Technologies for the production of energy from renewable sources in Tuscany: first evidence from an analysis of scientific publications.

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The purpose of this article is to create, starting from the analysis of scientific publications, a first framework of research activities related to the topic of energy production from renewable sources and on the methods, technologies and related applications carried out by subjects who operate in Tuscany. This is a field of research that over the years appears to be destined to an ever greater attention by the community in general, the production system and the system of planning, experimentation and analysis of public policies. The programming of the structural funds to be implemented soon, as well as the Next Generation Europe and therefore the Recovery Plan, are focused on supporting the transition towards technical-productive and socio-economic systems different from the past, following strategic and operational guidelines aimed to "*accelerate the twin green and digital transitions*"[2]. A key element of the green transition is the shift to an energy production that is increasingly independent of fossil sources.

To understand how the subjects of Tuscan research operate on the topic, reference was made to scientific publications, which represent the main form of communication through which individual researchers or research groups publish the methods and results of their work. The publications were extracted from the Clarivate Web of Science platform using, among other things, Incites, a research and in-depth tool (also developed by Clarivate), which makes it possible to carry out comparative analyses between selected groups of publications.

To identify the set of publications under investigation, that is the scientific articles referable to the topic of energy production from renewable sources, a search was set up (within the Web of Science Core Collection) which has as its central element the combinations of a selection of keywords contained in a validated and publicly accessible vocabulary developed by Siris Academics[3] as part of the Sustainable Development Goal 7 - Ensuring access to affordable, reliable, sustainable and modern energy services for all[4].

The list of keywords selected and used in combination to define the object of analysis are the following: agrivoltaic, alternative energy, bioenergy, biofuel, biogas, biogasoline, clean energy, clean fuel, geothermal energy, geothermal heating, geothermal power green energy, hybrid power, hydrogen fuel, hydrogen station, hydrogen technologies, photovoltaic power, photovoltaic system, renewable electricity, renewable energy, renewable fuels, renewable generation, renewable power, renewable sources, solar cell, solar charger, solar energy, solar panel, solar power, sustainable energy, sustainable power, thermophotovoltaic, tidal energy, wave energy, wave power, wind energy, wind farm, wind farms, wind generation, wind power, wood energy.

Among the forms of publication available, only the articles published in scientific journals were selected, thus excluding the reports published in conference documents, books (scientific monographs) or book chapters. The period considered is that of the last five years 2016-2020.
Through Web of Science, 130,725 papers have been extracted worldwide, these 5,268 papers include the participation of at least one author belonging to an organisation based in Italy. By applying the InCites "NUTS2 = Toscana" filter, 513 papers were identified in which at least one of the authors belongs to an organisation based in Tuscany.
After selecting some indicators found in InCites and available for download, the 3 groups of papers were exported and analysed in SQL (Structure Query Language) environment to carry out additional analyses.

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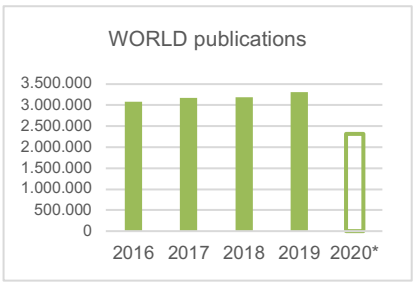
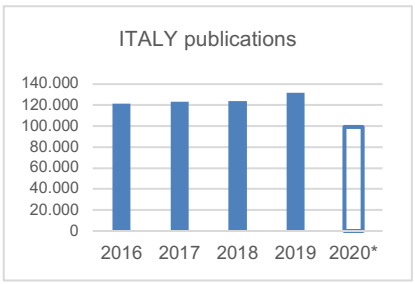
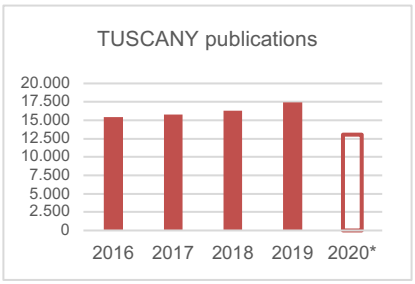
[1] IRPET – Regional Institute for Economic Planning of Tuscany
[2] Communication from the European Commission, Adjusted Commission Work Programme 2020, 27-5
[3] SIRIS Academic SL is an analysis and consultancy company on the topics of higher education, research and innovation
[4] The complete vocabulary for SDG7 is available at https://zenodo.org/record/3567769#.X8dptc1KhPZ.

