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Short Communication

“Solar Marsh”: Photovoltaic Solar Power Generation Collocated with Constructed Nutrient Capture Wetlands

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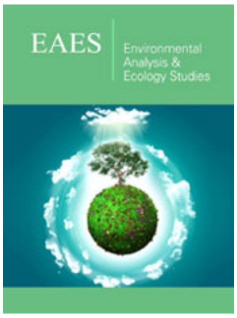

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Abstract

It is proposed that power companies, in fiscal and managerial cooperation with local land use agencies, such as the Army Corps of Engineers (the Corp, US-ACE) and Water Management Districts investigate, design, build and operate a co-operative solar power generation array over large constructed wetlands, also known as Stormwater Treatment Areas (STAs). Collocation of photovoltaic solar generation and STAs will lessen overall land use. Increasing the use of grid-tied solar energy is required to come in line with the KYOTO Protocol and the Paris Agreement. Increasing constructed wetland area will go far in mitigating the nutrient pollution that leads to harmful algal blooms and other ecological impacts. Data discussed herein reveals that Subaquatic Vegetation (SAV) and its periphyton in filtering marshes receive too much incoming solar radiation (INSOLATION) and synthesize large quantities of Photoprotective Pigments (PPP) to decrease and/or eliminate photoinhibition. Therefore, periphyton-based filtering marshes located under semi-transparent solar arrays should perform well.

Introduction

Reasons for proposing the “Solar Marsh” concept

A. Increasing demand for electrical power in obviously parallels large increases in population.

B. This increasing demand is forcing power companies to promote coal powered electrical generation which, regardless of claims to the contrary, will pollute the atmosphere and aeolian fallout will then contaminant (NO_x, SO_x, Hg, As etc.) the air and, by dry and wet fallout, land downwind of a plant.

C. Once solar plants are constructed, there will never be increases in fuel (sunlight) costs, only plant maintenance costs.

D. Placement over constructed wetlands (filtering marshes) should allow for a combined use of valuable land.

E. The constructed wetlands will store water, clean the water and act as a flow-ways.

Solar energy considerations

The cost of fossil fuel electricity can only go up in direct parallel with inflation and increased demands for cleaner technologies to remove CO_2, NO_x, Hg and other emissions. The cost of solar Photovoltaics (PV) cells dropped by about 15% each year between 2010 and 2020 as the global push for carbon-free power generation increased [1]. Solar energy is making large inroads into the overall power supply structure in many parts of the world. About 97% of solar power in utility plants is Photovoltaic (PV), according to estimates made in 2019 [2]. However, solar energy still only comprises less than 4% of total power generation [3].

Current Crystalline Silicon (c-Si) wafer technology may soon be replaced by newer technologies, such as CIGS (Copper Indium Gallium Selenide) thin films and are an existing technology. CIGS based solar arrays exist on a commercial scale, such as the "Rote Jahne" power plant in Germany. Thin Film Solar Cells (TFSC) are getting much closer to the so-called "critical tipping point" cost per megawatt [4,5]. TFCSCs are often made with amorphous silicon, copper indium gallium selenide, or cadmium telluride [6]. Transparent [7] and Semi-Transparent [8,9] thin films will have a transmissivity advantage that factors directly into this proposal. In other words, not all the incoming solar radiation (INSOLATION, sun light) is stopped by the thin films and the transmitted radiation is then directly available to photosynthetic organisms below the solar array.

Constructed wetlands

Wetlands, including riparian marshes, serve to capture and hold nutrients not only from natural biogeochemical cycling but also from anthropogenic pollution sources, such as agriculture and sewerage, notably septic systems (aka Onsite Sewerage Treatment and Disposal Systems, OSTDS) [10,11]. An overview of natural and constructed wetlands exists [12] and that publication contains numerous references on these topics. Worldwide, natural wetlands are estimated to cover 6.8 million square kilometres [12]. Constructed wetlands are designed and built to remove or at least decrease the amount of nutrient (nitrogen, phosphorus, other) pollution from surface waters thereby decreasing downstream effects and even percolation into surficial aquifers [11-15]. Constructed wetlands are also termed filtering marshes or stormwater treatment areas (STAs: [15,16])

