Why are Californian Farmers Adopting more (and Larger) Renewable Energy Operations?

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Introduction

Rising energy prices coupled with policies targeted towards reducing fossil-fuel consumption have led to an increase in the production of renewable electricity. This increase has spawned a wealth of research investigating the adoption decision at highly aggregate levels; however, little has been said regarding the potential for the agriculture sector to contribute.

The Nation's farm operators are increasingly investing in on-farm renewable energy generation. For example, the majority of both on-farm wind turbines (80 percent) and solar panels (89 percent) were installed after 2000 and more than half of all installations were after 2005. Electricity is a critical input in farming, and represents around 18 percent of total energy consumed on-farm, so the recent increases in energy prices are making on-farm generation more attractive. Generating electricity on-farm could reduce electricity expenditures and also insulate the producer from energy price fluctuations. Further, a renewable energy operation could provide the producer a dedicated energy supply in instances where electricity generation is difficult or impossible. It can also substitute for fuel and gas use powered or thermal needs on the farm, reducing transportation and maintenance costs as well as environmental concerns.

The 2009 On-Farm Renewable Energy Survey is the first national survey of farm operators to obtain information on renewable energy production (NASS, 2011). The survey provides data about the type, size, cost, incentives and estimated savings of the renewable energy production. This data was merged with the 2007 Census of Agriculture to provide information about the farm operation and primary operator (USDA, 2007).

California

California is a natural investigation arena for on-farm renewable energy adoption since it accounts for 23 percent of all farms reporting renewable energy production. This is partly a result of the availability of renewable resources; however, California has also been aggressive in its supportive policies. Further, California not only has much more renewable energy generating farms than the next state (Texas: 7 percent), it also has much larger installations than the average. The average farm in California with solar and/or wind technology has a generated capacity of 11 kilowatts (kw), versus 6.5 kw for all farms in the US.

Californian renewable energy operations are spread throughout the state (Figure 1); although the top 10 counties hold 50 percent of the state's total number of renewable energy farms. Out of the 56 counties, all but 3 have on-farm renewable energy production. San Diego has the highest number of operations; however, Napa has the operations with the largest size capacity on average.

Though the size of the renewable energy systems installed on farms varies considerably, we distinguish four size categories based on usage (Figure 2):

- $kW<1$ often represent off grid installations serving small needs;
- $1>kW\leq 5$ are typical for small on-grid needs;

- larger systems between $5>kW\leq 25$ are used for small commercial needs;
- systems with $kW>25$ represent large commercial installations.

Table 1 examines the farmer and farm characteristics by renewable energy system size:

- Machine value, total value product, and energy used are lower in farms with renewable energy. These values increase by ordered size category; and for large installations they are more than double the average for all California farms.
- Farm income as a percent of total farmer remuneration is generally lower for farms with renewable energy installations.
- Value of acres owned is also larger for farms with installed renewable energy with the exception of off grid systems.
- Farms with renewable energy have in general been operating for fewer years than the average California farm; however off grid and large commercial operations are older.

Figure 3 provides additional comparison:

- A higher share of California farms with renewable energy on-farm are organic and practice conservation methods, and are connected to the internet.

In terms of size, operations with large commercial renewable energy systems show identical characteristics with the average California farm and differ notably from other farms with renewable energy systems.

- For off-grid systems a couple of characterizations are that a higher share of these farmers are organic and report farming as their primary occupation, while a lower share reside on farm, are retired and hold high tenure on their farm.
- More farmers with small commercial systems practice conservation methods and are connected to the internet relative to other operations that have adopted renewable energy; while generally farmers with small grid connected renewable energy installations are retired, live on the farm and own most of the land in their operation.
- In terms of farm type there are more cattle farms but less fruit farms with renewable energy installations relative to all farms in California.

Objective and Model

This study examines the determinants of adopting renewable energy on-farm as well as what factors influence farmers to choose their size of renewable energy operation.

Let $y_i{*} = \beta X_i + \varepsilon_i$

Where $y*$ is the adoption intensity, expressed as the kw size of their renewable energy operation, X_i is a vector of explanatory variables that may influence the adoption decision and β are the parameters to be estimated for those variables, and ε_i denotes the standard error term capturing unobserved behavior. We utilize a double-hurdle model with a binary choice model for the first ‘participation’ stage, and a heteroskedastic ordered-binary choice model for the second ‘intensity’ stage. Based on the distribution of the dataset and the size needs depending on the farm applications we use the four above mentioned size categories.

Discussion

Renewable energy adoption on the farm is determined by a combination of factors (Table 2). The probability of adoption increases when a farm is connected to the internet, faces higher electricity prices, and has demonstrated interest in environmental practices: organic or conservation techniques. The probability for adoption also increases when the farmer has vested interest in his land by residing on the farm or holding tenure of the acres operated. Contrarily, the probability of adoption decreases for farmers who have farming experience. Additionally, the higher the household income share coming from the operation the lower the probability of adoption. A cattle farm has a higher probability for adopting renewable energy, while the probability of adoption decreases for fruit operations.

