

# Renewable Energy Focus

## Using Text Mining and Topic Modelling to Understand Success and Growth factors in Global Renewable Energy Projects

--Manuscript Draft--

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<b>Abstract:</b>	Renewable energy (solar, wind, geothermal and hydrogen) are means by which corporations and government hope to mitigate the effect of climate change. However, literature is rife with examples of renewable energy projects not being able to deliver as promised, with difficulties like energy transportation, energy output and subpar financial outcomes. Yet, the sector has experienced exponential growth in recent years, with new projects being continually sanctioned. This paper aims to utilize the method of text mining and topic modeling to probe why this growth occurs. Additionally, we will use these data analytic methods to rank, understand, and discuss contributing factors to this growth, by analysing a collection of 100 peer reviewed scientific articles which specifically discuss "renewable energy project success". The papers selected encompass policy, economics, technology, and engineering. Our results indicated that "softer" non-financial factors were more prevalent growth factors, but that financial considerations were not far behind.
<b>Response to Reviewers:</b>	

## Changes in response to reviewer comments

The reviewer comments are reproduced below, with our response given in bold italics below each point.

In addition to these changes recommended by the reviewers, some text (in particular in the Introduction) has been somewhat rewritten for increased clarity of presentation.

### **Reviewer #1**

Comments to the Author

Comments on Manuscript Number: REF-D-22-00297 “Using Text Mining and Topic Modelling to Understand Success and Growth factors in Global Renewable Energy Projects”

1. The journal's guidelines should be followed by authors.

***This change has been made.***

2. SCI literature should be enhanced and summary should be given in text.

***This change has been made. We have included a new paragraph and rewritten some aspects of the text for better clarity.***

3. There is no well explanation what an essential difference appear between previous other/same reviews in this field. It would be recommended to list shortly the achievements of each of these books and papers etc.

***We have included some comments in relation to this point, but truthfully, what we are trying to demonstrate is that that topic modeling is something not generally undertaken within the renewable energy sphere. This is the novelty of our method. While there are authors who have used this method in the past, it has been only with reference to journalistic articles, and within a highly localized domain. The only other major review of this nature was by Bickel in 2019, where he reviewed renewable energy articles using topic modelling, but within sphere of materials science, (biological) process engineering, and (digital) monitoring and control systems sphere.***

***Therefore, while we are indeed writing a review paper of the work of others, we are doing it computationally and looking at social science factors (essentially building on the work of Bickel) and in a novel manner.***

4. Nomenclature list should be added/checked

***This change has been made.***

# Title: Using Text Mining and Topic Modelling to Understand Success and Growth factors in Global Renewable Energy Projects

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**Abstract:** Renewable energy (solar, wind, geothermal and hydrogen) are means by which corporations and government hope to mitigate the effect of climate change. However, literature is rife with examples of renewable energy projects not being able to deliver as promised, with difficulties like energy transportation, energy output and subpar financial outcomes. Yet, the sector has experienced exponential growth in recent years, with new projects being continually sanctioned. This paper aims to utilize the method of text mining and topic modeling to probe why this growth occurs. Additionally, we will use these data analytic methods to rank, understand, and discuss contributing factors to this growth, by analysing a collection of 100 peer reviewed scientific articles which specifically discuss “renewable energy project success”. The papers selected encompass policy, economics, technology and engineering. Our results indicated that “softer” non-financial factors were more prevalent growth factors, but that financial considerations were not far behind.

**One-Sentence Summary:** This paper aims to determine and rank success and growth factors in renewable energy projects worldwide.

**Keywords (minimum 6):** Global Renewable Energy, Topic Modelling, Text Mining, Success Factors, Non-Financial Factors, Financial Factors, Holistic factors.

## 1. Introduction

As climate concerns increase, corporations and governments are seen to make increasing investments in renewable energy (RE) technologies in such diverse areas as solar, wind, hydrogen and biomass. The expectation with such renewable technology is that harmful greenhouse gases are reduced, along with other forms of pollution. There is also a secondary consideration driven more by an economic mindset; as fossil fuels become increasingly scarce, energy producers are only able to meet the growing demand at an ever-increasing cost. In either scenario however, an increase in contribution of renewable resources into the energy mix is a positive step.

However, several critical challenges still exist, and which reduces the efficacy of widespread RE adoption. First, RE tends to be a less reliable form of energy, due to the unpredictability associated with the natural environment. For instance, it was reported that in India, despite its RE footprint growing by ~20% from 2015-2020, ~15-20% of (wind and solar) projects underperformed during 2019-2020, primarily due to adverse weather conditions [1]. A mitigant to this is to use technology like batteries, but this adds capital and operational expenditures (CAPEX/OPEX) to projects that are sometimes already financially stressed. Another challenge associated with RE adoption has to do with its effect on legacy electrical grids; without a proper understanding of import capacity limits and load factors, RE can cause a deterioration of power factors and in fact escalate costs for operators [2].

The above are just snippets of issues associated with RE, its challenging path to commerciality and why widespread adoption is sometimes problematic. Despite this, investment in RE continues to build [3]. This is indeed puzzling. Since RE cannot be easily/cheaply stored, transported, has sub optimal production (at times) and is expensive to build, maintain and implement, what are the key motivating factors that are driving private and public sector stakeholders to sanction or fund RE projects? What would be the metric by which a successful RE project is defined? Is it purely perception driven or are there sound financials?

Literature itself is extremely polarized on this, with some authors arguing that economic, financial and technical metrics are key, [4, 5, 6], while others argue that political will, behavioral and social aspects are sufficient, if not more important [7, 8, 9, 10]. In Germany, Salm et al. (2016)'s research on investor's investment decisions found that factors of importance were the return of investments, holding time and technology preferences, project location and partnering investors [11]. Shrimali et al. (2014) identified that the existence of any government interventions which supported the financial needs of the RE sector had significance in propelling India's RE footprint [6]. In contradiction, Masini and Menichetti (2012) study on European investors identified that technical competencies for RE technologies had a stronger impact on investment decisions compared to the effectiveness of policies [9]. Maqbool's study in Pakistan (2018) found that critical success factors behind RE projects were communication, teamwork, technical, organizational factors [10]. There therefore seems to be a myriad of literature available that each detail what are the key RE success factors. Truly, it would take a significant amount of time to assess, and objective ranking would prove quite challenging.

