

# LEAP-RE

Long-Term Joint EU-AU Research  
and Innovation Partnership on Renewable Energy

## Strategy for Renewable Energy research-capacity in Africa

### Deliverable 5.8

31.12.2021

[www.leap-re.eu](http://www.leap-re.eu)

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**Abstract:** This study mainly focuses on renewable energy (RE) related research in African countries between 2011-2020. The study has been carried out under the project LEAP-RE (Long-Term Joint European Union - African Union Research and Innovation Partnership on Renewable Energy) *Task 5.3: Strategy for RE research-capacity in Africa* with the co-lead of MESRS (Ministry of Higher Education and Scientific Research, Algeria) and ZSI (Centre for Social Innovation, Austria).



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## List of abbreviation

AREI	Africa Renewable Energy Initiative,
AOSTI	African Observatory of Science, Technology, and Innovation
AU	African Union
UN	United Nations
AUC	African Union Commission
CSP	Concentrated Solar Power
ECOWAS	Economic Community of West African States
EU	European Union
GII	Global Innovation Index
HLPD	High Level Policy Dialogue
IP	Intellectual Property
JAES	Joint Africa–EU Strategy
KMCF	Knowledge Management and Communication Framework
LEAP-RE	Long European African Partnership in Renewable Energy
M&E	Monitoring and Evaluation
MENA	Middle East and North Africa
NEPAD	New Partnership for Africa’s Development
NIS	National Innovation System
OECD	Organization for Economic Co-operation and Development
R&D	Research and Development
RE	Renewable Energy
RECs	Regional Economic Communities
SDGs	Sustainable Development Goals
S&T	Science and Technology
SOM	Senior Official Meeting
STEM	Science, Technology, Engineering, and Mathematics
STI	Science, Technology, and Innovation
STISA-2024	Science, Technology, and Innovation Strategy for Africa 2024
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNSD	United Nations Statistics Department
WIPO	World Intellectual Property Organization
WoS	Web of Science

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## 1 Introduction:

STI is a key enabler to achieve the goals of the African Union Agenda 2063 [1] and the UN Agenda 2030 [2]. It requires specific instruments for socioeconomic growth including publication of scientific papers.

In this deliverable we focus on high ranked publications analysis in renewable energy in Africa. The use of scientometric techniques will help government, institutions, private sector, civil society and communities not only to measure the scientific and technological progress through quantitative analysis and its productivity, but helps to identify institutions which could serve as pillar to develop long term fruitful forefront cooperation in RE.

In order to deliver a comprehensive overview of national capacities and co-publication networks we shall use data from Clarivate's Web of Science (WoS) databases [3]. The methodology to select keywords and to extract data are explained in the next section. This mapping covers the identification of scientific networks and publications, as well as universities, faculties, research teams and their interconnexion. First results demonstrate that the number of scientific publications produced by Africans has risen significantly over the period 2011-2020, even it accounts for a tiny portion over the world. Compared to Europe, the regional, continental and intercontinental mapping generated using visualizing software [4], reinforce the urgent need to develop International partnerships and cooperation in energy mainly in the framework of the existing programme LEAP-RE [5].

The final target is to support new (or existing) mechanisms which may involve clustering networking, by matching researchers from both continents to create clusters and cluster networks in RE, teaming (for creating centres of excellence), twinning (institutional co supervision, post-doctoral programmes), and sharing infrastructures in a Knowledge Management and Communication Framework (KMCF). The framework of such vision was declined in the new Africa-Europe Alliance for Sustainable Investment and Jobs, Horizon Europe and the new Research Framework Programme for the period 2021-2027 that open up new opportunities in the join AU-EU strategy (5th SOM, AU-EU HLPD on STI) [6].

The organization of the Deliverable 5.8 "Strategy for RE research-capacity in Africa" is structured as follows. Section one [data source and keywords, page 8] is dedicated to the identification of appropriate key-words to build the query to select publications on RE, using the Web Of Science. These keywords have been extracted from main documents, African strategies STISA-2024, Africa 2063, Agenda 2030 and the different Multi-Annual Roadmap developed in PRE-LEAP-RE. In section two the methodology will be explained and first results will be displayed using visualization software [Methodology and results, page 13]. In Section three we shall provide national and regional analysis of teams and networks regarding the different areas of research [Regional analysis, page 20].

The results, which will be displayed in the following chapters, are generated through a cleaned, normalized and recategorized dataset created with the data collected from the Clarivate's Web of Science databases as mentioned.

A general overview of the yearly RE-related publication output in the European continent, will be followed by the most visible countries and organizations in Africa as well as the distribution of research domains and areas. The regional analysis generally deals with the most visible countries in each African region as well as their co-publication networks which also include interregional (partnerships with other African countries from other regions) and intercontinental (partnerships with countries from other continents) collaborations. Furthermore, the analysis also focuses on selected countries of each region to display the most visible organizations and organizational co-publication networks as well. The regional analysis also includes at least one selected organization from each selected country to



## Deliverable 5.8

present the most visible research areas and keyword/keyword pair networks on the organizational level. Finally, last section [Domain Analysis, page 58] approaches the RE research in Africa from another direction and by splitting publications into research domains in order to discuss the most visible co-publication pairings between organizations as well as most visible keywords/ keyword pairs in each distinct cluster of scientific areas. In conclusion we'll focus on the important next step of building the LEAP-RE research community (ies) in clusters and cluster networks in a Knowledge Management and Communication Framework (KMCF).



## 2 Data Source and keywords

Several important steps were analysed to identify relevant documents for extracting appropriate keywords which could conduct to main publications in renewable energy. We focus first on African strategies (Africa 2063, STISA), then on Sustainable Development Goals of the UN (SDGs) and European programmes (FP6, FP7, H2020). The LEAP-RE pathways or Multi-Annual-Roadmaps [7] allows us to increase our collection of selected keywords to be used for building the queries. To focus on African and European publications we extended our collection of keywords to the names of countries.

### 2.1 Extracting and cleaning keywords

#### 2.1.1 Analysing agendas in the field of RE (AU, EU, UN)

Agendas, policy and strategies in renewable energy exists in many countries, we'll focus mainly on continental and international programmes, first Agenda 2063 "Africa we want", Agenda 2030 or UN SDGs, and some EU projects developed in the framework of FP6, FP7 and Horizon2020.

##### 2.1.1.1 Agenda 2063, "Africa we want"

Agenda 2063 "Africa we want" [1] encapsulates Africa's development and transformation priorities for the coming four decades. Central to Agenda 2063 is the sustainable transformation of the continent (human capacities, infrastructures, employment, well-being, good governance).

Agenda 2063 is 7 aspirations, 34 priority areas, 20 goals, 174 targets and 200 indicators. Agenda 2063 is divided into five 10-year implementation periods. The first 10-year implementation plan covers the period 2013-2023 (corresponding to STISA programmes). The different goals connected to RE are:

1. A high standard of living, quality of life and well-being for all citizens
2. Well educated citizens and skills revolution underpinned by science, technology and innovation
3. Healthy and well-nourished citizens
4. Transformed economies
5. Modern agriculture for increased productivity and production
6. Environmentally sustainable and climate resilient economies and communities
7. Engaged and empowered youth and children

Agenda 2063 has targets for an increase of 50% in electricity generation, 50% distribution and 70% of Africans having access to electricity by 2023.

##### 2.1.1.2 STISA-2024

The STISA-2024 [8] has been developed when the African Union was formulating the long-term AU Agenda 2063. The STISA-2024 is the first of the ten-year incremental phasing strategies to respond to the demand for science, technology and innovation to impact six critical sectors:

1. Eradicate Hunger and ensure Food and Nutrition Security: Agriculture/Agronomy in terms of cultivation technique, seeds, soil and climate- Industrial chain in terms of conservation and/or transformation and distribution infrastructure.
2. Communication (Physical & Intellectual Mobility): Physical communication in terms of land, air, river and maritime routes equipment and infrastructure and energy- Promoting local materials- Intellectual communications in terms of ICT
3. Protect our Space: Environmental Protection including climate change studies- Biodiversity and Atmospheric Physics- Space technologies, maritime and sub-maritime exploration- Knowledge of the water cycle and river systems management

## 2.1.2 Agenda 2030 - UN Sustainable Development Goals

The 2030 Agenda [2] is a plan of action for sustainable development goals representing also Africa’s priorities for the post-2015 development agenda. SDGs are 17 Goals, with targets and indicators.

- SDG1: End poverty in all its forms everywhere in the world
- SDG2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture
- SDG3: Ensure healthy lives and promote well-being for all at all ages
- SDG4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
- SDG5: Achieve gender equality and empower all women and girls
- SDG6: Ensure access to water and sanitation for all
- SDG7: Ensure access to affordable, reliable, sustainable and modern energy
- SDG8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
- SDG13: Take urgent action to combat climate and its impacts
- SDG15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

For each Agenda2030 SDGs AND/OR Africa2063 targets a table extracted from a detailed excel file is constructed in [Annexe1, page(70)]. It includes the following information’s:

- a) Targets linked to renewable energy and its relevance [strong, high, weak]
- b) Associated keywords or string
- c) Which RE technologies could solve

## 2.2 Extracting keywords

### 2.2.1 Identification of keywords from SDGs:

#	SDGs	Keywords
1	<b>SDG1:</b> End poverty in all its forms everywhere	Energy, Microgrids, climate change, mitigation, # vulnerability to climate
2	<b>SDG 7</b> Ensure access to affordable, reliable, sustainable and modern energy for all.	# Access to (clean) Energy, # Transition from Fossil to Clean Energy, # Energy Efficiency, #1. Solar Photovoltaic Energy, #2. Wind Energy, #3. Energy Efficiency in the Building, #4. Solar Thermal Energy, #5. Marine energy, #6. Storage of Energy, #7. Geothermal Energy, #8. Bioenergy, # 9. Hydrogen and Fuel Cells, #10. Hydroelectricity, consumers energy, solar systems, solar panels, nuclear, alliant energy, solar, electricity companies, direct energy, wind turbine, stream energy, distributed generation, solar generators, natural gas, nuclear power plant, sun power, green mountain energy, solar power #11. Materials : (industrialization of certain components of renewable energy systems such as solar panels or wind turbine blades)].

<b>3</b>	<b>SDG13</b> Take urgent action to combat climate change and its impacts.	# Climate Adaptation strategies # CO2 harvesting and storage # Greenhouse Gas Reduction
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### 2.2.2 Extracting keywords from LEAP-RE multiannual roadmaps:

Within Pillar 2, eight projects broadly address the MARs (1, 3, 4, 5, 6), Pillar 1 with thirteen projects selected is still addressing the different pathways in RE. .

#	Multiannual Roadmaps (MARs)	Keywords
<b>1</b>	Mapping joint research and innovation actions for future RES development	energy access, energy transition, low carbon energy sources, energy infrastructure, energy access, energy uses, renewable energy systems (RES), off grid, decarbonization, thermal energy, demonstration systems, stand-alone systems, green electrification , geothermal resources, African electricity production, power plants, geothermal resources, geological data, geothermal energy systems, geothermal systems, climate resilience, rural electrification, green-field mini-grid, energy mix scenario, alternative energy sources, photovoltaic systems, flexible solar panels, solar powered generator, off grid, solar outdoor lighting, wind generator, solar panel installation, solar farm, best solar panels, pv panels, sustainable energy, , renewable energy resources, renewable sources of energy, solar tracker
<b>2</b>	End-of-life and second-life management and environmental impact of RE components -	solar panels, solar PV panels, photovoltaic panel waste, electric vehicles, storage systems, wind turbine blades, second life components, lead-acid batteries, Li-ion batteries, clean energy, off-grid solar, quality of life, e-waste stream, off-grid solar, storage products
<b>3</b>	Smart stand-alone systems (SAS) -	Smart stand-alone systems, energy mix, off-grid, clean cooking, lighting water pumping, small microgrid, mini grid stability, production of electricity, grid infrastructures, small-scale, off-grid systems, wind power, sunpower, solar panel cost, hydropower, panel solar, solar battery, renewable energy sources, biomass energy, solar cooker, energy efficiency, solar panels for home, alternative energy, sources of energy, solar panels for sale, photovoltaic cells, hydroelectric energy, solar generator, solar inverter, solar roof, energy resources, clean energy, outdoor solar lights, solar panel kits, solar shingles
<b>4</b>	Smart grid (different scale) for off grid application -	Smart grid, off grid, access to electricity, penetration of Res, decentralized electrification, coupling different RES, mitigating energy poverty, Hybrid and Smart RES Grids, storage systems.



<b>5</b>	Processes and appliances for productive uses (PRODUSE) –	off-farm employment, value chain segments, cold chain technologies, food processing, Clean cooking, cogeneration, , solar electricity production, solar system, solar panels, csp, wind turbine, solar city, solar battery charger, wind energy, renewable resources, green energy, photovoltaic,
<b>6</b>	Innovative solutions for priority domestic uses (clean cooking and cold chain)	clean cooking, firewood, charcoal, deforestation, land degradation; black carbon emissions; Indoor cooking, food waste, cookstoves, e-cooking, solar perovskites, Cooker design, storage of cold, power boosting, solar cooking, standalone solar cooker, silicon solar cells, solar water heater, energy conservation,

To identify how LEAP-RE projects could be connected to AU-EU R&I needs, we'll first use a matching process and comparison between the objectives of the six multi-annual roadmaps, thanks to the associated keywords, the technical keywords identified in the matrix of step [1] and the selected programs in Pillar2.

Multiannual roadmaps	PillarII projects	Keywords	Connexion to matrix (step1)
<b><i>Example with Multiannual roadmap 6....</i></b>			
6: Innovative solutions for priority <b>domestic uses</b> (clean cooking and cold chain)	WP10 PURAMS, solar cooking, standalone solar cooker, silicon solar cells,	clean cooking; energy poverty; improved cooking stoves; Electric clean cooking, Improved cookstove, Solar cooker, Cold chain, Supply chain, Cold chain logistics	saves health, time and money [SDG1], job opportunities [SDG8], Reducing smoke emissions, air pollution [SDG3], climate vulnerability [SDG11], girls kept out of school, etc...

### 2.2.3 Benchmarking EU-Africa research projects in FP6-FP7 and H2020:

The benchmarking process is used to identify and analyze previous projects to determine their impact on the local or regional community, and to identify the human capacity as potential resource for R&I. The characteristic of the R&I partnership is to strive to integrate research and innovation activities that have an impact on citizens. Thus, it will be assisted by the valuable lessons learned from projects developed or underway in the field of sustainable energy; these are AU grant projects in renewable and sustainable energies, or EU projects.

We can mention, but not limited to AREI (Africa Renewable Energy Initiative), CSP4Africa (Development of a cost-effective, modular and dry concentrating solar power for Africa), REELCOOP (REnewable ELectricity COOPeration), SOLPART(High temperature Solar-Heated Reactors for Industrials Production of Reactive Particulates), ECOWAS observatory for renewable energy and energy efficiency, EUROSUNMED "Euro-Mediterranean Cooperation on Research & Training in Sun based Renewable Energies.. ", etc. This overview of two binary digit research programs offers particularly to identify the gaps of research and cooperation activities, which is an issue of high priority to the EU-AU R&I Partnership in RE.





### 3 Methodology and Results

Following clarification of the motivation and methodology of the scientometric analysis on the renewable energy (RE) related research in Europe and Africa, this section is dedicated to the presentation of the different results.

After delivering a general overview on the most visible countries as well as distribution of scientific publications in European countries between 2011-2020, and the interaction between the two continent, we shall focus and deepen the analyses on African production in each of the 5 regions (Northern Africa, Western Africa, Central Africa, Eastern Africa, Southern Africa) individually.

Analysis of the geographic regions include:

- Most visible countries.
- Regional, interregional, and intercontinental collaboration networks.
- Collaboration networks of the academic organizations in *selected countries*.
- Analysis of the most visible research areas and the correlation network of the keyword/keyword pairs in the RE-related publications.

The analysis also focuses on selected countries in each region to display the most visible academic institution and organizational co-publication networks as well. The regional analysis also includes at least 1 selected organization from each selected country to present the most visible research areas and keyword/keyword pair networks on the organizational level.

At a second step The African publications will be analyzed under the 5 research domains Physical Sciences, Technology, Life Sciences & Biomedicine, Social Sciences and Arts & Humanities.

Analysis of each domain includes:

- Most visible inter-regional/ intercontinental collaborations
- Most visible and trending keywords/ keyword pairs.

#### 3.1 Terminology

**Scientometry:** This new domain in expansion is the study of measuring and analyzing science, technology and innovation, it is a sub-field of bibliometrics

**Research Area/ Research Domain.** Research areas are the scientific fields defined by the Web of Science (WoS). Research domains are the 5 parent categories (Physical Sciences, Technology, Life Sciences & Biomedicine, Social Sciences, Arts & Humanities) of the research areas.<sup>1</sup>

**Co-publication.** A publication that has been produced with the collaboration of at least 2 authors from 2 different organizations.

**Interregional co-publication.** Interregional in this Report refers to different African countries from different African Union (AU) regions. An interregional co-publication, therefore, is a paper published with the collaboration of at least 2 authors from African organizations from different regions of Africa.

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<sup>1</sup>Web of Science's categorization of research areas under research domains can be found under [https://images.webofknowledge.com/images/help/WOS/hp\\_research\\_areas\\_easca.html](https://images.webofknowledge.com/images/help/WOS/hp_research_areas_easca.html).



**Intercontinental co-publication.** Co-publications of at least 2 organisations located on different continents.

**Relative growth rate.** A simple indicator of how many folds the number of publications has been increased in comparison with the number of publications in the start year (2011). The equation is simply:

$$\text{rel\_growth\_rate} := \text{end\_value} / \text{start\_value}$$

### 3.2 General overview on yearly outputs for European countries

To give an idea on the potential of scientific cooperation and technological development with Europe, we introduce briefly some elements on research capacities in Europe. The number of papers published in journals indexed in the Web of Science for the European countries is 214,996, with many discrepancies between the top ranked Germany, Italy, Spain, France and Eastern countries. More than 50% of these papers are in Energy Fuels (26.16%), Engineering Electrical Electronic (12.64%) and Environmental Sciences (12.45%).

The European Commission is the top funder, followed by Spanish Government and the German Research Foundation. The top three African co-publisher countries are Tunisia (1258 papers), Algeria (1226) and South Africa (1217).

We don't focus on European publications, but it is relevant to illustrate the flux density of co-publications between Europe and Africa and vice-versa.

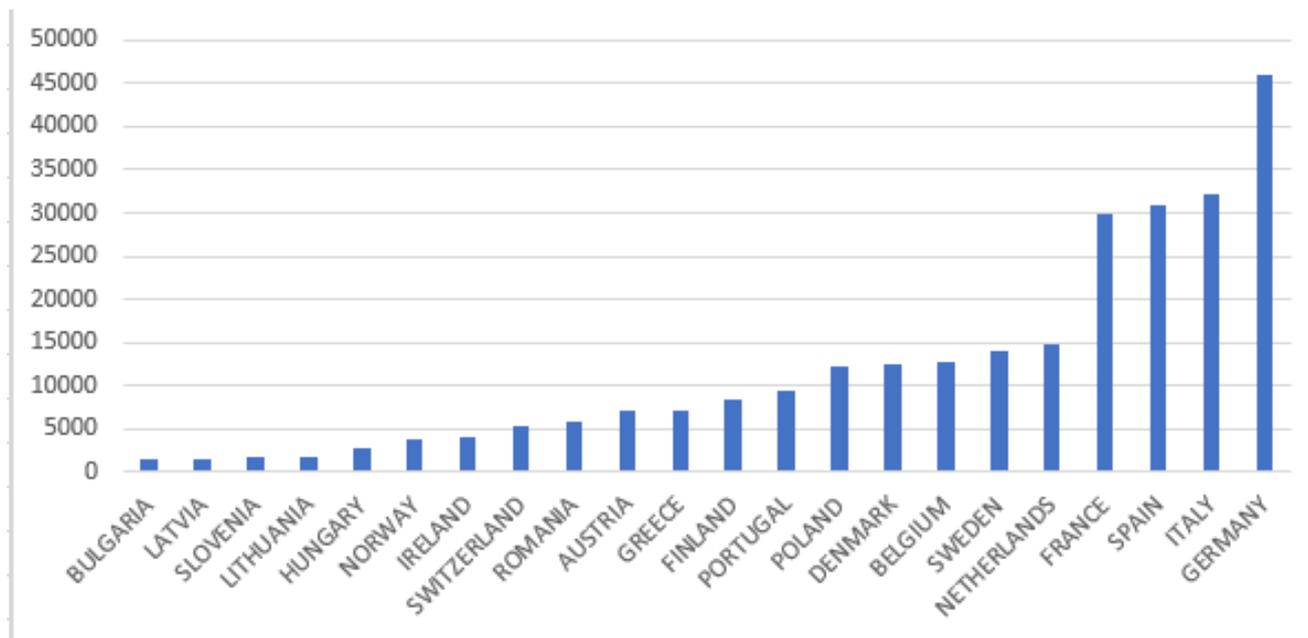


Fig 3: European publications in RE – Germany is leading continental countries followed by Italy, Spain and France.

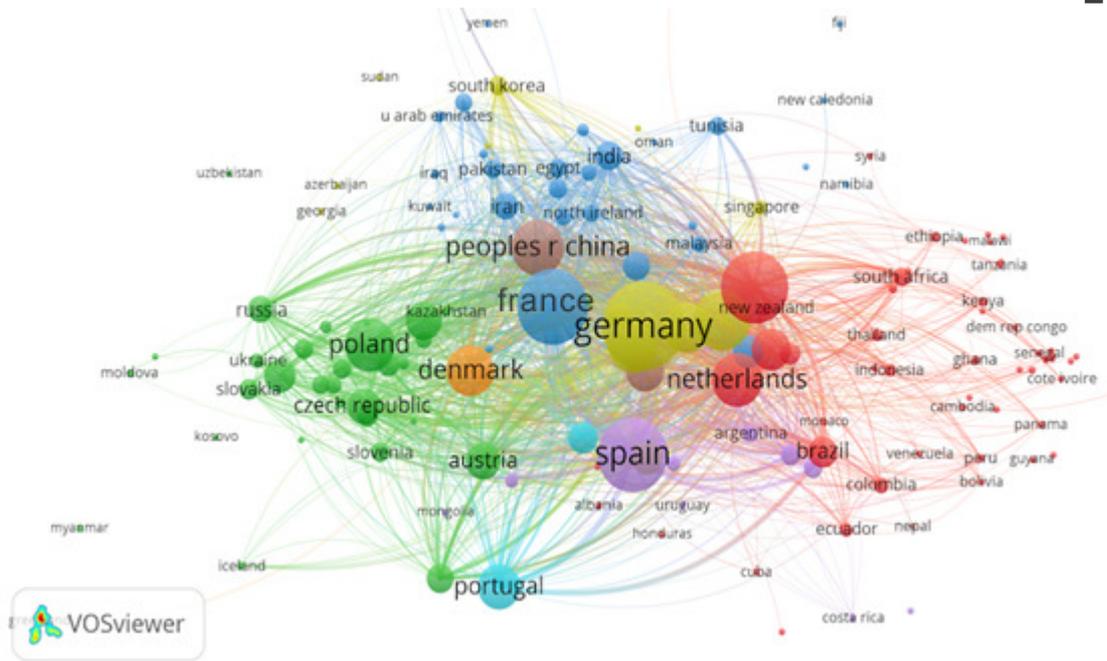


Fig 4: map of European publications and related networks. This map is generated using WoS records and the visualization software Vosviewer

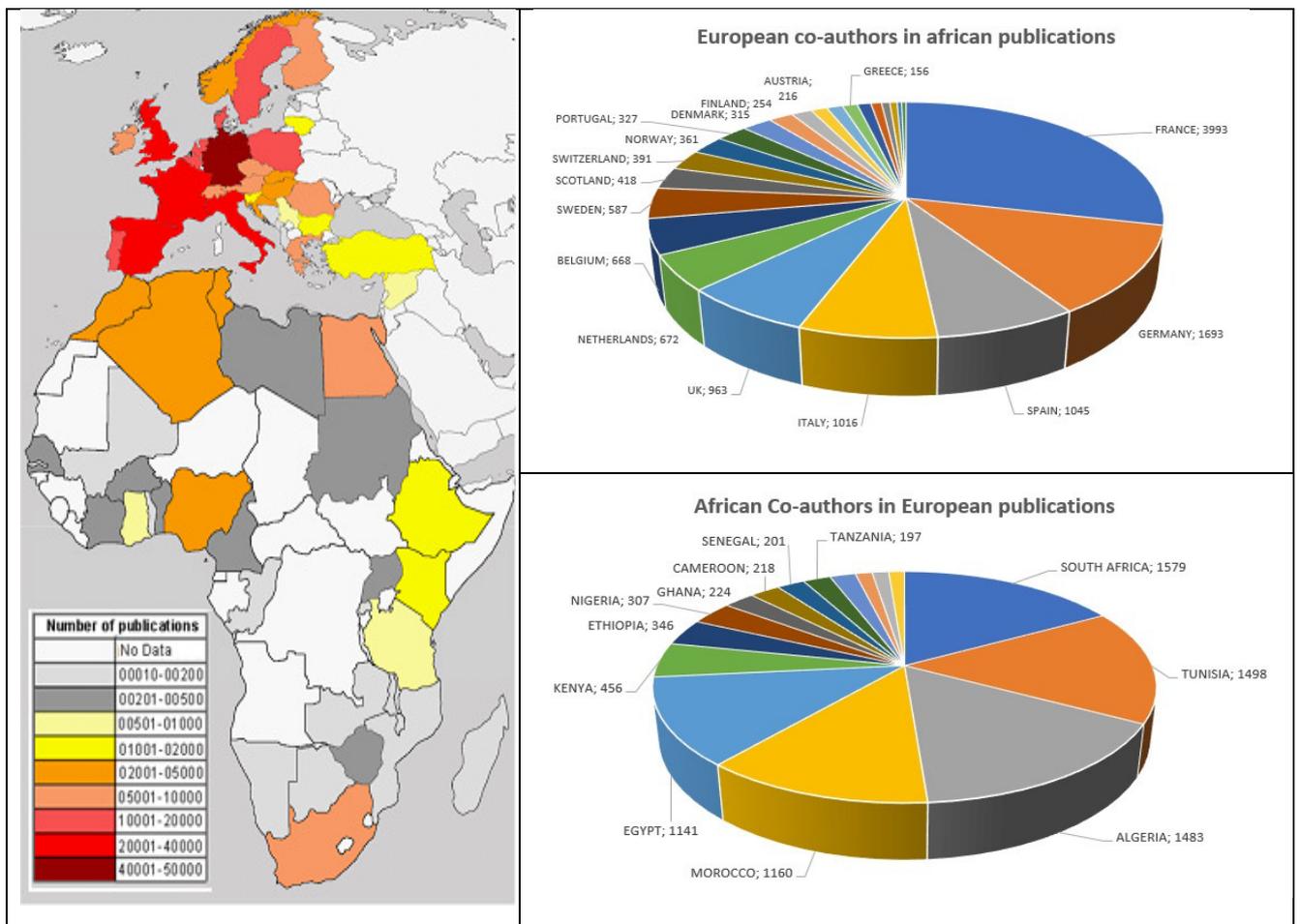


Fig 5 – Overview of European and African publications and the partnership in co-publications

The figure 5, shows clearly the predominance of European scientific production, first within Europe and then with the African Continent where South Africa and Egypt emerge. The more in-depth study of co-publications indicates that many European authors participate in publications domiciled in Africa. The reverse is also true. These clusters need to be strengthened and perpetuated.

