Energy transition

Betty Lemaire-Semail, Pascal Roussel, Aude Nanquette, Alain Bouscayrol

Energy transition: an approach from scientific features to societal issues

Betty Lemaire-Semail [1], Pascal Roussel [2], Aude Nanquette [1], Alain Bouscayrol [1],

[1] Univ. Lille, Arts et Metiers Institute of Technology, Centrale Lille, Junia, ULR 2697 - L2EP, F-59000 Lille,
[2] Univ. Lille, CNRS, Centrale Lille, Univ. Artois, UMR8181 – UCCS, F-59000 Lille
Corresponding author: betty.semail@univ-lille.fr,
URL: https://comasys.univ-lille.fr/chaire-odd

Acknowledgements

The authors want to thank the "Initiative of Excellence" from University of Lille for funding the Sustainable Goal Development chair "Energy Transition".

Keywords

"Efficiency", "Education tool", "Energy transition", "Environment"

Abstract

This article presents the experience conducted by researchers at the University of Lille on the technical, scientific and societal issues of the energy transition. Thanks to an academic chair on Energy Transition and an «open laboratory», cross-disciplinary views from the academic world, industry, civil society, local authorities and associations were raised and encouraged. The objective is to identify methods for implementing the energy transition that take into account citizens' aspirations, environmental constraints and technological limitation altogether.

Introduction

The energy transition is raising questions and even controversy at all levels of society. The need for this transition is sometimes questioned as in [1-4] where it is recalled that in the past, energy sources have been more added than substituted. In the research context, depending on whether one is sensitive to "human and social sciences" or "sciences and technologies", assessments differ regarding the approaches to be implemented, as well as the results to be expected. Moreover, the barriers are so important that it is fundamental to include the whole society in the thinking on what the energy transition must be to enable sustainable development.

In this context, the academic community is mobilizing to transfer scientific knowledge on energy to the greatest number. Science and society initiatives are being developed: for example, let us cite institutes such as the Institute for Environmental Transition of the Sorbonne University Alliance, or the Mediterranean Institute of Risk, Environment and Sustainable Development or Keney energy transition institute [5]. Other works propose time-limited projects such as in [6], dedicated to secondary school students regarding their literacy on energy. These initiatives are also evaluated by international rankings, such as the THE, Times Higher Education ranking [7], which values universities committed to the United Nation's Sustainable Development Goals (SDG). In 2023, the University of Lille created 7 chairs dedicated to such SDG's. These chairs are dedicated to (1) inequalities, (2) social economy of the commons, (3) sustainable urbanism, (4) education, (5) democratization, (6) health and (7) energy transition (Fig.1).

The general mission of these chairs is to structure and help interdisciplinary research projects to emerge. Moreover, they have to encourage new training programs on their related topic. Last but not least, their objective is also to transmit and communicate the university's activities to civil society, industry and local authorities. Regarding this last point, the Energy Transition chair has also been given the responsibility for the «Laboratoire Inspirons Demain» (LID), "let's inspire tomorrow" on energy. The LID is an open laboratory that brings together the main actors of the energy transition in the region Northern France.

This paper describes the main actions and first preliminary results of the chair «Energy

Transition», in terms of training, cross-reflections and communication.

The paper is organized as follows. Part 1 introduces both the objectives of the chair "Energy Transition", and the origin of the project. Part 2 describes a first action dedicated to the proposal of a multidisciplinary training (graduate program) in the field of energy. Part 3 describes the second action of the chair, ie the creation of the open-lab Let's Inspire Tomorrow (LID). Part 4 is a first analysis of the cross-views obtained during the LID meetings and provides some ideas to go towards a successful energy transition.

