnEC (FR) - Agenzia dell'Energie per l'economia - AEnEC (IT)	https://enaw.ch/
Energie Finder Schweiz	https://www.energie-finder.ch
Energie Network Schweiz	http://www.energienetwork.ch
Forum Energie Zuerich	https://forumenergie.ch/
GNI - Gebäude Netzwerk Initiative (DE) - Initiative Reseau Batiment (FR)	https://www.g-n-i.ch/
GSGI - Gruppe der Schweizerischen Gebäudetechnik-Industrie (DE) - Groupe de lindustrie suisse des techniques du batiment (FR)	http://www.gsgi.ch/
ICT Switzerland	https://ictswitzerland.ch/
IEA - International Energy Agency	https://www.iea.org/
ImmoClimat - GebaudeKlima Schweiz (DE) - ImmoClimat Suisse (FR) - ImmoClima Svizzera (IT)	https://www.gebaeudeklima-schweiz.ch/fr

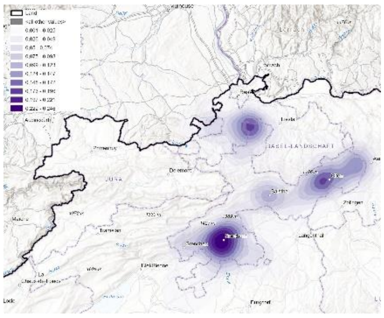
Figure A2: List of associations in Switzerland relevant to the diffusion of EMS.



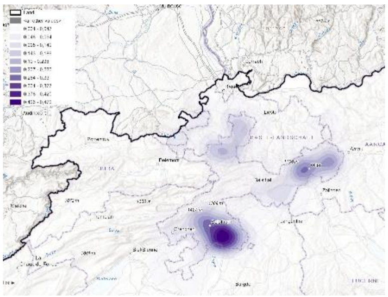
Solothurn: EMS home location



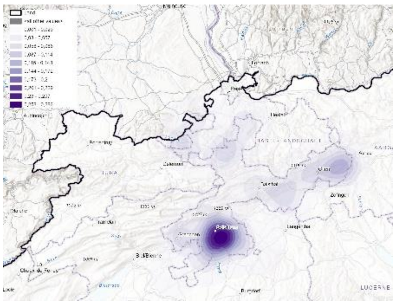
Solothurn: PV home location



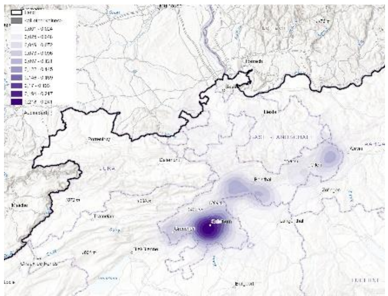
Solothurn: EV home location



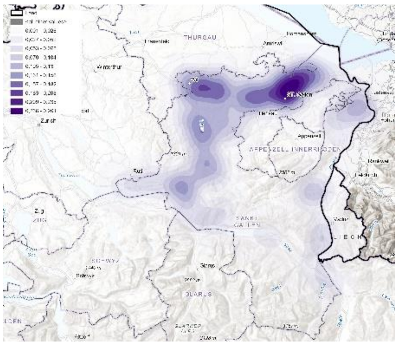
Solothurn: EMS information exchange location



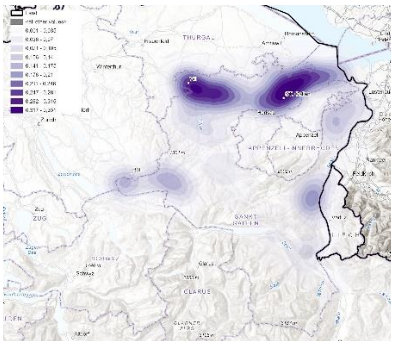
Solothurn: PV information exchange location



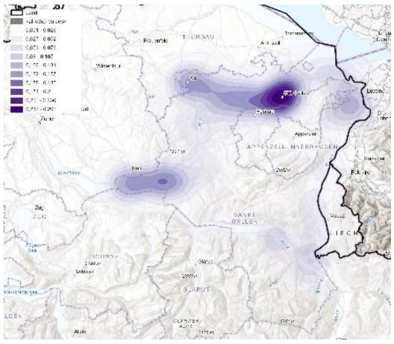
Solothurn: EV information exchange location



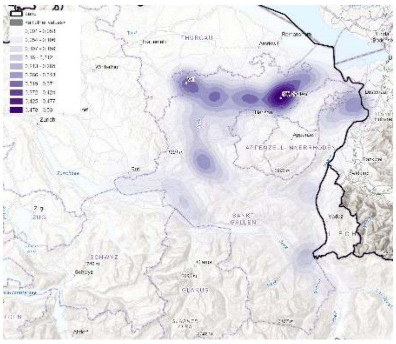
St Gallen: EMS home location



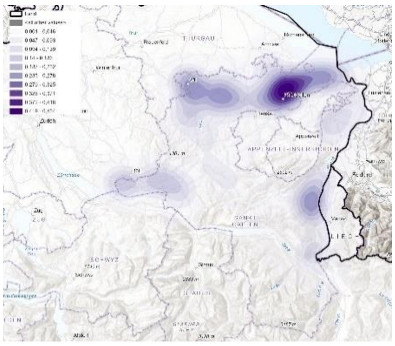
St Gallen: PV home location



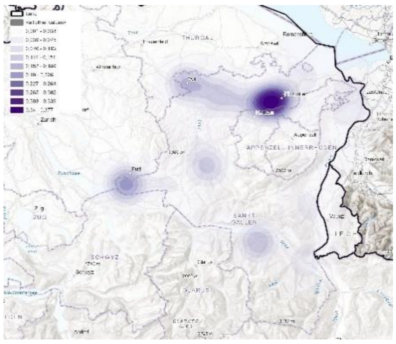
St Gallen: EV home location



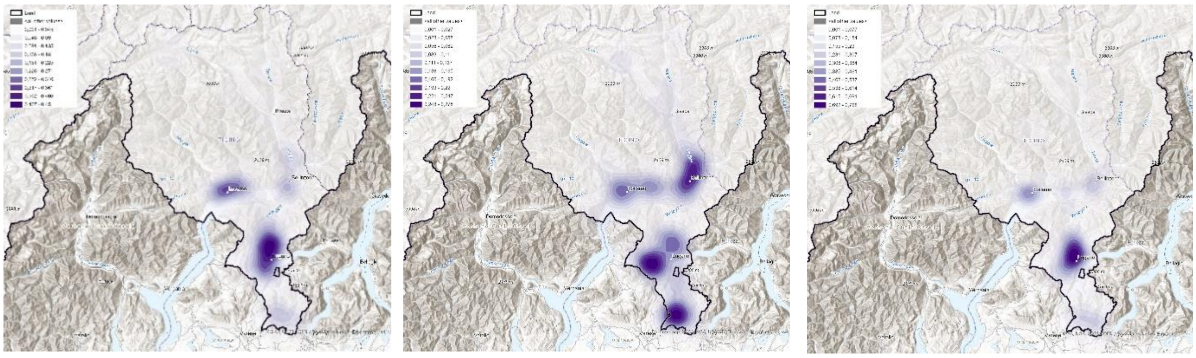
St Gallen: EMS information exchange location



