227 GW by 2022 considering that the country is well on its way to exceeding the previously set target, which includes 113.49 GW from solar, 66.65 GW from wind, 31 GW from floating solar, offshore wind, hybrid and manufacturing schemes, 10.5 GW from bio-power, and 5.98 GW from small hydro power. As of February 29, 2020, a total of 86 GW renewable energy capacities have been installed from all sources in the country (Table 1).

As already stated, integrating renewable sources with various viable storage systems at the generation end has the potential to supply firm renewable power on RTC basis. It resolves inherent issues of intermittency of renewable energy and helps in balancing infirm renewable power. Further, balancing of renewable power and the objective of supplying power on RTC basis can be achieved by bundling renewable power with other collated clean power sources such as gas from the supply side used for balancing. Renewable power can be supplied as and when generated and gas-based generation can be used to compensate for any deficit in renewable generation to make it firm supply on RTC basis.

Suitable techniques are, therefore, required not only for schedulable renewable power on RTC basis through a combination of renewable power projects and storage facilities, but also for balancing of grid by bundling renewable power with other clean power sources, such as gas from the supply side. The Internet of things (IoT), artificial intelligence (AI), blockchain technologies, along with smart grid projects, will have a major impact on both the way the power supply chain operates and in the scheduling and forecasting of RTC-based renewable projects. Business intelligence will enable decision-makers to arrive at more informed decisions. However, extensive use of information technology and digital networks is likely to make the system vulnerable to cyberattacks; hence, there is a need to strengthen the cyber security of the power system of RTC.

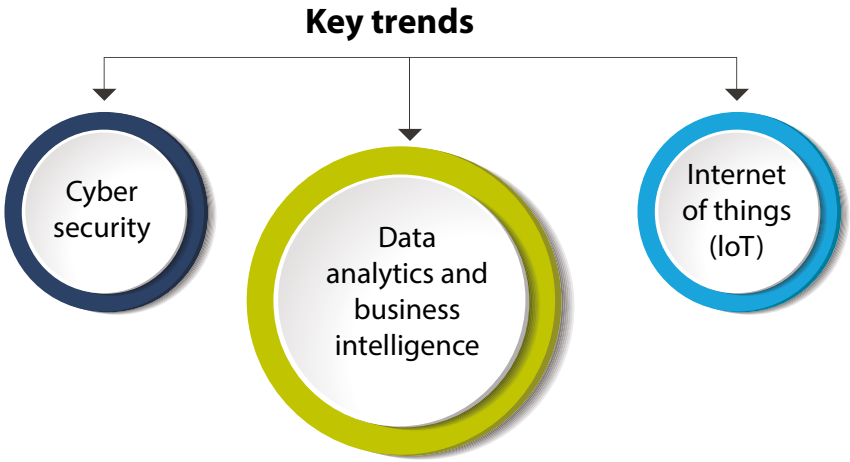
Table 1 Source-wise progress up to February 2020

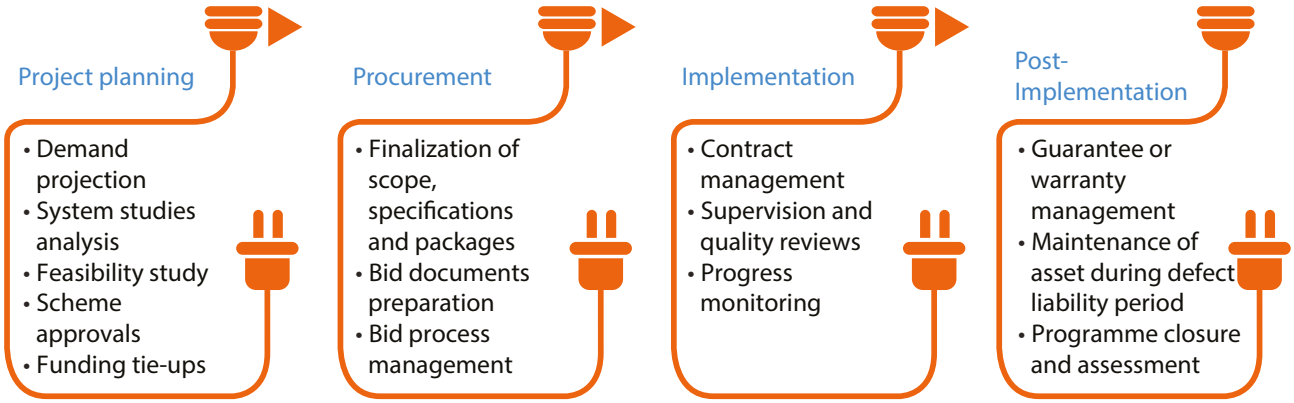
Renewable energy source	Cumulative installed capacity till February 2020 (in MW)
Wind power	37,669.25
Solar power – ground mounted	31,980.70
Solar power – rooftop	2,424.94
Small hydro power	4,683.16
Biomass (bagasse) cogeneration	9,186.50
Biomass (non-bagasse) cogeneration/ captive power	674.81
Waste-to-power	139.80
Total	86,759.16

Considering the complexities of various initiatives in power generation, transmission, and distribution, the success of the RTC power will largely depend on the way it is implemented in an integrated manner, including regular review of the progress and resolution of concerns by stakeholders. The programme implementation process in such a large sector can be broadly classified into four stages: project planning, procurement, implementation, and post-implementation.

Proposed Model

Rapid economic growth in India has led to a surge in energy demand. India, the fourth largest producer of electricity in the world, has witnessed a transformational change in the energy sector, with supportive policy interventions as well as sector reforms. Increasing penetration of wind power, photovoltaic, and other renewable energy resources has brought greater stochasticity and uncertainty to the power system, requiring power systems to have greater flexibility. Flexibility has gradually become a hot research problem in operation and dispatch. It is difficult to quantify the flexibility. Many organizations define flexibility by qualitative description. In this article, flexible ramp capacity (FRC) quantifies flexibility for maintaining power balance. At present, only traditional generations provide FRC. With the increase in renewable energy penetration, it is hard to effectively deal with the uncertainty of renewable energy. Therefore, some literatures have begun to study the potential 'flexible resources'.





This article proposes that emerging flexible sources such as wind–photovoltaic–storage can participate in providing FRC to improve the flexibility of the power system. Then, wind–photovoltaic–storage providing FRC can be integrated into a two-stage stochastic dispatching model, including day-ahead dispatch and real-time dispatch. The day-ahead dispatch takes an hour as the interval to determine the status of the conventional units and the approximate power output and FRC distribution of various energy sources. The power output and FRC distribution of various energy sources can be adjusted based on the latest 15 min forecast data.

Wind and Photovoltaic Providing Flexible Ramp Capacity

Figure 1 illustrates the ability of wind/photovoltaic (W/PV) to provide FRC. A_0 is the actual output of wind/photovoltaic power at time t, B_0 is the expected output at time $t + 1$, and B^* is the actual power output at time t + 1, which can be any point during the uncertain interval $[B_d, B_u]$.

Upward Flexible Ramp Capacity

The wind/photovoltaic must reload to provide more schedulable capacity for the subsequent time. For example, we can reduce the output from A_0 to A_1, which will increase the capacity $(A_0 - A_1)$ for the subsequent time. Considering the uncertainty of wind/photovoltaic, the upward FRC is limited by the point B_α, which is the lower α quantile of the predicted wind/photovoltaic power probability distribution.

