INNOSTORAGE – USE OF INNOVATIVE THERMAL ENERGY STORAGE FOR MARKED ENERGY SAVINGS AND SIGNIFICANT LOWERING CO_2 EMISSIONS

Beneficiaries:

Partners:

D7.2 - Report on Staff Exchanges

	Name and Institution	Date
Prepared by:	Dr. Ingrid Martorell (UdL) Dr. Marc Medrano (UdL)	September 2015
Checked by:	Pr. Dr. Mohammed Farid (University of Auckland)	October 2015
Approved by:	Prof. Dr. Luisa F. Cabeza Universitat de Lleida	September 2015

Contents

1 Objectives

This report comprises the results of two secondments realized at the same time by Prof. Ingrid Martorell and Prof. Marc Medrano, both from the University of Lleida (UdL), in Spain. They both visited Professor Dr. Mohammed Farid, at the University of Auckland (New Zealand) in August 2015. The objectives of the two secondments were:

1. To enhance the collaborations between the two institutions with a long term perspective.
2. To develop a research work on a literature review of zero energy buildings, with a special focus on the contribution of thermal energy storage to this type of buildings.

2 Introduction

The concept of zero energy buildings (ZEB) is not new, as many examples of off-grid isolated buildings which are self-sustained in energy terms can be found in the literature, even in the 70s or 80s. However, only in the last 5 years this term has gained momentum, as many developed regions in the World (especially Europe and the US) are promoting and passing bills for developing grid connected, new and retrofit, residential and commercial, net (NZEB), plus (plusEB) or nearly zero energy buildings (nZEB). This initiative is regarded as a powerful, integrated solution to tackle the problems of excessive energy consumption and CO_2 emissions in the building sector, normally the first consuming sector in many countries, in the range of 30 to 40% of the total energy. Many aspects of this new concept have been studied and developed in the recent literature, including the definition characteristics, methodologies to approach this distinct type of buildings, particular cases studies of early adopters, evaluation procedures, tools and indicators, contributions of specific technologies and combination of them, such as TES, policies and legislation developed by different countries, the importance of embodied energy and LCA, etc. Although there are some reviews available on a particular aspect of this multidisciplinary, broad topic, a good review paper with a broad approach, giving more insight in those issues not covered in previous reviews, is missing and can be interesting for the scientific and technical community involved in this area.

3 Description of work

The work done in the research stay has consisted in starting the different tasks associated with this project, having in mind a scientific paper as the final result of the work. Thus, the work to be done is summarized as follows as a list of tasks:

- Design paper structure, defining the scope, the originality and contributions, compared to previous review papers on similar topics, and what to include in every section.

- Extensive and systematic literature search and analysis of previous related papers and reviews on the topic, trying to identify original contributions to the scientific community.
- Elaborate summary tables collecting the most important characteristics of each reviewed paper, including classification keywords for easy and quick grouping capability of papers focusing on the same subtopic within the nZEB theme.
- Elaborate a database of useful references on the topic with Zotero, so that it is collect, manage and cite such a considerable number of papers, as required by a good review paper.
- Browse, collect and select the most interesting, representative and illustrative figures in other papers that can help the future readers understand the concepts and discussion in text. At the same time, elaborate own original plots, tables and diagrams, adapting or compiling the ones produced by other authors.
- Write the different review paper sections, perform several internal reviews by the co-authors and submit it.

4 Materials and Methodology

This is an analytical work, based on an extensive work of literature review and analysis. The tools used for addressing this work are literature citation software (Zotero), spreadsheets, plotting tools and text processing tools.

5 Results

During the short stay at the University of Auckland we have been able to move forward in several tasks of the project. The work done is summarised as follows:

- Preliminary structure of the paper (still open to be modified depending on the findings with similar review papers, to come up with an original approach).
- Done a thorough literature search for past papers targeting this topic (see references found and processed so far at the “Reference” section).
- Processed (read, classified and included in a library, using bibliographic software Zotero) about 100 recent papers (2014 and 2015) referring to this topic as a keyword, based on Scopus and Google scholar alerts collected during the last 12 months. Analyzed in detail the main review papers on this topic, identifying points not covered in previous reviews (see Figure 1, as an example).

Comparative table of previous NZEB paper and our paper

Identifying how we could differentiate from previous paper

Aspects	Deng et al. paper, 2014	Our paper, 2016
Main focus	Centered in NZEB evaluation	Could have several goals, not only evaluation
Keywords	Very few, only "net zero energy "when talking about nzeb	Should include as many as possible keywords, a lot refereeing to nzeb
References	Most of them before 2012. Only a few internet access of 2013	Most of them will be of 2014 and 2015. The basic ones about nzeb, previous to 2014 will be the same
Case studies	They are not included	They could be included somehow (Summary table, map, list of numbers per country…)
Definition of NZEB	The work seems comprehensive, including plots and tables. The details on how the definitions in the MS of the UE are evolving are not included.	Maybe we can find something new in the recent literature and present it in a different way, referring to his article for the things that cannot be improved.
EEM (energy efficiency measures or technologies)	They only discuss in detail HVAC, DHW and power generation, but not passive design measures (the authors come from the HVAC field!). They include a risk benefit diagram for EEM in NZEB.	Maybe we could be more comprehensive and include all of them, just refereeing to some recent papers and trying to find or create good plots or summary tables for them.
Methodology for evaluation zneb	It seems they say the evaluation methodology for nZEB includes normally embodied energy and operational energy, and generally simulation is preferred. Not clear how they come to this conclusion. 5 reviews the building simulation tools, they should be included in our paper, especially the one for nZEB (S. Attia et al, 2013)	They do not talk about the methodology for designing nZEB properly (integrated approach). This could be included.
Performance parameters for assessing a NZEB	They only include indoor comfort, energy balance and LCA. More parameters are discussed in literature. They spend a lot of lines on the LC-ZEB	We could include recent literature talking about other parameters for microgrids, etc. (load match, grid interaction indicators, life cycle cost, etc.). The paragraph on energy balance and references is scarce in the previous paper, and could be improved. Maybe some critical view on the need of LC-nZEB could be included.
Development trend	Not comprehensive. Only some initiatives in some countries referred. Second part is more some recommendations and insights of the authors on development trends for nZEB	It could be more thorough, including the most important initiatives in the world in terms of legislation and big international research projects.
Energy storage role	Good summary of both electrical and thermal energy storage, and future trends.	Similar wording should be included, maybe with other references and plots.
Load match and grid interaction	Good summary of these concepts. A lot of wording. They refer to a conference paper of Salom et al, 2011. We have more current references to include.	
Smart grid	Good summary of relation fo smart grid and nZEB. Maybe in our paper it could be skipped.	Maybe not necessary to include?

