An analytical study of supply chain planning process for solar renewable energy suppliers in Bangalore during year 2010-2015

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Under the Guidance of

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C E R T I F I C A T E

This is to certify that the thesis entitled ***"An analytical study of supply chain planning process for solar renewable energy suppliers in Bangalore during 2010-2015"*** which is being submitted herewith for the award of the Degree of Vidyavachaspati (Ph.D.) in **Management** of Tilak Maharashtra Vidyapeeth, Pune is the result of original research work completed by **Shri. Raj Kumar Shukla** under my supervision and guidance. To the best of my knowledge and belief the work incorporated in this thesis has not formed the basis for the award of any Degree or similar title of this or any other University or examining body upon him.

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Signature of the Research Guide

Pune

2nd March, 2016

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Raj Kumar Shukla

DECLARATION

I hereby declare that the thesis entitled ***"An analytical study of supply chain planning process for solar renewable energy suppliers in Bangalore during year 2010-2015"*** completed and written by me has not previously been formed as the basis for the award of any Degree or other similar title upon me of this or any other Vidyapeeth or examining body.

Raj Kumar Shukla

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Pune

2nd March, 2016

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Abstract

"An analytical study of supply chain planning process for solar renewable energy suppliers in Bangalore during year 201-15"

An evolved understanding in supply chain planning literature is to ensure that required material reaches to customers on time at a most optimum cost, in order to enhance supply chain surplus. Supplies chain "planning variables" are required to be considered depending solar industry sector. The study presented here hypothesising "planning variables" which are not covered specifically by literature for solar industry.

Following four umbrella hypotheses are concluded.

First hypothesis The research brings out an analysis on "planning" process from global supplies, as a means of optimization of cost and primary decision makers for "planning" across industry. Hypothesis discussion also brings out a specific role of planners, played by "state" to serve broader sustainability objectives, beyond just supply chain optimization.

Second hypothesis brings out prime factor for solar demand as a dependent variable, as a function of state support or a comparative support status of two or more than two states.

Third hypothesis describe, number of planning iteration carried out in a solar supply chain. Optimum iterations is dependents on degree of demand and supply visibility and variations in it. The research highlights some of such factors causing extra planning iterations in solar industry, directly affects demand and supply, unlike a matured supply chain planning.

Fourth hypothesis analyses the skills and competencies required to manage solar supply chain planning "width" factors. It is hypothesised that the generic planning skills and competencies alone are not sufficient to build a strong supply chain planning for solar industry.

<u>Chapter -1: Introduction</u>

Chapter covers the details of solar industry development, its value chain, challenges, trends and complexities imperative to supply chain planning.

Chapter-2: Literature Review

Solar supply chain planning variables, to improve supply chain efficiency, is not covered in available literature. Closest available general supply chain literature covers a number of supply chain studies on "coordination, "Collaboration" and "integration". These generic supply chain literatures, not specific to solar industry is considered as closest to build further solar supply chain planning framework.

Chapter 3: Objective Scope & Hypothesis

Chapter covers **objective** of this research work is to first start mapping global and Indian evolving trend (width variable) in solar industry supply chain planning. Research tries to learn width variables along with planning practices evolving among solar players in the country.

Three business segments respondents are - solar manufacturing, solar EPC contract or developer of solar projects and solar products.

There are four hypothesis further divided into sub-hypothesis to substantiate the main hypothesis discussed in chapter-5

Chapter - 4: Research Methodology

A small case study was undertaken in one of the solar company operating in all the three segments, to put forward research question and hypothesis. The study is conducted based on 25 semi structured interviews of respondents followed by 297 surveys to test the hypothesis objectively. An interview questionnaire is prepared to research the focused area through hypothesis. The objective is to substantiate the hypothesis formulated based on case study. Two of the solar companies allowed observing their planning session to better comprehend their planning practices.

Interview is followed by an objective survey. A different questionnaire is prepared, based on significant occurring images in interviews.

To include "state" view on supply chain planning, we took help of published reports by central and state government (MNRE).

Chapter -5: Analysis & Interpretation

A detailing of four hypotheses from HA 01 to HA 04 goes as follows

HA 01: Supply chain planning process for solar manufacturer/supplier need a wider view of global & domestic supplies, as critical inputs for effective planning.

First analysis, Procurement factors are Availability, Price and Quality & Technology in solar industry as independent variables, whereas planning decision is a dependent variable. Alternate hypothesis for this part is "HA 01: 01: Planning source of solar material is dependent on attributes of procurement - Availability, Price and Quality & Technology in solar industry". Acceptance of this hypothesis indicates that, in solar industry, source of supply planning in dependent on procurement factors, as a primary decision driver.

Second analysis in the research, correlate "global supply" as another "width" of supply chain, increases the supply chain planning complexities. The hypothesis tested for this purpose is "HA 01: 02: Wider global supply view requirement increases the domestic planning process complexities".

The planning decision pattern indicates that most influential decision of planning and buying solar cells and modules is of "state" followed by senior management in a solar organization.

Third Analysis in research thesis is to assess and establish planning objective by three categories of planners. There seems to be a significant difference between objective of industry level planners and state planner acting as a planner. An alternate hypothesis "HA01: 03: Planning objectives of State is sustainability of supply chain, whereas planning objective for material planners is short term cost and availability leverage".

"Planning" by objective has different goals for state and by material planners. The hypothesis tests sustainability of solar supply chain as an objective of state, whereas cost and short term availability leveraged, as a goal of material planner, to meet short term solar project requirements.

Fourth analysis, material stocking is a cost to company, not only a function of local demand but depends on global availability. Domestic solar industries tend to avoid stocking as against easy availability from global stock maintained by global (Chinese) players. The following stated hypothesis provides the relationship between domestic stocking and global availability. "HA 01: 04: Domestic material stocking in the form of raw material or finished goods depends on global availability". Acceptance of this hypothesis shows that planners foresee more confidence in terms of availability from global stock, as compare to manufacturing capacity or stock in domestic country.

Fifth Analysis is around small solar products, been sold in Indian market to be used primary in rural geographies. Solar products are sold off-the-shelf. Solar products being sold in retail market follow a local market level planning, to meet the requirements of a given geographical region. Research hypothesis is posed as "HA 01: 05: Off the shelf solar product planning is more effective at local place of demand, than at national aggregated demand".

HA 02: National and state level policy support to solar energy, to grow the sector, is a major width variable in supply chain planning.

First analysis of hypothesis is formulated to establish the fact that state support is a primary driver for solar energy deployment in India. "HA 01: Solar demand is a function of "state regulations and support", thus an input to supply chain planning".

Second analysis of alternate hypothesis (HA 02:02) is a support hypothesis to HA02, which establishes the fact that natural drivers are almost inexistent during the period of study. "HA 02: 02: Natural demand factors are less significant than a state support derived demand in solar industry".

HA 03: Existing practices of supply chain planning need more number of iterations to protect interest of buyers and sellers (Stakeholders) than existing in practice.

Following nine sub-hypotheses, from HA 03: 01 to HA 03: 09 are formulated to compare number of iteration is solar industry than in practice referred to FMCG companies.

HA 03: 01: Immature iterative design engineering, faster demand inflow than cash collection, inadequate safety stocks increases number of iterations.

This is a basic hypothesis, explaining problem salient to solar industry. Issues of immature design engineering, faster demand inflow than cash collection from customer and playing on minimum stock seems a chief cause for planning iterations. Reasons for extra planning iterations were grouped under following four categories as below.

1) Project site and design related changes
2) Availability of material related changes
3) Cost reduction related iterations changes
4) Customer requirement related changes

There is no relationship between the reasons of iteration and type or size of solar project. Number of iterations suggests that even though total numbers of iterations are dependent on size of project but causes of iterations are not related to the number of iterations.

HA 03: 02: Deviation in sequence of material procurement and dispatch, from a planned sequence, for project installation, increases number of iterations.

It is observed that most of the solar companies are not able to dispatch material in an ideal sequence to allow continuity of an uninterrupted installation work. This causes increase in number of iterations by planners at the last moment to minimize interruption at project site.

HA 03:03: Ambiguous project starting point, to begin material planning process, leads to increase in number of planning iterations.

Material planning for solar projects seems to have no clearly defined starting point to begin placing firm order on suppliers. This uncertainty in clarity is because of the stage, when an order is considered as “firmed” from customer.

HA03 04: Multiple projects execution at the same time leads to increase in number of iterations in supply chain planning.

Solar projects are mostly supported by one or other government sponsored program. Project approval and release of funds from government mostly takes place during the second half of the financial year, due to availability of fund allocation to ministry and processing time thereafter. Second half and especially last quarter of financial year, is the time when all projects are being executed at the same time in parallel. These multiple project execution takes place with only marginal increase in resources, including planners. Such skewed timing of projects, in a limited period of time, causes planners to plan large quantities of material at the same time. Expediting and de-expediting to meet projects requirement leads to extra iterations per project.

HA03 05: Number of iterations is function of fund availability to pay to suppliers by contractors on time.

Indian solar industry is cash crunched most of the time due to heavy liquidity suction in manufacturing plant, machineries and projects. Non-availability or delayed availability of funds with contractor leads to more number of planning iterations to satisfy customer requirements.

HA 03:06: Strict norms of declaring excess inventory in solar organizations impacts number of planning iterations.

There have been restrain exercised among respondent to promote ex-stock sale in solar industry. Strict norms are followed to declare an inventory as non-moving or excess stock. There has been observed, an estimated lower inventory carried by solar company, with more number of iterations. Solar planners opine that more number of days is provided to declare excess or non-moving stock; less number of planning iterations is expected.

HA 03:07: Supplier's credit period affects number of planning iterations.

Planning and procurement in solar industry is being encouraged on a longest possible credit period from suppliers. An important supplier's qualification criteria considered is as a long credit period. Respondents explained us that though credit term with longer credit period are pushing planners to have limited source, but at the same time it minimizes number of planning iterations, as alternate sources or material is not explored and supplies continues, irrespective of some delivery glitches.

HA03:08: Difference exists between in-house and contract manufacturing of solar modules, cell or solar products in planning iterations.

Solar modules carry about 50% value of solar installations in any solar project or products. In case, module manufacturing by a contractor is in-house, it has about 50% independence in planning by value. In other word half of the value of revenue is under the influence of in-house planners. A planner who has to plan modules from a source other than in-house manufacturing, from domestic or global sources, has to carry out more number of iterations to match prices, availability and quality aspects.

Effects on material planning iterations are always lesser, in case of finished goods than planning iteration for raw material for producing cells or modules. Our interview respondents indicated that even if in-house modules manufacturing may cause lesser number of iterations for finished goods, but at a child level raw material planning iteration may remain unchanged. For an in-house planner number of iterations for finished modules are minimal than raw material to produce solar cells and modules.

HA 03:09: Number of planning iterations is dependent on solar business segments.

Number of iterations increases with the size of project. Planning iteration increases more rapidly for every addition of 5 MW of solar project.

Fourth Hypothesis is detailed out as below

A requirement to study skills and competencies was felt, given a particular “width” of solar supply chain variables. The following hypothesis is stated to regarding strengthening of planning skills in solar industry.

HA 04: Roles of supply chain planners need to be strengthened with specialized skill mapping for effectiveness of solar energy companies.

The thesis compares the skills and competencies of generic supply chain planners. While asking a question from respondents about skill sets required for a planner in solar industry, we received an enlarged planning role for solar projects. Role of supply chain planners and project planners has major overlap in solar industry. Material planning and project planning role is hard to distinguish for solar industry.

Additional skills and competencies requirement of planners are grouped as below

a) Forecasting of central and state government solar regulatory environment.
b) Government tendering processes and its length to decide an order winner.
c) Understanding of specifications of solar products to have an efficient expediting.
d) Understanding on alternate usage of material based on best match of specifications, in case of an order cancellation or alterations.
e) Special state taxation structures on solar products.
f) Ability to connect to top most management for wider planning inputs.
g) An understanding of solar order to cash cycle, to manage healthy material supplies to fulfil on time customer demand and optimizing cost of fulfilment
h) Capability of judgment on probability of winning an order, in addition to view represented by sales staff.
i) Knowledge on solar project quality expectations and certifications requirement, as laid by state for solar projects and products.
j) Knowledge on financing schemes and their impact on solar projects and product demand.
k) A hang on project documentation with government agencies and customers.

At lower hierarchical level in a solar organization, all required skills sets had a weak match without a senior manager's representation in planning.

Chapter -6: Limitations of Study and Future Scope

Thesis presented, has tried to generalize some practices based on a set of solar players, primarily located in and around city of Bangalore. Chapters includes a number of probable future scope of research experienced by researcher during the study

Chapter – 7: Conclusion

In solar industry - price, ease of availability, competitive quality and technology available globally are powerful driving forces for planning and procurement decisions, in favour high volume producing countries. In absence of state support natural source of buying of solar equipment is from Chinese countries, an important planning width variable.

Complexities of solar supply chain, shifting planning role to higher hierarchical planners in the organization to take most optimal decision.

Planners foresee more confidence in terms of availability from global stock, as compare to manufacturing capacity or inventory stock in domestic country. Solar products being sold in retail market follow a very local level planning, to meet the requirements of a given geographical region depending on local state support and customer requirements. Solar product planning is indifferent of source of procurement either domestically or by import.

Solar project deployment in the country is strongly related to state support programs.

Number of planning iteration is more in solar industry in comparison to a fast moving product. The reasons for such additional iterations are on accounted in the third hypothesis

Number of planning iterations in solar projects is related to size of solar products. In general, with every addition of 5 MW size of project, number of iterations significantly increases.

Solar supply chain planner's skills are wider than a material planner. This role of material planner is closer to project planner. Such planners should have additional skills and competencies in addition to supply chain planning highlighted in fourth hypothesis.

Chapter -8: Suggestions & Recommendations

Solar project execution capability is yet to reach at its highest level of excellence. Reducing cost of solar project execution and delay is causing value deterioration. An excellence program across solar industry, to reduce cost and increase efficiency can help companies in long run.

Dr. Sanjay R Mali **Raj Kumar Shukla**

(Research Guide) **(Student)**

Chapter -1: Introduction

In this research, supply chain is considered as a central function for survival of solar industry. “Planning Process” act as a central brain of supply chain, not only managing efficiency of material supply but also various services like installation, commissioning and other support provided to the solar customers. A planner’s role in solar industry seems much wider, since some of the decisions are linked to survival of a solar firm. A planner can be a designated planner or a business manager responsible for taking key decisions depending on “Volume” of supplies and “Sentiments” towards solar industry during referenced time. Solar project management is considered subordinated to planning because of larger width of supply chain planning, beyond material planning. In this thesis a planner is considered as a second in command, after a business manager’s in a solar firm.

1.1 Context Setting

Solar industry worldwide is not able to make adequate returns and despite of huge demand, players in solar industry are bleeding financially. The thesis focuses on extra ordinary complexity variables on account of specific factors in solar supply chain involving complex decision making termed as planning. In literature, supply chain success has been largely considered as a success of all stakeholders, from customers to suppliers. In solar industry supply chain, there seems a departure; wherein industry is growing and solar supply chain is relatively becoming more efficient day by day, but still industry players are not able to sustain their businesses.

Energy is a prime mover of human life and responsible for development of an economy. Prime sources of energy generations have been fossils fuels which is known for its extinctive nature and responsible for most of green house emission and global warming. Global concerns on energy security and environmental challenges led to development of multiple sources of renewable energy. Most of these alternate renewable energy sources are late entrant into energy development foray, possess multiple challenges to reach to maturity to get deployed at a large scale e.g solar energy.

Although sun is a prime source of energy for human life and its support system, term "Solar Energy" mostly referred to a solar energy harnessing mechanism based on direct tapping thermal or solar radiation to convert into electricity. Solar energy helps in solving electrical power shortage by harnessing most abundant source of energy, spread on exposed surface of earth. Solar energy is very effective means of generating power in the category of alternate renewable energy to substantiate electricity requirements to existing sources or to human habitat not connected to electrical grid. Harnessing quantum of solar energy depends on degree of sunshine at a particular geographical region. More sunshine at a place, more energy can be harnessed into electricity. Different parts of the globe have different degree of sunshine and thus different potential available for harnessing into electrical power.

Solar energy harnessing takes place by two streams of solar technology. Most common technology is "Photo Voltaic" PV) electricity generation followed by "Solar Thermal" based technology. Both the form of solar technologies are used to convert solar energy directly either into electricity or used its heating effects for power generations. Since Solar PV is most commonly used technology for harnessing solar energy into electrical energy, the discussion on value chain and focus of the research is scoped primarily around PV based technology.

Conversion of solar energy into electricity is achieved by an array of solar cells, stringed into solar modules. These modules when exposed to sunlight generate electricity. Electricity amplification takes place by combining multiple solar modules to increase power. A solar electrical generating system has a set of solar modules supporting structures, electronics and storage system such as battery etc. (termed as BOS - Balance of Systems) to form a complete solar electrical generating units. The raw material for solar cell is poly-silicon wafer which is manufactured from poly-silicon ingot.

Solar Electricity generating system is further categorized into two groups based on size of single generating units. A set of standard sized modules and associated BOS, generally categorized as small solar products ranging between 1 watt-peak to a few kilowatt- peak, is termed as "Solar PV Product" group. Solar PV products are generally low cost lantern, home lights, street like or power packs used to run various applications. Second category of solar electrical generating system is small to large size solar power plants. Size of these solar plant based electrical power plant, varies from 5 KWp to about 1000 MWp. The solar plant projects are further classified as small solar plants, installed generally on roof-top of house hold or office buildings and large scale solar power plant used to generate electricity by corporate or power utility companies. Investment required to set up these plants is generally very large. Most of these solar PV products or plant projects are set up under various state supported programs to promote solar electricity generations. A major part of solar power plants are generally funded by banks or financial institutions. Large scale solar plant farms are set up by various power producers or corporate, whereas solar products are sold through retail channels, across the geography, sold to rural off grid customers. Solar power plant value chain is depicted in the schematic below.

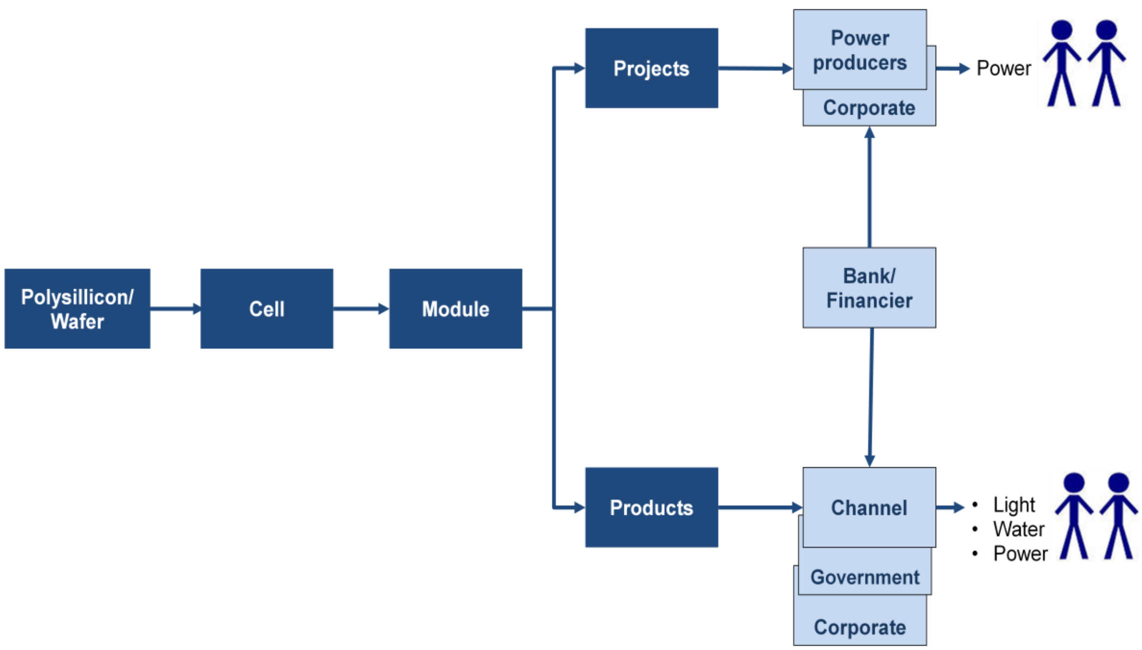

Fig 1-1: Schematic of Solar Value Chain

1.2 Solar Manufacturing or Integration

1.2.1 Silicon/Wafer Manufacturing

The raw material of most solar cells is crystalline silicon. Silicon is one of the most widely available elements in the form of sand. Silicon ingot is purified and cut into thin wafers.

1.2.2 PV Cell Manufacturing

Crystalline cells are made from silicon wafers by cleaning and doping the wafer. Cell manufacturing usage wafer as a base raw material for converting into smallest power generating unit called as a solar cell.

1.2.3 PV Module Manufacturing

Cells are stringed together to manufacture solar power generating unit called panel or module. Multiple solar modules are used as a basic element converting solar power into electrical power. The sizes of solar modules are available from 3Wp to 350Wp range to cater to various market segments. Typically 230Wp and above modules are termed as large area modules, are sold to large scale solar power plants, while less than 230Wp modules sometimes termed as “small” or “specialty modules” are used in making small solar products and roof top power plant.

1.2.4 Solar Products

There is range of solar photovoltaic products available in the market. Typical solar products are home-lights, street light, power back-up inverters for residential and small commercial establishments and water pumps used in irrigation by farmers.

In the lighting segment, portable lanterns, home lighting systems and street lighting systems cater to the requirements of homes, small businesses and community lighting. Multiple SKUs of each of these products are being sold by various manufacturers and distributors. There are range of efficient solar powered inverters and solar powered water pumps. These product categories are an ideal alternate to grid power, where there is no or limited access to grid. These solar products are sold through dealer channel spread across the country to residential, corporate or through government under state support programs.

1.2.5 Solar Projects

Solar project developers and EPC service providers are responsible for building ground mounted large scale and distributed rooftop solar PV plants for corporate, governments/PSU's as well as independent power producers. These players develop complete end-to-end solar power plant solutions from the preliminary stages of project feasibility assessment, design, installation, commissioning, operation and maintenance.

The following table reflects solar range of major value chain partners.

TABLE 1-1: Application of solar business segments

Solar Business Segments	**Product/Services**	**Application**
Manufacturing	Silicon Wafer	Raw material for cell manufacturing
	PV Cell Manufacturing	Component for module/Panel manufacturing
	PV modules/panel	Basic building block of any PV product or projects for solar developers
Solar Products	Lantern, Home Light Street Light	Domestic & community lighting
	Solar power inverter/back-up	Residential and small commercial establishments
	Solar pumps	Agriculture & household
Solar Power Plant Projects	Solar roof top	Power plants on building and office roofs
	Solar large projects	Power plants project to meet specific solar project developer's needs

1.3 Global Solar Energy Deployment

Global solar demand fundamentals are influenced historically by low financing cost, and policy response from states. Solar energy is expected to play a much bigger role in energy market in future power generation portfolio. This is because of rapidly increasing business and consumer power base. Solar system cost is continuously declining for last 3-4 years (between study period of years 2011-2015, and has potential to decline further. Declining cost of solar power system is making solar as a competitive source of energy in recent years than what it was in year 2000 (McKinsey & Company report, David Frankel, Kenneth Ostrowski, Dickon Pinner). On account of declining selling prices globally and development of latest technology, modules even with better power efficiency, investments in solar plants are not giving returns to manufacturers and most of solar companies across globe. Many solar players specifically in India are closing down their operation, since they are not able to manage their supply chain against unpredictable demand and sharp decline is profit margin. In a state support driven demand, solar power project developers look for subsidy, rather than fulfilling their need by natural drivers of demand. Solar product off-take from customers is becoming state support driven than a pure natural demand driven. These factors tend to add a number of unique supply chain planning variables, unlike convention planning process for products having predictable demand. During this declining phase of solar systems prices, Energy index fell by 50% between year 2011 and end of 2013, a period when dozen of solar companies went bankrupt or shut down their operations or sold off. Sharply declining costs are the key to increasing potential of solar energy due to ease of affordability and low financing cost. The prices of US residential consumer pay to install rooftop solar PV systems has come down from $7 per watt peak in year 2008 to $4 or less in year 2013. Most of this decline has been a result of upstream value chain cost, primarily fall in equipment module cost, which fell by nearly 30% between years 2008 to 2013. In addition to module cost decline, there is a huge opportunity on the downstream cost associated with installation and service, being focused by recent players. Financing customer aquition, regulatory incentives, and approvals put together become half the installing expenses in US. The trend in solar envisage that the downstream investment will be more promoted as opposed to upstream, which could limit capacity expansion and will push tight supply situation across upstream in value chain. (McKinsey& Company report, David Frankel, Kenneth Ostrowski, Dickon Pinner, Energetica May 2014).

European market is almost saturated with stagnant demand for solar products. Japan is looking for replacing their nuclear power plant into solar plant in wake of Fukushima nuclear damage. China has invested heavily in renewable energy development.

1.4 Supply Chain Players in Solar Industry

Supply chain players are divided broadly into following groups.

- Solar manufacturers- are engaged in manufacturing of solar modules, cells and wafers.
- BOS Manufacturers - These players are responsible for manufacturing of solar inverters, supporting structures, solar trackers, transformers and other electrical and electronics equipment used in the solar system.
- Solar Developers – Developers are individual, private and public companies or distribution companies or various private and government utilities, who are prime owner of solar plants and projects. They are responsible for development and operations of solar plants. They sell electricity as a product to distribution companies or to open access customers, by selling in open access market.
- Solar EPC contractor - Project developers not necessarily are experienced in plant set up, thus a players who is more experience in setting up solar power plant for developers on the basis of Engineering, Procurement and Construction, support to commission their plant under an EPC contractor.

1.5 Solar energy regulatory market environment in India

India has always been a country having shortage of supply of electricity against demand. There is a large population, not connected to grid and thus deprived of electricity. Conventional energy prices in India are climbing continuously as coal, a prime source of energy generations, is difficult to obtain, sources of domestic gas are shrinking, and there is more focus than in past, on the sustainability of environment. India has been a net coal importing country. Heavy coal import is one of the major reasons of huge foreign exchange outgo which in turn put pressure on foreign exchange reserves. There is a strong need to harness alternate sources of energy including renewable energy like wind, small hydro, biomass and solar, which will reduce dependence on coal and drive towards a sustainable environment.

India has a total installed power generation capacity of 230 GW. Power generation from renewable energy in India is gaining momentum with the share of renewable energy in the country in increased from 7.8 % in FY08 to 12.3% in FY13. India has an installed base capacity of about 28.1 GW of installed renewable energy capacity as March 31, 2013. Major share of renewable energy, about 68% is wind energy, with the 19.1 GW of installed capacity. Small hydro power (3.6 GW), bio energy (3.6 GW) and solar energy (1.7 GW) constitute the rest of the capacity. Share of overall renewable energy in the total pie of sources of energy generation is on continuous rise over past many years but India still has a vast potential untapped renewable potential energy that can be harnessed with a focus in this sector. Solar is becoming a crucial component of India's energy portfolio. A number of players are preparing themselves for future opportunities involved with the expected long term commitment of government. India's solar market has potential to become billions of dollars over the next decades. (Power Watch page 29& 77, April 2014*)* India's solar energy sector continues to be an attractive alternative for investors willing to target new markets on account of saturation achieved in European market. This trend has attracted an investment of $4.2 billion in 2011 – growing nearly seven-fold from 2010. In addition rapid fall in solar prices and increasing cost of conventional energy is bridging the gap between the costs of energy for consumer.

The Ministry of New and Renewable Energy (MNRE) is the primary government agency, in charge of guiding the national renewable energy policy while the IREDA (Indian renewable energy development agency), Ministry of Power and a host of other state nodal agencies assist in implementation of the MNRE policies. Jawaharlal Nehru National Solar Mission (JNNSM) is the umbrella program for India's strategy for solar power manufacturing and generation, launched officially in Jan, 2010. JNNSM had set a target of 20 GW of grid-connected utility scale installations, 2 GW of off-grid solar applications by year 2022. Till the end of year March 2015, the program is in Phase - II after completion of Phase – I in year 2013. Indian and state level government is providing following support mechanism to help growth of solar industry in India. New central government has announced to achieve 100 GW of solar power in India as against earlier target of 20 GW by year 2022.

1.5.1 Level playing field for Indian Manufacturer

The biggest regulatory driver on the solar supply side pertains to level playing field to Indian solar manufacturers against manufacturers from some countries (e.g., China) that receive significant support from their host governments and subsequently dump their solar supplies in India. Presently, the support to Indian manufacturers is being provided through Domestic Content Requirement (DCR). Under Batch-I of Phase-II, a total of 750 MW of solar PV projects were allotted to developers, of which 375 MW (50% of total size) were required to have domestically manufactured cells and modules. The Govt. of India was contemplating levying Anti-Dumping Duty (ADD) on import of solar supplies from select countries, however decided not to impose ADD.

A majority of solar components are presently either exempted or allowed concessional custom and excise duty. This helps in reducing the cost of production and thus helps in making Indian solar supplies price competitive.

1.5.2 Capital subsidy

MNRE provides subsidy for various solar plants including solar rooftops & off-grid installations and small solar applications. These subsidies are extremely helpful as it help make these solar segments commercially viable/ affordable to the user given the higher cost of solar power. However, there are huge delays in availing the subsidy and getting project clearances due to fund availability with central and state renewable development agencies. Ministry has removed to gradually many such subsidy programs and suggested its accredited channel partners to work out their plans to promote solar installations without subsidy.

1.5.3 Renewable Purchase Obligation (RPO)

Considering that solar power is presently more expensive than conventional power, a key driver towards growth of solar power is the solar RPO - a mandatory sourcing of specified percentage of total power from solar source. As the obligated entities under RPO are the distribution companies, open access consumers and captive consumers, RPO typically helps in deployment of grid connected solar projects. However, a lack of penal action for non-compliance, the bad financial health of most obligated entities, non-co-operation of state regulators and an out-dated Renewable Energy Certificate (REC) pricing mechanism have prevented it from having a more direct impact on solar demand. The Indian government is trying to figure out ways to fix the RPO mechanism which is still not helping in promotion of solar energy.

1.5.4 Net-metering

Net metering helps in growth of rooftop solar segment as it allows the generator to export surplus solar power to the grid and to receive the incentive (either tariff for exported power or credit for exported power to be offset in subsequent consumption). Till year 2014, five states (Gujarat, Andhra Pradesh, Uttarakhand, Tamil Nadu and West Bengal) have finalized the net metering policies and others are in process of drafting the same. Many states are planning to release their net metering policies.

1.5.5 Tax Incentives

The two key tax incentives are accelerated depreciation benefit and tax holiday under Section 80 IA are provided to developers of solar plants. These incentives help significantly in improving project financials and thus act as major catalyst in attracting a certain class of investors.

1.6 Challenges in Deployment of Solar Energy in India

Despite of huge demand of solar power, solar power is only 6% in the portfolio of renewable power and about 1% in overall power generations sources by the end of year

2013. Solar energy insolation in India is available at a much larger extent, yet the potential of harnessing is highly unexploited. As per estimates, only 0.8% of solar energy is being utilized to convert into power. India has average 300 sunny days a year, with an estimated energy generation potential of 6 billion GWh.

Major deterrents to wide spread deployment of solar power is as follows

- Solar power is more expensive than conventional coal based generated power because of huge capital investment required to put up a solar power plant.
- One time capital expenses is unaffordable to small solar customers. Bankability of solar projects is not lucrative. Banks have better options to fund viable non solar based power plants. Financers of solar power projects perceive solar plants as a riskier option because of early stage of deployment and poor confidence on technology.
- Uncertainty with respect to some regulatory policies does not augur well for investor’s confidence. Most of the regulatory support does not have a long term commitment. Stakeholders, especially manufacturers considering setting up Indian operations and developers planning projects and future expansion, believe India’s lack of long term, comprehensive and practical solar plan, is a major hurdle.

1.7 Indian Government Plan for Solar Power

Government of India has a plan to add renewable energy capacity target of 29.8 GW for the 12th Five Year Plan, making total renewable energy capacity almost 55 GW by the end of FY17. The break up includes 15 GW from wind, 10 GW from solar, 2.7 GW from biomass and 2.1 GW from small hydro. Proposed investment in renewable energy is expected to become four times to Rs. 3186 billion in the 12th FYP from Rs. 892 billion in the 11th FYP. This investment means average investment of Rs. 640 billion planned renewable capacity additions during the 12th FYP is almost one-third of planned conventional energy capacity additions during the same period.

1.8 Jawaharlal Nehru National Solar Mission (JNNSM)

Government of India (MNRE), in 2009 launched the aggressive targeted Jawaharlal Nehru Solar Mission - one of the eight key missions of the National Action Plan on Climate Change to install 20 GW of solar power by 2022. Solar energy capacity has witnessed rapid growth over the last few years to reach to 1.7 GW as on March 2013. JNNSM is playing a most significant role in the development of solar energy sector in India. The deployment of JNNSM is in three phases, aimed to achieve grid parity for solar energy and to install 20 GW of grid connected solar power by 2022. Three phases of JNNSM starting with Phase-I (2010-2013) targeting 1-2 GW of cumulative grid connected solar capacity, Phase-II (2013-17) targeting 4-10 GW, and Phase-III (2017-2022) is targeting 20 GW. (Sources of Power & Solar Page -29 Power Watch April14)

A Jawahar Lal Nehru National Solar Mission Target 2010 to 2022 broken down into various deployment segments is as below.

TABLE 1-2: JNNSM plan for deployment of solar power

Technology Used	**Phase-I (2010-2012)**	**Phase-II (2013 to 2017)**	**Phase-III (2017 to 2022**
Grid Connected/Rooftop	1000 MW to 2000 MW	4000 to 10000 MW	20000 MW
Off Grid Solar application	200 MW	1000 MW	2000 MW
Rural Solar Lantern/lighting	N/A	N/A	20 million systems

JNNSM three phases are referred as Seed Phase, Growth Phase and Acceleration Phase. During seed phase independent solar power producers is to support in kicking off the deployment of solar infrastructure and start learning for next phases. In growth phase, rising demand and favorable economies lead to rapid industry growth, attracting larger utilities into the solar foray (Softdesk - Sophia Parikh, May 2013).

Some of industry estimate proposes that JNNSM will not only meet its target but exceed with the continuous cost reduction and reaching grid parity. Very recently after formation of new Indian government in year 2014, it is proposed to increase the target of solar energy deployment to 100GW, way ahead of target of three phases of JNNSM.

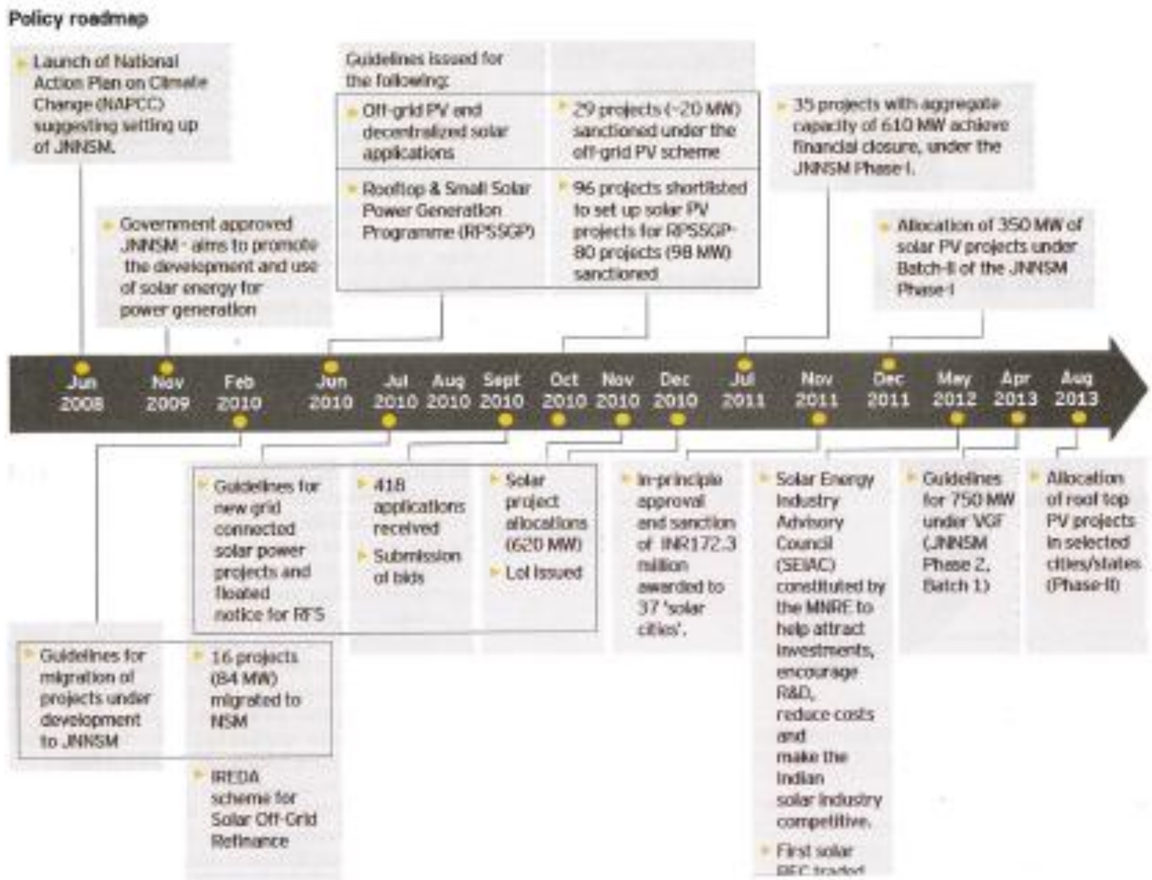

Fig 1-2: Journey of solar energy deployment

1.9 State Policies in Indian Solar Industry

The JNNSM has created impetus at both state and national level. Several Indian state governments have declared their state – level solar policies. Solar state wise target set for installed capacities by major states are – Gujarat- 500 MW in 2010-14, Karnataka 250 MW in 2013-16, Rajasthan – 600 MW in 2013-17, MP- 200 MW in 2012-13, Andhra Pradesh – 1 GW in 2013-17, Tamil Nadu – 3 GW in 2013-15.

Since the announcement of state level solar policies, it was observed that prices started falling at state level programs. There is an argument that state level programs has better profitability than central run program on account of higher feed-in-tariffs and other state level incentives. (Laying foundation for a bright Future)

1.10 Trends - important for solar "Supply Chain Planning"

Solar is becoming a viable energy source, not just as an alternative to other renewable sources but also to a significant part of conventional power. For the growth impetus in solar, cost improvements, procurement effectiveness is becoming a requirement. Longer term value will come from efficiency executed projects, low cost financing, and localization.(Softdesk, May 2013)

Indian solar manufacturing is not globally competitive in cost, quality or product availability, adversely affecting its further growth, especially in the absence of comparatively lower assistance by states. Second Phase of JNNSM is moving towards grid parity – Global Prices for PV modules are going down, reducing the overall cost of generating solar power. In India this led to a steep decline in the winning bids for JNNSM projects. A price of solar power $ 0.15-0.17 per KWh is already among the worlds lowest.

1.10.1 Overcapacity

With the condition of global overcapacity in modules, prices is continued to fall, causing constraint for solar supplier's capacity utilization. ASEAN counties, like China and Taiwan are much more ahead of solar technology than India in solar manufacturing, with their governments heavily investing in the industry since the early 2000s. Early developmental initiatives have allowed these nations to capitalize on the huge growth in the solar market. At present China is largest producer of solar equipment, with about 60% of global solar module production capacity followed by Taiwan is the world's second largest. Both the Chinese and Taiwanese solar industries are extremely export –

dependent. China exports 95% of its modules production and are facing overcapacities problems.

1.10.2 The less-developed and smaller size of India's solar manufacturing industry

India has constrained ability to achieve economies of scale, typically a dominant trend globally. Solar modules manufacturing plants globally has capacity around 75 MW. Such a large scale allows bargaining power for procuring raw materials and the option of increasing production without constantly incurring investment costs for plants expansions. However, in India solar module manufacturing plants are generally in the range of 10 to 40 MWp of capacity, forcing companies that wish to raise production to frequently make production plant investment that results in a higher price per watt. There is no rush to build module manufacturing capacity, since globally there is already overcapacity. Cost of module production in India is more than imported procured solar modules due to lower volume.

1.10.3 Low Utilization of existing capacities

Towards supply side, even though the demand is increasing but solar module manufacturing capacity is largely unutilized in past two years. Demand for Indian solar equipment took a bad hit as Indian manufacturer were not able to compete with their foreign counterpart, especially from China and US, on the price front. Indian manufacturer were contend with the problem of outdated technology and lack of availability of raw materials. Large part of raw material used in production of solar cells and modules is imported from suppliers abroad. Currently out of total solar module manufacturing capacity of about 2 GWp, only 30-40% is operational.

1.10.4 Fragmented Module manufacturing

Module manufacturing in India is highly fragmented on account of presence of several large companies like Moser Baer, Waaree, Solar Semiconductor, Vikram Solar, XL Energy, Emmvee Solar and Tata Power Solar. Among the major domestic manufacturers only Moser Baer and HHV Solar produces thin-film modules. Solar module production capacity in India is about 1100 MW. The majority of the domestic cell manufacturing capacity is with a few major players like Tata Power Solar, Moser Baer, Indosolar, XL Energy and Websol. There are very limited solar cell manufacturers including Indosolar, Jupitar Solar, Power and Euro multivision, rest others are present in downstream segments of solar value chain.

1.10.5 Evolution of EPC Contractors

JNNSM Phase-I acted as a mechanism to prove, test and assess the performance of solar plant developers, participating in these projects in early days, giving experienced entities an opportunity to prove their track record and provide a road to many project developers to enter the Indian solar market. In phase-1, a central force in solar market is EPC contractor. Since project developers have limited experience in solar industry, they are dependent heavily on EPC contractor to set up their plants. A thin profit margin on time lines to complete the project.

Indian companies are taking some time to learn and adjust themselves, but in the same time global players entering India first time are making much faster headway (Power Watch April 2014 & Softdesk, May 2013).

1.10.5 Fragmented Solar EPC contractors

Standalone EPC players are catering to independent solar power producers and corporate utilities. EPC market is highly fragmented with the presence of large number of players. This is leading to diminishing efficiency of scale. Rapidly decling cost and improving technology is creating environment for long term framework agreements for project development that is latest conventional energy procurement structure.

1.10.6 Leasing Manufacturing Capacities to foreign players

Considerable part of unutilized manufacturing capacity have been started leasing to foreign players to gain mutual benefit of lower production cost and adhering to DCR norms set by NSM.

1.10.7 Domestic Product Quality Perception

Solar developers and EPC contractors consider Indian solar products available for domestic consumption to be of lower quality in comparison with products from developed solar technology countries like Germany. This creates more pull towards imported solar equipments then sourcing locally in India.

1.10.8 Manufacturing is dominated by imported raw material

Imported suppliers are more experienced in supplying solar systems in Indian solar industry. Widespread uncertainty in solar market on demand is negatively affecting investment in solar manufacturing in India. Major value in solar industry is not in manufacturing. 50% of value of solar value stream lies in downstream of modules manufacturing, in-system design, integration, installation, operations and maintenance. 50% dependence of manufacturing on imported raw material causes further uncertainty of supplies.

1.10.9 Global Procurement Differentiation

Presently global procurement is a differentiators for a leading solar player. As more and more players are achieving scales and, this differentiator may cease to exist.

1.10.10 Narrow Scoped Supply

India has a very narrow scoped supply of solar products. Majority of Indian manufacturers are in solar module manufacturers. There is hardly a fully grown ecosystem of producing of raw materials to produce solar cells, inverters and balance of systems components. During recently time of year 2015, supplier base of “Balance of Systems” is under consideration by multiple global players in India with the help of foreign investment.