Fig.1: 7 chairs created at University of Lille related to the sustainable development goals of UN

Energy Transition chair objectives

Created in 2023 with 6 other chairs in the spirit of the UN's sustainable development goals, the chair "Energy Transition" has the following objectives: (1) to structure research in the field of energy and to stimulate new interdisciplinary and unifying projects; (2) to propose interdisciplinary training programmes in the field of energy, to respond to the challenges of new jobs in industrial and societal transformations; (3) to communicate and publicise these actions beyond the academic world among the general public, local authorities, associations and industry.

At the operational level, this chair is funded for 2 years, renewable, which allows the hiring of a project manager. To highlight the interdisciplinary philosophy of the chair, one may remark that the 2 co-leaders are respectively from electrical engineering science and chemistry, whereas the project manager is a sociologist. This person comes in support of the two academic holders of the chair and implements the various actions.

The Northern France region is a key area for the energy transition. Four giga-factories of batteries have been installed or are going to be installed there, (i.e. in the so called "French battery valley") and the region has many car manufacturers, wishing to change their production towards electric vehicles. Moreover, it has also heavy industries (steel mills and aluminium production plants) very energy-intensive and polluting, which are planning to decarbonize their production.

In this context, to ensure the energy transition, the change to clean energy carrier's such as "electricity" and/or hydrogen is therefore fundamental.

Driven by this regional context, as well as the international situation, the University of Lille questioned the scientific contribution it could bring to the question of energy transition. Two federative research actions served as a basis for reflection. The first action concerns the problem of low-carbon mobility (CUMIN project) [8], the second concerns energy production, recovery and storage (COMASYS project) [9].

CUMIN Project

CUMIN (Campus of University with Mobility based on Innovation and carbon Neutrality) is an interdisciplinary research programme of University of Lille focused on the development of electro-mobility [8].

Every 5 years, University of Lille conducts a carbon report on its greenhouse gases (GHG). The commuting (daily trips, home-university) represents more than 50% of the emissions. Moreover, the last mobility survey indicates that the fossil-fuel cars lead to 80% of the commuting GHG emissions despite only 25% of the commuting distances (Fig. 2). Therefore, replacing fossil-fuel cars by alternatives is of key interest.

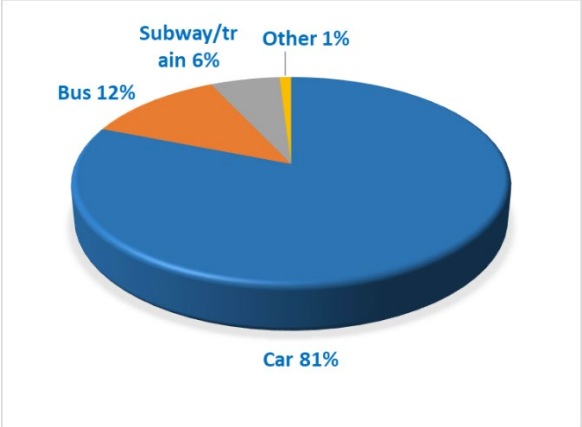

Fig. 1. GHG emissions of the commuting of University of Lille in 2020

In 2016, CUMIN has been developed by one sciences & technologies lab and one social & human science lab to study the technical and societal issues of electric cars [10]. Progressively, other research labs have been involved and other topics are now studied.
In 2023, CUMIN has been extended to any electric vehicles (from e-bike to subways, including e-cars) with many projects organized in 3 pillars (Fig. 3): energy, societal challenges and environmental impacts [11]. The consortium is now composed of three sciences & technologies labs, social & human science labs and the European Metropolis of Lille. Moreover, international partners are integrated such as Rochester Institute of Technology (USA), Ghent University (Belgium) and University of Quebec at Trois-Rivières (Canada). An International Associated Lab (eCAMPUS) has been concluded between University of Lille and University of Quebec at Trois-Rivières [11].