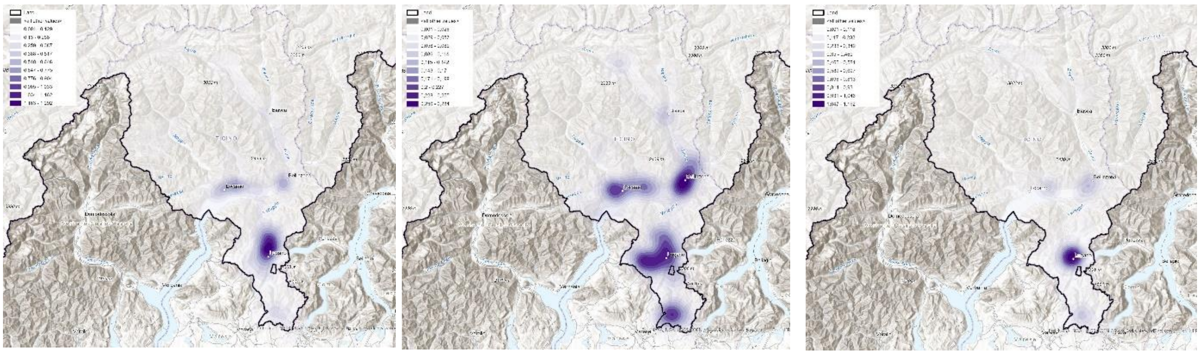
St Gallen: PV information exchange location



St Gallen: EV information exchange location



Ticino: EMS home location Ticino: PV home location Ticino: EV home location



Ticino: EMS information exchange location Ticino: PV information exchange location Ticino: EV information exchange location

Figure A3: Kernel density map of home locations and information exchange locations within the canton of St. Gallen, Solothurn, and Ticino.

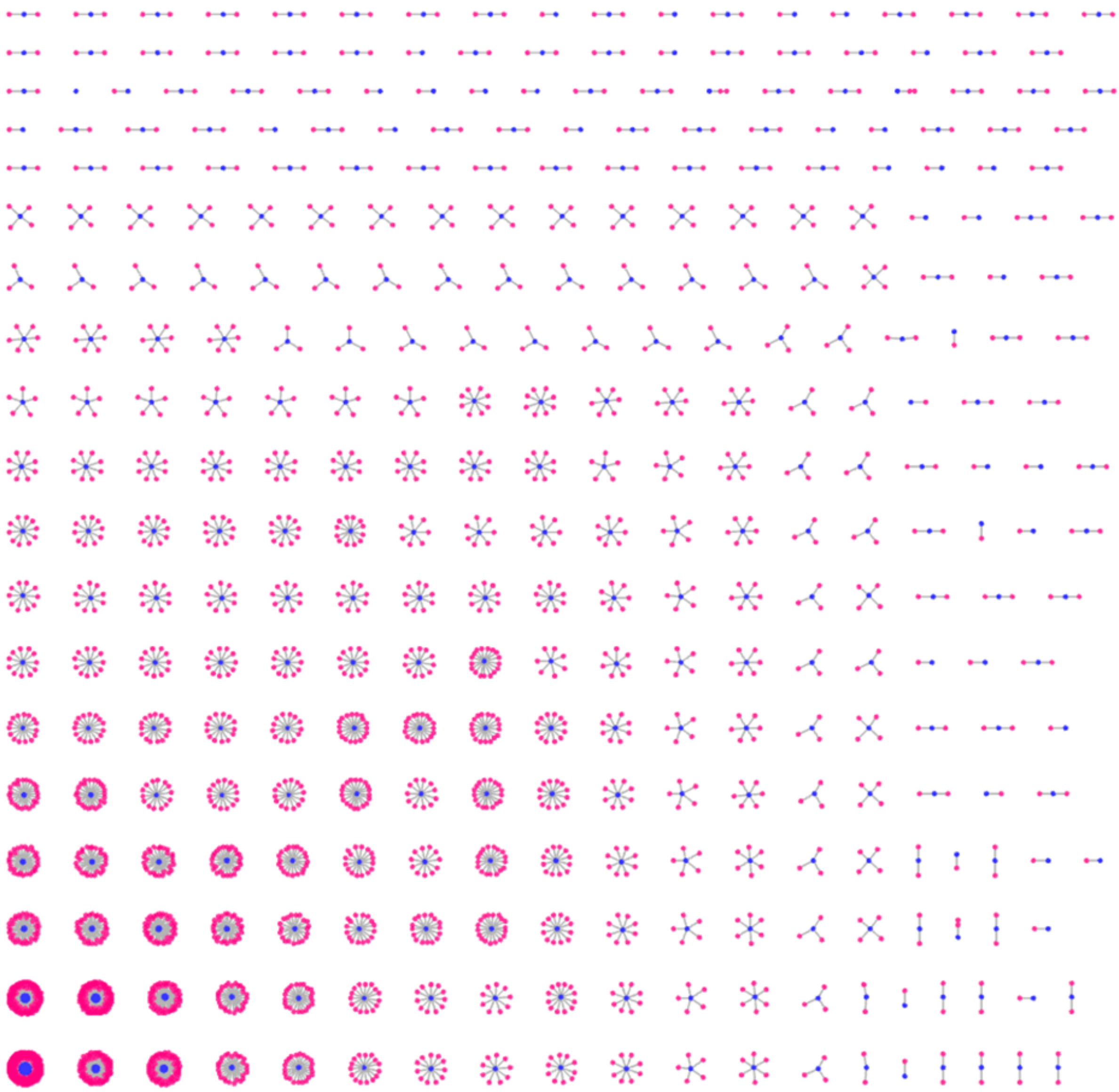


Figure A4: Number of times supply-side actors were mentioned by demand-side actors when asked *“If you think about the most relevant information exchange with a professional that helped you make your decision... Would you please give us the specific name of the company or institution of this professional?”* Supply-side actors in blue and demand-side actors in pink. Force-directed layout. One supply-side actor is mentioned more than 150 times (left lower corner), 70 actors were mentioned 10 times or more, 10 actors were mentioned 30 times, and 38 actors are only mentioned once.