Figure 1: Detail of the comparison tables with previous review papers

- Identified several figures to be included in the review (see the following, as some examples).

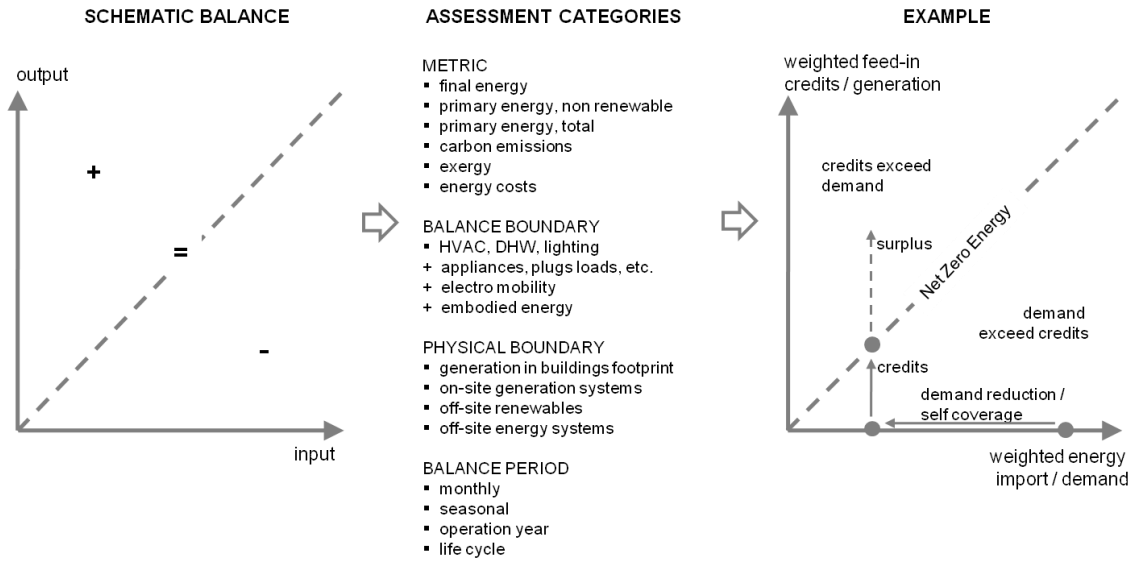

Figure 2:The graph represents the Net ZEB balance concept: balance of weighted energy import respectively energy demand (x-axis) and energy export (feed-in credits) respectively (on-site) generation (y-axis)., extractred from ('Net Zero Energy Solar Buildings SHC Position Paper, IEA SHC || Task 40 || Publications, 2015, http://task40.iea-Shc.org/', n.d.)

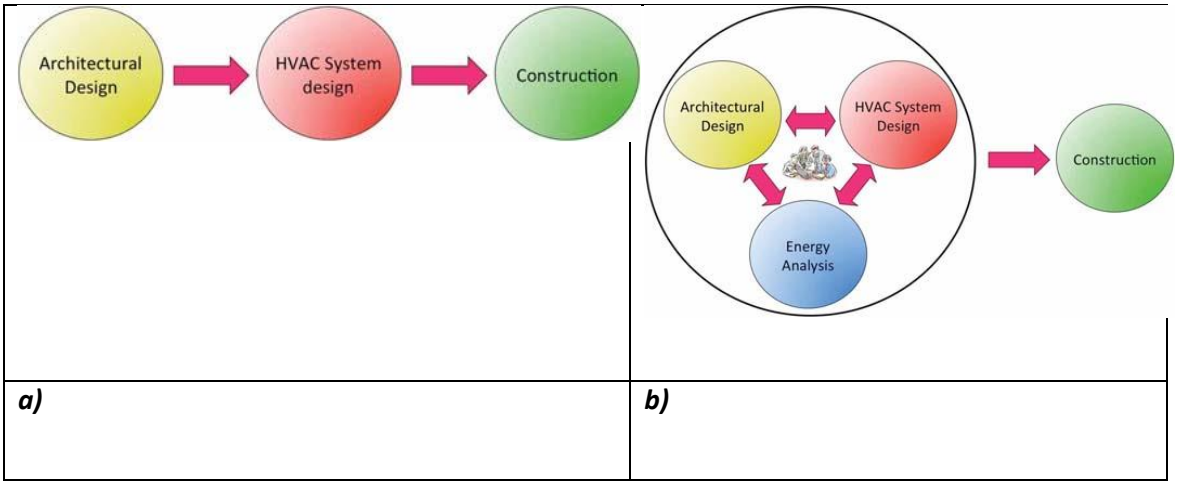

Figure 3: Usual Building design process (a) versus integrated design process required for nZEB, extracted from (Butera 2013)

