# Employment and GHG Emission effects of grid connected solar PV deployment in India: A multiregional Input Output (MRIO) based analysis

## 1 Introduction

Current Indian solar policy provides differentiated incentives for solar power projects utilizing domestically produced solar panels from those using imported solar panels. The impacts of this categorization would be reflected in the economy wide direct and indirect embodied GHG emissions associated with the solar deployment for the two categories.

Further a preference to greater imported element in the solar deployment can be traced into the economies of the exporting partners. The paper argues that the expected favorable impacts of solar deployment towards energy transitions for climate change mitigation are subject to the institutional and structural constitution of economies and regulated by degree of technological advancement of a country .

A multiregional input output model was constructed for the two categories of solar deployment in India and economy wide impacts transacting through economies contributing to inputs for solar deployment in India were simulated and compared. The results indicate that domestic manufacturing of solar panel brings substantial gains for Indian economy in terms of output GDP, employment and better quality of job generation, but it also produces greater GHG emissions accentuating the Development-Environment paradox.

The next section deals with issues of socio economic impacts of renewable scale up and various barriers associated with clean technology transfer to developing countries followed by discussion on methodology in section 3. Section 4 details analysis and results of the work , followed by conclusion in section 5

## 2 Indian Solar Scale up: Expectations and Predicaments

This study explores and attempts to understand predicament in Indian solar policy to balance expectations between leveraging socio economic benefits associated with domestic panel manufacturing in terms of regional growth prospects with adverse environmental impacts implicit in sticking to lower efficiency production processes. The study initially delineates various studies dealing with estimating socio economic impacts of renewable deployment and subsequently reflects on the significant barriers associated with clean technology transfer to developing economies . Thus setting in the context for estimating environmental impacts of DCR and open category solar deployments in India within the framework of sustainable development .

### 2.1. Socioeconomic Impacts of Solar scale up

Process of increased solar deployment can have favorable impacts on economies both during deployment and ex post. Increased deployment contributes to regional development (Lopez et al, 2007; Mıguez et al, 2006; Faulin et al, 2006) , enhanced employment opportunity especially in rural area (Caldes et al 2009 , Hillerbrand et al, 2006, Bergmann et al, 2006; El Bassam and Maegaard, 2004) along with improved health conditions due to minimized environmental impacts during energy generation. Moreover energy accessibility also has close links with alternative livelihood generation capabilities. The following section systematically studies the literature related to socio economic impacts of renewable deployment.

### 2. 1.1 Socio-economic impacts of Renewable deployment in an economy

There is a growing body of literature dealing with socio economic impacts of economy wide RET scale up. The existing literature can be broadly classified into two categories i.e. ex ante and ex post studies on the basis of pre and post deployment discourses. The ex antes s involve pre implementation policy impact forecasts of RET deployment. The studies are indicative of net positive impacts of the RET deployments. Ex post studies primarily involve post implementation impact analysis, pointing towards ambiguities associated with estimation of overall socio economic impacts of renewable energy scale up.

Ex Ante Studies: The main focus of these studies have been to determine the employment generating capacities of renewable energy deployment. The studies can classified into three groups according to the analysis framework i.e. 1) Policy Impact studies 2) Sectoral studies 3) Technology specific studies

The initial studies were the policy impact studies involved usually with forecasting impacts of greater engagement in renewable energy technology. These include initial studies by US DOE (1992) & Cook (1998) for USA , followed by Ecotech (1999) study on Agenda 2020 promoted by European Union . A study by Ministry of Human Resource Development on impacts of scaling up RETs in India (MHRD, 2008) also fall under this category

The positive effects of economy wide RETs deployment have been analyzed in a number of studies also involving whole energy system planning under an integrated frameform using IO based analysis (Pfaffenberger et al., 2003; Umweltbundesamt, 2004; Hillerbrand et al., 2006; Lehr et al., 2008)

Assessment of technology specific macroeconomic impacts of renewable deployment by IO analysis have been done by studies like Kulistic et al. (2007) for determining net impacts of biodiesel production on Croatian economy and Caldes et al.(2008) for determining the economy wide impacts of policy goals to install 500 MW of solar thermal capacity in Spain. Recently studies like Malik et al. (2014) dealing with analyzing impacts of biofuel refining in

Australia and Baer et al. (2015) analyzing job generation impacts of cogeneration for USA , involving economy wide Input-Output frame work. The current study also belongs to this group.

