No. 2/3/2017-EFM
Ministry of New and Renewable Energy

Block-14, CGO Complex,
Lodhi Road, New Delhi 110003

Dated: 24th January 2018

Request for comments/observations/feed-back etc. on the draft study report "*Economic Rate of Return for various Renewable Energy Technologies*"

Ministry of New and Renewable Energy has commissioned a study on "***Economic Rate of Return for various Renewable Energy Technologies***"**.** The objectives of the study include: a) economic impact of renewable energy; b) estimation of economic rate of return of various renewable energy technologies; c) comparing economic and financial rate of return; and d) estimation of justified level of incentives for select renewable energy technologies.

The draft report of the study has been prepared. It is proposed to finalize the report through due consultation process, incorporating views/inputs from the relevant stakeholders.

Accordingly, comments/observations/feed-back and other relevant inputs are solicited from industry, developers, policy research institutions, think tanks, academia, electric utilities and other stakeholders on the draft study report **"*Economic Rate of Return for various Renewable Energy Technologies*" (Link to pdf report)**.

Inputs, as above, may be sent through email to Shri Dipesh Pherwani, Scientist-B, Ministry of New and Renewable Energy (Email: dipesh.mnre@gov.in) latest by **15 February 2018**.

DRAFT REPORT

Economic Rate of Return
of various
Renewable Energy Technologies

Supported by
Ministry of New and Renewable Energy (MNRE),
Government of India

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Contents

1 Introduction and Background

1.1 About the study

In mid-2017, the Ministry of the New and Renewable Energy (MNRE) commissioned a research project to study "Economic Rate of Return for various Renewable Energy Technologies" in India. The Terms of Reference (ToR) for the study as defined by MNRE are:

- Study the economic impact of renewable energy both by taking into account their direct costs, as well as their positive impacts to the society, such as environmental benefits linked with a reduction in localized pollution and also CO2 emissions reduction, additional employment creation, etc.;
- Estimate Economic Rate of Return (ERR) of various renewable energy technologies including Wind, Solar, Waste-to-Energy, Biogas/ Bio CNG, Hydro (up to 100 MW capacity) taking into account the economic costs to society;
- Compare the ERR with the Financial Rate of Return (FRR) of the renewable energy technologies; and
- Estimate justified level of incentives for promoting select renewable energy technologies in view of economic/social benefits.

1.2 Background

Climate change is one of the greatest challenges facing mankind this century. Power generation from fossil fuel sources (primarily coal) is credibly recognized to be a major source of emissions that contribute to global warming. In late 2015, at the 21st Conference of Parties (COP21) in Paris under the United Nations Framework Convention on Climate Change (UNFCCC), more than 140 countries from around the world submitted their Intended Nationally Determined Contributions (INDCs) to reduce their greenhouse gas emissions. In its INDC, India pledged to:

– Reduce the emissions intensity of its GDP (Gross Domestic Product) by 33-35% by 2030 from 2005 levels; and

– Increase power generation capacity from non-fossil fuel sources to about 40% of total installed capacity in 2030.

In this context, renewable energy (RE) is expected to play pivotal role. With abundant natural resources for solar power, wind power, bio-energy and hydro power, the Government of India in 2015 set a target of achieving 175 GW of renewable energy by 2022. This target comprises 100 GW solar power, 60 GW wind power, 10 GW bio-energy, and 5 GW small hydro power. This is expected to increase the share of RE in India's electricity generation from 5% in 2015 to 10% in 2022 (NITI Aayog, 2015)[1].

While the need for RE deployment to curb emissions is well-recognized, there is a need to gain clarity of the full socio-economic costs and benefits of large-scale deployment of renewable energy sources, beyond reduction in emissions from fossil fuel-based generation.

There are a few major issues that need to be addressed to prepare for large-scale RE deployment, particularly for wind and solar power. The electricity generation from these renewable energy technologies (RETs) is variable, intermittent and non-dispatchable. Effective utilization of renewable energy sources for meeting the demand for electricity in a reliable and secure manner, therefore calls for additional infrastructure for balancing, providing flexibility, energy storage, etc. which have associated costs. These costs, like the costs associated with replacing ageing infrastructure or introducing smarter grid functioning or addressing rising peak demand, are borne by the consumers. However, it would be inappropriate to attribute these costs entirely to renewable energy, since most

[1] http://niti.gov.in/writereaddata/files/writereaddata/files/document_publication/report-175-GW-RE.pdf

of the aforementioned infrastructure would also be used for handling variation in load as well as generation from conventional sources and would contribute to more flexible grid operation – which in any case is a necessity even without RE in the generation mix.

In case of solar power, there is also a concern of growing outflow of foreign exchange reserves from the economy since the majority of the solar PV modules and inverters (which together make for up to 60-70% of project costs) used in India are imported. This would normally not have been a concern in the wind power industry since the domestic manufacturing base for wind turbines and other equipment is quite strong. However, the Government of India's (GoI) recent impetus to introduce competitive bidding in the wind sector has led to concerns among domestic manufacturers about ceding market share to foreign players as power producers may opt for foreign equipment to beat the competition. However, a trade deficit does not necessarily imply an economic cost, and this has been dealt with in detail in the relevant chapter.

Further, RETs offer certain distinct benefits that are commonly not accounted for. For instance, solar power presents significant potential for employment generation. This potential is even higher for the rooftop solar power segment, for which the Government of India (GoI) has set a target of 40 GW out of the total target of 100 GW solar power generation capacity by 2022. Studies suggest that solar power may have the highest potential for job creation among various power generation options, including wind, biomass, coal, gas, etc.[2]

Another oft-ignored benefit from RE is the avoidance of adverse health impact due to coal mining and coal-based power generation. The health costs of emissions from coal-based power plants include costs associated with premature cardiopulmonary deaths and illnesses from the chronic effects of long-term exposure and the acute effects of short-term exposure.

Climate change caused by GHG emissions also has numerous other environmental costs related to issues such as changes in net agricultural productivity, property damages from increased flood risks, etc. The full gamut of these costs is encapsulated into the Social Cost of Carbon (SCC), which is meant to be a comprehensive estimate of climate change damages.

Under the Sustainable Development Goals (SDGs) adopted by the United Nations as the post-2015 Development Agenda for the world, the following goals are of particular significance in this context:

- Goal 3 (Good Health and Well-Being) targets substantial reduction in the number of deaths and illnesses from pollution-related diseases
- Goal 7 (Affordable and Clean Energy) aims to ensure access to affordable, reliable, sustainable and modern energy for all
- Goal 13 (Climate Action) advocates urgent action to combat climate change and its impacts by regulating emissions and promoting developments in renewable energy

There is another economic benefit of renewable energy deployment that is commonly missed, i.e. its contribution toward 'strategic autonomy' for the country's energy sector. Decreased reliance on imports to meet the needs of a commodity as critical as energy supply is certainly a benefit for the economy.

In light of the foregoing, it becomes imperative that the costs and benefits of RE be quantified for India from an economic standpoint to serve the purposes of (i) advancing India's action towards contributing to the SDGs, (ii) improving energy access in the country, and (iii) aiding the government in the macro-level policy for the electricity sector by internalizing the social-economic cost-benefit of RE (viz. carbon taxation, RE deployment plans, budget outlay for electricity sector, etc.).

[2] "Putting Renewables and Energy Efficiency to Work: How Many Jobs Can the Clean Energy Industry Generate in the U.S.?", Max Wei, Shana Patadia, and Daniel Kammen, *Energy Policy*, 2010

2 The Economic Impact of Renewable Energy

2.1 Understanding the economic impact of RE deployment

It is widely acknowledged that electricity generation from renewable energy sources makes significant contribution to sustainable development. Apart from the significant environmental benefits, it has a lot to offer for social and economic development. Use of renewable energy reduces harmful greenhouse gas emissions, minimizes impact on natural resources and manmade capital including water, land, forests, infrastructure, and at the same time avoids damage to human health which would otherwise have been caused from fossil fuel-based electricity generation. Further, deployment of renewable energy creates employment opportunities and promotes investment and trade, thereby promoting economic growth. With regard to international trade, India is a net exporter of wind farm equipment, thus contributing to India's foreign exchange earning while generating spill over effects along the production and distribution network. In the context of benefit assessment, it is important to acknowledge various positive outcomes of the socio-economic conditions of decentralized renewable energy project beneficiaries. Access to reliable and clean electricity opens a plethora of opportunities for society that include improved health thereby reducing mortality, increased literacy, better quality of life through employment, etc. Based on the above discussion, the economic benefits and costs parameters for various renewable energy technologies have been categorized as presented in **Figure 1**.