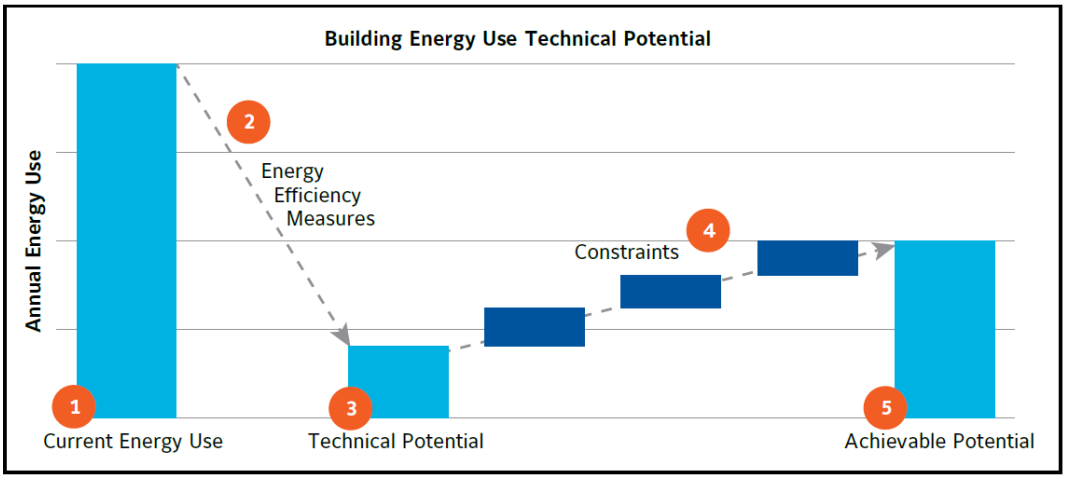

Figure 4: Tehcnical potentia process for retrofit Building energy efficiency, extracted from (C. et al. 2013)*:*

BUILDING SYSTEM DESIGN & OPERATION	CURRENT BUILDINGS	SMART NetZEBs
Building fabric/envelope	Passive, not designed as an energy system	Optimized for passive design and integration of active solar systems
Heating, ventilation and air conditioning (HVAC)	Large oversized systems	Small HVAC systems optimally controlled, integrated with solar systems, combined heat and power, seasonal storage and district energy
Solar systems/renewable generation	No systematic integration – an afterthought	Fully integrated: daylighting, solar thermal, photovoltaics, hybrid solar, geothermal systems, biofuels linked with smart micro grids
Building automation systems	Building automation systems not used effectively	Predictive building controls to optimize comfort and energy performance; online demand prediction / peak demand reductions
Design and operation	Design and operation of buildings typically considered apart	Design and operation of buildings fully integrated and optimized together subject to satisfying comfort

Figure 5: Current design Building situation and expected characteristics of nZEB design for major five Building subsystems, extracted from ('Net Zero Energy Solar Buildings SHC Position Paper, IEA SHC || Task 40 || Publications, 2015, http://task40.iea-Shc.org/', n.d.)*:*

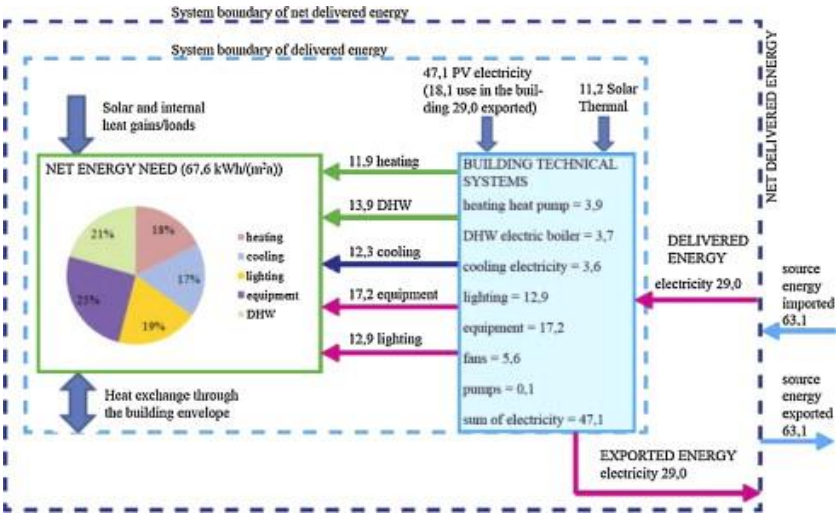

Figure 6: Energy flows and System boundaries for nZEB in Italy, extracted from (Becchio et al. 2015)