The studies concluded an overall positive impacts of future RET deployments

## Ex post Studies

A growing body of recent literature points to ambiguities in forecasted values of green job creation through renewable energy deployment in both meta and country specific studies. For instance Cameron et al (2015) found significant uncertainties in quoted figures of job creation potential for RETs, both across and within the existing studies. Jain & Patwardhan, (2013) analyse impacts of renewable energy policies in India and concluded mixed impacts of scaling RETs for Indian economy depending on character and configuration of specific RETs.

Further, Cai et al. (2011) estimated that a percentage increase in Solar PV generation in China will lead to 0.68% percent increase in total employment. A later study by the authors (Cai et al, 2014) also points towards aggravated gender inequality in the new, fast growing renewable energy sector for China.

Cox et al (2015) find a negative unconditional cross price elasticity of labour demand and rising electricity prices due to renewable installation. The study shows that increase in electricity prices would lead to output reduction with low and high skilled labour being impacted more than medium skilled thus resulting in adverse distributional effects and potential overall job losses by renewable energy deployment.

## 2.2 Barrier to Clean Technology Transfer

Developing countries on growth trajectory have high demand for clean and efficient processes and technologies but procurement of technologies is still prohibitive due to barriers to entry posed by trade policies and various intellectual property regulations. Post Bali convention (2007) stress on creation of global exchange forums and fluid technology transfer mechanisms for technology transfer to developing economies became strong. The draft technology transfer agreement pinpoints certain goals for future progress which includes technology needs assessment, joint R&D programs and a healthy technology transfer environment and licenses (Hasper, 2009).

Ironically the predominant mode of technology transfer adhered to and justified by most developed countries have been to eliminate numerous tarrifs and other barriers to trade towards climate change mitigation techniques thus facilitating flows of valuable skills and experience. The debate accentuates as developing countries viewed the strategy as "disguised protectionism" to boast exports from wealthy nations (UNCCC,2008).

The process of technology transfer is complex process involving multiple considerations specifically for a developing economy. Developing countries are expected to play a vital role in global sustainability transitions endorsing low carbon pathway. They have the opportunity to "leap frog" or shift over from conventional dirty technologies to cleaner technologies thus avoiding being trapped in carbon paradigms. According to Perkins, (2003) the efforts to leap frog have conventionally centered around five prerequisite conditions i.e. i) A shift to clean production, ii) Immediate action, iii) Technology transfer from developed countries iv ) strengthening of incentive regime and international assistance .

The initial focus of technology transfer was to concentrate on efficiency enhancement to reduce environmental damage (World Bank, 2000) but has now been replaced by greater vigor towards rapid installation of technology capacities. Initially the technologies were primarily made available through participation of transnational corporations ( Shankle, 1997). These transfers were conventionally viewed as requiring economic policy supporting competitive markets and strong governmental frameworks towards cleaner production commitments, augmented also by international assistance for bridging the gap in cost , information and competition.

But the predicament lies in the fact that these channels (transnational corporations, international assistance and convenient trade flow channels) incompletely address the technology change over requirements (World Bank,2000). The technology diffusion process has to critically involve indigenous firms which are better aware of local needs and conditions and can better implement technologies concomitant with the demand and economic potential of the surroundings (Worrel et al,2001). Further leap-frogging would require not only strong incentives but capability of local firms to respond to incentives in terms of skills and expertise to manage technological change(Dooley et al,2000) . Even the channels of FDIs and transnational companies do not guarantee a positive spill over to local learning (Felipe,2000) . Further developing smaller markets catering to low value items prevalent in developing countries cannot be tapped by trans nationals (Perkins,2003).

Post Bali convention there have been various international bodies and organizations working towards extending an array of technology transfer mechanisms and other solution to developing countries for instrumenting rapid clean technology dissemination. International agencies like International Energy Agency (IEA) and International Renewable Energy Agency

(IRENA) are playing a major role in renewable dissemination. Further Post Paris convention (Dec, 2015) India has initiated formation of International Solar Alliance . The alliance aims at integrating resources for solar deployment in about 121 countries which are lying fully or partially between Tropic of Cancer and Tropic of Capricorn are endowed with excellent solar insolation, but the potential remain largely untapped(MNRE 2016).

An effort towards regional cooperation may help in effective dissemination of solar technologies in the developing world but is yet to be. This study builds on the technology transfer discourse and attempts to provide a differentiation to the impacts associated with DCR and open category solar deployments in India. The aim is to map the socio economic impacts alongside the environmental impacts to bring in an more holistic perspective for solar scale up regime in India.

The next section details methodology and data sources used for estimating direct and indirect impacts of introducing a protectionist policy instrument in the form of domestic content requirement enabling growth of Indian solar sector. The estimations involve estimating multiregional impacts of solar deployment in India considering inputs coming from Germany and China which are major suppliers of invertors and solar panels to India ( Bridge to India , 2012).

