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U.S. TRADE AND DEVELOPMENT AGENCY

February 17, 2023

VIA EMAIL

Re: Freedom of Information Act ("FOIA") request 2020-029:

Thank you for your FOIA request to the U.S. Trade and Development Agency ("USTDA"), dated September 30, 2020, in which you asked for:

> "*A copy of the India - Clean Energy and Smart Grid Projects Desk Study prepared in the last three years by Continuum Associates; a copy of the India - Traditional Energy and Power Projects Desk Study prepared in the last three years by the Constant Group.*"

In accordance with FOIA, USTDA has conducted a reasonable search for the requested records. All responsive records are being released in their entirety and are enclosed. No other responsive records were found.

This constitutes the USTDA's final response to your FOIA request. If you choose to appeal, please submit the appeal in writing, describing the issue and basis for the appeal, within ninety (90) days from receipt of this letter. The appeal should include the request number written in the subject line above and be addressed to: FOIA Appeal Authority, U.S. Trade and Development Agency, 1101 Wilson Blvd, Suite 1100, P.O. Box 12268, Arlington, VA, 22209. Additionally, you may seek dispute resolution services from the FOIA Public Liaison or the Office of Government Information Services at the National Archives and Records Administration.

Thank you again for your inquiry. There is no charge for processing this FOIA request. If you would like to modify your request, please do so, and we will consider it. This is a final action on your request. If you would like to appeal this decision you may do so. Submit your appeal to USTDA's Chief FOIA Officer, Sam Kwon at skwon@ustda.gov. If you have any questions or would like to contact the FOIA Public Liaison, please e-mail foia@ustda.gov or call (703) 875-4357 and ask to speak with FOIA Associate Natasha Schultz or with me. Please do not hesitate to contact us if you have any questions about this letter.

Sincerely,

John Mantini

John C. Mantini
Attorney Advisor

PUBLIC VERSION

India Clean Energy and Smart Grid Desk Study Series

PUBLIC MARKET REPORT

USTDA Contract No. 1131PL-17-C-DS31081

United States Trade and Development Agency

October 17, 2019

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The U.S. Trade and Development Agency

The U.S. Trade and Development Agency (USTDA) advances economic development and U.S. commercial interests in developing and middle income countries. The agency funds various forms of technical assistance, early investment analysis, training, orientation visits and business workshops that support the development of a modern infrastructure and a fair and open trading environment.

USTDA's strategic use of foreign assistance funds to support sound investment policy and decision-making in host countries creates an enabling environment for trade, investment and sustainable economic development. Operating at the nexus of foreign policy and commerce, USTDA is uniquely positioned to work with U.S. firms and host countries in achieving the agency's trade and development goals. In carrying out its mission, USTDA gives emphasis to economic sectors that may benefit from U.S. exports of goods and services.

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PUBLIC VERSION

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Tables and Figures

1. Executive Summary

This Public Market Report describes the overall clean energy and smart grid market in India which was studied in detail as part of a desk study series for the United States Trade and Development Agency (USTDA). Specifically, three segments within the Indian clean energy and smart grid space are covered as part of this Public Market Report. The first segment consists of grid-scale clean power and energy segment. This primarily consists of grid-scale solar PV and wind energy sectors, as well as grid-scale battery energy storage systems (BESS). As part of the smart grid sector, our work focused on distributed energy resources (DERs). Within the DER segment, our work focused on various DER technologies such as rooftop solar PV, behind-the-meter energy storage systems, energy efficiency, electric vehicles, and active and passive demand response, including controllable loads. The report also provides details on the DER software platforms such as Distributed Energy Management Systems (DERMS). Lastly, the report details the synthetic ethanol market in India, with a focus on second-generation ethanol production used as a fuel blend in the transportation industry in India. Our work was specifically focused on production of second-generation ethanol from refinery off-gases in which certain U.S Companies possess proprietary technology and synthesis know-how.

The Public Market Report provides detailed information and depth on the Indian clean energy and smart grid market and covers the following topics in detail:

1. Background information on clean power & energy, and smart grid market in India
2. Potential of clean energy and smart grid market, as it pertains to the grid scale power generation technologies and synthetic production of ethanol for use as a transportation fuel blend
3. Detailed information on current market conditions including existing or expected sector regulations, projected investments in the sector, identification of the major stakeholders, growth trends and other useful factors pertaining to the clean power & energy, and smart grid markets in India
4. Foreign competition and market entry issues

Additionally, the report provides estimates of U.S. export potential, including estimates for the potential procurement of U.S. goods and services in the Indian clean energy and smart grid sectors.

Breakdown by category and dollar value of goods and services likely to be imported in the sector and an illustrative list of potential U.S. companies that may supply the goods and services to the Indian clean energy and smart grid markets is also covered. Lastly, a list of U.S. companies that have expressed interest in India's clean power & energy, and smart grid sectors is also provided for the three market segments.

2. Grid-Scale Clean and Renewable Energy Sector in India, and Need for Energy Storage

In the following sub-sections, we evaluate the current status of the clean and renewable energy sector in India, and the need for large-scale battery storage that may develop in the clean energy sector over the medium (0-5 years) and long-term (more than 5 years).

2.1 Clean and Renewable Energy Sector in India

India continues to have one of the most aggressive renewable and clean energy implementation targets globally. It intends to install 175 GW of renewable energy generation capacity by the year 2022. Based on the current peak demand of about 160 GW, this target represents 109 percent of the current peak power requirement. On the basis of India's current installed generation capacity of 331 GW, this represents 48 percent of the currently installed total generation capacity. Accounting for load increases between now and 2022, it can be concluded that India aims to power the majority of its load using renewable sources of energy, primarily solar PV and wind. If realized as planned, India would be the only country to have installed renewable energy at such a massive scale. There are significant challenges with increasing renewable energy penetration by such massive scale and energy storage can help mitigate some of these challenges.

In support of these stated targets, the Independent Power Producer (IPP) sector has aggressively participated in the recent tenders put out by Indian power distribution utilities and other Federal Government Agencies to procure renewable energy. The largest beneficiary of the aggressive renewable energy targets has been the grid-scale solar PV sector, which has installed over 12 GW of new power generation capacity within a period of eight years, since 2009 when the Jawaharlal Nehru National Solar Mission was first conceived. The total installed capacity of grid-scale solar PV until July 2019 was more than 29 GW. Wind energy development is a more established renewable IPP sector in India. The first wind power projects were set up in the mid-1980s. Currently, India has over 36 GW of grid-connected wind power projects installed and operating in the country.

2.2 Need for Grid-Scale Energy Storage Systems

Grid-scale battery energy storage systems (BESS) present many use cases, where it can be utilized to enhance the penetration of renewable energy resources, into the national energy mix. Grid-scale energy storage may be particularly beneficial in the case of India, which has very aggressive renewable energy targets, but a constrained transmission and distribution grid infrastructure.

Additionally, renewable sources of energy generation are highly location specific, i.e. solar PV and wind are developed where solar irradiation and wind resources are high, both qualitatively and quantitatively. Most high-quality wind and solar irradiation resources are usually found in remote areas, which are far from large load centers such as major cities. Such areas are also power transmission constrained, leading to curtailment of renewable power generation when solar irradiation and wind speeds may be the highest. In such a case, energy storage may help with energy generation curtailment by providing the ability to store energy when the generation is high and transmission capacity or load is limited. As a result, energy storage helps enhance available grid capacity, a critical factor in fostering large renewable energy development and generation.

In India, the aggressive renewable and clean energy goals are widely recognized to hit a road block due to India's transmission grid's insufficient grid capacity. Renewable sources of energy particularly need strong interconnecting grid networks due to their intermittent nature of power generation, which can further stress the grid under a variety of conditions. Under such developing conditions, grid-scale energy storage is being viewed as a viable option, which may mitigate some of the challenges of renewable energy such as intermittency and the particular need for strong grid infrastructure.

Additionally, as intermittent sources of generation become more mainstream and prevalent, they will be expected to provide grid ancillary services which fossil fuel fired sources of power generation have traditionally provided. These include frequency and voltage support, generation dispatch-ability, time shifting of power generation, and possibly energy arbitrage. Energy storage, coupled with intermittent sources of power generation, can provide many of these grid ancillary services, and act more like fossil fired power generation resource in terms of operational impact on the power grid. As a result, energy storage coupled with intermittent sources of power generation can reduce operational disruptions on India's power grid, as it transforms its energy mix to more renewable energy, primarily solar PV and wind from the current energy mix of majority coal-fired power generation.

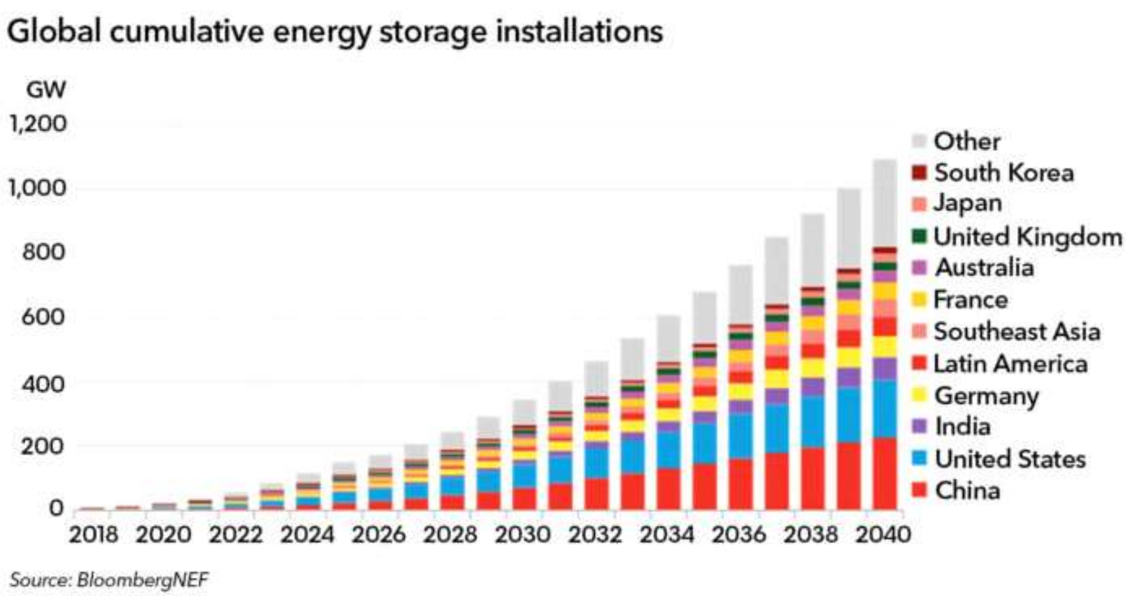
However, it should be noted that energy storage continues to be quite expensive for many of the grid services listed above. It is widely accepted that energy storage system prices must fall significantly (by at least 50 percent) to make it economic for large-scale adoption for the use cases presented here. Economics of grid-scale energy storage can be further complicated in a country such as India, where the cost of electricity is relatively quite low.

2.3 Market Potential and Export Potential for Clean Energy Technologies and Energy Storage in India

2.3.1 Grid Scale Energy Storage

Bloomberg New Energy Finance (BNEF) predicts that India could be the third largest market for energy storage in the world behind U.S. and China by 2040. In installed capacity terms, the market size for energy storage in the grid-connected segment could be between 50 GW and 80 GW by 2040. At average storage duration of two hours, the size of the storage component of the overall market in India is estimated to be between 100 GWh and 160 GWh. How much of these forecasts are actually realized will depend a lot on policies and tariffs which are required to be in place for large scale penetration of energy storage projects.

Figure 1: Expected Growth of Energy Storage Globally - Until 2040[1]



Though there were a number of solar PV plus storage tenders floated by Solar Energy Corporation of India Ltd. in 2018 and in 2019, but only one energy storage projects has materialized. Per our research India currently has only one operational project totaling 10 MWh that was commissioned and is currently in operation. This project was commissioned by Tata Power Delhi Distribution Limited in February 2019. The BESS was supplied by AES with balance of plant equipment supplied by Mitsubishi Corporation. A number of other energy storage projects are in various stages of tendering. However, the current status of project award or

[1] https://about.bnef.com/blog/energy-storage-investments-boom-battery-costs-halve-next-decade/

implementation is not known.

2.3.1 Grid Scale Solar PV and Wind

Grid-scale solar PV is expected to form the major component of the 175 GW renewable energy target that India intends to achieve by 2022. Over 29 GW of solar PV had already been installed by July 2019 out of a total goal of 100 GW of solar PV by 2022. However, the grid-scale solar power sector in India is almost entirely dominated by Asian suppliers such as China, Thailand, Vietnam, and Malaysia amongst others.

In wind energy sector, India has installed over 36 GW of power generation capacity achieving over 50 percent of its target of installing 60 GW of wind energy by 2022.

Table 1 below provides an assessment of manufacturing dynamics and the likelihood of procurement from the U.S. of different categories of major equipment

Table 1: Assessment of Manufacturing and Supply Dynamics of Major Clean Energy Technologies

Clean Energy Technology	Manufacturing Dynamics and Likelihood of U.S. Procurement
Solar PV	• The supply/ manufacturing side of solar PV remains very dynamic with large manufacturing and supply hubs based in Asia. • <u>*Solar PV panels*</u> - Most solar PV panel manufacturing has moved to Asia over the past few years, though limited manufacturing and assembly of high efficiency solar PV modules does happen in the U.S. We spoke to two high efficiency solar PV panel manufacturers based in the U.S. – Suniva and Mission Solar Energy. Both the manufacturers are U.S.-based and primarily supply their U.S.-manufactured stock to the Americas and in some cases to Africa. Both manufacturers confirmed that they will not be cost competitive in the Indian market due to severe competition from Asia-based manufacturers and the highly price sensitive nature of the Indian solar PV industry. Asia-based manufacturers currently dominate the Indian solar PV module segment". Our independent research confirms this. We believe the U.S. export potential to be zero for solar PV panels for the rooftop solar PV segment. • <u>*Solar inverters (Central Inverters and String Inverters)*</u>- Solar PV inverters have followed a similar path as the solar PV modules, where most of the manufacturing of these components has moved overseas. String inverters are now almost completely manufactured outside the U.S. Central inverters in the 150 kW to 1 MW and higher range can be sourced from U.S. companies, however, there is

	evidence that manufacturing of larger solar inverters is moving outside of the U.S. to lower cost manufacturing hubs as well. • Yaskawa – Solectria Solar is a major U.S. inverter manufacturer, which manufactures both string and central inverters. Though they still manufacture central inverters in the U.S., Solectria sources string inverters exclusively from a contract manufacturer in China. • Other major string inverter manufacturers such as ABB, SMA, Enphase, Eaton, Delta, and Sungrow manufacture all their string inverters outside the U.S. All these inverter manufacturers are active in India and dominate the utility scale inverter segment in the country. • *Solar PV Racking/Mounting and Balance of Plant* – U.S. manufacturers have been competitive in providing Solar PV racking for projects as far away as the Caribbean, South America, and Africa in some cases. We spoke to RBI Solar – a major Solar PV racking supplier and they confirmed that U.S. companies are not competitive in markets such as India which have well-established and highly competitive steel manufacturing – a key and majority component for Solar PV racking/mounting systems. We believe the U.S. export potential to be zero for solar PV racking or panel mounting systems. • *Balance of Plant* - Balance of Plant includes components such as wiring, switches, circuit breakers, low voltage circuit panels, wire harnesses, etc. These can all be classified as low technology, low voltage equipment for which India has a well-established supply chain. We believe the U.S. export potential to be zero for the Balance of Plant category. Overall, the U.S. export potential for the utility scale solar PV segment is expected to be negligible and close to zero, specifically in India's context. However, there is potential for U.S. exports in advanced power control, Supervisory Control and Data Acquisition (SCADA), and plant monitoring segments at the hybrid power plant level and at the Battery Energy Storage System (BESS) level. More details on this are provided in Section 2.3.2
Wind Power Generation Equipment	Wind turbine, generator, and other power equipment - For power generation equipment, Japanese and European suppliers are more competitive suppliers to the Indian market compared to U.S.-based suppliers. European wind turbine makers in particular have well-established in-roads into the Indian wind market. Some European wind turbine manufacturers such as Gamesa (now owned by Siemens of Germany), Enercon, and Vestas have manufacturing in India to supply the Indian wind power generation market. India also has very competitive, home-grown wind turbine makers such as Suzlon, Inox Wind Ltd., and ReGen Powertech

	which have cost and location advantages in the Indian market. Some of these Indian companies, such as Suzlon, are active globally and are active suppliers to North American and European markets. Amongst U.S.-based manufacturers, GE Wind has a manufacturing facility in Pune, India. Its Pune factory will most likely be the supplier of wind power generation equipment for wind projects in India, however some advanced power electronics may be sourced from U.S. sources depending on the wind turbines model(s) selected for the proposed Project.

