Fuel Mix Diversity, Sustainability, and Energy Security

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ABSTRACT

Increased energy security refers to a more resilient energy system, which is better able to withstand shocks with minimal disruptions in economic functioning, human health and environmental quality. States achieve increased resiliency via direct security measures such as increased surveillance, but more importantly by altering the structure of energy and economic systems. Such alterations include reducing risk by increasing redundancy in each system and by increased fuel and sectoral diversity in addition to increased relative supply of fuels, potentially by increasing energy efficiency. Also, an increase in the use of domestically produced fuels such as renewable energy, reduces security risks.

Because energy security is an important policy consideration in overall energy policy planning, states may reasonably consider the energy security implications of how their economy has changed over time, in addition to the energy security implications of their energy efficiency, renewable energy and carbon efficiency enhancing programs. Thus, the objective of this paper is to analyze at the state level, changes between 1980 and 2000, in fuel and sectoral diversity, energy efficiency and use of renewable fuels, focusing on industrial and electric utilities sectors

The results in this paper reveal substantial state level differences and demonstrate that energy security has overall increased in only two states, based on a simultaneous favorable movement in the three parameters analyzed. Only one state exhibits a non-favorable movement in all parameters and thus reduced energy security.

Introduction

Sustainable energy development (SED) is broadly defined as 'the provision of adequate energy services at affordable cost in a *secure* and environmentally benign manner, in conformity with social and economic development needs' (IAEA/IEA 2001) – implying interactions and potentially conflicting goals between the three dimensions of SED (the social, economic and environmental). SED has slowly made its inroad into the rhetoric behind US energy policy. President Bush in 2001 sought to develop energy policy that will "promote dependable, affordable, and environmentally sound production and distribution of energy for the future" – a description that closely aligns to the SED paradigm. The complex and dynamic interactions between the different but simultaneous goals of SED complicate any analysis of progress towards SED. Yet, given that the United States consider SED a priority, this progress must somehow be evaluated.

A central concept in the SED paradigm is energy security. Energy security refers to the "availability of energy at all times in various forms, in sufficient quantities, and at affordable prices" (WEA 1998), and thus is present in all dimensions of SED. The National Council of State Legislators (NCSL) states in their report called "Energy Security", that energy security refers to a resilient energy system that is able to withstand various threats such as attacks, supply disruptions and environmental threats such as climate change, and thus a secure energy system guarantees continuous availability of energy, of various types, in sufficient quantities and at reasonable prices (WEA 1998, Brown et al. 2003). Furthermore, the United States Energy Association (USEA), defines energy security as assured when "the nation can deliver energy economically, reliably, environmentally soundly and safely and in quantities sufficient to support our growing economy and defense needs" (USEA 2002). The goal of this paper is to examine using a limited number of parameters whether the United States as a whole, in addition to individual states and individual sectors, have progressed towards increased energy security or not since 1980. In particular, we focus on the role of the industrial sector and electric utilities. This paper is organized as follows. The following section briefly discusses a few core concepts important for state level energy security, focusing on the implications of the chosen parameters for each of those core concepts. The next section discusses each of the parameters that are used to assess movements towards or away from energy security, followed by our state level empirical results. The paper concludes with a discussion on whether it is possible to comment on changes in energy security based on this limited number of parameters.

Core Concepts in Energy Security

It is possible to derive from the definitions, given above, several core concepts important to energy security. Those are, economics, reliability, safety, sufficient quantities and environmentally sound. In essence what this indicates is that we should structure our discussion of energy security around four core concepts: infrastructure vulnerability, supply vulnerability and environmental/health vulnerability. Clearly, vulnerability needs to be reduced in each of those core areas, and below e discuss how states possibly can improve the energy security in the first two, leaving the issue of environmental health for later analysis.

Infrastructure Vulnerability

Much of the US energy system presents significant safety and security risks and past disruptions have adversely affected the economy and occasionally public safety (Union of Concerned Scientists 2002). For example, the recent electricity outage in Northeastern United States and Southern Canada, cost the US economy $6.8-$10.3 billion dollars (ICF 2004). The Union of Concerned Scientists expects our reliance on vulnerable infrastructure will continue to increase over time as our demand for energy grows. This is due to the expectation that we continuously will expand our consumption of natural gas in e.g. electric power plants[1], and thus increase natural gas transmission and distribution pipelines all over the country. The main issues associated with infrastructure vulnerability are related to the issue of centralized production and distribution vulnerability.