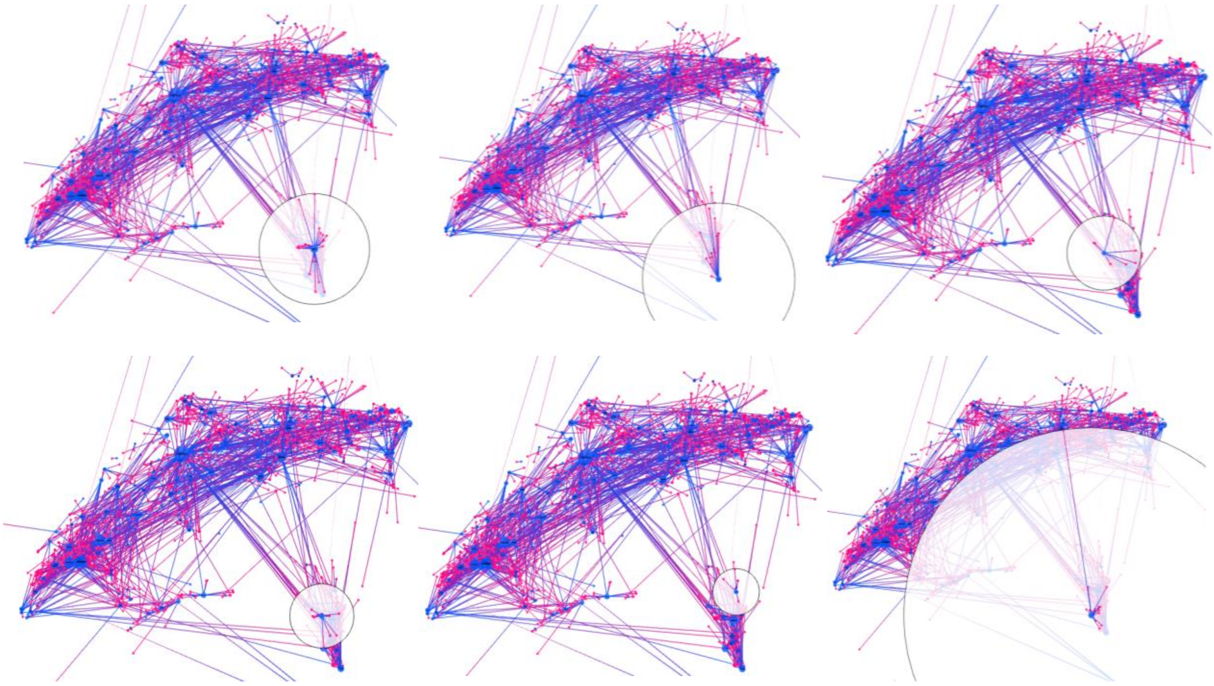


Figure A5: Supply-demand-side network in the Italian-speaking region.

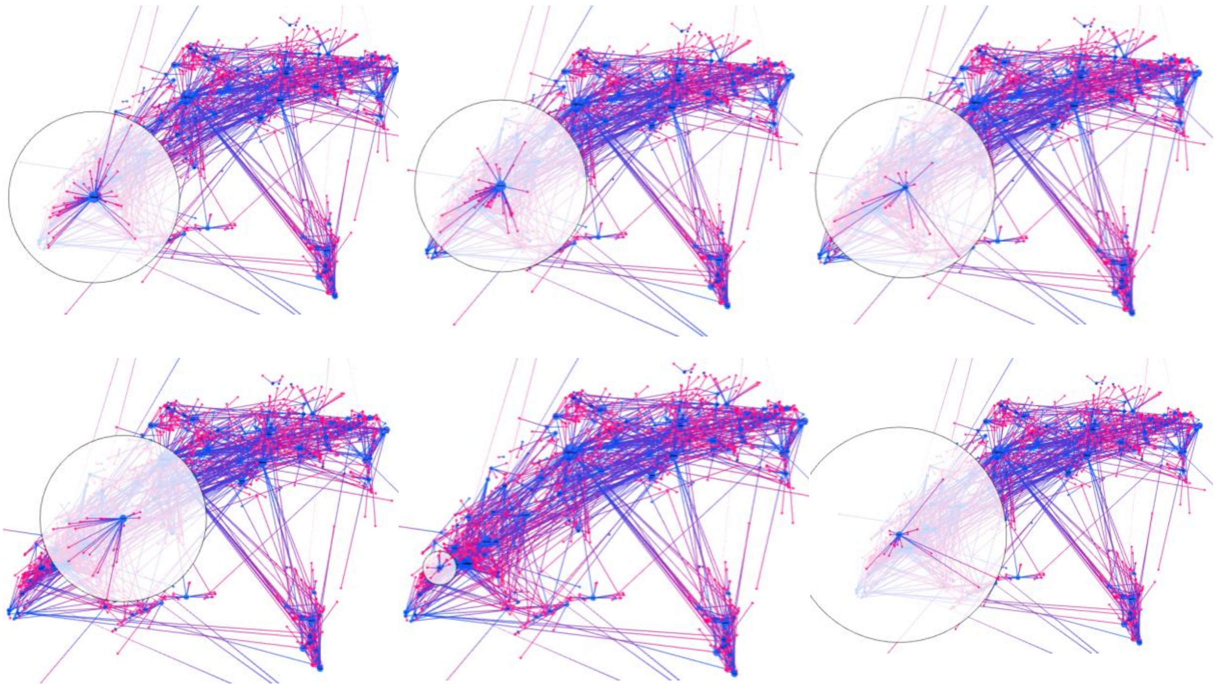


Figure A6: Supply-demand-side network in the in the French-speaking region.