2.3.2 U.S. Export Potential for Various Grid Scale Clean and Renewable Energy Technologies

Table 2 below details the U.S. export potential for various grid-scale clean energy technologies, primarily solar PV, wind, and grid-scale energy storage. Since solar PV and wind have very defined implementation targets set by the Government of India (GOI), those targets were used to estimate U.S. export potential. For BESS, the BNEF forecast was used to determine U.S. export potential.

Table 2: U.S. Export Potential for Various Grid-Scale Clean Energy Technologies

Major Equipment	Expected Market Size to Meet Renewable Energy Targets	Expected Total Project CAPEX Cost	U.S. Export Potential [Percent]	U.S. Export Potential [U.S. Dollar Amount]
Ground Mounted, Utility-Scale Solar PV, including Balance-of-Plant (1)	71 GW	$35.5B	5%	$1.8B
Wind Power Generation Equipment, including Balance-of-Plant (2)	24GW	$24B	10%	$2.4B
Large	Between	Between	15%	Between

Major Equipment	Expected Market Size to Meet Renewable Energy Targets	Expected Total Project CAPEX Cost	U.S. Export Potential [Percent]	U.S. Export Potential [U.S. Dollar Amount]
Centralized BESS, including Balance-of-Plant (3)	100 GWh and 160 GWh	$20B and $32B		$3B and $4.8B
Total U.S. Export Potential				**Between $7.2B and $9B**

Assumptions for CAPEX Costs for various

- Unit cost of solar PV CAPEX is assumed at $0.5 per watt or $500 per kW, based on DC wattage capacity installed.
- Unit cost of wind project CAPEX is assumed at $1,000 per kW of installed capacity.
- U.S. content for large centralized BESS varies between zero percent to fifty percent depending on the supplier. We assumed U.S. content for this segment to be an average of 15 percent. CAPEX cost for large, centralized BESS is assumed at $200 per KWh.

Balance of Plant – This category will consist of BESS housing assembly, monitoring and control hardware and software, thermal management and fire suppression hardware and associated software.

Power Conversion System – This primarily will include inverters for BESS, protection equipment such as switches, breakers, etc., and energy management system (EMS).

Additional Control Systems – This may include control systems such as battery management system (BMS).

U.S. export potential for grid-scale solar PV is estimated to be relatively small at about 5 percent and this will mostly constitute Balance of Plant equipment. As a result, even though India will install over $35.5 billion worth of additional grid-scale solar PV equipment, U.S.'s share in that market segment may be limited to only about $1.8 billion.

At an average price of $200 per kWh for BESS, the overall market for energy storage could be worth between $20 billion and $32 billion. At an estimated U.S. export potential of 15 percent in aggregate for the battery energy storage systems and balance-of-plant equipment, the cumulative export of U.S. goods and services for energy storage systems is estimated to be between $3 billion and $4.8 billion over the next 20 year period.

Overall, we have estimated U.S. export potential for goods and services for the wind projects to be around 10 percent. Unit cost of wind project CAPEX is assumed at $1,000 per kW of installed capacity. As a result, installation of 24 GW of wind energy capacity by 2022 or sometime after that will result in U.S. exports in the range of $2.4 billion. The total U.S. export potential across the three categories – Grid-scale solar PV, Wind Power Generation, and Large Centralized BESS is expected to be between $7.2 billion and $9.2 billion.

2.3.3 Major Stakeholders

The major stakeholders from a procurement perspective are clean energy project developers. These are the firms that develop solar PV and wind power projects in India. Such developers are likely to also develop grid-scale energy storage in the future, either as stand-alone basis or collectively with their solar PV or wind power project. Some of the most prominent and large grid-scale clean energy developers in India include:

- Adani Green Energy
- ReNew Power
- NLC India Limited, a GOI owned mining company
- ACME Solar
- Essel Infra
- Tata Power
- Greenko Group
- Azure Power

Other major stakeholders include Federal Government agencies and state-owned or private power distribution companies (DISCOs) that procure clean energy. Amongst the Federal Government agencies, the most important stakeholders are Solar Energy Corporation of India and National Thermal Power Corporation which have led the procurement of larger solar PV projects. Solar Energy Corporation of India has also been active in procurement of grid-scale energy storage since 2018.

2.3.4 Foreign Competition and Market Entry Issues

Foreign competitors are identified by category of major equipment required for the Project:

- **Solar PV** - Several international solar PV equipment suppliers are likely to be interested in the Project including some U.S.-based suppliers. The U.S.-based manufacturing for solar PV modules has pivoted towards high quality, high efficiency solar PV modules but are also more expensive. India is a highly price sensitive market, a fact established by aggressively falling project development costs and prices at which recent Power

Purchase Agreements (PPAs) have been signed. At these ultra-competitive PPAs for large-scale solar PV projects, U.S.-based manufacturers are not competitive in the Indian market.

Globally, Chinese suppliers dominate the solar module market. Table 3 shows a snapshot of the largest suppliers of solar PV panels globally.

Table 3: Solar Panel Manufacturing Locations

Company	Tech	Manufacturing Sites	Module Capacity	Cell Capacity	2015 Shipments
			MWp	MWp	MWp
Trina Solar	c-Si	China / Netherlands	5,100	3,700	3,631
JA Solar	c-Si	China / Malaysia	4,000	4,000	3,617
Hansha Q-Cells	c-Si	China / Germany / Malaysia / S Korea	4,300	4,300	3,400
Canadian Solar	c-Si	China	4,300	2,700	2,691
First Solar	CdTe/c-Si	U.S. / Malaysia	2,900	3,160	2,518
Jinko Solar	c-Si	China / Malaysia	4,700	3,000	2,400
Yingli Solar	c-Si	China	2,450	2,450	2,388
Motech Solar	c-Si	Taiwan / China	1,400	2,150	2,100
NeoSolar	c-Si	Taiwan / China	500	2,120	2,100
Shungfeng-Suntech	c-Si	China / U.S. (Suniva Investment)	2,000	1,800	1,970
Other			37,431	32,897	23,988
Total			69,081	62,277	50,803

Source: Renewable Energy World 8 April 2016

- **Battery Energy Storage Systems** - Within the different chemistries that are available in the BESS space, lithium-ion (Li-ion) is by far the most prevalent technology for large-scale grid applications. Li-ion based BESS also has the largest scale of implementation in the grid-scale energy storage category globally. For the purposes of evaluating this proposal, Li-ion was considered as the leading contender for the Project. Currently, the Li-ion cells and battery packs are not made in the U.S., except for by Panasonic. Other Li-ion based BESS integrators and battery pack suppliers in the U.S. import them from Asia. Panasonic manufactures Li-ion cells and batteries for captive use by Tesla at the Gigafactory. Panasonic and Sony (Japan), LG Chem and Samsung SDI (South Korea), and ATL and BYD (China) are the biggest suppliers of Li-ion cells and battery packs to global integrators of BESS. Asian suppliers are the most likely suppliers for this Project, due to their close proximity to India.

- **Wind Power Generation Equipment** – This segment primarily involves wind turbines and associated power generation equipment. The wind power generation industry is well established in India, with significant indigenous manufacturing. Amongst non-Indian companies, both European and American companies have manufacturing or assembly in India. Due to the low cost of sourcing wind power generation equipment from within India, most wind power generation equipment for the Project is likely to be supplied locally and not imported. Table 4 below provides a list of foreign (non-U.S. based manufacturers) suppliers established in the wind power industry in India.

Table 4: Foreign Wind Power Generation Equipment Manufacturers

India Based Suppliers	Non-U.S. and Non-India Based Suppliers
Vestas (European company with manufacturing in India)	Mitsubishi Power Systems (Japan)
GE Wind (U.S. Company with manufacturing in India)	Hitachi (Japan)
Gamesa (European company with manufacturing in India)	GoldWind (China)
Suzlon	China Guodian Corporation (China)
Inox Wind Ltd.	Hyundai Heavy Industries (South Korea)
ReGen Powertech	Sinovel (China)

The following points highlight our initial understanding of key market entry issues, both positive and negative, that may result from this Project.

Market Entry Issue	Evaluation
Procurement mechanism	• Procurement for grid-scale clean energy projects are mostly through competitive tendering. • Components such as BESS, which are novel in India's context, are likely to be procured through global tendering. • U.S. companies may have equal access, though they will face significant competition in most of the categories of major equipment that they compete in. India has significant downward cost pressures in clean energy procurement tenders which are likely to be a major challenge for U.S. suppliers.
Technology and licensing issues	• There are no major technology and licensing issues associated with procurement of solar PV, wind, or energy storage projects. Project developers may have to procure licensing for any BESS software and any control and SCADA software platform that may be installed during the implementation phase of BESS projects. This is the

Market Entry Issue	Evaluation
	standard software licensing mechanism followed by the industry.
Local industry capabilities	• Local suppliers and partners will likely provide installation services. Majority of the Balance of Plant equipment is likely to be sourced locally from India-based suppliers. • Most of the Project implementation services are likely to be supplied locally by Indian suppliers. • Wind equipment manufacturing is well-established in India. Even if a U.S. company such as GE Wind is selected to supply wind power generation equipment, it is likely to supply it from its manufacturing plant in Pune, India.
Geographic factors	• The U.S. has a geographical disadvantage in the Indian market context. India lies within or close to the Asian manufacturing hub for certain power generation technologies envisioned for this Project, such as solar, li-ion cells and batteries, and wind power generation equipment.

2.4 U.S. Companies Active in India and Interested in India's Clean Energy Sector

A number of U.S. companies, providing both goods and services are either active in the Indian market or have shown a strong interest in business opportunities in the Indian market. We spoke to several of these U.S. companies during the course of the desk study. A listing of the U.S. companies contacted and contacts for their business development staff is provided on the following page.

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	Form of Company	Firm/Organization	Contact Person First Name	Contact Person Last Name	Contact Title	Address	Address 2	City	Zip (Postal) Code	Country	Phone	Fax	Email Address
1	Solar PV Module Manufacturer	Mission Solar Energy	Aarn	Arriaga	Business Development	8303 S. New Braunfels Ave.,		San Antonio, TX	78235	USA	210-531-8646		aarriaga@missionsolar.com
2	Solar PV Module Manufacturer	Suniva	Johnny	Baumstark	Inside Sales	5765 Peachtree Industrial Blvd		Norcross, GA	30092	USA	770-656-0862		khughes@suniva.com
			Kenny	Hughes	Sales Director, Eastern United States and Caribbean Suniva Inc.	5765 Peachtree Industrial Blvd.,		Norcross, GA	30092	USA	404-838-7393		jwbaumstark@suniva.com
3	Solar PV Inverter Manufacturer	Solectria Renewables	Russ	David	Regional Sales Manager	4 Harmony Circle		Malvern, PA	19355	USA	610-291-4689		russ.dodd@solectria.com
4	Solar PV Inverter Manufacturer	Ingeteam	Nohra	Nasr	Head of PV Sales & Business Development	3550 W. Canal Street		Milwauke, WI	53208	USA	312-771-1943		nohra.nasr@ingeteam.com
5	Grid Scale Battery Manufacturer	Tesla	Jake	Milan	Business Development - Tesla Energy Products	3500 Deer Creek Road		Palo Alto, CA	94304	USA	206-409-5606		jmillan@tesla.com
6	Grid Scale Battery Manufacturer	Aquion	Nishant	Sharma	Business Development	684N 9th Street		San Jose, CA	95112	USA	415-737-5900		nsharma@aquion-energy.com
7	EPC and Consulting	Black & Veatch	Frank E.	Jakob	Technology Manager – Energy Storage	11401 Lamar Avenue, Overland Park, KS 66211 USA		Overland Park, KS	66211	USA	614-270-6327 |	913-458-3005	JakobFE@BV.com
8	Grid Scale Battery Manufacturer	AES Energy Storage	Kiran	Kumaraswamy	Market Development Director	4300 Wilson Blvd		Arlington, VA	22203	USA	571-527-8498		Kiran.Kumaraswamy@aes.com
9	DFI	International Finance Corporation	Peter	Moeckel	Principal Industry Specialist - Energy Storage	2121 Pennsylvania Ave NW		Washington, DC	20433	USA	202-473-1000		pmockel@ifc.org

3. Distributed Energy Resources

Distributed Energy Resources or DERs is a wide-ranging term that can mean a number of behind-the-meter technologies and services that can be implements by a power utility for its customers. In the context of our work completed for USTDA for the Indian market, DERs are generally comprised of the technologies listed below.

- Energy efficiency (also known as passive demand response)
- Active demand response
- Customer-sited generation options, primarily solar PV
- Energy storage, both coupled with behind-the meter generation such as solar PV and stand-alone energy storage (without any coupled or interconnected behind-the-meter generation)
- Electric vehicles
- Software tools such as Distributed Energy Resources Management (DERMS)

3.1 Technical Drivers for Distributed Energy Resources

Table 5 below provides the technical drivers that will determine the growth of DERs in India in the medium-term and long-term

Table 5: Technical Drivers for Distributed Energy Resources

Technical Drivers	Strong, Moderate, or Weak
Environmental Pollution	***Strong*** – India has some of the most polluted cities in the world. Most of the pollution in the capital city of New Delhi and other polluted cities are caused by transportation emissions and particulates produced as a result of heavy construction related activities, though power generation related emissions may be a significant contributor as well.
Reduction of greenhouse gas emissions	***Strong*** – India is a signatory to Conference of Parties, 21st meeting (COP21) accord of 2016 and has aggressive targets to reduce greenhouse gas emissions. The Government of India is particularly focused on reducing pollution from power generation resources, with a significant public policy focus on

Technical Drivers	Strong, Moderate, or Weak
	deploying solar PV and large-scale wind power. The focus has been to reduce power generation from fossil fuel fired generation, particularly coal.
Development of renewable energy resources, specifically behind-the-meter DERs and rooftop solar PV	***Moderate for behind-the-meter solar PV*** - In the context of customer-sited solar PV project, rooftop solar PV development has been slow, accounting for less than 1% of the total installed generation capacity in the country. ***Weak for other types of DERs*** – Currently, the penetration of other types of DERs, such as EVs, active demand response, and energy storage, in India is minimal. Though there is a renewed push to increase penetration of EVs, incentives to adopt DER technologies other than solar PV remain minimal and inadequate.
Need for advanced DER technologies due to power grid requirements	***Weak in short to medium term -*** The need may be moderate to strong over a longer horizon, but currently there are no such indicators for power sector in India.
Exiting tariff for energy and demand charge (Energy tariff or charge is the price paid by a retail customer for each KWh used and is measured in $/kWh. Demand charges are based on the maximum demand in KVA, measured over a billing period. It is measured in $/KVA/ billing period)	***Weak for demand charges*** – Demand charges are a significant driver for many DER technologies such as energy storage, energy efficiency, controllable loads and solar PV. Demand charges (in the highest tariff slab) are relatively very low at less than $2/ KVA/ month on an average across the country. Our discussion with various behind-the-meter BESS providers in the U.S. indicates that behind-the-meter BESS requires a demand charge of around $20/ KVA/ month to be economically feasible, in addition to other revenue streams and direct incentives. ***Moderate for behind-the-meter solar PV*** - Behind-the-meter Solar PV development is driven by both energy tariffs and demand charges. Energy charges across utilities in India are reasonable to foster a higher penetration of solar PV.

