APRIL 22, 2023

SALVIA AND BRANDLI'S ENERGY SUSTAINABILITY AT UNIVERSITIES AND ITS CONTRIBUTION TO SDG 7:

AN UPDATE

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SDG:4000 - UN SDGS

Term Paper

1 Introduction

Universities play influential roles in society, both from a cultural perspective and as discoverers and disseminators of knowledge. As such, they are often tasked with tackling the biggest, most intractable problems in society, the ones that planners and policymakers call wicked problems. Similarly, the United Nations' Sustainable Development Goals (SDG) address wicked problems, intending to provide guidance on how these societal challenges can be overcome. Though there may seem an alignment of purposes here, it is not always clear that the two institutions work toward the same end. The expectation is *not* that universities would be perfectly aligned with the UN SDGs, but as such influential components of society, to what degree should we place the responsibility of sustainability on the shoulders of universities? Measuring how closely the research produced by universities aligns with the SDGs might be a good place to start to assess the contribution they make in addressing sustainability issues.

Salvia and Brandli (2020) had a similar line of inquiry but specific to one SDG, namely SDG 7 which deals with affordable and clean energy. Through a systematic literature review of research articles available through the *ScienceDirect* and *Web of Science* databases, they determined: "Regarding the role of universities, it is important to note that this review points out that not only energy efficiency and sustainability could be improved, but that more attention should be paid to other areas as well…It indicates that universities could engage more [in broader areas of sustainable development]" (Salvia and Brandli, 2020). Their work suggests that by systematically reviewing the scientific literature the university system's contribution to sustainable development *can* be measured. The intent of this paper is to update Salvia and Brandli's literature review, to consider alternative methods of classifying or analyzing scientific articles using natural language processing (NLP), and to ruminate whether this approach can be extended to broader analysis of universities' role in pursuing sustainable objectives.

Aside from Salvia and Brandli's contribution, two other works should be highlighted to introduce this analysis, both of which Salvia and Brandli reference in their article. First, Walter Leal Filho's 2011 article in Higher Education Policy titled *About the Role of University's and Their Contribution to Sustainable Development* outlines five areas universities must pursue "concrete action" to promote sustainable development: curriculum greening, campus operations, research, extension (i.e., continuing education and further education programs), and concrete projects (Filho 2011). Filho goes so far as to call university efforts "useless" unless they incorporate action in at least one of the five areas. The problem with this list, however, is that Filho does not provide any justification for the force behind this claim. He does not provide any references that would add more context to the list or even say that this is just a widely understood list of actions with which sustainability practitioners are all familiar. It is almost as though by fiat expression Filho wills this to be the case. Notwithstanding, Filho (2011) is a good grounding in the relationship universities have to sustainable development, at least as of a little over a decade ago, and he reiterates in his conclusion a few items on the list: "the inclusion of sustainable development in university programmes can only succeed if schemes aimed at informing and mobilising people are combined with relevant structural measures such as *campus greening*, a robust sustainability *research programme* or a set of *concrete, practical demonstration projects*" (Filho 2011).

Though Salvia and Brandli reference Filho's unsubstantiated list of areas universities can contribute to sustainable development, they augment the rationale for the list with a report from the *Sustainable Development Solutions Network*'s Australia/Pacific division titled *Getting Started with the SDGs in Universities* (2017). Similar to Filho, this report identifies areas universities can contribute to SDGs, cutting the list down to four areas: 1) learning and teaching (Filho's curriculum greening); 2) research; 3) organizational governance, culture and operations of the university; and, 4) external leadership (Filho's extension and concrete projects fall into this category). The report defines these areas thoroughly and connects them with specific goals and targets from the SDG framework, which would be helpful for further analysis of university roles with other SDGs than SDG 7. For the purposes of this analysis, however, the text of these areas as defined in this report will become the basis upon which article abstracts will be compared using NLP techniques, to be explained in detail below in the methodology section.

One final note of introduction: in attempting to replicate Salvia and Brandli's search parameters of the *ScienceDirect* and *Web of Science* databases, I could not produce the identical results that they queried from the databases, particularly in the number of articles they found. I reached out to Dr. Salvia for some insight on why this might be the case, and she was not certain why but was able to confirm that she could also not now reproduce the same results that they had in the original study, at least confirming that it was not user error on my part. This is unfortunate for this study for the sake of direct comparison, but it will not hamper all of the potential analysis. With the new set of articles from the query results, article frequency over time can still be tracked, albeit just now on a smaller set of articles. The NLP analysis will also still be possible, hopefully producing fruitful insights and a proof of concept for even further analysis on the broader set of SDGs.

2 Methodology

2.1 Systematic Review and Descriptive Analysis

Referencing Denyer and Tranfield's (2009) definition of a systematic review, Salvia and Brandli begin their analysis by differentiating their approach from a standard literature review, clearly stating their intent: "to evaluate and synthesize the articles based on the following research question: what is the state of international scientific literature on the theme of energy efficiency and sustainability from the perspective of the universities' role?" (Salvia and Brandli 2020). To find an answer for their question, their methodology is quite simple. Using two search strings, they queried the *ScienceDirect* and *Web of Science* scientific literature databases to identify research potentially related to SDG 7, limiting their results to the prior ten years from their analysis date (2007 to 2017) and only to scientific articles, not books, edited volumes, conference papers, periodicals, or working papers because these latter pieces receive less scrutiny before being published (Podsakoff 2005). **Tables 1** & **2**, replicated from Salvia and Brandli, succinctly show the structure of their methodology. In the results section below, this paper queries the exact parameters for the same timeframe and adjusts the timeframe to include the most recent five years of data (2018-2022).