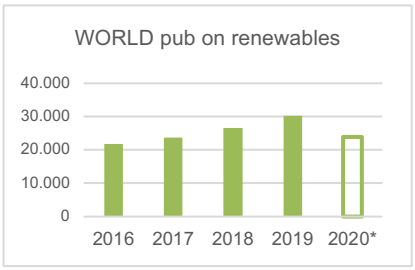
In the last 5 years, from 2016 to 2020, according to the data source used, about 3 million scientific articles have been published worldwide per year; the data that will be presented and commented below also shows 2020, even if the data for the current year are necessarily partial and provisional. In Italy there were about 120,000 publications per year; in Tuscany about 15 thousand. For each of the three territorial references considered, publications have grown over time, with the obvious exception of the last year.

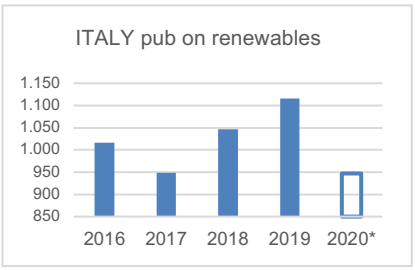


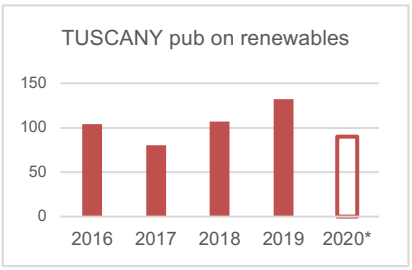




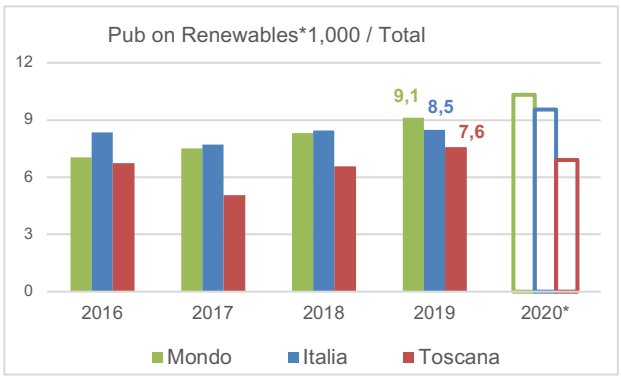
And the growing dynamic also occurs in the number of world publications relating to the issue of energy production from renewable sources. For Italy and Tuscany, on the other hand, the growing trend starts from 2017, which records a lower value than in 2016.

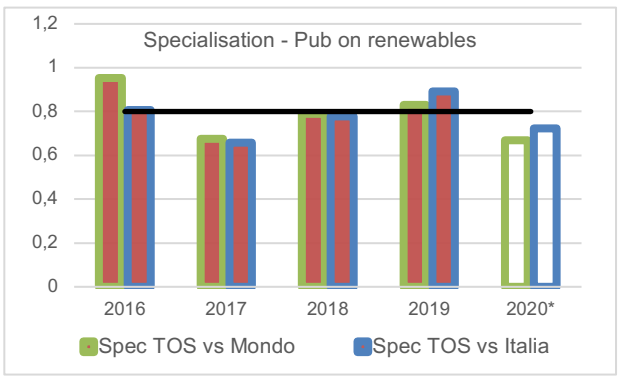






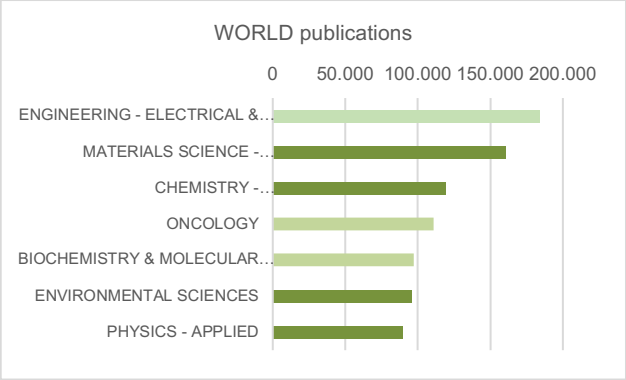
Since, as mentioned, 2020 is a year whose values are still provisional and being updated, the highest value of the number of scientific publications on the subject of energy production from renewable sources is recorded for 2019, the year in which about 30 thousand articles were published, over 1,100 in Italy, of which 132 in Tuscany.
The number of publications pertaining to the topic of energy production from renewable sources represents 7.6% of the total number of publications in Tuscany; the same share is worth 8.5 percentage points for Italy and 9.1 at the international level.

