Innovation, Technology, and Knowledge Management

Tugrul U. Daim
Leong Chan
Judith Estep *Editors*

Infrastructure and Technology Management

Contributions from the Energy, Healthcare and Transportation Sectors

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Energy

Chapter 1
Landscape Analysis: Regulations, Policies, and Innovation in Photovoltaic Industry

Dmitriy Moskovkin, Anna Mary Mathew, Qin Guo, Roli Eyetsemitan, and Tugrul U. Daim

1.1 Introduction

Reflecting concerns over the environment, health, and security stemming from the consumption of conventional fossil fuel energy sources, such as gas, oil, and coal, has been raised in the world, which increases the expectation of replacing fossil fuels with renewable energy [1]. In addition to these concerns, rising prices of fossil fuels have forced many countries to support the development of renewable energy sources, such as, solar, wind, biomass, and geothermal [3]. Among these renewable energy sources, solar photovoltaics (PV), which is also known as solar electric system, has long been considered as a clean and sustainable energy that directly converts solar radiation into current electricity by using semiconducting materials [4]. A PV system comprises a PV module and other electrical components, such as charge controllers, inverters, and disconnects. The direct conversion of sunlight to electricity occurs without any moving parts or environmental emissions during operation, which significantly protects the environment. Meanwhile, it has been

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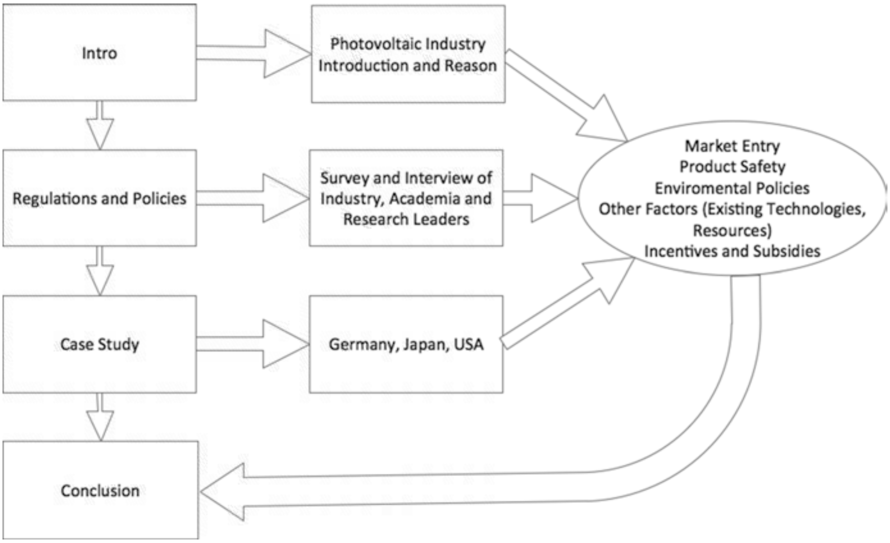

Fig. 1.1 The flow chart of the research

well proved that PV installations can operate for no less than 100 years with little maintenance, thus extremely reducing the operating cost [4]. As Fig. 1.1 shows, this report begins with a detailed analysis of policies and regulations influencing the current innovation activities of solar PV. In particular, this study pays attention to the government policy supporting technological innovation and market creation. In addition, this report profited substantially from the knowledge of a few experts and research leaders in the industry and academic field who made themselves available for interviews and other queries. Then followed with several case studies on three countries – Germany, Japan, and the USA – some data were collected to analyze how market entry, product safety, environmental policies, and incentives influence the innovation of PV industry. Finally, we provide conclusions and policy implications on the development of the solar PV industry.

1.2 Market Survey on Regulations Affecting PV Industry

Experts were consulted to gauge their feedback and further discuss the factors that affect the growth of the PV industry. The experts that were contacted were from industry, academia, and government laboratories (Table 1.1). The list of the experts is given below.

Telephone conversations and email correspondence were completed over a period of 3–4 weeks to discuss and analyze the information provided by the experts. The decision-making on this sector was done by the team based on a survey result. The survey that was put together had two questions.

Table 1.1 Expert panel from academia, industry, and government laboratories

Industry	Academia	Government laboratories
– First Solar – Accelerate Solar – Midnite Solar Inc. – Advanced Energy – Solar World – Absolutely Solar Inc. – SEIA – Accord Power	– Oakridge National Laboratory – MIT MECHE – WESRF (Wallace Energy Systems and Renewables Facility) – Portland State University – Sustainability – Penn State – Institute of Energy and the Environment	– NREL(National Renewable Energy Laboratory) – Argonne National Laboratory – Brookhaven National Laboratory – Lawrence Berkeley National Laboratory – Sandia National Laboratory

1. Rank the factors affecting the sector on a scale from 1 to 5, with 1 being the highest rank and 5 being the least. The factors that were listed were:
   (a) Market regulations
   (b) Product safety regulations
   (c) Incentives and subsidies
   (d) Environmental regulations
2. Any other factors affecting this sector.

The results of the survey are as follows:

The main comments that were obtained from the survey with respect to each of the regulations are listed below. The majority of the comments was related to incentives and subsidy regulations and was in line with the survey results indicating that incentives were the factor which had the most impact on this sector.

Comments Related to Market Regulations

"This can be a major problem when talking about grid tie equipment in Hawaii. The utilities throw up road blocks that make it hard for manufacturers to meet their requirements. The features that the utilities demand are in addition to UL and NEC standards. The utility companies are not solar friendly. What they say is not what they do. On the mainland there are utility companies that make it hard to have battery backup grid tie. They think people are going to sell their stored battery power to the grid. This doesn't make sense as it wears out the batteries. Batteries cost more than the utility power."

Anonymous Comments from the Survey Related to Market Regulation:

- Rate mechanisms (different than financial incentives) 4-grid integration technology.
- Permitting fees.
- Access to transmission lines is a barrier. I'm not sure where this fits into your classifications.
- Regulation of electric utilities.
- One of the largest challenges is the inconsistency of local jurisdiction on code requirements.

Comments Related to Product Safety Regulations
"This is a huge cost issue. The NRTL's go overboard on things that don't matter, but they have little choice. The people that make these standards set the rules. There are factors at work that sometimes have little to do with safety although it is rare. We have seen this happening first hand though on emerging standards. We spend a great amount of time and money on agency approvals. We have to do things that are not required in other countries. You have to wonder why? It affects cost of every installation, but we have no choice but to follow the rules. Standards are subject to interpretation and this also costs money needlessly. Standards change and that forces us to spend even more time and money to upgrade our products. That is senseless and wasteful" (Robin Gudgel, Midnite Solar).

Comments Related to Incentives and Subsidies
"These things help the solar and wind industry. There wouldn't be much of a solar industry without them. Conservative politicians do not see the benefit of solar so they continue to attempt to kill subsidies. They do not realize how much the oil industry is subsidized. The subsidies are not as visible. I would be all for no subsidies to any industry, but politics will never allow this. Big oil money talks big money. Solar cannot compete in the political arena. My company is heavily involved in the off-grid market where subsidies are not important. If you really need a solar system to light your house, you will get it with or without subsidies. I personally think that every house in America should have a battery based grid tie system installed. People would have more control of their power usage and would be more mindful of waste" (Robin Gudgel, Midnite Solar).

Survey Results of Panel Experts Related to This Regulation:

- Commitment to research funding.
- Support both basic and applied research at universities.
- Investment in research and development.
- Uncertainty affects growth because it potentially changes the rules. Implementing large incentive programs that flood the market with renewable energy credits waters down the price of credits for those who invested before the "free money" and is lingering disincentive after the "free money" is used up.
- Availability of low-cost solar financing.
- Research funding.
- Standards, regulations.
- Renewable portfolio standard (RPS), interconnection standards, solar access laws, training and support, building codes, solar community organizations, utility rate structures, emission requirements, R&D investments, import vs local (e.g., China vs USA).

1.3 Regulations Affecting the PV Industry

Based on the survey conducted of topic experts, the original theory of specific policies and regulations affecting growth and innovation in photovoltaic energy was confirmed. As some policies have direct impact due to involvement of governments by providing subsidies, incentives, and research funding, others may provide an indirect impact by regulating other traditional sources of energy (such environmental regulations), therefore making photovoltaic sources more cost competitive. Other regulations, which may act as financial burden for new companies entering the market, were also looked at: such as barriers for market entry and product safety requirements. Lastly consideration was also given to countries' available natural resources from existing competition as well as available solar insolation perspectives, infrastructure, and public perception to have a complete picture on a country's competitive position in regard to photovoltaic energy. The data was gathered, and comparative research was performed for Germany, Japan, and the USA. Regulations and policies in the following areas were considered: market entry, product safety, environment, other factors (existing competition, resources, and infrastructure), incentives, and subsidies.

1.3.1 Market Regulations

The product market regulations were categorized using the index developed at the OECD (Organization of Economic Cooperation and Development) on a scale from 0 to 6, with higher numbers being associated with policies that are more restrictive and stringent [5]. For each sector, the index combines information on state control (such as price control and ownership) (Fig. 1.1), barriers to entrepreneurship and administrative regulations (such as licenses and permits, administrative burdens, and legal barriers) (Fig. 1.2), and barriers to trade and foreign direct investment (such as tariffs and ownership barriers). It is evident from literature [5] that all three countries under evaluation have a total index scale below 1.3 with the USA being the least restrictive at 0.8 [5].

1.3.2 Product Safety Regulations

Product safety requirements in regard to hazards of electric shock, fire, electromagnetic capability, and hazardous substances exist in each country under evaluation. A manufacturer's Declaration of Conformity (CE marked) to applicable directives and national standards with countries' deviations is a minimum requirement for all products in the European Union and Japan. Furthermore, in Germany and Japan more stringent compliance standards (tested by accredited third-party agency such as TUV, VDE, and SEMKO) may be required by the distributors, which are particularly true for photovoltaic products including modules, inverters, and other energy interconnecting equipment. In the USA, similar requirements are governed by the National Electric Code, and authorities have jurisdiction for all electrical permanently installed products. The code requires that such products (modules, inverters, switchboard panels, charge controllers) to be listed by NRTL (National Recognized Testing Agency: UL, ETL, CSA).

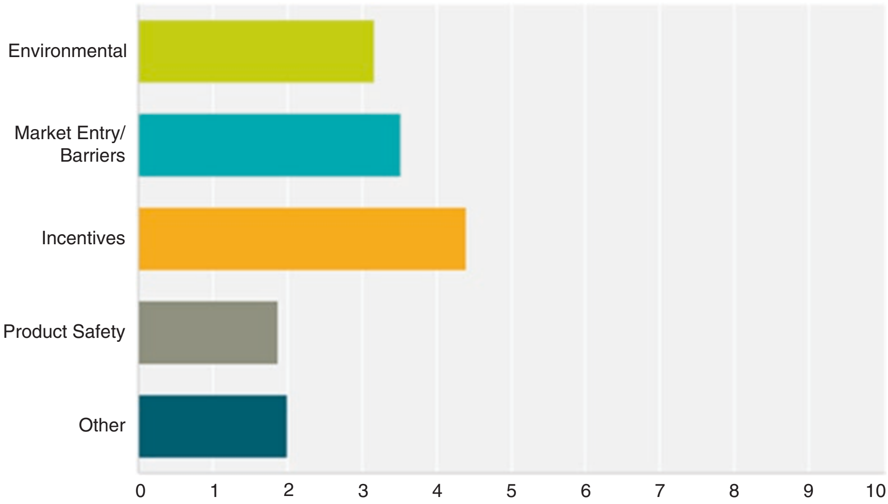

Fig. 1.2 Market survey results

1.3.3 Environmental Regulations

Environmental regulations provide an indirect positive contribution to the photovoltaic industry by setting standards and regulating those sources of energy that produce carbon emissions as their byproduct. According to OECD Environmental Directorate, a broader use of environmental taxation or an emission trading system would be one of the most efficient and effective ways of promoting green growth [6]. Taxes on pollution provide clear incentives to polluters to reduce emissions and seek out cleaner alternatives [7]. Germany (out of three countries under evaluation) is most regulated in regard to environmental regulations, it's important to note that this graph is based on revenues from taxes; therefore, countries' energy usage from all sectors needs to be taken in consideration. The next section discusses other factors related to existing competition, available resources, and infrastructure.