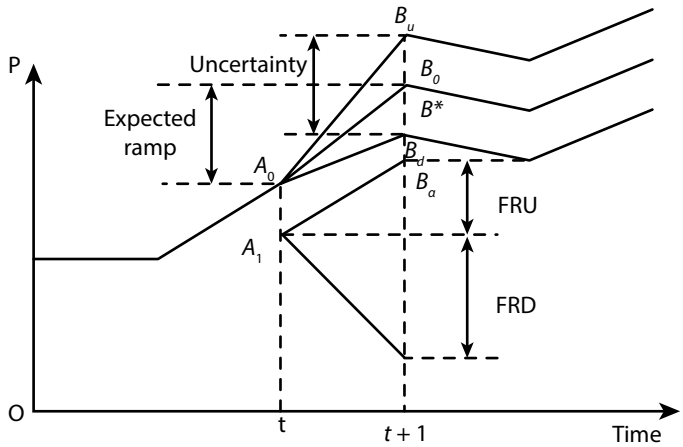


Figure 1 Wind/photovoltaic providing FRC

Downward Flexible Ramp Capacity

Wind/photovoltaic provides downward FRC directly through conducting curtailment, and the downward FRC at time t is limited by the predicted power output at time $t + 1$. Considering the uncertainty, the lower α quantile of the predicted wind/PV power probability distribution at $t + 1$ time is used to limit the wind/PV capacity to provide downward FRC.

Two-Stage Stochastic Scheduling Model

In order to study the influence of wind power providing FRC on dispatch, we integrate wind power providing FRC into a two-stage stochastic dispatch model. The model is divided into the upper day-ahead unit commitment with 1 h resolution and the subsequent real-time economic dispatch with 15 min resolution.

Objective Function

The main objective function is the system's total operating cost, which consists of the operating costs of conventional units, wind power, photovoltaic and energy storage, and the adjustment costs of the real-time economic dispatch, as expressed by

$$\min F = F_g + F_w + F_{pv} + F_{es} + F_{re-dispatch}$$

where F_g, F_w, F_{pv}, and F_{es}, respectively, represent the operating costs of conventional units, wind power, photovoltaic, and energy storage in the day-ahead unit commitment. $F_{re\text{-}dispatch}$ is the adjustment costs of conventional units, wind power, photovoltaic, and energy storage in the real-time economic dispatch.

Constraints

The unit commitment of the conventional units is determined once in every hour. After the unit status is determined, it remains unchanged in the subsequent real-time dispatch process, and we just consider generation capacity constraints and ramp rate constraints of conventional units during unit commitment and economic dispatch process. Meanwhile, we must consider startup and shutdown status constraints and minimum startup and shutdown constraints of conventional units during the unit commitment process, making the day-ahead process more complicated than the real-time process. The day-ahead constraints of W/PV are similar to the real-time process constraints, and so we model only the real-time constraints of W/PV.

Simulation Model Parameters

In this research, a modified IEEE 118-bus with 54 thermal units has been used to construct the simulation model. The model includes 91 load notes, five 400-MW wind power plants, nine 300-MW photovoltaic power plants, and five 120-MWh bulk energy storage power stations. The maximum ramp rate of each wind plant is 20 MW/min and that of photovoltaic plants is 12 MW/min. The compensation factor of wind power in providing FRC is 20% of the offered cost of energy. In this article, the scenario method has been used to describe the uncertainty of load, wind power, and photovoltaic. Load, wind power, and photovoltaic generate 500 power scenarios through Latin oversampling in a day-ahead dispatch and real-time dispatch and then reduce 500 scenarios to 5 scenarios using the scenario reduction technology. Hence, the total number of scenarios is equal to 125 scenarios. The MATLAB simulation platform with YALMIP modelling method was used to solve the optimization problem.

Simulation Result of a Typical Day

Figure 2 shows the expected day-ahead and real-time power for the wind, PV, and load, which are used to, respectively, generate 125 day-ahead and real-time scenarios.

In order to obtain the FRC distribution of all 'flexible sources' in a day, we calculate the FRC distribution result in day-ahead process, then calculate the adjustment FRC in each 15 min interval, and finally obtain the FRC distribution results. In order to figure out the advantage of coordinating wind, photovoltaic, and energy storage in providing FRC, we compare the FRC distribution result of conventional units solely providing FRC (C1) with wind, photovoltaic, and energy storage providing FRC (C2).

Figure 3 shows the final FRC distribution result.

It is easy to see from the C1 that the conventional units can meet the FRC requirements in most of intervals, but there are still FRC deficiencies in some intervals with high FRC requirements. Conventional units, wind power, and photovoltaic coordinate with energy storage providing FRC (C2) can meet

