The Use of Scientometric Methods for Evaluating National Research Programs

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Abstract

National science policy efforts can be understood, from an information science point of view, as deliberate attempts to change the relationship of research groups to the international literature over time. These relationships can be either active (publishing and citing) or passive (being cited, co-cited, etc.). This study examines the development of two highly comparable Dutch national research programs (one on "wind energy" and one on "solar energy") in terms of factors which can be associated with such relationships. The different outcomes of the two programs are analyzed in terms of the emergence of new journals in both areas. The key findings are: (1) An international core literature emerges between 1974 and 1984 in the solar but not in the wind energy literature. (2) The Dutch solar energy researchers, both in their journal articles and in their reports, link themselves to this literature. (3) The contributions of the solar researchers are in turn recognized in the international literature. (4) The wind energy researchers have less opportunity to participate with a clearly defined external professional community.

It has been argued that relationships among journals, individuals, references, and citations can be analyzed in terms of their structural properties, but the question remains whether one such analysis can be used as a baseline to calibrate our understanding of another.[1] This question becomes particularly relevant when we want to measure the effectiveness of national science policies: science policies as a rule aim to change cognitive levels of scientific development by steering, through institutional factors such as funding.[2] However, there is always also an "endogenous" cognitive development in the sciences—i.e., one independent of external efforts to direct its development. Hence, we have to find ways to distinguish among (i) institutional effects of science policies; (ii) cognitive developments in scientific fields which take place independently of the specific national science policy; and (iii) changes in the quality of the national output which have been brought about, at least in part, by science policy efforts.[3]

Elsewhere[4], we have argued that the relations among journals as measured through the factorial structure of their aggregated mutual citations can be used as a baseline for changes taking place at other levels of analysis.[5] The structure at this level can thus—at least in the natural sciences[6]—be accounted for in terms of the differentiation between the fields and subfields as the most important element. In journal to journal citations, we find a structure which can be readily understood, easily plotted, and followed over the years on the basis of the data in the *Journal Citation Reports* (JCR) of the *Science Citation Index* (SCI). We have previously expressed the hope that this baseline of journal-journal citations may help to solve the calibration problem in the measurement of change in science, and hence of the relative success of using policy to promote the various forms of change which we have distinguished above.[7]

In this article we attempt to use these techniques to assess the relative success of two national Dutch research programs in energy research over the period 1974-1984: one on solar energy and one on wind energy. We selected these two programs because they have been very similar, both in management structure and in financial input. In fact, the one (on solar energy) is a deliberate copy of the other (on wind energy). Both programs were set up by the Dutch government in response to the oil crisis of 1973, and

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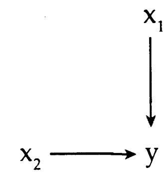
received over the relevant period an extra stimulus equivalent to about $20 million each. More important for the comparison, however, was the creation of an almost identical strong management structure for the national research efforts in both fields.

The results of these programs have included the production of 366 scientific reports from the National Research Program on Wind Energy in the period 1974-1982, and 120 reports from the National Research Program on Solar Energy since 1976. The programs actually took off on a larger scale in 1977 and in 1978, respectively. Therefore, at first glance, the Wind Energy program seems to have been more productive in quantitative terms.

However, Holland was not the only country which stimulated wind and solar energy research from 1974 onwards. In fact, both fields were internationally recognized as possible alternative sources for energy in the long term, and since energy is a matter of state concern in many societies, both were made priorities of state science policies in many advanced countries. Hence, the subject matter was also an object of international competition, from a scientific and technological point of view as well as from a business point of view.

In this study we limit our attention to the science policy effects of the two programs, leaving the technological and industrial outputs and implications as a matter for separate analysis. Our primary questions are: What can such input from the political arena mean for the scientific enterprise at the national level? How do the relevant researchers react in terms of their publications and their participation in the development of the relevant sciences? Did the policy initiative indeed stimulate the researchers involved to shift their attention and reorient their research towards new research goals? If so, was this achieved up-hill against the established matrix of the scientific disciplines, or was it facilitated by cognitive developments at the level of internationally organized fields? Did the political incentive change the position of the Dutch researchers in these fields as net consumers or producers of international knowledge in these areas? Or to ask the question more cynically: can an advanced industrial country—like the Netherlands—establish a leading edge in a new field by stimulating its scientists in certain directions, or is such a national science policy merely an epiphenomenon of international scientific development, at best paving the way for scientists to follow paths which are being traced by the international community anyhow?

The answer to this question is likely to be that effectiveness in science policy is dependent on some synergism between the local and the cosmopolitan dimensions. On the one hand, resources must be available, and on the other, publication and career opportunities for scientists within the scientific community have to be favorable. Analytically, however, the local and cosmopolitan dimensions can be distinguished easily, leading to the following general scheme:



In this scheme x_1 stands for the international environment—later in this article to be operationalized as the journal-journal structures—and x_2 for the policy effort. The dependent variable y represents the research strategies and hence the choices made by the scientists involved.

Further elaboration of the model

This very general scheme of a local and cosmopolitan dimension in the scientific enterprise[8] indicates classes of variables which have to be elaborated for every specific case. In this study, x_2 is held constant: we selected the two policy programs because of their similarity. Both programs are supposed to induce changes in the choices (y) made by the relevant actors with respect to the international environment (x_1).

However, we should be aware that this distinction cannot be identified with the distinction between the social and the cognitive. Both cognitive and social elements play a role at both levels. We may conjecture that at the cosmopolitan level in the natural sciences, the social elements (such as reputational structure, reward structure, etc.) are largely derived from the scientific substance of the contributions of the authors, while at the local level politico-cognitive vocabularies function within what are primarily social relations.

As a first operationalization for the international environment, the journal-journal citation structure may be a useful indicator. In line with the argument in the former section, the selections which researchers and research communities make in these environments can be specified as: (i) the journals in which they publish, and (ii) the journals from which they cite. The journals in which they are cited, although not an active selection by the authors, also indicate a relationship between their articles and the international literature.