1.10.11 Solar Manufacturers Diversifying into downstream

Several solar equipment manufacturers in India are diversifying themselves into downstream solar value chain e.g. the downstream value chain includes solar project development or EPC (engineering, procurement and construction) space where full solar plant is set up. Solar supply chain industry is growing much faster in downstream than upstream industry; this trend is a complete contrast against the global trend where equal emphasis is being given to solar manufacturing as well. Some manufacturer are trying to tap niche segment in solar off-grid, rural electrification as good number of states are announcing net-metering infrastructure to allow small roof top installation of solar plant.

1.10.12 Profit Margin Pressure on Solar Equipment Suppliers

Continuous competitive bidding by government support solar plants under model of JNNSM is putting a huge profit margin pressure on solar energy equipment suppliers. It poses challenges on supply chain to reduce cost and improve surplus.

1.10.13 Domestic Content Requirement

From an organization's perspective, the greater the value chain participation by domestic solar players, the larger the value captured by the domestic solar market. Domestic solar manufacturing offers technical flexibility and maneuverability so that plants can manufacture product varieties e suited to existing and contemporary circumstances. During the first two phases of JNNSM, some capacity of solar plant is mandated with domestically manufactured solar cells or modules or both. Indian manufacturer have already invested into solar cell and module manufacturing capacities left unutilized. DCR is intended to give some breathing space to domestic manufacturer to promote local solar infrastructure development in the country. Solar manufacturing blocks a very high investment and technologies, but state support is not always encouraging, deterrent to capacity addition in cell and module manufacturing. The primary reason for Indian unutilized manufacturing capacity is outdated manufacturing technology set up and poor management of cost of manufacturing.

With an increased in solar plant development activities at state level, impact of DCR is reducing slowly over a period of time. Several states like MP, Karnataka, TN, Rajasthan, AP and Orissa have introduced their own solar programs which do not mandate requirement of domestic content.

1.10.14 Increase in size of solar projects

In India solar plant size is increasing rapidly. The solar project size in India is about 150 MWp to be called as a large project. However, recently ultra Mega projects of over 1000 MW have also is being announced.

1.10.15 Solar Project Approval Process under JNNSM

The draft policy for Phase-II (2013-2017) of the JNNSM has targeted 9 GW of capacity addition through grid connected projects. 5.4 GW of this 9 GW is to be set up through state –level programs. However tendering process in most of the states distressed by uncertainty and delays. There is a lack of visibility of the project pipelines and a lack of discipline with regards to project commissioning, thereby adversely impacting investors' confidence. In most of the places there is no penalty imposition on delay causing no auto correction mechanism (Renewable Watch June 2014). Ideally solar projects have to meet laid down timelines by JNNSM. A typical series of events in project award and development is as follows. This is very long approval process.

TABLE 1-3: Steps involve in project allocation under MNRE support

Jawahar Lal Nahru National Solar Mission Project Process		
Process Steps	**Timing**	**Description**
Solicitation	Day 1	MNRE and NTPC Vidyut Vitran Nigam (NVVN) request bids from project developers
Bidding	Day1+30 days	Project Developers Submit bid, which undergoes initial screening to ensure it meets technical criteria
Selection	Day 1+120 days	MNRE and NVVN choose technically qualified bids through reverse auction mechanism based on lowest-priced bids. Selecting winning projects until the available MW capacity allotted.

Entering LOI	Day 1+135 days	MNRE and NVVN issue letter of intent within 15 days of selection
Signing PPA	LOI+PPA	NVVN signs PPA (power purchase agreement) with project developer
Financing	PPA+180 days	Project Developer secures project financing, typically with financial institution, by financial closure deadlines
Commissioning	PPA+365 days	Solar developer must produce solar power by commissioning deadlines, paying penalty fee to NVVN for delays up to 6 months, at which time PPA is terminated
Monitoring	Ongoing	NVVN monitoring project to ensure that power commitments are met

(Council of Energy Environment and Water Natutal Resources Defense Council)

1.10.16 Project Delays

Given the substantial cost of solar projects, project delays are creating trouble and hitting profitability of solar developers. Projects are often slowed by infrastructure issues and unreliable local suppliers and vendors. Stakeholder management at national and state levels has always been a concern to solar project developers.

1.10.17 Financing Environment

India is one of the fast pacing countries in installed renewable based power plant capacity and as a preferred destination for investment in the sector. Approximately INR 5100 Cr was invested in Indian renewable energy, more than one third is in solar projects. Further it required greater fund availability to harness to maximize tapping available solar potential in country. Even though understanding of solar industry within some limited pocket is on rise but conservative finance sector continue to perceive a risk in investing in solar energy. This is hampering solar industry to attract investment as a main stream power industry.

For Phase-I, project developers were required to come up with the financial closure in a span of 180 days after PPA sign off with NVVN. Developers achieved financial goals by accessing domestic and overseas fund and utilizing their company equity. Fund arrangement from external sources remained a challenge. During investment for Phase-I solar project financing institutions perceived multiple risks that are preventing JNNSM supported projects from securing domestic financing support. The main reasons are as below

- Solar energy is new sector and technology in India.
- Longer payback due to high capital cost involved.
- Domestic interest rates are higher than overseas attractive finance.
- Poor financial ability of Discom makes bank reluctant to freely invest in solar projects.

1.10.18 Renewable Purchase Obligation

More and more independent power producers (IPPSs) are participating in order to meet their obligation. RPO & SRPO is a mechanism mandated for power generating & distribution companies and corporate to generate certain percentage of their portfolio from renewable energy sources. Larger utilities companies are still not ventured into solar in full swing, they are waiting to come and consolidate market captured by small IPPs.

1.10.19 Trends in Off-grid Solar Power

1.10.19.1 Funding of solar decentralized off-grid Power Plants

Most of commercial banks and non-banking finance companies are interested in funding large grid connected solar projects. The primary reason is high cost of off-grid solar solution and poor creditworthiness of targeted customers. Inspite of government classification of such loan under priority sector lending to ensure better participation from commercial banks. The key financers in this sector are microfinance institution, non-profit organization and regional rural banks (RRBs). These institutions are sponsored by commercial banks. Institutions funding off-grid systems are Aryavart Gramin Bank (AGB), the Self Employed Women’s Association (SEWA), Bank, the Weaker Section

Development Society and Prathama Bank. These institutions raise capital from sources like National Bank for Agriculture and Rural Development (NABARD), their sponsors and private equity funds. Kiva, is a microlending service, provides financing through WSDS to rural customers for buying solar lamps. International funding agencies and foreign social ventures are collaborating with local NGOs, like (SHGs) solar solution providers and self help group to provide credit facility to rural customer base. Subsidies from central government through NABARD is playing an important role, a state government is funding these customer upfront a part of cost of solar systems. For example Rajasthan government has offered a subsidy of 86% to farmers for installation of pumps on solar power; customers were supposed to pay only 14% of the total cost of Rs. 4.25 Lacs. Subsidy disbursal is a lengthy process and involves issues like getting approvals from multiple government authorities. One of such off-grid financing is being offered by Aryavart Gramin Bank offering credit to rural customers in UP for many years. Under this program government provide loan for two solar home light systems – Venus -1 (35 Wp modules) and Venus -2 (70 Wp PV modules). This loan is provided to existing customers of bank. Customers are required to make 20% down payment for solar light and rest is financed through loan. Loaned amount can be paid over a period of five years in six monthly or monthly installments. RRB Prathama Bank provides credit under the Prathama Solar Jyoti financing scheme. Bank provide loan of Rs. 13000 for a systems of Rs. 14000. The loan is to be repaid in seven years with a rate of interest of 9%.

1.10.19.2 Off-grid solar plant in Phase-I of JNNSM

Aim was to deploy 200 MW of off-grid solar systems in the first phase along with 1000 MW grid connected systems. MNRE installed 4315 solar pumps systems in addition to solar lighting systems like lantern, home lighting, street lighting and solar water heating systems. Under the phase-2, MNRE plans to implement 10,000 solar pump systems via financial assistance from NABARD, regional rural banks, commercial and cooperative banks.40% of this will be provided by central government, 10% will be contributed by user and 50% will be provided through bank loan at a commercial rates.

1.11 Solar Power Situation before JNNSM Announcement

Prior to JNNSM, Indian, manufacturing of solar components was export dependent for their raw material but were also exporting about 70% of solar cells and 80% of solar modules to Europe, the US, Japan, and Australia. The overall Indian solar market has grown significantly since the mission's announcement in January 2010, and while this growth is positively influencing domestic production, manufacturing related concerns are yet to be addressed on account of state support to solar developer not manufacturer. Domestic manufacturing of solar systems and their deployment in the country, is a more sustainable way to develop domestic market ecosystem.

1.12. Distribution of Value in Solar Value Chain

Based on some published reports, about 30% of value along the solar silicon PV value chain is attributed to cells and modules (about 20% & 10% respectively). The remaining 70% value lies downstream, in inverters, balance of systems, mounting structure, site preparation, labor and other needs such as engineering, legal processes, financing and distribution. In the thin film technology based solar power plant, modules account for about 40% of value, while the remaining 60% lies in downstream.

For the Indian market, MNRE suggests approximately 50% of value chain can be attributed to solar cells and modules. Since half or more of the value could be captured through activities downstream, primarily targeting resources-intensive and investment-intensive manufacturing activities upstream is not optimal, especially at the outset.

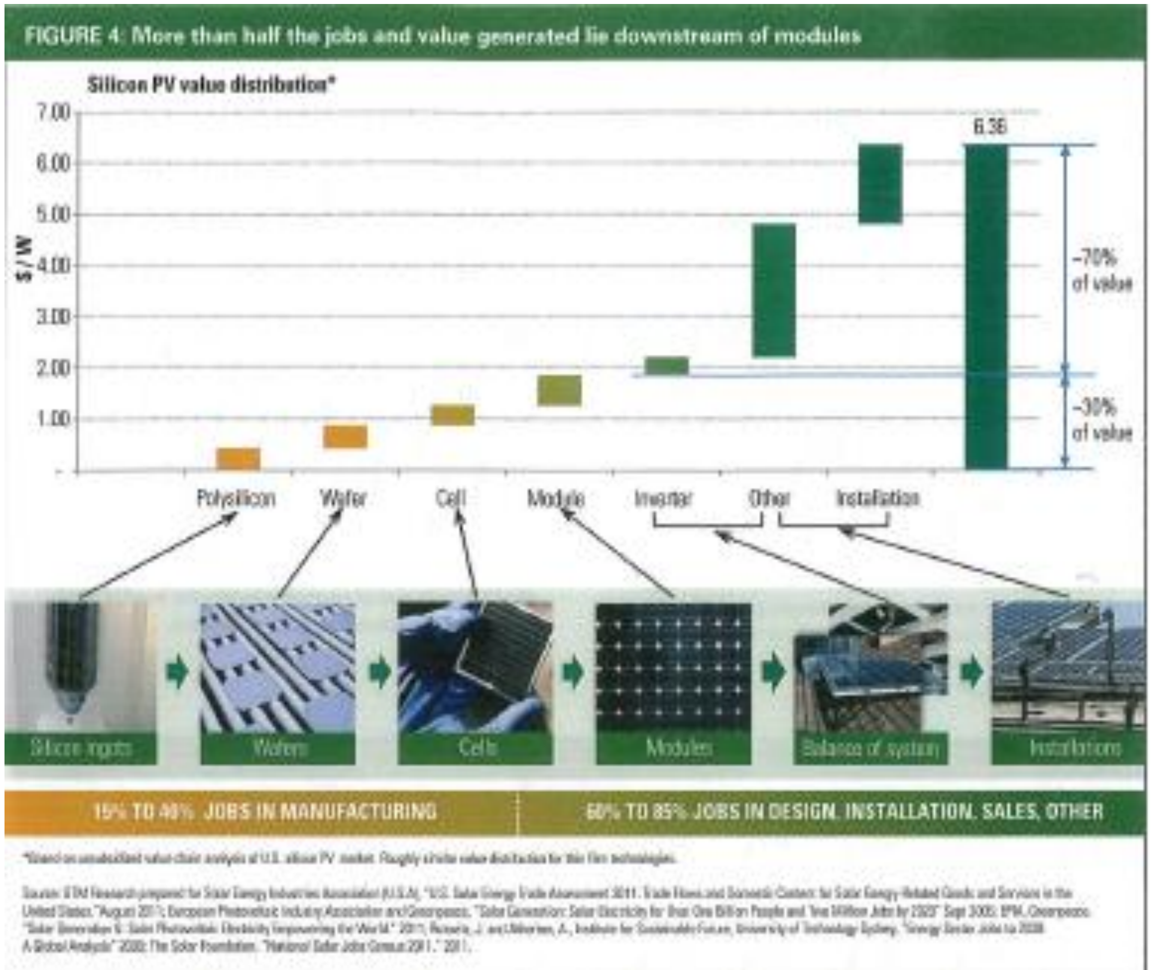

Fig 1-3: A pictorial depiction of solar value chain

1.13 Domestic Content Requirement’s Effects on Manufacturing & Stakeholder Reactions

The domestic content requirement (DCR) is turning out to be one of the JNNSM’s most debated and hot subject, garnering a large spectrum of stakeholder’s favoring and opposing reactions at the same time. Even though, the initial JNNSM document did not mention a DCR, but later Mission Guidelines for both Phase-I batches have included local content requirements to promote the JNNSM’s goal of creating a solar manufacturing industry in the country. The mission’s guidelines for Phase-I’s batch - I mandated that crystalline silicon modules be manufactured in India, and this requirement was extended to silicon PV cells and modules for Batch -II. Thin film technology was exempted from the DCR in Batch-I and developers do not have to be use domestically manufactured module if they are using thin film based solar modules. Phase-I & II mandated, DCR for crystalline silicon components manufactured within India.

1.13.1 Stake Holder's Reaction to DCR

Many Indian solar industry players have praised the JNNSM's DCR as transparent and necessary part for deployment of large scale solar energy. There is a strong belief that this opportunity for India to become a major solar player depends on support for domestic manufacturing. Already, many established foreign players are dominating the solar field with cheap solar cells and modules, without DCR, there will a little incentive or no incentive to manufacturing of solar components as high cost of solar plant is unviable with a given price of power. There is also wide spread thought that in absence of DCR, India will not be able to achieve the JNNSM's goal of creating a local solar market and thus reducing dependence on heavy foreign imports to develop solar plants. Another set of stakeholder perceive DCR to increase project cost and thus criticize for unaffordable projects that are then unable to achieve large scale. These stakeholders have a belief that the DCR is increasing solar projects costs by prohibiting access to low cost solar components and technology abroad, thereby creating an unviable rate of return on investment. They fear that uneconomic viability of the Mission's silicon PV projects may retard the rate of solar project installations initially, until infrastructure for domestic manufacturing is matured and established, and believe that it undermines the JNNSM's goal of low-cost solar power. Additionally some stakeholders believe that if India were to impose a DCR on silicon wafers and ingots in early days, the domestic manufacturing industry is likely fail to scale up quickly and cost effective enough to serve upcoming large demand in the country.

1.13.2 Emerging Bias for Thin Film Technologies

Many stakeholders also believe that in contrast to original intentions, the DCR is creating an uneven playing field and has promoted significant unutilized overcapacities in the domestic solar silicon PV manufacturing industry. Since thin film PV technologies were exempted from the local manufacturing requirement during Phase-I, many solar players believe the DCR is not creating the conducive conditions for manufacturing in India.

Factors led to a thin film bias for JNNSM PV projects, were, developers access to low-cost International financing for thin film based technology due to export requirements and second, the exemption of DCR for this film imports, leading to lower module costs than domestically manufactured crystalline modules. The global solar market does not reflect the same thin film trend as it appeared in India during Phase-I of JNNSM. Thin film deployment both cumulatively has been approximately 15% of the total PV deployment globally which is a complete different trend in India in contrary to abroad. Thin film technology had been used for more than 70% of all installations through November 2011. The data available from NVVN shows that thin film technology is used in about 50% of approximately 140 MW by year 2012 under the JNNSM's first batch of projects. Unfortunately, Indian thin film bias had caused significant overproduction of local silicon PV, about 80% of available manufacturing capacity. Indian silicon based manufacturers have failed to benefit from DCR despite growing and robust market demand for PV components.

1.13.3 DCR Focus was on upstream manufacturing

Since more than 50% of the value is created down streams of solar modules manufacturing, the DCR's present only focus on solar cell and module manufacturing. It may not be the best way to exploit higher value creation from full solar industry. Many solar players wish that policy should also focus on downstream manufacturing activities. This could increase the Mission's another objective of enhancing employment-generation and boost the captured values for solar PV significantly. A healthy domestic solar modules manufacturing industry is central to the solar supply chain and it create divide between technology-intensive steps upstream and labor intensive steps downstreams. NSM mission document outlines, government incentives to be technology neutral, particularly as the solar industry continues to evolve.

1.14 Other Prevalent Issues in Solar Energy Environment

1.14.1 Land Acquisition: Irradiance Data & Clearance

There is a barrier to land aquition and acquiring requisite clearance to use in large scale solar projects. Land cost is generally to the tune of about 5% of the total solar project cost. Land cost is small but a portion of major project delay takes place due to slow rate of land acquisition and conversion into non-agricultural. After allocation under a lease or sale by state government, clearing the hurdle of multiple claimants is big hurdle. Identified high solar irradiance close to grid with adequate plant resources, in absence of limited geographic mapping and solar irradiance data, is another hurdle solar project has to cross.

1.14.2 Power Evacuation Grid Connectivity

Connectivity to grid for utility scale projects depends on capacity available in grid, proximity and availability. Developers find it difficult siting projects in area of adequate grid capacity resulting in delays in projects.

1.14.3 Community Involvement & Habitat Protection

Solar development can have negative social and ecological impacts if planned poorly. With a 5-10 acres of land required to install per Mega Watt of solar capacity, majority of Phase-I projects are in remote locations where primary contentious issues are conflicting land claims and land allocation for grazing.

1.14.4 Implementation issues and regulations

Implementation issues and regulations including renewable purchase obligations (RPOs), renewable energy certificates (RECs), and net metering, is expected to ease out the market.

1.14.5 Solar Electricity Pricing

In line with the terms and condition for determining tariff from Renewable Energy Source Regulation, 2012, CERC (Central Electricity Regulatory Commission) notifies generic levelized tariff for various renewable energy sources. The tariff order year 2014-15 follows the high trend in 2013-14 order sets high benchmark tariffs for all renewable energy sources except for solar PV and thermal. For solar, CERC has set Rs. 6.95 per KWh for a period of 25 years for project commissioned in 2014-15. This is lower than the bench mark tariff of 2013-14 at Rs. 7.87/KWh. Since 2010-11 the solar tariff has been decreased by about 54% from Rs. 14.95 /KWh. In addition to CERC released order for renewable energy projects, its real impact depends on state Electricity regulatory commissions (SERCs) incorporate appropriate revision in their tariff orders. SERCs have often failed to revise market condition led tariff for their states. Trend of CERC average benchmark renewable energy tariff (Rs per KWh)

TABLE 1-4: Year wise electricity tariff

	2009-10	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**
Wind*	4.31	3.51	3.71	4.29	4.64	4.80
Biomass*	4.68	3.83	4.13	5.29	5.66	7.25
Non-Fossil fuel based cogeneration	4.99	4.07	4.37	5.05	5.39	5.77
Small Hydro*	3.72	3.14	3.35	3.85	4.05	4.11
Solar PV	17.14	14.95	12.94	9.35	7.87	6.95
Solar Thermal	12.54	12.85	12.69	11.22	10.69	10.65
*Average net levellised Tariff						
Source CERC						

(CERC – Page 14 Renewable Watch June, 2014, Page 16)

1.14.6 Environmental Issues

The entire solar manufacturing supply chain particularly upstream solar manufacturing has environmental costs through its use of chemicals that are often carcinogenic and toxic. Upstream PV manufacturing is highly energy intensive. Robust environmental policy and safeguards are needed to safely expand manufacturing in India.

1.15 Future Solar PV Modules/ Cell Demand & Supply capacity trends

According to (solar market research and analysis firm NPD Solarbuzz), global demand for PV modules is expected to increase by 36% in 2014. This can have some positive impact on module manufacturers who were struggling to operate their capacity at optimal levels. The Asian market known for its supply side lead is also leading in demand of modules too. This report also estimates that there are currently about 150 module manufacturers as compared to 250 in year 2010. These remaining manufacturers are in better situation to respond to demand side of solar projects (GTM research) also estimates that some capacity expansions in modules are taking place across the value chain. This research also estimates that in year 2014, the available capacity will exceed polysilicon demand by 16%, wafer demand by 20%, cell demand by 19% and module demand by 40%. These estimates show major improvement over excess capacity that existed between year 2011 and 2013, when module demand was half of the total production. However analysis also indicates that poly-silicon is expected to be bottleneck for downstream manufacturing of wafer, cell and modules. Reasearch published by (Stanford University's Stegfan Reichelstein and Anshuman Sahoo in Feb, 2014,) high lights that every time the cumulative volume of modules produced doubles, prices fall by 19-20% per cent has not been not applicable in last three years.with prices falling much faster than the rate of manufacturing. The research also project that if demand peaks sudden, there can be temporary shortage of silicon accompanied with high prices (Renewable Watch May 2014).

Secure, timely and cost efficient supply of raw material is a most important driver for any industry especially solar. This increases production processes efficiency, rationalises production cost. In Indian context, demand side incentives are driving demand but equipment manufacturing segment failed to benefit from growth in demand. Federation of Indian Chambers of Commerce and Industry Solar Energy Task Force, highlights the demand opportunities and key supply chain issues.

TABLE 1-5: Current and Projected requirements for solar equipments

	Capacity in 2010-12	Capacity Needed to meet domestic requirements in 3-4 years	Capacity needed to meet the domestic requirement in 5-10 years
PV modules (MW/year)	1800	2500-3500	3500-6000
Solar Inverter (MW/Year)	Less than 100	2500-3500	3500-6000
Trackers (million)	nil	2.5-3.5	25
Single Axis tracker for PV projects (%)	nil	50	50
Double Axis trackers for thermal projects 95)	nil	50	50
Solar Batteries (for off-grid application) MW	Negligible	300-1000	3000-5000

1.16 JNNSM Phase -I Highlights & Success

Both the batches of JNNSM Phase-I were initial had good successes for the Mission. Reverse auction process in Batch-I, 36 projects were selected, with nearly 400 solar developers participated in bid in late 2010. A total of 140 MW were allotted to 28 PV projects and about 470 MW to seven solar thermal projects. The government of India migrated existing projects to include in the solar mission at a premium tariff of Rs 17.91/KWh, providing 84 MW additional capacity. The GOI started price of Rs.17.91/KWh for reverse auction. The lowest bid price was Rs. 12/KWh.

Even though many stakeholders appreciated the reverse auction for its transparency, the challenges to commission the solar for Batch-I projects remains a challenge. The grid connected PV projects in Batch-I were due to complete in January 2012, the GOI had fined 14 PV projects developers for not meeting commissioning deadlines and 14 developers were warned. Only by late March, 100 MW of PV projects were commissioned and rest in April 2012.

Batch-II, reverse auction had its impact on international solar market. The lowest winning bid from Solaire Direct, a French company was at Rs. 7.49/KWh for a plant size of 5 MW. This was remarkably lower than the expectation. This indicated that solar energy can attain grid parity earlier than the anticipated. Nationwide average grid price of residential energy are 4.7 KWh. The difference between bid price of Rs. 7.49/KWh is only Rs 1.6 /KWh short of grid parity and at par with diesel parity. Batch -II Awarded contract to 22 companies with total winning bids of 27 (Laying foundation for a bright Future).

1.17 Need and Significance of study of solar supply chain planning

Supply Chain Planning in solar energy companies has a number of challenges unique to this industry on account of the detail cited above. Supply Chain planning need additional "perspective", to be included specific to the sector, as against planning process and model in literature for a typical fast moving or planned product categories. Following areas need specific attention which is not fully addressed in the available supply chain planning literature.

a) Sustainability of companies due to heavy capital requirements as suppliers is facing peak and trough in demand. This peak and trough in demand is on account of interruption in release of subsidy block. Supplier's facing peak and trough in demand and thus not able to plan business sustainability in long run with uncertain factors.
b) Failure of conventional planning process, since many a time material to be used in solar project is kept ready and no visibility of demand is seen or vice versa.

c) On-time availability of material to EPC projects remains a concern due to heavy cash requirement and high debtors, impacting deployment of multiple large solar projects necessary to build sizeable power plants.
d) Demand at a given point of time is not representative of market demand trend. An artificial bull-whip effect is created with support structure laid down by state. Demand at any given point of time may not be necessarily a representative of a true demand.
e) Employees, channel partners, manufacturing team face unpredictable sudden peak and lean demand. This creates unbalanced load on supply and manufacturing. A load level is hardly achieved in the long value chain and caused inefficient outcomes. This causes poor moral across the supply chain players.

With this back ground of demand fluctuation, Supply chain planner has to start visualizing before seven months minimum and up to twelve months approximately for their planning decision.

There is a strong need to review the existing supply chain planning practice including S&OP. Research will try to include more specific variables and practices being used by solar suppliers specifically focused in Bangalore region. This proposed analysis in the thesis is putting forth an applied research helpful for further refinement of planning process model to meet the supply chain needs of Indian solar industry.

Chapter 2 - Literature Review

Solar supply chain literature is mostly focused on solar upstream and downstream material availability at different steps of supply chain in different part of the world. From the time solar industry started evolving, the shortage and excess of solar material in different part of the world have been witnessed. Solar supply chain upstream and downstream is elaborated in Chapter-1 Introduction.

Solar Supply chain planning specific variables, to take decision across the industry, to improve supply chain efficiency, is not covered in available literature. Closest available general supply chain literature covers a number of supply chain studies on "coordination, "Collaboration" and "integration". These generic supply chain literatures, is considered as closest base to build solar supply chain planning research framework. This research work connects remote threads to supply chain planning, with existing literature covering collaboration, coordination, integration in solar renewable energy supply chain.

The aspects of solar supply chain collaboration, coordination, integration and related skills requirements are knitted together to see solar supply chain planning complexities, which are being managed in solar industry, specific to Bangalore area suppliers. Presented below literature is attempted to relate as far as possible to our research theme.

As the CSCMP (Council of Supply Chain Management Professional) describes the integration of supply and demand as a fundamental objective for SCM throughout the supply chain (Mentzer and Gundlach, 2010). The demand side in terms of coordination and collaboration with channel partners, in an attempt to create value and customer satisfaction, is believed to be the main reason for planning focus of supply chain. In solar industry, demand factors are very unique such as state support, nature of newness of industry, a research variable to improve coordination and collaboration requires a study.

From this standpoint the term supply chain may be too limited and a more appropriate term is the value delivery network which contains all channel members who align their activities to improve performance of the overall chain and deliver customer value (Kotler and Armstrong, 2011). Value delivery for solar supply chain cannot be aligned unless specific unique solar variables are studied objectively and relationship is established.

Renewable energy offers a number of potential benefits and increasingly efforts are devoted to support its deployment. However, constraints along the supply chain may prevent deployment at the rate required to meet global energy and climate change objectives. Many of these bottlenecks are related to supply demand imbalances. Initially, supply not being able to ramp up at the same rate as fast increasing demand, some are due to absolute constraints on materials, and some to regulation. While many of these bottlenecks are expected to be felt after 2015, some are already affecting the wind and Solar PV sectors today (Lehner, Rastogi, Sengupta, Vuille, Ziem, 2012). At later years, during 2012 onward this trend may see a complete reverse. In some countries they have completely shut down their solar manufacturing plants, whereas some countries had excess capacities. There are more capacities of solar production globally than demand. This caused shifting of direction of flow of solar material from excess capacities to the place where manufacturing capacities could not sustain.

Solar PV Boom & Bust PV market Cycle is a decision making uncertainty in PV market which is a major anticipation point for supply chain planners. Players along the PV supply chain, particularly solar module suppliers, have scaled aggressively to meet this growing demand, but not without risk. The complex interaction between volatile PV demand— largely driven by policy—and the supply chain are dictating the market environment. This study, details the planning practices utilized to overcome the mixed affects of regulatory, financial, technology, and demand hurdles shaping the solar market for PV component suppliers currently (Global Solar Supply Chain Strategies: 2010-2015).

As suggested by existing literature, details and frequency of planning process is typically sub-divided into time horizon and multiple hierarchical based planning levels. Each level has a planning cycle as follows.

- Strategic or high-level planning, typically done yearly or on an ad-hoc basis.
- Tactical or mid-level planning, typically done quarterly or monthly.

Operation or low level planning – largely involving scheduling, rescheduling, and execution is typically done weekly, daily, or by shift (Advance Manufacturing research, 1998). Solar, energy sector need a specific review of the strategic and tactical level of Supply Chain planning management. The literature considers the level and time horizon of planning but which attributes needs to be considered for planning, is not covered for solar supply chain.

One of the objectives of supply chain planning process is to achieve optimum for minimizing cost and increasing efficiency of supply chain. Regarding an optimum plan, there is a need to include all players to understand a company level optimum. Each piece of a plan in isolation from other plans does not guarantee that optimization is achieved for the total planning process. Vendors are now moving towards more holistic optimization. Planning process is synchronized since any change in the "downstream" plans is automatically reflected in the "upstream" planning process. Optimization is more useful and mature, relatively non-volatile manufacturing industries where product demand and manufacturing processes are more predictable. (Advance Manufacturing research, 1998). Solar industry demand is largely unpredictable, downstream planning is highly volatile, eventually causing uncertainty in upstream supply chain as well. The factors of such upstream and downstream, creating planning uncertainty needs to be correlated with the help of next research. Such research work will support vendors to achieve holistic optimization from a planning process, creating better synchronization.

An effective materials planning system has the capability to integrate the entire material and supply chain work processes. Effective materials management governs the material- and quantity-related activities by providing proactive management of potential surpluses and shortages. An ability to forecast material availability – looking ahead by 30, 60, or 90 or more number of days, is critical to have an optimized plan (Intergraph, 2012). An adaptive supply chain management is a key to optimize supply chain performance. An adaptive planning (iterative) is a method of planning in which the plan of a supply chain is modified periodically by a change of parameters of the supply chain or characteristics of control influences on the basis of information feedback about a current condition of a supply chain, the past and the updated forecasts of the future. An adaptive supply chain is a complex multi-structural system. A supply chain can be named adaptive if it can adapt to (1) changes in the market environment and uncertainty impacts, (2) changes in the operations execution environment, and (3) internal changes in the supply chain itself by means of additional structural-functional reserves and better coordination through an extensive application of information technologies, especially Web services (Ivanov, Sokolov, 2010). Solar specific adaptability needs to be researched to adapt to meet changing market environment due to state and regulatory aspects. In additional to external factors, solar industry specific factors, related to inter functions like engineering, procurement and business development is creating such uncertainty in demand. Supply chains can be considered not only from organizational point of view, but also from a process point of view (Beamon, 1998). Even though adaptive supply chains are a strong trend in practice, research into adaptive supply chains is still limited. During year 2000–2007, a number of research studies have been conducted in Chemnitz, Germany and Saint Petersburg, Russia with multiple industrial and academic areas. One of the main supply chain structures is informational. Structure of information flows according to the coordination strategy (Ivonov; Sokolov, 2010). An information technology in Indian solar industry context in given period of year 2010-2015, is very weak. To enable information technologies, a framework and relationship would be prior stage before their IT enablement.

Improving the performance of a supply chain, sales and operation planning to have a 360 degree view of business to take decisions, has been a part of traditional literature. Modeling methods for optimization has been into some focus. Customer demand and competition have made supply chain planning and scheduling more challenging and complex (Supply Chain Planning Optimization: Just the Facts, 1998). Competition scenario in solar industry is very much concentrated around Chinese suppliers. Such

Chinese suppliers are owners of solar manufacturing capacities whereas rest of the world is effectively acting as a consumer. This trend dependent on various protections by their state to their home manufacturing. Such a solar customer demand and competition is a focus of existing research.

A study to isolate supply chain, a customer Order Decoupling Point (CODP) shows how deeply the customer order penetrates into the supply chain. It is the distinction between the order-driven and forecast driven parts of the supply chain for a particular product market combination (De Kok, 2002). In a solar supply chain, de-coupling to optimize surplus is still remote. The reasons for such a non-existence of decoupling point are subject of research work. Without an understanding of order penetration into demand of solar supply chain, decoupling can leads to extra inventory. Forecast is more a process than a reality since its base is very weak in solar industry.

There is a need to manage planning & scheduling at different level of organization's personnel for solar renewable, since scheduling decision is generally a domain of some lower level organizational function than the supply chain planning decision, taking this scheduling decision at higher level may infringe upon this organizational design (Meal, 1984). With regards to information asymmetry, note that the actual schedule will be constructed at a later stage when more information will be available. As a consequence actual schedule may vary different from projected detailed schedule constructed to make supply chain plan. Unfortunately, this interaction between the supply chain planning level and the detailed scheduling level has not been researched under asymmetric information condition, so we do not know the impact of this effect on operational performance for solar industry. A fresh look for the aspects of planning decision and skill required has been considered for this research. With regards to dynamically adjusting the information which can help in planning based on aggregate status information, the impact is even less clear (De Kok, 2002). Factors causing dynamism of information for solar industry are researched in the present work.

Simulating every process and activity in the supply chain in detail would be a supply chain manager's dream. Variable involved are extremely varied and depends a lot on multiple factors like industry sector. Development of a supply chain model often involves compromises between detail level and number of built-in processes. (Hellstrom; Johnson). As a pre-stage to simulation, process variable is the first stage of research for solar industry to form based for a reasonable degree of simulation.

Project-driven supply chains (PDSCs) are the combinations of project activities and their supporting material supply chains where the demand for the latter is driven by the material requirement of the former. For capital intensive projects, material supply often constrains the project schedules and affects the system-wide costs. Hence, it is clear that supply chain decisions and project decisions are intertwined .While one can maximize the project scheduling/planning flexibility; the inventory costs can be prohibitively high. Because the material availability and project decisions serve as mutual constraints, models should be developed to make the decisions on inventory, activity duration and project schedule jointly so as to strike a balance between supply chain costs and project costs (Chen, Zhao). When company faces time or cost deviations in projects, uses to modify only the procurement Strategies (Papallo). In solar industry major investment goes into large scale capital intensive solar projects, attracting high inventory cost. Inventory relationship in solar project and planning is drawn in the next step in this thesis to minimize dependence on short term procurement strategies alone.

A CFO led sales, operations, and financial planning will be more agile, detailed reliable and efficient. Data gathered from supply chain functioning can prove to be of immense value to predict customer buying trends supply-demand forecasting, inventory turns etc. (Ramachandran, 2010). In solar industry prevalent cash crunch situation involve multiple intervention from finance department in the planning process. One of the hypotheses under study is to see impact of fund availability and supplier credit period on number of planning iterations.

The correlations exist between variables such as procurement methods, overall satisfaction with project procurement and the frequency of conflicts in identified conflict centers (Data, 2013). When multiple processes work united it is obtained in a successful way the final product (Mula, Polar, Garcia, 2004). Identification of some of conflict centers for solar project is considered under hypothesis for further study.

With respect to collaboration, several maturity levels of supply chains have been defined:

Stage 1: Functional Focus: Operating discrete supply chain processes with functional management of resources. Supply chain processes and data flows are well documented and understood.

Stage 2: Internal Integration: Company-wide aligned and integrated supply chain processes continuously measured and steered to achieve common objective

Stage 3: External Integration: Collaboration with strategic partners (customers, suppliers, and service providers) including joint objectives, shared plans, common processes and performance metrics.

Stage 4: Cross-Enterprise Collaboration: Information Technology and e-business solutions resulting in real-time planning, decision making, and execution of customer requirements (Roussel, Skov 2007).

A few companies realize collaboration beyond stage 2; thus, today collaboration between independent legal entities is not very common. However, it should be recognized that the evolution does not necessarily follow this sequence and that some stages may be skipped (Knolmayer, Zeirer, Dickersbach, 2009). Solar industry planning is unsure as to which stage a solar players sees their level of collaboration. Different solar companies are considered at different levels depending on their operation management, segment they operate, and existing regulatory framework.

A number of case studies methods have been used to understand supply chain integration across end to end supply chain like logistics, operations and internal and external players as found in literature. These researches are correlating organizations integration and performance (e.g. Frolich and Westbrook, 2001) (Gao, Joseph,Bird 2005 & Murray, Kotabe, Zhou, 2005) suggest that mutual dependence with specialized processes & unique products and services, is required. Therefore the focus in present thesis has been kept on studying process very specific to solar industry relating such aspects “chain” and “integration”.

On the micro level, firms strive to successfully manage supply and demand which requires extensive integration between demand and supply functions and activities.

Two primary sets of processes of moving goods and information through supply chains through which the firm creates value for its customers. These processes are, namely, demand-focused and supply-focused processes. Organizations have historically invested resources to develop competitive advantages in these fields. The major problem resides in planning each side separately resulting in conflicts between demand (what customers want) and supply (capacity)). Empirical research on the concept of market orientation has long (Esper, 2010). Since SCM is the integration of activities associated with goods and information flows from raw material to customers, external integration is essential factor in SCM to achieve sustainable competitive advantage (Park, Cho, Kim 2014). One of such critical information of state support deployment mechanism is further studied under one of the hypotheses for solar industry. It suggests that successfully managing such integration requires extensive research on demand-focused and supply-focused processes. This integration facilitates forecasting and planning of real-time customer demand and ongoing supply capacity constraints (Esper, 2010). Although inter-functional integration was strongly supported in scholarly work, very little empirical research has been done on integrating the demand side managed by marketers and the supply side managed by the supply chain department within businesses (Oliva and Watson, 2011; Esper, 2010; Juettner, 2007). Functions like purchasing, production and marketing are now included under the SCM scope (Ballou, 2007). Consequently, SCM became responsible for major firms functions and thus is judged for the level of performance. Thus SCM has to involve a high degree of intra- and inter-organizational integration. A larger attention on marketers and supply managers is paid in the existing work, to avoid losing sight on such stakeholders.

As market continue to globalize, firms have more and more turning to supply chain alliances to provide competitive advantage. (Fowett, Magnan, Magnan, 2005) indicate that a globalized view of multiple firms is a becoming a requirement for competitive supply chain. A global view for solar industry is major hypothesis detailing about major sources of competitive supplies in this research work.

The studies referred in literatures explain about structure and culture of the supply chain operation, quantum of formal and informal communication across functions. A general lack of integration indicates that the process working at cross purpose leads to lower level of organization performance (Pagell, 2004). These are industry specific reasons for this lack of integration, which can be studied by further research. In solar industry situations where communication is further more discrete, a culture is more derived from more informal communication. A formal communication requires a higher confidence level on demand side. Aspects of communications, wherein a number of internal and external players are involved, mechanized structures and cultures that were very functionally oriented tended to discourage communication and encouraged creation of measures that optimized locally, not globally (Pagell, 2004). Integration for this global communication factors are required to be studied industry specific to have a global optimum. The existing research only touches some aspects but not necessarily on the process of communication to ensure their deployment.

Propositions for top management support are required, to create an internally integrated supply chain. This particular proposition leads to an active role of top management in complex global optimization which is not widely visible in literature (Pagell, 2004). In solar supply chain, top management role is studied in multiple hypotheses presented here, considering critical project cost and schedule impacting decisions.

Another proposition is that low level of integration has direct linkage with the consensus on strategy of supply chain. Results for this non-consensus leads to multiple planning changes (iterations) not sufficiently studied by literature since it can have dependency on industry sector. Author focuses on real time informal communications as a better solution over formalized, scheduled communications. A measurement of iterations on various supply chain aspects can be a measure to prove the hypothesis more objectively. Author points out, mismatch between flow of work and flow of information, as lower level of communications (Pagell, 2004).

Internal cooperation may serve to disseminate new knowledge acquired through external cooperation, thus an internal cooperation may function as a coordination mechanism to deal with the complexities of external cooperation (Hillebrand, Biemans 2003). The literature explains internal cooperation as a genesis of external cooperation. There is number of literature published on internal cooperation but there need some research on external (global) cooperation playing a role is planning supply chain management. Internal factors taking toll on planning iterations are subject of study under the research. Synergistic working relationship represents a very small fraction of all supply chain relationship (Fowett, Magnan, Magnan, 2005). The same seems true for solar industry as well. Focus of planning in research is an attempt to study synergistic variables for solar sector in India.

Companies are dedicating more resources understanding and fulfilling unique need of the important customers indicates the importance of resources. This cover need of resources, not their competencies, a sector specific competencies and skill set can prove to be a next research in this direction (Fowett, Magnan, Magnan, 2005). Author also argues that lack of rigorous and pro-active alliance management practices appears to represent a significant barrier to the establishment of world class supply chain. Also same authors have demonstrated that the majority of firms do not yet have the alliance skills needed to build a cohesive supply chain. Another argument that leading supply chain companies recognizes the need to do everything they can to help build the skills of the entire supply chain team. They also are focusing on increasing supply chain capability dramatically (Fowett, Magnan, Magnan, 2005). Uniqueness of solar supply chain planning skill are mapped under this study.

Subjective forecasting faces multiple challenges like over-confidence, anchor and adjustment, and optimism. The idea as given by author indicate that without an optimized number of iteration the factors of subjective forecasting will leads to a poor forecast (Makridakis, 1998). Solar iterations also follow such overconfidence to manage demand and supply side.

Irrelevant informations, negatively affects judgment. Such poor forecasting can lead to mismatch is planning and extra cost in sensitive planning scenario like solar (Gaeth and Shanteau, 1984). Existence of exaggerated information seems to be affecting forecast in solar industry under study. Poor information provided, forecaster may spend a little effort to ensure that forecast are accurate. The part which calls in the direction of that “a little” need to be researched for a sector (Beach, 1986).

New sources of biases after deployment of the coordination system, there is an adaptive nature of game played by actors. The statement by author shows that there exists a natural inclination to adapt to the deployment of the coordination. An information bank for such decision coordination can be further helpful with future research (Watson, Oliva 2007).

If a certain function in the organization or member of the supply chain plans for a given capacity to meet their perceived demand, the other party would prefer not to invest in any more capacity as a part of explanation of misalignment. These aspects direct towards need of arriving at more realistic optimum scenario by skillful iteration process (Kraiselburd and Watson 2007). Author also explains the role of integrators, intermediaries and supporting structure serves as conduit for sharing perception helping with elucidation of perceptions and then their translation, for assimilation of the information. Thus there is a need to identify these integrators, intermediaries and supporting structure responsible to share perceptions of right forecasting (Kraiselburd and Watson 2007). Quality of demand and supply planning can be roughly related to quality of information used, the quality of the inferences made from available data of forecast and plan, and the organization’s conformance to the plan that are generated. The same needs demonstration is a particular industry under discussion (Kraiselburd and Watson 2007).

By nature, cross functional supply chain requires collaboration across multiple thought worlds, due to which they face a highly uncertain and complex task. The expression of thought world can have linkages to internal and external organizations players, requires some research work (Mohrman 2003).

A situation can be described as a status with regards to conditions or circumstances at a given moment or at a state of affairs. A situational theme describes a situation where in an inputs for planning iteration need to be converged for a situation (Kelly 2003).

(Raj, Kevi, Adam 2008) explains that an organization can face abysmal consequences if they ignore changes in preferences of their customers, behaviors of their competitors, or changes in technology. A further research is required to understand as to what elements required to include in preference of such stakeholders in a solar industry.

(Agnihotri, Trainor, Rapp, 2008) explains role of senior managers or supervisors as to attempt to assess and augment the level of shared mental models within a team to ensure the effective and efficient execution of processes. It describes the need of involvement of senior management is making planning model robust to have effective and efficient execution. Same is considered to further substantiate for solar industry decision makers.

Key decision areas dependent on cross functional integration between marketing and manufacturing. The areas are strategic planning integration, strategic or visionary forecasting, new, tactical forecasting, demand management and operational integration. The paper describes multiple ways to look for planning and forecasting under specific conditions (Malhotra and Sharma, 2002). Author also showed that the lack of integration between manufacturing and marketing has been a recurrent theme in past research (Malhotra and Sharma, 2002).