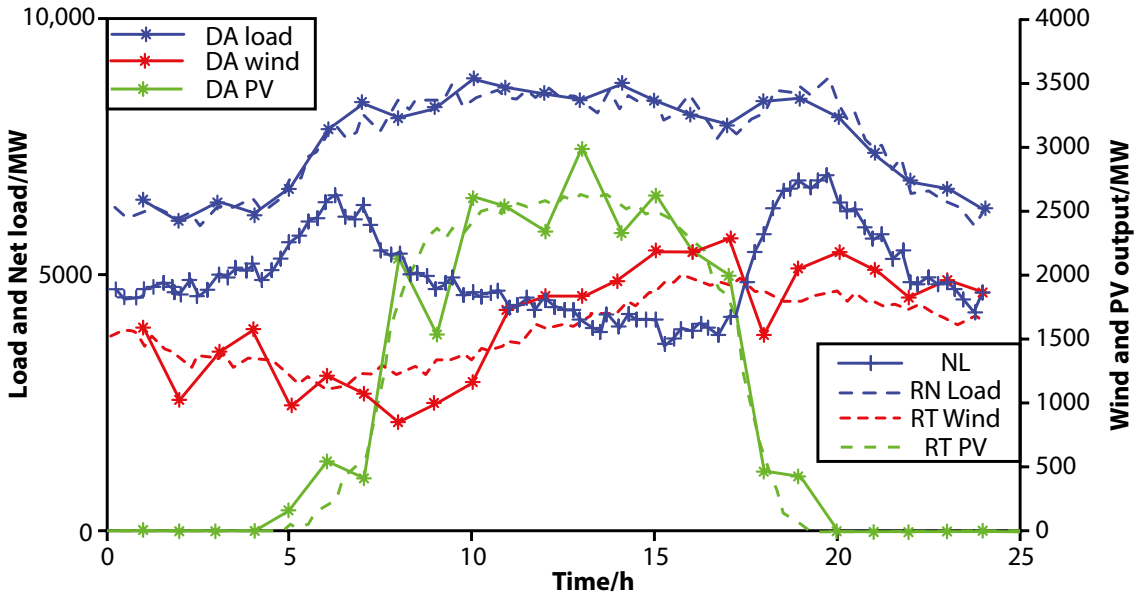


Figure 2 Expected load wind and photovoltaic power curves

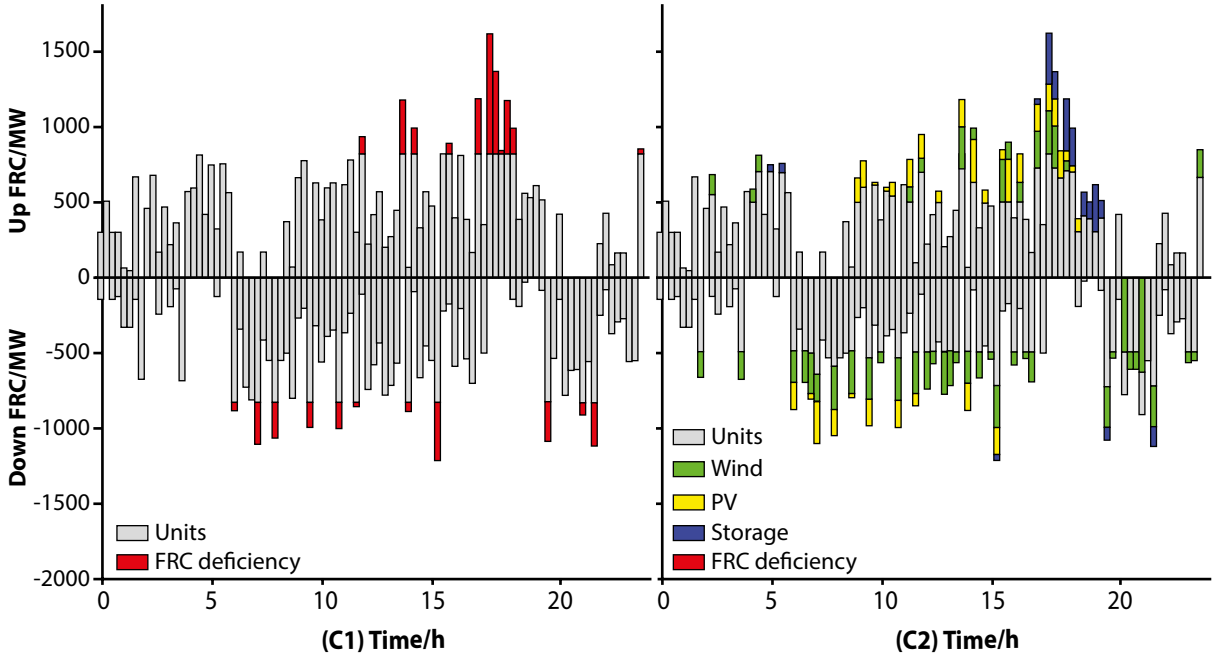


Figure 3 Real-time FRC scheduling of C1 and C2

the FRC requirements in all intervals. From the perspective of FRC distribution results, C2 is the optimal strategy.

Economic Analysis of Different FRC Dispatch Strategies

Since load shedding does not occur in the dispatch process, there is no penalty cost for load shedding. On the basis of the initial calculation of 24 h operation cost of C1 and C2, operating costs can be divided into four categories, namely, conventional units' operation cost, operation cost of wind power, FRC cost provided by wind power, and the penalty cost of FRC deficiency. It is found from the perspective of the system's FRC distribution and economic benefits that (C2) FRC provided by wind, photovoltaic, and energy storage is a better strategy than C1.

Flexibility Assessment of Different FRC Requirements

Fluctuations in load, wind power, and PV power directly lead to system's FRC demand. Table 2 gives the flexibility assessment comparison of C1 and C2 under different FRC requirements. In this article, we consider economic flexibility and technical flexibility. We use the total operation cost of the system to assess economic flexibility and the capacity of FRC deficiency to assess technical flexibility.

The results indicate that when the penetration of wind power and PV in power system increases to a certain extent, the additional FRC provision of wind–photovoltaic–storage has more economical and technical flexibility than conventional units solely participating in providing FRC.

Conclusions and the Way Forward

The proposed emerging 'flexible sources' such as wind power, photovoltaic, and energy storage that participate in providing FRC have been analysed using MATLAB and then integrated into 'wind–photovoltaic–storage', providing FRC in a two-stage stochastic dispatch model, including 1 h day-ahead unit commitment and 15 min real-time economic dispatch. The validity of the model was verified by a modified IEEE 118-bus with 54 thermal units. From the above results, it is clear that the

Table 2 Flexible evaluations in different FRC requirements

FRC requirements (MW)	Strategy	Total operation cost (in $)	FRC provided by wind–photovoltaic–storage (MW)	FRC deficiency (MW)
9,437	C1	6,975,515	–	0
	C2	6,975,515	0	0
11,796	C1	8,419,473	–	141
	C2	6,993,116	787	0
14,156	C1	9,591,681	–	319
	C2	7,016,365	1,549	0

conventional units can meet the FRC requirements in most of intervals, but there are still FRC deficiencies for some intervals with high FRC requirements. The additional FRC provision of wind–photovoltaic–storage provides a significant improvement in the FRC deficiency of the system and increases the economic efficiency of the system.

Further, for systems with high wind power and PV penetration, the participation of wind–photovoltaic–storage in providing FRC shows better economic and technical flexibility. Therefore, the promotion of RTC-based techniques through a combination of renewable power projects, storage facilities, and bundling renewable power with other clean power sources, such as gas from the supply side, is required for reducing the variability in renewable power generation and achieving better grid stability. This would also enable a framework from both supply and demand sides for development of schedulable renewable energy market on RTC basis or as per demand of the offtaker. Thus, this schedulable renewable power can help DISCOMs in multiple ways, such as allowing them to meet the base load for specified duration, meet peak load by ensuring energy availability during peak hours, address the issue of changing patterns of peak load by ensuring energy availability as per demand under the same contract, and meet solar and non-solar RPO obligations.

Major takeaways from the study are summarized as follows:

» Going forward, we need both centralized and decentralized control in the power sector for integration and we cannot do with just one of them. As the Solar Park Scheme of the Ministry of New and Renewable Energy took part with around 40 GW share of solar capacity by 2022 out of 175 GW of renewables by 2022, there is a need for a decentralized market structure, wherein each individual has greater responsibility, freedom, choice, and accountability, and on top of that there is a need for a country-wide thin centralized layer.

» The second important requirement for the RTC integrated transmission system is scheduling, metering, accounting, and a settlement system at the state or regional level. The states have failed to implement open access and the intra-state transmission network has not been strong enough as compared to the inter-state network. The absence of a basic ecosystem at the state level has

been one of the key reasons behind this.

» Another requirement of the power market is bid-based economic dispatch. Ultimately, there has to be economy in dispatch at the pan-Indian level. In order to do so, we must call more frequent bids and the day is not far when generators will be asked to bid every hour to despatch renewable energy. Forecasting of transmission requirement needs to be undertaken in the same way as the load generation balance and load forecasts are being done.

» Apart from this, there is a need to expand beyond volumetric tariffs to focus on energy efficiency and demand response and to promote energy storage systems and smart grids. Further, a confluence of energy and transportation with the introduction of electronic vehicles is expected to promote e-mobility.

Overall, the market and system design must accord high priority to consumer freedom and choice for integration. Besides this, the market design cannot be based on general knowledge; it has to be designed by people with domain knowledge and with the knowledge of economics, laws, and governance.

Acknowledgement

Ideas and detailed techniques included in this paper and an earlier version of this paper will also be presented in CIGRE Conference. Views expressed in this paper are those of the authors; they do not necessarily represent the views of institutions to which the authors belong. The authors wish to acknowledge the technical support and assistance given by CEA, NLDC, POSOCO, NISE, MNIT, and RTU in preparing this article. EF

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Which Solar PV Module Should I Select?

With the massive growth of the solar photovoltaic market in India, and the consequent explosion in the range of products available, deciphering which system and technical requirements meet a user's needs can be difficult. In this article, **Lucky Aggarwal** discusses common parameters mentioned in manufacturers' datasheets and takes readers through common factors that should influence their decisions.

In the past few years, the solar photovoltaic (PV) market has grown enormously in India. With this growth, a lot of PV module manufacturers have entered the market with a diversified range of products. Owing to almost similar technical ratings and warranty terms, it can sometimes become difficult for users to select a the right solar PV module for their system. This article is an attempt to summarize different factors one should consider while selecting a solar PV module for their system.

Efficiency of the Module

There is often a wrong conception that people make regarding efficiency of PV modules. It is not always correct to say that if we select a higher efficiency module, we will get higher energy output. Let us understand how efficiency affects energy output from the project and how efficiency factors should be considered before selecting a solar PV module.