Table 1. Search strings used for the systematic review

Search string 1	"energy sustainability" (topic, abstract, title/abstract/keywords) AND "universit*" (topic, abstract, title/abstract/keywords)
Search string 2	"energy efficiency" (topic, abstract, title/abstract/keywords) AND "universit*" (topic, abstract, title/abstract/keywords)

Table 2. Selection criteria for the systematic review

Criterion	**Inclusion**	**Exclusion**
Time Frame	2007-2017	Any study published before 2007 and after 2017
Language	English, Spanish or Portuguese	Any other language
Publication Type	Peer-reviewed academic journal (Articles)	Any other type (e.g. books, contributions to edited volumes, conference papers)
Research area	Energy, Engineering, environmental science, social sciences	Any other research area

2.2 Keyword, Clustering, and Similarity Analyses

In the description of their methodology of article classification, Salvia and Brandli do a good job of defining the four categories of classification, but they do not explain at all *how* they classified the articles as they did. Without assuming too much, it is probably most easily implied that they "handpicked" the articles for each category by reading them. In correspondence with Salvia, it was confirmed that the entire text of the body of the article was used for classification, but it was not made clear whether the authors read each individual article or if they used text analysis or NLP tools to classify the articles. For this study, full texts of the articles were not acquired, so classification analysis using NLP techniques was performed on the abstract of each article using three methods: keyword, clustering, and similarity analyses. Prior to running any of these analyses, some preprocessing of the data was required, including removing unnecessary attributes, standardizing attribute titles, types, formats, and sizes, merging the data from each database, deleting records with NULL values, and deleting duplicate records (preprocessing and analyses Python scripts will be submitted with this paper).

Keyword analysis was applied to the collections of the abstracts as a whole, for both the original dataset (parameters identical to Salvia and Brandli's outlined in **Table 1** & **2**) and the dataset updated for more recent articles (2018-2022). The abstracts were individually tokenized, and parts-of-speech tags were applied to the tokenized words. The words were then collected in an array that lists the word and the count of how many times the word appeared throughout the abstracts. Stopwords—common words like "the", "and", or "in"—were removed from these collections, both a standardized list of stopwords and a localized list identified through the first collections output (just removed three results: "paper", "study", and

"results"). The final process applied to the keywords was network analysis, which found connections between keywords that occurred in the same abstract.

Using Term Frequency-Inverse Document Frequency (TF-IDF) and *k*-means clustering, four collections of the abstracts were identified for analysis as a potential way to classify the abstracts. TD-IDF is a method of counting terms in a document then assigning a weight to those terms based on their importance within that document, in this case a single abstract is considered a document. Each term and document are then placed in a vector, or table, where the terms are in the attribute position and the documents are in the records position. Within this vector, a certain number of observations are produced that can be plotted on x and y coordinates. Finally, the unsupervised algorithmic *k*-means clustering technique will calculate based on the specified number of clusters desired (in this case, four) and will then label each abstract with a number (0-3) based on the predictive modeling of *k*-means clustering.

Two forms of similarity analysis were performed on the abstracts: Jaccard similarity coefficient and cosine similarity. The former is the simpler equation, dividing the size of the intersection of a set by the size of the union of the set. Applied to texts, all matching words are the intersection, and the union is the total set of words. The larger the intersection, the larger the similarity between texts. Cosine similarity uses much more complicated math. Basically, it uses TF-IDF again to create vector observations of the texts that can then be plotted three dimensionally. Measuring from zero to the three-dimensional point of the observation of two texts, a cosine angle can be determined, and the smaller the cosine angle the more similar the two texts are to each other. Each method returns a ratio between 0 and 1, with scores closer to 1 having a higher similarity. For this study, the textual descriptions of the four categories in SDSN Australia/Pacific's *Getting Started with the SDGs in Universities* were compared using Jaccard and cosine methods to each of the abstracts to return a similarity score for each method. For each of those methods, the highest score across the four texts was then used to place each abstract to one of the four categories.

3 Results

3.1 Systematic Review and Descriptive Analysis

The exact search parameters outlined in the methodology section were used to try to replicate Salvia and Brandli's results, unsuccessfully unfortunately. Where their initial string queries produced 218 and 675 articles for strings 1 and 2 for the *Web of Science* database and 143 and 581 articles for strings 1 and 2 for the *ScienceDirect* database (**Figure 1**; 1617 total between the four searches), the updated query only produced 7 and 313 for *Web of Science* and 6 and 196 for *ScienceDirect* respectively (at roughly a third of the original amount at 522). Change over time in the databases was expected, but not in this direction or to this degree. Perhaps with time, it was posited the databases would add journals which would increase the numbers for articles the queries would produce, so the dramatic drop in the volume of articles is curious. Regardless of the reason why, fruitful analysis is still possible.

Figure 1 also shows that after some preprocessing removal of duplicate articles between the two databases, as well as a close reading of titles and abstracts, Salvia and Brandli cut the

original article count to 545, which is much closer to where this paper's analysis will begin with 403 articles after removing duplicates. Summary statistics were also not that far off. In the original analysis, the 545 articles represented 149 different publications, with just 15 of those publications accounting for nearly 60% of the articles produced. For the 403 articles produced for this analysis, 138 publications are represented, with the top 15 accounting for roughly 53% of the articles (**Figure 2**). Ten of the 15 publications in the new list are also listed as Salvia and