It suggests that multiple competitive criteria had a positive covariance in the planning model, indicating that the managers seek a high performance in multiple competitive criteria simultaneously. Therefore when companies seek higher performance in more than one competitive criterion, it is important to integrate their functional areas internally. The studies suggests that manufacturing and marketing integration and cross functional orientation are directly related to competitive priorities based on a cumulative capability approach. Cost and quality has been basic capability because they influence directly manufacturing and marketing integration. Delivery and flexibility would be the capability in the sequence because they presented a positive correlation with cross functional orientation (Paiva, Gavronski 2009). For solar industry cost, quality and delivery aspects are tested further for industry as a contributor to width of planning.

The primary conclusion of this line of research is that forecast accuracy can be substantially improved through the combination of multiple individual forecasts. Multiple forecasts are multiple level and multiple thought plans of individual functions (Clemen, 1989).

Global view on a solar supply chain can be accessed from an outsourcing perspectives in which case there exists an analogy to transfer all or a part of supply chain activities to other organization either domestically or out of country. In case of the purpose of outsourcing is to search for flexibility and eased capacity load, despite being strategic, the make-or-buy decision can also be of operational in nature in supply chain context like external suppliers as a part of the supply chain (Fine, 2000). Global outsourcing view of solar supply chain draws an analogy for width in existing study.

A number of factors have been suggested to affect the decision like supply chain planning areas, such as the frequency of need, uncertainty, asset specificity, capabilities and resources, coordination requirements, and strategic control and risks (Hayes, 2005; Heikkilä and Gordon, 2002; McIvor, 1997). Focus on studying the use of integration mechanisms in managing uncertainties that are created by engaging in contract manufacturing. This addressed the uncertainties from the perspective of the firm who outsources part of its activities. A global supply chain view is most frequently can be looked from an outsourcing angle as players are having customer supplier's relationship (Kaipia, Laiho, Turukulainen 2010).

Firms with an external-focus and a flexibility orientation are to have a higher degree of supply chain integration than those with other organizational culture traits (Yunus and Tadisina, 2010).

It becomes critical for organizations to manage the entire network of supply to optimize overall performance (Lee, 2002). An overall management includes a global view on supply chain. It proposes that organizations need to integrate their supply chains to secure maximum support for competitiveness in the market they operate (Hill, 2000).

Supply chain integration is established when the self-seeking dominant partner is convinced of the need for integration and takes the initiatives to mobilize all partners This dominant partners internally needs a global view and need involvement of senior management personnel to make it happen (Jespersen and Skjøtt-Larsen, 2005). The areas of such roles are to be established for solar industry.

(Frohlich and Westbrook, 2001; Rosenzweig, 2003) Most empirical studies have focused on either upstream integration (Peterson, Handfield and Ragatz, 2005) or downstream integration (Rosenzweig, 2009); however, an empirical study by (Frohlich and Westbrook, 2001) has shown that companies with the widest degree of integration with both suppliers and customers have the strongest association with performance improvement.

Three dimensions constitute supply chain integration and determine the level of supply chain integration (Lee, 2000). These dimensions are information sharing, coordination and resource sharing, and organizational relationship linkage. Lee's study, (Simatupang, 2002) extend this framework by offering different modes of coordination required to integrate the supply chain processes of different partners.

(Frohlich and Westbrook's study, Rosenzewig, 2003) suggest that supply chain integration is required to enable firms to deal with increasing complexity and uncertainty in the environment. They argue that highly integrated firms will gain competitive advantage over their competitors due to the increased information visibility and operational knowledge shared among members of their supply chain, as well as the reduction of the overall supply chain costs (Rosenzweig, 2003).

Coordination modes indicate that the focus of an organization is more on outward orientation, defined as global view in our study, rather than just inward. The supply chain integration process will require extensive joint activities with suppliers and customers, and even to suppliers' suppliers or customers' customers (Fawcett and Magnan, 2002). Positioning this characteristic on the internal-external focus continuum, supply chain integration will be more dominant in the external-focus side (global view) rather than the internal-focus side. Internal focus means integrating and buffering to sustain the existing organization, while external focus reflects a focus on adaptation and interaction with the existing environment (Denison and Spreitzer, 1991).

Business environmental uncertainty is significant external force driving information sharing in SCM. In today’s competitive environment, markets are becoming more international, dynamic, and customer driven; customers are demanding more variety, better quality, higher reliability and faster delivery (Thomas, and Griffin, 1996).Previous research (Li, and Lin.) studied information sharing and information quality in SCM within environmental uncertainty.

Many researchers have considered environmental uncertainty as an important driver for information sharing and information quality (Alvarez) (C. Chandra, and S. Kumar, 2000). Previous research (Spekman, Kamauff, and Myhr, 1998) suggests that uncertain industry structure and market environment encourage the construction of strategic partnership. Solar industry can be viewed from a long term strategic partnership that may evolve over a period of time.

(Mathuramaytha, 2011) suggests higher the level of customer uncertainty higher the level of information sharing and decision synchronization leads to organizational performance and competitive advantages. Apparently, it seems not to be true for solar industry but still more research may objectively conclude this fact.

When companies achieve a high level of internal integration, this level of integration leads to a better absolute performance. The contribution of SCM to gain a competitive advantage is affected by the level of SCM implementation in the industry. Future research should apply this study to other sectors in order to consider different sector structures and different levels of SCM implementation (Giménez and Ventura, 2003) including solar.

It is requirements for the “Purchasing and Supply chain Management (PSM)” function to achieve integration in the decision-making processes of internal stakeholders and to cultivate relationships with them (Carter and Monczka 2005). Unless effective co-operation with its internal customers is achieved, PSM will be unable to meet its evolving responsibilities such as oversight and coordination of the supply chain, or deliver added value to the organization (Rozemeijer 2000). In most companies, PSM does not have any formal control over other functions because there is usually no common central authority other than at CEO and Board of Management level. Therefore, co-ordination cannot be achieved based on direct supervision by the purchasing function (Kaiser and Reinhardt).

As a result, decision-making is usually delegated and decentralized in functionally specialized organizations, to make most effective use of specialist knowledge and expertise in the various intra-organizational functions (Herzberg 1974). An interview insight seeks more clarity for solar industry and decision delegation.

There are two fold practical implications: First, managers should foster adaptations towards the exchange partner which improve the coordination of the relationship. Such adaptations represent resource ties and facilitate the development of activity links based on information exchange (interaction) and collaboration. Second, managers of internal suppliers should ensure that a positive relationship atmosphere exists in the relationship of their organization with its internal customers (Kaiser and Reinhardt). These factors are not considered in existing research.

The study of (Amaro 1999) points that, for non make-to-stock companies, customization is only a qualifier to compete with similar companies. In consequence, the companies are forced to improve order management and production planning/scheduling functions.
Decision Support System (DSS) for production planning and scheduling (Respício, 2002) evolved to an interface between marketing and production, so reducing cross-functional conflicts. Marketing and production interaction evolve many variables proved by various hypothesis for solar industry under study.

If the operation can’t satisfy schedules dates, the situation is analyzed and the order might be delivered late or the delivery date is renegotiated with the customer. In both cases, the customer service quality is reduced and time is spent trying to fix the situation between marketing and operation. Re-planning (iterations) is also a key issue to deal with instability of the demand (due to very flexible order management. To avoid frequent changes of plans (that give too much "noise" to the system), schedules are fixed, for a short planning horizon, and only just before its implementation. Optimal schedules for the beginning of the planning horizon are frequently independent of the demand data from future periods (Respicio and Captivo, 2002).

Different decision makers, with distinct functional perspectives, share common procedures. Use of the system has improved the coordination between the different phases of the global decision problem. Regarding customer order acceptance, the large number of interaction cycles between marketing and production was dramatically reduced better performance. The benefits for the company are a global manufacturing cost reduction. In short term, savings are due to improving the quality of solutions, and speeding up their generation. Such quality is studied for presented research here. On the long term, due to a better organization of information regarding production, better coordination of the planning process, reductions in lead times, and improvement of customer service (Respicio and Captivo, 2002). Lead time affecting solar industry is presented solar sector as a part of hypothesis.

It is generally accepted that coordination and integration of marketing and manufacturing improves firm performance by removing suboptimal practices. Coordinating mechanisms such as referral upward, decision rules/controls, planning processes, personal contacts meetings, liaison roles, committees task forces were investigated and the correlation among mechanisms were presented in (John, Caron and Rue,1991).

Within management science, connecting the various levels of analysis from individual to group to firm to industry and finally to global frames is precisely an ongoing challenge (De Konning, 1996).

As more and more information becomes available to all managers through powerful information technology and dynamic personal networks, efficient evaluation of the information flood becomes more and more of a challenge (De Konning, 1996).

It is observed that better decisions (as measured by firm performance) were made by top management firms that acted quickly, and contrary to previous assumptions the faster decisions used more information and more group discussion of that information, than slow decision making teams (Bourgeois and Eisenhardt, 1987, 1988, 1990). Even though speed of decision is not part of existing study but role and level of planning decision are included in the research work.

Author explains five steps of strategic planning process – Determining current and future needs, Establishing s strategically aligned world class supply base, Establishing a bookshelf of viable technology and suppliers, determining the supplier's role and setting targets, information sharing and learning from the experience (Monczka, 2000). Out of these aspects world class supply base is a major factor under global width presented in the solar sector.

(Wynstra, Echtelt) proposes a total of 15 key managerial processes, divided into two main areas: long-term, strategic and tactical processes on the one hand and short-term, operational processes on the other. According to our perspective, the key challenge of managing supplier involvement is to balance two types of processes. Forecasting information sharing between retailer and supplier can notably increase the ratio of order-fulfillment in the situation of non-stable demand. (Angulo; Nachtmann; Waller, 2004).

Results suggest that higher performance in simultaneous competitive criteria is a goal for companies that seek to integrate their functional areas internally. The results also suggest that large companies are possible more capable to integrate manufacturing and marketing areas and to achieve high performance in multiple competitive criteria (Paiva 2008).

It suggests three methods to improve material handling: better capacity utilization, higher asset turning, and improved supply synchronization. Asset turning involves the reduction of expensive stock (Christopher 2005). Solar projects focuses in such stock optimization efforts leading to extra number of planning iterations, substantiated in the hypothesis under further study presented here.

SCM has evolved over time becoming more multidisciplinary in nature which enabled it to profit from a lot of concepts developed in a variety of disciplines as marketing, information systems, system dynamics, economics logistics, operations management, and operations research. SCM is being considered as a strategic factor in strategy for creating value for customers (Juentter, 2007).

After reviewing a significant number of papers discussing the integration of marketing and supply chain (e.g. Lambert and Cooper, 2000; Alvarado and Kotzab, 2001; Flint, 2004; Juettner, 2007; Mentzer and Gundlach, 2010; Juettner, 2010), and in particular papers describing and analyzing the existing body of knowledge on the integration aspect (e.g. Knoppen, 2010; Juettner, 2010), this paper uses the classification of one of the most recent and comprehensive paper, conceptualizing the integration from a strategic perspective by (Juettner, 2010; Lambert and Cooper, 2000) who are major contributors to the marketing and SCM integration perspective, identify two aspects of integration which are the inter-functional aspect and the cross-organizational aspect. This classification has been supported since then by scholars and by the CSCMP. (Juettner, 2010) further divided the current research carried out on the integration into three perspectives, namely, an inter-functional perspective, a process perspective and the perspective of integrating business concepts.

The five case studies are following the Sales and Operation (S&OP) planning process which is becoming more common for managing supply chain planning (Chen, 2006; Lapide, 2005; Van Landeghem and Vanmaele, 2002). An observation of a two solar companies witnesses the S&OP process as existing in a representative solar industry.

(Esper, 2010) argues that although S&OP usefulness as a tool for improving practical integration, has been verified, it still does not reach the goal of common understanding. This perspective is supported by (Moon, 2006) who agrees that S&OP is a tactical process that usually involves mid-level managers generating a simple balance between demand forecasts and production capacity. Moreover, (Esper, 2010) claims that the majority of the S&OP processes concentrate on operational plans for guiding short to mid-term production, logistics, and procurement activities. It considers changing the decision-making process, they informational analysis used for decision-making, the scope of duties and the skilled workforce involved (Lapide, 2005).

The integrated business concepts are built to establish solid competitive advantages enhancing performance of supply chain against competing chains (Zhao, 2008) emphasized that supply chain partners have to encompass competitive performance advantages such as quality, price, delivery speed, responsiveness, flexibility, and dependability. Moreover, these integrated business concepts aim at closing the gap between SCM and the market (Jüttner; Christopher; Godsell, 2010), which is defined by marketing scholars as a set of actual and potential buyers (Kotler and Armstrong, 2011). So, again the focus has to be put on the market, i.e. the customers, whether by responding quickly to demand changes, improving customer service or shorter delivery cycles. The marketing and SCM scholars and researchers have to unify their efforts to generate a clear understanding of SCM and marketing as interrelated disciplines that cannot be separated, especially when cross-organizational coordination and collaboration is involved (Haddad and Ren).

Literature has still fallen short in understanding, besides “why” marketing and SCM should collaborate, “how” M-SCM interface is (should) be managed, i.e. the ways through which marketing and SCM collaborate, as well as the factors leading to different managements of the interrelations (Pero, Lamberti, 2013).

This outcome is reasonable, especially analyzing how increasing the level of integration within an organization requires significant resource commitments (Barki and

Pinsonneault, 2005). Other elements making integration potentially underperforming deal with knowledge ambiguity (e.g. Levin and Cross, 2004; Simonin, 2004; Szulanski, 2004): tacitness, specificity and complexity of the underlying knowledge to be transferred from function to function have been observed as constituting elements of knowledge ambiguity, decreasing the attitude of functions to collaborate (e.g., Zhao and Arnand, 2009), but also making integration-oriented policies either ineffective or inefficient (e.g., De Luca and Atuahene-Gima, 2007).

In recent times the span of collaboration goes beyond normal commercial relationships which involve organizations and enterprises working together (Matopoulos, Vlachopoulou; Manthou; Manos, 2007). (Andraski, 1999), (Anderson and Lee, 1999, 2001) (McCarthy and Golicic, 2002) elaborate further on the importance of supply chain collaboration from micro and macro perspectives separately in the body of supply chain literature.

It has transformed into a relational exchange, where the roles of the supplier and buyer are no longer narrowly defined in terms of the simple transfer of ownership of products (as cited in Matopoulos, 2007).

Supply chain collaboration is classified into two main parts. The first one involves three-step process: firstly, selecting the appropriate partner based on the expectations, perceived benefits and drawbacks, and the “business fit” of companies; secondly, deciding on the “width” of collaboration; then thirdly, on the “depth” of collaboration (Sahay, 2003; Chopra and Meindl, 2001; Fawcett and Magnan, 2002; Chopra and Meindl, 2001; Fawcett and Magnan, 2002). The combination of those three elements comprises the intensity of collaboration. The more the depth (from operational to tactical and strategic), the width (from simple supply chain activities to more complex such as new product development) and the number of entities (two or more entities, upstream-downstream) the more intense the collaboration is.

(Hayes, 2002) argued that operations management has changed in many ways in the New Economy era. The author proposed that operations analysis should consider not only the operating unit, but also a group of independent parts where companies develop on-going relationships with suppliers, customers and complementors. These relationships seek to develop complementary products and to manage ever-changing processes and networks.

In proposed hypothesis by (Paiva, Gavronski, D'Avila, 2011) integration. Externally they involve integration with suppliers and internally they involve integration of a company's functional areas, including manufacturing, marketing and R&D. Similar multi function integration is studied in the presented research work for solar industry in India.

(Pimenta , Silva, Tate 2014) Demand Planning (DP) is a department that manages several permanent cross-functional teams, one for each product line. Teams are operationalized by the figure of the 'Demanders', whose function is to adjust the short-term forecast and coordinate the demand chain. The Demanders coordinate teams, which are also composed of members from the fields of Marketing, Sales and Production, which meet monthly. The DP team also has the goal to manage the Sales and Operations Planning (S&OP) though joint planning of monthly Operations and Logistics needs from the demand forecast

(Pimenta, Silva, Tate, 2014) CFT members' skills: as the current investigation was primarily concerned with teams' processes, some issues related to human resources were not addressed. Future research may investigate about the necessities of the teams in terms of members' skills, specifically in processes related to demand and supply management, in order to address questions like: a) which functions should be included? b) what are the necessary skills and knowledge? c) which individual skills are adequate for each configuration of CFT? Richer qualitative data can be collected through observation of team meetings, in depth interviews and analysis of meeting documents.

There are many potential advantages to delegating decision making to functional managers. However, unless care is taken to design the right mechanism to motivate the resulting independent entities, much of the efficiency possible through joint coordination will be lost. The measures needed to coordinate cross functions, that is to ensure incentives are in place to mitigate this loss, appear to depend strongly on exactly what the various parts of the supply chain actually do, what value they add (Li, Atkins, 2002). It provide insights into the setting where the downstream player's marketing activities affect the demand uncertainty in a defined way, while the upstream player's cost is affected by the uncertainty in a way different from that of the downstream player (Li, Atkins, 2002).

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Chapter 3: Objective, Scope & Hypothesis

3.1 Need and Significance of study

Supply chain planning is an established discipline is operational supply chain, and matured is some business segment than others. Supply chain discipline optimizes cost and ensures material delivery at the time of customer requirement. Depending on maturity of demand/ supply equilibrium and complexity "width factors", a "planning" in a specific business segment can be evaluated as a degree of maturity. One of the measures, of supply chain planning maturity depends on consistency & predictable nature of demand and supply. As business gets older, supply chain planning process inside an industry gets matured by experiencing factors of variations in demand and supplies. From a firm's perspective, supply chain planning maturity is achieved by learning demand and supply trend and modeling of their variations in a given business environment. Supply chain planning factors and process for some of the products and customers can be termed as an established one, like planning for an FMCG based product. An FMCG sector, have been evolved in last hundreds of year, there is a good consolidation and assimilation of learning across the FMCG organizations. Some product segments have a moderately matured supply chain, like a supply chain run by an engineering company. Such a supply chain is more complex, in terms of handling large number of SKUs (low volume high variety), has an industry learning somewhat moderately matured as against an FMCG supply chain. Size and volume of revenue being handled by a supply chain does not decide the maturity of supply chain alone. There are many business models evolving with very high revenue and volume off-takes, e.g. demand for a wind turbine or solar energy in last fifteen years. Supply chain practices are moderately established for such industries because they are having very latest and unique complexities width factors, not fully experienced earlier. These supply chains are struggling to understand multiple factors causing demand/supply variations and building a model to forecast. Better understanding of width factors in model will make it possible to replicate planning close to matured supply chain similar to FMCG. Learning can be used to train upcoming planners and other players of supply chain to manage delivery at optimum supply chain surplus.

Supply chain maturity also depends on how various supply chain players are linked to thread of networks with each other. There exists a bond of collaboration among all such players. For example, in case of an FMCG based matured supply chain, various manufacturers, stocking point managers, transporters, distributors etc are well networked, either through self learnt practices or engrain in them with supply chain maturity over a long period of time. There exists very strong coordination and communication links collecting and disseminating information from /to all players in the network. Such a closely knitted network helps in passing on accurate and correct information, to ensure deliveries by supply chain, when required. Some of such communication links are automated through CRM or an ERP depending on maturity of practices in a firm. A matured communication links minimizes manual interventions to allow seamless flow of information. Investment on these technologies has been paid off to such firms in long run. Stronger the communication network, lower the cost of service by a supply chain.

Contrary to an evolved supply chain, a late business entrant supply chain tries to catch up on those planning width variables to reach to maturity. It may not be possible to replicate existing practices into a new supply chain, before learning curve completes over a period of time. This time difference in adopting practices is because of new width variables affecting complexities of modeling a supply chain planning.

Newer supply chain had shorter learning curve to acquire maturity, since some practices are already existing and not known widely except academics and professional in the field. Pace of learning are dependent on the planners who play a central role to consolidate learning and disseminate to the various parts of supply chain as a part of their coordination role.

An evolved supply chain planner may be only looking for a demand and supplies and matching both with a predictive commitment, but in an evolving supply chain, planners role get expanded to ensure the objectives of costs and order fulfillments to much greater degree. Such planner may have to extend their role to coordinate, demand, supplies, logistics, sales, and multiple allied supplies like meeting quality, design and documentation requirements. The role of a planner during this phase may get enlarge from material management to resource management, project management and operational coordination for a limited period of time till maturity of supply chain is achieved. This temporarily expansion of role to consolidate learning is essential for the planners to acquire knowledge and spread out same to appropriate set of planning team to do their job as a part of supply chain planning. Faster a supply chain planning role is expanded, faster learning institutionalize takes place.

A business having more natural demand drivers, it is easier to plan by mapping patterns. It become complex as external factors begin influencing either demand or supplies. This deteriorate natural variations in demand and supplies and thus difficult to map in a model.

Solar energy development is a similar chain which is still evolving given its infancy. This segment has prominent skewed demand and supply factors with only a small component of natural demand drivers. Demand and supply variation, which evolve over a period of time are also in its stage of infancy for solar industry.

Solar as an alternate source of energy is in demand by varieties of customers and developers of solar plants as this industry is evolving given shortage of fossils fuel. At prima facie it seems that this can replace all conventional sources of energy, saving environment and limit risks of energy security. Beginning with the development of harnessing solar energy, it is plagued with a number of width factors of supply chain, affected either demand or supply in major way. Such factors are high cost of generating solar energy as compare to conventional energy sources, scare silicon to be use to manufacture solar devices, un-affordability due to high cost, extra capacity worldwide and sudden fall of prices in a short period, state support etc. These factors are still establishing their trend to reach to a band where they can be modeled to create a demand and supply forecast more accurately. In a period of five years (2010-2015) since this sector started to get rooted in India, learning is even less matured than some larger solar companies across the globe. Some of the solar supply chain trends across the globe are established but it is still evolving in Indian environment. Therefore role of so called "planner" is even more important to understand the dynamics and mature learning to arrive on an established state of solar supply chain.

This study terms the special complexities of solar supply chain under the nomenclature "Width" factor of planning variables" of supply chain. "Width" refers to supplies complexity factors in the industry in a given geographical region of operations. "Width" factors considered in the thesis are project financing, material availability, quality & technology, multiple sources - global or domestic etc. Solar industry worldwide is passing through basically three phenomenons - excess capacities globally, especially largest supplies from China, falling prices and various state supports influencing this sector during the period of study. This adds to width factors of supply chain planning. Countries across the world are offering some support to grow the solar power to meet their power challenges with clean energy sources. The primary reason for this support is renewable nature of solar energy and a clean fuel. In a given country including India, these width factors play a major role to decide on what unique planning, procurement and other supply chain influences may be helpful to decide the development of solar power.

3.2 Objective:

Objective of this research work is to first map global and Indian evolving trend (width variable) in solar industry supply chain planning. With the help of interview and survey of solar players, study width variables, influencing demand and supply. Research tries to learn width variables along with planning practices evolving among solar players in the country. The research focus is to get into a level deeper for solar industry than what is mapped in planning literature in a generic supply chain. Research tries to know and validate some of variables planners are tracking to shape up their planning outcomes. The research also tries to create linkages of such variables with some of global trends in solar energy sector.

Source of the information for research is planners, designated individuals or a team, involved in procurement, logistics and solar project planning execution etc. to consolidate variables and practices, expected to create a learning model and can take solar supply chain to its maturity. The objective of this research is also to observe some of the group activities such as sales and operation planning wherein multiple players come together to optimize the supply chain outcomes. During the research we are also mindful of touching senior management in a solar company to tap learning from across all hierarchical level in case some parts are not captured by designated planners. In addition, research will also identify prominent external factors like state support, global demand and supply situations, influencing planning and decision making for solar supply chain.

"Number of iterations" in a given set of supply chain planning situation, is an indirect measure used in the research to relate various dependent variables. Any "number of changes" either in supply ordering, changing customer order, changing stocking quantities, change in material destination, change in logistic decision etc is included in "planning iteration" decision in the research. This research tries to comprehend "number of iterations" as a measure of complexities involved in planning. Iterations by planners are a lead indicator of uncertainty in demand & supplies and supply chain maturity. To adjust for the dynamics of demand and supply variations, planners iterate multiple times as material dispatch event is closer to execution of a customer order. There can be both internal and external factors affecting number of iterations. More number of iteration means more uncertainty in planning. Factor of iteration is measured and studied in the research work in relation to various width variables.

It was not possible to collect exact data of number of iterations carried out in a particular situation but an attempt has been made to quantify with the best estimate from respondents.

It has been attempted to understand the planning tools, ordering process, stocking norms, short term and long term planning practices, base and peak stocking, existing lead time from different sources of material, aggregation and economies of scale, critical material for solar projects and some supplier's management practices in planning during the research period. A small comparison has been made with an FMCG planning model, to set a context of a maturity bench mark for a supply chain planning. The basic assumption made about FMCG supply chain is its better maturity, being one of the oldest supply chain known to management researchers.

Research classifies solar business segments into three business segments - solar projects, solar products, and solar cells and module manufacturing, to capture maximum possible width variables within solar industry in Bangalore and some outside.

Planner's role sometimes can be a hypothetical role as presented in research, since no single person may performs such role in an evolving supply chain till a reasonable level of maturity is reached. Required planning skill sets and competencies are mapped back to the new width variables and complexities in solar energy industry. During the course of research, planner's role has been posed as a nerve center, to manage solar supply chain in a cost effective way to assimilate learning in the industry. It has been also attempted to map people oriented width variables, inside or outside solar companies influencing solar planning decisions across industry. In research, multiple planners from different upstream or downstream solar businesses, interacting with each other, have been mapped to arrive on requirement of comprehensive competencies and skills sets. An attempt has been made to understand whose role is prominent in decisions of class of solar materials to see if it differs from type material to material.

During the research "practice perspective" has been focused more than a "process perspective", since a process is attempted to be evolved by assimilations of multiple practices in a solar supply chain maturity. It hypothesizes in the research work that processes is not sufficiently matured to rely on the approach for a research. During the research work we have termed some practices as a process and vice versa to have a more holistic view.

3.3 Problem to be solved by research

Research is attempting to solve following problems, known to be affecting the solar supply chain planning as below.

a) Solar manufacturing need heavy capital investment. Manufacturers are facing large peak and trough in demand and supply, thus not able to plan business sustainability in long run. Employees, channel partners including manufacturing team faces unpredictable sudden peak and lean demand period. This creates unbalanced loading on supply and manufacturing. In recent past, a load level is hardly achieved in the long solar value chain operation, led to inefficient outcomes. This causes poor moral across the supply chain players.
b) Inexistence of proven planning process and practices in solar industry. Examples of such processes are S&OP process, forecasting process, demand management etc.
c) Demand projection at a given point of time is not representative of true demand. A number of major changes in actual off-take of solar product are being observed across the industry. An artificial bull-whip effect is created with support structure laid down by state from time to time.
d) On-time availability of material to a solar project remained a concern due to heavy cash requirement and high debtors of solar companies, impacting deployment of multiple large solar projects, necessary to build sizeable power plants. Building of such power plant is an important need in power scarce country like India.

There is a strong need to review the existing supply chain planning model and practices including S&OP. Research will try to include more specific practices being used by solar suppliers. This proposed analysis in the thesis will put forth an applied direction for further refinement of planning process to meet the planning needs of the solar industry.

3.4 Research Questions

This research focuses on research questions around the concept of demand and supply variability, arising out additional width factors, specific to solar industry. The research identifies those variables, having potential to create a refined model for planning for optimum outcomes of supply chain for solar industry in India.

Research questions, to prove the effect of unique factors on solar supply chain is being posed as below

a) What is the width of visibility of variables are required for Supply Chain Planning process for solar manufacturer or suppliers?
b) What is the role of state support (subsidies, duty and taxes etc) variables on supply chain planning process?
c) What level of planning iterations is deployed to match the interest of buying and selling organizations in the solar value chain?
d) What is the roles and skills requirement of supply chain planner's, to bring in required level of "Collaboration" to achieve a level of "optimum" for organization?

3.5 In Scope

Research focus is on supply chain planning practices from solar equipment suppliers located in the area of Bangalore (referred as "solar energy suppliers" in thesis title). The reason for choosing the Bangalore area is concentration of large solar manufacturers of cells and modules, solar products and project components. Sizeable solar think tank, corporate houses deploying multiple roof top solar projects as a developer can be easily tapped in this region of city. Maximization of mix of all variety of solar stake holders in one place makes an ideal case to select Bangalore for the purpose of research. Oldest solar company in the country, Tata Power Solar is also having their operation in this city.

Stakeholders responsible for solar supply chain are very diverse. Possibility of single point assimilation of learning, as expected to be with solar supply chain planners, may be an optimistic idea, thus scope of studies is expanded to interview and survey some senior and very junior level respondents in solar companies. Sampling from such a wide base of players, ensure possibility of maximizing learning necessary for research. The focus of study would be primarily on solar photo voltaic (PV) technology based solar projects, products and manufacturing solar players. Following two umbrella themes further explore in the research.

1. Internal and external width factor covering demand/supply variability and respective relationship with the supply chain planning process.
2. Affects of internal and external width factors on planning iterations as an objective of supply chain planning.
3. Planning model specially S&OP, with specific width variables contributing to solar industry.
4. Research and discussion on special skill required to manage width of variables for supply chain planning for a solar industry.

3.6 Out of scope

Thesis does not include study of solar energy plant owners (supplier of electricity) who sell power to consumers. These areas have been excluded to simplify objective for effective research outcomes. Some of such excluded areas have potential to intermix or cumulate to create complex confounding effects. For the purpose of right scoping, some factors are assumed as constant to avoid confounding effect. A brief description of some of such variables, but not limited to, are excluded from research.

1. Study of government support, on achievement of objectives and vision stated by Ministry of New and Renewable Energy/State Nodal Agencies.
2. Combined effects of multiple state policies or supports acting at the same time to plan a net impact on solar demand, supplies and planning.
3. Study of consumer behavior based on state support to solar industry, impacting on demand.

4. Cost of solar power and financial viability of solar sectors related to cost of supply chain.
5. Thermal solar products and projects have not been focused as this segment is very limited by volume in entire Indian solar industry.
6. Technological trend in solar power, creating obsolescence of existing inventory and affecting supply chain planning.
7. Usage of detailed planning tools for solar industry supply chain planning.
8. Comparison with any other renewable energy material planning like wind, hydro, biomass etc, to distinguish an extremely overlapping supply chain scenario. Some of similar renewable industry may have same width variables but not studied here.
9. Coverage of dynamics of demand and planning based on individual materials used in solar product or project.
10. Planning related non-material aspects of a solar project like land, power evacuation lines etc.
11. State to state support policy variations and their effects on supply chain planning.
12. Process of government bidding and their effects on supply chain planning
13. Environment sustainability effects on supply chain planning.
14. This is generic model – variation from solar player to player can vary. This comparison of planning practices in excluded in the research.

3.7 Hypothesis under Study

Based on the research questions four umbrella hypotheses are stated as an alternate hypothesis (HA: H, stands for "Hypothesis" and A, stands for "Alternate"). These hypotheses are further divided into elemental hypothesis to support the umbrella hypothesis. Data required to substantiate these hypothesis is qualitative and quantitative, in the form of information and estimates, as understood from various solar players. In addition, it is also attempted to substantiate qualitative information into quantitative hypothesis to conclude more objectively to state interpretation. Primarily nature of study is exploratory by interviewing; a secondary back up quantitative study with the help of survey is included to ensure qualitative data validity and reliability.

There are four hypothesis further divided into sub-hypothesis to substantiate the main hypothesis. Literature survey suggest to go step ahead in qualitative research, but to enhance the validity, quantitative support is added. A comprehension from interview of respondent is modeled into objective survey questionnaire with discrete attributes.

HA 1: Supply chain planning process for solar manufacturer/supplier need a wider view of global & domestic supplies, as critical inputs for effective planning.

This hypothesis has four main attributes related to supply chain planning. These attributes are explained as below before discussion on each hypothesis.

a) **Solar supply chain planning process:** Supply chain planning process is a chain of planning events to ensure required material under planning reaches to customer on time by involving multiple players influencing decision. These internal players are sales, procurement, design and engineering. Sometimes very senior officers in a solar organization take role of an important planning player.

   During the study, this process has a start and end which sometime is very vaguely defined in solar industry. The definition of starting and ending this process vary from solar organization to organization or from time to time. For the purpose of research, we are not making an attempt to define it accurately; else main theme of "critical inputs from width variable" involved in the planning process may get lost. Defining it accurately and then collecting information may still creates varied images in the mind of respondents and research focus may get wasted in elaboration, then collecting information related to planning inputs. In some organization planning process starts when policy to promote solar energy is announced by state, other starts when customer order is under discussion or at different stages of order confirmation or cash advance received etc. In similar way some solar organization has an understanding of planning process is over, once all high value material reaches to customer site or some consider it close when solar project site is fully complete and running. Keeping this in mind, we are avoiding getting into an exact defined scope of planning process.

b) **Wider view of global and domestic supplies:** This attributes describes the availability, pricing, qualitative and technologically advancement and ease of financing in a country for solar products, being acquired by customers from domestic (India) and global sources. Product off take (purchase) by customer is a function of availability, pricing, qualitative and technologically advancement and ease of financing in a country at a given point of time.

c) **Critical Inputs:** A critical inputs for supply chain planning refers to an input necessary to be evaluated before various decisions on planning to optimize the outcomes are made.

d) **Effective supply chain planning:** A planning is a sequence of optimization decisions e.g. what to order, in what quantity at what time, to reduce overall cost of material, stocking, logistic and procurement in a supply chain. An effective planning leads to increase in overall supply chain surplus for an organization. The surplus is in terms of more margin & customer satisfaction.

During the testing of this hypothesis, it is assumed that all other supply chain planning variables mentioned in the literatures are impacting but "width of global supplies" visibility, as mentioned above, is "critical inputs" to be considered additionally before planning material.

In testing of this hypothesis it is considered that planning material supplies has following salient attributes to decide the source of procurement – Easy availability, Price, and Quality & Technology. Following sub-hypothesis is stated as below to prove that each of these elements

HA: 01:01: Planning source of material is dependent on attributes of procurement (Availability, Price, and Quality & Technology) in solar industry

HA: 01:02: Comparative domestic and global supply view increases the domestic planning complexities.

HA: 01:03: Planning objectives of State is sustainability of supply chain whereas planning objective for material planner, is short term cost and availability leverage.

HA: 01:04: Material stocking in the form of raw material or finished goods depends on availability factor globally.

HA: 01:05: Off the shelf solar product planning is more effective at local place of demand than at national aggregated demand**.**

Linked to second research question, the role of state support in supply chain planning process is explored under following main hypothesis and followed by two sub-hypothesis.

HA 2: National and state level policy support to solar energy, to grow the sector, is a major width variable in supply chain planning.

Two sub hypotheses are emphasizing on the same aspect from two different directions. These two hypotheses stated inverse of each other to specify that demand is primarily derived by state and natural demand factors are comparatively less significant.

HA: 02:01: Solar demand is a function of "state regulations and support", thus an input to supply chain planning.

HA: 02: 02: Natural demand factors are less significant than a state support derived demand in solar industry.

Third hypothesis is stated below is detailed out for width variables, as a measure of number of planning iterations. These iterations are performed by planner on account of uncertainty in planning. Factors of uncertainty are further divided into nine independent width variables studied as sub-hypotheses.

HA 3: Existing practices of supply chain planning need more number of iterations to protect interest of buyers and sellers (Stakeholders) than existing in practice.

In this above hypothesis three main attributes are explained as below

a) **"Number of Iteration"**: Iterations are defined as number of changes in the plan to optimize availability of material and cost without adversely impacting customer service, to ensure right material reaches at right time in right quantity. The number of iterations is performed by planners in the light of improving forecast and better customer requirements.

b) **“Interest of buyers and suppliers”:** To improve overall supply chain cost and operating margin, planners in buyers and seller organization tries to manage availability of material precisely at the time when it is desired, at most optimum cost. The cost is inclusive of material, stocking, logistic and procurement cost.

c) **“Existing practices in matured product demand & supply”:** A matured supply chain planning process is referred to a typical evolved FMCG organization model. FMCG has built multiple planning forecasting and planning models in industry space. A Solar supply chain planning processes are compared with a FMCG supply chain planning.

In a matured supply chain it is expected that the number of iterations are minimum. This situation can be achieved in case of a good demand visibility and lesser degree of changes in demand and supplies. In solar industry demand and sources of supplies are dependent of state regulatory factors. It causes more number of iteration as compare to a typical matured supply chain like in FMCG, where demand and supply factors are matured and can be predicted more accurately.

Following hypothesis are laid down to compare number of iteration is solar industry than in practice (referred to FMCG) correlation with their reasons.

HA 03:01: Immature iterative design engineering, faster demand inflow than cash collection, inadequate safety stocks increases number of iterations.

HA 03:02: Deviation in sequence of material procurement and dispatch, from a planned sequence, for project installation, increases number of iterations.

HA 03:03: Ambiguous starting point, to begin material planning process, leads to increase in number of planning iterations.

HA 03:04: Multiple projects execution at the same time leads to increase in number of iterations in supply chain planning.

HA 03:05: Number of iterations is function of fund availability to pay to suppliers by contractors on time.

HA 03:06: Strict norms of declaring excess inventory in a solar organization impacts number of planning iterations.

HA 03:07: Supplier's credit period affects number of planning iterations

HA 03:08: Difference exists between in-house and contract manufacturing of solar modules, cell or solar products in planning iterations.

HA 03:09: Number of planning iterations is dependent on solar customer segments.

Solar industry specific width variables are substantiated with the help of above three hypotheses. We felt a need of fourth hypothesis to study requirements of skills and competencies, given a particular width of solar supply chain variables. The finding under this hypothesis will focus on personnel skill requirement as a part of the study. This hypothesis is included since solar supply chain maturity is the ultimate objective. A mere study of width of supply chain variables cannot become a foundation of maturity until skills and competencies required for such planning is also given due attention. Our basic premise that solar supply chain is not sufficiently matured in India; it can be strengthened by special skills and competencies requirements. The following hypothesis is stated to study which area need more strengthening of planning skills in solar industry.

HA 4: Roles of supply chain planners need to be strengthened with specialized skill mapping for effectiveness of solar energy companies.

The idea of study this hypothesis related to skills and competencies is not to get in a full people development side in solar industry, but restricted only to one main hypothesis. A future research can further detail this area. This hypothesis is primarily captured to include people development as a part to give an applied direction to a management research.

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Chapter 4 – Research Methodology

4.1 Problem to be researched

This research focuses on questions around the concept of demand and supply variability in solar industry, more specifically in the area of Bangalore to understand supply chain planning processes, practices, and specific variables arising out of factors, specific to solar industry. The research also tries to bring up a planning practices used in industry for “solar project planning” to achieve an optimum results. Such supply chain practices are picked either from designated solar industry supply chain planner or by senior management influencing planning decisions or state getting involved in influencing decision from a country level perspective. There are primarily three segments of solar business segments existing in industry, which draw individual specialized planning skills. These set of people are prime respondent to understand planning practices in solar industry. These business segments are - solar manufacturing, solar EPC contract or development of solar projects and solar products. The three different solar segments have varied planning factors and thus research is intended to put a balanced focus on all the three solar business segments. Demand driver of solar industry as explained in the chapter-1: Introduction. The research is intended to get objective views of respondents to capture the solar industry factors on supply chain planning process as experienced by people involved in planning. The research took samples from all India solar players with a specific focus in player in Bangalore region. Researcher feel country level generalization is possible but sufficient representation is not considered from population since Bangalore area is a prominent focus in sampling.

A small case study to create an understanding from all the three solar companies is used to put forward research question and hypothesis. The case studies company chosen in such a way that it should represent all three business segments to ensure comprehensive supply chain research problem is formulated. During case study, an understanding of supply chain planning process is understood before increasing sample size. An understanding is sought with the help of case study to bring out elements different in solar supply chain planning than a conventional supply chain to draw attention specific to solar industry. Research questions, linked to f unique factors on solar supply chain planning are posed as below.

1. What is the width of visibility required for Supply Chain Planning process for solar manufacturer or suppliers?
2. What is the role of state support (including subsidies, duty and taxes etc) variables on supply chain planning process?
3. What level of planning iterations is deployed to match the interest of buying and selling organizations (stakeholders)?
4. What is the roles and skills requirement of supply chain planners, to bring in required level of "Collaboration" to achieve a level of "optimum" for organization?

4.2 Hypothesis back-drop

Based on the research questions four umbrella hypotheses is formulated. These hypotheses are further broken into small hypotheses supporting the umbrella hypothesis. Initial data required to substantiate hypothesis is qualitative in the form of information as understood by various solar players who responded to our interviews. In addition, to qualitative data a quantitative hypothesis is used to gain more confidence on interpretations of qualitative results. Following hypothesis is under study according to which research methodology is formulated. Primary start of study is exploratory; followed by back up of quantitative study, with the help of survey to ensure qualitative data validity and reliability.

HA 1: Supply chain planning process for solar manufacturer/supplier need a **wider view of global & domestic supplies**, as critical inputs for effective planning.

HA 2: **National and state level policy support** to solar energy, to grow the sector, is a major variable in supply chain planning.

HA 3: Existing practices of supply chain planning need **more number of iterations to protect interest of buyers and sellers (stakeholder)** than existing in practice.

HA 4: Roles of supply chain planners need to be strengthened and **specialized skill mapping** for effectiveness of solar energy companies.

Likewise, sub-hypotheses are further defined to substantiate the main hypothesis. Literature survey suggested to go step ahead with qualitative research in such exploration work, but to enhance the validity to the sector focused quantitative support is added. A comprehension from interview of respondent is modeled into objective discrete attribute based survey.

4.3 Population to be studied

Objective of research is to study area of Bangalore region wherein there are approximately five major solar players, manufacturers of solar cells or modules - Tata Power Solar, EMVEE solar, HHV Solar and Kotak Urja. In addition about 8 small solar product distributors and whole sale retailers are considered for samplings who are distributing products for these companies. Some players interviewed out of Bangalore region as well who has, significantly contributed to solar industry in India. Bangalore based players considered for sampling include Lanco Solar, Indo-solar, Vikram Solar and Moser Baer etc. Expected number of subject matter expert related to supply chain planning at planner and senior management level is expected to be about 400 including EPC contractor and developers in the targeted region.

A sample of subject matter experts (SME), from solar industry is interviewed in an unbiased manner. The research has been conducted in a limited controlled environment to include a limited set of variables based on study of solar player in a city in Indian solar industry context.

Research is to find out practices from the industry for a period of time between years 2010 to 2015, under given market conditions; hence it forms an applied research, giving an understanding of supply chain planning for solar industry. Limited period of research specifies certain prevalence of specific state policy, market conditions and practice adopted, were required to be studied in relation to each other during this period. Solar industry is on its learning curve during the period after starting journey is year 2010 after announcement of JNNSM, thus assumption of maximum learning is expected as a part of supply chain evolution. As time passes, a number of learning may be useful to give insight on solar industry supply chain planning, which forms the base of evolution of solar industry supply chain. Further applications of this research can be in areas of solar industry or similar industry under government or any external supported supply chain framework. Since research is expected to propose an applied direction, it is combination of descriptive and correlation in nature. Practices in supply chain planning have been described in solar industry environment, with an aim of establishing correlation with the supply chain planning factors. Research tries to establish correlation with the help of multiple qualitatively view point and quantifying views through survey by using statistical and graphical method, establishing relationship wherever possible.

The research is covering more in breadth and less in depth to capture supply chain planning more holistically, including global and local supplies comparison. This research is unique since hardly any research work has been done on the specific subject of solar supply chain planning.

4.4 Uniqueness of the research objective

Solar industry worldwide is passing through three phenomenons excess capacities globally, especially largest supplies from China, falling prices and various state supports influencing this sector. Countries across the world are offering support to grow the solar power to meet their power challenges with clean energy. The primary reason for this support is renewable nature of solar energy and a clean fuel. In a given country including India, these three factors play a major role to decide on what unique planning, procurement and other supply chain influences may be helpful for efficient solar business outcomes. The research objective is to find out specific factors and practices in solar supply chain planning, given global and home country supply chain planning factors.

