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Renewable Energy Technologies and Policies: Status and Prospects

Christopher Flavin and Seth Dunn*

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I. INTRODUCTION

The 1990s mark a turning point in the development of renewable energy.[1] Two decades of research and the introduction of scores of new policies to promote renewable energy have led to unprecedented growth in the commercial use of the new technologies. The fastest progress is now occurring in the advanced industrial countries, but some of the technologies are also being transferred to the developing countries--particularly in Asia.

This article assesses development of four renewable energy sources: biomass energy, wind power, solar photovoltaic power, and geothermal energy. Biomass and wind energy are already economical in many applications, and show the greatest potential for near-term development. Solar photovoltaics have near-term potential in off-grid applications, and within a decade could be widely used in industrial countries. Geothermal energy is unlikely to soon become a major energy source, but has great potential in selected countries.

This article also analyzes recent policy innovations in renewable energy in industrial countries. During the 1990s, leadership in renewable energy has shifted from the United States to Europe as a result of many successful new policy initiatives in Europe. The most successful policies are well-designed tax incentives and guaranteed grid-access and purchase prices for the new energy sources.

II. TECHNOLOGY AND MARKETS

Renewable energy sources are the most abundant forms of energy found on the earth, exceeding current fossil fuel use by more

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[1] *See* CHRISTOPHER FLAVIN & NICHOLAS LENSSEN, POWER SURGE: GUIDE TO THE COMING ENERGY REVOLUTION 382 (1994) (providing a detailed discussion of renewable energy).

than 1,000 times.[2] However, harnessing these relatively diffuse, intermittent energy sources and turning them into useful chemical fuels presents major technical and economic challenges which are just now being overcome by public and private researchers around the world.

Today, renewable energy sources provide roughly 19 percent of world energy supplies, with biomass making up 13 percent of the total, and hydropower 6 percent.[3] However, a host of "new renewables" are now entering the market, thanks to nearly two decades of government research and development (R&D), as well as new commercialization incentives introduced in the 1990s. The most rapid progress has occurred with small-scale, modular conversion technologies.

This article focuses on four renewable energy options, the most promising near-term ones of which are biomass energy from crop residues and urban wastes--economical in many circumstances--and wind power--already cost-competitive with coal-fired power plants. Solar photovoltaics have enormous long-term potential, but will require substantial additional investments to be a competitive source of grid electricity. Geothermal energy has a role to play in a few countries, but is likely to remain a minor source globally.

A. Biomass

Biomass, or plant matter, provides about 15 percent of energy use in the world and 38 percent of energy in developing countries.[4] Derived from agricultural and forestry residues and organic waste from industrial processes, it was the leading fuel in most countries

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[2] Thomas B. Johnson et al., *Renewable Fuels and Electricity for a Growing World Economy, in* RENEWABLE ENERGY: SOURCES FOR FUEL AND ELECTRICITY 1 (Thomas B. Johansson et al. eds., 1993).

[3] FLAVIN, *supra* note 1, at 176, 189.

[4] David O. Hall et al., *Biomass for Energy: Supply Prospects, in* RENEWABLE ENERGY: SOURCES FOR FUELS AND ELECTRICITY 593 (Thomas B. Johansson et al eds., 1993).

until the late nineteenth century and is the main energy source for approximately half of the world's population, primarily for rural cooking and heating.[5] Its theoretical potential is great: a report commissioned by the 1992 UN Conference on Environment and Development estimates that the equivalent of 55 percent of today's total energy use could, by 2050, be met with biomass.[6] But future use will be constrained by water and land limitations, as well as potentially more valuable uses for biomass, including lubricants, plastics, and chemical feedstocks.

The U.S. accounts for 58 percent of biomass use among industrialized countries, utilizing some 56 million tons of oil equivalent and generating 8,000 megawatts of electricity.[7] Biomass totals 4 percent of total energy use in the U.S., mostly from the forest products industry and home and district heating.[8] Another major use is corn-derived ethanol for transportation fuels.

Technical advances have greatly improved the feasibility of biomass power. High-efficiency gas turbines make biomass electricity economical at scales below 100 megawatts.[9] Biomass can also be used as feedstock for fuel cells, which convert hydrogen into electricity and which can be cost-competitive at less than 1 megawatt.[10]

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5 *Id.* at 594.