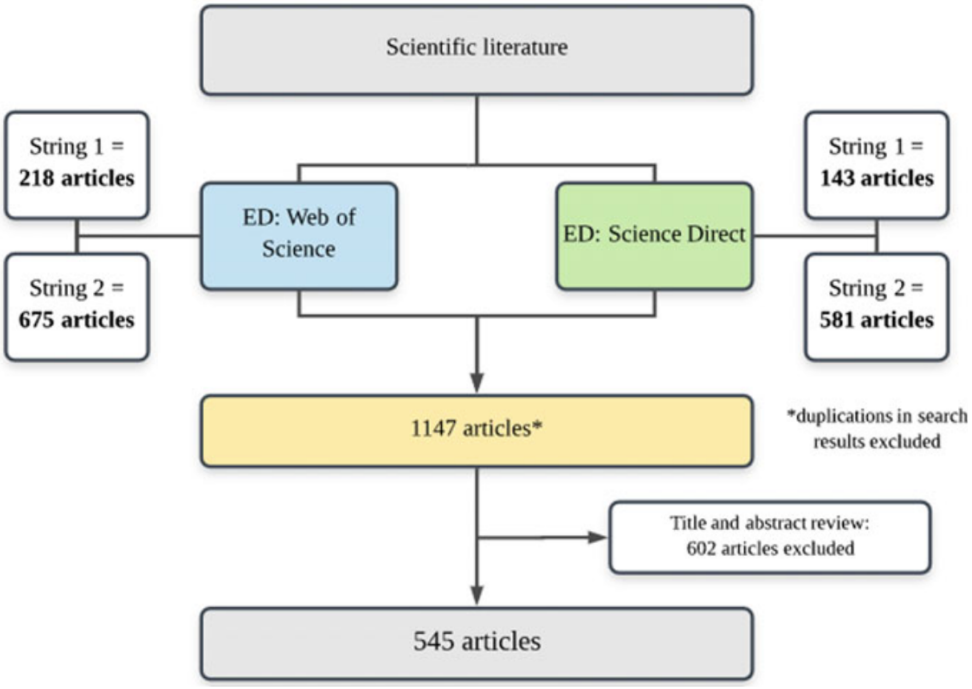


Figure 1. Mapping the systematic search for articles. *Source* Salvia and Brandli (2020) and Schulze (2016)

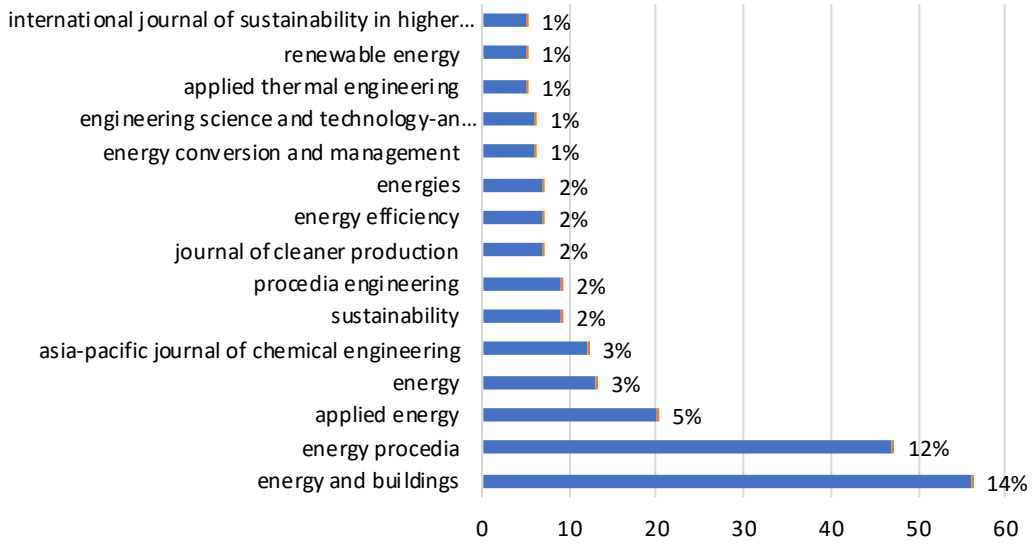


Figure 2. Number and percentage of articles per journal for 2007 through 2017 (original in Appendix)

Brandli's top publications, with *Energy and Buildings* topping both lists. Furthermore, researchers have shown more interest the topic over the decade, with a clear trend of increasing publications culminating at over a quarter of them in 2017 (**Figure 3**). This trend is nearly identical to the one Salvia and Brandli identified.

Updating the data for the past five years of publications (2018-2022), the patterns look similar, with the top 15 publications accounting for over half of the articles (57%) and the trend in volume continuing to rise albeit more slowly. The total number of articles and publication sources for this five-year period outpaced the prior decade, with 514 articles from 147 journals. Though *Energy and Buildings* is still toward the top of the list (21 for 4%), *Sustainability* and

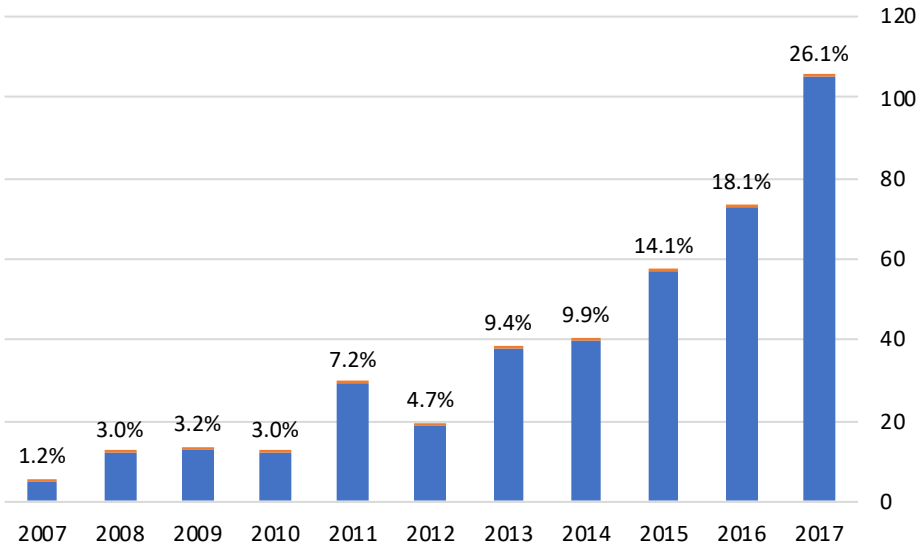


Figure 3. Number and percentage of articles for 2007 through 2017 (original in Appendix)