It is evident that the determinants influencing the technology adoption are different than those that influence the size of the renewable energy system chosen (Table 2). For example farm size and tenure increase the probability of adoption but have no impact on the size category chosen. Organic operations with higher probability of adoption, adopt smaller systems sizes. Surprisingly the price of electricity is not a significant consideration when the system size is chosen but influences the decision of adopting the renewable energy technology. Additionally, economic factors like TVP, acre value, and whether farming is the operator's primary occupation (which have no impact on the choice of adopting renewable energy) are influential determinants for the size of the installed system.

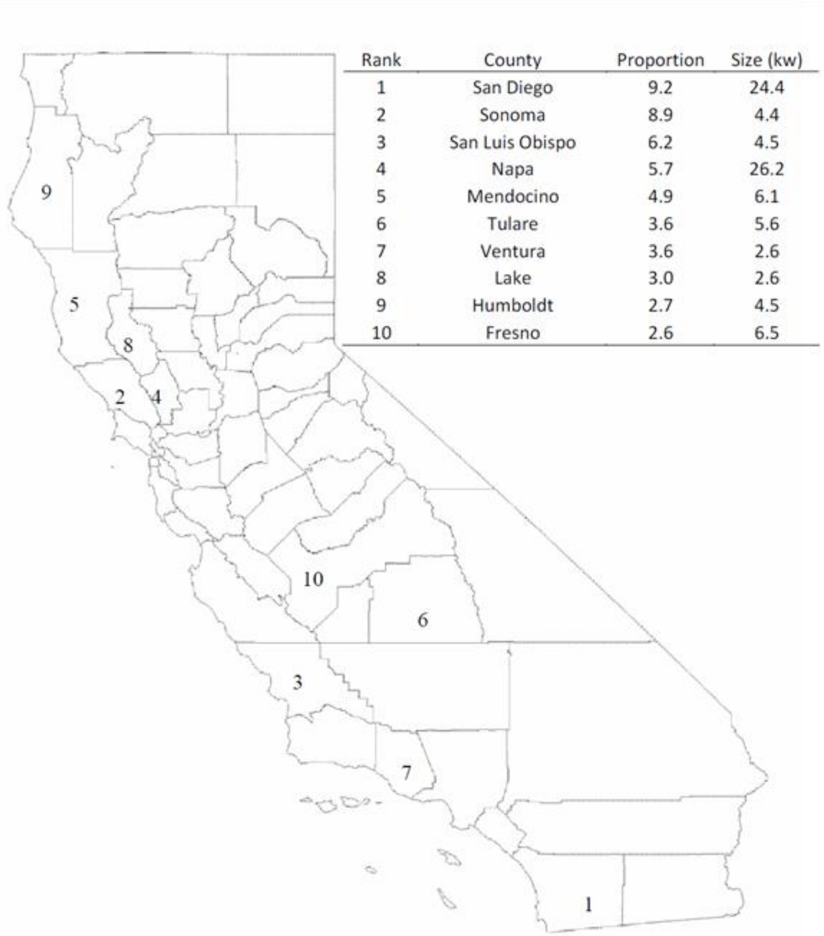
The adoption of different system sizes is influenced by distinct characteristics and there seems to be a very distinct divide between commercial and non-commercial systems (Table 3). For example, conservation practices increases the probability of adopting a commercial-size system while organic operations have a higher probability of adopting small and off grid systems. Operation type also shows an interesting interaction: larger systems are installed on fruit operations, but the probability of adoption is low. Cattle and organic operations with higher probability of adoption, adopt small systems sizes.

Conclusions

The study further underlines the importance of evaluating the choice of the size adopted in addition to the technology adoption choice. Renewable energy system size has increased over time (Xiarchos and Vick 2011); thus understanding the interplay of the determinants for adoption and size choice, will assist with policy formation and targeting.

Tables and Figures

Figure 1. Top Ranked Counties in California for Renewable Energy Operations with Average System Size



Rank	County	Proportion	Size (kw)
1	San Diego	9.2	24.4
2	Sonoma	8.9	4.4
3	San Luis Obispo	6.2	4.5
4	Napa	5.7	26.2
5	Mendocino	4.9	6.1
6	Tulare	3.6	5.6
7	Ventura	3.6	2.6
8	Lake	3.0	2.6
9	Humboldt	2.7	4.5
10	Fresno	2.6	6.5

Figure 2. Share of On Farm Renewable Energy Systems by Category

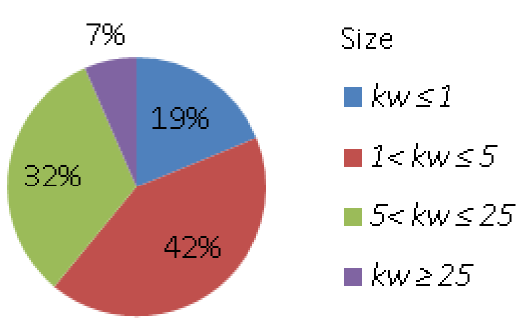


Table 1. California Farm Characteristics with Detail for Different Size Categories

Average	All Farms	RE On Farm	Renewable Energy on Farms by Size: kw ≤ 1	1 < kw ≤ 5	5 < kw ≤ 25	kw > 25
Machine value ($)	148,137.8	102,197.5	59,277.5	64,654.5	129,812.0	310,316.0
Tvp ($)	659,339.6	332,605.6	78,283.3	88,354.6	204,311.0	1,669,740.0
Farm income (%)	26.8	21.3	22.5	19.5	19.6	40.6
Size (Acres)	456.5	1,011.7	1,008.8	2,067.4	306.5	355.4
Year farming	20.6	17.8	21.4	17.0	15.6	24.4
Acre value ($)	64,444.1	72,277.7	19,693.8	72,222.4	94,059.2	75,767.2
Energy used ($/year)	1,787.3	893.0	316.9	398.3	1,050.0	3,079.7
Price ($/kw hour)	13.8	13.9	13.8	13.9	14.1	14.0

Figure 3. California Farmer Characteristic Shares with Detail for Different Size Categories

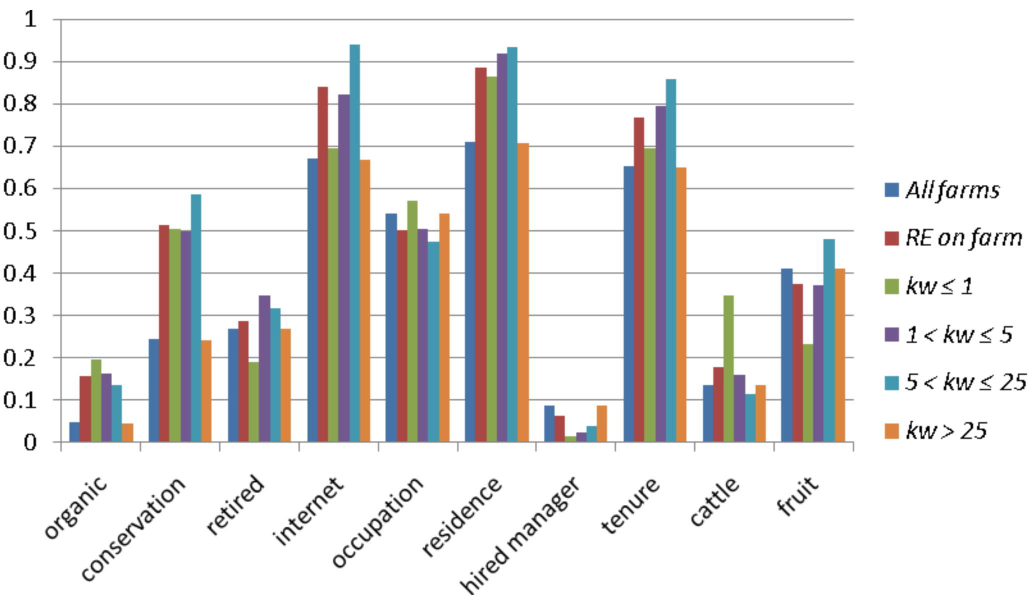


Table 2. Summary of Technology Adoption and System Choice Determinants

	CHOICE	
	ADOPTION	SIZE
Conservation	+	+
Machine value	i	i
Retirement	i	i
TVP	i	+
Income Share	-	i
Size	+	i
Year	-	-
Internet	+	+
Acrevalue	i	+
Organic	+	-
Electricity	i	i
Fruit	-	
Cattle	+	i
Primary Occupation	i	i
Residence	+	i
Pkwh	+	i
Tenure	+	i
Hired Manager		+
Funding		+
		VARIANCE
Conservation	NA	+
Retirement	NA	-
Year	NA	+
Residence	NA	-
Funding	NA	-
Loglikelihood	-3899.4881	-519.6678
Pseudo R2	0.0933	0.2174

+ positive - negative i insignificant NA not applicable

Table 3. Summary of Determinants for Each Size Category

AVERAGE MARGINAL EFFECTS

	Off grid	Small Residential	Commercial	Large Commercial
Conservation†	i (-)	-	+	+
Machine value	i (-)	i (-)	i (+)	i (+)
Retirement†	-	i (+)	+	-
TVP	-	-	+	+
Income Share	i (-)	i (-)	i (+)	i (+)
Size	i (-)	i (-)	i (+)	i (+)
Year	+	i (-)	-	i (+)
Internet†	-	-	+	+
Acrevalue	-	-	+	+
Organic†	+	+	-	-
Electricity	i (+)	i (+)	i (-)	i (-)
Fruit†	i (-)	i (-)	i (+)	i (+)
Cattle†	+	+	-	-
Primary Occupation†	i (+)	i (+)	i (-)	i (-)
Residence†	i (-)	+	i (-)	-
Pkwh	i (-)	i (-)	i (+)	i (+)
Tenure†	i (-)	i (-)	i (+)	i (+)
Hired Manager†	-	-	+	i (+)
Funding†	-	-	+	+

+ positive   - negative   i insignificant