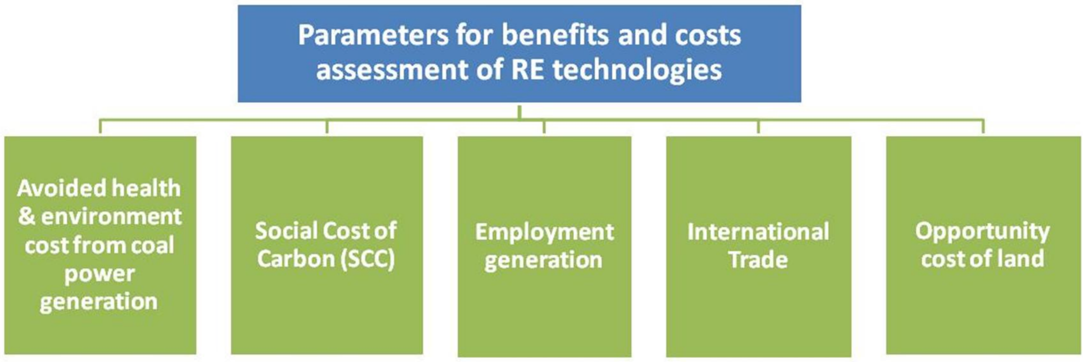


Figure 1: Cost Benefits Parameters for economic assessment of various RETs

From **Figure 1**, the parameters for socio-economic benefits and costs include: (i) avoided health and environment cost from coal-based power generation, (ii) Social Cost of Carbon, (iii) employment generation, (iv) international trade, and (v) opportunity cost of land.

In this regard it is important to make a distinction between financial rate of return (FRR) and economic rate of return (ERR). The parameters that have been considered for the ERR estimation is completely different from that considered for FRR. Hence ERR and FRR estimates are mutually exclusive.

2.2 The Boundary Conditions

2.2.1 Value Chain

A comprehensive study encompassing the entire value chain, covering direct as well as indirect and induced impacts or cascading impacts of benefits and costs, requires development and use of integrated econometric models. While an integrated assessment based on rigorous application of econometric and/or other relevant tools requires a fair amount of data in regard to employment, investments, flow of capital, direct and indirect economic impacts on project beneficiaries, etc., a holistic assessment including quantification of key benefits (wherever feasible) and costs of deployment of renewable energy has been undertaken based on secondary data and rapid appraisal of select stakeholders. In the assignment, special emphasis has been given to the construction, installation and O&M phases of the value chain as these stages are expected to generate the bulk of the benefits in the renewable energy sector. Further, data limitations for upstream activities across various RETs constrain a full-scale analysis across the entire value chain.

2.2.2 Conservative estimates of net socio-economic benefits of RE

Across the various socio-economic factors affecting ERR, the approach has been to arrive at conservative estimates of socio-economic benefits of RETs as well as moderate/aggressive estimates of socio-economic costs. For example, avoided cost of coal imports has not been considered while evaluating benefits of power generation from RETs. This has been done in order to avoid over-stating the net socio-economic benefits of RE.

2.2.3 Water use

Water use in both coal-based power generation and RE generation has not been included into the estimation of economic benefits due to difficulty in apportioning accurate socio-economic costs. However, it is noted that the average water usage in coal power generation is higher than that in solar power generation[3]. Further, water usage in solar can be mitigated by way of substitution of water with either human resource or mechanized equipment. As such, this assumption is consistent with the assumption of conservative estimates of RE's socio-economic benefits.

2.2.4 Employment in coal power sector

The study has not considered the impact of technology upgradation on employment generation due to data limitations. Also, the impact of technology upgradation on employment generation is not limited only to renewable energy sector; similar impact has been observed in coal-based power generation as well. However, it has not been considered in the study and could be an interesting point to cover in future research, using rigorous analytical tools like CGE that can capture the labour substitution/switching effects across various sectors.

Given the assumptions and boundary conditions stated above, this study may be best utilized to establish a standardized framework for estimation of Economic Rate of Return (ERR) and the Justified Level of Incentives for various Renewable Energy Technologies (RETs) which can be further expanded, subject to a realistic elimination of the respective boundary conditions.

2.3 Trade

The increase in the share of renewable energy in the total energy mix will impact India's trade performance. India is a net fossil fuel importer, which spends around 3.5% of the national income on energy imports (largely crude oil and coal, although in recent years coal imports have seen a declining trend)[4]. Renewable energy has trade implications because it promotes technologies that will create an ecosystem of research and development activities, manufacturing of components, and related services thereby creating opportunities to serve other geographies through the exports of related goods and services. At the same time it helps to reduce the expensive imports of fossil fuels, particularly coal and crude oil. It also provides a healthy and clean source of energy, creates indirect and direct job opportunities and investments thereby making economic sense.

There are many technologies in the renewable energy space that have trade implications. A study undertaken by ICTSD in 2010 had prepared an exhaustive list of components used in the renewable energy space along with harmonized codes used for commodities that are traded in the international market. However, in the Indian context, the components that have trade implications are used

[3] https://www.nrel.gov/docs/fy15osti/63011.pdf
[4] Estimates based on DGFT data and World Development Indicators (WDI) database, 2016-17

primarily in solar and wind technologies. For the purpose of the study, only those components have been considered whose use can be fully attributed to these RETs.

In the solar sector, key product categories that have been considered are solar cells, modules, collectors and lighting systems. The trend in export and import of these technologies over the last seven years has been analysed and is presented in **Figure 2**.

Between 2010 and 2016, India emerged as a net importer of various solar components. During the period, exports fell by 9% per annum, while imports increased at an annual growth rate of 27%. India recorded a negative trade balance of INR 211 billion in 2016.

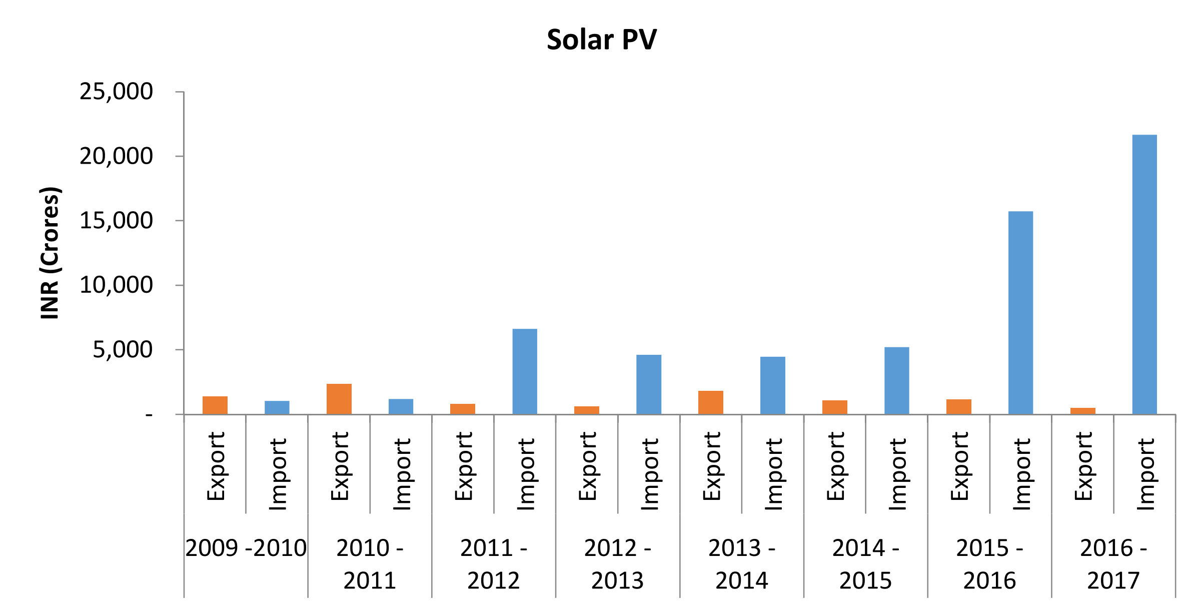


Figure 2: Export and import of solar components (INR lakhs)

Source: DGFT 2017[5]

In the wind sector, key product categories considered are wind mill, wind turbine/engine, and related equipment. The trend in export and import of these technologies over the last seven years has been analysed and is presented in **Figure 3**.

