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Acronym	**Eco-SESA / Smart Energies in Districts**
Title	Eco-district with Safe, Efficient, Sustainable and Accessible energy
Co-Project investigators	Gilles Debizet and Frédéric Wurtz (successor of Nouredine HadjSaîd)
Start date	01/01/2017
Budget IdEx	1,7 M€

Issues and challenges, state of art

As our societies face the challenges of climate change, renewable energies are confronted to the classical – centralized, unidirectional – operating mode of urban grids, and the relationship of individuals and communities to energy at large.

Based on observations at the building and district scales, the project Eco-SESA aims to produce knowledge, concepts, tools and methods to rethink the planning, management and governance of urban energy systems, as well as the design of their components. Therefore, the contributions of the cross-disciplinary program Eco-district with Safe, Efficient, Sustainable and Accessible energy (Eco-SESA) the contributions were based on observations and collaborations with city and energy stakeholders and have been shared with several scientific communities.

The integration of on-the-spot renewable energies in urban areas requires rethinking the link between variable - partially predictable - renewable productions and consumptions, depending on the behaviours of individual and collective users. At the district scale, there is a strong need for coordination of energy between different stakeholders, and an articulation with public networks - strongly regulated by State - and with local/urban policies. Therefore, a new energy system cannot be designed and committed without considering the transactions between stakeholders (producers, consumers, utilities, incumbent suppliers, regulators...), the variability of renewable production, and the potential of energy storage. To summarize, the design of the system requires rethinking energy operations, and energy planning requires rethinking the governing of energy.

As such, the societal challenge of energy transition in inhabited areas is also a scientific challenge that calls for interdisciplinary collaborations. This is why the CDP Eco-SESA is organised into 5 work packages, each corresponding to an international cross-disciplinary research front (RF).

1. *Interactive solutions to involve building occupants (RF1)*
2. *Emerging behaviours, from the individual to the community (RF2)*
3. *Modelling interactions between buildings and with grids in a district (RF3)*
4. *Architectures for the local integration of renewable on-the-spot generation (ROG) (RF4)*
5. *Components and materials: specifications for a proper integration into systems (RF5)*

The Grenoble peninsula is home to several energy-related laboratories, and is the perimeter of a very ambitious urban project in terms of energy performance and renewable energy. This veritable living lab has served as fieldwork at the building or neighbourhood level, in addition to external sites carefully chosen in France and Switzerland for their pioneering and innovative character.

After 4 years of operation, the work of the senior and junior researchers involved in the CDP has led to significant results in several fields of research and innovation:

- *Overcoming methodological barriers and gaining new knowledge*
- *Developing methods to manage interdisciplinary research*
- *Increasing national and international visibility of the site*
- *Making diversified tools available to energy and urban stakeholders.*

1. Quality: results obtained, technological or methodological barriers overcome

Results obtained

The Eco-SESA CDP can demonstrate an abundant and high-quality academic publication activity, with nearly 250 publications in colloquiums, conferences and journals.