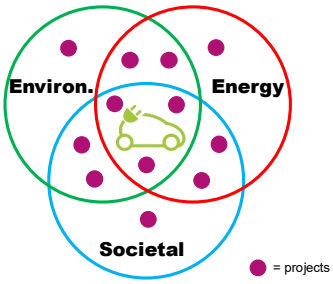

Fig. 3. Interleaved pillars of CUMIN

The transition of the mobility is related to the energy transition: from a fossil-based mobility to an electricity-based mobility. All the CUMIN projects are interdisciplinary or intersectoral or international projects. From these experiences, CUMIN will bring a relevant contribution to the chair "Energy Transition" and will benefit from the cross-view of various socio-professional categories developed by this chair.

COMASYS Project

COMASYS (COntinuum of energy from MAterial to SYStem) is an interdisciplinary project involving material scientists, chemists, micro-electronics engineers and electrical engineers [9]. The project is divided into two axes, both dedicated to energy, but at very different scales (from MW to µW). The first axis concerns the combined production of nuclear energy and hydrogen, with the heat generated by nuclear fission being used to carry out water hydrolysis for the production of H2 (or the reverse scheme, H2 fuel-cell) under accurate conditions. The second axis is focused on micro-scale energy recovery and storage in micro-devices (micro-batteries or micro-super capacitors). Both axes benefit from a common methodology for modelling and representing the complete system. The EMR (Energetic Macroscopic Representation) formalism [12] is used to describe the system following the natural causality, which allows for deducing a control structure by inversion. In addition, models may be of different granularity, depending on whether a specific physical phenomenon is to be highlighted at a given scale (for example, the losses or saturation of a static energy recovery converter). The ultimate goal is to optimize the complete system by choosing each of its components or component materials, including control laws. Another objective is the monitoring of the system through the establishment of a digital twin based on the Bond Graph representation, particularly suitable for diagnosis and fault detection [13]. The global organization of the COMASYS project is given in Fig. 4.

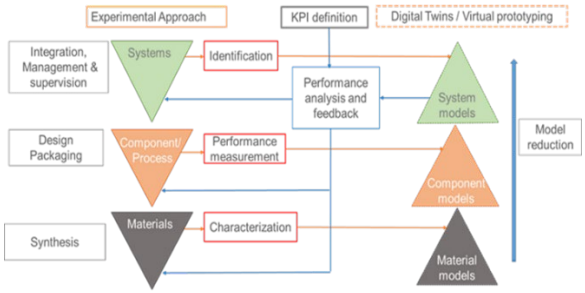

Fig. 4: General organization of COMASYS

Graduate program proposal

In accordance with its objectives already presented in the introduction, the "Energy Transition" chair is working also to make the education programs related to energy transition more visible. For that aim, a graduate program (GP) "Sustainable Energies and Applications" has been proposed. This program combines master's degrees (1st and 2nd year) and engineering training (4th and 5th year). The GP's objectives are: (1) to provide in-depth training in the field of energy transition, (2) to ensure an interdisciplinary opening towards other competences related to energy, (3) to propose an international training opportunity, (4) and above all, to accentuate the link between master and doctorate degrees and hence research-based education.

To achieve these objectives, the graduate program is organized as follows. In a first time, to start, two master degrees have been identified as well as an engineering training: the master « Automatic control and Electrical Systems», with 3 second year specialities dealing respectively with electrified mobility, with electric energy grids, and with electrical engineering for sustainable development. Note that this last speciality is entirely taught in English. The second identified master is called “Physics for energy transition” and deals with materials for energy, energy recovery and energy storage. Last, an engineering training is focused on new energies and industry processes especially with electricity and hydrogen.

A common training unit (3 ECTS, European Credit Transfer System) is proposed to the students involved in the graduate program, during the first semester. This unit aims to raise students' awareness of the interdisciplinary aspects of the energy transition. This unit is taught in English. Following this first experience of interdisciplinarity, students decide to continue the experience and are offered other interdisciplinary units in English, which are common to doctoral courses. In addition, interdisciplinary projects and research laboratory internships are offered to help volunteer students get involved in energy transition research at an early stage and encourage them to undertake a PhD. Fig. 5 summarizes this arrangement.

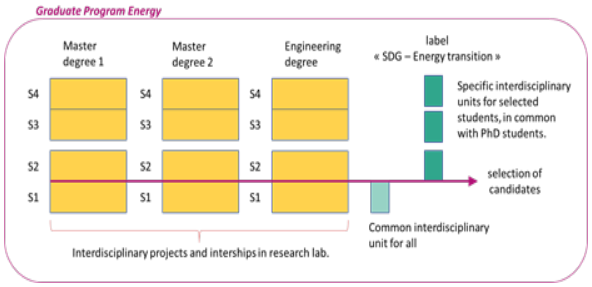

Fig. 5: GP proposal general arrangement

“LID” experience

The “Energy” LID succeeds a first “Inequalities” LID carried by the chair of the same name in 2022-2023. This is an original experiment to bring together people with very different profiles, (from S&T and H&S) but all stakeholders in the energy transition: scientists, industrials, local authorities and associations.

The idea is to bring together different perspectives on what the energy transition should be, how everyone perceives it, what is expected, and how everyone thinks to implement it. These cross-sectional views allow to avoid the pitfalls of too techno-centric solutions, they allow to have a global point of view, while providing solid scientific answers, far from the “clichés” sometimes conveyed by the mainstream media.

To meet these objectives, the work steps are as follows. First, a representative sample of the above categories was contacted. . The scientists are almost all from the University of Lille and have themselves helped to form a group of 70 people ready to work in the LID. The distribution regarding the professional categories is given in Fig. 6.

These 70 people participate to a first working meeting to define themes related to the energy transition around which they wanted to work and brainstorm. These themes were defined through a participatory science approach (Fig. 7). The process was conducted in three stages: initially, a number of keywords were defined by each participant. These keywords were then used to form five affinity groups. Then, within each group, participants verbalized their ideas and attempted to classify them according to more specific keywords and suggestions for actions.

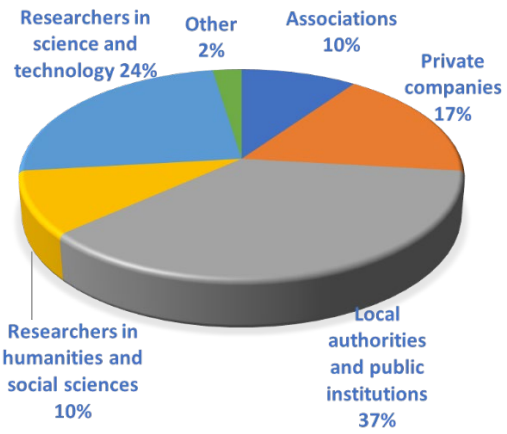

Fig. 6: Participants regarding their professional origins at the first LID meeting.

Finally, a review of each group at the end of the working meeting made it possible to highlight the distinct ideas and overlaps in some proposals.

Fig. 7: first working meeting of the LID illustrating the participative approach used to collectively decide the objectives

Analysis of the cross-views obtained during the LID meeting

Prior to this meeting, a reflection had been conducted on the topics that would be relevant to address and/or deepen on the issue of energy transition. A classification on 1) energy production, 2) housing, 3) mobility 4) decarbonisation of industry had thus been highlighted at this step. All the contacted potential participants were targeted as being able to bring their skills in one of these categories. However, in a way that surprises us, at the end of the first LID meeting much more general and societal-oriented themes emerged: 1) how to link energy transition with social justice; 2) how energy transition involves energy sobriety, 3) how to decarbonize society, 4) how to accompany and lead society towards the energy transition, 5) how to think about energy networks to ensure the energy transition? (Table I)

The emergence of these questions can be explained on the one hand by the participatory science approach that has been adopted, and on the other hand, by the ownership of the issue of energy transition by participants, both personally and professionally. Within each of these categories, similar sub-questions were asked. For example, participants in group 5 raised the issue of awareness on energy networks, so that the largest number could understand the economic investments needed at the level of the electricity grid. This same question was naturally raised in group 3 which worked on the feasibility of a decarbonized company; and also in group 4 on the issue of convincing the company to invest in the energy transition.

Table I: working groups defined after the first meeting

Working groups	Associated keywords
Energy transition and social justice	Equality vs inequalities knowledge sharing, imaginary, accessibility, sobriety/efficiency, regulation, resource conservation, systemic approach, common goods
Energy transition and sobriety	public policy vs individual behaviour, responsibility, growth, change the socio-economic model, rethink the uses mobility impact.
Society's decarbonisation	rethink the uses, neutral mobility impact, energy efficiency, sobriety, skills development, decarbonize energy production, nuclear, renewable energies, financial cost of decarbonization.
Accompany towards energy transition	Mobilize and convince, induce and choose, democratize, accompanying, education, adaptation, accessibility, technical appropriation, acceleration, empower, re-industrialization, business model, suitable infrastructure
Energy grids	Explain and convince, optimize energy networks, couple energy networks, governance, socio-economic strategy, training and human resources

The concrete objectives of the LID are first and foremost to communicate these reflections, during a colloquium and through written or video media, for different audiences. A "white paper" for regional decision-makers is also being considered. Secondly, and in the longer term, it is also a matter of creating links between participants on specific questions that can be addressed by research projects to be set up. It is therefore necessary to structure the ideas and refocus them on the specific energy problem of the Northern France region. Therefore, we proposed a new structure of the ideas within four thematic groups as described in Table II.

Table II: Thematic groups defined after structuration.

Thematic groups	Associated keywords
Energy transition: why, for whom, with which society model?	History of energy transition, fight against climate change, save resources, social and regional inequalities, energy growth, energy decline
Rethink the uses	Sobriety, consumption patterns, accompanying individual behaviour changes, rethink mobility, avoiding the rebound effect
Inform and train	raise awareness, convince, democratize knowledge about energy, inform the decision, train future technicians/engineers
Systemic organization	governance, scale of decision, regulations, technological solutions to rethink energy networks, fundings, commons

Preliminary results

The thematic groups from Table II have been proposed to the participants during a second workshop. The participants had to choose the group which fits best with their concern and their skills. The objective of this second meeting was to precise the questions to be discussed during the feedback symposium (or any other expected deliverable), regarding the four topics. One of the constraints was to focus as most as possible on the typical situation of Northern France region.

As expected, the first thematic group which raises very general questions, had many difficulties to extract priority issues. Nevertheless, the history of energy production and consumption seems to be important to understand the current transition process. Another key point is the issue of energy consumption, linked to the question of growth versus decline.

The second thematic group discussed how to rethink the uses at the individual scale. Three main questions were raised. The first one is about mobility and the way people can choose, desire and agree to switch to greener mobility alternatives. The second one deals with the building and the new facilities regarding thermal isolation. And above these questions, the issue of awareness, financial encouragement, financial constraint is pregnant: to what extend the public policy versus the individual decision may co-exist?

The third group focused on information and training program. In agreement with the topic "re-think the uses", the participants consider highly relevant the large public information. Several ideas were brought to increase public awareness: through teaching, even at early stages, like in [10], and through public advertising campaign and exemplarity. Regarding the student training, the common idea is to increase the interdisciplinarity of the courses, in order to train people with high scientific skills but also open eyes on societal and human issues, and *vice et versa.* The attractivity of scientific training courses near women has also been raised.

Last but not least, the topic on systemic organization focused mainly on two questions. The first one is about the availability of and maturity of technological solutions to perform energy transition. The second one deals with the funding of the energy transition and the cost of inaction regarding the climate change. For both issues, a high level planification is necessary, with a particular attention to the temporal scales which have to be synchronized.

