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Upfront resource requirements for large-scale exploitation schemes of new renewable technologies

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Abstract

Large-scale global use of new renewable energy sources (RES) necessitates massive physical resources. Present study shows that more than 99.5% of the materials needed in new RES systems are basic construction materials and metals abundantly available. Special elements may constitute future bottle-necks in some PV technologies. The extra financial resources needed over traditional energy to achieve a breakthrough in PV and wind power range from 100 to 500 billion $ for a period of 20–30 years influenced by technology progress and speed of penetration, but in solar heating much less. This upfront support could be paid back within 15–25 years later through cheaper and cleaner energy. Compared to nuclear power the resource numbers estimated are of the same order of magnitude.

Keywords: Renewable energy; Resource requirement; Diffusion; Public support

1. Introduction

The global energy problems call for large-scale sustainable solutions. According to the UN IPCC over half of the CO_2 emissions from fossil fuels need to be eliminated during the next half of a century. During the same time period the reserves of oil, which is presently the dominating primary energy source with a 37% share, will run out [1]. Energy scarcity and energy related environmental problems will be the driving factors for developing better energy technologies, which are considered to be the key for solving the challenges ahead.

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The number of different technological solutions available is vast ranging from energy demand side measures to energy supply options [2]. In several energy scenarios, the renewable energy sources (RES) rank high and form an important part of the energy production around 2050, even up to 30–40% of all energy [3,4]. Traditional RES such as biomass and hydropower have been for a long time on the market, produce around 10% of world energy, and will extend their influence far into the future. The main growth in RES would, however, come from new renewable technologies such as solar energy, wind power and new forms of biomass, e.g., biofuels which have insignificant market shares or less than 0.1% of primary energy and are characterized as embryonic technologies.

To meet the high expectations in future energy production, the capacity of new renewables would need to grow several hundred fold from present. Taken the fact that most new renewable energy sources are more expensive than traditional energy sources, not only large physical resources but also major public financial support would be needed to realize the growth. Some of these resources could turn out to be critical, for example, the availability of photovoltaic materials or the suitable land area for on-shore wind power. The speed into a large-scale penetration phase is not only influenced by the available resources but also through the inertia of the social and energy systems.

The main objective of this paper is to investigate the need of physical resources and time factors associated with massive introduction of new RES technologies. The catalytic role and amount of public support in bringing new technologies on the market is also an important theme of the paper. The analytical part of this paper is mainly based on physical resource theory, technology diffusion and learning models.

The new RES technologies chosen for the analyses were photovoltaics, solar heating and wind power. The reason of choosing these technologies and not, e.g., biomass was to focus on truly new technologies and avoid too complicated fuel cycles that could distort the findings. Nuclear energy was chosen for a reference case as it is a non-fossil and the newest energy source in large scale, it has a notable 6% share of world primary energy [1], and technology development activities supported by the public hand were important to enable penetration. RES and nuclear differ in many aspects, but the history of nuclear offers an interesting case from the process point of view of bringing a new energy technology from scratch into a high volume market.

2. Historical view

Major changes in the global energy economy have required several decades. For example, the share of oil of all energy grew by 0.5%/year in average from late 19th century to peak around the oil crises in late 1970s [5]. The share of oil remains still 37% of primary energy [1,6]. The nuclear energy penetrated initially relatively fast and would have gained 0.7% market share per year but early saturation dropped it to 0.3%/year.

Fig. 1 shows the market development of the four technologies. Key parameters relevant for world primary energy are summarized in Table 1. The nuclear represents an earlier technology wave with a phase shift of about 30–50 years to the RES technologies. The slope of the penetration of PV and wind seems to be steeper than for nuclear but definite conclusions cannot yet be drawn due to low market shares. The natural resource of RES is huge and exceeds manifold the global energy demand. The potential estimates used here are based on a stronger market basis and represent long-term targets for RES utilization. A straightforward extrapolation of the present trend in Fig. 1 assuming an exponential