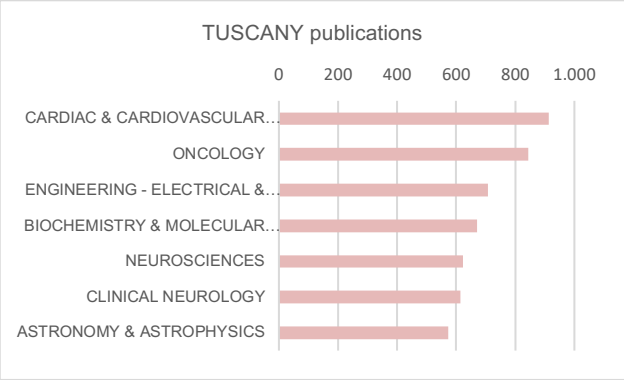




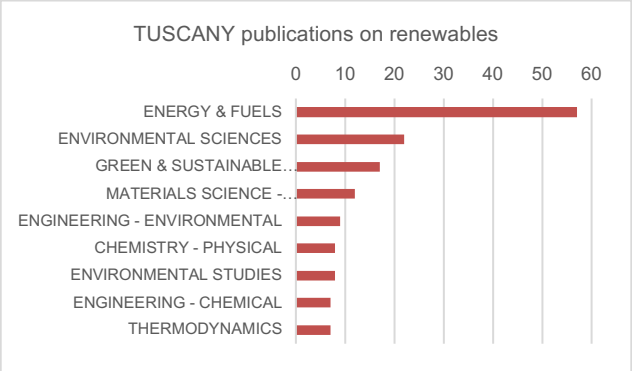
Tuscany is therefore not specialised in the creation of scientific publications on the subject of energy production from renewable sources, neither with respect to Italy, nor with respect to publications made worldwide. The specialisation index, however, over the last few years seems to be approaching 1: the percentage of scientific publications on the subject of energy production from renewable sources recorded in Tuscany is gradually approaching the percentage of scientific publications on the subject of production of energy from renewable sources registered in Italy and worldwide.

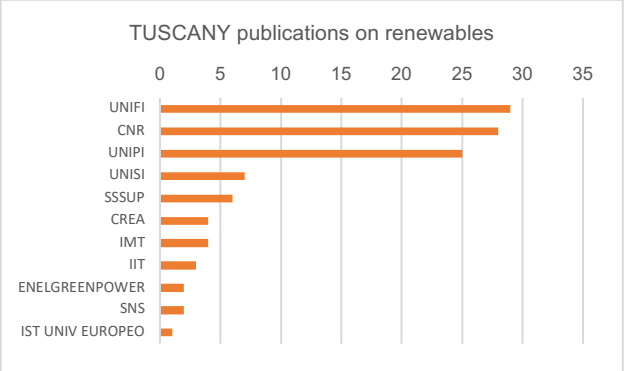
The differences in terms of specialisation further emerge if, instead of considering a synthetic index of specialisation in scientific publications on the subject of energy production from renewable sources, one examines the research areas to which the publications produced in the 2019 by territorial area in detail.
Moving on to this level of analysis, it should be remembered that, since each of the publications can be associated with one or more research areas, the total number of publications will be less than the sum of the number of publications associated with each of the research areas.





Considering the main research areas by number of publications and number of citations, in the case of publications at an international level, four of the seven areas to which individual publications can be traced are also attributable to the topic of energy production from renewable sources. For Tuscany, however, none of the main research areas refers to publications related to the topic of energy production from renewable sources: the evident specialisation is in publications that can be traced back to the topic of health and more generally to life sciences.
The research area which can be associated with the highest number of scientific publications on the subject of energy production from renewable sources carried out in Tuscany is that of Energy & fuels; the number of publications, again on the subject of energy production from renewable sources, which can be associated with other research areas is much lower.