However, researchers who participate in programs like these produce both articles and reports. Therefore, one way for them to deal with the local and cosmopolitan dimensions of science may be to keep the two audiences apart—to use citations from and publications in the international literature as sources of legitimation for their (local)

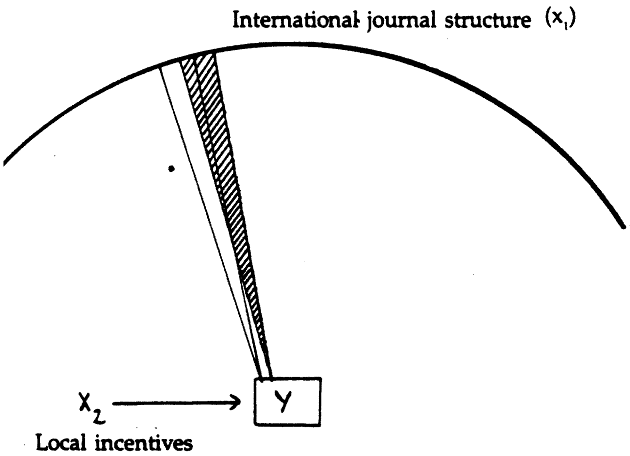


Figure 1. Summary of the relevant selections. 1. Research groups publish in international journals. 2. Research groups quote from international journals. 3. Research groups are quoted in international journals. 4. Research groups use references in their local reports (transfer function).

reports, while they address a different (scientific and international) audience in their articles and books.[9] Such behavior might be stimulated by the language difference between the (mainly Dutch) reports and the (mainly English) articles.[10] Taking this into account, we specify as a fourth measure of relationship with the international environment the references in their reports, as distinguished from the references in their (international) articles. The four indicators are summarized in Figure 1.

In sum, we maintain that from an information science point of view, science policy efforts amount to attempts to change the selections made by the relevant national (or at least institutionally defined) research communities with respect to the international literature.[11] Only with a full text analysis could one determine precisely what is being channeled through these selections, but in the context of this article we limit ourselves to the formal relations between developments in the international literature and changes in the selections which the relevant research groups make from them, since these can be measured with available scientometric techniques.

Methods

Because both solar and wind energy programs were strongly managed from a central office, a complete list could be obtained of all the reports produced between 1974 and 1982. A list of all the authors of these reports served as input for a publication search in the *Science Citation Index* from 1974 onwards. For these publications references in them and citations to them are further analyzed. Because it is common practice for authors to write articles about their research only after having finished their contracts, and because publications and citations each have their specific delays, the publication and citation analyses were extended to the end of 1984.

To generate the relevant journal set to form a baseline, we conducted short interviews by telephone with leading researchers in the groups involved. These interviews identified a consensus about eight important journals in the case of solar energy; they were used as entry points for later analysis. But in the case of wind energy no agreement about important journals could be reached in this way. Therefore, in the latter case, those journals were taken as entry points which contained more than one publication by authors from the original list, with at least two different institutional addresses. This procedure resulted in five journal titles, of which one was not included in the SCI. Hence, four journals were taken as entries. (See Table 1 for both lists.)

For 1974, 1978, 1982, and 1984, the two journals which cited each of these entry journals most heavily, and the two journals which were most heavily cited by each journal were located in the *Journal Citation Reports* of the SCI. This procedure was reiterated for the two new batches of journals in the Cited and the Citing Journal Packages of the *Journal Citation Reports* until the lists converged, or until we moved more than two citations links from any entry journal. The journals in the set at this point were treated as the "core" of the international literature for the areas. A full journal-journal citation matrix containing the exact citation rates was generated for the core journals for each year. (Rates of less than five were not included since they are not listed in the JCR). The full matrices were analyzed further as described in our earlier article, using factor analysis and multidimensional scaling.[12]

Table 1:
Entry journals for *solar* and *wind* energy:

Solar Energy
1. Solar Cells
2. Solar Energy
3. Solar Energy Materials
4. Applied Energy
5. Energy Conversion (and Management)
6. International Journal of Energy Research
7. Journal of Applied Physics
8. Journal of the Electrochemical Society

Wind Energy
1. Transactions of the American Nuclear Society
2. Journal of Aircraft*
3. Applied Scientific Research
4. Journal of (Wind Engineering and) Industrial Aerodynamics

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* The *Journal of Aircraft* is included in the Citing Journal Package of the *Science Citation Index* only.

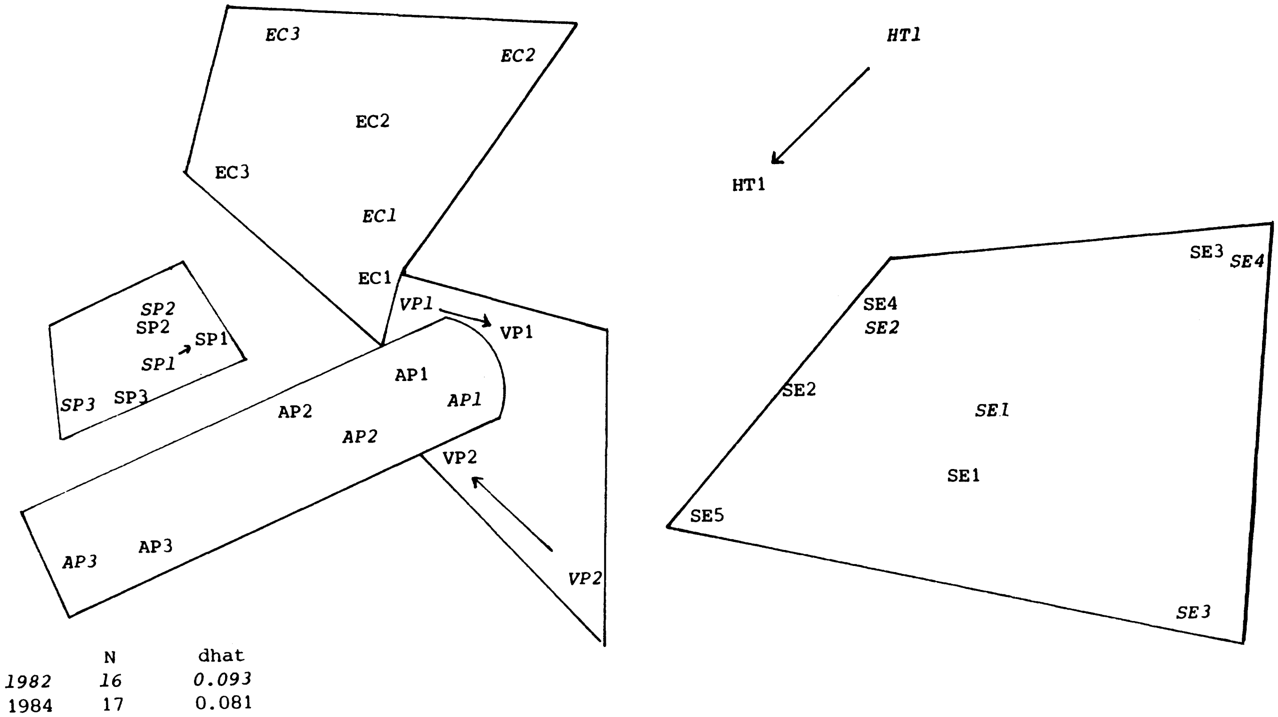

Figure 2. Stabilization of solar energy journals in 1982 and 1984. The figure represents the juxtaposition of MD-SCAL solutions for 1982 and 1984. The journals are labelled as follows: *Solar Energy* (SE1) Energy Conversion (SE2) Solar Energy (SE3) International Journal of Energy Research (SE4) Applied Energy(SE5) Journal of Solar Energy-Transactions of the ASME; *Various physics* (VP1) Solar Energy Materials (VP2) Solar Cells; *Applied Physics* (AP1) Journal of Applied Physics (AP2) Applied Physics Letters (AP3) IEEE Journal of Quantum Electronics; *Solid State Physics* (SP1) Physical Review B—Condensed Matter (SP2) Solid State Communications (SP3) Physical Review Letters; *Electrochemistry* (EC1) Journal of the Electrochemical Society (EC2) Electrochimica Acta (EC3) Journal of Electronanalytical Chemistry and Interfacial Electrochemistry; *Heat Transfer* (HT1) International Journal of Heat and Mass Transfer

The lists for the four years of journals for solar and wind energy respectively were then combined and matched against lists of publications from the two research programs to divide them into "core" and "non-core" solar- or wind-energy publications. Citations were down-loaded for all publications; the "core" publications only were further analyzed in terms of their citing patterns as well.[13] For each set of reports—solar and wind energy—the references to journals were also divided into core and non-core groups.

It should be noted that two different on-line versions of the SCI were used, one available through DIALOG Information Services and one through the German DIMDI installation since the citing references are included only in the latter one. Although there are slight differences in coverage between the two, these were not found to affect the analysis.

In the following section we first present the results of the analysis. The results are examined along following dimensions in turn:

1. journals and the dynamic development of their relations;
2. publications in international journals and local reports (output variables);
3. citations;
4. citing references in the articles; and
5. references in reports.

Within each dimension we focus first on the solar energy case and then on the wind energy case. In the last section, we then return to the central questions of the article to draw conclusions with respect to the effectiveness of these science policy-induced research programs.

Results

The development of journal structures

Solar energy journals. The journal analysis for solar energy, which started with the eight central journals of Table 1, led to clear results. (These results are also used later in this article to explain some of the data on publications and citations.)

In 1974, 21 journals constituted the environment of the only solar energy journal of that time, *Energy Conversion.* In that year, this journal exhibited a strong relation in its citation pattern to two electrochemical journals, the *Journal of the Electrochemical Society* and *Electrochimica Acta.* In 1978 the structure of the matrix, now composed of 32 journals, became much more complex, indicating that the field was going through transition. Two new solar energy journals, *Solar Energy* and the *International Journal of En-*

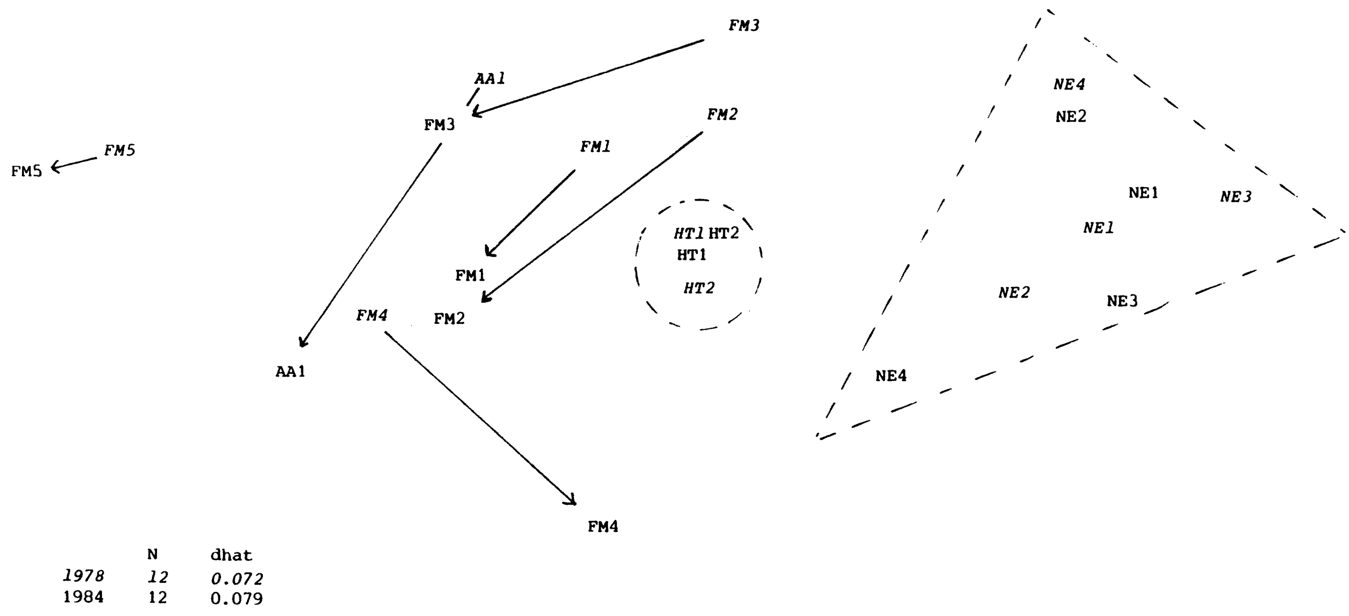

Figure 3. Development of Wind Energy Journals between 1978 and 1984. Wind energy journals are labelled as follows: *Heat Transfer* (HT1) International Journal of Heat and Mass Transfer (HT2) Journal of Heat Transfer-Transactions of the ASME; *Nuclear Energy* (NE1) Transactions of the American Nuclear Society (NE2) Nuclear Science and Engineering (NE3) Nuclear Technology (NE4) Journal of Nuclear Materials; *Fluid Mechanics* (FM1) Journal of Fluid Mechanics (FM2) Physics of Fluids (FM3) Proceedings of the Royal Society of London (FM4) Applied Scientific Research (FM5) Journal of Wind Engineering and Industrial Aerodynamics; *Aeronautics and Acoustics* (AA1) AIAA Journal.

ergy Research, load together but only on a twelfth factor explaining 4.1% of the common variance. In 1982, four solar energy journals, now also including *Energy Conversion,* load on a second factor which account for 17.7% of the common variance of a matrix of 27 journals. Other new journals such as *Solar Cells, Solar Energy Materials* and Thin Solid Films are been included in the list by 1982, but load diffusely on various factors which can be associated with the different specialties of physics (such as solid state physics). By 1984, however, these "loose" solar journals also form a clear structure linked to "applied physics," and this factor (the first) explains 18.9% of the common variance. A second factor, "solar energy," now consisting of five journals, explains 15.1% of the common variance. The nucleus of 5 solar energy journals and 5 applied physics journals, of which two explicitly use the adjective "solar" in their titles, has become stable.

In Figure 2 the stability of this cluster in later years is illustrated by superimposing the multidimensional scaling solutions for the intersection of the 1982-journal list and the 1984-list for both years.

Wind energy journals. Several features of the wind energy analysis indicate that no clear focus on basic wind energy research ever emerged in the international literature. First, in contrast with the solar energy journals the wind energy journals show rapid turnover between the years. Starting with four entries, our analysis located 72 related journals, of which only 20 play a role in more than one year of the analysis. With solar energy, half or the journals (30 out of 60) appeared in multiple years.

In the wind core, ten journals form a stable background fordevelopment over the period 1974-1984. Among these, two journals emerge in 1978 as particularly relevant for our subject in the later years, the *AIAA Journal* and the *Journal of Wind Engineering and Industrial Aerodynamics.* In 1982, four more journals appear which carry over to 1984. By their subject matter, these four are more connected with applied problems about "wind" in general (such as the construction of windmill facilities) than with wind energy research in a narrow sense.[14]

Second, factor analysis of the journal-journal citation-matrices also fails to show the emergence of a separate cluster of journals with "wind energy" as a topic. This can best be illustrated with the juxtaposition of the multidimensional scaling solutions for the 12 journals which were present both in 1978 and in 1984 (Figure 3). Among these journals are three of the four entry journals for the analysis: the *Transactions of the American Nuclear Society, Applied Scientific Research,* and the *Journal of Wind Energy and Industrial Aerodynamics.*[15] The picture clearly shows the stability of the "nuclear energy" and the "heat transfer" journals, while the "fluid mechanics" journals move away from "nuclear energy" during this period. Two journals which were already eccentric to the "fluid mechanics" group in 1978 move further away from it in the subsequent period: *Applied Scientific Research* turns somewhat back to nuclear energy, but specifically to its "electronics" component (approaching much closer to the *Journal of Nuclear Materials*), while the *Journal of Wind Engineering and Industrial Aerodynamics* moves still further away from the "nuclear energy" part of the picture.

In summary, the pattern is dominated by movement and turnover of journals with low impact factors, particularly among those with special interest to our subject. The most relevant journals which carry over move away from "nuclear energy" toward new fields with an emphasis on application and engineering. In 1984, not only "water research" and "civil engineering," but also other fields of engineering such as "agricultural engineering" start to play a role in the journal matrix. The set is also becoming more diffuse: no fewer than 41 journals (reduced to only 16 factors through factor analysis) are relevant in 1984.

From these results we may generate the hypothesis that the research phase for wind energy never really gained momentum as a separate specialty. Before this could happen, problems of implementation and diffusion took over. This hypothesis is consistent with background knowledge about wind energy research.

Publications in international journals and local reports

As noted above, the starting point for the analysis of Dutch publications was the set of authors of local reports, archived in the managing office of the two programs. The publications of these authors in the international literature were retrieved from the *Science Citation Index*. Some publications may have been missed by using the SCI. The in-between category of publications in less visible journals (such as engineering journals and trade journals in Dutch, for instance), could not be retrieved, nor is there a simple alternative procedure for finding them. In addition, particularly in fields such as these, with high policy relevance and emerging journal structures, major publications may also have been published in journals which had not (yet) been included in the *Science Citation Index.*

However, from the perspective of our original question, a database restricted to journals which are included in the SCI is sufficient. We are primarily interested here in the relation between reports, which are oriented toward funding agencies, and the scientific contributions of the researchers to their relevant professional communities. This relationship can be dealt with adequately using the set of publications which pass the selection criteria of the *Science CitationIndex.*[16]

Solar Energy. In the National Research Program on Solar Energy, 120 reports were written by 57 authors, for an average of 2.1 reports per author.These 57 authors published 63 articles in 32 journals which are included in the on-line installation of the SCI on DIALOG.[17] Of these 32 journals 14 belong to the core journal set for solar energy.