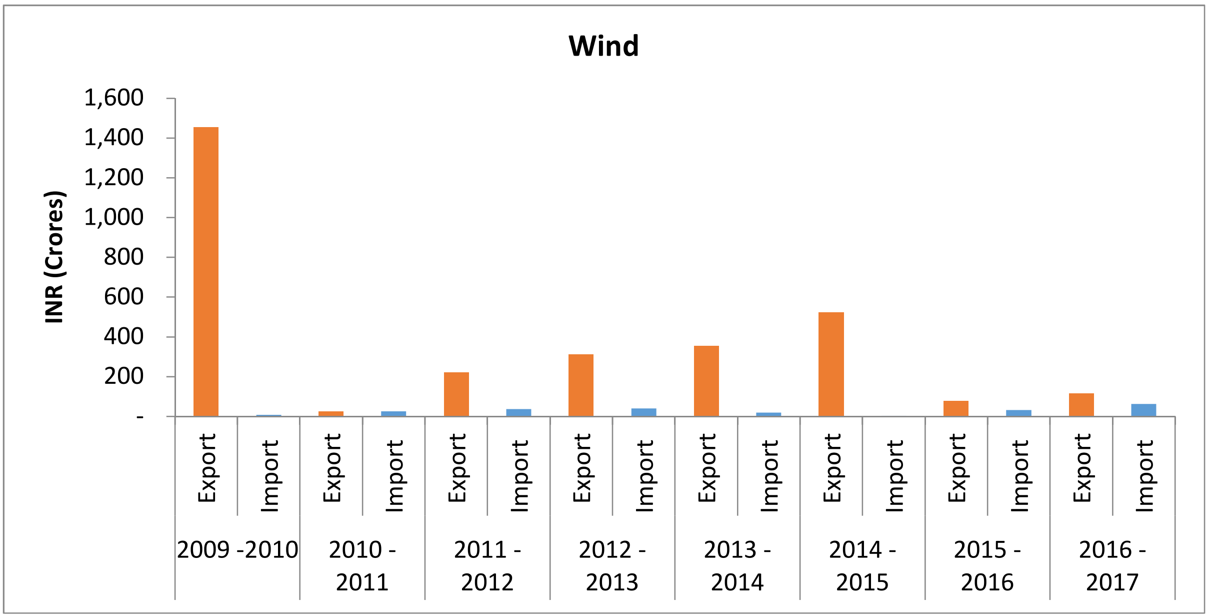


Figure 3: Export and import of wind components (INR lakhs)

[5] Export Import Data Bank , http://commerce.gov.in/eidb/ecntcomq.asp

Source: DGFT 2017[5]

India earlier enjoyed a positive trade balance in the sector. However since 2011, there has been a substantial change in the trend where the positive trade balance declined from INR 1.2 billion to INR 0.6 billion. Exports declined at 12% per annum, while imports have increase at 10% per annum. The Indian wind energy market is undergoing a transitionary phase at present after the government initiated competitive bidding for capacity addition in a manner similar to the solar power sector; there are concerns in the manufacturing base that the competition will lead to higher imports in an effort to cut costs. In this context, it is possible that the trade balance in the wind sector will look very different going forward.

2.4 Employment

The promotion and generation of renewable energy has direct as well as indirect benefits; one among the most important benefits being generation of employment. Employment generation enhances the socio- economic development of the country by not only creating more job opportunities but also by providing female empowerment, skill development, improved standard of living. Job estimates for renewable energy sector include direct and indirect jobs, skilled and semi-skilled labour and Full Time Equivalence (FTE).

There are few studies which have estimated the employment generation in renewable energy sector. Within renewable energy, employment potential has been analyzed mainly for two sectors: solar (mainly PV) and wind sector with focus on grid based technology. Employment potential was calculated on the basis of stakeholder consultation, primary survey of companies, literature review and discussion with sector experts. IRENA (2013) in their annual job review specified three methodologies for estimating employment (direct and indirect) in renewable energy: for direct employment, employment factor approach; and for indirect employment multiplier analysis, supply chain analysis and input-output analysis. However, most of the studies have used employment factor approach for calculation of current and future estimates.

According to IRENA (2017), there are approximately 0.39 million jobs (excluding large hydro) in this sector in India. It has been estimated that globally the renewable energy sector employed 9.8 million persons (directly and indirectly) in 2016 – a 1.1% increase over 2015. Among renewables, the most consistent increase has come from jobs in the solar PV and wind categories, together more than doubling since 2012.

Employment estimates in renewable energy sector have been prepared largely post 2009 after declaration of series of policy measures by the government to promote renewable energy in India. Report by MNRE and CII (2010) was the most cited paper by majority of the study focusing on employment estimates in the renewable energy. In the report, direct as well as indirect jobs have been calculated for various sectors such as wind, solar PV (both grid and off-grid), solar thermal, biomass (on-grid and gasifier), biogas and small hydro. It has been estimated that renewable energy sector in India employed 3,50,000 persons (both direct and indirect) in 2010 which will reportedly increase to approximately 14 lakhs by 2020 (assumed that growth rate is 15%). It concluded that all sectors of renewable energy will witness significant growth with employment in wind and solar PV (on-grid) will increase from 42,000 to 1,60,000 and 40,000 to 152,000 from 2010 to 2020 respectively under high growth scenario. The job estimates were provided corresponding to following profiles: manufacturing; fabrication; installation; operations & maintenance; project development; and marketing.

Another study by Bridge to India (2014) has considered four scenarios in solar sector: small rooftop; large rooftop; ultra-scale; and ultra-mega scale. They assessed that approx. 0.32 million new jobs will be created in small rooftop scenario in the next ten years and around 71,000 cumulative jobs will be created in utility-scale scenario. They concluded that least employment will be created in the ultra-mega scale category even though a significant number of people will be employed for every single project of this scale. The total number of jobs created in this scenario comes to around 63,000 in ten years.

Upadhyay and Pahuja, (2010) has provided employment generation potential for solar and wind for the period 2010-2050. They have evaluated low carbon employment generated in two phases:

construction & installation; operation & maintenance. To estimate the employment generation, they have used analytic method and developed three growth scenarios: high growth scenario (100% realization of the stated annual target); moderate growth scenario (75% realization of the stated annual target; low growth scenario (50% realization of the stated annual target. The study had made certain crucial assumptions that all capacity installed is manufactured domestically; construction and installation is completed in one year; all jobs accrue to India; and India has limited and fixed wind energy capacity and once this capacity is reached, all construction/installation will stop. They have considered job creation estimates for wind sector given by EPRI (2001), Indian Wind Energy Outlook (2009) and TERI (2009) while for solar sector considered estimates given by Greenpeace (2001), Renewable Energy Policy Project (2001) and Greenpeace & EPIA (2009). On the basis of the estimates of each report, they calculated job creation for three separate growth scenarios discussed above. They had estimated that in the wind sector job creation could range anywhere from 6,929 in to 243,225 in 2020; from 8,929 to 225,975 in 2030; and from 9039 to 225,975 in 2050. In case of solar sector, they had estimated job creation could range anywhere from 3,271 to 234,350 in 2020; from 106,850 to 4,214,000 in 2030; and from 166,250 to 2,150,000 in 2050 with the base year 2008.

Detailed stage wise assessment for jobs in renewable energy sector has been presented in studies by CEEW and NRDC (2014; 2015). The data regarding the requirement of number of skilled or unskilled worker was collected through surveys. The survey has been conducted through an online tool and telephonic interviews. However, they have confined their analysis to two sectors mainly wind and solar sector.

In case of renewables, all jobs are not created throughout the lifetime of the projects. Short term jobs are created in the business development; design and pre-construction; and construction phase. However, long term jobs are created in the operation and maintenance phase till the lifespan of the project. Thus, it becomes crucial to evaluate full time equivalents (FTE)[6]. However, this has been contemplated only in studies by CEEW & NRDC and SCGJ. Other studies have not clearly specified in their analysis whether they have taken into account full time equivalents or not.

CEEW and NRDC (2014; 2015) have evaluated employment generation in various projects such as for solar rooftop PV, they have looked into the Hero Motororp's 80 KW project in Haryana. Similarly, they evaluated 20 MW solar plant in Rajasthan by Kiran Energy and 85 MW wind project, Gamesa-Renew Power's in Jath, Maharashtra. **Table 1** provides us with the relevant figures of FTE during the first year, FTE post-commissioning and FTE per MW.