This paper will use a more efficient way to process large volume of research articles, via text mining and topic modelling. This method has been used in areas as diverse as social science [12], journalism [13], engineering and data science [14, 15]. However, to our knowledge, topic modelling is relatively nascent in the RE space, with Bickle (2019) using topic modelling to study the transition of topics being discussed in scientific literature from 1990-2016, but primarily in material science and process engineering. He concluded that general aspects of social science related to economic, environmental and political issues must be better correlated to engineering topics like modern technology for balanced discourse [16]. In a separate study, KyuSik et al (2015) has tried topic modelling on newspaper articles from Korea, in an attempt to forecast the growth potential within the country [17]. Dehler-Halland et al (2021) too attempted topic modelling on German media articles; the authors attempted to understand the changes that took place with time and in particular the emotive sentiment expressed in published articles. Both studies were highly localised and did not use scientific articles in deriving the conclusions [18].

## 2. Scope & Methods

This paper will attempt to understand and rank key determinants in RE project success and growth. Given both the polarization of opinion as well as sheer volume of discourse in academic literature in this area, this question lends itself quite readily to methods in data science related to ‘Text Mining’ and ‘Topic Modeling’ (TM+TM) [18, 16].

Both are part of the Natural Language Processing (NLP) set of tools and will be used to understand the patterns present in unstructured data sources like words, phrases, sentences, and strings of text. NLP algorithms transform unstructured text formats into structured data, enabling unsupervised machine learning processes to be applied. The algorithms automate procedures of categorising, clustering, tagging, and classifying texts, and can extract information on sentiment, topics or intent, all with the goal to uncover hidden structures or commonalities binding the text [18].

For this paper, NLP is implemented using Latent Dirichlet Allocation (LDA) and Non-Negative Matrix Factorization (NNMF). LDA uses statistics to identify hidden structures within text, while NNMF utilizes linear algebra. By applying weightages to individual words based on their similarities, each algorithm can cluster the family of words into a topic [19, 20]. A key assumption in LDA is that each text block contains ‘ $k$ ’ number of topics, represented by the word distribution [21].

The algorithms are applied to a collated collection of 100 scientific articles with the terms “renewable energy success” present as a subject matter. The selection of scientific articles was based on the criteria that (a) each research article should explain factors of success and growth in renewable energy projects, and (b) the understanding of success was from each article’s own definition of success. We have not analysed veracity of the financial metrics, like return on investment (ROI), nor have we considered technical outcomes like the output capacity and facility uptime. Rather, we will only discuss said success factors within the socio-economic sphere (with considerations to policy, economics, and technology readiness) across global datasets. Shown in Figure 1 is the breakdown of the source material. While we have attempted to be unbiased in our sampling, a vast proportion of authors publish in ‘Energy Policy’, followed by ‘Sustainability’ and ‘Energy’. To offset this, we also collected articles from unique journals, which we collectively refer to as “Others”. In combination, this offsets potential bias from the dependence on 1 or 2 primary journal sources.

## Journal Source Breakdown

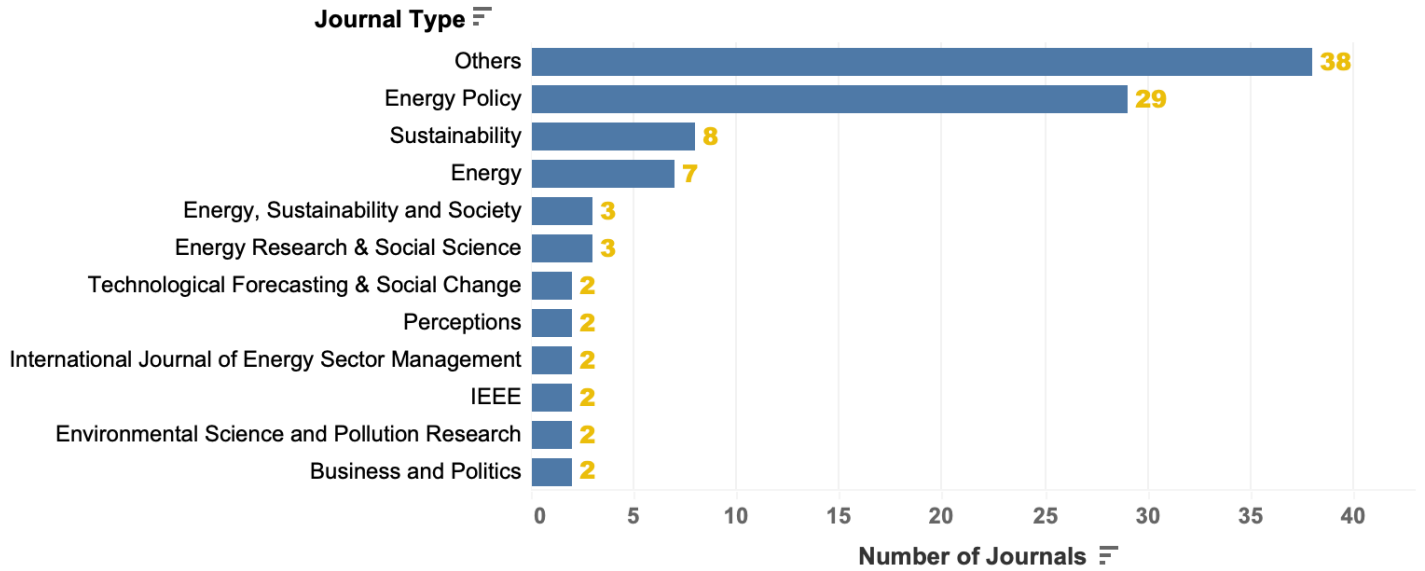


Figure 1: Breakdown of dataset, the sources of journal articles

In order to avoid extended processing times and to ensure that longer articles (with higher word counts) do not unnecessarily skew the evaluation, only text from the abstract and conclusion sections were analysed, the assumption being that they are the most succinct and distilled form of information pertaining to the article. The working hypothesis is that, while brief on detail, these 2 text blocks still contain sufficiently insights to arrive at a meaningful conclusion. Each article is briefly checked to ensure the relevancy to the main question being addressed. Pre-processed, the total word count from these 100 articles was ~76,311 words.