## 3 Methodology & Data Collection

This research traces impacts of installing grid connected utility scale solar PV plants using either domestically manufactured panels or imported solar panels on productive relations in Indian economy using Multiregional input output analysis. The deployment process not only derives input from India but also Chinese and German economies featuring in imports. The methodology includes three steps i.e. i) Constructing solar blocks for the two project categories detailed in section 6.3.1 followed by methodology for MRIO analysis detailed in section 6. 3.2. The last step involves estimation of GDP and employment generation, distributive efficiencies of wage generated and estimating embodied GHG emissions in the solar deployment process for the two categories.

### 3.1 Constructing the solar block

Miller & Blair (1986) propose two approaches to capture new economic activity: i.e. through construction of a new final demand vector or through addition of new elements in technical coefficient table of an economy. Both the approaches assume already existing technical coefficients

This study introduces solar generation as a new production activity for Indian economy through construction of a separate final demand vector. As solar deployment uses characteristically different inputs as compared to prevelant coal based power generation, an Independent solar I-O blocks for both deployment are constructed and integrated as an additional sector in 35x35 national input output table (2011) available in world input output databases (WIOD).

As there do not exist substantial contribution of grid connected PV solar based power generation in Indian energy mix till 2011 a solar production block is designed using expert data integrating engineering principles as elaborated later in the text. Direct coefficients for employment and household income were used to estimate output multipliers. Table3.1 & 3.2 delineate solar block formulated for two category of projects distinguished by domestically manufactured and imported solar panels .

Both solar blocks compile data at purchaser's price obtained from 2013, MNRE benchmark pricing which include prices for C-Si PV panels, mounting structure, power conditioning unit, construction, preoperative costs, operation and maintenance along with various financial intermediation activities undertaken in India during deployment of ground mounted solar power plant. This is followed by adjustments for existing fiscal elements like applicable subsidies, VAT, excise duty and incurred transportation costs. The input data is prepared to producer price for IO analysis

The domestically manufactured panel block is differentiated by dissociation of solar panel manufacturing Industry into inputs for manufacturing module, wafer and cells within the economy for domestic manufacturing while in case of imported panels solar blocks , solar panels feature in the imports column connected to panel manufacturing in Chinese economy. The inputs for inverters feature in import for both the category and is connected to manufacturing in Germany economy. The constructed solar blocks are added at a new sector (36th) in already existing 35X35 IO table obtained from WIOD data base. The following subsection details the IO analysis undertaken

## 3.2 Input Output Analysis

I-O methodology facilitates integrated analysis by assessing direct and indirect economy wide impacts of growing solar sector on all other sectors of Indian economy. The study uses the basic Leontief I-O model of linear equations tracing out sources of each sectors inputs, whether they are purchased from other firms in the economy, imported or contributed by labour (wages and salaries). It also provides sales of each sectors output with sales to other industry and of final demand along with consumption, gross fixed capital formation. The MRIO also includes the impacts of solar deployment on exporting partners (China & Germany)

The information from IO table has been utilized in the general form of Leontief model

$X=AX+Y$ (1)

Where A is the matrix of technical coefficient, X the vector of sectoral output and Y is the vector of sectoral final demand component. Eq 1

$X= (I-A)^{-1}$ (2)

Where I is an identity matrix, Matrix $(I-A)^{-1}$of interdependence. Each element of that matrix indicate total (direct & indirect requirement of sector i for final demand output of sector j).

The impacts of the imports obtained for the deployment project in the form of inverters from germany and panels or silicon Ingots from China are estimated by using 35 sector, national IO table (2011) for China and Germany available in WIOD. The process involves estimating multipliers by creating leotief matrix and subsequent estimation of multipliers for the relevant sectors engaged in production of Indian imports

The WIOD database also provides associated annual Socio Economic Accounts (SEA) providing industry wide wages and employment by skill type and satellite environmental accounts for the three economies which are used in further analysis.

The simulation assumes grid connected solar PV installations is a new economic activity thus all fixed assets are newly purchased and calculated through perpetual inventory method (Quang Viet, 2000). This is to make block maximally adjusted to existing national peculiarities.

A commodity flow table was created to ensure balanced supply and use of inputs and or outputs of solar block and adjusted to conventional form of I-O table. The output of solar sector is in the form of electricity directly connected to the grid, the new sector is assumed to supply its entire output to the electricity sector. The study initially simulates the inter industry exchanges involved in an year when the solar power plant is installed.