Periphyton-assisted stormwater treatment areas filtering marshes are typically shallow and consist primarily of Subaquatic Vegetation (SAV) with heavy growths of epilimnion called periphyton. Periphyton-assisted STAs, or PASTA, are designed to mimic nature in that they remove nutrients from the water and store these within accumulating biomass and peat [15]. Figure 1 is a representation of a wetland, natural or constructed. This figure emphasizes phosphorous as P has no significant gas phase and becomes internally loaded, forming internally loaded (aka legacy) Phosphorus [17-19]. However, the wetlands obviously also capture nitrogen and other nutrients (e.g. iron, silica). Nitrogen in fixed nutrient forms (ammonia, nitrate, nitrate) can and does undergo denitrification leading to nitrogen gas which can escape the sediments and water into the atmosphere [20,21]. Recently, we showed that small ditches running perpendicular to the flow direction within STAs (constructed wetland) retained more phosphorus per unit area than in the STA [22]. In addition, many elements (Al, Ca, Cu, Fe, Mg, Mo, Pb, Zn) were also trapped in these ditched wetlands [22].

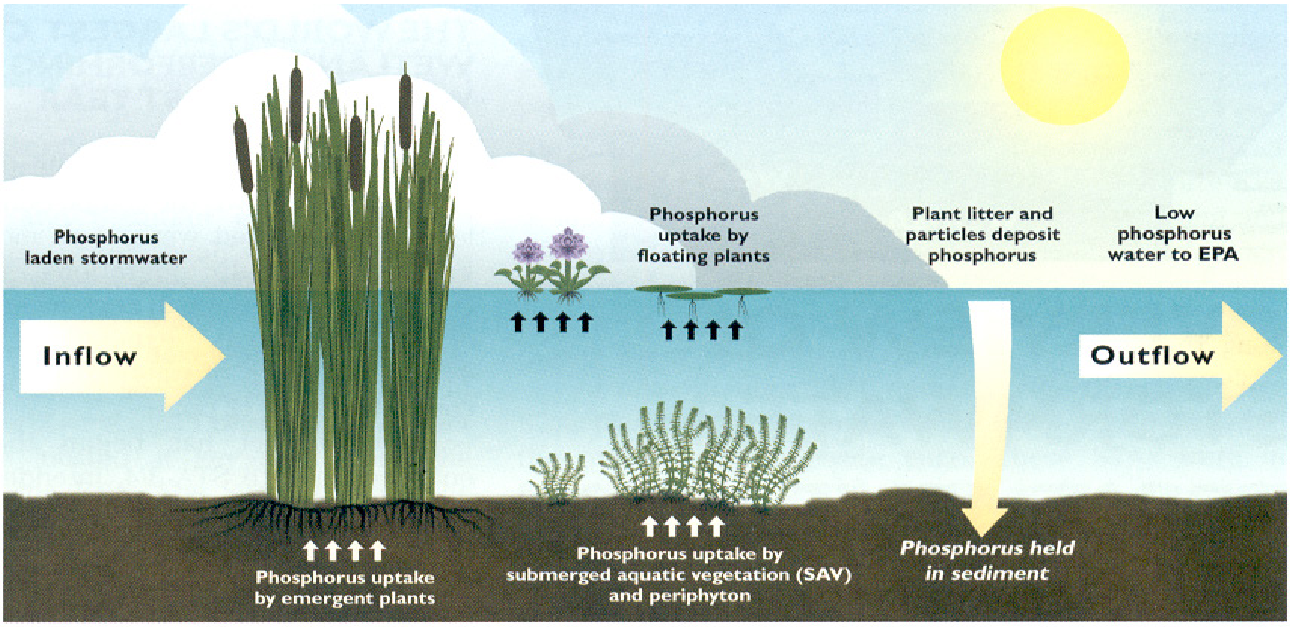

Figure 1: Conventional storm water treatment area (STA) or filtering marsh utilizing many types of aquatic vegetation. (from http://www.sfwmd.gov).

Light, pigments, and marsh plants, algae, and periphyton

Photosynthetic organisms, here referring to the SAV and periphyton of the wetland, utilize Photosynthetic Accessory Pigments (PAP), such as the chlorophylls, for the capture of solar radiation energy and photosynthetic Protective Pigments (PPP), such as various carotenoids, to capture excess photon flux density

(PFD) to protect the photosynthetic system from photoinhibition such as free radical generation [23]. Studies have shown that Subaquatic Vegetation (SAV) and periphyton growing in the high light environments produce large amounts of ultraviolet and visible light sunscreen pigments (PPP) to counteract photoinhibition and other deleterious metabolic effects of too much PFD [24-27]. It has been reported that periphyton grows very well in only 10-20% of the ambient solar flux reaching the surface [28]. Wetlands have high rates of Evapotranspiration (ET), the combined effects of the physical process evaporation and the biological process of transpiration (metabolic 'pumping' of water through any emergent plants into the air). Solar arrays placed over a filter marsh should lead to reflux (evaporation/condensation cycling) and lower water loss to the atmosphere. Emergent plants would be minimized and/or may have to be removed periodically.