In Figure 1, it can be seen that different power rating modules have different efficiencies despite having the same physical size. Let us consider WS-340 model with power rating 340 Wp, efficiency 17.52%, and size 1960 mm × 990 mm and see how efficiency is calculated for this:

$$\text{Efficiency} = \frac{\text{Rated power of module at STC}}{\text{Irradiance at STC} \times \text{Area of module}}$$

$$\text{Efficiency} = \frac{340}{1000 \times (1.960 \times 0.990)} = 17.52\%$$


Electrical Characteristics

MODELS	Pmax (W)	Vmp (V)	Imp (A)	Isc (A)	Voc (V)	Module Eff. (%)
WS-300	300	37.05	8.10	8.65	46.10	15.46
WS-305	305	37.20	8.20	8.80	46.20	15.72
WS-310	310	37.35	8.30	8.90	46.30	15.98
WS-315	315	37.50	8.40	9.00	46.40	16.23
WS-320	320	37.65	8.50	9.15	46.50	16.49
WS-325	325	37.80	8.60	9.20	46.60	16.75
WS-330	330	37.95	8.70	9.25	46.70	17.01
WS-335	335	38.10	8.80	9.30	46.80	17.26
WS-340	340	38.25	8.90	9.35	46.90	17.52
WS-345	345	38.35	8.95	9.40	47.00	17.78
WS-350	350	38.90	9.00	9.45	47.10	18.04

Design Specifications

Mechanical Characteristics

Length × Width × Thickness (L × W × T) - mm	1960 × 990 × 40

Figure 1 Sample PV module datasheet

Now let us consider two scenarios and see the effect of efficiency under these scenarios.

» Scenario 1: 10 kWp system with WS-330 (efficiency 17.01%) and 10 kWp system with WS-345 (efficiency 17.78%) model

Under this scenario, we have an option to select from either 17.01% or 17.78% efficient module. Since the installed capacity of the system is fixed, that is, 10 kWp, it does not make any difference whether one selects WS-330 or WS-345. Energy output will remain same in both the cases.

» Scenario 2: 20 number of WS-330 (efficiency 17.01%) and 20 number of WS-345 (efficiency 17.78%) model modules

In this scenario, as the number of modules is fixed, the energy generated from 20 number of WS-345 modules will be more than the energy generated from 20 number of WS-330 modules. The reason for the higher energy is the higher installed capacity of 20 number of WS-345 modules as compared to installed capacity of 20 number of WS-330 modules.

Thus, a module with greater efficiency will not be beneficial if the installed capacity of the project is fixed. However, a more efficient module will be beneficial to meet the higher energy and higher installed capacity in case

roof space is a constraint. Hence, one should select a higher efficiency solar PV module when there is a space constraint to meet the expected solar PV installed capacity.

Temperature Coefficient of Power

Temperature coefficient of power is mentioned on the module datasheet. This is a very important parameter one should consider while selecting a PV module between different manufacturers.

We know that temperature has a negative impact on the performance of PV modules, that is, as the cell temperature increases, the power of the module decreases. This decrease is indicated as the temperature coefficient of power on the module datasheets. A few examples taken from various module datasheets are shown in Figures 2 and 3.

It can be seen from Figures 2 and 3 that the sample Module 1 has a temperature coefficient of power equal to 0.41%/°C, while the sample Module 2 has 0.39%/°C. This implies that at higher temperatures, Module 1 will have more power losses as compared to Module 2. Hence, a module with lower temperature coefficient of power should be selected if the project is designed for higher temperature regions.

Cell Temperature Coefficients	
Open circuit voltage	- 0.32 % / °C
Short circuit current	+ 0.049 % / °C
Nominal power	- 0.41 % / °C

Figure 2 Temperature coefficient of power for sample Module 1

Temperature Coefficients And Operating Conditions

Temperature coefficient of Current α (%/°C)	0.0051
Temperature coefficient of Voltage β (%/°C)	-0.2775
Temperature coefficient of Power γ (%/°C)	-0.3859
NOCT (°C)	46 ± 2
Operating Temperature Range (°C)	-40 to 85
Maximum System Voltage (IEC& UL)	1500VDC

Figure 3 Temperature coefficient of power for sample Module 2

Nominal Operating Cell Temperature Values of the Module

Every manufacturer provides NOCT (nominal operating cell temperature) values of the solar PV module on the

technical datasheet. NOCT values define the expected cell temperature at different ambient temperatures.

As can be seen from Figures 4 and 5, Module 1 has a NOCT value of 47°C and Module 2 has a NOCT value of 48°C. Let us use these values to estimate the maximum cell temperature for both the modules, considering the maximum ambient temperature of 45°C.

The highest expected cell temperature can be calculated by the following modified formula:

$T_{\text{cell maximum}} = T_{\text{ambient maximum}} + \text{NOCT} - 20$

For Module 1:

$T_{\text{cell maximum}} = 45 + 47 - 20 = 72°\text{C}$

For Module 2:

$T_{\text{cell maximum}} = 45 + 48 - 20 = 73°\text{C}$

From the above calculations, it can be seen that at the same ambient temperature, the cell temperature of Module 1 is lower than the cell temperature of Module 2. Hence, there will be more power losses in Module 2 compared to Module 1, as we know that the higher the cell temperatures, the higher will be the power loss. Hence, a module with the lowest NOCT is always preferable.

Power Tolerance of the Module

In the market, two types of power tolerance modules are available—positive tolerance and negative tolerance. Negative power tolerance means that the power rating of the module can be less than the peak rating mentioned in the datasheet. For example, a 330 Wp (±5% tolerance) means that the module rating can be anywhere between 313.5 Wp and 346.5 Wp. So, there is always an ambiguity whether one will get higher rating module or lower rating module. On the other hand, a 300 Wp (0, +5% tolerance) means that the module rating can be anywhere between 330 Wp and 346.5 Wp. Hence, in case of positive tolerance modules, there is no ambiguity that one will get lower power rating module. Therefore, positive power tolerance module should be preferred over negative power tolerance module.

In this article, a few major parameters are discussed; however, there are many other parameters that should also be considered while selecting a solar PV module. These parameters are given in the following table.

Parameter	Choice for best module
Price	Competitive
Availability	Commercially available
Fill factor	Higher
NOCT	Lower
Temperature coefficient of power	Lower
Efficiency	Higher (if space is a constraint)
Power tolerance	Positive
Number of cell busbars	Higher
Number of bypass diodes	Higher
PID	PID free

Selection of solar PV module should not be done only on the basis of cost price. Consideration of other factors is also very important. EF

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OPERATING CONDITIONS

Maximum System Voltage	1000V/1500V DC(IEC)
Operating Temperature	-40°C~+85°C
Maximum Series Fuse	20A
Maximum Static Load,Front	5400Pa
Maximum Static Load,Back	2400Pa
NOCT	45±2°C

Figure 4 NOCT value for the sample Module 1

Temperature Coefficients And Operating Conditions

Temperature coefficient of Current α (%/°C)	0.0051
Temperature coefficient of Voltage β (%/°C)	-0.2775
Temperature coefficient of Power γ (%/°C)	-0.3859
NOCT (°C)	46 ± 2
Operating Temperature Range (°C)	-40 to 85
Maximum System Voltage (IEC& UL)	1500VDC

Figure 5 NOCT value for the sample Module 2

MLINDA RURAL ELECTRIFICATION PROJECT

Access to reliable and affordable energy is universally acknowledged as a key requirement for economic development; however, technical and economical factors have traditionally limited the access of rural consumers to energy sources. With its ability to provide decentralized and modular power, solar power has the potential to change this paradigm. In this article, **Urvi Nitish Naik** discusses Mlinda's efforts and initiatives in providing clean and reliable energy to support rural development through their evolving models of small-scale grids.

Background and Context

Mlinda Foundation was created in 2005 as a result of passion for wildlife conservation and a deep concern about the adverse impact of economic growth on the environment. Mlinda tackles the root causes of climate change with targeted interventions, which are viable, scalable, and open-sourced.

The front line of Mlinda's work is India, which is a fast-growing economy with the dichotomous status of being one of the biggest contributors to GHG emissions in the world, while simultaneously having among the lowest per capita emissions. Mlinda's work aims to contribute to India's economic growth, while ensuring that GHG emissions are reduced by researching, developing, investing, and sharing improved modes of production and consumption.

Mlinda started work in the renewable energy sector and has been active in the field since 2013. Work started first in West Bengal and has since slowly expanded to Jharkhand. Between 2013 and 2015, 310 pico-grid systems were installed, with each system having a capacity between 220 Wp and 8 kWp and being shared by 8–10 households. By the end of 2015, 90 kW was installed, powering 1900 households, 3 marketplaces, 90 shops, 1 school, and 1 hotel.

