LARIS
Laboratoire angevin de recherche en ingénierie des systèmes
EA7315

PhD Thesis proposal

Contrat Doctoral Établissement Campagne 2023 – Université d'Angers

Title:

Study of the present and future energy and environmental performances of domestic heat pumps

Subject:

The building sector is one of the key sector to meet today's energy and environmental global challenges [1,2]. The life cycle assessment (LCA) methodology [3,4] can be used as a suitable eco-design tool to assess and help mitigating the impacts of the built environment. Due to the long lifetime of buildings, most of the energy consumption and of the environmental impacts are linked to the operation stage (50 to 80%), the remaining impacts being caused by the other life cycle stages (construction, renovation and end-of-life) [5]. An accurate modelling of the systems used during the operational stage is thus required, and dynamic LCA can be used for a reliable assessment of the related environmental impacts [6,7]. In addition, the building and its systems change (e.g. replacement of materials) during its long lifetime, and so does the context of the building (e.g. change in the electricity mix supplying the building, or climate change) [8]. Prospective LCA can be used to build and assess possible future scenarios [9,10]. In this context, the objectives of the thesis are (i) to precisely assess the temporal evolution of performance of energy systems in the present (short-term) and in the future (long-term) context; and (ii) to obtain the corresponding environmental impacts using dynamic prospective LCA.

The energy systems investigated in this work will be mainly heat pumps, as this equipment is increasingly used in French housings. LCA of heat pump is still an open field of research [11]. Instead of assessing the performance of heat pumps using a physical model, a data-driven approach will be followed. Data from real installed heat pumps will be processed with machine or deep learning algorithms, as suggested in [12–15] in the context of faults detection, prediction of coefficients of performance, or optimisation of control strategies. Furthermore, heat pumps can be coupled to other energy systems to increasing the overall energy efficiency and the environmental benefits of such coupling will be investigated as well.

The PhD project will be carried out as follows. After literature reviews on LCA of heat pumps, on application of machine learning algorithms to assess the real performance of heat pumps, and on the development of prospective scenarios for building LCA, three aspects will be explored.

- In a first part, data from monitored heat pumps will be statistically analysed in order to assess their performance in different contexts, such as different building location, age, or size. Clustering algorithms will be applied to identify additional drivers of the heat pumps energy performances. Then machine or deep learning algorithms, able to handle time series, will be used to develop performance prediction models. The aim is to obtain performance models valid in different climatic contexts, both for heat pumps newly installed and in operation for some years.
- In a second part, the opportunity of coupling heat pump with additional energy systems will be investigated. On-site electricity production such as PV panels is an interesting option to decrease the heat pump primary energy consumption. As electricity is not necessarily produced at time when heating or cooling is required, a dynamic assessment of the energy

gains will be required. Energy storage such batteries or phase change materials will be studied as well.

- In a third part of the thesis, prospective scenarios will be developed in order to assess the energy performance of building heated or cooled with heat pump on the long term. The performance prediction model will be updated in order to be consistent with potential climate change scenarios. Several end of life scenarios for heat pumps will be developed and heat pumps typical lifetime will be investigated.

Within each part, parametric LCA studies will be carried out in order to assess the environmental impacts of housings heated or cooled with heat pumps. In the current context, environmental impacts will be computed for different buildings typologies (use, location, age or size), with different heat pump technologies (e.g. using different refrigerants), and with complementary systems (photovoltaics, phase change materials). Using prospective scenarios for the future context, the impacts will be assessed for different evolutions of the building context (electricity mix, climate change), or of the buildings energy system (replacements by equivalent or improved systems at the end of the heat pump lifetime, consideration of different end-of-life scenarios). Finally, as many assumptions made for the energy and environmental modelling may be uncertain or variable, uncertainty and sensitivity analyses will be carried out on the LCA results.

Keywords:

Building; Heat Pump; Prospective; Life Cycle Assessment; Data-driven

Required skills:

The PhD candidate must hold a Master 2 or equivalent. Knowledge is expected in the fields of building or energy systems. Knowledge of life cycle assessment or machine learning would be an advantage. In addition, English language skills (read, written and spoken) are required. Candidates must be motivated by the subject, curious, rigorous and must demonstrate independence and initiative.

Doctoral school:

The student will be registered in the “Engineering and Systems Sciences” Doctoral School (SIS, Sciences de l'Ingénierie et des Systèmes) (https://ed-sis.doctorat-paysdelaloire.fr/).

Thesis location:

The thesis will take place at the LARIS laboratory of the University of Angers: 62 Avenue Notre Dame du Lac, 49 000 Angers.

Thesis direction:

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