AN ENVIRONMENTAL POTENTIAL OF PV SYSTEMS IN JAPAN BY UTILIZING THE ECOLOGICAL FOOTPRINT

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ABSTRACT

This paper gives an environmental potential of PV systems in Japan by utilizing the Ecological Footprint (EF). It is a measure of how much biological productive land and water area that humanity uses to produce the resources and to absorb the waste. To weigh the EF of PV systems against fossil fuel energy, the authors calculated the PV EF and the fossil fuel EF and PV biocapacity of Japan. The calculations represent the fossil fuel uses more than sixty percent of the total EF of Japan. Assuming 100GW PV systems are installed in Japan that is shown in “PV2030” which is Japanese PV roadmap, we compared the annual electricity by 100GW PV systems with equivalent electricity by fossil fuel energy. The result is the EF of PV systems is much smaller than the same amount of energy from fossil fuel. That is, PV systems reduce consumption of biological resources and the calculation of the PV biocapacity show that they increase the biological productive area.

1. INTRODUCTION

1.1 Background and Objective

The world economy is rapidly developing because of increase of the world population and the consumption per capita. We will have to exceed the limit of ecosystem if nothing is done. Actually, we can see the problems of global warming all over the world. And since the late 1980s, we have been in overshoot – the Ecological Footprint (EF) has exceeded the Earth’s biocapacity – as of 2003 by about 25%. If we will be able to increase the Earth’s biocapacity, we can evade the state of overshoot. In the conventional calculation of EF, the several land types are regarded as the degraded land. But we will be able to consider that they are energy land by PV systems. Therefore, my study is showing added value of PV systems by utilizing the EF. Especially, because the traditional calculation of the EF and the biocapacity did not calculate about PV systems, this paper gives Photovoltaic Ecological Footprint and biocapacity in Japan.

1.2 The Ecological Footprint as an Indicator of Sustainability

The EF is a measure of how much biologically productive area an individual, a country, or humanity uses to produce the resources and to absorb the waste (see Fig. 1). This area can be located anywhere in the world. For instance, the EF of imports is calculated as the EF of the country that imports them. The EF is expressed in units of global hectares [gha]. The global hectare is normalized to the area weighted average productivity of biologically productive area, because different land types have different productivity. The weighted factor is called equivalence factor. For example, croplands have an equivalence factor of 2.21 (see Table I) that means croplands have over twice productivity of world average productivity. And a hectare with world average productivity has an equivalence factor of 1. The equivalence factors are the same for all countries in a given year. But yield factor is a factor that accounts for differences between countries in productivity of a given land type and a given year.

The biocapacity is the all biological productive areas to produce useful biological materials and to absorb waste materials generated by humans, or the supply side of the equation (EF is the demand side). The biocapacity is also expressed in units of global hectare.

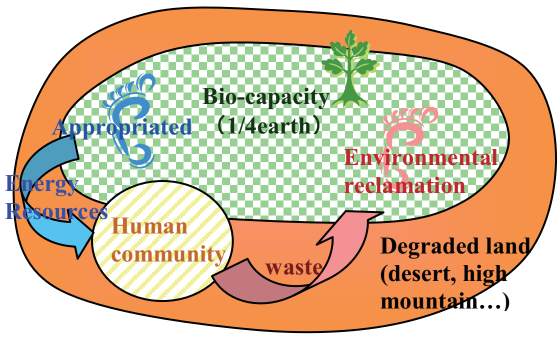

Fig. 1. Image of the Ecological Footprint

Table I. Equivalence factors (2003)

Land type	Equivalence factor[gha/ha]
Cropland	2.21
Pasture land	0.49
Forest land	1.34

2. METHOD

2.1 The Calculation Method of the Fossil Fuel EF

The fossil fuel EF is calculated by estimating the forest land area that is needed to assimilate carbon dioxide by burning fossil fuels and subtracting the percentage of this carbon dioxide sequestered by oceans. We calculated the carbon emissions from amount of the used fossil fuel in a year, and multiplied forest land equivalence factor and divided into the amount of world average carbon sequestration and population. So, this calculation gives the forest land area that a human uses to absorb the carbon dioxide by burning fossil fuel in a year.