Although this model brought solar energy to households through very small, jointly owned pico-grids linking up to 10 households, it had its limitations. The pico-grids did improve the standard of living to some extent; however, they did not meet the aspirational needs of the communities for powering productive electric devices during the day and were limited to lighting and mobile phone charging at night.

Rural Electrification Project

In order to meet the aspirations of local communities for productive utilization of energy, Mlinda evolved its model to village-wide solar powered mini grids in 2016. Villages in Gumla district of Jharkhand were chosen for the project as they were amongst the poorest in India in terms of energy security. The overarching aim of the project has been to bring these villages on a low carbon based development path.

Our model for mini grid installation and support to the community is anchored in close ties with villagers and deep understanding of their energy needs. Mlinda designs, installs, and operates solar-powered mini grids in the villages. It supports the community to transition from kerosene and diesel to renewable energy and improve livelihood and income. Each mini grid is on average 23 kWp in size and provides both single phase and three phase, 24x7 reliable and good quality power for domestic, productive, and commercial needs. Energy storage is through lead acid batteries. A diesel genset has been provided as a backup. The connected households are provided with smart prepaid meters, which add transparency to the system. The inverter systems are also incorporated with a remote monitoring system that facilitates in overseeing the grid performance and taking corrective measures in terms of repair and maintenance. A high level of lightning protection system has been incorporated in the grid, which includes sophisticated earthing matrix, electrodes, air terminals, lightning arrestors, and surge protection devices on both AC and DC sides. Till date, 40 mini grids have been set up, powering

5973 households and 1090 productive and commercial loads in Gumla district of Jharkhand.

The consumers pay an upfront connection fee and then pay for energy usage through prepaid meters. An engineer and a local operator stay in the village and work with the communities, individual entrepreneurs, women's self-help groups, and farmer groups to convert diesel powered devices to electric powered ones. These close ties ensure that relations of trust are built and maintained with the community and that quality service is provided. Local operators are also trained in repair and maintenance of the mini grids.

Productive uses of clean energy have been recognized as a core element for the financial sustainability of the mini grid models. At the same time, they enhance the social and economic impacts of the mini grids. As the main aim of our rural electrification model is to bring about integrated rural development, Mlinda grows demand responsibly to ensure that increased utilization leads to improved incomes in the following ways:

» We work towards improving the agricultural infrastructure available to farmers in these villages by replacing inefficient diesel-based irrigation pumps, rice hullers, and wheat mills with efficient electric ones that would make farming and agri-processing more viable and increase profit margins for the farmers.
» We facilitate the creation of micro enterprises, such as wheat and corn mills, rice hulling businesses, and spice grinding units, with a focus on adding value to the locally grown agri produce.
» An end-to-end business based on mustard oil and pulverized corn has been set up in 10 villages till date. A market has been created in Gumla and the surrounding areas for approximately 12 tons per month of edible mustard oil and 30 tons per month of pulverized corn for the cattle feed industry. This activity has also created demand for 50 tons of mustard seed per month and 32 tons of corn in the project and surrounding villages. Farmers are encouraged to grow mustard and corn and their produce is procured in the villages at market prices.
» Activities involving non-farm loads, such as poultry coops, cold storage, metal fabrication units, air compressors, freezers, shops, electric vehicles, and sewing machines, are incubated in order to make the economy resilient to seasonality of agricultural businesses.
» Institutional loads such as health centres, schools, banks, and post offices have also taken up connection to the mini grids. In addition, we are

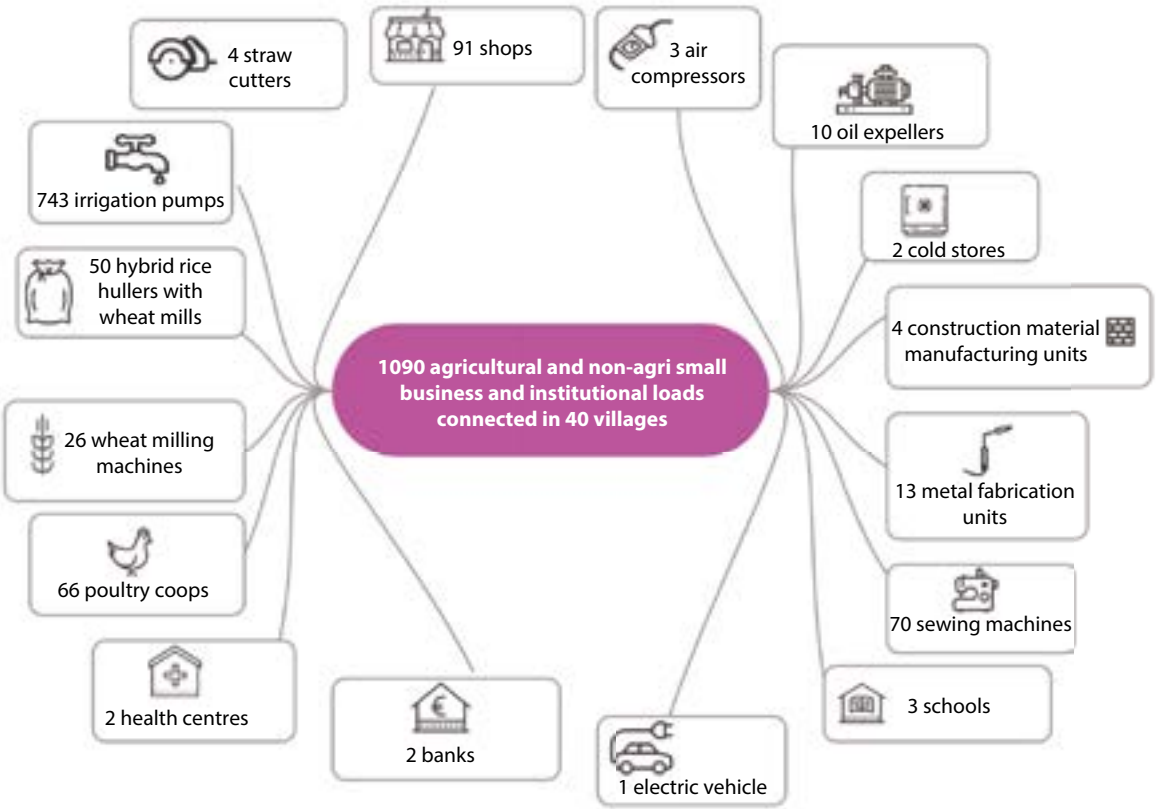

Figure 1 Productive load profile

working to set up training centres to provide job linked skill development to the local youth.

» Efforts are also being made to promote energy efficient domestic appliances, such as refrigerators, television sets, grinders, fans, freezers, induction plates, and washing machines.

Project Outcomes

The project has been monitored on a regular basis by our operations team based out of Gumla in terms of grid management, increase in grid utilization, new connections, revenues, repair and maintenance functions, and so on. The impact of the project is being evaluated by an independent monitoring and learning organization entity. On the basis of the evaluation study and the recommendations, strategies and corrective measures are developed.

Our main outcomes of interest are:

» Reduction in GHG emissions
» Improvements in household income
» Energy efficiency and economic growth (i.e., low carbon development)
» Increasing the profits of micro enterprises

Figure 2 shows the results of the rapid assessment study undertaken in February 2019.