Table 1: Full time equivalent job generation potential for selected renewable energy technologies

Sector	Project	MW	FTE during first year	FTE in Post-commissioning Phase	FTE per MW	Grid/Off-grid
Wind	GAMESA-RENEW Project, Jath Maharashtra	85	438	102.5 (20)	5.15	Grid
Solar PV	Kiran Project, Rajasthan	20	180.8	44.5 (25)	9.04	Grid
Solar rooftop PV	Hero Motorcorp, Haryana	0.08	2.71	0.549	33.86	Off-grid

Source: CEEW and NRDC (2014; 2015)

However, CEEW and NRDC also estimated employment generation for country as a whole. They have highlighted that solar photovoltaic (PV) sector generates more jobs per unit of energy than any other source and within project, construction and commissioning phase generates majority of employment. They estimated that the solar market generated 23,884 cumulative jobs for installation of 2,616 MW from 2011 to 2014 (solely from commissioned projects currently producing electricity). Smaller projects up to 5 MW in size may provide the most employment opportunities per MW. The analysis

[6] CEEW and NRDC defines FTE as "An employment opportunity of 1 FTE is a job that exists for 1 person to work on for the duration of 1 year or 2 persons to work for 6 months each and so on. The calculation assumes 260 working days per calendar year."

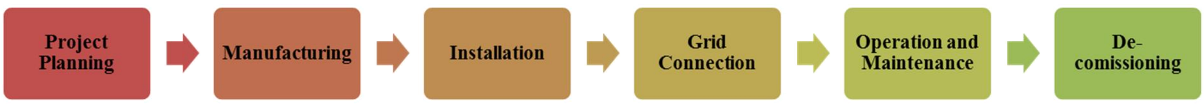
shows that increasing the installed capacity base of solar PV power generation creates long term employment and continuous and sustained addition to existing installed capacity also increases short term employment (CEEW and NRDC, 2014).

In another study, CEEW and NRDC (2015) had evaluated job generation in both solar and wind sector. In solar sector, they had estimated approximately 1 million FTE jobs will be generated to achieve the target of 100 GW grid connected capacity by 2022. They have analysed the potential under three scenarios based on MNRE's proposed mix of projects to achieve the 100 GW goal by 2022. In scenario I, if policy shifts toward vast solar parks then 1,080,000 FTE jobs can be generated by 2022 (789,000 short-term FTE and 296,000 long-term FTE jobs). In scenario II, if the government's policy approach focused primarily on 5-10 MW grid-connected large-scale projects then potential 1,140,000 FTE jobs can be generated by 2022 (850,000 short-term FTE and 296,000 long-term FTE jobs). In scenario III (60 GW Rooftop, 40 GW Large-Scale Projects), solar rooftop is prioritized and create a potential 1,310,000 FTE jobs by 2022 (1,000,000 short-term FTE and 310,000 long-term FTE jobs). Of the three scenarios presented, third scenario reflects the maximum job potential due to its focus on labour-intensive technology i.e. rooftop solar. In the wind sector, they estimated that 183,500 FTE (excluding manufacturing) will be generated to achieve the 60 GW target by 2022.

In a recent study, CEEW and NRDC (2017) estimated employment generation in rooftop solar, ground mounted solar, wind sector and in case of solar PV module manufacturing. They have estimated that rooftop solar projects create maximum number of job years per MW i.e. 24.72 job-years per MW while jobs in ground-mounted solar projects create 3.45 job-years per MW. In case of wind projects 1.27 job-years per MW is created. They have also analysed the part of indirect employment generated in case of solar PV module manufacturing which generate 2.60 job-years per MW. They concluded that solar power jobs will be well distributed throughout the country while jobs in wind power will be concentrated in few states such as Rajasthan, Gujarat, Madhya Pradesh, Maharashtra, Andhra Pradesh, Telangana, Tamil Nadu and Karnataka. IREDA, Deloitte and INAE (2017) have provided employment estimates for solar sector only. In total 11,16,400 trained personnel are required to achieve target of 100 GW of solar PV projects across utility and rooftop PV segment by 2022.

The data on employment estimates for renewable energy sector is limited and has been analyzed mainly for two sectors; solar (mainly PV) and wind sector with focus on grid based technology. Also, few studies have done the stage wise analysis (mainly two stages: construction and commissioning; operation and maintenance) while others have not carried out stage wise analysis for estimating employment potential. Studies by CEEW and NRDC have specified stage wise requirement for skilled and unskilled worker covering four stages mainly business development; design and pre-construction; construction and commissioning; operations and maintenance. Employment generation in upstream sector has been analyzed only in one study conducted by CEEW and NRDC (2017). However, they have restricted their estimates to manufacturing of equipment's and excluded employment generation in other sectors such as banking, financial services etc. None of the study has carried out employment generation across the value chain (given in **Figure 4**) and supportive processes such as policy making, financial services, education, research and development and consulting. Due to paucity of data, in our study, we have restricted our analysis to downstream sector covering four stages (business development; design and pre-construction; construction and commissioning; operations and maintenance).

Figure 4: Value chain in renewable energy sector



The study has not considered the impact of technology up gradation on employment generation due to data limitation. Also, the impact of technology up gradation on employment generation is not limited only to renewable energy sector; similar impact has been observed in thermal power plant as well. However, it has not been considered in the study and could be an interesting point to cover in future research. For the purpose of our study, we have considered the figures provided in "Skill Gap Report for Solar, Wind and Small Hydro Sector" by Skill Council for Green Jobs (SCGJ) published in 2016[7]. They have clearly outlined the assumptions, provided detailed information on capacity addition and disaggregation of employment into skilled, semi-skilled and unskilled. On the basis of figures reported in SCGJ report (2016), we have calculated FTE per MW. In the subsequent sub-sections, assumptions for each sector have been highlighted separately.

2.4.1 Solar PV

Jawaharlal Nehru National Solar Mission was launched on 11th January 2010 with following targets:

1. deployment of 20,000 MW of grid connected solar power by 2022
2. 2,000 MW of off-grid solar applications including 20 million solar lights by 2022
3. 20 million sq. m. solar thermal collector area

Subsequently, in a cabinet meeting held on June 17, 2015 cumulative targets under National Solar Mission (NSM) have been revised from 20 GW to 100 GW by 2021-22 for Grid Connected Solar Power Projects. To estimate the manpower required for achieving this 100 GW target for Solar PV (Rooftop and ground mount), the major assumptions considered in the Skill Council for Green Jobs (SCGJ) report (2016) are:

- A target of 250 GW solar power generation capacity till 2030 has been considered in order to estimate capacity addition till 2030. Further, a distribution of 50:50 in regard to ground-mounted and rooftop solar has been assumed.
- Distribution of project sizes for ground-mounted solar power has been considered on the basis of secondary and primary data collected as mentioned in **Table 2**. The same distribution has been assumed for each year till 2022.

Table 2: Distribution of Project Size

Project Size	Assumed distribution
>50 MW	5%
5 MW- 50 MW	60%
1-5 MW	35%

- Solar rooftop were categorized according to the sizes into two categories:
    - Less than 50 KW – Residential and Small Commercial Category
    - 50-500 KW – Large Commercial and Industrial Category
- The total number of days has been taken as 240 in a year
- They have considered that as the size of the project increases, due to economies of scale, the manpower requirement per MW reduces
- Current maximum installation of solar PV ground mount projects done in a year is 3700 MW
- For estimating the number of people required in the sector, a deployment of 80% in projects in a year has been assumed for the manpower in all phases
- Manpower has been estimated for two phases: EPC phase (Engineering, Procurement and Construction) and O& M phase (Operations and Maintenance)

2.4.2 Wind

Among all renewable energy (RE) options, wind power is the most commercially competitive mainly due to technological maturity, proven installed base and lower setup and running costs. Currently, wind sector accounts for over 70 per cent of the installed renewable energy (RE) capacity in the

[7] Skill Gap Report for Solar, Wind and Small Hydro Sector", SCGJ, 2016

country[7]. According to 12th Plan, government has envisaged to achieve target of 60,000 MW by 2022. To estimate the manpower required for achieving this 100 GW target for Solar PV (Rooftop and ground mount), the major assumptions taken by SCGJ report (2016)[7] are:

- They have taken wind power potential in India as 102 GW and estimated that the sector would reach its potential by 2026-27;
- Average size of wind farms in the future would be 50-100 MW. Further, due to economies of scale the manpower required for the project size is similar across the project size;
- Manpower has been estimated for two phases: EPC phase (Engineering, Procurement and Construction) and O& M phase (Operations and Maintenance); and
- Post FY 2025, they estimated growth rate of 10% for 1-2 years and the wind sector will reach its estimated potential by 2026-27. No extra manpower would be required for Planning and EPC activities. However, since Operation and Maintenance is a year-long activity, manpower required for O&M activities will increase.