### 2.1 Data Preparation and Preliminary Exploration

A complete flow chart highlighting the NLP process is given in Figure 2. A modified “stop word” dictionary was created to remove words such as “renewable”, “energy” and “success”, as these would be occurring at a high frequency, thus affecting the resulting distribution of words. The process of “tokenization” and “lemmatization” is as done in other NLP processes [22]. The output of this process was visualized using a word cloud where the top 10 most frequent words were highlighted; indeed, a preliminary assessment of the word cloud indicated that the randomly selected articles were suitable for use in the next stage of analysis (Figure 3). Post-processed, the final output is a database of ~40,263 words, or 47% of the original dataset.

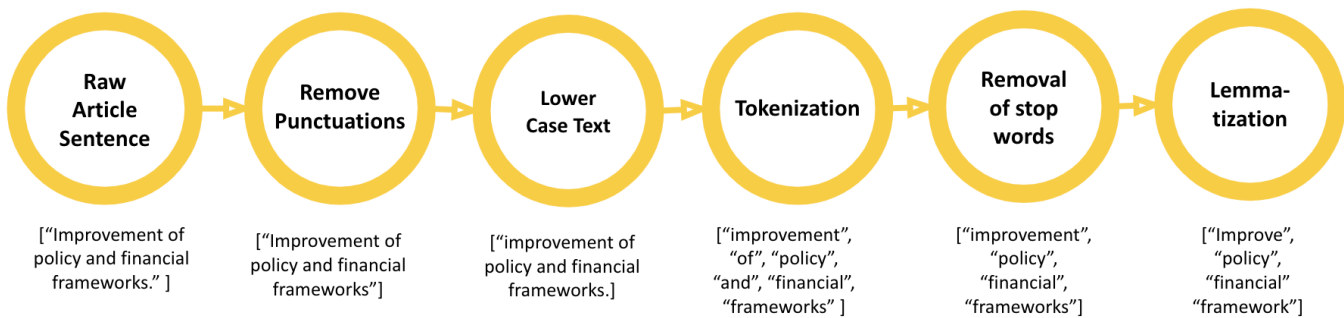


Figure 2: Flow chart highlighting text processing stages applied to the scientific articles in question.



Figure 3: Top 10 words with highest frequency.

## 2.2 Topic Modelling with LDA

The LDA algorithm is implemented via the use of 2 open-source python libraries, namely “Gensim” and “Mallet” (MACHINE Learning for Language Toolkit) (hereafter referred to as ‘Gensim LDA’ and ‘Mallet LDA’ respectively). The former creates a unique dictionary like structure where each word is given a unique id and frequency count of occurrence and also doubles as a visualization library. Mallet is used complementarily to Gensim for coherence analysis. Coherence here is a measure of effectiveness of the topic model. A coherence score measures the degree of semantic similarity between the top scoring words in each topic and also facilitates decisions relating to the optimal value of ‘ $k$ ’ (the number of topics). As ‘ $k$ ’ varies, so too does the coherence score, with higher coherence scores generally representing better model.

Figure 4 shows the coherence score obtained, as a function of the number of topics. We define the optimal number of topics at the first point of inflection, and as shown in the figure, this occurs after 5 topics. In order to demine topic distinctiveness and prevalence, an intertopic distance map (Figure 5, left) is used, with each bubble representing a topic. Through the use of multidimension reduction scaling (PCA/t-sne), the topic’s probability distribution can be visualized to determine the degree of overlap or similarity. The bubble size itself is a measure of the topic prevalence. From the visualisation, we observe that (a) topics 1-3 and 3-2 overlap very slightly, while topic 4 and 5 are uniquely distinct. For the former, we observe that the overlap is insignificant and thus, the 5 topics can be considered distinct enough to take this work forward. Furthermore, topic 1 appears to be the most prevalent topic, constituting 29.9% of the tokens. Figure 5 (right) is a sequence of stack bar graphs with the most prevalent words per topic. As an example, the top 3 words to appear under topic 1 are “policy”, “technology”, and “industry”, and are highlighted by the blue bars.

However, in topic modelling, the relevance of a word is very important, as it leads to the topic being more obvious. This is where a relevancy metric,  $\lambda$ , is useful [23], and is defined as:

$$r(w, k | \lambda) = \lambda \log(\phi_{kw}) + (1 - \lambda) \log\left(\frac{\phi_{kw}}{p_{kw}}\right)$$

where  $\phi_{kw}$  is the probability of word  $w$  in topic  $k$  and  $\frac{\phi_{kw}}{p_{kw}}$  is the lift in term’s probability within a topic to its marginal probability across the entire corpus. A lower  $\lambda$  gives more importance to the term  $\frac{\phi_{kw}}{p_{kw}}$ , which in turn gives more importance to topic exclusivity. Given in Figure 6 is the effect of reducing  $\lambda$  by 48%; the word “policy” remains unchanged, but interestingly, words like “industry” and “technology” swap places. Additionally, gone are the words “government” and “environmental” from the top 5 words within the topic, replaced instead with words like “firm” and “adoption”. For this work, we have kept  $\lambda = 1$  for the entire modelling.

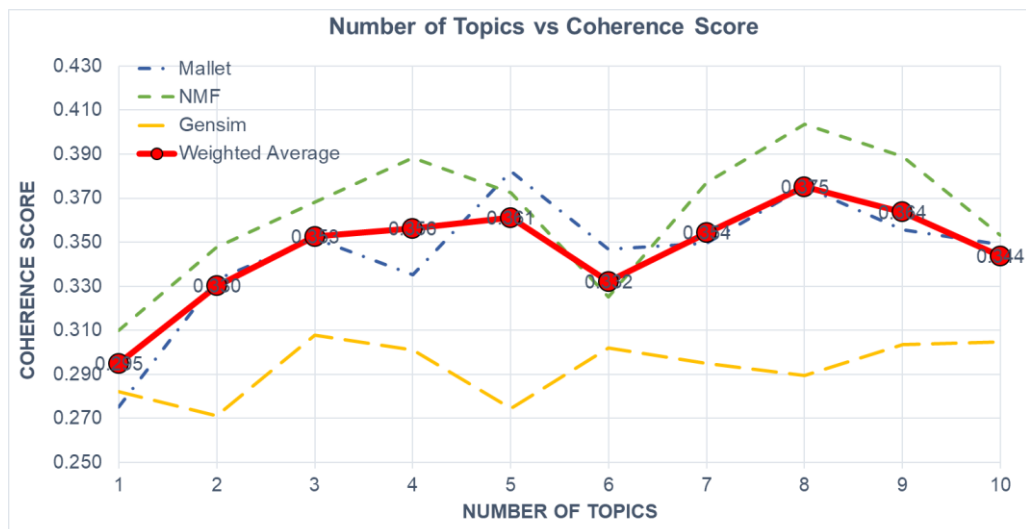


Figure 4: Coherence score as a function of topic number; generally, past 5 topics, the score does not vary significantly.