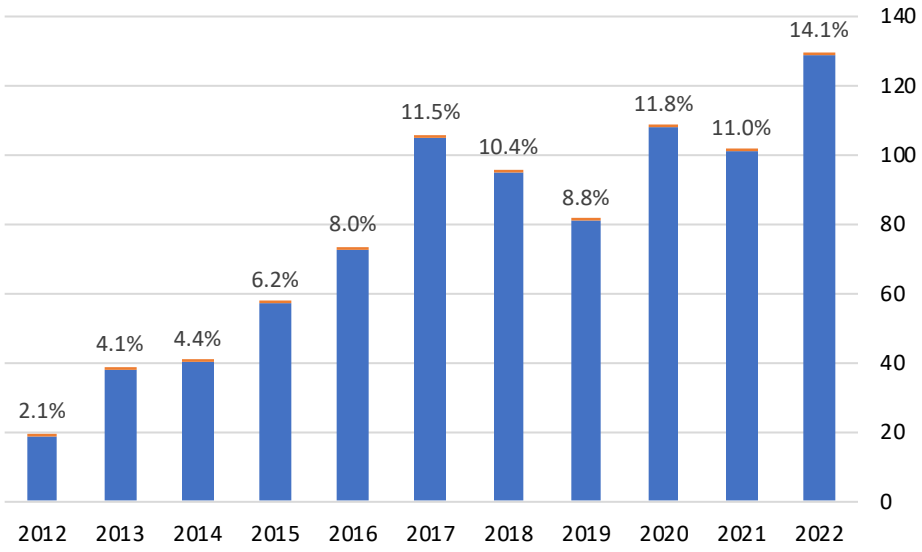


Figure 4. Number and percentage of articles for 2012 through 2022

Energies—both of which were in the top 15 but with much fewer articles—nearly doubled and tripled *Energy and Buildings* (40 for 8% and 57 for 11%, respectively). Only seven of the top 15 from Salvia and Brandli's list carried over to the updated list for the more recent publications. Though the growth in the number of articles published has slowed, the trend is still upward (**Figure 4**). The numbers dipped slightly in 2018 and again in 2019, but they bounced back in 2020 and saw their largest production in 2022.

3.2 Keyword, Clustering, and Similarity Analyses

As expected, across all abstracts, the highest frequency keywords produced by the analysis include: "energy", "university", "efficiency", and "sustainable". These were part of the original search query for article, so it is no surprise that they are highly represented in keyword frequency. Other keywords with high counts seem to fit nicely into one of the four abstract classifications modeled by Salvia and Brandli: 1) learning and teaching; 2) research; 3) organizational governance, culture and operations of the university; and, 4) external leadership. The word "research" has high frequency in the original dataset (136 instances) and words like "data", "analysis", "model", and "method" suggest other content related to research in both datasets. **Table 3** lays out other potential matches for the four categories and **Figure 5** displays the keywords in a word cloud for the 2018-2022 dataset:

Table 3. Possible classifications of keywords

Learning and teaching	"presents", "students", "case"
Research	"research", "analysis", "method"
Organizational governance, culture and operations	"campus", "buildings", "system"
External leadership	"environment", "development"

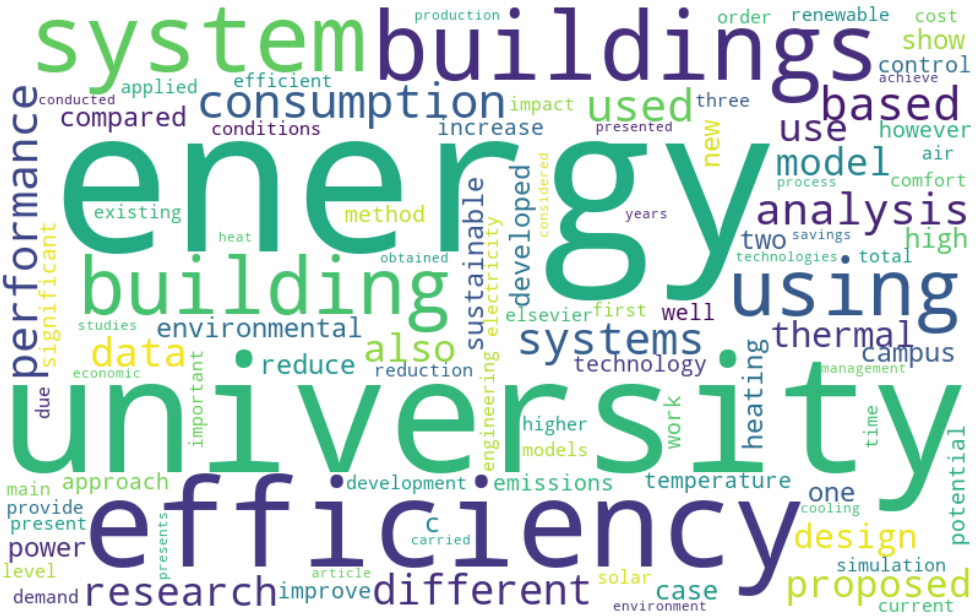


Figure 5. Word cloud for keywords in 2018-2022 dataset (2007-2017 word cloud in Appendix)

Connections between these keywords can be visualized through a keyword network analysis, which creates co-occurrence lists of the keywords and plots nodes and edges that display the frequency and connects between the keywords. Larger nodes denote higher frequency, and thicker edges denote higher instances of co-occurrence. **Figures 6** and **7** show a circular and random representation of the network analysis:

