Climate Change, Vol. 2, No. 6, April-June, 2016

VIEWPOINT

ISSN 2394–8558
EISSN 2394–8566

Climate Change

Environmental impacts from the solar energy technologies

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Article History

Received: 27 January 2016

Accepted: 12 March 2016

Published: 1 April 2016

Citation

Akinnubi RT, Akinwande DD, Ikusika A, Adeoye-Oladapo OO, Komolafe DA. Environmental impacts from the solar energy technologies. *Climate Change*, 2016, 2(6), 104-109

ABSTRACT

Solar energy technologies (SETs) provide obvious environmental advantages in comparison to the conventional energy sources, thus contributing to the sustainable development of human activities. Not counting the depletion of the exhausted natural resources, their main advantage is related to the reduced CO_2 emissions and, normally, absence of any air emissions or waste products during

their operation. On the other hand, it must be realized that no man-made project can completely avoid some impact to the environment, so neither can SET installations. This article therefore, reviews various environmental aspects of the deployment of SETs and illustrates the ways that can be used to successfully address potential burdens to the environment.

1. INTRODUCTION

Every energy generation and transmission method affects the environment. As it is obvious conventional generating options can damage air, climate, water, land and wildlife, landscape, as well as raise the levels of harmful radiation. Renewable technologies are substantially safer offering a solution to many environmental and social problems associated with fossil and nuclear fuels. Solar energy technologies (SETs) provide obvious environmental advantages thus, contributing to the sustainable development of human activities. Not counting the depletion of the exhausted natural resources, their main advantage is related to the reduced CO_2 emissions and, normally, absence of any air emissions or waste products during their operation. Concerning the environment, the use of SETs has additional positive implications such as; reduction of the emissions of the greenhouse gases (mainly CO_2, NO_2) and prevention of toxic gas emissions (SO_2, particulates); reclamation of degraded land; reduction of the required transmission lines of the electricity grids; and Improvement of the quality of water resources. In regard the socio-economic viewpoint the benefits of the exploitation of SETs comprise: increase of the regional/national energy independency; provision of significant work opportunities; diversification and security of energy supply and support of the deregulation of energy markets; and Acceleration of the rural electrification in developing countries (Tsoutsos, *et al*., 2001). This article overviews various environmental aspects of the deployment of SETs and illustrate the ways that can be used to successfully address potential burdens to the environment.

2. POTENTIAL ENVIRONMENTAL IMPACTS OF SOLAR ENERGY TECHNOLOGIES AND MITIGATION MEASURES

The unfavourable effects of SETs are usually minor and they can be minimized by appropriate mitigation measures. The potential environmental burdens of SETs are regularly site specific, depending on the size and nature of the project. These burdens are usually associated with the loss of amenity (e.g. visual impact or noise during the installation and the demolition phases) and the impacts can be minimized by the appropriate sitting of central solar systems, which involves careful evaluation of alternative locations and estimation of expected impact (away from densely populated areas and not in protected areas or areas of significant natural beauty); the residential solar systems can be installed anywhere, especially integrated in the roofs; the appropriate operational practices (including rational water use, safety measures, waste disposal practices, use of biodegradable chemicals, etc.); the engagement of the public and relevant organizations in the early stages of planning, in order to ensure public acceptance; the use of the best available technologies/techniques and the improvement of technology (e.g. use of air as the heat-transfer medium in central tower systems, ‘advanced’’ Stirling engines);the integration in the building’s shell; the sensible planning constraints and pre-development assessments (e.g. on water use, habitat loss, estimation of expected CO_2 savings, etc.); the training of workers, use of special sunglasses during operation and construction, use of heat insulating uniforms, familiarization with the system; the re-establishment of local flora and fauna, giving the environment enough time to come up to its previously state again; and thorough Environmental Impact Assessment Studies for central solar systems (Tsoutsos, *et al*., 2001).