The industry specific literature indicates ( Bridge to India, 2013, MNRE, 2013) that on an average it takes 10 months for solar power plant to start its operation fully after successful land acquisition. Therefore in the year of commissioning (t) output equivalent to 2 months of solar generation is considered with average normative capacity utilization factor of 19 % (CERC, 2009) prevalent in India. The year t includes all the inputs required for installing the solar power plants along with factor inputs in terms of labour and capital formation and output in terms of 2 months of power generation. MW of solar power generated was converted to million dollars of value using latest input output table for India (2007) adjusting for inflation and currency depreciation.

Input ouput linkage in terms of Leontief coefficients were obtained for the two scenarios. These were used to obtain value of output, income and employment impacts on the economy due to solar power plant deployment for the two categories under study.

### 3.3 Estimating distributive efficiencies and embodied emission for the solar PV deployments

Further, distributive efficiencies of the two categories of deployment are estimated in terms of type of labour compensation generated. The total sectoral direct and indirect output generated due to the two deployments was used to estimate sectoral employment coefficient for India by integrating data from WIOD Socio Economic Accounts (SEA). The accounts also provide data for sectoral labor distribution in terms of low skilled labour, medium skilled labour and high skilled labour. The data was used to estimate job compensation distribution for the two categories of solar deployment in all the three economies.

The overall output generated along with the sector specific GHG emission coefficients for the three economies was used to determine overall GHG emissions for the two category of deployments in kilotonnes of $CO_2$ per million US dollars of output generated. The results obtained for all the estimations are detailed in the next section.

The figure 3.1 & .3.2 below delineates the solar block structure and sectoral dissociation within and across the three economies

## Figure 3.1Solar Block for projects using domestically manufactured panel

| Inputs Solar Sector | Solar Panels | Balance of Operation | Charge Controller and Switches | Inverter | Construction and Civil Work | Land Transport | Water Transport | Insurance Pre-operative Cost | Financing Cost | Project Management Cost | Land acquirement |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sector Concordance for WIOD IOT | Solar Sector (36) | Basic & Fab Metal (12) | Electrical & Optical equipments (14) | | Construction (18) | Surface travel (23) | Water Travel (24) | Financial Intermediation (28) | | | Capital formation |

| Input Solar Sector | Module | | | | | | Cell | | | | | Silicon Wafer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sector concordance | Packaging | JB, Ribbon, Back sheet | Frame | Electricity | Maintenance | glass | Screen | Energy | Chemicals | Maintenance | Metal Paste | IMPORT |
| Sector Concordance for WIOD IOT | Paper & pulp(7) | Basic & Fab Metal (12) | Basic & Fab Metal(12) | Electricity supply (17) | Machinery (13) | Other non metal (11) | Basic & Fab Metal (12) | Electricity supply(17) | Chemical (9) | Machinery (13) | Basic & Fab (12) | Solar Sector (36) |

CHINA

| Inputs Solar Sector | Solar Panels | Balance of Operation | Charge Controller and Switches | Inverter | Construction and Civil Work | Land Transport | Water Transport | Insurance Pre-operative Cost | Financing Cost | Project Management Cost | Land acquirement |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sector Concordance for WIOD IOT | IMPORT Solar Sector (36) | Basic & Fab Metal (13) | Electrical & Optical equipments (15) | | Construction (23) | Surface travel (23) | Water Travel (25) | Financial Intermediation (28) | | | Capital formation |

Figure 3.2 Solar Block for projects using imported panel

Import from Germany

| Input Solar Sector | Module | | | | | | Cell | | | | | Silicon Wafer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sector concordance | Packaging | JB, Ribbon, Back sheet | Frame | Electricity | Maintenance | glass | Screen | Energy | Chemicals | Maintenance | Metal Paste | IMPORT |
| Sector Concordance for WIOD IOT | Paper & pulp(7) | Basic & Fab Metal (12) | Basic & Fab Metal(12) | Electricity supply (17) | Machinery (13) | Other non metal (11) | Basic & Fab Metal (12) | Electricity supply(17) | Chemical (9) | Machinery (13) | Basic & Fab (12) | Solar Sector (36) |

