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Economic impact of substituting solar photovoltaic electric production for tobacco farming

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ABSTRACT

Solar photovoltaic (PV) technology represents a promising method to prevent dangerous global climate change, however full solar penetration demands substantial surface areas, possibly encroaching on arable land. To avoid repeating the mistakes of previous attempts to convert agricultural land to energy, arable land currently used for crops with known health hazards can be considered for conversion. Tobacco is the leading cause of avoidable death globally, and despite increasingly stringent controls on tobacco, economics provides an incentive to continue tobacco production. However, with the economics of PV ever improving, this study investigates the potential economic benefits of photovoltaic conversion of farms during tobacco's decline. This study analyzes key factors influencing conventional tobacco farming economics in the U.S. over a sensitivity of realistic future values. Then tobacco crop profit is compared to a sensitivity analysis covering the profits of solar PV farming on the same land. The results show that considering existing electric prices, escalation rates, and installed costs, PV farm substitution for tobacco farming makes economic sense in many U.S. cases already. In a case study of North Carolina, 30GW of PV power capacity was found to be economically viable on existing tobacco farms and if conversion took place over 2000 premature deaths could be prevented from pollution reduction alone. This meets the State's peak summer loads. Land use policies are discussed to facilitate such land use conversions for the benefit of the economy, the environment and human health.

1. Introduction

Rapid growth in solar photovoltaic (PV) global production capacity (Masson et al., 2014), improvements in the solar energy conversion efficiency (Green et al., 2015), and improved financing mechanisms (Alafita and Pearce, 2014) have all resulted in a radical decline in the price of solar electricity. This decline has resulted in a levelized cost of electricity that is now less expensive than traditional power in many regions (Branker et al., 2011). Thus PV represents an economical method of providing for a growing fraction of society's electrical needs. This is important as the total global energy consumption has increased substantially and it is projected to reach 34,454 TWh by 2035 (World Nuclear Association, 2015). To prevent dangerous global climate change (Moss et al., 2010; International Energy Agency, 2015) and avoid externalities associated with other alternative energy sources (Pearce, 2008), this power will need to be supplied by renewable energy sources (Pearce, 2002; International Energy Agency, 2012; The National Conference of State Legislatures, 2010; First, 2009; Jacobson and Delucchi, 2011).

To produce thousands of TWhs with solar electricity will involve the use of considerable land area (Zweibel et al., 2008). Although much of this needed demand can be met with aggressive building integrated PV and rooftop PV (Wiginton et al., 2010; Nguyen and Pearce, 2013; Nguyen et al., 2012; Duke et al., 2005; Hoffmann, 2006), to meet all demands while avoiding the costs and negative externalities associated with conventional grid expansion (Fouillet et al., 2006; Vine, 2012; Klinenberg, 2008), some arable land could be converted to PV farming.

Previous attempts to convert crop land to energy (e.g. ethanol production) have been blamed for rising global food prices and an expansion in hunger related suffering and mortality (Brown, 2008; Lagi et al., 2012; Albino et al., 2012; Fargione et al., 2008; Heimlich et al., 2008). A more sensible and universally beneficial policy would first target energy production on arable land that currently grows crops with known health hazards and, consequently, shrinking economic markets. This would result in both a private and a social benefit. As the health-related dangers for tobacco (World Health Organization, 2011, 2013; Barendregt et al., 1997; Murray and Lopez, 1997; Peto and Lopez, 2004) are well known to the medical community (tobacco use causes

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~6 million deaths per year globally and represents the leading cause of preventable deaths (World Health Organization, 2011)), it presents a suitable target crop. Despite substantial effort by public health officials to institute control policies (Jha, 1999; Fichtenberg and Glantz, 2000; Wakefield et al., 2008; Farrelly et al., 2008), the U.S. Department of Health and Human Services considers the use of tobacco an epidemic (US Department of Health and Human Services, 2010) and controls have even been placed internationally such as the WHO's Global Treaty on Tobacco Control, which places broad restrictions on the sale, advertising, sponsorship, promotion, shipment, and taxation of tobacco products (World Health Organization, 2003). Despite these restrictions, economics provides an incentive to continue tobacco production. However, with the economics of PV ever improving, it may provide an economically beneficial path for tobacco farming decline.

This paper investigates the economic impact of substituting solar photovoltaic farms for tobacco farms in the U.S. First, a sensitivity analysis on key factors influencing conventional agricultural economics is performed over a sensitivity of realistic future values including: i) crop yield (pounds/acre); ii) crop price ($/pound), iii) agricultural costs ($/acre/year) and iv) the profits ($/acre/year). Then the tobacco crop profit, is compared to a sensitivity analysis covering the profits of PV farming including: i) price per unit power installed ($/W), ii) solar energy production as a proxy for conversion efficiency (kWh/acre), iii) electricity rates ($/kWh) and iv) revenue earned per unit area ($/acre). The tobacco estimates are generous as tobacco demand in north America is falling due to public health efforts. These values are then used to determine the potential profit for the farmers ($/acre) for tobacco crop substitution with solar photovoltaic farming. Finally, a selection of policy mechanisms are explored to evaluate methods to facilitate the land use conversions from tobacco farming to solar electric production for the benefit of the economy, the environment and human health.

