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Innovation compared with materials production: current trends in green energy production and materials

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The need for clean and renewable energy sources due to environmental concerns and resource depletion has continued the trend for innovation in green energy technologies. Recent literature has displayed a strong interest and a wide variety of research, development and innovation in many areas of renewable energy including solar, wind and biofuel disciplines. Publically available data concerning U.S. energy production and issued patents both show growth trends that correlate with each other and are supported by the interest in green energy innovation shown in the current literature.

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Introduction

A combination of environmental concerns related to the affects of the generation of energy and the continuing depletion of natural resources, including those related to energy production, point to the need for an examination of innovation in energy and the production of materials related to such innovation. Over the past few years the literature contains many articles concerning renewable and clean energy sources. A small representative sampling of such articles is reviewed here with the focus being placed upon innovation in green energy and materials [1,2•,3,4,5•,6–23,24•,25–27,28•,29–43]. A majority of the articles reviewed concern solar power and biomass energy, but there is also a great interest in hydrogen and fuel cells, and to a much lesser extent geothermal, nuclear, wind and hydropower energy. Innovative thinking is displayed in various combinations of renewable energy technology to achieve cleaner and more efficient and effective sources of energy production.

Data released by the Energy Information Administration (EIA) at eia.doe.gov in 2013 and international patent totals available from the European Patent Office (EPO) search engine espcenet.com has been compiled and analyzed to give a picture of current trends in energy production and innovation that further verify the ongoing and increasing interest in innovation in renewable and green energy that is prevalent in the current literature.

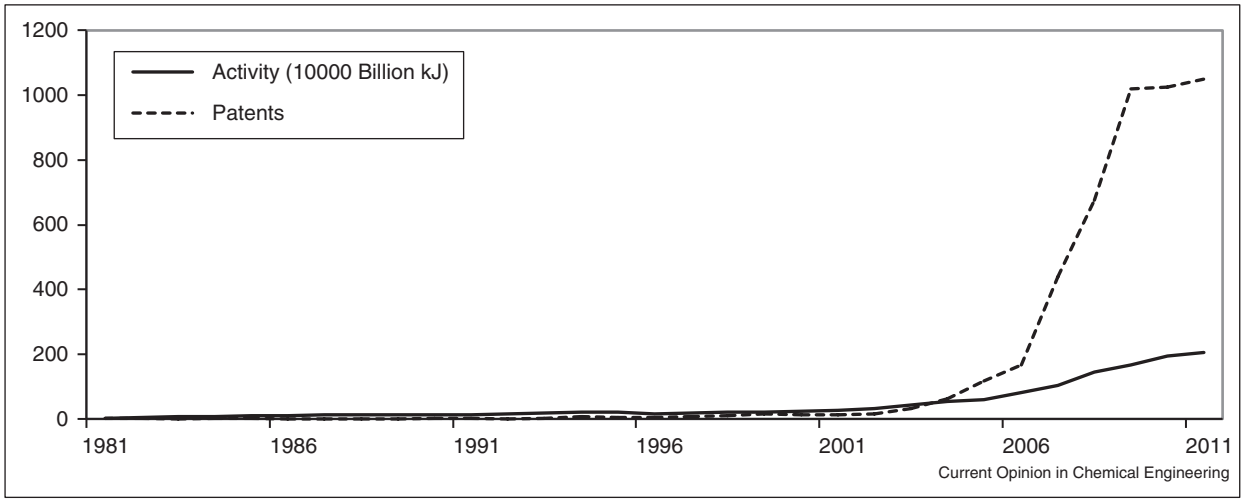
Along with a review of the current literature, presented here is a continuation and an update of a study of the relationship between energy production and related materials first presented by M.C. Connelly in *An Analysis of Innovation in Materials and Energy* [44] which as an expansion of a previous study concerning the relationship between patents relating to metals and technical innovation [45,46]. In *An Analysis of Innovation in Materials and Energy* it was shown that material or energy production paralleled related innovation trends. In particular, in all cases there was some correlation between the upward or downward shifts of U.S. energy production and innovation in related materials as measured by issued worldwide patents, meaning that growth or shrinkage of a certain type of energy production is generally mirrored by growth or shrinkage in innovation related to that type [47•,48,49•]. It is not always clear if the innovation causes the increased production or if innovation itself causes an increase in production. It seems likely that, due to dwindling sources of fossil fuels and environmental concerns, innovative activity related to renewable energy may be driving the increase in green energy production as an answer to these concerns [50].