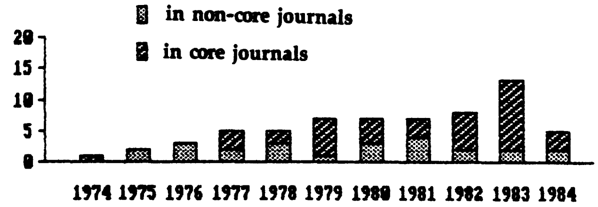

Figure 4. Number of Publications for Dutch Solar Energy Authors in Solar Energy and Non-Core Journals. In non-core journals, N = 24; in core journals, N = 39; total, N = 63.

Thirty-nine of the 63 publications were published in the 14 core journals. Hence, we can speak of a focus on these journals in the publications.

Over the years, the number of publications also grew steadily from 1 in 1974 to 13 in 1983.[18] (See Figure 4.) The share of the publications in core solar journals increased even more rapidly, as is also evident from this figure.

Wind Energy. In the Dutch National Research Program on Wind Energy, 156 authors produced 366 reports (an average of 2.4 per author). These 156 authors also produced 61 SCI publications, which appeared in 44 journals. Only 14 of these journals belong to the wind energy core. The full set of data for wind energy, in comparison with solar energy, is given in Table 2.

In Table 2, we note that although the group of wind energy authors is nearly three times as large as the solar energy group (156 versus 57) and published also about three times as many reports (366 versus 120), both groups pub-

Table 2
Comparison of Output data for
Solar and Wind Energy Programs

	SOLAR ENERGY			WIND ENERGY		
No. of reports			120		366	
Actually archived:			144		348	
No. of authors			57		156	
No. of SCI-publications			63		61	
	Solar energy *journals*			Wind energy *journals*		
	core	non-core	total	core	non-core	total
Journals	14	18	32	14	30	44
Publications	39	24	63	24	37	61
Citations	83	40	123	36	76	112
(+self-cites	28	9	37	9	18	27)
citations per pub.	2.1	1.7	2.0	1.5	2.1	1.8
References	138	336	474	42	183	225
Refs. in reports	99	80*)	179	44	183*)	227

* All other international journals

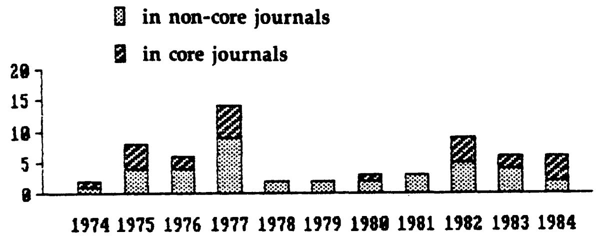

Figure 5. Number of Publications for Dutch Wind Energy Authors in Wind Energy and Non-Core Journals. In non-core journals, N = 37; in core journals, N = 24; total, N = 61.

lished roughly the same number of publications in international journals (61 versus 63). Moreover, the wind energy authors published in a much more scattered set of journals than their solar energy colleagues (44 versus 32) and they focussed less on core journals (only 24 publications in core journals for wind energy as against 39 for solar energy). Clearly, the solar group has a more structured relationship to the international literature.

The absolute number of publications over the years in wind energy also follows a pattern which is different from that of the solar energy case. Although moderately productive in the earlier years (14 publications in 1977), in the 1978-1981 period, this group of authors produced only 2 or 3 publications per year, with none in the core set of journals in 1978, 1979 or 1981. (See Figure 5.)

If we look at the journals in which these authors published in the different years, we see a connection between subject matter and production of international papers. Before 1978 the wind energy authors were active in the nuclear energy field. Only from 1982 onwards do we find publications which we can identify as having typical wind energy issues as their subject matter. However, even in these later years we find more publications of this group in the "nuclear energy" journals than in the journals with the word wind in their title. One problem here, to which we will return in dealing with the citing patterns, is that perhaps more than in the case of solar energy, the new wind energy journals may have remained under the threshold of inclusion in the *Science Citation Index* (such as, for example, is the case for *Wind Engineering*).[19]

Citations to "solar" and "wind" energy publications

The full set of 63 articles in international journals from solar energy authors received 160 citations. Thirty-seven of these were self-citations, which we removed from the analysis, leaving 123 citations. The set of 39 articles, which were published in "core" journals for solar energy, received 83 non-self citations. They were thus more frequently cited than the non-core publications, although on the average they are younger and appear in relatively newer journals. In the wind energy case the full set of 61 received about the same number of non-self citations, 112; but the 24 core wind energy documents received only 36 citations, a lower average number (c/p) than the publications in non-core journals. (See Table 2.)

The development of the being cited patterns over the years is also different for solar and wind energy publications. (See Figure 6.) However, in both cases a substantial percentage of the citations to publications in core journals come from core journals: 42% and 44% for solar and wind energy respectively.

Development of citing patterns

What publications are cited in the articles published by Dutch authors in these two fields in the core of their international literature? For reasons of cost-effectiveness, we confined our analysis to the document set which had been published in core solar energy journals and wind energy journals. A longitudinal analysis of "being cited" and "citing" patterns for these core solar and wide energy publications was compared with citing patterns in the reports of the two programs.

For this analysis we had to use the DIMDI-installation of the SCI since only on that edition the references in the source articles are included as well. However, in this installation we could find only 38 of the 39 solar energy articles which we found in the DIALOG installation. These 38 solar energy articles contain 474 references while 24 wind energy publications contain 225. Hence, the average number of references in a core wind energy publication is somewhat lower than in a core solar energy publication (9.4 versus 12.5). The percent of references to core journals varies considerably over the years. (Figure 7 gives these percentages for 38 solar energy core publications and 24 wind energy core publications distributed according to their

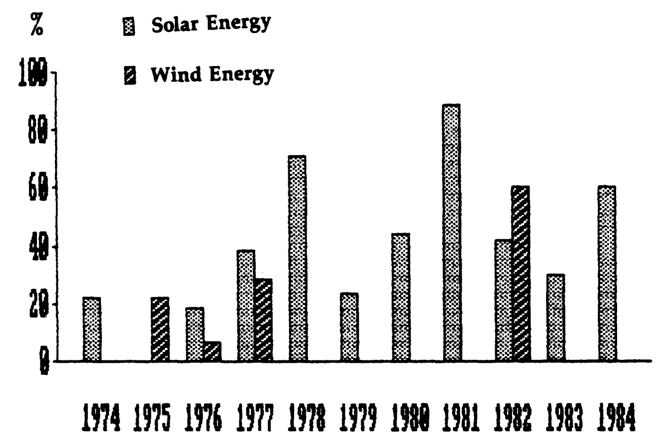

Figure 6. Percentage of Citation in Core Journals for Solar and Wind Energy Respectively, 1974-1984. Self Citations are included. Hence there are 63 publications and 160 citations in solar energy, and 61 publications and 143 citations in wind energy, for a total of 124 publications and 303 citations.

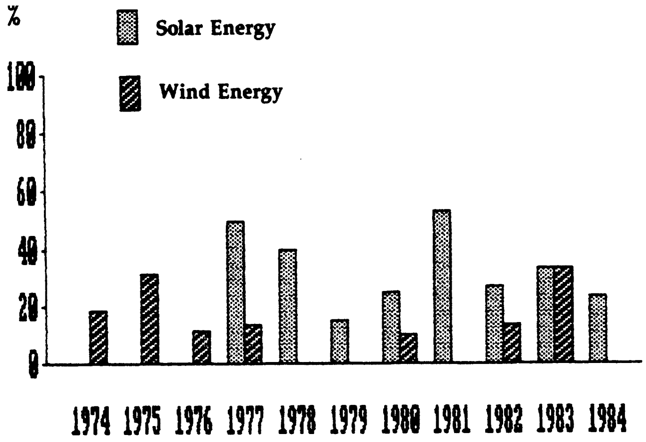

Figure 7. Percentage of References in Articles from Core Journals for Solar and Wind Energy Respectively, 1974-1984. Self Citations are included. Hence there are 38 publications and 474 references in solar energy, and 24 publications and 225 references in wind energy, for a total of 62 publications and 699 references.

publication years.[20]) However, in the case of solar energy this percentage is on the whole 10% higher than in the case of wind energy. Again, this indicates a stronger relation to the international literature in the solar energy case than in the wind energy case.

References in the reports

Finally, as has been noted above in both programs a substantial number of reports were produced as well. The official records of the National Research Program on Solar Energy lists 120 reports by 57 authors, and those of the National Research Program on Wind Energy 366 reports by 156 authors. In the archives of these programs we found 144 reports on solar energy (that is, 24 more than were registered) and 348 reports on wind energy (which is 18 fewer than were registered); hence what we located were approximately the full sets. We compared the citing patterns in these reports with the citing patterns in the articles produced by the two groups of authors.

The wind energy reports contain 7.4 references per report as against 6.2 for the solar energy reports. In the solar energy reports 20.1% of these references are to publications in international (non-Dutch) journals, while this figure is only 8.8% in wind energy. Of the international references in the solar case, 55.3% (79) are to publications in core solar energy journals, as against 19.4% (44) in the wind energy case.

Also notable in the wind data is the growth of references to English and German journals which are not included in the SCI but which have the word wind in their titles. From 1978 onwards, 46 such references occur in the reports, amounting to another 20% of the international references. (Some references to these journals also appear in the international publications of this group.)

Therefore, we see the wind energy researchers here in need of an international literature to which they can refer, while the solar energy researchers can refer to this international literature in their reports—and do so to a much larger extent than in their international publications. In terms of the scheme we introduced earlier in this paper, we conclude that in the solar energy case, when an international journal set emerges, scientists support their local resource relations by referring to an international context. In the case of wind energy, resource relations cannot be nourished with such legitimation, and we may expect other mechanisms in these relations to be more important.

Conclusions

1. The solar energy document set reflects the emergence of a solar energy journal set, while the wind energy document set shows some differentiation from what is essentially a nuclear energy document set. After a period in which the latter group of authors seems not to have published or only in journals which are not included in the Science Citation Index, in the more recent years some publications in journals devoted to wind energy issues can be found.
2. Authors publishing in core solar energy journals make more references to other authors publishing in these journals than do their wind energy counterparts. However, both groups have to gain a substantial part of their rewards in terms of "being cited" in non-core journals.
3. In the case of wind energy, publications in non-core journals gained more credit, as measured in citations of these publications, than publications in the core journals. The opposite situation occurs in the case of solar energy.
4. In general, although both document sets cite, and are being cited in, more publications in non-core journals than publications in core journals, the solar energy core set of publications (i) refer less to the non-core set journals, and (ii) are being cited in the non-core journals is to about the same extent, but (iii) have a much higher part of the total of relevant citations within the cluster. This confirms the points made in earlier sections on journal-journal citations and their developments in the two areas: in solar energy research, we are witnessing the growth of a much more stable structure both in terms of journals and in terms of authors referring to each others' work.
5. The relevant Dutch scientific communities which have served as our entries to the analysis seem to follow these international developments with a modest contribution. At the national level, we can witness the emergence of a specialty and its participation in the specific international literature in the case of solar energy from 1978 onwards. In wind energy the development of relevant journals occurs later (1982) and is weaker in its struc-

ture, and the relevant Dutch community, which consists of authors who left the nuclear energy field, did not find publication outlets in the intervening years in journals that are internationally visible. In later years they either returned to the nuclear energy journals or to a small extent they started to publish in the "wind energy" core journals. This smaller extent corresponds to the weaker position of these journals.

Hence, our results suggest that in these fields the international publication (citing and being cited) patterns of the local communities are highly dependent on the development of international developments as measured by journal-journal relations. If any, the effects of science policy efforts at this level are probably to enhance such participation.

6. Lacking international publication outlets, Dutch wind energy research seems to have remained a more local activity than solar energy research. Solar energy researchers back up their reports with references to specific international literature, while wind energy researchers work much more in a local network whose members cannot easily refer to a specific set of international journals.

Discussion

It has not been our purpose in this article to draw conclusions about whether the one program has been more successful than the other. This is a question for policy analysts, and one which deals precisely with a variable which we have held constant in the present study. Our topic here—the changing relationship with the international literature by the relevant research communities in response to policy initiatives—strongly suggests only that there is a straightforward dependence of the publication and citation behavior of these communities on the development of structure among international journals.

On the one hand, the solar energy group, which started from about the same level as the wind energy group, found its way to an emerging set of journals, from which in turn it could profit in terms of legitimation. Although it clearly failed to meet the original objectives of the National Research Program—producing relatively few reports, with hardly any commercial value[21]—the research community managed to gain autonomy over the years to such an extent that when in 1982 the Ministry of Economic Affairs had to decide on the prolongation of the program, it chose to support "more fundamental research".[22] Since then, part of the funding for this research has been channeled through a division of the National Research Organization for Fundamental Research.[23] This suggests that not only were the selections made by the research community guided by international scientific developments, but that in this case the development was strong enough to force the polity to adapt.

On the other hand, wind energy never gained theoretical focus as a research field during the later 1970s and the early 1980s. Although some theoretical questions arose in the beginning of the program (such as those concerning "tipvanes"), engineering problems definitively took over during the 1980s. The focus of the later program and its continuation lie in the commercial development of windmills. Hence, the central problems have shifted from basic research questions to problems of industrial application. At the level of substance, we can understand this if we realize that aerodynamics is of major concern to the aircraft and space industries, and that major theoretical problems may have been solved in that context. But this is an ex post interpretation. In the beginning, there were no major differences between the two situations. In the early 1970s, the major problems of both wind energy and solar energy belonged to sciences with high industrial relevance: in the one case aerodynamics and in the other case solid state physics and electrochemistry. In terms of the methodology applied here, we can say at the very least that if there were any differences in substance they were not visible at that time yet. Over the years it seems that the balance between research and industrial application has developed in the wind energy case completely differently from the former case: the researchers involved have produced reports in response to the demand. We speculate that as researchers they followed a strategy of publishing in non-wind energy journals in order to maintain their academic standing. However, only a percentage of them manage to do so, sometimes because they are still linked in their research efforts with the more prestigious field of "nuclear energy" from which they were originally recruited.

The efforts made in this study to look at the "citing" patterns as well have been less rewarding, given the amount of software development which was required for the purpose. The major point which could be made is that the solar energy researchers indeed used two types of referencing patterns for their two relevant audiences. (Even in the "wind energy" case we can detect some, although much weaker, attempts to do this.) On the one hand, when they publish in scientific journals, they link their publications up to the international literature in more general journals, even if they publish in the narrowly focused journals of their specialty. However, in their reports they draw from their specialty journals, probably because that legitimizes the status of their specialty.

Let us conclude by returning to the social and cognitive dimensions which we discussed in the introductory section. During the research, a shift has been made from the original "group of authors" as unit of analysis to the different "document sets" they produced.[24] On the one hand, if we want to stick to the traditional science policy questions involved—where to spend money and why?—we are inclined to see the proper unit of analysis as institutions, and hence, in terms of scientometric methods, as groups of authors. On the other hand, the results of this study suggest a strong linkage between the outcomes of science policies and the development of the international scientific literature. The base for this linkage is not "authors" but articles, or to put it more technically: document sets. The crucial question becomes: what makes a scientific article a significant contribution? From this perspective, science policy issues inevitably assume a more cognitive aspect.

Notes and References

1. K. E. Studer, D. E. Chubin, *The Cancer Mission. Social Contexts of Biomedical Research* (Beverly Hills/ London: Sage, 1980), 269.

2. G. Küppers, P. Lundgreen, P. Weingart, "Umweltprogramm und Umweltforschung", in *Geplante Forschung*, ed. W. v.d. Daele, W.Krohn, P. Weingart (Frankfurt a.M.: Suhrkamp, 1979), 239-286. On funding, see S. E. Cozzens (ed), "Funding and Knowledge Growth", theme section of *Social Studies of Science*, 16 (1986), 9-150.

3. Cf. I. Spiegel-Rösing, *Wissenschaftsentwicklung und Wissenschaftssteuerung*, (Frankfurt a.M.: Athenäum Verlag, 1973), 106-131.

4. L. Leydesdorff, "The Development of Frames of Reference," *Scientometrics* 9 (1986), 103-125.

5. In most cases the variables load on a second factor only in the second decimal, and hence the split is almost complete. The factorial complexity of citing or being-cited patterns can in such cases be used as an indicator of the "interdisciplinarity" of a journal.

6. In the social sciences, there is more evidence that particularistic criteria may be influential even at this level. See also: W. C. Yoels, "The Structure of Scientific Fields and the Allocation of Editorships of Scientific Journals: Some Observations on the Politics of Knowledge," *The Sociological Quarterly* 15 (1974), 264.

7. L. Leydesdorff, "Various Methods for the Mapping of Science", *Scientometrics* 11 (1987) 291-320. See also Leydesdorff, "Frames," 122.

8. A. W. Gouldner, "Cosmopolitans and Locals: Toward an analysis of latent social roles," *Administrative Science Quarterly* 1 (1957), 281-306, and *Administrative Science Quarterly* 2 (1958), 444-480.

9. R. D. Whitley, *The Intellectual and Social Organization of the Sciences* (Oxford: Oxford University Press, 1984).

10. P. Groenewegen, "Attracting Audiences and the Emergence of Toxicology as a Practical Science," in *The Social Direction of the Public Sciences: Causes and Consequences of Co-operation between Scientists and Non-Scientific Groups*, Sociology of the Sciences Yearbook, vol. XI, eds. S. Blume, J. Bunders, L. Leydesdorff, R. Whitley (Dordrecht/ Boston: Reidel, 1987).

11. Of course, in addition to this substantive purpose science policy may also strive to improve the institutional management of research.

12. See for a detailed description of the methods L. Leydesdorff, "Frames." Additionally, in this study factors have been extracted obliquely to test whether they were related among each other.

13. This limitation is introduced because of cost-effectiveness: searching citing-patterns in publications without access to the ISI-tapes requires considerable connect time with the host.

14. These journals are: *the Journal of the Structural Division ASCE*, the *Journal of the Water Pollution Control Federation*, *Water Research* and the *Journal of Geophysical Research*.

15. The fourth entry journal, the *Journal of Aircraft*, has not been included in the quantitative analysis because it is included only in the Cited Journal Package of the JCR.

16. About inclusion in the Science Citation Index, see S.Maricic, "Scientific Journals: Selection Criteria for Information Services," *4S-Letters* 5 (1980/1), 6-8; E. Garfield, *Current Contents*, November 5, 1979. (Also in *Essays of an Information Scientist*, vol. IV, 309-312 (Philadelphia: ISI-Press, 1981).

17. In the printed edition four additional book titles could be found, but 10 article titles were not found! These differences seem to us a relevant argument in the discussion about the use of the printed or the on-line edition of the SCI for scientometric research. See, for example: J. Irvine, B. R. Martin, "Basic Research in the East and West: A Comparison of the Scientific Performance of High-Energy Physics Accelerators," *Social Studies of Science* 15 (1985),309; H. F. Moed, A. F. J. van Raan, "Critical Remarks on Irvine and Martin's Methodology for Evaluating Scientific Performance," *Social Studies of Science* 15 (1985), 545.

18. The reason for the low values in 1984 is that the analysis was conducted until December 31, 1984 as the date of entry, while some of the 1984 publications were not published and registered until 1985.

19. See note 15.

20. One should keep in mind that the "wind energy" set is empty for 1978, 1979 and 1981, and hence does not contain any references.

21. A. Rip, P. v. d. Schaar, "Het Nationaal Onderzoeksprogramma Windenergie," in *Implementatie van Prioriteiten in het Wetenschappelijk Onderzoek bestudeerd aan de hand van enkelecasestudies*, eds. A. Rip, R. Hagendijk, H. Dits ('s-Gravenhage: Staatsuitgeverij, 1986); M. Jochem, "Waarom Wind-enZonne-energie de markt nog niet hebben veroverd?" *Wetenschap & Samenleving* 8 (1986), 20-25.

22. *Zonne-energie in Nederland. Programma voor de tweede fase van het. Nationaal Onderzoekprogramma Zonne-energie (1982-1985)*, Bureau Energie Onderzoek Projecten (BEOP)-15, (Petten: Energieonderzoek Centrum Nederland, 1982).

23. *Energieaspekten* 1984, no. 4, 260; *Energieaspekten* 1985, no. 5/6, 14.

24. On the choice of the unit of analysis in cognitive or social terms, see also: H. M. Collins, "The Possibilities of Science Policy," *Social Studies of Science* 15 (1985) 554-558; B. Martin, J. Irvine, "Evaluating the Evaluators: A Reply to Our Critics," *Social Studies of Science* 15 (1985): 559.

Notes continued from page 21.

4. Exemplary studies from the Tremont group include: Elihu Gerson, "Scientific Work and Social Worlds," *Knowledge* 4 (1983): 357-77; S. Leigh Star, "Simplification in Scientific Work: An Example from Neuroscience Research," *Social Studies of Science* 13 (1983): 208-26; Adele E. Clarke, "Research Materials and Reproductive Science in the United States, 1910-1940," in *Physiology in the American Context, 1850-1940*, Gerald Geison, ed. (Bethesda: American Physiological Society, 1987), 323-50; Joan H. Fujimura, "Constructing 'Do-able' Problems in Cancer Research: Articulation Alignment," *Social Studies of Science* 17 (1987), forthcoming.

5. Michael Schudson, *Advertising, The Uneasy Persuasion* (New York: Basic Books, 1984), quotations at 43 and 210. I have found the literature on adverising—much of it written by economists—dull and rarely pertinent to the arguments here, with one notable exception: Roland Marchand's *Advertising the American Dream* (Berkeley: University of California Press, 1985) is a beautiful sociological study of the role of advertising in cultural reproduction.

6. Hugh Rank, *How to Analyze Ads: The Pitch:* . . . (Park Forest, Illinois: The Counter-Propaganda Press, 1982), 98.

7. Schudson, *Advertising*, 215.

8. I am grateful to Mr. William Schmidt of the Coca-Cola Museum in Elizabethtown, Kentucky, for the opportunity to photograph from his fine collection of Coca-Cola advertisements. For a history of Coca-Cola, cf. Pat Watters, *Coca-Cola: An Illustrated History* (Garden City, N.Y.: Doubleday, 1978) or Oliver Thomas, *The Real Coke, The Real Story* (New York: Random House, 1986). I also wish to thank Carl Briggs for photographic assistance.

9. Scientists are of two minds on the use of science in advertising and, more generally, on its presentation in mass media. The ambivalence is noted in Dorothy Nelkin's brand new book *Selling Science: How the Press Covers Science and Technology* (New York: W. H. Freeman, 1987 at page 169): "Scientists today see improved press coverage as a means of fulfilling their obligation to bring science to the public and attracting support from legislators, corporate leaders, and foundation executives. But they have also carried over values from a time when science was less accountable and more isolated from public affairs. . . . [Scientists] worry about the corruptive influence on science of self-promotion and the encouragement of scientists more skilled in public relations than in research."

10. I thank Anne Figert for this example.

11. Schudson, *Advertising*, 27.

12. The boundary between science and non-science has been the object of earlier work: Thomas F. Gieryn, "Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists," *American Sociological Review* 48 (1983): 781-95. This endnote is an advertisement for my forthcoming book, *Boundaries of Science: Theory and Episodes*.

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