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National patterns of research output and priorities in renewable energy

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Abstract

This paper attempts to compare the research output and priorities of 25 major countries in renewable energy research. The main objective is to assess the research priorities of the major countries in frontier areas/subjects of renewable energy using some bibliometric measures based on renewable energy literature. Subjects of high activity and subjects of low activity are identified for two time periods (1996–1997 and 1998–1999). Our findings show that the output of publications including articles, reviews, letters, notes, editorials, and book reviews of India, Greece, and Belgium declined between 1996–1997 and 1998–1999. All measures indicate that in the USA all subjects of renewable energy received more or less the same priority. The rest of the countries had differentiated high- or low-priority profiles in different subjects. Among the main research subjects of renewable energy only photovoltaic technology (PV) had a fairly homogenous profile for all countries. © 2002 Elsevier Science Ltd. All rights reserved.

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1. Introduction

The publication pattern of a country is tantamount to a signature (Ojasso et al., 1994). It is an indicator of its capacity and commitment to perform mainstream research in certain specific areas. The research output in different areas/subjects of science in a country is not a random event. It is the cumulative effect of resources allocation and policy decisions in the past for different areas/sub-areas of science, whether explicitly or implicitly. If there are more publications in a particular area compared to another, it means more resources and more facilities in that particular area compared to the other. Thus the publication profile of a country can be visualized as an indicator of its research priorities (Uzun, 1998). Tracking the imbalances in the structure of research priorities is of fundamental concern to science/research policy. Policy makers are frequently confronted with such questions: What priorities are being given to different areas/sub-areas of science? How do they compare with those of other countries? What are the areas that are receiving low priority in the country, but are accorded high priority elsewhere and vice versa?

The main objective of this paper is to identify priorities and potential holes in the research agenda of major countries in the field of renewable energy, using a bibliometric indicator. This indicator, based on the distribution of publications in different subjects, is concerned with the structure rather than the size of the research area in countries of different sizes.

In the national context, an earlier study (Van de Ven and Feary, 1984) has suggested that in order to understand the policy process, it is essential to take a dynamic view of the underlying variables rather than a static snapshot. The same is true in the case of research policy too. Therefore, a collateral objective would be to track the priorities over long periods, e.g., at least four or five years.

2. Data and methodology

The data on publication output of 25 major countries in nine subjects (see Appendix A, and 2 for the names of the countries, and the details of the nine subjects respectively) of renewable energy were compiled from

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the CD-ROM versions of the Science Citation Index (SCI), and Social Science Citation Index (SSCI) databases for two time-spans: indexing years: 1996–1997 and 1998–1999. The period of two years is considered as minimum essential to smoothen, as far as possible, the year-to-year fluctuations in the publication output of individual countries in different subjects. These countries are selected on the basis of their publication output in 1998–1999.

The CD-ROMs were scanned through the ''abstract-word search field'' to compile the data. SCI and SSCI databases have been used frequently in recent years as a bibliometric tool for cross-national comparisons of publication profiles in different fields (Moed et al., 1995; Braun et al., 1995; Uzun, 1996; Bhattacharya, 1997).

3. Findings

3.1. General overview of the data

The output and world share of publications in different subjects for two time-spans: 1996–1997 and 1998–1999 are given in Table 1. The largest topic-PV-alone accounts for more than 65% of the total output in each time-span (68.2% in 1996–1997 and 65.9% in 1998–1999).

The world share of low energy architecture (LEA), Wind Energy Generation, and Geothermal applications increased significantly in the intervening period between 1996–1997 and 1998–1999. These topics registered above-average growth rates. On the other hand, world share of PV technology, and Solar Energy Materials decreased significantly.

The output and world share of publications of the countries, ranked according to the publication counts in 1996–1997 are given in Table 2. The six countries at the top of the table; the USA, Japan, Germany, England, France, and Canada account for 67.9% of the total output for the period from 1996 to 1999.

The outputs of India, Belgium and Greece declined between 1996–1997 and 1998–1999 by 3.4%, 16.7% and 11.1%, respectively whereas the output of the remaining 22 countries increased. Among the high producing countries, Spain recorded the maximum growth (81.2%), followed by Germany (57.6%), and Australia (50%). Among the less producing countries, the output of Brazil increased by 107.1%, Russia by 162.5%, Austria by 183.3% and Mexico by 433.3%. However, notice that the latter high percentages are due to the so-called 'small number effect', i.e. a small change in a small number reflects as a high percentage change.