3. ENVIRONMENTAL IMPACTS FROM SOLAR THERMAL HEATING SYSTEMS

Though the production of solar thermal (ST) systems requires reasonable quantities of materials, insignificant amounts are also consumed during their operation; at that time the only potential environmental pollutant arises from the coolant change, which can be easily controlled by good working practice. The accidental leakage of coolant systems can cause fire and gas releases from vaporized coolant, unfavourably affecting public health and safety. On the contrary, the large-scale deployment of ST technologies will significantly reduce the combustion of conventional fuels and will consequently; reduce the environmental impacts associated with these fuels (EC, 1998; 1997; 2002).

4. LAND USE

For low/medium heat systems it is the characteristics of the chosen system, which define the land use. For instance, in the case of single-dwelling hot water or space heating/cooling, no land will be required since the system will usually be added to the roof of the existing building. Communal low-temperature systems might use some land, though again the collection surfaces might well be added on already existing buildings. The principal additional use of land might be for heat storage. For high temperature systems, the land-use requirements of concentrating collectors providing process heat are more problematical. Concerning the loss of habitat and changes to the ecosystem due to land use in the case of large-scale systems, provided that predevelopment assessments are carried out and ecologically important sites are avoided, these are unlikely to be significant (ETSU, 1996; Frantzeskaki *et al*., 2002)

5. ROUTINE AND ACCIDENTAL DISCHARGES OF POLLUTANTS

During the operation of the ST system coolant liquids may need change every 2–3 years. Such discharges require careful handling. In some cases, the coolant will be water based; but all indirect systems are likely to contain anti-freeze or rust inhibitors, as well as substances leached from the system during use. Heat transfer fluids might therefore contain glycol, nitrates, nitrites, chromates, sulphites, and sulphates. Higher temperature applications would use more complex substances, such as aromatic alcohols, oils, CFCs, etc. The large-scale adoption of SETs might well require control on the disposal of these substances. Except for the normal use, there may be the risk of accidental water pollution through leaks of heat transfer fluid. In parallel, solar converters can achieve relatively high temperatures if their coolant is lost (up to 200^{o}C).Consequently, at this temperature, there is a fire risk, with the additional problem of out-gassing from panel components (insulant, plastic components, epoxies) and the release of heat transfer fluids in gaseous state or following combustion (e.g. burnt Freon), (Gekas *et al*., 2002; Hestnes, 1995).

6. VISUAL IMPACT

Till recently ''integration'' used to be synonymous with ''invisibility''. It was actually considered desirable to hide the fact that the solar elements were different than other building elements. This trend, fortunately, changed. Architects have discovered that solar elements can be used to enhance the aesthetic appeal of a building, and their clients have discovered the positive effects of advertising the fact that they are using solar energy. The solar elements are used as architectural elements in attractive and visible ways. The aesthetic impact of solar panels is evidently a matter of taste, though .at panels usually are designed in such a way as to fit closely to the existing roofline and produce little glare. Modern ST Systems allow for the manufacturing of collectors that can be easily integrated in buildings in anaesthetically pleasant manner (OECD/IEA, 1998).

7. EFFECT ON BUILDINGS

Theoretically the ST placement in the shell of the buildings could increase fire risk and water intrusion into the roof. This can be easily avoided, since only four holes per panel on the roof will be integral part of the roof (Raptis *et al*., 1995; Angeline Mary *et al*. 2015; Javaria Manzoor Shaikh, 2015; Hemant Kumar Singh *et al*. 2015).

8. ENVIRONMENTAL IMPACTS FROM SOLAR THERMAL ELECTRICITY

The limited deployment of ST electricity to date means that there is little actual experience of the environmental impacts that such a scheme may have. Similarly to other SETs, ST electricity systems present the basic environmental benefit of the displacement or the avoidance of emissions associated with conventional electricity generation. During their operation, these systems have no emissions. Some emissions do arise from other phases of their life cycle (primarily materials processing and manufacture), but they are lower, compared to those avoided by the systems operation.