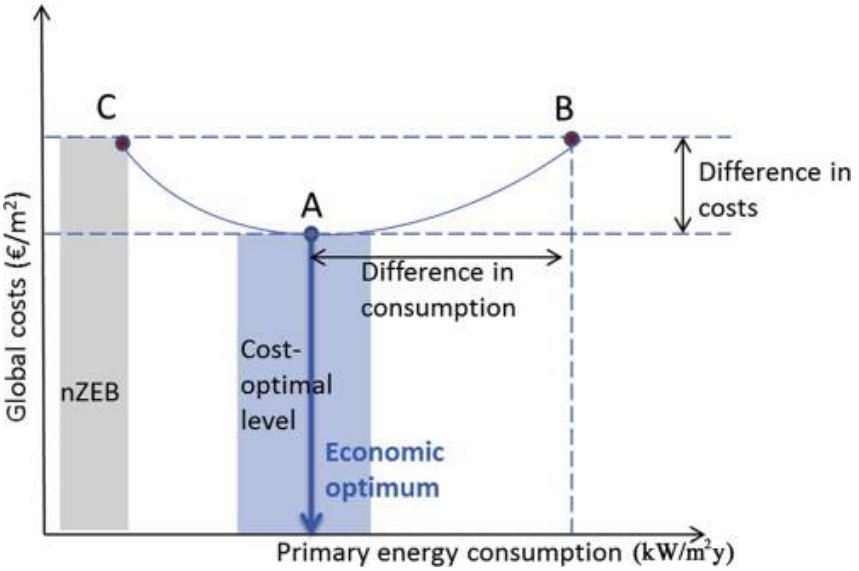

Figure 7: Global cost curve (A = economic optimum, B = requirement in force, C = cost neutral compared to requirement in force), source (Baglivo et al. 2015)

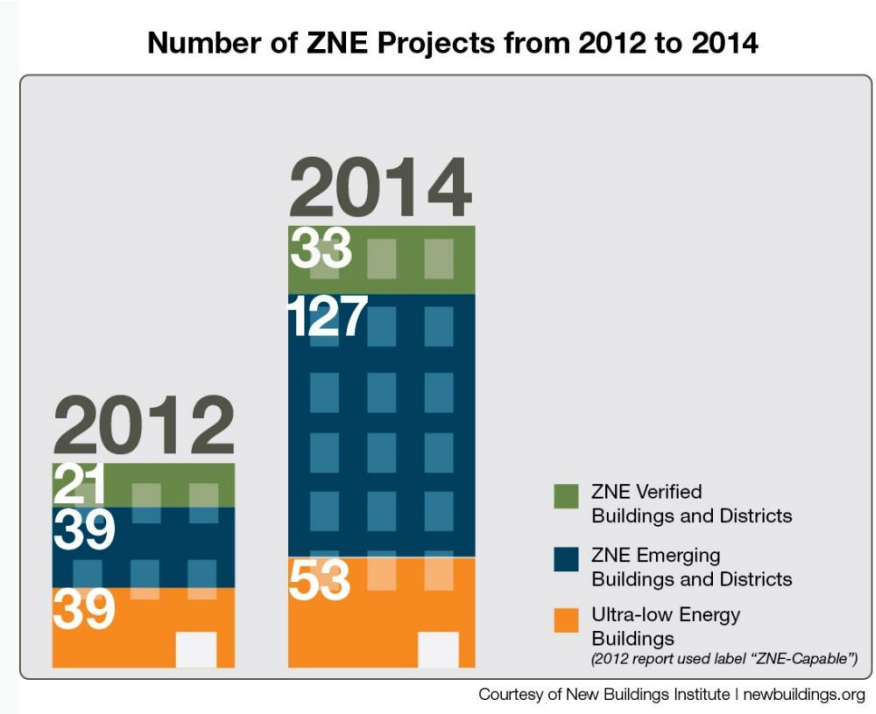

Figure 8: Increase in number of ZNE projects in the US from 2012 to 2014, source (New Building Institute report 2014)('Net Zero Energy Solar Buildings SHC Position Paper, IEA SHC || Task 40 || Publications, 2015, http://task40.iea-Shc.org/', n.d.)*:*

- Created a summary table classifying processed papers in several categories, related with the proposed structure and chapters of the paper, so that it will be easier to select the right papers for each part of the review.

No	Scopus and Google Scholar alert date	Paper title	Journal	nZEB main topic or just introduction for specific technology?	Main Classification contents 1	Second classification contents	In Zotero nZEB?
1	23/10/2014	Analysis of load match and grid interaction indicators in net zero energy buildings with simulated and monitored data	*Applied Energy*	YES	1. nZEB indicators (load match LM and grid interaction GI)		YES [12]
2	23/10/2014	Multi-objective optimization analysis for high efficiency external walls of zero energy buildings (ZEB) in the Mediterranean climate	Energy and Buildings	NO.(external walls thermal mass)	3. Study of particular technology		YES [13]
3	23/10/2014	A simulation-based optimization method for cost-optimal analysis of nearly Zero Energy Buildings	Energy and Buildings	YES	2. General study for optimizing several parameters in French home		YES [14]
4	23/10/2014	Zero energy buildings and the rebound effect: A solution to the paradox of energy efficiency?	Energy and Buildings	YES	7.Other aspects related to nZEB		YES [15]
5	23/10/2014	Energy performance assessment of a complex district heating system which uses gas-driven combined heat and power, heat pumps and high temperature aquifer thermal energy storage	Energy and Buildings	NO (energy performance of district heating with CHP)	3.Study of a particular technology		YES [16]

...

101	29/6/2015	**Consensus-based low carbon domestic design framework for sustainable homes**		NO			
102	29/6/2015	**Innovative technologies for transparent building envelopes: experimental assessment of energy and thermal comfort data to facilitate the decision-making process**		NO (PCM in windows)			
103	29/6/2015	**A survey of the effects of renewable energies and components of Zero-Carbon Building & Zero-Energy Building On environment and improving life level of society**		YES (review)			
104	15/7/2015						

Figure 9: Detail of the processing summary table for the more than 100 papers read and processed during the stay at the University of Auckland.