2. Materials and methods

2.1. Traditional tobacco agriculture value over 25 years of land use

A case study is performed for tobacco growth in North Carolina (North Carolina Department of Agriculture and Consumer Services, 2012; United States Department of Agriculture National Agricultural Statistics Service, 2011). The yield ranged from 2389 in 2009 to 2148 pounds/acre in 2015. The decrease in yield from the year 2015 onwards is primarily due to the end of the Tobacco Transition Payment Program (also known as the tobacco buyout) in 2014, which saw federal government payments towards tobacco producers and tobacco quota holders come to an end (Brown, 2013; United States Department of Agriculture, 2009; van der Hoeven and Michael Till, 2009). This along with the reduced incentive for the intensive labor and complex farming techniques required for tobacco farming, caused by a decrease in demand due to the strict anti-smoking policies and tax regulations (Womach, 2003a; Liang et al., 2006; Huntrods, 2012) lead to the decrease in the yield of tobacco. The price for tobacco was $1.61/pound in 2013. Based on USDA National Agricultural Statistics Services the yield is assumed to increase 1.5% per year and the price to increase 1% per year for 25 years.

The profits (P_{tob}) [$/acre/year] earned by a farmer from conventional tobacco agriculture is:

$$P_{tob} = Y * C - E \tag{1}$$

Where Y is the yield [pounds/acre/year], C is the crop price [US $/pound] and E are the expenditures [US $]. E is held constant at $4000/acre following (NETAFIM USA, 2013). The cost of tobacco farming is extremely high in comparison to food crops due to high pre-harvesting variable & harvest variable costs (NETAFIM USA, 2013; Eberly, 2008; Foreman, 2006; David Reed et al., 2012). The values of profit per acre of tobacco farming are graphed as a function of time for the sensitivities.

Table 1
Optimal geometries for Jacksonville, NC with a fixed tilt of 31° and 0° azimuth. study.

Packing Factor: kW/acre	Number of Modules	Area of Modules m2	Shading Loss	Energy Output (MWh/year)
109	360	691.6	1.6%	167.6
126.6	420	806.8	1.6%	187.4

2.2. Solar photovoltaic farm value over 25 years of land use

By analyzing the land usage and requirements for solar PV farms in the United States of America, the acres of land used to produce solar power can be evaluated [MW/acre] (Ong et al., 2013). The packing factors are taken from the worst case published scenario of 0.109 MW/acre to the average NREL studied packing factor of 0.1266 MW/acre (Ong et al., 2013).

These packing factors are used to create a model one acre PV solar farm at the locations for the case study from Section 2.1. Solar Advisor Model (SAM) (v2015.1.30, 64 bit) is used to determine the energy output (MWh/year) for the above packing factors. Table 1 summarizes the values used and the resulting energy outputs, which are then used as inputs into the economic model described below.

A sensitivity analysis is performed on the rates of 5, 10, 15 and 20 cents/kWh, which envelope the ranges in the standard rates of electricity, using three historical electrical rate escalations of 1) 0.3% (from 2010), 2% (2016 projected) and 5.7% (from 2008) (EIA Independent Statistics and Analysis U.S Energy Information Administration, 2015), representing the low, average and high cases, respectively. To be clear these electric rates are generic as they can represent either a displaced generation rate at the lower end (e.g. for a utility) up to a displaced residential consumer rate at the higher end (e.g. for a microgrid or PPA). Depending on the electricity market a decision maker is targeting, the appropriate rate in the range can be used for analysis as the sensitivity covers the entire range.

The levelized cost of electricity (LCOE) produced by the PV followed the calculation from Branker et al. (Branker et al., 2011):

$$LCOE = \frac{\sum_{t=0}^{T} \frac{I_t + O_t + M_t + F_t}{(1+r)^t}}{\sum_{t=0}^{T} \frac{E_t}{(1+r)^t}} = \frac{\sum_{t=0}^{T} \frac{I_t + O_t + M_t + F_t}{(1+r)^t}}{\sum_{t=0}^{T} \frac{S_t(1-d)^t}{(1+r)^t}} \tag{2}$$

Where:

T = Life of the project (years)

t = year t

E_t = Energy produced for t [kWh]

I_t = Initial investment/cost of the system including construction, installation, etc. [$]

M_t = Maintenance costs for t [$]

O_t = Operation costs for t [$]

F_t = Interest expenditures for t [$]

S_t = Rated energy o/p per year. [kWh/year]

1-d = Degradation factor

r = discount rate.

The values for the PV LCOE parameters are lifetime T = 25 years, initial investment (I_t) was given by P nominal times the cost per unit power was taken over a range: $0.80/Wp, $1.00/Wp, $1.50/Wp and $2.00/Wp (International Energy Agency, 2014), Mt + Ot was set at 1.5% of I_t and d was taken to be 0.5% (Branker et al., 2011). The ranges of initial investment costs are taken to cover all possible scenarios.

The SAM is also is used to calculate the LCOE values for the case study location using the above assumed parameters. In addition,