6 FLAVIN, *supra* note 1, at 11, 12.

7 Stephen Peake et al., *Policy and Technology Aspects of Renewable Energy in IEA Countries, in* THE WORLD DIRECTORY OF RENEWABLE ENERGY SUPPLIERS AND SERVICES 1996 (1996).

8 Hall, *supra* note 4, at 594.

9 Johnson, *supra* note 2, at 18.

10 Robert H. Williams & Eric D. Larson, *Advanced Gasification-Based Biomass Power Generation, in* RENEWABLE ENERGY: SOURCES FOR FUELS AND ELECTRICITY 760 (Thomas B. Johansson et al. eds., 1993).

B. Wind

Wind power, with potential that is five times the current global electricity use, is the world's fastest growing energy source--though it provides less than 1 percent of the world's electricity.[11] Global wind power generating capacity surged 26 percent in 1996, reaching 6,070 megawatts.[12] Since 1990, installed wind power capacity has tripled, representing an annual growth rate of over 20 percent.[13]

Wind power in the 1990s is dominated by Europe, promoted by its environmental advantages. Most development so far has occurred in northern Europe: in the windy north German state of Schleswig-Holstein, wind power provides 10 percent of the region's electricity.[14] The U.S., whose Great Plains and surrounding regions could meet one-fifth of its current power needs--still leads the world in total capacity, but is likely to be surpassed by Germany next year.[15] India, Denmark, and Spain are also experiencing wind booms, while China, Canada, Russia, and the United Kingdom are believed to have large wind potential.[16]

While more abundant in some places than others, wind power is one of the most widely distributed resources; more countries have wind power potential than large resources of hydropower or coal. Wind power is now competitive with fossil fuel power plants in many regions. As wind turbines are further improved and produced in greater quantity, costs will fall further, making wind power one of the world's most economical electricity sources.[17]

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11 Christopher Flavin, *Wind Power Growth Continues*, *in* VITAL SIGNS 1997: THE ENVIRONMENTAL TRENDS THAT ARE SHAPING OUR FUTURE (Lester R. Brown et al. eds., 1997).

12 *Id.* at 52.

13 *Id.* at 53.

14 *Id.*

15 *Id.*

16 *Id.*

17 *Id.* at 52.

C. Solar PV

Solar photovoltaic (PV) cells, semiconductor devices commonly made of silicon, fill a small but important niche in the world power market.[18] Global shipments of PV cells have experienced double-digit growth for three consecutive years, with a cumulative output of nearly 700 megawatts.[19] Most of these are used in off-grid applications, including telecommunications, water pumping, lighting, and consumer devices.[20]

Rural communities in the developing world are emerging as the early market for PVs: some 400,000 off-grid homes now receive their electricity from PVs.[21] Major industrial country users include Germany, Japan, Mexico, Netherlands, and the United Kingdom.[22] The U.S., the leading PV manufacturer, exports 70 percent of its cells.[23]

Since their origin in the 1950s PVs have declined dramatically in price, opening a market estimated at $1 billion in 1996. However, further price declines of a factor of three to five will be needed for use in wider applications, such as communication satellites, and large-scale grid-connected applications, to be economical. A large number of PV technologies are being explored, and experts believe that additional price reductions can be achieved through further advances in cell efficiency and manufacturing, and through mass production.[24]

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18 Molly O'Meara, *Solar Cell Shipments Keep Rising, in* VITAL SIGNS 1997: THE ENVIRONMENTAL TRENDS THAT ARE SHAPING OUR FUTURE 54 (Lester R. Brown et al. eds., 1997).

19 *Id.*

20 *Id.*

21 *Id.*

22 *Id.*

23 *Id.*

24 *Id.*

D. Geothermal

Geothermal heat from deep in the earth provides more than 7,000 megawatts of power from 250 power plants in 22 countries, most of them in the developing world.[25] It is also used directly for heating and cooling in 40 countries.[26] While its potential is great in certain areas, it also faces social, economic, and environmental constraints.

In the U.S., the leading geothermal user, geothermal power supplies enough power for nearly a million people.[27] An estimated 2,800 megawatts are currently installed in California, Hawaii, Nevada and Utah.[28] But only 30 megawatts have been added since 1990, with none installed in 1996, as a number of fields were found to have insufficient or declining heat, stalling several projects.[29]

Social concerns have blocked geothermal development in culturally valuable places, such as the U.S. Yellowstone National Park. These power plants can also cause health problems and require substantial up-front investments.[30] A variety of simpler and cleaner ways to tap and use geothermal heat are being tested. The direct application of geothermal energy, generally heat pumps, is growing in many countries, including the U.S.[31]

III. POLICIES

The mid-1970s witnessed the first serious efforts to promote renewable energy. In response to soaring oil prices, governments

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25 Seth Dunn, *Geothermal Power Rises, in* VITAL SIGNS 1997: THE ENVIRONMENTAL TRENDS THAT ARE SHAPING OUR FUTURE 50 (Lester R. Brown et al. eds., 1997).