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Import from China

Table 3.1 Solar Block for Projects using domestically manufactured solar panel

| Products at purchasers price | Intermediate Industries | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Solar Sector (36) | Basic & Fab Metal (12) | Paper (7) | Other non Metals(C11) | Chemicals (C9) | Maintenance (19) | Electricity (17) | Construction (18) | Electrical & Optical equipments (14) | Financial Intermediation (28) | Water travel (24) | Surface Travel (23) | Total Economy | Gross capital Formation | Total industry output at base price |
| Solar Silicon wafers (Imported) | 193.43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 193.43 | 0 | 193.43 |
| Backsheet, ribbon,Frame, Screen, metal paste | 0 | 103.79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 103.79 | 0 | 103.79 |
| Hot Galvanized Steel Frames | 0 | 21.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21.9 | 0 | 21.9 |
| Packaging | 0 | 0 | 4.84 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4.84 | 0 | 4.84 |
| Glass | 0 | 0 | 0 | 24.18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24.18 | 0 | 24.18 |
| Chemicals | 0 | 0 | 0 | 0 | 14.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14.5 | 0 | 14.5 |
| Maintenance | 0 | 0 | 0 | 0 | 0 | 29.01 | 0 | 0 | 0 | 0 | 0 | 0 | 29.01 | 0 | 29.01 |
| Electricity | 0 | 0 | 0 | 0 | 0 | 0 | 14.5 | 0 | 0 | 0 | 0 | 0 | 14.5 | 0 | 14.5 |
| Ground Leveling & civil work | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 27.56 | 0 | 0 | 0 | 1.10 | 28.66 | 0 | 28.66 |
| Wires & transmission, Switches charge controller infrastructure, | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33.64 | 0 | 0 | 0 | 33.64 | 0 | 33.64 |
| Invertors | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26.50 | 0 | 0.55 | 0.34 | 26.84 | 0 | 26.84 |
| Insurance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.72 | 0 | 0 | 1.72 | 0 | 1.72 |
| Contingency | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5.16 | 0 | 0 | 5.16 | 0 | 5.16 |
| Interest during construction | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17.20 | 0 | 0 | 17.20 | 0 | 17.20 |
| Project Management | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.44 | 0 | 0 | 3.44 | 0 | 3.44 |
| Financing Cost | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.44 | 0 | 0 | 3.44 | 0 | 3.44 |
| pre operative cost | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.44 | 0 | 0 | 3.44 | 0 | 3.44 |
| Water Transport | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Land transport | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Land Cost | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10.32 | 10.32 |
| VAT | 0 | 2.28 | 0.106 | 0.531 | 0.319 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.232 | 0 | 3.236 |
| Net Custom duty | 0* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.76 | 0 | 0 | 0 | 0.76 | 0 | 0.76 |
| Subsidy | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | (-1.20) | 0 | 0 | 0 | -1.20 | 0 | -1.20 |
| Total Output at Base Price | 193.43 | 127.97 | 4.95 | 24.71 | 14.82 | 29.01 | 14.5 | 27.56 | 59.7 | 34.4 | 0.55 | 1.44 | 533.04 | 0 | 542.81 |

Net custom duty 5.5% and subsidy on panel import 4.2% , VAT @ 2.2 % All values adjusted to Million USD (2011) exchange rate 46.42 ( WIOD database), custom duty is wavered for solar grade semiconductors

## Table 3.2: Solar Block for Projects using imported solar panels

| Products at purchasers price | Solar Sector(36) | Basic & Fab Metal (12) | Construction (18) | Electrical & Optical equipments (14) | Financial Intermediation (28) | Water travel (24) | Surf e Trav (23 |
|---|---|---|---|---|---|---|---|
| Solar Panel (Imported) | 189.27 | 0 | 0 | 0 | 0 | 18.91 | 1.79 |
| Hot Galvanized Steel Frames | 0 | 21.94 | 0 | 0 | 0 | 0 | 0 |
| Ground Leveling & civil work | 0 | 0 | 27.56 | 0 | 0 | 0 | 1.10 |
| Wires & transmission, Switches charge controller infrastructure | 0 | 0 | 0 | 33.64 | 0 | 0 | 0 |
| Invertors | 0 | 0 | 0 | 26.50 | 0 | .55 | .34 |
| Insurance | 0 | 0 | 0 | 0 | 1.72 | 0 | 0 |
| Contingency | 0 | 0 | 0 | 0 | 5.16 | 0 | 0 |
| Interest during construction | 0 | 0 | 0 | 0 | 17.20 | 0 | 0 |
| Project Management | 0 | 0 | 0 | 0 | 3.44 | 0 | 0 |
| Financing Cost | 0 | 0 | 0 | 0 | 3.44 | 0 | 0 |
| pre operative cost | 0 | 0 | 0 | 0 | 3.44 | 0 | 0 |
| Water Transport | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Land transport | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Land Cost | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| VAT | 0 | 0.504 | 0 | .76 | 0 | - | - |
| Net Custom duty | 11.37 | 0 | 0 | 1.58 | 0 | - | - |
| Net Subsidy (-) | (-)9.27 | 0 | 0 | -1.20 | 0 | - | - |
| Total Output at Base Price | 191.37 | 22.444 | 27.56 | 61.28 | 34.4 | 19.46 | 3.23 |

# 4 Analysis & Results

Deployment of ground mounted solar PV capacity generates economy wide impacts in terms of direct and indirect sectoral demand , employment generation along with concomitant GHG emissions embodied both in manufacturing as well as service inputs for the installations. Further, structure of inputs and outputs would differ for the projects using domestically manufactured solar panels to those opting use of imported crystalline silicon panels.