Solar industry has a very low entry barrier and thus solar players are very much fragmented, starting from a low cost solar product player to a high capital intensive manufacturing of solar cells and modules. Such wide spectrum has many views which are common and also contrasting with each other on various fronts. The varieties of views are confounding with each other to deterrent to decision making in the industry as a part of supply chain planning. Thus the research has challenges of including a common study by avoiding conflicts and retaining signals from all confounded effects of multiple solar business segments.

The ecosystem of solar power players in India is quite complex. On one hand India had a target of large scale deployment of solar power and on other hand, declining global modules prices putting adverse pressure on Indian manufacturer and deterring manufacturing capacity additions. State has challenge of promoting solar power, by growing Indian solar Industry and employment in the country at the same time, to promote an inclusive growth of the industry. Even though not all supply chain planning factors are in the local hand but an ecosystem of supplies are extremely complex having impacts on multiple factors interacting with each other.

The factors considered in the research hypotheses are only significant one and can get managed effectively to survival of industry, keeping a long term view of development. The hypotheses is around factors- like solar ecosystem requires a "wider width of supplies” of solar equipments, can only be considered if global view is taken by any solar player. The research is not intended to study all global drivers, but considers effects of global factors on Indian solar industry, which would be critical for domestic solar industry.

Domestic state support structure, extended by various government to help boost the solar power deployment, is a critical factors for planner to have multiple iterations in dynamic environment from a medium to long term horizon, is a basic factor to decide on the course. To shape up planning process and execution in most professional and efficient manner, a complete special set of supply chain planning skills are required to be deployed which is not so easily available in the market. The research will investigate such skill factors through interviewing of key solar players. The objective of this research is to identify such factors, into their right depth of details to come up with a most optimum planning cost and service model. These research inputs can be captured by more quantitative interviewing, included in the methodology.

Large solar power players are extremely fragmented. They deal in EPC contracting, owning large solar assets like megawatt scale projects, manufacturing cells or modules etc. There are about another more than 200 players in solar space who are dealing in variety of solar equipment manufacturing, support or distribution. These solar players are specialized in their particular segments like manufacturing, large solar project installations or manufacturing. There is hardly a solar operator who is specialized in all areas, making study a bit more wide spread to represent all such players in the sample. The objective of interviewing various solar players is to trace practices and compare how they are trying to maximize their returns by maximizing supply chain surplus. A survey further helped to broad base the finding during interviewing from limited sample respondents to ensure whether views considered during interviewing are consistent or not.

Width of supplies from domestic and global sources is always viewed differently by different set of solar players based on their location, their local and country government support mechanism and the solar sector they operate in. It becomes imperative to have subjective discussions with a set of players present in the all three business segments.

Even though the sampling is being considered from the area of Bangalore, but some players were considered from out of Bangalore to ensure the central government view common for entire country is understood more widely. It is a matured sample to consider from Bangalore area major pioneers players in solar space are based out of this place.

4.5 Structure of Interview

Interviews were semi-structured wherein main question is generic but as respondent proceed; follow up questions were modified or tweaked. An interview questionnaire is prepared to research the area focused through hypotheses. This interview questionnaire is designed to capture all the key themes emerging across the industry. Questionnaire is some time using some technical terms thus interviewer were planned to explain such terms, before seeking responses, to have a better understanding. Each of the interview questions is posed in front of interviewer with the best of language he can understand. Some Kannada speaking people were explained by a Kannada speaking people who accompanied along with researcher. A basic premise of the topic is explained to respondents, in the form of sequence of events happened in solar industry between year 2010-15, to bring out relevant images from the interviews. Interview respondent were requested to think through before they response, they were also asked to relate to the particular solar segment, they operate in. Interviewees were requested to help in relating to supply chain planning meeting they conduct or participate in their companies to plan solar material. This helped us to closely relate to their actual planning environment. All interviewees were requested to help provide an opportunity to witness one or two such planning meeting in their company, where planning decisions are taken. Two such interviewees who allowed us to visit and witness for the supply chain planning process were visited for observations.

Interview questionnaire was sent in advance to respondents to go through as a pre-read, to minimize the discussion time and bring out more relevant voices and images on questions. Interviewers were also requested to help with written responses of their views to minimize the error in interpretation during the comprehension process. Out of 25 interviewees only 7 had written subjective answer but it was only bullet points which they explained us during the interviewing process. Interviewing process questions followed a sequence in which hypotheses were framed, rather than a most relevant response from natural flow. Interviewees were not interrupted, in case they wish to change the sequence to suits their natural flow. This had some sequencing issues and repetitions of some images and voices. Later on while interpretation we considered unique images. Some of the views were repeated in case they emphasized same points, from a different perspective, to retain the relevance of hypothesis. Such repetitive sections were categorized separately into “Interview insight and discussion” section under “Chapter -5 Analyses and Interpretation” under each of the four hypotheses.

Questionnaire was planned in such a manner that there are leading questions and then follows up questions. Follow up questions are to create better understanding on the questions under hypothesis. Follow up questions allowed us to give lead to get responses in a direction of our hypothesis. Respondents who had gone through the questionnaire well before the interview were better prepared than those who responded instantly. Many of respondents who had seen the questionnaire were able to talk about the subject more efficiently without follow up questions formally asked. Rest of respondents took some reasonable time from interviewer to understand the questions and their context. Many a times, such respondents had tendencies to explain some other un-related areas. We did allow some flexibility for them to talk the subject even it is not part of follow up question. Initially five pilot interviews were conducted to add or modify follow up questions to ensure all themes are adequately covered, to substantiate factors in the hypothesis. Our preference was to take interviews face to face to have comprehensive discussions. 16 interview respondents were interviewed face to face and 9 interviews conducted over phone. We ensured that telephonic interview takes place later, since face to face interviews gave a more learning opportunity by understanding the sentiments about the industry respondents had. A face to face discussion was helpful to judge the gravity of planning process and situation more closely. Telephonic interviews were more of increasing the base of images we received from the initial face to face responses. After completion of 16 face to face interviews, we were very much sure on right follow up questions and significant common themes to be considered in the research. Interviews responses were represented by 5 solar developers, 9 solar EPC contractors, 9 solar product distributors and 3 manufacturers. The summary is represented in the table as below.

TABLE 4-1: Sampled solar companies for interview

Category of Solar Player	**Sampled Numbers**	**Names of solar companies represented**
Solar Project Developers	5	Lanco Solar, Emami Cement, HP, Bharuka Power Corporation, ACME
Solar EPC contractor	9	Juwi, Tata Power Solar, Lanco, EMVEE Solar, Harsha Abakus Solar, Sterling and Wilson, AI Ansari Power Technologies, Shan Solar, Jj PV Solar
Solar Product Distributors	8	Pai Power Solution, SRM Systems, Yash Technologies, Pratham Solar System, Alveena Designers & Engineers, Anu Solar- Reddy Technologies, Goecorp Ecos,
Manufacturers	3	Tata Power Solar, Indo-solar, EMVEE Solar

4.6 Structure of Questionnaire

Sequence of questions for a given hypothesis is designed in such a way, to take most efficient discussion sequence from high ladder of abstraction to lower ladder of abstraction. In interview and survey questions numbers are mentioned in such a way to relate to the hypothesis. A standard format of sequencing of questions is used as below

Q: Number A: Number B - “Q” stands for question, “Number A” stands for hypothesis number and “Number B” stands for sub-hypothesis number. Similarly “FQ” abbreviation is used for follow up questions suffixed with number.

Question, Q: 01:01 starts with a general remark on deciding the demand of various components of solar power plants. Follow up questions FQ1, FQ2 & FQ3 attempts distinguishing local and global supplier’s inputs being considered in present planning environment. An inputs not related to procurement was pulled down. Priority is given in the order of relevance to most important planning attributes, to stay focused on primary images and voices.

Questions, Q: 01:02 is to create an understanding of complexities in a global and local supply situation in solar industry. This question was focused on researching on uncertainty leading to complex planning situation based on interviewee’s responses in Q: 01:01. A follow up question to understand “who” takes such planning decision is asked. Some respondents named, position of influencer, based on their internal hierarchy and some informed based on role. During the interpretation from this follow up question is categorized based on role played in the organization as planner, senior management etc who are accountable for business performance or state governed factors related to planning.

Question, Q: 01:03: Interview respondents were asked about the differences in objective of role based planning decision. The view point of involvement of multiple stakeholders was supposedly considered different. During interview it was ensure to capture separately, if objective of one or more of these players is prominently similar. Other than difference in skill level and wider solar industry visibility was another differentiating factor during most of the interviews. Therefore further questions were asked to focus on role base understanding.

Questions, Q: 01:04 focused on researching where central planning is taking place. Local level solar product players were not in a position to distinguish but national level players were able to talk about consumption pattern and aggregation level of planning with clear explanations given to them by interviewer.

An understanding of state level objective was discussed with the respondents, based on objectives published in MNRE charter, to understand whether there is any deviation in an objective over a period of time.

Questions Q:02:01 is trying to understand how various elements of state support is impacting in supply chain planning process with one main and six follow up questions. This question was a bit tricky to relate to material planning, since most of the interviewees were related to industry's existing knowledge, rather than exactly how they are getting affected.

Questions, Q: 02:02 is a reverse question to assess the success of state support vis-à-vis extent of natural demand. Since it is difficult in the industry to find out how much demand is due to state support and how much demand has non-state supported (natural demand), follow up questions FQ6 and FQ7 tries it relate to the supply chain planning process and visibility of demand based on such state supported factors.

"Hypothesis HA:3" is an operational hypothesis, which assumes a significant more number of changes (iterations) in a complex environment of solar demand and supplies, due to presence of global, state and local solar industry factors. Horizon of iteration is not restricted in the questions but an operational question is intended to capture the iteration in short to medium term, varying from a few months to two years of duration in general. During the discussion respondents were clarified about this time horizon by the interviewer.

Researcher hypothesized that number of iterations are more in solar industry due to demand and supplies uncertainty, thus a comparison is drawn to compare with the local

FMCG industry to make the discussion more objective in Q03:01 as a follow up questions. A brief about FMCG industry was given to respondents during the interview to arrive on a comparative view. A question to understand safety stocking was captured as a last follow up questions, which took respondents to operation level enquiry.

Questions, Q03:02 is an operational understanding of "sequence" of supply of material category wise. Since multiple supply sources are hypothesized to reach in wrong sequence, provided demand is uncertain, and supply sources are global, with state support playing a role. Follow up question tries to research the extent of deviation and reasons for deviation in supply sequence. Reasons of deviation in supply sequence are also captured in the form of multiple images and voices. Interviewees were allowed to speak freely on this question. Later on these images and voices were categorized based on affinity diagram.

To plan supplies to fulfill customer order, starting point was hypothesized to be varying, to deal with the risk of order cancellation, foreign exchange variation or avoiding additional stoking days of inventory. Respondents were asked to understand the point of order placement to procure material against demand to assess practice in solar industry

Questions, Q03:04 & Q03:05 are specifically planned to understand an "objective iterations" closer to project deadlines and liquidity constraint leading to more number of iterations in solar supply chain planning environment.

Question, Q03:06 are focused on internal practices inside solar industry to declare a non productive inventory as excess or obsolete. To meet inside industry norms of excess or obsolescence of material stocks, which is expected to leads more number of iterations as per hypothesis.

Question, Q03:07 and follow up questions are focused on effects of expected supplier credit on planning iterations. Supplier's credit pushes suppliers and buyer to change the source, time of delivery or quantity.

Questions, Q03:08 & Q03:09 are focusing on whether there is any effect of in-house or outside or contract manufacturing and solar business segment on planning iterations.

Question, Q 04:01 with seven follow up questions are intended to understand skill gap in planning to meet solar industry complexities.

4.7 Analysis of "Voices" and "Images" from interview

During interview prominent themes were categorized and have been captured qualitatively as a part of "interview insight and discussion on hypothesis" in each section of "Chapter 5 - Data Analysis and interpretation". Since these voices and images have been captured with the help of 25 respondents, it is decided to validate the prominent voices and images through a set of objective questionnaire with a larger sample size than number of people interviewed. A questionnaire is prepared to capture quantitative and objective data from a larger group of respondents. This questionnaire was a mix of objective questions on Likert ranking scale 1 to 5, Yes/No or interval scale responses. The base objective themes for questions were derived from interview responses to convert them into discrete numerical data, as estimated from survey responses.

Survey was conducted during Inter Solar Summit, India on 22nd September, 2014 in Bangalore, to maximize the responses from respondents from solar industry. A hard copy of questionnaire was used with respondents based on his willingness to respond to our survey. A small gift was also given away to create interest among respondents, to increase number of responses to our questionnaire. The survey was facilitated by team of three trained members including researcher, to help with clear explanations to respondents on technical terms, which helped them better understanding and avoiding partial or incomplete responses. To maximize the participation of representative from a solar industry, a mix of business development, procurement, and solar engineering designer and industry watchers were included.

Some of the numerical estimates were seemingly not relevant in samples, so such outliers were taken out to have a more accurate estimate on discrete data collected from respondents.

4.8 Research Methodology

Research focuses on solar supply chain planning practices in dynamics and wider demand and supply of solar industry environment; therefore interviews were conducted with the help of subject matter experts and supply chain planners from solar industry. Following role wise respondents were selected for interviewing.

a) **Universe of respondents to be contacted & approximate sample size of people involved in interviews:**

TABLE 4-2: Role wise sampled companies for interview

Respondents	**Central Planners**	**Procurement Planners**	**Senior Management**
Solar Cells & Modules Manufacturers	1	1	1
EPC Contractor & Developers	6	6	2
Solar Product Distributors	4	3	1
Total			**25**

It has been attempted to keep a larger sections of respondents during surveying since voices and images received from interview might not have been representative a universe under study.

The survey conducted is a “convenient sampling” since survey respondents were those present in vicinity of Bangalore. These respondents were first asked about their role is solar industry to categorize appropriately depending on hypothesis. Only those respondents were selected for survey who were in active in solar industry, either to create demand for solar equipments or affect supply side. Their roles were classified into three categories – central planner, procurement planners and senior management planners, same as categorized during interviews. Respondents were asked to fit their role closest to any one of the three categories. Since it was a convenient sampling, controlling number of respondents into each of these three specific categories was difficult. An uncontrolled number of responses into these three categories eventually distributed as follows.

TABLE 4-3: Role and solar business segment wise survey sample

Respondents	Central Planners	Procurement Planners	Senior Management
Solar Cells & Modules Manufacturers	13	19	9
EPC Contractor & Developers	37	42	12
Solar Product Distributors	43	87	35
Total			**297**

b) **Research Methods**

The data collected for the research purpose was through responses during the interview. An understanding gained regarding planning process is divided into multiple themes. We got about 42 first level themes based on classification suited us for building on our hypothesis. These themes were further classified into four categories and four hypotheses. Even though the interview questionnaires were designed based on hypothesis but multiple voices and images got mixed in different set of questions. So these relevant images were re-categorized into the correct group of responses. An affinity grouping tool was used to classify these relevant images. Some voices and images were relevant to the hypothesis but still could not be logically related to the hypotheses, were categorized separately as a part of miscellaneous one. Some of such images directed researcher to next research areas captured under future scope for research. A due care has been exercised to avoid enhancing the area from a scoped one for this thesis.

Sentences were framed as they were spoken by interview respondents to minimize error in interpretation from interview responses. Similar verbatim were evolved together and interpreted as late as possible during the course of research. A first interpretation was done only before preparing an objective survey questionnaire. Final interpretation was deferred till survey data is collected and tabulated. Final interpretation was completed one by one for all 42 themes to comprehend the data. A care has been exercised to ensure qualitative and quantitative data remains together to draw a logical conclusion. A few follow up clarifying interviews were conducted with the same interviewees where some contradictions were reported during our comprehension. These views were considered in the report, only after arriving on consensus with the interviewees. Those images were discarded from the interpretation where there were direct contradictions to avoid an aggressive and emotional view from respondents.

Final interpretation after theme formation, were run through three selected planners who had participated in the interviews, to ensure consistencies before finalizing research report.

During survey discrete and continuous data estimations is collected from respondents. Chi-square testing tool is used to test discrete hypothesis testing, depending on number of columns and rows required to test individual hypothesis. Wherever possible available a continuous data was used for regression analysis to evaluate the robustness of regression coefficient and R-square.

An effort has been made to statistical hypothesis testing as far as possible to clearly interpret results based on statistical significance. For regression, many places number of data points were less, still it is attempted to put a hypothesis testing model to verify hypothesis with a confidence level of minimum 90%. Data has been tabulated in Chi-square table and graphical representation is also presented wherever required to have a pictorial representation for readers who are not conversant with the statistical terms.

To have a comprehensive view based on both interviews and survey, a discussion section is added under each hypothesis interpretation section.

c) **Sampling Plan**

There has been a limitation on number of respondents who can undergo a detailed interview since each interview varied between 45-90 minutes of duration. There was also limitation on number of subject matter expert, potential respondents, in a given territory of Bangalore under research. It has been attempted to include maximum possible players in Bangalore region who significantly influence the solar industry in India in solar project, product or manufacturing. During research, it is tried reaching about 41 people for, but only 25 agreed to respond to interview. These 25 interview respondents were covering entire spectrum of respondents from solar industry space, thus the data is considered as representative of study. Other 16 respondents were from same industry so their views could have strengthened the study, even though we got sufficient number of respondents. To include “state” view on supply chain planning we took help of published reports by central government (MNRE) in which views of senior officials is considered. There has been a limitation on getting appointment from such officials to respond for the purpose of academic research. These officials have shown their hesitation of giving their views on behalf of their department, for our research.

For the purpose of surveying a sample size, total size of population in Bangalore area is estimated to be approximately 15000. With a confidence level of 99.9% and a confidence interval of 10% is 264 considered for the research.

On line sample calculator is used on 30 Aug 2014 (http://www.surveysystem.com/sscalc.htm).

While attempting a sample size of 264 we could collect data from 297 sufficient to conclude the hypothesis. Since most of the hypothesis testing is done through Chi-Square test, all cells should have minimum numbers, to performed test without breaking tests of Chi- square assumption. The sampling used is non-probability sampling from the people available randomly in the Solar Summit, as many randomly selected respondents did not agree to complete survey.

A sample size of 297 respondents for surveys is carried out in addition to interview of 25 people over face to face and over telephone.

d) Research Design:

The proposed Research design consists of interviews, systematic observations of supply chain planning process, and interpretation of data collected from objective surveys.

Following steps were used during the study:

- Determine and define research questions and hypothesis before arriving on detailing of questionnaire for interview.

- A basic interview questionnaire is prepared under each hypothesis. This questionnaire was run as pilot for 5 interviews to make some major refinements and changes in order of questions and deletion of some redundant questions.
- Some existing data and models published in international journal were also used to facilitate the interview.
- Alignment of similar images together to prepare objective questionnaire for survey for hypothesis testing.
- A survey questionnaire is prepared and data is collected from 297 respondents.
- To collect supporting secondary data to substantiate interview and observations.
- Visit to witness two companies who allowed observing formal planning process.
- Re-validation of observations and data captured with interviewees involved with three industry planners from different companies to see consistencies.
- Develop a proposed planning model
- Prepare the Report.

e) Rational of Data Collection Method & techniques

Study involves capturing views of people involved in supply chain planning processes to validate first, second and fourth hypothesis. An "**interview approach"** would be suited to collect data and information from players involved. There is a need to observe the formal planning process, as it takes place within their organizations, initially respondents from five company piloted for interview, followed by 20 more people at different levels involved in supply chain planning process. The interview finding is validated by observation of two planning meetings.

The data received from interview and observation need to be correlated to inventory sizing, fill rate to customers with the supply chain planning process, a representative case company is chosen to get the initial detail to base hypothesis. (Eisenhardt, 1989)

A company having continuity of operation for substantial period of time is selected for case study, to ensure maturity of processes observations. This case study company chosen for initial hypothesis were relatively stable and operate in all customer segment and range of solar products. The company chosen for case study, had a planning or equivalent process, having reasonable integration of sales, procurement and manufacturing plants.

f) Sources of Secondary Data

Existing solar journals already published research by various consultancy companies is used in research work.

Data and information exist with the company in their ERP, is used to substantiate some aspects of research work. Solar firms responded, were extremely cautious to give very selective data. Though there has been limitation in terms of analyzing the actual data, some of data used, were estimated by some solar consulting publications, to substantiate the hypothesis and results

g) **Estimation methods**

Research includes some solar industry estimates. To arrive on these estimates, multiple linkages with existing published data are cross checked for any major inconsistencies. These data have been used for some minor arithmetic and numerical conclusion with due care.

h) **Coverage of study**

Study focuses primarily in Bangalore areas thus there may be a major influence of localized views. Researcher feels that the same may be applicable across country since solar industry is a national, not local one, but such results were validated in a limited way for an area larger than Bangalore with a few respondents out of Bangalore.

i) Observations

Two companies allowed witnessing supply chain planning process during their S&OP meeting. Researcher attended two such meetings, to witness images to improve better understanding of planning process.

j) Team for Interview and Survey

Researcher has conducted all interviews personally with all respondents. During interview, a notes taker was accompanied to ensure correct capturing of information, since the researcher is busy in asking questions. A group of two people have supported researchers to conduct surveys during exhibition on solar. This opportunity was utilized to avoid non-response bias in interpretation.

Survey supporting team was trained on understanding of questionnaire to help explain survey respondents, in case of any difficulty. Some minor understanding is corrected before full scale survey undertaken.

k) Interview Content Analysis

Step 1**:** Identification of prominent themes in total of 42 categories. The comprehension is deferred as much as possible to retain the originality of thought through exact verbatim.

Step 2: A tally is allotted to each verbatim as to how many number of times each verbatim is appearing during interviews and multiple times across the same respondents. Even though the tally number varies between 2 to 8, it helped identifying priority themes to be considered in detail survey.

Step 3: The primary themes having tally 6 to 8 were considered as prime themes and comprehension is carried out for rest of the images in the light of most prominent themes.

Step 4: Description is developed based on prominent themes in the research report.

l) Tools used for data analysis

Statistical tool of Chi-square testing was used from an on line tabulation and analysis on website given below. Regression analysis is carried out in Microsoft excel. Tabulation of data was done manually and consolidation of data is done in spread sheet.

http://www.physics.csbsju.edu/stats/contingency_NROW_NCOLUMN_form.html

m) Limitation of methodology used

1. Sufficient attempt has been made to ensure the representation of all stake holders in interviewing and surveying, still there has been some limitation because of representation of respondents within a city of Bangalore under study.
2. Representative from all segment of solar companies have been tried to be included in interview or survey still some non-response bias might have occurred, since not all respondents responded to interview and survey.
3. Senior management people had limitation in terms of giving sufficient time to complete the interview. A shorter version of interviewing is also used based on the availability of their time.
4. Depending on respondent's role and seniority, there were some particular views; researcher tried to balance such views based on overall responses, but can have some limitations in terms of views leveling.
5. It is tried to interview respondents on an day of weekly off or a convenient time in their calendar, but some interviews carried out in office time in presence of their staff. This can limit some openness and transparent flow of views.
6. Some of the commonly used term in supply chain methodology is not uniformly understood by all respondents. An attempt has been made to help them comprehend as much as possible.

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Chapter – 5: Analysis, Interpretation and Discussion

5.1 Testing, Interpretation and comments on Hypothesis -1

5.2 Interview Insight & discussion on Hypothesis -1

5.3 Testing, Interpretation and comments on Hypothesis -2

5.4 Interview Insight & discussion on Hypothesis -2

5.5 Testing, Interpretation and comments on Hypothesis -3

5.6 Interview Insight and discussion on Hypothesis -3

5.7 Testing, Interpretation and comments on Hypothesis -4

This chapter includes data interpretation, testing of hypothesis based on data collected during interviews and survey of solar supply chain participants. Chapter is categorized is such a way that all relevant quantitative descriptions, hypothesis tests and explanations based on qualitative information received from respondents are presented into one section for better comprehension. Qualitative data received from respondents are grouped into emerging themes based on their logical groups. Quantitative tabulation, graphs and various statistical tests on data received from surveys are linked to the emerging themes during interviews. Grouping of theme is based on interview responses, not based on objective survey, is on account of most prominent information, as respondents during interviews were subject matter expert involved fully into day to day supply chain planning across solar industry. Survey respondents include additional respondents who are observing solar industry. Combination of survey along with interviewing is to increase the quantitative data base to prove stated hypothesis in research. Since survey questionnaire is prepared based on initial interviews, so it made more sense to group the titles based on prominent themes emerging during the interviews.

Interview questionnaires were grouped among four primary hypotheses, consisting of context setting related to information being sought, creating images in the mind of respondents and sometime putting leading questions to get the precise information being sought to test of hypothesis. This chapter is divided into four major sections based on hypothesis to be tested.

5.1 Testing, Interpretation and comments on Hypothesis -1

HA 1: Supply chain planning process for solar manufacturer/supplier need a **wider view of global & domestic supplies**, as critical inputs for effective planning.

This hypothesis has four main attributes related to supply chain planning. These attributes are explained as below before discussion on each hypothesis.

a) **Solar supply chain planning process:** Supply chain planning process is a chain of planning events to ensure required material under planning reaches to customer on time by involving multiple players influencing decision. These internal players are sales, procurement, design and engineering. Sometimes very senior officers in a solar organization take role of an important player.

   During the study, this process has a start and end which sometime is very vaguely defined in industry. The definition of starting and ending this process vary from solar organization to organization or from time to time. For the purpose of research, we are not making an attempt to define it accurately; else main theme of "critical inputs from width variables" involved in the planning process, may get deviated. Defining it accurately and then collecting information may still creates varied images in the mind of respondents and research focus may get wasted more in elaboration, then collecting information related to planning inputs. In some organization planning process starts when policy to promote solar energy is announced by state, other starts when customer order is under discussion or at different stages of order confirmation or cash advance received etc. In similar way, some solar organization has an understanding of planning process is over once all high value material reaches on customer site or some consider it close when site is fully complete and running. Keeping this in mind we are avoiding getting into an exact defined scope of planning process.

b) **Wider view of global and domestic supplies:** This attributes describes the availability, pricing, qualitative and technologically advancement and ease of financing in a country for solar products, being acquired by customers from domestic (India) and global sources. Product off-take (purchase) by customer is a function of availability, pricing, qualitative and technologically advancement and ease of financing in a country at a given point of time.

c) **Critical Inputs:** A critical inputs for planning refers to an input necessary to be evaluated before various decisions on planning process to optimize the outcomes.

d) **Effective supply chain planning:** A planning is a sequence of optimization decisions like what to order, in what quantity at what time to reduce overall cost of material, stocking, logistic and procurement. An effective planning leads to increase in overall surplus for an organization. The surplus is in terms of more profit margin & customer satisfaction.

During the testing of this hypothesis, it is assumed that all other supply chain planning variables mentioned in the literatures are impacting but "width of global supplies" visibility, as defined above, is "critical inputs" to be considered additionally before planning a source of material.

Testing of this hypothesis it is considered that planning material supplies has following salient attributes to decide the source of procurement – Easy availability, Price, and Quality & Technology. Following sub-hypotheses is stated as below to prove that each of these elements

HA: 01:01: Planning source of solar material is dependent on attributes of procurement (Availability, Price and Quality & Technology) in solar industry.

The data assessment into three categories as basic factor of supply chain "width" is assessed as Availability, Price and Quality & Technology in solar industry as an independent factors, whereas planning decision as a dependent variable. The relationship with these variables indicated in below Tabulation of survey responses in Chi-square format is as below

TABLE 5-1: Relationship between Procurement factor and planning preference

Planning Procurement Factor	Decision – YES (rated 4 & 5 on scale of 1 to 5) "A"	Decision – NO (Rated 1 to 3 on a scale of 1 to 5) "B"
Easy availability	201	96
Price	254	43
Quality/Technology	196	101

The results of a contingency table Chi-square statistical test performed.

Data: contingency table

	A	B	Total
1	201	96	297
2	254	43	297
3	196	101	297
	651	240	891

Expected: contingency table

	A	B
1	217	80.0
2	217	80.0
3	217	80.0

Chi-square = 35.3

Degrees of freedom = 2

Probability = 0.000

This Chi-square tabulation has a P-value = 0.0

Null Hypothesis of "no relationship between row and column variable" has to be rejected

Our interview data indicates that global solar products have much easier availability on account of more capacities than demand. Chinese player stocks material to make it available to any global demand immediately on receipt of order from any part of the world. This is a cause for almost zero manufacturing lead time in case of solar cells and modules. Domestic planners are leveraging on the stocks kept by these Chinese suppliers on your own cost of stocking. Interviews with the respondent reveal that it is only a shipping time experienced by purchaser from global sources in most of the cases. Domestic solar capacity takes a longer lead time to start and manufacture, since these domestic manufacturers procure raw material for modules and cell from same global suppliers who can supply fully manufactured solar modules. There is a high degree of dependency for raw material from the same set of suppliers from the same countries who supplies ready solar cells or modules. Since most of the domestic manufacturing has a long start time, it is convenient to plan and procure finished solar material from global sources at a price cheaper than domestic cells and modules.

The table below (Financial Year 2014-15) shows comparison of indicative prices, supportive policy environment and relative market sizes in their respective country for local consumption. Lower prices, availability in large volume and lower demand in their domestic market leads to easy availability for global consumption. This trend is incentivizing Indian solar planners to source from global sources as against domestic Indian manufacturers.

TABLE 5-2: Global market, price and policy comparison

Markets ->	**USA**	**Europe**	**India**		
			Imported from China	*Indian modules with Chinese cells*	*Indian modules with Indian cells*
Landed price (US$/W)	$0.72-$0.78	$0.66-$0.72	$0.55-$0.60	$0.58-$0.64	$0.70-$0.73
Policy environment	• ADD imposed against China in 2012 • Revised upwards in 2014, included Taiwan	• Imposed ADD against China in 2013 • Negotiated a settlement with China with a Minimum Import Price (MIP)	No restrictions	MNRE capital subsidy market (Projects & Products)	JNNSM Ph2 Batch 1 DCR carve out
Market size in 2014	5-6 GW	9-10 GW	600-700 MW	40-50 MW	375 MW

Prices of procuring modules from China is only \$0.55-\$0.60 as against Indian modules with Indian cell \$0.7- \$0.73, which is about 27% more. These extremely low prices from China sometimes becoming case for Anti-dumping duty imposition or minimum import prices (MIP) in developed country like USA and Europe. India is not having any such restriction therefore planners has an opportunity to source from this low priced country. Indian solar market size is much smaller than the market size of other countries, forcing an immature supply capacities and dependencies on large capacities countries that enjoy a number of factors helping to reduce cost and economies of scale. The global countries are ahead on technological and product quality development of solar products as they had been in the fray for a longer time than Indian solar manufacturers.

A large capacity of solar modules and lesser in-house consumption leads to price drop worldwide solar market and flow of solar product inclined from low cost market to high cost market. The inflow of such a low cost material is being fought with a DCR and ADD. The below Chi-Square tabulation suggest a strong preference towards global supplies as compare to domestic by existing industry players.

TABLE 5-3: Planning Procurement Factors and preference to global or domestic supplies

Planning Procurement Factor	**Prefer Global Supplies "A"**	**Prefer Domestic Supplies "B"**
Easy availability	176	121
Price	273	24
Quality/Technology	205	92

The results of a contingency table Chi-square statistical test performed.
Data: Contingency table

	A	B	Total
1	176	121	297
2	273	24	297
3	205	92	297
	654	237	891

Expected: contingency table

	A	B
1	218	79.0
2	218	79.0
3	218	79.0

Chi-square = 85.5
Degrees of freedom = 2
Probability = 0.000

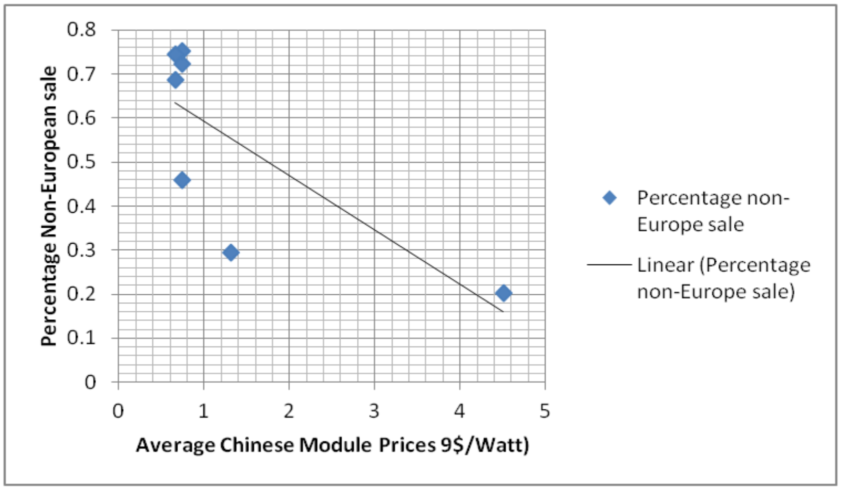
This Chi-square tabulation has a P-value = 0.0

Null Hypothesis of "no relationship between row and column variable" has to be rejected.

Europe had been a largest consumer of solar modules and a majority of global production used to get sold in European territory. The below secondary data estimate (Photon consulting, solar annual 2013 page 4 & 13) shows as to how average prices of Chinese solar modules suppliers are changing and non-Europe supply share in increasing. One of such destination is India where this Chinese module supply is landing.

TABLE 5-4: Relationship between Chinese Prices and Non-European sale

Year	**Average Chinese Module Prices ($/W)**	**Percentage non-Europe sale**
2010	4.5	0.203125
2011	1.31	0.294964
2012	0.74	0.459064
2013	0.66	0.6875
2014	0.73	0.722222
2015	0.74	0.752418
2016	0.66	0.744879



GRAPH 5-1: Correlation between Chinese Prices and percentage non-European sale

TABLE 5-5: Regression Table showing strength of correlation of graph 5-1

SUMMARY OUTPUT						
Regression Statistics						
Multiple R	0.757074253					
R Square	0.573161425					
Adjusted R Square	0.48779371					
Standard Error	0.165570526					
Observations	7					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	0.184055735	0.184055735	6.714030305	0.048769227	
Residual	5	0.137067996	0.027413599			
Total	6	0.321123731				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.717249523	0.089343336	8.028013671	0.000484892	0.487585166	0.94691388
X Variable 1	-0.123830228	0.047789779	-2.591144594	0.048769227	-0.246677767	-0.00098269

The regression analysis above indicate that estimated R-square is 57.3%, thus only 57 % of variation in volume of solar modules going out of European countries can have relationship with the price point offered by China. Rest variation may be described by other variables. P-Value of intercept and share of global sale is 0.0004 and 0.048 indicates that null hypothesis of no relationship can be rejected.

HA: 01:02: Comparative domestic and global supply view increases the domestic planning complexities.

Our interviews revealed that to manage supplies from global sources, a number of global as well as domestic factors need to be tracked continuously before placing an order. These factors are derived from prevailing regulatory framework, laid down to support domestic solar developers and domestic solar industry by state. For example, in India, state offers financial support in various forms if solar module, cell or both are domestically manufactured. Similarly sometimes state support is applicable for a particular solar technology. For example, in Phase-I of JNNSM, thin film solar modules were excluded from domestic content requirements. This framework incentivized more thin film based technology deployment to minimize cost of solar projects. Domestically manufactured C-Si based technology was more expensive even after domestic capital subsidy. Solar developers had more thin film based solar power plant before JNNSM Phase-I batch –II, when the subsidy is offered on both Crystalline Silicon and Thin-film based technology.

During Aug-2014, there was a plan to impose an anti dumping duty on solar modules procured from outside country by ministry of commerce. Anticipations were on for about three months July to Sep, 2014 till finally it is decided not to impose. In a situation of ADD, supply source could have been shifted completely towards domestic suppliers from global suppliers.

Such drastic expected shifts in decision of sourcing involve senior management and liaisons across the solar industry, to act as a planner to take such risky decisions. Role of planners in such an uncertain situation is very wide, may be difficult to handle by routine operational planners. For manufacturers, it is positive news but for a solar project developers or EPC contractors, it may lead to increase in cost of domestic solar modules. Such complex planning view is taken by a senior management who is more knowledgeable and has better connect with the industry and state regulator. Even in some routine high value project material procurement, it is observed that senior management get involved in planning to decide source of supplies. The idea of involvement of senior leaders is to ensure latest development of recent regulatory situations, cost, technology and availability is considered, which might have been overlooked by routine operation planners.

State decides regulation and solar support framework, depending on solar market, sustainability in the country and promotion of domestic developers and manufacturer. State decisions are largely govern by three perspectives – development of inexhaustible solar energy sector, generation of employment and energy security of nation. Time to time state changes policy regulations in the forms of various inclusions and exclusion in their central and state government support mechanism. Following Chi-Square tabulation maps their relationship between various category of solar material and their planning decision by role in solar organizations. These roles are categorized as a operational material planner, senior management and at state regulator.

TABLE 5-6: Relation between type of material and planning decision by role

Material Category	**Material Planner "A"**	**Senior Management involvement in Planning "B"**	**State involvement in Planning "C"**
Solar cells & Modules	69	93	141
Solar BOS	83	111	103
Solar Products	200	64	33

The results of a contingency table Chi-square statistical test performed.

Data: contingency table

	A	B	C	Total
1	63	93	141	297
2	83	111	103	297
3	200	64	33	297
	346	268	277	891

Expected: contingency table

	A	B	C
1	115	89.3	92.3
2	115	89.3	92.3
3	115	89.3	92.3

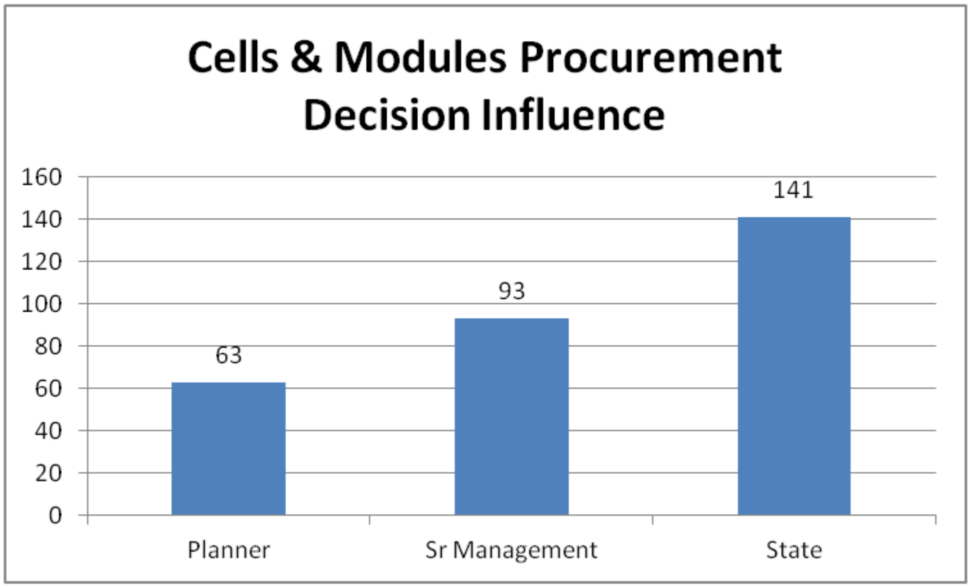
Chi-square = 173.

Degrees of freedom = 4

Probability = 0.000

This Chi-square tabulation has a P-value = 0.0

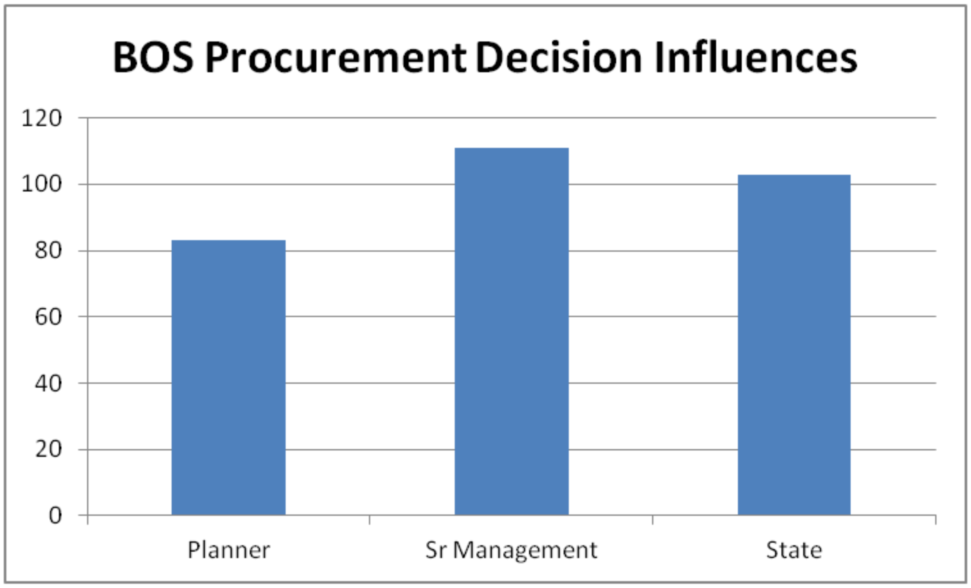
a) Most influential decision for planning Solar cells and modules



GRAPH 5-2: Influential decision of cells & module by role

The above graph shows that most influential decision of buying solar cells and modules is in the hand of "state", followed by senior management. This indicates that planner has a minimal decision making role in the procurement of cells and modules for solar application.

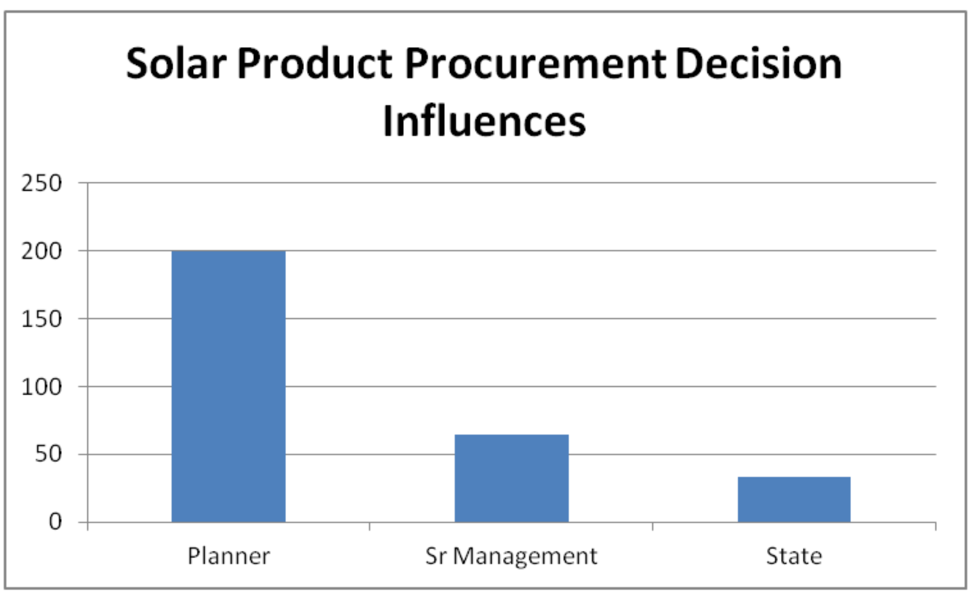
a) Most influential decision for planning Solar BOS



GRAPH 5-3: Influential decision of BOS by role

In BOS procurement the most prominent decision is of senior management in a solar company. State contribution is only to the tune of driving support by providing exemption in excise and custom duty support to some selected BOS items.

a) Most influential decision for planning Solar Products



GRAPH 5-4: Influential decision of solar products by role

In case of solar products procurement decision are mostly influenced by operational planners. This is a normal course in supply chain planning management like many FMCG supply chain planning.

HA: 01:03: Planning objectives of State is sustainability of supply chain whereas planning objective for material planner, is short term cost and availability leverage.

“Planning” by objective has different goals for state and by material planners. The hypothesis tests sustainability of solar supply chain as an objective of state, whereas cost and short term availability leveraged, as a goal of material planner, to meet short term solar project requirements.