The proposed "Solar Marsh"

It is proposed that power companies, in cooperation with State, County, and national (US-ACE) water management agencies design, build and operate a solar power generation array over several hundreds of acres of constructed wetlands. The solar panels in such a system could also be self-powered to track the sun for maximal output. As most power is used during daylight hours but noting that energy is required at night, existing fossil fuel plants and new biomass conversion plants could be used to complete the power grid. Biomass conversion plants, requiring particulate and other scrubbing technology, would also have an advantage. That is, rather than placing vegetative wastes into landfills, that material could be burned as fuel. While it is true that biomass conversion adds CO_2 to the atmosphere, it does so on a more realistic time scale when compared to fossil fuels. That is, fossil fuels contain carbon that was sequestered millions of years ago while biomass conversion can be considered 'recycling'. Ultimately, solar energy may fulfill 24 hour a day energy needs but electrical storage technologies (e.g. batteries) lag behind production capabilities for now.

Figure 2 is rendering of the proposed "Solar Marsh". The preliminary proposal for this concept was in 2017 [29] and now is greatly enhanced by the testing of "semi-transparent spectrally selective thin films" with food crop plants by others [9]. Wavelength selective solar panels will allow passage of photosynthetically active radiation (PAR; 400-700nm) to underlying plants, algae, SAV, and periphyton while generating electricity with the non-PAR parts of solar radiation (INSOLTION).

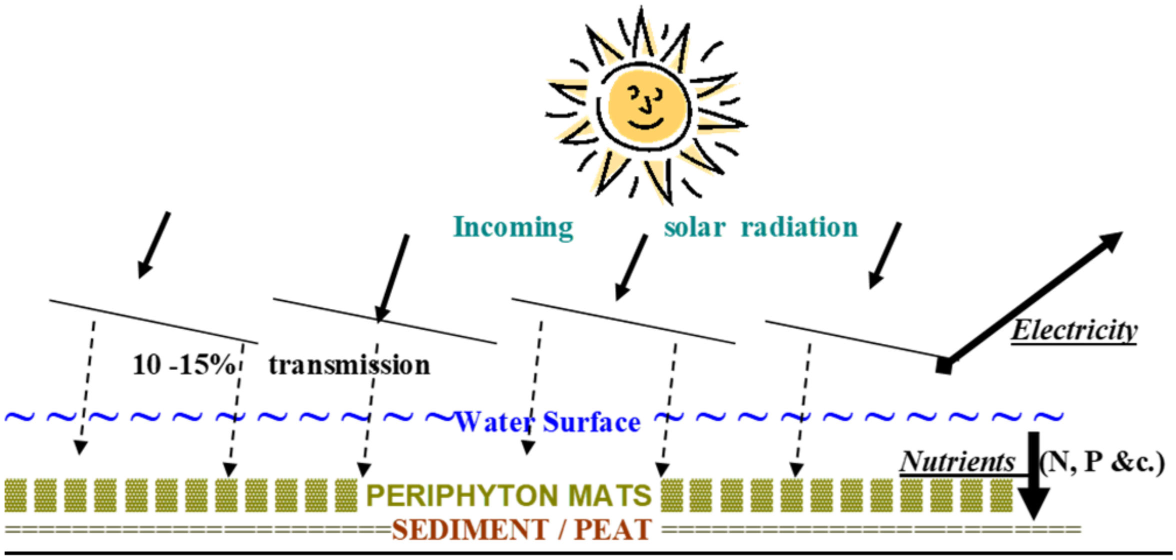

Figure 2: Conceptualized "SOLAR MARSH". Vertical cross section of Semi-Transparent Solar Cells over a periphyton-SAV constructed wetland, aka filtering marsh (figure by author).

Conclusion

Collocation of semi-transparent photovoltaic solar arrays placed over periphyton based filtering marshes could: (1) generate electricity, (2) remove nutrients from polluted surface waters, and (3) allow concurrent use of land area, decreasing overall net land use. Significant engineering study will be required to adapt solar array insulation from the water environment and to allow upkeep and maintenance activities to occur. Increasing the use of grid-tied solar energy is required to come in line with the KYOTO Protocol and the Paris Agreement. Increasing constructed wetland area will go far in mitigating the nutrient pollution that leads to harmful algal blooms and other ecological impacts. Combining these two goals decreases overall land area use. Moving forward with imaginative non-polluting carbon-neutral energy sources is required to slow, stop, and hopefully reverse climate change.

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