1.3.4 Existing Competition and Available Resources

Energy available resources, public perception, and energy cost play a significant role in government direction as well as public interests. Table 1.2 shows each country's energy consumption by source, while Table 1.3 shows the net export of fossil fuel energy sources. It's worthwhile to note that although the USA's net export for petroleum and natural gas is negative, it is the largest producer of petroleum and natural gas in the world (12,343 Thousand Barrels per Day for Petroleum and 29,542 Billion

Table 1.2 Breakdown of compliance requirements by country

Countries	Requirement	Standards
USA	OSHA accredited NRTL: UL, ETL, CSA.	UL 1703, UL 1741, UL 6142, IEEE 1547.
Germany	Self-declaration CE mark: Low voltage, EMC, and machinery. RoHS. Volunteered accredited by GS: TUV, VDE, SEMKO	IEC 60904, IEC 62109, IEC 61400, IEC 61727, IEC 62116, IEC 60364-7-712 With applicable Germany deviations.
Japan	PSE: Safety + EMC	IEC 60904, IEC 62109, IEC 61400, IEC 61727, IEC 62116, IEC 60364-7-712 With applicable Japan deviations.

Table 1.3 Energy consumption per source in 2013 [8]

Energy source	USA, %	Germany, %	Japan %
Coal	39	43	21
Natural gas	27	9.6	17
Petroleum	1	0.6	46
Nuclear electric power	19	15.9	11
Hydroelectric power	7	3.4	3
Geothermal	<1	4.3	<1
Solar/PV	<1	5.8	<1
Wind	4.13	8.6	<1
Biomass	1.48	7.0	<1

Cubic Feet of Natural Gas) [8]. Specific to natural resources, the tables below show it is evident that the USA has an overall energy independence compared to Germany and Japan, suggesting these two countries should be more aggressive when searching for alternative energy resources. Also, negative public perception for nuclear power (which is relatively a large source in Germany and Japan) adds to the trend of renewable energy, making PV a more attractive source in Germany and in Japan.

1.3.5 Incentives

Incentives are direct policy aimed to stimulate the competitiveness and growth of renewable energy technologies. Most recently, policy makers have looked to the fast-increasing demand for goods and services associated with renewable energy as an engine of economic growth. To help boost the rate of development of renewable energy in general, or photovoltaic in particular, all three countries under evaluation use market-based instruments that favor electricity generated from renewable energy [9]. Table 1.4 shows applicable methods of incentives by country with an explanation. In addition to direct subsidies for installation and growth, governments

Table 1.4 Energy net exports per source in 2013 [8]

Energy source	USA	Germany	Japan
Petroleum net exports (thousand barrels per day)	−5137.350	−2224.62	−4559.24
Coal (million short tons)	+919	−56.068	−192.852
Natural gas (billion cubic feet)	−1311	−2400.25	−4294.69

Table 1.5 Available incentives per country

Countries	Feed-in tariff	Feed-in premiums	Quota obligation	Tradable green certificates	Tax incentives	Net metering
Germany	Yes	No	No	No	No	Yes
Japan	Yes	Yes	Yes	Yes	No	Yes
USA	No	No	Yes	Yes	Yes	Yes

of countries under evaluation have other forms of incentives. These include funding research and development in an effort to raise the efficiency of renewable energy, improve its reliability, and reduce its costs. This type of incentive is further developed in the case study (Table 1.5).

Feed-In Tariffs (FIT) Renewable energy power investors are compensated for the power they provide to the grid and receive a long-term contract with a rate higher than the rate for traditional sources of energy [10].

Feed-In Premiums Payment level is based on a premium offered above the market price for electricity enabling developers to enjoy high returns when market prices increase, but also run a risk of losses when they decrease [10].

Renewable Portfolio Standards/Quota Obligation It is a regulation set by government where utility companies are obligated to generate a certain percentage of their power from renewable sources [11].

Tradable Green Certificates These are tradable certificates awarded for the generation of a given amount of power from solar sources [12].

Tax Incentives These are federal tax credits for development and deploying of renewable energy technologies.

Net Metering It is a billing mechanism where electricity generated by consumers and fed in to the grid is used to offset electricity consumed by the consumer [13].

1.4 Case Study: Photovoltaic Sector in Germany, the USA, and Japan (1990–2015)

The overall ranking of the countries based on solar energy generation by MW and other factors such as solar intensity, GDP, and population is considered. Patent activities in the green patent family which include the EPO (European Patent Office), PCT (Patent Cooperation Treaty), and USPTO (US Patent and Trademark Office) were considered. The country that emerged as the leader in the solar photovoltaic energy generation was Germany by producing nearly 27% of the total power generated using this technology. The two other countries that were studied were the USA as the country leads in patent activity in this domain and also contributes to 11% of the total solar power generated globally and Japan which falls close behind the USA with a contribution of 10% of the total solar power generated from photovoltaic.

1.4.1 Case Study 1: Japan

The Japanese photovoltaic (PV) market is expanding rapidly. By 2013, the installation of PV was over twice the amount in 2011, which places Japan among the world's largest PV markets, along with Germany, China, and the USA [2]. The national and local governments have implemented a variety of policy measures to support the innovation and diffusion of solar PV technologies in Japan (major policies are summarized in Table 1.6). These policies can be divided into two sections: demand side and supply side.

Demand-side policies could be used to "create a new market and develop demand for a new technology," including subsidies for purchase of "a particular product, tax breaks, and renewable portfolio standards." [1] For example, in July 2012, Japan introduced the FIT, which requires utilities to pay renewable energy producers a fixed price per kWh of production over a period of 10–25 years. Purchasing tariffs are reduced on annual basis but may be adjusted if deemed necessary. The government guarantees a purchasing rate of 37 yen (FY 2014) per each kilowatt-hour (kWh) for a time period of 10 years for systems smaller than 10 kW while larger get 32 yen (FY 2014) per kWh (excluding taxes) for a contracting period of 20 years granted for the total electricity production. The Japanese FIT will remain in place until 2021 with a revision of the scheme conducted every 3 years [3].

Supply-side policies are used to encourage firms to directly conduct innovation activities, including subsidies for R&D, illustration, and sometimes in early phases of commercialization [2]. For example, In the 1970s, the scarce local fossil fuel reserves and multiple issues associated with acquiring oil from foreign countries motivated the Japanese government to pursue the development of solar PV technologies. In 1974, the government launched the Sunshine Project, focusing on the development of solar cells and modules, which opened up an opportunity for most of the Japanese solar manufacturers, such as Hitachi, Toshiba, and NEC Corporation, to be involved in solar PV research and development (R&D). From 1993 to 2000, an additional R&D program, called the New Sunshine Project, was launched to develop the balance of system (BOS) technologies with the funding from the Japanese government (including inverters, mounting equipment, monitoring systems, and site assessment). The solar cell production had increased significantly since 1974. These national research and funding programs contribute to both the technological development and the growth of solar PV market in Japan (Table 1.7).

Table 1.6 Summary of major policies related to solar PV technology (demand side)

Demand-side policies		
Year	Policy	Notes
1974–2006	National residential subsidy	First phase: 1994–1996 Second phase: 1997–2001 Third phase: 2002–2006 (March)
1997	Act on special measures for the promotion of new energy use	Financial support for the business operators who use the new energy including solar energy
2003	Renewable portfolio standard	Requiring electricity retailers to supply a certain amount of renewable electricity to grid consumers
2009	National residential subsidy resumed	National residential subsidy will end in 2014
2012	Feed-in tariff	Electricity utility companies are obligated to purchase excess electricity generated through PV facilities

Table 1.7 Summary of major policies related to solar PV technology (supply side)

Supply-side policies		
Year	Policy	Notes
1974	Sunshine Project	A national R&D project for “new energy” including solar energy
1980	Establishment of the New Energy and Industrial Technology Development (NEDO)	Act on the promotion of development and introduction of alternative energy
1993–2000	New Sunshine Project	The successor of the Sunshine Project
2001–2005	NEDO 5-year plan	Development of technology to achieve 482,000 kW of installation of PV by 2010
2004	NEDO Roadmap 2030	Direction of photovoltaic technology development toward 2030
2009	NEDO Roadmap 2030+	Update of the Roadmap 2030

Japan’s PNV industry witnessed remarkable growth in 2013 after the establishment of the feed-in tariff program in 2012. The feed-in tariff has been known to result in rapid growth in the renewable energy market in areas where it has been implemented. The Japanese government had one of the most generous feed-in tariff rates in the world, and they did not anticipate the growth that resulted from the program. The infrastructure to handle the amount of solar power produced was not in place, and as a result the utility companies were overwhelmed and started blocking access to the grid for new power solar generation. The country has since reviewed the programs and reduced the support [22].

1.4.2 Case Study 2: Germany

Solar power in Germany consists mostly of photovoltaic (PV) and accounted for an estimated 6.2–6.9% of the country's net-electricity generation in 2014 [14].

Germany is the world's top PV installer with an overall installed capacity of 38,359 megawatts (MW). The renewable energy sector contributes nearly 31% of the total electricity produced in the country. The German government long-term minimum targets of renewables' contribution to the country's overall electricity consumption are 35% by 2020, 50% by 2030, and 80% by 2050.

Factors Affecting Growth in Solar Sector

Boom period in Germany was during 2010–2012. More than 7 GW of PV capacity had been installed annually during this period. Due to the large amount of electricity produced, the country is currently facing grid capacity and stability issues. The country is increasingly producing more electricity than it requires, driving down prices and exporting its surplus to other countries (record exported surplus of 32 TWh in 2013 and 34 TWh in 2014) [15]. New installations of PV systems have declined steadily since 2011 and continued to do so throughout 2014. As of 2012, the FIT costs about €14 billion (US$18 billion) per year for wind and solar installations. The cost is divided across all ratepayers in a surcharge of 3.6 €ct (4.6 ¢) per kWh (approximately 15% of the total domestic cost of electricity).

The legislative reforms stipulate a 40–45% share from renewable energy sources by 2025 and a 55–60% share by 2035 [14].

1.4.3 Case Study 3: The USA

US Solar Innovation Timeline

Innovation in solar technologies began as far back as the seventh century and has continued to this day. Just like with the PC industry, there has been development and milestones achieved that have opened the way for new opportunities and growth in the industry. The USA has recorded tremendous progress in research and development in the PV sector; also noteworthy is the increased number of solar technology-related patents. The activities in the sector have been stimulated by the government's dedication to supporting research and development activities which would drive low cost and improve efficiency of solar PV systems. A timeline of US Solar Innovation is shown below [20]:

- 1955 Researchers at Bells lab overcome difficulty to create 6% efficiency PV.
- 1959 Manufacturers hit 10% efficiency.
- 1970 Western electric patents coating for solar cells.
- 1972 Institute of energy conversion formed.
- 1977 Department of Energy formed.
- 1978 California passes solar right act.
- 1980 Manufacturers break 1 MW barrier PV module in 1 year and IEC exceeds 10% efficiency.

- 1985 Stanford produces 25% efficiency cell.
- 1986 First commercial thin film solar module produced.
- 1993 Utility company installs first PV distributed system.
- 1994 NREL develops 30% efficient cell.
- 1996 National Center for PV created.
- 1998 Million Solar Roof initiative.
- 2000 First Solar builds world's largest PV manufacturing plant.
- 2011 SunShot Initiative announced.