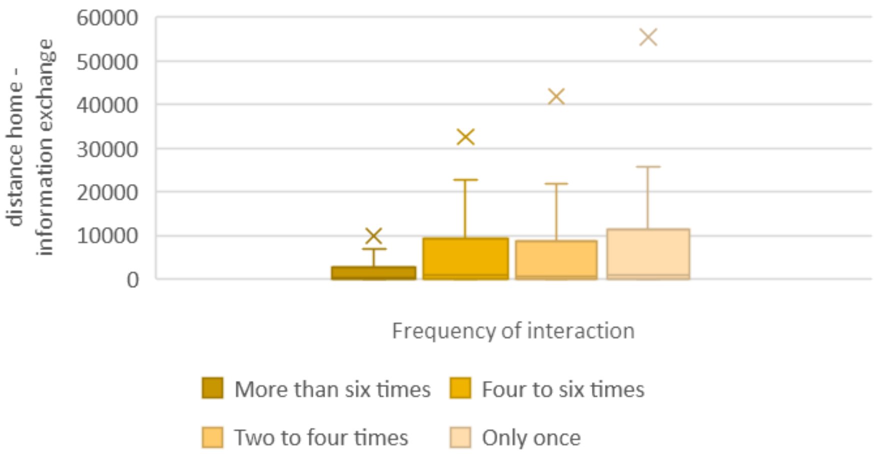


Figure A7: Distance between home and information exchange location (m) by frequency of interaction.

Tables

Table A1: Supply-side actors that were mentioned by demand-side actors when asked *"If you think about the most relevant information exchange with a professional that helped you make your decision… Would you please give us the specific name of the company or institution of this professional?"*

Actor	Category	Domain	Canton	Degree centrality
Helion	Energy technology provider	Energy	Solothurn	179
Solstis	Energy technology provider	PV	Vaud	98
Romande Energie	Energy utility entity	Energy utility entity	Vaud	90
Agena Energies	Energy technology provider	Energy	Vaud	73
amag	Energy technology provider	Vehicles	Zug	63
Groupe-e	Energy utility entity	Energy	Vaud	50
Youenergy Solar SA	Energy or e-mobility service company	Energy	Vaud	39
IngEne Sagl	Energy technology provider	PV	Ticino	37
Mons Solar	Energy technology provider	Energy	St Gallen	33
Clevergie Gbmh	Energy technology provider	Energy	Bern	30
Axova	Energy technology provider	PV	Basel Land	29
Electro Sol SA	Energy technology provider	PV	Vaud	28
ch-solar	Energy technology provider	PV	Zurich	27
Ecosinergie Tienergy SA	Energy technology provider	PV	Ticino	27
EKZ	Energy utility entity	Energy utility entity	Zurich	27
Elettricita Bronz SA	Energy technology provider	PV	Ticino	26
Stich Solar	Energy technology provider	Energy	Solothurn	24
Heizplan AG	Energy technology provider	Energy	St Gallen	24
CKW	Energy technology provider	Energy	Luzern	24
TRITEC	Energy technology provider	PV	Bern	22
SB energetica	Energy technology provider	Energy	Ticino	21
MBRsolar	Energy technology provider	Energy	Thurgau	20
solarmotion	Energy technology provider	Energy	St Gallen	19
SEFA Societe Electrique des Forces de l'Aubonne	Energy technology provider	Energy	Vaud	19
G&O Sunsolutions GmbH	Energy technology provider	PV	St Gallen	18
Streule + Alder AG	Energy technology provider	PV	St Gallen	18
scdi	Energy technology provider	Energy	Vaud	18
Kunz Solartech	Energy technology provider	PV	Aargau	17
MT Systems Energy	Energy technology provider	Energy	Ticino	17
stg energy	Energy technology provider	Energy	Vaud	17
BKW SA	Energy utility entity	Energy utility entity	Bern	17
Edion AG	Energy technology provider	Energy	St Gallen	16
Solenergy sàrl	Energy technology provider	PV	Vaud	16
TSE. Top Sun Energy SA	Energy technology provider	Energy	Neuchatel	16
Altersol SA	Energy technology provider	Energy	Ticino	16
Soleol SA	Energy technology provider	Energy	Freibourg	15
Genos Energie AG	Energy technology provider	Energy	Solothurn	15
GTS Solar SA	Energy technology provider	Energy	Vaud	15
Winsun AG	Energy technology provider	Energy	Valais	15
Solar Manager AG	Energy technology provider	PV	Aargau	14
MCR-e	Energy technology provider	Energy	Vaud	14
Seetal Solar	Energy technology provider	PV	Luzern	13
EKZ Eltop AG	Energy technology provider	Energy	Zurich	13
Elektrobedarf Troller AG	Energy technology provider	Energy	Aargau	12
AWS Solar	Energy technology provider	PV	St Gallen	12
Swissolar	Association	PV	Zurich	12
RESPECT Energies	Energy technology provider	Energy	Vaud	12
eConnect	Energy technology provider	Energy	Zurich	12
GLB Thun Oberland	Energy technology provider	Energy	Bern	12
Benetz	Energy technology provider	PV	Luzern	12
ewz	Energy utility entity	Energy utility entity	Zurich	12