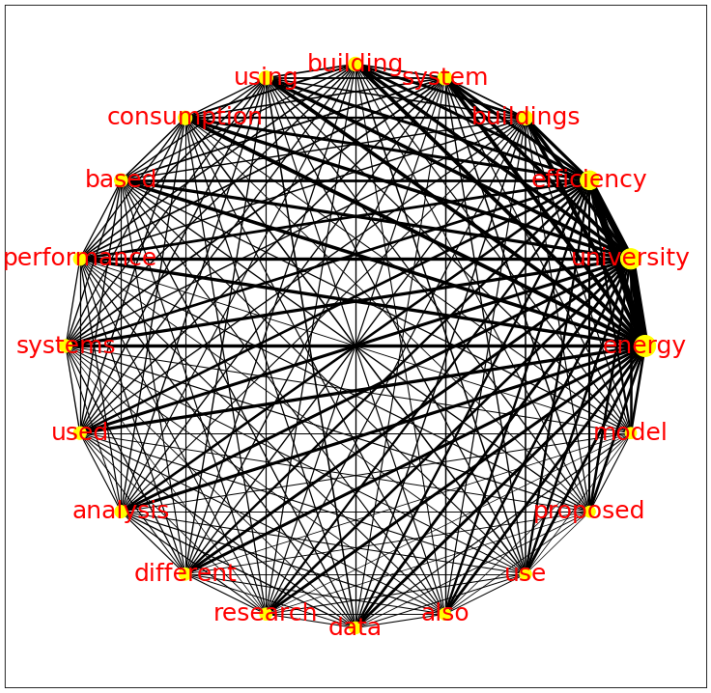


Figure 6. Circular keyword network analysis for 2018-2022 dataset (further results in Appendix)

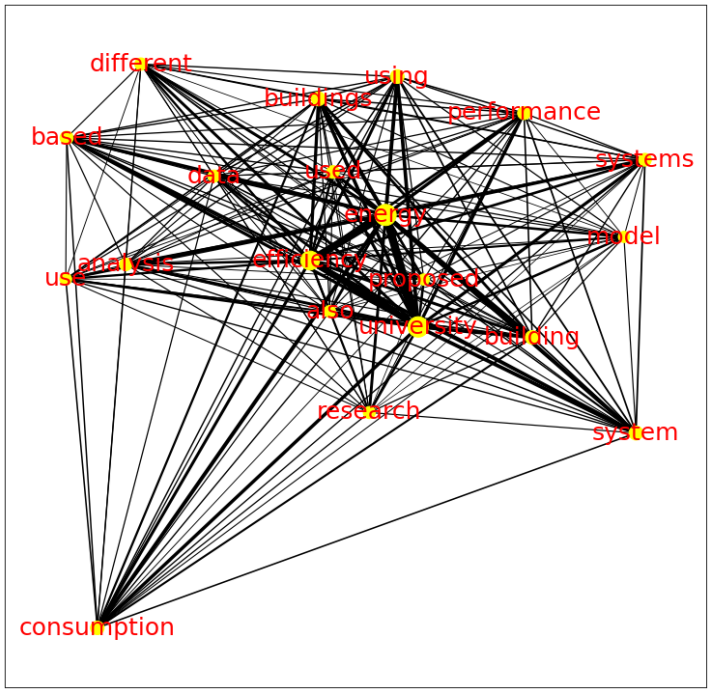


Figure 7. Random keyword network analysis for 2018-2022 dataset

Where the keyword analyses provide insight over the scope of all the abstracts in the datasets, *k*-means clustering can possibly identify the characteristics of a preset number of clusters or bins that the article abstracts fall into. For the purposes of this study, Salvia and Brandli identified four categories into which they classified the articles: 1) learning and teaching (Filho's curriculum greening); 2) research; 3) organizational governance, culture and operations of the university; and, 4) external leadership. The question is: can the unsupervised learning of *k*-means clustering make predictable categories that match with those of Salvia and Brandli? For results, *k* equaled four, outputting four clusters for each dataset and returning four groups of the top 30 keywords per cluster. Theoretically, the words in those clusters would correspond to words that identify the four categories above. The challenge, however, is that the clustering produces many duplicates over each cluster (see Python scripts and outputs for full results), so it perhaps makes most sense to identify words in each cluster that do not appear in any other cluster. **Tables 3** and **4** show the words that do not repeat over each cluster for the 2007-2017 dataset and the 2018-2022 dataset. For the most part, it does not appear that the clusters pre-

Table 3. Non-repeating words per cluster for 2007-2017 dataset

Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**
impact	new	data	students
measures	temperature	proposed	management
order	experimental	method	social
reduce	one	obtained	education
project	compared	electricity	process
savings	main	conditions	higher
	control	network	knowledge
			engineering
			implementation
			role

Table 4. Non-repeating words per cluster for 2018-2022 dataset

Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**
control	c (program)	sustainable	solar
design	elsevier	development	renewable
indoor	compared	sustainability	electricity
air	method	environmental	demand
savings	show	new	increase
temperature	article	emissions	electrical
	engineering	education	photovoltaic
	work	institutions	cost
	technology	one	generation
	network	two	water
		strategies	

dict the expected categories. Cluster 4 for the 2007-2017 dataset includes the words *students*, *higher*, *education*, *knowledge*, and *engineering*, which might suggest learning and teaching, but it is not necessarily obvious. The other clusters for that dataset do not seem to suggest clear meanings that correspond to the expected clusters. Similarly, for the 2018-2022 dataset, cluster 1 includes words that include *control*, *indoor*, *air*, *savings*, and *temperature*, which could perhaps suggest operational control over HVAC systems. Overall, for this dataset, there does not appear to be correspondence to the categories identified by Salvia and Brandli. Though *k*-means clustering produces interesting results, it has limited import for producing meaning out of the abstracts for each dataset.