26 *Id.*

27 *Id.*

28 *Id.*

29 *Id.*

30 *Id.*

31 *Id.*

diversified their investments in energy options to include the previously neglected sources of biomass, wind, geothermal, and solar.[32]

These efforts had mixed results: sizable funds were wasted on questionable technologies and inefficient development strategies, though significant industries were established in some areas--such as California, which added some 5,000 megawatts of renewables during the 1980s.[33]

The first wave of renewables support crested in the early 1980s with the price of oil. Research and development budgets declined, and many tax incentives were phased out. However, since 1990 support of renewable energy has increased steadily, this time driven by concern over atmospheric pollution--particularly carbon dioxide and its contribution to climate change.

Renewable energy policies now in place fall into five broad categories: national goals; research and development; purchase prices and obligations; tax incentives and subsidies; and green power marketing. Research and development was the main focus of renewable energy policies in the 1970s and 1980s, and while R&D budgets have risen modestly since 1989, the main focus is now on commercialization, including a new generation of tax incentives and subsidies and newer policies such as guaranteed purchase prices and obligations. A number of governments (and many entrepreneurs) are also focusing on the idea of pricing and marketing renewable electricity as "green power," which may be preferred by some businesses and consumers as retail electricity markets are opened to competition in the years ahead.

The new policies enacted since 1990 have benefitted from the successes and mistakes of the 1980s, and have in general been more effective than the earlier policies. They are intended both to compensate for the high up-front capital costs of renewable energy

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32 FLAVIN, *supra* note 1, at 248-250.

33 U.S. OFFICE OF TECHNOLOGY ASSESSMENT, RENEWING OUR ENERGY FUTURE (1995).

technologies and to overcome the reluctance by electric utilities to allow renewable power into their monopoly power grids. Rapid growth in renewable energy use in Europe in the 1990s is a direct reflection of these new policy initiatives. However, during the next few years these efforts will be complicated by growing competition in electric power markets, which will likely require further adjustment of these policies.

A. National Goals

National goals have been used since the 1970s to promote renewable energy. Renewable energy targets, which can be useful in focusing government efforts and raising public awareness, have had a catalytic effect in several countries. Beginning in 1990, Germany established a series of wind power targets, each of which was surpassed. It is now the second-leading wind power user.[34]

Germany also uses targets for PV applications, with a goal of installing 100,000 roofs and facades.[35] Japan has a similar 70,000 roofs program.[36] The U.S. is currently preparing a Million Roofs Solar Power Initiative.[37]

Japan, Denmark, and the Netherlands have the most ambitious targets for increasing the share of renewables in overall energy. The European Union is moving toward a regional goal: the European Commission calls for a doubling of the renewables share (to about 12 percent) by 2010.[38] Goal setting is likely to continue as industrial countries seek to accelerate the development of renewable sources of

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34 Flavin, *supra* note 11, at 52.

35 EUROSOLAR, *'100,000 Roofs and Facades Programme' in Germany, in* THE YEARBOOK OF RENEWABLE ENERGY 1995/96 (1995).

36 OFFICE OF TECHNOLOGY ASSESSMENT, *supra* note 33, at 240.

37 O'Meara, *supra* note 18, at 54.

38 European Commission, *Energy for the Future: Renewable Sources of Energy,* GREEN PAPER FOR A COMMUNITY STRATEGY (1996).

energy in order to meet commitments to reduce carbon dioxide emissions.[39]

B. Research and Development

Renewable energy R&D spending within the OECD peaked in 1980, fell sharply during the 1980s, and has risen gradually during the 1990s to around $1 billion, less than half the 1980 high.[40] Renewables account for less than 9 percent of total energy spending.[41] Several countries have begun shifting nuclear and fossil R&D toward renewable energy, but overall spending has declined, resulting in only a modest increase for renewables.[42]