3.2 Public Policy Drivers for Distributed Energy Resources

The public policy drivers are strong for the adoption of certain DER technologies and weak for others. In this section, we address the public policy drivers for each of the DER technologies that may be developed in the wider Indian market.

Table 6: Public Policy Drivers for Distributed Energy Resources

DER Technology	Public Policy Drivers – Weak, Moderate, or Strong
Rooftop Solar PV (Behind-the-meter)	***Strong*** - Implementing solar PV has a strong public policy push at the federal level, which has trickled down to the state level.
Electric Vehicles	***Weak, but evolving*** – India has had a public policy push and subsidies in place in some form or the other since 2010, but very little has actually happened on the ground. EV penetration in India was an abysmal 0.011% in 2016.
Controllable Loads	***Weak –*** Controllable loads need smart control devices such as smart thermostats and other smart temperature control devices. Our research indicates there is no public policy push or incentives at either the federal level or the state/territory government level to foster the growth of controllable load technologies.
Energy Efficiency	***Moderate to Strong, but focused mostly on LED lighting*** - The present federal government has pursued strong policies to foster the implementation of energy efficient lighting, primarily LED lighting. Energy efficiency labeling for other types of equipment such as air conditioners and refrigerators has existed for a long time in India. There is no specific public policy push to increase the penetration of such devices and compliance by customers is mostly voluntary.

3.3 Economic Drivers for the Distributed Energy Resources

In this section, we evaluate economic drivers for DERs and large-scale implementation of DERs in a typical power distribution utility's market.

Table 7: Economic Drivers for the Distributed Energy Resources

Economic Drivers	Strong, Moderate, or Weak
Cost of Electricity (energy charge)	***Moderate*** – The average cost of electricity for residential and commercial customers in large cities such as New Delhi starts at about 6.2 cents/ KWh and increases up to 13.2 cents/ KWh, as the usage increases. The lower end of the range is not attractive to increase the penetration of DERs including solar PV because DERs (including solar PV), need a higher rate than 6.2 cents/ KWh to be economically feasible. The upper price range of 13.2 cents/ KWh makes certain DER technologies such as solar PV and energy efficiency attractive, but not for many others such as energy storage and controllable loads.

Demand Charges or Fixed Charges	***Weak*** - Demand charges are critical to the economic viability of most DER technologies, such as energy storage and controllable loads. On an average for residential and commercial customers in the capital city of New Delhi, demand charges are very low - between 62 cents/ month to $1.54/ month. At this rate, most DER technologies are not expected to be competitive. Charges in other smaller cities are even lower. On the industrial customer's side, demand charges are higher, ranging between $1.24/KVA/ month and $2.23/ KVA/ month. Though the rates are higher compared to residential and commercial rates, they are still significantly lower than the price points at which certain DER technologies such as energy storage are cost effective. For example, behind-the-meter energy storage is currently economical only in a small subset of geographies in DER-leading countries such as the U.S. These include parts of California, New York City, Long Island, and parts of Connecticut. In all these regions, demand charges exceed $20/ KVA/ month. In addition to high demand charges, a behind-the meter BESS needs other revenue streams and other direct subsidies to be economical. Most of these types of direct incentives are likely to be a non-starter in a developing country like India. Additional revenue streams required to make DERs feasible need an additional cost recovery based tariff mechanism which would lead to increase in rates for retail customers. Increase in energy rates can become a politically sensitive issue in India.

3.4 Current State of Affairs - Distributed Energy Resources Sector in India

DERs, in general and except of rooftop solar PV are in very early stages of adoption and development in India. Below are some of the highlights of DER related progress that has been make in the wider Indian market.

- Over 250 million LED bulbs have been distributed under the Unnat Jeevan by Affordable LEDs and Appliances for All (UJALA) program by the Federal Government, in addition to over 2.8 million LED tube-lights and 1 million energy efficient fans.

- Approximately 3.9 GW of rooftop solar PV was installed in India at the end of CY2018.

- In 2018, India had about 1.5 million battery-powered, three-wheeled rickshaws.

Implementation of other DER technologies in India is minimal and non-existent. No credible source on the extent of implementation of other DER technologies could be found during our research.

3.5 Market Potential for Distributed Energy Resources in India

The U.S. export potential for DERs could vary significantly based on the scope of DER adoption in India. Scope of DER adoption will in-turn depend on the maturity of DERs in the Indian context and the underlying economics of DERs compared to other modes of energy supply, both renewable and conventional. As detailed in previous sections of this report, the economic and technical drivers for a large-scale DER roll-out are expected to be weak in the Indian context in the short (0-3 years) to medium term (0-5 years). U.S. firms' competitive advantages are expected to be very limited in the hardware segment for various DER technologies but could be substantial in the software segment. We discuss the manufacturing dynamics of the software and hardware segment for each proposed DER technology and the likelihood of their procurement from U.S. sources in the sections below. The information presented in this section is based on interviews with various DER hardware and software suppliers based in the U.S., a desktop assessment of current DER market dynamics in India, and DER adoption trends in the U.S.

The following general assumptions are made in calculating the export potential for U.S. goods and services for DERs:

- The DER adoption rates and trends will generally follow adoption rates and trends as seen in the U.S., a leading country in DER adoption.
- In terms of the timeline for DER adoption, India will lag the U.S. by at least five years. We believe this assumption is highly optimistic, considering that the DER market is largely non-existent in India in general.

Table 8: Manufacturing Dynamics and Likelihood of U.S. Procurement for DER Technologies

DER Technology	Manufacturing Dynamics and Likelihood of U.S. Procurement
Rooftop Solar PV	• The supply/ manufacturing side of solar PV remains very dynamic with manufacturing and supply hubs across the world. • *Solar PV panels* - Most solar PV panel manufacturing has moved to Asia over the past few years, though limited manufacturing and assembly of high efficiency solar PV modules does happen in the U.S. We spoke to two high efficiency solar PV panel manufacturers based in the U.S. – Suniva and Mission Solar Energy. Both the manufacturers are U.S.-based and primarily supply their U.S.-manufactured stock to the Americas and in some cases to Africa. Both manufacturers confirmed that they will not be cost competitive in the Indian market due to severe competition from Asia-based manufacturers and the highly price sensitive nature of the Indian solar PV industry. Asia-based manufacturers currently dominate the Indian solar PV module segment. Our independent research confirms this. We believe the U.S. export potential to be zero for solar PV panels for the rooftop solar PV segment. • *Solar inverters (including smart solar inverters)* - Solar PV inverters have followed a similar path as the solar PV modules, where most of the manufacturing of these components has moved overseas. String inverters are now almost completely manufactured outside the U.S. Central inverters in the 150 kW to 1 MW and higher range can be sourced from U.S. companies, however, there is evidence that manufacturing of larger sized solar inverters is moving outside of the U.S. to lower cost manufacturing hubs as well. • Yaskawa – Solectria Solar is a major U.S. inverter manufacturer, which manufactures both string and central inverters. Though they still manufacture central inverters in the U.S., Solectria sources string inverters exclusively from a contract manufacturer in China. • Other major string inverter manufacturers such as ABB, SMA, Enphase, Eaton, Delta, and Sungrow manufacture all their string inverters outside the U.S. • We believe the U.S. export potential to be zero for solar PV inverters for the rooftop solar PV segment. • *Solar PV Racking/Mounting and Balance of Plant* – U.S. manufacturers have been competitive in providing Solar PV racking for projects as far away as the Caribbean, South America, and Africa in some cases. We spoke to RBI Solar – a major Solar PV racking supplier and they confirmed that U.S. companies are not

DER Technology	Manufacturing Dynamics and Likelihood of U.S. Procurement
	competitive in markets such as India which have well-established and highly competitive steel manufacturing – a key and majority component for Solar PV racking/mounting systems. We believe the U.S. export potential to be zero for solar PV racking or panel mounting systems. • *Balance of Plant -* Balance of Plant includes components such as wiring, switches, circuit breakers, low voltage circuit panels, wire harnesses, etc. These can all be classified as low technology, low voltage equipment for which India has a well-established supply chain. We believe the U.S. export potential to be zero for the Balance of Plant category. Overall, the U.S. export potential for the rooftop solar PV segment is expected to be negligible and close to zero, specifically in India's context.
Electric Vehicles and EV Chargers	*Electric Vehicles* – This segment can be broadly sub-divided into electric cars, light commercial electric vehicles, and electric buses. This segment can be further sub-divided into the following categories: Electric Cars: This segment includes either fully built electric vehicles (EVs) or assembly kits for EVs or plug-in hybrid vehicles exported from the U.S. to India. Examples include Tesla Model S, Model X, and Model 3, Chevy Bolt, Ford Focus Electric, Ford C-Max Energi, and Ford Fusion Energi. There are several factors which do not favor any significant export of EVs from the U.S. to India: • None of these models are currently available in India. The cheapest EV currently manufactured in the U.S. is the Ford Focus Electric starting at about $29,120. With import duties that can be as high as 125%, the landed or off-the-shelf cost of such a vehicle would be approximately $65,520, over 12x the cost of the best-selling car in India (the Maruti Suzuki Alto which currently retails for approximately $5,108 for the lowest cost version). • Prominent U.S. auto manufacturers, which are also active in the EV space, have pulled back from an anticipated EV foray in the Indian market. Part of this can be blamed on the Government of India (GOI)'s ambiguous policies which require high localization content for the automobile sector. Our discussion with Tesla confirmed that they do not have a firm timeline on when Tesla automobiles may be available in India. General Motors in general is pulling back from India, and Ford pulled out of an EV consortium in 2016 looking to

DER Technology	Manufacturing Dynamics and Likelihood of U.S. Procurement
	create a supplier base for EVs and hybrid EVs in India. • Some of the Asia-based suppliers and manufacturers of automobiles in general such as Suzuki, Hyundai, BYD, and Mitsubishi are well-entrenched in the Indian market, with significant manufacturing presence. They are also better positioned to comply with high localization content that the GOI requires in the automobile sector. Additionally, Asian manufacturers are more focused on manufacturing compact and sub-compact cars, the most popular category of automobiles in India and the likely candidates for early electrification. U.S. manufacturers, on the other hand, are more focused on manufacturing bigger sedans, which are high on luxury and generally more expensive. <u>Light Commercial Vehicles</u>: Our research indicates that there is no significant opportunity for U.S. companies in this segment. U.S. manufacturers have no presence in this segment in India. Generally, this is also one of the more neglected segments of EV across the value chain even in the U.S., trailing electrification of other classes of EVs. We believe the U.S. export potential for EVs in this segment to be non-existent. <u>Electric Buses:</u> Electrification of intra-city bus transportation has gained some traction in recent years. Some cities in India have started pilot projects in this segment. The market in general remains very small with little to no presence of U.S. suppliers. Most active players in this segment are Chinese suppliers such as BYD and Indian manufacturers such as Tata Motors and Ashok Leyland. Currently, procurement for electric buses is minimal at fewer than 100 units per year through various pilot programs. Indian manufacturers such as Tata Motors, Mahindra, and Ashok Leyland are in the early stages of discussions to set up electric and hybrid bus manufacturing facilities in India. BYD has a substantial manufacturing base in China, and is expected to export EV buses from China before local manufacturing can be established in India. None of the U.S. manufacturers or assemblers of electric buses, such as Astonbus, BYD Electric Bus, and Smith Electric Vehicles, have announced plans to manufacture EV buses in India. As a result of this analysis, we conclude that the U.S. export potential in this segment may be close to zero in the short (0-3 years) to medium term (0-5 years).

DER Technology	Manufacturing Dynamics and Likelihood of U.S. Procurement
	EV Charging Equipment – EV charging equipment generally consists of low voltage charging pods, set up to form a charging station. In general, it is low technology equipment which can be manufactured locally without the need for any significant import. India is a 50 Hz electrical grid system vs. 60 Hz in the U.S. GE is a major manufacturer of EV chargers for the U.S. market. Eaton is another established U.S. manufacturer that manufactures EV chargers for U.S. market. Both manufacturers are primarily focused on the U.S. market. The European and Chinese EV charger market follows the same specifications as India and so European and Chinese companies manufacture 50 Hz equipment. We conclude that, initially, Europe and/ or China are much more likely contenders to export EV charging pods and charging station equipment to India. Eventually, if EV penetration reaches a critical mass in India, EV chargers are likely to be manufactured locally. Consequentially, U.S. export potential in this segment may be zero.

Battery Energy Storage Systems (BESS)	Within this segment, BESS can be sub-divided into two categories –
	
	• Large centralized BESS – these fall in the multi-MW range and usually interconnect directly to the electric transmission and distribution lines or to a utility's electric substation. A power distribution utility – Tata Power Delhi Distribution Limited (TPDDL) currently has a 10 MW centralized pilot BESS on its network which was installed in collaboration with AES and Mitsubishi. We believe this segment of BESS to be limited in the context of major city DISCO, such as TPDDL due to the following reasons. Use case of TPDDL is just used as an example for easier understanding of the discussion.
	  ◦ Space constraints – Large centralized BESS need a significant amount of space, similar to building traditional substations. If limited space is available to develop new T&D infrastructure this is a concern for TPDDL that is not likely to be mitigated by large centralized BESS
	  ◦ Firming up solar PV generation – Intermittency of renewables, primarily solar PV is not a concern until solar PV penetration has reached at least 20% penetration. California installed large scale BESS in the 2014-2015 timeframe when solar PV penetration was between 25% and 28% of its peak load. Our calculations indicate that this level of penetration in TPDDL's service territory may not be reached until 2030, based on current solar PV penetration levels.