The world share of the following countries increased significantly: USA, Germany, Spain, Austria, Brazil, Russia, and Mexico. There was no significant change in the world share of England, Australia, Sweden, Switzerland, Netherlands and Poland.

3.2. Publication output in different subjects

The distribution of publications of 25 countries in different subjects of renewable energy for the years 1996–1999 is given in Table 3.

On their own, raw counts of publications in this table do not convey much information as they are confounded by the sizes of the countries and the sizes of the subject areas. For example, China has more publications in PV technology (37) than Austria (18). Does it mean that China gives more priority to PV than Austria? England has more publications in PV (137) than in LEA (66), but what inferences can we draw from these figures? Can we say that England does more research in (or gives greater priority to) PV technologies than LEA?

Table 1
Publication output and world share of nine topics of renewable energy

Topic[a]	Number of publications			World share (%)[b]		
	1996–1997	1998–1999	Change (%)	1996–1997	1998–1999	Significant change[c]
Policy[c]	8	5	−37.3	0.6	0.3	0
LEA	226	344	+52.2	17.7	20.4	↑
PV	870	1113	+27.9	68.2	65.9	↓
Ther	44	64	+45.5	3.4	3.8	0
Wind	54	82	+51.8	4.2	4.9	↑
Bio	36	43	+19.4	2.8	2.5	0
RT	6	7	+16.6	0.5	0.4	0
Mater	28	29	+3.6	2.2	1.7	↓
Geo	5	17	+240.0	0.4	1.0	↑

[a] Key: Policy = policy issues, LEA = low energy architecture, PV = photovoltaic technology, Ther = solar thermal applications, Wind = wind energy generation, Bio = biomass conversion, RT = related topics, Mater = solar energy materials, Geo = geothermal applications (see Appendix B).
[b] World is represented by the set of 25 major countries.
[c] A change in the world share of a topic is assumed to be significant if it is 0.5% or more from 1996–1997 to 1998–1999.

Table 2
Publication output and world share of major countries in all subjects combined

Country[a]	Number of publications			World share (%)		
	1996–1997	1998–1999	Change (%)	1996–1997	1998–1999	Significant change[b]
USA[b]	380	525	+38.0	29.8	31.0	↑
JAP	128	142	+10.9	10.0	8.4	↓
ENG	97	136	+40.2	7.6	8.0	0
GER	92	145	+57.6	7.2	8.6	↑
FRA	89	116	+30.3	7.0	6.8	0
CAN	77	88	+14.2	6.0	5.2	↓
ITA	62	75	+20.9	4.9	4.4	↓
SPA	32	58	+81.2	2.5	3.4	↑
ISR	30	33	+10.0	2.3	1.9	0
IND	29	28	−3.4	2.2	1.6	↓
SWE	29	39	+34.4	2.2	2.3	0
SWI	29	41	+41.3	2.2	2.4	0
AUS	28	42	+50.0	2.1	2.4	0
NET	26	37	+42.3	2.0	2.2	0
PRC	24	28	+16.6	1.9	1.6	0
DEN	21	26	+23.8	1.6	1.5	0
FIN	19	20	+5.3	1.5	1.2	0
BEL	18	15	−16.7	1.4	0.9	
GRE	18	16	−11.1	1.4	1.0	0
BRA	14	29	+107.1	1.0	1.7	↑
NOR	10	11	+10.0	0.8	0.6	0
RUS	8	21	+162.5	0.6	1.2	↑
AUT	6	17	+183.3	0.4	1.0	↑
POL	6	7	+16.6	0.4	0.4	0
MEX	3	16	+433.3	0.2	0.9	↑

[a] For abbreviations see Appendix A.
[b] A change in the world share of a country is assumed to be significant if it is 0.5% or more from 1996–1997 to 1998–1999.

Table 3
Publication output of major countries in different subjects of renewable energy in 1996–1999