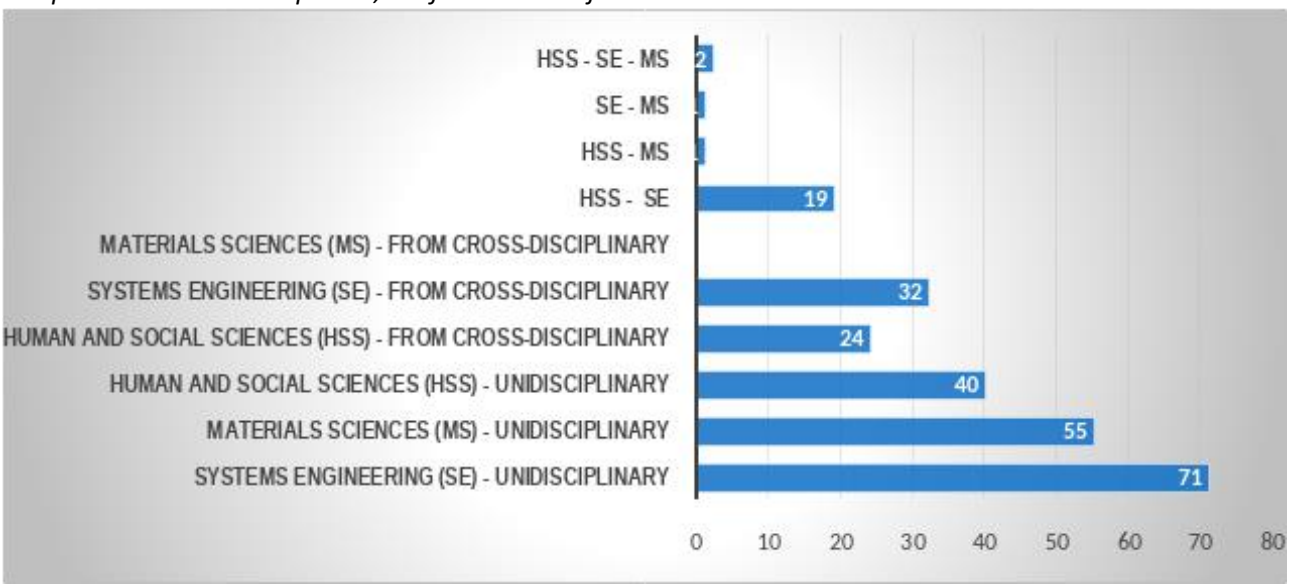

Figure 1 : Balance of publications between scientific areas

The balance of publications between Human and Social Sciences (HSS), Systems Engineering (SE) and Materials Sciences (MS), showing respects the distribution of the human resources. It also shows the current reality of publication channels, which still remain massively UNIDISCIPLINARY, as do the evaluation and recruitment processes for professors, that usually do not recognize interdisciplinary journals. Despite this current structural obstacle to the dissemination of an interdisciplinary scientific body of work, it should be noted that 9% (i.e., 23 out of 245) of the publications were produced with authors from at least 2 fields, and we estimate that nearly 23% of the other publications were irrigated and inspired by CROSS-DISCIPLINARY fertilization . It therefore seems relevant to focus on a certain number of results produced, emblematic of the level of quality, and, the crossing of disciplinary barriers.

Focus 1A - Machine learning and annotation by occupants (RF1) - *The G-SCOP lab, together with the APTIKAL team in LIG lab, have developed a new kind of learning algorithm: interactive and cooperative learning for supporting inhabitants of buildings to annotate their activities for a better a posteriori analysis, but also to develop data model-based interactive energy management, much more realistic for mass deployment. It is a combination of 2 innovative algorithms: an interactive learning algorithm (Aymayri PhD 2017), that determines the best moments to ask for information to inhabitants; and cooperative learning (Awada PhD 2017), that is interacting with inhabitants, asking them for labels and adjustments, in order to yield a consistent representation shared by the artificial system with its sensors and inhabitants with their implicit knowledge. It relies on several mechanisms: (1) An optimization mechanism is used to adjust a qualitative meaningful representation extracted from the sensors, reducing confusion, e.g. assignment of different labels to a same state representation perceived by the artificial system; (2) an error correction mechanism that supports inhabitants to detect erroneous labelling. Both mechanisms open new perspectives to understand the impact of inhabitants' behaviour on their environment.*

Focus 1B - Micro-spatial approaches of energy uses in community (RF1-2-3) - *According the sociology of practice (Shove), individual practices are deeply embedded with the material system. Few publications prove an impact of community membership on energy use. None describe how the combination of community governance and technical devices influence the practices of individuals, and conversely how the latter adapt to the former. Ethnography of spatial occupation practices in two kind of communities - an office building and two participatory residential buildings - produced new knowledge. Investigations of the office building show*

the ambiguous role of facilities staff and the transgression of occupants: they highlight a gap between projected and effective uses (Pappalardo & Reverdy 2020). In the residential building, where community electricity (PV) production is used in common rooms and in dwellings, analysis highlighted unexpected and original results. The more individual practices are visible and "accountable" by the other community members, the more explicit the governance will be and will introduce a mechanism of "justice" between the members. The more the spaces are private, the more the discussion on energy use will be weak and informal (Pappalardo & Debizet 2020).

A narrow collaboration with electrical and automation scientists enables social scientists to understand the complex energy system regulation, to translate the technical requirements in comprehensive terms for social survey, and to focus ethnographic observation to key technical devices. Conversely, this collaboration and results were re-used in order to model the stakeholders logics in OMEGALPES (Morriet et al. 2020) and to design instructions of an HMI e-consultant (Alyafi et al. 2018).

Focus 1C - Evaluation of the effectiveness of public policies based on nudges (RF2) - *The integration of renewable energy in energy systems requires fine and rapid adjustments of supply and demand at different scales of the distribution network. The GAEL and G2ELab studied the effectiveness of non-monetary incentives to reduce household demand during peak consumption. An in-situ experiment, the only one of its kind in France, involving two hundred households in the Grenoble region, tested a variety of nudges (a priori commitment to receive alerts during critical periods, individualised feedback on the impact of behaviour) and enabled the estimation of the flexibility of household electricity consumption during consumption peaks (see figure 2).*