von arx systems ag	Energy technology provider	PV	Solothurn	11
seic. Société Electrique Intercommunale de la Cote	Energy utility entity	Energy utility entity	Vaud	11
Planair	Energy technology provider	EMS	Freibourg	11
primeo energie	Energy utility entity	Energy utility entity	Basel Land	11
Swiss Photovoltaic AG	Energy technology provider	Energy	Solothurn	11
Pons Energia Solare	Energy technology provider	PV	Ticino	11
SAK St. Gallisch-Appenzellische Kraftwerke AG	Energy utility entity	Energy utility entity	St Gallen	11
Energietal Toggenburg	Association	Energy	St Gallen	11
Industrielle Werke Basel	Energy technology provider	Energy	Basel Land	11
JGE Jaeggi Gmünder Energietechnik AG	Energy technology provider	Energy	Zurich	11
Genossenschaft Elektra	Energy technology provider	Energy	Bern	11
solAlpes énergie	Energy technology provider	PV	Valais	11
Schweizer Solaire	Energy technology provider	Energy	Freibourg	10
OIKEN	Energy technology provider	Energy	Valais	10
CE Concept Energy AG	Energy technology provider	Energy	Thurgau	10
Soltop energie	Energy technology provider	PV	Zurich	10
Franz Hasler AG	Energy technology provider	Energy		10
Solaire 1300	Energy technology provider	PV	Vaud	10
Auto Hermann	Energy technology provider	EV	St Gallen	10
Energie Genossenschaft Schweiz	Energy technology provider	Energy	Bern	9
Solar Ticino	Energy technology provider	Energy	Ticino	9
Elektro Wäger AG	Energy technology provider	PV	St Gallen	9
ABC Solar sarl	Energy technology provider	PV	Freibourg	9
RUTZ Gruppe AG	Construction sector	Energy	Zurich	9
RESiQ	Energy technology provider	Energy	Bern	9
Helvetia Energy SA	Energy technology provider	Energy	Geneva	9
Eco-Soluce Sarl	Energy technology provider	Energy	Vaud	9
Eigenmann AG	Energy technology provider	EV	St Gallen	9
EBL	Energy utility entity	Energy utility entity	Basel Land	9
Faivre Energie SA	Energy technology provider	Energy	Jura	9
Hansesun AG	Energy technology provider	Energy	St Gallen	9
Swisstherm AG	Energy technology provider	Energy	Aargau	8
Dachdecker	Academia	Energy	St Gallen	8
Lenz AG	Energy technology provider	Energy	St Gallen	8
AgriMess	Energy technology provider	PV	Ticino	8
Evosun SARL	Energy technology provider	Energy	Valais	8
AIL. Industrial Companies of Lugano	Energy utility entity	Energy utility entity	Ticino	8
Swiss Green Engineering Sàrl	Energy technology provider	PV	Freibourg	8
Eco6therm Sarl	Energy technology provider	Energy	Jura	8
Jenni Energietechnik AG	Energy technology provider	PV	Bern	8
Elektrofachgesch	Energy technology provider	Energy	Bern	8
A. Lehmann Elektro AG	Energy technology provider	Energy	St Gallen	8
EFISOL SA	Energy technology provider	PV	Valais	8
Roth Elektro Kerzers AG	Energy technology provider	Energy	Freibourg	8
Büchel-hoop photovoltaik ag	Energy technology provider	PV		7
CVG SA	Energy technology provider	Energy	Geneva	7
SunTechnics Fabrisolar	Energy technology provider	PV	Zurich	7
Photosun Solar energy	Energy technology provider	Energy	Geneva	7
PIKEY SOLEY	Energy technology provider	PV	Basel Land	7
Elektro Hunziker AG	Energy technology provider	Energy	Bern	7
Kobler Energie AG	Energy technology provider	Energy	St Gallen	7
ECO Optimum	Energy technology provider	Energy	Ticino	7
Alka Solar	Energy technology provider	Energy	St Gallen	6
Sunkraft SA	Energy technology provider	Energy	Geneva	6
Swiss Renewable Energy	Energy technology provider	Energy	Freibourg	6
Burlet Bau GmbH	Construction sector	Energy	St Gallen	6
Blanchard Iso Solar	Energy technology provider	PV	Vaud	6
Tech Insta SA	Energy technology provider	Energy	Ticino	6
Greenkey Sagl	Energy technology provider	PV	Ticino	6
Allemann Automobile	Energy technology provider	EV	Bern	6
IBW AG	Energy technology provider	Energy	Aargau	6

e-solaire	Energy technology provider	PV	Neuchatel	6
MORE Engineering	Energy technology provider	PV	Ticino	6
EWJR. Elektrizitätswerk Jona-Rapperswil AG	Energy utility entity	Energy utility entity	St Gallen	6
Sun Energy	Energy technology provider	Energy	Geneva	6
Grob AG Gebaudehullen	Construction sector	Energy	St Gallen	6
Hoval	Energy technology provider	Construction	Zurich	6
Amaudruz SA	Energy technology provider	Electrical and electronic industries	Vaud	6
Energieagentur St.Gallen GmbH	Energy technology provider	Energy	St Gallen	6
Elektro Egli AG	Energy technology provider	Electrical and electronic industries	St Gallen	5
Hablutzel AG	Energy technology provider	Energy	St Gallen	5
SIG	Energy utility entity	Energy utility entity	Geneva	5
Apak Energy	Energy technology provider	Energy	Ticino	5
VO Énergies	Energy technology provider	Energy	Vaud	5
Brunner + Imboden AG	Energy technology provider	Energy	Bern	5
BTsun SA	Energy technology provider	PV	Vaud	5
Seeland-Solar	Energy technology provider	PV	Bern	5
AEW	Energy technology provider	Energy	Aargau	5
Concept Energy	Energy or e-mobility service company	Energy	St Gallen	5
LidER concept sarl	Energy technology provider	Energy	Vaud	5
Alsolis SA	Energy technology provider	PV	Ticino	5
Siemens Schweiz AG	Energy technology provider	Energy	Vaud	5
Suncrest GmbH	Energy technology provider	PV	Basel Land	5
Alsol AG	Energy technology provider	Energy	Thurgau	5
Furrer Solartechnik GmbH	Energy technology provider	Energy	Zug	5
Solar4you AG	Energy technology provider	PV	Basel Land	5
Regio Energie Solothurn	Public and non-profit entities	Energy	Solothurn	5
Elektro Imboden	Energy technology provider	Energy	Aargau	4
IET Energietechnik	Energy technology provider	Energy	St Gallen	4
AMB. Bellizona Multiservice Company	Energy utility entity	Energy utility entity	Ticino	4
Studio Termotecnico GFR	Energy technology provider	PV		4
NewSol AG	Energy technology provider	PV	Zurich	4
Kippel AG	Energy technology provider	Energy	Bern	4
Steinegger Elektro AG	Energy technology provider	Energy	Schwytz	4
O. Kohler AG	Energy technology provider	Energy	Aargau	4
Centorbi SA	Energy technology provider	PV	Ticino	4
Oberhänsli AG	Energy technology provider	Energy	St Gallen	4
Grossmann Brauchli AG	Energy technology provider	Electrical and electronic industries	Thurgau	4
go Solar GmbH	Energy technology provider	PV	Zurich	4
eltanorm GmbH	Energy technology provider	Energy	Bern	4
Feuz GMBH	Energy technology provider	Energy	St Gallen	4
greencover ag	Energy technology provider	Energy	St Gallen	4
esg-ost	Energy technology provider	PV	St Gallen	4
Solaire Romand	Energy technology provider	Energy	Valais	4
Lutz Bodenmüller AG	Energy technology provider	Energy	Schaffhausen	4
EW Hofe	Energy utility entity	Energy utility entity	Schwytz	4
EVS Energieversorgung Schanis AG	Energy utility entity	Energy utility entity	St Gallen	4
Inauen AG	Energy technology provider	Construction	St Gallen	4
Studioenergia Sagl	Energy technology provider	Energy	Ticino	4
Hustech Installations AG	Energy technology provider	Energy	Zurich	4
WSG AG	Energy technology provider	Construction	Zurich	4
Spinelli SA	Energy technology provider	Energy	Ticino	4
Hp Hardegger AG	Energy technology provider	Electrical and electronic industries	St Gallen	4
EVU Partners	Energy or e-mobility service company	Energy	Aargau	3
Nyffenegger Solar	Energy technology provider	PV	Solothurn	3
Etablissements Techniques Fragniere SA	Energy technology provider	Energy	Freibourg	3
Pronovo	Energy technology provider	PV	Aargau	3
Impact Living	Energy technology provider	Energy	Vaud	3