PV Growth in the USA

There has been tremendous growth in the US PV industry in the last 4 years especially in utility and residential PV installation. 2014 witnessed a growth that was about three times what it was in 2011 and seven times what it was in 2010. In the first half of 2014, over half a million home owners and businesses had installed solar PV, and solar represented 36% of new energy that came online in 2014 [16].

Solar energy accounts for 0.3% of the total energy consumed in the USA. The capacity of utility scale solar has increased from 334.2 megawatts in 1997 to 6220.3 megawatts in 2013 [21].

One reason for the tremendous growth in the US PV sector in the last few years is the presence of low-cost PV modules from Japan in the US market. Although this increased the installation of solar systems, US manufacturers have been impacted and the US government imposed tariffs on PV systems from China, leading Chinese manufactures to outsource PV manufacture to Taiwan. US manufacturers have petitioned the government to impose tariffs on Chinese PV systems from Taiwan, a PV manufacturer in Hillsboro, Oregon. Solar World is in the forefront of this struggle.

Another reason for the growth in the sector is government incentives. Most governments at the state and federal level offer incentives to spur investment in the renewable energy sector. These incentives make investment in the renewable energy sector more appealing for public and private entities. Incentives are mostly financial and are in the form of loans, grants, tax deductions, or exemption [17].

US Federal Incentives

Incentives offered by the federal government to encourage growth in the PV sector include

Grants

- Tribal Energy Grant program provides funding for tribes to develop community and commercial scale renewable energy projects.
- USDA (Rural Energy for America Program (REAP) and Energy Audit and Renewable Energy Development Assistance (EA/REDA)) assists agricultural and small rural businesses with the development and setup of energy efficiency and renewable energy systems.

Loan Programs

- US Department of Energy (loan guarantee program) provides loan for new or improved technologies that reduce air pollution.
- FDA PowerSaver loan program is granted by the Federal Housing Authority to provide assistance to homeowners for energy efficiency and renewable energy upgrades.

- Qualified Energy Conservation Bands and Clean Renewable Energy Bonds – These bonds are used to finance renewable energy projects [18].

Tax Incentives

- Corporate tax credit
- Business energy investment tax
- Renewable electricity production tax credit
- Corporate tax exemption
- Personal tax credit
- Residential renewable energy tax credit
- Personal tax exemption
- Residential energy conservation subsidy exclusion

State Incentives

The USA is an amalgamation of 50 states with individual political processes, electricity prices, and unique sets of incentives and regulations to stimulate growth. PV sector state incentives include:

- FIT – This incentive has been proven to stimulate explosive growth in the renewable sector in areas where it is implemented, so much growth that the regulation has to be constantly reviewed. The feed-in tariff or some variation of it existed in California, Hawaii, Maine, Oregon, Rhodes Island, Vermont, and Washington in 2013 [19].
- Rebate for purchasing renewable generation equipment.
- Renewable portfolio standards to ensure that utility companies generate a percentage of power from renewable sources.
- Net metering – Power produced by consumers and supplied to the grid is used to offset the power he consumes.
- Tax incentives.

Another important factor promoting the growth in the US PV market is Research and Development.

Research and Development

The US government has not been as aggressive as Germany and Japan in their use of subsidies as incentives. Although the feed-in tariff has been adopted in some states, it has never been a federal initiative in the USA. The USA chose a slightly different approach to pursue growth in the PV industry. Given the fact that the cost of solar power is very high, even in Germany and Japan where it has been widely adopted, the USA is actively and aggressively involved in research and development in solar technologies to drive down costs and increase efficiency of solar systems. A number of programs have been established to help with this.

SunShot Initiative

The SunShot Initiative was established by the Obama administration in 2011, and it involves a 10-year plan by the Department of Energy aimed at making competitive solar power a reality. The plan is to reduce the cost of solar power and bring it to par with other traditional sources of power by 2020.

The goal is to drive this through innovation in manufacturing, installation, and market solutions. Less than halfway through the project lifetime, over a half of the goals have been accomplished, and solar power has been reduced to 11cents/kwh [5]. However, the goal of 6cents/kWh by 2020 seems rather ambitious considering the fact that China currently has the lowest cost in the world and their low cost is driven by government subsidy rather than innovation. The solar industry in China is heavily subsidized by the government; this is a strategy by the government to make China the world leader in the PV industry. If the USA is able to drive low cost by innovation, this would cause explosive growth in the US PV market.

1.5 Conclusion

In addition to differences in overall technological levels and life standards, reviewed regulations and policies although important do not completely explain cross-country differences in innovation.

The research showed that incentives and subsidies play a major role in emerging technologies during the initial process of "jump starting" the industry; however, transformation from directly subsidizing a somewhat mature industry to investments in Research and Development (Academia and Industry) and Public Education (Environmental Policies) is a critical step in innovation. As it appeared in case with Germany, simply increasing PV installation capacity and other renewable energy sources didn't translate into patent growth or reduction in cost, but rather had an opposite effect (refer to summary table below), due to excessive feed-in tariffs and grid management problems. Additionally, Germany's carbon output and global warming impact is actually increased despite increased in PV energy capacity, due to utilities being forced to use of dirty coal power because it's only a nonsubsidized power source.

Country	Solar energy capacity in GW in 2011	Solar energy patents global % in 2011	$/kWh in Cents in 2011	2009–2014 CO_2 emissions %
Germany	35.5	6.1	35	+1.2
Japan	13.6	34.1	26	+1.3
USA	12	14.1	12	−3.4

The combination of policies, market, and product safety deregulation is a very effective method of inducing innovation in emerging technology such as PV energy; however, the extent and aggressiveness of these policies should depend on a country's resources, infrastructure, and existing competition. Additionally, product safety regulations may set higher standards in efficiency, safety, and reliability, positively effecting innovation.

References

1. Takeda, C. "Government policy and innovation activity: a patent study of solar photovoltaic balance of system in Japan," *PhD diss*, 2014.
2. Friedman, B., Margolis, R., & Seel, J. "Comparing Photovoltaic (PV) costs and deployment drivers in the Japanese and U.S. Residential and commercial markets," *National Renewable Energy Laboratory (NREL)*, 2014.
3. Kimura, O., & Suzuki, T. "30 years of solar energy development in Japan: co-evolution process of technology, policies, and the market," *Berlin Conference on the Human Dimensions of Global Environmental Change: "Resource Policies: Effectiveness, Efficiency, and Equity,"* Nov, 2006.
4. Wikipedia. (2015, Mar). Photovoltaics. [Online].
5. Wolfl, A., Wanner, I., Kozluk, T., & Nicoletti, G. *The years of product market reform in OECD countries – insights from a revised PMR Indicator* 24-Apr-2009. Available: www.oecd.org/eco/working-papers. Accessed 14 Mar 2015.
6. OECD, Environmental Directorate. Environmental policy tools and evaluation. Available: http://www.oecd.org/env/tools-evaluation/environmentaltaxation.htm. Accessed 14 Mar 2015.
7. Braathen, N. A., & Greene, J. OECD, Environmental Directorate. Centre for Tax Policy and Administration. Available: www.oecd.org/env/taxes/innovation. Accessed 14 Mar 2015.
8. U. S. Energy Information Administration. Available: www.eia.gov. Accessed 14 Mar 2015.
9. Domestic incentive measures for renewable energy with possible trade implications. OECD Trade and Environment Paper No. 2013/01. Available: www.oecd.org/trade/envtrade. Accessed 14 Mar 2015.
10. Wikipedia. Available: http://en.wikipedia.org/wiki/Feed-in_tariff. Accessed 14 Mar 2015.
11. Wikipedia. Available: http://en.wikipedia.org/wiki/Renewable_portfolio_standard. Accessed 14 Mar 2015.
12. Wikipedia. Available: http://en.wikipedia.org/wiki/Renewable_Energy_Certificate_%28United_States%29. Accessed 14 Mar 2015.
13. Wikipedia. Available: http://en.wikipedia.org/wiki/Net_metering. Accessed 14 Mar 2015.
14. Wikipedia. Available: http://en.wikipedia.org/wiki/Solar_power_in_Germany. Accessed 10 Mar 2015.
15. http://www.germanenergyblog.de/?page_id=283. Accessed 15 Mar 2015.
16. http://www.renewableenergyworld.com/rea/blog/post/2014/09/u-s-solar-industry-continues-rapid-growth. Accessed 12 Mar 2015.
17. http://aceee.org/topics/financial-incentives-energy-efficiency. Accessed 11 Mar 2015.
18. http://programs.dsireusa.org/system/program?state=TER. Accessed 2 Mar 2015.
19. http://www.eia.gov/todayinenergy/detail.cfm?id=11471. Accessed 5 Mar 2015.
20. http://energy.gov/eere/sunshot/solar-innovation-timeline. Accessed 13 Mar 2015.
21. http://instituteforenergyresearch.org/topics/encyclopedia/solar/. Accessed 9 Mar 2015.
22. http://www.japantoday.com/category/opinions/view/japans-feed-in-tariff-program-becomes-a-solar-shambles

Chapter 2
Landscape Analysis: Fracking Technology

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2.1 Introduction

Hydraulic fracturing of oil- and gas-bearing rocks, also known as fracking, is an established technology. Hydraulic fracturing was first started experimentally in 1947 in the Hugoton oil field in Kansas [1]. Fracking is an old technique that is used to increase the production of oil from the worked-out oil wells. However, it is considered as a new tool for producing natural gas. Fracking has been developed gradually by some international companies and organizations with no government support until the success has been proven.

Lately, in 2011, the shale gas boom has started to introduce the fracking technology with more power in the oil and gas industry. In the USA, researchers showed their interest to investigate the role of federal agencies in supporting gas industry experimentation by using shale fracking technique. The Department of Energy played a significant role in improving this technology. Also, the National Laboratories made a big contribution in developing the hydraulic fracking process.

Indeed, the fracking technology is considered in the oil and gas industry as a newly developed drilling technique because it is depending on a complicated process such as a high pressure, specific chemical solutions, and a huge amount of water mixing with the sand. These components are used to free oil and natural gas from the shale rocks under the earth's surface. This technology has made a lot of profit for oil and gas companies. However, fracking has some challenges, such as people from different societies arguing that fracking creates a negative impact on human and environmental health. On the other hand, others are saying that this

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technology helps to meet the current and future energy needs. Also, it could save the countries' economies from collapsing.

Therefore, most of oil and gas companies work hard to make sure that the fracking is a sustainable development process for money-making opportunities. Most of these companies often give large sums of money to societies by running some social investment programs or sustainable development projects. These initiatives aim to develop the people and their facilities around areas of fracking operations.

2.1.1 Fracking Process

The Environmental Protection Agency (EPA) described the hydraulic fracking as a high technology process which is drilled vertically or at a measured angle. This process is starting from the well surface to a depth of 1–2 miles (approximately 1.6–3.2 km, some times more). During the drilling, the vertical well is coated by steel or usually by the specific material of cement to ensure the well doesn't run the risk of leaking [2].

Once the vertical well reaches the layer of rock that includes the natural gas or oil, the drilling converts horizontally along that rock layer. Then, the horizontal drilling curves about 90°, and the drilling can extend more than a mile (1.6 km) after the end point of the vertical drilling process.

After the fracking well is fully drilled and protected (shielded) by adding a coating of steel or specific cement around the well formation, fracking fluid is pumped down into the well at extremely high pressure.

The high pressure that is created by high power machines is powerful enough to fracture the surrounding rocks. The high pressure is used to create cracks through the rocks that help the oil and gas flow to the surface.

The slick water is the fluid that is pumped into the well which contributes to fracture the deep rocks. The fluid is mixed sand, salts, and chemical components. The rate of the chemical solution that is added to the fluid is usually about 0.5–2%, while the remaining percentage consists of plain water. Sands and clay particles are also added to the fluid. Both of these elements are pumped into the fracking well to open the fractures through the rocks. The fluid is formed under high pressure to ensure that gas and oil can continue to flow out from the fractured rocks. The chemical solution helps the fluid to keep liquefied and direct the oil and gas to the surface even after the pumping pressure is released.