Scaling and Replication

Mlinda is currently preparing to scale and replicate its model to 125 villages in other countries, including Nepal, Myanmar, Nigeria, and Ethiopia. A significant headway has been made

Figure 3 Mlinda mini grid in Narotoli village. Grid capacity 23.4 kWp

Figure 4 Sewing machine run on mini grid electricity by a woman entrepreneur in Basua village. Such swarm loads promote a gender balance in entrepreneurship

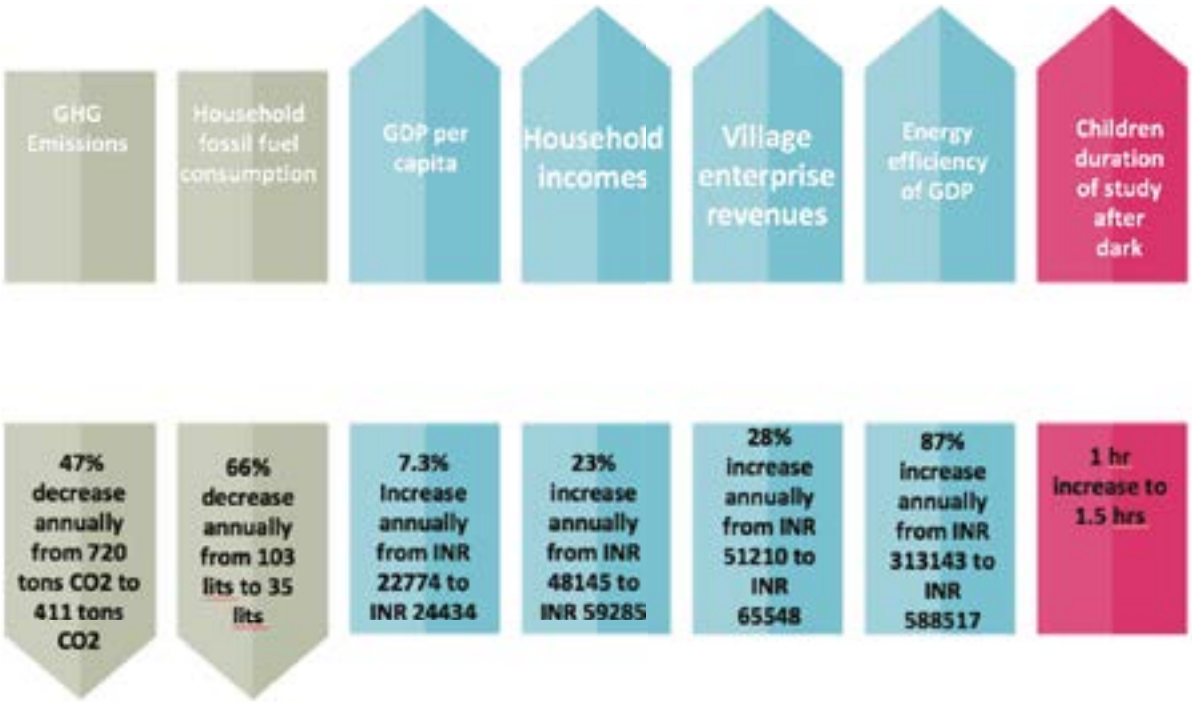

Figure 2 Assessment study of Mlinda's activities

Figure 5 An entrepreneur using a metal cutter that runs on Mlinda mini grids. There has been an increase in non-agri enterprises like metal fabrication units

Figure 6 A couple runs their rice hulling and wheat milling enterprise using three phase electricity provided by Mlinda mini grids

Figure 7 An increase in ownership and usage of domestic appliances is seen as a result of reliable energy provided by Mlinda mini grids

Figure 8 Reliable access to good quality electricity through Mlinda mini grids has led to an increase in time spent by children in their studies after dark by one hour

Figure 9 The end-to-end micro enterprise based on edible mustard oil that functions on three phase electricity is currently present in 10 villages

Figure 10 Mlinda powered irrigation pumps carry water from rivers, canals, check dams to fields that are over a kilometre away

in this regard and initial work with partner organizations has begun. We are working on three aspects of the model, namely, technological innovation, a more diverse and generic set of micro enterprises, and organizational development. We are also working to produce documentation of our best practices, lessons learned, training modules, and infrastructure in order to train potential replication partners. EF

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TRANSITIONING TOWARDS CLEAN ENERGY

Dramatic steps have been taken to reduce emissions and transition to cleaner sources of energy. Apart from efforts for steep reduction in climate change consistent with the Paris Agreement, it is equally import to reduce air pollution and provide universal electricity access to people. **David Turk**, IEA, in conversation with *TCA Avni* for *Energy Future* talks about challenges and progress to meeting clean energy transition goals.

Could you tell us a little about IEA's 'India 2020: Energy Policy Review'?
We felt that it was a particular privilege to be asked by the Indian government to do this kind of in-depth policy review. We were very impressed by the cooperation of the Indian government across a variety of ministries, NITI Aayog and other key stakeholders, including TERI. We felt very good about the bilateral relationship between IEA and India, and it was a terrific opportunity to do this in-depth review. It provided an opportunity to really explore some of the terrific progress that has been made in India over the last several years and also use our analysis to highlight some of the continuing challenges that need to be focused.

In the review, the IEA mentions that despite making progress on reducing emissions intensity, transitioning towards low carbon electricity has remained challenging. Could you talk a little about what do you see as the way forward?
To put this in a bit of a broader context, there are varying levels of progress made by different governments around the world, and there are continuing opportunities for even more progress for every country, whether you talk about electricity or clean energy transitions more generally.

India – as every other country – has its own challenges and opportunities. In the context of India, I think the progress has been quite impressive – certainly some of the progress and investments which have taken place in renewables, recently on solar, and also in other areas (such as the air pollution standard setting and other measures along those lines). There are challenges that remain, which we try to lay out in concrete, actionable terms. We try to make sure that our analysis is actionable and that there are steps that can be undertaken and are pointed out in the analysis. Diversifying the power mix is important for every country, and there are opportunities to do that further in the Indian context, keeping in mind India's large and relatively young coal fleet. And it is not only about focusing on a wide range of renewables. We feel that natural gas can play a very helpful role as well. So diversification focuses on the supply side, but there is a very important energy efficiency component as well, and this is an area on whose opportunities the Indian government, TERI, and the Bureau of Energy Efficiency (under the leadership of Dr Ajay Mathur, before he was in TERI, and now under Mr [Abhay] Bakre) have certainly focused.

Another thing we have pointed out in our report is to have better planning of the power system – the transmission, the plants, and how all the systems work together. We've got some ongoing in-depth work not only with the national government and NITI Aayog, but also with state governments, trying to think through the power system optimization how all these components can be brought together and how variable renewables can be integrated as efficiently as possible to take advantage of those resources. So these are just a few of the areas where we feel that while there have been some challenges, there are also big opportunities to be had.

One of the major challenges facing the power sector has been of ensuring the financial health of the generation and distribution companies. How would you expect policy frameworks to address the balancing of access, affordability, and financial health?
This is again a challenge, certainly in the Indian context, and also for a variety of other governments. It is trying to get those market signals in the best way possible to provide those incentives for additional renewables and clean energy generation to come and additional energy access, whether done in a centralized grid manner or by using some of the decentralized opportunities that solar and batteries can provide. And I will say that getting effective regulation and incentive structures of the power system and power markets is frankly a challenge for all countries around the world. It is an area where we try to look a lot at the lessons learned from what happened in various countries that may be applicable, and a lot of people are interested to see what's happening in India and learning from those experiences as well, both for the positive and the challenging lessons learnt. India's circumstances in particular are further complicated by the current financial position of the distribution companies, and that's something that really needs to be looked at and focused on in a robust manner, while keeping the access, affordability, and energy security aspects in focus as well, making sure the lights stay on both for residential customers and for commercial and industrial customers.

As we've laid out in the in-depth review, the reform of tariff structures can be a helpful component in terms of getting the long-term functioning of incentives and market signals as well. The report carries detailed analysis and recommendations and is in a frame that is constructive, useful, and operational going forward. One thing we are particularly excited about is that our Executive Director has announced that *World Energy Outlook* (our flagship publication), which does a country focus every year, will cover India as the country focus for 2020. October of this year will have another step of this analysis, which will be building on the in-depth review, and we hope this will be very helpful in the Indian context. This is a big deal for us and is something that we very much look forward to working in partnerships with government agencies, organizations like TERI, and others over the next many months.