Country	Policy	LEA	PV	Ther	Wind	Bio	RT	Mater	Geo	Total
USA	2	174	607	30	40	27	3	16	6	905
JAP	3	24	213	4	6	6	1	9	4	270
GER	1	37	149	20	11	7	7	3	0	237
ENG	1	66	137	4	16	3	0	2	4	233
FRA	0	31	148	3	4	9	0	10	0	205
CAN	0	41	107	1	10	5	0	1	0	165
ITA	0	28	94	1	6	0	0	2	4	137
SPA	0	11	67	7	3	0	0	1	1	90
AUS	0	12	45	10	0	1	0	1	1	70
SWI	0	11	45	6	5	1	1	1	0	70
SWE	1	20	34	0	5	3	0	5	0	68
ISR	0	8	45	6	1	2	0	1	0	63
NET	1	10	48	1	1	2	0	0	0	63
IND	1	3	42	7	4	0	0	0	0	57
PRC	1	6	37	2	4	0	0	1	1	52
DEN	0	20	18	1	8	2	0	0	0	47
BRA	0	6	31	2	2	1	0	1	0	43
FIN	0	11	24	0	3	1	0	0	0	39
GRE	0	9	13	3	8	0	0	0	1	34
BEL	0	10	21	1	0	1	0	0	0	33
RUS	0	3	21	2	1	1	0	0	0	29
AUT	0	3	18	1	0	0	1	0	0	23
NOR	1	8	8	1	0	2	0	1	0	21
MEX	2	13	0	0	2	0	0	1	1	19
POL	0	3	9	0	1	0	0	0	0	13

Table 4
Priority profiles of major countries in 1996–1999

Country	Policy	LEA	PV	Ther	Wind	Bio	RT	Mater	Geo
USA	−−	0	+	0	0	0	−−	0	0
JAP	++	−−	+	−−	−−	−−	0	++	−−
GER	0	−−	0	++	0	0	++	−−	−−
ENG	0	++	−	−−	++	−−	−−	−−	++
FRA	−−	−−	0	−−	−−	++	−−	++	−−
CAN	−−	+	0	−−	++	+	−−	−−	−−
ITA	−−	0	0	−−	0	−−	−−	−−	0
SPA	−−	−−	+	++	−−	−−	−−	−−	++
AUS	−−	−−	0	++	−−	−−	−−	−−	++
SWI	−−	−−	0	++	++	−−	++	−−	−−
SWE	++	++	−	−−	++	++	−−	++	−−
ISR	−−	−−	0	++	−−	+	−−	−−	−−
NET	−−	−−	+	−−	−−	+	−−	−−	−−
IND	++	−−	0	++	++	−	−−	−−	−−
PRC	++	−−	0	0	++	−	−−	0	++
DEN	−−	++	−	−−	++	++	−−	−−	−−
BRA	−−	−−	0	+	0	−−	−−	+	−−
FIN	−−	++	0	−	++	0	−−	−	−−
GRE	−−	++	−	++	++	−−	−−	−	++
BEL	−−	++	0	−−	−−	+	−−	−	−−
RUS	−−	−−	0	++	−−	+	−−	−	−−
AUT	−−	−−	++	+	−−	−−	0	−	−−
NOR	+	++	−−	++	−−	++	−−	++	−−
MEX	++	++	−−	−−	++	−−	−−	++	++
POL	−−	+	0	−−	++	−−	−−	−−	−−

As we shall see later, the situation is just the opposite. Hence, we have computed an index, called research Priority Index (*PI*), for cross-National comparisons. *PI* is computed by the following formula:

$$PI = \frac{n_{ij}/n_{io}}{n_{oj}/n_{oo}} \times 100,$$

where n_{ij} = the number of papers of country i in subject j, n_{io} = the number of papers of country i in all subjects, n_{oj} = the number of papers of all countries in subject j, n_{oo} = the number of papers of all countries in all subjects.

Here 'all' refers to the comparison set (i.e. the set of 25 major countries). This index is very similar to the research activity index developed in 1970s (Frame, 1977). The value of $PI = 100$ indicates that research priority of a country for a given subject corresponds precisely to the average of all countries, i.e. average priority. $PI > 100$ indicates higher than average priority and $PI < 100$, lower than average priority. However, it should be kept in mind that by virtue of the definition of *PI* no country could have high or low priority in all subjects. From the values of *PI*, we can compare:

The priorities of a given country to different subjects in a given time-span.

The priorities of different countries to a given subject in a given time-span.

The priorities of a country to a given subject in different time-spans.

The priority status of different subjects in 25 major countries for the years 1996–1999 is given in Table 4. Here, we have adopted the procedure suggested in an earlier study (Barre, 1987) for fixing bench-marks for qualitative description of the relative status of a subject within a country. We have used the following five-point scale for fixing the bench-marks:

Scale	Priority status	Symbolic representation
$PI \leqslant 70$	Low	—
$70 < PI \leqslant 90$	Below average	–
$90 < PI \leqslant 1100$	Average	0
$110 < PI \leqslant 130$	Above average	+
$PI > 130$	High	++

In Table 4, a row represents the priority status of different subjects in a given country, whereas a column represents the priority status of a given subject in different countries.