As the stay was relatively short, several tasks could not be finished there and we will be working on them in the following months. The pending tasks are:

1. Finalize the paper processing. The last two months of alerts are still to be processed.
2. Decide the final structure of the paper, based on the thorough assessment of previous reviews and info presented in the rest of last two years´ papers on this topic.

3. Start writing the different chapters, using the created summary table for picking the right papers of each chapter and using Zotero for easy references management.
4. Generate original tables and/or diagrams condensing previous work or proposing a new idea/concept/interpretation in the topic.
5. Include an acknowledgment section for the Innostorage funding.

6 Outcomes or future work

As stated above, the initial work realized by the two secondments will be continued and finished in the following months, with the collaboration of Pr. Farid, at the University of Auckland. We expect to elaborate a good quality review paper to be published in a prestigious scientific journal. The links and personal interactions we developed in the stage will certainly be beneficial for future collaborations and joint projects.

7 References

[1] Voss, K., 2012, “Nearly-zero, Net zero and Plus Energy Buildings,” REHVA J. Dec.

[2] Torcellini, P., Pless, S., Deru, M., and Crawley, D., 2006, “Zero energy buildings: a critical look at the definition,” Natl. Renew. Energy Lab. Dep. Energy US.

[3] “Net Zero Energy Solar Buildings SHC Position Paper, IEA SHC || Task 40 || Publications, 2015, http://task40.iea-shc.org/.”

[4] C., Carmicahel, K., and Managan, 2013, “Reinventing Existing Buildings: Eight Steps to Net Zero Energy.”

[5] Butera, F. M., 2013, “Zero-energy buildings: the challenges,” Adv. Build. Energy Res., 7(1), pp. 51–65.

[6] Nejat, P., Jomehzadeh, F., Taheri, M. M., Gohari, M., and Majid, M. Z. A., 2015, “A global review of energy consumption, CO 2 emissions and policy in the residential sector (with an overview of the top ten CO 2 emitting countries),” Renew. Sustain. Energy Rev., 43, pp. 843–862.

[7] Deng, S., Wang, R. Z., and Dai, Y. J., 2014, “How to evaluate performance of net zero energy building–A literature research,” Energy, 71, pp. 1–16.

[8] Mohamed, A., Hasan, A., and Sirén, K., 2014, “Fulfillment of net-zero energy building (NZEB) with four metrics in a single family house with different heating alternatives,” Appl. Energy, 114, pp. 385–399.

[9] Lützkendorf, T., Foliente, G., Balouktsi, M., and Wiberg, A. H., 2015, “Net-zero buildings: Incorporating embodied impacts,” Build. Res. Inf., 43(1), pp. 62–81.

[10] Berggren, B., Hall, M., and Wall, M., 2013, "LCE analysis of buildings–Taking the step towards Net Zero Energy Buildings," Energy Build., 62, pp. 381–391.

[11] Kolokotsa, D., Rovas, D., Kosmatopoulos, E., and Kalaitzakis, K., 2011, "A roadmap towards intelligent net zero-and positive-energy buildings," Sol. Energy, 85(12), pp. 3067–3084.

[12] Salom, J., Marszal, A. J., Widén, J., Candanedo, J., and Lindberg, K. B., 2014, "Analysis of load match and grid interaction indicators in net zero energy buildings with simulated and monitored data," Appl. Energy, 136, pp. 119–131.

[13] Baglivo, C., Congedo, P. M., Fazio, A., and Laforgia, D., 2014, "Multi-objective optimization analysis for high efficiency external walls of zero energy buildings (ZEB) in the Mediterranean climate," Energy Build., 84, pp. 483–492.

[14] Ferrara, M., Fabrizio, E., Virgone, J., and Filippi, M., 2014, "A simulation-based optimization method for cost-optimal analysis of nearly Zero Energy Buildings," Energy Build., 84, pp. 442–457.

[15] Bourrelle, J. S., 2014, "Zero energy buildings and the rebound effect: A solution to the paradox of energy efficiency?," Energy Build., 84, pp. 633–640.

[16] Zeghici, R. M., Damian, A., Frunzulicə, R., and Iordache, F., 2014, "Energy performance assessment of a complex district heating system which uses gas-driven combined heat and power, heat pumps and high temperature aquifer thermal energy storage," Energy Build., 84, pp. 142–151.

[17] Baglivo, C., Congedo, P. M., and Fazio, A., 2014, "Multi-criteria optimization analysis of external walls according to ITACA protocol for zero energy buildings in the mediterranean climate," Build. Environ., 82, pp. 467–480.

[18] Michalak, P., 2014, "The simple hourly method of EN ISO 13790 standard in Matlab/Simulink: A comparative study for the climatic conditions of Poland," Energy, 75, pp. 568–578.

[19] Renau, J., Domenech, L., García, V., Real, A., Montés, N., and Sánchez, F., 2014, "Proposal of a nearly zero energy building electrical power generator with an optimal temporary generation-consumption correlation," Energy Build., 83, pp. 140–148.

[20] Alaidroos, A., and Krarti, M., 2015, "Optimal design of residential building envelope systems in the Kingdom of Saudi Arabia," Energy Build., 86, pp. 104–117.

[21] Alrashed, F., and Asif, M., 2015, "Analysis of critical climate related factors for the application of zero-energy homes in Saudi Arabia," Renew. Sustain. Energy Rev., 41, pp. 1395–1403.

[22] Jones, P., Hou, S. S., and Li, X., 2015, "Towards zero carbon design in offices: Integrating smart facades, ventilation, and surface heating and cooling," Renew. Energy, 73, pp. 69–76.