Centralized production. US energy production is highly centralized which makes it more vulnerable to attacks and breakdowns. A typical nuclear power plant serves 1.25 million homes whereas a large coal fired power plant serves about half a million homes and only about 150 refineries nation-wide produce fuel for over 200 million cars (Union of Concerned Scientists 2002). The significant centralized nature of production highlights the problem of the lack of redundancy and diversity in the US energy system. Methods to reduce supply vulnerability include decentralizing power production (via. e.g. investing in renewable energy) and increase

[1] For example, the National Energy Policy is based on a forecast that will require the building of 1300- 1900 new power plants over the next 20 years

redundancy in addition to enhance surveillance at those sites that have been deemed the most vulnerable.

Distribution vulnerability. The US network for distributing fuel and electricity is also highly vulnerable, where large oil pipelines are particularly vulnerable, and natural gas pipelines are increasing in importance. The electricity grid is similarly vulnerable, where a single substation is critical for a large geographical area (Union of Concerned Scientists 2002). A long-term solution to this vulnerability is to facilitate decentralization, increase diversity and redundancy, and at the same time ensure that economic competitiveness and environmental health is maintained.

Supply Vulnerability

The United States are largely reliant on the use of scarce fossil fuels, which over time become more scarce, eventually leading to higher prices and possibly supply disruptions. Our oil dependence, in particular makes us vulnerable to risks posed by energy markets beyond our control leading to volatile price movements. For example, reliance on the economically powerful OPEC cartel and the politically unstable Persian Gulf Nations will only grow over time as oil supplies dwindle and our demand continues to increase (Union of Concerned Scientists 2002, USEA 2002). On the other hand, most of our gas supplies are produced at home, alleviating the issue of lack of stability elsewhere, but unfortunately does not alleviate us from the physical fact that natural gas is a carbon emitting, scarce fossil fuel resource. A long term reduction in supply vulnerability, can be achieved by increased diversity in fuel imports (in terms of location of supply), overall reduced reliance on imported fuels, and increased reliance on renewable locally generated substitutes. Other measures are increased fuel diversity. Fuel diversity is particularly important in this case, because an economy that is heavily reliant on a particular energy type, is much more vulnerable to supply disruptions than an economy that depends on a more diverse fuel base. An increase in available domestic economically available energy supply also would reduce supply vulnerability, which can be achieved via increases in fossil fuel reserves as a result of increased exploration, increased investment in renewable energy and reduced energy intensity.

Summary

Based on this very brief discussion, it is clear that numerous factors can be used to assess whether energy security has increased or decreased over time in the United States. Such factors include, for example:

- To reduce infrastructure vulnerability:
  - Defining vulnerable infrastructure and then enhancing surveillance of those identified structures.
  - Decentralizing power generation, such as via increased investment in renewable energy that tend to be small scale – and thus will reduce the necessity for long transmission lines.
  - Increasing redundancy in the energy system via increased diversity and more decentralized structures.

- To reduce supply vulnerability:
  - Enhancing energy supply by investing in increased energy efficiency and increased use of local /renewable energy sources.
  - Reducing reliance on imported fuels by investing in locally derived energy and enhancing energy efficiency.
  - Diversifying the energy supply, to guard against shocks to the supply system, and to maximize the resilience of the system.

Every State shares these goals in the long run, but the means by which these goals are attained ought to be based on local circumstances and thus State specific. Thus in the remainder of this paper we examine more closely three of those parameters that could indicate how state level energy security has changed over time since 1980 and the contribution of industrial and electricity sectors to state level energy security.

Measuring Progress Towards Enhanced Energy Security: Defining and Estimating the Parameters

Defining the Parameters[2]

We explore changes in three paramters to examine if each state-economy is becoming more or less secure. Those parameters are discussed below and are:

- Energy intensity
- Percentage share of renewable energy in energy supply
- Energy supply diversity

Those three parameters provide a basis for judging whether a change in the state of a system is more or less secure, based on a pre-selected point in time, here 1980. Obviously we can never know what the exact sustainable or secure position of the energy system is but given our current level of knowledge we do know the direction in which we should head.