The injecting of fluid by high-pressure pumps is the most critical process in the hydraulic fracking operation. This fluid requires millions of gallons of freshwater and high-pressure pumps that are able to trap and extract the natural gas and oil to inject them back to the surface [2].

2.1.2 Research Objectives

This research aims at general Assessment of Fracking Technology in Energy Industry without being constrained to any specific issue. Thus, it had three distinct objectives which are designed as questions:

Q1. Why is the energy industry jumping into fracking?
Q2. What are the economical, environmental, social, political, and technical effects/impacts of adopting fracking technology?
Q3. Is fracking a suitable technology for future energy?

2.1.3 The Big Energy Source and Its Future Challenge

The future of energy has changed especially in the oil and gas industry. In the past, the growth in production was measured based on the western market demand. Natural gas has a significant role in the future energy. New technologies are being developed to explore and extract the conventional and unconventional gas with many ways to get a maximum benefit from its abundance. Increase in the natural gas production has improved producer countries' GDP growth [1]. During the past decade, oil and gas prices have moved to a permanently high level. Power companies have been working hard to produce more efficient power plants and transportation facilities and supply alternative fuels to reduce the future impact of the full dependency and the huge demand of the oil and gas in some industries. On the other hand, always there are new innovative technologies and techniques which have been introduced by some international companies and manufacturers to improve the production process and to reduce the production cost and uncertainty of producing unconventional oil and gas in this world. So, there is a question of why natural gas is the most inspiring product in the future? To answer this question, we should discover the oil challenges in the energy market in two scenarios (low and high price):

2.1.3.1 Low Oil Price Scenario

The Organization of Petroleum Exporting Countries (OPEC) is the organization that manages the oil and gas production market shares among its members. Although the significant efforts of OPEC are continued to control the oil and gas production, in the low oil price scenario, the results are still less successful in restricting production. As a result of OPEC effort in this scenario, its share of total world liquid production is expected to increase reaching 49% by 2040. On the other hand, in spite of the lower price of oil and gas in the world market, the non-OPEC producers are expected to maintain their production at roughly 54 million barrels per day, through 2030. Moreover, due to high cost, they decline to use the enhanced oil recovery (EOR) technologies to develop the existing worn-out fields. In the case of the low oil and gas price, the average costs for resource development are considered high. For this reason, the non-OPEC countries are not able to develop their worn-out fields. As the non-OPEC production rises slightly in the projection through 2030, the expectation indicates to return their crude oil production to roughly 51 million barrels per day in 2040. In 2015, the crude oil price had fallen below $80 per barrel and then to $70 after a few months. In 2016, the price fell below $50 and is expected to follow by a slow increase to average $75 per barrel in 2040. Due to lower economic growth especially in non-OECD (Organization for Economic Cooperation and Development) countries, the oil price impacted negatively the world [2].

2.1.3.2 High Oil Price Scenario

In this scenario, the GDP growth in non-OECD indicates that its rapid growth is more than the projected in the reference case. The liquid fuel consumption per unit of GDP is declining than projected in the reference case. Due to the continuing restrictions on oil production, OPEC maintains its market share of total liquid fuel production. OPEC produces about a million barrels per day which about 37–40% of the world market share. This value is lower than the value in the reference case. The limited access to the existing resources and lower discovery rates lead to consider the increase in the oil prices in non-OPEC petroleum production expanding approximately as the rate in the reference case. Other liquids rise to eight million barrels per day and are considered as strong in response to the higher prices in 2040. In the high oil price case, the oil increases from $155 per barrel to $237 in 2020 to 2040, respectively. Based on the increase in the robust price, the total world demand maintains within the range of expected production capabilities [2].

2.2 The STEEPLE Method (History and Rationalization)

The PEST (political, economic, sociocultural, technological) analysis technique was innovated by professor Francis Aguilar at Harvard. In the early 1970s, Arnold Brown came up with the acronym “STEPE” when he added a second “E” for Ecological issues in addition to Aguilar’s Social, Technical, Economic, and Political Perspectives [3]. The technique went through a sequence of changes. Various acronyms used by practitioners are as follows: PEST (political, economic, sociocultural, technological), PESTEL (political, economic, sociocultural, technological, environmental (or ecological), legal), PESTLIED (political, economic, sociocultural, technological, legal, international, environmental (or ecological), demographic), and STEEPLE (sociocultural, technological, environmental (or ecological), economic, political, legal, ethical) [4]. STEEPLE analysis identifies the changes in the macro environment external to the organization in order to respond to the changing environment in a timely and appropriate manner [3]. In the energy sector, STEEPLE analysis helps

Table 2.1 Importance of STEEPLE for energy technologies [6–9]

Issues	Description
Social	It is important to clarify social acceptance at the initial stage of energy technology development. Conflict may cause a blockade of the technology. It is important to understand the intensity of rejection of the technology to manage or take a decision at the early stage of development
Technological	Energy technology systems need to be clarified objectively. Rather than relying on developers or practitioners, technology needs to be critically analyzed by experts to identify and recognize all consequences and issues
Economical	Initial investment and leveled cost of the technology needs to be assessed in order to rationalize its adoption
Environmental	Energy technologies should reduce emissions. A full assessment is needed to reveal consequences that may affect the plant, animal, and human species
Political	Political interference can significantly affect energy technology adoption. Political pressure can make the government facilitating the development or arranging subsidy programs or other incentives contribute in increasing the number of beneficiaries. On the contrary, politicians may exacerbate the adoption by propaganda
Legal	Legal or policy instruments enhance the adoption and commercialization of energy technologies. The government is the key player in formulating policies that pervade all other criteria. Social, technological, economical, and environmental consequences can promote adoption or rejection of a certain energy technology. However, these consequences are mediated by government policies
Ethical	Any technology that harms the environment and puts human life in jeopardy is ethically unjust. In spite of its huge potential, the development of energy technologies gets hindered if it cannot live up to ethical codes

to analyze technology from a different perspective. It facilitates the development and diffusion of energy technologies [5]. Table 2.1 describes the importance of different perspectives for energy technologies.

2.2.1 Description of the Model

The STEEPLE model in Fig. 2.1 describes the different issues that are considered in assessing the fracking technology.

2.3 Fracking Technology Assessment

2.3.1 Social Perspective

Social perspective identifies aspects that affect society positively or negatively [10]. Four important aspects in social perspective are public perception, employment, health and safety, and Local Infrastructure Development.

Fig. 2.1 STEEPLE for fracking technology assessment

2.3.1.1 Public Perception

Views that are shared by population, social norm, and media coverage shape the perception of the mass. Public perception is reflected in aesthetics, lifestyle, social benefits, and social acceptance. National polling data published in the year 2014 found American population to be mostly ignorant or ambivalent toward fracking. A small minority who knows about fracking are equally divided into a pro-fracking and antifracking stance. Those who are in opposition to fracking are found to be mostly women, open minded, and knowledgeable about fracking issues as these women possess a habit of reading the newspaper more than once a week and talks about the impact of fracking on the environment. People in favor of fracking are mostly older; minimum educational qualification is bachelor's degree, conservative political views, watch TV, and appreciative about the economic and energy supply effect due to fracking. The accepted perception that better education creates negative impression toward fracking is proved wrong through the survey [11].

2.3.1.2 Employment

Employment is pertaining to job. It clarifies job creation, availability of workers, and poverty alleviation. The creation of job opportunities by fracking is an issue of controversy. Different groups have conflicting claims. Pro-fracking groups claimed the creation of 48,000 jobs from the end of 2009 to early 2011. However, antifracking parties denied this claim in the plea that these were new hires and the actual number was proven to be 5700 during the same period. Bureau of Labor Statistics revealed that the employment created by oil and gas operations (onshore and offshore) is less than 1/20th of 1% of the overall US labor market since 2003–2011. Moreover, employment of less educated workforce and high wage lead to increased number of dropouts of college students in these counties and cripple the ability for future development [12]. Migration of more people in the fracking areas burdens existing services, traffic, and accommodations, and there is a struggle for limited resources that sometimes leads to animosity among people from different cultures and places.

2.3.1.3 Health and Safety

Health and safety are concerned with safety, health, and welfare of people, society, and workplace. Technology should not affect public safety and work safety and should not cause long-term health issues. People and workers are vulnerable in areas of fracking to different contaminants emitting out of fracking operation. This causes many forms of respiratory diseases. Occupational health hazard of workers in the fracking industry is an issue of concern. Workers may get affected by chemicals and also machineries used in fracking sites. Workers are exposed to dust, crystalline silica, and fracking fluids that cause fatal health hazards. Also, workers may get hit by moving equipment and high-pressure lines, be entrapped in between two moving parts of a machine, or suddenly be exposed to high-pressure release. Due to flammable gas and materials in fracking sites, there is a high probability of fire explosion. Worker sometimes needs to work in a confined space under high power lighting. All these events may lead to fatal injury, disability, or sometimes death [13]. The nonoccupational health hazard is caused by polluting gases and harmful chemicals and silica that are used in the fracking process and contaminate groundwater or atmosphere. Sudden economic expansion or recession which is known as "Boom and Bust" sometimes causes mental stress to people in the community. Fracking causes a sudden increase in economic activity. This increase in local economic activity is often followed by a rapid decrease upon depletion of the resources. Living cost soars as oil and gas industry can pay more. This creates hardship for the community.

Local Infrastructure Development Infrastructure development is supposed to improve transportation, help to develop related industry, and better productivity and quality of life.

Due to the construction of well pads, waste pits, access roads, pipelines, compressor stations, and other infrastructure, pristine landscapes are ravaged by industrial zones. Spoiled infrastructure and economic, environmental, and social degradation are the aftermaths of a sudden halt of fracking. The cost of destruction is shared by taxpayers. Human habitats are replaced, lands are divided, open spaces are sacrificed, and sometimes tourist attractions are crushed to make way for fracking [12].

Many probable actions have been proposed by government, practitioners, and researchers to minimize or eliminate the negative impacts of fracking. Occupational Health and Safety Administration (OSHA) and National Institute of Occupational Health and Safety (NIOSH) developed a detailed guideline for protecting workers of fracking industries. Protective equipment, planned work process, engineering control, worker training, and mostly minimizing exposure of workers to harmful chemicals are some of the suggestions made by the organizations [14]. In many states, the probable impact of fracking is assessed for a certain locality and ranked based on their severity. Depending on the intensity of impact, preventive measures and action plans are prepared ahead of time to reduce the negative effect of fracking on human health [15]. Several states as well in many countries, for example, in South Africa near diamond production zones, industries are compelled to pay an impact fee, and it is saved as fund during the boom period. This fund is utilized when fracking process discontinues or the bust period starts, to compensate the people impacted, restore the landscape, or drive the economic activity. Rural, forests, farmlands, and locations of tourist attractions are impacted with fracking constructions. This can be reversed by implementing zonal restrictions by the government and protecting places and landscapes of public importance [16].

2.3.2 Technical Perspective

The oil and gas industry has a positive impact on the economy by introducing the new fracking technology to extract hydrocarbons from areas and distances that previously thought unreachable. The new technology improves the horizontal drilling in addition to the enhanced oil recovery (EOR) [17, 18]. The fracking new technology could extract oil or gas double recoveries of that amount in the conventional drilling [19]. Recently, light and medium oil and gas production have started to get more attention by smaller players in oil and gas business. They are focusing on the more profitable light-to-medium oil production. Also, as a result of increasing market demand regarding the natural gas, international oil and gas companies develop sour gas plants to increase the natural gas liquid productivity [20].