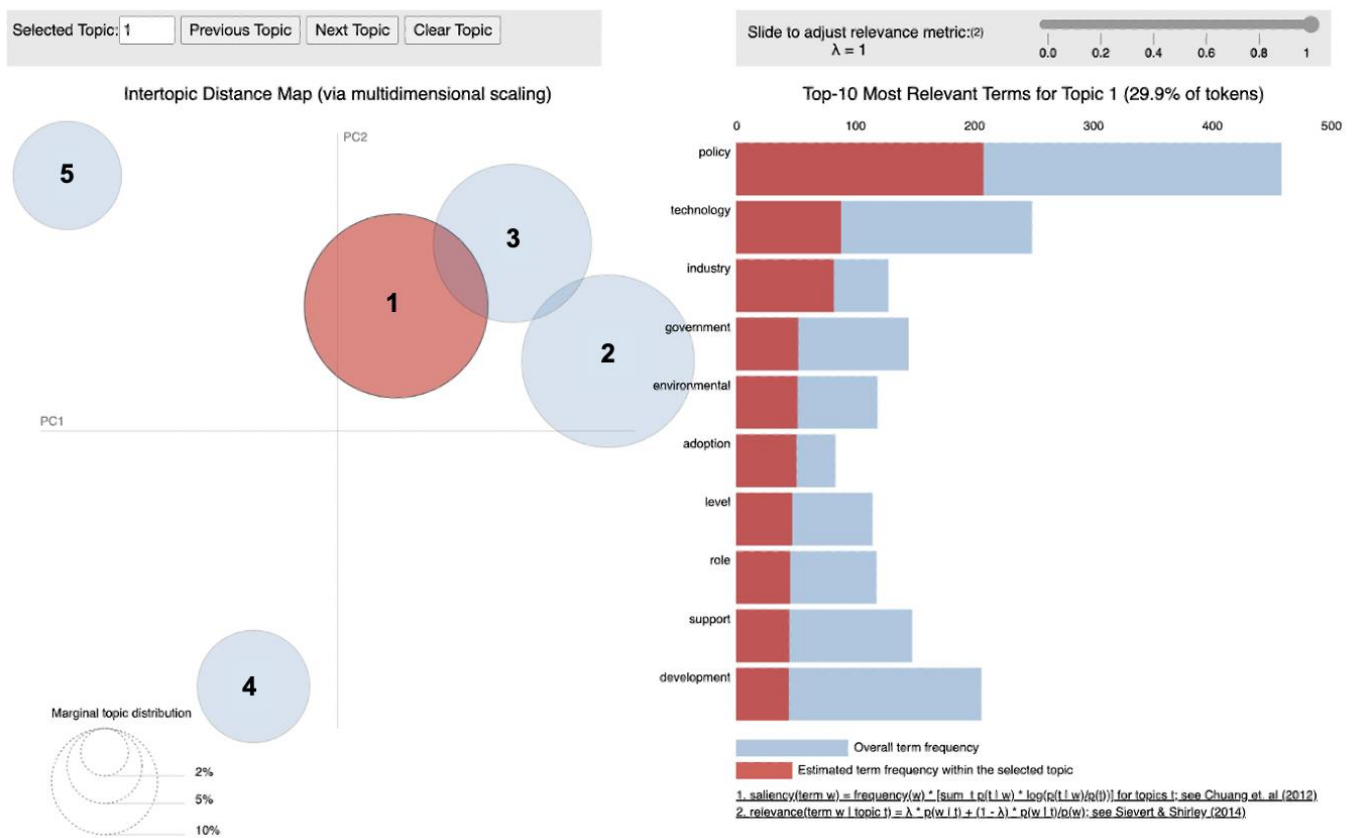


Figure 5: Topic Visualization using a Bubble map and the corresponding top 10 terms in each topic