DER Technology	Manufacturing Dynamics and Likelihood of U.S. Procurement
	• Demand Management – Demand Management using BESS is only feasible in cases where the variability in load is high and spikes in load increases are observed for relatively short periods of time (couple of hours). TPDDL's average load is relatively flat and uniform over the year. TPDDL's increase in load is in the form of plateaus rather than peaks extending beyond a couple of hours. There may be niche applications that may exist at power distribution companies (DISCOs) for large-scale BESS. Considering that large-scale BESS penetration remains well below 0.5% on a base of total installed generation capacity in DER leading economies such as the U.S. (and California within U.S.), optimistically we assume that penetration of large-scale centralized BESS will reach 1% of the peak load within a 5-year period from 2019 to 2023 in India. • Distributed BESS Coupled with Rooftop Solar PV – This segment includes small BESS systems in the 1 KW to 10 KW range, installed on the premises of the retail utility customer and tied directly with rooftop solar PV. Distributed ESS is connected behind-the-meter with solar PV at a customer's premises. A relatively new concept, growth in this segment in the U.S. has been varied. Current projections of behind-the-meter BESS is about 15% of the total BESS installed capacity in the U.S. The U.S. had 380 MW of total BESS installed by the end of 2016. Assuming penetration of 15%, the U.S. penetration of behind-the-meter BESS was about 57 MW. With average battery storage of 2.5 hours, the MWh rating is estimated at 142.5 MWh in the U.S. As an example, TPDDL's peak load as a percent of India's peak load demand in 2015-2016 was 1.42%. Based on TPDDL's peak load as a percent of India's total peak load demand in 2015-2016, we estimate that as much as 0.8 MW and 2 MWh of behind-the meter BESS may be installed in TPDDL's service territory by 2022 – 2023. • Within the different chemistries that are available in the BESS space, lithium-ion (Li-ion) by far has been the most successful technology for large-scale grid applications. Li-ion based BESS also has the largest scale of implementation in the grid-scale energy storage category globally. For the purposes of evaluating this proposal, Li-ion was considered as the leading contender for the BESS, both for large centralized BESS and behind-the-meter BESS. Currently, most Li-ion cells and battery packs are not made in the U.S. and are imported

DER Technology	Manufacturing Dynamics and Likelihood of U.S. Procurement
	from Asia. Panasonic, Sony (Japan), LG Chem and Samsung SDI (South Korea), ATL and BYD (China) are the biggest suppliers of Li-ion cells and battery packs to U.S.-based integrators. Tesla, in collaboration with Panasonic, is the only U.S.-based manufacturer of Li-ion cells and battery packs. Tesla may be a supplier of U.S.-manufactured Li-ion cells and batteries from its Gigafactory, but this is not likely due to strong and unfulfilled demand for batteries for Tesla's automobiles for which the Gigafactory will be the primary supplier of the necessary Li-ion batteries. For use in India, Li-ion cells and battery packs can more economically be procured from various Asian suppliers.
Energy Efficiency	Energy efficiency or passive demand response in the context of India has been focused on LED lights, energy efficient ceiling fans, and energy efficient air conditioning. India has a local manufacturing base to supply such energy efficient equipment. All this equipment is low cost with low technology content and is also readily available from other Asian countries such as China, Vietnam, South Korea, and others via established import channels. We believe that there is no potential for exports in this category from the U.S.
Load Control (Active Demand Response Software) and DER Control and Management Software	Load control and DER control and management software includes software platforms such as Distributed Energy Resources Management System (DERMS) which utilities procure to control and manage variable loads and DERs after their penetration has reached a critical level. Our own experience in working with DERMS vendors and various utilities has indicated that utilities tend to procure DERMS software when the DER penetration has reached about 10% of the peak load. U.S. competitiveness is high in the DERMS or DER control software segment. The market is dominated by U.S.-based and Western Europe-based companies. European vendors in this segment include ABB, Siemens, and Smarter Grid Solutions. We spoke to a number of U.S.-based DERMS vendors, such as Autogrid and Spirae, and conclude the probability of a U.S.-based vendor to be selected to supply a pilot DERMS platform at 70%.

3.3.1 U.S. Export Potential for DER Related Technologies

Table 9 provides the U.S. export potential for various DER technologies based on discussion in previous sections.

Table 9: U.S. Export Potential Estimates

DER Category or Technology	Expected Penetration by 2023 - India	Expected Total CAPEX Cost	Additional Implementation Labor	Total Initial Cost	U.S. Export Potential
Rooftop Solar PV (1)	40 GW	$60B	$0 (no U.S.-based labor will be used for implementation)	$60B	$0M
Electric Vehicles (2)	9,200	$138M	$0 (no U.S.-based labor will be used for implementation)	$138M	$0M
EV Chargers (3)	15,000	$30M	$0 (no U.S.-based labor will be used for implementation)	$30M	$0M
Behind-the-Meter BESS (5)	60MW/ 150MWh across India	$105M	$0 (no U.S.-based labor will be used for implementation)	$105M	$16M
Distributed Energy Resources Management (DERMS) Software Platform (6)	Up to 10 DISCOs install DERMs software platforms	$200M	$1,000,000	$201M	$141M
Total U.S. Export Potential					**$157M**

Assumptions:

- CAPEX cost for rooftop solar PV is assumed at $1.5 per watt. We are assuming that Indian will meet its target of installing 40 GW of rooftop solar PV
- Electric Vehicles – EV growth projections are based on a 30% growth rate per annum for the years 2017 through 2023, though current penetration of EVs in India is negligible at about 0.011% of total vehicle sales in 2016.
- EV chargers' penetration is assumed at 15,000 EV chargers across India by 2023. We believe these numbers are optimistic, considering that Tesla had less than 5,000

chargers around the world in early 2017.

- Behind-the-meter BESS penetration numbers are based on penetration trends in the U.S, collected through publicly available information. We assumed U.S. content for this segment to be 15%. CAPEX cost for behind-the-meter BESS is assumed at $700 per KWh.
- DERMS software platform estimates assume $250,000 in base licensing cost for a pilot license, plus $5,000 per MW of DER load managed through the DERMS platform. Both cost components are annually recurring. It is assumed that the DERMS pilot is installed in 2020-21, and an additional 2-year annual licensing fee is included in the estimate. Lastly, the estimate assumed 70% probability of being procured from a U.S. vendor vs. a competing Western Europe based vendor.

3.3.2 Major Stakeholders

Major stakeholders in the DER procurement space are state-owned and privately-owned DISCOs across the country. Some of the most prominent and larger DISCOs that may be looking to procure DER related technologies, both goods and services are listed below.

- Assam Power Distribution Company Limited (APDCL), Assam
- Andhra Pradesh State Electricity Board (APSEB), Andhra Pradesh
- Uttar Haryana Bijli Vitran Nigam Limited
- Dakshin Haryana Bijli Vitran Nigam
- Brihanmumbai Electric Supply and Transport
- BSES Rajdhani Power Ltd. Delhi
- Bangalore Electricity Supply Company
- BSES Yamuna Power Ltd. Delhi
- Calcutta Electric Supply Corporation
- Chamundeshwari Electricity Supply Corporation Limited
- Damodar Valley Corporation
- Dakshin Gujarat Vij Company Ltd. (DGVCL) Surat
- India Power Corp. Ltd.
- Goa Electricity Board
- Gulbarga Electicity Supply Company Limited.
- Hubli Electricity Supply Company Limited
- Karnataka Power Corporation Limited
- Kerala State Electricity Board

- Madhya Gujarat Vij Company Ltd. (MGVCL) Vadodara
- Maharashtra State Electricity Distribution Company Limited
- Mangalore Electricity Supply Company Limited
- Madhya Pradesh Paschim Kshetra Vidyut Vitaran Company Ltd.
- Madhya Pradesh Poorv Kshetra Vidyut Vitaran Company Ltd.
- Madhya Pradesh Madhya Kshetra Vidyut Vitaran Company Ltd.
- Manipur State Power Distribution Company Limited
- National Thermal Power Corporation
- Neyveli Lignite Corporation
- Noida Power Company Limited
- Paschim Gujarat Vij Company Ltd (PGVCL) Rajkot
- PowerGrid Corporation of India
- Reliance Infrastructure
- Southern Electricity Supply Company of Orissa
- Tamil Nadu Electricity Board
- Tata Power
- Tata Power Delhi Distribution Limited (TPDDL), Delhi
- Torrent Power Ltd
- Essel Vidhyut Vitran Ujjain Pvt. ltd.
- Torrent Power Ltd, Ahmedabad
- Torrent Power Ltd, Surat
- Uttar Gujarat Vij Company Ltd (UGVCL) Mehsana
- Torrent Power Ltd, Agra
- West Bengal State Electricity Board (WBSEDCL)
- North Bihar Power Distribution Company Limited
- South Bihar Power Distribution Company Limited
- North Eastern Supply Company of Odisha Ltd
- Punjab State Power Corporation Limited
- Power Development Department
- Uttar Pradesh Power Corporation Limited
- Jaipur Vidhyut vitran Nigam Ltd
- Ajmer Vidyut Vitran Nigam Ltd

- Jodhpur Vidhyut Vitran Nigam Ltd
- Tripura State Electricity Corporation Limited (TSECL)

3.3.3 Foreign Competition and Market Entry Issues

- Rooftop Solar PV and BESS – Please see Section 2.3.3.

- Energy Efficient Equipment – Asia dominates manufacturing for energy efficient lighting, specifically LED lighting. India also has a significant LED manufacturing and assembly base, though most of the silicon wafers to manufacture LED lighting are imported from countries such as China, Taiwan, Malaysia and South Korea amongst others. U.S.-based manufacturers are not competitive in supplying energy efficient equipment to the Indian market.

- Electric Vehicles – Foreign competition in this segment is expected to mainly come from Asian manufacturers, which manufacture EVs in Asia and in the same class or category that are popular in India. Foreign competition in this segment is expected to be from Toyota (Japan), Honda (Japan), Nissan (Japan), Mitsubishi (Japan), Hyundai (South Korea), and Suzuki (Japan), all of which have some manufacturing presence in India. All these manufacturers have hybrid electric, light hybrid, full hybrid, or full electric vehicles available in their offerings which are likely to be imported into India before local manufacturing can be established.

  Some European auto manufacturer such as BMW, Audi, and Mercedes Benz are also active in the Indian market and, in the future, will be able to offer either full electric or hybrid electric vehicles in the Indian market in the premium or luxury segment.

  Electric Buses – The competition here is expected to be from well-established Chinese players such as BYD, which has provided a very limited number of buses for trial runs/pilots to city transportation authorities in India. Indian manufacturers such as Ashok Leyland, Tata Motors, and Mahindra may also become active in this segment and set up local manufacturing for electric buses when demand crosses a critical threshold.

- Distributed Energy Resources Management Systems (DERMS) – There is significant competition in the DERMS software segment from well-established European players such as ABB (Switzerland), Siemens (Germany), and Smarter Grid Solutions (UK). Japanese DERMS providers in this segment include Hitachi and Toshiba. There are some Canadian players in the segment as well, which include Enbala and LocalGrid. Generally, U.S. companies are competitive in this segment based on the advanced technology that they offer.

The following points highlight our initial understanding of key market entry issues, both positive and negative, for DER related procurement with Indian DISCOs:

Market Entry Issue	Evaluation
Procurement mechanism	• Procurement of any DER related hardware and software by an Indian DISCO is expected to be through a competitive, confidential bid mechanism. The bid is expected to be solicited globally. • U.S. companies are expected to have equal access, though they will face significant competition in the DER segments that they compete in.
Technology and licensing issues	• There are no major technology and licensing issues associated with DER technologies. A DER technology procuring DISCO will have to procure licensing for any BESS software and any DERMS software platform that it intends to procure. This is the standard software licensing mechanism followed by industry.
Local industry capabilities	• Local suppliers and partners will likely provide installation services. Some balance of plant equipment may be sourced locally from India-based suppliers, but most of the major equipment is likely to be imported. • India has a robust software services industry. Most of the software implementation labor for the DERMS platform is expected to be locally sourced from India. • We expect about 20% of the software implementation labor to be sourced from the U.S. for software products sourced from U.S. companies.
Geographic factors	• The U.S. has a geographical disadvantage in the Indian market context. India lies within or close to the Asian manufacturing hub for certain DER technologies such as solar PV, BESS, and EVs. It is not economical to ship these DER technologies from the U.S. to India due to high shipping costs

We conclude that U.S. companies face significant market entry challenges for certain DER technologies such as EVs, BESS, and rooftop solar PV.
U.S. companies are competitive in software products such as DERMS and DERMS related software products.

3.3.4 U.S. Companies Interested in Distributed Energy Resources Sector in India

A number of U.S. companies, providing both goods and services in the DER space were contacted by Continuum Associates LLC during the course of the Desk Study. Many of the U.S. companies contacted showed a strong interest in business opportunities in the Indian market. A listing of the U.S. companies active in the DER space that showed a keen interest in doing business in India and contacts for their business development staff is provided on the following page.

	Form of Company	Firm/Organization	Contact Person First Name	Contact Person Last Name	Contact Title	Address	Address 2	City	Zip (Postal) Code	Country	Phone	Fax	Email Address
1	Solar PV Module Manufacturer	Mission Solar Energy	Aarn	Arriaga	Business Development	8303 S. New Braunfels Ave.,		San Antonio, TX	78235	USA	210-531-8646		aarriaga@missionsolar.com
2	Solar PV Module Manufacturer	Suniva	Johnny	Baumstark	Inside Sales	5765 Peachtree Industrial Blvd.,		Norcross, GA	30092	USA	770-656-0862		khughes@suniva.com
			Kenny	Hughes	Sales Director, Eastern United States and Caribbean Suniva Inc.	5765 Peachtree Industrial Blvd.,		Norcross, GA	30092	USA	404-838-7393		jwbaumstark@suniva.com
3	Solar PV Inverter Manufacturer	Solectria Renewables	Russ	David	Regional Sales Manager	4 Harmony Circle		Malvern, PA	19355	USA	610-291-4689		russ.dodd@solectria.com
4	Solar PV Inverter Manufacturer	Ingeteam	Nohra	Nasr	Head of PV Sales & Business Development	3550 W. Canal Street		Milwauke, WI	53208	USA	312-771-1943		nohra.nasr@ingeteam.com
5	Grid Scale Battery Manufacturer	Tesla	Jake	Milan	Business Development - Tesla Energy Products	3500 Deer Creek Road		Palo Alto CA	94304	USA	206-409-5606		jmillan@tesla.com
6	Grid Scale Battery Manufacturer	Aquion	Nishant	Sharma	Business Development	684N 9th Street		San Jose, CA	95112	USA	415-737-5900		nsharma@aquion-energy.com
7	DERMS Platform Developer	AutoGrid Inc.	David	Garcia	VP - Global Business Development	255 Shoreline Drive, Suite 350		Redwood City, CA	94065	USA	303-250-5319		dave.garcia@auto-grid.com
8	Behind-the-Meter ESS	STEM	Matt	Owens	Director - Business Development	100 Rollins Road		Millbrae, CA	94030	USA	510-390-2175		matt.owens@stem.com
9	DERMS Platform Developer	Spirae Inc.	Sunil	Cherian	CEO - Spirae Inc.	243 N College Ave, Fort Collins		Fort Collins, CO	80524	USA	970-484-8259		sunil@spirae.com