2.3.2.1 Diesel Fumes

The hydraulic fracking uses the diesel fuel as the main source to power the drilling machines in the drilling and production process. However, the diesel-powered equipment can be a high potential risk or annoying source of harmful pollutants. Also, it can be a source of the carbon emissions that might affect the environment and cause global warming. Recently some international companies announced that the natural gas would be the primary source of fracking power machines. The natural gas will reduce the carbon emission and the fuel cost that is used during the fracking operation by about 40%. Solar panels are another energy source which has been adapted by Halliburton oil and gas service company in the fracking process. The company innovated the sand castle vertical storage silo technique to use entirely with the solar panel. Moreover, Halliburton was successful in reducing the consumption of power on site by 70%. They developed the powered pump trucks to be working at the location of the natural gas [21]. The diesel fuel contains BTEX compounds (benzene, toluene, ethylbenzene, and xylene). These compounds are considered as risk that might impact the human health through its potential leaks to the drinking groundwater [22]. Now companies are working hard to sophisticate engines and turbines that use natural gas as a fuel [23–25].

2.3.2.2 Fracturing Period

There are differences between the typical use of hydraulic fracturing between the US states. The fracking process may take weeks to get access to the oil or gas sources through the reservoir rocks. Horizontal drilling is a complicated process which requires lengthy fracturing periods. Also, the horizontally drilled production wells need about four to eight millions of gallons of water. This amount of water is injected under the surface with constant pressure which might need extended period of time to complete its process. However, the fracking in California has sophisticated by using innovative technology to reduce the fracturing time. They use less fluid to fracture within a narrow vertical band along a well; then they change the direction of drilling horizontally only a few hundreds of feet from the last point of vertical drilling [26]. To integrate a steam fracking process, the use of low-gravity hydrocarbons as a diluent for the targeted heavy oil can decrease the fracturing periods [25, 27].

2.3.2.3 Safety: Blowout Prevention

According to statistics of energy wire organization, the federal labor section, the oil and gas industry workplace fatalities result in about 10% of deaths caused by fires and explosions during the past 5 years. Safety has become increasingly important in the oil and gas industry. Due to fracking boom which pushes into closely populated areas, oil and gas companies are required to perform the safety process before, during, and after the drilling and production operations. Also, the workforce and people inside and around the operation areas should have enough knowledge of safety procedures.

Recently, the Wall Street Journal reported that “At least 15.3 million Americans lived within a mile of a well that had been drilled since 2000, that is more people than live in Michigan or New York City” [28]. Also, a research paper from the Public Health School at the University of Colorado noticed that “Accidents at well sites don’t simply threaten workers but can also expose those who live nearby to fires, explosions and hazardous chemicals” [28].

Fracking companies are required to comply with all safety procedures and processes that are recommended by the American Petroleum Institute (API). They should carry out all blowout prevention equipments of inspection process during the drilling and production. Companies are required to register and record all inspection and closure test as scheduled by the safety department. In case blowout prevention equipment is not functioning well, the operation should hold the blowout prevention equipment until it is fixed and retested [29].

2.3.3 Economic Perspective

2.3.3.1 Abundance of Shale Gas Reserve/Supply

The US Energy Information Administration (EIA) assessed 48 shale gas basins in 32 countries, with a result of 6622 Tcf (trillion cubic feet) shale gas and 6609 Tcf conventional gas worldwide. This means that the shale gas reserve contains a similar amount of conventional natural gas [30]. Later, EIA report indicated that 2013 estimation for the total world would be increased to 7299 Tcf, considering 41 countries, 95 basins, and 137 formations, as shown in Table 2.2 [31]. It appears that the global estimation of shale gas reserve has been promising over the recent years.

In the USA, the Marcellus Shale is reported to contain large amount of shale gas across western New York, Pennsylvania, and Ohio states. The reserve has been estimated to be sufficient for 45 years of the consumption [30]. By looking at the estimation reports over the past few years, the reserve of the shale gas seems to be increasing, due to more basins and formations being discovered and incorporated.

Table 2.2 Reports of shale gas reserve from EIA 2011 and 2013 [31]

ARI report coverage	2011 Report	2013 Report
Number of countries	32	41
Number of basins	48	95
Number of formations	69	137
Technically recoverable resources, including the USA		
Shale gas (trillion cubic feet)	6622	7299
Shale/tight oil (billion barrels)	32	345

2.3.3.2 The Increase of Natural Gas Production

As a result of the sufficient reserve fund, the gas production has been stimulated and growing. For instance, the natural gas production in the USA has been increased over a decade. The shale gas is considered as the largest contributor to this growth from 2012 to 2040 [32]. EIA (2015) reported that the total natural gas had been produced 35% more during the period 2005–2013, which is mostly attributed to developing shale gas in 48 states. In addition, for the year 2040, the shale gas production is estimated to be increased by 73% and reach to 19.6 Tcf under reference case [33]. These figures and numbers reflect the significant increase in natural gas production in the USA over the past 10 years and the tendency of the continuous growth for the next 25 years.

2.3.3.3 Lower Natural Gas Price

Shale gas has depressed natural gas prices in the USA significantly, compared to the major markets. The natural gas price is estimated to be 2.5 times higher by 2050 if shale gas has not been developed. This may facilitate global competition and geopolitical shifts that break long-standing monopolies. For example, this could lessen European dependence on Russian gas, reducing Russia's ability to leverage higher prices [30].

2.3.3.4 Increased Global Investment in Fracking Wells

It has been reported that International Energy Agency (IEA) predicted global investment of $6.9 trillion in the shale gas development including lots of expected new wells during the period 2012–2035. This causes the rise of unconventional oil and gas and a fast shift from traditional producers to plentiful domestic resources. It has been estimated that 80% of natural gas well drilled in the next decade is expected to employ hydraulic fracturing [30, 34]. With more fracking well established, the production of shale gas will continue to grow accordingly.

2.3.3.5 Economic Development Growth

Some evidence has been reported about the economic development as a result of the increase in shale gas production. For example, in Pennsylvania, the active wells grew from 350,000 to 650,000 and generated 29,000 new jobs in 2008. For the Marcellus Shale across West Virginia and Pennsylvania, it was reported to bring $4.8 billion in gross regional product, caused 57, 000 new jobs, and generated $1.7 billion in tax collections. For Texas at the Barnett Shale, $11.1 billion annual output

Table 2.3 Direct and indirect economic benefits from shale gas production in the USA

Shale play	Estimated impact	In the year	To the economy of
Marcellus	$4.2B in output 48,000 jobs	2009	Pennsylvania
Marcellus	$8.04B in revenues 88,588 jobs	2010	Pennsylvania
Barnett	$11B in revenues 111,131 jobs	2008	Dallas/Ft. worth area
Haynesville	$2.4B in revenues 32,742 jobs	2008	Louisiana
Fayetteville	$2.6B in revenues 9533 jobs	2007	Arkansas
Marcellus	$760M in revenues 810 jobs	2000 wells over a 10-year period	Broome county, NY
Marcellus	$2.06B in revenues 2200 jobs	Gas production per year	Broome county, NY

Adapted from Kinnaman (2011) [35]

and 100, 000 jobs have been reported [30]. These direct and indirect economic benefits from shale gas production are shown in Table 2.3:

It also has been observed that fracking has transformed the USA into an energy super power. In 2013, the USA has become the world's largest producer of oil and natural gas. The personal income is projected to be increased to $3500 more per home in 2025. Fourty percent more oil and natural gas jobs has been estimated during 2007–2012. Government revenue is estimated to be $1.6 trillion increase to federal, state, and local government from 2012 to 2015. $180 billion trade deficit is estimated to be reduced by 2022. $1.14 trillion is predicted to be spent on infrastructure between 2014 and 2025. $533 billion increase in US GDP in 2025 is forecasted [36].

2.3.3.6 The Effect of Trade Shock

One of the potential effects induced by fracking is to impose trade shock on the exporters and importers of oil and gas. There is an estimation of economic effects of a 50% reduction in the volume of US gas and oil imports over the period 2007–2012. As a result, some countries may encounter some negative effects. For example, Canada appears to experience a reduction of 0.5% of GDP. Other countries such as Yemen, Egypt, Qatar, Equatorial Guinea, Nigeria, Algeria, and Peru have also been estimated to experience a decline in GDP of up to 0.5% [37]. This indicates that fracking can provide major benefits to some countries like the USA, but also may create significant negative economic impacts on some countries relying on exporting oil and gas.

2.3.3.7 The Profitability of Drilling Shale Oil

Since fracking involves more sophisticated drilling and extraction process, it is considered costlier to operate. In views of the declining oil price, oil companies are forced to consider the cost of expensive compared to less expensive fracking extraction methods. A report from *The Wall Street Journal* revealed that at $90 a barrel and below, many hydraulic-fracturing projects start to become uneconomic and the break-even point may lie around $80 to $85 [38]. Another article shows that fracking may still survive below $60 per barrel. However, new exploration and production may decrease, and some wells with higher cost have been shut down [39]. This information did indicate that further oil price declining risk is very likely to make expensive shale drilling unprofitable. Therefore, for a drilling company, more investigation and analysis on profitability challenge are deemed necessary, in light of the higher cost of fracking and the declining price of oil.

2.3.4 Environmental Perspective

Fracking requires an enormous amount of water as much as four to eight million gallons per well. The Environmental Protection Agency (EPA) in America indicated that about 35 thousand of fracking wells during drilling annually required a huge amount of water (equivalent to five million usages) [40]. Also, the big issue that the water sources are used for fracking operations varies and is not well documented or monitored. Some studies referred to the danger of the chemical solutions that are used in the fracking process; about 25% of fracking chemicals could cause cancer or other diseases.

Also, fracking can be one of the reasons of climate change because it produces methane which harms the environment. Methane is often released from the fracking wells during the drilling and production process. Some studies have shown that if the percentage of leakage is more than 3%, the burning of natural gas can be worse for the climate [41].

Fracking operation can also cause earthquake even though it is sometimes considered as small or under low-risk category. Many reasons can cause earthquake; in fracking, earthquake can be caused by drilling vibration or injecting water under a high pressure. Researchers referred to some actual cases that exposed to significant earthquakes because of the abuse of using underground injection during fracking. Those cases were registered in Oklahoma and Prague; many local homes were impacted and thousands of dollars worth of damage [41].

Wildlife also has been affected by fracking which comes with strong and fast industrial development, including the massive truck traffic. Fracking requires multiple routes for trucks to transport millions of freshwater from its sources to the operation areas. Animals are poisoned by chemicals added to water, and they are pushed to leave the wild areas to survive [41].

Human, animals, earth, water, and weather have been affected by the oil and gas industry operations [42]. Its processes have significant impacts on the environment because of the lack of control and complying with the environmental policy and regulations [43]. Due to the fast growth of the fracking operations in North America, people and some health and environment organizations continue protesting and asking to band the fracking activities [44, 45]. Recently, Alberta Energy Regulator (AER) issued a restrictive policy regarding the fracking operations including a list of requirements. Fracking companies are required to provide all information relating to the fracking operation such as the amount of waters used during the process and its sources and also the type of chemicals and solutions added into the water and used in each single operation.

Richards [43] pointed to the debate and the miscommunication between the environmental organizations and the producer companies regarding the propaganda and fact. The industry is always fighting back to prove that all information and data provided against the fracking are classified under the misrepresentation, misinformation, or misunderstanding category [46].

2.3.4.1 Water Use

Fracturing technology and its risk to water resources gained much attention from both environmental organizations and the media. They argue against the chemicals used in mixing with the fracking operation fluid and its risk for groundwater contamination. Water management is required to reduce the environmental and the media debate surrounding the fracking operation areas. Despite the continued development of fracking technology, using and reusing the vast quantities of produced water during the fracking process is one of the key issues that need to find alternative management strategies for managing this issue [47]. Drought contingency plans are started to be legally required by water companies for assessing the potential risk of using water resources before approving its use for fracking. Moreover, minimizing water consumption and reusing of fracturing fluid are challenges that need comprehensive management and disposal of wastewater plans [41, 47].