2.4.3 Small Hydro

In the renewable energy target of 175 GW by 2022, 5 GW is allocated to small hydro power. It is estimated that India has close to 20 GW potential of Small Hydro projects in various states[7]. As per the SCGJ report, current levels of manpower would suffice for installation of the target 5 GW capacity. To install this capacity of 5 GW, SCGJ report has estimated the current manpower that can cater to the capacity increase.

- To estimate future growth till 2022 and 2025, annual capacity addition of 250 MW has been assumed. No significant growth in this sector is envisioned in the coming years.
- The current average project size is 0-10 MW. As per growth trends, year-on-year capacity addition of 250 MW of small hydro capacity has been assumed.
- A small hydro project requires full time deployment of the team for a span of close to 1-2 years. The same team is usually deployed for both phases (design and construction) unlike solar or wind sector.
- As operation and maintenance is a year-long activity, it has been assumed that the manpower required for this phase will increase with increase in the installed capacity

Based on cumulative figures reported in SCGJ report, FTE per MW is estimated for three sectors: Solar PV (Ground mount and Rooftop), Wind and Small Hydro (**Table 3**). For Solar PV, per MW employment estimates are higher in EPC phase compared to O&M phase. However, in case of small hydro, per MW estimates are higher for O&M phase (13 per MW) compared to EPC. Also, FTE per MW were calculated for different type of skill employment i.e. skilled, semi-skilled and unskilled (**Table 4**). Semi-skilled jobs are generated more than skilled and unskilled jobs for all three technologies.

Table 3: Employment estimates for different RETs

Year	Sector		Total (per MW)	Capacity (MW)
	Solar PV (Ground Mount and Rooftop)			
	EPC (per MW)	**O&M (per MW)**		
2016	4.75	3.15	7.90	7805
2022	4.25	2.52	6.78	102802
	Solar Rooftop			
	EPC (per MW)	**O&M (per MW)**		
2016	14.19	9.40	23.59	740
2022	5.38	3.18	8.55	40540
	Solar Ground Mount			
	EPC (per MW)	**O&M (per MW)**		

2016	3.75	2.49	6.24	7065
2022	3.48	2.07	5.55	62265
	Wind Sector			
	EPC (per MW)	**O&M (per MW)**		
2016	0.51	0.60	1.11	26932
2022	1.28	0.60	1.88	60000
	Small Hydro			
	EPC (per MW)	**O&M (per MW)**		
2016	3.07	10.75	13.82	4274
2022	2.27	11.11	13.38	5774

Source: Calculation based on SCGJ report, 2016
*Note: * EPC: Engineering, Procurement and Construction*
***O&M: Operations and Maintenance*

Table 4: Employment estimates for skilled, semi-skilled and unskilled workers

Year	Sector			Capacity (MW)
	Solar PV (Ground Mount and Rooftop)			
	Highly Skilled (per MW)	**Skilled (per MW)**	**Semi-skilled (per MW)**	
2016	0.97	4.41	2.50	7805
2022	0.57	4.17	1.99	102802
	Solar Rooftop			
	Highly Skilled (per MW)	**Skilled (per MW)**	**Semi-skilled (per MW)**	
2016	3.03	18.06	2.50	740
2022	0.66	6.04	0.48	40540
	Solar Ground Mount			
	Highly Skilled (per MW)	**Skilled (per MW)**	**Semi-skilled (per MW)**	
2016	0.75	2.98	2.50	7065
2022	0.51	2.96	2.08	62265
	Wind Energy			
	Highly Skilled (per MW)	**Skilled (per MW)**	**Semi-skilled (per MW)**	
2016	0.08	0.76	0.25	26932
2022	0.17	1.21	0.69	60000
	Small Hydro			
	Highly Skilled (per MW)	**Skilled (per MW)**	**Semi-skilled (per MW)**	
2016	0.32	7.85	4.93	4274
2022	0.24	9.01	4.86	5774

Source: Calculation based on SCGJ report, 2016[8]

[8] The SCGJ Report has used NSQF framework for defining occupational map and divided jobs into 10 levels. On the basis of this classification, we have calculated FTE per MW estimates for three types of skill category: Highly Skilled (Level 6-10); Skilled (Level 4-5); and Semi-skilled (Level 1-3).

The Ministry of Labour periodically notifies minimum daily wages for selected sectors by skill. In the present study, the minimum daily wages of workers by skill for the construction sector has been considered for the analysis. The real income increase has been considered at 5%, which is approximately the compounded annual growth rate of GDP between 2012 and 2015.

2.5 Opportunity Cost of Land

The opportunity cost of land was estimated with respect to agricultural income for the year 2015-16. To estimate minimum opportunity cost of land per acre, total agricultural income per acre and the total area under cultivation has been used from the data released by Ministry of Statistics and Program Implementation (MoSPI) and the Directorate of Economics and Statistics, Ministry of Agriculture respectively. Agricultural income (excluding mining and quarrying) for 2015 was used along with the area under cultivation (for rabi and khariff crops) to estimate the income per acre. Review of existing literature suggests that the average land requirement per MW of solar power installed capacity is in the range of 4-5 acres while the average land requirement for 1 MW of wind power is around 1 Ha (or 2.47 acres). Review of selected bagasse cogeneration projects indicates an average capacity per unit of land of around 2.5 MW per acre. Hence, the opportunity cost of land is estimated in terms of (agricultural income/acre) / (installed capacity/acre), i.e. (Rs./Acre)/(MW/Acre). The average annual increase assumed for the entire duration of the project is 2.8%, which is equal to real growth in agricultural income in India between 2010 and 2014.

It is important to note that there might be multiple application of land and accordingly the opportunity cost of land will vary depending on the activities the land is put to use. This may vary from state to state as well as with the policies of the state governments.

2.6 Avoided health and local environment cost of coal-based generation

Traditionally, India has been dependent on coal-based electricity and the sector contributes to almost 65% of the total electricity generation in the country. However, coal based power generation is associated with various externalities (Currie et al., 2014). External costs refer to cost of damage imposed on the environment and society but are not accounted for in market price of the resource.

On the basis of the principle, that the polluter needs to pay the full price of the product (here electricity production) the use of life cycle cost as an approach for estimation of above externalities is increasingly being used for valuing true cost of electricity generation. There are many approaches to the estimation of external costs due to coal mining and coal-based power generation. They can broadly be classified as (i) top down and (ii) bottom-up approach. The top down approach was extensively used by Hohmeyer (1988) for the first time to arrive at the external costs of all major fuels used in electricity generation in Germany and relied on secondary macro level estimates related to total damages. In the early 1990s, Bernow and Marron used the cost of pollution control as a proxy for possible valuation of environmental externalities for energy planning and operations. Through the ExternE Project EU (2003) and use of Ecosense software, it has been able to estimate marginal external costs, due to production and consumption of energy-related activities such as fuel cycles.

However, it is understood that there are limitations with regard to the EcoSense tool where the benefit assessment is only confined to health and environment cost and ignores other parameters along the lifecycle of the project as identified earlier in this report. For example, it allows calculation of only location specific marginal external costs of a stationary source (e.g. a power plant) due to emissions of air pollutants. Further the discounting of future benefits have to be estimated externally using suitable assumptions of social discount factors, for which extensive review of literature is required. EcoSense LE is the software developed under the EXTERN E project, which is an online tool for estimating costs due to emissions from a stationary source (e.g. power plant, industry, and transport) or all sources of a sector in an EU country or group of EU countries. It is based on European data for receptor (population, crops, building materials) distribution, background emissions (amount and spatial distribution), and meteorology. The input data used are annual emissions of NO_x,

SO_2, PM_{10}, Non Methane Volatile Organic Compound (NMVOC), CO_2, N_2O, CH_4. The cost calculation is based on ExternE exposure-response function and monetary values in Europe.

The economic principle behind the use of cost of pollution control as estimation of external cost is that the marginal abatement cost of emissions is equal to the marginal damage cost. Bottom up approaches on the other hand; use both primary and secondary data, that project/location specific, in estimating the external cost. For example, Ottinger, et.al (1990) in estimating the environmental costs of electricity and, Pearce (1992) in estimating the social cost of fuel cycle, have used the bottom up approach using secondary information. Despite enjoying certain advantages due to better results, there are challenges associated with collection of primary data. For instance, primary data collection may be time consuming because it involves the employment of dose–response functions to track the emission path way from the source to the receptor (D. Mahapatra et al, 2011). Other concerns include consequent monetization of the impacts, difficulty in learning the project specific social impacts in the form of displacement and loss of livelihood and finally, the involvement of multidisciplinary teams.