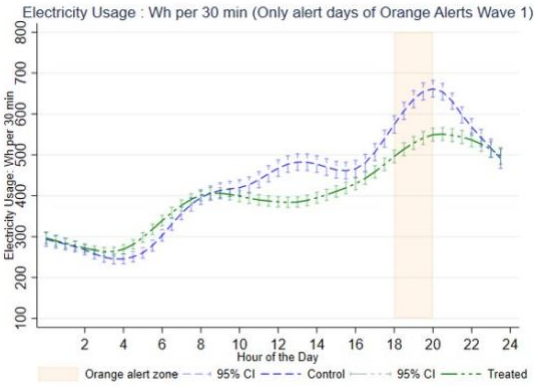

Figure 2: Control and randomized test for measuring flexibilty of housholds

The average load curve of a control group of 80 households (blue curve) is compared to the average curve of a group of 95 households (green curve) that are exposed to a policy of flexibilisation for their electricity consumption. The difference in consumption during the critical period (18:00/20:00) is significant and is estimated at 20.4% (Shahid et al. 2020, Buckley et al. 2021, Shahid et al. 2021).

Focus 1D - New generations of led and solar cells (RF5) : *Material science plays a key role when one wants to fabricate new materials that are optimized in terms of physical properties and low environmental footprint in order to reach an efficient integration into devices. Eco-SESA has been active in this regard, for instance by searching for new active layers for efficient lighting without rare earth elements (Gaffuri et al. 2020), or a new deposition method for the low-cost deposition of thin layers for applications in next generation solar cells [Nguyen et al. 2021). This deposition method is the Spatial Atomic Layer Deposition, which allows the deposition of thin layers with well-controlled properties in a way which is low-cost, fast, vacuum-free, and easily scalable (A. Sekkat, et al. accepted). These material science approaches are also combined with deep characterization tools, modelling approaches, and correlation with consumers' behaviour. These multidisciplinary collaborations ensure an efficient development and integration of devices towards applications in energy systems.*

Methodological Barriers

Among the methodological barriers that have been overcome, we focus on the following examples

Focus 1A: Modelling and representing socio-metabolic assemblages and spatial devices (RF1-2-3) *How do the actors involved in renewable energy or waste heat recovery projects coordinate? This question is a growing topics in international literature relative to sustainability transitions. Geographers and sociologists emphasise the importance of community-based or local initiatives (bottom-up), while economists and policy scientists respectively emphasise the importance of state-regulated markets and sociotechnical regimes. The*

notion of socio-energy assemblage was proposed to explore spatial processes between local innovation niches and regimes (Geels). This notion allows us to identify the actors in the energy chain and the technical systems they operate, to highlight the interfaces between systems and actors. Although this notion applies well to the modelling of systems (Morriet PhD 2021), it obscures the volumetric dimension of reality and the perception of an initial urban situation and possible transformations. The transect, which reveals technical and spatial devices and the natural environment, has been tested many times over these three years: it has enabled researchers from different disciplines and actors in the construction of the territory to grasp the complexity of a situation (Ramirez, Tribout, Debizet Accepted). The graphic articulation of the socio-energy, and now socio-metabolic (Debizet 2018), assemblages with their territory in a landscape dimension as well as a user dimension, gives the transect an additional interest (Tixier & Laroche 2019). Graphic research was carried out to show this interplay of scales. The notion of energy neighbourhood emerged, to think of energy as a link between the local environment and the inhabitants and users of a neighbourhood.

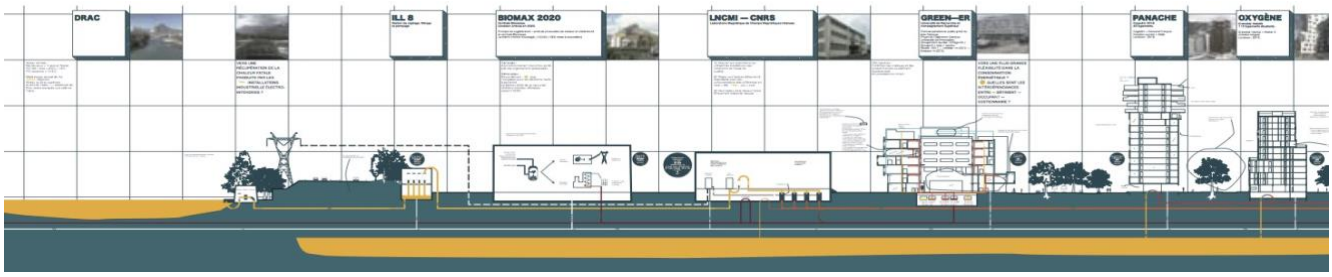

Figure 3: Urban transect and socio-metabolic assemblage of Grenoble Peninsula, 2020