### 3.3 Analysing African publications

#### 3.3.1 Overall Figures

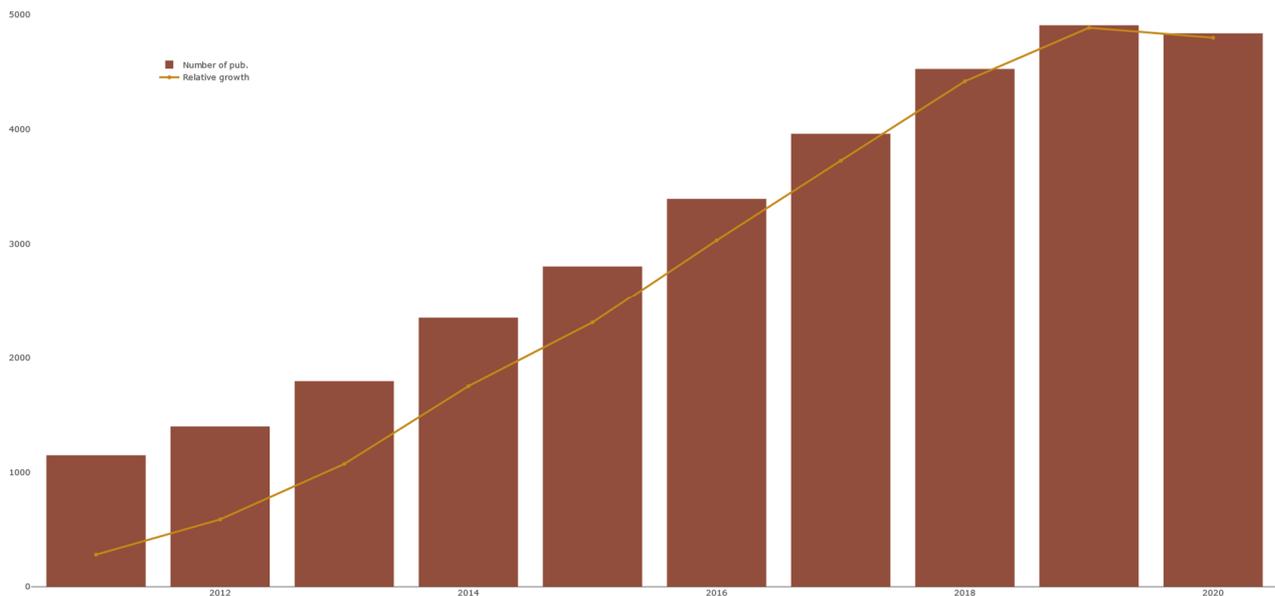


Figure 6: Number of RE-related publications in African countries over the years between 2011-2020

African countries have collaborated in approximately 31k renewable energy (RE) related publications in the 10 years range between 2011-2020. The number of those publications has been constantly increasing until 2019. Slightly declining publication numbers between 2019 and 2020 (see Figure 6) is likely caused by the latency in the database entries according to the explanation of Web of Science.

Even after including the possibly incomplete amount of publications in 2020, the number of RE-related publications from the African countries in total increases from ~1.1k in 2011 to ~4.8k in 2020 which is an increment by factor ~4.2.

As Figure 7 shows, South Africa and Egypt are the most visible countries with 6.8k and 6.6k RE-related publications respectively. 20 African countries stay under 40 RE-related publications in total between 2011-2020.

The most visible countries are distributed diversely on the continent, however, other than the Northern African countries and South Africa only Nigeria contributed to over 1000 RE-related publications (2252 pub.) between 2011-2020.

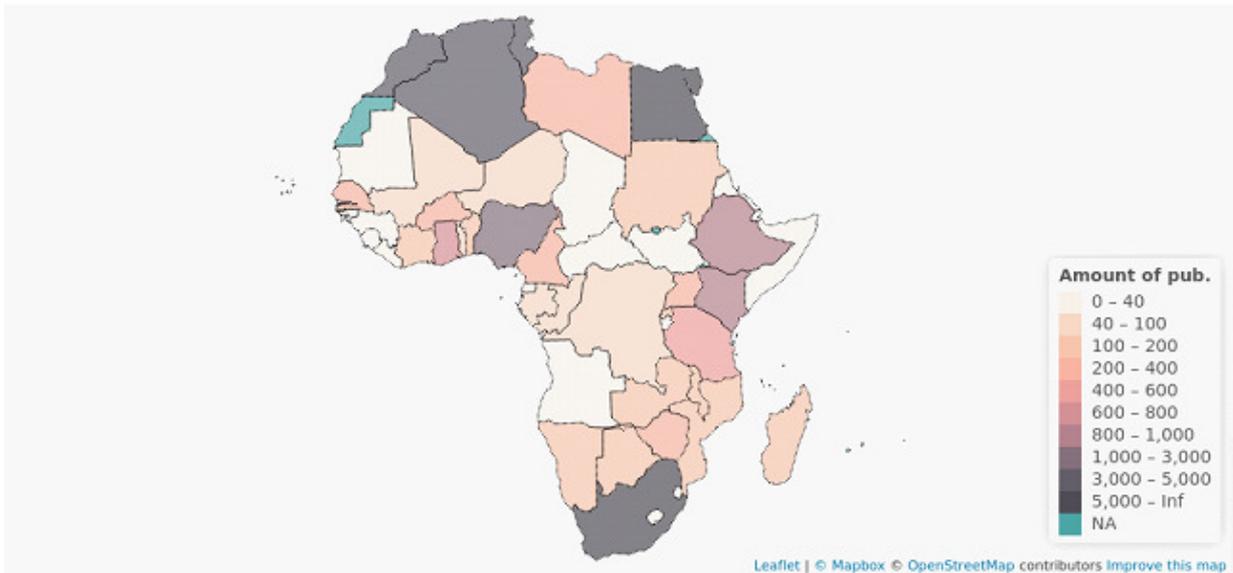


Figure 7: Total number of RE-related publications in African countries between 2011-2020

Although total publication output is a strong indicator of the most visible countries, it does not show the growth rate in the numbers. African countries that show a high increment rate in the number of publications despite having a relatively lower total amount of publications will be analyzed in the following chapter.

Four of the most visible 5 organizations (*University of Kwazulu-Natal, University of Cape Town, Stellenbosch University, and University of Pretoria*) in RE-related publications are located in South Africa.

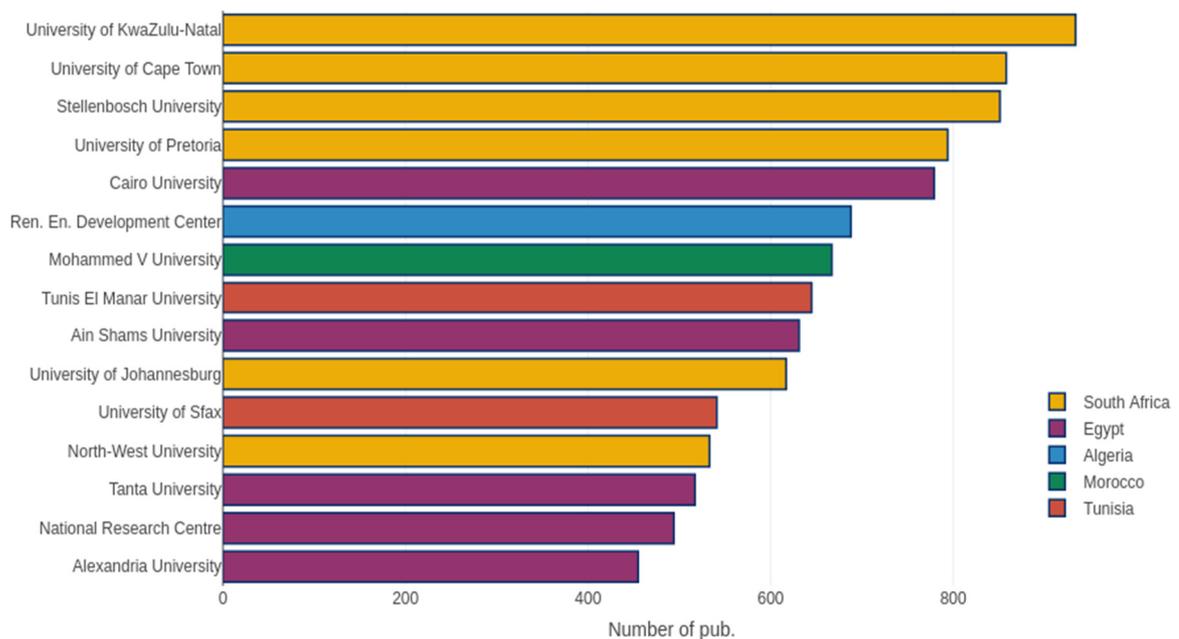


Figure 8: Most visible 15 African institutions in RE-related publications 2011-2020

Each of them has close to or over 800 publications between 2011-2020, Cairo University from Egypt is following them with ~780 publications. Four other Egyptian institutions; namely Ain Shams University, Tanta University, National Research Centre of Egypt and Alexandria University are also among the 15 most visible organizations.



### 3.3.2 Regional Analysis

Following the overall figures of the RE-related publications in Africa, this section introduces the geographical regions of Africa to broaden the analysis further. Focusing on different regions of Africa prevents the over-representation of already relatively more visible countries in terms of publications and also enables a detailed analysis for individual countries and organizations.

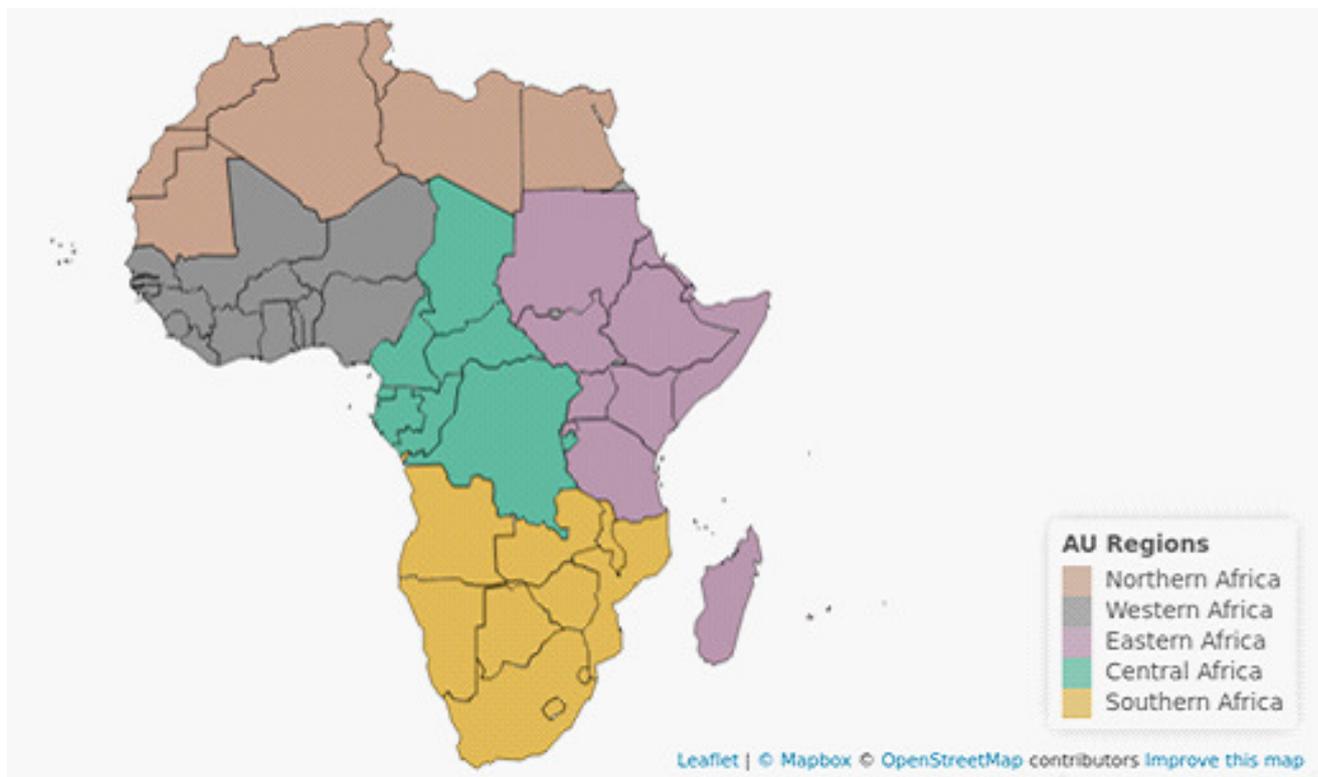


Figure 10: African Union Geographic Regions

To determine the African regions, this study uses [African Union Geographical Regions](#) instead of the [United Nations Statistics Department](#) (UNSD). A presentation of the African Union regions can be seen in Figure 10.

As Figure 8 summarizes, four of the most visible African countries in the RE-related publications are from Northern Africa.

South Africa has the highest number of RE-related publications (~6900) between 2011-2020, only other member country of Southern Africa in the most visible 15 countries is Zimbabwe with 230 RE-related publications between 2011-2020.

Nigeria, Ghana, Senegal from Western Africa; Ethiopia, Kenya, Tanzania, Uganda from Eastern Africa; and Cameroon, the only country from Central Africa, are among the 15 most visible countries following the most visible 5 countries.

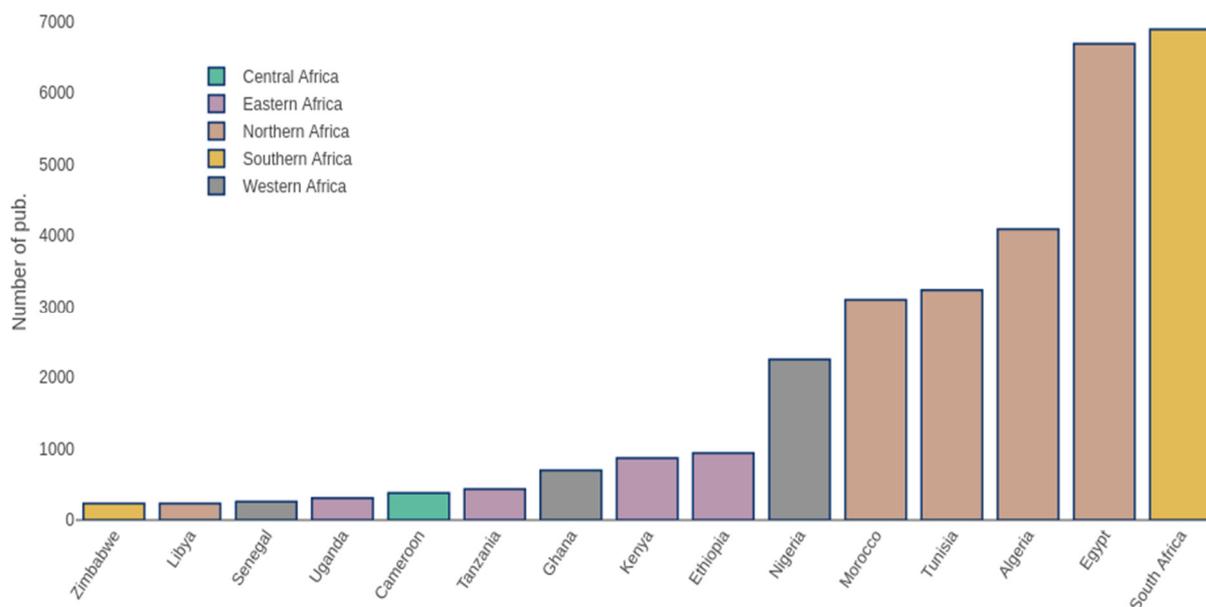


Figure 11: The most visible 15 African countries in RE-related publications between 2011-2020

### 3.3.2.1 Northern Africa

Country	2011	2020	Rel. growth rate (2011-2020)	Total num. of pub. (2011-2020)
Egypt	218	1344	6.17	6689
Algeria	152	412	2.71	4093
Tunisia	127	383	3.02	3240
Morocco	34	543	15.97	3101
Libya	4	32	8.00	233

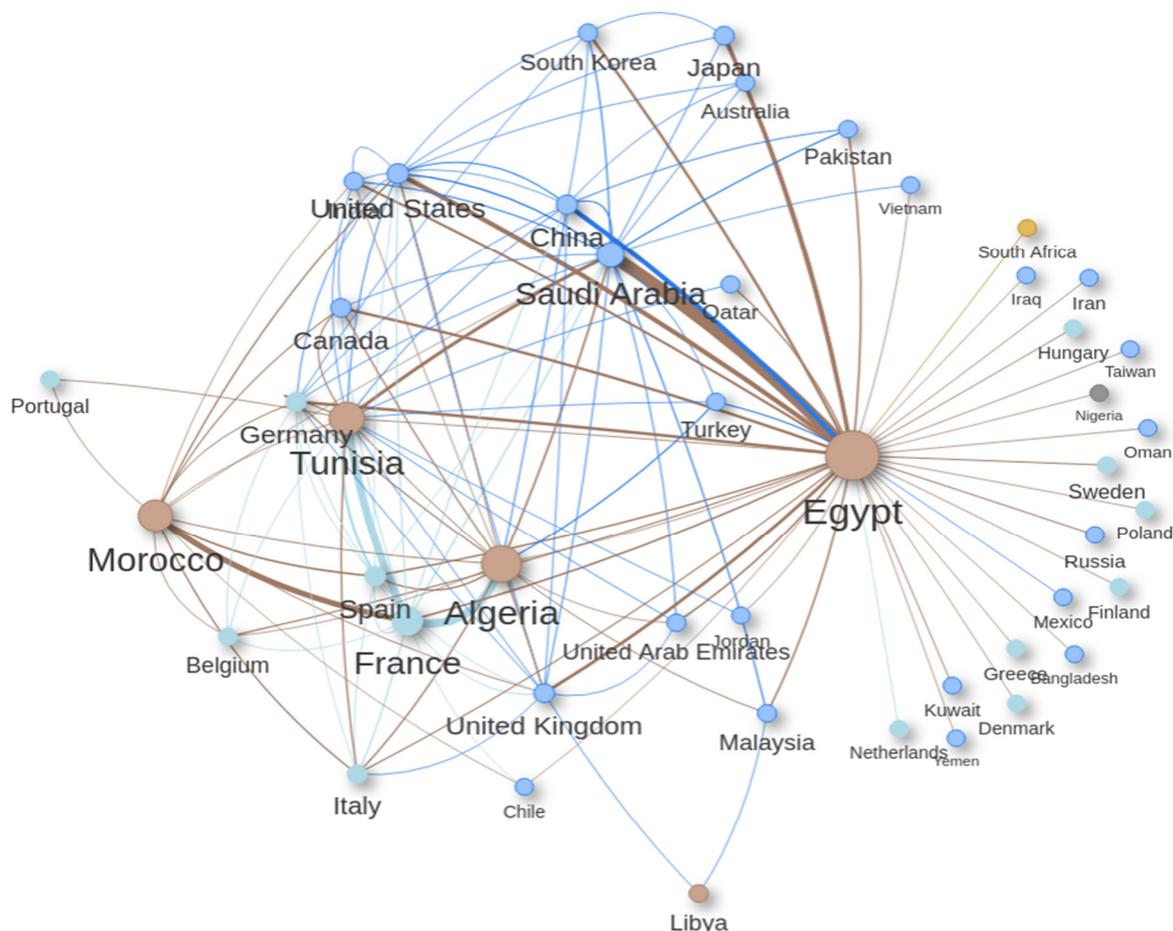
Table 1: RE-related publication output in the most visible Northern African countries

Member countries of Northern Africa have collaborated approximately in half of the total number of all RE-related publications (17116 publications out of 31099) in Africa between 2011-2020. 4 of the 5 most visible African countries in RE-related publications are from the northern region; namely Egypt, Algeria, Tunisia and Morocco.

As Table 1 presents, all of the Northern Africa countries increased their number of RE-related publications until 2017. Although, as discussed in the previous section, slight declines in the number of publications between 2019-2020 are most likely caused by the delay of document entry into the Web of Science databases, Algeria and Tunisia show an earlier start of the decline in their number of publications starting in 2017 and 2018 respectively. In the case of Libya, however, volatility in the number of publications is expected as their total publication outputs are relatively lower.



Another important observation is in the relative growth rates<sup>2</sup>, Morocco's number of RE-related publications in 2020 are approximately 16 times higher than the number in 2011. This growth rate is not only the highest in Northern Africa but in the whole continent among the most visible countries in RE-related research.



\*Collaboration links with fewer than 25 co-publications have been removed.

RE-related co-publications of the Northern African countries show a rich international network but the collaboration with other African regions seems to be relatively less dense. Only African countries from other regions which have co-published over 25 RE-related papers with Northern African countries are South Africa (28 pub.) and Nigeria (26 pub.). Egypt, the most visible country in Northern Africa in terms of RE-related publications, plays a central role in the network with ~6.6k publications in total. The relatively uniform distributed co-publication network of Egypt includes over 10 EU-27 countries as well as a number of countries from other regions of the world like the USA, China, India, United Kingdom. Egypt's strongest link in the co-publications, however, is with organizations from Saudi Arabia.

Tunisia, Algeria and Morocco have relatively high numbers of collaborations with French organizations with 751, 881 and 601 co-publications respectively. France in general is the

<sup>2</sup> Relative growth rate value in this report does not indicate a percentage as it is usually calculated, instead the equation is simply  $\text{end\_value}/\text{start\_value}=\text{growth\_rate}$ .





## Deliverable 5.8

most visible EU-27 country in the RE-related co-publications with African countries. Out of France's ~3250 RE-related co-publications with African countries ~2350 of those have been published with the collaboration of Northern African countries whereas Algeria and Tunisia being the most visible Northern African countries in those collaborations. The closest following EU-27 country in terms of RE-related co-publications is Spain (~580 out of ~820 co-publications with African countries) and Germany (~490 out of 1334 co-publications with African countries).

The 4 mentioned Northern African countries so far, Egypt, Algeria, Tunisia and Morocco are co-publication-wise relatively well interconnected, however, Libya stays out of the co-publication cluster in Northern Africa, from Libya's 233 RE-related publications in the last 10 years none of the Northern African countries had over 25 co-publications with Libya. Instead, Libya's most visible collaborators are United Kingdom (38 co-pub.) and Malaysia (29 co-pub.).

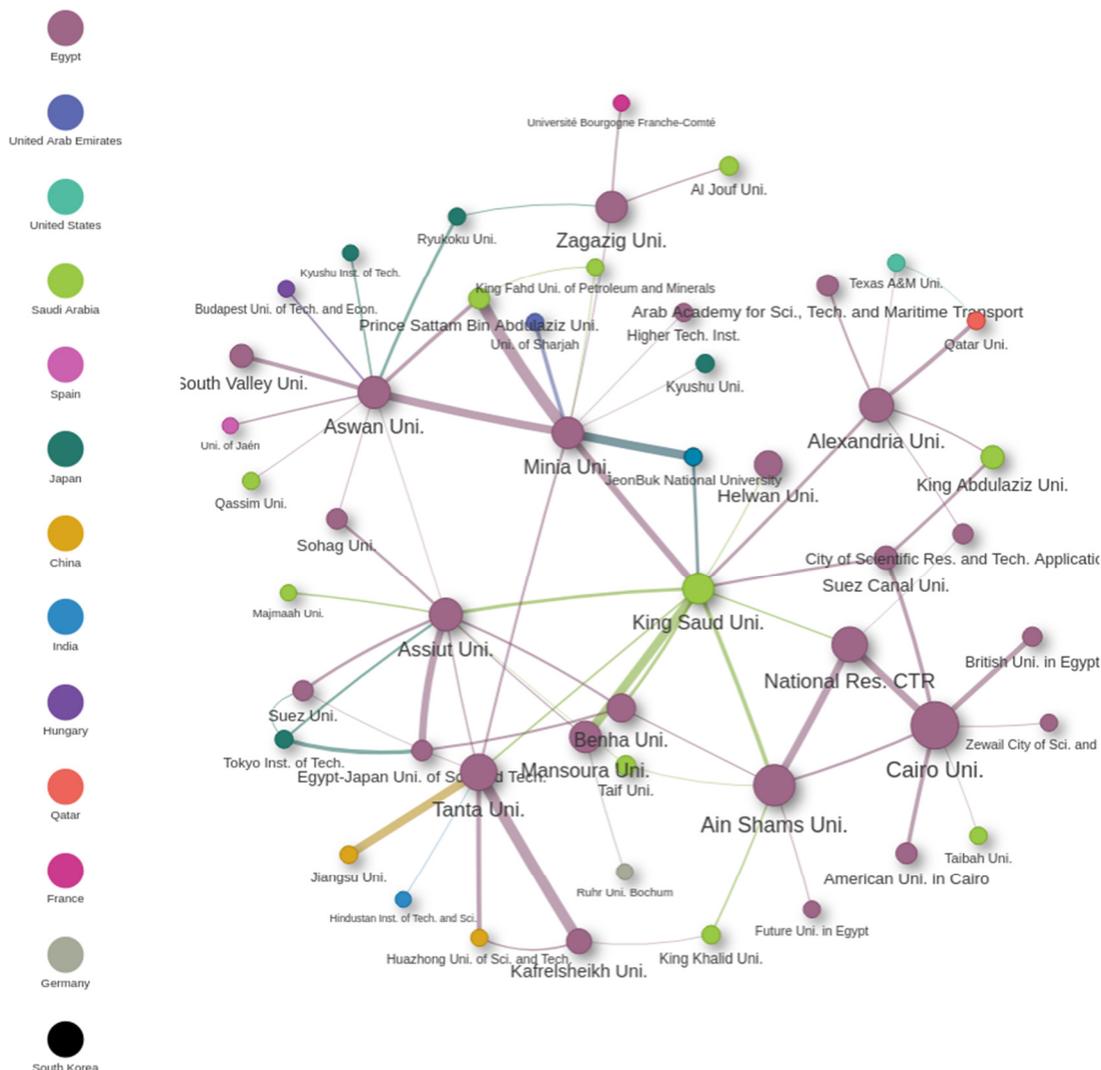
Following the given analysis of RE-related publication outputs in Northern Africa; Egypt, Algeria and Morocco have been chosen for the deeper analysis of the individual countries. While Egypt and Algeria hold the highest numbers of RE-related publications in the northern region, Morocco has been mainly chosen for the high growth rate in the number of publications.

## 3.3.2.1.1 Egypt

Organisation	2011	2020	Rel. growth rate (2011-2020)	Total num. of pub. (2011-2020)
Cairo University	29	128	4.41	779
Ain Shams University	22	104	4.73	631
Tanta University	9	124	13.78	517
National Research Centre	28	93	3.32	494
Alexandria University	19	74	3.89	455

Table 2: Re-related publication output of the most visible Egyptian organisations

The most visible Egyptian organization in the RE-related publications is *Cairo University* with a total of 779 publications between 2011-2020. All of the most visible 5 organizations of Egypt display a fairly linear growth in the number of RE-related publications. However, Ain Shams University and Tanta University show a stagnation between 2019-2020 which might be caused by the delay of document entries into the Web of Science system as mentioned above. Furthermore, Tanta University, which had yearly fewer than 50 RE-related publications until 2016, published in 2019 and 2020 ~125 RE-related papers, this is a growth rate of ~14 fold with respect to the 9 publications in 2011.



\*Collaborations with fewer than 20 co-publications have been removed

Figure 12: Co-publication network in RE-related publications in organisations from Egypt between 2011-2020

The Co-publication network of Egyptian organizations shows a relatively dense collaboration structure between *Cairo University*, *Ain Shams University* and *National Research Centre* of Egypt. *National Research Centre* has over 50 co-publications with each of the other universities in that cluster. *Cairo University* is also in the Centre of other 4 Egyptian organizations; namely *Suez Canal Uni.*, *British Uni. in Egypt*, *Zewail City of Sci. Tech* and *American Uni. in Cairo*, with over 20 co-publications each.

Other visible collaboration links are between *Minia* and *Aswan Universities* with over 50 publications and between *Tanta* and *Kafrelsheikh Universities* with over 70 publications together. In general, collaborations with organizations from Saudi Arabia are highly visible in the network, especially *King Saud University* is a central node in the network with ~400 RE-related co-publications with Egyptian organizations.

Other than that, East Asian organizations also have a visible presence in the co-publication network of Egypt. *Tanta University's* collaborations with Chinese Institutions *Jiangsu Uni.*



and *Huazhong Uni* include 60 and 40 co-publications respectively. Several Japanese universities have collaborations with *Aswan University*, *Zagazig University*, *Assiut University*, *Suez University*, *Egypt Japan University* and *Minia University* with over 20 co-publications each. *Minia University's* collaboration with South Korean institution *JeonBuk National University* also includes 60 RE-related co-publications between 2011-2020.

Visible organizations from EU-27 countries are *University Bourgogne Franche-Comté* of France (over 25 co-publications with *Zagazig University*), *Ruhr University Bochum* from Germany (22 co-publications with *Mansoura Uni.*), *Budapest University of Technology and Economics* from Hungary and the *University of Jaen* from Spain (both over 25 co-pub. with *Aswan University*).

### 3.3.2.1.1.1 Cairo University

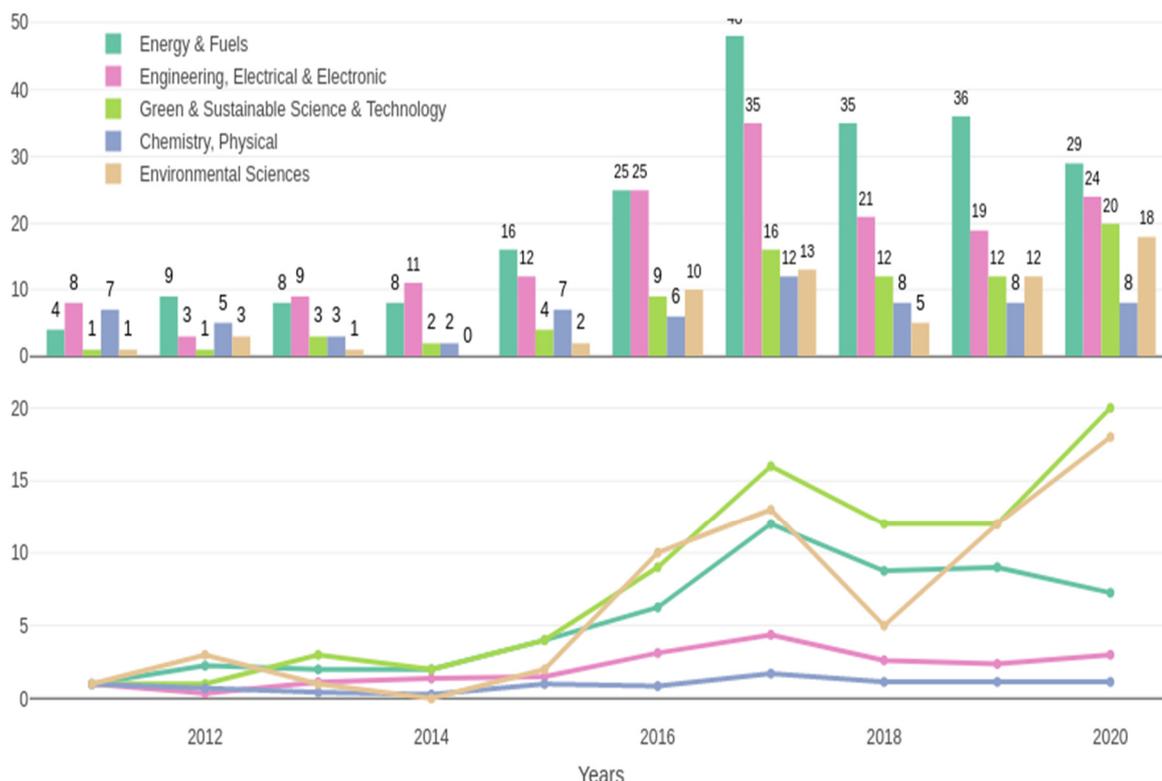


Figure 13: Absolute and relative growth of the most visible research areas in RE-related publications of Cairo University between 2011-2020

Looking into the most visible research areas of *Cairo University*, out of 779 publications in total, the most visible research areas are aligning with the most visible research areas in RE-related publications from African countries in general.

*Energy & Fuels*, as well as *Electrical & Electronic Engineering* are the most visible research areas in Cairo university, however, the number of RE-related in those areas are not growing in the last years. After the spike in 2017 with ~50 publications, the number of publications from *Energy & Fuels* has fallen to ~30 publications in 2019 and 2020.

*Green & Sustainable Science & Technology* and *Environmental Sciences* on the other hand display relatively steady growth in numbers. Considering there was only 1 from each area in 2011, ~20 RE-related publications in 2020 makes those the fastest growing research areas in the RE-related publications of Cairo University.

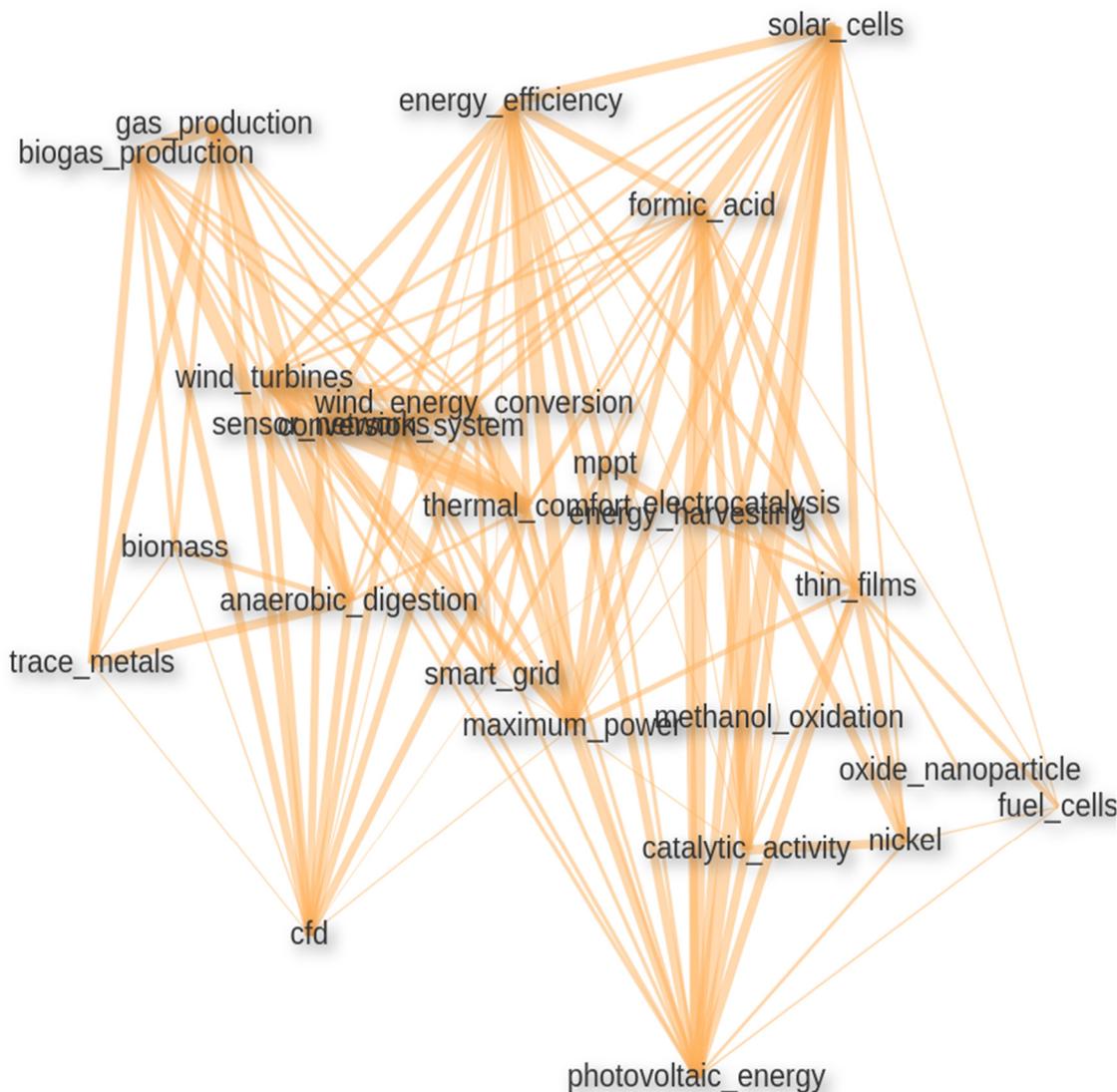


Figure 14: Keyword/keyword pair correlation network in RE-related publications of Cairo University

Figure 14 displays the correlation network between the most common keywords and keyword pairs in the RE-related publications of *Cairo University*. As the clusters on the network graph indicate, there is a strong emphasis on solar energy, photovoltaic systems related keywords in *Cairo University's* publications which is widely the case in African countries.

In relation, substances and technologies aiming to improve the efficiency of the effectiveness of solar cells like formic acid, MPPT (Maximum Power Point Tracking, an algorithmic DC-DC

converter that increases the efficiency of photovoltaic cells) are also among the visible keyword pairs. Other clusters include wind energy-related keywords as well as biogas/biomass related keywords. The approaches like electrocatalysis that aims to increase the output of solar and wind energy are also often mentioned in the RE-related publications of *Cairo University*.

### 3.3.2.1.2 Algeria

Organisation	2011	2020	Rel. growth rate (2011-2020)	Total num. of pub. (2011-2020)
Renewable Energy Development Center	25	54	2.16	688
University of Sciences and Technology Houari Boumediene	30	44	1.47	381
École Nationale Polytechnique d'Oran	8	35	4.38	259
University Ferhat Abbas of Setif	3	29	9.67	241
University of Batna	10	25	2.50	239

Table 3: Re-related publication output of the most visible Algerian organisations

Renewable Energy Development Center, Algeria’s dedicated institution for RE-related research is the most visible organization in the country with ~690 publications. However, the number of RE-related publications of the institution is falling after a spike in 2018 with 127 publications. Although the latency in the record entry process in WoS databases might be causing a proportion of the decline, the number of publications in 2020 seems to be less than half of the number in 2018 (54 pub.).

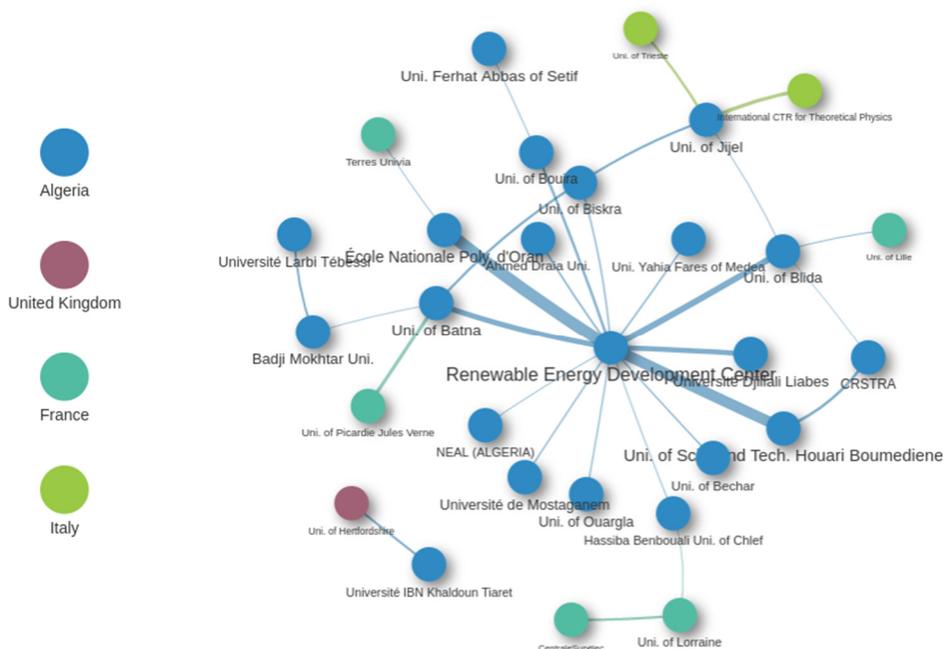


Figure 15: Co-publication network in RE-related publications in organisations from Algeria between 2011-2020

Houari Boumediene University of Sciences is another Algerian institution that publishes RE-related papers consistently. A similar decline in the number of publications like in the case of Renewable Energy Development Center can be observed in the publications of Houari Boumediene University of Sciences after 2018 (from 75 publications to 44 publications in 2020). École Nationale Polytechnique d’Oran University, Ferhat Abbas of Setif and the University of Batna are other organizations with similar numbers of RE-related publications (259, 241, 239 pub. respectively), each of those has increased their

yearly RE-related publication output to ~30. The decline in the number of publications after ~2018 can be observed in all of the most visible 5 organizations of Algeria.

Co-publication network of Algerian organizations mostly gathered around *Renewable Energy Development Center*, the to RE-related research dedicated institution collaborates with a number of other Algerian academic institutions, from which 14 of the collaboration links include close to or over 20 co-publications. The most visible collaborations with *Renewable Energy Development Center* are with *Houari Boumediene University of Sciences* and *École Nationale Polytechnique d'Oran University*, both with an output of over 60 co-publications.

Most of the international collaborators with more than 25 co-publications with Algerian institutions are French, the collaboration between *University of Batna* and *University of Picardy Jules Verne* is the most visible one with 27 co-publications between 2011-2020. *University of Jijel* collaborates often with Italian institutions like *University of Trieste* (23 co-pub.) and *International Centre for Theoretical Physics* (28 co-pub.). Other than that, *University of Hertfordshire* is the only organization from the UK that has more than 20 RE-related co-publications with an Algerian organization (*University Ibn Khaldun*) between 2011-2020.

### 3.3.2.1.2.1 Renewable Energy Development Center

The most visible research areas in the RE-related publications of *Renewable Energy Development Center* are *Energy & Fuels* and *Green & Sustainable Science in Technology*. All of the most visible 5 research areas are declining in numbers after 2018 which indicates that there was at least some effect caused by the delayed entry of the publications into the Web of Science databases. However, even after the possibly missing publication from the last years Thermodynamics seems to be becoming one of the consistently visible research areas in the RE-related publications of Renewable Energy Development Center.

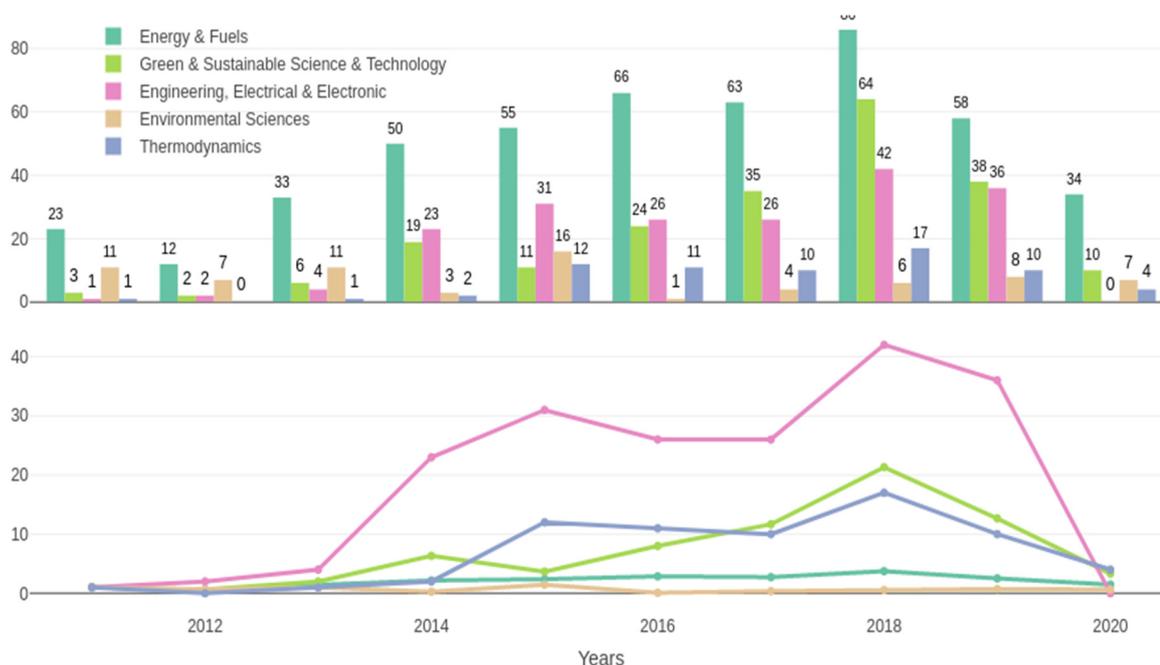


Figure 16: Absolute and relative growth of the most visible research areas in RE-related publications of Renewable Energy Development Center between 2011-2020



Environmental Sciences which already included relatively high number of publications in 2011 (11 pub.) is also becoming a consistent area despite having volatile yearly number of publications between 2014-2017.



Figure 17: Keyword/keyword pair correlation network in RE-related publications of Renewable Energy Development center

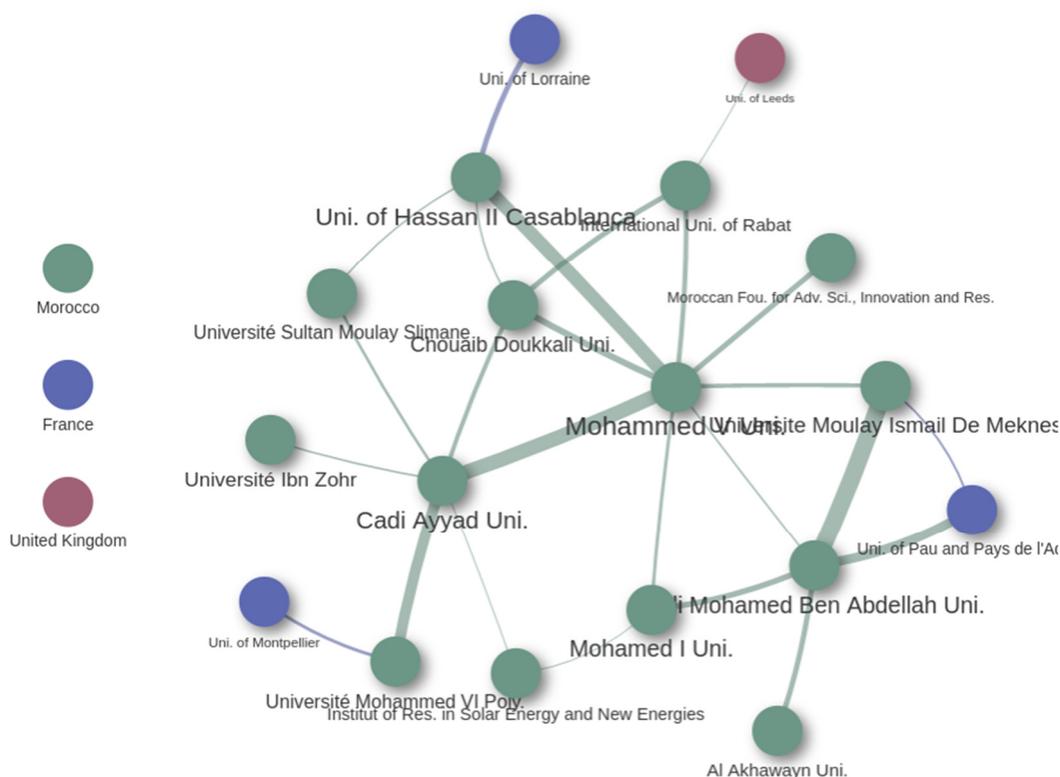
Keyword/keyword pair correlation network also displays heavily solar energy-related topics. We are seeing that the exploitation of Algerian Sahara for solar energy production is an often-reoccurring theme in the publications of *Renewable Energy and Development Center*. Wind energy-related topics are also emphasized in the most visible keyword pairs.

The reason, why water pumping systems are relatively highly correlated with the solar energy keywords is the recent technological advances to build photovoltaic water pumps. Algeria is one of the most active countries in Africa that search for photovoltaic water pumping solutions especially for the isolated sites which are not connected to an electrical grid (see [Benghanem and Arab \(2007\)](#) for further reading [10]).

### 3.3.2.1.3 Morocco

Organisation	2011	2020	Rel. growth rate (2011-2020)	Total num. of pub. (2011-2020)
Mohammed V University	4 	104	26.00	667
University of Sfax	9 	73	8.11	541
University of Hassan II Casablanca	5 	88	17.60	415
Cadi Ayyad University	7 	76	10.86	348
Mohamed I University	2 	49	24.50	288

Table 4: Re-related publication output of the most visible Moroccan organisations



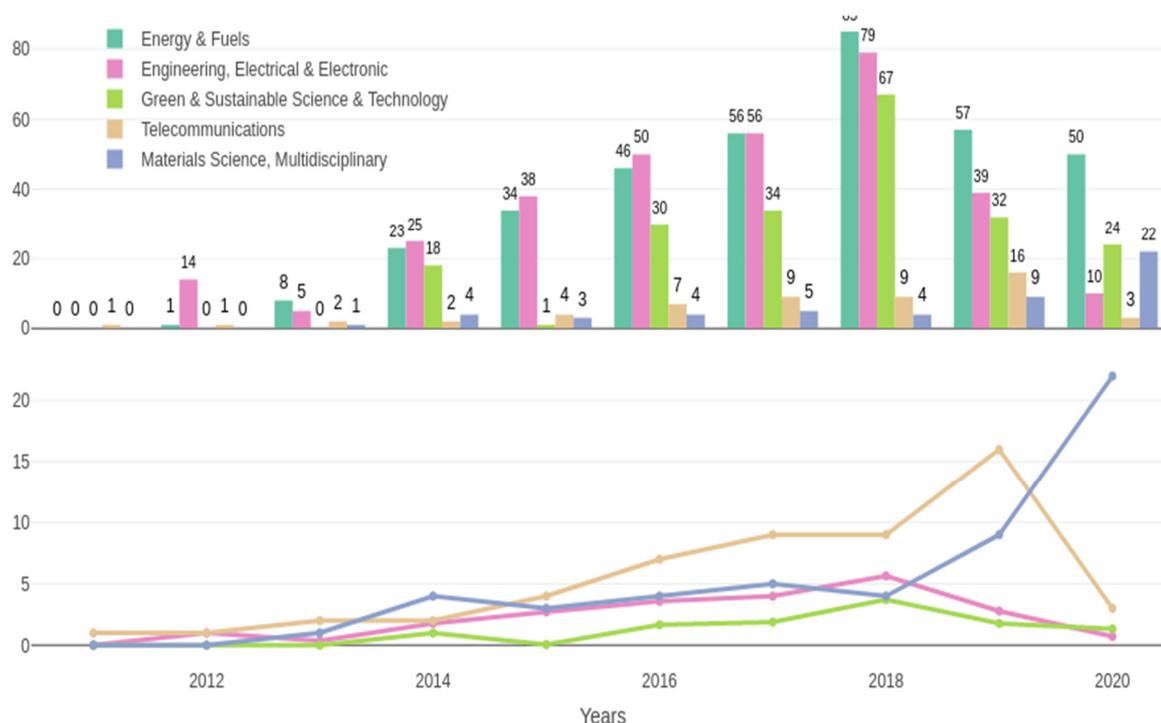
Morocco has the most rapidly growing number of publications in the 15 most visible African countries in RE-related publications with having 543 publications in 2020 in comparison with 34 RE-related publications in 2011. The same pattern is also observable in the publications of Moroccan Institutions. Each one of the RE-wise most visible 5 organizations in Morocco had 1 digit RE-related publications in 2011 and each of those have published at least ~8 fold of those numbers in 2020. *Mohamed V University* is the most visible Moroccan institution in the RE-related publications with 667 publications in total between 2011-2020. There is a slight decline in the number of publications after 2018 but the university still collaborates in over 100 RE-related publications yearly. *Mohamed V* and *Mohamed I Universities* are both published in comparison with 2011 ~25 times more in RE-related papers. The *University of Sfax*, *University of Casablanca* and *Cadi Ayyad University* are most visible 2., 3. and 4. organizations respectively.



Moroccan organizations are well interconnected in RE-related publications. Although *Mohamed V University* stays in the center of the network, institutions are evenly distributed. Especially the number of co-publications of *Mohamed V Uni.* with *Cadi Ayyad Uni.* and *Uni. of Hassan II Casablanca* (41 and 39 co-publications respectively) as well as the co-publications between *University Moulay Ismail de Meknes* and *Sidi Mohamed Ben Abdellah University* (~50 co-publications) are most visible collaborations in Morocco.

Only a few intercontinental collaborations have an output of more than 15 co-publications with Moroccan organizations. *Uni. of Lorraine*, *Uni. of Montpellier* and *University of Pau and Pays de l'Adour* from France, *Uni. of Leeds* from the UK are the most visible intercontinental collaborators.

### 3.3.2.1.3.1 Mohammed V University



Similar to the other selected universities from the Northern Africa region *Energy & Fuels* has a strong presence also in the publications of *Mohamed V Univ.* Considering, there was no recorded renewable energy-related publication from *Mohamed V University* in 2011 and only 1 publication in 2012 in Web of Science databases, 2018 shows a strong contrast with 85 RE-related publications to the previous years. *Electrical and Electronic Engineering* is following *Energy and Fuels* closely in total RE-related publication from *Mohamed V Univ.*

Although, there are no recorded publications in *Green and Sustainable Science & Tech.* before 2014, it stays as the 3. most visible research area in the total numbers. In contrast to the other selected organizations so far one of the most visible research areas in the RE-related publications of *Mohamed V University* is *Telecommunications* and publications in *Multidisciplinary Material Science* are also increasing since 2015.

*Multidisciplinary Material Science* is also the only research area that was increasing in numbers between 2019-2020 in the RE-related publications of *Mohamed V University*.

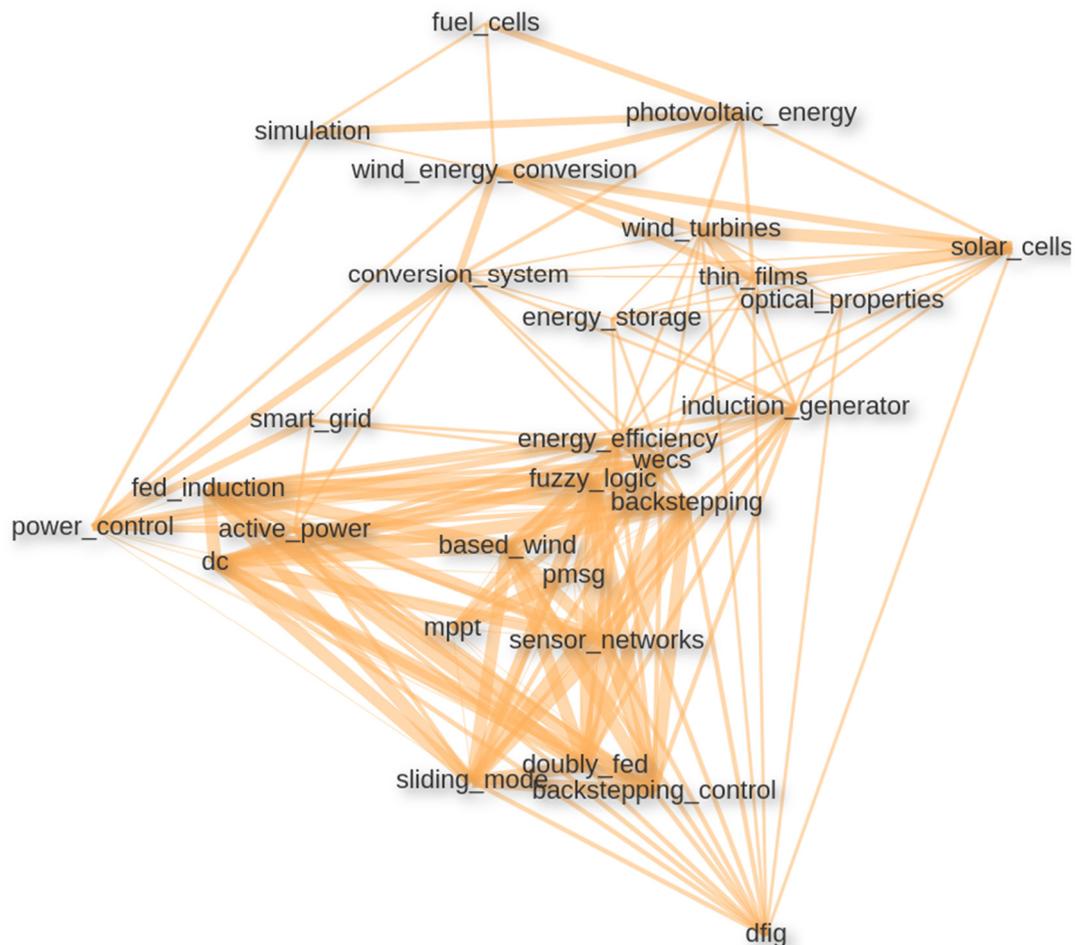


Figure 18: Keyword/keyword pair correlation network in RE-related publications of Mohammed V University

The keyword/keyword pair correlation network of *Mohamed V University* also includes a number of solar energy and wind energy-related themes. Especially different types of conversion systems (wind energy conversion systems *Mohamed V University*. In relation, hybrid energy approaches like *doubly fed induction generator* (dfig) or backstepping control system that supports wind tribunes and photovoltaic systems (see [E. Ahmed and S. Yuvarajan \(2012\)](#)[11]) are emphasized. Also, dc-dc converter technologies like MPPT that aims to increase the efficiency of the photovoltaic systems are among the most visible keywords.

### 3.3.2.2 Western Africa, Central Africa, Eastern Africa

Western Africa, Central Africa and Eastern Africa are corresponding to a vast area of the African continent, however, on organizational level number of RE-related publications are relatively fewer in comparison. Therefore, although on country level those 3 regions will be analyzed individually as in previous sub-chapters, on organizational level; firstly, table of most visible organizations will include organizations from selected 3 countries from each region and organization network they will include all 3 regions on a single graph.

## 3.3.2.2.1 Western Africa

Country	2011	2020	Rel. growth rate (2011-2020)	Total num. of pub. (2011-2020)
Nigeria	74 	481	6.50	2252
Ghana	20 	153	7.65	696
Senegal	13 	28	2.15	259
Burkina Faso	11 	30	2.73	222
Benin	13 	16	1.23	162

Figure 19: RE-related publication output in Western African countries

Western African countries Nigeria and Ghana have been increasing their RE-related publication output in a consistent manner in the 10 years range without any stagnation. Although Nigeria's number of publications in 2011 was already relatively high in comparison (74 pub.), the number of publications in 2020 was ~6.5 fold (481 pub.) of that. In a similar fashion, Ghana has increased its RE-related publication output from 20 in 2011 to 153 in 2020 which is an increment of a factor of ~7.5.

Senegal, the third most visible country in the region shows a volatile progression with a sharp decline in the number of RE-related publications after 2018 from 48 yearly publications to 28. Burkina Faso is following Senegal with relatively less volatility and Benin's volatile numbers are expected since the total output of RE-related publications is fewer in comparison.

Nigeria, the highest of the region in terms of the total number of RE-related publications, is also the center of mass in the co-publication network of the Western African countries. It is the only Western African country with more than 25 co-publications with a Northern African country (Egypt, 26 co-pub). In a similar manner, together with Ghana, Nigeria is the only Western African Country with more than 25 co-pub. with South Africa (277 pub.).

Ghana and Nigeria have a collaboration link with 40 RE-related co-publications between 2011-2020. However, the collaborations between the two most visible countries in the region with the other countries are relatively sparse. Côte d'Ivoire, Benin, Senegal, Burkina Faso and Mali are mostly engaged in their own cluster. The most visible international partner of that cluster is France.

French academic organizations have co-published ~400 papers with Western African countries between 2011-2020 and most of those have been carried out with the mentioned 5 countries. Germany is the second most visible EU-27 country in the region with ~215 co-pub. with Western African countries followed by the Netherlands with 90 co-publications. Those 2 countries along with other EU-27 members like Sweden, Denmark and Italy are mostly engaged with the Nigeria-Ghana cluster.

Especially Nigeria has other international collaborations with relatively high output in terms of RE-related publications. A few examples of those are the collaborations with Malaysia (275 co-pub.), United Kingdom (215 co-pub.), United States (160 co-pub.) and China (40 co-publications).

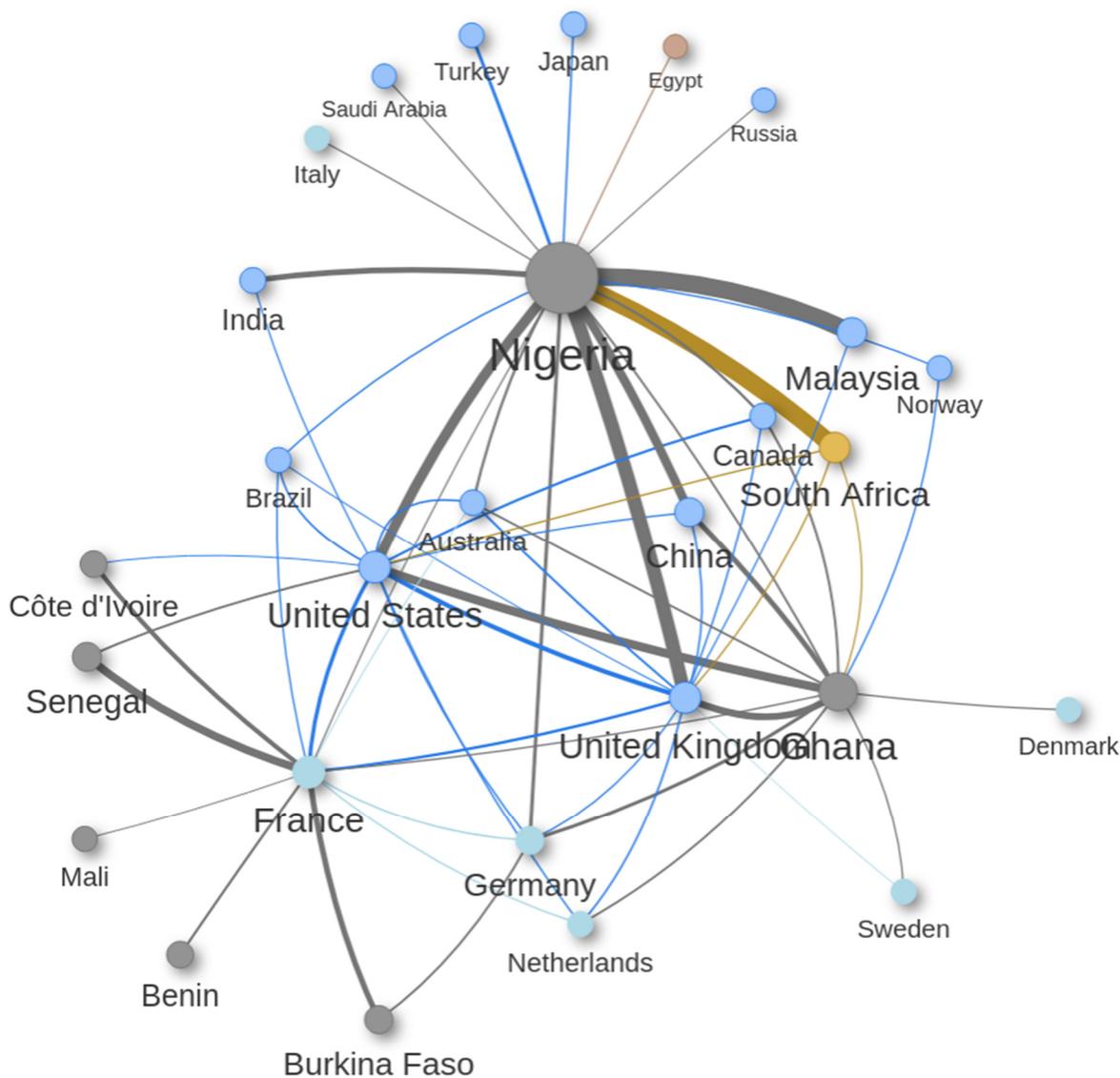


Figure 20: Co-publication network of Western African countries in RE-related publications between 2011-2020

Organisation	2011	2020	Rel. growth rate (2011-2020)	Total num. of pub. (2011-2020)	Country
Covenant University	9	37	4.11	250	Nigeria
University of Ibadan	7	25	3.57	197	Nigeria
University of Nigeria	4	46	11.50	185	Nigeria
Kwame Nkrumah University of Science and Technology	4	30	7.50	166	Ghana
University of Ghana	7	32	4.57	140	Ghana

Table 5: The most visible organisations from Nigeria, Ghana, Senegal cluster

All of the most visible 3 organizations in the Nigeria, Ghana, Senegal cluster are from Nigeria. The number of RE-related publications of *Covenant University*, the most visible organization in the region, seems to be declining presumably because of the latency in document entries into WoS databases after 2019.

Other than *Covenant University* total RE-related publication outputs of other most visible organizations in Western Africa are relatively close to each other. The *University of Nigeria* has the highest relative growth rate of 11.5 (from 4 pub. in 2011 to 46 in 2020). Other than the *University of Ibadan*, the other 3 organizations were also consistently increasing numbers of their Re-related publications despite two Ghanaian organizations showing slightly more volatile progress.

### 3.3.2.2.2 Central Africa

Country	2011	2020	Rel. growth rate (2011-2020)	Total num. of pub. (2011-2020)
Cameroon	13	64	4.92	379
Dem. Rep. Congo	3	19	6.33	97
Congo	5	12	2.40	63
Gabon	4	12	3.00	61
Central African Rep.	2	4	2.00	12

Table 6: RE-related publication output in Central African countries

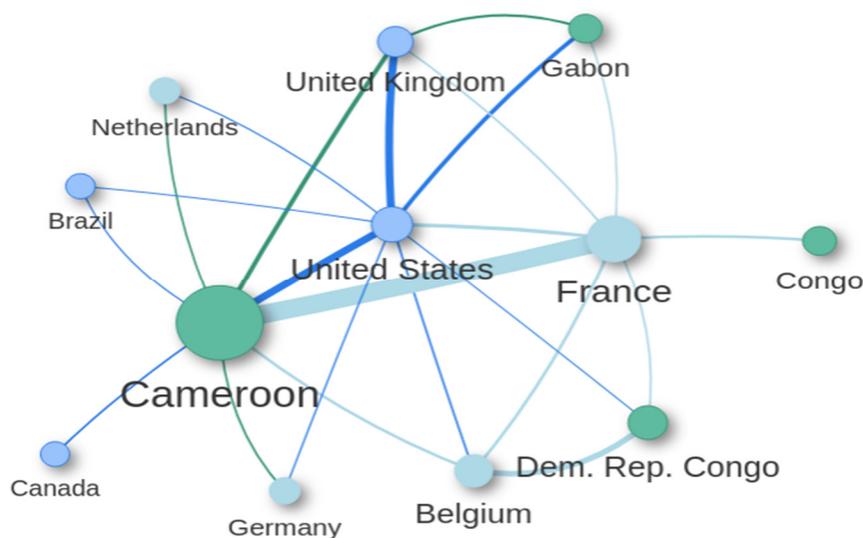


Figure 21: Co-publication network of Central African countries in RE-related publications between 2011-2020

In the Central African region, the publication output in RE-related topics is relatively volatile. Cameroon shows a steady increment between 2011-2020 with a total output of 379 RE-related publications in 10 years. Other than Cameroon, the total number of RE-related publications in other Central African countries stays under 100 in total between 2011-2020. Democratic Republic of Congo (DRC) is the second most visible country in the region; although DRC displays high volatility in number of yearly RE-related publications, 19 publications in 2020 is over 6-fold of the 3 publications back in 2011. Following 2 countries Republic of Congo and Gabon share similar numbers in general. Both of the countries have a total of ~60 RE-related publications in the 10 years range and the closest following country is Central African Republic with 12 RE-related publications in total.



Although the publication output is not high in comparison with other regions, most of the publications in Central Africa are produced through intercontinental cooperation. France is the most visible intercontinental collaborator in the co-publication network in Central Africa with 180 co-pub. in the region; 121 of those co-pub. have been published by collaboration with Cameroon. Belgium is following France with ~90 co-pub. with Central African countries.

All of the visible international collaborators have published at least 25 RE-related co-publications with Cameroon. However, none of the Central African countries seems to have a co-publication link with another Central African country with an output of over 25 publications.

Organisation	2011	2020	Rel. growth rate (2011-2020)	Total num. of pub. (2011-2020)	Country
Université de Yaoundé I	4	30	7.5	170	Cameroon
Université de Dschang	1	18	18.0	76	Cameroon
University of Buea	2	9	4.5	45	Cameroon
University of Ngaoundéré	1	7	7.0	45	Cameroon
Center for International Forestry Research	1	8	8.0	44	Cameroon

Table 7: The most visible organisations from Cameroon, Dem. Rep. Congo, Gabon cluster

In the Cameroon, Dem. Rep. Congo and Gabon cluster, all of the most visible 5 organizations in the region are from Cameroon with the most visible organization being *University de Yaoundé I* with 170 RE-related publications in 2020. None of the organizations in the region has published more than 5 RE-related publications in 2011.

*University de Yaoundé I* is followed by *University de Dschang* which increased its 1 RE-related publication in 2011 to 18 in 2020 with a total of 76 RE-related publications in the 10-year range. The RE-related publication output of the following 3 organizations; *University of Buea*, *University of Ngaoundéré* and *University of Douala* is still fewer than 10 yearly publications.

### 3.3.2.2.3 Eastern Africa

Country	2011	2020	Rel. growth rate (2011-2020)	Total num. of pub. (2011-2020)
Ethiopia	28	226	8.07	940
Kenya	32	132	4.12	871
Tanzania	17	62	3.65	435
Uganda	7	53	7.57	308
Sudan	11	28	2.55	191

Table 8: RE-related publication output in Eastern African countries

The most visible 5 Eastern African countries have been steadily increasing their numbers of RE-related publications. Ethiopia and Kenya are the most visible ones with 940 and 870 publications respectively. Ethiopia's number of publications in 2020 (226 pub.) is approximately 8-fold the number in 2011 (28).

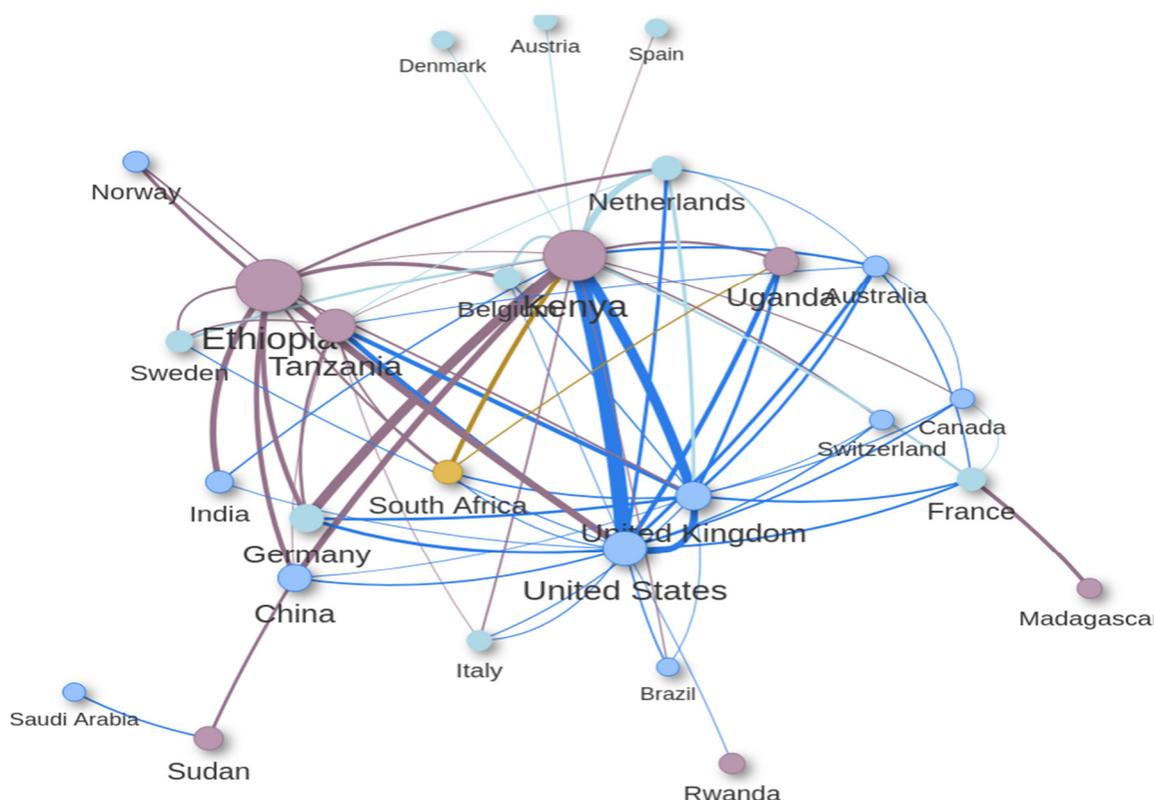
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The second most visible country in the region, Kenya's yearly output of RE-related publications was also linearly increasing after its already relatively high number in 2011 (32 publications). Tanzania follows Kenya with a fairly stable increment despite having approximately half of Kenya's total RE-related number of publications. Despite having 7 RE-related publications in 2011 Uganda is 4. most visible country in Eastern Africa after increasing its RE-related publication output  $\sim 7.5$  fold. Sudan is the 5. most visible country in Eastern Africa with  $\sim 200$  publications in total.

The 4 most visible countries in Eastern Africa; Ethiopia, Kenya, Tanzania and Uganda are fairly interconnected in terms of RE-related co-publications with each other as well as with international collaborators. A number of EU-27 countries like France, Italy, Germany, Belgium, Sweden, Netherlands, Austria, Spain and Denmark are engaged in co-publications with Eastern African countries. Both Ethiopia and Kenya display a significant number of co-publications with Germany (72 and 134 pub. respectively). Although Ethiopia has the highest number of RE-related publications, Kenya seems to have more international co-publication links with relatively high co-publication output.

Several Eastern African countries have only international collaborations with more than 25 co-publications. That includes Madagascar with France as the only collaborator (63 co-pub.), Rwanda with United States (26 co-pub.), and Sudan with Saudi Arabia and China.

Other than EU countries the United States and the United Kingdom are also visible international partners engaged in RE-related research with Eastern African organizations. The United States has  $\sim 500$  (out of 2360 co-pub. with African countries) co-publications with the countries of Eastern Africa.



*Figure 22: Co-publication network of Eastern African countries in RE-related publications between 2011-2020*

South Africa is the only African country from another region that has more than 25 RE related co-publications with the Eastern African countries. South Africa's total RE-related co-publication output with the Eastern African countries between 2011-2020 is 199.

Organisation	2011	2020	Rel. growth rate (2011-2020)	Total num. of pub. (2011-2020)	Country
Addis Ababa University	9 	43	4.78	246	Ethiopia
World Agroforestry Centre	6 	17	2.83	150	Kenya
Mekelle University	3 	28	9.33	135	Ethiopia
University of Dar es Salaam	5 	13	2.60	124	Tanzania
University of Nairobi	4 	17	4.25	120	Kenya

Table 9: The most visible organisations from Ethiopia, Kenya, Tanzania cluster

Most visible countries from the selected countries in Eastern Africa, namely Ethiopia, Kenya Tanzania are diverse. *Addis Ababa University* from Ethiopia is the most visible one with 246 RE-related publications between 2011-2020. The number of publications of *Addis Ababa University* has been increasing steadily since 2013.

Although *World Agroforestry Centre* operates in different countries, the main location of the institution is registered as Kenya. *World Agroforestry Centre* is the second most visible organization in the Ethiopia, Kenya, Tanzania cluster with a total number of 150 publications between 2011-2020. However, the yearly number of publications are declining since 2016.

*Mekelle University* of Ethiopia is the third most visible organization with steady growth in the number of RE-related publications and *University of Dar es Salaam* is the only organization from Tanzania in the 5 most visible countries in the selected countries of East Africa followed by the *University of Nairobi* of Kenya.

#### 3.3.2.2.4 Selected Institutions and Institutional Co-publication Network

Collective organization network of Western, Central and Eastern African regions displays a couple of interconnected co-publication clusters. Organizations from Cameroon are one of the most visible clusters where *University Yaoundé I* stands as a central connection node. *University de Dschang*, *Uni. of Buea* and *University De Ngaoundéré* are the other academic organizations from Cameroon which co-published visible amount of RE-related publications with *University Yaoundé I* (22, 17 and 17 co-publications respectively).

The network of Cameroonian universities is connected to French and British organizations with a visible amount of publications. On the French side *Uni. of Montpellier* and *CIRAD* both have 22 co-publications with *University Yaoundé I* and on the other side *Uni. of Leeds* has a collaboration of 18 RE-related co-publications with *University Yaoundé I* where other British academic organizations like *UCL*, *Uni. of Oxford* and *York Uni.* are also present in a number of those co-publications.

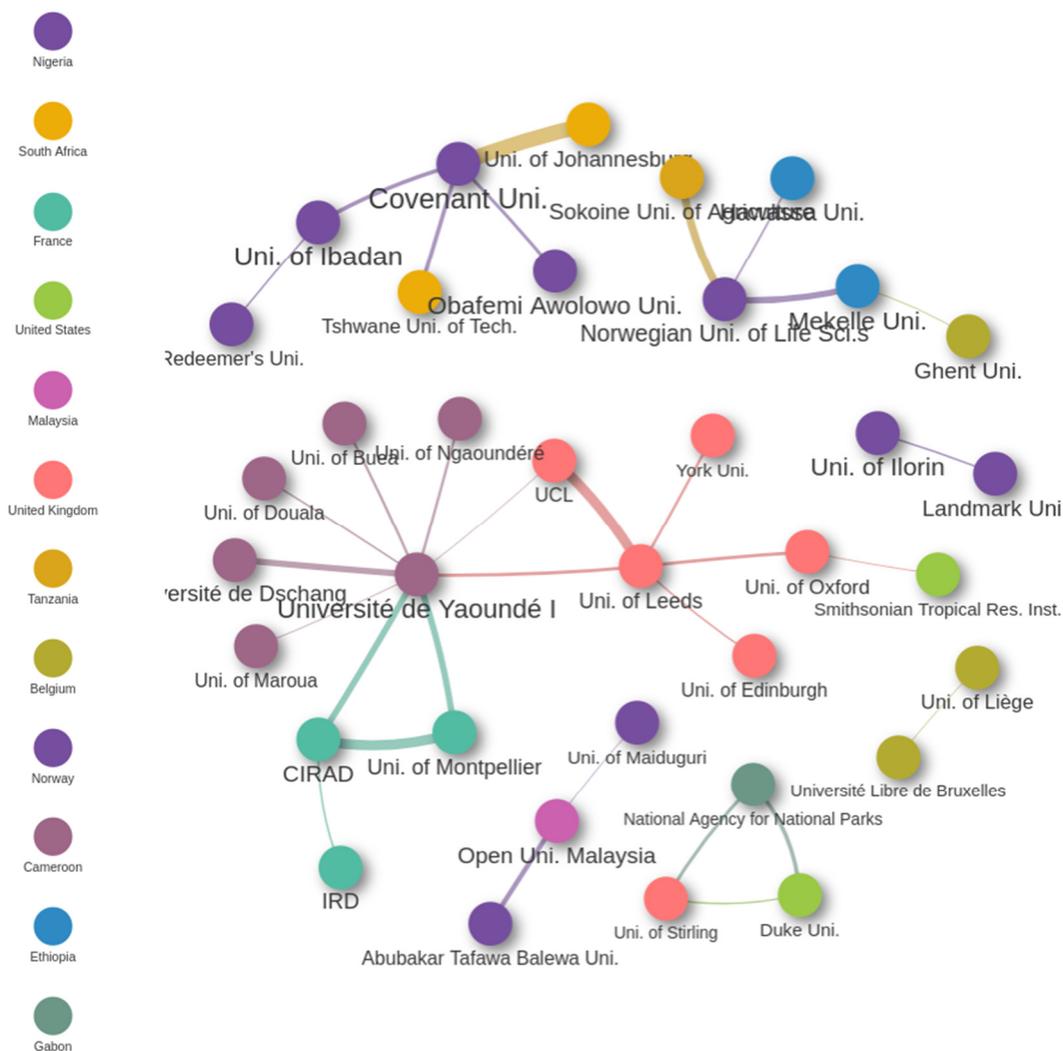


Figure 23: Co-publication network of Western, Central, Eastern African organizations in RE-related publications between 2011-2020

Nigerian Universities form another visible cluster in the co-publication network whereas *Covenant University* plays a central role. *Uni. of Ibadan* and *Obafemi Awolowo Uni.* both have ~20 co-publications with *Covenant University*. Also, *Covenant University's* collaborations with South African institutions are in the most visible co-pub. connections in the region, *University of Johannesburg* has co-published 34 RE-related publications with *Covenant University*.

Other visible collaborations are *Norwegian Uni. of Life Sciences'* co-publications with Tanzania's *Sokoine Uni. of Agriculture* (24 co-pub.) and with Ethiopia's *Mekelle University* (22 co-pub.).

### 3.3.2.2.4.1 Covenant University (Nigeria)

The most visible research areas are *Energy & Fuels* and *Green & Sustainable Science & Technology* respectively in RE-related publications of *Covenant University*. 2019 is in terms of RE-related publications a peak point for *Covenant University*, the 2 two most visible areas include 20 and 30 publications respectively in this year.

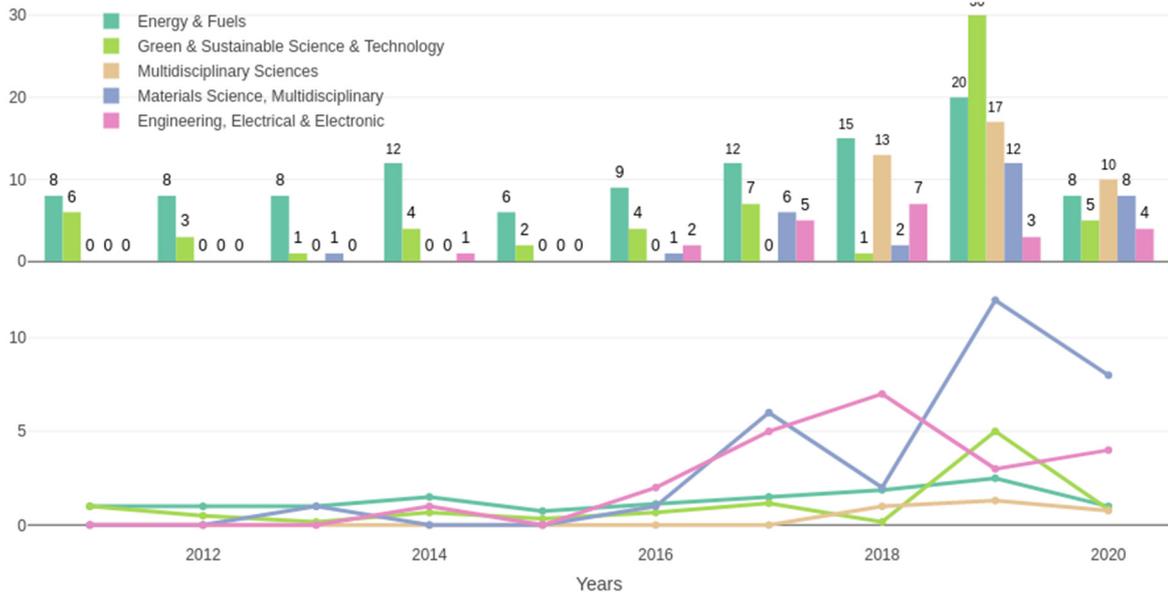


Figure 24: Absolute and relative growth of the most visible research areas in RE-related publications of Covenant University between 2011-2020

None of the last three research areas *Multidisciplinary Sciences*, *Material Science* and *Electrical & Electronic Engineering* had more than 1 yearly RE-related publication in *Covenant University* until 2016. However, although there weren't any publications in *Multidisciplinary Sciences* until 2017, the research area has become one of the most visible research areas in *Covenant University's* RE-related publications with yearly over 10 publications.

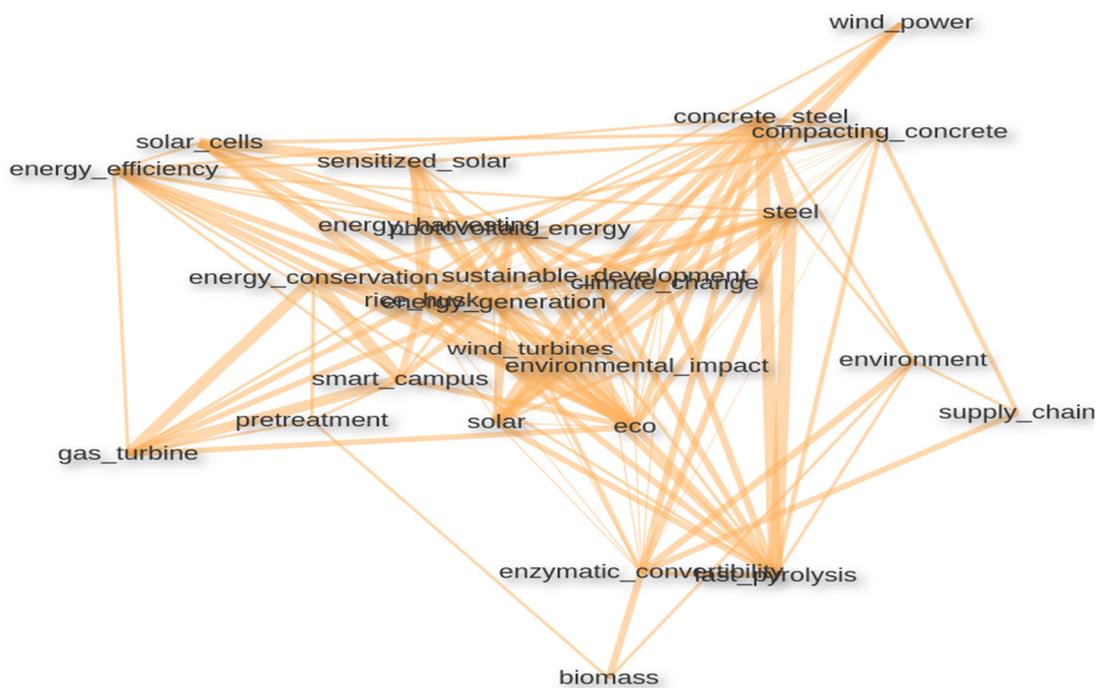


Figure 25: Keyword/keyword pair correlation network in RE-related publications of Covenant University

Similar to the research areas keyword/keyword pair correlation network of *Covenant University* also includes some differing elements. Along with a heavy emphasis on solar

and wind energy-related topics, one of the central keyword pairs indicates the research on using rice husk, a byproduct of rice growing, as a biomass fuel. Presumably several mentions of concrete and steel, firstly, relates to the production of those materials with renewable energy, and secondly, as *compacting\_concrete* indicates research on producing environment-friendly forms of (self-) compacting concrete which has more than one benefit for sustainable development (further reading: [Long, Gao, and Xie \(2015\)](#) [12] and [Gupta, Siddique, and Belarbi \(2021\)](#) [13]).

Also, keyword pairs like *fast\_pyrolysis* and *enzymatic\_convertibility* indicate a high number of biomass related studies.

### 3.3.2.2.4.2 University of Nigeria

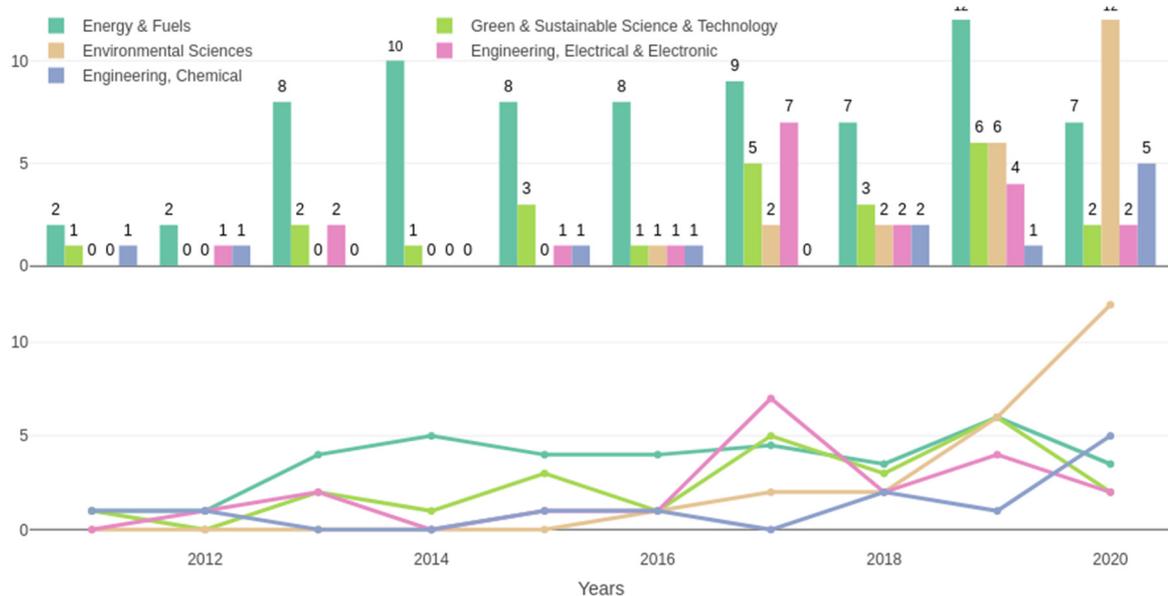


Figure 26: Absolute and relative growth of the most visible research areas in RE-related publications of University of Nigeria between 2011-2020

The *University of Nigeria* also starts with a fairly low number of publications in the now trending research areas. Until 2013 none of the most visible 5 research areas includes a yearly output of over 2 RE-related publications.

Energy & Fuels spikes in the later years followed by Green & Sustainable Science & Technology. However, while the two most visible areas are stagnating or declining Environmental Sciences starts to grow in numbers and become together with Chemical Engineering the only areas still rising in 2020

The *University of Nigeria* also includes some unique keyword pairs. Along with the usual emphasized renewable energy forms like solar and wind energy RE-related publications of the *University of Nigeria* puts high emphasis on biomass related topics. In relation, also micro- and macroalgae are often reoccurring keywords in the RE-related publications of *University of Nigeria*, these are recently discussed in the renewable energy-related areas because of their potential to be used as biofuel (see [Khan, Shin, and Kim \(2018\)](#)[13]). Also, a couple of keywords pairs indicate wastewater treatment, removal and recycling of waste plastics are also visible topics in the publications of *University of Nigeria*.

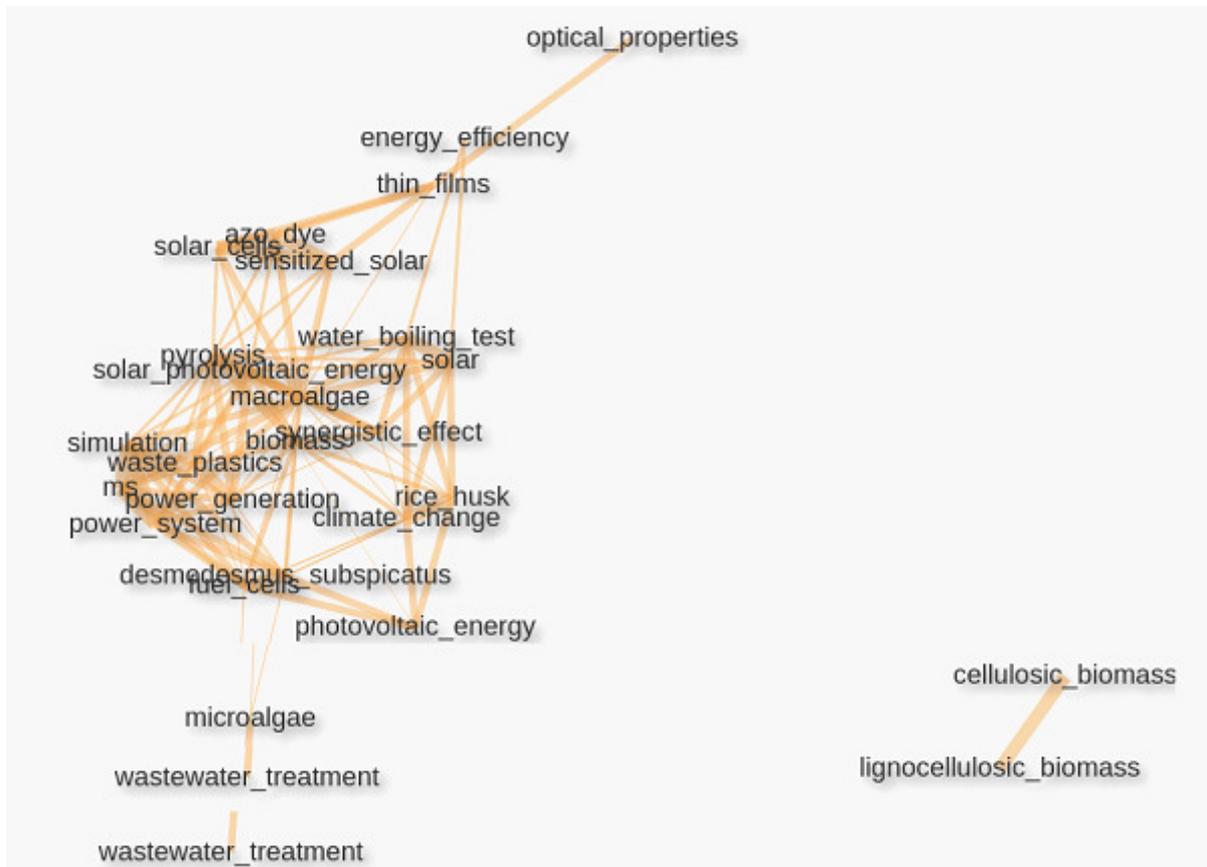


Figure 27: Keyword/keyword pair correlation network in RE-related publications of University of Nigeria

### 3.3.2.2.4.3 Université de Yaoundé I (Cameroon)

Most visible research areas in the RE-related publications of *University de Yaoundé I* are relatively uniformly distributed. Energy & Fuels is the most visible one followed by Green & Sustainable Science & Technology.

However, starting with 2015 Forestry, Ecology, and Environmental Sciences gain visibility. Especially the visibility of the research area Forestry is unique to *University de Yaoundé I* among the most visible organizations in Africa.

Keyword/ keyword pair correlation network also shows the influence of the research area Forestry. Forest/ground biomass research along with tropical forest and forest structure topics shows the main directions of the Forestry research, we also see the use of cocoa shells for green energy often explored in the RE-related research of *University de YaoundéI*.

Other than the biomass and solar energy-related topics keywords also indicates research on different modelling approaches.



Figure 28: Absolute and relative growth of the most visible research areas in RE-related publications of Université de Yaoundé I between 2011-2020

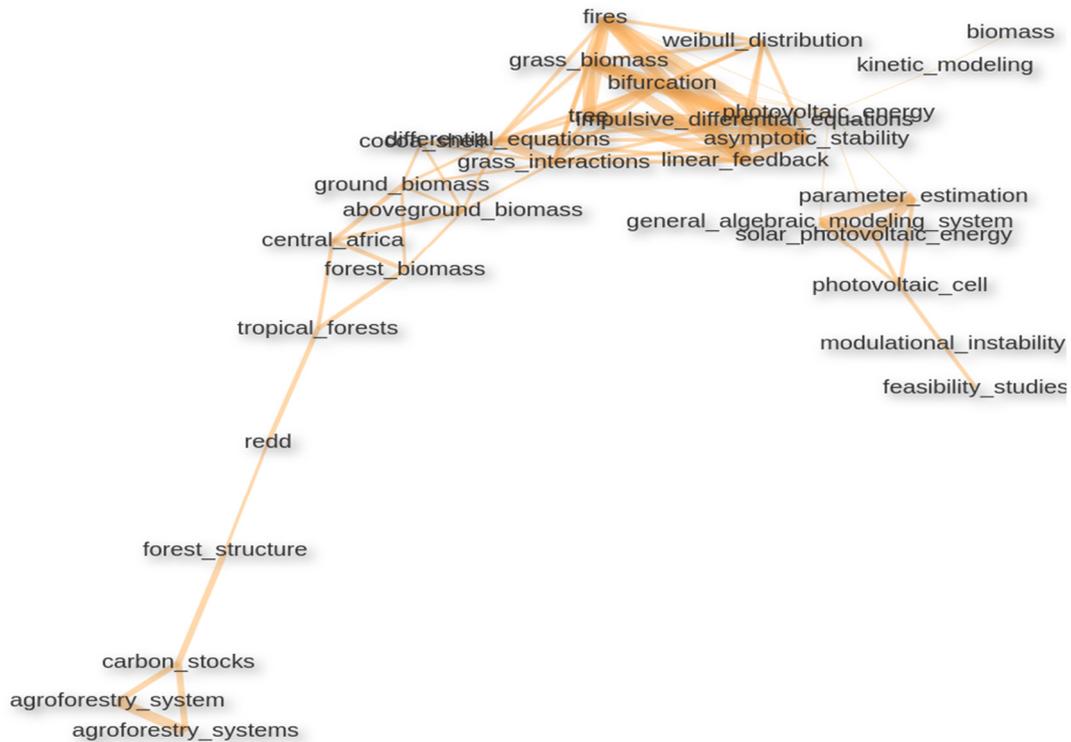


Figure 29: Keyword/keyword pair correlation network in RE-related publications of Université de Yaoundé I

### 3.3.2.2.4.4 Addis Ababa University (Ethiopia)

Similar to the previous visible organizations the most visible research area in the RE-related research of *Addis Ababa University* is Energy & Fuels. However, Environmental Sciences is the most rapidly increasing area in the number of RE-related publications followed by Ecology, Green & Sustainable Science & Technology, and Multidisciplinary Chemistry.

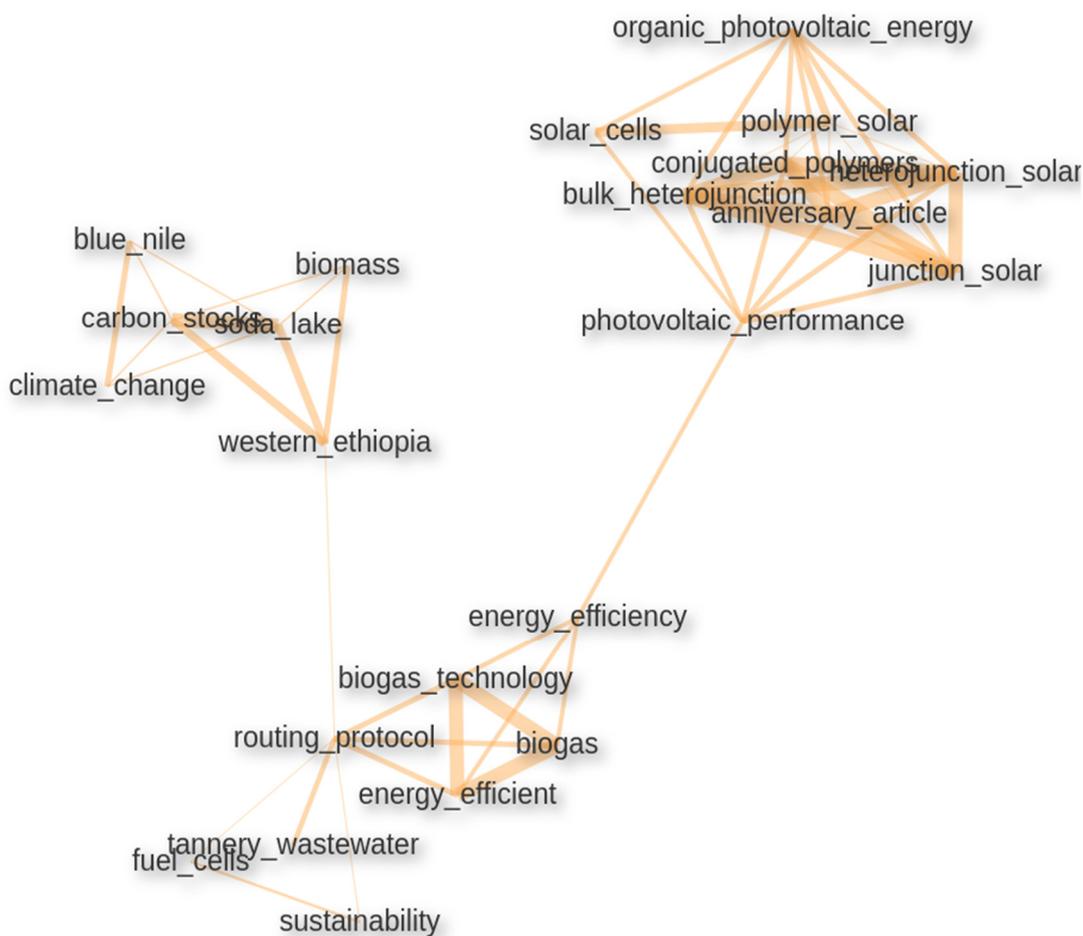


Figure 30: Keyword/keyword pair correlation network in RE-related publications of Addis Ababa University

3 clusters of the keyword/keyword pairs in the RE-related publications of *Addis Ababa University* roughly include biomass, biogas, and solar energy related keywords. In the solar energy cluster, there are keyword pairs that indicate research on different production approaches for photovoltaic components like organic photovoltaic cells (OPV, see [Rwenyagila \(2017\) \[14\]](#)) and conversion technologies like the heterojunction approach.

In the biomass cluster, there is also the mention of soda lake as there are several soda lakes in the borders of Ethiopia, there is also the Blue Nile Project mentioned which is a massive hydroelectric project on Blue Nile River.

### 3.3.2.2.4.5 Mekelle University (Ethiopia)

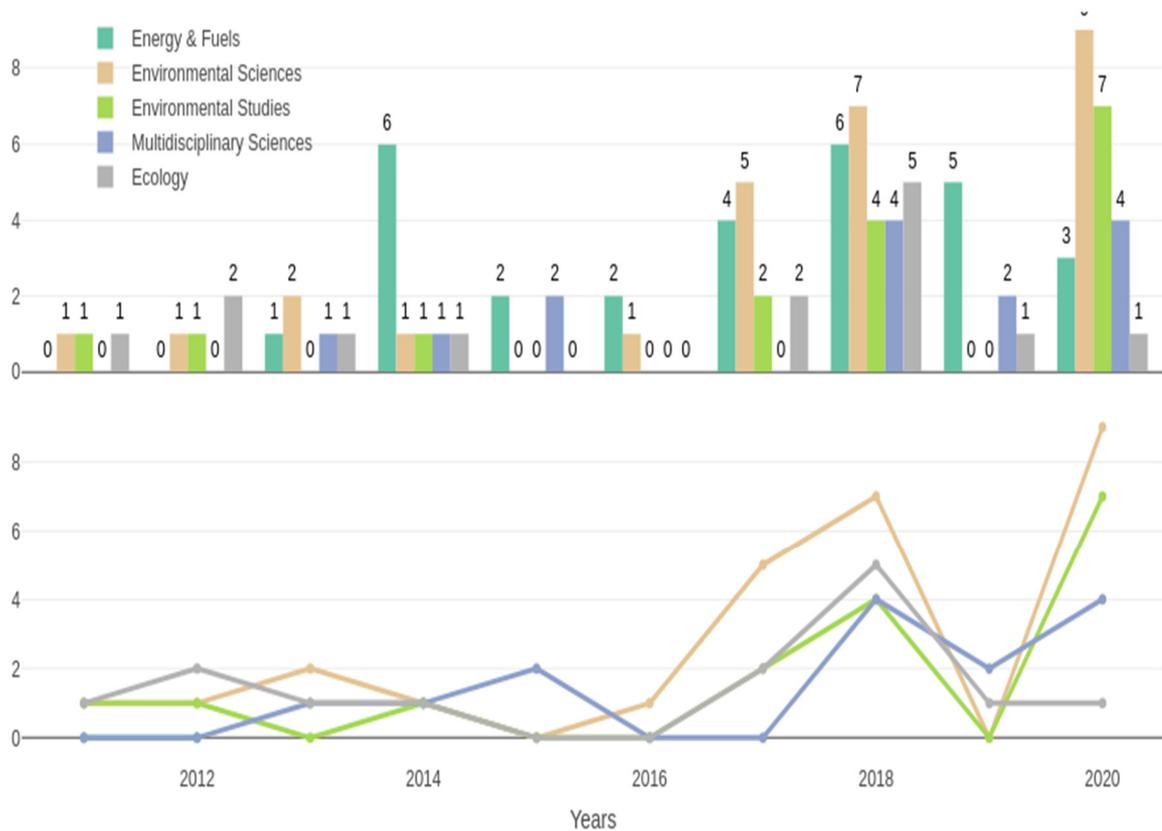


Figure 31: Absolute and relative growth of the most visible research areas in RE-related publications of Mekelle University between 2011-2020

The most visible research areas of *Mekelle University* are Energy & Fuels, Environmental Sciences, Environmental Studies, Multidisciplinary Sciences, and Ecology. Both Environmental Studies and Sciences spike in 2020 after 0 RE-related publications in 2019.

*Mekelle University's* keyword pair correlation network displays 2 different clusters which can be roughly labelled as environmental topics and biogas related keywords.

In the first cluster, Ethiopia's environmental issues like land degradation, diversity of species, water conservation, soil moisture, better land use are the emphasized topics. In relation, there is a high number of publications that mention the use of by-product materials from trees and shrubs as biomass material.

In the second cluster along with the biogas topics, there is an emphasis on health status, indoor air pollution, remote communities like rural Tigray where is an ongoing crisis in the isolated because of the complete isolation from the outer world.

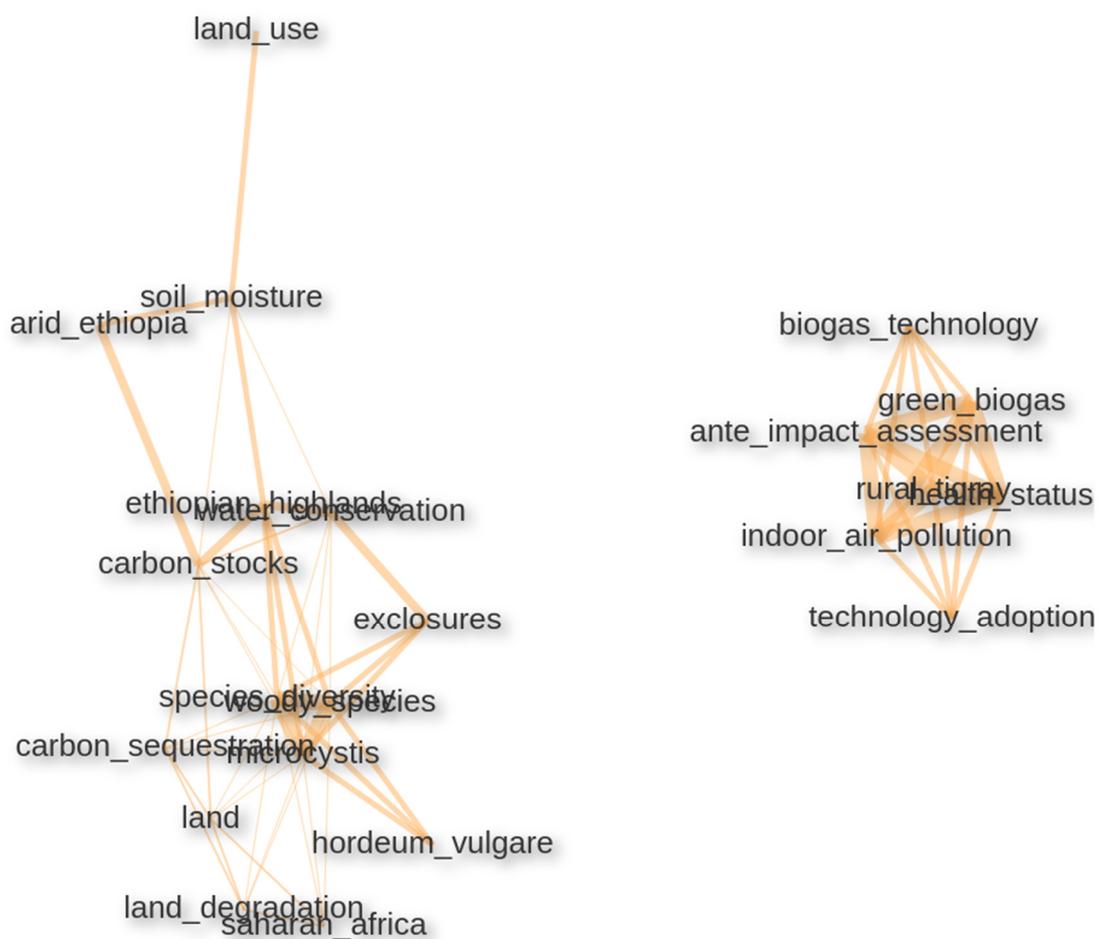


Figure 32: Keyword/keyword pair correlation network in RE-related publications of Mekelle University

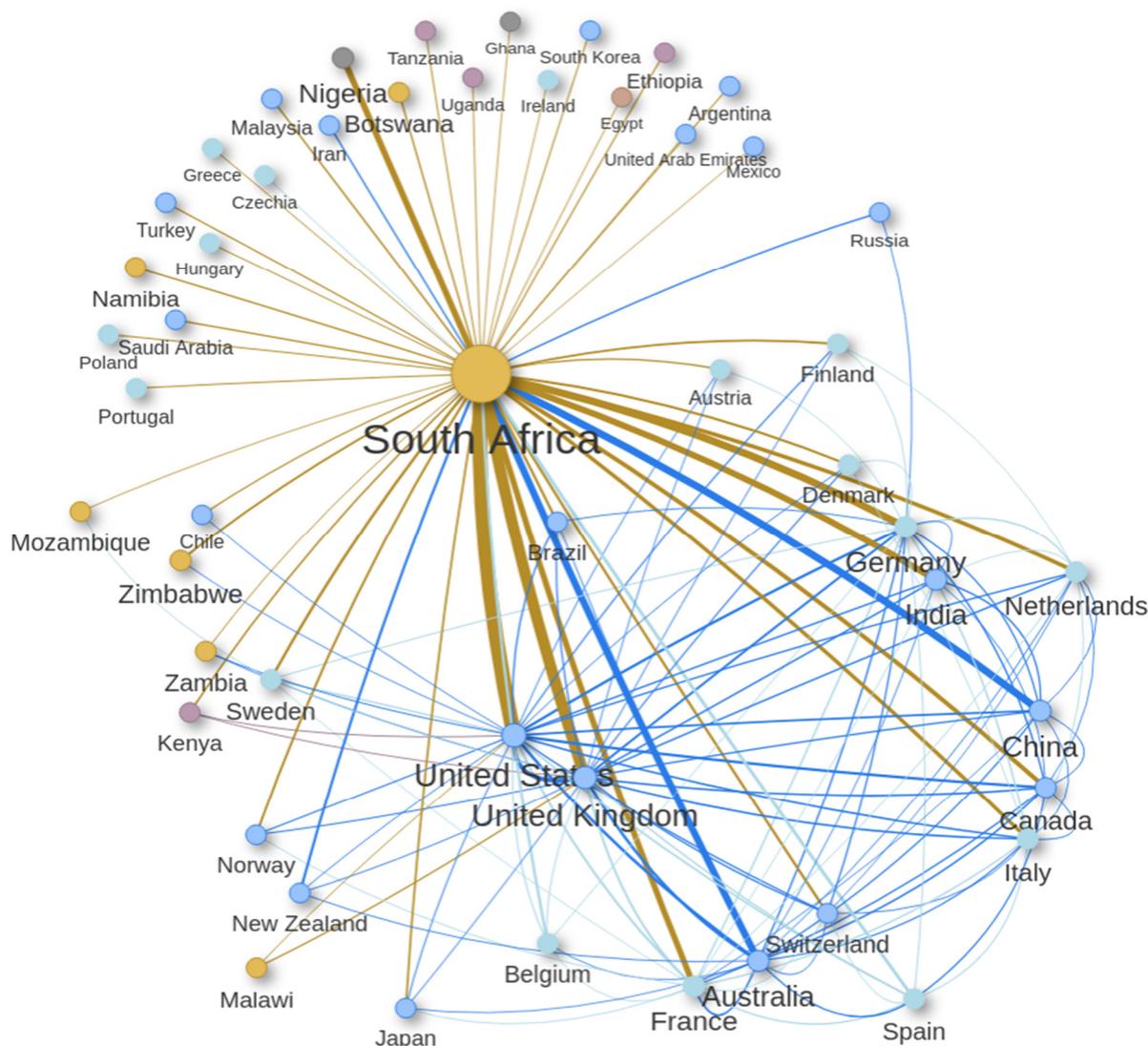
### 3.3.2.3 Southern Africa

Country	2011	2020	Rel. growth rate (2011-2020)	Total num. of pub. (2011-2020)
South Africa	322	920	2.86	6893
Zimbabwe	8	34	4.25	230
Botswana	2	27	13.50	152
Zambia	6	22	3.67	151
Mozambique	2	25	12.50	138

Table 10: RE-related publication output in Southern African countries

There is a strong contrast between the Southern African countries in terms of RE-related publication output. While South Africa is the most visible country in the whole continent with ~6900 RE-related publications between 2011-2020 the closest follower Zimbabwe have 230. Other than South Africa and Zimbabwe, the following countries Botswana, Zambia and Mozambique ~150 RE-related publications between 2011-2020 each.

In alignment with the total number of publications, South Africa is the center of mass in the co-publication network of Southern Africa. All the other visible South African countries have collaborations with South Africa with more than 25 co-publications. South Africa also has strong interregional collaboration with other African countries, which includes Egypt (~30 co-pub.) from Northern Africa; Nigeria (277 co-pub.) and Ghana (27 co-pub.) from Western Africa; Ethiopia (44 co-pub.), Tanzania (38 co-pub.), Uganda (32 co-pub.) and Kenya (68 co-pub.) from Eastern Africa, which makes South Africa the most visible African country also in interregional collaborations. None of the Southern African countries has a collaboration link with more than 25 co-pub. without the involvement of South Africa.



*Figure 33: Co-publication network of Southern African countries in RE-related publications between 2011-2020*

The most visible EU-27 country in the region is Germany with involvement in 373 co-publications. Germany is followed by France with 290 co-pub. and Spain 150 co-publications. However, South Africa’s most visible collaborations are with the United Kingdom and the United States 533 and 701 co-pub. respectively out of United States’ 812 and UK’s 614 co-publications in the region.



### 3.3.2.3.1 South Africa

Organisation	2011	2020	Rel. growth rate (2011-2020)	Total num. of pub. (2011-2020)
University of KwaZulu-Natal	50	122	2.44	934
University of Cape Town	60	99	1.65	858
Stellenbosch University	37	121	3.27	851
University of Pretoria	28	91	3.25	794
University of Johannesburg	10	111	11.10	617

Table 11: Re-related publication output of the most visible South African organisations

The most visible 5 organizations in the region are all from South Africa. *University of KwaZulu-Natal* is the organization with the highest output of RE-related publications (934 publications). However, the organization’s RE-related publication output is stagnating since 2017. *University of Cape Town* is steadily increasing its RE-related publications since 2011 with a total output of ~860 publications. *Stellenbosch University* is closely following with ~850 RE-related publications between 2011-2020 which despite the decline after 2019 only 1 publication behind *University of KwaZulu-Natal*. *University of Pretoria* and *University of Johannesburg* are following with ~800 and ~620 publications respectively.

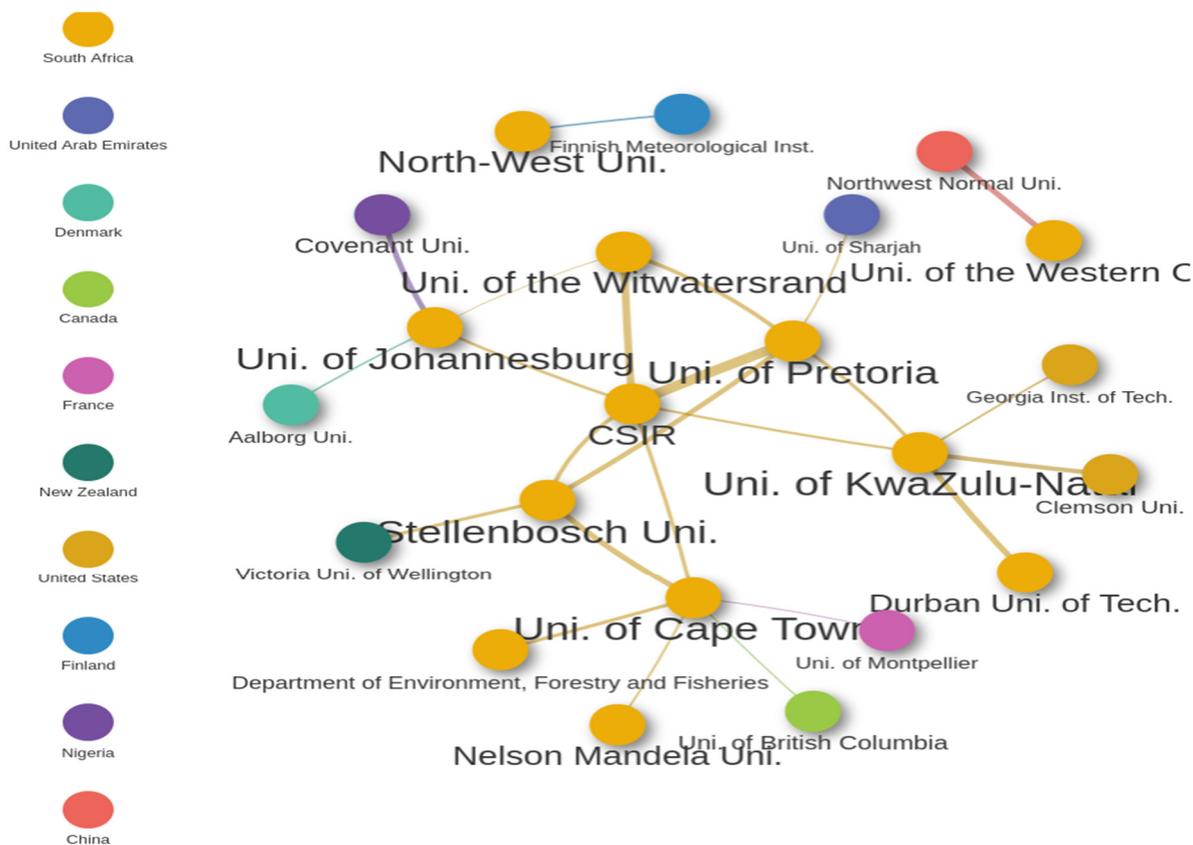


Figure 34: Co-publication network of Southern African organisations in RE-related publications between 2011-2020



The Organization network of South Africa displays a relatively well interconnected co-publication structure with a number of intercontinental collaborators. None of the organizations seems to be the center of mass in the network.

Some of the notable international collaborations are between China's *Northwest Normal University* and *University of Western Cape* (36 co-pub.), Denmark's *Aalborg University* and *University of Johannesburg* (23 co-pub.), UAE's *Uni. of Sharjah* and *University of Pretoria* (22 co-pub.), New Zealand's *Victoria University of Wellington* and *Stellenbosch University* (~30 co-pub.), France's *University of Montpellier* and *University of Cape Town* (20 co-pub.) and Canada's *Uni. of British Columbia* and *University of Cape Town* (23 co-pub.). Also, as an interregional collaboration between African organizations, Nigeria's *Covenant University* has 34 RE-related co-publications with *University of Johannesburg*.

### 3.3.2.3.1.1 University of KwaZulu-Natal

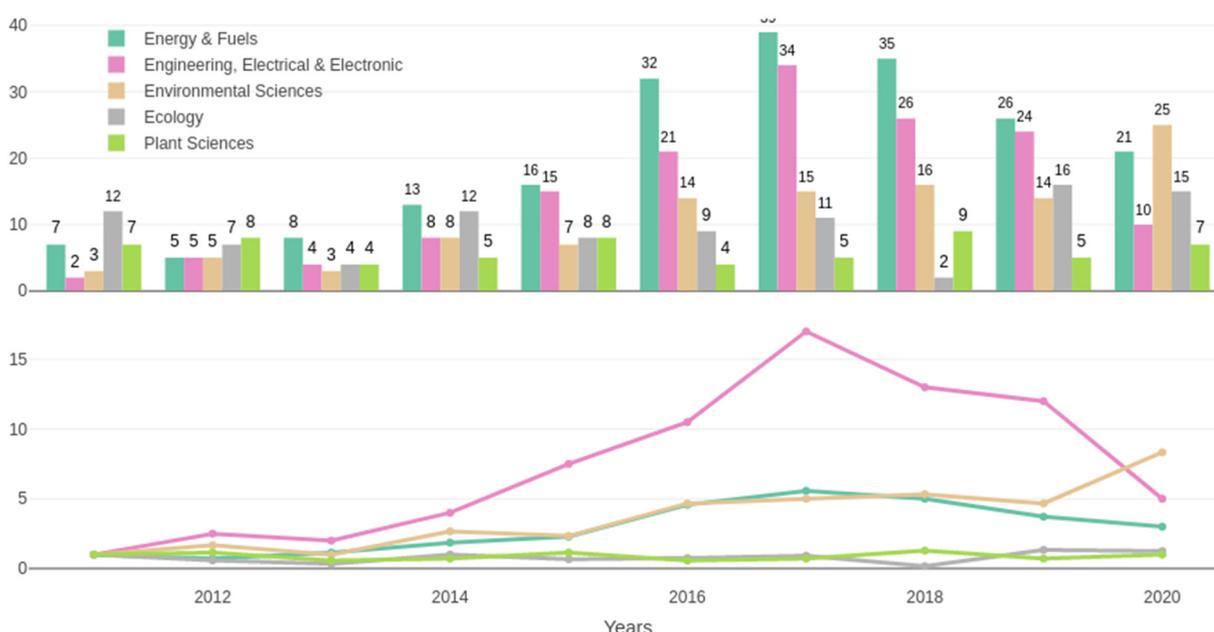


Figure 35: Absolute and relative growth of the most visible research areas in RE-related publications of University of KwaZulu-Natal between 2011-2020

The most visible areas in *University of KwaZulu-Natal's* publications are Energy & Fuels and Electrical & Electronic Engineering. However, as seen previously in other organizations both of those fields start to decline in numbers after 2017. Instead, the number of publications in Environmental Sciences keeps growing followed by Ecology in a relatively stable manner. Other than this reoccurring pattern *University of KwaZulu-Natal* has uniquely Plant Sciences as one of the most visible areas.

As unique keyword pairs, *University of KwaZulu-Natal's* keyword correlation network includes the mention of estuarine lakes. The exploitation of the tidal energy where salty and freshwater meet is an often discussed topic (see for example [Ross et al. \(2021\)](#) [15]) and the largest estuarine lake in Southern Africa, namely Saint Lucia, is located in South Africa.

Other keyword pairs show great diversity. Generally trending topics like solar and wind energy-related keyword pairs are also present in *University of KwaZulu-Natal's* network. As a unique biomass related keyword, c4 grass type is often mentioned in the publications

in *University of KwaZulu-Natal* which are referring to a specific type of grass that can be used effectively for biofuel production.

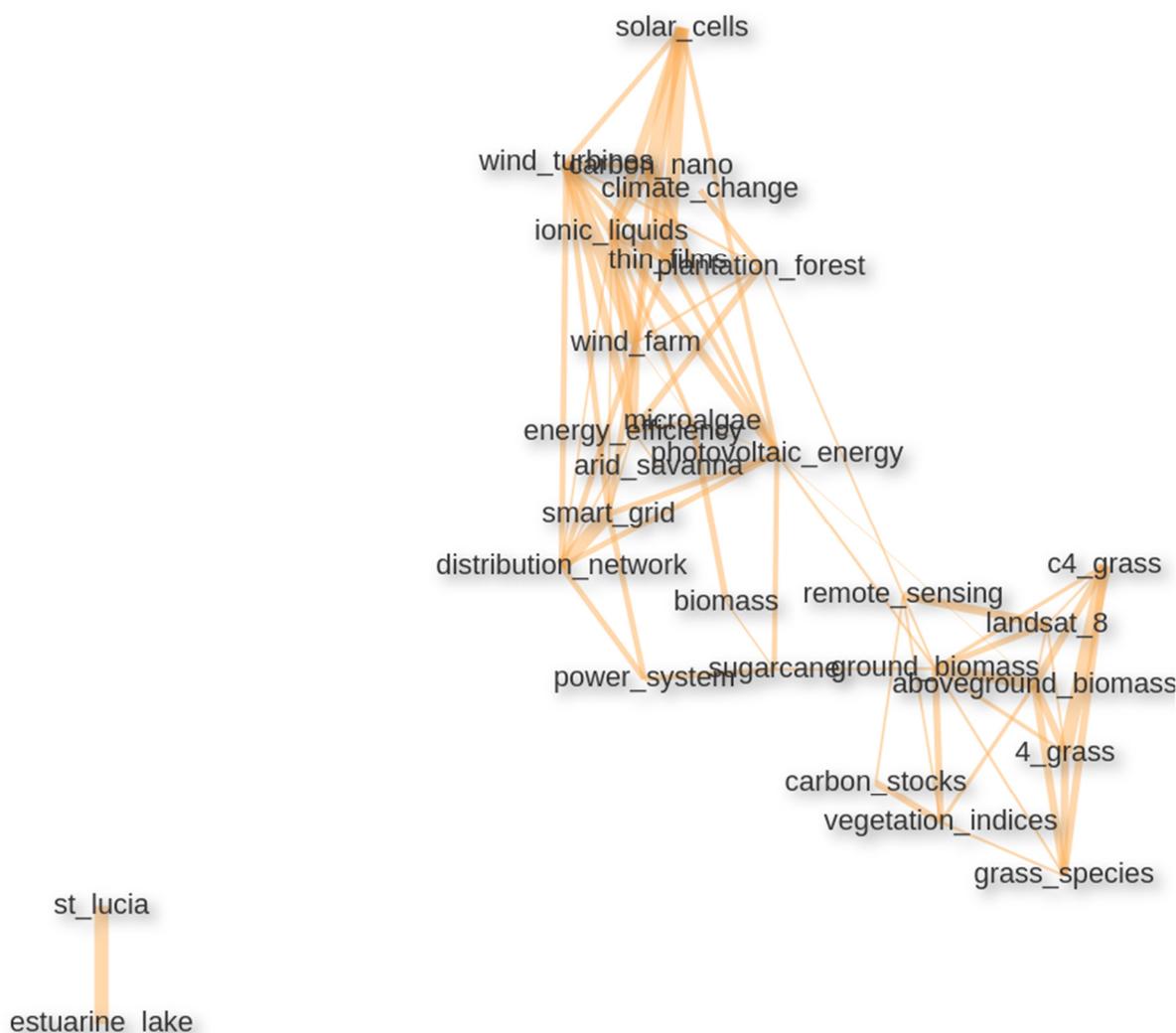


Figure 36: Keyword/keyword pair correlation network in RE-related publications of University of KwaZulu-Natal

### 3.3.2.3.1.2 University of Cape Town

Similar to *University of KwaZulu-Natal*, the most visible research areas in the RE-related publications of *University of Cape Town* are Energy & Fuels and Electrical & Electronic Engineering followed by Ecology. Uniquely, the most visible 5 research areas of *University of Cape Town* include Marine & Freshwater Biology which stays number of publication wise relatively stable over the years. Despite the decline in numbers in 2020 Environmental Sciences is steadily growing in numbers.

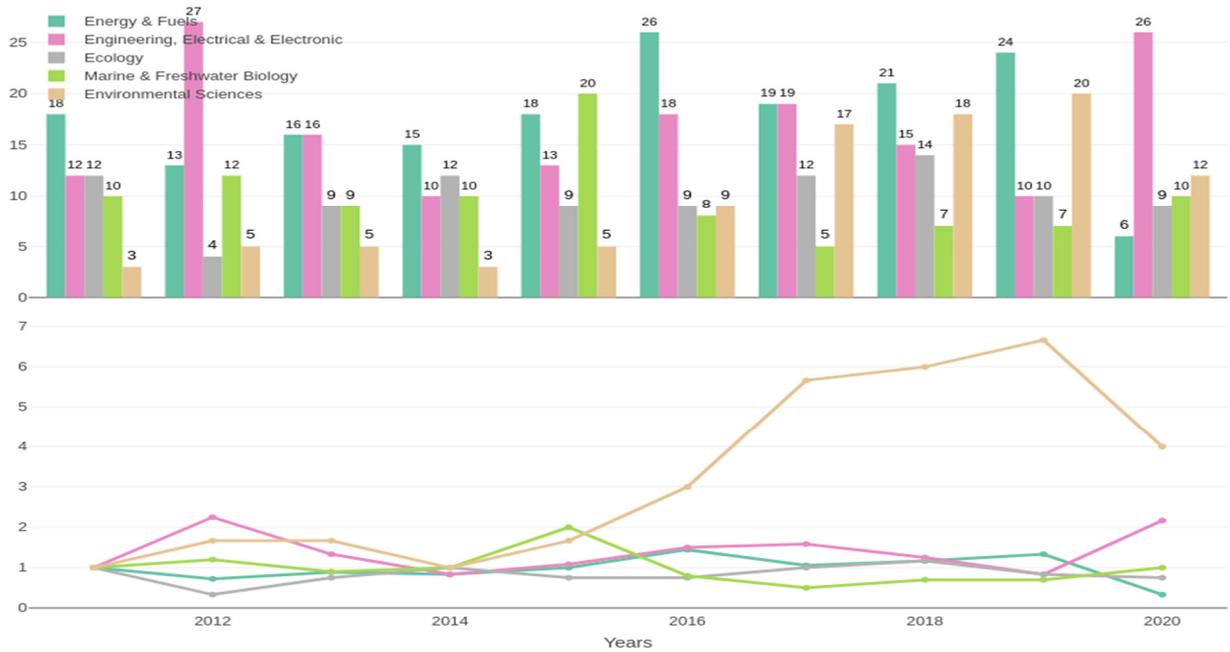


Figure 37: Absolute and relative growth of the most visible research areas in RE-related publications of University of Cape Town between 2011-2020

University of Cape Town’s keyword/keyword pair network clearly shows the influence of Marine & Freshwater Biology in one of its clusters. Marine ecosystem especially in Southern Benguela is a reoccurring topic in the publications of the University of Cape Town. Other than that, along with the high emphasis on photovoltaic energy environmental topics like environmental impact and carbon footprint are also visible keyword pairs.

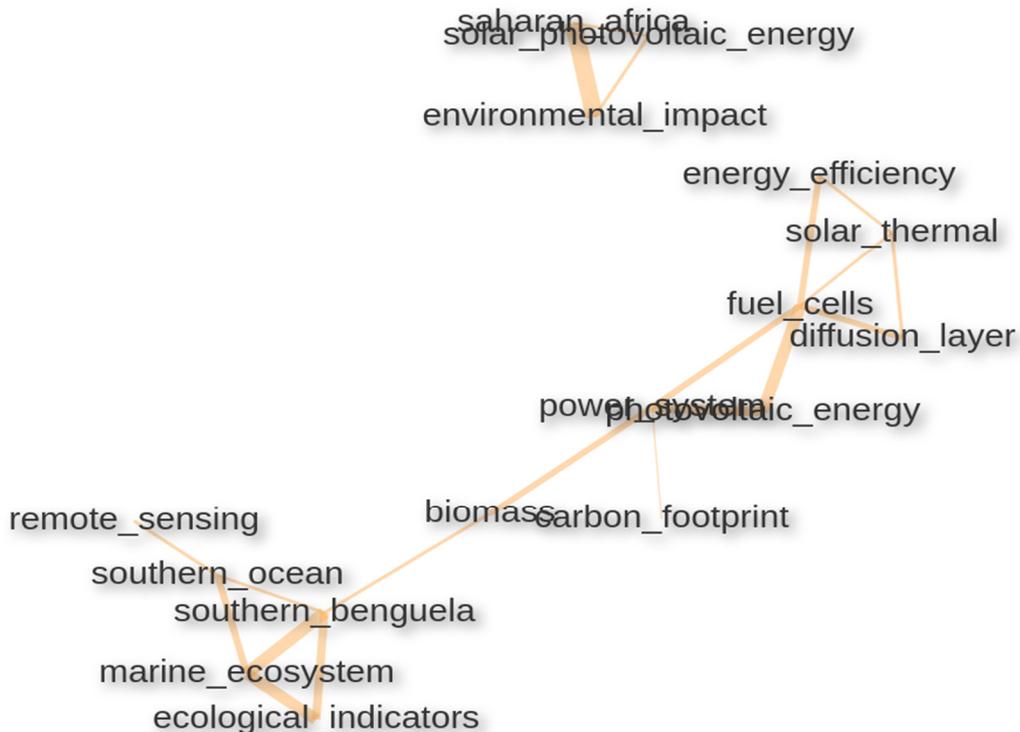


Figure 38: Keyword/keyword pair correlation network in RE-related publications of University of Cape Town

### 3.3.2.3.1.3 Stellenbosch University

Similar to the other South African organizations *Stellenbosch University's* most visible research areas are Energy & Fuels and Electrical & Electronic Engineering. A unique research area Biotechnology & Applied Microbiology is following the most visible 2 research areas in a consistent manner. Ecology and Green & Sustainable Science & Technology are following those with Ecology having the highest number of publications in 2020.

Wind energy-related keyword pairs are emphasized more in the publications of *Stellenbosch University* than in any other South African country.

Research on types of yeast like *Pichia Pastoris* and fungi like *Saccharomyces Cerevisiae* presumably because of the high number of publications in Biotechnology & Applied Microbiology (see [Benjamin, Bakare, and Effiong \(2020\)](#) [16] and [Siripong et al. \(2018\)](#) [17] for their possible uses for RE).

Other than that, a number of biomass, biogas and bioprocessing methods are also highly emphasized in the RE-related publications of *Stellenbosch University*.

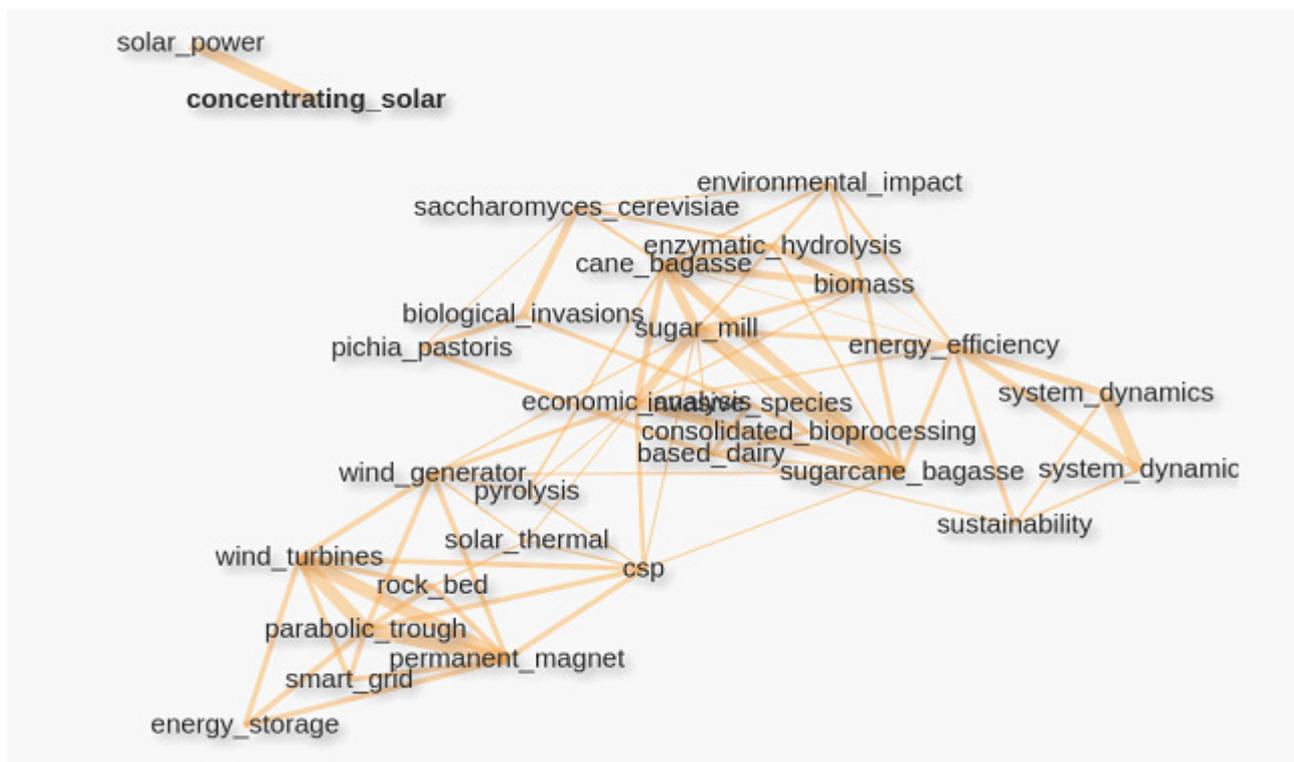


Figure 39: Keyword/keyword pair correlation network in RE-related publications of Stellenbosch University

### 3.3.3 Domain Analysis

This chapter is mainly interested in analyzing RE-related publications of African countries separated into the 5 research domains (Physical Sciences, Technology, Life Sciences & Biomedicine, Social Sciences, and Arts & Humanities) in order to offer a different perspective on the characteristics by reviewing the most visible institutional pairings and trending themes in each category. In order to exclude pairings from the same country institutional pairings have been chosen from the collaborations with at least an interregional partnership.



### 3.3.3.1 Physical Sciences

Looking at the international collaborations in the research domain of Physical Sciences the top pairings seems to be the co-publication partnerships between African and East Asian countries. Co-publication partnership between Egypt's *Minia University* and South Korea's *Jeonbuk National University* is the most visible one in terms of RE-related number of co-publications followed by the collaboration between *University of the Western Cape* of South Africa and China's *Northwest Normal University*.

Country 1	Partner 1	co-pub.	Partner 2	Country 2	Most Visible Res. Area
<b>Northern Africa</b>					
Egypt	Minia University	45	Jeonbuk National University	South Korea	Chemistry, Physical
Egypt	Minia University	32	King Saud University	Saudi Arabia	Chemistry, Physical
Egypt	Ain Shams University	22	King Khalid University	Saudi Arabia	Materials Science, Multidisciplinary
Egypt	Mansoura University	22	Ruhr University Bochum	Germany	Astronomy & Astrophysics
Egypt	Tanta University	21	Jiangsu University	China	Chemistry, Analytical
<b>Western, Central, Eastern Africa</b>					
Nigeria	Covenant University	17	University of Johannesburg	South Africa	Materials Science, Multidisciplinary
Cameroon	Université de Yaoundé I	13	University of Montpellier	France	Multidisciplinary Sciences
Cameroon	Université de Yaoundé I	11	University of Leeds	United Kingdom	Multidisciplinary Sciences
Gabon	National Agency for National Parks	10	University of Stirling	United Kingdom	Multidisciplinary Sciences
Gabon	National Agency for National Parks	10	University of Leeds	United Kingdom	Multidisciplinary Sciences
<b>Southern Africa</b>					
South Africa	University of the Western Cape	36	Northwest Normal University	China	Electrochemistry
South Africa	North-West University	23	Finnish Meteorological Institute	Finland	Meteorology & Atmospheric Sciences
South Africa	North-West University	18	University of Stuttgart	Germany	Polymer Science
South Africa	University of the Witwatersrand	13	Delft University of Technology	Netherlands	Chemistry, Multidisciplinary
South Africa	North-West University	12	Ruhr University Bochum	Germany	Astronomy & Astrophysics

Table 12: The most visible co-publication pairings in Physical Sciences



Deliverable 5.8

The most visible Co-publication pairings in Northern and South Africa are occupied by Egyptian and South African organizations because of their high number of RE-related publication outputs. Egypt’s high number of co-publications with Saudi Arabian institutions is also visible among the pairings, 2 of the most visible 5 pairings are between Egypt’s *Minia* and *Ain Shams Universities* collaboration with Saudi Arabia’s *King Saud* and *King Khalid Universities* respectively. 2. and 3. of the 5 most visible pairings in Southern Africa belong to *North-West University* of South Africa with *Finnish Meteorological Institute* and *University of Stuttgart*.

In the Western, Central and Eastern Africa cluster the most visible pairing is between Nigeria’s *Covenant University* with South African *University of Johannesburg* which is the only interregional African collaboration in the most visible co-publication collaborations in Physical Sciences. Other than *University de Yaoundé I’s* (Cameroon) collaborations with *University of Montpellier* of France and the UK’s *University of Leeds* are also in the most visible organizational pairings. *University of Leeds* has also together with *University of Stirling* visible co-publication partnership with *National Agency for National Parks* of Gabon.

The most visible keywords and keywords pairs in Physical Sciences refer to solar energy and components used in photovoltaic systems like thin films as Figure 40 displays. In relation, those keywords are also increasingly trending in the last years as in Figure 41. One of the rising keyword pairs in the last couple of years is indicating research on the optical properties of different substances which can play a critical role in the advancements in the absorption of solar energy. Similarly, solar adsorption cooling/ refrigeration systems are also often mentioned in RE-related publications in the Physical Science domain.

Technologies like fuel cells that convert the energy from fuels more effectively into electricity in comparison with their fewer green counterparts like combustion engines are also in the trending keywords. Biomass and wind energy-related keyword pairs are also following the solar energy topics. Other than, using green energy forms to produce hydrogen instead of fossil fuels is also a visible topic in the Physical Science keywords.

Environmental topics are also often mentioned in the RE-related topics. Other than measuring the environmental impact of different kinds of energy production types there are also keyword pairs mentioning water/wastewater treatment, desalination.

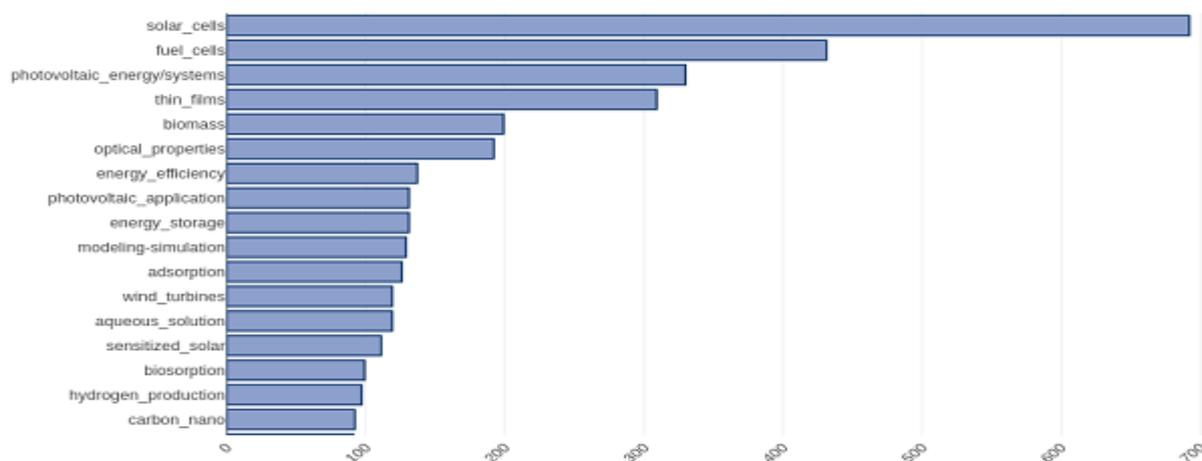


Figure 40: The most Visible keywords/ keyword pairs in Physical Sciences



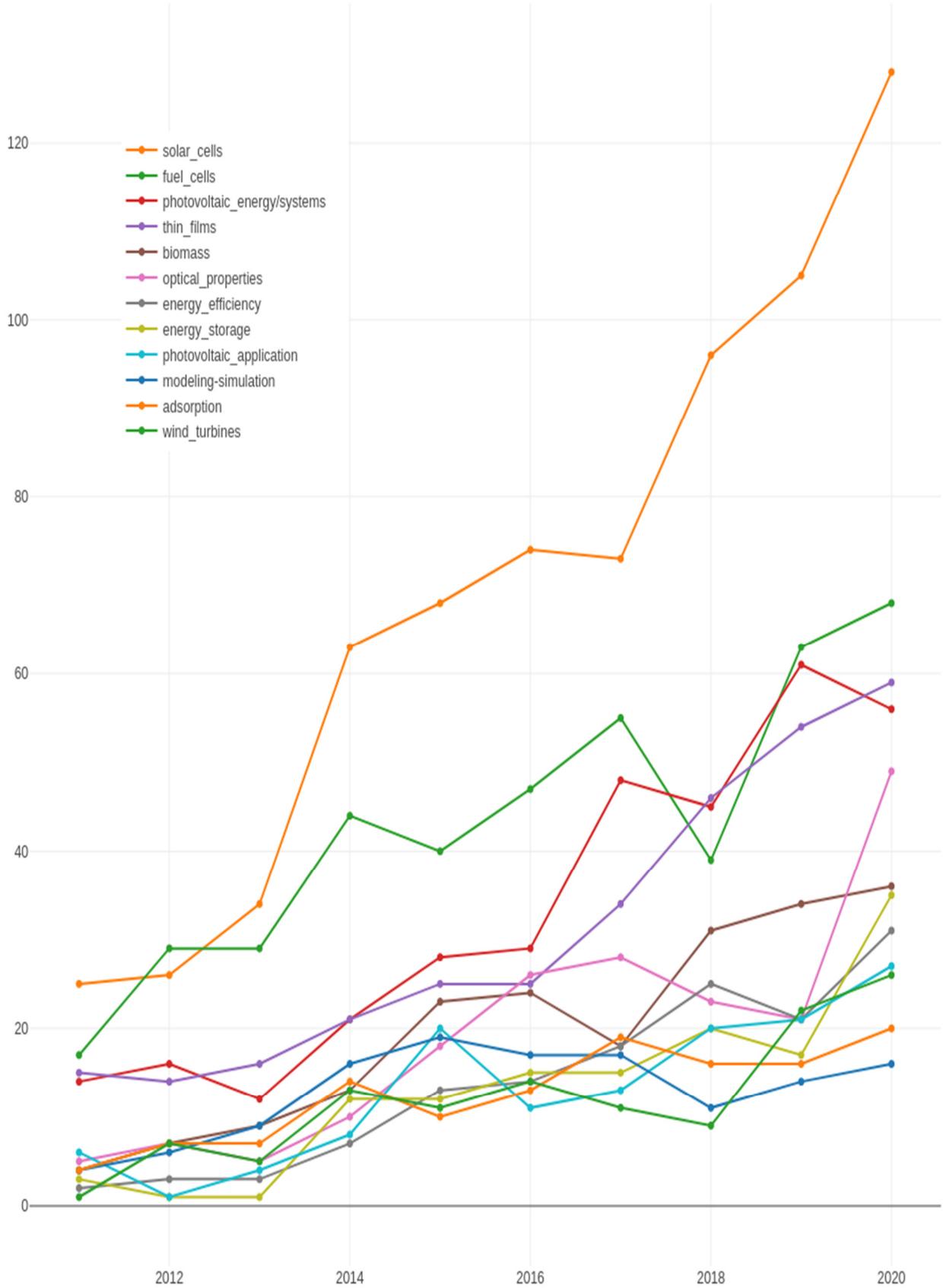


Figure 41: The most visible keywords/keyword pairs over the years in Physical Sciences

## 3.3.3.2 Technology

Country 1	Partner 1	Num. of co-pub.	Partner 2	Country 2	Most Visible Res. Area
<b>Northern Africa</b>					
Egypt	Minia University	66	Prince Sattam Bin Abdulaziz University	Saudi Arabia	Energy & Fuels
Egypt	Mansoura University	51	King Saud University	Saudi Arabia	Energy & Fuels
Egypt	Tanta University	47	Jiangsu University	China	Energy & Fuels
Egypt	Tanta University	40	Huazhong University of Science and Technology	China	Energy & Fuels
Egypt	Alexandria University	38	Qatar University	Qatar	Engineering, Electrical & Electronic
<b>Southern Africa</b>					
Nigeria	Covenant University	28	University of Johannesburg	South Africa	Green & Sustainable Science & Technology
Nigeria	Abubakar Tafawa Balewa University	16	Open University Malaysia	Malaysia	Energy & Fuels
Nigeria	Covenant University	15	Tshwane University of Technology	South Africa	Energy & Fuels
Nigeria	University of Maiduguri	13	Open University Malaysia	Malaysia	Energy & Fuels
<b>Western, Central, Eastern Africa</b>					
South Africa	University of KwaZulu-Natal	34	Clemson University	United States	Engineering, Electrical & Electronic
South Africa	University of Johannesburg	28	Covenant University	Nigeria	Green & Sustainable Science & Technology
South Africa	Stellenbosch University	27	Victoria University of Wellington	New Zealand	Energy & Fuels
South Africa	University of KwaZulu-Natal	24	Georgia Institute of Technology	United States	Engineering, Electrical & Electronic

Table 13: The most visible co-publication pairings in Technology

2 of the most visible collaborations in the Technology domain are between Egyptian and Saudi Arabian organizations, namely between *Minia University* and *Prince Sattam Bin Abdulaziz University*, and between *Mansoura University* and *King Saud University*. All of the first 5 most visible pairings are from Northern Africa and specifically from Egyptian universities. *Tanta University's* 2 partnerships with Chinese organizations *Jiangsu University* and *Huazhong University of Science and Technology* are the most visible 3. and 4. pairings followed by *Alexandria University's* collaboration with *Qatar University*.

All of the most visible pairings in Southern Africa are associated with South African organizations with the most visible one being between *University of KwaZulu-Natal* and *Clemson University* from the United States. The following partnership between *University*

of Johannesburg and Covenant University of Nigeria is also the most visible pairing in the Western, Central, Eastern Africa cluster. All of the most visible pairings from this cluster are occupied by the Nigerian Universities. 2 of them are with Malaysian organizations and another one is again between Nigerian Covenant University and South African Tshwane University of Technology.

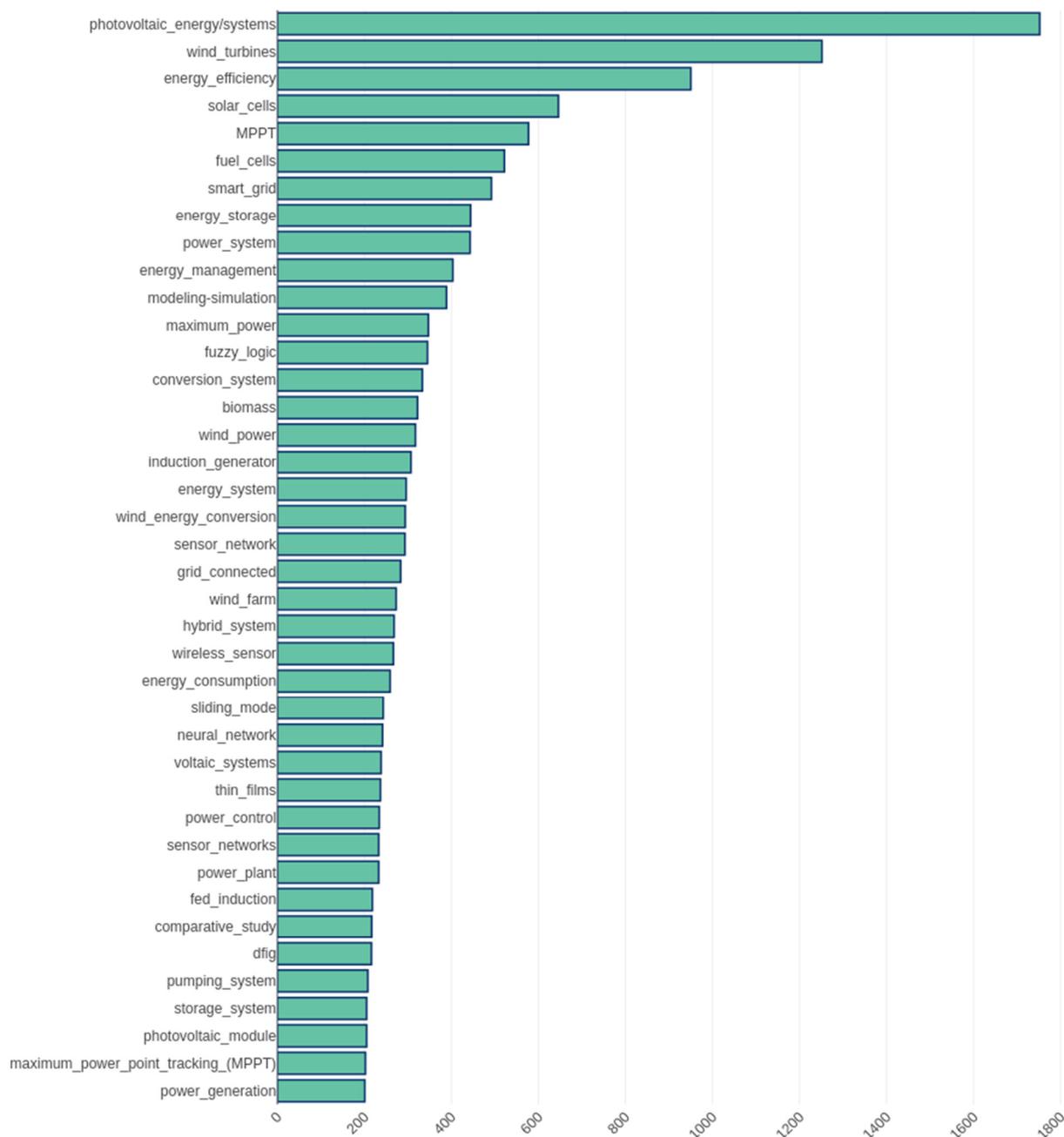


Figure 42: The most visible keywords/ keyword pairs in Technology

The most visible keywords and keyword pairs in Technology show similarity to the trending topics in Physical Sciences. Photovoltaic systems, wind tribunes, fuel cells are among the most visible keyword pairs. The maximum power point tracking (MPPT) technique for algorithmic improvement for the energy extraction from (mostly) photovoltaic systems is one of the most often mentioned keywords. Similarly,

algorithmic control systems for photovoltaic and wind energy like fuzzy logic are also among the trending keyword pairs in the Technology domain. Research areas under Technology seem to be also focusing heavily on energy management methods like energy storage, conversion, maximization.

As on Figure 42 the most visible keyword pairs under Technology seems to be either stagnating or falling in terms of number of publications after 2017. This might indicate there are other topics growing in Technology related areas which are not apparent yet.

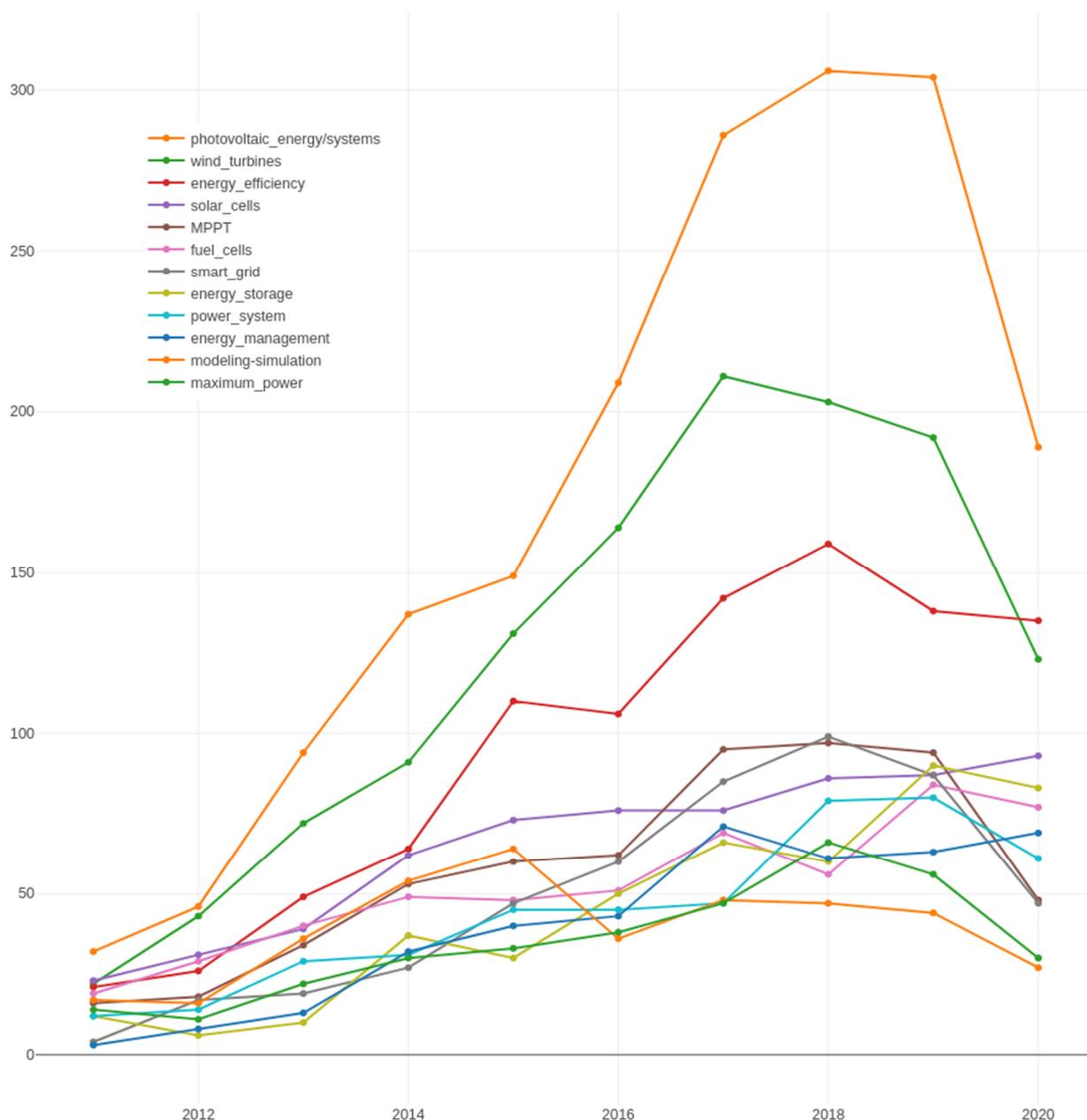


Figure 43: The most visible keywords/keyword pairs over the years in Technology

### 3.3.3.3 Life Sciences & Biomedicine

The most visible pairing in Life Sciences & Biomedicine is between Egypt’s *Tanta University* and *Jiangsu University* of China. All the following 3 pairings are between Egyptian organizations *Assiut*, *Suez Canal* and *Alexandria Universities* with *King Saud University* of Saudi Arabia.



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2 of the most visible pairings in the West, Central, East Africa cluster are the collaborations between Ethiopian *Mekelle University* and Tanzanian *Sokoine University of Agriculture* with Norwegian *University of Life Sciences*. French organizations *CIRAD* and *University of Montpellier* 's collaborations with *University de Yaoundé I* (Cameroon) and *Cheikh Anta Diop University* (Senegal) are other visible collaborations from the region.

Country 1	Partner 1	Num. of co-pub.	Partner 2	Country 2	Most Visible Res. Area
<b>Northern Africa</b>					
Egypt	Tanta University	27	Jiangsu University	China	Biotechnology & Applied Microbiology
Egypt	Assiut University	21	King Saud University	Saudi Arabia	Environmental Sciences
Egypt	Suez Canal University	21	King Saud University	Saudi Arabia	Plant Sciences
Egypt	Alexandria University	20	King Saud University	Saudi Arabia	Environmental Sciences
<b>Western, Central, Eastern Africa</b>					
Ethiopia	Mekelle University	19	Norwegian University of Life Sciences	Norway	Forestry
Tanzania	Sokoine University of Agriculture	19	Norwegian University of Life Sciences	Norway	Environmental Sciences
Cameroon	Université de Yaoundé I	15	CIRAD	France	Forestry
Senegal	Cheikh Anta Diop University	14	University of Montpellier	France	Plant Sciences
Gabon	National Agency for National Parks	14	Duke University	United States	Ecology
<b>Southern Africa</b>					
South Africa	University of KwaZulu-Natal	16	Wageningen University & Research	Netherlands	Ecology
South Africa	North-West University	16	Finnish Meteorological Institute	Finland	Environmental Sciences
South Africa	University of Cape Town	16	University of British Columbia	Canada	Ecology
Malawi	Malawi-Liverpool-Wellcome Trust Clinical Research Programme	13	Liverpool School of Tropical Medicine	United Kingdom	Respiratory System
South Africa	University of Cape Town	13	University of Montpellier	France	Ecology

Table 14: The most visible co-publication pairings in Life Sciences & Biomedicine

In Southern Africa, the most visible pairing is between *University of KwaZulu-Natal* of South Africa with the Netherlands' *Wageningen University* followed by *North-West University*'s collaboration with *Finnish Meteorological Institute* and *University of Cape Town*'s collaborations with *University of British Columbia* (Canada).

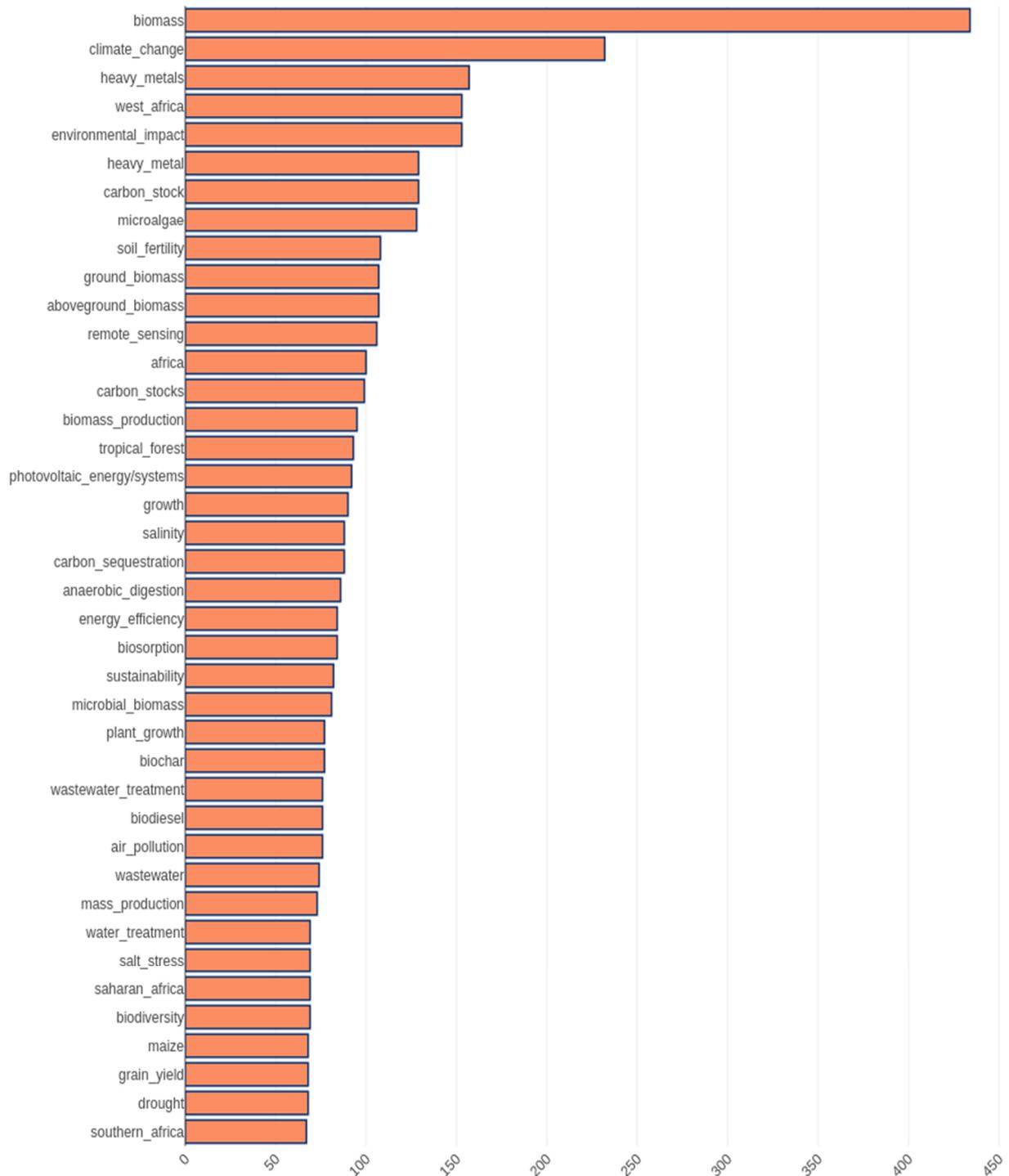


Figure 44: The most visible keywords/ keyword pairs in Life Sciences & Biomedicine

Biomass related keywords are by far the most visible ones in the RE-related publications in Life Sciences & Medicine. Climate change and environmental impact related keywords are also among the most often mentioned topics and are increasingly more often mentioned. Also as related trending topics soil fertility, water/wastewater treatment, plant/grain growth topics are heavily emphasized in the RE-related publications under Life Sciences & Biomedicine. Air pollution, as well as heavy metal waste, are also among the visible keywords.

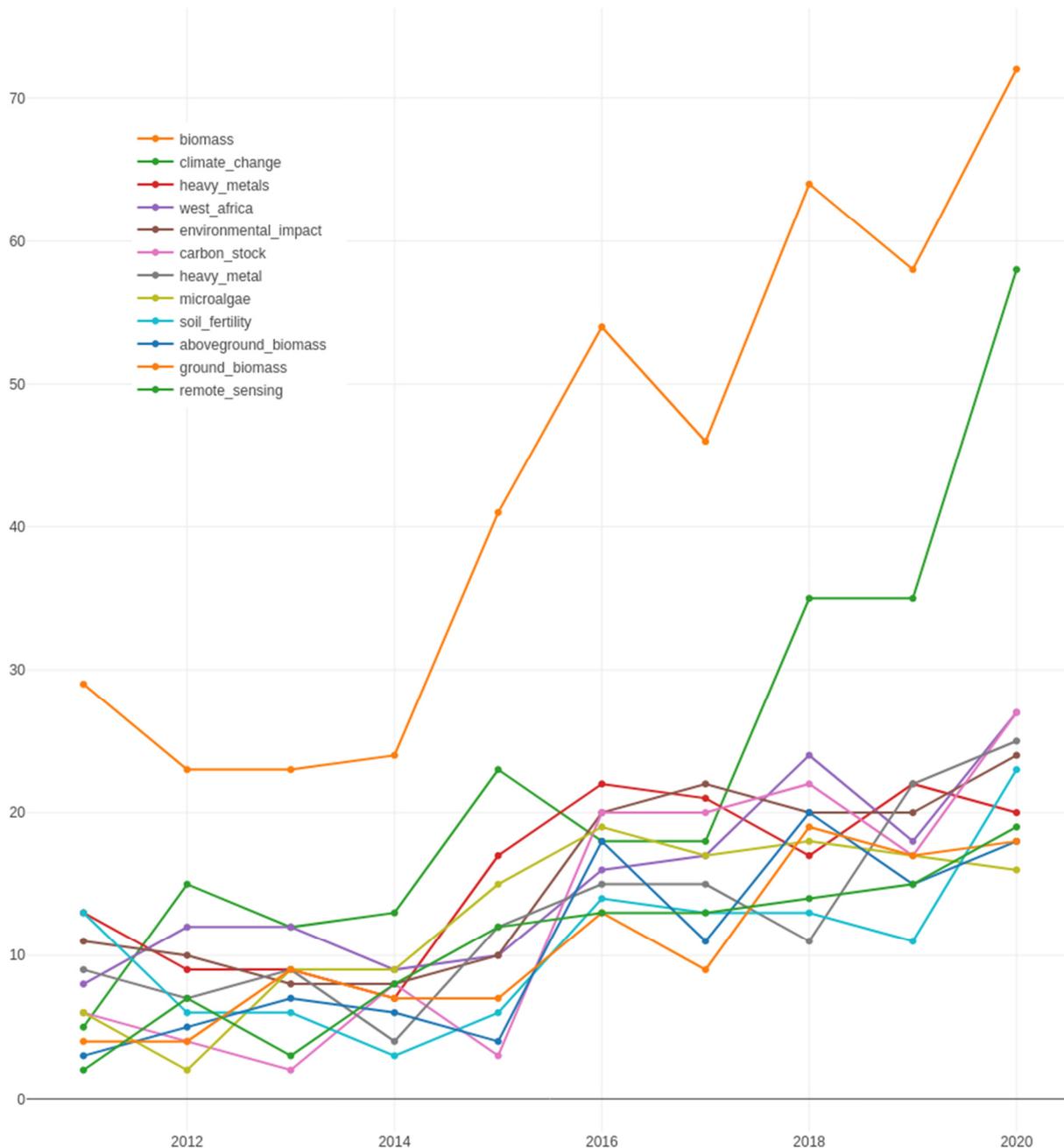


Figure 45: The most visible keywords/keyword pairs over the years in Life Sciences & Biomedicine

### 3.3.3.4 Social Sciences and Arts & Humanities

The most visible 2 collaboration partnerships in Social Science and Arts & Humanities (SSH) is between South Africa’s *North-West University* and the UK’s *University of East Anglia* as well as *University of Liverpool*. As in the case of almost all of the visible collaborations in SSH the dominant research area in those collaborations is Environmental Studies.

Country 1	Partner 1	Num. of co-pub.	Partner 2	Country 2	Most Visible Res. Area
<b>Northern Africa</b>					
Egypt	Assiut University	7	Majmaah University	Saudi Arabia	Environmental Studies
Egypt	Mansoura University	5	King Saud University	Saudi Arabia	Environmental Studies
Egypt	Mansoura University	4	Majmaah University	Saudi Arabia	Environmental Studies
Egypt	Assiut University	4	King Saud University	Saudi Arabia	Environmental Studies
Egypt	Minia University	4	Prince Sattam Bin Abdulaziz University	Saudi Arabia	Environmental Studies
<b>Western, Central, Eastern Africa</b>					
Ethiopia	Addis Ababa University	4	University of Gothenburg	Sweden	Economics
Rwanda	University of Rwanda	3	Georgia Institute of Technology	United States	Environmental Studies
Ethiopia	Mekelle University	3	Tottori University	Japan	Environmental Studies
Ethiopia	Bahir Dar University	3	Tottori University	Japan	Environmental Studies
Ethiopia	Mekelle University	3	Ghent University	Belgium	Environmental Studies
<b>Southern Africa</b>					
South Africa	North-West University	15	University of East Anglia	United Kingdom	Environmental Studies
South Africa	North-West University	7	University of Liverpool	United Kingdom	Environmental Studies
South Africa	Stellenbosch University	7	Victoria University of Wellington	New Zealand	Environmental Studies
South Africa	University of Cape Town	4	University of Cambridge	United Kingdom	Environmental Studies
South Africa	University of Cape Town	4	University of Oxford	United Kingdom	Education & Educational Research

Table 15: The most visible co-publication pairings in Social Sciences and Arts & Humanities

*Stellenbosch University's* collaboration with New Zealand's *Victoria University of Wellington* and Egypt's *Assiut University's* with Saudi Arabian *Majmaah University* are other visible pairings in SSH. From the Western, Central, Eastern Africa cluster the most visible pairing is between *Addis Ababa University* (Ethiopia) and *University of Gothenburg* (Denmark) which are exceptionally mostly co-published Economics related papers.

Climate change related keywords are the most visible cluster in the RE-related keywords from SSH areas. Environmental impact assessment, climate resilience, environmental sustainability, CO<sub>2</sub> emissions are just a few of those. In relation, energy consumption, strategy and policy are also emphasized keyword pairs in RE-related SSH publications from African organizations.



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Another cluster of keywords indicates discussion about the economic aspect of renewable energy innovations as well as the economic impact of climate change related issues.

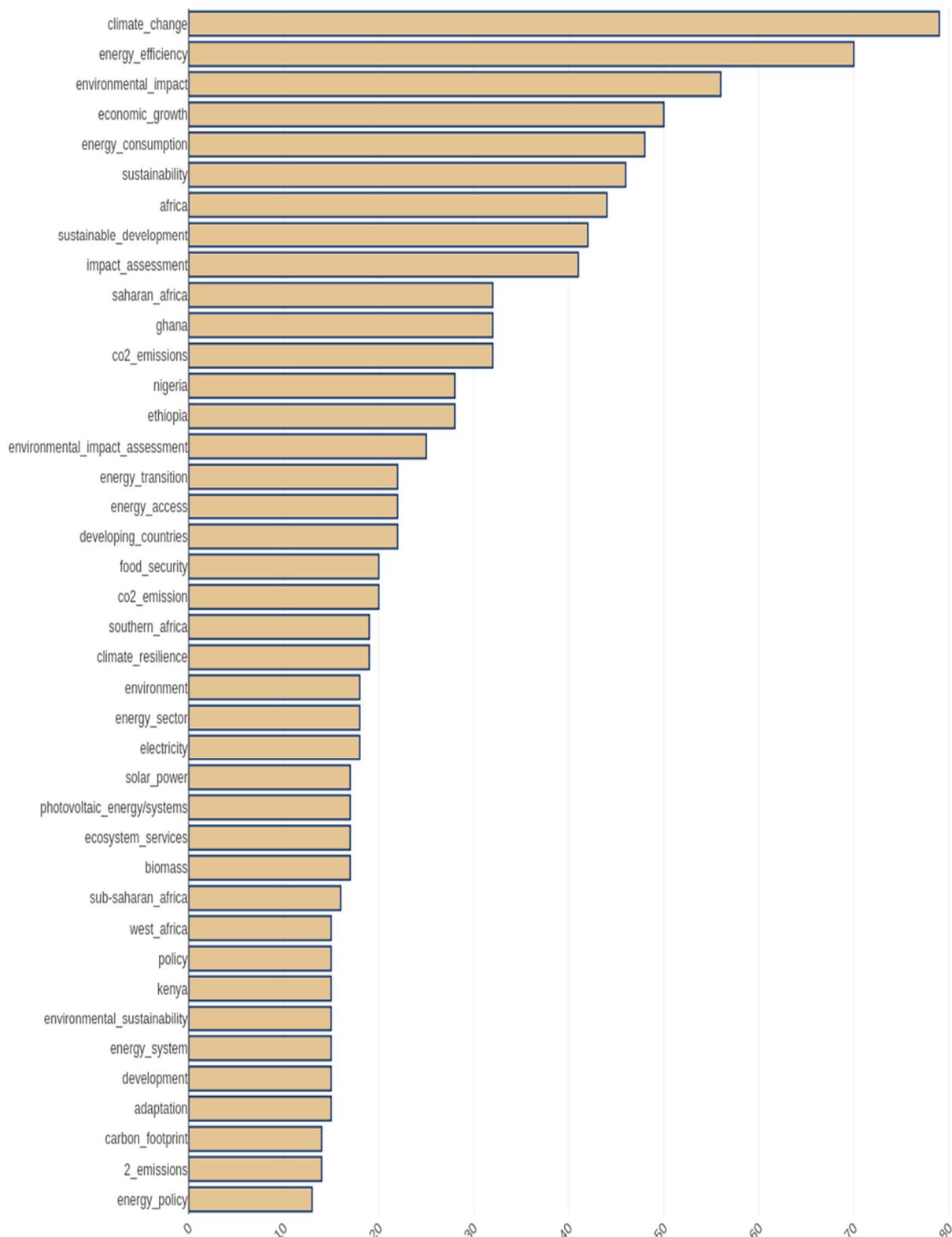


Figure 46: The most visible keywords/ keyword pairs in Social Sciences and Arts & Humanities

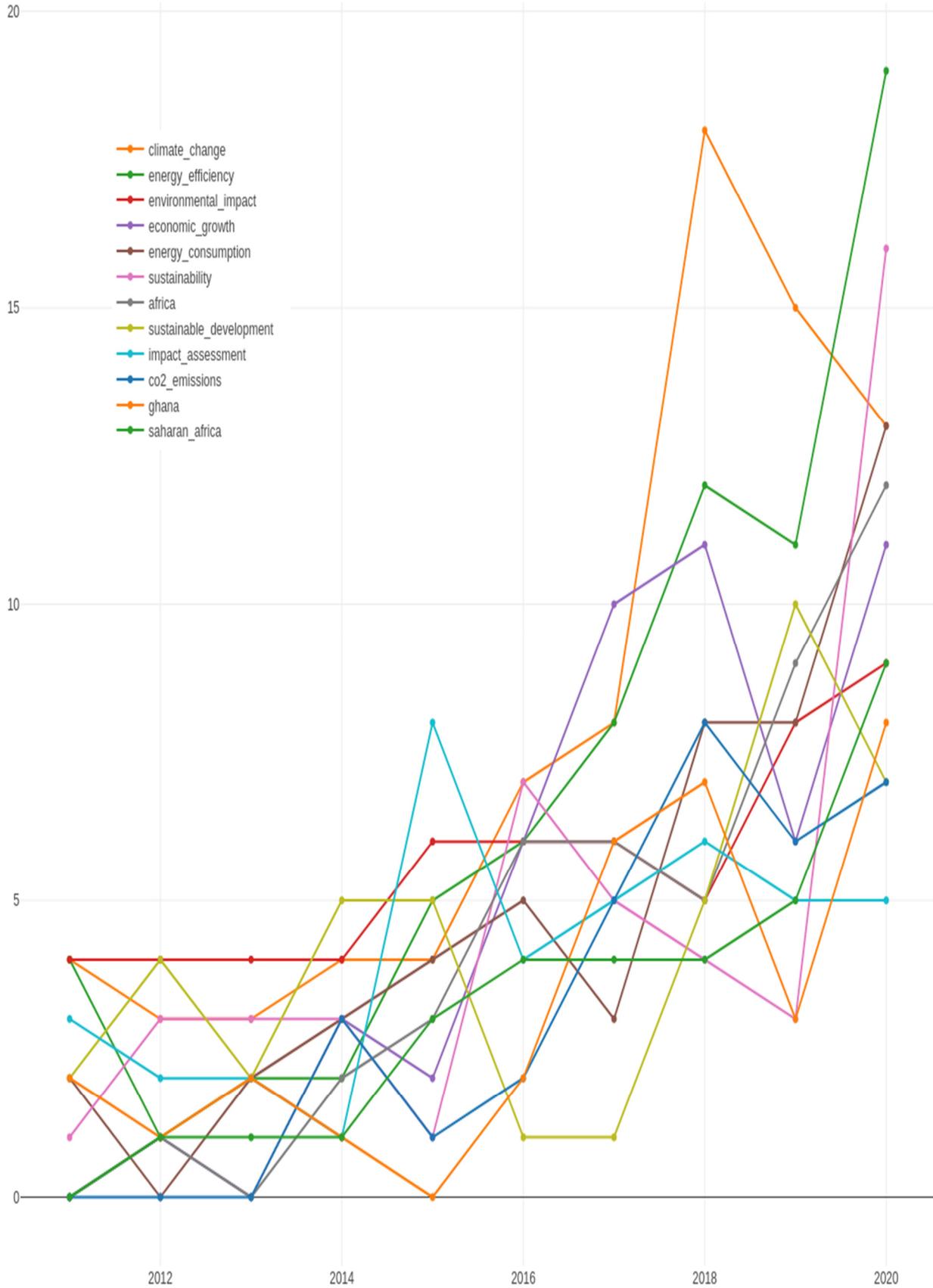


Figure 47: The most visible keywords/keyword pairs over the years in Social Sciences and Arts & Humanities

## 4 Conclusion

This study has aimed to achieve a comprehensive analysis of the renewable energy research capacity in Africa. Although renewable energy research is a fairly broad topic and solely relying on scientometric research cannot cover all of its aspects, the study results yielded some important observations about the general situation of RE research capacity in African countries.

The number of RE-related publications is increasing in every region of Africa. Although Northern and Southern Africa publishing the biggest part of the total RE-related publications in Africa, lots of countries from Western, Central and Eastern Africa are increasing their output rapidly.

African regions seem to be fairly well interconnected in their individual regions and several of them show a considerable amount of co-publications with intercontinental partners. However, in general, there is a lack of interregional collaboration in the African continent. Only some of the most visible countries appear in other regions as one of the most visible collaborators. In relation, a number of African countries also tend to collaborate with a specific cluster of intercontinental partners with very little diversity.

The content of the RE-related publications in Africa displays a strong emphasis especially on solar energy related science and technology in recent years followed by wind energy and biomass related topics. Furthermore, African academic organizations also increasingly research geographical specifications of their regions that could be beneficial for a specific kind of RE approach.

The analysis of the trending research areas in the most visible organizations also displayed that in the last couple of years there is a sudden decline in the most visible research areas in terms of yearly publications (e.g. Energy & Fuels). Simultaneously, there are a few previously less visible researches areas that are rapidly growing in numbers. Questions like if there is a real shift in RE-related research away from previously dominant areas or if specific topics are categorized under other disciplines than before, furthermore, if the same academicians working in other areas or a new cluster of researchers are working in the newly trending research areas are questions that can only be answered with further research.

This study will be followed in the next coming years (second deliverable 5.3) by special actions for strengthening existing mechanisms or launching new mechanisms for networking by:

- matching (researchers to create scientific communities)
- teaming (by creating centres of excellence),
- twinning (institutional co-supervision or R&I, post-doctoral programmes),
- sharing or pooling infrastructures or research (technology platforms, joint labs)

The target universities and research institutions are those involved in LEAP-RE projects, including institutions which submitted project is rejected. This list will be extended to Pillar2 projects and probably other partners involved in AU-EU RE projects.

We can mention (by country):

## Algeria

- CDER UDES (9 projects)
- Ecole Nationale Polytechnique Alger
- University of Annaba, LabGED Laboratory
- Centre Recherche Technologie des Semiconducteurs pour l’Energétique (CRTSE) (3 projects)
- CRAPC (*Centre de Recherche Scientifique et Technique en Analyses Physico – Chimiques*)
- University of Sidi Bel-Abbes
- Ferhat ABBAS University, Setif (UFA)
- Center for Development of Advanced Technologies (CDTA)
- Univ. de Tlemcen, LAT (UT)
- PAUWES

## Benin

- Ecole Polytechnique d’Abomey-Calavi (UAC) Bénin

## Botswana

- Botswana International University of Science and Technology (BIUST)

## Egypt

- Suez Canal University (SCU)
- Cairo University via Faculty of Engineering (CU) (II)
- MU Faculty of Science
- Helwan University (HU) Helwan
- King Salman International University (KSIU)
- The British University in Egypt (BUE)

## Ethiopia

- Adama Science and Technology University (ASTU)

## Kenya

- Technical University of Kenya

## Morocco

- Univ Hassan 1er – Cité de l’innovation
- Université Polytechnique Mohamed 6 (2 projects)
- Green Energy Parc (8 projects)
- Cluster Solaire
- Faculty of Sciences Semlalia(FSSM)
- Moroccan Foundation for Advanced Science, Innovation and Research – MAScIR
- IRESEN (2 projects)
- Cadi Ayyad University (2 projects)
- Faculty of science Semlalia
- Faculty of Sciences and Technologies in Mohammedia
- University Mohammed Premier (UMP) (3 projects)
- University Sultan Moulay Slimane (USMS)
- Mohamed V University of Rabat, Ecole Nationale Supérieure des Arts et Métiers
- International University of Rabat (IUR) (3 projects)
- University of Fes
- University of Sidi Mohamed Ben Abdellah Fez(UFE)



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- Ecole Nationale des Sciences Appliquées d'Oujda (ENSAO)
- UCA-IMED public university
- MATSI - Mathématiques Appliquées, Traitement du Signal et Informatique (projet PVsystem)
- Ibn Tofail University (UIT)
- Material Science, Energy and Nanoengineering (MSN)

**Mozambique**

- Eduardo Mondlane University (UEM)
- National Directorate of Geology and Mines (DNGM)
- Osuwela (OSW)
- Higher School for Rural Development (ESUDER)

**Namibia**

- Namibia University of Science and Technology (NUST) (2 projects)

**Nigeria**

- Enugu State University of Science and Technology (ESUT)

**South Africa**

- Nelson Mandela University (3 projects)
- Uni. Cape Town (2 projects)
- Cape Peninsula University of Technology (CPUT) (3 projects)
- Univ. of Limpopo (3 projects)
- Tshwane University of Technology (TUT) (2 projects)
- University of Pretoria (3 projects)
- University of Venda (2 projects)
- Mangosuthu University of Technology
- University of the Western Cape (2 projects)
- Stellenbosch University (STELL) (2 projects)
- The Council for Scientific and Industrial Research (CSIR)
- University of the Witwatersrand (WITS) (2 projects)
- Human Sciences Research Council (HSRC)
- Walter Sisulu University (WSU)
- University of Fort Hare (UFH)

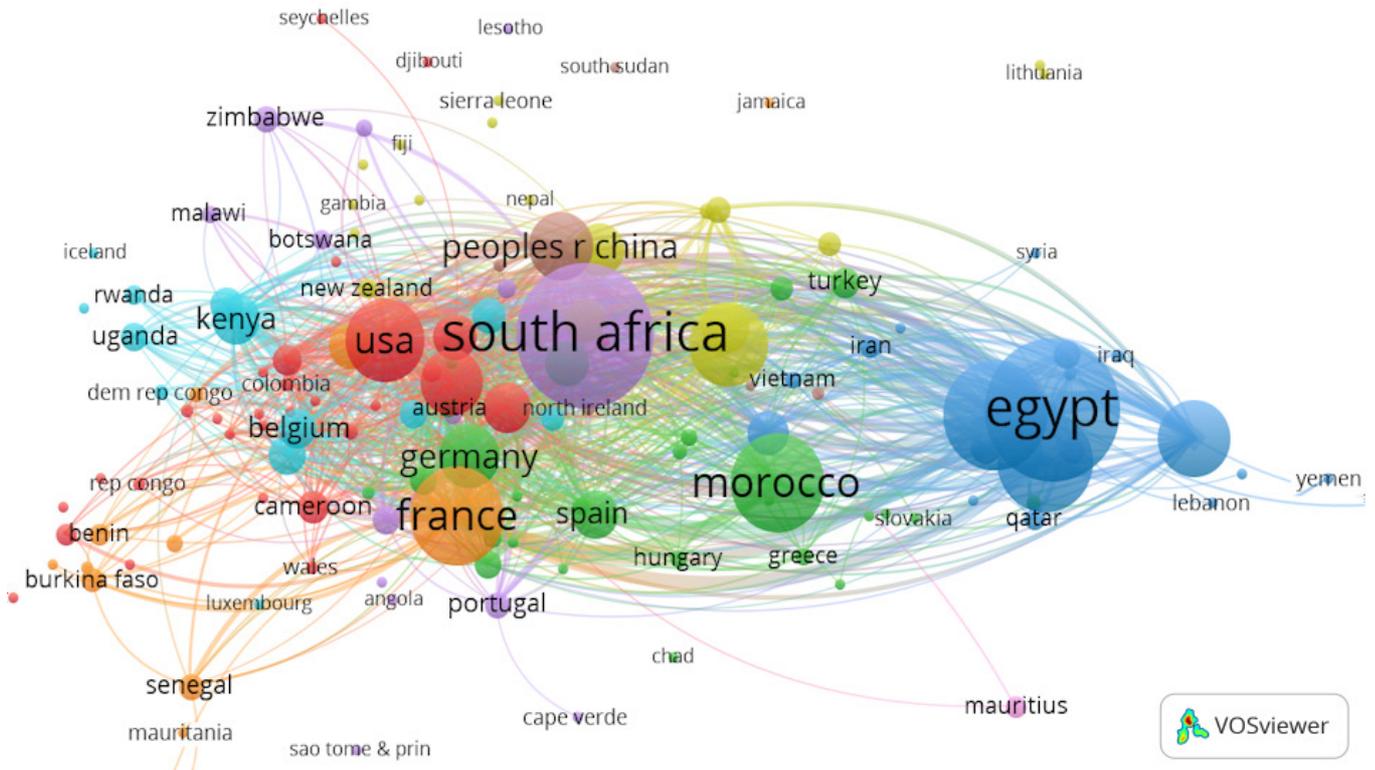
**Togo**

- Université de Lomé (5 projects)

**Tunisia**

- ENSIT
- CRTEn
- Université de Tunis El Manar (UTM)

**Relaxing image**



*Most African researchers have co-publications with partners from France, China, USA, Germany, Spain, Portugal, Belgium etc.. but also with regional countries*

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## 6 Annexes

- *Annexe 1: The SDGs, Agenda 2063 Goals and STISA Tools for Leap-RE project matching*

- Annexe 2: Main Wos Query

## **Annexe1: The SDGs, Agenda 2063 Goals and STISA Tools for Leap-RE project matching**

<b>Classe</b>	<b>SDG &amp; Title</b>	<b>Effect of RE on Goal SDG s</b>	<b>Agenda 2063 Goals</b>	<b>STISA-2024 priority areas</b>	<b>relevant Keywords</b>
<b>Renewable Energy to end poverty, to end hunger, to ensure healthy lives,</b>					
#C1	<b>SDG1:</b> End poverty in all its forms everywhere	<p># 1.4: free the financial and time resources of the rural population used for procuring energy.</p> <ul style="list-style-type: none"> <li>- microgrids, can significantly improve worker productivity in rural households</li> <li>- By mitigating climate change, RE can reduce the poverty risks of climate change</li> <li>- Access to modern energy forms (electricity, clean cook-stoves, high-quality lighting) help alleviate chronic and persistent poverty. Modern energy access can also help to free up resources (e.g. time, money)</li> </ul>	<p>#1: A high standard of living, quality of life and well-being for all citizens.</p> <ul style="list-style-type: none"> <li>- Incomes, Jobs and decent work</li> <li>- Environmentally sustainable climate resilient economies and communities</li> <li>- Full gender equality in all spheres of life</li> </ul>	<p>#1: Eradicate Hunger and ensure Food and Nutrition Security</p>	<p>Energy, Microgrids, climate change, mitigation,</p> <ul style="list-style-type: none"> <li># vulnerability to climate</li> <li># Access to Basic Goods and Services</li> <li># Financial Inclusion</li> </ul>
#C2	<b>SDG2:</b> End hunger, achieve food security and improved nutrition and promote sustainable agriculture	<p># 2.1: Energy will increase agricultural production for assuring food security and ending hunger.</p> <p># The intensification of land use relies on mechanization and the use of fertilizers and pesticides, all of which is energy intensive</p>	<p>#5 : Modern agriculture for increased productivity and production</p> <ul style="list-style-type: none"> <li>- Transformed economies and job creation</li> <li>- Environmentally sustainable climate resilient economies and communi</li> </ul>	<p>#1: Eradicate Hunger and ensure Food and Nutrition Security</p>	<p># end hunger, food security,</p> <ul style="list-style-type: none"> <li># nutrition,</li> <li># sustainable agriculture,</li> <li># Food Waste</li> <li># Healthy Food</li> <li># Small Holder Farms</li> </ul>

#C3	<b>SDG3:</b> Ensure healthy lives and promote well-being for all at all ages	<ul style="list-style-type: none"> <li>- Energy will improve public health services</li> <li>- clean energy reduce exposure to indoor air pollution and the frequency of acute respiratory infections by burning biomass or utilization of kerosene lanterns.</li> </ul>	<p>#3: Healthy and well-nourished citizens.</p> <ul style="list-style-type: none"> <li>- Health and Nutrition</li> <li>- Environmentally sustainable climate resilient economies and communities</li> <li>- Full gender equality in all spheres of life</li> </ul>	<p>#2: Prevent and Control Diseases and ensure Well-being,</p> <ul style="list-style-type: none"> <li># Better understanding of endemic diseases,</li> </ul>	<ul style="list-style-type: none"> <li># Access to Healthcare,</li> <li># Aging,</li> <li># Maternal and Reproductive Health,</li> <li># Mental Health,</li> <li># Disease Prevention and Response,</li> <li># Fitness and Well-Being,</li> <li># Biotechnology</li> </ul>
<b>Renewable Energy for knowledge and capacity development</b>					
#C4	<b>SDG4:</b> Ensure inclusive and equitable education and promote lifelong learning opportunities for all	<p>RE could extend the time spent to study, and to access to e-learning platforms</p> <p>Acquired knowledge and skills can then be drawn upon to promote sustainable development, potentially influencing the technological, financial, and political solutions that are feasible</p>	<p>#2: Well educated citizens and skills revolution underpinned by science, technology and innovation.</p> <ul style="list-style-type: none"> <li>- Education and science, technology and innovation (STI) driven skills revolution</li> <li>- African cultural renaissance is pre-eminent</li> <li>- Full gender equality in all spheres of life</li> <li>- Engaged and empowered youth and children</li> </ul>	<p>#Intellectual communication in terms of ICT</p>	<ul style="list-style-type: none"> <li># Access to Education</li> <li># Education Systems</li> <li># Upskilling]</li> </ul>
#C5	<b>SDG 5</b> Achieve gender equality and empower all women and girls.	<p>RE could save time to procure traditional biomass and cooking since women are mostly responsible for these tasks. The saved time could be used for girls' school enrollment and for women paid employment. Free time could be used too in watching TV, which has been shown influence in reducing violence toward women and increase women's autonomy.</p>	<p>#17: Full gender equality in all spheres of life</p> <ul style="list-style-type: none"> <li>- Women and girls empowerment</li> <li>- Healthy and well-nourished citizens</li> <li>- World class infrastructure crisscrosses Africa</li> </ul>	<p># Education and human resource management</p>	<ul style="list-style-type: none"> <li># Products and Services for Women</li> <li># Women Inclusive Corporate Policies</li> <li># Women Leadership and Capital</li> </ul>

Renewable Energy for energy security and Climate change					
#C6	<b>SDG 7</b> Ensure access to affordable, reliable, sustainable and modern energy for all.	RE creates significant synergy effects on climate change and energy security. This makes countries more independent of imports of fossil fuel resources. research efforts aim to improve already existing technical solutions, so that "the global technical potential of RE sources will not limit continued growth in the use of RE".	<ul style="list-style-type: none"> <li>- 1 : A prosperous Africa based on inclusive growth and sustainable development,</li> <li>- people have access to affordable and decent housing with all the basic necessities of life such as, water, energy, ICT;</li> <li>- harnessing all African energy resources to ensure modern, efficient, reliable, cost-effective, renewable and environmentally friendly energy</li> <li>- Environmentally sustainable climate resilient economies and communities</li> <li>- World class infrastructure crisscrosses Africa</li> </ul>	#Infrastructures and energy	<ul style="list-style-type: none"> <li># Access to (clean) Energy</li> <li># Transition from Fossil to Clean Energy</li> <li># Energy Efficiency</li> </ul> <p><b>Which RE technologies could solve</b></p> <ul style="list-style-type: none"> <li>#1. Solar Photovoltaic Energy,</li> <li>#2. Wind Energy,</li> <li>#3. Energy Efficiency in the Building,</li> <li>#4. Solar Thermal Energy,</li> <li>#5. Marine energy,</li> <li>#6. Storage of Energy,</li> <li>#7. Geothermal Energy,</li> <li>#8. Bioenergy,</li> <li># 9. Hydrogen and Fuel Cells,</li> <li>#10. Hydroelectricity,</li> <li>#11. Materials : (industrialization of certain components of renewable energy systems such as solar panels or wind turbine blades)].</li> </ul>
#C7	<b>SDG13</b> Take urgent action to combat climate change and its impacts.	Africa contributes little to greenhouse gas emissions, but remains the continent most vulnerable to the impacts of climate change in all climate scenarios above 1.5 degrees Celsius. Africa's population is growing rapidly .and effective climate change mitigation will not be possible without the contribution of Africa. A growth strategy without regard for the environment is likely to be	<ul style="list-style-type: none"> <li>- Modern agriculture for increased productivity and production</li> <li>- Environmentally sustainable climate resilient economies and communities</li> </ul>	# Environmental protection including climate change	<ul style="list-style-type: none"> <li># Climate Adaptation strategies</li> <li># CO2 harvesting and storage</li> <li># Greenhouse Gas Reduction</li> </ul>

		based on coal, will impact climate targets.			
<b>Renewable Energy for economic growth</b>					
#C8	<b>SDG 8:</b> Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	There is a strong correlation between economic growth and the availability of abundant energy. The high cost of energy has effect on industrial growth in Africa. Africa is heavily dependent on energy imports.	#1: A high standard of living, quality of life and well-being for all citizens. - Social security and protection, including persons with disabilities #4: Transformed Economies - Sustainable and Inclusive economic growth	#create wealth #ensure well-being	# Developed World Jobs # Developing World Jobs # Fair Trade and Ethical Supply
<b>Renewable energy and terrestrial ecosystems</b>					
#C9	<b>SDG 15</b> Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.	The need for fuelwood has effect on the forest ecosystems. By contributing to climate change mitigation, RE can reduce the risks of climate change for damage to ecosystems and halt deforestation	#4: Transformed Economies STI driven manufacturing, industrialization and value addition - Economic diversification and resilience - Environmentally sustainable climate resilient economies and communication	# Exploitation and management of mineral resources, forests, aquatics # soil and climate conservation	# Animal Welfare # Sustainable Managed Landscapes # Biodiversity and Conservation

## Annexe 2: Main Wos Query

(TS=("energy transition" OR "low carbon energy sources" OR "renewable energy systems (RES)" OR "decarbonization" OR "thermal energy" OR "green electrification" OR "geothermal resources" OR "African electricity production" OR "geothermal resources" OR "geothermal energy systems" OR "geothermal systems" OR "climate resilience" OR "rural electrification" OR "green-field mini-grid" OR "photovoltaic systems" OR "flexible solar panels" OR "solar powered generator" OR "solar outdoor lighting" OR "wind generator" OR "solar panel installation" OR "solar farm" OR "best solar panels" OR "pv panels" OR "sustainable energy" OR "renewable energy resources" OR "renewable sources of energy" OR "solar tracker" OR "solar panels" OR "solar PV panels" OR "photovoltaic panel waste" OR "wind turbine blades" OR "lead-acid batteries" OR "Li-ion batteries" OR "off-grid solar" OR "e-waste stream" OR "Smart stand-alone systems" OR "energy mix" OR "clean cooking" OR "lighting water pumping" OR "small microgrid" OR "mini grid stability" OR "production of electricity" OR "grid infrastructures" OR "off-grid systems" OR "wind power" OR "sunpower" OR "solar panel cost" OR "hydropower" OR "panel solar" OR "solar battery" OR "renewable energy sources" OR "biomass energy" OR "solar cooker" OR "energy efficiency" OR "solar panels for home" OR "solar panels for sale" OR "photovoltaic cells" OR "hydroelectric energy" OR "solar generator" OR "solar inverter" OR "solar roof" OR "outdoor solar lights" OR "solar panel kits" OR "solar shingles" OR "Smart grid" OR "penetration of Res" OR "decentralized electrification" OR "coupling different RES" OR "mitigating energy poverty" OR "Hybrid and Smart RES Grids" OR "off-farm employment" OR "value chain segments" OR "cold chain technologies" OR "cogeneration" OR "solar electricity production" OR "solar system" OR "solar panels" OR "wind turbine" OR "solar city" OR "solar battery charger" OR "wind energy" OR "renewable resources" OR "green energy" OR "photovoltaic" OR "clean cooking" OR "land degradation; black carbon emissions; Indoor cooking" OR "e-cooking" OR "solar perovskites" OR "power boosting" OR "solar cooking" OR "standalone solar cooker" OR "silicon solar cells" OR "solar water heater" OR "energy conservation" OR "Solar energy" OR "Wind energy" OR "Hydro energy" OR "Tidal energy" OR "Geothermal energy" OR "Biomass energy" OR "Marine energy" OR "Photovoltaic" OR "Concentrating solar power" OR "Solar thermal heating and cooling" OR "Biomass" OR "Tidal power" OR "Wave power" OR "Fuel Cells" OR "Low Energy Architecture" OR "Low Energy Buildings" OR "Ocean Energy" OR "Solar Thermal Systems" OR "Energy Efficiency" OR "Energy Utilization" OR "Renewable Energy Resources" OR "Solar Energy" OR "Energy Conservation" OR "Biomass Energy" OR "Renewable Resource" OR "Renewable Energies" OR "Environmental Impact" OR "Renewable Energy" OR "Wind Power" OR "Carbon Footprint" OR "Polar Panels" OR "wind turbines" OR "wind turbine" OR "wind technologies" OR "wind farm" OR "wind energy" OR "wind driven" OR "water turbine" OR "wastewater reuse" OR "wind farm" OR "wind farming" OR "urbanization decarbonization" OR "decarbonization" OR "understanding renewable" OR "trends renewable energies" OR "treatment biomass" OR "transition green" OR "transition fuel" OR "transition evolution" OR "transition electricity" OR "green transition dynamics" OR "energy transition" OR "tidal turbine" OR "renewable thermal electricity" OR "renewable thermal energy" OR "technology renewable" OR "renewable energy technologies" OR "solar wind" OR "solar water" OR "solar thermal" OR "solar renewable" OR "renewable energy-consumption" OR "renewable energy technology " OR "carbon footprint" OR "renewable energy consumption" OR "renewable energy sources " OR "wind-pv " OR "hybrid renewable energy system" OR "hydrokinetic" OR "renewable energy policy" OR "concentrating solar power" OR

"renewable energy capacity" OR "renewable energy projects" OR "renewable energy foreign direct investment" OR "innovation in renewable energy technologies" OR "renewable sources of energy" OR "wind farm") AND (CU=NIGERIA OR CU=ETHIOPIA OR CU=EGYPT OR CU=DEM REP CONGO OR CU=TANZANIA OR CU=SOUTH AFRICA OR CU=KENYA OR CU=UGANDA OR CU=ALGERIA OR CU=SUDAN OR CU=MOROCCO OR CU=ANGOLA OR CU=MOZAMBIQUE OR CU=GHANA OR CU=MADAGASCAR OR CU=CAMEROON OR CU=COTE IVOIRE OR CU=NIGER OR CU=BURKINA FASO OR CU=MALI OR CU=MALAWI OR CU=ZAMBIA OR CU=SENEGAL OR CU=CHAD OR CU=SOMALIA OR CU=ZIMBABWE OR CU=GUINEA OR CU=GUINEA BISSAU OR CU=EQUAT GUINEA OR CU=RWANDA OR CU=BENIN OR CU=BURUNDI OR CU=TUNISIA OR CU=SOUTH SUDAN OR CU=TOGO OR CU=SIERRA LEONE OR CU=LIBYA OR CU=REP CONGO OR CU=LIBERIA OR CU=CENT AFR REPUB OR CU=MAURITANIA OR CU=ERITREA OR CU=NAMIBIA OR CU=GAMBIA OR CU=BOTSWANA OR CU=GABON OR CU=LESOTHO OR CU=MAURITIUS OR CU=ESWATINI OR CU=DJIBOUTI OR CU=COMOROS OR CU=CAPE VERDE OR CU=SAO TOME PRIN OR CU=SEYCHELLES))