Conclusion

This paper presents an experiment conducted at the University of Lille in the context of the energy transition: the creation of a chair on « Energy Transition ». The aim is to structure university activities in this field and to disseminate knowledge to society. Structured actions concern research, education and interaction with society. First, two research programmes are considered as the scientific background of this chair. Second, a draft interdisciplinary graduated program on the

energy transition is proposed to reinforce the university degrees on Energy. As far as the dissemination of knowledge is concerned, an open laboratory "let's inspire tomorrow" (LID) has been created. This open laboratory aims to cross-reference the views of different socio-professional categories, around researchers, in order to raise key questions on the energy transition and contribute to providing answers. In order to confine the debate, the question is territorialized to the Northern France region, particularly affected by the energy transition due to its industrial network (past, present and future). The LID is limited in time but it should be a breeding ground for other joint actions and projects. For the follow-up, a symposium on exchange restitution is planned, as well as a white paper and other forms of scientific mediation to the general public.

References

[1]. Astrid Kander, Paolo Malamina, Paul Warde, "Power to the People. Energy in Europe Over the Last Five Centuries" Princeton University Press, 2013, DOI: 10.2307/j.ctt4cgb93

[2]. Arnulf Grubler, « Energy Transitions Research : Insights and Cautionary Tales », Energy Policy, vol. 50, pp. 8-26, 2012, DOI: 10.1016/j.enpol.2012.02.070.

[3]. Louison Cahen-Fourot, Nelo Magalhães, "The accumulation–metabolism nexus: internationalization, labour–capital relations, and material flows of French capitalism since the post-war era", Socio-Economic Review, vol. 22, no. 4, pp. 1921–1946, November 2023, DOI:10.1093/ser/mwad062

[4]. Jean-Baptiste Fressoz, "Pour une histoire des symbioses énergétiques et matérielles », Annales des Mines - Responsabilité et environnement N°101(1):7 DOI:10.3917/re1.101.0007, January 2021

[5]. https://www.energy-transition-institute.com/

[6]. Karpudewan, M., Ponniah, J. & Md. Zain, A.N. Project-Based Learning: An Approach to Promote Energy Literacy Among Secondary School Students. Asia-Pacific Edu Res vol. 25, pp. 229–237, 2016. DOI: 10.1007/s40299-015-0256-z

[7]. Times Higher Education (THE), [online] https://www.timeshighereducation.com/ consulted in February 2025.

[8]. CUMIN website, [online] https://cumin.univ-lille.fr/

[9]. COMASYS website, [online] https://comasys.univ-lille.fr consulted in February 2025.

[10]. A. Bouscayrol, E. Castex, P. Delarue, A. Desreveaux, O. Ferla, J. Frotey, R. German, J. Klein, W. Lhomme, J.F. Sergent, "Campus of University with Mobility based on Innovation and carbon Neutral", IEEE-VPPC'17, Belfort (France), December 2017, doi: 10.1109/VPPC.2017.8331039.

[11]. A. Bouscayrol, L. Boulon, E. Castex, S. Miaux, "Electro-mobility for CAMPus of Universities based on Sustainability", IEEE-VPPC'19, Hanoi (Vietnam), October 2019, doi: 10.1109/VPPC46532.2019.8952215.

[12]. A. Bouscayrol, B. Lemaire-Semail, "Energetic Macroscopic Representation and Inversion-Based Control ", Encyclopedia of electrical and electronic power engineering, Vol. 3, pp 365-375, Elsevier, DOI : 10.1016/B978-0-12-821204-2.00117-3, ISBN : 978-0-12-823211-8, 2023.

[13]. I. Abdallah, A.L. Gehin, B. Ould Bouamama, Event driven Hybrid Bond Graph for Hybrid "Renewable Energy Systems, International Journal of Hydrogen Energy". Vol. 43, ref. 22088-22107, 2017, DOI: 10.1016/j.ijhydene.2017.10.144