The U.S. is the largest spender on renewables, though they receive only 13 percent of total energy R&D despite overwhelming public support.[43] U.S. R&D has recently shifted from demonstration projects to cost-shared commercialization projects with private industry. This emphasis is evident in PV support, which receives half of the total, and has helped the U.S. regain its lead in world manufacturing.[44]

As in the U.S., renewables R&D in Japan and Germany focuses on PV and, to a growing extent, wind. The European Union is increasingly helping governments pool R&D funds as well. Overall, the quality if not the scale of R&D is improving, though R&D is an

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39 Seth Dunn, *The Berlin Climate Summit: Implications for International Environmental Law*, INTERNATIONAL ENVIRONMENT REPORTER, May 31, 1995 at 440; Seth S. Dunn, *The Geneva Conference: Implications for UN Framework Convention on Climate Change*, INTERNATIONAL ENVIRONMENT REPORTER, Oct. 2, 1996 at 908.

40 Michael Renner, *R & D Spending Levels Off, supra* note 11, at 113.

41 INTERNATIONAL ENERGY AGENCY, ENERGY POLICIES IN IEA COUNTRIES, 1996 REVIEW (1996) at 340-341.

42 *Id.*

43 *Id.*; SUSTAINABLE ENERGY BUDGET COALITION, AMERICA SPEAKS OUT ON ENERGY; A SURVEY OF 1996 POST-ELECTION VIEWS (December 1996).

44 OFFICE OF TECHNOLOGY ASSESSMENT, *supra* note 33.

essential but not sufficient condition for developing a renewable energy industry.

C. Tax Incentives

Tax incentives have been widely used to promote renewables since the 1970s.[45] Consisting of tax credits, deductions and exemptions for investment and power generation, they help compensate for the up-front costs of near-commercial renewables, such as wind. They are less useful for those needing larger cost reductions, such as PVs.

Denmark has employed tax incentives effectively to become the leading producer and exporter of wind turbines. The U.S., in contrast, applied incentives inconsistently, causing its domestic industry to collapse after several years of growth.[46] Japan and Germany offer generous capital subsidies for rooftop PVs, while several European countries have recently shifted the focus of their incentives from investment to power generation.[47]

Several European countries have also used carbon taxes to support renewables.[48] The European Union has considered a Union-wide energy or carbon tax in recent years.[49] These can work powerfully with tax incentives to spur renewable energy development.

D. Purchase Prices and Obligations

In recent years, the establishment of minimum purchase prices has proven effective in promoting renewable electricity. These

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45 FLAVIN, *supra* note 1, at 117.

46 *Id.* at 119-120

47 Peake *supra* note 7.

48 CHRISTOPHER FLAVIN & ODIL TUNALI, CLIMATE OF HOPE: NEW STRATEGIES FOR STABILIZING THE EARTH'S ATMOSPHERE (Worldwatch Paper 130, 1996) at 57.

49 *Id.*

policies help companies overcome the low prices established by utilities. If set high enough, they close the gap between conventional and renewable energy prices--often exacerbated by coal and nuclear subsidies.

The 1978 U.S. Public Utility Regulatory Policies Act (PURPA), which set renewable electricity prices at the "avoided cost" of conventional generation, was supplemented by similar policies in California to help create $10 billion in renewable power investments in the state in less than a decade.[50] Germany's 1991 Electricity Feed Law, which established competitive prices for renewable projects, helped add 1,500 megawatts of wind power by 1995.[51] Several other European countries have recently set guaranteed purchase prices, while Japan offers a price equal to that of consumers.[52]

In a related approach, fourteen U.S. states employ "net metering," which allows renewables producers to reverse their meters when generating more electricity than is demanded.[53] In the United Kingdom, the "non-fossil fuel" purchase obligation under the privatization program has attracted a large number of bids for renewable electricity projects.[54] As part of utility restructuring, the U.S. is considering a renewables portfolio standard; first proposed in California, it was replaced by a charge on transmission system users to support renewables.[55]

E. Green Power Pricing and Marketing

Green power development is the newest innovation to emerge under utility restructuring. In several countries, a public preference

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50 OFFICE OF TECHNOLOGY ASSESSMENT, *supra* note 33.

51 Flavin, *supra* note 11, at 53.

52 Peake, *supra* note 7.

53 Yi-huei Wan, *Net Metering Programs*, TOPICAL ISSUES BRIEF, NATIONAL RENEWABLE ENERGY LABORATORY (Dec. 1996).

54 Peake, *supra* note 7.

55 *California Abandons Renewables Portfolio Standard*, GLOBAL ENVIRONMENTAL CHANGE REPORT, Oct. 11, 1996 at 2.

for renewable power is evidenced in a willingness to pay more for "green" electricity. Currently at the pilot stage, these experiments include both pricing programs and direct marketing programs where retail competition is permitted.