[23] Rodriguez-Ubinas, E., Montero, C., Porteros, M., Vega, S., Navarro, I., Castillo-Cagigal, M., Matallanas, E., and Gutiérrez, A., 2014, "Passive design strategies and performance of Net Energy Plus Houses," Energy Build., 83, pp. 10–22.

[24] Rodriguez-Ubinas, E., Rodriguez, S., Voss, K., and Todorovic, M. S., 2014, "Energy efficiency evaluation of zero energy houses," Energy Build., 83, pp. 23–35.

[25] Jin, Y., Wang, L., Xiong, Y., Cai, H., Li, Y. H., and Zhang, W. J., 2014, "Feasibility studies on net zero energy building for climate considering: A case of 'all Green House' for Datong, Shanxi, China," Energy Build., 85, pp. 155–164.

[26] Desideri, U., Arcioni, L., Leonardi, D., Cesaretti, L., Perugini, P., Agabitini, E., and Evangelisti, N., 2014, "Design of a multipurpose 'zero energy consumption' building according to European Directive 2010/31/EU: Life cycle assessment," Energy Build., 80, pp. 585–597.

[27] Ferreira, M., Almeida, M., Rodrigues, A., and Silva, S. M., 2014, "Comparing cost-optimal and net-zero energy targets in building retrofit," Build. Res. Inf., pp. 1–14.

[28] Di Giuseppe, E., and D'Orazio, M., 2015, "Assessment of the effectiveness of cool and green roofs for the mitigation of the Heat Island effect and for the improvement of thermal comfort in Nearly Zero Energy Building," Archit. Sci. Rev., 58(2), pp. 134–143.

[29] Sun, Y., 2015, "Sensitivity analysis of macro-parameters in the system design of net zero energy building," Energy Build., 86, pp. 464–477.

[30] Zhao, Y., Lu, Y., Yan, C., and Wang, S., 2015, "MPC-based optimal scheduling of grid-connected low energy buildings with thermal energy storages," Energy Build., 86, pp. 415–426.

[31] Mandley, S., Harmsen, R., and Worrell, E., 2015, "Identifying the potential for resource and embodied energy savings within the UK building sector," Energy Build., 86, pp. 841–851.

[32] Martinopoulos, G., 2014, "Solar Heating Systems as a Viable Solution Towards Nearly Zero Energy Buildings," American Society of Mechanical Engineers, pp. V002T10A012–V002T10A012.

[33] Comodi, G., Giantomassi, A., Severini, M., Squartini, S., Ferracuti, F., Fonti, A., Nardi Cesarini, D., Morodo, M., and Polonara, F., 2015, "Multi-apartment residential microgrid with electrical and thermal storage devices: Experimental analysis and simulation of energy management strategies," Appl. Energy, 137, pp. 854–866.

[34] Ordonez, J. C., Yang, S., Ordonez, C., Vargas, J. V. C., Solano, T., Bublitz, M., and Collins, E., 2014, "Thermal Simulation of an Off-Grid Zero Emissions Building," ASME, p. V002T06A005.

[35] Zeng, Z., Hurt, R., and Boehm, R. F., 2014, "The 2013 University of Nevada Las Vegas Solar Decathlon House: Strategy, Design, Simulation and Results," ASME, p. V002T10A010.

[36] Hassoun, A., and Dincer, I., 2015, "Analysis and performance assessment of a multigenerational system powered by Organic Rankine Cycle for a net zero energy house," Appl. Therm. Eng., 76, pp. 25–36.

[37] Sánchez, E., and Izard, J., 2015, "Performance of photovoltaics in non-optimal orientations: An experimental study," Energy Build., 87, pp. 211–219.

[38] Alonso, M. J., Liu, P., Mathisen, H. M., Ge, G., and Simonson, C., 2015, "Review of heat/energy recovery exchangers for use in ZEBs in cold climate countries," Build. Environ., 84, pp. 228–237.

[39] Bomberg, M., Gibson, M., and Zhang, J., 2015, "A concept of integrated environmental approach for building upgrades and new construction: Part 1--setting the stage," J. Build. Phys., 38(4), pp. 360–385.

[40] Xu, J., Kim, J.-H., Hong, H., and Koo, J., 2015, "A systematic approach for energy efficient building design factors optimization," Energy Build., 89, pp. 87–96.

[41] Lu, Y., Wang, S., Zhao, Y., and Yan, C., 2015, "Renewable energy system optimization of low/zero energy buildings using single-objective and multi-objective optimization methods," Energy Build., 89, pp. 61–75.

[42] McKinstray, R., Lim, J. B. P., Tanyimboh, T. T., Phan, D. T., Sha, W., and Brownlee, A. E. I., 2015, "Topographical optimisation of single-storey non-domestic steel framed buildings using photovoltaic panels for net-zero carbon impact," Build. Environ., 86, pp. 120–131.

[43] Iyiegbuniwe, E. A., 2014, "Net-zero energy: a case study on renewable energy and policy issues at Richardsville Elementary School, Kentucky," Int. J. Energy Technol. Policy, 10(1), p. 61.

[44] Becchio, C., Dabbene, P., Fabrizio, E., Monetti, V., and Filippi, M., 2015, "Cost optimality assessment of a single family house: Building and technical systems solutions for the nZEB target," Energy Build., 90, pp. 173–187.

[45] Hong, T., Lee, M., and Kim, J., 2014, "Development of the Process for Deploying Optimal Photovoltaic System," Energy Procedia, 61, pp. 1544–1548.

[46] Scognamiglio, A., Adinolfi, G., Graditi, G., and Saretta, E., 2014, "Photovoltaics in Net Zero Energy Buildings and Clusters: Enabling the Smart City Operation," Energy Procedia, 61, pp. 1171–1174.