The final analytical method is text similarity, using two different techniques: Jaccard indexing and cosine similarity. Recalling that each abstract in the database was compared to each of the descriptions of the four categories of contributions universities can make to sustainable development, scores were rendered for text similarity based on the technique when comparing abstract to description. Admittedly, neither technique produced great results, with the highest score a Jaccard comparison produced being 0.141 and the highest score a cosine comparison produced being 0.528 (**Table 5**). The average scores by technique were

Table 5. Minimum, maximum, and average Jaccard and cosine scores for 2018-2022 dataset

JACCARD INDEXING	**Minimum**	**Maximum**	**Average**
Learning and Teaching	0.025	0.126	0.064
Research	0.022	0.118	0.062
Organizational Governance	0.021	0.13	0.064
External Leadership	0.028	0.141	0.072
COSINE SIMILARITY			
Learning and Teaching	0.006	0.301	0.05
Research	0.012	0.528	0.076
Organizational Governance	0.016	0.279	0.084
External Leadership	0.008	0.195	0.051

closer to each other but low, with Jaccard between 0.062 and 0.072 and cosine between 0.050 and 0.084. Still, by identifying the max score per article across the four categories, the abstracts can be categorized into each field. For the Jaccard scores, most articles were assigned to the External Leadership category, followed by Organizational Governance, Learning and Teaching, and then Research. For cosine similarity, the scores were ordered: Organizational Governance, Research, Learning and Teaching, and External Leadership (**Figure 8**). Between the two techniques, cosine similarity comes closer to the proportion that Salvia and Brandli identified in their analysis, with External Leadership (Extension) and Learning and Teaching (Curriculum Greening) lower than 10% and Research and Organizational Governance (Campus Operations) accounting for most articles—the main difference being that the latter two categories were swapped in terms of most and second most (**Figure 9**). The Jaccard technique essentially produced the opposite results as Salvia and Brandli, with the top category (Research) swapped with the bottom category (External Leadership).

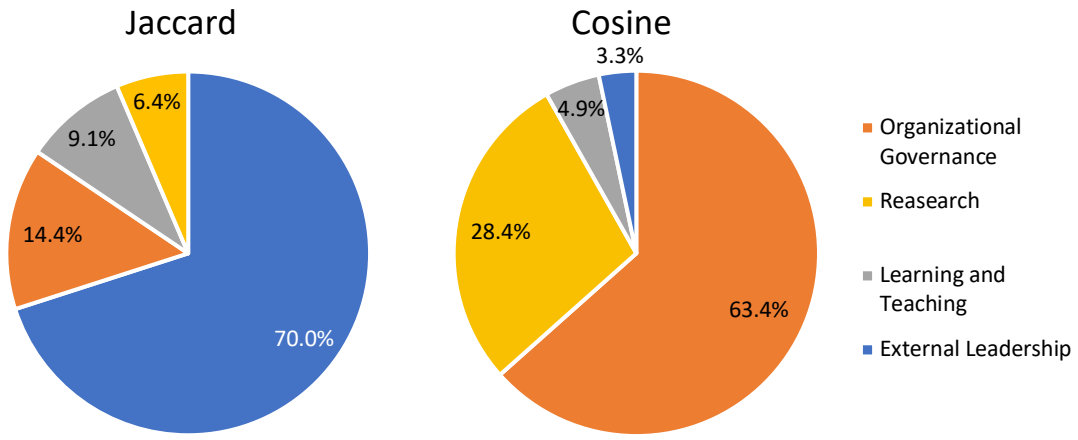


Figure 8. Proportion of articles categorized by technique for 2018-2022 dataset

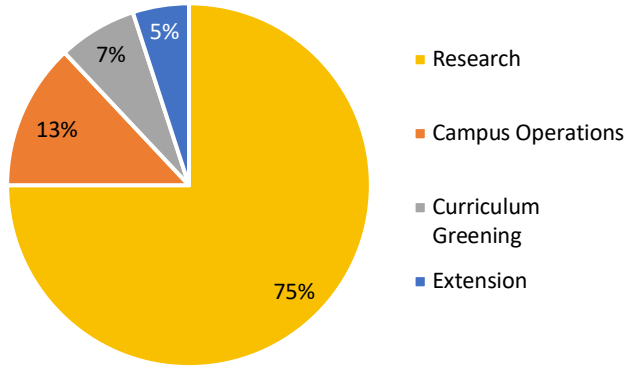


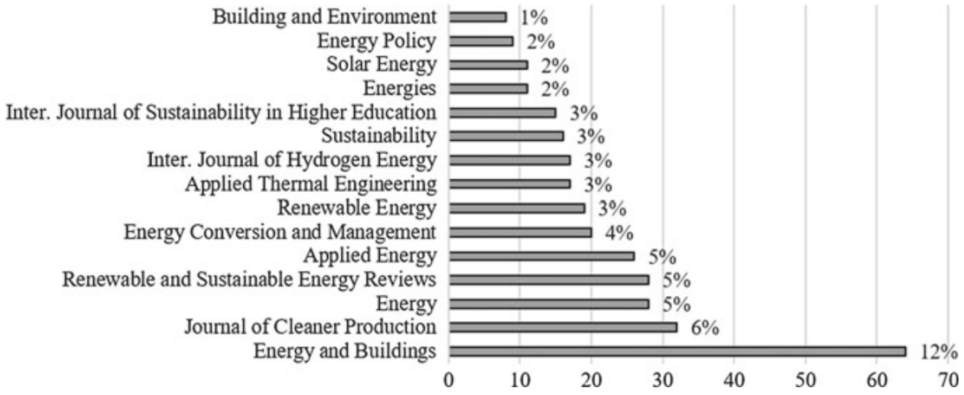
Figure 9. Proportion of articles categorized by Salvia and Brandli