Following Chi-square table is testing the hypothesis, whether primary decision driver is supply chain leverage - a primary objective, is related to type of planner in a solar industry or out of industry (state).

TABLE 5-7: Relationship between role and planning objective

Primary decision Role	**SCM Leverage – YES (“A”)**	**SCM Leverage – NO (“B”)**
Planner/Senior Management	213	85
State Planner	53	244

The results of a contingency table Chi-square statistical test performed.

Data: contingency table

	A	B	Total
1	213	85	298
2	53	244	297
	266	329	595

Expected: contingency table

	A	B
1	133	165
2	133	164

Chi-square = 173.
Degrees of freedom = 1
Probability = 0.000

This Chi-square tabulation has a P-value = 0.0

This means null hypothesis is rejected and there exists relationship between planning role and type of planning objective.

The below Chi-square tabulation is a reverse testing of hypothesis from the same responses asked questions in reverse orders and shows that the null hypothesis is rejected in this test also, emphasizing the primary planning roles are different for different planners type.

TABLE 5-8: Relationship between planning role and SCM sustainability objective

Primary decision Role	**SCM Sustainability – YES ("A")**	**SCM Sustainability – NO ("B")**
Planner/Senior Management	92	205
State Planner	196	101

The results of a contingency table Chi-square statistical test performed.

Data: contingency table

	A	B	Total
1	92	205	297
2	196	101	297
	288	306	594

Expected: contingency table

	A	B
1	144	153
2	144	153

Chi-square = 72.9

Degrees of freedom = 1

Probability = 0.000

This Chi-square tabulation has a P-value = 0.0

Material planning at a state level has a different objective than material planning by solar industry planners or senior management. State attempts to keep a long terms view of interest of sustainability of solar manufacturers and developers, whereas senior management as a planners anticipate and refine their planning decision depending on the state framework to maximize short term benefits. An operational material planner makes decision on a routine pattern, established based on stable trend by state and senior management.

This situation is completely contrary to a operational material planning wherein all given situations are based on demand and supply. In such situations, operational material planner's role is complex which includes three levels of planning decisions for solar industry.

HA: 01:04: Domestic material stocking in the form of raw material or finished goods depends on availability factor globally.

The below Chi-Square tabulation draws relationship between approach of stocking and global availability

TABLE 5-9: Primary decision driver of stocking from global and domestic source

	Primary decision driver	Global Availability	Domestic Availability
Stocking Approach	Yes	181	116
	No	133	164

The results of a contingency table Chi-square statistical test performed.

Data: contingency table

	A	B	Total
1	181	116	297
2	133	164	297
	314	280	594

Expected: contingency table

	A	B
1	157	140
2	157	140

Chi-square = 15.6

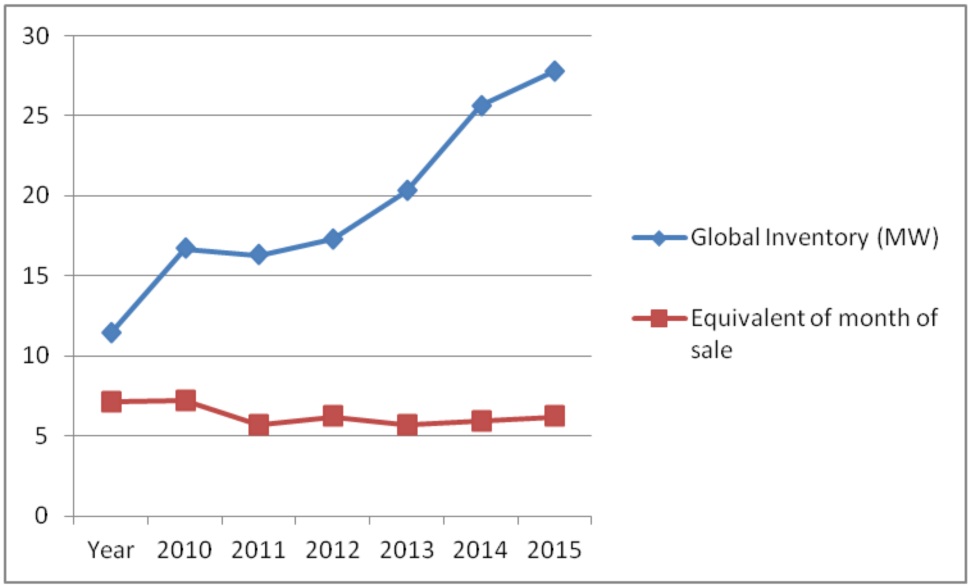
Degrees of freedom = 1

Probability = 0.000

This Chi-square tabulation has a P-value = 0.0

The null hypothesis is rejected. It shows that domestic and global stock confidence is related to ensure availability in the view of solar industry. There seems to have more confidence on global stocks than the stocks expected to be available domestically.

The following is inventories as estimated by (Photon Consulting I Solar Annual 2013: Build your Empire - page 66)



GRAPH 5-5: Pattern of global and sale equivalent inventories

A trend depicted above shows increase in global inventory giving more confidence to planners on availability and at the same time putting pressure on global prices of cells and modules

It is observed that solar manufacturers, EPC players or developers are completely relying on global stocking. Planners have a very good confidence of this stock availability. Though these stocks are available at a far off- distance. A quick transport turnaround and lower than domestic price leads planners to trade off a small extra cost of procurement in order to avoid risk of stocking domestically.

HA: 01:05: Off the shelf solar product planning is more effective at local place of demand than at national aggregated demand.

Solar products are used by rural a customer who have limited grid connectivity. Solar products being sold in such areas follow a very local level planning to meet the requirements of a given geographical region.

Majority of solar product demand is supported by central as well as state level policies. These support policies promote such solar products under the categories of home lighting, street lighting, power packs or irrigation pumps. State to state demand trend varies and thus local level product integrators are emerging as more successful in managing a low cost supply chain than a national level player aggregating demand and planning at a national level. A solar product stock adequate enough to meet local demand at the place of consumption requires planning locally. The demand of solar products varies from time to time and geography to geography. Even though the source of solar components going into products can be locally or globally sourced, need varies from state to state and place to place. Respondents feel that a more effective planning takes place at a local level of solar product integration as compare to national level. Different solar products have different level of complexities and thus affected almost equally by domestic and global price and availability. The below Chi-Square tabulation proves the hypothesis.

TABLE 5-10: Relationship between planning hierarchy and decision effectiveness

Primary decision level	**Model Effective – YES ("A")**	**Model Effective – NO ("B")**
Local Level	234	53
National Level	108	189

The results of a contingency table Chi-square statistical test performed.

Data: contingency table

	A	B	Total
1	234	63	297
2	108	189	297
	342	252	594

Expected: contingency table

	A	B
1	171	126
2	171	126

Chi-square = 109.

Degrees of freedom = 1

Probability = 0.000

This Chi-square tabulation has a P-value = 0.0

Thus null hypothesis is rejected and alternate hypothesis that local level planning is more effective in solar product planning is accepted. Following follow up Chi-Square is tested to conclude whether source of supplies from global or local sources also have any impact on choosing local or national level aggregated planning.

TABLE 5-11: Relationship between planning hierarchy and global sourcing

Primary decision level	**Global Supplies – YES (“A”)**	**Global Supplies – NO (“B”)**
Local Level	162	135
National Level	152	145

The results of a contingency table Chi-square statistical test performed.

Data: contingency table

	A	B	Total
1	162	135	297
2	152	145	297
	314	280	594

Expected: contingency table

	A	B
1	157	140
2	157	140

Chi-square = 0.676

Degrees of freedom = 1

Probability = 0.411

This Chi-square tabulation has a P-value = 0.411

TABLE 5-12: Relationship between planning hierarchy and domestic sourcing

Primary decision driver	**Domestic Supplies - YES**	**Domestic Supplies - NO**
Local Level	131	166
National Level	122	175

The results of a contingency table Chi-square statistical test performed.

Data: contingency table

	A	B	Total
1	131	166	297
2	122	175	297
	253	341	594

Expected: contingency table

	A	B
1	127	171
2	127	171

Chi-square = 0.558

Degrees of freedom = 1

Probability = 0.455

This Chi-square tabulation has a P-value = 0.455

Second Chi-Square tabulation explains that local or national level planning is not affected by global supplies. This indicates that even though local level solar material planning is more successful, role of global or domestic supplies is almost inexistent. Either from global or from domestic sources, planning model at local level is more successful and effective.

5.2 Interview Insight & discussion on Hypothesis -1

Solar modules, used in projects are procured primarily based on competitive prices available globally. Factors like technology, reliability and quality takes second priority while planning procurement source for modules, contributing about 50% of the value in entire solar installation. A natural procurement decision, based on market competitive price is from China and Taiwan on account of lowest available price as compared to some of the developed solar equipment manufacturing industries in Europe and USA, competing in solar supplies across global market. Natural inclination to procure from low cost countries is a short term cost benefit objective achievement. Planners having long term objective of success, arising out of short lead time, flexibility of customization and getting a better aftermarket service support is seen as constraints, even though such a low cost is very attractive in short term. Procuring from Chinese countries is beneficial to solar project developers but solar manufacturers are having tough time to manage their sustainable business since they have dependencies on lead time, design customization and post sale services. Prime reason for non-sustainable solar supplies from domestic suppliers is on account of skewed financial support towards solar project developers in comparison to solar manufacturers. Thus supply chain surplus is not getting distributed to across all the supply chain stakeholders. Solar manufacturers are less sustainable business than developers during the period of study. Planners have a daunting long term latent need to develop a value creation nearest to their use; despite they are favoring sourcing from China to meet a short term cost objective. Long term objective of procuring locally and developing manufacturers and suppliers is beyond the purview of planner sitting inside the organization. Existing price difference between Chinese and Indian solar modules does not allow planners to even consider local manufactured modules. Long term planning role is shifting towards state, to ensure a long term value creation from point of view of domestic solar supply chain sustainability. Planners role keep on shifting from a lower hierarchical of planner to senior most people inside a company, to plan source of material - local or global manufacturers. Central government ministry MNRE plays a role of strong planner for sustaining supply chain in the country. Evolution of

JNNSM is an attempt by central government to take the role of planner by laying down multiple support frameworks to meet long term supply chain objective, along with short term objective being achieved by planners inside solar industry.

Developed low cost global suppliers enjoy high end of technology, highly skilled manpower and large volume to become global solar supplies giant overpowering small domestic manufacturers. State is trying to give a level playing field in some of such areas of technology, skill of manpower and financial support but still the same cannot be replicated in a short period of time. These initiatives are being launched in a phased manner under JNNSM and various state level policies. These state initiatives promote a strong solar infrastructure in the country like development of latest production plant, equipment, machinery and skilled manpower. The development of solar supply chain in the country is overpowered by other developed country solar supply chain, can only be neutralize by state planners. These planners take multiple decision regarding supplies to meet the current need and ensure securing supply chain in future. A strong outlook of solar energy demand in India in a period of about 5 year from 2010-2015 is attributed to mixed planning, growing from industry planner dominated to state planners dominated.

State Planners have an additional role to influence demand which is not the case with industry planners. Role of industry planners is to support with the supplies against an independent demand. A state planner function is more effective not only in creating demand but also directing supply sources by creating differentiation of support based on source. Solar energy to larger masses like rural electrification and community lighting is a latent demand in India since conventional electricity is not reaching in sufficient quantity to people across far flanged areas. This demand was latent till such time when solar products were put into their life. Solar has come up as an alternate to conventional power providing clean and more effective power as compare to fuels like kerosene. Rural electrification has come up as a big market in last 5 years and has expected demand of about INR. 1000 Cr. per annum. On other hand, larger level concern for energy security and climate change objective pushing state to create demand for large scale solar energy generating products. Off-grid rural solar products demand evolved with a supply planning first, whereas large projects evolved with a demand planning as a starting point.

Customers in rural areas experienced these products and find benefiting later on demand started getting boost with more and more number of rural customers started using solar energy either by self funding or by state financial assistance. Large solar projects are replacing conventional energy with clean and renewable sources of energy. Both these objectives helped in creating more overall demand in market. In case of large scale solar projects, domestic supplies could not keep pace with the demand side, as imported solar equipments were available at much lower landed cost than domestically manufactured one. The condition is extremely ironic; supply side is getting ruined by extra ordinary capacities and low cost global availability. In fact supply side is growing with a demand but in some other part of globe, may not be at the point of demand in domestic market.

A supply chain planner works on a concept called base and peak demand. Base demand in a typical supply chain caters to minimum assured demand without any risk of keeping inventory stock. Peak demand is a function of seasonal and other demand factors like seasonality or some specific extra need driven by any particular or combination of factors. In solar supply chain, managing large utility scale project, there is difficulty in arriving at the base and peak demand. End utilization of solar equipment, is increasing multifold year on year. Solar planners wishing to cater immediate availability to solar project developers are in a major dilemma since they are not sure about the anticipated demand. For example, a planner planning a base stock to meet demand is not sure if the stocked solar modules prices will remain constant or the stock purchase is not creating a risk to organization. Continuously falling prices are biggest risk to plan for a base demand. Another risk driver to plan for base stock is instability of foreign exchange. These factors are driving planners to make small window of planning say plan base on demand, a horizon no longer than two to three months. These planners are compromising all matured supply chain learning like economies of scale, creating more availability to increase demand or planning local capacities which may be low efficient on account of falling global prices and fast outdating technology.

Year on year increasing solar project demand trend suggest a continuous increase in base demand. It provides planners an opportunity to keep on planning for peak demand safely. Despite this increasing demand trends planners are avoiding planning stock sufficient enough to meet base demand for large utility scale solar projects. On other hand, comparison of base stock in rural solar lighting and power systems are being managed with some base stocks in the entire supply chain, even though the major supplies in rural product segment is also sourced from China. Planners managing off-grid solar product supplies are catering to good portion of natural demand, having a more predictable trend than a utility scale large solar project, despite major procurement from China like large solar project scale procurement.

a) A part of solar module manufacturing is done in India to cater to some of the demand planned by state planners under DCR scheme or use of domestic modules by some of state owned companies and PSUs. Modules manufactured in India also have solar cells; a major imported components, until and unless specified to use domestically manufactured cells. Even if the cell is manufactured in India, major raw material, wafer, is imported from China. This indicates that the capacity available in India has large dependency on global supplies especially from China. Worldwide capacity of wafer production is limited, thus price, a major factor for determining source of procurement is more stable than cells or modules. As a raw material wafer level base stock planning is considered more efficient than planning at cell or module level. Chinese cell manufacturers' procurement wafers in much larger quantity than cell manufacturers in India.

   Very nature of Indian fragmented solar manufacturer, not allowing any demand aggregation to take place to get advantage of economies of scale. Second reason for uncertainty of use of domestically manufactured cells itself, which can only be used if state planners, planned its use in domestic modules. Such opportunity of managing base stock is practically not at discretion of solar cells planners in India.

b) Indian module or cell manufacturer keep a base stock of long lead item raw material for production. Raw material for base stocking like EVA & back sheets to be used to manufacture solar modules, are planned for base demand. These items do not block major liquidity and have flexibility to use in any size of solar modules production, varying from small modules used in off-grid products to modules used in large scale projects. Other raw material for manufacturing of module orders is procured back to back depending on time of delivery.

TABLE 5-13: Major solar supplies and their supplies

	Modules	Projects	Products
Major Suppliers and Partners	**Wafer-** Osung, Nexelon **Equipments** – Komax, Centrotherm **Silver-** DuPont **Backsheet-** Mitsubishi **EVA sheet-** STR	**Inverters** – ABB, Vacon, SMA **Structures** – Pennar, Ganges **Cables** – KEI, Polycab **BOS** – GE **Panels-** Canadian Solar, Emmvee	**Inverters** – East power, Consul, Amararaja **Battery** – Amararaja, HBL, SBL, Exide **Lighting** – Philips, Promptec, Fujian **Pumps –** Lorentz, Rotomag, CRI **VFD -** Vacon, Delta **Structures-** Ganges

c) Low value raw material like modules frames and glass, are readily available for multiple domestic suppliers at a competitive prices. The reason for difference in easy availability of such material as compare to other material used in manufacturing of solar modules is universal nature of these raw materials. These raw materials are used in abundance in non-solar application. Planners are always in a better position to keep a base stock due to its nature of long obsolescence period. Domestic material like frames and glasses can be procured with much better flexibility than other imported material procured from China and other countries. Even though small in value but supply chain of such raw material is close to managing by a typical raw material planners, without involvement of any senior management representative in industry or by a state planners.

d) Major global supplies lead time for manufacturing of modules as expressed by planners during our interviews are as follows. The table below suggests that with a lead time, between 10 -15 weeks, planners are reluctant to keep a base demand material till such time they have firm supply order in hand. We could not see during our interview companies are operating at a base stock more than 6 weeks as against lead time of 10 -15 weeks for replenishment.

TABLE 5-14: Solar Material and illustrative lead time

Supplier	Category	Manufacturing Lead Time	Transit Lead Time	Total Lead time
Jiangsu Akcome Solar Science & Technology Co. Ltd.	Frames	6	4	10
Bizlink	Junction Box	5	5	10
Hennan Glass	Glass	6	4	10
First EVA	EVA	7	4	11
Henkel Pune	Sealant	6	6	12
STR Malaysia	Crane EVA	8	4	12
Mitsubishi Polyester Film, Inc	Polyester	8	6	14
Sunshow	TCI	10	5	15

e) **Solar PV Product:** In PV product supply chain planning, like solar lantern, home lighting systems, street lighting systems and power packs, a large part of integration design engineering dependency is on global suppliers. A low cost readily available product is a need to satisfy a typical rural customer, having limited affordability. There are two ways to plan fulfillment of such products to customers, one by directly importing complete integrated products, and other is to procure components and integrate locally. Most of solar products in the market are being sold under some or other state supported financial assistance. State has laid out specification to be met for such products before its launch to avail financial assistance schemes. Planners factor-in opportunity to customize either completely imported or locally integrated product from localization perspective to meet state laid down specifications. Heavy components like storage batteries are procured locally to avoid cost of inbound transportation, which may make it more expensive at the point of use, because of additional logistic cost. In product supply chain planning, it seems there is mix of local and global participation in value chain to some better reasonable extent than large scale manufacturing of cell, modules or setting up utility scale projects.

Local solar product integrators are able to better manage availability in local market due to timely information and fast turnaround time of demanded products than a global sourcing dependent integrator.

Some branded products being supplied by national players have a huge market demand in retail but these players are lacking in distribution network. More local companies like D-Light, Green Planet, Topson, Warie etc. are having much better availability in lantern segment and lighting segment. For example District level reach of national players is extremely limited than a local level players.

Planners, in national level solar companies, have an option to flood market with products to increase availability and thus demand but they perceive high risk of inventory obsolescence. The obsolescence is on account of more innovative products in-flow on a continuous basis, low cost local products, or long average sitting inventory without movement. Planners from these national level integrators follow a cautious approach to avoid such inventory obsolescence. As market awareness on solar product will go up, suppliers will face challenges of availability even more than what they are now. Supply Chain of local players is in better position to manage the pull by having a continuous stock replenishment from Chinese sources than domestic integrators. Planners from domestic distribution or integration companies, local level players, have a complete different approach to supply chain planning than a national level player who is more cautious on account of less flexibility on managing latest product and aggressive price points for customers.

Interviews with planners indicate that a trend of local level integrators will manage supply chain more efficiently than those who are integrating at national level with purchased modules from manufacturers. These module manufacturers may even be national level players. This model is more efficient as against integrating product at national level and distributing across country. A national level players can be successful if invest very regional level warehousing and integration facility to cater to the need of local players. These warehouses can either procure locally or in multiple lots from other ASEAN countries like China. In such distributed supply chain network, local level supply chain planners play a vital role than national level central planners. Central planners can help these local level planners to manage aggregation and exploit some more economy of scales.

5.3 Testing, Interpretation and comments on Hypothesis -2

HA 2: National and state level policy support to solar energy, to grow the sector, is a major width variable in supply chain planning.

During the study of prime driver of solar energy demand in India, it is found that JNNSM has played a major role. Though demand trend is correlated with the various stages and quantum of state policy support under JNNSM, split into three phases and multiple batches into each phase. It was cross surveyed whether the decision of state policy support is an input for supply chain planning and procurement decisions. Following sub-hypothesis were tabulated to establish relationship of policy support on variables of planning.

HA: 02:01: Solar demand is a function of "state regulations and support", thus an input to supply chain planning.

Support and policy for solar deployment can be traced back to year 2006 when National Tariff Policy included 0.25% of solar RPO to promote deployment of solar power in the country. As a next promotional step, National Action Plan on Climate Change (NAPCC – year 2011) increased 0.25% solar RPO to 3% by 2022. Third significant step towards to promote increase in solar deployment was in 2011 when NSM Phase-I, Batch -1 was announced. Batch -II of NSM announced immediately next year and continuously increase in level of solar deployment is taking place. Between years 2010 to 2013 a strong correlation is being seen in terms of solar installed capacity deployment and promotional policy support by state.

State regulations provides support in the form of regulation like various subsidy based on domestic content requirement, capital support, low or no excise and custom duties or various financing schemes etc. These factors derive demand for solar energy rather than factors like latent customer demand. Following correlation between demand and various phases and batches of JNNSM and state level schemes showing increase in demand, is plotted. The chart and relationship indicates that demand volume has grown substantially from year 2010 onward after state support structure, to grow sector is launched in year 2010. Before the year 2010, when there was no major focused planning from state, demand has remained extremely weak. A strong correlation value suggests that state regulations and support factors are significant one to decide demand in the country.

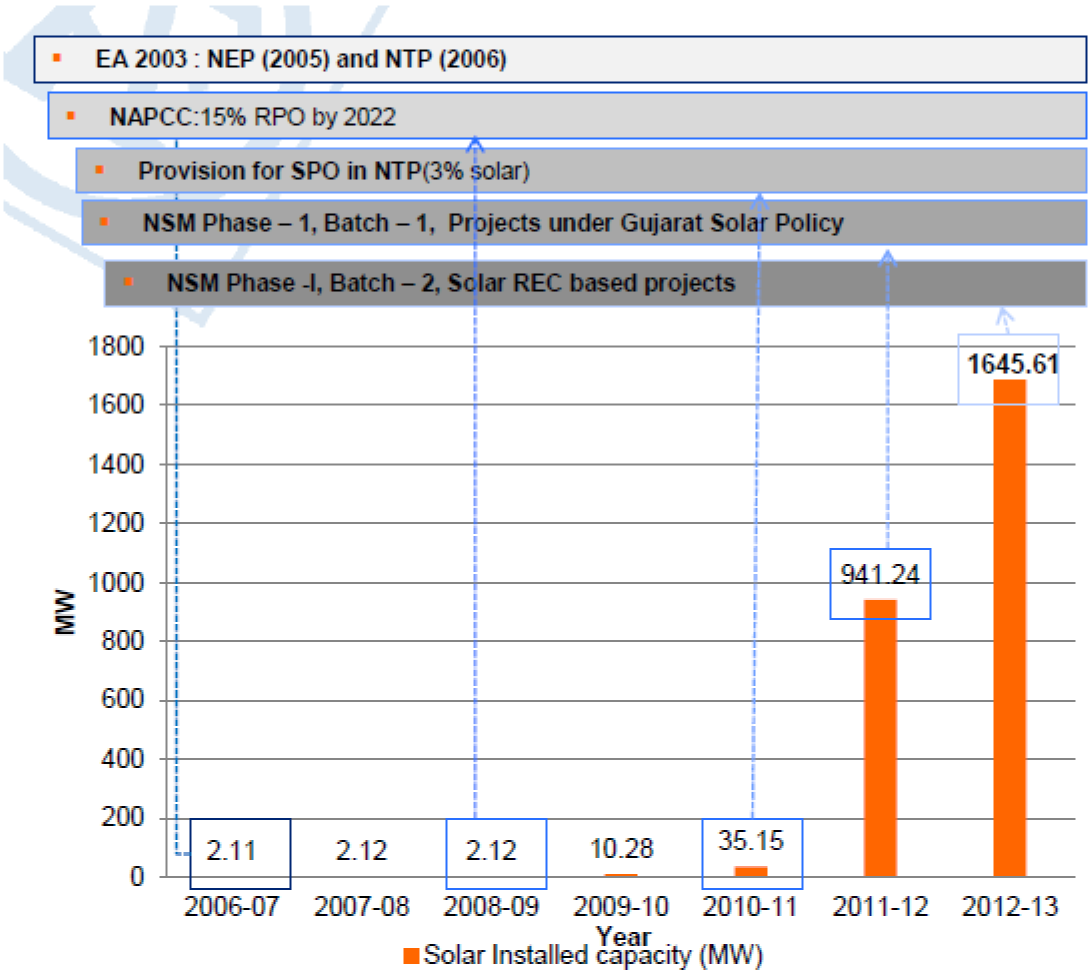
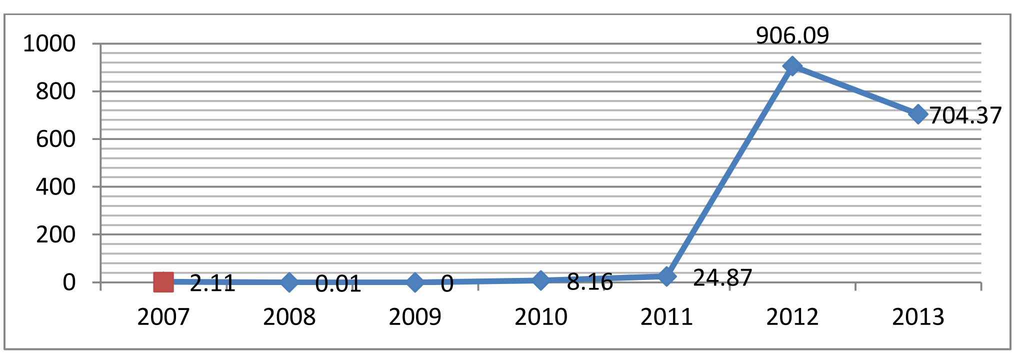


Fig 5-1: Mapping of solar installation versus extent of state support

Source: Anish De, AF - Mecados EMI, Hyderabad, May 23, 2013



GRAPH 5-6: Relationship between the solar installations and state support

HA: 02: 02: Natural demand factors are less significant than a state support derived demand in solar industry.

Natural demand signifies demand arising out of latent need of customers. A natural demand factor decides source and type of purchases independently, based on market factors like price, availability, quality and technology, as proved in hypothesis the HA01:01. In solar industry the market did not grow till major support is extended in year 2010, after the announcement of JNNSM. (Refer previous depiction). During previous years from year 2007 till 2010 natural demand factors were same still solar deployment was not picking up. Demand ramped up immediately after the announcement of JNNSM. This proves the hypothesis that during the period of study natural demand factors were weaker than the demand causing out of state support.

JNNSM focuses support to solar plant based on the domestic content requirement. State support was offered if plant was using domestically manufactured solar modules. JNNSM Phase-1 excluded thin film solar technology from domestic content requirement. As a consequence a lot of investment flown into thin film since it was cheaper to import even as compare to taking domestically manufactured Crystalline Silicon based solar modules in India. The above correlation between increases in demand of thin film as compare to C-Si is an indicator that natural demand factors are not so significant. Development of thin film took place during JNNSM in phase-1, despite of lower power generation efficiency of thin film based modules which was known from the beginning. Majority of solar project developers imported thin film modules because they were cheaper than India-made solar modules of crystalline silicon technology. In addition, developers got cheap project financing from Export- Import (EXIM) bank of the US, which mandated that to avail loan, they will have to import panels from the US. Around 50 per cent of the projects in batch-1 of the first phase of JNNSM were of imported thin film technology. The percentage increased to around 70% in batch-2 of the phase-1. On average, about 60% project investment of PV based solar technology took place in thin film based solar technology during phase-1. Contrary to Phase-1, both C-Si and thin film both included in DCR resulting in only 4% deployment of thin film based solar modules. Majority portion, 96% is into C-Si. A technology neutral solar technology deployment brought down overall thin film deployment to 13.5% in total installed base.

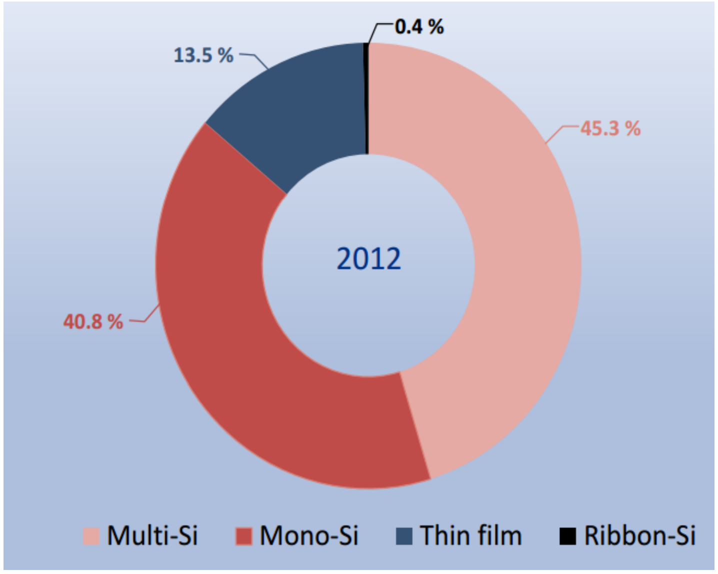


Fig 5-2: Share of solar installation split by technology of modules

(Source: Solar Energy Southeast Asia IMPACT Arena, Bangkok, Thailand, 10th Dec, 2013 23, 2013)

Below Chi-Square tabulation comparing development of type of solar technology promotion and difference in approach of support structure by government shows a dependence which further proves that natural factors of demand are less significant than support structure by state. Even during phase-1 consequences of support structure played completely opposite result than expected.

TABLE 5-15: Solar technology biased state support and share deployment

	Thin Film % share	**Non-thin film % Share**
Non inclusive thin film modules in JNNSM Support Phase-1	60	40
Inclusive thin film modules in JNSSM Support Phase-II	4	96

Data: contingency table

	A	B	Total
1	60	40	100
2	4	96	100
	64	136	200

Expected: contingency table

	A	B
1	32.0	68.0
2	32.0	68.0

Chi-square = 72.1
Degrees of freedom = 1
Probability = 0.000

5.4 Interview Insight & discussion on Hypothesis-2

There is hardly a natural demand arising out of latent customer need in utility scale large solar projects. This is an artificially created demand by state forces, for sustaining environment and meeting energy security need without any major risks like risk associated with nuclear energy generations. Some of the major winners of solar large projects in last few years are listed in the table. The below table shows that all major installations are supported by either central government or state government support irrespective of developers or EPC contractors as the end beneficiary.

TABLE 5-16: A depiction of various central and state solar programs and bid winners

Particulars	Allocation date	Announced (MW)	Tendered (MW)	PPA signed (MW)	Major winners
NSM Phase 1 batch 1 & 2	Batch 1 – Jan '11 Batch 2 - Feb '12	Solar PV 650 Solar Thermal 500	Solar PV 650 Solar Thermal 500	Solar PV 650 Solar Thermal 500	Welspun, Azure, Acme, Solairedirect, Lanco, Reliance Power, Essel infra, Green Infra, Mahindra Solar, Kiran Energy, Fonroche Energie, IOCL, GAIL, Sunborne, Sunedison, Punj Lloyd
Karnataka Phase 1	Phase 1 - Apr'12	200	80 – Phase 1	80	Lanco, Sunborne, Jindal Aluminium, Essel Infra, United telecom, Sai Sudhir
Madhya Pradesh Ph 1	May '12	225	225	200	Acme, Welspun, Moser Baer, Alfa Infra
Mahagenco	EPC – Sept '12	EPC – 150	EPC – 150	EPC – 150	EPC – Lanco, Megha Engg.
Rajasthan	Mar '13	600 (by 2017)	100	75	Essel mining, Energo Engg., Roha Dyechem, Sungold energy, Arjun green power, Star solar power
UP	June '13	500	200	140	Jakson, Moser Baer, Azure, Essel Infra, Reflex Energy, DK Infracon,
Tamil Nadu	June'13	3000	1000	~690	Mohan breweries, Sai Maithili, Sunedison, SAR capital, Welspun, Waaree, GRT Jewellers, Omikron, Rasi green, Alex green
Andhra Pradesh (before Telangana)	June '13	1000	1000	LOI: 600 MW PPA : 350 MW	Sunborne, New Generation Power, Maheshwari Mining, First Solar
Punjab	June '13	300	300	250	Azure, Welspun, Indiabulls,Moser Baer, Lanco, Essel Infra, Punj Lloyd, Solairedirect, Focal Energy, Supreme Infra, SAR Capital
Karnataka Ph 2	Jul'13	500	130 – Phase II 500 – Phase III	80 Yet to be signed	Welspun, Azure, Bhoruka power, Hero future energy, Acme,Waaree, Astonfield, Alfa Infra, Sharda Constructions
NSM Phase 2 batch 1	Feb '14	DCR – 375 MW Open – 375 MW	DCR – 375 MW Open – 375 MW	DCR – 355 MW Open – 355 MW	Welspun, Azure, Acme, IL & FS, Today Homes & Infra, Solairedirect, Waaree, Focal energy, Hero future energy, GPCL, GSECL, Sunedison, Belectric, KPCL, Fortum, Palimarwar, Sharda Constructions
Madhya Pradesh Ph 2	Feb '14	100	100 – Phase II	120	Today home & infra, Focal energy, Renew Power, KRBL, Bhadresh Power
Mahagenco	Revenue sharing – Apr'14	50	50	50	Welspun
Chattisgarh	May '14	100	100	100	Azure, Acme, Welspun, Waaree, Interocean

While our survey, we asked respondent as to how many projects are having driver as state support and how many of them are non-supported projects. Our results indicate majority of projects in the category of solar project or products from multiple level of respondents are showing relationship with the growth of the sector under state support mechanism.

- **Level playing field support announced by MNRE like DCR or anticipation of probable imposition of additional duty**

  Since there is a triggered demand by state forces, natural demand drivers are almost absent. Entire demand of utility scale solar project is derived from central and state government policy and regulations. A planner follows various demands triggering mechanism announced or expected to be announced at state and central government level. Following support mechanism have affected supply chain planning decision during last five years after announcement of famous JNNSM, having aggressive demand pushing capability. JNNSM acted as a most important demand driver in India, laying down foundation for an aggressive solar project deployment target. JNNSM outlines solar energy deployment target in India but the support mechanism provided is not firmed for long run. Being a new and learning of government, the course corrections is made almost every year in the mechanism of providing support to the sector. Since support structure from government changes year on year, planners cannot have a clear visibility of demand and potential procurement sources, creating a demand visibility not more than 2 years. Some of the support mechanism for development of solar energy is laid down into following buckets. These variables individually, or combination of more than one together, influences demand and sources of solar equipment procurement.

- **Supply Chain Planning Variables emerged to create a level playing field for Indian solar cell and module Manufacturers:** During recent years, India had more capacity than demand till year 2012, after the announcement of JNNSM in 2010, within 3 years of intended demand trigger. Any positive forecast based on just demand may not give favorable result for solar players e.g. demand trends showing increasing trend at a rate of 35% but still, solar manufacturing growth is not following an encouraging trend. Any demand forecast by extrapolation of demand trend can be deterrent to manufacturer. The biggest regulatory driver on the supply side pertains to level playing field to Indian solar manufacturers against manufacturers from some countries (e.g., China) that receive significant support from their host governments and subsequently dump their solar supplies in India e.g. in year 2013, the support to Indian manufacturers is being provided through "Domestic Content Requirement" (DCR). Under Batch-I of Phase-II, a total of 750 MW of solar PV projects were allotted to developers, of which 375 MW (50% of total size) were required to have domestically manufactured cells and modules. The Govt. of India was contemplating levying Anti-Dumping Duty (ADD) on import of solar supplies from select countries in year 2014, however decided not to impose ADD. Decision of usage of domestic content volume or a further ADD can leads to large forecast error for capacity creation based on prevailing announcement of DCR or ADD. Planner's iteration includes not only the Indian trend but also how regulatory environment in developed in solar industry over year's e. g Germany outpaced in roof top project by a favorable net metering policy. If the trend is followed in India for residential and commercial establishment, demand can get boost in roof top segment as well. In present situation India roof top deployment is less than 5% of solar deployment whereas in Germany, this ratio of solar deployment between roof top and ground mount large project is approximately 50:50. The difference is deployment level is on account of policy favor differences in India and Germany

A majority of solar components are presently either exempted or allowed concessional custom and excise duty. This helps in reducing the cost of production and thus helps in making Indian solar supplies price competitive.

Planner's role begins from a point when such policies of DCR, ADD or duty and excise exemption in proposal stage itself. Solar power developers and manufacturers lobby with the government to influence these variables. State tries to undertake multiple views of developers and suppliers to arrive on final conclusion of providing such support. Supply chain planners start watching government views, inclinations and favors influencing till such time support structure is announced. For example in Phase-I of JNNSM support domestic content was mandated for crystalline silicon (C-Si) based PV technology whereas thin film based PV project kept out of scope of domestic content requirement. Planners of solar projects shifted themselves to thin film demand planning more than C-Si based PV products, since they felt thin film without DCR is most effective than C-Si with support provided by government. This development was in contrary to the expectation. More capacities were installed by planners for thin film based solar projects than C-Si. It caused India to have about 50% installation of thin film based technology. In phase-2, taking learning from Phase-1, government mandated DCR for both C-Si and thin films. Now planners have their focus back to C-Si, since this is more cost effective and country has more utilizable domestic manufacturing capacity. Planners from module and cell manufacturing are now having base demand and peak demand defined from customers within 3-4 months of announcement of Phase-II. The planners are having a time which provides them an opportunity to have much smoother planning than before Phase-II announcement. Even in this situation, planners do not have visibility of module and cell demand for more than a year. Demand beyond a year is still having same uncertainty as it was before the announcement of JNNSM Phase-I. This causes planners in terms of avoiding capital investment is increasing capacity of manufacturing plants. For any increase in demand within a year is planned to be met by local outsourcing where the manufacturing firm is not bankable on their own. Still solar manufacturers are not able to decide on expansion of their manufacturing capacities. Outsourcing or contract manufacturing helps, unutilized manufacturing plant to utilize their investments and keep work force engaged. This helps contract manufacturers as well to recover their fixed cost as against not-utilizing their sunk investment in solar manufacturing. The planning process in this situation has a very limited vision. Though this helps in utilizing existing capacity in country, state planners have challenges of assessing how much domestic manufacturing capacity can be utilized cost effectively. Any plan for over utilization of domestic manufacturing capacity can be deterrent to developers to have financially viable projects since cost of products from these plants are higher than global market and quality may also be inferior. Respondents feel imposition of ADD could have led to un-viability of solar projects and the solar sector development can get retarded for the same reason. Planners kept a tab to factor in only domestically manufactured modules, after the time when ADD was proposed, till such time a final decision not to impose was announced by government. ADD imposing could have created altogether different planning variables for planners. Either all solar module procurement could have dependent on domestic manufacturing or solar sector could have been relatively unviable. In both the situation solar planner had multiple planning iterations immediately after announcement of ADD. Both the views had their merits and de-merits and solar players were divided on both the views. Manufacturing capacity forecast is much shorter in time horizon, say less than two year. Any attempt in betting on more than two year run with a risk of excess unutilized inventory or capacity. Any un-favorable policy, global prices for manufacturing can lead to these risks. Planning iterations cannot cover up for such high level of risks in investing in manufacturing.

- **Capital subsidy:** MNRE provides subsidy for various solar project categories including solar rooftops, off-grid installations and solar applications. These subsidies are extremely helpful to investors, as it help them make these solar segments commercially viable/ affordable to make investment. However, there are huge delays in availing the subsidy and getting project clearances due to funding un-availability. In the recent circulars, Ministry has hinted to gradually remove the subsidy and suggested its accredited channel partners to work out their plans to promote solar installations without subsidy. Delay is approval of such projects create uncertainty to in planning. Customers and solar installers are unsure about the time when project will get approved. The time of approval goes beyond sometimes beyond 4-5 months. During such times a planner do not have any clear visibility of approval. During the period of application, many orders get cancelled because customer cannot wait endlessly and has other option to invest. A planner has to incur inventory carrying cost for 4-5 months in case an advance planning is done to complete such pending projects on time immediately after approval of subsidy. On other hand, if material is not planned to execute project within six to 8 weeks of approval of subsidy, all project approval in one go will create shortage of material in the market since all solar player find it a peak time for installation as subsidy block approval takes place for all solar players to start installation for their investor. In general for such roof top projects, planners wait and refine their approach based on expected time of approval during first half of financial year. In second half or more specifically saying, in last quarter of financial year, all such approved project has to be installed to meet dead line of commissioning of such project before March 31. Such skewed planning leaves sub-optimal utilization of resources, plant and equipment of solar EPC contractor. Most of present roof top projects are under MNRE sponsored program and are expected to receive capital subsidy support. With an upcoming multiple state policies, having varying policies on capital subsidy and FiT in net-metering, role of planner is going to be even more complex, since planners has to keep watch on various state policies to plan material which meets investor expectation and March end deadlines to commission solar projects.

- **Net-metering:** Net metering helps in growth of rooftop solar segment as it allows the generator to export surplus solar power to the grid and to receive the incentive (either tariff for exported power or credit for exported power to be offset in subsequent consumption). So far, five states (Gujarat, Andhra Pradesh, Uttarakhand, Tamil Nadu and West Bengal) have finalized the net metering policies and others are in process of drafting the same. With the major development of solar roof top project in European country, there can be same trend of larger scale roof top installation in India. The speed of announcement of net-metering policy is going with a very slow pace; hence this variable is not playing a strong role in supply chain planning process at present. A few projects may get started in five states mentioned above, can have some planning implications as more and more state announce net-metering of solar power and large scale deployment of rooftop project takes place.

- **Renewable Purchase Obligation (RPO):** Considering that solar power is presently costlier than conventional power, a key driver towards growth of solar power is the solar RPO - a mandatory sourcing of specified percentage of total power from solar. As the obligated entities under RPO are the distribution companies, open access consumers and captive consumers, RPO typically helps in deployment of grid connected solar projects. However, a lack of penal action for non-compliance, the bad financial health of most obligated entities, non-co-operation of state regulators and an out-dated Renewable Energy Certificate (REC) pricing mechanism have prevented it from having a more direct impact on solar demand. The Indian government is trying to figure out ways to fix the RPO mechanism. Since this variable seems a weak variable to create substantial correlation with the planning complexities, planners are less focused on the obligations by various such entities. Going forward, with more stringent deployment and penal action, this variable may also need a watch by planners.
- **Tax incentives:** The two key tax incentives are accelerated depreciation benefit and tax holiday under Section 80 IA. These incentives help significantly in improving project financials and thus act as major catalyst in attracting a certain class of investors. AD benefit in an optional variable chosen by a set of customers. This factor does not create any skew in demand therefore most of planners don't give a special weight age to this variable in planning supply chain. Rather this variable creates s consistent and regular demand for solar power projects. Encouraging such support structure in future may help planner to have a consistent base demand throughout the year.

On the side aggregated demand for EPC players installing large utilities scale projects and solar roof top projects under capital subsidy or tax support scheme, create a consistent base demand at an aggregated level. These roof top projects are much smaller than large projects thus base demand created by these factors is almost immaterial. This is just sufficient for module & cell manufacturers to continue running their line without rusting. If this sector outgrow than large projects to the tune of European development of roof top solar projects, planner will have a clear base demand in their planning process. These developments will further mature solar supply chain processes.

5.5 Testing, Interpretation and comments on Hypothesis -3

HA 3: Existing practices of supply chain planning need more number of iterations to protect interest of buyers and sellers (stakeholders) than existing in practice.

In a matured supply chain it is expected that the number of iterations are minimum with a given level of supply chain surplus. A level of minimized iterations can be achieved in case of good demand visibility and minimal degree of changes in demand and supplies. In solar industry, demand and sources of supplies are dependent on state regulatory factors. It causes more number of iteration as compare to a typical seasoned supply chain like in FMCG, where demand and supply factors are matured and can be predicted more accurately.