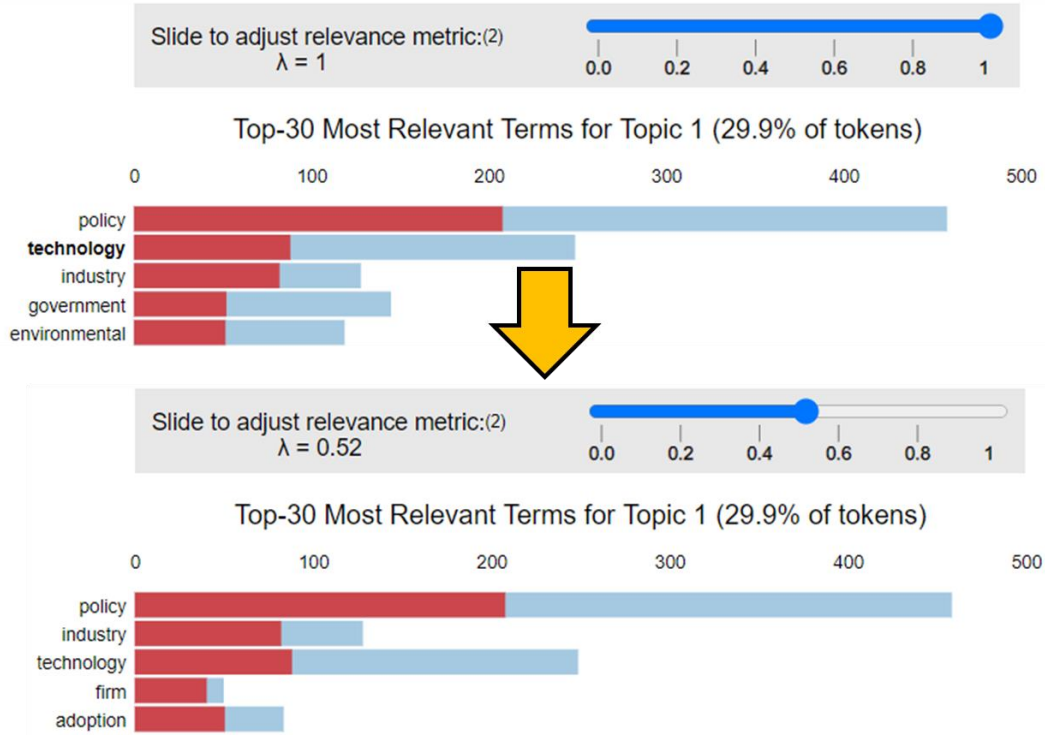


Figure 6: Effect of relevancy metric,  $\lambda$

### 2.3 Topic Modelling with NMF

As another machine learning tool, NMF is useful as it is able to dimensionally reduce the text data and create topics by grouping words with higher coherence [20]. It does this through a vector multiplication of “ $W$ ” columns and “ $H$ ” rows, with “ $W$ ” representing the weightage of each word in a sentence (‘words-topics’ matrix) and “ $H$ ” represents the words in each column (‘topics-documents’ matrix). The product, “ $V$ ” is referred to as the ‘words-documents’ matrix. In factorizing “ $V$ ” for uses in topic modeling, we are breaking down the corpus into “ $W$ ” and “ $H$ ”. As this approach is based on linear algebraic optimization, the outcome would be an approach that is independent of the probabilistic method utilized by LDA.

$$\begin{pmatrix} a & b \\ c & d \\ e & f \end{pmatrix} \times \begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{pmatrix} = \begin{pmatrix} a1 + b4 & \dots & a3 + b6 \\ \dots & \dots & \dots \\ e1 + f4 & \dots & e3 + f6 \end{pmatrix}$$

### 3. Results

Given in **Error! Reference source not found.** are the top 10 keywords per topic rank, sorted in order of importance. Each of the algorithms presents a slightly different result, although common repetitive words do occur as an output of each algorithm. It is interesting to note the order of the words themselves and how each algorithm places importance on different words.

Algorithm	Top 10 Sorted Words	Category	Sub-Topic	Key Concept	Rank Topic
Gensim LDA	'policy', 'development', 'community', 'power', 'sector', 'government', 'investment', 'state', 'country', 'program'	Qualitative	Community Development Policies	Government (Policy)	1
	'stakeholder', 'policy', 'industry', 'climate', 'trade', 'retrofit', 'efficiency', 'impact', 'analysis', 'country'	Quantitative- 'Qualitative	Industry and Trade	Public-Private (Corisking)	2
	'technology', 'policy', 'community', 'investment', 'system', 'development', 'adoption', 'support', 'financial', 'roadmaps'	Quantitative	Financial Investments	Fiscal Mechanism /Term	3
	'community', 'technology', 'policy', 'process', 'local', 'industry', 'international', 'development', 'power', 'transition'	Quantitative- 'Qualitative	Transition and Development of Local Community	Talent	4
	community', 'value', 'sustainability', 'firm', 'process', 'cocreation', 'literature', 'environmental', 'minigrids', 'support'	Qualitative	Community Involvement	Community (Support/ Involvement)	5
Mallet LDA	policy', 'state', 'level', 'country', 'electricity', 'barrier', 'support', 'analysis', 'renewables', 'article'	Qualitative	Government support	Government (Policy)	1
	community', 'local', 'industry', 'case', 'government', 'support', 'social', 'international', 'development', 'change'	Quantitative	Community Involvement	Community (Support/ Involvement)	2
	'power', 'development', 'program', 'sector', 'emission', 'cost', 'future', 'country', 'government', 'capacity'	Quantitative	Financial Requirement	Fiscal Mechanism /Term	3
	'technology', 'investment', 'stakeholder', 'role', 'investor', 'performance', 'framework', 'analysis', 'finding', 'environmental'	Quantitative- 'Qualitative	Technology investment within a framework	Public-Private (Corisking)	4
	system', 'process', 'management', 'community', 'plant', 'model', 'sustainability', 'implementation', 'adoption', 'quality'	Qualitative	Operations	Talent	5
Non-Negative Matrix Factorization	'policy', 'technology', 'industry', 'sector', 'development', 'country', 'trade', 'government', 'mix', 'firm'	Qualitative	Country-Sector development	Government (Policy)	1
	'stakeholder', 'communication', 'retrofit', 'relationship', 'team', 'organizational', 'mediating', 'method', 'variable', 'satisfaction'	Qualitative	Stakeholder Relationship Satisfaction	Public-Private (Corisking)	2
	'community', 'local', 'program', 'beneficiary', 'management', 'social', 'development', 'participation', 'partnership', 'rural'	Qualitative	Community Involvement	Community (Support/ Involvement)	3
	'investment', 'investor', 'preference', 'technology', 'portfolio', 'performance', 'financial', 'policy', 'retail', 'belief'	Quantitative	Investor preference	Fiscal Mechanism /Term	4
	'state', 'expansion', 'system', 'power', 'electricity', 'plant', 'promotion', 'fit', 'capacity', 'scheme'	Quantitative- 'Qualitative	Operations	Talent	5

Table 1: Top 10 significant words per algorithm, proposed categorization, sub-topic and key concept selection, sorted in order of importance

As an example, the results of row 1 from the Gensim LDA has sorted words: 'policy', 'development', 'community', 'power', 'sector', 'government', 'investment', 'state', 'country' and 'program'. These words are plotted in Figure 7 (left) as a function of word count (light green) and weightage (dark green). Similarly, the NMF algorithm has sorted words: 'policy', 'technology', 'industry', 'sector', 'development', 'country', 'trade', 'government', 'mix' and 'firm' in Rank 1 (word count – light blue and weightage – dark blue). Between the 2 rank 1's, there are common words: 'policy', 'sector' and 'country'.

Both algorithms give the same word count, but the algorithm weighs each word differently to topic importance. Sometimes, a word can have a high word count, but is less relevant overall. Here, Gensim LDA has weighted the word “community” higher, despite its lower word count (i.e. it is more relevant given its exclusivity).