TERI (2014) undertook a detailed study for the erstwhile Planning Commission, on equitable sharing of benefits arising from coal mining and power generation among resource rich states in India. Coal mining and electricity production have various affects like impact on health due to air and water pollution, occupational disease and accidents, impact on agriculture, forests and global warming potential, etc. While some of the costs may be internalized as mandated under various environmental rules and regulations, certain external costs may still go unaccounted for. The broad impact category along the life cycle of coal based power generation is presented in **Table 5**.

Table 5: Avoided cost of power generation from coal – Pollution Based Impact (incl. Public Health Costs)

Stage	Major Activities	Impacts	Status
Coal Mining	i. Exploration ii. Mine development and mining iii. Transportation	Rehabilitation and Resettlement	Compensated
		Dust emissions from mining operations	Compensated
		Water pollution	Not compensated
		External cost due to water pollution due to coal washing	Compensated
		Forest lost	Compensated
		Land degradation	Not compensated
Power Generation	i. Land development for coal based thermal power plant ii. Coal combustion iii. Electricity generation and transmission	Impact of PM10 release from thermal power stations on human health	Partially compensated
		External cost of power generation on agricultural production	Not compensated
		External cost of power generation on building	Not compensated

Stage	Major Activities	Impacts	Status
		materials	
		Externality due to fly ash	Compensated

Source: TERI, 2014 [9]

One of the key activities undertaken was estimation of the negative impact of coal mining and coal based power generation on land, rehabilitation & resettlement, environmental and ecological degradation, physical infrastructure and health cost in the resource rich host state. Based on that exercise, the uncompensated local pollution based damage including health impacts from coal based power generation have been estimated at INR 1.07/kWh. Hence, if one unit of electricity is produced from any renewable energy technology, it would be able to reduce pollution based damage cost amounting to Rs 1.07. The Government of India however levies a 'Clean Energy Cess' which act as carbon tax and is levied as a duty of Excise under section 83 (3) of the Finance Act, 2010 on Coal, Lignite and Peat (goods specified in the Tenth Schedule to the Finance Act, 2010) in order to finance and promote clean environment initiatives, funding research in the area of clean environment or for any such related purposes. Since its introduction in 2010, the amount has been revised periodically and the currently 1 tonne of coal fetches a cess of INR 400. In order to avoid double counting, the cess has been adjusted from the damage cost and the revised pollution based damage cost amounts to INR 0.81 per unit of electricity produced. However, this estimate is for the year 2015, and the benefit needs to be assessed for the entire project life of 25 years. Since the ERR needs to be estimated for the entire life of a typical solar project life of 25 years, it is assumed that the cost of inaction by 2040 is comparable to the lifecycle cost of coal based power generation of China. NRDC estimates the damage of electricity produced from coal at 302 Yuan/ton in 2015 which makes INR 2.9/kWh at 2015 prices[10]. The intermediate years estimates are linear interpolation.

2.7 Environment Cost of Coal – the Social Cost of Carbon

The second category of environmental damage is equal to the cost associated with CO2 emission. The social cost of carbon (SCC) is a widely prevalent concept for understanding and implementing climate change policies. This term represents the economic cost caused by an additional ton of carbon dioxide emissions or its equivalent in the atmosphere (Nordhaus, 2017). There are models that have been used to estimate the monetized costs of carbon emission. Researchers have estimated the social cost of carbon using various models that represent the economy and society, the world's climate and the ways they interact. Estimates of the social cost of carbon vary because of different assumptions about future emissions, how climate will respond, the impacts this will cause and the way we value future damages. Climate damages increase with economic growth, which tends to put more assets at risk and creates wealthier people who are more willing to pay to avoid impacts. This means that integrated assessment models assumptions and equations for GDP growth are important, too. For the study, the estimates from Nordhaus (2017) have been used. Nordhaus (2017) study presents the results of a fully revised version of the DICE model and is the first major revision since the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. The DICE model views climate change in the framework of economic growth theory. In a standard neoclassical optimal growth model known as the Ramsey model, society invests in capital goods, thereby reducing consumption today, to increase consumption in the future. *The DICE model modifies the Ramsey model to include climate investments, which are analogous to capital investments in the standard model. The model contains all elements from economics through climate change to damages in a form that attempts to represent simplified best practice in each area.* The DICE model estimates the Social Cost of Carbon at 2010 prices for year 2015 as US$ 2.93/tCO2. The INR equivalent, in 2015

[9] "Equitable sharing of benefits arising from coal mining and power generation among resource rich states", TERI, 2014

[10] China is one of the few developing countries that have provided life cycle cost from coal based power generation for 2015, which eventually is also the base year for the above analysis. Further, India's coal based power generation in low renewable growth scenario by 2040 is estimated to be relatively closer to China's current installed coal based power generation capacity of around 900 GW (TERI, 2017)

prices, is Rs 0.14/kWh. Since the ERR needs to be estimated for the entire life of a typical solar project life of 25 years, it is assumed that the cost of inaction by 2040 is comparable to the lifecycle cost of coal based power generation of China. Nordhaus estimates the SCC for China at US$ 6.61/tCO2. The Indian currency equivalent for the same is INR 0.30/kWh. The intermediate years estimates are linear interpolation.

3 The Economic Rate of Return

3.1 Defining the ERR and selecting an appropriate SDR

Assessment of socio-economic costs and benefits and the rate at which present value of net benefits becomes zero is known as social rate of return. However, the incorporation of capital cost in this estimation would help in deriving the economic rate of return (ERR). It is defined as the rate at which the values of the cost of a project as well its benefits, discounted over its life, are equal. In other words, it is the rate at which the net discounted cash flows, i.e. the net present value is equal to zero (Gordon, 1974). It subsumes the socio-economic benefits generated during the life of a project or intervention. It is represented by the formula:

$$\sum_{0}^{end\ year} \left\{ \frac{(future\ stream\ of\ benefits)^t}{(1+ERR)^t} - \frac{(costs\ incl. initial\ capital\ costs + potential\ opportunity\ costs)^t}{(1+ERR)^t} \right\} = 0$$

For estimating the discount benefits (i.e. net present value of net benefits), a discount factor is used, discount rates applied for such estimation (often defined as social rate of discount) are applied for evaluating total costs and benefits from projects and interventions from a societal or economy perspective, while individual discount rates are applied to model investment decision making reflecting the expected return of an investor. In order to describe the social perspective, there is a consensus favouring "declining risk-free discount rates over a long time horizon" Kolstad et al., (2014).

There are different methods for estimation of discount factors. One of the most common methods is the weighted cost of capital method used for the assessment of public sector investments projects. The weighted cost of capital method is based on the assumption that the discount rate for capital investments should be the economic opportunity cost of funds obtained from the capital markets. Other methods include the social rate of time preference method, the marginal productivity of capital in the private sector projects; and a method that uses an accounting or "sliding" discount rate (World Bank, 2014). For the purposes of the study, the weighted average cost of capital for 2015 is considered and adjusted with the long-period consumer price index for the past 20 years to arrive at the real discount rate. Hence, the real discount rate considered for ERR calculation is 4.5%.

3.2 ERR results

The net present values and the economic rate of return are various renewable energy technologies based on the above approach have been estimated and are presented in **Table 6**. The various assumptions used in estimating the technology-specific rates of return are illustrated in **Annexure-I** for reference.

Table 6: ERR and economic NPV estimates for various RETs

S. No.	RETs	NPV (per-MW)	ERR
1	Wind	INR 32 Lakhs	4.9%
2	Solar (Ground Mounted)	INR 1.6 Crore	7.4%
3	Solar (Roof Top)	INR 1.7 Crore	7.0%
4	Small Hydro	INR 11.4 Crore	10.3%
5	Bagasse Cogeneration	INR (70 Lakhs)	5.93%

3.3 Financial Rate of Return for various RETs

A Financial Rate of Return (FRR) measures the attractiveness of a project or investment, expressed as a percentage. The Internal Rate of Return (IRR) is one of the most widely used indicators for a project's financial viability. In this study, the IRR has been used as the financial rate of return on RET projects. The study's approach toward estimation of FRR comprised a combination of primary and secondary research and detailed financial modelling of various renewable energy projects. Stakeholder approached for FRR estimation of different RETs included project developers, banks &FIs.

Accordingly, financial models for various RETs were developed and preliminary FRR results are reported hereunder. It is to be noted that the financial models developed are based on zero government incentives, and would therefore reflect the true market rates of return in a no-subsidy scenario. Further, assumptions were set to reflect general market conditions prevailing in the market in recent years. Another point of note is that certain market risks such as payment delays or curtailment have definitive impacts on project FRRs for dispersed projects across the different RETs; this is to say that these risks affect some projects more than others. While the present analysis does not consider the impact of these risks on the project FRRs, it is understood that realization of these risks in the operation phase of projects would only lead to a reduction in project FRRs.

The FRR assumes significance in the subsequent framework for justified level of incentives for different RETs since strong financial viability (even without subsidy) of an RET would indicate that there is no need for subsidy in that particular RET for private sector to invest, regardless of the socio-economic costs and benefits of that RET.

The preliminary results of FRR calculations for the various RETs are given in **Table 7** below. A range of FRR results has been estimated for each RET based on common variations in capital costs, O&M expenses, business model, etc. Illustrative assumptions are provided in **Annexure-II** for reference.

Table 7: FRR estimates for various RETs

RE technology	FRR range
Wind Power	9% - 11%
Grid-Connected Rooftop Solar PV	9% - 11%
Ground-Mounted Solar PV Power	9% - 11%
Bagasse Cogeneration	9% - 13%
Small Hydro Power	9% - 10%

4 Justified Level of Incentives for RETs

4.1 The Need for a Justified Level of Incentives

During its infancy, any product based on new technology is not cost-competitive with existing products on account of a number of factors such as costs being spread across lower volumes, higher costs of financing, lack of visible trajectory for penetration as well as buying capacity of consumers. All new technologies therefore need policy, regulatory and financial support during their infancy. Same has been the story of RE across the world. While RE has seen strong penetration in developed countries, the same in developing countries like India is underway. At present, RE generation costs are falling on account of technological advances, supportive policies, increasing volumes, etc. while the cost of supply of coal is likely to see an increase due to various technical and policy-related issues. In this regard, it is considered prudent to present the economic, social and environmental benefits and different RETs in the Indian context.

4.2 Proposed Framework for Justified Level of Incentives

Based on estimates of ERR and FRR, the following decision framework is proposed for estimating the justified level of incentives for various RE technologies (**Table 8**):

Table 8: Framework for justifying provision of incentives to a particular RET

Mandatory Conditions			Then...
ERR **>** Social Discount Rate	*and*	FRR **>** Market Discount Rate	Economic Support <u>not required</u>
ERR **>** Social Discount Rate	*and*	FRR **<** Market Discount Rate	Economic Support is <u>Justified</u>
ERR **<** Social Discount Rate	*and*	FRR **>** Market Discount Rate	<u>No case</u> for economic support
ERR **<** Social Discount Rate	*and*	FRR **<** Market Discount Rate	<u>No case</u> for economic support

As evident from **Table 8**, if the ERR is greater than the social discount rate, while the FRR is the greater than the market discount rate, it indicates that the project is economically viable and has substantial socio-economic return and therefore calls for no incentives. However, if the ERR is greater that the discount rate, while the FRR is less than the market rate, then the project calls for financial support. However, if the economic rate of return is less than the social discount rate, then the project does not require any incentive, irrespective of the fact whether the FRR is greater, equal or less than the market discount rate.

Now that there is a reason to have a justified level of incentive for promoting selected RETs in India, based on the above criterion, the incentive for the selected technology can be estimated. There are costs associated with any incentive. Although there may be complex econometric / and or CGE models that can assess the opportunity costs. Reserve Bank has well defined obligations and provides several banking services to the governments in the form of maintaining receipts, custody and disbursement of money from the consolidated fund, contingency fund, and public account to state governments etc. Varying subsidy as a percentage of the capital cost will lead to different ERR and FRR as well as NPVs. Hence the justified level of incentive would be set where:

Social Marginal Cost = Private Marginal Benefit

5 Conclusions and Remarks

India is a developing country with vast complexities; numerous needs of the nation in the short-term, medium-term and long-term compete for limited resources and funds and the Government of India is required to make decisions that are in the best interest of the populace. A "fire fighting" mode of resolving immediate issues, while alleviating short-term concerns, leads to inefficient utilization of resources and hinders long-term progress and development. Therefore, the country needs to flexibly manoeuvre the present interventions in order to address immediate concerns as well as chart a path for long-term progress; informed decision-making can be an integral enabler in this effort. For the government to choose the correct course of action, it requires a thorough understanding of the near-term and long-term costs and benefits of each course of action.

One of the prominent developmental needs of the nation is to build a flexible and efficient electricity sector that can meet the country's burgeoning energy needs in a clean and green manner, while also meeting India's international commitments for mitigating climate change. Renewable energy is critical to this objective, and has received strong policy push by the Government of India.

In this study, the following broad parameters encapsulating the social, economic and environmental impacts of deploying several renewable energy technologies have been studied:

i. Avoided health and environment impact from coal-based power generation,

ii. Social Cost of Carbon,

iii. Employment generation,

iv. International trade, and

v. Opportunity cost of land.

The study considers these parameters across the EPC and O&M activities in the respective RET value chains; an analysis across the full value chain (including, for instance, the upstream activities of manufacturing, distribution, etc.) would be desirable but issues such as present-day data limitations constrain the scope of the current analysis.

The current study presents a comprehensive metric, i.e. the Economic Rate of Return (ERR), that can be used for understanding the socio-economic costs and benefits of renewable energy technology options as well as a decision framework for designing broad government policy with respect to each technology.

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7 Annexure-I: Assumptions for ERR estimates

Social Discount Rate		
Social Discount Rate	*%*	4.50%
Social Cost of Carbon (SCC)		
SCC for India in 2010	*USD 2010 / tCO2*	2.93
USD 2010 - INR 2010 Exchange Rate	*INR 2010 / USD 2010*	45.00
Emission factor (CO_2 emissions from 1 kWh of coal power produced)	*tCO2/kWh*	0.00082
SCC for India in 2010 (Rs.)	*INR 2010 / tCO2*	131.85
SCC for India in 2010 (Rs.)	*INR 2015 / tCO2*	172.05
Avoided SCC (for non-emissions RETs) in year 0	*INR 2015 / kWh*	**0.14**
SCC for China in 2010 (used as approximation for Indian SCC in 2040)	*USD 2010 / tCO2*	6.16
SCC for India in 2040	*USD 2010 / tCO2*	6.16
SCC for India in 2040 (Rs.)	*INR 2010 / tCO2*	277.20
SCC for India in 2040 (Rs.)	*INR 2015 / tCO2*	361.71
Avoided SCC (for non-emissions RETs) in year 23	*INR 2015 / kWh*	**0.30**
Opportunity cost of land		
Total agriculture income in 2015-16	*Rs. (crore)*	21,75,547
Area under cultivation	*hectares*	122,650,000
Agriculture income per hectare	*Rs. / hectare*	177,378
Agriculture income per acre	*Rs. / acre*	71,813
Escalation rate in opportunity cost of land (growth rate in real agriculture income)	*%*	2.80%
Pollution based health + environment cost		
Avoided cost in 1st year of operation from 1 kWh generated [11]	*Rs./kWh*	0.81
Manpower		
Weighted average per-day wages [12]		
Highly skilled	*Rs./day*	*693.00*
Skilled	*Rs./day*	*637.00*
Semi-skilled	*Rs./day*	*579.00*
Avg. per-day wages	*Rs./day*	636.33
Number of working days in a year	*days/year*	261
Growth in real income (escalation rate)[13]	*%*	5%

[11] TERI (2014)
[12] Ministry of Labour, based on minimum wage notified in 2015-16, and weighted by FTEs
[13] Average growth in real GDP between 2012-2015

8 Annexure-II: Assumptions for FRR estimates

The assumptions laid out in this section are presented in per-MW basis in the interest of convenience.