4. Synthetic Ethanol

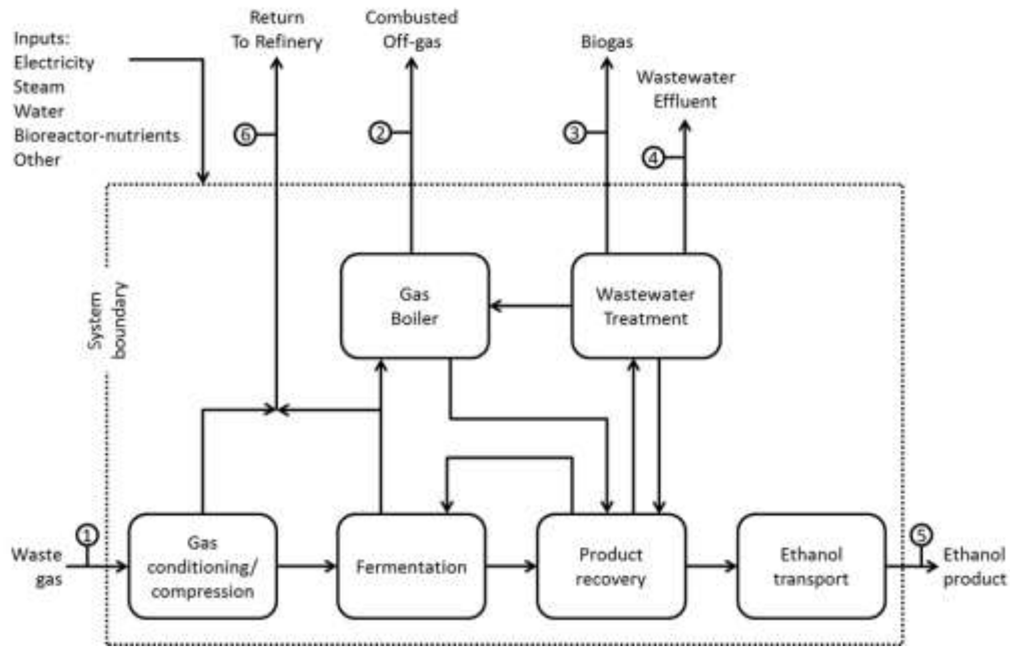
4.1 Synthetic Ethanol – Overall Manufacturing Process

This section defines the generic process through which synthetic ethanol is processed and manufactured. In this case, synthetic ethanol processing from non-food feedstock is discussed since ethanol production from food sources is not allowed in India. As part of the synthesis process, refinery waste gas is converted to ethanol using a biochemical catalyst through a gas fermentation process. The refinery waste gas (Gas Feed) is piped into an *optional* holding tank (1), if needed to ensure constant supply to the fermentation. The collected gas is compressed and passed through clean up steps specific to the gas feed stream (2) to extract CO, H_2 and CO_2 from refinery waste gases. The treated gas is introduced into a purpose-built gas fermentation bioreactor containing microbial biomass suspended in a nutrient broth (3). The bioreactor is designed to dissolve the gas in the nutrient broth, in which the CO, H_2 and CO_2 components of the gas are converted to ethanol using bacteria. The ethanol product is continuously produced and secreted by the bacteria and accumulates in the nutrient broth. The bioreactor broth, containing both bacterial biomass and ethanol, is continuously distilled for ethanol recovery (4). The ethanol product is stored awaiting distribution or blended with gasoline. The process is shown in Figure 2.

Figure 2: Overview of Synthetic Ethanol Fermentation Process

Figure 3 shows a block diagram with typical configuration of gas fermentation, including primary inputs and outputs.

Figure 3: Typical Process Configuration to Manufacture Synthetic Ethanol



4.2 Ethanol Industry in India – Production and Uses

4.2.1 Ethanol Production in India

India is a significant ethanol producing country, ranking amongst the top ten ethanol producers globally in 2016. On the supply side, ethanol in India is primarily produced from biomass, though production from petrochemicals is also allowed under current regulations. The GOI mandates use of non-food sources of feedstock in the production of ethanol, and as a result, first-generation ethanol, which is produced directly from food crops, is not allowed. Second generation ethanol, which primarily involves manufacturing ethanol from non-food biomass or food crops after they have fulfilled their food purpose, is the only type of ethanol allowed to be manufactured in India, in addition to ethanol produced from petrochemicals.

Till about June 2015, molasses was used exclusively as the feedstock to produce ethanol as second-generation ethanol. However, policy changes made by GOI's Union Cabinet in June 2015 opened the doors for using other non-food based sources of feedstock to produce ethanol, in addition to using petrochemicals to make ethanol. Molasses continues to be the preferred feedstock for ethanol production in India, constituting the vast majority of feedstocks used in the production of ethanol. Since molasses is a byproduct of sugar refining, the amount of ethanol produced in India is directly tied to production of sugarcane and sugar refining. Sugarcane production, harvesting, and sugar refining from sugarcane juice fluctuates significantly from year to year and has depended on variety of factors including:

- Acreage dedicated to sugarcane production from year to year;
- Minimum support price provided by GOI for the procurement of sugarcane crop, as part of its crop procurement policies;
- Demand and supply dynamics for sugar and byproducts produced from sugarcane and the sugar production process;
- Weather conditions that may directly impact the production of sugarcane crop such as temperature, rain, flooding, and dry spells; and
- Import and export of sugarcane depending on local and international demand, and supply dynamics.

As a result, ethanol production in India can fluctuate significantly from year to year. Gaps between demand and fluctuating supply are increasingly being made up by ethanol imports, and the U.S. is the single largest exporter of ethanol to India, making up approximately 80 percent of India's ethanol imports in 2016. In terms of volume this was 320 million liters in 2016. Brazil is the next biggest exporter of ethanol to India, meeting about 18 percent of India's imported ethanol needs. In terms of volume of ethanol imported into India in 2016, this amounted to 72 million liters. India's remaining ethanol imports in 2016, totaling eight million liters in 2016 were supplied by countries such as Pakistan and Bhutan. In India, sugar mills are the largest manufacturers and suppliers of ethanol, produced from molasses. Oil refining companies such Indian Oil Corporation Limited (IOCL) and certain other chemical manufacturing companies such as India Glycols Ltd., which have a growing demand for ethanol, -either for their own use or due to customer demand, are increasingly venturing into setting up their own ethanol production facilities. Most of these future facilities are proposed to be developed using second-generation ethanol production technologies.

4.2.2 Ethanol Use in India

Ethanol consumption in India materialized due to policy interventions by GOI, primarily to use the vast amount of biomass that India produces as a byproduct of its agricultural activities. Over the years, the GOI has encouraged increased production of ethanol, and its use specifically in the transportation fuel segment as a blended fuel to reduce dependence on crude oil imports. India currently imports over 80 percent of the crude oil it needs to meet its energy needs. Consequentially, the GOI has a stated focus to foster the growth of indigenous ethanol production technologies which can help increase ethanol production and reduce crude oil imports for use in the transportation sector.

In India, ethanol is primarily used in three major industries – as an alcohol-based solvent in the chemical industry, as potable alcohol as the base agent in the liquor manufacturing industry, and as a blended transportation fuel in the transportation fuel industry. In 2011, the liquor manufacturing industry was the largest consumer of available ethanol, consuming over 45 percent of all available ethanol. The chemical manufacturing industry was the next largest consumer, utilizing about 40 percent of ethanol supply. The remaining 15 percent was used as a transportation fuel blend. Based on information available from the All India Distillers' Association, by 2015 the demand from these three industry segments had changed significantly, with the liquor manufacturing industry consuming about 36 percent of available ethanol, the chemical manufacturing industry consuming 27 percent of available ethanol, and the remaining available ethanol being used as transportation fuel blend.

4.2.3 Demand for Ethanol in India

In this section, we primarily discuss the demand of ethanol for use as a transportation fuel blend. Demand for ethanol in certain other industry segments, such as the potable liquor industry, cannot be determined due to opaqueness around ethanol demand and supply in the industry. The potable liquor industry is highly regulated and taxed in India, and as a result involves significant unreported and undocumented transactions involving ethanol, a key ingredient of liquor manufacturing. Hence, most numbers available through various publications are unreliable and do not reflect actual supply and demand for that industry segment.

India's current gasoline demand is about 554,000 barrels per day or about 202.2 million barrels/ 32 billion liters per year. At GOI's ethanol fuel blending target rate of 10 percent, the annual demand for ethanol to be used as a transportation fuel blend is 3.2 billion liters. In 2016, approximately 1.1 billion liters of ethanol was blended with gasoline, leaving an unmet demand of 2.1 billion liters or 65 percent of the total ethanol demand. For 2017, ethanol available for transportation fuel blending was estimated to be approximately 700 million liters with the availability expected to rise to about 850 million liters in 2018. The drop in ethanol availability for fuel blending in 2017 and 2018 has been attributed to below average production of sugarcane in India, particularly in the southern part of the country. The current demand for ethanol required for fuel blending is 3.2 billion liters of ethanol.

4.2.4 Use of U.S. Ethanol Exported to India

India is a significant market for U.S. produced ethanol. In 2016, India was the fourth largest importer of U.S. produced ethanol globally behind Canada, Brazil, and China. Trade press indicates that U.S. ethanol exports to India at the port of exit are labelled "Undenatured fuel-grade", indicating wide use and applicability in India. However, India's Ethanol Blending Program for fuels follows an 'indigenous ethanol only' policy, requiring that ethanol used as a blend with transportation gasoline be sourced from India; no imported ethanol is allowed in gasoline blending. Consequentially, it can be concluded that U.S. exports of ethanol to India are primarily being used in the production of potable liquor and as a solvent in the alcohol-based chemical industry. Reliable numbers on the breakdown of U.S. ethanol exports used in the two

Indian industries are not available. However, various sources on ethanol supply and demand dynamics in India indicate that the chemical industry in India has traditionally faced ethanol shortages which have been met by imports. This may indicate that the chemical industry in India is the majority consumer of U.S. exported ethanol.

4.3 U.S. Exports of Ethanol to India - Current and Past Trends

India is an important and growing market for U.S.-produced ethanol. In 2016, India was the third largest export market for ethanol exports from the U.S. In 2016, India imported almost eight percent of total U.S. ethanol exports. The table below shows total U.S. ethanol exports and exports to India from 2010 through 2016.

Table 10 U.S. Exports of Ethanol to India - 2010 through 2016

Measure	2010 [Annual-Thousand Barrels]	2011 [Annual-Thousand Barrels]	2012 [Annual-Thousand Barrels]	2013 [Annual-Thousand Barrels]	2014 [Annual-Thousand Barrels]	2015 [Annual-Thousand Barrels]	2016 [Annual-Thousand Barrels]
Total U.S. Ethanol Exports	9,488	28,457	17,656	14,737	20,149	19,811	27,864
U.S. Ethanol Exports to India	687	242	6	506	956	886	2,175
U.S. Ethanol Exports to India as a Ratio of Total U.S. Ethanol Exports	7.2%	0.85%	0.03%	3.4%	4.7%	4.4%	7.8%

Source: U.S. Energy Information Administration; www.eia.gov

India is considered an important market for U.S. ethanol exports with the ability to import increasing amounts of U.S. ethanol in the future.

4.4 India's Ethanol Industry as a Share of the Global Ethanol Industry and in Comparison to the U.S. Ethanol Industry

The United States is, by far, the leader in ethanol production producing more than double the amount produced by the next largest producer Brazil. In 2016, the U.S. produced 15,329 million gallons of ethanol. In comparison, India was ranked eighth globally in ethanol production. In 2016, India produced 225 million gallons of ethanol, approximately 1.5 percent of U.S production in that year.

Table 11: Top Ethanol Producing Countries in the World

Region	Millions of Gallons
United States	15,329
Brazil	7,295
European Union	1,377
China	845
Canada	436
Thailand	322
Argentina	264
India	225
Rest of World	490

Source: RFA analysis of public and private data sources

4.3 Market Potential for Synthetic Ethanol in India

Expected demand for synthetic ethanol, to be used in transportation fuel blending can potentially reach almost 93,000 barrels per year if India keeps up with its relatively fast growing demand for gasoline and makes an earnest effort to meet the E10 blending targets. Demand projections for ethanol to be used as a gasoline bend to meet the E10 targets are shown in Table 12. However, significant impediments remain to this target as discussed in the next section, in addition to the string of underlying drivers for synthetic ethanol demand.

Table 12: Projections for Expected Growth in Demand for Ethanol to meet E10 Blending Targets

Year	Expected Growth in Demand for Gasoline [in percent]	Expected Demand for Gasoline in Barrels	Expected Demand for Ethanol in Barrels to meet E10 Targets
2018		554,000	55,400
2019	4.70%	580,038	58,004
2020	4.70%	607,300	60,730
2021	4.70%	635,843	63,584
2022	4.70%	665,727	66,573
2023	4.70%	697,017	69,702
2024	4.70%	729,776	72,978
2025	4.70%	764,076	76,408
2026	4.00%	794,639	79,464
2027	4.00%	826,425	82,642
2028	4.00%	859,482	85,948
2029	4.00%	893,861	89,386
2030	4.00%	929,615	92,962

4.3.1 U.S. Export Potential

Developing generic U.S. export potential for ethanol exported from U.S. to India or the underlying technology that may be required to meet India's ethanol demand for E10 blending targets is difficult due to the following reasons. Due to these reasons, any attempt to develop U.S export targets for ethanol or the underlying technology to supply second-generation ethanol to the transportation industry is both inadequate and most likely not very accurate.

- GOI policies around ethanol blending have consistently missed targets with the GOI making no serious efforts to force the oil refining industry to meet the stipulated targets.

- GOI has onerous restrictions on use of certain type of ethanol such as first-generation ethanol for use in fuel blending. GOI also does not allow use of imported first-generation ethanol for fuel blending. First-generation ethanol in is most abundant globally. Hence, to meet the aggressive fuel blending targets (E10) that GOI has, it may have to start allowing use of imported first-generation ethanol in some capacity.

- There are significant technical challenges in manufacture and successful production of second-generation ethanol. Many of the companies that ventured into this industry segment have failed or exited commercial production. One reason for this could be the lack of formally established policies and binding targets for fuel blending using second-generation ethanol globally. This may change in the future but currently there are no strong or definite indications for such a change.

- GOI appears to be pivoting much more strongly towards EVs rather than fostering cleaner and renewable fuels such as ethanol for the transportation sector. Such policy directions will likely impede the development of second-generation ethanol production in India or import of ethanol into India for fuel blending, if it were ever to be allowed.

4.3.2 Major Stakeholders

The major stakeholders in sector are the oil and gas refiners – both privately owned and GOI owned. Since the mandate to meet the E10 targets is with the oil refiners, oil refining companies will play the most important role in meeting the E10 targets and as a result, increase the consumption of ethanol in the country.

The other important stakeholder is the GOI which is tasked with making public policy decisions. In the past few years, GOI has been lenient with the oil refiners when they have consistently not met their E10 blending targets. For India to meet its stated objective to reduce dependency on imported crude oil and to meet certain emission targets GOI will have to take a much more proactive and stringent approach to meeting E10 blending targets. Monetary punitive actions, in the way of increased levies and taxes may help with the objective of getting the oil refiners to meet and comply with E10 blending targets. The following table provides a list of oil refineries in India where ethanol synthesis equipment to process ethanol from refinery off-gasses can be installed to produce second-generation ethanol.