2.3.4.2 Methane Emissions

Methane is a type of gas that is usually located under the Earth's surface. Due to the fracking process, methane released from the land to the air creates poisoning emissions. Recently, some governments and environmental organizations have taken some steps to control the gas emissions produced by conventional and unconventional gas industry. Releases of methane have long been noticed and recorded in several parts of the world. After completing the fluid injection process, the fluid returns to the surface combined with significant quantities of methane gas [48].

Nowadays, there is an innovative technology that helps reduce the methane gas emissions by up to 90%. This technology is called the reduced emission completion (REC), and it is used during the flow-back period. However, this technology requires a proper implementation process such as installing special pipelines to the well in preparation for the fracturing completion [48]. Fracking companies have shown high interest in making more business than investments to reduce methane gas emissions. In this case policies and regulations are needed to push these companies for complying the reducing of methane emission rules [49].

In America, the federal oil and gas leases pointed to the study that proved the difference of methane emission rate among regions. The Utah state has strict regulations regarding reducing the methane emissions compared with the state of Colorado [50]. On the other hand, the study mentioned that in some areas with no fracking activity, a methane emission increase was recorded; the origin of the trends in the data is far from clear. So additional measurements and research are required by the US Energy Information Administration (EIA) [51].

2.3.4.3 Seismicity

The hydraulic fracking induced seismicity during or after the fracking operation. It typically forms an elongated cloud of event locations [52]. Recently, several innovative technologies were implemented to control seismicity occurrence and mitigate the seismic hazard. Increasing number of sensible earthquakes would be a sign of real seismicity that might increase the rate of damages and fatalities. Fracking is a complicated process, and the injecting of fluid under high pressure is considered the most difficult stage that may cause seismicity. The shear slip may occur during the fracking process due to high pressure that might lead to creating shear stresses. This explanation is still under studies, and some researchers argue in the way of creating the seismicity during the fracture operation [54]. However, some of them pointed to the induced shear slip might lead to the diversity of fracture surfaces and create new layers formation [55]. EIA experts illustrated in their report that in over 35,000 hydraulically fractured wells, only four wells had noticeable earthquakes in the USA [56]. To avoid this issue, fluid injections should be short-lived and injected at lower pressures [53].

2.3.4.4 Land/Surface Use

Usually, in the conventional oil and gas industry, the operations need a huge land area, but in the unconventional, operations by fracking technology require less land use. However, in both types, the surface that uses resources is still the main issue in some cases. Environmental and safety organizations continue complaining against the fracking operations in regard to negative environmental impacts. Some cases that had harmed the land or surface during the oil and gas operation were recorded by the industry or environmental and safety organizations. In Louisiana (2009), some animals were poisoned by chemicals and founded near a drilling area. In Pennsylvania (2008), the Monongahela River was contaminated by chemicals and a high level of salt content found in the river. In the same state (2009), a spill of fracking fluid into a surface and the depth water results to death of organisms that live in the river [57]. So, the impacts of surface disturbance can extend over large areas and both plant and animal species. Continuous improvement of best practices is required by industry organizations [58].

2.3.4.5 Groundwater Contamination

The fluid that is injected into the oil or gas reservoir contains from more than 750 distinct chemicals. Fracking uses high-pressure pumpers to pump fluid through the drilling well to the host rocks [59]. The chemical represents about 2% from the total fracturing fluid volume. Large quantities of wastewater are generated during the fracking process and represent about 98 percent of the volume. The Environmental Protection Agency in America has started since 2010 to identify the potential risk of hydraulic fracturing on drinking water [60]. The fracking companies are getting benefits from exemption under the regulation of Safe Drinking Water (SDW) that was issued by the Energy Policy Act (EPA) in 2005. However, the environmental agencies are still working to identify contamination from shale gas exploration. Scientists explained the reason of limited identification of the groundwater contamination from shale gas operation. They emphasized that the large-scale exploration of shale gas has begun recently compared to groundwater flow rates. So, the much longer time frame is needed to identify and evaluate possible groundwater contamination.

> *The fraction of drinking water wells that had chloride concentrations >250 mg/L (EPA threshold for drinking water) in groundwater from Garfield County doubled between 2002 (4%) and 2005 (8%), with chloride up to 3000 mg/L in drinking water wells.*

Overall, there might be real cases that exposed chemicals affected the groundwater in some areas, but many researchers and environmental agencies believe that conventional and unconventional oil and gas exploration has an impact on the environment and health [61–64]. For eliminating the impact of this issue, more studies are undertaken by EPA including a review of the literature, analysis of existing data, laboratory studies, and real case studies [59].

2.3.5 Political Perspective

The political perspective deals with players and factors that can potentially influence the creation and/or modification of policies and also with players and factors that can influence and modify the perception and attitude of those whom policies are made for. Although usually overlooked, this perspective can be very important and change the competitive scenario in many cases.

Regarding the case of fracking technology, the most important factors and players identified are as follows:

The Environmental Protection Agency (EPA) The agency's mission is to protect human health and the environment [65]. After 1997, EPA was mandated (by law) to regulate fracking fluids, as they caused many health and environmental concerns. Since then, it has started to conduct several studies about fracking fluids and also to regulate its usage (what would be the allowed and not allowed substances and chemicals) [66]. EPA, with their studies and regulations, might have the ability to hinder shale gas extraction and put more pressure on the oil industry through public opinion. On the other hand, EPA representatives have already stated that fracking can be done without harming the environment [67].

Policy-Makers and Legislators Either on the State or Federal level, there are clearly two distinct movements, a pro-fracking and an antifracking. Both have power depending on the state/region. Pro-fracking movements highlight and trust the economical and strategic benefits America would get from exploring more natural gas reservoirs, and they open an opportunity to the industry when they are open to discuss how to use fracking techniques while decreasing environmental impact (e.g., Colorado and Texas) [67]. Antifracking movements highlight the environmental and social hazards that may surge from fracking and state that potential economical benefits are not worthy of the risk. They pose a threat as they do not want to take chances and are leaning toward banning the technique (e.g., NY and Vermont) [66].

Nongovernmental Organizations (NGO's) Nongovernmental organizations play a major role in today's policy-making [73], and their importance is growing in every sector. For fracking technology, the ones that are most relevant are environmental organizations and activist groups. These organizations can be very powerful in influencing the public opinion, by organizing constant protests, manifestations, and making studies showing the potential hazards of fracking.

Public Opinion The public opinion is the perception of public over any given issue/subject. The public in general can exercise strong influence over policy-makers and legislators [74]. Public opinion against fracking can make it very difficult for activities to continue, once policy-makers would then be leaning toward more restrictive policies and regulations.

Federal Agencies Strong agencies include Department of Energy (DoE), Department of Defense (DoD), and Department of Homeland Security (DHS). Such powerful institutions could, once they decide to support any given initiative/movement, influence policy-makers (not through political lobby but through the experience and expertise of its employees and leaders) [75]. These agencies might easily realize the benefits of the expansion of fracking and future American independence from foreign fossil fuels. In that case, the fracking industry might gain powerful allies.

2.3.6 Legal Perspective

The legal perspective deals with factors that reflect the legality or illegality of the technology, namely, laws, standards, codes, and regulations. The importance of these factors is obvious, given the fact that once a technology (or anything related to it) is set outside the limits of any legal instrument, it automatically becomes not suitable. Regarding the fracking technology, these are the legal factors that should be considered:

The Fracturing Responsibility and Awareness of Chemicals Act (FRACT Act) In 2009, twin laws were passed in the House of Representatives and in the Senate [68, 69], giving EPA authority to regulate fracking and mandating fracking companies to disclose the chemicals used in the fracking fluids. The law was seen as a threat since the industry would have to deal with more regulations. Also, it would have to disclose some of their trade secrets, the fracking productivity highly depends on how the cracks in the shale rocks are kept open, and these cracks are "produced" and sustained by the chemicals and other substances used in the fracking fluid. Therefore, no company wants to publicize the composition of its fluids.

Federal Laws As of now, eight different federal laws apply to fracking (same as to conventional drilling) [72]. The discussion evolves around the question of whether or not new laws and regulations would be needed. It presents an opportunity for companies to argue that no extra or specific laws and regulations are needed. Nonetheless, antifracking movements argue that none of these existing laws properly deal with fracking, because fracking involves different techniques and therefore different hazards when compared to conventional drilling and oil/gas extraction.

The "Halliburton Loophole" The Halliburton Corporation is one of the biggest companies in the oil sector, providing services of several natures to the oil companies [76]. In 2005, a provision in an energy bill exempted fracking from the Safe Drinking Water Act, removing any authority of EPA over fracking activities [69, 70]. Although it helped the industry in the short term, it was terrible for the image of fracking and oil companies in general (especially because the then vice-president, Dick Cheney, was a former Halliburton CEO, which has risen numerous suspicions).

The Ban on Fracking In December 2014, New York joined Vermont by banning fracking activities in the State [71]. Those laws pose a serious threat to fracking. If public opinion supports it, several other states might join the ban.

Prospective Laws Potential laws that might be enacted could present either opportunities or pose threats, depending on the content. As an action plan, the industry should pay close attention to all political factors and players, as these can be a motivation for new laws.

2.3.7 Ethical Perspective

Technological innovations have changed our lives in an unprecedented way. However, new technological innovations are never without dispute as there are many shades of gray underlying its application. The same technology can shape our future on the one hand when used to make this world more humane, while on the other hand, it can make us disconnected or extinct as a human race due to dishonest demagoguery [78]. Fracking technology is no exception to this controversy and has sparked dichotomy between its benefits and potential drawbacks. The key stakeholders in this issue are industry, government, pro-fracking and antifracking advocacy groups, landowners, and community or neighbors.

Ethics is a standard that guides human behavior in different context. Many times, innovators are ignorant or possess a telepathy mindset about the impact of technology [77]. Some of the issues that cause conflict among social norms, moral values, and technological innovation are information use; human interaction, reproduction, privacy, values, and discrimination; sustainability; power disparity; and international relations. Ethical perspective is intended to anticipate diabolic consequences of technology and address ethical issues not only during technology development but also during the whole life cycle of the technology and prevent probable backlash [78].

In an attempt to analyze the ethical perspective of fracking, a model known as "CAT scan" is used. The tool was first proposed by Goodpaster, a former professor at Harvard Business School, in his book *Conscience and Corporate Culture* in the year 2006 [77]. The CAT scan is a matrix that combines five steps of case analysis and discussion with four ways of ethical analysis.

Describe There could be several interest groups or people. It is important to identify the people whose actions prompt ethical questions. Clarifying relevant facts and information helps to find out ethical implications.

Discern There could be several ethical issues. But it is imperative to find out the most important ethical issue(s) and trace the connection or impact to other issues.

Display Understanding the players and the ethical issues facilitates to list out probable actions by the actors. However, the actions need to be specific, brief, and doable.

Decide At this stage, the players must choose optimal solution considering the environment. It should be the best ethical response in the prevailing contexts.

Defend Finally, the decision should be backed up by moral principles [77].

The four major means of ethical analysis are interest based, duty based, right based, and virtue based.

2.3.7.1 Interest-Based Thinking

In this view, ethics is related to actions that impact a human being. Hence, a certain action or policy is only ethically acceptable if the outcome positively serves the interest of the human society or reduces the cost of achieving benefit.

2.3.7.2 Right-Based Thinking

An action is morally agreeable if it ensures social justice or "fairness." Everyone should get an equal share of opportunity, wealth, liberty, or freedom.

2.3.7.3 Duty-Based Thinking

The motto of this philosophy is whether an individual is contributing their share as part of the whole community. Hence, ethical behavior is playing one's part according to social and legal norms.