[47] Song, Y., Sun, J., Li, J., and Xie, D., 2014, "Towards Net Zero Energy Building: Collaboration-based Sustainable Design and Practice of the Beijing Waterfowl Pavilion," Energy Procedia, 57, pp. 1773–1782.

[48] Kneifel, J., Healy, W., Filliben, J., and Boyd, M., 2015, "Energy performance sensitivity of a net-zero energy home to design and use specifications," J. Build. Perform. Simul., pp. 1–14.

[49] Kuznik, F., and Johannes, K., 2014, "A Review on Chemisorption Heat Storage in Low-energy Buildings," Energy Procedia, 57, pp. 2333–2341.

[50] Morau, D., Rakotondramiarana, H. T., Ranaivoarisoa, T. F., and Andriamamonjy, A. L., 2014, "Thermal behavior of green roof in Reunion island: Contribution towards a net zero building," pp. 1908–1921.

[51] Garde, F., Lenoir, A., Scognamiglio, A., Aelenei, D., Waldren, D., Rostvik, H. N., Ayoub, J., Aelenei, L., Donn, M., Tardif, M., and Cory, S., 2014, "Design of Net Zero Energy Buildings: Feedback from International Projects," Energy Procedia, 61, pp. 995–998.

[52] Huang, Y.-C., Chan, C.-C., Wang, S.-J., and Lee, S.-K., 2014, "Development of Building Integrated Photovoltaic (BIPV) System with PV Ceramic Tile and its Application for Building Façade," Energy Procedia, 61, pp. 1874–1878.

[53] Scognamiglio, A., Garde, F., and Røstvik, H. N., 2014, "How Net Zero Energy Buildings and Cities Might Look Like? New Challenges for Passive Design and Renewables Design," Energy Procedia, 61, pp. 1163–1166.

[54] Castaing-Lasvignottes, J., David, M., Garde, F., Maillard, F., Ottenwelter, E., Garnier, R., and Tranier, P., 2014, "Modeling of a Compressed Air Energy Storage Connected to a PV Field for NZEB in Tropics," Energy Procedia, 61, pp. 1175–1178.

[55] Zhang, H., Li, J., Dong, L., and Chen, H., 2014, "Integration of Sustainability in Net-zero House: Experiences in Solar Decathlon China," Energy Procedia, 57, pp. 1931–1940.

[56] Spiegelhalter, T., 2014, "Energy-efficiency Retrofitting and Transformation of the FIU-college of Architecture + The Arts into a Net-Zero-Energy-Building by 2018," Energy Procedia, 57, pp. 1922–1930.

[57] Peng, C., Huang, L., Liu, J., and Huang, Y., 2015, "Design and practical application of an innovative net-zero energy house with integrated photovoltaics: a case study from Solar Decathlon China 2013," Archit. Sci. Rev., 58(2), pp. 144–161.

[58] Ferreira, M., Almeida, M., and Rodrigues, A., 2014, "Cost optimality and net-zero energy in the renovation of Portuguese residential building stock – Rainha Dona Leonor neighbourhood case study," Int. J. Sustain. Build. Technol. Urban Dev., 5(4), pp. 306–317.

[59] Papanicolas, C., Lange, M. A., Fylaktos, N., Montenon, A., Kalouris, G., Fintikakis, N., Fintikaki, M., Kolokotsa, D., Tsirbas, K., Pavlou, C., Vasilakopoulou, K., and Santamouris, M., 2015, "Design, construction and monitoring of a near-zero energy laboratory building in Cyprus," Adv. Build. Energy Res., 9(1), pp. 140–150.

[60] Berry, S., and Marker, T., 2015, "Residential energy efficiency standards in Australia: where to next?," Energy Effic.

[61] Ferrara, M., Virgone, J., fabrizio, E., Kuznik, F., and Filippi, M., 2014, "Modelling Zero Energy Buildings: Parametric Study for the Technical Optimization," Energy Procedia, 62, pp. 200–209.

[62] Tabrizi, A., and Sanguinetti, P., 2015, "Life-cycle cost assessment and energy performance evaluation of NZEB enhancement for LEED-rated educational facilities," Adv. Build. Energy Res., 9(2), pp. 267–279.

[63] Sun, X., Brown, M. A., Cox, M., and Jackson, R., 2015, "Mandating better buildings: a global review of building codes and prospects for improvement in the United States: A global review of building codes and prospects for improvement in the U.S.," Wiley Interdiscip. Rev. Energy Environ., p. n/a–n/a.

[64] Szalay, Z., and Zöld, A., 2014, "Definition of nearly zero-energy building requirements based on a large building sample," Energy Policy, 74, pp. 510–521.

[65] Lu, Y., Wang, S., Sun, Y., and Yan, C., 2015, "Optimal scheduling of buildings with energy generation and thermal energy storage under dynamic electricity pricing using mixed-integer nonlinear programming," Appl. Energy, 147, pp. 49–58.

[66] Fiorentini, M., Cooper, P., and Ma, Z., 2015, "Development and optimization of an innovative HVAC system with integrated PVT and PCM thermal storage for a net-zero energy retrofitted house," Energy Build., 94, pp. 21–32.

[67] Safa, A. A., Fung, A. S., and Kumar, R., 2015, "Comparative thermal performances of a ground source heat pump and a variable capacity air source heat pump systems for sustainable houses," Appl. Therm. Eng., 81, pp. 279–287.