Energy intensity. Energy consumption per GSP captures the general relationship of energy consumption to economic growth. One of the main goals of enhanced energy security is to secure future energy supply, and one way to do so is to be able to produce more economic output from each unit of energy input. As a result a decline in energy intensity indicates a movement towards increased energy security. Besides, a reduction in energy intensity, by more efficient use of energy increases state and industry competitiveness. In this study, aggregate energy intensity and energy intensity in the industrial sector is measured as total primary energy consumed measured in billion BTU's, and divided by either total gross state product (GSP) or by total value added in the sector measured in million 1996 US$. To capture more specifically changes in intensity in the electricity sector, we assess changes in technical intensity, using a purely physical measure, or energy consumed measured in BTU's divided by BTU's produced.

[2] All energy data, both for diversity index, energy intensity and use of renewable energy is derived from EIA State Energy Data Book, available at: http://www.eia.doe.gov/emeu/states/_states.html. State level economic output data is available from the Bureau of Economic Analysis (BEA) data set.

Energy diversification. Energy supply diversification is one way of minimizing risk, where risk minimization necessitates that a given energy choice is evaluated in the context of the entire energy system and not as an individual choice. An energy portfolio with favorable risk qualities should be composed of elements with, at least, partially offsetting risks. For example, if one option is to use coal driven power plants, and the other is to use wind farms, which will generally not be cost effective unless the price of coal increases, effective risk management would imply investing in both rather than one or the other (IEA/OECD 2001). Such a strategy effectively treats non-fossil fuel based energy sources as an insurance against the inevitable increase in fossil fuel prices. Another diversification option is to diversify the supply sources of a given fuel, e.g. oil (IEA/OECD 2001). By definition an energy system that relies on a single fuel, or a single transmission line is inherently more vulnerable than one that relies on a diversity of resources. This implies that there is value in planning an energy system that achieves resiliency through diversity and redundancy (NCSL 2003).

One potential measure of energy diversification is the Sterling Index (IEA/OECD 2001 Sterling 1999), which was designed to describe the level of diversity in electricity systems, and is based on what is called Shannon-Weaver equations more commonly used to measure biodiversity.

This diversity index (DIV) is defined as: $$DIV = -\sum_i p_i \ln p_i \qquad (1)$$

Here, p_i represents the proportion of fuel type i in an overall portfolio. This is measured as the proportional share of each fuel in Total Primary Energy Supply (TPES). The value of the DIV index increases as the number of different supply sources increases and as the distribution of contributing shares of each fuel equalizes (IEA/OECD 2001). Consequently, an increase in fuel diversity or an increase in the Sterling Index, indicates a movement towards increased energy security.

However, the Sterling index is controversial in that it treats "evenness" and diversity as simply desirable, and makes no distinction between desirable versus un-desirable diversity (IEA/OECD 2001). Thus it important to also examine changes in the share of renewable energy in energy supply at the state level, as discussed below.

Renewable energy. Renewable energy systems are desirable not only because by definition they are renewable, but also because they are environmentally friendly,[3] can be installed as stand-alone systems, and potentially create local investment and employment opportunities if produced at home, all of which enhance the self-sufficiency of the local energy system. That is not to say that self-sufficiency can only come from the use of locally produced, renewable sources. To the contrary, self-sufficiency can also be improved by using locally extracted, non-renewable fossil fuels. This effect could be captured in an indicator that captures changes in energy self-sufficiency, or to put it another way, changes in a state's dependence on foreign energy sources. In this study, however, we only focus on the share of renewable fuels in total state level primary energy supply. Given what was discussed above, an increase in the share of renewable fuels indicates a favorable movement towards increased energy security.

[3] At least when compared to fossil fuel systems.

Results

State Level Results

In order to analyze the relative impact of industrial and electricity sectors, we first examine change in energy diversity, energy intensity and use of renewable fuels at the aggregate state level. Results are presented in Table 1, below. The results indicate substantial differences between states in each of those three parameters. State level fuel diversity ranges from 0.79 in Rhode Island to 1.50 in Alabama and Arkansas. Fuel diversity increased for 34 of the 48 states analyzed, ranging from an increase of 0.56% in Idaho and 0.58% in Nebraska, to an increase of 47.75% increase in Massachusetts and 49.23% increase in Louisiana. Other states that have increased their state level fuel diversity of over 30% are Connecticut, Delaware, New Hampshire and New Jersey. Fourteen of the 48 states experienced a decline in fuel diversity, or from a decline of 0.14% to a decline of 16.79% in North Dakota.