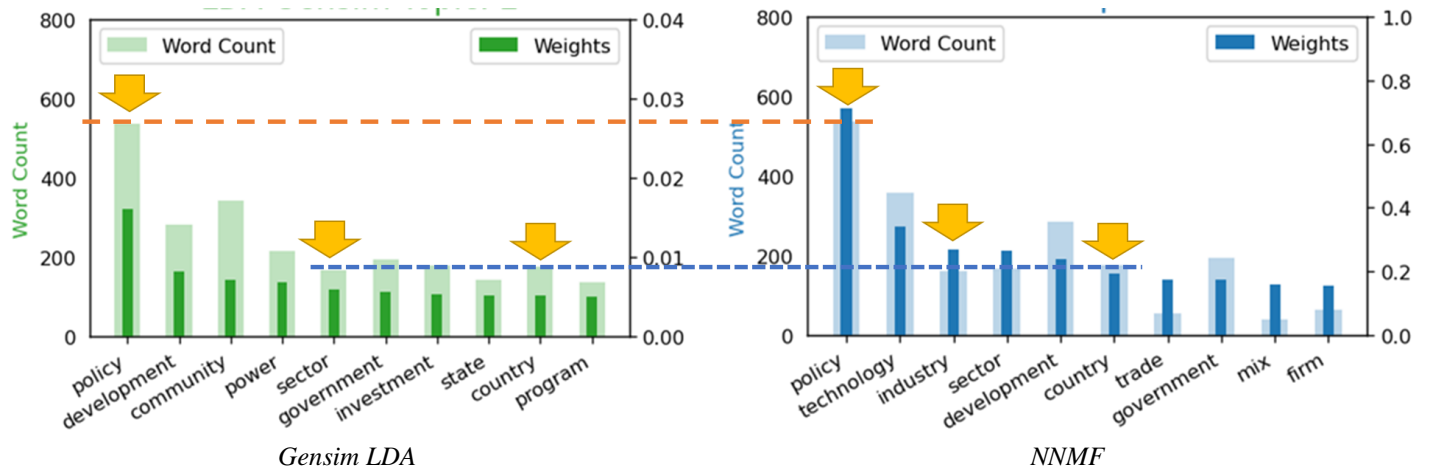


Figure 7: Frequency and weightage of top 10 words in Topic 1

We also consider the words within each topic collectively, to get a sense of whether topics can be categorised as being more ‘quantitative’ or ‘qualitative’. For instance, words like 'financial', 'performance' and 'investor' imply quantification, and thus, a subtopic of “financial performance” seems reasonable. This step is perhaps the most subjective step of this entire process and key word identification helps. The human element of interpreting, understanding, and applying a judgement as to the most suitable subtopic, based on ones understanding of the words, is something that is necessary to this process. Good topic models therefore require (apriori) that the modeler have some background knowledge of the subject matter.

We next consider all subtopics collectively and then generalise them into several key concepts, which then becomes the final topic model to be discussed in later sections. Generalisation removes some of the bias that may come about from subtopic selection and allows for comparisons between the outputs of the algorithms.

We repeat this process of (a) collating the ranking of the words with respect to count and weightages, (b) determining key words that help categorise the output as either ‘quantitative’ or ‘qualitative’, (c) deciding on a subtopic for each of the 3 algorithms and (d) generalisation of the key topics. Finally, an additional step we take is to rank the key topics. To do this, we cumulatively sum the weightage of the words from each algorithms output, normalize it before sorting it from highest to lowest. This is what is presented as “rank topic” in **Error! Reference source not found.**

### 3. Discussion and Implications

In order from most important to least, the analysis presented above ranked the following success and growth factors for RE projects: (1) Government (Policy), (2) Public-Private (Corisking), (3) Community (Support/Involvement), (4) Fiscal Mechanism /Term and (5) Talent. In looking at the results, aside from (4), all the other results speak of non-financial factors as being more important to RE projects. However, the fact that ‘Fiscal Mechanism /Term’ ranked in the list indicates that financial considerations are very important to decision makers as well.

### 3.1 Government (Policy)

In the articles analyzed in this study, we learn that Government (policy) is a broad but overarching theme for almost every paper analysed. The topic addresses a gamut of strategies, including (but not limited to) financial, research and development, infrastructure, consumer adoption rates, socio-economical acceptance of RE, and overall development of the sector. We learn that government involvement is important as a signaling mechanism to producers, of the strategy towards domestic energy resilience. Governments also act as financial buffers through subsidies and grants (tying this quite closely to the “Fiscal Mechanism/ Term” factor), which according to the International Energy Agency, has amounted to US\$180 billion in 2020 [24].

External to our articles, we find specific examples of this signaling mechanism when we look to the United States of America (USA), where State Energy Programs<sup>1</sup> or the 2005 Energy Policy Act<sup>2</sup> has contributed to RE usage growing by 42% from 2010 to 2020 [25, 26]. The introduction of energy legislation, legal consequence and government financing support has thus allowed renewables to become the fastest-growing energy source in the USA, making up close to 20% of total energy source [27, 28].

In Singapore, given its small size and interdependence to the global community, government policies tend to contain a geopolitical element e.g. development of a shared regional power grid [29] or the “SUN Cable” project between Singapore to Australia [30], aside from the more “local centric” solutions like research and development in space-saving energy storage technologies. At the national level, the government has set a mandate to increase solar usage by 7 times from its measured 2019 usage [31].

On the flip side also indicates the impact of the absence of adequate government backing. Debt-ridden economies, or countries that are dealing with socio-economic crisis will naturally have failed RE initiatives, simply because green energy is not a priority. In Ghana, goals towards 10% RE penetration rate of electricity by 2020 are failing. They have only achieved a 0.5% penetration rate since 2006, and failure was contributed to the lack of clarity in the RE policies, absence of technical regulation, legislative instruments, and regulatory assessment. Ghana’s Energy Act was not regularly assessed and updated to ensure effectiveness in meeting their set targets. Even when there were policies present, the ability to execute and review the policies to ensure that objectives are met is lacking; this too hinders development of RE projects. Subsequently, as investors lose confidence in the government’s ability to deliver, less investments will be given to future project, constituting a failure case [32]. The lack of enforcing regulations, coupled with lack of scientific and technical expertise, and high cost of capital for technologies and development, are all contributors to the large barrier of success for RE projects in developing nations like Ghana [33].

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<sup>1</sup> The State Energy Program provides both financial and technical assistance for energy projects that are coherent with nationwide green energy goals.

<sup>2</sup> The Act (passed by congress) established a legal requirement for federal agencies to derive at least 7.5% of energy consumption from renewable sources.