A Multiregional Input Output (MRIO) model was constructed to simulate input flows for solar deployments in India . Solar deployment was treated as a new sector in the economy. The projects using domestically manufactured panels import invertors from Germany and silicon ingots from China. The projects using imported panels include estimations of demand & output flow for panel manufacturing in China and inverter manufacturing in Germany.

The output flows (GDP generation ) associated with solar deployment along with sector specific GHG emission coefficients (Kilo ton $CO_2$/MUSD) for the three economies was used to estimate embodied GHG emissions for the two categories of solar installations.

The figure 4.1 (a & b) illustrates GDP and employment generation profile for the two categories of solar deployment

Figure 4.1(a) GDP and employment generation profile for the two categories of deployment

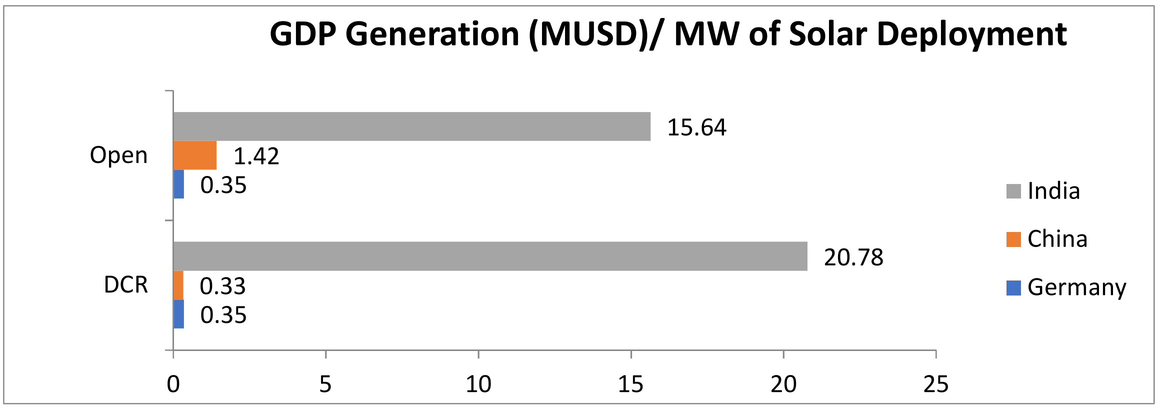
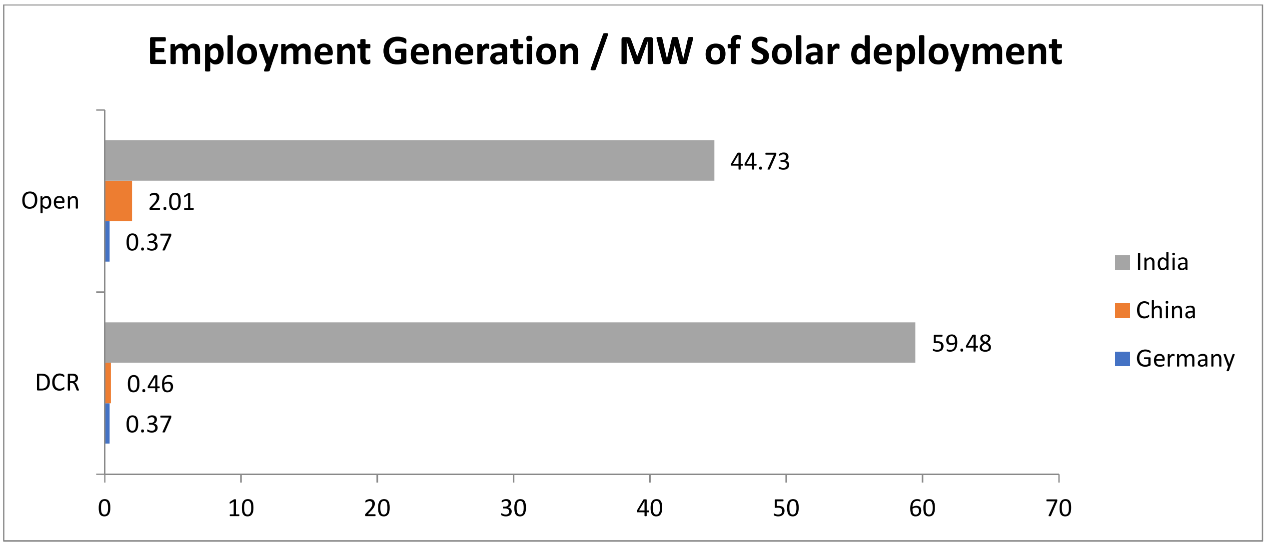