8.1 Wind

PROJECT DETAILS		
Project size	MW	1
CUF	%	**25.00%**
Losses due to soiling, insects, etc.	%	0.2%
Useful life	years	**25**
CAPITAL COST		
Cost of Equipment and Material Inputs	Rs. (lakh) / MW	450.00
Cost of Land	Rs. (lakh) / MW	20.00
Cost of construction, civil works, erection, testing & commissioning	Rs. (lakh) / MW	100.00
Pre-operative expenses (w/o IDC)	Rs. (lakh) / MW	4.00
Contingency costs	%	0.10%
Interest during construction	Rs. (lakh) / MW	22.98
per-MW capital cost	**Rs. (lakh) / MW**	**597.56**
DEBT + EQUITY		
Interest During Construction	%	12%
Construction period duration	months	8
Debt component	%	70%
Cost of debt	%	10.50%
Debt tenor	years	15
Moratorium period	years	0
Equity component (% of CAPEX)	%	30%
Required return on equity (post-tax)	%	16%
OTHER FINANCIAL ASSUMPTIONS		
Income Tax rate	%	34.61%
MAT rate	%	21.34%
Discount Rate	%	9.61%
Insurance expenses (as % of net block)	%	0.10%
O&M expenses – 1st year	Rs. (lakh) / MW	10.00
O&M expenses Escalation rate	%	4.50%
Interest on Working Capital	%	12.50%
DEPRECIATION ASSUMPTIONS		
Book Depreciation (per Companies Act 2013)		
Book Depreciation rate	%	4.32%
Residual Value	%	5%
Tax Depreciation (per Income Tax Act 1961)		
Tax Depreciation rate	%	15%
REVENUE ASSUMPTIONS		
Which model of revenue?	#	**FiT**
Avg. Sale of Power to DISCOM	Rs./kWh	4.00

8.2 Grid-connected rooftop solar PV

PROJECT DETAILS		
Project size	MW	1
CUF	%	**15.00%**
Module degradation	%	0.5%
Useful life	years	**25**
CAPITAL COST		
Cost of Equipment and Material Inputs	Rs. (lakh) / MW	450.00
Cost of Land	Rs. (lakh) / MW	-
Cost of construction, civil works, erection, testing & commissioning	Rs. (lakh) / MW	50.00
Pre-operative expenses (w/o IDC)	Rs. (lakh) / MW	4.00
Contingency costs	%	0.10%
Interest during construction	Rs. (lakh) / MW	7.57
per-MW capital cost	**Rs. (lakh) / MW**	**512.07**
DEBT + EQUITY		
Interest During Construction	%	12%
Construction period duration	months	3
Debt component	%	70%
Cost of debt	%	10.50%
Debt tenor	years	10
Moratorium period	years	0
Equity component (% of CAPEX)	%	30%
Required return on equity (post-tax)	%	16%
OTHER FINANCIAL ASSUMPTIONS		
Income Tax rate	%	34.61%
MAT rate	%	21.34%
Discount Rate	%	9.61%
Insurance expenses (as % of net block)	%	0.10%
O&M expenses - 1st year	Rs. (lakh) / MW	5.00
O&M expenses Escalation rate	%	4.50%
Interest on Working Capital	%	12.50%
DEPRECIATION ASSUMPTIONS		
Book Depreciation (per Companies Act 2013)		
Book Depreciation rate	%	6.33%
Residual Value	%	5%
Tax Depreciation (per Income Tax Act 1961)		
Tax Depreciation rate	%	15%
REVENUE ASSUMPTIONS		
Sale of Power to DISCOM	Rs./kWh	5.50

8.3 Ground-mounted solar PV

PROJECT DETAILS		
Project size	MW	1
CUF	%	**20.00%**
Module degradation	%	0.5%
Useful life	years	**25**
CAPITAL COST		
Cost of Equipment and Material Inputs	Rs. (lakh) / MW	335.00
Cost of Land	Rs. (lakh) / MW	20.00
Cost of construction, civil works, erection, testing & commissioning	Rs. (lakh) / MW	30.00
Pre-operative expenses (w/o IDC)	Rs. (lakh) / MW	4.00
Contingency costs	%	0.10%
Interest during construction	Rs. (lakh) / MW	15.58
per-MW capital cost	**Rs. (lakh) / MW**	**404.96**
DEBT + EQUITY		
Interest During Construction	%	12%
Construction period duration	months	8
Debt component	%	70%
Cost of debt	%	10.50%
Debt tenor	years	15
Moratorium period	years	0
Equity component (% of CAPEX)	%	30%
Required return on equity (post-tax)	%	16%
OTHER FINANCIAL ASSUMPTIONS		
Income Tax rate	%	34.61%
MAT rate	%	21.34%
Discount Rate	%	9.61%
Insurance expenses (as % of net block)	%	0.10%
O&M expenses - 1st year	Rs. (lakh) / MW	3.00
O&M expenses Escalation rate	%	4.50%
Interest on Working Capital	%	12.50%
DEPRECIATION ASSUMPTIONS		
Book Depreciation (per Companies Act 2013)		
Book Depreciation rate	%	4.32%
Residual Value	%	5%
Tax Depreciation (per Income Tax Act 1961)		
Tax Depreciation rate	%	15%
REVENUE ASSUMPTIONS		
Power Purchase Tariff	Rs./kWh	3.00

8.4 Bagasse cogeneration

PROJECT DETAILS		
Project size	MW	1
CUF	%	**62.50%**
Losses due to soiling, insects, etc.	%	0.5%
Useful life	years	**20**
CAPITAL COST		
Cost of Equipment and Material Inputs	Rs. (lakh) / MW	420.00
Cost of Land	Rs. (lakh) / MW	-
Cost of construction, civil works, erection, testing & commissioning	Rs. (lakh) / MW	20.00
Pre-operative expenses (w/o IDC)	Rs. (lakh) / MW	4.00
Contingency costs	%	0.10%
Interest during construction	Rs. (lakh) / MW	13.33
per-MW capital cost	**Rs. (lakh) / MW**	**457.78**
DEBT + EQUITY		
Interest During Construction	%	12%
Construction period duration	months	6
Debt component	%	70%
Cost of debt	%	12.50%
Debt tenor	years	12
Moratorium period	years	0
Equity component (% of CAPEX)	%	30%
Required return on equity (post-tax)	%	16%
OTHER FINANCIAL ASSUMPTIONS		
Income Tax rate	%	34.61%
MAT rate	%	21.34%
Discount Rate	%	10.52%
Insurance expenses (as % of net block)	%	0.10%
O&M expenses - 1st year	Rs. (lakh) / MW	157.00
O&M expenses Escalation rate	%	4.50%
Interest on Working Capital	%	13.50%
DEPRECIATION ASSUMPTIONS		
Book Depreciation (per Companies Act 2013)		
Book Depreciation rate	%	4.75%
Residual Value	%	5%
Tax Depreciation (per Income Tax Act 1961)		
Tax Depreciation rate	%	15%
REVENUE ASSUMPTIONS		
Power Purchase Tariff	Rs./kWh	5.00
Avg. savings in Captive Consumption	Rs./kWh	6.50
Escalation in grid electricity prices	%	3%
In-Season Operation		
Days of power plant operation - In-Season	days/year	180
Capacity utilization	%	95%
Power generation	MW	0.95
Captive consumption	MW	0.1
Surplus power - exported	MW	0.85
Off-Season Operation		
Days of power plant operation - Off-Season	days/year	60
Capacity utilization	%	95%
Power generation	MW	0.95
Captive consumption	MW	0.1
Surplus power - exported	MW	0.85

8.5 Small hydro power

PROJECT DETAILS		
Project size	MW	1
CUF	%	**40.00%**
Auxiliary consumption	%	1.0%
Useful life	years	**35**
CAPITAL COST		
Cost of Equipment and Material Inputs	Rs. (lakh) / MW	217.04
Cost of Land	Rs. (lakh) / MW	29.20
Cost of construction, civil works, erection, testing & commissioning	Rs. (lakh) / MW	541.15
Pre-operative expenses (w/o IDC)	Rs. (lakh) / MW	94.19
Contingency costs	%	1.00%
Interest during construction	Rs. (lakh) / MW	62.33
per-MW capital cost	**Rs. (lakh) / MW**	**952.72**
DEBT + EQUITY		
Interest During Construction	%	12%
Construction period duration	months	14
Debt component	%	70%
Cost of debt	%	11.00%
Debt tenor	years	15
Moratorium period	years	0
Equity component (% of CAPEX)	%	30%
Required return on equity (post-tax)	%	16%
OTHER FINANCIAL ASSUMPTIONS		
Income Tax rate	%	34.61%
MAT rate	%	21.34%
Discount Rate	%	9.84%
Insurance expenses (as % of net block)	%	0.10%
O&M expenses - 1st year	Rs. (lakh) / MW	28.58
O&M expenses Escalation rate	%	4.50%
Interest on Working Capital	%	13.00%
DEPRECIATION ASSUMPTIONS		
Book Depreciation (per Companies Act 2013)		
Book Depreciation rate	%	2.38%
Residual Value	%	5%
Tax Depreciation (per Income Tax Act 1961)		
Depreciation allowance (% of actual cost)	%	3.40%
REVENUE ASSUMPTIONS		
Power Purchase Tariff	Rs./kWh	4.29