### 3.2 Public-Private (Corisking/ Perception)

This topic can be linked to behavioral finance and decision sciences, where perceived impressions towards the RE industry can affect investment decisions and is somewhat linked to the earlier topic of Government (Policy). In a way, it is a measure of confidence, be it towards state of technology (present or future), policy bodies, institutions, and investor experience. Private sectors are essentially profit-driven and focused on return on investments and achieving corporate objectives. However, the public concerns are more complicated, as they are driven by legislation, regulations, political opinion, risk minimization and social value maximization [34]. Public and private corporation and alliance can have mutual added value [35]. Therefore, strong ties between both is key to advancing renewables [36]. The International Renewable Energy Agency (IRENA) highlighted the need for regulatory frameworks to support renewable energy installations, as well as the need for better coordination among parties ranging from government officials to private and public corporations to workers and civil society [36]. Both private and community-based investors need nondiscriminatory market access and locally adapted instruments to participate in energy transition. Government policies can facilitate the private sectors transitions and assist in investments of RE projects.

From the topic modelling process and from the articles present in our study, we learn that ‘Public-Private Partnerships’ (PPP) are popular models for joint projects that facilitate collaboration between public and private sectors. They are long term agreements between both government and private agencies for the provision of public services. Private companies are responsible for design, construction, financing, operation management and maintenance while the public sector is responsible for distribution of energy through the national power company. Revenues are paid to the private party, backed by strong public incentives outlines in power purchasing agreements (PPA) or feed-in tariffs (FIT) [37].

Singapore operates such a model where private sector involvement comes in the form of infrastructure construction and maintenance, often supported with PPAs. Each PPA can be uniquely structured, with some organizations leasing their available space/infrastructure to the energy provider, before purchasing the energy generated at a lower price, while others receiving Renewable Energy Credits (REC) as a means to offset carbon cost. Sembcorp, for example, signed a 25-year PPA with the Singaporean National Water Agency with regards to operation of a floating solar farm in the Tengah Reservoir [38], as well as a PPA with the national carrier, Singapore Airlines (SIA) [39]. Another example is Sunseap, which is an established private sector solar operator. In this case, Sunseap operates and manages solar panels, installed on public housing in Singapore [40].

In the case of Philippines and Indonesia, FIT schemes were deployed at the same time, but the Philippines yielded better results, with 1381 MW of installed RE capacity compared to Indonesia, which only achieved 36.8 MW within the same period. One of the explanations for this disparity was investor perception associated with government effectiveness, regulation quality and legislation rules [41].

The Philippines has extensive market-based reforms that privatised a large portion of their power generation, transmission operations and distribution. They also established an autonomous regulatory agency (the Energy Regulatory Commission) which reduced subsidies but implemented performance-based regulatory mechanisms. The emphasis on performance led to a growth in investor trust, which boosted the overall RE growth rate [42]. In contrast, costs of FIT schemes were largely borne in Indonesia by the national utility system, Perusahaan Listrik Negara (PLN). The PLN has a monopoly on energy, allowing them to determine the payment that private players

receive, while also reducing the competitiveness of independent power producers for energy market share. There was also perceptions of lack of transparency and fairness in PLN led public-private partnerships. Frequent policy changes also created a perception of unpredictability and mistrust, which lowered overall investor trust [42].

It is reported that in countries such as USA, China, South Africa, and India, where the public sector has cooperated with the private sector, there tends to be higher amounts of investment [43]. This correlation is because investors perceive less (regulatory) risk [44]. As noted by Langniss et al [45], “mitigating risk is certainly an alternative to raising the level of compensation”. Thus, investor perceptions and confidence of the risks involved are important to the success of a project.

### **3.3 Community (Support/ Involvement)**

The articles analysed in this study point to community participation as one of the key factors in project growth. From the text present in the studied articles, we learn that traditional top-down executive-run projects can be less effective, due to their inability to identify and meet the community’s needs. Two examples of how collaborative approaches to decision making are effective would be from Nepal [46] and rural areas in Indonesia [47]. In both cases, we learn that active participation and collaboration has promoted positive engagement (with the authorities and private sector), a greater sense of ownership from the community (resulting in increasing acceptance and utilisation of the solution), improved livelihoods, and has provided alternative perspectives (local knowledge) which resulted in timely completion of the project. The local community is provided opportunities in the form of job security and leadership in said projects as well.

Our studies also point to promising RE initiatives failing, due to community disapproval. In Ontario, Canada, wind project success is largely determined by public support, and this support can be lacking because of fears associated with property values being negatively impacted by wind turbine locale. Another community level grouse is the view that there is unequal compensation and inequitable distribution of income from energy producers, who compensate landowners, and not the remaining (inconvenienced) members of the community [48]. In the UK, a planned biomass energy development was opposed actively by the community, for reasons like the possibility of unpleasant smells and increased noise. Without public acceptance, planning permission was not given, effectively stonewalling the project [49].

In summary, consultations with the community should go beyond a minimal level. Rather, it is often crucial to engage the community early and value their considerations, for any successful RE venture.

### **3.4 Fiscal (Mechanism/Terms)**

It has proven challenging to obtain financial metrics like ROI, profit margins or cash flow for the different types of RE projects being developed. Some RE projects are privately funded and clear auditable (profit-loss) statements are hard to locate and verify. Instead, our review has found it more common for authors to discuss fiscal mechanisms like subsidies (including removal of fossil fuel subsidies), carbon pricing, taxation, and electricity pricing reforms, as means to pave the way for RE success [50, 51, 52]. Thus, in our topic modeling work, we focus on similar areas. Fiscal mechanism can either be applies as an incentive for producers, or as a deterrent to consumers.

In Europe, producers are incentivized via fiscal mechanisms like FIT, Feed-in Premiums (FIP), loan guarantees, soft loans, investment grant and tax incentives as financial schemes to enhance RE development in the region.



FITs have been the most significant positive influence on the development and profitability of solar energy, specifically in Germany, Spain, Italy and France. According to the International Energy Agency (IEA), FITs represent 61% of total subsidies for solar energy technology in Europe [53]. Tariffs are pricing instruments where governments set funding for RE technologies. In a nutshell, these fiscal regulations encourage investment in REs and make adoption more financially manageable, boosting the RE success rate.