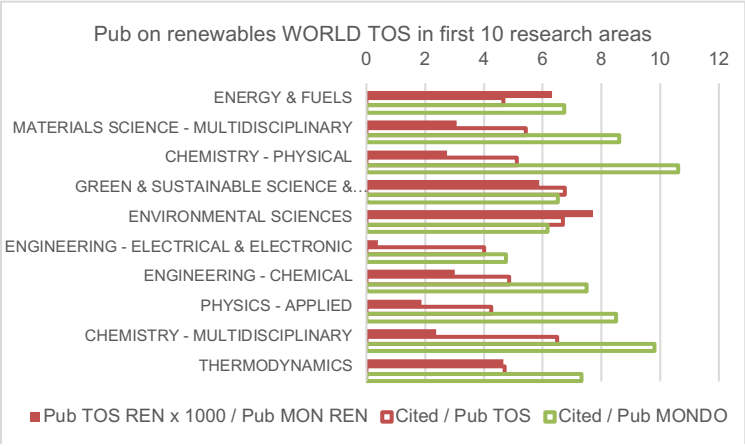
As mentioned with regard to the research areas, each publication can be produced in collaboration by authors belonging to different research organisations, therefore the same publication can be associated with several universities or research bodies. The research organisations that most participate in the creation of scientific publications on the subject of energy production from renewable sources are the University of Florence, the University of Pisa and the CNR.

Taking the scientific publications on the subject of energy production from renewable sources in which at least one author belonging to a Tuscan research subject participated in 2018 as a reference, it is possible to represent the distribution by research area and research subject. Clearly, as already highlighted, each publication can be associated with several research areas and with several research subjects.
With 100 the number of associations of scientific publications on the subject of energy production from renewable sources carried out in Tuscany by research subject and area of research, about one third can be referred to publications referring to the areas Energy and Fuels, Green and Sustainable Science and

Technology, Environmental Sciences and Materials Science Multidisciplinary and in which at least one author from the CNR or one of the three universities of Florence, Pisa and Siena participated.

	CNR	UNIFI	UNIPI	UNISI	SSSUP	IIT	CREA	SNS	ENELGREENPOWER	IMT	ISTI_UNIV_EUROPEO	*Other Subjects*	*Total Pub_Ren*
Energy and Fuels	6.0	5.0	5.5	0.5	0.5	0.5	0.5		0.9		0.5	*1.4*	*21.1*
Green and Sustainable Science and Technology	1.8	1.4	1.4	1.4	0.5		0.5		0.5			*1.4*	*8.7*
Environmental Sciences	1.4	2.3	0.5	1.8	0.5		0.5				0.5	*0.5*	*7.8*
Materials Science Multidisciplinary	1.8	0.5	0.9		0.5	1.4		0.5				*0.5*	*6.0*
Chemistry Physical	1.8	0.9	1.4			0.9		0.5				*0.5*	*6.0*
Engineering Environmental	0.9	1.8	0.5	1.4	0.5		0.5						*5.5*
Engineering Chemical	1.4	0.9	2.3		0.5							*0.5*	*5.5*
Engineering Electrical and Electronic	0.5		1.8	0.5					0.5	0.5		*1.4*	*5.0*
Nanoscience and Nanotechnology	1.8		0.9			0.9		0.5				*0.5*	*5.0*
Biotechnology and Applied Microbiology	1.4	1.8	0.5				0.5					*0.5*	*4.6*
Forestry	0.9	0.9					0.5					*0.5*	*2.8*
Agricultural Engineering	1.4	0.5					0.5					*0.5*	*2.8*
Chemistry Multidisciplinary	0.9					0.5		0.5					*2.3*
Engineering Mechanical		0.9	0.5		0.5								*1.8*
Mechanics		0.9			0.5					0.5			*1.8*
Multidisciplinary Sciences	0.5			0.5						0.9			*1.8*
Thermodynamics		1.4	0.5										*1.8*
Environmental Studies		0.5					0.5	0.5			0.5		*1.8*
Physics Applied	0.5	0.5										*0.5*	*1.4*
Other research areas	*0.5*	*1.8*	*2.8*		*0.9*							*0.5*	*6.4*
Total Pub_Ren	*23.4*	*22.0*	*19.3*	*6.0*	*4.6*	*4.1*	*3.7*	*2.3*	*1.8*	*1.8*	*1.4*	*8.7*	*100*

If from a criterion of mere counting of the number of publications we also consider some first quality indicators of the publications produced, we can note research areas associated with publications on the subject of energy production from renewable sources in which Tuscany seems to have a leading role. This is the case of the research areas for which, for example, the average number of citations per publication on the topic of energy production from renewable sources in Tuscany exceeds the average number of citations per publication on the topic of energy production from renewable sources made internationally.



In these cases, in the graph shown above, the bar outlined in red exceeds the bar outlined in green and highlights the good quality of the publications related to Green & sustainable science & technology and Environmental sciences. In these areas, the scientific publications on the subject of energy production from renewable sources made by the subjects of Tuscan research, although they represent respectively only 6 per thousand and 8 per thousand of the number of scientific publications on the subject of energy production from renewable sources made internationally in the same areas, seem to show good quality characteristics. The same cannot be said of the area that can be associated with the largest number of scientific publications on the subject of energy production from renewable sources, namely the Energy and fuels area.

Overall, scientific publications on the subject of energy production from renewable sources made in Tuscany show good quality indicators in recent years, as shown in the table below[5].

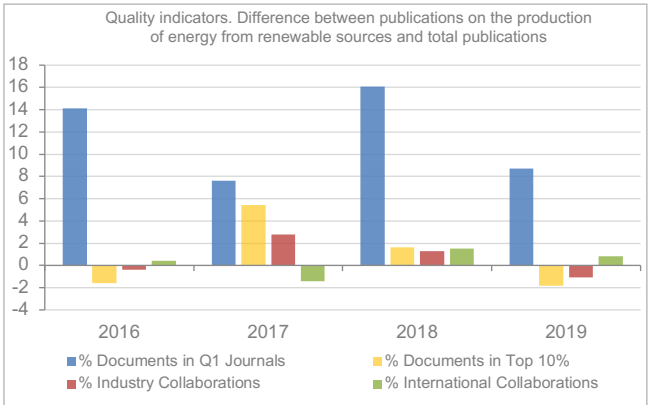
Tuscany publications on renewables	**2016**	**2017**	**2018**	**2019**	**2020***	**2016-2020**
Documents in Q1 Journals	66	48	68	73		255
Documents in JIF Journals	93	77	97	120		387
% Documents in Q1 Journals	***71.0***	***62.3***	***70.1***	***60.8***		***65.9***
Documents in Top 10%	14	16	18	15	16	79
Web of Science Documents	104	80	107	132	90	513
% Documents in Top 10%	***13.5***	***20.0***	***16.8***	***11.4***	***17.8***	***15.4***
% Industry Collaborations	***3.8***	***6.3***	***4.7***	***2.3***	***2.2***	***3.7***
% International Collaborations	***46.2***	***43.8***	***49.5***	***49.2***	***52.2***	***48.3***

With reference to the percentage of publications present in journals and by Impact Factor placed in the first quartile and with reference to the first decile of publications by number of citations as well as with reference to the share of publications in which a company has also collaborated and with reference to the share of international collaborations, the values shown by the set of scientific publications on the subject of energy production from renewable sources carried out in Tuscany demonstrate values (shown in the following table) generally higher than the total of publications in which at least one relevant author has participated to a Tuscan research subject.

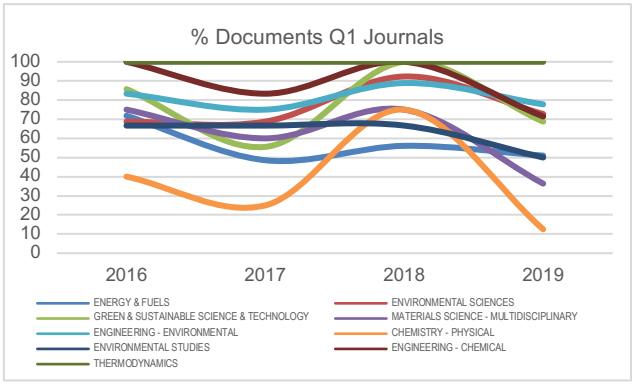
Tuscany publications	**2016**	**2017**	**2018**	**2019**	**2020***	**2016-2020**
Documents in Q1 Journals	6,682	6,600	6,839	7,516		27,637
Documents in JIF Journals	11,737	12,060	12,667	14,413		50,877
% Documents in Q1 Journals	***56.9***	***54.7***	***54.0***	***52.1***		***54.3***
Documents in Top 10%	2,342	2,310	2,468	2,303	1,542	10,965
Web of Science Documents	15,460	15,813	16,265	17,446	13,036	78,020
% Documents in Top 10%	***15.1***	***14.6***	***15.2***	***13.2***	***11.8***	***14.1***
% Industry Collaborations	***4.2***	***3.5***	***3.4***	***3.4***	***2.5***	***3.4***
% International Collaborations	***45.8***	***45.2***	***48.0***	***48.4***	***49.2***	***47.3***

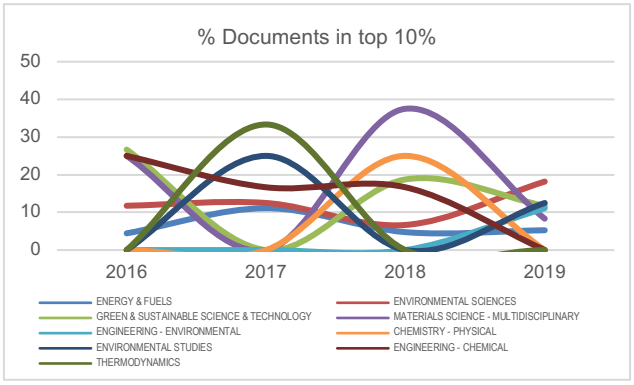
Although the considerations expressed are on average valid for the last five years, delving into the detail of the individual annuities, the general positive judgement on the quality of scientific publications on the subject of energy production from renewable sources must be attenuated. For all years, the percentage of publications appearing in the first quartile of journals for Impact Factor is higher for scientific publications on the subject of energy production from renewable sources than the total number of publications. For the other indicators, a better performance of scientific publications on the topic of energy production from renewable sources is generally noted in relation to the years 2017-2018, but not in relation to 2016 and 2019. With reference to the percentage of publications that have at least one co-author from a University, a Research organisation or a company that has its headquarters abroad, the performance of scientific publications on the subject of energy production from renewable sources is better than that of total publications for all years, with the sole exception of 2017.

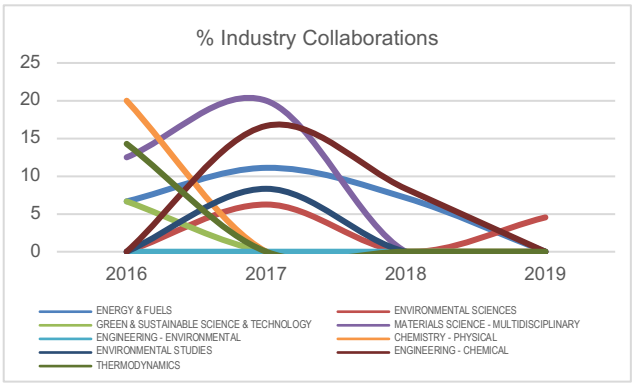
[5] Key to the indicators shown in bold: % Documents in Q1 Journals: Percentage of publications appearing in the top quartile of journals sorted by Impact Factor. The impact factor is estimated for a substantial part of the journals, but not for all. On average, in the period 2016-2019, the journals for which an Impact Factor is estimated represent 94% of the total journals;
% Documents in Top 10%: Percentage of publications contained in the first decile, based on the number of citations by research area, year and type of publication;
% Industry Collaborations: Percentage of publications that have a co-author attributable to a company;
% International Collaborations: Percentage of publications that have at least one co-author from a University, a Research Body or a company that have their headquarters abroad.

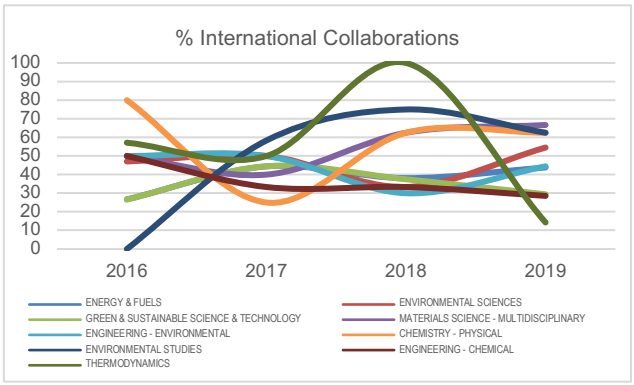


If, from scientific publications on the subject of energy production from renewable sources at the aggregate level, we try to enter the main research areas to which these refer, we can identify some elements of particular quality, as well as others of relative criticality.
The block of graphs below allows you to follow the progress of the publications referable to each of the main research areas belonging to the topic of energy production from renewable sources for each of the indicators chosen.
Some elements emerge: with regard to the share of publications in Q1 journals, in addition to the excellent performance of publications also attributable to the Thermodynamics area (all in the first quartile of JIF publications), there is a sort of polarisation: a group of research areas remains at around 70% of the share of publications in Q1 journals (Environmental sciences, Green & sustainable science & technology, Engineering - environmental, Engineering - chemical); the rest of the areas register values of around 50% or less, until they reach values below the threshold value for the first quartile.
There are not many research areas that manage to mark a persistence of the share of publications that fall within the first decile of the most cited publications above 10%, a threshold value for being able to give a positive judgement with respect to this indicator. The results achieved in the Environmental sciences, Green & sustainable science & technology, Engineering - chemical areas generally appear to be positive, while in the other areas there is a process of producing scientific publications on the subject of energy production from renewable sources with peaks and greater discontinuities.
The analysis of the indicator relating to Industry Collaborations highlights a general decline in publications created through collaborations with the business system. The consideration is valid for all the main research areas involved in the creation of scientific publications on the subject of energy production from renewable sources, with the partial exception of the Environmental Science area which maintains, on average, the low share of publications with companies over time. As regards this indicator, in our opinion, it is also necessary to consider the difficulty in correctly mapping the affiliation of the authors, especially with reference to the identification of the relationship between author and private company not subject to research; this difficulty could partly explain the fact that in 2018 there were collaborations with the business system in two research areas and in 2019 in only one area.









For the share of scientific publications on the topic of energy production from renewable sources made in collaboration with authors from foreign research organisations, 2018 was a year in which the areas were divided into two blocks, which have remained substantially as such in the following year. Materials science – multidisciplinary, Chemistry – physical, Environmental studies, which are also close to the Environmental Sciences area, belong to the block that has the highest share of international collaborations[6].

In summary:

- The number of publications on the subject of energy production from renewable sources represents 7.6% of the total number of publications in Tuscany.
- Tuscany is not specialized in the creation of scientific publications on the subject, however the specialisation index has been growing over the last few years and the percentage of scientific publications on the subject of energy production from renewable sources registered in Tuscany is gradually approaching the percentage of scientific publications on the subject of energy production from renewable sources registered in Italy and worldwide.
- The research area to which the highest number of scientific publications on the subject of energy production from renewable sources produced in Tuscany can be associated is that of Energy & fuels.
- The research organisations that most participate in the creation of scientific publications on the subject are the University of Florence, the University of Pisa and the CNR.
- About one third can be referred to publications referring to the areas Energy and Fuels, Green and Sustainable Science and Technology, Environmental Sciences and Materials Science - Multidisciplinary and in which at least one author from the CNR or one of the three universities of Florence, Pisa and Siena participated.
- Overall, scientific publications on the subject of energy production from renewable sources carried out in Tuscany show values generally higher than those relating to the total number of publications in which at

[6] Although apparently similar, the areas of Environmental Science and Environmental Studies concern distinct disciplines. The Environmental Sciences area is a research area focused on the study and analysis of fundamental scientific knowledge in mathematics, chemistry, physics and biology aimed at an advanced scientific and quantitative understanding of contemporary environmental challenges. The Environmental Studies area is a research area focused on the study and analysis of the social, political and historical aspects of contemporary environmental challenges.

least one author belonging to a Tuscan research subject has participated for: i) percentage of publications present in the first quartile of publications in journals for which an Impact Factor is estimated; ii) first decile of publications by number of citations; iii) share of publications in which a company has also collaborated; iv) share of international collaborations.

- Recent dynamics show some evidence that highlights the positive trend in some areas of research, with reference to each of the indicators used:
  - with regard to the share of publications in Q1 journals, a group of research areas stands at around 70% (Environmental sciences, Green & sustainable science & technology, Engineering - environmental, Engineering - chemical);
  - with regard to the top 10% publications, not many research areas have remained in this category in recent years: the results achieved in the areas of Environmental sciences, Green & sustainable science & technology, Engineering - chemical appear generally positive;
  - with regard to Industry Collaborations, there is a general decline in publications produced through collaborations with the business system, partly due to the difficulty in correctly mapping the affiliation of authors, with the partial exception of the Environmental Science area;
  - with regard to the share of publications produced in collaboration with authors belonging to foreign research organisations, the areas that have the greatest share of international collaborations are Materials science – multidisciplinary, Chemistry – physical, Environmental studies, which are also close to the Environmental area Sciences.