Focus 1E - DeepExpé / Sensor implementation strategies for smarthome data (RF1-2) *Because Eco-SESA is focusing on the involvement of human actors in energy management, field observations were needed. A low-resolution observatory was made with many (about 180) households with data coming from the Linky power meters. As a complement, a high-resolution observatory was set up. Indeed, 5 households were selected to validate solutions proposed by Eco-SESA researchers. There are more than 100 sensors per household (motion detectors in all rooms, temperature, humidity, CO2 concentration, contact sensors on doors and windows, acoustic pressures, power consumption of appliances with plugs, Linky data,…) in order to get a better understanding of inhabitants' reactions to different stimuli, in particular to signals coming from the grid, like green (can consume more) or orange (reduce consumption) periods, but also different kinds of feedbacks like automatically generated analysis reports. The high-resolution sensor systems led to a fine analysis of inhabitant reaction to different kinds of signals (Amayri et al. 2020, Najed et al. 2019). GDPR implementations for the low-resolution and high-resolution observatories are different. For the low-resolution one, data are anonymized and owned by UGA.*

2. Structuring character and interdisciplinarity

High-quality results were obtained and methodological barriers were overcome thanks to cross-disciplinary dynamics. Four of the 5 research fronts touched both the HSS and the ES fields. Therefore, many scientific questions were written in order to require both HSS methods and ES methods or aims. During the first year, cross-disciplinary collaboration was also stimulated by workshops that were transversal to the Research Fronts. The specific scientific positions of each disciplinary field were regularly discussed in the collaborations and gradually considered as strengths for the project. ***How to address the real complexity of physical and social systems through methods, platforms and "scenes" of interdisciplinary complementary research?*** *Our research topic is complex, entangling the complexity of material, physical and energy systems with the complexity of the actors, their social, economic and legal inter-relations. The interdisciplinary method which emerged during the program can be qualified as a Y strategy, breaking down the complexity of reality:*
- On the one hand by studying the complexity of material and physical systems in materials and systems laboratories (from the "applied physicist" bench to engineers' component and systems platforms).
- On the other hand by studying the complexity of individual and collective dynamics. HSS combine "in vivo" surveys and, sometime, an "in vitro" approach using questionnaires and focus group approaches which is typically an experimental economics skill, that reduces complexity using strong experimental protocols.

*At the foot of the two branches of the "Y", GreEn'ER building, the LNCMI (representative of an electro-intensive type actor illustrating the issue of waste heat recovery at district level) and the peninsula of Grenoble were **living labs** where both social scientists and engineering scientists can observe human practices/behaviour, measure energy and physical flows, and therefore experiment some sociotechnical innovative devices. Research on real and representative fields have also be implemented by several disciplines: the Expesigno program tested the ability of 180 households to respond - in their daily lives - to flexibility signals (by controlled & randomized trials); collective self-consumption in different energy communities was studied by social scientists, in collaboration with engineering scientists.*
It is remarkable to note that the "in vivo" type approaches are historically associated to HSS research, as a science of observation of social dynamics: Eco-SESA will have made it possible to bring in the actors of the sciences of matter and physical and energy systems. The effectiveness of this structuring synergy can be illustrated by the following focuses.

***Focus 2A - HMI efficiency analysis of Pareto-Slider devices (RF1–2) -** HMI devices in the field of energy consumption management of inhabitants have been tested by a very original behavioural experimentation that has opened new horizons in the field of proof of concept (Laurillau et al. 2021; Alyafi et al. 2018). The major contribution of this cross-disciplinary collaboration lies in the development of new methodological opportunities for experimental economics on the one hand, and in the integration of new protocols for measuring HMI performance on the other. The figure below presents the two devices tested with more than 178 inhabitants.*

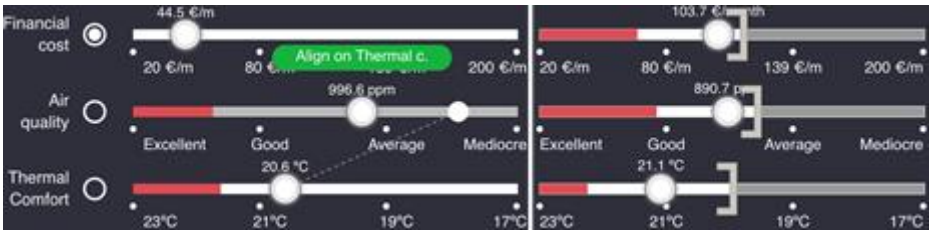

Figure 4: (left) Screenshot of Sliders4DM, the adapted version of TOP-Slider used for the comparative experiment, (right) Screenshot of P4DM, our own implementation of PSS.