Hypersolaire	Energy technology provider	Energy	Jura	3
Rezzonico Eco Energie	Energy technology provider	Construction	Ticino	3
ES Elektro Seftigen AG	Energy technology provider	PV	Bern	3
Tech-elec SA	Energy technology provider	PV	Vaud	3
B+S Elektro Telematik AG	Energy technology provider	Energy	Basel Land	3
Reusser Dach und Fassaden AG	Energy technology provider	Construction	Bern	3
Scherer Architekten AG	Energy technology provider	Construction	Basel Land	3
Baur AG	Energy technology provider	Energy	Zug	3
Schatzmann Engineering	Energy technology provider	PV	Aargau	3
FL Architecture & Associes SA	Energy technology provider	Real Estate	Vaud	3
Enalti SA	Energy technology provider	PV	Ticino	3
Halter AG	Energy technology provider	Energy	Zurich	3
Die Dachexperten GmbH	Energy technology provider	Energy	Luzern	3
C & G Electricite Sarl	Energy technology provider	Energy	Vaud	3
Artho Elektro	Energy technology provider	Energy	St Gallen	3
Prime Energy Technics	Energy technology provider	PV	Geneva	3
Grunenwald AG	Energy technology provider	Energy	Zurich	3
SES. Swiss Energie Foundation	Association	Energy	Zurich	3
Kibernetik AG	Energy technology provider	Energy	St Gallen	3
elentec GmbH	Energy technology provider	Energy	Bern	3
Eusolar Energy Sagl	Energy technology provider	Energy	Ticino	3
Sinergy Infrastructure et Commerce SA	Energy utility entity	Energy utility entity	Valais	3
Agrola	Energy utility entity	Energy utility entity	Zurich	3
Elektro Schmid AG	Energy technology provider	Energy	St Gallen	3
Iontec GmbH	Energy technology provider	PV	St Gallen	3
SSFE	Energy technology provider	PV	Vaud	3
E-ME Energies	Energy technology provider	Energy	Vaud	3
cablex ag	Energy technology provider	Energy	Bern	3
Käser AG	Energy technology provider	Energy	Solothurn	3
Garage Marti AG	Energy technology provider	EV	Solothurn	3
solarenergy	Energy technology provider	PV	Zurich	3
Rossi Dach AG	Energy technology provider	Construction	St Gallen	2
EW Sirnach AG	Energy technology provider	Construction	Thurgau	2
Trunova AG	Energy technology provider	Energy	St Gallen	2
Schubiger Energie-Dämmtechnik	Energy technology provider	Energy	St Gallen	2
EW Quarten	Energy technology provider	Construction	St Gallen	2
Heeb AG Heizungsservice	Energy technology provider	Energy	St Gallen	2
Thurwerke AG	Energy utility entity	Energy utility entity	St Gallen	2
Solarpartner GmbH	Energy technology provider	Energy	St Gallen	2
Vionnet SA	Energy technology provider	Energy	Vaud	2
RB Energia Sagl	Energy technology provider	Energy	Ticino	2
Ponzio Solar SA	Energy technology provider	Energy	Vaud	2
CAP ENERGIE	Energy technology provider	Energy	Geneva	2
Renevier energies sarl	Energy technology provider	PV	Vaud	2
Krebs AG	Energy technology provider	Energy	Zurich	2
Senero AG	Energy technology provider	PV	Zurich	2
Solateur	Academia	Energy	Bern	2
Elektro Grogg AG	Energy technology provider	Electrical and electronic industries	Bern	2
ENERGITECH sarl	Energy technology provider	Energy	Valais	2
EW Wald	Energy technology provider	Energy	Zurich	2
ebs Energie AG	Energy utility entity	Energy utility entity	Schwytz	2
Flückiger Elektro AG	Energy technology provider	Electrical and electronic industries	Aargau	2
Gebäudetechnik	Energy or e-mobility service company	EMS	Aargau	2
HASLER SOLAR	Energy technology provider	Construction		2
Gruyere Energie SA	Energy technology provider	Energy	Freibourg	2
as-automotion ag	Energy technology provider	PV	Bern	2
SH Power	Energy utility entity	Energy utility entity	Schaffhausen	2
Jura Energie	Energy technology provider	Energy	Jura	2
Catech Photovoltaik-Solaranlagen	Energy technology provider	Energy	Ticino	2
Gemperle AG	Energy technology provider	Energy	Aargau	2
Eichholzer Haustechnik AG	Energy technology provider	Energy	Aargau	2