Cesses and subsidies are seen as attractive tools in framing policy, but they also have the effect of distorting markets. What do you believe is their use as tools in energy policies?
One thing I think that's useful to think about, and sometimes governments themselves can lose sight of this, is that

there really are a broad range of tools available for countries thinking about how to deal with energy systems – certainly taxation, energy subsidies, and other non-regulatory approaches can be quite powerful as well. It is complicated to get it all right and that the signals are appropriate. This is where we try to help avoid distortions in the market, figuring out how all these policies interact with each other and we are not getting cross-competition.

With regard to the Indian context, one of the things which came out, and we will focus on this further, is the need to further streamline and rationalize the subsidies, so that they are part of a plan that makes sense. There has been progress made by the government, and we point this out on petroleum products and some of the progress on that front. One of our recommendations was to bring natural gas into some of the schemes that have already been done. Creation of a goods and services tax is a good step to bring down overlapping taxes across India as well. So it is trying to get all these pieces in a synced up way not only for the power systems for today, but also for the power systems of the future.

It is a very dynamic time for power systems and, more generally, for India, with the economic growth and some of the opportunities going forward. It is trying to get in place these systems, subsidies, and non-regulatory approaches that will not only work for India now, but will hopefully also work for India in the future. It is good to not only keep an eye on the ball right now, but also to keep your eye on the ball for what's going to be needed in the future.

What is your view on the role of nuclear energy in decarbonization and energy transition?

We've done a lot of analysis on this over the years. We put out a report last year on this, in particular on nuclear energy's role, in terms of the historical role it has played in decarbonization and also prospectively. One of the particular insights was that in certain economies, such as the US, Japan and Europe, where there is a lot of existing nuclear capability, there is the question of lifetime extension of those plants.

Different countries are making different decisions about nuclear, and what we did in this analysis was point out that those lifetime extension decisions can, in many cases, be quite cost-effective to have sources of decarbonized energy going forward, especially since the infrastructure has already been built. Of course, there will need to be upgrades, and safety will always need to be taken into account, but if you start taking those plants offline, that is a lot of base load, carbon-free power that you wouldn't have and that would need to be picked up by a range of other efforts as well. So there is big deal on the decarbonization front when it comes to these decisions about the lifetime extensions.

There are also some really interesting opportunities and a lot of technologies and innovative development as well focused on a new generation of nuclear, the small modular reactors and other kinds of technologies that could be part of the solution going forward. Different governments make their decisions about whether nuclear is part of their mix going forward. It is one of those decisions that has political dimensions as well, with different resonances for different countries.

Our philosophy more generally at the IEA is that we are an 'all of energy technology' agency. We analyse different energy technologies out there. Again, it is for different countries to pick and choose what they are excited about. But certainly countries want to take dramatic steps on the clean energy transition for carbon reduction and air pollution reduction. If you start taking different technologies off the table, it makes it much more challenging to make the kind of dramatic progress that science tells us that we need to make on the decarbonization front.

I've read about some very interesting discussions on modular nuclear reactors and microreactors[1] in the US recently…

Well, it is an interesting area. Having worked in the US Government previously, there are a number of national labs focused on different technologies, and some really interesting developments being done. There are some private sector investors as well, Bill Gates, for example, is a prominent investor on the nuclear side, and some of the new generation nuclear pieces as well. So it is interesting to watch, and it is good to have as many tools in the toolbelt as possible for decarbonization, given the challenge that we need to overcome in very short order.

You mentioned that you had previously worked in the US Government. Could you tell us a little about your experience in the Department of Energy on managing the political economy aspects of power transitions? Are there similarities to those faced in India?

I worked in the US Government in a variety of capacities – in the executive branch and 8 years working in the Congress, the Senate, and the House of Representatives. I am a firm believer that in thinking about various policies, schemes, or other systems that might be employed whether at the national, state, or provincial government or local level, you need to think about the politics and the support for those efforts for a variety of key constituents that are there.

If you do not think about the political economy, realities, and landscape, you are not going to get very far. Even if you have a temporary majority and you can implement something, if it is not well thought through and does not have sustained support over a period of time, you can have swings in policy that you see in several governments around the world, in ways that don't provide the

[1] Details available at https://www.wired.com/story/the-next-nuclear-plants-will-be-small-svelte-and-safer/

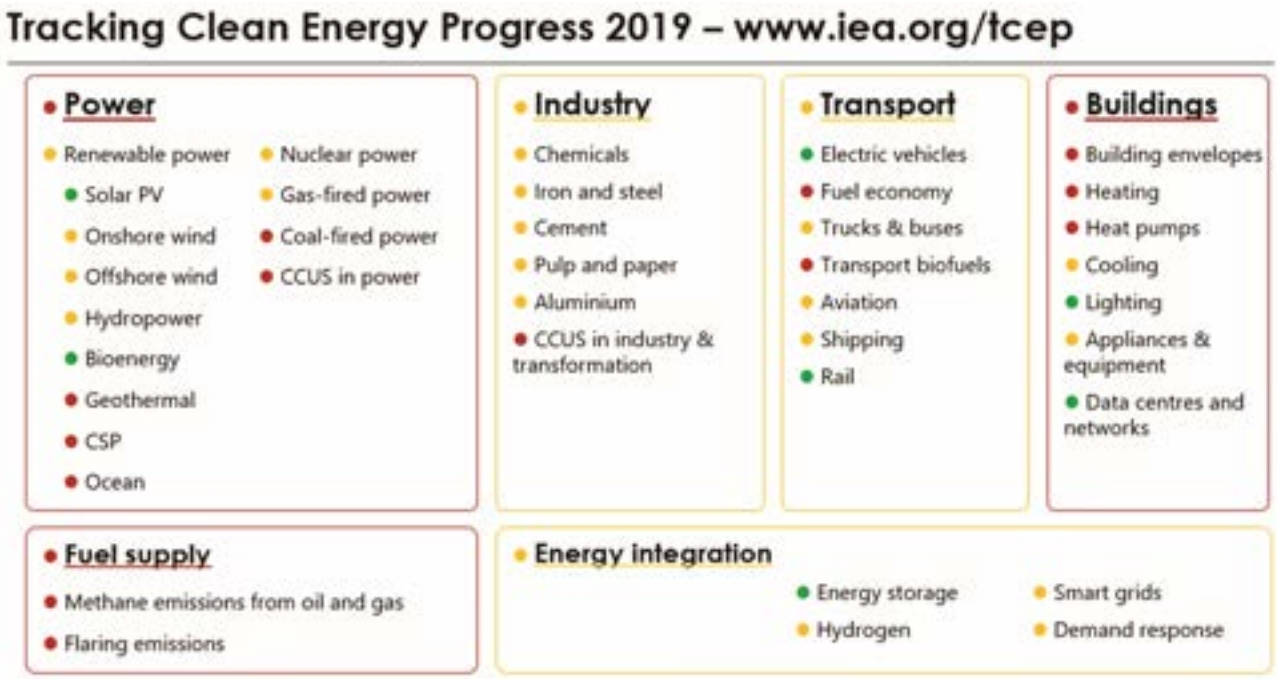
certainty that investors like, the kind of long-term signals that can be helpful in achieving long-term goals. So there is an art on making things happen in the real world.

From my vantage point, you have to have good, sound, rigorous analysis, as TERI and the IEA try to do; you need to learn lessons from other countries. Not only lessons from an economics or engineering perspective, but you need to also be very cognizant of the real-world, political landscape. When you are talking about energy transitions, make sure that you are thinking about how the different policy changes will impact different parts of society, jobs, livelihoods, and costs, especially those parts of society that are more vulnerable and don't have the ability to absorb costs or other implications of decisions. I think we all need to do sophisticated analysis that takes into account the political economy and political reality – different countries have different political systems.