Energy intensity similarily varies between states, ranging from 5.26 in Massachusetts, 5.28 in New York and approximately 5.8 in California, Connecticut and Rhode Island to 44.75 in Wyoming. Changes in energy intensity range from a decrease of 55.75% in Delaware, and a decrease of over 40% in Massachusetts, California, Connecticut and Oregon to an increase in only two states, Wyoming and North Dakota, of 23.02% and 34.72%, respectively.

The fractional share of renewable fuels, in total state energy supply (TPES) ranges from less than 1% in Delaware, Kansas and Texas, to close to 40% in Washington state and Oregon, and over 30% in Idaho and Maine. Several states have experienced substantial percentage increases in the fractional share of renewable fuels such as a 158% increase in Maryland, 106% in New Jersey 85% increase in Louisiana and an increase of 75% in Pennsylvania, 70% in Massachusetts and 64% in Florida. All in all 16 states increased their share of renewable fuels, but all others have experienced a declining share ranging from 1.53 in Ohio to a decline of 53.35 in North Dakota. Upon close inspection of the performance of individual states, it is apparent that the same states that have experienced the largest decline in fuel diversity are the same that have experienced the largest decline in the share of renewable fuels, and the largest increase in energy intensity (North Dakota) and those that have done the best in terms of increasing fuel diversity, reducing energy intensity and increasing the share of renewable fuels are somehwhat the same ones as well, e.g. Massachusetts. Overall, 14 states experienced a favorable movement in all three parameters (California, Connecitcut, Delaware, Florida, Georgia, Illinois, Lousiana, Maryland, Massachusetts, Minnesota, Mississippi, Nevada, New Jersey, New Mexico, Oklahoma and Pennsylvania) and thus we can conclude that those states seem to have enjoyed increased energy security between 1980 and 2000. Of course now the question becomes, how did those states achieve this performance, can other states imitate this development, and has this occurred at a substantial economic cost? Only Wyoming and North Dakota experienced an unfavorable movement in all three parameters and thus a decline in energy security. Other states provide inconclusive evicence since they exhibit a mix of favorable and unfavorable movements in the three paramters. See Table 1, below.

Table 1. State Results

State	Fuel Diversity 2000	Fuel Diversity % 1980-2000	Energy Intensity 2000	Energy Intensity % 1980-2000	Renewable Share % 2000	Renewable Share % 1980-2000
Alabama	1.50	-1.37	21.78	-25.21	10.49	-14.95
Alaska	N/A	N/A	N/A	N/A	N/A	N/A
Arizona	1.49	12.01	10.47	-31.68	6.69	-53.14
Arkansas	1.50	11.35	17.67	-20.30	8.67	-8.95
California	1.16	14.84	5.81	-43.56	11.99	11.13
Colorado	1.19	-4.01	7.98	-36.16	2.57	-21.95
Connecticut	1.27	34.13	5.84	-40.92	5.76	14.37
Delaware	1.02	37.01	7.49	-55.75	0.99	44.73
Florida	1.31	24.67	8.74	-31.44	5.06	64.73
Georgia	1.46	5.36	10.39	-38.43	7.78	0.82
Idaho	1.16	0.56	10.61	-37.71	35.68	-9.58
Illinois	1.47	8.98	10.21	-31.13	2.93	26.09
Indiana	1.07	-4.83	17.16	-28.70	1.18	-46.73
Iowa	1.30	-3.61	13.69	-17.93	3.28	-47.81
Kansas	1.32	21.54	14.94	-29.93	0.64	-38.05
Kentucky	1.04	-7.70	18.03	-19.52	1.83	-48.44
Louisiana	1.17	49.23	32.06	-9.22	3.80	85.34
Maine	1.01	-2.67	15.13	-21.43	35.62	11.21
Maryland	1.46	9.78	8.02	-32.66	9.68	158.06
Massachusetts	1.22	47.75	5.26	-45.94	8.54	69.82
Michigan	1.36	-0.22	10.31	-32.41	3.30	-5.28
Minnesota	1.41	0.85	9.48	-30.54	5.91	21.93
Mississippi	1.41	30.05	17.76	-12.91	6.98	55.17
Missouri	1.25	8.04	10.69	-29.00	1.12	-51.85
Montana	1.33	2.55	25.87	-1.84	21.83	-23.82
Nebraska	1.43	0.58	12.64	-23.61	3.34	-16.05
Nevada	1.30	4.83	10.32	-26.75	8.94	7.56
New Hampshire	1.36	38.89	8.17	-34.04	10.80	-27.58
New Jersey	1.26	36.81	7.25	-36.05	6.08	106.34
New Mexico	1.15	0.64	15.09	-38.16	1.25	28.80
New York	1.37	10.15	5.28	-38.66	10.68	-2.04
North Carolina	1.40	9.45	9.91	-31.98	5.21	-33.69
North Dakota	0.93	-16.79	36.41	34.73	3.95	-53.35
Ohio	1.31	8.89	11.33	-37.28	2.62	-1.53
Oklahoma	1.18	20.21	17.67	-17.67	2.66	13.24
Oregon	1.18	17.58	8.97	-44.06	39.88	-11.90
Pennsylvania	1.48	15.97	12.84	-28.71	6.24	75.06
Rhode Island	0.79	17.40	5.81	-24.35	2.21	-43.34
South Carolina	1.45	-2.53	16.02	-20.91	5.00	-24.81
South Dakota	1.29	3.45	11.94	-35.90	23.29	-17.88
Tennessee	1.43	11.60	12.50	-31.05	5.44	-46.74
Texas	1.14	18.47	17.99	-34.55	0.91	-10.69
Utah	1.12	-4.26	13.82	-26.45	2.10	-18.28
Vermont	1.14	-0.14	9.57	-30.79	13.36	-26.08
Virginia	1.40	11.62	8.83	-24.35	4.92	-14.63
Washington	1.27	15.55	11.10	-38.88	40.61	-23.52
West Virginia	0.84	-10.45	34.97	-19.78	1.33	-15.53
Wisconsin	1.42	-5.26	11.01	-29.42	7.03	-44.96
Wyoming	0.94	-13.02	44.75	23.02	1.90	-29.46
United States	1.43	6.84	10.72	-32.97	6.65	-5.28