ESB Energie Service Bienne	Energy utility entity	Energy utility entity	Bern	2
Garage Keigel	Energy technology provider	EV	Basel Land	2
viteos	Consulting	Energy	Neuchatel	2
Rüegsegger Elektro AG	Energy technology provider	Electrical and electronic industries	Bern	2
Solarblitz	Energy technology provider	PV	Solothurn	2
Autovoltaic-VS	Energy technology provider	PV	Valais	2
CSEM. Swiss Center for Electronics and Microtechnology SA	Energy technology provider	Energy	Neuchatel	2
Breu AG Schwarzenburg	Energy technology provider	Construction	Bern	2
Indasol	Energy technology provider	PV	Luzern	2
Energinno SA	Energy technology provider	Energy	Vaud	2
Ammann Elektro	Energy technology provider	Energy	Zurich	2
Devisol AG	Energy technology provider	Energy	Bern	2
GM Energievorteil GmbH	Energy technology provider	Energy		2
Ivolt AG	Energy technology provider	Energy	Bern	2
kabeltechnik swiss ag	Energy technology provider	Energy	Aargau	2
Heinz Schmid AG	Energy technology provider	Energy	Zurich	2
LAVEBA Genossenschaft	Energy technology provider	Energy	St Gallen	2
OST. Eastern Switzerland University of Applied Sciences	Academia	EMS	St Gallen	2
HQ Energie AG	Energy technology provider	Energy	Aargau	2
Solaris	Energy technology provider	Real Estate	Aargau	2
Marti Elektro-Intstallationstechnik AG	Energy technology provider	Electrical and electronic industries	Basel Land	2
EWS	Energy utility entity	Energy utility entity	Schwytz	2
Holinger Solar AG	Energy technology provider	Energy	Basel Land	2
Energy Uster AG	Energy technology provider	Energy	Zurich	2
Alternative CARs	Energy technology provider	EV	Vaud	2
Garage ERTA	Energy technology provider	EV	Ticino	2
Säntis Energie AG	Energy technology provider	Energy	St Gallen	2
Helios Energies SA	Energy technology provider	Energy	Geneva	2
EO Elektro Oberland GmbH	Energy technology provider	Energy	Zurich	2
Hesshaus	Energy technology provider	Energy	Basel Land	2
Buderus	Energy technology provider	Energy	Vaud	2
Baldegger Automobile	Energy technology provider	EV	St Gallen	2
Michel Rime SA	Energy technology provider	Construction	Vaud	2
Ticino Energia	Association	Energy	Ticino	2
VS Solarstrom AG	Energy technology provider	PV	Valais	2
Solar Conseil Sàrl	Energy technology provider	PV	Bern	2
Gwerder Energy	Energy technology provider	PV	Zurich	2
EW Vilters Wangs	Public and non-profit entities	Public authorities	St Gallen	2
Eltech System Sarl	Energy technology provider	Energy	Vaud	2
Energy Optimizer	Energy technology provider	Energy	Bern	2
Implenia Schweiz AG	Energy technology provider	Energy	Zurich	2
Installateur Barloggio SA	Energy technology provider	Energy	Ticino	2
Soleis AG	Energy technology provider	Energy	Solothurn	2
ABT Automobile	Energy technology provider	EV	Basel Land	2
JM Electric	Energy technology provider	Energy		2
Garage P-A Keller Bussigny	Energy technology provider	EV	Vaud	2
elektro scherzinger ag	Energy technology provider	Electrical and electronic industries	Zurich	2
SunStyle AG	Energy technology provider	Energy	Bern	2
Electrasim SA	Energy technology provider	Electrical and electronic industries	Ticino	2
Liechtensteinische Kraftwerke	Energy technology provider	Energy		2
EWB Energie Wasser Bern	Energy utility entity	Energy utility entity	Bern	2
CIEL Electricité SA	Energy technology provider	Electrical and electronic industries	Vaud	2
AUE. Amt für Umwelt und Energie	Energy technology provider	Energy	Basel Land	2
Garage Chuard	Energy technology provider	EV	Vaud	2
arento AG	Energy technology provider	Construction	Zurich	2
energy unlimited GmbH	Energy technology provider	Energy	Bern	2
Elosolar Gmbh	Energy technology provider	Energy	Bern	2
Swiss eMobility	Energy technology provider	EV	Bern	2

Activ Solar	Energy technology provider	PV	Zurich	2
Bonnet Electricite SA	Energy technology provider	Electrical and electronic industries	Vaud	2
energie-service	Energy technology provider	Energy	Vaud	2
Dimab Groupe	Energy technology provider	EV	Neuchatel	2
TechCom electro AG	Energy technology provider	Energy	St Gallen	2
WPC	Energy technology provider	Energy	Bern	2
Garage Kolb AG	Energy technology provider	EV	Zurich	2
Emoti	Energy or e-mobility service company	EV	Ticino	2
Garage Tognetti SA	Energy technology provider	EV	Ticino	2
SEVJ Societe electrique de la Vallee de Joux	Energy technology provider	Energy	Neuchatel	2
Enphase Energy	Energy technology provider	Energy		2
Bischofsbergerdach bedachunger AG	Energy technology provider	Construction	St Gallen	2
AEK Elektro AG	Energy technology provider	Energy	Solothurn	2
EWG Basel	Energy technology provider	PV	Basel Land	1
Swissbau Innovation Lab	Construction sector	Construction	Basel Stadt	1
FreeSuns	Energy technology provider	PV	Vaud	1
Elektro Schonenberger AG	Energy technology provider	Energy	St Gallen	1
Energo	Energy technology provider	Energy	Bern	1
Proptech	Construction sector	Real Estate		1
Swiss Ohm	Energy technology provider	Energy	Geneva	1
GEAK Der Gebäudeenergieausweis der Kantone	Association	Energy	Basel Stadt	1
Eli10	Energy utility entity	Energy utility entity	Neuchatel	1
Dimension Solaire Sarl	Energy technology provider	PV	Freibourg	1
BantigerElektro	Energy technology provider	Energy	Bern	1
Tabelco SA	Energy technology provider	Energy	Freibourg	1
EWO. Elektrizitätswerk Obwalden	Energy utility entity	Energy utility entity	Obwald	1
Forum Energie Zürich	Association	Energy	Zurich	1
Alder & Streule AG	Energy technology provider	PV	St Gallen	1
Alenso	Energy technology provider	PV	Bern	1
sun2wheel	Energy technology provider	EV	Basel Land	1
Stiebel Eltron	Energy technology provider	HP	Aargau	1
Swissgrid	Energy utility entity	Energy utility entity	Aargau	1
Auto Olivier	Energy technology provider	EV	Vaud	1
SGSW	Energy technology provider	Energy	St Gallen	1
ElCom	Public and non-profit entities	Public authorities	Bern	1
Vaillant GmbH	Energy technology provider	Energy	Zurich	1
Energie 360	Energy utility entity	Energy utility entity	Zurich	1
Elettro Gabutti	Energy technology provider	Energy	Ticino	1
Empa	Academia	EMS	Zurich	1
Colombo Clima Sagl	Energy technology provider	Energy	Ticino	1
NeoVac	Energy technology provider	EMS	St Gallen	1
Alpiq	Energy or e-mobility service company	Energy	Vaud	1
AET. Electricity company Ticinese	Energy utility entity	Energy utility entity	Ticino	1
SBB CFF FFS	Industrial services	Public Transports	Bern	1
Institute of Applied Sustainability to the Built Environment. SUPSI	Academia	EMS	Ticino	1
Di Leo Motors	Energy technology provider	EV	Ticino	1
Elektro Nova	Energy technology provider	Energy	Valais	1
Elektro Mohl	Energy technology provider	Energy	St Gallen	1
ElectroSuisse	Association	Energy	Zurich	1
e-wende. Energiewendegenossenschaft	Energy technology provider	Energy	Bern	1
Solar TEC SA	Energy technology provider	PV	Ticino	1

Table A2: Information exchanges with personal contacts that fall within 500m from home, 500m from home excluding the area taken by the commute route, 250m from work, 100m from the commute route, 100m from the commute route excluding the areas within the home and work buffers, 150m from leisure locations, or within the activity space (the area where demand-side actors conduct most of their regular weekly activities).