#	Oil Refinery	Oil Company/Owner	Sector	State	Location	Capacity (MMTPA)
1	Jamnagar Refinery	Reliance Industries Limited	Private	Gujarat	Jamnagar (SEZ)	33
2	Jamnagar Refinery	Reliance Industries Limited	Private	Gujarat	Jamnagar (DTA)	27
3	Nayara Energy Refinery	Nayara Energy Limited	Private	Gujarat	Vadinar	20
4	Kochi Refinery	Bharat Petroleum Corporation Limited	Public	Kerala	Kochi	15.5
5	Mangalore Refinery and Petrochemicals Limited	Oil and Natural Gas Corporation	Public	Karnataka	Mangalore	15
6	Paradip Refinery	Indian Oil Corporation Limited	Public	Odisha	Paradip	15
7	Panipat Refinery	Indian Oil Corporation Limited	Public	Haryana	Panipat	15
8	Gujarat Refinery	Indian Oil Corporation Limited	Public	Gujarat	Koyali	13.7
9	Mumbai Refinery	Bharat Petroleum Corporation	Public	Maharashtra	Mumbai	12

#	Oil Refinery	Oil Company/Owner	Sector	State	Location	Capacity (MMTPA)
		Limited				
10	Mumbai Refinery	Hindustan Petroleum Corporation Limited	Public	Maharashtra	Mumbai	7.5
11	Guru Gobind Singh Refinery	• Hindustan Petroleum Corporation Limited • Hindustan Mittal Energy Limited (HMEL)	Public	Punjab	Bathinda	11.3
12	Manali Refinery	Chennai Petroleum Corporation Limited	Public	Tamil Nadu	Chennai	10.5
13	Visakhapatnam Refinery	Hindustan Petroleum Corporation Limited	Public	Andhra Pradesh	Visakhapatnam	8.3
14	Mathura Refinery	Indian Oil Corporation Limited	Public	Uttar Pradesh	Mathura	8
15	Haldia Refinery	Indian Oil Corporation Limited	Public	West Bengal	Haldia	7.5
16	Bina Refinery	Bharat Oman Refinery Limited	Public	Madhya Pradesh	Bina	7.8
17	Barauni Refinery	Indian Oil Corporation Limited	Public	Bihar	Barauni	6
18	Numaligarh Refinery	• Bharat Petroleum Corporation Limited • Oil India • Government of Assam	Public	Assam	Numaligarh	9
19	Bongaigaon Refinery	Indian Oil Corporation Limited	Public	Assam	Bongaigaon	2.735
20	Guwahati Refinery	Indian Oil Corporation Limited	Public	Assam	Guwahati	1
21	Nagapattnam Refinery	Chennai Petroleum Corporation	Public	Tamil Nadu	Nagapattinam	1

#	Oil Refinery	Oil Company/Owner	Sector	State	Location	Capacity (MMTPA)
		Limited				
22	Digboi Refinery	Indian Oil Corporation Limited	Public	Assam	Digboi	0.65
23	Tatipaka Refinery	Oil and Natural Gas Corporation	Public	Andhra Pradesh	Tatipaka	0.07
24	Barmer Refinery	• Hindustan Petroleum Corporation Limited • Government of Rajasthan	Public	Rajasthan	Barmer	9

4.3.3 Foreign Competition and Market Entry Issues

4.3.3.1 Foreign Competition

Foreign competition is non-existent for conversion of industrial waste/off-gases to ethanol, a second-generation method of producing ethanol. Non-U.S. major players in the ethanol conversion process and technology area have included Coskata and INEOS Bio. Both the companies have either ceased commercial operations recently or have made significant changes to their corporate structure, impacting their business. Most other second-generation ethanol producers or technology vendors focus on using biomass as the feed for their ethanol conversion process, rather than using industrial/ refinery off-gases.

- Coskata's technology used methane rich natural gas as the feed-gas to convert into ethanol. The technology was targeted towards markets with low natural gas prices, such as the U.S. Since Coskata ceased commercial operations in 2015, its technology has been relaunched as Synata Bio, a new company that hired a significant portion of the previous Coskata scientific staff. Our research indicates that Synata Bio uses gas fermentation technology to produce second-generation ethanol. However, Synata Bio's process uses methane as a feed-gas, which can be an expensive feedstock to produce ethanol, depending on its availability.

- INEOS Bio's technology has been sold to an unnamed foreign entity and its U.S. assets are being sold to be used in cellulosic ethanol production. INEOS Bio recently announced that it is selling its bio facility in Vero Beach, Florida. This facility, with capacity to produce eight million gallons of ethanol per year, was built as a joint venture with New Planet Energy Holdings, LLC. In July 2013, the company announced successful production of ethanol at the Florida facility. In September 2014, operational changes were completed to optimize the technology and debottleneck the plant to achieve full production capacity.

However, as indicated earlier, there is significant competition in biomass to ethanol conversion technologies to produce second-generation ethanol. Over 99 percent of ethanol currently used as transportation fuel is derived from biomass to ethanol conversion processes. Indian competition in this sector includes Praj Industries, which manufactures equipment for both first-generation and second-generation ethanol production. Praj Industries is a well-established manufacturer of ethanol production equipment. It has partnered with Indian Oil Corporation Limited (IOCL) to demonstrate the efficacy of its ethanol conversion process. Praj Industries has signed cost-sharing agreements with IOCL to set-up two ethanol production plants at IOCL's Dahej and Panipat refineries. It is also under contract to set-up a third ethanol production plant at another undisclosed IOCL refinery. Praj Industries' method produces second-generation ethanol using biomass.

Other competitors in this segment that are active in India and have demonstration projects in development include Royal Dutch Shell (Netherlands), Chempolis (Finland), and the Institute of Chemical Technology (Indian engineering school specializing in chemical engineering), and Beta Renewables (Italy). Royal Dutch Shell has set-up a five tons per day ethanol production demonstration plant at its own R&D facility in Bangalore, Karnataka. Finland-based Chempolis Ltd. has signed a partnership agreement with Numaligarh Refinery Ltd. (NRL), an enterprise of the Indian government, to build a second-generation cellulosic ethanol and chemical production facility in Assam, India. NRL is a Government of India Public Sector Undertaking which operates a 3.0 MMTPA Refinery at Numaligarh in the District of Golaghat, Assam since 2000. NRL is a subsidiary of Bharat Petroleum Corporation Ltd (BPCL). The Institute of Chemical Technology has tied-up with one of India's largest engineering, procurement, and construction conglomerates - Larsen and Toubro (L&T) to set-up second-generation biomass based ethanol production facilities for third-party clients. It has set up a demonstration plant at Indian Glycol Limited's Kashipur chemical plant to produce 750,000 liters of ethanol per year. In October 2015, Beta Renewables, Novozymes and CVC India Infrastructure Pvt. Ltd. signed a Memorandum of Understanding to develop a bio-refinery in the state of Punjab, India using wheat and paddy straw as feedstock. The previously announced project for a bio-refinery in the state of Punjab and plans for five more around India by Beta Renewables are expected to require an investment of around $1 billion.

Though competition to proprietary technology and process for conversion of industrial waste/off-gases to ethanol may be limited, competition also includes alternative uses of refinery off-gases. Direct combustion of off-gases is the easiest and the cheapest method of utilizing and disposing off refinery off-gases. It may continue to be the preferred method of utilizing refinery off-gases, in absence of strong environmental regulations. This method is currently utilized at the Panipat refinery, owned and operated by IOCL. This method of using refinery off-gases is particularly attractive in an industrial park or industrial zone setting, where refinery off-gases can be sold to neighboring industries through an "over the fence" transfer pricing and with modest capital investment. Strong environmental regulations in the future may lead to stricter emission requirements pertaining to oil refineries and may require refinery operators to find alternate methods to reduce carbon emissions.

Other methods of using refinery off-gases include combusting them to produce electricity in steam turbines or using them as a heating fuel. The method of using off-gases to generate electricity is well-established and proven. However, it may not be economical in every instance. Depending on the location of the refinery, it may be more economical to procure electricity from the local utility or self-generate bulk amounts of electricity in a dedicated power generation facility.

4.3.3.2 Market Entry Issues Related to Ethanol Industry in India

Table 13: Market Entry Issues

Market Entry Issue	Evaluation
Procurement mechanism	• Procurement for major equipment for ethanol production by Indian oil refiners is likely through a global tender. • Some products such as engineering support and proprietary technology may provide certain companies with proprietary technology an advantage in the procurement process.
Public Policy and Fuel Blending Policy	• India requires oil refiners to achieve ethanol blending of ten percent in case of gasoline used for transportation. • Oil refiners have consistently missed this target and compliance is generally loose.
Technology and licensing issues	• Synthetic ethanol manufacturers' business model is based on licensing its proprietary method and technology to produce ethanol from refinery off-gases. • Under the technology licensing mechanism, a company possessing the second-generation ethanol manufacturing technology is likely to license its technology through appropriate technology transfer agreements. Technology transfer is generic industry terminology used widely to address licensing of technology under specific agreement, namely the licensing agreement, engineering agreement and the guarantee agreement. It does not mean transfer of IP ownership. • As a result of the technology transfer agreements with the oil refiner, the US Company is expected to earn royalties and licensing fees for a certain period of time. Another similar mechanism, involving royalties or a licensing fee, or some combination of both may be considered as well.
Local industry capabilities	• Local industry capability in India is fairly well-developed to compete with a US Company providing second-generation ethanol manufacturing technology. Most Indian companies are active in the category of first-generation and second-generation biomass to ethanol conversion. Currently, local industry has no capability or expertise in the refinery or industrial off-gases to ethanol conversion

Market Entry Issue	Evaluation
	process. • Local competitors include Praj Industries and ICT developed second-generation ethanol conversion technology. IOCL is proceeding with demonstration projects with Praj industries, using their second-generation biomass to ethanol conversion technology. Two of the three ethanol production facilities at IOCL refineries are proposed to be commissioned by 2020. The ICT and L&T joint venture has set up a demonstration plant to produce second-generation ethanol at India Glycol's chemical production facility in Kashipur, Uttar Pradesh. The consortium has also signed Memorandums of Understanding with Bharat Petroleum Corporation Limited and Hindustan Petroleum Corporation Limited for technology transfer for setting up second-generation biomass ethanol bio-refineries at Bina (Madhya Pradesh) and Bhatinda (Punjab). • GOI may have a preference for indigenous technologies, since it intends to promote Indian technologies at a global scale.
Geographic factors	• U.S. suppliers have been active in the Indian oil and gas sector. Though the oil and gas sector has competitive suppliers in Asia, such as those from South Korea and Japan. U.S. companies have generally not been disadvantaged due to geographical factors.

We conclude that US Companies may face little to no competition in certain niche applications for second-generation ethanol manufacturing such as the industrial off-gases to ethanol conversion market segment in India. However, there are indicators of significant and quickly developing competition in the second-generation biomass to ethanol conversion market segment. Both Indian and European companies are active in this segment. Competition for ethanol conversion technologies and plants is expected to be particularly severe from Indian vendors such as Praj Industries and the ICT plus L&T consortium.

4.3.4 U.S. Companies Active in India and Interested in Clean Fuels Sector in India

The following table provides a list of U.S. companies and pertinent business development contacts at U.S. companies that are either active or have shown interest in participating in the India petrochemical and chemical processing industries.

Name	Title	Organization	Address	City, State	Country	Phone	Email
Chris Petrak	Vice President	Petrak Industries, Inc.	17250 New Lenox Rd	Joliet, IL 60433	USA	(815) 483-2290 ext.1101	chris@petrakinc.com
Travis Dunlap	Regional Sales Manager	Gardner Denver Nash	Alta Vista Business Park 200 Simko Blvd	Bentleyville PA, 15314	USA	(724) 239-1500	nash@gardnerdenver.com
M. A. Stine	Senior Director Hydrogen	UOP, a Honeywell Company	25 East Algonquin Road	Des Plaines, IL 60016	USA	(847) 391-2000	margaret.stine@honeywell.com
John Scalise	Business Development Manager	Praxair USA	1585 Sawdust Road, Suite 300	The Woodlands, TX 77380	USA	(630) 730-8554	john_scalise@praxair.com
Christopher J. Brown	President	Thermal Kinetics	85 Northpointe Parkway, Suite 2	Amherst, NY 14228	USA	(716) 691-3291 Ext 104	cbrown@thermalkinetics.net

Vimal Kapur	VP GM	Honeywell Process Solutions	1250 W. Sam Houston Pkwy, Suite 150	Houston, TX 77042	USA	(832) 252-3500	Vimal.kapur@honeywell.com

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Public Market Report

India Traditional Energy and Power Desk Study Series

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The U.S. Trade and Development Agency

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Table of Contents

List of Acronyms

Bcm	Billion cubic meters
CBM	Coal bed methane
CCEA	The Cabinet Committee on Economic Affairs
CG	Constant Group LLC
CGD	City Gas Distribution
DGH	Directorate General of Hydrocarbons
DS	Desk Study
E&P	exploration & production
EPA	Environmental Protection Agency
EPC	Engineer, Procure, Construct
EU	European Union
FDI	foreign direct investment
FiT	Feed-in-tariff
GDP	Gross Domestic Product
GOI	Government of India
GWh	Giga-watt hour
HELP	Hydrogen Exploration and Licensing Policy
HV	High voltage
IFC	International Finance Corporation
IPP	Independent Power Production
ITA	International Trade Administration
Km	Kilometers
kV	Kilo-volt
kVA	Kilo-volt-ampere
LNG	liquefied natural gas
mbpd	Thousand barrels per day
MDG	Millennium Development Goals
MMT	million metric tons
MoE	Ministry of Energy
MW	Mega-watt
MWh	Mega-watt hour
NELP	New Exploration Licensing Policy
O&G	Oil and gas
O&M	Operations and Maintenance
O&NG	Oil and natural gas
OIDB	Oil Industry Development Board
PPA	Power Purchase Agreement
PRG	Partial Risk Guarantee
PSU	public sector undertakings
PV	Photovoltaic
TCN	Transmission Company
TCF	trillion cubic feet
UNFCCC	United Nations Framework Convention on Climate Change
USTDA	U.S. Trade and Development Agency

Executive Summary

The U.S. Trade and Development Agency (USTDA) awarded Constant Group LLC ("CG" or "Consultant") a contract for the India Traditional Energy and Power Desk Study Series. Under this contract, the Consultant performed full assessment of two and partial assessment of one projects, including:

1. Feasibility Study for Coal Bed Methane (CBM) Project;
2. Hydrocarbon Conversion Project; and
3. Bottom Upgrading Project Study for Refinery (partial review).

These projects were performed for private and public developers in India and were directed at upstream and downstream oil and gas sectors, including exploration and production.

The oil and gas sector is among the eight core industries in India and plays a major role in influencing decision making for all the other important sections of the economy. India's economic growth is closely related to energy demand; therefore the need for oil and gas is projected to grow more, thereby making the sector quite conducive for investment.

India is expected to be one of the largest contributors to petroleum consumption growth globally. Oil imports rose sharply to US$ 87.37 billion in 2017-18 from US$ 70.72 billion in 2016-17. India was the third largest consumer of oil in the world in 2017 with consumption of 4.69 mbpd of oil in 2017, compared to 4.56 mbpd in 2016. India was the fourth-largest Liquefied Natural Gas (LNG) importer in 2017 after Japan, South Korea and China. LNG imports increased to 26.11 bcm in 2017-18 from 24.48 bcm in 2016-17[1].

Traditionally, India's oil and gas (O&G) sector has been dominated by public sector undertakings (PSU's), accounting for over 80 percent of domestic oil and gas production and almost 70 percent of the refining capacity. In recent years, the Government of India (GOI) has taken significant steps to deregulate the industry and encourage private participation and investment.