The energy production was measured in kilojoules per year. In the original study, data was collected from the earliest available year up until 2008. Here the data has been updated to 2011 which is the latest year available for the energy production data. Energy production originated from the Energy Information Administration (EIA) at eia.doe.gov and represent US energy production for the specific energy source indicated in each case. Patent totals per year came from the European Patent Office (EPO) search engine espcenet.com and are based on a worldwide patent search of keywords related to the particular energy source. This analysis seems to reinforce the theme of increased production of, and innovation in, renewable and green energy technologies and point toward a continued interest in the near future.

Data analysis

The following figures and table show the correlation between the production and innovative activity related to specific types of renewable energy. As examples of this correlation, data is presented for US production of

Figure 1



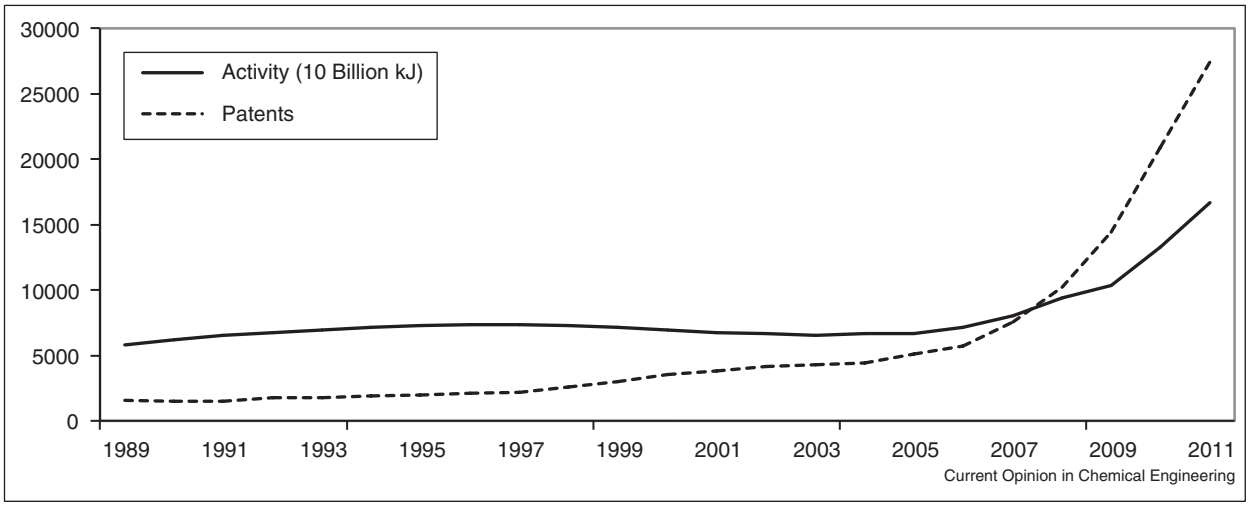
US biofuel: production and innovation. Production is measured in billion kJ produced in US per year. Innovation is measured in related worldwide patents issued per year.

biofuel, solar and wind power compared with worldwide patents related to these energy sources as well in Figures 1–3. Upon a search of the literature, solar, wind and biomass energy appear to be among the renewable energy technologies with the strongest interest in innovation and largest growth in production. Correlation is shown to exist between these specific sources of energy as well as biomass, geothermal, hydroelectric, nuclear and total renewable energy. With the exception of nuclear energy there is a continuing increase in both the innovative activity, as measured in patents, and the production of energy in the various types (Table 1).

According to data from the EPO patents relating to biofuel had an increase of 14–1049 issued patents worldwide from 2001 to 2011. During the same time frame, patents relating to solar technology increased from 3794 to 27,442 and issued patents concerning wind power technology increased from 5401 to 19,371. Though not as dramatic, the energy produced for each energy technology increased as well over the same time period.

Patent data is available into 2013 and continues to show a steep growth trend for the number of patents issued relating to renewable energy sources and technologies.

Figure 2



US solar energy: production and innovation. Production is measured in ten billion kJ produced in US per year. Innovation is measured in related worldwide patents per year.