***Focus 2B - Combining "in vivo" field experiments and energy measurement to assess consumption flexibility (RF2-4) -** The impacts of public policies are generally evaluated ex post, after their implementation at various scales but always in a systemic manner, making it difficult to analyse causal relationships in detail. In the field of experimental economics, new opportunities for ex ante evaluation have emerged with the implementation of in situ behavioural studies. The resources allocated to the CDP have made it possible to develop a methodology, original in France, of "fied experiment" to evaluate the flexibility of household electricity consumption as a function of alerts relating to the electricity network or meteorology (see Orange, Green, Prediction and (auto)consumption figure 5). On the one hand, an algorithm has been developed by the G2ELab and GAEL laboratories to format and address the alerts to the households' mobile phones. On the other hand, a protocol that is as neutral as possible and respects the European Union GDPR was designed to retrieve the consumption data. The combination of experimental economics methodologies (GAEL) with the fine measurement of energy consumption/production flows (G2ELAB) constitutes a major and promising methodological advance (Shahid et al., 2021).*

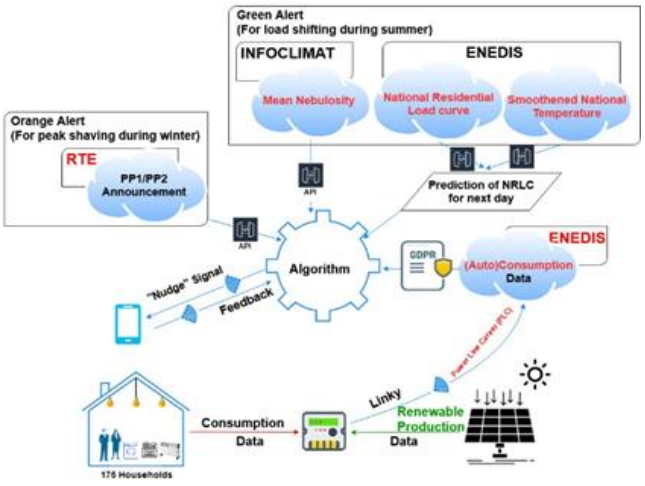

Figure 5 : Organisation of alerts and energy data collection (ExpeSigno experiment)

Focus 2C - Consumer appreciation of the scarcity of LED component materials (RF 2-5) - *The CDP has also established an unpredicted and original collaboration between experimental economics and materials science. A technological solution to the rare earths used in LED production was confronted with the trade-offs made by consumers (Gaffuri et al., 2021). Conversely, this collaboration has consolidated the experimental methodologies used to reveal consumer preferences, particularly in terms of perception and valorisation of environmental characteristics at the production process level (generally studied in the context of food products, and therefore partly biased by health considerations for the consumer).*

Focus 2D - Open-source software at the interface of social science and engineering paradigms (RF3-4) - *OMEGAlpes is an open-source modeler / solver of district-wide energy optimization problems initiated and produced by Eco-SESA. It is remarkable to note that the models and modules of OMEGAlpes have overcome interdisciplinary barriers by synthesizing:*

- *paradigms from the social sciences with the approach of socio-energy nodes developed at PACTE that directly inspired, via Lou Morriet's thesis, the Modelling module in which actors and actor interactions can be taken into account through the formulation of constraints and objectives associated to them around energy systems (Morriet PhD 2021)*
- *paradigms from engineering sciences like optimization and decision theory at the heart of the optimization modules used, or the paradigms of object-oriented programming and model engineering at the heart of the modelling formalisms used (Pajot -2019- hal-02285954)*
- *paradigms stemming from fundamental physics with the development of the exergie module, allowing the major innovation of a decision support for the actors being able to relate as much to the optimization of the quality of energy (and the non-destruction of "exergy"), as on the minimization of energy consumption or the impact in terms of CO_2. This module was developed as part of the RETHINE program by LOCIE in Chambery (Hodencq et al. 2021, Fito et al. 2020)*

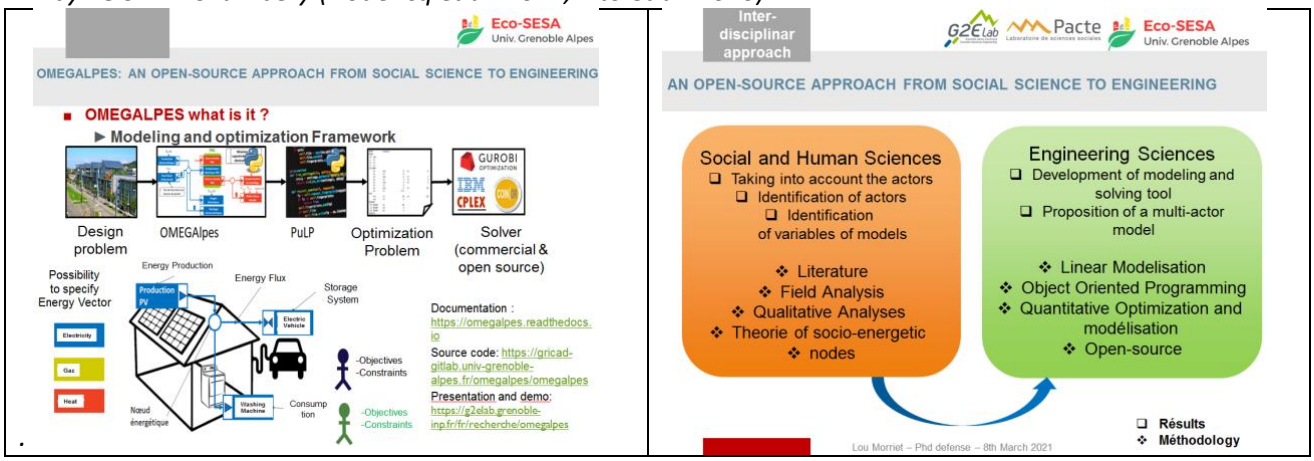

Figure 6: OMEGAlpes: a framework produced by interdisciplinary work from SHS to systems science

Focus 2E - intertwining between urban/architectural/landscape design and energy system design (RF 3-4)
In France as in Europe, urban projects are increasingly including renewable or waste energy installations with on-site self-consumption. French and English literature deals with the governance of the energy aspects of urban projects, but it does not deal with the formal interactions between architectural and energy design. A survey of two case studies (Freiburg Switzerland and La Motte-Servolex France) with comparison of several collective self-consumption projects on existing buildings in both countries produced original results: 1) situations of synergistic dependencies, compatible dependencies or incompatibilities between renewable energy systems and urban guidelines, 2) the need to go beyond sequential design processes, in favour of governance and methods that are more integrative of energy and urban issues (Ramirez-Cobo & Tribout. 2019 ; Ramirez-Cobo et al. 2021). Therefore, a 3-dimensional graphic showing the different forms of dependences had been elaborated. Electrical and thermal scientists helped translate the technical requirements and defined spatial morphologies of energy systems. Conversely, the intertwined modelling of energy design and urban design processes became one of the use cases of energy system modelling developed by G2elab and Locie Laboratories (Morriet, Debizet, Wurtz 2019 ; Fito, Ramousse et al. 2020).

3. Outreach and visibility: international relations, attractiveness of talent

International partnership

A broad majority of the publications and papers are aimed at an international audience and collaborations. This was not only to increase the visibility of our research but also to take advantage of the numerous feedbacks on the development of energy research communities abroad (often more advanced than in France). We focus here on some strong points and international results obtained: organisation of a symposium, publishing of books, research projects, writing of articles, initiation of thematic networks.

Focus 3A - A forthcoming collective book - *Entitled « Towards energy smart homes ». a book published by Springer USA. The preface, written by Frédéric Wurtz, describes how the CDP Eco-SESA was important for this book (Ploix, Amayri, Bouquila, 2021).*

Focus 3B - An international webinar series on the emerging topic of « energy communities » with a collective book in preparation. *This series was co-organised with the Plan Urbanisme Construction Architecture, an innovation agency of the French Ministries of Ecological Transition and Territorial Cohesion. The webinars brought together thirty speakers, mostly European and English-speaking, and over 300 attendees. Over the course of 9 webinars, taking place between June and October 2020, this remote conference offered a multidisciplinary look at upcoming research questions related to energy communities: what are the internal dynamics that lead to the emergence of self-production and collective self-consumption projects? How do regulations adapt to frame them? How do energy communities federate and spread? How can we design and manage technical and spatial energy-sharing devices? The final session summarizes prior sessions (Debizet & Wurtz 2020), and brought together the main people responsible for translating European directives on energy communities into French law. The result is a special issue of the journal Flux (end-2021) and a Handbook edited by Routledge (currently in preparation).*

Focus 3C - **Initiation and development of a very dynamic network of international collaborations**

Switzerland *- Thanks to a co-mentored PhD (PhD of Lucas NEVES MOSQUINI), co-funded by IDEX International Strategic Partnerships 2020 and the ambitious CEVALER Program (answering to the FEDER INTERREG Franco-Suisse Program, we developed a cross-disciplinary program with another department of HES-SO in order to address the question of local energy communities.*