[68] Todorović, M. S., Ećim-Đurić, O., Nikolić, S., Ristić, S., and Polić-Radovanović, S., 2015, "Historic building's holistic and sustainable deep energy refurbishment via BPS, energy efficiency and renewable energy—A case study," Energy Build., 95, pp. 130–137.

[69] Lima, P. M., Jmonteiro, O. F., and Castro, O. S., 2014, "Impact of design options in zero energy building conception: The case of large buildings in Portugal," pp. 480–487.

[70] Baglivo, C., Congedo, P. M., D'Agostino, D., and Zacà, I., 2015, "Cost-optimal analysis and technical comparison between standard and high efficient mono-residential buildings in a warm climate," Energy, 83, pp. 560–575.

[71] Krarti, M., and Deneuville, A., 2015, “Comparative evaluation of optimal energy efficiency designs for French and US office buildings,” Energy Build., 93, pp. 332–344.

[72] Perlova, E., Platonova, M., Gorshkov, A., and Rakova, X., 2015, “Concept Project of Zero Energy Building,” Procedia Eng., 100, pp. 1505–1514.

[73] Rosales Carreon, J., and García-Díaz, C., 2015, “Exploring Transitions Toward Sustainable Construction: The Case of Near-Zero Energy Buildings in the Netherlands,” J. Artif. Soc. Soc. Simul., 18(1), p. 10.

[74] Carutasiu, M.-B., Tanasiev, V., Ionescu, C., Danu, A., Necula, H., and Badea, A., 2015, “Reducing energy consumption in low energy buildings through implementation of a policy system used in automated heating systems,” Energy Build., 94, pp. 227–239.

[75] Colclough, S., and McGrath, T., 2015, “Net energy analysis of a solar combi system with Seasonal Thermal Energy Store,” Appl. Energy, 147, pp. 611–616.

[76] Peng, C., Huang, L., Liu, J., and Huang, Y., 2015, “Energy performance evaluation of a marketable net-zero-energy house: Solark I at Solar Decathlon China 2013,” Renew. Energy, 81, pp. 136–149.

[77] Reda, F., Tuominen, P., Hedman, Å., and Ibrahim, M. G. E., 2015, “Low-energy residential buildings in New Borg El Arab: Simulation and survey based energy assessment,” Energy Build., 93, pp. 65–82.

[78] Alnaser, N. W., 2015, “Building integrated renewable energy to achieve zero emission in Bahrain,” Energy Build., 93, pp. 32–39.

[79] Pikas, E., Thalfeldt, M., Kurnitski, J., and Liias, R., 2015, “Extra cost analyses of two apartment buildings for achieving nearly zero and low energy buildings,” Energy, 84, pp. 623–633.

[80] Shan, M., Wang, P., Li, J., Yue, G., and Yang, X., 2015, “Energy and environment in Chinese rural buildings: Situations, challenges, and intervention strategies,” Build. Environ., 91, pp. 271–282.

[81] Tsalikis, G., and Martinopoulos, G., 2015, “Solar energy systems potential for nearly net zero energy residential buildings,” Sol. Energy, 115, pp. 743–756.

[82] Tiwari, R., and Jones, J. R., 2015, “Mapping the Integrated Early Design Process of the Largest Net-Zero Energy Office Building,” American Society of Civil Engineers, pp. 594–605.

[83] Kokkaliaris, S., and Maria, E.-A., 2015, “The legislative initiatives for smart metering as a precondition to zero energy: the case of Greece,” Adv. Build. Energy Res., 9(1), pp. 55–72.

[84] Leal, V. M. S., Granadeiro, V., Azevedo, I., and Boemi, S.-N., 2015, "Energy and economic analysis of building retrofit and energy offset scenarios for Net Zero Energy Buildings," Adv. Build. Energy Res., 9(1), pp. 120–139.

[85] Höfler, K., Knotzer, A., and Venus, D., 2015, "Renovation concepts for net zero energy buildings–best practice residential building Kapfenberg/Austria," Adv. Build. Energy Res., 9(1), pp. 107–119.

[86] Pyloudi, E., Papantoniou, S., and Kolokotsa, D., 2015, "Retrofitting an office building towards a net zero energy building," Adv. Build. Energy Res., 9(1), pp. 20–33.

[87] Salom, J., Widén, J., Candanedo, J., and Lindberg, K. B., 2015, "Analysis of grid interaction indicators in net zero-energy buildings with sub-hourly collected data," Adv. Build. Energy Res., 9(1), pp. 89–106.

[88] Schuetze, T., 2015, "Zero Emission Buildings in Korea—History, Status Quo, and Future Prospects," Sustainability, 7(3), pp. 2745–2767.

8 Assessment

8.1 Assessment by Marc Medrano

This secondment gave me the great opportunity to experience other ways of conducting research and organizing a research team, share and exchange ideas and knowledge with researchers with different cultural and geographical references, and develop personal relationships than will be useful for future collaborations. This has been indeed an enriching experience and I would like to express here my gratitude to the Innostorage Programme for granting me this interesting research stay at University of Auckland, with Professor Dr. Mohammed Farid.

.

8.2 Assessment by Ingrid Martorell

This secondment has been an unique experience to interact with researchers from another university and start a collaboration with Pr. Farid that hopefully will not finished with this project. I had the privilege of exchanging research ideas with Pr. Farid and some of his PhD students. It was also very interesting to participate of the daily experience of working in one of the most populated and prestigious universities of New Zealand. We took advantage of the powerful library of University of Auckland to collect any kind of published information regarding the topic of this project. I want to thank the Innostorage Programme for the opportunity of conducting this research stay at the University of Auckland in New Zealand.