2.2 The Calculation Method of the PV EF

The PV EF is calculated by the annual electricity and the effective yield (annual electricity per hectare). "PV2030" says the potential of the domestic installation area is 8000GW. If we can install PV systems all over the domestic area, the annual electricity per hectare is 2049[MWh/yr/ha]. But it is an imagination; we consider that the 100GW PV systems will have been installed until 2030. We calculated the PV EF by using equation1.

PV EF = Effective production [kWh/yr] × Equivalence factor [gha/ha] × Yield factor [-] ÷ Effective yield [kWh/yr/ha] ÷ population (1)

And we will consider that the carbon footprint by producing PV modules. Our need growth rate is 7%/yr to realize 100GW PV systems installed until 2030. So, we will have to produce 7.7GW PV modules in 2030. The manufacturing line that they produce 100MW poly-Si PV systems in one year exhausts 235g carbon per watt (see Table II). We calculated that each kind of modules occupy production in 2030. If poly-Si PV modules will be made 7.7GW, we will emit 1.8×10^{6} ton carbon in 2030. The EF of this amount of carbon is calculated as well as fossil fuel EF. But we don't consider that the EF of rejection and recycling PV modules as yet.

Table II: CO2 emission of producing four type of PV module (100MW/line) [3]

	CO2 emission[g-C/W]
poly-Si	235
a-Si	123
CdS/CdTe	134
CIGS	117

2.3 The Calculation Method of the PV Biocapacity

The biocapacity of an area is calculated by multiplying the actual physical area by the yield factor and the equivalence factor. In the calculation of the PV biocapacity, the actual physical area can be regarded as the 100GW PV systems installed area. And we calculated the coefficients (equivalence and yield factor) as one.

3. RESULTS AND DISCUSSIONS

The calculation of fossil fuel energy in Japan (2004) was 2.53 [gha/cap] that represents more than 60% of the total EF in Japan. The result of the PV EF in Japan (operating) was 0.0037 [gha/cap] and the result of the poly-Si PV EF in Japan (producing) was 0.014 [gha/cap] in 2030. So, total PV EF (poly-Si) was 0.018 [gha/cap]. Others are shown in Table III. And we compared the annual electricity by 100GW PV systems with equivalent electricity by fossil fuel energy. This result was 0.057[gha/cap]. And the biocapacity of 100GW PV systems was 0.0004[gha/cap]. By the way, the total biocapacity in Japan is 0.7[gha/cap] in 2003. These results show that PV systems reduce consumption of biological resources than the fossil fuel energy and increase biological productive area.

Table III. PV EF (to produce 7.7GW PV modules)

	PV EF(producing) [gha/cap]	PV EF(total) [gha/cap]
poly-Si	0.0141	0.017
a-Si	0.0074	0.011
CdS/CdTe	0.0080	0.012
CIGS	0.0070	0.010

4. CONCLUSION

This paper presents an environmental potential of PV systems in Japan by utilizing the Ecological Footprint. It is a measure of how much biological productive land and water area that humanity uses to produce the resources and to absorb the waste. The calculation of the fossil fuel EF in 2004 are 2.53[gha/cap] and 100GW total PV EF are from 0.010 to 0.017[gha/cap]. The details of total PV EF are operating and producing PV modules. So, these results show that PV systems can reduce consumption of biological resources than the fossil fuel energy and the producing PV modules needs about 2.5 times land more than operating PV systems. In addition, the calculation of the PV biocapacity was 0.0004[gha/cap]. Therefore they can also increase biological productive area slightly. In the EF, deserts, paved road and high mountains and so on are regarded as degraded lands. Degraded land is not included in the biocapacity. We will be able to regard that these areas are energy land by PV systems. That is, we can increase the biocapacity by PV systems and we will be able to evade the state of overshoot.

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