2.3.7.4 Virtue-Based Thinking

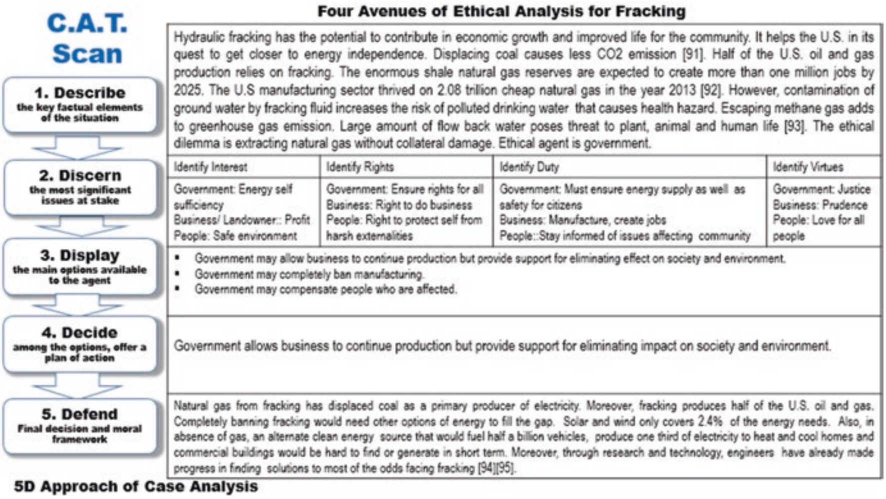
Ethical actions are measured against prudence, temperance, courage, justice, faith, and love. Deviation from these virtues is considered as unethical action or behavior [77].

The ethical analysis using CAT scan model is shown in Table 2.4.

Half of US oil and gas is now being produced by fracking [79]. Marcellus Shale formation is assumed to contain 489 trillion cubic feet of natural gas. At the present rate of consumption of natural gas in the New York State, the reserve is calculated to last for 400 years. However, some of the potential impacts of fracking are contamination of groundwater, tributary, and the difficulty of disposing a large amount of flow-back water. The gas employees and shareholders of the gas companies are benefitted economically. Landowners also gain from leasing. However, the landowners are at risk in case the surface water gets contaminated as it would reduce the property value [80].

A number of cities, states, and countries have banned fracking. Two California counties (Boulder County, Colorado) – New York and even in Texas where the technique was developed – have banned fracking. Also, there are other states who joined in this group such as Pittsburgh, Pennsylvania (2010); Philadelphia, Pennsylvania (2012); Broadview Heights, Mansfield, Oberlin, and Yellow Springs, Ohio, (2012); Hawaii County (2013); Mora County, New Mexico (2014); and Beverly Hills, California (2014). Internationally, fracking is prohibited in some European countries such as Germany, France, Scotland, Northern Ireland, and Bulgaria [81].

Table 2.4 Ethical analysis of fracking technology by CAT scan model [77–80]



C.A.T. Scan

Four Avenues of Ethical Analysis for Fracking

5D Approach of Case Analysis				
1. Describe the key factual elements of the situation	Hydraulic fracking has the potential to contribute in economic growth and improved life for the community. It helps the U.S. in its quest to get closer to energy independence. Displacing coal causes less CO2 emission [91]. Half of the U.S. oil and gas production relies on fracking. The enormous shale natural gas reserves are expected to create more than one million jobs by 2025. The U.S manufacturing sector thrived on 2.08 trillion cheap natural gas in the year 2013 [92]. However, contamination of ground water by fracking fluid increases the risk of polluted drinking water that causes health hazard. Escaping methane gas adds to greenhouse gas emission. Large amount of flow back water poses threat to plant, animal and human life [93]. The ethical dilemma is extracting natural gas without collateral damage. Ethical agent is government.			
2. Discern the most significant issues at stake	Identify Interest	Identify Rights	Identify Duty	Identify Virtues
	Government: Energy self sufficiency Business/ Landowner:: Profit People: Safe environment	Government: Ensure rights for all Business: Right to do business People: Right to protect self from harsh externalities	Government: Must ensure energy supply as well as safety for citizens Business: Manufacture, create jobs People::Stay informed of issues affecting community	Government: Justice Business: Prudence People: Love for all people
3. Display the main options available to the agent	• Government may allow business to continue production but provide support for eliminating effect on society and environment. • Government may completely ban manufacturing. • Government may compensate people who are affected.			
4. Decide among the options, offer a plan of action	Government allows business to continue production but provide support for eliminating impact on society and environment.			
5. Defend Final decision and moral framework	Natural gas from fracking has displaced coal as a primary producer of electricity. Moreover, fracking produces half of the U.S. oil and gas. Completely banning fracking would need other options of energy to fill the gap. Solar and wind only covers 2.4% of the energy needs. Also, in absence of gas, an alternate clean energy source that would fuel half a billion vehicles, produce one third of electricity to heat and cool homes and commercial buildings would be hard to find or generate in short term. Moreover, through research and technology, engineers have already made progress in finding solutions to most of the odds facing fracking [94][95].			

2.4 Conclusion

The aim of this chapter is to analyze the hydraulic fracturing (fracking) technology through the STEEPLE methodology. STEEPLE assesses a technology from different perspectives, namely, social, technical, economical, environmental, political, legal, and ethical. The model concludes if fracking technology would be an oprion for addressing energy challenges by the USA in the near future.

Specifically, the three research questions posed are why is the energy industry jumping into fracking? What are the STEEPLE factors that come into play when adopting fracking? Is fracking a suitable technology for the future? The first question is addressed in the introduction part where the present industry situation is discussed, and the reasons why the key players are interested in fracking are identified. The second question is addressed in the assessment section where each perspective of the methodology is analyzed, and main factors and players are identified, explained, and discussed. The third question is addressed in this section.

A summary of the technology assessment with pertinent benefits and/or challenges for each perspective is captured in Table 2.5.

As discussed earlier, there is an ethical dilemma involved in choosing whether to use fracking or not. Also, the political and legal perspectives may offer benefits and/or challenges depending on how the many players behave. On the technical side, there are minor benefits and challenges (The technology is not new, and it is evolving. It is perfectly feasible from a technical standpoint). The economical perspective is, by far, the most positive. It presents several advantages that could be beneficial for the USA. However, both social and environmental factors are unfavorable and offer serious challenges for the technology to be fully deployed.

Table 2.5 Analysis summary table

Perspective	Benefit	Challenge
Social	NO	YES
Technical	YES	YES
Economical	YES	YES
Environmental	NO	YES
Political	NO YES	NO YES
Legal	NO YES	NO YES
Ethical	YES	YES

Taking the perspectives altogether, one can say that fracking is a very promising technology, but it has extremely serious adversities associated with it. It is clearly feasible from the technical perspective, and it has great economical potential. Ethically, it has been proved to be acceptable. Nevertheless, the social and environmental issues make it unsuitable as an energy option. The key point is, if negative impacts are taken care of – al least mitigated – fracking can become a suitable energy technology for the near future of the USA. In order for that to happen, the technology needs to evolve to deal with those issues, and at the same time, all the political players involved need to be willing to talk and negotiate.

2.5 Recommendations

As some major environmental drawbacks associated with fracking technology have been identified, other alternatives such as renewable energy sources as well as exploring safer means of extracting natural gas may need to be taken into account for meeting sustainable energy expectations. Besides, in order to enhance the commitment of environmental protection and social welfare, the laws and regulation pertaining to fracking technology need to be reviewed and improved by involving all stakeholders and considering all relevant perspectives and impacts.

In view of the diverse arguments of fracking technology, both research works and monitoring of fracking activities are deemed essential and required to be reinforced by the US Energy Information Administration (EIA) and Environmental Protection Agency (EPA). These efforts are expected to clarify the relevant benefits and challenges, reduce the negative impacts, and validate the suitability of being a future sustainable energy technology. In addition, all environmental groups and O&G companies should support and encourage the Center for Sustainable Shale Development (CCSD) to continue the implementation of improvement and innovative practices for fracking technology development, because the sustainability consideration cannot be thoroughly enhanced without close collaboration among all stakeholders.

References

1. Mitchell, J. What next for the oil and gas industry? The Royal Institute of International Affairs, October 2012.
2. Energy Information Administration. (2013). *Annual energy outlook 2013 with projections to 2040*. Washington, DC: US Department of Energy.
3. DCOSTA (Amanda), '*PESTLE analysis history and application*', in Bright Hub Project Management, May 2011, Accessed 11th May 2015. http://www.brighthubpm.com/project-planning/100279-pestle-analysis-history-and-application/
4. Cadle, J., Paul, D., & Turner, P. (2010). *Business analysis techniques: 72 essential tools for success* (p. 260). British Comp Society Series (BCS), The Chartered Institute, 2010 – Business analysts.
5. Zalengera, C., Blanchard, R. E., Eames, P. C., Juma, A. M., Chitawo, M. L., & Gondwe, K. T. (2014). Overview of the Malawi energy situation and A PESTLE analysis for sustainable development of renewable energy. *Renewable & Sustainable Energy Reviews, 38*, 335–347.
6. Daim, T. et al. (2011). "*Technology Assessment: Forecasting the Future Adoption of Emerging Technologies", Operation and Technology Management* (pp. 1–5), Erich Schmidt Verlag, Book.
7. Zalengera, C., Blanchard, R. E., Eames, P. C., Juma, A. M., & Chitawo, M. L. (2014). Sustainable development of renewable energy. *Renewable and Sustainable Energy Reviews, 38*, 335–347.
8. Daim, T., et al. (2015). Policies and programs for sustainable energy innovation: Renewable energy and energy efficiency. In *Business & Economics* (p. 454). Switzerland: Springer International Publishing.
9. Stephan, S., & Mader, K. (2013). *Bridges between science, society and policy: Technology assessment-methods and impacts* (Vol. 22). Springer Science & Business Media.
10. Sheikh, N. J. (2013). Assessment of solar photovoltaic technologies using multiple perspectives and hierarchical decision modeling (Ph.D. Dissertation), *ProQuest/UMI (UMI Number 3568075)*, pp. 1–238, 2013.
11. Boudet, H., Clarke, C., Bugden, D., Maibach, E., Roser-Renouf, C., & Leiserowitz, A. (2014). "Fracking" controversy and communication: Using national survey data to understand public perceptions of hydraulic fracturing. *Energy Policy, 65*, 57–67. http://doi.org/10.1016/j.enpol.2013.10.01.
12. ASBC (American Sustainable Business Council). (2014). The business case for rethinking fracking.
13. Asadourian, B. L. (2012). *Health effects that may result from fracking* (p. 1). 25: Lehigh Edu.