Carbon taxes are a form of green taxation, meant to disincentive the consumer from consuming pollutive forms of energy. In Singapore, a carbon tax was introduced at \$5 per tonne of emissions in 2019, with the eventual aim to increase it to \$80 per tonne by 2030. Obviously, this will have a negative effect on the financial health of major emitters, and thus, it is in their interest to increase the proportion of energy consumed from renewal sources. Additionally, Singapore aims to issue up to \$35 billion in green bonds by 2030 to support green infrastructure projects [54]. Again, this would only encourage further RE development. Singapore is, at this moment, on track to achieving her 2030 emission targets, utilizing fiscal mechanisms that both penalize and encourage. This is also what is occurring in Europe as well [55].

The sensitivity of operators to fiscal terms and tariffs is demonstrated in this example from Romania, where a change in legislation that introduced a 1.5% property tax on wind turbine infrastructure negatively impacted the wind farm operations and growth for this particular type of energy resource [56]. The result of new taxes had reduced the predicted profits of wind energy projects, which impacted development plans on future projects. In another example, Spain is the second largest producer of wind energy in Europe and the industry was growing steadily. However, changes in tariff conditions caused a downturn in the installment of wind projects [57]. The financial crisis as well as debt laden Europe forced the government to cut spending on subsidies for RE projects as well. Thus, poor fiscal terms have a significant impact on RE growth and success as well.

### **3.5 Talent**

In our review, we have found that access to RE expertise, skills are the final success factor for RE growth. However, unlike the earlier factors, we view this as more of a second order effect. We say this because if there is no mandate for RE projects within a certain jurisdiction given the earlier factors, no amount of cutting-edge talent will assist in RE growth and success. This is perhaps why it is ranked last.

From our analysis, we have found that there are significant resources devoted to RE education and training in Europe (41%) and North America (33%), with there being less in Asia (12%), Latin America (7%), Africa (3%) and Oceania (3%) [58, 59]. In developing countries, there is often a (1) shortage of education and training, (2) a mismatch in real life applicability of education curriculum, and (3) a mismatch between education resources and industry demand. These issues contribute to a critical shortage of skilled human resource in developing nations that hinders the RE market development. If RE adoption is to continue to grow in these countries, there must be a collaboration between industry and government to identify and the knowledge gaps. Such a collaboration is successfully demonstrated in the USA between Madison Area Technical College and the National Alternative Fuel Training Consortium (NAFTC), where the former launched an academy that provided training for educators in RE technologies but utilizing training centers and curriculum supported by the NAFTC. The aim was to expose educators to relevant industry practices, and to train a cadre of instructors skilled in Solar Electrics, Science Technology, Engineering and Mathematics (STEM) and wind energies [60, 61, 58], and it was largely a successful venture, with 96% of participants expressing an interest in the RE industry, boding well for a future available talent pool.

## **4. Limitations of Study and Conclusions**

This study adopted TM+TM methods to identify common topics related to successful RE projects, in current scientific research. We have tried to rank and justify our observations with illustrations and examples of the numerous factors contribute to success and growth of RE projects, and that it is often the more “softer” aspects that dominate, with 4 out of 5 of our topics being non-financially focused. In order of importance, we have modeled the major areas of consideration to be: (1) Government (Policy), (2) Public-Private (Corisking), (3) Community (Support/ Involvement), (4) Fiscal Mechanism /Term and (5) Talent.

For (1), this covers policies that have a strong signaling mechanism to the private sector, with adequate legislative protection in place for market participants. For (2), we shared an example of how PPAs and FITs between the public and private sectors can act to the benefit or detriment of RE growth, especially when the perception of risk and equitability is considered in the mix. For (3), we illustrate some RE project examples with community support (or lack thereof) and explain why active engagement is important. For (4), we discuss the economic push/pull factors that act as incentives or deterrents and finally for (5), we illustrate how the lack of the human capital means RE growth and success rates are impacted globally.

We note the limitations present in this study. Firstly, it is constrained by its query phrase search. If relevant articles do not have any of the query phrases “renewable energy success” in their subject, they will not be included in the dataset, which may result in data inconsistency or bias. Secondly, the data size could be increased, but this significantly increases the processing time. Thirdly, while we do our best to avoid it, personal bias can impact our choice of keywords, which we use in sub-topic and final topic selection. Beyond the scope of this work is the use of other predictive models to identify the fit of key topics, with additional statistics used to estimate the accuracy of concepts assigned to the keywords of each topic.

Still, given the complexity and vastness of the RE sector, this study demonstrates that holistic approaches should be considered in the analysis of success metrics, aside from just hard-core technical arguments. Indeed, looking at RE through a social science lens can provide alternative perspectives, to create a more balanced discourse in supporting the global climate change agenda. Future extension of a social perspective in RE research can support future policies and systems that can propel sustainable transformations.

## 5. Nomenclature

<u>RE</u>	<u>Renewable energy</u>
<u>CAPEX</u>	<u>Capital Expenditure</u>
<u>OPEX</u>	<u>Operational Expenditure</u>
<u>TM+TM</u>	<u>Text Mining &amp; Topic Modeling</u>
<u>NLP</u>	<u>Natural Language Processing</u>
<u>LDA</u>	<u>Latent Dirichlet Allocation</u>
<u>NNMF</u>	<u>Non-Negative Matrix Factorization</u>
<u>k</u>	<u>Number of topics</u>
<u>ROI</u>	<u>Return on Investment</u>
<u>Mallet</u>	<u>MAchine Learning for Language Toolkit</u>
<u><math>\lambda</math></u>	<u>relevancy metric</u>
<u><math>\phi_{kw}</math></u>	<u>probability of word w in topic k</u>
<u><math>\phi_{kw} / p_{kw}</math></u>	<u>probability within a topic to its marginal probability</u>



<u>IRENA</u>	<u>International Renewable Energy Agency</u>
<u>PPP</u>	<u>Public-Private Partnerships</u>
<u>PPA</u>	<u>power purchasing agreements</u>
<u>FIT</u>	<u>feed-in tariffs</u>
<u>REC</u>	<u>Renewable Energy Credits</u>
<u>PLN</u>	<u>Peusahaan Listrik Negara</u>
<u>FIP</u>	<u>Feed-in Premiums</u>
<u>IEA</u>	<u>International Energy Agency</u>
<u>NAFTC</u>	<u>National Alternative Fuel Training Consortium</u>

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**Declaration of interests**

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: