

PUBLIC VIEWS OF THE VALUE, POTENTIAL, AND SUSTAINABILITY OF ENERGY SOURCES OVER THE LAST 30 YEARS IN THE PACIFIC NORTHWEST, USA

ROBERT L. MAHLER

Department of Soil and Water Systems, University of Idaho, USA.

ABSTRACT

The use of renewable energy has been an important topic in the four Pacific Northwestern states for the last 30 years. Large, statistically designed public surveys were conducted in the region in 1990, 2000, 2010, and 2020 to determine the perceived sustainability, future viability, and acceptance of the following ten energy sources: biomass, coal, geothermal, hydropower, natural gas, nuclear, oil, solar, tidal, and wind power. The survey questions were identical in all 4 years of the survey. These surveys were delivered by the US Postal Service to over 3500 randomly chosen residents in each survey year. The public response rate exceeded 50% in each survey year. Demographic data about age, gender, education level, community size, and state of residence of survey respondents were also collected. The survey data were statistically analyzed. In general, the public was literate identifying the renewable and nonrenewable energy sources as the majority of survey respondents correctly identified biomass, geothermal, hydropower, solar, and wind as renewable energy sources. Based on survey results, over 75% of Pacific Northwest residents considered it important or very important that their energy resources were renewable in 2020. The findings of this study were important because it shows that the public is in line with the scientific community with the goal of greatly reducing energy reliance on C containing nonrenewable energy sources including oil, coal, and natural gas. In summary, (1) the public strongly supports the transformation to a sustainable energy system using primarily renewable energy sources, (2) the use of traditional nonrenewable energy sources like natural gas should not be discouraged in the present; however, they should be phased out over the short and medium terms, (3) solar and wind energy should be significant sources to meet future energy needs in the region, and (4) the renewables including biomass and geothermal have a place in the future energy mix within the Pacific Northwest.

Keywords: *hydropower, public opinion, renewable energy, solar energy, sustainable energy, wind energy.*

1 BACKGROUND

Climate change has the potential to have a serious negative impact on human civilization. The climate has warmed by over 1.2 °C in the last 220 years. A temperature increase of over 2 °C is predicted to have negative impacts on human health, food production, water supply, and biodiversity. Increasing emissions of CO₂ are largely responsible for this observed temperature change. It is believed that almost 75% of CO₂ emissions are caused by the burning of oil, coal, and natural gas to produce energy for society [1]. Consequently, it is imperative that the energy industry transform itself into a carbon-neutral system in the next 25 years to protect life as we know it on Earth.

2 INTRODUCTION

The threat of catastrophic climate change will require rapid decarbonization of the world's current energy systems making renewable energy sources an important part of the solution to this issue [1]. Compared to coal, oil, and natural gas, nuclear, wind, solar, geothermal, tidal, and biomass power result in low carbon emissions and consequently may be important in the mitigation of the adverse effects of climate change [2]. China and the United States, the two largest sources of global CO₂ emissions, are currently promoting the use of renewables

including nuclear power as a necessary response to limit global climate change [3]. Many countries have signed on to the Paris Accord that has the primary goal of limiting carbon emissions. Several developed countries including Germany, France, Japan, and the United Kingdom have developed goals to significantly decrease carbon emissions by 2030. Even though the United States has been slow to accept the goals of the Paris Accord, CO₂ emissions have greatly decreased in the last 6 years as energy produced from coal declined because it has become more expensive than other less C emitting energy sources. On the other hand, over 400 additional coal burning power plants have been proposed in just four rapidly growing countries in Asia – China, India, Indonesia, and Vietnam to meet growing energy needs. Many agree that nuclear power is a viable option to control global greenhouse gas emissions; however, future development and utilization of the nuclear option will require both public acceptance and cooperation [4]. In 2019, renewable sources met 22.3% of the world's energy needs. This 22.3% was split between modern renewables (13.3%) and traditional biomass (9%), which include wood, charcoal, straw from fields, and animal dung. Many scientists discount traditional biomass because, although renewable, it may not be sustainable, and it releases CO₂ into the atmosphere. Modern biomass and hydropower production account for upwards of 70% of this renewable, and sustainable energy, while wind, solar, tidal, nuclear, and geothermal energy account for the other 27% of modern renewable energy.

From an energy source standpoint, the four Pacific Northwest states (Alaska, Idaho, Oregon, and Washington) are unique in the United States because a large share of their electricity is furnished by hydropower [3–6]. In fact, Washington, Oregon, and Idaho are responsible for 45% of the United States's hydropower generation capacity. This results in a larger percentage of their energy being renewable than in other regions of the country. Three of these four states (Washington, Oregon, and Idaho) have also invested in other renewables, including wind, solar, biomass, and geothermal. As of 2019, electricity generation in Washington was 60% hydropower, 16% natural gas, 10% nuclear, and 12% other renewables [3]. In Oregon, hydropower, natural gas, and other renewables accounted for 40%, 36%, and 24% of electricity produced, respectively [4]. In Idaho, hydropower, natural gas, and other renewables (wind) accounted for 55%, 16%, and 29% of electricity produced, respectively [5]. Alaska, having the largest oil and natural gas reserves in the United States, was different as these fossil fuels accounted for 67% of the produced electricity while hydropower supplied the remainder [6]. When hydropower and the other renewables (geothermal, biomass, solar, and wind) are combined, the share of electricity provided by renewable sources was 72%, 64%, 84%, and 33% in Washington, Oregon, Idaho, and Alaska, respectively.

The public must be supportive and engaged for the energy infrastructure system across the planet to be successfully converted to a carbonless renewable energy system. The four Pacific Northwestern states of the United States are a region where a significant portion of energy resources are already considered renewable. Consequently, a repeated measure survey instrument of public opinions was developed to determine public views of the value, potential, and sustainability of energy resources in the four Pacific Northwest states in 1988. The survey was designed to do the following: (1) understand the energy sources the public consider the most important for both energy and electricity use, (2) determine the importance the public places in moving toward a carbon-free energy system, (3) learn how the public identifies renewable and nonrenewable energy sources, (4) identify energy sources the public feel are more viable for sustainability, and (5) see if the public energy source conversion time frame is in line with what the scientific community says needs to be done in a timely fashion. The public was asked about the following 10 energy sources: biomass, coal, geothermal,

hydroelectric, natural gas, nuclear, oil, tidal, and wind. The mail-based survey was designed to be administered to the public every 10 years from 1990 to 2020. This study summarizes the findings of these survey questions.

3 METHODOLOGY

A survey instrument was developed to determine public views of the value, potential, and sustainability of energy resources in the four Pacific Northwest states in 1988. This survey was sent to 3500 residents in 1990, 2000, 2010, and 2020. The six survey questions in each of the four surveys were as follows:

Q 1. Which of the following energy sources are renewable (sustainable)? Check all that are renewable: *biomass, coal, geothermal, hydroelectricity, natural gas, nuclear, oil, solar, tidal, wind.*

Q 2. What is the most important energy source for all energy uses in the Pacific Northwest? Choose one: *biomass, coal, geothermal, hydroelectricity, natural gas, nuclear, oil (gasoline), solar, tidal, wind.*

Q 3. What is the most important electricity source in the Pacific Northwest? Choose one: *biomass, coal, geothermal, hydroelectricity, natural gas, nuclear, oil, solar, tidal, wind.*

Q 4. How important to you is it that the energy being used in the Pacific Northwest is renewable within 20 years? Choose one of the following: *very important, important, no opinion, not important.*

Q 5. Which of the following energy sources will become more important (viable) in the Pacific Northwest over the next 20 years? Check all that will become more important: *biomass, coal, geothermal, hydroelectricity, natural gas, nuclear, oil, solar, tidal, wind.*

Q 6. Compared to today, which energy sources SHOULD become MUCH more dominant in the Pacific Northwest in the next 20 years? Check all that should become more dominant: *biomass, coal, geothermal, hydroelectricity, natural gas, nuclear, oil, solar, tidal, wind.*

The survey target audience was a representative sample of the 9,500,000 adult residents of Idaho, Oregon, and Washington that live within the four PNW states. In addition, demographic information, including state of residence, community size, gender, age, and educational level, was also collected.

Each survey was developed using the Dillman methodology and was delivered to clientele via the United States Postal Service [9,10]. A sufficient number of completed surveys was the goal to result in a sampling error of 3–5% [11]. The survey process was also designed to receive a completed survey return rate more than 50%. Addresses were obtained from a professional social sciences survey company (SSI, Norwich, CT). Over 3500 surveys were sent out in each mailing event. Four mailings were planned to achieve the 50% return rate. The mailing strategy used was identical to other surveys that had been routinely conducted in the region [12–15]. It only took three mailings to achieve the target return rate of 50% in 1990 and 2000. Conversely, it took four mailings to achieve the 50% return rate in 2010 and 2020.

Survey answers were coded and entered into Microsoft Excel. Missing data were excluded from the analysis. The data were analyzed at two levels using SAS [11]. The first level of analysis generated frequencies, while the second level evaluated the impacts of demographic factors. Significance ($P < 0.05$) to demographic factors was tested using a chi-square distribution [10,11]. Since similar response rates were observed in all survey years, data analysis procedures were identical for each sampling.

4 RESULTS AND DISCUSSION

The survey methodology was designed to be able to compare resident responses over time so that useful information about energy attitudes could be evaluated. Using the mail-based Dillman survey methodology, response rates of 51.3%, 52.5%, 50.9%, and 51.6% were achieved for the surveys conducted in 1990, 2000, 2010, and 2020, respectively. The goal of greater than a 50% response rate was achieved for all surveys, resulting in a sampling error of less than 5%.

When this survey was first initiated in 1990, the population of the four Pacific Northwest states was approximately 9,000,000 [16]. However, by 2020, the region's population had grown to over 14,800,000 [17]. This 64% population increase resulted in the region becoming more urban and more concentrated in communities with more than 100,000 people over the 30-year study period.

There were several instances in this survey study where the demographic factors of gender, age, education level, community size, and state of residence impacted respondent answers. These instances will be discussed in the following sections.

4.1 Energy and electricity sources

The public perceived oil (gasoline), hydropower, and natural gas as the three most important energy sources in the Pacific Northwestern states in 1990, 2000, 2010, and 2020 (Table 1). Compared to the 1990 survey results, the importance of oil and hydropower declined by 2020, while the importance of natural gas as an energy source increased. The public views were very close to the actual energy production data – as oil, natural gas, and hydropower were the most important energy sources. The public view of the decline of the importance of hydropower and consequent increase in the importance of natural gas by 2020 was correct as stagnant hydropower production and rapid population growth resulted in a greater share of energy coming from natural gas. Between 2% and 8% of survey respondents felt that nuclear power was the most important energy source in the region. Conversely, the other six energy sources (biomass, coal, geothermal, solar, tidal, and wind) were never ranked as the most important energy source in the region.

Table 1: The public views of the most important energy sources in the Pacific Northwest based on regional surveys conducted in 1990, 2000, 2010, and 2020.

Energy source	1990	2000	2010	2020	Significance
	%				
Oil (gasoline)	38	39	37	34	**
Hydroelectricity	31	29	26	24	**
Natural gas	26	29	32	34	**
Nuclear	5	2	5	8	NS
Other	0	0	0	0	
Significance	****	****	****	****	

NS = not significant; **, ***, and **** = significant at the 95%, 99%, and 99.9% level of probability, respectively.

The demographic factors of gender, community size, and state of residence impacted survey respondent choices. Males were more likely to view oil as more important than females, while females ranked hydropower and natural gas as more important than males. Residents of communities larger than 100,000 were more likely to consider oil and natural gas more important than respondents in towns with less than 7000 people. Residents of Alaska were more likely to consider oil more important than residents of Idaho, Oregon, and Washington. This was expected since Alaska has the largest oil reserves in the United States, and the state's economy is very oil dependent. The demographic factors of age and education level did not affect respondents' answers to this survey question.

The vast majority of survey respondents identified hydropower as the main source of electricity in 1990, 2000, 2010, and 2020 (Table 2). This observation is correct when compared to the actual generation of electricity data. However, the percentage of respondents that identified hydropower as the major source declined over time. Hydropower was the main electricity source cited by 90%, 89%, 85%, and 77% of the public in 1990, 2000, 2010, and 2020, respectively. The decrease over time is similar to actual generation data and can be attributed to two related factors. The amount of hydropower produced in the region has been relatively stagnant over the last 30 years, while the demand for electricity has increased by over 45% due in large part to an increase in the region's population. The additional electricity has been provided by natural gas. Although not nearly as important as hydropower generation, there has been a significant growth in electrical power generation by both natural gas and wind since 2000. Some consumers noted this as they chose increased natural gas and wind energy production in 2020 and 2010 compared to 1990. The other seven electricity sources (biomass, coal, geothermal, nuclear, oil, solar, and tidal) were never identified by more than 2% of the public as being the major electricity source in the region.

The demographic factors of gender, age, education level, and state of residence impacted how the public chose their major electricity producer in the region. Females were more likely

Table 2: The public views of the most important electricity sources in the Pacific Northwest based on regional surveys conducted in 1990, 2000, 2010, and 2020.

Energy source	1990	2000	2010	2020	Significance
	% -----				
Hydropower	90	89	85	77	***
Natural gas	6	5	7	10	**
Wind	0	1	3	7	**
Solar	2	2	2	2	NS
Nuclear	1	2	2	3	NS
Geothermal	1	0	0	0	NS
Biomass	1	1	1	1	NS
Tidal	0	0	0	0	NS
Coal	0	0	0	0	NS
Oil	0	0	0	0	NS
Significance	****	****	****	****	

NS = not significant; **, ***, and **** = significant at the 95%, 99%, and 99.9% level of probability, respectively.

than males to choose hydropower as the major electricity source than males. Conversely, males were more likely than females to choose natural gas and wind as the major electricity producers. Survey respondents over 50 years old were more likely than younger people to rank hydropower the major electricity source. Residents with a college degree were more likely to choose hydropower as the major electricity source than people with only a high school diploma. Residents of Alaska were less likely to choose hydropower as their major source of electricity than residents of Idaho, Oregon, and Washington. The demographic factor of community size did not affect survey respondent choices.

4.2 What is renewable energy?

Survey year did not affect how residents rated the renewability of 8 of the 10 energy sources evaluated (Table 3). Survey year only impacted the rating of geothermal and wind energy. In general, the public was literate identifying the renewable and nonrenewable energy sources. The majority of survey respondents correctly identified biomass, geothermal, hydropower, solar, and wind as renewable energy sources. Conversely, coal, natural gas, nuclear, and oil were correctly identified as nonrenewable. On the other hand, the public was split about tidal energy – the same controversy is seen in the scientific community where most view tidal as renewable but possibly not sustainable because of adverse impacts on aquatic life. Overall, the public exhibited good literacy in the identification of renewable energy resources.

4.3 Importance of renewable energy

Based on survey results, over 75% of Pacific Northwest residents considered it important or very important that their energy resources were renewable in 2020 (Table 4). The percentage

Table 3: The percentage of surveyed public in 1990, 2000, 2010, and 2020 that considered 10 energy sources as being renewable (sustainable) in the Pacific Northwest. Based on surveys conducted in Alaska, Idaho, Oregon, and Washington.

Energy source	1990	2000	2010	2020	Significance
-----renewable, %-----					
Biomass	50	46	61	55	NS
Coal	6	9	4	4	NS
Geothermal	64	70	79	81	***
Hydropower	86	91	84	80	NS
Natural gas	18	21	16	13	NS
Nuclear	22	26	31	27	NS
Oil	10	4	6	8	NS
Solar	90	93	89	94	NS
Tidal	45	38	43	38	NS
Wind	84	86	90	95	**
Significance	****	****	****	****	

NS = not significant; **, ***, and **** = significant at the 95%, 99%, and 99.9% level of probability, respectively.

Table 4: The importance of energy being renewable (sustainable) in the Pacific Northwest based on Alaska, Idaho, Oregon, and Washington survey data.

Importance	1990	2000	2010	2020	Significance
----- % -----					
Very important	45	53	57	60	***
Important	19	15	13	18	NS
Not important	30	24	20	16	***
No opinion	6	8	10	6	NS
Significance	****	****	****	****	

NS = not significant; *** and **** = significant at the 99% and 99.9% level of probability, respectively.

of survey respondents indicating that it was very important for energy resources to be renewable was 45%, 53%, 57%, and 60% in 1990, 2000, 2010, and 2020, respectively. Conversely, the percentage of the public indicating that it was not important for their energy resources to be renewable declined from 30% in 1990 to only 16% in 2020 (Table 4). These data are important because it shows that the public in this region are willing to remove carbon from the energy generating system and support a renewable energy system. Thus, it is likely that the residents will support both public and private initiatives that will increase the use of both solar and wind renewable energies. This should be relatively straight forward in the case of wind because it is already cost competitive with other widely used energy sources. On the other hand, solar is currently not as cost competitive; however, as this technology improves, it should be embraced in geographic areas in the region with the appropriate amount of sunlight.

All demographic factors impacted how residents answered the renewability question (Table 5). Females were more likely than males to support renewable sources of energy. People younger than 30 years old were most likely to support renewable energy, while residents older than 75 years old were the least likely. People with college education were the most likely to support renewable energy, while residents with 12 or less years of education were least likely to support renewable energy. Support for renewable energy was greatest in communities with more than 100,000 people, while the smallest communities (<3500) had the lowest support level for renewable energy. Oregon and Washington residents were most likely to support renewable energy, while the least amount of support was found with Alaska residents.

4.4 Viability of renewable energy in the region

Based on the data evaluated in the three previous sections, there is good evidence that the public feel the region should convert to primarily renewable energy resources. Currently, nonrenewable energy resources generate over 50% of the region's electricity and approximately 28% of the region's overall energy needs.

The public considers biomass, geothermal, solar, tidal, and wind as energy sources that will become more viable in the region in the next 20 years (Table 6). The public has also

Table 5: The impact of demographic factors on the willingness of people to support the use of renewable energy based on surveys conducted in 1990, 2000, 2010, and 2020.

Demographic factor	Significance	Most pro renewable	Least pro renewable
Gender	***	Female	Male
Age	**	< 30 years old	> 75 years old
Education	**	College	12 years or less
Community size	**	> 100,000 people	< 3500 people
State of residence	****	Washington + Oregon	Alaska

, *, and **** = significant at the 95%, 99%, and 99.9% levels of probability, respectively.

Table 6: The percentage of surveyed public in 1990, 2000, 2010, and 2020 that considered energy sources to become much more viable in the region over the next 20 years in the Pacific Northwest. Based on surveys conducted in Alaska, Idaho, Oregon, and Washington.

Energy source	1990	2000	2010	2020	Significance
-----more viable, %-----					
Biomass	8	15	17	25	**
Coal	2	4	3	1	NS
Geothermal	10	13	13	20	**
Hydropower	65	60	51	38	***
Natural gas	18	16	23	23	NS
Nuclear	16	22	26	21	NS
Oil	12	8	15	17	NS
Solar	35	40	44	46	**
Tidal	2	6	12	15	**
Wind	27	30	37	48	***
Significance	****	****	****	****	

NS = not significant; **, ***, and **** = significant at the 95%, 99%, and 99.9% level of probability, respectively.

viewed these energy sources as more viable in 2020 compared to their feelings about viability in 1990. Based on the data shown in Table 6, the potential viability of solar power has increased from 35% of the public in 1990 to over 46% by the public in 2020. Likewise, the percentage of the public considering wind power as a viable energy source increased from 27% in 1990 to 48% in 2020. Although the public was less confident in the short-term viability of biomass (25%), geothermal (20%), and tidal (15%) energy in 2020, these numbers are substantially higher than they were in 1990, 2000, and 2010 (Table 6).

The demographic factors of gender, age, education level, and state of residence impacted public answers to this question. Females were more likely than males to say that solar and

wind energy are viable renewables in the short term. Survey respondents less than 40 years old were more likely than respondents older than 70 to consider solar, wind, and biomass viable energy sources in the short term. Respondents that attended college were more likely to support future viability of renewable energy sources than respondents without exposure to college. Finally, Alaskans were the least likely residents to consider most renewable energy sources viable in the future.

Residents were asked to identify the energy sources that should become much more dominant in the future (Table 7). Note, e.g., hydropower is already a dominant energy source – so relatively few people would say it should become much more dominant. Evaluating the 2020 survey data first, 44%, 35%, 32%, and 29% of respondents said that wind, natural gas, solar, and geothermal energy should become much more dominant over time in the region, respectively. It should be noted that only natural gas is a nonrenewable energy source.

At this point, the public have answered six different questions about energy resources. When the results of these questions are compiled, the following can be said: (1) the public strongly supports the transformation to a sustainable energy system using primarily renewable energy sources, (2) the use of traditional nonrenewable energy sources like natural gas should not be discouraged at the present; however, they should be phased out over the short and medium terms, (3) solar and wind energy should be significant sources to meet future energy needs in the region, and (4) the other renewables including biomass and geothermal have a place in the future energy mix within the Pacific Northwest.

Compared to 1990, residents increasingly said that biomass, geothermal, natural gas, nuclear, solar, tidal, and wind should become more important in the energy mix in 2000, 2010, and 2021. This increasing upward trajectory over time may indicate that people want energy system conversion at a much faster rate than has traditionally occurred over the last 50 years. The demographic factor of gender did have an impact on how people answered this

Table 7: The energy sources that should become much more dominant in the region based on views of the surveyed public in 1990, 2000, 2010, and 2020 in Alaska, Idaho, Oregon, and Washington.

Energy source	1990	2000	2010	2020	Significance
	% -----				
Biomass	6	5	11	19	***
Coal	2	6	6	3	NS
Geothermal	6	10	16	29	***
Hydropower	6	10	7	8	NS
Natural gas	10	18	29	35	***
Nuclear	7	12	16	15	**
Oil	4	9	6	10	NS
Solar	18	24	29	32	***
Tidal	1	3	7	5	**
Wind	30	34	38	44	***
Significance	****	****	****	****	

NS = not significant; **, ***, and **** = significant at the 95%, 99%, and 99.9% level of probability, respectively.

question as females were more likely to say that biomass, geothermal, nuclear, solar, tidal, and wind should become more dominant over time than males.

5 CONCLUSIONS AND RECOMMENDATIONS

The major findings of this 30-year survey study were as follows:

- The public perceived oil (gasoline), hydropower, and natural gas as the three most important energy sources in the Pacific Northwestern states in 1990, 2000, 2010, and 2020. These observations are in agreement with actual energy generation data.
- The vast majority of survey respondents identified hydropower as the main source of electricity in 1990, 2000, 2010, and 2020. This observation is in agreement with actual electricity generation data.
- In general, the public was literate in the identification of the renewable and nonrenewable energy sources as the majority of survey respondents correctly identified biomass, geothermal, hydropower, solar, and wind as renewable energy sources.
- Based on survey results, over 75% of Pacific Northwest residents considered it important or very important that their energy resources were renewable in 2020. The percentage of survey respondents indicating that it was very important for energy resources to be renewable was 45%, 53%, 57%, and 60% in 1990, 2000, 2010, and 2020, respectively.
- The public considers biomass, geothermal, solar, tidal, and wind as energy sources that will become more viable in the region in the next 20 years. The public has also viewed these energy sources as more viable in 2020 compared to their feelings about viability in 1990.
- Based on the data evaluated in this paper, there is good evidence that the public feel that the region should convert to primarily renewable energy resources.
- The public are eager to have their energy mix within the region become more renewable over the next 20-year period.

The demographic factors of gender, age, formal education level, state of residence, and community size often affected the response of residents to survey questions. Females were more likely than males to support movement to renewable energy sources. Residents of Idaho, Oregon, and Washington had similar feelings about the need to transition toward a more renewable, sustainable energy environment. Conversely, residents of Alaska, a state rich in natural gas and oil reserves, were less likely to support renewable energy resources. The findings of this study were important because it shows the public is in line with the scientific community goal of greatly reducing energy reliance on C-containing nonrenewable energy sources including oil, coal, and natural gas.

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