4 Conclusions

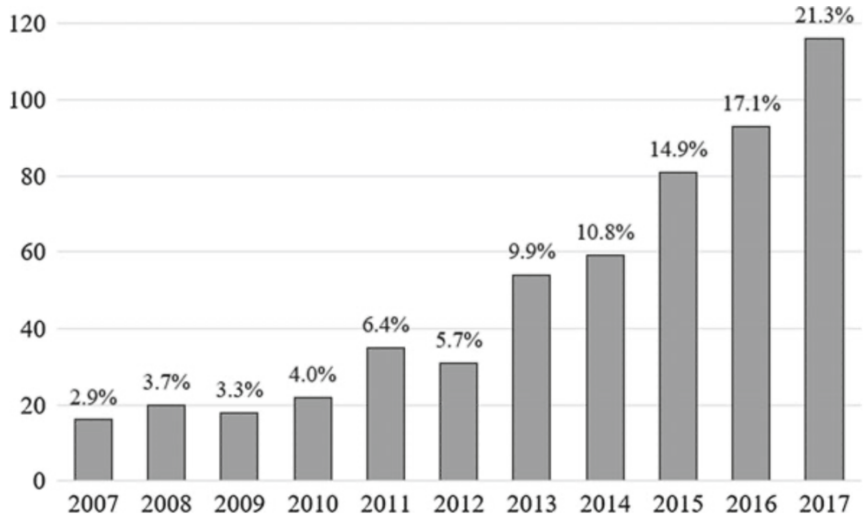
Though some interesting results were produced by the techniques deployed above, further adjustments are needed to produce confidently meaningful results. Perhaps combining methods would work. For instance, instead of applying keyword analysis to the abstracts as a whole, it could be applied to the designated categories from the similarity analysis, providing further insight into the abstracts placed into the four categories. The same could be true of combining clustering and keyword analysis or similarity analysis. Additionally, for the similarity analysis, some initial refining of the comparison texts could produce better results when the analysis is engaged. Regardless, these techniques show promise and when combined with Salvia and Brandli's original methodology can provide further insight into the roles universities play in sustainable development. Furthermore, by updating the timeframe of Salvia and Brandli's study, it is clear that the university's contribution to energy efficiency and sustainability is still a growing topic of interest. As far as this study's broader applicability to the study of universities and sustainable development, that is a question left to another day to be answered but perhaps a step closer has been taken.

APPENDIX

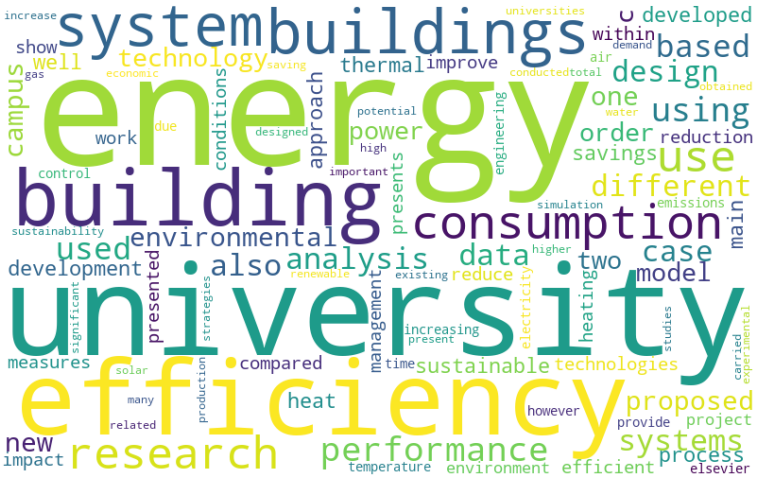
Original top 15 publications by number and percentage in Salvia and Brandli



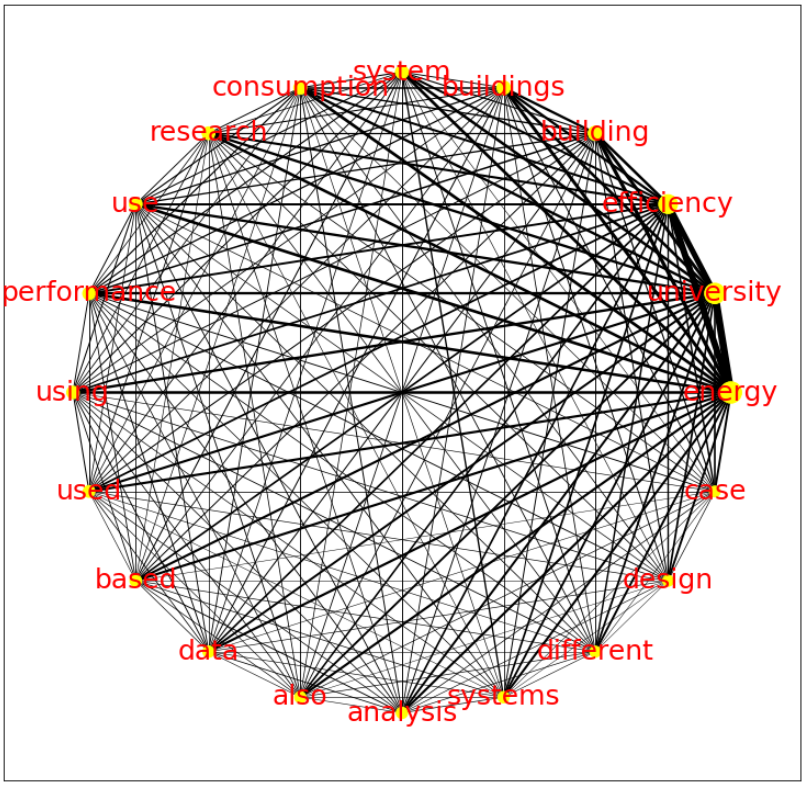
Original breakdown of annual publications by number and percentage in Salvia and Brandli