Portugal - *Collaboration with the WattIs company https://watt-is.com and Lisbon Higher Technical Institute, to analyse how load disaggregation can improve interactive learning (by generating new features) of consumer practices. In particular: (1) estimated consumer practices are used to give relevant feedback to end-users, to increase their flexibility and reduce their energy bill with application to IRISE (i.e., a 100-house database); (2) improvement of load forecasting based on disaggregation thanks to the estimation of activities (from knowledge or interactive occupant feedback) with application to H358 office. Testing match-load (self-consumption, self-production, coverage rate, loss of load,) and usage indicators (fridge usage, washing machines) to improve analysis capabilities of energy providers. Use of home historical data to generate relevant advice about better energy management strategies (Silva Amayri Basu 2021 Forthcoming ; Amayry Silva Ploix Submitted).*

European projects in material sciences *- Several European projects have been obtained lately (strongly linked to RF5). For instance: FET Proactive European project HARVESTORE (2019-2022), FET Proactive European project EPISTORE (2021-2024), M-Era-Net INSTEAD (2021-2024). These projects focus on materials science and energy applications. LMGP is one of the laboratories that are actively involved in them.*

Brazil *- G2elab developed a collaboration with universities like University Federal of Santa-Catarina (USFC), with one co-mentored PhD candidate linked to energy management in the GreEn-ER Building, resulting in some shared publications (Nascimento-2020 ; Pereira-Pinto 2020). Another collaboration with São Paulo State University enabled the publication of an important meta-analysis about obstacles and drivers to building energy-saving technologies (Cristino et al. 2021).*

Canada - *Collaboration with the Faculty of Engineering & Computer Science at Concordia University and the Ericsson company in Montreal, Canada. AI technologies are used to create intelligent, robust, data-driven*

systems, including a fifth generation (5G) network in Canada. The Montreal hub GAIA is part of a network that spans India, Sweden, and the United States. The goal of the work is to develop Interactive machine learning and data mining algorithms relying on non-intrusive common sensors in smart buildings (i.e., load, PV, radiation forecasting, desegregation, data analysis and fault detections, occupancy estimation, activity recognition). The project directly aligns with Ericsson's IoT mission and expands its operator opportunities by exploiting a dimensionality in real-time automation, monitoring and tracking, and smart surveillance (Balouch et al. 2021; Nasfi et al. 2020; Amayri et al. 2020; Amayri et al.2021; Graja et al. 2021).

***India** - A collaboration with the Indian Statistical Institute and the Jadavpur University at Kolkata has been initiated, dealing with energy management while keeping humans in the loop. Multi-objective approaches have been developed to support inhabitants in reducing energy waste, while taking into account thermal and air quality comfort, costs, but also limiting actions on the home system. Moreover, machine learning tools have been developed to analyse load profiles in commercial buildings using smart meter data (Pal et al. 2016; Pal et al. 2017; Alyafi et al. 2018; Pal et al. 2019; Ploix et al. 2021).*

***Vietnam** - ES and the HSS scientists of Eco-SESA launched the creation of an international European-Vietnamese network. This program, led by Benoit Delinchant, did not ultimately benefit from European funding (H2020-MSCA-RISE-2020 -call). Nevertheless, it brought together researchers working on electricity-producing buildings* at the district level. *BREVES is the acronym of "Buildings with Renewable Energy for Vietnam, to Empower Sustainability". It consisted of a staff exchange program involving 267 deployments of both experienced and early-stage researchers from 8 EU institutions and 7 Vietnamese organisations.*

***Singapore** - Eco-SESA is integrated in a very ambitious co-created PROGRAM funded by CNRS and NRF Singapore. It will fund 2 PhD candidates and 10 post-doctoral years, as part of a Smart Demonstrator program using AI, and involvement in the energy part at various scales, from the building to the urban networks. A collaboration was also initiated, after the Phd work from Soleiman Galeshi funded in RF4, with 1 PhD in France and 1 PhD in Singapore, studying new topologies of power electronic converters for local energy production and sharing.*

Focus 3D - LOWTRE: emergence of a French-speaking international community around low-tech

The cross-disciplinary dynamic initiated by Eco-SESA gathered numerous scientists of the University Grenoble area, in order to launch an international forum on low-tech (see https://forum-lowtre-ecosesa.univ-grenoble-alpes.fr/). The "low-tech" topic concerns new technical and organisational solutions that are simpler, more robust, safer, and more sustainable. These solutions can involve local stakeholders from the design and construction phases to the use phase, in an open-science approach as described by Hocdenca in 2020. A two-day seminar addressed technical, social, ethical, philosophical and policy considerations. Its audience was comprised of a hundred social scientists, engineering scientists and activists. The specific website continues to be frequently viewed.