In this hypothesis two main attributes used in discussion are explained as below

a) **"Number of Iteration"**: Iterations are defined as "number of changes" in the plan to optimize availability of material and optimize cost, without adversely impacting customer service, to ensure right material reaches at right time in right quantity. The number of iterations is performed by planners in the light of improving forecast and better customer requirements.

b) **"Interest of buyers and suppliers":** To improve overall supply chain cost and operating margin, planners in buyers and seller organization tries to manage availability of material precisely at the time when it is desired, at most optimum cost. The cost is inclusive of material, stocking, logistic and procurement cost.

c) "Existing practices in matured product demand & supply": A matured supply chain planning process is referred to a typical evolved FMCG organization model.

FMCG has built multiple planning forecasting and planning models in industry space. A Solar supply chain planning processes are compared with a FMCG supply chain planning.

Following nine sub-hypotheses, from HA 03:01 to HA 03:09 are formulated to compare number of iteration is solar industry as against being practices in FMCG industry. HA 03:01 is a basic hypothesis used to test the salient issue creating planning iteration in solar industry. Explanation of all nine hypotheses is substantiated based on survey data and interview responses, to establish an objective correlation, supported by their explanations. It was difficult to get a ready available data indicating number of iterations from solar organizations to prove hypothesis objectively. An estimate, based on multiple respondents and averaging them out was considered for hypothesis testing. On an average iterations in solar projects and product planning are captured under various hypotheses.

During the interview and surveys, stakeholders were asked about estimated number of iterations and then an arithmetic average is taken under following different solar segment categories. All the responses were averaged out to arrive on a number to be referred to.

Number of planning iterations in "existing practice" from FMCG, is benchmarked as 2, by speaking to a few FMCG planners. These planners work on forecast, which is sometimes revised once, just before the supply or twice in case sudden increase or decrease in demand anticipation. Planners in FMCG indicated that their average iterations are pegged at 2.

Number of iterative changes in small solar project (less than 1 MW), solar project (more than 1 MW) and solar products is referred as 8, 24 and 3 respectively. This is summarized in the table below.

TABLE 5-17: Relationship between solar business segment and planning iterations

Solar Business Segment	Average Iterative Changes
Small solar project (less than 1 MW)	8
Large solar project (more than 1 MW)	24
solar products	3

HA 03:01: Immature iterative design engineering, faster demand inflow than cash collection, inadequate safety stocks increases number of iterations.

This hypothesis is a basic hypothesis, explaining problem salient in solar industry. Issues of immature design and engineering, faster demand inflow than cash collection and playing on no- safety stock. This hypothesis was derived from the basic case study conducted before beginning of detailed interview and survey. We included this hypothesis to build a foundation to validate whether these are industry facts or just related to industry under case study. We started our interviews with a leading question on these three aspects and found respondents agreeing that solar industry planning has strong dependence on first time right design to meet customer requirement but expresses it is almost impossible to capture accurate requirement upfront before start of project design. Design engineering of solar projects in India is also relatively young, therefore first time right design is also a constraint creating material planning challenges for planners.

Solar projects are heavy capital intensive and required substantial liquidity in material procurement. During the course of project execution, there seems mismatch between inflow of cash from customer and outflow of cash in direct and indirect procurement. The basic reasons for mismatches are poor customer requirement capturing, immature project design and non-availability of buffer inventory stock to absorb any delay is material from a number of reason attributed to supply variations. These basic reasons, put pressure on planner to match interest of buyers and suppliers by planning iterations.

During interviews we tried to understand broad group of reasons for extra number of iterations used by planners in solar projects. These reasons for extra iterations were grouped under following four categories.

1. Project Site and design related changes
2. Availability of material related changes
3. Cost reduction related changes
4. Customer requirement related changes

It was observed that reasons of iterations were also dependent on size of solar projects. Following data shows variations in number in small project, large projects and solar products, as estimated by survey respondents.

TABLE 5-18: Relationship between reasons of iteration and size of solar installations

Reasons of iteration	**Small Projects (“A”)**	**Large Projects (“B”)**	**Solar Products (“B”)**
Site & Design Changes	13	44	4
Material Availability Changes	4	45	3
Cost reduction changes	5	15	2
Customer requirement changes	10	25	3

The results of a contingency table Chi-square statistical test performed.

Data: Contingency table

	A	B	C	Total
1	13	44	4	61
2	4	45	3	52
3	5	15	2	22
4	10	25	3	38
	32	129	12	173

Expected: Contingency table

	A	B	C
1	11.3	45.5	4.23
2	9.62	38.8	3.61
3	4.07	16.4	1.53
4	7.03	28.3	2.64

Chi-square = 6.89

Degrees of freedom = 6

Probability = 0.332

This Chi-square tabulation has a P-value = 0.332

This P-value suggests that we have to accept null hypothesis that there is no relationship between the reasons of iteration and type or size of solar project.

The above tabulation of number of iterations suggests that even though total numbers of iterations are dependent on size of project but causes of iterations are not related to the number of iterations. Some of major site and design related changes are attributed to project site changes, as against planned. In addition, a rough estimate of site at the time of project bidding and unclear quality assurance plan (QAP) causing these iterations.

Lower level causes in supply chain planning iterations are analyzed under following eight more hypotheses formulated based on the case study company.

HA 03:02: Deviation in sequence of material procurement and dispatch, from a planned sequence, for project installation, increases number of iterations.

Solar projects or product installations follow a sequence of supplies, based on sequence of requirements. An ideal sequence is project foundation, installation of supporting structure, mounting of modules, connection of electronics equipments and followed by installations of power transformers. During project execution, critical material requirement becomes bottleneck to execute installation in right sequence to satisfactorily meet customer requirement. Support structures are required immediately after civil foundation work, but either non-availability of structures on time or non-availability in adequate quantities to start the site work, have been found as show stopper to meet project deadlines. It has been found during interviews that solar companies ship the immediate available material in their stock to project site, even prior to structures, which is suppose to supply before, in the installation sequence. A rather solar module reaches at project site and waiting for structure to arrive to start the installation work. The reasons for wrong supply sequence are slow supplies of structures from suppliers, as they are heavy fabricated items, locally procured from less capacity fabricators, to supply in large volume. Structure supplier's capacity and quality problems have been observed as a factor being dealt by large scale solar companies to ensure timely project installations. Volumes of solar structures are so huge that logistics and continuous supplies from suppliers to far off project site is challenging. Solar developers receive excise duty concession on structures, so suppliers are required to be approved in advance from MNRE to get such benefit. In event of non-supplies or non-performance of suppliers, changing and resuming supplies is observed a challenging task for EPC contractors, since approval of suppliers from MNRE is a long drawn process. A bottle-neck structure supplies to meet solar plant structure requirement in large quantity, does not allow changing and approving alternate suppliers, in event of failure to meet the required quantity and quality. Much lesser constraints have been observed in supplies of solar modules as it is readily available from inventory of global sources or from continuous running manufacturing lines domestically.

Ideal sequence of supply of major solar material group is as below

First – "Supporting Structures Group">Second – "Solar Module Group">Third – "Power Transformers Group">Fourth- Other Balance of Systems (BOS)

A typical sequence in practice is observed as below during our interviews

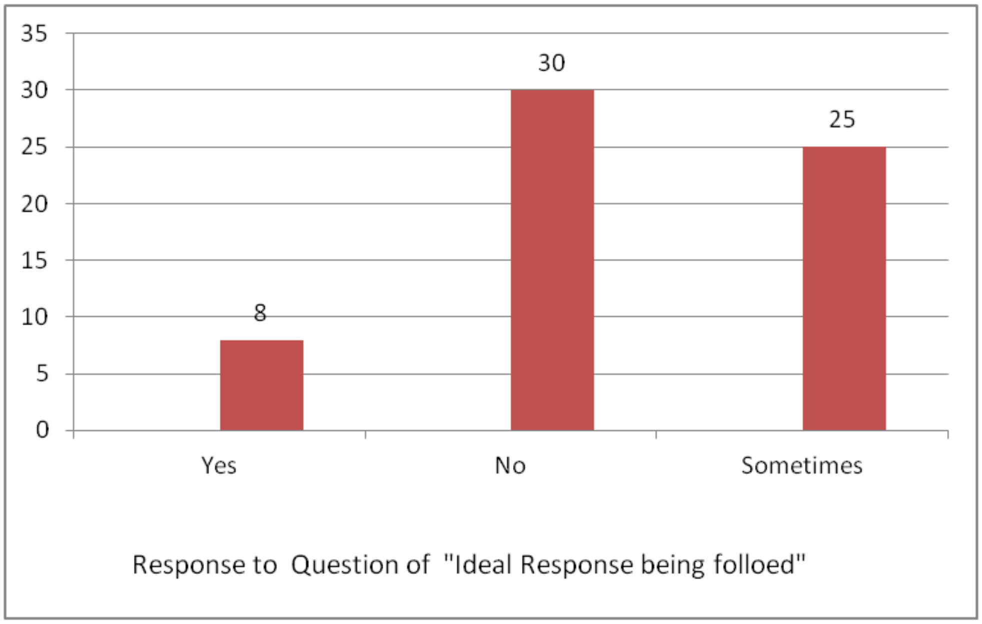
First – Modules & small quantities of structures Group >Second – Full modules & structures Group >Third – Power Transformers Group >Fourth- left out BOS group.

This is observed that most of the companies are not able to follow ideal sequence of material to solar project sites for an uninterrupted installation work. This causes increase in number of iterations by planners at the last moment, to minimize such interruption at project site. The below table indicates number of respondents interviewed respondent to agree or disagree to have a reasonably correct sequence of material dispatch as per requirement.

TABLE 5-19: Assessment of extent of ideal sequence of material being followed

	Response	**Number of responses**

Ideal Sequence being followed	Yes	8
	No	30
	Sometimes	25



GRAPH 5-7: Extent of ideal sequence of material dispatch is being followed

Most of the respondent agreed that change in sequence can give a short term leverage of booking revenue early on, during the project execution. It further leads to increase in number of iterations for planners. Thus it becomes one of the challenges for the planner to ensure material is planned in such a way so that it follows right sequence, as close as possible. Right material supply sequence helps a continuity of project execution at project site without interruption and loss of man-hours of project operation.

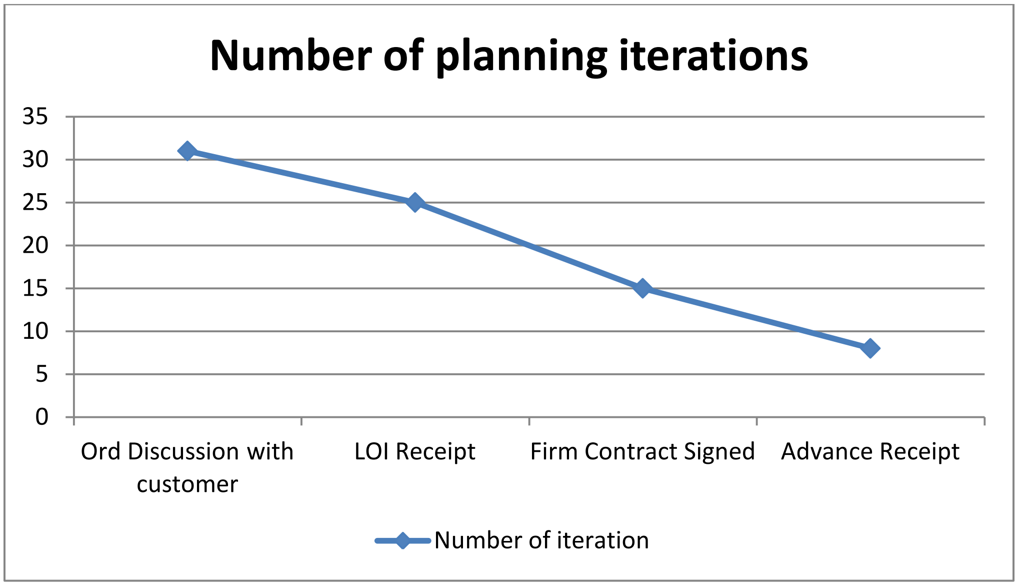
HA 03:03: Ambiguous project starting point, to begin material planning process, leads to increase in number of planning iterations.

Material planning for solar projects seems to have no clearly defined starting point to begin placing firm order on suppliers. The reason for such ambiguous start point is unclear confirmation of an order receipt from customer and beginning of installation. This uncertainty in clarity is because of the stage, when an order is considered as "firm order” from a solar developer. A solar project order get matured with a number of stages starting with a Letter of intent, Signing of Power Purchase Agreement, Financial closure, receipt of advance etc. There have been a number of cases of customer order not getting firmed up even though solar developer has shown a high level of urgency for contracting for project. Once order contract is confirmed by developer, but if the advance is not receipt by solar EPC contractor, it has been viewed as a weak commitment from developer. Respondents have told us that even after advance and firm contract, an order has not been through from MNRE and causes order cancellation at later stage. There are a varied practice to start placing purchase orders on suppliers, depending on planners own learning from previous projects and understanding of nature of developers. A solar organization generally tries to delay placing orders on their suppliers to ensure high probability of ascertaining an order is a firmed order. A missed order after procurement of material, can lead to excess stock lying in inventory and solar contractor may fall in the trap of liquidity constraints, to perform other firmed orders which can rotate cash faster. Material procured for a custom designed solar project may not even get consumed in other projects to free up liquidity.

Our interview revealed that there are multiple points during the various stages of order winning, when a planner starts planning and placing orders on suppliers. Different solar players had different terminology of stages of an order. Some contractor has more stages of orders than other. We tried to capture the stages the way it was put forth by respondents in front of us. Later on a most rational four stages have been finalized for the purpose of analysis. Contractor who revealed more number of stages or less number of stages were tried to map on same four staged process depending on the most occurring and salient stages by respondents. These varied starting points are

1. Order discussion with customer
2. Receipt of letter of intent
3. Receipt of firm order
4. Receipt of advance payment from customer

Planners feel, a late starting of planning process during customer acquisitions state, allows less number of iterations as estimated and shown in the correlation coefficients below.



GRAPH 5-8: Stage of order and planning iterations

TABLE 5-20: Correlation between stage of order and planning iterations

SUMMARY OUTPUT						
Regression Statistics						
Multiple R	0.995702					
R Square	0.991422					
Adjusted R Square	0.987133					
Standard Error	1.161895					
Observations	4					
ANOVA						
	df	*SS*	*MS*	*F*	*gnificance F*	
Regression	1	312.05	312.05	231.1481	0.004298	
Residual	2	2.7	1.35			
Total	3	314.75				
	Coefficients	*andard Err*	*t Stat*	*P-value*	*ower 95%*	*Upper 95%*
Intercept	39.5	1.423025	27.75777	0.001295	33.37722	45.62278
X Variable 1	-7.9	0.519615	-15.2036	0.004298	-10.1357	-5.66428

The above average estimate indicates that number of planning iterations is linearly correlated with R-Square = 0.99 & P-value 0.0012 & 0.004.

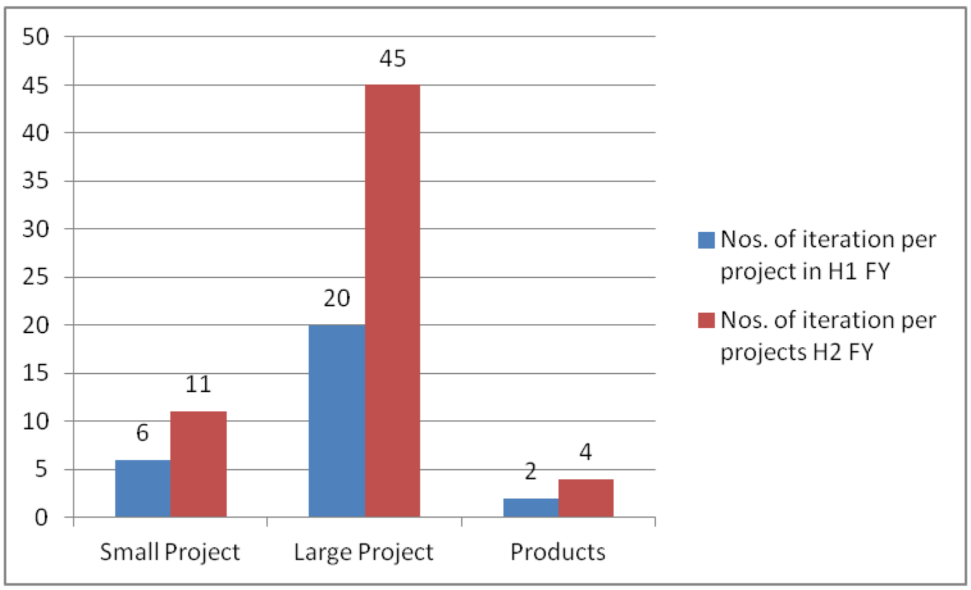
The respondents are of the opinion, even if contractors begins planning material at early stage of an order, clarity of customer need of "design of project" and exact requirement of material gets firmed later. Developer's interactions with sales and design team of contracting company help educating developers regarding various options to choose from, to better meet their requirements. In case a project is designed and accordingly material order is placed on suppliers, it needs to be changed later on, due to customer's evolving need along with such design interactions. A late order placement satisfies developer better for their requirements and reduces number of iterations for planners, even though it causes some delay is project commissioning.

HA 03:04: Multiple projects execution at the same time leads to increase in number of iterations in supply chain planning.

Solar projects are mostly supported by one or other government sponsored program. Project approval and release of funds from government takes place during the second half of the financial year, due to availability of fund allocation to ministry and processing time thereafter. Second half and especially last quarter of financial year, is the time when all projects are being executed at the same time in parallel with the marginal increase in resources including planners. This skewed timing of all project execution, in a limited short period of time, causes planners to plan multiple project material at the same time. This situation is sometime beyond the manageable limit of planners to respond to multiple project requirements. Expediting and de-expediting leads to more number of iterations per project in this rush to meet requirement coming from all projects. Planners face challenges of managing multiple suppliers and variety of material at the same time. This period of time is considered as chaotic for all planners, especially in the event of non-ERP based planning which is more common in solar industry during the study period. Respondent indicated that this situation causes approximately 20-40% extra number of planning iterations depending on time and project.

TABLE 5-21: Iteration related with business segment and time of year

Solar Segment	Nos. of iteration per project in H1 FY	Nos. of iteration per projects H2 FY
Small Project	6	11
Large Project	20	45
Products	2	4



Graph 5-9: Segment wise nos. of iterations in first and second half of year

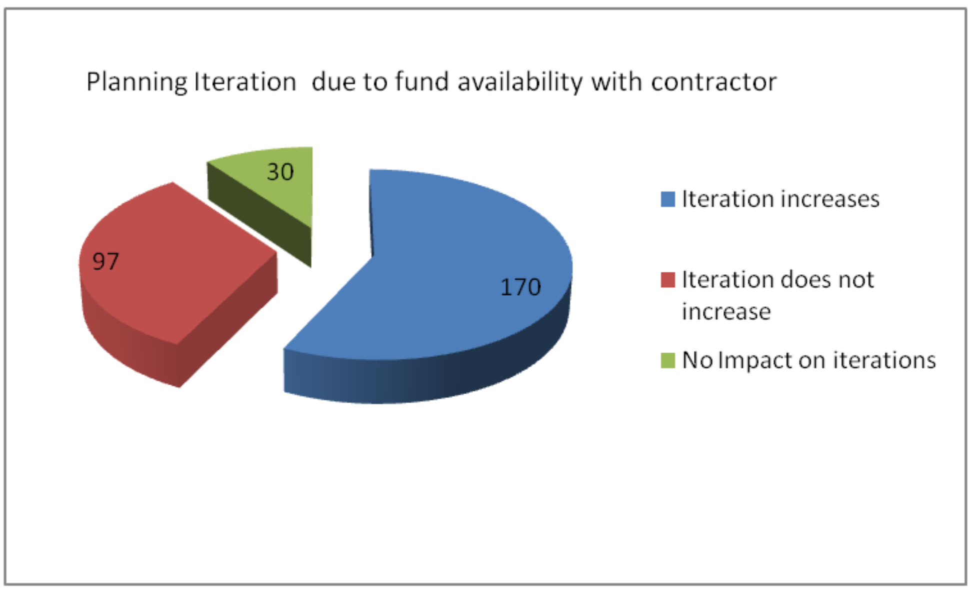
Solar procurement teams and equipment suppliers told us during the interview, that peak manufacturing and solar system integration load is pushing them into ad-hoc internal supplies and resource management. Requirement of raw material and skilled manpower goes up by 30-40% during this peak time. These additional resources cannot be ramped up for only project execution need during only second half of the year. This is an ad-hoc management of somewhat sub-standard resources, in which case substantial deterioration of quality of supplies and logistics management has been faced by respondents.

HA 03:05: Number of iterations is function of fund availability to pay to suppliers by contractors on time.

Indian solar industry is cash crunched most of the time due to heavy liquidity suction in manufacturing plant and machineries. Less investor confidence in solar and high cost of funds, adds to the problem of material planning on time as per requirement. Non-availability or delayed availability of funds with contractor leads to more number of planning iterations to satisfy customer requirements. Below tabulation compare responses from respondents whether find availability pushes more planning iteration. Data indicates a clear difference in number of planning estimated iteration for solar material planning.

TABLE 5-22: Relationship between fund availability and iteration increment

	Iteration increases	**Iteration does not increase**	**No Impact on iterations**
Fund Availability	170	97	30



Graph 5-10: Split between response of iteration based on fund avaiability

The pie chart and table above indicates that more than majority of respondent believe that fund availability affect planning iterations.

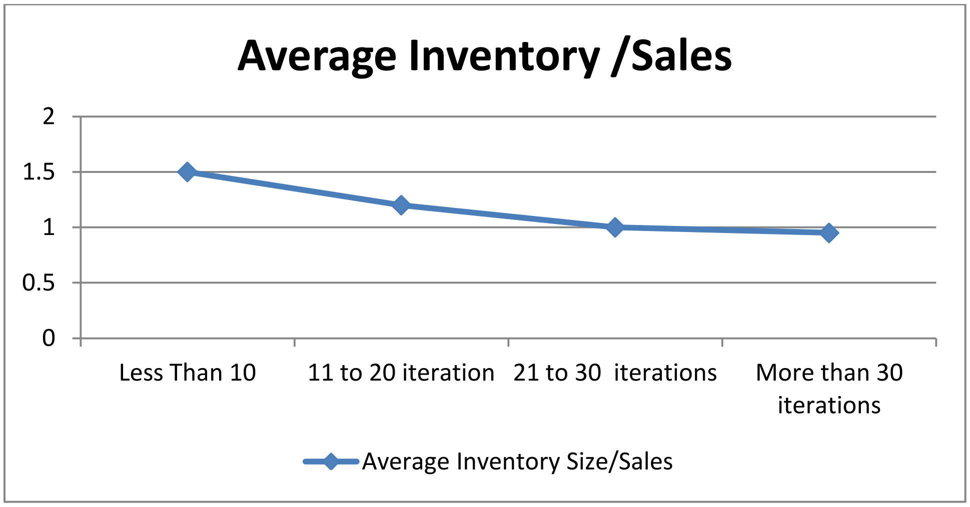
HA 03:06: Strict norms of declaring excess inventory in solar organizations impacts number of planning iterations.

There was a profound concern on keeping extra buffer inventory than required to fulfill a customer order, in solar industry. There have been restrain exercised among respondent to promote ex-stock sale, as found during interview. Solar organizations have their very strict norms to declare an inventory as non-moving or excess stock. Some solar companies are stricter than other depending on their internal norms and financial liquidity comfort. Three types of inventory norms to declare excess/obsolete were being used in most of the solar organizations, during the period of research – greater than 60 days, greater than 90 days and greater than 120 days to declare non-moving. The frequency of analyzing inventory as excess or obsolete, were not very well established across solar organizations, but planners interviewed agreed, that their companies follow one of these inventory norms. Some larger solar companies are very particular in analyzing inventory aging fortnightly, than other smaller companies who analyze once in a quarter. The strict norms for excess or non-moving inventory put pressure on planners to plan very tightly to ensure a very thin safety stocks or no stocking of material, if order is not firmed up. This is to minimize the risk of inventory excess or obsolescence as per their company laid down in their company discipline to align financial norms. Expectations of solar project material fulfillment still remain high, similar to off-the-shelf solar products. Planners struggle to establish a balance to optimize availability and strict inventory norms laid down in their company. This is achieved by continuously refining and revising planning as the demand visibility increases.

TABLE 5-23: Non-moving inventory declaration and planning iterations

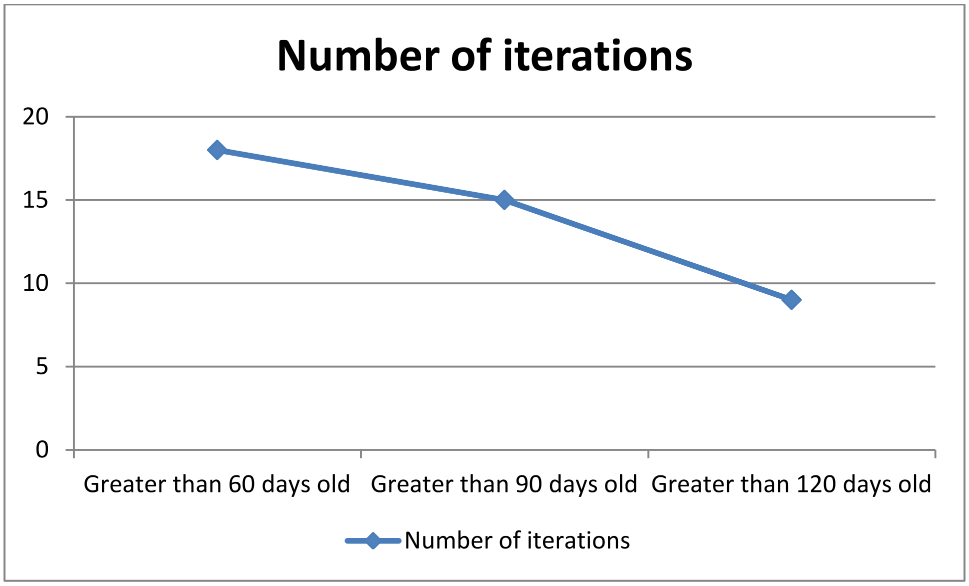
Norms of Inventory excess/non-moving	**Nos. of planning iterations**
Greater than 60 days old	20 to 40
Greater than 90 days old	10 to 18
Greater than 120 days old	6 to10

There has been observed, an estimated lower inventory carried by solar companies with more number of iterations as shown in an estimation based on respondent's views. The below figure depict ratio of inventory to sales with respect to estimated number of iterations.



GRAPH 5-11: Relationship between inventory per unit of sale and iterations

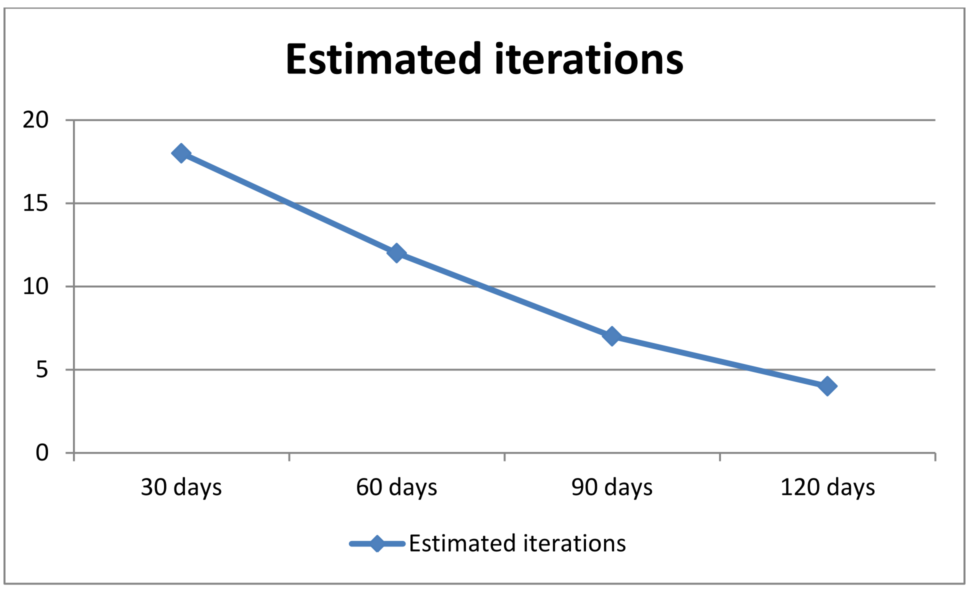
The data below shows that solar planners opine that more number of days is provided to declare excess or non-moving stock, less number of planning iterations are expected.



Graph 5-12: Inventory excess/non-moving and iterations

HA 03:07: Supplier's credit period affects number of planning iterations.

Procurement in solar industry is being encouraged on a longest possible credit period from suppliers on account of cash crunch situation in the industry. During our interview, it has been found that one of the important supplier's qualification criteria considered is a long credit period. This affinity towards longs credit period of solar contractors has tendency to trade-off on delivery performance and quality of material, from a supplier who can match long credit days. A limited number of such suppliers, who has capability to offer longer credit period, make contractor highly dependent on them. A contractor looses ability to switch to alternate source in case of any supply, quality or delivery constraints, during the project execution stages. Respondents explained us that though credit term with longer credit period are pushing planners to have limited source, but at the same time it minimizes number of planning iterations, as alternate sources or material is not explored and supplies continues, irrespective of some delivery glitches.



Graph 5-13: Relationship between credit period and iterations

Hypothesis stated is proved with the above estimated numbers of average iterations to show how less number of credit days, causes more iterations during the planning and revision process.

HA 03:08: Difference exists between in-house and contract manufacturing of solar modules, cell or solar products in planning iterations.

Solar modules carry about 50% value of solar installations in any solar project or products. In case, module manufacturing by a contractor is in-house, it has about 50% independence in planning by value. In other word half of the value of revenue is under the influence of in-house planners. A planner who has to plan modules from a source other than in-house manufacturing, from domestic or global sources, has to carry out more number of iterations to match prices, availability and quality aspects. A Chi-Square table below shows that in-house and contract manufacturing has relationship with the number of planning iterations.

TABLE 5-24: In-house/Outsourced manufacturing and iterations

		Increases Iterations ("A")	**Does not increases iterations ('B")**
Module Manufacturing source	**In-house**	130	167
	Outsourced	186	111

The results of a contingency table Chi-square statistical test performed.

Data: contingency table

	A	B	Total
1	130	167	297
2	207	90	297
	374	220	594

Expected: contingency table

	A	B
1	169	129
2	169	129

Chi-square = 40.7

Degrees of freedom = 1

Probability = 0.000

This Chi-square tabulation has a P-value =0.000

Thus null hypothesis is rejected and alternate hypothesis of dependency of in-house and out-sourced manufacturing effects on number of iterations. Table below estimates range of planning iterations if contractor has capability to produce about 50% of material used in solar projects, in house.

TABLE 5-25: Quantum of in-house value and iterations

	Number of Iterations
Greater than 50% value in-house	8-15
Greater than 50% value procured or contracted	10-30

A larger proportion of material by value manufactured in-house reduces dependence on outside source and thus number of planning iterations. Same may not be true for planning iteration of other raw material used for solar module or cell manufacturing as revealed by respondents. Effects on material planning iterations are always lesser, in case of finished goods than planning iteration for raw material for producing cells or modules. Our interview respondents indicated that even if in-house module manufacturing may cause lesser number of iterations for finished goods, but at a child level of raw material planning iteration may remain unchanged. At the level of raw material, module procurement takes place irrespective of a particular module specification. To some extent there is de-coupling between raw material and finished solar modules. For a planner, planning of finished goods modules and number of iterations are minimal than a planner planning raw material to produce solar cells and modules.

HA 03:09: Number of planning iterations is dependent on solar business segments.

Planning complexities varies from segment to segment and thus affects planning iterations. Solar customer base can be broadly divided into three segments - small solar projects (less than 1 MW), large projects (more than 1 MW) and solar product segment.

The number of iterations is highly dependent on these segments. Our interview respondents estimated following number of iteration in different solar business segments,

TABLE 5-26: Business segment and iterations

Solar Segment	Number of Iterations
Small Projects	2 to 5
Large Projects	6 to 50
Solar Products	2 to 3

A large solar project involve variables like topography of land to be used for solar project installations, state government regulations, metering and monitoring instruments, grid compatible equipment etc. Such complexities are much lesser in smaller projects, especially roof top installations, wherein the roof topography and other project design aspects are more predictable from the beginning. Further solar products are standard product or solution designed to suit universal customer requirement.

A level of customization in solar product is almost inexistent. This is the primary reason to have a more predictable material requirement in standard solar products segment. It allows planners to have safety stocks and interchangeable usage of components and helps in reducing number of planning iterations.

Solar cell and module manufacturing, a key component of solar, has raw material iteration, not factored in the above analysis.

5.6 Interview Insight and discussion on Hypothesis -3

A supply chain planning process in published literature is based on existing information with the planners regarding trends of consumption, past seasonality and demand growth or decline to arrive on a derived demand pattern. Such statistical forecast forms the basic foundation to apply further market intelligence, to arrive on a plan to fulfill customer requirement. Planner's skills of planning are primarily focused in establishing a balance to protect interest of organization by creating an optimum between inventory and customer service level. A number of optimization tools simplify the processes to have a most optimal stocking and ensure customer service levels at the same time. In solar organization under research, we did not see usage of any supply chain planning tool to optimize inventory and service level. It seems that the planning variables as studied in the hypothesis are too much diverse to model in a particular tool. During our research, we found planner using spread sheets, and not an optimization tools. Planners view each planning situation is unique one, depending on prevailing global and domestic capacities & price (refer hypothesis 1), size of projects, state regulation and support structure and approval process delay (refer hypothesis 2). A planning tool seems not helping in building such complex planning scenario to take care of all factors in one automated planning model. None of the solar suppliers, we spoke to were using any such tools except some spread sheet with macros to have different load consolidation into a full truck load for dispatch, to optimize transportation cost. Planners were supposed to plan for transportation load consolidation as a prevailing practice of planning, in solar companies to keep minimized cost. These spread sheets won't have even a basic statistical trend forecasting. A condition where planning is unique to each project with no base demand, planners spends about their 70% of time in iterating the demand volume and expected time of dispatch.

Any material buying before the dispatch event, leads to a complex situations in solar industry. In case of an advance buying, planner cannot dispatch material till such time all order formalities including advance money from customer is received or high level project design is frozen and approved by customer or their representative. Time difference between procurement and dispatch increases cost of material stocking and liquidity crunch. An advance material procurement on one hand is helpful to complete the project on time, but on other hand increases cost of project due to increase in stocking and liquidity cost. Advance material stocking can happen if solar project developer absorb additional cost in the price, incurred to ensure on time delivery. Contractors are not loading such cost in initial project costing which causes them to be uncompetitive.

Project developers who are dependent on government support do not find sufficient margin to protect their interest in such advance buying. A delayed buying can also adversely impact material availability, since these project orders has an end date of plant commissioning before closure of financial year to avail accelerate depreciation and meet PPA requirements. In such a given uncertainty, planning on account of multiple complex variables, as explained in hypothesis 1 & 2, pushes planners to forecast status of these variables from best of knowledge gained from published and unpublished solar news and company liaison.

In solar manufacturing and projects, majority of plant loading and installation is skewed towards second half of the financial year, as March end is solar project deadline for commissioning in state supported projects. In practice, first half of the financial year is spent in firming up orders and getting clearances from the central and state nodal agencies. Solar manufacturing plant and project operations are facing a lean period during this period. Suppliers avoid keeping FG stock for solar project in first half of the year to reduce overall cost of stocking. Some of the manufacturing plants told us during our interview that they keep orders for raw material on suppliers to keep some agility to ramp up production in case of increase in volume. Since most of plant capacities are underutilized during first half of financial year, it is in practice to load plant more as order gets firmed up rather than keeping a finished stock.

Planners are connected to internal sales teams, are primarily state policy speculators, to include in planning. In such multiple levels of speculative planning wherein sales and planning speculations together creates an extremely complex planning scenario, planners were observed to be considering multiple informal inputs to iterate their demand and supply planning.

A simple thumb rule approach is being practiced up by these planners in situation of insufficient and uncertain demand information. They stock for standard solar products, keep a small time stock for roof top projects but no stock for a large projects material. In other word, there is no base stocking for any large project except some small time stocking for small projects. All large projects are planned “Make To order” (MTO).

Planners feel themselves very confident to plan for any such sudden large solar project orders by compromising on cost of premium paid on urgent delivery of material. Planners spend extra cost for premium delivery rather than spending in stocking and incurring cost of material in advance. Except some high value material like solar inverters and structures, wherein project design compatibility evaluation makes it customized material in nature, rest of the material is available at a very predictable lead time away from suppliers. Even if premium cost is paid to procure on urgent basis, but planners has a high level of confidence on performance against committed lead time to ensure availability of material to commit to solar project developers. Respondent planners had shown least concern about poor performance in supply lead time against committed by solar suppliers. Offshore ASEAN suppliers like Chinese companies are able to make margin with readily available stock to fulfill demand, on an extremely short notice and with a lead time just equivalent to transportation time.

During our objective discussions with interview respondents, they revealed that planners consider number of planning iteration increases more rapidly for every addition of 5 MW of orders. Larger the size of solar project, more number of iterations are expected by planners. Beyond a bench marked project size of 5 MW, planners have to look out for additional source of possible material capacities or variation in design to meet from alternate sources. Solar planners view the situation of increasing complexities with an increase in size as a common situation in planning but senior management planner; view it as a chaotic planning. One of the companies we met were found to have biggest process improvement project in "improving chaotic planning" wherein a largest cross functional team was working to balance load and create more accurate forecast. Companies see an opportunity to stagger some load, even if operation views unavoidable higher loading in second half of the financial year. Planners view this solely from lead time management perspective for material management, whereas senior management planners view this from end to end project supply chain, project commissioning and handover of project to customers. A chaotic planning management has direct bearing of completion of project on time and collection of money from customers due to incomplete projects. Solar companies were managing operations with extremely thin inventories on account of their high value back to back planning approach against receipt of customer order. In case of extreme urgent order fulfillment requirement, a planner prefers to divert material from an ongoing project, rather than taking a chance by keeping extra stock.

Stocking of material is not only a function of supply chain planning but also project design engineering plays a major role in it. Project design engineering is integral part of material planning process to help accurately and first time right decision of required material. Project design engineering process time and FTR also decides number of iterations in supply chain planning.

Solar project design has a set of standard material components which can be used in any project, irrespective of project and customers. Another set of material is specific to project and customer requirement. A planner has an opportunity to identify these two groups of material uniquely, to keep a general stock and a project specific procurement. Firming up required material continues even during the execution of projects. The reason for such late firming of material requirement is incomplete captured customer demand in the beginning. This causes firming of material till project requirement is fully developed. A project design continues throughout project execution phase. This causes unavailability of material precisely when required. Such planning has a very short lead time to expedite material on time.

During our interviews, there was a common agreement of all hierarchical levels of planners that they are not able to take advantages of economies of scale at any stage of supply chain. This is because a particular project based material planning practice is more prominent, than having a common material stocking to optimize economies. The primary reason for this sub-optimal planning is fragmented market of solar contractors and developers, causing disintegrated demand, losing out a cost saving opportunity for solar industry in India as a whole.

Solar product business planning depicted drastically different supply chain planning management. Suppliers of solar products or local product integrators keep stocks in regional warehouse near distribution point close to customer. Safety stocking of solar product have been seen more often than a solar project. Our discussions with interviewees revealed that even players in solar product segments, do not carry sufficient safety stock quantities to build buffer against demand variations. More often there is situation of stock-out at distribution warehouse or in mother warehouse. Planners of solar product suppliers and integrators complained about availability of solar module from branded sources in insufficient quantities. The situation of module shortage from suppliers of repute is replaced by filling the gap with local or Chinese modules. Solar product planning is also passing through good number of iterations but degree of iterations is much lesser than for solar project planning.

In solar products, where procurement and installation is being done under government supported program, velocity of volume of material demand is faster than the cash collections to solar companies due to multiple stages of inspection, documentation and approval from nodal agencies involved. This is causing multiple challenges to continue material supply on account of non-payments or delayed payments from such state nodal agencies or customers. Only a few solar companies unconstrained on liquidity, are able to sustain continuous supplies, rest majority of suppliers have tendency to supply material intermittently. This causes delay in completing deliveries on contracted time. Typically, cash inflow from one state nodal agency sponsored program, is not available to rotate to re-procure material and continue supplies to the same project. Cash collection from one state nodal agency program is available to fund next project as cycle of supply, installation, inspection and collection, is extremely long. Solar companies are dealing with the situation of high cost of funds, in such situation of long sale to collection cycle.

For PV products company level material planners told us that demand uncertainty is so prominent that order forecast received from field sales officers is not being taken into planning without an additional round of iteration to rationalize forecasted number. This additional round of iteration reduces multiplication effect of forecasted quantity of material, due to multiple levels of speculations by field sales staff and their supervisors. In case of compelling situation posed by field sale staff to planners to plan material against an anticipated order, where planners has a opinion of lower required quantity, it is attempted to seek a semi confirmation evidence from customer, like “letter of intent” or “part advance” etc. This establishes customer commitment, to avoid cancellation of order after material procurement.

In solar products, demand has high variability depending on SKU. This is a result of wide range of cost competitive products in the market, not allowing planners to have a clearly laid down safety stocking norms on account of risk of inventory obsolescence. Planners keep safety stock which is just sufficient or about 10-20% extra against expected demand. Most of the demand is forecasted based on anticipated tenders by nodal agencies. Retail solar product demand fluctuation, being sold through regular dealer channel, is minimal, except seasonal variation. Aggressive players out of Bangalore responded with the facts that, they are using more safety stocking to avoid any sales loss as they are only dealing is solar products. Small solar players are not operating in manufacturing and projects space other than component integration into product. These small players, who are mostly integrators, do not need to have a large blockage of cash and their order to collection cycle is much shorter than a large solar player operating its distribution at national level. Even though this segment is more organized from safety stocking and fill rate perspective, there is no defined practices for replenishment of stock and increasing velocity of material by using established practices like KANBAN, VMI etc.

Project Material Planning Sequencing: In an immature project designing process, engineering design goes almost hand in hand with the project execution as discussed in sub-hypothesis HA03:02. Planners play an additional role to coordinate design, costing, logistic etc. to ensure timely solar project execution.

In large solar projects, there is a time lag of about 4 to 8 weeks between solar module supplies and installation, this delay is on account of pending land clearance issues, local disturbances by neighborhood to acquire land and right of way. To start project installation, module supporting structures are first priority material followed by modules and other BOS. Planners' leverages this priority sequence to buy time to procure material supposed to use at later stage of project during the installation. This optimization practice further reduces chances of any extra days of inventory resulting in blocking unutilized cash. Availability of solar module structures is in the critical path of solar project management milestone, since structures installation is the starting point in a project. The strong supervision is involved for solar structure design, validation, production, quality checks and monitoring continuity of supplies. Major supply failures have been witnessed in structures, elongating overall project timelines and delay in commissioning. Module structures availability is the key material, being tracked by solar planners.

As against large project in which 4-8 weeks of lag exists in large solar projects, there is only about a week lag in small roof top solar project installations, since they get completed much faster, sometime within lesser than a week. For roof top installations hardly there is any gap in supply of various components in installation of project. Once project is approved all material is required in one go. Material dispatch sequencing hardly matter in small projects.

Large solar module manufacturer who are also installing such project with smaller size solar module, try not to engage in-house capacity to produce small size modules. Large modules production gives a better yield and more MW production per unit of time. These planners procure modules from small manufacturers from country like China to minimize number of planning iterations required in plant changeover from large modules to small one and vice-versa. Such a bulk procurement of major volume from an off-shore supplier causes some planning uncertainty in placing order and expediting to receive on time.