The introduction of the New Exploration Licensing Policy (NELP) by Indian government was aimed at intensifying activities in oil and gas exploration, while the government allowed full foreign direct investment (FDI) in the sector including natural gas, petroleum products, and refineries, among others. In addition, the

[1] Based on https://www.ibef.org/industry/oil-gas-india.aspx

Hydrocarbon Exploration and Licensing Policy (HELP) was launched by the government to address many issues plaguing the oil and gas sector and allowing a revenue sharing model and pricing freedom for gas discoveries.

The GOI announced plans to raise the share of natural gas in India's energy mix from 6 percent in 2016 to 15 percent by 2022. Currently, over half of India's supply of natural gas comes from local production while the other half from imported LNG. With higher forecasted demand, the country broadened its international supplier base and negotiated long-term supplier contracts. However, for greater LNG imports and local gas distribution are limited due to underdeveloped infrastructure required. Today, India has over 16,500 km of gas pipelines are in operation and over 11,900 km under construction. The existing City Gas Distribution (CGD) network covers 11 percent of the India's geography, reaching 19 percent of the population. Upcoming projects intend to expand coverage to 35 percent of India's geography and 49 percent of India's population[2].

Coal Bed Methane (CBM), an unconventional source of natural gas is now considered as an alternative source for augmenting India's energy resource. India has the fifth largest proven coal reserves in the world and holds significant prospects for exploration and exploitation of CBM. The high level estimate for CBM resources in the country is about 92 TCF (2,600 Bcm) located in 12 states. To-date, 33 CBM blocks were awarded for development. Most CBM exploration and production activities in India is pursued by domestic companies. Total estimated CBM resource for awarded 33 CBM blocks, is about 62.4 TCF (1,767 Bcm)[3].

Hydrocarbon conversion projects typically include fairly small scale conversion of natural gas into oil and oil products. In India, such projects are still in R&D and pilot phases. Hydrocarbon conversion scale is much smaller than usual refinery processes and should be viewed as supplemental revenue stream and technology optimization at existing refineries.

Consultant estimates U.S. exports for CBM and hydrocarbon conversion projects at over $500 million. There are no real formal obstacles to these exports in terms of country regulations and markets for the U.S. suppliers.

The oil and gas sector has been identified as a key metric that will drive future GDP growth. From an economic and financial perspective, investment in O&G is lucrative, with substantial prospects in India. Given the growing demand for crude oil in India and its wide application in household and industrial activities, it is

[2] Based on https://www.export.gov/article?id=India-Energy
[3] Based on http://dghindia.gov.in/index.php/page?pageId=60&name=INDIA%E2%80%99S%20E%20and%20P%20REGIME

apparent that there will be major investments in this industry in future. While the Government of India resolves initial obstacles in the O&G sector, the landscape in the O&G sector promises to be dynamic with scope for growth for many business entities. The USTDA and other U.S. government agencies' assistance helps with first-mover advantage of the U.S. companies in India, which is important to their success.

Market in the Sector and Host Country

Background

Before 1999, the Indian Government and national oil companies had a monopoly over the oil and gas sector. In 1999, the government adopted the New Exploration Licensing Policy under which acreages for explorations of hydrocarbons were awarded through international competitive bidding, and domestic and foreign companies were given equal opportunity. Nine rounds of bids were concluded under NELP, in which production sharing contracts for 254 exploration blocks were awarded.

The government has permitted 100% foreign direct investment through the automatic route in exploration activities, and there has been participation from the private sector, both domestic and foreign.

Public sector enterprises, Oil and Natural Gas Corporation Limited and Oil India Limited play a dominant role, contributing to over 70% of O&G production. The remaining 30% is produced by private/joint venture companies under the production sharing contract regime[4].

Supply and Demand

India's oil demand has outpaced supply and this gap is expected to widen in future.

OIL -- Projected crude oil production for the year 2017-18 was 37.37 million metric tons (MMT), which is 3.64% higher than in 2016-17. Around 49% of total production was from onshore fields and 51% from offshore fields. Estimated crude oil import for the year 2017-18 was 217.08 MMT, which is 1.47% higher than in 2016-17. Even though India is a net importer of crude oil, it is a net exporter of petroleum products due to its significant refining capacity. The estimated import of petroleum products for the year 2017-18 was 35.64 MMT, which is 1.78% lower than in 2016-17. Estimated petroleum products export for the year 2017-18 was 66.47 MMT, which is 1.45% higher than in 2016-17.

[4] Based on https://uk.practicallaw.thomsonreuters.com/4-635-5648?transitionType=Default&contextData=(sc.Default)&firstPage=true&bhcp=1

GAS -- Projected natural gas production for the year 2017-18 was 35.24 billion cubic meters, which is 10.47% higher than in 2016-17. Around 70% of the total production of natural gas was from offshore blocks, while the remaining 30% was from onshore blocks. Coal bed methane (CBM) production from four operating blocks was about 2.28 million metric standard cubic meters per day in December 2017. Projected imports of liquefied natural gas (LNG) in 2016-17 was 18,631 thousand metric tons. Imports have increased steadily over the years and have risen by around 87% from the level of import in 2010-11. India does not export LNG[5].

Government policy objectives

The government's Hydrocarbons Vision 2025[6] envisages a framework in the hydrocarbons sector. Its key focus areas are to:

- Develop the hydrocarbon sector as a globally competitive industry by upgrading technology and building capacity.
- Have a free market and promote healthy competition and improve customer service.
- Ensure oil security for India keeping in view strategic and defense considerations.

The objectives for the exploration and production sector include:

- Undertaking an appraisal of Indian sedimentary basins to tap hydrocarbon potential and optimize production of crude oil and natural gas with the aim of having a reserve replacement ratio of more than one.
- To be at the technological forefront in the global exploration and production industry.
- Achieving as near as zero impact on the environment.

The objective with regard to external policy and oil security is to supplement domestic availability of oil with a view to providing adequate, assured and cost-effective hydrocarbon energy to India.

There are specific government policies to encourage the exploration and production of unconventional gas or oil. One of the major policies encouraging the exploration and production of coal bed methane was the CBM Policy in 1997, under which four rounds of bidding were implemented, resulting in 33 CBM blocks, covering 16,613

[5] Based on https://uk.practicallaw.thomsonreuters.com/4-635-5648?transitionType=Default&contextData=(sc.Default)&firstPage=true&bhcp=1
[6] http://petroleum.nic.in/sites/default/files/vision.pdf

square kilometers. In addition, in 2013, the government granted permission for shale gas exploration and production to national oil companies in onshore nomination blocks (that is, blocks awarded to the national oil companies before the New Exploration Licensing Policy regime). The policy was announced with the sole purpose of promoting shale gas and oil operations in existing blocks operated by national oil companies. The government has also been promoting more exploration of shale gas and gas hydrates.

In August 2018, the cabinet introduced a new policy framework for exploration and exploitation of unconventional hydrocarbons[7]. The policy seeks to grant a uniform license to all existing oil and gas blocks. Therefore, existing contractors under the production sharing contract will be allowed to tap the potential unused unconventional hydrocarbons like shale oil/gas, CBM, and others.

Regulatory Framework[8]

The main laws affecting the O&G Industry are:

- ***The Petroleum Act, 1934 -*** This act regulates the import into India, transfers within, storage, production, refining and blending of petroleum and deals substantially with midstream activities.

- ***The Oilfields (Regulation and Development) Act, 1948 -*** This act constitutes the basic statute for licensing and leasing of petroleum and gas blocks by Government of India, empowering the same with broad authority to make rules providing for the basic regulation of oilfields and for the development of mineral oil resources. Along with Petroleum Rules, the Oilfields Act governs the grant of Production Exploration Licenses and mining leases.

- ***The Petroleum and Natural Gas Rules, 1959 -*** These rules provide a framework for grant of exploration licenses and mining leases, and together with the Petroleum Act, 1934, regulate the sale and distribution of petroleum and petroleum products.

- ***The Petroleum and Natural Gas Regulatory Board Act, 2006 -*** This act provides for the setting up of the Petroleum and Natural Gas Regulatory Board to regulate the refining, processing, storage, transportation, distribution, marketing and sale of petroleum, petroleum products and natural gas (excluding production of crude oil and natural gas).

[7] http://petroleum.nic.in/policy-framework-exploration-and-exploitation-unconventional-hydrocarbons-under-existing-pscs
[8] Based on http://www.nishithdesai.com/fileadmin/user_upload/pdfs/Research%20Papers/Oil_and_Gas_Industry_in_India.pdf

- ***NELP -*** NELP was formulated by Government of India and the Directorate General of Hydrocarbons ("DGH") as the nodal agency in 1997-98 to provide a level playing field to both public and private sector companies in E&P of hydrocarbons, though NELP is not a law by itself and is not passed in exercise of any rule-making powers. NELP promotes investments in E&P Sector by facilitating allotment of exploration blocks through international competitive bidding. NELP has now been replaced by HELP.

- ***Hydrogen Exploration and Licensing Policy (HELP) -*** HELP aims to enhance domestic oil and gas production by encouraging exploration in sedimentary basins, and introduces a number of measures including a uniform license regime for conventional as well as non-conventional hydrocarbons, an open acreage licensing policy, a revenue sharing model and freedom in marketing and pricing (subject to certain limits)[9].

Framework for CBM

The Cabinet Committee on Economic Affairs (CCEA) in early 2017 allowed companies producing coal bed methane to sell gas to its own affiliates, by giving marketing and pricing freedom for CBM[10]. As per the decision, while discovering the market price for arm's length sales, the contractor has to ensure a fully transparent and competitive process for sale of CBM with the objective that the best possible price is realized for the gas without any restrictive commercial practices.

CBM contractors have also been permitted to sell the CBM to any of their affiliates, in the event the contractor cannot identify any buyer. Royalty and other dues to the government, however, shall be payable on the basis of petroleum planning and analysis cell notified prices or selling prices, whichever is higher.

The policy is expected to incentivize the CBM operation in the country to boost gas production and generate economic activities which in turn will be beneficial by creating more employment opportunities in CBM operations and related activities.

[9] Based on http://www.nishithdesai.com/fileadmin/user_upload/pdfs/Research%20Papers/Oil_and_Gas_Industry_in_India.pdf
[10] https://www.thehindubusinessline.com/markets/commodities/cabinet-approves-framework-for-coal-bed-methane-extraction-by-coal-india/article23505855.ece

Key Regulators[11]

There are primarily three regulators which monitor the O&NG industry in India i.e., DGH, Oil Industry Development Board, and Petroleum and Natural Gas Regulatory Board.

Directorate General of Hydrocarbons (DGH) - DGH was established under Regulation No.O-20013/2/92-ONG, D-III on April 8, 1993. The DGH, under the administrative control of the Ministry of PNG, is responsible for the environmental, safety, technological, and economic activities related to the oil and gas industry. The DGH facilitates E&P activities through regulation as well as research. In unexplored or poorly explored areas, the DGH conducts studies, surveys, information drilling, and other related activities. The DGH reviews the exploration programs and reservoir production of companies for adequacy and advises the Government of India on such activities. Further, the DGH oversees matters concerning production sharing contracts for discovered field and exploration blocks.

Petroleum and Natural Gas Regulatory Board (PNGRB) - The Petroleum and Natural Gas Regulatory Board was established in 2006 in terms of Section 3 (2) of the Petroleum and Natural Gas Regulatory Board Act, 2006. The Regulatory Board is empowered to regulate the refining, processing, storage, transportation, distribution, marketing and sale of petroleum and petroleum products and natural gas, and to foster fair trade and competition amongst oil and gas companies. The Regulatory Board registers entities to market petroleum and natural gas products, establish and operate liquefied natural gas terminals, and establish storage facilities for petroleum, petroleum products, or natural gas that exceed capacity specified by regulations.

Oil Industry Development Board (OIDB) - OIDB was established through the Oil Industry Development Act of 1974 (Oil Development Act). This legislation was enacted in response to increasing international prices of crude oil since the 1970s. Accordingly, the Oil Development Act's purpose was to facilitate increased self-reliance in petroleum and natural gas through various measures such as providing financial assistance to the organizations engaged in development programs of the oil industry. The OIDB renders assistance in the following: (a) prospecting for and exploration of mineral oil within India (including the continental shelf thereof) or outside India; (b) the establishment of facilities for production, handling, storage and transport of crude oil; (c) refining and marketing of petroleum and petroleum products; (d) the manufacture and marketing of petrochemicals and fertilizers; (e) scientific, technological and economic research which could be, directly or indirectly,

[11] Based on http://www.nishithdesai.com/fileadmin/user_upload/pdfs/Research%20Papers/Oil_and_Gas_Industry_in_India.pdf

useful to oil industry; and (f) experimental or pilot studies in any field of oil industry[12].

Key Players

Exhibit below provides key oil and gas companies in India with percent of ownership and total income for FY2019.

Key oil and gas companies in India

Company	Ownership (per cent) as of FY18	Total Income from Operations in FY19 (US$ billion)
Indian Oil Corporation Limited	56.98% state-owned	86.68
Reliance Industries	Public Listed	81.70
Bharat Petroleum Corporation Limited	54.31% state-owned	48.73
Hindustan Petroleum Corporation Limited	51.11% state-owned (through ONGC)	42.75
ONGC	68.07% state-owned	12.16
GAIL India Limited	53.59% state-owned	10.74
Oil India Limited	66.13% state-owned	1.52

Source: India Brand Equity Foundation, August 2019, https://www.ibef.org/industry/oil-gas-india.aspx

U.S. Export Potential

In 2017, International Trade Administration (ITA) published Upstream Oil and Gas Equipment Top Markets Report where it identified India in top 30 U.S. O&G export markets out of 151 markets assessed. Markets ranked highly represent those countries with significant potential for increased U.S. O&G equipment exports.

[12] Based on http://www.nishithdesai.com/fileadmin/user_upload/pdfs/Research%20Papers/Oil_and_Gas_Industry_in_India.pdf

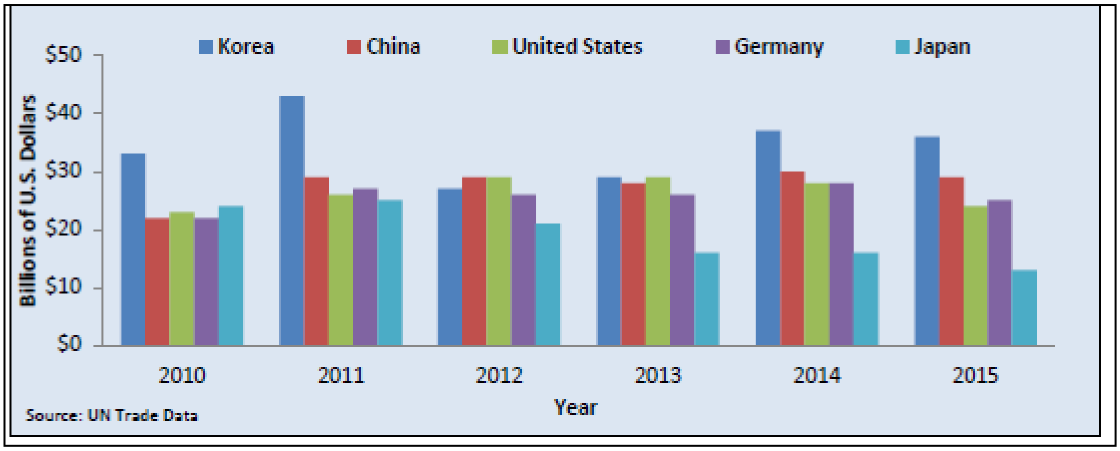
In the years ahead, ITA projects global trade in O&G equipment to increase as stable oil prices result in increased investments. Today, the United States is the world's fourth largest exporter of upstream O&G equipment, with close to $18 billion in annual exports worldwide. Generally, U.S. exporters face local content requirements, local labor requirements and other trade restrictions, increasing costs and reducing competitiveness of U.S. exports. These issues are not very profound in India.