To conclude, each month several proposals for international collaborations reach the different researchers involved in the operation of the CDP. A significant number of European H2020 projects have been submitted, including ambitious projects such as REDAU, where our ability to offer a cross-disciplinary approach has been recognized as a distinctive factor, and a source of scientific credibility for European call projects.

Attractiveness

The program really showed national and international attractivity, as shown in the following table.

Recruitments since the start of the CDP		
Type of position	**Nationalities**	**Parity**
7 PhD positions 10 postdoctoral fellows 9 engineers 4 project management positions	18 French, 3 Vietnamese, 2 Turks, 2 Italians, 1 Iranian, 1 Chinese, 1 Syrian, 1 Pakistani, 1 Moroccan, 1 Mexican, 1 Spanish	16 women 14 men

As an example, we won a co-funding in the very competitive international program MOPGA (Make our Planet Great Again), in which we had the opportunity to integrate in our team Jesus Contreras, from the University of Washington, Seattle, which resulted in a publication of our best review in the field of smart grids.

Focus 3E - Summer schools
Every year, Eco-SESA has participated and supported international summer schools, such as Energy Solutions for Eco-districts, Ecole Internationale de l'Energie (EIE), Smart Energies, The concept of Internet of Energy for a future smart eco-district,

Socio-economic and cultural partnership (see below)

4. Valorisation of research products

The program has largely reached historical players in the sector such as companies, community institutions and the French government. Local partnerships mainly concern Grenoble Alpes Metropole, GreenAlps (distribution and supplying operator), the CCIAG (Compagnie de Chauffage de Grenoble). The appendix summarizes up to 36 complementary national fundings, and many of them were concluded in collaboration with national socio-economic partners like Schneider Electric, the Centre Scientifique et Technique du Bâtiment (CSTB) and several start-ups (Enogrid, Arkolia...). ***A total of 69 partnership projects were launched, for a financial contribution of 6.2 million euros.***

Dissemination and outreach toward socio-economic and cultural partners
The production objectives towards the scientific community were achieved, and Eco-SESA was strongly involved in the transfer of knowledge toward socio-economic and territorial actors concerned by the challenges of renewable energies at local scales. "Conferences for the general public, socio-economic actors and / or students", the 4th appendix of this report, summarizes 40 conferences targeting socio-economic actors, community representatives and citizens. It shows that the program has fully achieved one of these objectives, namely to promote the knowledge, concepts, tools and methods. A significant number of interventions were aimed at schoolchildren, notably through "science festivals" events.
For example, we can mention:
- the development of 3 serious games, 1 of which is currently used to introduce tenants of a social housing project (Grenoble Habitat partner) to collective self-consumption,
- the use of the urban transect with students and inhabitants of the Grenoble peninsula,
- 6 videos presenting the societal issues and the scientific challenges around theoretical notions such as collective self-consumption, recovery of heat waste, and soon energy storage, living labs and energy communities,
- 7 press articles,
- 6 interventions in national public debates relative the French energy multi-annual programme or toward energy regulation or research programming organisations,
- not to forget the 1,000 households that volunteered for experiments.

Ficus 4A - Live arts show - *As part of the design of its new show "ONIRI 2070", the company Organic Orchestra (https://www.organic-orchestra.com/) contacted the Atelier Arts-Sciences to discuss with researchers. Their challenge was to design a sober, autonomous, and transportable energy system for their live arts show. Eco-SESA junior scientists worked with them during residencies and exchanges to define their constraints and objectives, and thus propose touring energy scenarios thanks to the open-source tool OMEGAlpes. Specifically, these scenarios enabled the specification of battery charge/discharge phases, facilitating their sizing and operation in the field. ONIRI's first tour took place in 2020. The ONIRI show is required to evolve artistically and technically, and the models developed can thus be mobilized to take into account the rest of the show*[1].

Focus 4B - Valorisation of the open-source software OMEGALPES: *The quality of the open-source software produced with the flagship OMEGAlpes project, is measured not only by the number of high-ranking academic publications produced (see above) but also by the fact that OMEGAlpes is at the heart of a significant number*

[1] See https://gricad-gitlab.univ-grenoble-alpes.fr/omegalpes/omegalpes_examples/-/blob/master/notebooks/oniri_exp_fr.ipynb

of collaborative projects that have emerged around Eco-SESA (2 CIFRE theses with CSTB, 1 CIFRE thesis with the start-up Enogrid, the Horizon H2020 Collectief program, the LNCMI's fatal heat recovery studies at the scale of the peninsula of Grenoble...). As such, the open-source approach was a good approach, allowing an attractive dynamic with many partners, since it is collaborative and open, making the models, data and hypotheses of studies accessible, which becomes a request from partners and funders such as ADEME, in line with the quality and outreach objectives that we must meet in the context of open science.