In large scale solar projects, engineering drawing and design approval from customer takes place before project execution. Project is design and engineered either by EPC contractor or by an external party appointed by contractor or combination of both. Once design is approved by customer or their consultant, EPC contractor are allowed to continue erection. This stage of customer design approval, leads to major changes in required material specification or change in quantity of material required. This also led to internal multiple deliberations and review, before making such changes effective within EPC contractor’s organization. This intermittent design changes at this stage, before or during project execution causes un-assured material supplies causing iterations. Planners cannot directly plan material to respond to either increase or change in material till such time requirements is approved internally by relevant stakeholders.

Structures are required for starting of projects but it takes maximum time to finalize since structure depends on land or roof topography which has been seen changing in large solar projects. A detailed survey is carried out before finalizing structure design for solar projects. An accurate project site survey is an important aspect, deciding exact design and material requirement for a solar plant. This has been observed in practice that a site survey is approximated during the order discussion with customer on account of low order conversion rate observed by contractors. Solar contractors do not wish to invest in full site survey till they are assured of winning an order. A site survey expenses before order is received, is a tentative to invest less time and money. Such an estimated site survey can lead to change in cost and uncertainty at later stage of material planning. In rooftop solar projects where design is largely dependent on roof topography and orientation of roof, so many site survey at initial stage of order acceptance is not practically feasible. Since many government supported roof top projects do not get through, even suppliers are not given confidence to start preparing for the supplies. Many contractors mobilization is also expedited during project execution stages, to avoid losing opportunity, when material is short in an on-going project.

New upcoming retail model in roof top solar projects is mandating to standardize solar structure to plan faster and quick turnaround of projects. In such cases planners have to order in multiples of standardized solar sets. These modular designs are interchangeable among multiple customer requirements. This will ease out in terms of creating one to multiple lines items from supplies to projects, improving number of SKUs, logistics and administration cost. A special solar dealer partners are being appointed by solar companies to distribute and install such projects similar to solar product distribution.

Material procured but not shipped to customer site, or delay in cash collection from customer due to delayed invoicing, after installation and commissioning, creates ripple effects in terms further cash rotation for further material procurement. Various roof top project approval from agencies like SECI/MNRE/DISCOM creates bottleneck in smooth project execution. This creates planning challenges in term of manufacturing, procurement, shipment and project completion. In such situations, planning for material required at later stages, to build peripherals of solar project like building, roads, drainage, cleaning systems etc get compromised. Material for support peripherals becomes a last priority in planning, as planners are busy in expediting solar project installation material.

There are many solar projects which are commissioned but still do not have these support peripherals because of poor project cash flow to contractors.

Completeness of information received in the project kick off from internal sales team is another cause other than inaccurate land survey. An estimated site is leveraged to win order but inaccurate information about commitment to customers, further creates planning iterations. Eventually at times such lapses surprise at later stage of project execution, causing major cost deviation, causes planned margin wipe out.

Customer quality expectation differs in the beginning or evolved over a period of time during project execution. An agreement with the customers on exact QAP (Quality Assurance Plan) is challenging in the beginning of solar projects. Planner material undergoes iterations during the evolution of QAP. QAP keeps developing along with the stages of project execution, as solar project developer learn and able to visualize installation better at later stage, than at the time of project design while capturing project requirements. This causes multiple materials and method changes. Planners have to keep planning till last instant of project execution due to such uncertainties. Experienced planners wish to get a reasonable agreement with customers in the beginning of the project over and above specified by project designer with the help of informal discussions and help solar design department to include such inputs.

There are a number of solar project delays because of reasons from developers or contractor side. Such reasons are avoided to get logged in a log register correctly, for some or other reasons. It has been found that some of reasons are attributable to material planning, which planners disagree during our interview. Many a times, it is inefficiency of log, not representative to analyze the reasons for solar project delays.

During S&OP process maximum iteration takes place in plan to ascertain material required for a solar project. Some time, it leads to hot discussions among the participants from sales and project function to bridge differences on changing material requirements.

What should be a starting point of planning of material for a solar project- Is always a ambiguous. Project start and end point is understood differently by different players. Planner’s keeps on discussing with S&OP stakeholders what should be the point to start to order material for solar project. This ordering point is very dynamic and depends a lot on customer, projects and solar company's strategic and tactical view on it.

a) Multiple Project Execution Planning: Number of projects execution at the same time by a contractor causes increase in planning iterations. At the time of closure of financial year, situation of multiple project execution at the same time is a very usual by a solar EPC contractor. All supplies are highly skewed towards last month, as project commissioning deadline falls during end of March month of the year. This trend can be eased out by having multiple staggered commissioning times during the year. During the rush in shipping of material for multiple projects causes material mixing, mismatched tagging, wrong material dispatches etc in managing solar logistics. Most of the warehousing and logistics are not adequately manned and causes a huge material mismatches, short and wrong supplies on account of multiple project execution at the same time. This increases planning iterations and causes project delay.

b) Planning iterations on account of shortage of funds: In solar industry, fund management is a major concern to most of companies as responded by interviewees. Cash realization cycle is very long for products and projects sold directly without intermediaries like dealers or a third party. Direct sales in a state level solar product tenders deals with installation, commissioning and inspection stages before receiving payment. A most efficient cash management cycle is not less than 90-120 days from day of start of material dispatch. Further planning of material procurement is dependent on previous cash collection. Planners iterate a number of times to match payment to vendors within their credit period agreed with them. Many planners had concerns around delay in material and revisions in iteration on account of delayed payment to suppliers and reported disruption is supplies. A company supported by external funding can only run the show by incurring some interest cost. Most of solar companies in India are not having strong credit lines or cannot bear high cost of funds, are finding difficult to continue their supplies.

Long cash conversion cycle lead to high interest cost which is deterrent for many solar companies. Factoring this extra interest cost in price may not be always possible, still planners tries to build it to minimize iterations by giving a little extra cost to suppliers for having longer credit period. Solar companies are watching on cash flow negative projects to reprioritize in supply planning, but it seems not always possible to change priority. Such reprioritization can further worsen the cash flow situation from the project which may adversely impact on-time project completion and collection of full payment from solar developers. Planners are focusing to be cash positive as far as possible from the beginning stage and during the project duration, to consciously paying and getting continuous material for suppliers.

c) Developer's side issues causing planning iterations: For a solar developer, external factors like clearance of land for project, laying & approval of power evacuation lines and CEIG approval play a significant role to decide on project start and completion time. These issues causes uncertainty in planning and causes iterations as visibility of projects improves. The large part of these delays is in developer's scope of work, whether solar supplier is doing only supplies or managing full EPC. A planner for developer cum EPC contractor has to factor in all such aspects to plan timely receipt of material and minimizing cash blockage. Project contracts wish to start clock to count the time only after all approvals, like a signed Power Purchasing Agreement and land acquisition is completed by developers. EPC contractor support such approval but not willing to take a complete responsibility even though their planning get affected on account of such issues which are generally in solar developer's scope. A developer takes services of some professional agencies experienced in these approvals to manage risks and adversely affecting supply chain planning.

d) Material inventory norms and affects on iterations: Norms for inventory aging is relatively stricter in solar industry. A stock more than 60 to 120 days is being considered as slow moving material stock by most of solar players. Planners are extremely cautious to meet these norms and try to minimize an inventory falling in age more than the norms. Some of the solar planners are having their KRAs to manage E&O inventory less than 5%, which is one of the stricter norms for managing inventory. To minimize dealing with number of planning SKUs, planners recommend a solar kit to be prepared to ensure lesser number of SKUs at child part level. Iteration of planning at low value child part level may be prohibitive, thus solar kit can play a major role in helping planning process to ease procurement and planning.

e) Logistics practices adding to iterative environment: In solar industry, role of planner have been extended to managing end to end delivery of material to ensure timely project completion. They track material from suppliers and delivery till project site including dealing with a number of commercial and taxation issues. Planners incur multiple iterations, during the time material is planned and dispatched either from suppliers or from warehouse till it reaches to final destination. This is an extension of material planning role in solar industry. Interview respondents spoke about logistic practices in solar industry lacks in accurate information and communication gaps between transporter, warehouses and customer's project site. Some of situations like uncertainty of supply location (an exact project site), is causing delay and inaccurate supply at intended location. Planner play role of navigator to identify site location and direct material to its destination. Solar project material is preferred to be sent directly from suppliers to project site to minimize multiple loading, unloading and transportation to minimize costs. Decision and communication to logistics provider is an additional role taken over by planners, to ensure material reaches on time at right place. Respondents have told us that many a times there are last minute decision to change either source or destination or both, in anticipation of tax optimization to save cost. Such changes are forced by multiple people and thus cause confusion. Decision from planner is consider as a more authenticated one to minimize the multiple contradicting instructions which leads to an ambiguous situation. Most of planners consider that this is additional job they have to undertake to minimize chaos.

Profit margin in solar projects is very thin and any extra cost of taxation is avoided to safeguard interest of EPC contractor. Some source of material decisions are also taken based on vicinity of use, to optimize logistics cost or optimize extra cost on local taxes.

Solar projects and product supplies have potential to be distributed anywhere in the country thus, solar companies wishes to have supplier base across the country to minimize cost of transportation. In practices respondents agreed that development of such a broad based suppliers is not realized by any solar players in the country. Age of solar suppliers is on an average not more than 5 years by the end of FY 2014. In such a small period of time it is difficult for any solar manufacturer to develop such a large supplier base, to meet requirement of local procurement. Present project volumes and their spread is so fragmented that it is not sufficient enough to keep the continuity of distributed supplier’s volume.

Planners told us that they have solar projects where material reaches on site but site clearance or right of way issues causes, project execution delay and non-availability of material storage at site. Once this material is at site, it cannot be shifted to other ongoing project because of additional logistic cost involved in material transit, in event of any deadlock. Planners monitor such clearance of projects from multiple agencies, for revising their planning to decide dispatch.

Transportation cost is a prime driver in a throat cut solar competitive market. Exploiting load consolidation (Full Truck Load- “FTL”) is practice to manage an outbound shipments or as far as possible for in-bound shipment. In terms of trading-off between availability and FTL, later is given more priority. It seems planners do not manage “availability” as first priority; instead they prefer avoiding extra cost on logistics and transportation. A supply from mother warehouse to regional warehouses, located in multiple parts of country, is preferably sent through FTL. Load consolidation exercise is also being advised by planner through iterations to arrive on a full truck load.

Generally solar product dealers and integrators manage their own transportation from regional warehouses to their premise in small vehicle load. Local transportation is considered difficult to manage by national solar players with an optimum cost, thus it is left to the local distributor, to act as a hub for small retail dealers. Small solar manufacturers have shared distribution centers managed by a third party.

f) Planning Iterations depend on solar business Segment

Planners' faces following additional factors and variables to take care while planning for a particular solar business segment

I. **Standard Solar Products** – This business segment need off-the-shelf availability for retail distribution, as most of the customers are walk-in customers at retail outlets. This business segment is similar to a typical FMCG product segment except the fact that most of solar product sales by volume take place with support received in the form of subsidy or financing support from state or banks. Financing options are through various gramin banks through NABARD, or state level subsidy support which decides timing and volume of sale in a year. Some of such big orders under state government nodal agency scheme are in the form of tenders with a large volume off-take. Such large volume solar product off-take creates huge demand in a limited period of time, for one or more than one solar player. These large scale orders for solar product are treated similar to large solar projects. Retail sales through various channels like retail shops, malls and e-commerce etc are new selling modes coming up. Planning to sell through such formats is still in evolution stage.

Demand for solar retail channel peaks during off-monsoon season. During monsoon, demands for these solar systems installation are very low. Peak seasons for these solar products generally vary are from October till June month of the year. Solar product can be categorized into two buckets based on their movement pattern.

II. **Fast moving solar products sold in open market** – Supply variability are minimal in solar products as many Chinese suppliers are supplying without any constraints on material availability. A price of these products varies between a few hundred rupees to about fifteen thousand rupees. These products are being picked up by rural customers for replacing their kerosene based lantern or unreliable electric supplies.

a. **Procured through state tenders** – Supply variability is a major planning factor as it requires special specifications lay down by MNRE or state nodal agencies. This causes a limited group of suppliers to participate in these tenders. During the tenders stage demand generally goes to a limited set of suppliers who can ensure specification of products within a short period of filing a tender. Demand is always skewed and thus planning takes place against a firm order for such product demand.

b. Solar products are integration of multiple components procured from multiple suppliers. Time available to respond to tenders is limited and thus meeting exact specification and cost is a challenge for solar suppliers. Most of suppliers thoroughly validate their integrated product design to ensure reliability of these integrated products at customer premise. In an event of poor product reliability, some solar companies have ended up losing from their profit or faced financial losses. Since these products are being tendered, cost minimization is a primary focus for solar player and in turn planners. Planning decisions affecting cost for these integrated products create challenges either to win the tender or supply a substantial portion of deliveries in a short period of time.

III. **Manufacturing of Modules & Cells**

First preference to supply solar modules in domestic market is catered through procured cells and modules from China, as this is cheaper option than domestically manufactured one. Cell manufacturing is run only in cases where there is requirement of domestically made cells under domestic content requirements (DCR). Wherever situation warrants, cells are imported and modules are made in India until specified that both should be domestically manufactured. Because of overcapacity worldwide large volumes of solar modules are imported from China. There is huge capacity and off-the-shelf availability of cells and modules from such Chinese suppliers. Supply consistency is a major qualifier from Chinese suppliers. Demand variability is all that is being watched for planning process by planners to link with procurement. Raw material stocking in domestic plant is done only in small quantity just to meet a small demand. Intermittent running of these manufacturing plants causes a substantial portion of workforce not employed during lean period. In solar cell or module manufacturing, high level of skilled manpower is required. Manpower which is not consistent in employment has tendency to move to non-solar job when solar job is not available. It is difficult to employ such a skilled work force on intermittent basis. Planner needs to iterate their plan subject to such intermittent availability of skilled manpower.

IV. Solar EPC Project Business

Solar developers are installing projects for Independent Power Producers (IPPs) or for power utility companies. Majority of solar developers does their own EPC contracts. The first preference of EPC contractors is to use imported modules. Imported modules are available at much lower cost from Chinese market than one manufactured in home country. But MNRE is giving level playing field by putting conditions of domestic content requirement. Solar projects under DCR schemes are a primary driver for material planning from domestic source for EPC contractor, developers and manufacturers. Demand for DCR is driven from allotted capacities to developers by MNRE or PSUs. This DCR regime decides the demand and also source of procuring material, to fulfilling. Demand is always in the form of projects where in two factors decide most,

1) Whether developers does their own EPC or
2) Cells/ modules are required from domestic manufacturer or imported.

In solar project, design and finalization of list of COGS or WBS takes time before start of material planning. This becomes a major bottleneck at times, since finalization of WBS/COGS requires long time to complete a set of activities of project site survey and completion of engineering design. Projects are installed in different part of country thus transfer of skilled manpower is difficult from one project to other. Most of the places skilled project manpower can be mobilized to deploy on a solar project in a radius of maximum 200 Km. Planners have to plan based on contractor's skills, to ensure reasonable competent manpower is deputed in solar projects execution.

V) Large Project Developers

Developers of solar projects are customer for solar power generating assets. They are responsible for owning and generating solar power for themselves or supply to end customers. Developers of solar project either do their own project EPC or contract with an outside party to mitigate risk arising from solar project execution, more professionally. Solar EPC companies, contracting with developers or solar manufactures are usually found it convenient, if the project cash flow is managed by planner in developer's company. A planner in solar developer's space, play an important role of coordination with EPC contractor, land approving agencies or various power evacuation related approvals. Within EPC Company, planner coordinates material, manpower and other required resources. These two levels of planners are considered to be more effective with a common line of aggregated coordination. In absence of developer's level planning, an overall project planning is suboptimally coordinated and leads to project delays. Following requirement from an EPC contractor by developers causes planning lapses.

- **Quality standard** – Developers appoint their consultants who are specialized in solar project. Planner of EPC contractor has to ensure that upstream and down streams supplies and installation standard are acceptable to developer or their consultant without much negotiation. Any delay in settling the acceptance of delivery causes project delay. Continuity of supplies is affected on account of disagreement on acceptable and unacceptable level of quality standard. In situations of such disagreements, supplies and project handover gets delayed. Planner helps to coordinate with developers and internal company functions to satisfy customer with the quality specifications.

- **Documentation in terms of deliverables** – A planner has to ensure contractual obligation is completed and delivered in the form of clear and complete "documents" on time. Stage wise document handover to customer serves as a formal evidential stage wise project completion for solar project developer. Without completion of documents, it leaves a room for interpretation, whether contractual obligations are met or not for a particular stage. A best practice as told by interviewees in this segment is to handover internal documentation from one department to other. Planners centrally plan and administered such inter-department document handover to ensure it is delivered as per agreement to developer along with stage completion. This practice eases out final project handover to developers, since document handover systematically gets completed by the time of project commissioning. The formal process is being coordinated by planner in a solar company.

VI) Individual small roof-top solar projects

Roof top solar projects are generally falls under capital subsidized programs. The subsidy approval takes place in a fixed block of solar projects submitted to MNRE/SECI, say one block can be of 500 KW size for multiple customers. There are chances of order cancellation, if subsidy approval is not through or delayed due to high cost. Even after a confirmed order, till the subsidy is approved customer order is not considered firm. Planners coordinate with the subsidy approval liaison, sales function and suppliers.

g) Role of finance function impacting planning iteration in a solar company

For distributed solar product products under state government nodal agency program**,** finance function is always challenged in paying suppliers on time due to lack of cash which is mostly locked in debtors of from nodal agencies or their customers. Non-availability or inadequate bank credit limits on account of slow collections from customer, planners are always constrained on procuring material on time. Planning of solar products is just enough to meet a firmed demand. Any additional stocking to improve availability is always constrained.

For large solar projects, finance function review of project Bill of Material (BOM) takes place, before order acceptance and material procurement. All cost structures need special approval from finance department to correctly provision all interest, warranty, service & support and foreign exchange hedging cost. This takes time and adds to lead times of 1-2 weeks in addition to time taken by operations.

Finance department always tries to seek project wise procurement details, which is deterrent to increase economies of scale for planners. Aggregated material ordering and project linked material ordering are two contradicting objective planners are suppose to achieve. This contradicting objective leads to sub-optimal planning outcomes.

h) **Other Miscellaneous Issues affecting planning iterations**

I) Supplier's Strategy & Credit

Risk of delivering material on time is ensured by having alternate suppliers, in case of any untoward supply constraints. In solar module manufacturing, instead of creating capacities, a sudden demand is met by costlier sub-contracting, but avoid risk of investing in additional capacity creation, which may remain unutilized in long run.

In projects, solar planners give preference to MTO. Some innovative efforts are on to standardize module supporting structures to suit roof top installations. Respondents told us that they are engaged in building relationship with suppliers to keep stock for them without a firm commitment of order, to cater to an anticipated demand. The logic of such stocking by supplier is aggregation of similar demand from multiple EPC contractors. A stock can get consumed by other contractors who may win such orders, if same order is lost by other EPC contractor. Suppliers are pushed to be ready for any sudden gearing up for demand, but module suppliers view it as a win-loss game and thus do not want to stock.

One of the major factors deciding selection of supplier is maximum credit period they can offer to contractor. In solar industry, credit period are longer than industry. Suppliers having supplies to both solar and non-solar industry can better manage such portfolio to balance out cash flow from a solar and non-solar supplies with varying credit period. These suppliers are BOS suppliers like cable, inverters, structures etc. The solar procurement experts are attempting to manage longest possible credit period.

II) Demand Aggregation

For retail solar products, demand is aggregated at regional level but solar modules demand is aggregated at mother plant or preferably at raw material level to built flexibility of varieties in supplies. This is only part of base or averaged out demand.

Aggregation is not being considered as a priority to reduce cost for solar projects. Even for small size solar projects, there is one to one line connected for project and material planning, except some small time aggregated material like power cables & data loggers, procured for stocking. There was trend to have long term wafer supply contract for solar cell manufacturing, but due to falling module prices globally, it became a liability to enter into such contracts. So, no long term contract is being undertaken by any solar entities in such a volatile environment. Module plant capacity aggregation has not paid returns to manufacturers worldwide. For example, China has world's largest solar module and cell plant capacity aggregated, equivalent to half of the world solar demand but still found having cash losses at the end of year 2015. Expected antidumping duties imposed by US and Europe or DCR environment is being reviewed in counties, from time to time. World's demand can continue to met with the already created unutilized capacity.

i) Planning Iterations during Sales & Operation (S&OP)

I) S&OP for Project Planning

Once material requirements are ascertained, a planner places back to back orders on suppliers. The major decision for dispatching material depends on availability of road permits and cash advance receipt from customers. Material planner has to monitor these two milestones, in addition to ensuring material availability at planned time. Reprioritization of sequence of material dispatch to solar project site, takes place based receipt of advance and road permit from customer. Project S&OP is mostly focused around updating and decision making based on these two inputs from sales team. During S&OP process, roll of government liaison play an important role to create exact visibility of material demanded. Participants of S&OP help in arriving on a view to create demand visibility beyond two months. S&OP process in solar industry generally runs weekly, to optimize and decide right priority. Inspite of such a frequent S&OP, solar companies are not sure about right prioritization in many complex situations of solar project approval from government agencies on multiple fronts. To fulfill demand for solar projects, S&OP is participated by, entire project execution team.

ii) Manufacturing S&OP

Solar cell or module manufacturing has a shorter lead time for production after receipt of demand. Plant planners keep thin raw material stock, to manage a base demand and adapt to any sudden increase. Companies get back to back funding in the form of advances from customers or rely on creditors to fund their supplies. On the material planning front, this S&OP

is much smoother and have much better flexibility to adjust the production with an increase or decrease in demand. In case of large orders, special S&OP sessions are planned along with sales, manufacturing and quality team, to plan for raw material, required product certification and desired quality. Manufacturing capacity decisions, in the event of increase in demand due to implementation of DCR, or excise duty changes are taken at a highest level, with senior management planners.

In solar S&OP planning there are multiple group meetings for a longer period, with high frequency, but still limited demand visibility has been observed. Demand visibility improves when project is in pipe line, not before that.

5.7 Testing, Interpretation and comments on Hypothesis -4

HA 4: Role of supply chain planners need to be strengthened with specialized skill mapping for effectiveness of solar energy companies.

Supply Chain Planning for an FMCG is a well established model, forming a base for further complex planning models, having additional variables to be considered for different products and customer segments under evolution. An FMCG planner has following most significant skill sets as observed in literature -

a) Statistical Forecasting
b) Stock planning based on demand, seasonality and special demand factors
c) Tracking movement patterns of SKUs
d) Keep track of inventory and customer fulfillment
e) Tracking stock outs

While asking a question from respondents about skill sets required for a planner in solar industry, we understood an enlarged role to "solar project planning", not just material planning. We learnt that role of supply chain planners and project planners, has major overlap. Solar planners are supposed to have skill of anticipating solar market, which is largely governed by central and state government planning. Planners are considered as challenging entities in event of high demand quantity forecast by solar sales team. In the event, a solar supply chain planner is not able to rationalize demand, there is probably of large unutilized stock accumulation with the firm. Solar supply chain planner interfaces with multiple planners in solar developer and manufacturer's organization on day to day basis, after award of contract. An end to end understanding of solar project, from order winning to project commissioning, including various statutory approval, quality assessments and expectation of stage wise documentation is also suppose to be a competency of a solar planner. Solar planner skill sets, are required to be of a virtual team leader along with having a skill of planning. As a team leader he is expected to drive a demand view point consistent across all stakeholders in a solar company. In a solar company multiple stakeholders has a varied view about the demand. A realistic view consistent with the solar market is difficult to achieve without a rational demand view. Solar industry respondent were highly dependent on planner's view, as a most realistic one, rather than other personnel involved in value chain. Stakeholders as a part of the solar organization seems to have a limited or biased demand view, depending on their role and personal interest derived from the function they belong to. For example, sales view is highly optimistic whereas finance department and operations view is most pessimistic. A limited or biased view on supply chain planning may not be an optimum for solar industry. Planner in solar industry should be able to plan based on global capacity and stocks. Such a planning decision is based on leveraging short term and long term cost for solar projects. Based on images and requirements, expressed by respondent, a solar company planner should have an additional set of skills. These skills are -

a) Forecasting of central and state government solar regulatory environment
b) Government tendering processes and its length to decide an order winner
c) Understanding of specifications of solar products to have an efficient expediting
d) Ability to explore on alternate usage of material based on best match of specifications, in case of an existing order cancellation or alterations.
e) Special state taxation structures on solar products
f) Ability to connect to top most management for wider planning inputs.

g) An understanding of solar order to cash cycle of a firm, to manage healthy material supplies to fulfill customer demand on time and optimizing cost of fulfillment
h) Capability of judgment on probability of winning an order, in addition to a view represented by solar sales staff through tenders.
i) Knowledge on solar project quality expectations, certifications requirement and specifications as laid out by state solar nodal agencies for solar projects and products
j) Knowledge on financing schemes and their impact on solar projects and product demand
k) A good hang on project documentation required by government agencies and solar developers.

The above list overweighs the general planner's requirements, as expressed in skill set required for a base level planning, in a typical FMCG company. This indicates a solar supply chain planner skill requirements are far beyond FMCG planners. The above additional skill sets, makes job description for a solar planner beyond a material planner as compared with a FMCG firm's planner's skills. Our interviews with solar players revealed that the additional skill requirements in solar supply chain planning is much beyond a conventional planning skill sets. Thus across solar industry, it needs to be further strengthened with newer skill set mapped and development thereon. A secondary data analysis in introduction chapter has already indicated that matching skill sets for solar planners, at lower hierarchical level, does not exists readily. Thus it required specialized focused development of solar planners.

Interview Insight and discussions on Hypothesis -4

Our interviews revealed that supply chain planning process in solar firms is additionally being handled by senior officers in solar companies, including their CEO and MD. This is because of gap in skill sets required and available with existing planners, working in solar firms. Senior management of a solar firm, have a solar clout, networked in government and other solar association and manufacturers. Senior officers are considered to have a better anticipation of solar demand, being affected by multiple regulatory and market factors. In addition, senior management team keeps a close watch on leading indicators of solar demand to build back end supplies, either by procuring, manufacturing or sub-contracting. Supply Chain infrastructure expansion decision for distribution, warehousing and logistics goes to highest level for approval because of gap in skill level of evaluation by supply chain planners. Respondents feel that finance controlling function is influential in setting supply fulfillment priority, based on speed of expected cash flow from customers. With mapped skill enhancement, this role can be handled by planners, most ideally.

In **solar product** planning, a typical supply chain planner skill sets is a basic requirement. Over and above, planner should know various subsidy schemes runs by central (MNRE) and state level nodal agencies. The time of material dispatch depends on tender bid opening and formal order placement by customer or nodal agencies. Solar planners should know details of various tendering process run by state and central government. Planner's planning iterations starts from the stage of tendering itself. A number of insights go into defining and refining material planning decisions. Planners are expected to have a visibility of an alternate use of the material e.g. in case ordered material is not utilized for existing tender, what are other alternate usage. Alternate utility for such material may be sought in event of an order lost or quantities in an order are reduced. At times, alternate use of material may not be possible; planner must possess a skill to seek possibility of liquidation of material to release cash, e.g. selling planned material to a solar player who may have similar order from a similar tender or in a different requirement. Planner should be able to judge solar peak and trough in demand, during the planning horizon, to adjust the forecast. Planners have to remain connected to last mile in retail channel e.g. dealers to understand the new product entry in the market, especially from China and see how demand is getting substituted by similar product, to refine demand forecast. Planners should know working of various state solar nodal agencies like Rajasthan Horticulture, Tamil Nadu Energy Development Agency (TEDA) etc.

In case of **solar manufacturing planning,** some of critical specifications like solar cell and module energy conversion efficiency should be understood by planners. Energy conversion efficiency is critical specification, customer is specifying in their order. During manufacturing, cell efficiency has large variations due to equipment, skill and process parameters. Any miss in the efficiency performance against specification, can lead to non-acceptance of modules by customer and increases inventory byproduct. Such byproduct neither can be supplied to intended customer nor easily liquidated. These byproduct modules need to be discounted to sell in the market causing loss of revenue. A solar manufacturing planner needs to keep watch on cell and module efficiency in manufacturing, to match customer expectation of size of solar plant. A large volume of module with low efficiency production can lower down production volume and delay in fulfilling customer order as planned. A planner should also be able to pro-actively plan customers whose specification is of lower efficiency, to liquidate normal byproducts to recover best possible revenue. The planner need basic knowledge on solar module engineering to suggest design department, to include modules in ongoing projects, to seek possibility of inventory liquidation to maximize revenue in a solar firm.

Planners can play a major role in procurement, by exploring possibilities of placing bulk orders, to take advantage of economies of scale. Planners can have a visibility for a little longer term, since some of raw material is generic in nature and can be planned in advance to procure an "economic order quantity". With a close watch, planners can get help in consumption of solar cells and modules lying in stock.

A planner need to be aware about state policies expected to be rolled out by ministry of commerce related to excise duty structures on various solar procurement items, to see if demand is shifting from one source to another (specially domestic source to abroad or vice versa) due to levying of new duties or obsolescence of old ones.

Planners are expected to be able to create an environment of coordination, with internal as well as external customers. He or she should be able to convince finance, design, engineering and related stakeholders about the importance of planner's decisions to maximize revenues and profits for solar firm.

Planners are expected to be skilled to connect seamlessly to top management, to assess factors in larger business environment e.g. decision on how much and which project need to be executed in the light of new government regulations and support. Planner should be able to relate business leader's perspective on a planning decision is being made. They are responsible for achieving organization level optima, not at stakeholders and department level narrow optimization.

Planners are expected to be a cash manager; he should have an understanding of firm's liquidity situation to ensure organization wide optimum. A right group of planners should include a policy, taxation, supply chain and commercial skills, so not only department but the industry view can be considered by them. Planner must know anticipated cash collection from customers and falling payment due dates to suppliers. They should be able to prioritize the right material dispatch sequence to match correct procurement sequence. The supply chain surplus measurement should takes place at a planner's level rather than at finance department level to have an effective control. Planners should be a traffic controller, coordinating with both finance and operation functions.

Planner should have experience of domestic and international solar project sales to judge probability and size of an orders and time of delivery, since sales department tends to enforce extra optimism on demand, to seek planning priority. Planners experience shows that there is large variation say 12-16 weeks in term of actual and expected delivery of material. Different solar business segments have different probabilities of order winning on early on prioritization for planning e.g. an export supply order realization has different probabilities depending on their domestic availability, regulatory structures, incentives and stage of technology evolution as compare to a demand to a local solar project. Similarly, same set of variables for domestic supply planning can be viewed very differently depending on factors in own country. Planning team has to pass through high stress, in an attempt optimize upward sales volume forecast distortion by solar sales team, since sales teams are incentivized on fulfilling sales volume irrespective of size of inventory. Such push-push creates pressure on "planning" for prioritization.

Planners should also be aware about international certification to meet the conditions of various orders requirement for exporting solar modules. Even if product is ready, but if appropriate certifications are not acquired, supply cannot be made and lead to cash blockage.

Integration of various solar product configurations is supposed to be known to a planner to ensure meeting specifications for satisfactorily customer supply. The reasons for consideration of a particular configuration should be known to planner from customer requirement perspective, since maximum integration takes place near point of consumption locally.

The planners are not readymade supply chain professionals trained in operations management. A supply chain professional exposed in policy matters and project execution experience would be an idle match for solar industry. A planner needs to go through nitty-gritty of the solar sector and company, to play a role of an effective planner.

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Chapter 6 - Limitation of Study and Future Scope

The research work undertaken is an attempt to bring up a body of knowledge in solar industry in Indian context. Thesis presented, has tried to generalize some practices based on a set of solar players, primarily located in and around city of Bangalore but some large scale solar firms have also been taken from out of Bangalore as well to avoid missing comprehensive salient key signals of industry. The reason for selection of Bangalore is representation of all variety of solar equipment suppliers and contractor's availability.

Researcher has tried to capture a view which is a representative view of solar industry players but there can be multiple limitations in terms of following.

There are multiple objectives being served by solar industry players and or state (government of India or its states). The research is more inclined to take view of players on solar industry development. The primary analysis undertaken is to substantiate the hypothesis from industry player's perspective only. Published objective of government of India is considered as an objective in the research work. There can be multiple areas within the various department of government wherein there can be a possibility of difference in view e.g. MNRE and ministry of commerce can have a different view as to how to grow the sector whether by passing on financial support or enforcing antidumping duty, which is not studied in the thesis. In the same way ministry of human resource development may have a more inclined view for the development of skill in the direction of creation of more employment. Following are further limitation of research, not covered in the research work. There can be future studies in following areas

a. A supply chain study can be undertaken to understand, departure from fossils based fuel to be used against renewable sources of energy. This can help in analyzing whether dependency on conventional sources are coming down with the growth of renewable energy or not. A supply chain aspect can cover how cost effectively solar energy deployment is taking place.

b. India is one of largest sun shine receiving geography, vis-à-vis many other countries, a perfect conducive environment to develop solar market and supply chain. How much successful, we have been on a comparative basis to tap such large solar power potential. Such research can help giving direction to weak links of supply chain to boost the solar energy deployment in the country.
c. Comparison of supply chain distributing solar products and kerosene across the country can be a future research. Kerosene oil lights most of un-electrified or partially electrified rural homes in India. There are reasons why distributing and managing solar products are more efficient than a kerosene distribution through a public distribution system. The research is required to understand comparison and efficiency of both the supply chain.
d. A research can be undertaken to compare centralized and de-centralized solar project state support mechanism, with reference to their supply chain, to maximize in meeting large scale solar power deployment target in the country.
e. Is local manufacturing is sustainable with the evolution of solar energy sector in India? This research can bring up aspects needs to be worked upon by industry and state to ensure solar energy deployment takes place along with development of manufacturing development in the country.
f. Development of concentrated solar technology and scope for growth as compare to PV solar deployment technology. Both the solar technology has not seen same growth in solar industry. The supply chain of both the technology has a number of important critical factors to be considered as a comparative study for recommendations.
g. A research, finding out variation is supply chain practices from solar firm to firm, can be undertaken to see differences as against the existing research, wherein supply chain practices are being pooled together.

Geographical limitation like company to company variation exists in terms of managing supply chain planning risk. Different solar players have different supply chain risk appetite depending on their standing and supply chain structure they have build. A research work can be undertaken to map supply chain risk profile of Indian solar companies and their relative market success.

h. There is a possibility that very aggressive and more integrated solar energy deployment may need a globally integrated supply chain with seamless flow of material and information, to set up solar power plants. Even though this solar model is still coming up, it can have a model completely different than in the study. A future research can be undertaken to study such integrated global solar supply chain to learn their strengths and weaknesses.
i. Research work has indicated a small comparison with an FMCG model for solar products. But a complete comparison can be undertaken to benchmark the distribution for solar products. Solar product players engaged in solar product integrations and distribution can follow a model much closure to FMCG. This trend will further emerge wherein FMCG way of distribution will be required after withdrawal of state subsidy. Withdrawal of subsidy will allow solar demand to be more natural demand. Presently these future models are not included in the study. Study is more concentrated to derive implications from government supported programs.
j. New models like "pay –as – use" consisting of innovative financing options need a special planning study. This is a micro financing model empowering customers to acquire solar assets in installments. This study may not explain this entire new business model evolving in the market. A separate supply chain planning can be evolved to cater to this upcoming solar segment.
k. To achieve grid parity, cost of solar installations has to be reduced. This reduction is possible with the help of an efficient supply chain. A research

correlating all such factors can be a path forward to understand affects on each factor on deployment of solar energy.

l. A research possibility exists to revisit impacts of various government support structure and its affect on development and maturity of supply chain.
m. Solar industry created overcapacity across the globe. A research can be undertaken to track back this bull-whip effect. Its reason and extent of the bull-whip.
n. Prioritizing solar energy development in un-electrified area can be with the help of two modes of mini-solar grid solar projects or solar products sold through retail channel. A comparative study can bring out potential to achieve large clean energy and more reliable solar energy systems. A mini-localized grid can be more efficient and cost effective in some given circumstances where as retail solar product can be more effective in terms of meeting certain other circumstances.
o. How far solar supply chain development in India has been successful in achieving vision of India's economic development in renewable energy deployment. This research work can be an academic research suggesting direction to various support arms of MNRE, responsible for solar development like R&D, financing, power purchases etc.
p. Depth and effectiveness of role of states in India in complimenting central government, in meeting solar deployment objective by localized supply support like land, PPA and human capital. This research can substantially bring focus on collaboration between central and state government in support solar energy deployment in sync.
q. It is expected to have a demand pull into roof top solar installation which is primarily being driven by solar subsidy to the tune of developed country like Germany, may require additional supply chain competencies. A research can be undertaken to cater to understand evolution of the market trend.

r. Supply and demand, derived under government support program may have consumer behavior, which is not completely modeled by way of traditional mathematical and statistical methods. A research can be conducted to predict structure of state support program similar to a seasonality factor which creates pull and push in the supply chain.

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Chapter 7 – Conclusion

Research work is concluded with summary of following findings, as learnt by researcher during the research work. To put forward more effectively, conclusions are divided into six broad headings, more relevant in context of Bangalore and largely may be applicable to Indian solar equipment suppliers industry. Since solar industry is national industry, it is difficult to only restrict to Bangalore region based on players considered and their national wide approach.

7.1 Global Demand & Supply with reference to Indian solar industry

Research concludes that solar supply chain, in any part of the world, is tightly linked to demand and supply situation, across the globe. Following points detail out the findings.

a) Local solar equipment industry need a wider scanning, across global sources and demand, for solar equipments, to create plan cost effectively and efficiently, to have better supply chain surplus, irrespective of intended consumer location in any part of the world.
b) There is large mismatch between capacity and demand of solar equipments in some countries, especially solar cells and modules, which decides flow from large capacities and inventory pools to country in which there is high demand.

Difference in capacity and consumption of solar equipments, leads to price fall across the globe, where prices are lowered to an extent that local manufacturers are hardly viable. China proved to be a major solar capacity hub for world offering solar cells and modules at lowest price and easiest availability.

c) There is a co-relation between Chinese module price and their share of solar market acquisition in an aggregated global market demand. This share has continuously increased in favor of Chinese solar players, as prices have fallen for solar modules produced in the country.

d) Price, ease of availability, competitive quality and technology available globally, are driving forces for supply chain planning and procurement decisions in favor of these low priced and high capacity countries. Among all such forces, primary force is price, pulling global procurement from these countries.

e) Solar equipment suppliers are facing high capacity and inventory challenges for their domestic products from imported sources. The reasons for such alternates are price, availability and competitive quality and technology. These players have a high confidence to have reliable supplies from imported source with the help of excess stocks and availability, as compare to their local suppliers. Time of transportation of 4 to 10 weeks, from such a low priced country, to a destination country of consumption, is hardly able to influence on-time-availability, from high capacity and high inventory stocking players abroad.

f) Major import of solar equipments or raw material is being procured from China, thus dependency of prices from China and risk of foreign exchanges is increasing, for domestic importers, exposing them to substantial financial risk.

g) Global solar inventories are increasing from year 2010 till now. There is expected to be a discouraging pressure on domestic solar cells and module manufacturers, being small in installed capacity base. The reason for such pressure is easy accessibility of global inventory to procurement and planners, at the place of requirement.

h) Domestic and some global solar manufacturers have recently shut down or underutilizing their capacities. These players are trying to make these capacities available to solar companies across the globe to utilize cost effectively.

Equivalent months of inventories from running manufacturing sources are continuously increasing despite such manufacturing capacity shut down.

7.2 State support, creating primary solar energy demand in country

State (National or state level) are a major force boosting solar power growth in India through their multiple support programs sponsored by governments. Following points detail out the findings.

a) In solar industry, demand driver are prominently state support in the form of feed-in-tariff, capital financing, REC or tax holiday or a combination of more than one, depending on schemes. JNNSM has put forward a comprehensive support structure for development and deployment of solar power in the country, along with multiple state level policies.

b) State policy support is a critical parameter to decide promotion of solar energy in a country. Better state supported countries have more demand of solar energy deployment. Source and destination of solar energy equipments is decided by level of support offered by state from a comparative perspective. A higher support to solar manufacturing in one country makes it a strong source of solar equipment supplies to other countries where support from local state is meager on a comparative basis.

c) Domestic state support on a particular type of solar technology indirectly promotes non-supported solar products, available at a lower cost without subsidy. As in India, deployment of solar thin film based solar PV deployment took place in much larger volumes, in Phase-I (Batch-I) of JNNSM even though it was not supported by state. During this phase support was not being offered to thin film technology based solar projects. In Phase-1 (Batch-II) onwards both the solar technologies were included under support program as a corrective action to make state support technology neutral.

d) Even though solar industry is growing at fast pace, say 35% of CAGR, growth rate of domestic solar manufacturing is sluggish. State (through MNRE) has launched program to promote domestic solar manufacturers, by providing level playing field, at par with internationally low price manufacturers. Solar project developers have to buy domestically manufactured solar equipments under DCR requirements, to give boost to domestic solar manufacturers.

e) Significance of natural demand factors, arising out of inherent customer need, is weaker than state supported demand. Growth of solar sector in India is attributed to support program run by central and state governments.

f) Solar products have a large natural demand in rural market. Demand for solar products is growing at a faster pace, replacing kerosene usage, which in unclean fuel, used in country. Therefore solar products have comparatively large natural demand as compare to solar projects. Unfortunately high initial cost and less affordability by needy rural customers is still causing distortion in natural demand of solar products. Rural consumers wait for subsidy or micro financing by various state schemes to convert their need into a demand for a solar products.

7.2 Solar Industry planning complexity factors (Planning Width)

Planners keep a watch on the solar state support policies and regulations, as announced from time to time. Watch on solar state policies and their enforcement process are intended to consider in their planning and procurement source. Planners begin visualizing decision for a source of solar material procurement, depending on visibility of the state support policies horizon. Source decides lead time to procure material against an order on suppliers. In turn, back end time calculation is done for an order placement, to receive the material at the time of requirement. A material arriving before, causes inventory and liquidity concerns, whereas a material reaching late causes project delays. Both are sub-optimal outcomes for a solar firm. Chief causes of planning iterations are change in visibility horizon of state support policy and anticipating of exact order placement time, to receive material on time. Some fine point conclusions are as follows.

a) Planners have to be cautious in deciding whether to increase module/cell production capacity or not. Other alternates are use of domestic contract manufacturing or source from Chinese suppliers. Manufacturing capacity additions can lead to capital at risk, in the event of procurement from domestic manufacturing is not supported by state or an unviable cost of production. Reason for non-viable cost of manufacturing is lowest price availability from China. Visibility of demand through state supported are not beyond two years of horizon in one go.

b) Delay and withdrawal of subsidy from solar roof top projects is causing multiple planning concerns in the event of delay or withdrawal of subsidy, after customer has agreed to put up solar plant. There is a trend of gradually reduction in state subsidy. Two contradictory forces are working at the same time, one side investors are waiting for subsidy to get approved and others side there is a fear that subsidy may go off.

c) State level local subsidy and net-metering, as announced by some states in the countries, has potential to cause very large solar business upside, depending on success of deployment. In case of any slowdown of roof top solar project deployment, it may affect forecasted capacity planning, to build large capacity of such solar installations. This is similar to obligation posed on state to deploy solar energy through SRPO mechanism, which has failed to create any demand for solar energy.

d) Tax holiday and accelerated depreciation create a pull for solar energy deployment from investors. This is watch out for planners for any expected increase in demand for effective planning. This width factor is more consistent than a direct cash subsidy program. This creates a constant demand from investor throughout the year since government is not forced to transfer any cash outflow directly.

e) Planning material from idle lying manufacturing capacity is a prevalent trend in case of shortage of domestically manufactured solar modules, instead of creating additional manufacturing capacity.

f) Strict review of customer contract and “bill of material (BOM)” by finance controlling function is to assure profitability, causes extra number of planning iterations in a solar firm.

g) Planners are getting extended to plan full solar projects including smaller level details like dispatch and completion of documentation required for projects like QAPs, engineering drawings, invoices and road permits. They reprioritize dispatch to a project site based on all statutory and customer clearances.

h) Supply chain planning for solar equipments in India, is conservative by nature. The reason for this conservatism is large fluctuation is prices and demand due to unpredictable state support structure. These fluctuations cause risk of increasing manufacturing or inventory stocking capacities across the supply chain. In long run demand is expected to be growing rapidly but in short term unstable prices and state support do not allow supply chain planners to be optimistic in planning. Market and state support to solar projects will continue to show high demand signals but planners remain realistic in planning. Nature of realistic or a bit pessimistic planning in solar industry is attributed to business survival, in high volatile market. A planner doubly or triply ensures that they procure material against a firm demand or customer commitment.

i) Sales team in solar companies act as a "solar demand speculator" and forecast given to planners are far beyond the actual demand. In some companies the errors between demands forecast and actual off-take varies up to +/- 500%. Solar companies in India have a very low reliance on forecast. This pushes solar companies to runs on extremely thin stocks and plan material back to back against an order.

j) Since solar industry planning goes back to back, a base stocking model is not evolved, which is suppose to take care of a base minimum demand. The reason is liquidity shortage, falling prices and probable value loss of inventories due to obsolescence.

k) Fragmented solar market in India is not allowing aggregation of demand for supply chain planning coming from a few large solar players, to reap benefit of economies of scale. Thus players are neither able to gain surplus them nor able to pass benefit to customers.

l) Solar products stock is still being managed, even if it is fast moving project stocks. In principle solar projects follow only "MTO" plans and Project wise material planning and procurement is encouraged. Stocking for solar products is most liberal across solar industry, followed by small rooftop based projects and no stocks for large mega watt scale projects. Planners expedite material by diverting to other projects, in case of similar requirement is in projects getting executed earlier than the project for which material was ordered, to keep inventory stock to a minimum.