Figure 4.1b Employment generation profile for the two categories of deployment

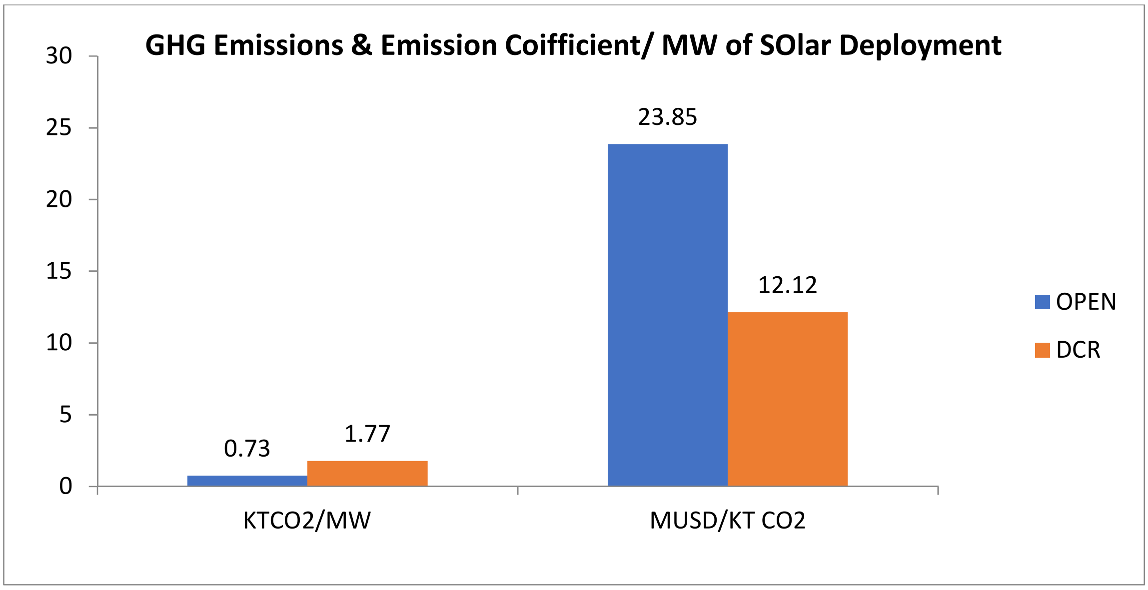



The open category deployment leads to 1.42 M USD of output generation for China which is 0.33 M USD in case of DCR projects. The DCR category leads to 1.73 Million USD generation in case of DCR deployments. The open category leads to employment generation of 2 per MW of open category deployment in India.

The economic exchanges induced by Indian solar deployment projects under both domestic and imported categories have embodied GHG emissions located in all the three economies. GHG emission coefficients for the three economies were first estimated using WIOD Environmental satellite accounts and individual national input output table. An estimation of GHG emissions in terms of kilotons of $CO_2$ emissions per million USD of GDP generated shows that domestic panel manufacturing would lead to substantially higher emission when compared with imported panel scenario. The results can be attributed to higher sectoral emission coefficients for existing Indian manufacturing Industry compared to China and Germany.

Figure 4.2 Illustrates the GHG emission profile for domestic and imported solar panel based deployments in India

Figure 4.2: GHG emissions and & Emission Coefficients




The GHG emission per MW of solar deployment were estimated for the DCR and open category deployments . The GHG emission associated with DCR deployments is 58 % higher indicating an overall inefficiency of production processes. The emission coiefficient estimates in terms of GDP Generated/ KTon of $CO_2$ emission is 49% lower in case of DCR deployments. This profile provides a strong evidence towards the need of clean technology transfer for developing countries like India.

The profile for distributive efficiency of labor compensation (Table 6.4.1) reveals that DCR deployments lead to greater low and high skill labor generation and Open category deployment shows more medium skill labor generation for India.