9. MATERIALS' PROCESSING AND MANUFACTURE

Energy use and gas emissions in materials' processing and manufacture of ST systems are noticeable. The impacts of these emissions vary according to location, and are fewer than those of conventional fossil fuel technologies.

10. CONSTRUCTION

These projects have the usual environmental impacts associated with any engineering scheme during the construction phase impact on landscape, effects on local ecosystems and habitats, noise, virtual intrusion, and topical vexation such as noise and temporally pollutant emissions due to increased traffic because of transportation of workers and of material, occupational accidents, temporal blindness, etc.

11. ECOSYSTEM, FLORA AND FAUNA

Attention during the planning, construction and operation phases can minimize the effects on vegetation, soil and habitat. Furthermore, the shade offered by the reflectors has a beneficial effect on the microclimate around the scheme and on the vegetation, too. Provided that such schemes are not deployed in ecologically sensitive areas or in areas of natural beauty, it is unlikely that any of the above changes would be considered as significant. Central concentrator power systems could pose a danger to birds, but operational experience shows that birds avoid any danger areas (possibly by being sensitive to air turbulence). Flying insects can also be burnt when flying close to the reflector's area. The loss of the insect population is insignificant.

12. NOISE

Likewise, noise is insignificant in comparison to any other power option, such as the conventional, the wind power generation, and the gas turbines. The noise from the generating plant of large-scale schemes is unlikely to cause any disturbance to the public. Noise would be generated primarily only during the day; at night, when people are more sensitive to noise, the system is unable to operate. The Stirling engines of stand-alone parabolic dish systems are a source of noise during operation, but they are unlikely to be any noisier than the stand-by diesel generating sets, which they generally displace. Also, new (technological) advanced Stirling engines are constructed to operate noiselessly.

13. WATER RESOURCES

Parabolic trough and central tower systems using conventional steam plant to generate electricity require the use of cooling water. This could place a significant strain on water resources in arid areas. In addition, there may be some pollution of water resources, through thermal discharges and accidental release of plant although the latter can be avoided by good operating practice. Stand-alone parabolic dish systems require no water, other than for periodic cleaning of reflective surfaces and so they have little impact on water resources.

14. HEALTH AND SAFETY (OCCUPATIONAL HAZARDS)

The accidental release of heat transfer fluids (water and oil) from parabolic trough and central receiver systems could form a health hazard. The hazard could be substantial in some central tower systems, which use liquid sodium or molten salts as a heat-transfer medium. Indeed a fatal accident has occurred in a system using liquid sodium. These dangers will be avoided by moving to volumetric systems that use air as a heat-transfer medium. Central tower systems have the potential to concentrate light to intensities that could damage eyesight. Under normal operating conditions this should not pose any danger to operators, but failure of the tracking systems could result in straying beams that might pose an occupational safety risk on site (Tsoutsos*et al*., 2003 a; 2003 b).

15. CONCLUSIONS AND RECOMMENDATIONS

SETs present tremendous environmental benefits when compared to the conventional energy sources. In addition to not exhausting natural resources, their main advantage is, in most cases, total absence of almost any air emissions or waste products. In other words, SE can be considered as an almost absolute clean and safe energy source. Furthermore, the use of SETs can have additional environmental benefits, associated with:

(i) The SE potential to be employed in stand-alone applications (e.g., avoidance of grid connection, with all associated impacts on the ecosystem and the landscape; feasibility of installation and continuous/remote operation of equipment that perform functions related to protection or rehabilitation of environmental media, such as air quality monitoring, lake- water re-aeration, etc.),

(ii) multi-purpose applications of SETs (e.g. combined solar systems for water and space heating).

Finally, the use of SETs has significant socioeconomic benefits, such as diversification and security of energy supply, provision of significant job opportunities, support of the restructure of energy markets, reduction of the dependency on fuel imports and acceleration of the electrification of rural communities in remote/isolated areas. On the other hand, it must be realized that no man-made project can completely avoid some impact to the environment, so neither can SET installations.

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