7.3 Factors driving planning iterations in Indian solar industry

Indian solar firm follows an extraordinary iterative supply chain planning process, given an uncertainty in demand, supplies, state support and other given internal and external firm's environment. There is about 35% year on year growth in demand of solar industry, and high confidence in future upside trend, planning material for solar energy is extremely iterative and discrete in nature. Following points detail out the findings.

a) Planner's first dilemma is to judge the time to start planning of material, for a solar project under discussion. This dilemma prevails from a stage of engagement of customer for order discussion till a firm contract order is signed or cash advance is received from customer. Different solar projects have different degree of order winning probability. On one hand an early material planning helps in meeting project deadlines, on other hand it can lead to risk of blockage of liquidity, in event of delay or non-materialization of order. This fact drives planner into iterations, carried out at various stages.
b) A few planners also believe that planning process should not start after getting purchase order, but only after getting contracted advance amount from customers. Postponing material planning at the later part of the order receipt stage, reduces number of iterations and also satisfies developers even though some delay takes place in commissioning and handover of a solar project.
c) Solar project design changes causes material planning iterations. A solar project design keeps on evolving, due to reasons internal or external to firms. Some of

design changes are requested from customer; other reasons of design changes are due to project site change, material non-availability and cost optimization.

d) Very small or no buffer inventory stocking leads to supply chain planning iterations, to match demand and requirements with multiple combinations. Inventory turns increases with more number of iteration performed by planners in a dynamic solar firm.

e) Stricter norms of inventory obsolescence and excess, causes constrained situation for planners. It has been observed that more numbers of iterations are performed by planners to meet these internal norms of a firm.

f) In solar projects, sequence of an ideal material supply, is being followed loosely. Solar modules supporting structures, required in the beginning of project, faces major supply bottle neck, and thus get delayed in getting dispatch. Modules structure bulkiness, fabrication capacities, galvanization process and quality problem causes multiple iterations in planning. Under the state support program material used in project are required to be procured from MNRE approved suppliers. Once order is placed on such a supplier, it is time consuming to seek approval from MNRE for a different supplier, in case contracted supplier is not meeting delivery performance. Modules supplies to a solar project are faster than rest of the material supplies. This causes dispatch and invoicing of solar modules much ahead than required by a project. It adds to planning iteration when cash collection from customers causes delay in further delivery of material.

g) Fund availability of company procuring solar material delays payment to suppliers which further leads to more number of planning iterations on account of schedule of downstream procurement. Cash collection from state nodal agency is for various solar installations is very slow. Thus it becomes difficult to rotate cash for the same project for which procurement was undertaken. For every such supplies companies goes for extending their line of credit to ensure availability of working capital.

h) Longer supplier credit period reduces number of planning iterations. It leaves no room for changing the supplier, in case of any issue faced by buyer or supplier at later stage.

i) A large proportion of outsourced value of material causes more dependence on suppliers and causes more planning iteration. A larger portion of in-house manufacturing of solar module or cells lowers numbers of iterations in planning.

j) Solar raw material planning for manufacturing cells and modules for in-house manufacturing causes extra planning iterations, than what is required for finished goods.

k) Numbers of planning iterations are dependent on solar business segment – large project has more number of iterations, followed by small project and solar products.

l) State supported solar product tenders are filed within a very limited period of time from the date of announcement of proposal for bidding. Solar companies are not able to come up with a complete design and estimation of cost in such a limited period, causing extra planning iterations at later stage to manage supplies

m) Solar planners are using spread sheets as a planning tool, rather than an automatic material planning like standard MRP. Each project is being considered as unique planning situation by planners, which causes project wise planning and manual iterations.

n) Planning iteration increases non-linearly (more rapidly) with addition of block of about 5 MW. Within a block of 5 MW supplies are more predictable. Therefore planning is more iterative with every increase in 5 MW of solar project installations.

o) Multiple solar project execution at the same time during second half of the Indian financial year leads to more number of iterations. Multiple on-going projects at the same time, causes chaotic planning and causes delay in projects commissioning. Planners are undertaking a large number of iterations to meet requirements of all ongoing projects from a limited sources of material.

p) An approximation is used in project land site survey during customer order acceptance stage, causing multiple iterations before firming up of project design. The reason for rough project site survey is under multiple assumptions, to minimize effort and cost at initial assessment of an order of solar project, which may or may not get materialize.

q) Evolution of QAP during the project execution also causes planning iterations thus experienced designer tries to keep provision in the beginning for such changes on account of specific quality requirement from customer.

r) Many developers' related issues like project site availability and statutory clearances are monitored by planners to iterate and ensure timely availability of material.

Broadly more number of iteration take place to manage cost in a project after winning tender/orders.

7.5 Solar business segment specific Supply Chain Planning

Supply chain planning attributes, specific to a solar business segments are summarized below

a) Solar Projects Planning

I) As a part of conservative material planning in Indian solar industry, buying for solar projects is extremely conservative, to avoid incurring additional cost of stocking and holding liquidity.

II) Entire planning and procurement for solar projects is dependent on lead time from suppliers. Lead time of supply either from China or from local manufacturing varies between 10 to16 weeks including transportation. Thus lead time to deliver material has hardly any difference from the two sources. There is high confidence to ensure availability from global module inventory stocks to support delivery of solar projects in India. Planners do not mind even if it cost some premium to expedite supplies on priority from China. Planner trade off and pay premium shipment charges, if required, rather than stocking in house. Lead time from China is only equivalent to transportation time of 4-8 weeks, since they carry high volume inventories to cater to solar customers worldwide.

III) Economies of scale are not being explored due to high fragmented EPC contractors and developers in the country.

IV) It is difficult and unmanageable to plan material project by project in small solar installations. A project solar planner has an opportunity to identify two groups of material, one general material stock which can be used in any project, second is project specific stock, required in a particular solar project.

V) Planned materials for a solar project is not being procured in one go. Firming up purchase order on suppliers keeps on releasing, even during the execution of projects, as not all requirements have been captured in the beginning. Some specific material is procured during project execution stage as per need expressed by customer or to meet actual design or project site conditions. This causes unavailability of material exactly when it is required.

VI) Module mounting structures fall in critical path for a large mega watt scale solar projects. High volume supplies from limited vendors causes constraints on production capacity and quality. Planning of mounting structures has largest potential to delay a solar project from material related reasons.

VII) Solar project contractors wish to enhance a wide supplier base, spread across country. A wide spread suppliers base, especially for structures helps reducing extra logistic cost. A wide spread supplier base reduces cost of project, but limitation in having such large supplier base, on account of demand fragmentation among multiple solar contractors, is being faced by a solar firm.

VIII) Direct dispatch from suppliers to solar project site is preferred in the planning process by project installers, as it minimizes cost of procurement of material by saving on multiple transportation and logistics.

IX) To minimize number of SKUs in small solar projects, a material kitting is being recommended by planners to have an ease of planning and logistics management. Kitting can minimize number of wrong and short supplies at project site causing project delays.

X) Solar EPC contractors are pushing suppliers of solar modules to stock for them without a firm order. Module suppliers are seen as generic suppliers, carrying pooled solar module inventory, for any contractor who wins order for solar projects. A module supplier seems not in agreement with this view of contractors.

XI) A supplier, who offers longest credit period, is being given more preference to source material. This is causing sustainability of smaller suppliers, constrained on liquidity.

XII) Solar project demand visibility horizon is generally up to two years, whereas solar product demand visibility is up to two months during study between years 2010-2015.

Numbers of average estimated iterations in planning a solar project are between 5 to 8 as against 2 iterations, in a fast moving product.

b) Solar Product Planning

I) Solar product planning aggregation is more efficient at local level of demand than national level. At the point of consumption, demand of a solar product depends on customer and local state government support.

II) Retail demand fluctuation for solar products, being sold through retail dealer channel is minimal, except small seasonal variation. Large order for solar installations against state nodal agency supported tenders causes demand spikes, creating large suction of capacity. Such large demand is causing bottle neck in supply, project installations and quality. These issues are handled by solar players at later stage. Time of arrival of such large solar product order varies significantly, depending on time of program announcement by state nodal agencies.

III) Solar product range is so wide that it is difficult to keep safety stock of all variety due to risk of inventory obsolescence. Procurement of material takes place depending on specific order. Solar players are focusing their distribution in a few selected product categories, e.g. solar lights, pumps, power packs or thermal heaters. A regular stock replenishment practices in solar product business is not well established. Supply chain player evaluate requirement of items every time before ordering.

IV) An only solar product retailer keeps a marginal safety stock to avoid sales loss at their counters. Confidence of retailers, to stock for a base demand is increasing continuously over a period of time. A safer option is to keep stocks of one month, without any major risk of inventory obsolescence. In recent year last mile dealers and retailers are getting better comfort to keep stock of solar material. Solar product business segment is very similar to FMCG, for retail customers. Except the fact that there is large forecast error to the tune of +/-500%, as observed by of solar product supply chain planners.

V) Solar product demand, seasonality plays an important role in planning. Demand for solar product is always higher in summer and dry winter when sun light is adequate for generation of solar power. During rest of the year, especially in rainy season, sales trend goes down substantially.

VI) Solar product demand visibility horizon is generally less than two months, whereas solar project demand visibility is up to two years during study between years 2010-2015.

VII) Solar product demand is geographical region specific localized, varying from region of state to state, depending on their state promotion policy to a particular solar product. Whereas solar project planning is more efficient at national level, by aggregating demand, spread out in the country. Global or local sourcing, to meet requirement of such a local level or national level planning does not influence optimum planning outcomes.

VIII) National level solar product players have limited distribution network. Only a few national level product suppliers has multi state distribution channel. Solar products available in the market are mostly from local state level companies, as their cost of service and meeting local customer requirement is more effective. Solar product players keep stock in regional warehouses to cater to these retailers near customer. National level players find it difficult to reach to retailers in a given cost.

IX) Full truck load transportation is preferred from mother warehouse. Local transportation is managed by dealer, integrators or retailers. Big opportunity exists to follow milk run from regional warehouses to retailers after solar supply volume goes up, with growth in solar market size.

c) Solar manufacturing planning for cells & modules

Capacity of solar cells and modules manufacturing by Indian solar manufacturers is very small, as compare to worldwide manufacturing capacity. Availability of low price and speedy delivery from large sized manufacturing capacity of global sources, to Indian solar project contractors is very convenient, unless project is mandated under DCR requirement by state. Domestic manufacturers stock raw material, more optimistically than a finished solar modules. Manufacturers feel safe to manufacture solar modules against a firm demand. Raw material stocking to manufacture cell and modules provide flexibility to manufacturers to produce modules of any specification as per customer requirement.

In solar module manufacturing, most of the raw material is imported. Except a few low value or bulky items incurring high transportation cost in import, is being procured locally like module frame and glass etc.

7.6 Sales & Operation Planning

In solar industry sales and operation planning, is used extensively to collaborate views of multiple stakeholders regarding demand and supply. Firms have created either dedicated or part time "operation planning" functions to carry out sales and operation planning (S&OP). This function balances both the views of optimistic sales and pessimistic inventory planning, to reach an optimum between the two. This is a cross function team formed by a set of people who represent from sales, project execution and supply chain planning. This department also tries to minimize cost by advising to explore source and guide regarding appropriate material destination, to optimize taxation and transportation.

There is large mismatch and reprioritization of material dispatch taking place, based on cash advance receipt from customers and availability of road permit to release material from warehouse to customer sites. S&OP process generally runs weekly to set a latest priority. Solar firms are prioritizing dispatches based on short term liquidity inflow management, but are not sure whether it will lead to adverse long term expected customer relationship.

During S&OP planning process, government liaison and advocacy plays a role to create accurate demand visibility. Participants of S&OP help in creating visibility more than one month and help in demand and supply planning. Solar project S&OP is part of their project execution. In practice it has been seen that solar firms focus more on current material shortages issues at project sites to complete an ongoing project, than spending time on creating demand visibility for future. In a regular S&OP, long term a very limited demand visibilities have been observed.

Manufacturing S&OP, to plan for raw material is much smoother and flexible than for solar project planning. In case of any large order, special S&OP is planned with sales, manufacturing and quality team, to create visibility of required raw material, certification and desired quality.

7.7 Role of planners in complex decision making

a) Operational planner in solar industry has a limited view to independently plan and procure material. Uncertainty of demand, large liquidity requirement and extremely thin profit margins, pull senior management staff of solar industry in supply chain planning. To safeguard the interest of solar industry, supply chain as a whole, government (state) also acts as a planner to protect long term interest of country from solar power deployment perspective. Objective of state planning is to provide clean power to masses and ensure sustainability of solar industry in the country. Complexities of solar supply chain, shifting planning role to higher hierarchical in an organization is to ensure most optimal decision. Solar planner role is much wider than a material planner; they are extended to project and cash flow planning in a solar firm till project is handed over to customer. An enlarged role of planner required special skills and competencies than a routine material supply chain planner.
b) Planning role in solar industry is shifting from a solar firm to state, but the objective of industry and state planning is uniquely different. Industry planners make most appropriate decision to safeguard interest of solar firm in short term.

But state planners save interest of solar ecosystem in country at large. Industry planners are dependent on state planning, to make their decisions as a leading one.

c) In solar industry, role of planner have been extended to manage end to end delivery of material. This end to end planning by a planner ensures accurate and correct supplies at intended place. With a number of complex scenarios, senior management involvement in solar planning is evident. Planner establishes a seamless communication with senior management to collaborate with regards to, demand visibility, source of material, cost and solar project design engineering requirements.

d) Role of planner in solar developer firm is critical to connect and manage seamless coordination with EPC contractor's planners and manufacturing planners simultaneously.

e) Project design, quality and documents expectations; keep evolving by customer as project proceeds. Such evolution of requirement and design changes causes multiple planning conflicts, disagreement and delays. Planners are supposed to coordinate with the function supporting such requirement along with material and project planning, to timely meet customer's requirement.

f) Planner should have special skills of knowing quality of solar project, documentation requirement, state and central government policies, tendering process, state and central taxation on solar products, judgment of probability of winning order and financing schemes on solar products,

g) In a solar firm, decision of cells and module planning is influenced by state planners. BOS procurement decision is influenced by senior management planners, followed by state. In case of solar products planning, operational planner decisions is most influential.

h) One of the competencies required by a planner is to be able to utilize material for alternate use, to minimize blockage of liquidity in inventory.

……………………………………………………………………………………

Chapter 8 - Suggestions & recommendations

Research work led researcher to understand emerging areas having potential to help development of solar energy in Indian context. These suggestions are based on researcher's analysis and extension of salient thoughts based on insight gained during the study. This chapter is included as a part of a thesis, to capture applied learning, directing towards development and strengthening of solar energy sector as it is an important driver for the growth of economy.

In India, energy supply is increasing but still not able to keep pace with the growth of demand. Solar energy market can develop much quickly in coming decade and has potential to replace many conventional sources of energy, provided cost of solar energy deployment comes down. During study period, solar energy players are viewing this sector as a most risky one for variety of the reasons described in the thesis. Recommendations mentioned in this chapter are categorized under solar project, solar manufacturing and solar products as each of these needs a specific focus. At the end of this chapter, some general suggestions are included which is applicable for all the solar business segments.

8.1 Large solar projects

a) Recent expected revision of target for JNNSM from 20 MW to 100 GW by 2022, a fivefold increase in target for solar energy, indicating that there is very large upcoming demand in Indian solar market. The player who would be able to design, procure and commission project at a lowest cost are expected to be more successful. Competitive reverse bidding model is expected to continue, rather may get used more forcefully, to put pressure on cost of installation of solar plants. Domestic players need to build their solar project development capability, with a renewed focus, to be ready for upcoming sizeable demand.

I) EPC market is fragmented and is expected to remain fragmented in future. A low cost structure with lower overheads, to mobilize resources is going to be a key deciding factor for sustainability of solar EPC contracting business.

II) Solar developers are extending into their in-house EPC to tap a large and cost effective business opportunity. The same extension can be undertaken by solar EPC contractor to become a solar developer, to continue sustaining in solar business for longer term. Otherwise they are exposed to risk of becoming non-competitive, due to standalone EPC provider which may not be cost effective in future.

III) A number of independent power producers (type of developer) are expected to be either developing solar assets or consolidating smaller solar assets own by fragmented players. A player can look for a long term IPPs, if they can manage short term risk and uncertainty.

IV) Financing from a low interest cost country such as Japan, and procurement from low material cost country, like China is going to be a thumb rule to plan and manage supply chain in short term. Solar companies should always look for these opportunities to tap to minimize overall cost.

V) Solar project execution capability is yet to reach at its highest level of excellence. Reducing cost of project execution and delay causing value deterioration. An excellence program across solar industry, to reduce cost and increase efficiency, is yet to take root in India.

VI) A special focus on deriving more value by improving planning and procurement can bring major cost efficiency. Some of these efficiency initiatives can add to change the view of solar from an alternate source to a viable source of energy with grid parity, given continuous decrease in cost of solar equipment globally. Global procurement is no more a differentiator for solar players.

VII) In solar energy deployment, material procurement is taking place from global sources but local project contractors would be able to pace up their project execution capabilities locally, before multiple international players tap this segment with their better competencies in this field.

VIII) India, being a service specialized economy, exporting services, should look for global scale export of solar contract to put up solar power plant at a reasonable globally competitive cost. The design and development of solar services can be managed locally, whereas project EPC can be executed at site in the country where solar plant is to be set up.

IX) Solar players who are innovating on local design and development will have better chances of success. Innovative solar inverters and BOS designs can eliminate some of the traditional expensive components in solar plants. This will also suit more local requirements, as against standard global solutions, which may not be suitable in India. An early global joint venture can be ground breaking to tap future growth of solar energy in harnessing better solar design and engineering capabilities.

X) In solar industry contracting, good projects kick off process need an immediate focus. Many a time even planner is not clearly identified. There is ambiguity between project manager and supply chain planners. A person participating maximum in coordination project activities becomes a default planner. This is more ad-hoc role rather than structured appointment of planner with right skill sets. A structured communication explaining salient features of contract should be widely published to all stakeholders like procurement, quality, manufacturing etc. This helps optimizing number of planning iterations, since awareness level is much better and planner's coordination effort is much more simplified.

XI) Planner should be involved from an early stage of project negotiation with the customer. Involving planner from an early stage brings in past experience, to manage project execution risks better, in an upcoming project. Planners view is a most rationale one to decide un-anticipated or unknown potential risks in the project. Solar company can either cover such risks by pricing or undertaking initiative to avoid or minimize. The involvement of planner can be from the time when an order in under discussion with developer. Learning from previous projects is better consolidated by planner than rest of the stakeholders. Other stakeholders might have known or influenced part of the entire supply chain but it is necessarily have a most rational and realistic view by a planner.

XII) Solar planners should work to acquire skill in costing of solar projects, to know the cost of each activity during planning. This helps in optimizing required activities or steps to execute a project. There is a need of a high level of project planning skills, managing end to end supply chain etc. Development of these professionals, specialized in solar planning is a top priority for players eyeing on long term business.

XIII) A team of strong project managers are expected to be essential part of value chain. Building such teams will be “a core competence” for a solar company. This will help them to compete against international players, who have better developed engineering and project management capabilities. Foreign companies intended to come up these capabilities locally may not be cost effective. This opportunity can be a winning proposition for domestic solar players to take first mover advantage.

8.2 Small solar project

a) Solar players should prepare themselves for upcoming small scale roof top solar projects business opportunity. This business segment has potential to grow much faster than large scale utilities scale project. Solar players should step forward in the direction of building a strong supply chain capability to procure and distribute roof top solar project material across the country. Specialized solar players with strong planning and distribution competencies are expected to grow faster than players who will wait for clear business opportunities at first place.

b) For rural electrification "gram panchayat" can play a role of energy promoter and distributor. They can act as a small profit making organization, involved in local level planning and distribution of the solar equipment with much better understanding of customer's need.

c) Residential segments should be encouraged to put up small solar plants on their roof tops by a special price support under net-metering, as against supplying price regulated conventional electricity to benefit to customers. Cost of roof top solar installations can be further minimized with the exclusion of storage batteries in case of net-metering projects. Usage of roofs of residential establishment will avoid cost of laying electrical lines since major electrical infrastructure is already in place.

d) Roof top solar financing plans is to be developed by banks and institutions, to show better ROI to customers as compare to conventional electricity after paying an interest cost. This reduces cost approximately by 30-40% lesser.

e) Standard solar plant design to "plug and play" can be launched to sell small solar power plant like a small solar product, which can be installed within a day of purchase, to start generating power.

f) Small solar grid to optimize cost for rural electrification can be promoted as an initiative of cooperatives. Such systems on per KWh basis will be much lesser expensive and reliable than small solar products fitted in individual houses.

8.3 Solar Products

Solar products are an essential requirement in un-electrified rural market. This market needs large geographical distribution network and very affordable prices to build volumes for solar company to sustain in long run. Following areas can be looked by solar product players in Indian context.

a) Solar players should categorize their offerings into two - branded products and a low price affordable product. These two categories of product offerings can be distributed more cost effectively. A branded product may bring more margins but with a low volume sale whereas low price affordable products can build large volumes. This can help maximizing overall surplus to sustain high cost of distribution. This can also create better satisfaction in customers to own a product, depending on their need.

b) In solar product business, availability at right place and at right time is utmost important to meet need of customers. In general, there is lack of good distribution network reaching to larger intended customer base. At a given place, and particular time, there are multiple evidences of non-availability of required solar products across the country. For an effective solar distribution network, a tie up with rural network like Fertilizer or petroleum companies can be an ideal model to create synergy along with their distribution, to ensure it reaches to remote rural location, being same target customer base. Such synergy will reduce overall cost of distribution and improve product availability at affordable price.

c) Electronics and electrical goods shops can act as last mile retail for various solar products. These shops are widely available in the rural market and catering to similar products. Solar products also fall in similar category and required by a similar customer base. This product range can provide additional business opportunities to these small rural shopkeepers.

d) Solar product planning and distribution channel should be managed locally near the place of consumption, not at national level. Variety in product demand, advantages of aggregation at national level seems not very economical unlike other FMCG products. National level planning is not only inefficient but product obsolescence and excess risks are not well addressed by national players. A set of local solar product players are more effective to respond to local need. A local player is getting more demand hits who can manage responding to customer better and faster.

e) Solar product distributors can be viewed in two different mindsets. A distributor catering to bulk supplies under government supported program through tenders and other distributor or dealers sell in retail market without any subsidy. Both these dealers required different set of skills to minimize risk of sub-optimal planning. Firms should see these two distributions separately with different planning approaches. Distributors participating in large bulk orders are conservative in stock planning, whereas dealer focused on retail distribution are flexible to keep sufficient buffer stocks to manage demand and supply variation. Any interchangeability in planning view of two different dealers can be a risk of not extracting full planning benefit.

f) Solar products seasonal demand pattern is not well modeled by planners. A bulk pull of solar products created by state support schemes can distort the seasonal demand pattern. For solar products, summers are supposed to be peak seasons. Demand goes down during rainy seasons due to meager availability of sun light. Supply against a state tendered order; do not follow any seasonal pattern. Timing of these bulk demands can hit at any time during the year. These distortions in the demand pattern create unknown complexities for a planner. Planner should also aggregate demand separately - for large tender order and retail, to avoid distortion of seasonal signals.

g) Quality of product and installation under bulk supply program in not meeting all expectations of customers or tendering state agency, due to suboptimal project management. Large scale solar products are contracted along with installations by state renewable nodal agencies. The installation takes place in much wide geography across the state. Being s very large spread of such installed base causes lack of local supervision, quality of skills and product abuse etc. For a solar contractor, it becomes difficult to control such wide installed base. Solar players entering into such bulk supplies should plan more pro-actively to avoid any failure of product or installation, either due to internal or external problems of firm.

8.4 Solar manufacturing

a) Most of the manufacturing is dominated by import of solar modules. Given the global overcapacity, no investment in manufacturing is expected until consolidation of market takes place. A solar manufacturer, who would be able to sustain manufacturing capability in this tough time, will be able to build future supply chain more effectively. Solar supply chain can only be sustained with low cost and small investments, to tap expected growth in future.

b) With the rise of very large scale, ultra mega watt projects (more than 100 MW) with the consolidation of independent power producers, demand for domestic manufacturing may again increase provided regulatory support for manufacturing remain favorable. Manufacturers can think of sustaining their capability through these times. In present phase, wherein government is committed to support solar manufacturing in the country through DCR, can help manufacturers sustaining in long term. Solar manufacturers can look for a joint venture to tap some low cost and high technology manufacturing, to build their volumes against DCR, and build competence to meet future domestic manufacturer’s requirements.

c) Solar manufacturers should devise a manning model in such a way to be flexible enough to scale up or scale down capacity along with increase or decrease in demand e.g. reducing high fixed cost of employees.

d) All idle capacity of cells and module production should be consolidated by a few large solar manufacturers who can run these facilities, to achieve economies of scale of procurement and production.

e) Tier-II suppliers, who supplies to solar and non-solar industry both are expected to have a less riskier business portfolio e.g. many electronics components or storage battery suppliers has solar as one of the supplies streams. They generate sufficient cash from non-solar business to fund solar business. They supply similar products to other non-solar players. Solar suppliers can develop a non-solar stream to balance their liquidity risk portfolio to their business sustenance.

8.5 De-risking of solar business portfolio

A solar business has multiple streams like solar large scale solar projects, small projects, products and modules manufacturing. These segments of solar business required different set of competencies. It is a challenge to manage all the three capabilities by an organization due to its large varieties.

In present uncertainty of large scale solar project demand, domestic manufacturer of solar modules can de-risk themselves by selling to solar products, being sold to retail channel. A sudden fall in demand of solar modules to projects can continue to an alternate customer segment. Retail solar product business can continue to generate revenues when demand for solar projects is low. A portfolio of manufacturing for solar project and solar product can hedge a solar manufacturer from peak and trough of demand to some extent. For example solar module manufacturing and retails solar products has faster cash conversion cycle, than solar products being supplied to government supported programs, where supply terms defer payment towards last handover of project. Central planning into multiple solar businesses can create synergy among smaller hierarchical planners, to pool possible inventory stocks.

Major constraint in solar industry is availability of cash liquidity to execute solar projects. Cash conversion cycle in solar industry is generally long. Projects with a faster cash rotation should be prioritized, as compare to prioritizing supplying based on only profit direct generating.

To create a most optimal cost, subordinating rest of the functions of a solar organization to “planning”, to have a common line of coordination in procurement, logistics, taxes and resources can be helpful. A centralized planning of all resources can minimize inefficiencies in a solar firm.

…………………………………………………………………………………………..

List of Abbreviation

AD	Accelerated Depreciation
ADD	Anti-Dumping Duty
AGB	Aryavart Gramin Bank
AP	Andhra Pradesh
ASEAN	Association of Southeast Asian Nations
BOM	Bill of Material
BOS	Balance of Systems
CAGR	Compound Annual Growth Rate
CEO	Chief Executive Officer
CERC	Central Electricity Regulation Commission
CFO	Chief Financial Officer
CFT	Cross Functional Team
CODP	Customer Order De-coupling Point
COGS	Cost of Goods Sold
CRM	Customer Relationship Management
CSCMP	Council of Supply Chain Management Professional
C-Si	Crystalline Silicon
DCR	Domestic Content Requirement
DF	Degree of Freedom
Discom	Distribution Companies
DP	Demand Planning
DSS	Decision Support System
E&O	Excess & Obsolete

EPC	Engineering, Procurement and Construction
ERP	Enterprise Resource Management
EXIM	Export - Import
FG	Finished Goods
FMCG	Fast Moving Consumer Goods
FTL	Full Truck Load
FTR	First Time Right
FQ	Follow up Question
FY	Financial Year
FYP	Five Year Plan
GOI	Government of India
GW	Giga Watt
GWh	Giga Watt Hour
H1	First Half of Financial Year
H2	Second Half of Financial Year
HA	Alternate Hypothesis
INR	Indian National Rupees
IPP	Independent Power Producers
IREDA	Indian renewable energy development agency
IT	Information Technology
JNNSM	Jawaharlal Nehru National Solar Mission
KRA	Key Result Area
KWp	Kilo-Watt-Peak
LOI	Letter of Intent
MD	Managing Director

MIP	Minimum Import Price
MNRE	Ministry of New and Renewable Energy
MP	Madhya Pradesh
MRP	Material Requisition Planning
M-SCM	Marketing – Supply Chain Management
MTO	Make to Order
MW	Mega Watt
N/A	Not Applicable
NABARD	National Bank for Agriculture and Rural Development
NAPCC	National Action Plan for Climate Change
NEP	National Electricity Policy
NGO	Non-Governmental Organization
NSM	National Solar Mission
NTP	National Tariff Policy
NTPC	National Thermal Power Corporation
NVVN	NTPC Vidyut Vitran Nigam
PDSC	Project-Driven Supply Chain
PPA	Power Purchase Agreement
PSM	Purchasing and Supply chain Management
PSU	Public Sector Undertaking
PV	Photo Voltaic
QAP	Quality Assurance Plan
R&D	Research & Development
REC	Renewable Energy Certificate
RFS	Request for Service

ROI	Return on Investment
RPO	Renewable Purchase Obligation
RPSSGP	Roof-top & Small Solar Power Generation Program
RRB	Regional Rural Banks
S&OP	Sales & Operation Planning
SC	Supply Chain
SCM	Supply Chain Management
SECI	Solar Energy Corporation of India
SERC	State Electricity Regulatory Commission
SEWA	Self Employed Women's Association
SKU	Stock Keeping Unit
SME	Subject Matter Experts
SRPO	Solar Renewable Purchase Obligation
TEDA	Tamil Nadu Energy Development Agency
TN	Tamil Nadu
UP	Uttar Pradesh
US	United States
VFD	Variable Frequency Drive
VGF	Viability Gap Funding
VMI	Vendor Managed Inventory
WBS	Work Break Down Structure
WMP	Mega Watt-Peak
Wp	Watt-Peak

Annexure – I: Interview Questionnaire

Name (Optional)……………………………………………………………………………….

Company Represented (Optional) ………………………………………………………..

Solar company's major focus (Choose One) –

- **Solar Developer** ☐
- **Solar EPC Contractor** ☐
- **Solar product Distributor** ☐

Role is solar company (Choose One) –

- **Central Planning** ☐
- **Procurement Planning** ☐
- **Senior Management** ☐

Interview Questionnaire

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Q: 01:01: How do you determine demand & Supplies of your solar cells, modules and Balance of Systems in present global sourcing environment?

> FQ1: What global and local supplier's inputs you consider to plan and decide the delivery of raw material and finished goods from your suppliers?
>
> FQ2: What procurement attributes your organization considers for source of material.
>
> FQ3: What is the most prominent single attribute for sourcing material?

Q: 01:02: What global factors influence planning decision complexities?

> FQ: Who takes decisions in complex situation arising out of such factors?

Q: 01:03: What are similarities or differences in planning objectives of planners, senior management and state?

Q: 01:05: How demand of solar product and planning is matched at a place of consumption and from source of delivery? Is local or nationalized level of planning more effective since demand of type of product vary from place to place?

.

Q: 02:01: What state regulation (central and state government) impacts the supply chain planning of solar material.

FQ1: What are salient central and state policies impacting solar demand in India.

FQ2: Please help how each of such policies decided growth of volume of solar energy deployment in country.

FQ3: Please help with an elaboration how does it work affecting planning process?

FQ4: Which part of planning you feel impacting more- short term or long term solar deployment in country?

FQ5: What are major challenges being posed for your planning process for solar installation?

FQ6: How any other country's regulatory or support policies affect your domestic solar planning?

Q: 02:02: In a situation of no support mechanism by state, do you feel solar installation in India would have been grown to the extent today?

FQ1: Why presence of natural demand without support mechanism seems weak?

FQ2: Is there any change in need of support has occurred, which helps in pushing natural demand phenomenon in recent past?

FQ3: Does factor like customer duty changes or antidumping duty affects demand? If yes how?

FQ4: How level playing field support is being seen by manufacturers, developers and EPC contractors of solar energy.

FQ5: How planners factors in various state and central regulations? Please elaborate?

FQ6: How adding or reducing solar module and cell manufacturing capacities are decided by planners?

FQ7: What horizon of visibility is available to planners in present support framework being announced by state from time to time?

FQ8: In smaller roof top project how policy frame work is different than large scale solar project deployment?

Q 03:01: What aspects in solar industry caused more number of iteration?

FQ1: To what extent solar design and engineering causes number of iterations & Why?

FQ2: Please elaborate, how demand hit in solar is compared to a FMCG industry?

FQ3: Do you see any difference between a "demand hit" and "cash collection" in solar and FMCG industry supply chain?

FQ4: How you plan safety stocking for your solar product?

Q 03:02: What is the sequence of material receipt from supplier's vis-à-vis planned sequence by planners in first iteration.

FQ1: What is an ideal sequence in terms of requirement for solar installation?

FQ2: To what extent this sequence is adhered to?

FQ3: What are reasons for deviation is supply sequence?

Q 03:03: What point of commitment, during the order winning from developers or customers, do your planners start planning and placing orders on suppliers?

FQ1: What are major stages of an order winning process?

FQ2: Do you firm up planning at later part of commitment for all developer or it varies from developer to developer?

FQ3: What are the broad reasons for late planning of supplies?

FQ4: What is a stage when probability of order cancellation is highest?

Q 03:04: Most of projects under government support program have a commissioning deadline of March end of financial year. Do you see number of planning revisions from such a specific deadlines?

FQ: All projects – small or large, anywhere in India had deadline of March end. Is this trend causes any supply chain planning problem?

Q 03:05: What are financial issues faced by industry?

FQ: Is there any correlation between fund availability of supply chain planning iterations?

Q 03:06: What norms are being followed to declare as an excess or obsolete inventory in your organization?

FQ1: What is the difference in norms varying from for a solar products or projects?

FQ2: How frequently do your organization analyze to excess and obsolete inventory position?

Q 03:07: Does supplier contracted credit period affects number of planning iterations?

FQ1: What credit duration from suppliers is in practice for solar material procurement?

FQ2: What is the impact of credit duration on way material planning takes place?

Q 03:08: Is there any effect on in-house manufacturing of solar products and planning iterations?

FQ1: Is there any relationship of large proportion of in-house manufacturing and planning process.

FQ2: In case of large value of out-sourced manufacturing, how planning iterations gets affected?

Q 03:09: Based on your experience do you see solar segment to segment variations in planning iteration?

FQ: What are segments which derived the large difference in planning iterations?

Q 04:01: What are skill sets required by a solar industry planner?

FQ1: What skill are lacking at present among these planners?

FQ2: What planning skills are being substantiated by senior management planners?

FQ3: What specific customer segment specific skills are required in planners?

FQ4: What is required by planner in manufacturing of solar cells and modules?

FQ5: What regulatory environment related knowledge is required by a solar planner?

FQ6: What are sales and operation planning (S&OP) related attributes specific to solar industry?

FQ7: How planner handles such sales and operation planning (S&OP)

Annexure – II: Survey Questionnaire

Name (Optional)………………………………………………………………………………

Company Represented (Optional) …………………………………………………………..

Solar company's major focus (Choose One) –

- **Solar Developer** ☐
- **Solar EPC Contractor** ☐
- **Solar product Distributor** ☐

Your role is solar company (Choose One) –

- **Central Planning** ☐
- **Procurement Planning** ☐
- **Senior Management** ☐

Survey Questionnaire

Q: 01:01: On a scale of 1-5 (1 is least preferred and 5 is most preferred), please give your organization's preference to following attributes to plan your procurement.

Ease of Availability…………………………	1	2	3	4	5
Price…………………………………………..	1	2	3	4	5
Quality and/or technology of product…..	1	2	3	4	5

FQ: Based on the above procurement attributes, do you prefers domestic or global supplies

Ease of Availability …………………………………...Global ☐ *Domestic* ☐

Price ………………………………….........Global ☐ *Domestic* ☐

Quality and/or technology of product ………………Global ☐ *Domestic* ☐

Q: 01: 02: Whose decision is most prominent in influencing purchasing decision under following material categories?

Solar Cells and Modules –

Material Planner ☐ *Senior Management* ☐ *Decides based on state policy* ☐

Solar BOS -

Material Planner ☐ *Senior Management* ☐ *Decides based on state policy* ☐

Solar Products-

Material Planner ☐ *Senior Management* ☐ *Decides based on state policy* ☐

Q: 01: 03: Primary decision influencer for supply chain planning, in solar company is by

a) ***Planners & Senior Management to achieve objective of Supply Chain Leverage***
   Yes ☐ ***No*** ☐
b) ***State in ensuring sustainability of solar Supply Chain***
   Yes ☐ ***No*** ☐

Q: 01:04: Since single most important decision of sourcing is easy availability globally, which supplier's base has high tendency to have ex-stock availability?

a) ***More probable ex-stock availability from global suppliers stocking***
   Yes ☐ ***No*** ☐

b) ***More probable ex-stock availability from domestic suppliers stocking***
   Yes ☐ ***No*** ☐

Q: 01:05: Which level of planning is most effective for solar products?

Local ☐ ***National*** ☐

FQ1: If the source of supplies is out of country planning level more effective

Local ☐ *National* ☐

FQ2: If the source of supplies is within country planning level more effective

Local ☐ *National* ☐

Q: 03:01: Please help in estimating supply chain planning iterations are expected under following situations. Please provide estimated number in the box provided.

a) How many supply chain planning iterations are expected in a FMCG industry ☐
b) How many planning iterations are expected in small solar project, less than 1 MW ☐
c) How many planning iterations are expected in large solar project, less than 1 MW ☐
d) How may planning iterations are expected in small solar products ☐
e) Expected number of iterations due to <u>design changes</u> in following project
  a. Small Projects ☐
  b. Large Projects ☐
  c. Solar Products ☐
f) Expected number of iterations due to <u>non - availability of material</u> in supply chain following project
  a. Small Projects ☐
  b. Large Projects ☐
  c. Solar Products ☐
g) Expected number of iterations due to <u>cost reduction changes</u> in supply chain following project
  a. Small Projects ☐
  b. Large Projects ☐
  c. Solar Products ☐
h) Expected number of iterations due to <u>customer requirement changes</u> in supply chain following project
  a. Small Projects ☐
  b. Large Projects ☐
  c. Solar Products ☐

Q: 03:02: Do supplies to solar project site follow a planned sequence?

Yes ☐ ***No*** ☐ ***Sometimes*** ☐

Q: 03:03: Based on your best estimates, how many number of times changes (Iterations) are made in planning under following circumstances when…..(Please write estimated number in the box provided)

a) Supplier orders are placed at the stage of "order under discussion" with customer/developer ☐
b) Supplier orders are placed at the stage of receipt of "Letter of Intent" from customer/developer ☐
c) Supplier orders are placed at the stage when "customer/developer has signed contract" with contractor ☐
d) Supplier orders are placed at the stage when advance is received from customer/customers ☐

Q03:04: How many estimated number of planning changes (iterations) is being observed in following projects? (Please write estimated number in the box provided)

a) Large Projects (more than 1 MW) ☐
b) Small Projects (less than 1 MW) ☐
c) Solar Products ☐

Q03:05: Fund shortages with a solar company increase planning iterations

Yes ☐ ***No*** ☐ ***Does not affect*** ☐

Q03:06: Please estimate number of iterations

a) in case of following excess and obsolete norms

Greater than 60 days old ☐

Greater than 90 days old ☐

Greater than 120 days old ☐

b) How many times do you anticipate inventory with following number of changes in planning iteration? (Please write estimated number in the box provided)

Less than 10 iterations ☐

11-20 iteration ☐

21-30 iteration ☐

More than 30 iterations ☐

Q 03:07: Please estimate number of iterations in case of following credit duration from suppliers to buyers

30 days ☐

60 days ☐

90 days ☐

Q 03:08: Please estimate number of planning changes (iterations) in following cases.

a) *Number of iterations increases in case of in-house manufacturing*
   Yes ☐ *No* ☐
b) *Number of iterations increases in case of outsource manufacturing*
   Yes ☐ *No* ☐

c) *What is number of estimated iteration in case of more than 50% of value in-house manufacturing (Please write estimated number in the box provided)* ☐

d) *What is the number of estimated iterations in case of more than 50% of value is outsources manufacturing (Please write estimated number in the box provided)* ☐

Q 03:09: How many estimated planning iterations you have experienced in following customer segments. (Please write estimated number in the box provided)

Large Project Installation Planning ☐

Small Project installation planning ☐

Solar Product Planning ☐

Research Publications

Research Thesis includes four umbrella hypotheses, divided further into fourteen sub-hypotheses. Each of the four umbrella hypotheses is published in internationally refereed research journal in full along with all sub-hypotheses to ensure uniqueness and sanctity of research findings.

PAPER - 1

An alternate Hypothesis (HA 01): Supply chain planning process for solar manufacturer/supplier need a wider view of global & domestic supplies, as critical inputs for effective planning.

Published as title **INDIAN SOLAR INDUSTRY SUPPLY CHAIN PLANNING – A GLOBAL SUPPLY VIEW**

Researchers World – Indian Journal of Management Science (IJMS), EISSN 2231-279X – ISSN 2249-0280.Vol.– V, Issue – 1, June 2015, Page 32-42.

http://www.scholarshub.net/ijms/vol5/issue1/Paper_04.pdf

PAPER -2

An alternate Hypothesis (HA 02): National and state level policy support to solar energy, to grow the sector, is a major width variable in supply chain planning.

Published as title **SOLAR ENERGY DEMAND – A FACTOR OF STATE SUPPORT**

Indian Journal of Commerce & Management Studies, ISSN: 2240-0310 EISSN: 2229-5674. Volume VI Issue 3, Sep 2015, Page 77-80.

http://www.scholarshub.net/ijcms/vol6/issue3/Paper_12.pdf

PAPER - 3

An alternate Hypothesis (HA 03): Existing practices of supply chain planning need more number of iterations to protect interest of buyers and sellers (Stakeholders) than existing in practice.

Published as title **UNCERTAINTY AND PLANING ITERATIONS IN SOLAR SUPPLY CHAIN**

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http://www.researchersworld.com/ijms/vol2/issue1/Paper_09.pdf

PAPER - 4

An alternate Hypothesis (HA 04): Roles of supply chain planners need to be strengthened with specialized skill mapping for effectiveness of solar energy companies.

Published as title **PLANNING SKILLS FOR SOLAR SUPPLY CHAIN MANAGEMENT**

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http://www.scholarshub.net/ijcms/vol6/issue3/Paper_08.pdf

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