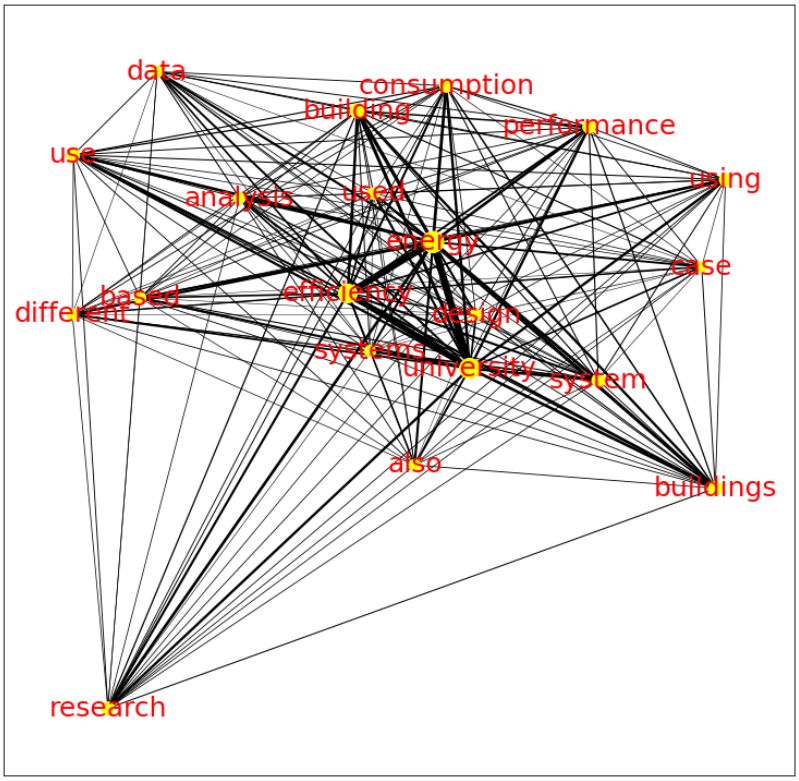
Word cloud for 2007-2017 articles



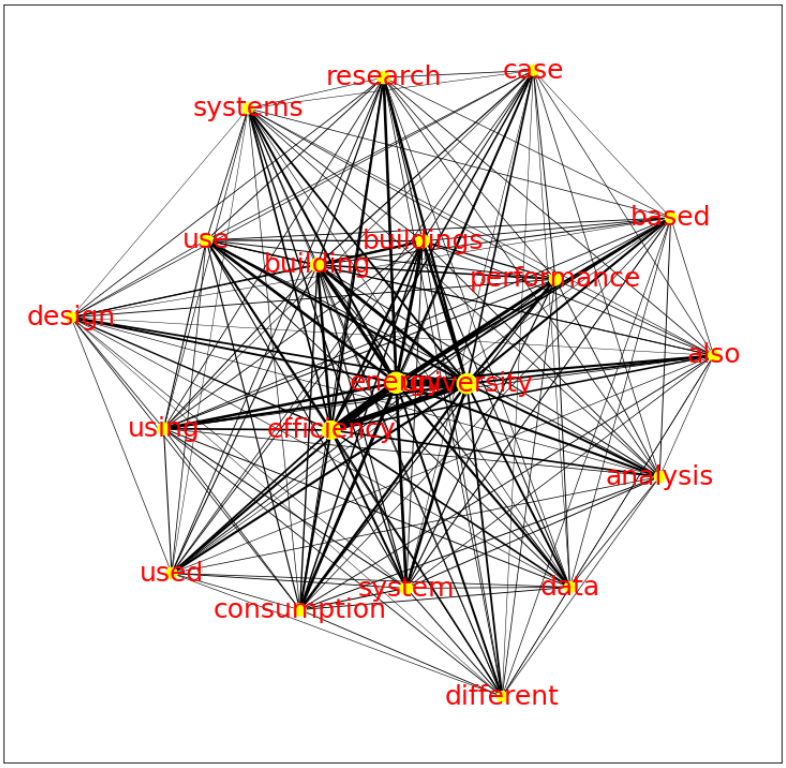
Circular keyword network analysis for 2007-2017 dataset



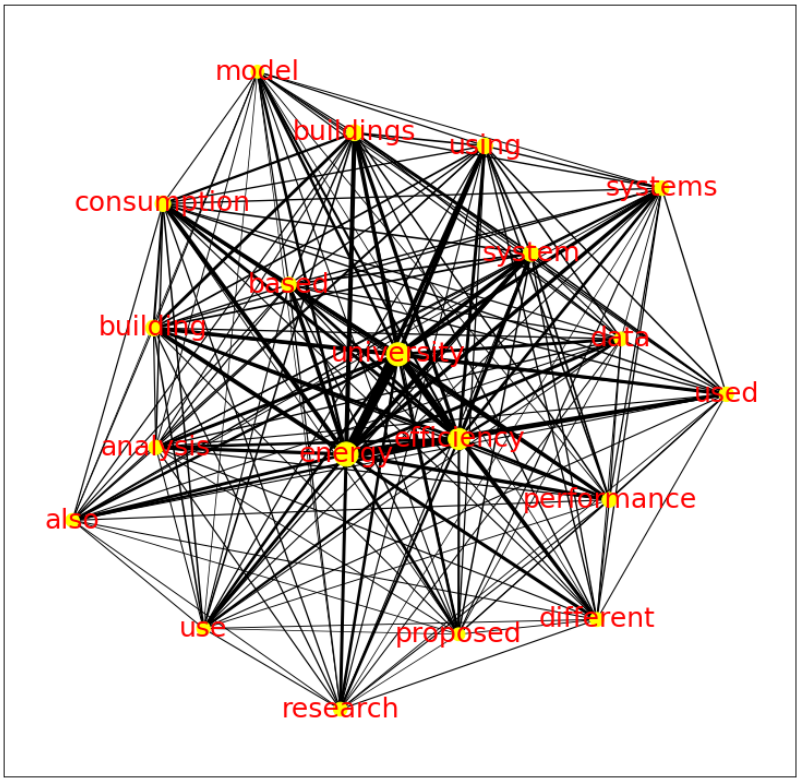
Random keyword network analysis for 2007-2017 dataset



Spring keyword network analysis for 2007-2017 dataset



Spring keyword network analysis for 2018-2022 dataset



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