Table: 4.1 Distributive Efficiency of Labour Compensation Generation

| HIGH SKILL LABOUR (00 USD) | SECTORS | Domestic | Imported |
|---|---|---|---|
| 1 | Financial Intermediation | 167.31 | 103.28 |
| 2 | Electrical and Optical Equipment | 65.98 | 41.23 |
| 3 | Machinery, Nec | 50.06 | 9.28 |
| 4 | Electricity, Gas and Water Supply | 46.50 | 11.83 |
| 5 | Health and Social Work | 30.45 | 10.28 |
| 6 | Rest of the Sectors | 237.03 | 125.68 |
| 7 | Total | 597.33 | 301.59 |
| MEDIUM SKILL LABOUR 00 USD) | SECTOR | Domestic | Imported |
| 1 | Construction | 94.46 | 52.56 |
| 2 | Financial Intermediation | 48.30 | 29.81 |
| 3 | Electrical and Optical Equipment | 48.06 | 30.04 |
| 4 | Basic Metals and Fabricated Metal | 46.58 | 9.50 |
| 5 | Machinery, Nec | 44.84 | 8.32 |
| 6 | Rest of the Sectors | 329.21 | 298.82 |
| 7 | Total | 611.46 | 429.04 |
| LOW SKILL LABOUR (00 USD) | SECTOR | Domestic | Imported |
| 1 | Construction | 181.60 | 101.04 |
| 2 | Other Non-Metallic Mineral | 42.37 | 11.70 |
| 3 | Basic Metals and Fabricated Metal | 29.66 | 6.05 |
| 4 | Private Households with Employed Persons | 28.25 | 12.11 |
| 5 | Mining and Quarrying | 8.12 | 2.71 |
| 6 | Rest of the Sectors | 232.78 | 225.87 |
| 7 | Total | 522.78 | 359.48 |

Table 6.4.2 Skill based Labour Compensation generated in Germany due to a unit MW of Solar Deployment in India

| | SECTORS | Domestic & Imported |
|---|---|---|
| HIGH SKILL LABOUR (00 USD)1 | Electrical and Optical Equipment | 134.39 |
| MEDIUM SKILL LABOUR 00 USD)M2 | Electrical and Optical Equipment | 188.64 |
| LOW SKILL LABOUR (00 USD) | Electrical and Optical Equipment | 31.56 |

Table 4.3 Skill based Labor Compensation generated in China due to a unit MW of Solar Deployment in China

| Category | Sector | High Skill | Medium Skill | Low skill |
|---|---|---|---|---|
| Imported | Paper & Pulp | 0.20 | 2.16 | 2.56 |
| | Chemicals & Chemical | 2.07 | 9.60 | 7.66 |
| | Other non Metallic Mineral | 3.37 | 42.30 | 80.80 |
| | Basic Metals & Fabricated Metals | 19.05 | 127.41 | 137.68 |
| | Machinery | 5.74 | 30.99 | 29.57 |
| | Transport Equipment | 6.97 | 19.38 | 5.76 |
| | Financial Intermediation | 4.00 | 8.23 | 0.15 |
| Total (00USD) | | 41.39 | 240.07 | 264.19 |
| Domestic Total (00USD) | Silicon Ingot (aggregated output 5 sectors) | 6.17 | 25.03 | 20.10 |

The distributive efficiency of labour compensation generated in India , China and Germany in the process of deploying a MW of solar capacity in terms of High , medium and low skilled labor compensation generated is estimated for the both categories of deployment project under study . The results show that domestic manufacturing leads to greater high skill wage generation in high tech industries for India when compared to imported panel deployment. The wage generation for Germany lies predominantly in medium and high skill sector while China generates predominantly medium and low skill labour in the deployment process.

The positive trend of moving towards greater high quality jobs in India as demonstrated by the domestic manufacturing option indicates a possibility to move up the value chain but is eclipsed by concomitant high emission trajectory of the growth path . A win- win developmental strategy for the economy needs also to alleviate adverse environmental impacts . This warrants an urgent need for facilitating appropriate and affordable technology transfer to avoid suboptimal lock-in of global resources.

## 5 Conclusion

India as an emerging economy is posed with conditions of energy poverty, greater climate change vulnerabilities and high population growth rates. Thus policy decision to logarithmically scale up renewable energy technologies like solar PV need a greater scrutiny for efficiency to meet multiple goals focusing not only towards cleaner development agenda but also sustainable economic growth and domestic employment for Indian economy. The exiting option of domestic manufacturing provides an option to move up the supply chain for India but for simultaneously actualising the global green agenda a more deeper engagement of international governance towards technology transfer and adaptation of clean technology mechanism need to be created.

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