In India, U.S. O&G equipment suppliers face strong competition from local, Chinese, Korean, and German O&G equipment manufacturers. By comparison, U.S. companies are particularly competitive in high-end sinking and boring parts and parts for derricks, whereas Korean exports are concentrated in vessels with few sinking or boring parts, and Chinese exports are concentrated in vessels with drilling platforms and equipment and pipe. As per ITA, these trends will likely continue, with U.S. exports weighted more toward specialized high-tech equipment, especially relating to unconventional and ultra-deepwater O&G exploration and production.

The projected increase in demand for U.S. exports of O&G equipment through 2020 may be further driven by the fundamental changes in U.S. O&G production during the last several years. Having been among the first in the world to develop unconventional and ultra-deepwater resources, U.S. equipment manufacturers and service suppliers have the opportunity to seize the first-mover advantage in overseas markets that are seeking to emulate the United States' rapid expansion in energy production. At the same time, significant utilization of such equipment at home may reduce the offer availability worldwide.

Generally, the international O&G equipment market is dominated largely by five countries: Korea, China, Germany, United States, and Japan. The exports profile of these countries are characterized by a heavy manufacturing for the ships and offshore platforms in Korea, low cost inputs originating from China, and high-tech components and advanced manufacturing from the United States, Germany, and Japan. As per ITA, in 2015 (latest statistics available), Korea was the world's largest O&G equipment exporter, exporting $36 billion to global markets, while China and Germany were the next largest O&G equipment exporters to the world with $29 billion and $25 billion in exports, respectively. The United States was the fourth largest exporter in 2015, exporting $24 billion to global markets ash shown on Exhibit below.

Top Five Oil & Gas Equipment Exporting Countries



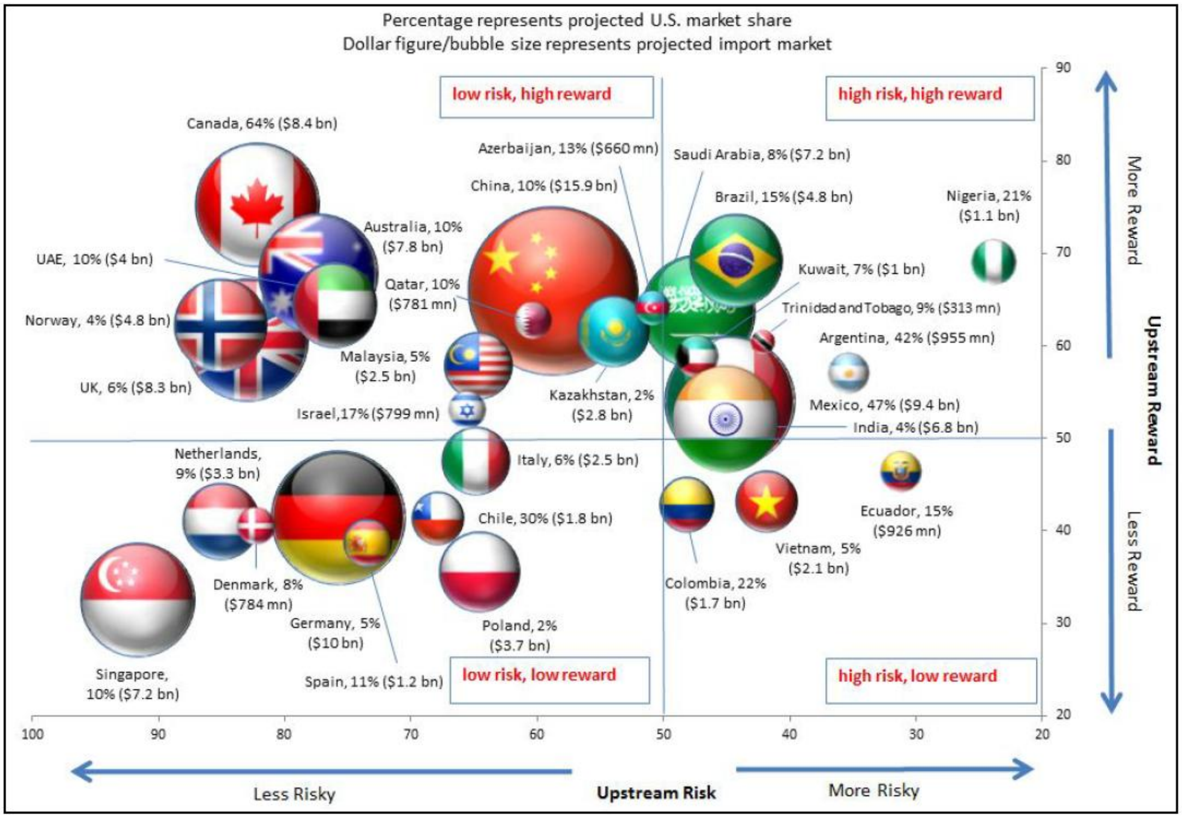
Source: ITA, 2017, https://www.trade.gov/topmarkets/pdf/Oil_and_Gas_Top_Markets_Report.pdf

While the United States is likely to remain competitive in the O&G equipment sector, the share of U.S. equipment being exported to the global market, as a proportion of world O&G equipment exports to the global market, is projected to decline in the years to come. This may be a demonstration of greater consumption of U.S. equipment domestically, but is also a reflection of greater competition from foreign equipment producers, as other countries have increased the proportion of equipment exports to the global market[13].

The top thirty import market countries from the 2017 Upstream Oil and Gas Equipment Top Markets Report are plotted on a Risk- Reward Matrix, as per Exhibit below, illustrates each country's relative upstream challenges and opportunities. The rewards are heavily weighted toward below-ground resources, while the risks are more weighted toward government policy. In a case such as Singapore, for example, a company might encounter few unanticipated regulatory challenges (i.e. low risk), but would also have lower profits (i.e. lower reward) from investments. In contrast, a high risk, high reward country, such as India, may potentially yield significant profits in the O&G equipment sector, but there is a greater number of risks (i.e. import regulations, corruption, infrastructure constraints) that companies will have to consider when conducting business there.

[13] Based on https://www.trade.gov/topmarkets/pdf/Oil_and_Gas_Top_Markets_Report.pdf

Top Thirty Import Markets for U.S. O&G Equipment Exports in 2020



Source: ITA, 2017, https://www.trade.gov/topmarkets/pdf/Oil_and_Gas_Top_Markets_Report.pdf

The United States has recently exported a large amount of energy related equipment and machinery to India. Exhibit below provides the details of U.S. exports to India by category (as per Standard International Trade Classification, or SITC). SITC and other classification systems employed by the U.S. Department of Commerce do not break out oil and gas related equipment. In the last few years, the value of energy related equipment and machinery was close to $1.2 billion per year in U.S. exports. Many types of equipment listed below are used in oil and gas exploration.

Energy Related Equipment and Machinery U.S. Exports to India ($M)

Item	2014	2015	2016	2017	2018
Filters	119	131	111	113	157
Valves	158	189	128	134	130
Switches	71	81	92	99	120
Pumps	112	84	106	105	113
Gas Turbines	74	105	116	126	99
Air Pumps	120	95	63	70	92
Electic Boards	68	53	61	77	83
Combustion Turbines	15	3	8	47	71
Wires	58	51	57	60	71
Bearings	72	72	76	82	66
Converters	62	57	56	61	63
ICE	23	34	33	68	50
Batteries	44	47	34	16	41
Generators	48	55	22	28	28
Capacitors	12	10	11	12	26
Motors	18	23	22	35	25
Lab equipment	49	24	21	15	15
Heat pumps	16	16	14	18	14
Furnaces	40	65	40	5	10
Boilers	25	11	1	3	3
TOTAL	**1203**	**1206**	**1074**	**1173**	**1277**

Source: CG and ITA data, https://www.trade.gov/

The following U.S. manufacturers have been identified key components exports:

- Drilling equipment – Halliburton (Texas), Schramm (Pennsylvania), Atlas Copco (Texas), M.D. Cowan (Texas), Petro Rigs (Oklahoma), Gefco (Oklahoma), Schlumberger (Texas), Weatherford (Texas);
- Gas compression and processing – GE (Texas), Exterran (Texas), J-W Power (Texas), Ariel (Ohio), Dresser-Rand (Texas), SNC-Lavalin (formerly Valerus Compression Services (Texas);
- Hydraulic fracturing – Halliburton (Texas), Schlumberger (Texas), Baker Hughes (Texas), Producer Services (Ohio), Weatherford (Texas);
- Gathering systems - AMCO Machining and Manufacturing (Mississippi), American Genesis Oil Field Equipment (Texas);
- Logging/Certification – Netherland, Sewell & Associates, Inc. (Taxes), PetroTel Inc. (Texas), Weatherford (Texas), Schlumberger (Texas), Baker Hughes (Texas), Miller and Lents Ltd. (Texas), MHA Petroleum Consultants (Colorado), SiteLark a Flotek Company (Texas);

- Spare Parts and Consumables - Rubicon Oilfield International (Texas), JH Oilfield Equipment (Texas), Core Laboratories International (New York), National Oilwell Varco, Inc. (Texas), Cameron International Corporation (Texas).
- Steam reformers - Pan American Hydrogen (TX);
- Compressors - Frick Johnson Controls (WI);
- Pumps – Flowserve (TX); and
- Controls – Rockwell (WI).

The following manufacturers/service providers have confirmed their interest in CBM projects in India:

- GE Oil and Gas;
- Schlumberger;
- Baker Hughes;
- Netherland, Sewell & Associates, Inc.;
- Pan American Hydrogen
- Valerus Compression Services (now part of SNC Lavalin); and
- Miller and Lents, Ltd.

Most of these companies have a very significant U.S. content to their products.

The Consultant estimated the potential for CBM and flaring projects reviewed. The single CBM lifecycle project U.S. export estimate was ~$100 million. Based on the research conducted, there are at least four significant potential CBM projects in India with can result in $400 million of U.S. export potential. For multiple hydrocarbon conversion projects, the U.S. export estimate was ~$110 million. Overall U.S. potential for these two types of oil and gas projects is over $500 million.

Foreign Competition and Market Entry Issues

Some of the most active companies in O&G sectors worldwide include:

- Drilling equipment/Exploration – Oil Country Tubular Ltd (India), Primepoint Drilling Pte Ltd (Singapore), Lundin Oil AB (Sweden), Hongkong Offshore Oil Services Limited (China), Statoil (Norway), Greka Drilling Limited (China/India), Atlantic Directional Inc. (Canada);
- Gas compression and processing – Gas Processing Equipment Pvt. Ltd. (India), GCE (India), INOXCVA (India);
- Hydraulic fracturing – ICI Artificial Lift Inc. (Canada), Ember Resources (Canada), Tundra Gas Inc (Japan);

- Gathering systems - Mobility Oil and Gas Limited (UK), Kosun (China), Regent Energy Group (Canada);
- Logging/Certification – RBR Drilling (Spain), Status Scientific Controls Ltd (UK); and
- Spare Parts and Consumables – ThyssenKrupp (France), Tasman Oil Tools (Australia).

While not all of these companies express interest in exporting to India, they all have the potential and therefore can be treated as competition to the U.S. companies competing in this space.

Country Specific Projects

India has been very active in promoting projects for oil and gas exploration and refining expansion, production enhancement, diversification into non-core resources, and many other activities. A list of some of such current and planned activities is provided below. The list includes mostly large projects by well-respected Indian companies. The bulk of projects are in expansion of existing capacity.

Expansion Projects:

- In September 2018 the Government of Gujarat selected Energy Infrastructure Limited a subsidiary of the Netherlands based Energy Infrastructure Butano BV, to set up a Liquefied Petroleum Gas terminal at Okha with an investment of Rs 700 crore ($104.4 million).
- H Energy is planning to invest Rs 3 500 crore (US $540 million) to build Liquified Natural Gas terminals and lay down a 60 km pipeline.
- State run energy firms Bharat Petroleum, Hindustan Petroleum and Indian Oil Corp plan to spend $20 billion on refinery expansions to add units, by 2022.
- Indian Oil Corp plans to make an investment of $23 billion, including $7.6 billion for expanding its existing brownfield refineries, in the next 5 to 7 years Moreover, the company plans to lay the nation's longest LPG pipeline of 1,987 km, from Gujarat coast to Gorakhpur in eastern Uttar Pradesh, to cater to growing demand for cooking gas in the country.
- India targets $100 billion worth investments in gas infrastructure by 2022 including an addition of another 228 cities to city gas distribution network This would include setting up of RLNG terminals, pipeline projects, completion of the gas grid and setting up of CGD network in more cities.

- Reliance Industries Ltd is planning to expand its Jamnagar oil refining capacity by about 50 per cent. After the expansion, the plant will then be able to process about 30 million tones crude oil per year.
- As of January 2019 H Energy is going to invest Rs 3 700 crore ($0.5 billion) for construction of an LNG project in West Bengal.
- As of January 2019, the Cabinet Committee on Economic Affairs has approved the capacity expansion of Numaligarh Refinery from 3 MMTPA to 9 MMTPA which will be completed within 48 months.
- As of March 2019, Brookfield is going to acquire Reliance Gas Transportation Infrastructure, now known as East West Pipeline for Rs 13 000 crore ($1.80 billion).

Investments to enhance production

- Indian Oil Company is planning to invest Rs 1 43 lakh crore ($22 billion) to nearly double its oil refining capacity to 150 million tons by 2030.
- Reliance Industries is planning to enter into a Joint Venture with the world's largest oil exporter Saudi Arabia in petrochemicals and refinery projects.
- To boost hydrocarbon production and to improve oil recovery from offshore fields, ONGC plans to invest more than $0.5 billion in Mumbai High.

Diversification and non-conventional and small energy resources

- The Government of India is planning to set up around 5,000 compressed biogas plants by 2023. Private sector units like Adani, Sun Petrochemicals and few new entrants have contracted 1/3rd of small oil and gas fields.
- Oil and Natural Gas Corp has started Shale Gas exploration by spudding the first Shale Gas well RNSG 1 in Burdwan District of West Bengal.
- ONGC has started supply of Piped Natural Gas in Bhubaneswar from October 2017 and is currently laying down natural gas pipeline in Varanasi.
- In May 2018 India launched its biggest auction of City Gas Distribution. The successful companies will be permitted to sell Compressed Natural Gas and Piped Natural Gas in 86 geographical areas The auctions are expected to lead to investments worth Rs 70 000 crore ($10.86 billion).
- Oil producer Oil India Ltd is planning to build and operate refineries, while Indian Oil is planning to enter oil and gas exploration.[14]

FDI equity inflows during April 2014-March 2016 increased by 267% (3.7 times) to USD 1.2 billion from USD 327 million during the same period in 2012-14[15].

[14] Based on data from India Brand Equity Foundation, 2019
[15] Ministry of Petroleum and Natural Gas, Achievements Report, 2017