Dr. Enrique Granada Alvarez, PhD in Industrial Engineering and Associate Professor in the University of Vigo. Acting as a reviewer of Doctoral Dissertation of Karolina Petela titled Analysis of solar energy application into hybrid heat nodes.

To Whom it may concern.

REVIEW.
General Remarks
The PhD thesis entitled “Analysis of solar energy application into hybrid heat nodes” by Karolina Petela approaches the subject of solar support in thermal plants through the modeling of energy and exergy efficiency. Tools as energy and exergy balances are supplemented with control algorithms proposals which potential effect is computationally simulated but not experimentally proven which is a little weakness but do not affect the high quality of the document.

For developing the thesis the doctoral student demonstrated her skills on the used tools that ensures her capabilities as a researcher that guaranties future autonomous leadership in research which is the requirement to obtain the PhD. Apart the transversal skills (critic assessment of the results, scientific document writing, bibliographic documentation...) the student demonstrate specific skills mainly in theoretical and practical energy and exergy balances. Remarkable is the solar radiation exergy discussion and calculation finally based in Petela’s approach references [65,83,84]. This reviewer assume this Petela R. is not Karolina who collects all approaches in reference [82]. In any case may be useful to have a Curriculum of the student to better assess her scientific trajectory. The Methodology chapter is clearly and fully understandably presented.

Advantages of the thesis
This dissertation contribute to increase the general knowledge and the efficiency of heating and cooling systems supported by solar energy. Due to climate change prognoses, heating and cooling demand is expected to vary significantly in the coming years and due to that, this thesis is tackling with a current technical concern about how to efficiently meet that future demand. Because all that, the interest of this thesis is clearly motivated by a social demand and the specific research done is fully justified by the state of the art reviewed.

Two different solar installations, Italy and Poland locations, were analyzed through energy, exergy and cumulative exergo-enonomic analyses. Simulation models of both were created by means of a modular structure, and was possible to analyze both installations under Italian and Polish climate conditions and compare performances. That is considered right and very valuable.

It is considered related but slightly out of the focus of the thesis, the proposed two control algorithms. It is great to develop environmental friendly algorithms for energy savings but perhaps should be better to dedicate this effort to deep into the energy-exergy-economic analyses done.
Despite this, it is considered a worthy contribution.

The literature review about Solar Absorption and Adsorption chillers, Energy storage, Hybrid heating and cooling and the exergy application to solar assisted heating and cooling systems is considered properly developed and focused in the topic of the thesis.

Literature review conclusions clearly lead to the objectives of the thesis which try to fill current challenges such as to establish rules for smart management of the system performance and to establish an strong energy, exergy and economic based assessment methodology to analyze the system performance. Those are substantiated in the proposed objectives, control algorithms and in the energy, exergy and cumulative exergo-economic analyses.

Although simple balances of mass and energy (black box model mainly) are applied and many simplifications as steady state, Thermodynamic equilibrium and negligible pressures and heat losses are taken into account and most devices are simulated as a shell and tube heat exchangers, those assumptions does not underestimate the main achievement of the thesis, the exergy and energy balances.

Critical comments
As being climate change generally accepted, its influence in cooling demand will be critical in the following years. Although estimations of future growing in cooling demand are tackled in the introduction section (pg. 1), only three references [5 (2009), 6 (2017), 7 (2009)] really support what the dissertation stated about future cooling demand and two of them [5, 7] are not updated. On the other hand, European Union Energy Strategy about how to meet the future heating and cooling demand is properly worked with updated references. To sum up heating and cooling demand is presented and the energy strategy to meet this demand are well worked. Both justify the necessity of the thesis.

Abstract assertions as “Although the operational costs in the solar thermal cooling systems are incomparably lower than...” or “...application of control algorithms for both systems may bring measurable operational profits.” Or “The procedure applied for the control system of a solar cooling plant allows for the increase of solar fraction. The magnitude of this effect is however dependent on location and the type of solar collectors installed.” Or “The control procedure applied for a hybrid heating and cooling node may contribute to decreasing the operational economic cost- and environmental-impact indicators.” Should be quantified even in the abstract because in other case are too obvious and do not supply useful information in this section. This is not a critical comment because all information is in the document, is just a style suggestion.

Considering solar energy to satisfy cooling demand is considered right because, as the student asserts, “... highest cooling demand usually coincides with the highest solar radiation availability”. But this reviewer do not fully agree with the comment “...solar energy should be considered as the best renewable energy candidate to be coupled to the production of cold.”. Depending on the case and the necessary temperature, geothermal energy (not time dependent availability) could be a serious competitor for cooling purposes. Although there are many
techniques to avoid the solar time dependent availability as thermal storage or vapor accumulation.

**Detailed critical comment**

- When is stated “The primary aim of the work is to investigate the energy and exergy consumption indicators that may be caused by exploiting solar assisted cooling installations of two different types working under two different meteorological conditions” I suppose the idea is to say “…under two different climate conditions.”. In many parts of the text, meteorology and climate seems to be used indistinctly when have different meaning.

- “loss”, “cold”, “heat” subscripts in figure 3.2 are no referenced in the “List of chosen Nomenclature”. Is understandable in any case.

- This reviewer consider Peltier as a thermoelectric phenomenon not a photoelectric one. Because that I not fully agree with the classification of figure 3.3. In any case Peltier modules heating based on solar exposition receive are heated through infrared radiation. Is it photo? Open to discussion. In any case, it does not affect the quality of the thesis at all.

- About single-stage lithium bromide chillers is not fair to consider “It is expected to have a real perspective for further building market penetration [29].” With a reference, [29] of 2009. This does not affect the quality of the thesis.

- Reference [32] (2012) cannot be considered exactly “…current research”

- In pg 15 is no suitable to assert “The scientific literature offers many examples of energy, exergy and thermo-economic analyses of solar absorption chillers of variable cooling power and working under various climate conditions.” Without list those examples from the scientific literature. Specially if the topic is fully related with the present thesis.

- In pg 20 assertions like “Scientists claim that because of this lack, hybrid solar systems cannot be fully objective and reliably presented to become competitive with conventional gas boilers or compression chillers [52].” is only supported by one paper, which is not a revision paper. It is not considered totally suitable.

- Reversibility or irreversibility are related to processes, is not a property of any system. Care with the expression “…the environment is free of irreversibilities…”. Perhaps is trying to say something that is not clear for this reviewer. In any case it does not affect the quality of the thesis at all.

- Figures 5.3 and 5.4 have not temperature scale. Figure 6.8 has not COP scale.

- Main weakness of the simulation it is the lack of full experimental validation. The control procedure based on the reference installation in Florence is not experimentally validated. About the control procedure of Wroclaw installation the information and results are too much restricted.

- Main strength, apart from the methodology employed, was the comparison of both installation in two different climates zones.

**Summary**

Demonstrated specific skills of the doctoral student are energy and exergy balances, exergoeconomic analysis and control algorithms [145]. About transversal skills of the student as critic assessment of the results, scientific document writing and bibliographic documentation are fully demonstrated in the thesis document and in the following papers that are referenced in the thesis.
and published in high impact journals:


Six publications in peer review high impact journals referenced in the thesis is an objective probe of the quality of the thesis.

Energies Journal (Ed. MDPI, Open Access) 2 papers. Impact factor 2.676. Rank Q2 (48/97 Energy&Fuels)

Although it is necessary to clarify the contribution of Karolina in any of these papers during the public defence, in my opinion, the dissertation of Karolina Petela deserves a distinction because the extension and the quality of the research done.

Because that I recommend an honours degree (summa cum laude).

Signed: Enrique Granada Alvarez
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