If all the subjects are concentrated in the middle three categories of the five-point scale, the profile can be considered more or less homogeneous, i.e. research effort is diffused and there are no clear-cut priorities. On the other hand, if none of the subjects are in the middle three categories, the profile is differentiated, i.e. there are clear-cut priorities. We shall further discuss the priority status of a few countries/subjects to illustrate the usefulness of priority index.

It can be easily seen from Table 4 that the USA has a homogeneous profile; there is no field of high or low priority. On the other hand, England has a high differentiated profile-high priority (+ +) to LEA, wind energy generation, geothermal applications; and low priority (–) to solar thermal applications, biomass conversion, solar energy materials, and related topics.

In the case of subjects, only PV technology has more or less a homogeneous profile. Only one country (viz. Austria) has accorded high priority, whereas Denmark, Greece, Norway, and Mexico have given low priority to it. The profiles of the rest of the subjects (except LEA) are highly differentiated for the fact that the publication activity in these subjects/areas has been extremely low.

4. Conclusion

A comparative analysis of the research priorities, particularly the identification of areas that need to be emphasized or de-emphasized, has important implications for strategic planning in science, especially the allocation of resources to different areas and identification of research areas and countries for transnational cooperation in research. Tracking of trends and priorities in time can provide important insights into the impact of resource allocation decisions taken in the past.

The research priorities can be assessed through input indicators like the distribution of scientific manpower among different fields or allocation of financial resources to different areas. But the data on these indicators, particularly the breakdown of the research manpower at the level of topics are not available for many countries. On the other hand, the framework and methodology presented in this study for cross-national assessment of priorities does not suffer from any of these limitations, since bibliometric data can be collected rather easily at different levels of breakdown of scientific fields and are also amenable to cross-national comparisons.

Appendix A

The names of the countries and their trilateral codes is shown in Table 5.

Appendix B

Classification scheme for renewable energy is shown in Table 6[1].

[1] Adopted from the classification scheme of the topics of the World Renewable Energy Congress-VI, Brighton, UK, 1–7 July, 2000.

Table 5
The names of the countries and their trilateral codes

Australia (AUS)	France (FRA)
Austria (AUT)	Germany (GER)
Belgium (BEL)	Greece (GRE)
Brazil (BRA)	India (IND)
Canada (CAN)	Israel (ISR)
Denmark (DEN)	Italy (ITA)
England (ENG)	Japan (JAP)
Finland (FIN)	Mexico (MEX)
Netherlands (NET)	Spain (SPA)
Norway (NOR)	Sweden (SWE)
Peoples Rep. China (PRC)	Switzerland (SWI)
Poland (POL)	United States (USA)
Russia (RUS)	

Table 6
Classification scheme.

Name of the topic/subject	Abbreviation used
Policy issues	Policy
Efficiency and conservation	
Renewable energy availability	
Local and global environmental concerns	
Major commercial projects	
Educational initiatives	
Effective policies	
Low energy architecture	LEA
Comfort and indoor climate	
Lightning and visual environment	
Building design, forms, elements and materials	
Cities, airborne and noise pollution	
Ventilation	
Photovoltaic technology	PV
Solar cell technology	
BOS components	
PV for rural development	
PV for stand-alone systems	
PV in the built environment	
Institutional issues and barriers	
Solar thermal applications	Ther
Collector technology	
Solar water heating	
Thermodynamic systems/solar thermal electricity	
Solar thermal fundamentals	
Rural applications	
Wind energy generation	Wind
Wind power/national programs	
Technological advances and problems	
Offshore wind power	
Wind resources and planning	
Small and hybrid wind energy systems	
Trading, markets and social issues	
Biomass conversion	Bio
Heat and electricity generation	
Energy crops	
Liquid fuel	
Environmental impacts	
Economics and case studies	
Related topics	RT
Water technologies	
Hydrogen technology	
Wave, tidal and ocean thermal energy	

Table 6 (*continued*)

Name of the topic/subject	Abbreviation used
Country reports	
Solar energy materials	Mater
Transparent materials	
Switchable glazing	
Solar absorbers	
Daylighting materials	
Optical properties measurement techniques	
Window technologies	
Geothermal applications	Geo
Geothermal power production	
Experiences of operating + 40 Mew plants	
New plant and reservoir developments	
Geothermal power generation, deregulation and emission compliance	
Geothermal heat utilization	
Operating geothermal district heating systems	
Single user geothermal systems for domestic and commercial purposes	
Integration of geothermal heating and cooling technologies	

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