14. Musick, T.. (2014). "*Fracking and worker safety: U.S. oil boom is in full swing, as are questions about hazards*". Safety + Health: Official Magazine of NSC Congress and Expo. http://www.safetyandhealthmagazine.com/articles/11434-fracking-and-worker-safety
15. Boyle, M. D., Payne-Sturges, D. C., Sangaramoorthy, T., Wilson, S., Nachman, K. E., Babik, K., Jenkins, C. C., Trowell, J., Milton, D. K., & Sapkota, A. (2016). Hazard ranking methodology for assessing health impacts of unconventional natural gas development and production: The Maryland case study. *PLoS One, 11*(1), 1–15. https://doi.org/10.1371/journal.pone.0145368.
16. Pennsylvania, Guiding Southwestern, Through Shale, and G A S Development. (2014). "Getting the boom without the bust." *Center for Energy Policy and Management: Environmental Law Institute and Washington & Jefferson College*.
17. Cattaneo, C. (2011). New age for old oil. *Financial Post*. http://business.financialpost.com/2011/01/29/new-age-for-old-oil/
18. Tait, C., & Cryderman, K. Alberta's new boom from old oil, 2013 http://www.theglobeandmail.com/reporton-business/industry-news/energy-and-resources/albertas-new-boom-from-oldoil/article11790035/
19. Cattaneo, C. (2011). New Age for Old Oil. *Financial Post*, 2011. http://business.financialpost.com/2011/01/29/new-age-for-old-oil/
20. Government of Alberta. *Alberta Oil & Gas Industry, Quarterly Update, Fall 2013*. http://www.albertacanada.com/files/albertacanada/OilGas_QuarterlyUpdate_Fall2013.pdf
21. Kiger, P. J. Green fracking? 5 technologies for cleaner shale energy, National Geographic, March 2014.
22. Smith, M. U.S EPA supports natural gas extraction/fracking, March 2013. http://benitolink.com/us-epa-supports-natural-gas-extractionfracking
23. Golden, J. M., & Wiseman, H. J. (2014). The fracking revolution: Shale gas as a case study in innovation policy. *Emory LJ, 64*, 955.
24. The Nat Geo website, http://news.nationalgeographic.com/news/energy/2014/03/140319-5-technologies-for-greener-fracking/. Accessed on 31 May 2016.
25. The Breaking energy website, http://breakingenergy.com/2013/05/23/cabot-using-natural-gas-instead-of-diesel-to-power-fracking-equipment/. Accessed on 31 May 2016.
26. The Conservation website, http://www.conservation.ca.gov/dog/general_information/Pages/HydraulicFracturing. Accessed on 31 May 2016.
27. The Slo County Water website, http://www.slocountywater.org/site/Water%20Resources/Advisory%20Committee/pdf/HF%20Technical%20Resources.pdf. Accessed on 31 May 2016.
28. The EE News website, http://www.eenews.net/stories/1060007532. Accessed on 31 May 2016.
29. The Pacode website, http://www.pacode.com/secure/data/025/chapter78/s78.72.html. Accessed on 31 May 2016.
30. Sovacool, B. K. (2014). Cornucopia or curse? Reviewing the costs and benefits of shale gas hydraulic fracturing (fracking). *Renewable and Sustainable Energy Reviews, 37*, 252–254.
31. US EIA, Technically recoverable shale oil and shale gas resources: An assessment of 137 shale formations in 41 countries outside the United States, p.2, June 2013.
32. US Energy Information Administration, Annual Energy Outlook 2015 with projections to 2040, pp. MT 23, April 2014.
33. US Energy Information Administration, Annual Energy Outlook 2015 with projections to 2040, pp. 20–21, April 2015.
34. Sovacool, B. K. (2014). Cornucopia or curse? Reviewing the costs and benefits of shale gas hydraulic fracturing (fracking). *Renewable and Sustainable Energy Reviews, 37*, 252.
35. Kinnaman Thomas, C. (2011). The economic impact of shale gas extraction: A review of existing studies. *Ecological Economics, 70*, 1243–1249.
36. American Petroleum Institute, Hydraulic Fracturing: Unlocking America's Natural Gas Resources, July p. 4, 2014.

37. ODI, The development implications of the fracking revolution, pp. 14–15, April 2014.
38. Gold, R., & Ailworth, E. Fracking firms get tested by oil's price drop, Oct. 9, 2014. http://www.wsj.com/articles/fracking-firms-get-tested-by-oils-price-drop-1412899027 Retrieval date: 26 May 2016.
39. Rosenberg, E. Can fracking survive at $60 a barrel? INVESTOPEDIA, http://www.investopedia.com/articles/investing/072215/can-fracking-survive-60-barrel.asp Retrieval date: 26 May 2016.
40. Beckwith, R. (2010). Hydraulic fracturing: The fuss, the facts, the future. *Journal of Petroleum Technology, 62*(12), 34–41.
41. Environmental Protection Agency (EPA), www.epa.gov. Accessed on 31 May 2016.
42. Alberta Energy, Oil Frequently Asked Questions: Does crude oil production have environmental consequences? 2013. http://www.energy.alberta.ca/Oil/764.asp
43. Richards, T., Spills and Leaks. Alberta Views. (2013). https://albertaviews.ab.ca/2013/10/02/spills-and-leaks/
44. Alberta Energy Regulator. (2014). What is Hydraulic Fracturing? http://www.aer.ca/about-aer/spotlight-on/unconventional-regulatoryframework/what-is-hydraulic-fracturing.
45. Foster, J. (2013). The fossil fuels war. *Monthly Review, 65*(4), 29.
46. Grant, P. (2013). The facts of fracking: The drilling industry gets proactive. *Business in Calgary, 23*(9), 87–93.
47. Vidic, R. D., Brantley, S. L., Vandenbossche, J. M., Yoxtheimer, D., & Abad, J. D. (2013). Impact of shale gas development on regional water quality, science.sciencemag.org.
48. Greenhouse gas emissions reporting from the petroleum and natural gas industry. Background Technical Support Document. http://www.epa.gov/climatechange/emissions/ downloads10/Subpart-W_TSD.pdf. Accessed 3 Jan 2011.
49. Harris, D. A. (2010). *Determining lost and unaccounted for gas loss* (pp. 1–7). Houston: Tech. Rep.
50. Federal oil and gas leases: Opportunities exist to capture vented and flared natural gas, which would increase royalty payments and reduce greenhouse gases. GAO-11–34 U.S. General Accountability Office Washington DC, 2010. http://www.gao.gov/new.items/d1134.pdf
51. Howarth, R. W., Santoro, R. & Ingraffea, A. (2011) Climatic change 106: 679. https://doi.org/10.1007/s10584-011-0061-5
52. Phillips, W. S., Fairbanks, T. D., Rutledge, J. T., & Anderson, D. W. (1998). Induced microearthquake patterns and oil-producing fracture systems in the Austin chalk. *Tectonophysics, 289*(1), 153–169.
53. Pearson, C. (1981). The relationship between microseismicity and high pore pressures during hydraulic stimulation experiments in low permeability granitic rocks. *Journal of Geophysical Research, 86*, 7855–7864.
54. Moriya, H., Nakazato, K., Niitsuma, H., & Baria, R. (2002). Detailed fracture system of the Soultz-sous-Forets HDR field evaluated using microseismic multiplet analysis. *Pure Applied, 159*(1–3), 517–541.
55. Brown, S. R., & Bruhn, R. L. (1998). Fluid permeability of deformable fracture networks. *Journal of Geophysical Research*, *103*, 2489–2500.
56. U.S Energy Information Administration (EIA). https://www.eia.gov/
57. Vaughan and Pursell, A.D. Vaughan, D. Pursell. (2010). *Fracking attack: Risks, hype, and financial reality of hydraulic fracturing in the shale plays*. Reservoir Research Partners and Tudor Pickering Holt and Co, Houston.
58. U.S. House Committee on Energy and Commerce. Chemicals used in hydraulic fracturing: Minority Staff, April 2011.
59. U.S. House Committee on Energy and Commerce. Chemicals used in hydraulic fracturing: *Minority Staff*, April 2011. http://democrats.energycommerce.house.gov/sites/default/files/documents/Hydraulic%20Fracturing%20Report%204.18.11.pdf
60. EPA. Draft Hydraulic Fracturing Study Plan. (2010). http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/index.cfm

61. Osborn, S. G., Vengosh, A., Warner, N. R., & Jackson, R. B. (2011). Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. *Proceedings of the National Academy of Sciences of the United States of America.*
62. Jackson, R. B., Vengosh, A., Darrah, T. H., Warner, N. R., Down, A., Poreda, R. J., Osborn, S. G., Zhao,K., & Karr, J. D. (2013). Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction. *Proceedings of the National Academy of Sciences of the United States of America.*
63. Warner, N. R., Jackson, R. B., Darrah, T. H., Osborn, S. G., Down, A., Zhao, K., White, A., & Vengosh, A. (2012). Geochemical evidence for possible natural migration of Marcellus Formation brine to shallow aquifers in Pennsylvania. *Proceedings of the National Academy of Sciences of the United States of America.*
64. Thyne, T. (2008). Review of phase II hydrogeologic study (Prepared for Garfield County).
65. The Environmental Protection Agency website, https://www.epa.gov/aboutepa. Accessed on 30 April 2016.
66. Rahm, D. (2011). Regulating hydraulic fracturing in shale gas plays: The case of Texas. *Energy Policy, 39*(5), 2974–2981.
67. The What is fracking website, http://www.what-is-fracking.com/epa-cut-pollution-fracking/. Accessed in 30 April 2016.
68. The Government Track website, https://www.govtrack.us/congress/bills/112/s587/text. Accessed on 1 May 2016.
69. The NY Times website, http://www.nytimes.com/2009/11/03/opinion/03tue3.html?_r=0. Accessed on 1 May 2016.
70. The Gasland The Movie website, http://www.gaslandthemovie.com/whats-fracking/faq/what-is-the-halliburton-loophole. Accessed on 1 May 2016.
71. The Forbes website, http://www.forbes.com/sites/judeclemente/2015/06/07/why-new-yorks-fracking-ban-for-natural-gas-is-unsustainable/#7dc77dae27b0. Accessed on 1 May 2016.
72. The What is Fracking website, http://www.what-is-fracking.com/which-federal-laws-apply-to-shale-development/. Accessed on 1 May 2016.
73. The National Academy press website, http://www.nap.edu/read/10240/chapter/20. Accessed on 1 May 2016.
74. The Guardian website, http://www.theguardian.com/public-leaders-network/2012/sep/03/public-opinion-influence-policy. Accessed on 1 May 2016.
75. The DoD website, http://www.defense.gov/About-DoD. Accessed on 1 May 2016.
76. The Halliburton Corporation website, http://www.halliburton.com/en-US/about-us/corporate-profile/default.page?node-id=hgeyxt5p. Accessed on 16 May 2016.
77. Goodpaster, K. E. (2007). *Conscience and corporate culture. Book, philpapers.org*. Wiley-Blackwell.
78. Palm, E., & Hansson, S. O. (2006). The case for ethical technology assessment (eTA). *Technological Forecasting and Social Change*, *73*(5), 543–558.
79. USA Today Editorial Board. (2016, April 21). "*Objections to fracking are weak*" http://www.newsleader.com/story/opinion/editorials/2016/04/21/objections-fracking-weak/83363870/
80. Potter, A., & Rashid, M. H. (2013). "An ethical approach to hydraulic fracturing," *2013 ASEE Southeast Sect. Conf.*, pp. 1–7.
81. Baddour, D. (2015, February 2). *List of places than ban fracking keeps growing*, http://www.chron.com/business/article/List-of-places-thanban-fracking-keeps-growing-6057266.php

Chapter 3
Landscape Analysis: Connected Lighting System

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3.1 Introduction

The lighting industry has gone under major transformations in recent decades. These changes are both at components/luminaires and system level. In 1999, Haitz stated that lumen per package will increase by a factor of 30 and the cost per lumen will decrease by factor of 10 [1]. This is also known as Haitz's law [2]. In 2011, Haitz's law is revisited; though the cost per lumen decremental rate remained the same, lumen per package incremental rate dropped to 20 [3]. According to revised Haitz's law, LED has entered to era that can overcome its adoption barrier—high lamp price and low light output per emitter [2, 4]—in general lighting section. Next Generation Lighting Industry Alliance (NGLIA)'s presentation to the Department of Energy (DOE) shows that LED would disrupt the traditional lighting resource and dominate the lighting market by 2020 [5].

The benefits of LED at luminaires level include high-energy efficiency, long lifetime, design flexibility, directional light, robustness, dimming capability without color shift, absence of regulated toxic substances (e.g., mercury), absence of heat or UV in light beam, and low-voltage DC operation [2] among others. However, the digital nature of LED offers new opportunities at a system level to change the symbolic meaning of lights as well as the industry landscape and improve the value of lighting. For instance, LED enables the visible light communication which has values such as high-rate data communication and indoor positioning [6, 7]. All of this new lighting functionality, coupled with new wireless communications protocols, the ubiquity of smartphones, the emergence of home automation, the Internet of Things (IoT), and the large-scale data collection and analytics, will enable a vast

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