* N/A: not applicable

Industrial Sector

The industrial sector in the United States in 1980 accounted for 29% of total primary energy use (TPEU). This value gradually declined to 22.8% in 2000, but regardless indicates the importance of the industrial sector in contributing to enhanced energy security. This share ranges from 6.3% in Arizona to 54.8% in Louisiana. The sector also accounts for a significant proportion of total use of renewable energy, but stayed constant at 29% from 1980 to 2000. Table 2, below, presents the overall results for the industrial sector.

Table 2. Industrial Sector Results

State	Fuel Diversity 2000	Fuel Diversity % 1980-2000	Energy Intensity 2000	Energy Intensity % 1980-2000	Renewable Share % 2000	Renewable Share % 1980-2000
Alabama	1.55	-1.26	23.15	-40.40	24.73	36.00
Alaska	N/A	N/A	N/A	N/A	N/A	N/A
Arizona	1.30	-11.68	3.59	-68.10	0.75	-89.12
Arkansas	1.42	4.72	17.37	-36.91	19.34	16.08
California	1.37	9.70	5.68	-52.35	2.67	-35.65
Colorado	1.16	-13.23	7.42	-44.22	0.77	20.56
Connecticut	1.36	18.67	3.06	-56.34	3.68	-71.89
Delaware	1.16	23.23	13.39	-11.13	0.43	>500
Florida	1.48	10.59	7.44	-41.98	19.04	99.40
Georgia	1.54	7.77	10.75	-38.84	26.46	55.49
Idaho	1.56	5.25	9.05	-58.52	18.10	44.23
Illinois	1.49	13.54	9.23	-48.92	1.81	-46.39
Indiana	1.40	2.12	14.31	-52.40	1.65	-34.26
Iowa	1.46	1.42	12.28	-35.74	6.49	-44.15
Kansas	1.04	6.30	15.82	-38.38	1.02	>500
Kentucky	1.31	0.04	13.95	-27.44	0.76	-67.56
Louisiana	1.03	25.27	51.64	-17.57	5.96	118.64
Maine	1.00	20.91	26.24	-7.92	58.34	-11.26
Maryland	1.46	9.58	7.52	-57.92	6.45	11.19
Massachusetts	1.35	22.49	3.40	-37.06	3.92	-79.75
Michigan	1.51	13.47	7.14	-47.90	6.72	14.62
Minnesota	1.53	25.48	9.03	-36.52	10.06	-2.13
Mississippi	1.39	36.74	19.10	-16.17	20.88	78.17
Missouri	1.31	8.23	5.68	-52.17	0.57	-72.59
Montana	1.39	16.32	26.55	-18.32	11.52	65.84
Nebraska	1.27	12.32	9.16	-44.39	1.11	>500
Nevada	1.44	15.11	6.90	-44.03	0.50	>500
New Hampshire	1.23	3.78	4.05	-56.82	16.42	-57.55
New Jersey	1.22	45.09	6.39	-51.02	1.27	-63.05
New Mexico	0.99	5.41	9.53	-59.45	0.51	-42.08
New York	1.53	3.44	4.89	-41.89	6.42	-11.94
North Carolina	1.53	1.15	7.28	-26.74	14.98	8.84
North Dakota	1.14	30.31	37.60	112.31	0.62	>500
Ohio	1.47	1.32	9.66	-54.76	5.76	44.54
Oklahoma	1.15	12.82	17.08	-32.47	3.40	80.46
Oregon	1.35	-4.18	3.92	-77.06	10.82	-67.42
Pennsylvania	1.59	11.31	9.83	-58.12	5.03	-0.67
Rhode Island	1.25	34.89	2.95	-50.78	0.01	46.96
South Carolina	1.57	2.69	12.89	-39.99	16.51	75.03
South Dakota	1.22	17.39	7.71	-48.34	0.90	-66.75
Tennessee	1.57	0.69	11.04	-47.37	10.47	-0.72
Texas	1.00	2.92	32.82	-31.99	1.29	51.87
Utah	1.38	5.45	13.10	-57.26	0.31	-9.70
Vermont	1.26	2.38	4.30	-55.74	19.12	-58.08
Virginia	1.60	5.81	10.57	-20.66	18.58	26.04
Washington	1.34	-4.39	11.22	-32.03	13.34	-31.77
West Virginia	1.50	-1.09	22.12	-53.11	2.79	6.72
Wisconsin	1.50	-1.09	9.79	-37.87	15.37	-51.45
Wyoming	1.38	10.52	27.00	-14.49	0.01	-98.46
United States	1.46	3.33	11.78	-43.00	6.95	8.56