In the U.S., ten green pricing programs are underway, with two dozen in preparation and at least 20 utilities exploring the concept.[56] Programs have also begun in Canada and a number of European countries.[57] In many of these cases, consumer demand has exceeded the expectations and capacity of the program.[58]

Growing utility interest will make it necessary to assure the credibility of "green power" marketing claims. A certification program has been set up in Sweden, where six utilities have been approved; similar efforts are underway in the U.S.[59] Accounting systems will also be required to distinguish the generating source of power purchases.

IV. CONCLUSION

Several major themes emerge when considering the status and prospects of renewable energy:

1) Renewable energy technologies and policies are now evolving at a rapid pace, requiring frequent reevaluation of the proper mix of policies. Experience in the 1990s shows that new policy initiatives can allow individual countries to rapidly assume leadership in

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56 John Flesher, *Consumers Willing to Pay More for Wind Generated Electricity,* CHARLESTON GAZETTE, Jan. 2, 1997, at P5B.

57 *Early Adopters Find Mixed Success with Green Pricing*, GLOBAL ENVIRONMENTAL CHANGE REPORT, Aug. 23 1996. *See also* Paul Gipe, *Europe Takes Wind Energy Lead,* INDEPENDENT ENERGY, June 1997, at 47-50.

58 Flesher, *supra* note 56.

59 Tore Wizelius, *Green Power Favoured in Privatized Market*, WINDPOWER MONTHLY, May 1996 at 29; DR. JAN HAMRIN AND NANCY RADER, INVESTING IN THE FUTURE: A REGULATOR'S GUIDE TO RENEWABLES (National Association of Regulatory Utility Commissioners, Feb. 1993).

particular technologies even if their past experience is limited. Similarly, countries can fall quickly behind the international competition if effective policies are not implemented.

2) Several renewable energy technologies have reached maturity and cost-competitiveness with fossil fuels in the 1990s. Wind power and biomass energy are economically ready to play a major role in the world energy system, displacing fossil fuels and lowering carbon dioxide emissions. Solar photovoltaics may reach a similar stage within the next decade, while prospects for geothermal energy growth are limited to several countries in the near future.

3) Leadership in the development of renewable energy has shifted from the United States to Europe in the 1990s, with Germany, Denmark, and the Netherlands now playing the dominant role. Japan and the United States retain considerable technological strength in renewable energy, but if their commercial markets for renewable energy are not opened soon they may lose this advantage as well.

4) Within the next decade, the developing countries will almost certainly become the largest market for renewable energy technologies, as their energy markets expand at rates of 5-10 percent annually. Industrial countries are likely to compete vigorously for access to these potential $100 billion markets. So far, the governments of Denmark and Germany have the strongest export promotion programs for renewable energy.

5) Government research and development funding for renewable energy has expanded modestly in the 1990s; this growth, however, has now stopped or reversed in many countries as government budgets come under greater pressure. Still, renewable energy's share of government R&D is now rising in most countries, and private R&D is increasing as commercial markets expand.

6) The focus of government renewable energy policies has shifted

from R&D and demonstration to commercialization in recent years. New tax incentives, subsidies, and guaranteed grid access and purchase prices have been implemented in many countries. The most effective policies appear to be well-designed tax incentives for power generation, and minimum purchase prices for grid-connected power projects. Most impressive is Germany's Electricity Feed Law, which has led to the installation of over 1,500 megawatts since 1992.

7) In most industrial countries, competition is likely to be introduced to the electric power industry during the next few years. This will create both difficulties and opportunities for the development of renewable energy. One of the most promising options is to allow consumers to choose the source of power they receive, since market surveys show a considerable interest in the purchase of "green" electricity from renewable energy sources--even if the cost is a little higher. Several power marketers in the U.S. and Europe are now running pilot programs to test this concept.

8) Stronger political commitment to address climate change may further spur the development of renewable energy. In 1995 industrial countries began negotiating a legally-binding agreement under the U.N. Framework Convention on Climate Change to reduce greenhouse gas emissions. This agreement, to have been signed in December 1997, could accelerate the introduction of new policies to promote renewable energy.