	Home (500m) N = 2'187	**Home** (500m) -Commute N = 1'197	**Work** (250m) N = 1'729	**Commute** (100m) N = 1'342	**Commute** (100m) -Home & -Work N= 1'312	**Leisure** (150m) N = 1'107	**Activity space** N = 939
EMS	57%	25%	18%	42%	1.2%	6.4%	73%
PV	59%	27%	20%	40%	2.6%	6%	70%
EV	42%	22%	18%	29%	1.6%	3.3%	65%
Total	**54%**	**25%**	**19%**	**38%**	**1.8%**	**5.4%**	**70%**

Table A3: Information exchanges with professionals that fall within 500m from home, 500m from home excluding the area taken by the commute route, 250m from work, 100m from the commute route, 100m from the commute route excluding the areas within the home and work buffers, 150m from leisure locations, or within the activity space (area where demand-side actors conduct most of their regular weekly activities).

	Home (500m) N = 2'*125*	**Home** (500m) -Commute *N = 1'197*	**Work** (250m) *N = 1'655*	**Commute** (100m) *N = 1'268*	**Commute** (100m) -Home & -Work *N = 1'235*	**Leisure** (150m) *N = 1'070*	**Activity Space** *N = 903*
EMS	64%	29%	18%	42%	0.7%	4%	75%
PV	66%	29%	17%	48%	2.5%	6.3%	76%
EV	22%	12%	7.7%	14%	2.3%	0.7%	56%
Total	**53%**	**25%**	**15%**	**36%**	**1.8%**	**4%**	**70%**

Table A4: Supply-side actors that were mentioned by supply-side actors when asked *"If you think about the most relevant information exchange with a professional that helped you make your decision… Would you please give us the specific name of the company or institution of this professional?"*

Actor	Category	Domain	Times mentioned
Solar Manager	Energy technology providers	PV	7
Swiss eMobility	Energy technology providers	EV	4
SFOE	Public and non-profit entities	Public authorities	4
Swissolar	Association	PV	3
SIG	Energy utility entity	Energy utility entity	2
Romande Energie	Energy utility entity	Energy utility entity	2
CSEM	Energy technology providers	Energy	2
Solaredge	Energy technology providers	Energy	2
Novagrid	Energy technology providers	Energy	2
Solstis	Energy technology providers	PV	2
Energie Cluster	Association	Energy	2
Planair	Energy technology providers	EMS	1
EMPA	Academia	EMS	1
TRITEC	Energy technology providers	PV	1
Krannich	Energy technology providers	PV	1
Casafair	Association	Real Estate	1
VSEAES	Association	Energy	1
EATON	Consulting	Energy	1
Cerutti	Energy technology providers	Construction	1
INERA	Consulting	Energy	1
Viessmann	Energy technology providers	Energy	1
SUPSI	Academia	EMS	1
EKZ	Energy utility entity	Energy utility entity	1
Eitswiss	Association	Electrical and electronic industries	1
DAfi	Energy technology providers	Energy	1
Enerpeak	Consulting	Energy	1
Hoval	Energy technology providers	Construction	1
Erstfeld Gemeindewerke	Energy utility entity	Energy utility entity	1
Echo6therm	Energy technology providers	Energy	1
Emch Berger Revelio	Consulting	Energy	1
AEW	Energy technology providers	Energy	1
Vaillant	Energy technology providers	Energy	1
Loxone	Energy technology providers	EMS	1
St. Gallen Stadt	Public and non-profit entities	Public authorities	1
Swiss Cleantech	Association	Energy	1
Sun2wheel	Energy technology providers	EV	1

Electro Suisse	Association	Energy	1
Energiestadt	Association	Energy	1
CKW	Energy technology providers	Energy	1
NeoVac	Energy technology providers	EMS	1
Pronovo	Energy technology providers	PV	1
Ventisei Swiss	Energy technology providers	Energy	1
MCRe	Energy technology providers	Energy	1
Stiebel Eltron	Energy technology providers	HP	1
Kropf	Energy technology providers	Energy	1
Econnect	Energy technology providers	Energy	1
Smart Fox	Energy technology providers	EMS	1
Cybertech	Consulting	Energy	1
Solarfox	Energy technology providers	PV	1
Sun Network	Energy technology providers	PV	1
ARUVE	Association	EV	1
ElCom	Public and non-profit entities	Public authorities	1

Table A5: Events mentioned by supply side respondents when asked *"Which of these events do you attend to exchange information about [EMS/PV/EV]? Please, select all that apply."*

Event	**Degree centrality** (times mentioned)	**Betweenness centrality** (brokerage)
Powertage	19	600
AEE Congress	13	326
Innovationsforum Energie	11	240
Smart Energy Party	10	218
E-World Fair	4	94
Energy Startup Day	4	23
Jahrestagung Verteilnetzforum	3	93
ETHZ Energy week	3	7
Annual Conference SCCER SOE	2	47
New Energy Investors Summit	1	0

Table A6: Associations mentioned by supply side respondents when asked *"Which of these associations do you use to exchange information about [EMS/PV/EV]? Please, select all that apply."*

Association	**Degree centrality** (times mentioned)	**Betweenness centrality** (brokerage)
Swissolar	70	2179
Electro	54	992
VSEAES	35	510
Mobility	24	200
EIT	24	214
VESE	23	140
eMobile	21	202
Energie-cluster	21	170
SIA	21	190
Swisscleantech	20	77
Smart Grid	16	64
Eco2	14	77
EnAw	13	5
Gni	6	21
Swiss ICT	5	41