* N/A: not applicable

Clearly in states where the sector accounts only for a small proportion of total energy use, an increase in either energy diversity or use of renewable fuels or a decline in energy intensity, has smaller impact on state-wide energy security. Twenty-three states experienced a simultaneous favorable movement in all three parameters between 1980 and 2000, indicating an increase in the energy security of the industrial sector (see table 2 above). Those state are: Arkansas, Colorado, Delaware, Florida, Georgia, Idaho, Kansas, Louisiana, Maryland, Michigan, Mississippi, Montana, Nebraska, Nevada, North Carolina, North Dakota, Ohio, Oklahoma, Rhode Island, South Carolina, Texas, Utah, Virginia and West Virginia. Clearly due to the large share of primary energy use in for example Texas and Louisiana consumed by the industrial sector, the improvements in energy security in those two States have significant implications for overall energy security.

No state experienced an absolute decline (worsening in all dimensions) in the energy security of the industrial sector. As before, substantial regional differences were observed. Fuel diversity declined in 7 States, ranging from a decline of about 1% in West Virginia and Wisconsin to a 13.23% decline in Colorado. In general, however, those states that experienced a decline in fuel diversity in the industrial sector, did not experience a decline at the state level. Several states experienced significant increases in industrial sector fuel diversity. For example, New Jersey experienced a 45% increase, and Mississippi, North Dakota and Rhode Island all experienced over 30% increase. Energy intensity varies similarly between states, ranging from an increase in only one states (112% in North Dakota) to a decline of over 50% in Arizona, California, Connecticut, Idaho, Indiana, Maryland, Missouri, New Hampshire, New Jersey, New Mexico, Pennsylvania, Vermont and Utah, and a decline of 77% in Oregon. The share of renewable fuels declined in 24 states, however most of the states that experienced a large percentage decline (or a large percentage increase) only had a small proportional share of renewable fuels to begin with. Thus the only substantive decline was in Iowa, where the decline was 44% reducing the share of renewable fuels to 6.49%, Oregon, and Wisconsin, where the share declined 67%, and 51%, respectively, to a share of 10.8%, and 15.4%, respectively. Overall, most states seem to be enjoying some to substantial improvement in energy security in the industrial sector.

Electric Utilities

Electricity generation in the United States in 1980 accounted for 29% of total primary energy use (TPEU). This value increased to 38% in 2000, and indicates the importance of electric utilities in contributing to enhanced energy security in the country. Substantial state level differences are observed where this share ranges from 11% in Maine to 66% in West Virginia.
The sector also accounts for a significant proportion of total use of renewable energy in the United States, which increased from 54% in 1980 to 57% in 2000. As in the industrial sector, the relative importance of the electricity generation sector in enhancing energy security is determined by how much of total primary energy is actually consumed by that sector, and how much of renewable energy is actually consumed by the sector.

Table 3, below, presents the results for electric utilities. The table indicates that fuel diversity declined in 28 of the 48 states analyzed, and overall by 10% in the United States, where changes at the state level ranged from a decline of 92.95% in Rhode Island to a decline of less than 1% in Minnesota. This led to Rhode Island having the least favorable fuel diversity in the Nation or 0.03, with almost all of its energy coming from natural gas. Other states with unfavorable diversity are West Virginia (0.05) and Idaho (0.09), but both of those states rely mostly on renewable fuels. Fuel diversity increased, however, in 20 states, ranging from an increase of over 100% in Louisiana, Massachusetts, Missouri, Ohio and Washington, increasing the diversity rating in those states to 1.17, 1.39, 0.60, 0.44, 0.85, respectively. New York had the highest fuel diversity rating or 1.56, followed by Massachusetts with 1.39.

Table 3. Electric Utilities - Sector Results

State	Fuel Diversity 2000	Fuel Diversity % 1980-2000	Energy Intensity 2000	Energy Intensity % 1980-2000	Renewable Share % 2000	Renewable Share % 1980-2000
Alabama	0.92	-4.17	2.87	-6.99	5.12	-56.66
Alaska	N/A	N/A	N/A	N/A	N/A	N/A
Arizona	1.20	17.54	3.04	-4.25	9.57	-62.82
Arkansas	1.06	-26.10	2.95	-7.58	5.48	-33.32
California	1.12	-6.84	2.41	-25.08	37.21	7.51
Colorado	0.56	-27.88	3.04	-6.14	3.37	-50.57
Connecticut	1.24	66.77	2.84	-10.60	10.40	>500
Delaware	0.74	-19.29	2.98	-4.91	0.31	>500
Florida	1.33	2.43	2.76	-11.52	3.57	>500
Georgia	0.87	18.71	2.80	-7.34	2.00	-71.32
Idaho	0.09	N/A	2.58	-15.17	98.42	-1.53
Illinois	0.82	-10.08	3.06	-5.40	0.66	>500
Indiana	0.14	47.70	2.96	-3.59	0.55	-17.64
Iowa	0.52	-23.78	3.10	-0.01	3.42	-16.56
Kansas	0.78	6.97	3.22	-6.05	0.03	5.50
Kentucky	0.16	-34.51	3.03	-0.24	2.46	-52.21
Louisiana	1.17	249.65	2.38	-24.82	0.85	>500
Maine	0.91	-7.24	1.11	-66.22	48.30	177.54
Maryland	1.12	-8.59	2.91	-6.44	5.76	49.31
Massachusetts	1.39	124.76	2.66	-9.87	9.74	>500
Michigan	0.91	-4.92	2.91	-7.67	2.75	95.96
Minnesota	0.85	-0.96	2.83	-12.58	4.61	140.40
Mississippi	1.27	25.42	3.02	-5.98	0.00	0.00
Missouri	0.60	155.76	3.09	-0.57	0.61	-45.62
Montana	0.72	-6.71	2.73	-12.78	34.95	-44.24
Nebraska	0.88	-22.25	3.12	-7.21	4.97	-36.18
Nevada	0.89	-22.41	2.84	-14.22	14.40	-6.95
New Hampshire	0.91	-8.98	2.64	-21.50	17.15	24.00
New Jersey	1.09	-21.43	2.84	-12.85	3.88	>500
New Mexico	0.44	-27.23	3.04	-3.07	0.66	78.78
New York	1.56	2.20	2.79	-12.18	20.23	-12.71
North Carolina	0.82	33.24	2.85	-4.06	2.52	-68.48
North Dakota	0.25	-42.98	3.27	-11.35	6.20	-57.19
Ohio	0.44	135.94	2.97	-3.14	0.46	>500
Oklahoma	0.78	18.72	3.01	-0.42	3.85	29.52
Oregon	0.68	24.91	2.80	10.97	78.35	-4.82
Pennsylvania	0.84	23.09	2.99	-3.25	2.42	>500
Rhode Island	0.03	-92.95	2.46	-33.48	2.84	>500
South Carolina	0.78	-28.20	2.92	-5.12	0.49	-92.98
South Dakota	0.84	21.42	3.05	3.56	57.85	-8.98
Tennessee	0.86	67.66	2.90	-2.79	5.57	-63.01
Texas	1.02	51.24	2.73	-13.22	0.41	-19.04
Utah	0.28	-37.86	2.96	-3.07	3.29	-51.26
Vermont	0.52	-15.07	2.58	-15.40	24.85	25.54
Virginia	0.97	-19.94	2.91	-8.63	N/A	N/A
Washington	0.85	106.65	2.96	-11.99	75.16	-15.69
West Virginia	0.05	-31.31	2.83	-2.22	0.81	28.23
Wisconsin	0.80	-13.78	3.04	-5.88	3.73	-22.09
Wyoming	0.14	-35.74	3.08	0.18	2.69	-41.72
United States	1.23	-10.92	2.86	-8.44	9.26	-24.52

* N/A: not applicable

Energy intensity varied less than in the industrial sector, or from 1.11 in Maine (which mostly relies on nuclear energy and hydroelectric power), to 3.10 in Iowa, which mostly relies on coal to generate electricity. Energy intensity declined in all but three states, Oregon (10% increase), Wyoming (0.18% increase) and South Dakota (3.56% increase). Maine experienced the largest decline or 66%, followed by a 33% decline in Rhode Island.

A wide variation can be seen in the share of renewable fuels, ranging from a share of 98% in Idaho, to a share of approximately 0% in for example, Mississippi. Twenty-one states experienced an increase in the share of renewable fuels, ranging to an increase of 177% in

Maine. Several states enjoyed very large increases but as before, those states that enjoyed such a drastic an increase in the share of renewable fuels had a very low percentage of renewables to begin with. The largest declines in renewable share experienced in a state that had a considerable use of renewable was in Arizona where the percentage share of renewables declined to 9.57% in 2000, a decline of 63%.

On the one hand, only eight states (Connecticut, Florida, Kansas, Maine, Massachusetts, Ohio, Oklahoma and Pennsylvania) experienced a favorable movement in all three parameters, indicating an increase in energy security in electricity generation. On the other hand only Wyoming experienced an unfavorable movement in all three parameters.

DISCUSSION

This paper has analyzed trends in three different parameters, fuel diversity, energy intensity and percentage share of renewable fuels, that reveal whether a state and state specific sectors are moving towards or away from increased energy security and sustainable energy development. Of course those three parameters are only a small subset of a multitude of parameters that could (or should) be included in a multi-dimensional metric of energy security and sustainable energy development (see e.g. a international implementation of such a metric in Davidsdottir et al 2005). Other parameters should be for example, expenditures on energy at the state level as a percentage of total expenditures, volatility of energy prices, import dependency, various environmental parameters and a metric that captures concentration of supply and transmission lines. Consequently, based on the results in this paper we are not able to with certainty conclude that a state has become more or less sustainable, but what we are able to conclude is that a number of states have significantly enhanced their energy security both at the state level and in individual sectors, based on a relative movement in this limited number of parameters. Those states are Florida, and Oklahoma. One state has become less secure overall (Wyoming). On average we can only conclude that in aggregate United States have increased energy security of the industrial sector, but reduced the security of the electric utilities sector by reduced use of renewable fuels and reduced fuel diversity.

The most serious weakness of the analysis in this paper is the lack of weighting factors enabling the assessment of change in states that do not experience a favorable (or unfavorable) movement in all parameters simultaneously. Each parameter should eventually be weighted according to their relative impact on SED or energy security, but this remains for future efforts. Yet, despite weaknesses, this analysis does reveal the general path each state is taking (or not) towards SED and enhanced energy security. The next step, in addition to define weighting factors, is to address how those states that successfully have achieved movement in all parameters have done so, and use that as a learning experience for other states. No attempt should be made to rank states against one another as it is acknowledged that each state faces different resource, economic and geographical realities. The real emphasis in any analysis of energy security or SED should be on the fact that each individual state needs to and can do better regardless of their initial position (or static rankings). This emphasis, in contrast to more antagonistic static rankings, is more likely to stimulate change since it is primarily through collective action, based on decisions made by individual states, that slowly will move the United States towards SED and increased energy security.

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