There are some similarities between India and the US, both as democracies and in some of the federal systems; there are also some differences. But any government that wants to get things done needs to be very sophisticated in its technical analysis and takes into account the political realities and brings all of the society along, in what our Executive Director has called (on the energy transition front) the need for a Grand Coalition. You need a lot of different actors within society all working together. They are not going to agree on everything, but fundamentally, being part of the discussion and the process, coming up with different schemes and taking them forward so that you have sustainability in different efforts.

Can you also talk a little about what do you see as the role technology has to play in the energy landscape?

Technology has, from my vantage point, an incredibly important role and will be essential for India to achieve its energy and climate goals. Not only new technologies that might be developed in laboratories, universities, or the offices (or garages) of entrepreneurs, but also the continual performance improvement and price reduction efforts. So even for existing technologies, it is about continuing to reduce the price points so that the technologies are much more attractive. Certainly, solar is a case in point, where we have had dramatic reductions in the cost of solar PV over time. We see that as a key driver in terms of what we are seeing in India and in countries around the world with respect to that technology. Similarly, the reduction



in the cost of batteries , lithium ion in particular over the last several years, is allowing storage opportunities, especially in the hourly storage range, to become much more attractive in terms of the economy.

So while the reality of what technology is out there, sometimes there is a perception of where technology or price points are, which is not exactly where the reality is, and we can end up having a lag from investors, policymakers, or others. So what we try to do at the IEA is put out all the latest technology numbers, deployment numbers, and price points. We have this exercise we call our Tracking Clean Energy Progress (TCEP) Report, which we put out annually. It looks at 45 different sectors and technologies across the energy landscape to talk about what are the latest numbers and what are the latest investment decisions, so that perception will be accurate to the reality, and if you continue to drive those price points down and work on different schemes to do that, you are really going to make it that much easier to have a policy that can use that technology.

The IEA's TCEP report ranks technologies by how far they have come and many of them are still in the red. However, given that innovations can be unpredictable, how do you see the landscape evolving and what do you see as the role stakeholders can play in responding to changes going forward?

One of the things which is really important in this space is making sure that everyone has an accurate picture of where the technologies are, so that the perception can be where the reality really is, and governments or private sector players can base their decisions on where the price points are. That is why our Tracking Clean Energy Progress web portal is such a useful tool. What we try to do is provide not only the latest numbers, but also give some sense of whether the technology is doing its share to get us to what we call the sustainable development scenario, which is not only steep reductions in climate change consistent with the Paris Agreement, but also steep reductions in air pollution and providing universal electricity access to people as well, which are the kinds of issues governments around the world are trying to solve.

We look at each of these technologies and sectors – not only in power, but also industries, buildings, and transport – to see if a particular technology is doing enough, is cheap enough, and is being deployed widely enough to get us from the status quo scenario where we are currently headed into the future versus where we want to go to achieve our climate, air pollution, and energy access goals. And what we find when we do that and when we rank those technologies – mostly as a conversation starter, as opposed to the definitive word coming from the IEA – is that of the 45 technologies that we map, only 7 are green and on track to get us to the sustainable development scenario. Some of those are the obvious examples of where we've seen real price reductions and deployment – that solar PV is one of them is no surprise. But there are a lot of others that are yellow and a lot of others that are red, with yellow meaning that some progress is happening but more efforts are needed, and others that are red in those areas means they are not on track.

Given the complexity of energy systems around the world – there is complexity within electricity systems, in transport, building spaces, and industrial applications (including some sectors that are harder to decarbonize) – there is a whole class of technologies on which we are focusing more and more and which we have put in the energy integration basket. It includes digital tools, smart grids, and hydrogen, which could have versatile leveraging opportunities across the other range of technologies in a variety of other sectors, including sector coupling as well.

The first part is to get an accurate picture of what which technology is doing where, and as I said our approach at the IEA as an all energy technologies agency is examining all those technologies. It is tough to predict with any certainty. In fact, I think given the complexity of systems, we are going to have a whole multitude of decisions, solutions, and technologies working. Some may become bigger stars in that constellation of technologies which are successful – solar PV is certainly having a moment, where it is showing terrific progress not only in India but in a number of countries around the world, but even in the renewables side, offshore wind is a really interesting technology that offers some real possibilities, especially if those price points can be brought further down.

What we are doing more and more is examining not only where we are with those technologies, but also doing a very detailed technology mapping of where we see those big opportunities are going forward, including looking at those technologies and trying to point out the ones that could be the stars of the future and important for a variety of different sectors. We published an Innovation Gaps framework last year, which identifies key long-term technology challenges for research, development, and demonstration that need to be filled in order to meet long-term clean energy transition goals.[2] We also have a publication coming out this year, called the *Energy Technology Perspectives*, which will include this very rigorous and detailed technology mapping, looking at all the technologies out there and providing some thoughts from our end – where government might want to focus their investment in R&D, or where companies, investors, or entrepreneurs might find real opportunities.

[2] Details available at https://www.iea.org/reports/innovation-gaps#

Again to try to provide actionable information for a variety of actors, and there are a variety of actors, there is a very strong role for governments to do funding and there is a role for government–industry partnerships for some of these technologies. So there are a variety of solutions and modalities to try to get all these technologies, but the challenges on sustainability are so big that we need to have a variety of actors and solutions coming to the fore.

The IEA's TCEP report recognizes solar PV and electric vehicles as energy technologies which are 'on track' for reducing emissions. However, a 2017 World Bank report [The Growing Role of Minerals and Metals for a Low Carbon Future] estimates significant increases in mineral requirements should their deployment be in line with projections. Could you comment on this?

Yes, it is an issue which is getting more and more attention, and rightfully so, especially as you have greater needs for lithium, cobalt, and other rare earths or minerals to power or support the emergence or growth of these clean energy technologies, whether it is solar PV, lithium ion batteries, or a variety of other technologies. We've done a good bit of analysis and will have some more this year, including in our *World Energy Outlook* on this issue in particular. We are really trying to think about this issue and avoid any supply chain bottlenecks, disruptions, or price spikes that can disrupt the market and more generally try to figure out where are those supplies of these minerals around the world. There are deposits of these critical minerals in various places around the world.

A Canadian colleague pointed out to me recently that there is a town in Canada named Cobalt because there are huge cobalt deposits there. Now the market is such that sometimes these mines can get shut because the mining is not economic at a particular point of time, but there is a need for governments and others to think through how much we are going to need of these substances and initiate the investments in them now so that there can be a steady stream of these minerals, which are going to be so important in the clean energy revolution that is happening.

There is also a lot of opportunity in innovation here, certainly on the recycling side. A lot better job can be done on recycling some of these minerals so that they can be recycled back into the economy, making them more efficient, less energy intensive, and better for the environment. We can look for alternative technology solutions as well that may not need as much of a mineral or can use minerals that are cheaper or more readily abundant. This year's *World Energy Outlook* will do a deeper dive into some of the supply chain issues.

Thank you so much for your time. Finally, could you tell us a little about what was your experience at the WSDS?

I really enjoyed coming to India a few weeks ago, and I thought it was a terrific conference. I've been a big fan of TERI for many years and have known Ajay Mathur for many years as well, and I think what TERI is doing under his leadership is frankly phenomenally important not only in the Indian context, but also globally. I think the analysis that you all are doing has been terrific, whether it is the technology report looking at the iron and steel sector or the floating photovoltaics. I thought the meeting was terrific, bringing forward key actors not only in the Indian context, but some international experts as well, and the IEA felt very privileged to have received the invitation to participate.

We very much value the partnership with TERI in particular, and I think there are so many opportunities to do good in the energy world that we need to have key organizations working collaboratively and together. So the conference was a great opportunity to get a feel for what is going on, not only in TERI but in India as well. I find that the people who are working in TERI are incredibly talented, with energy and passion to make India better and the world better as well. EF

David Turk is Acting Deputy Executive Director, International Energy Agency.

RAPIDLY CHANGING ENERGY LANDSCAPE

Energy is an essential factor in the effort to achieve sustainable development. India has taken significant steps to enhance its energy security. It is investing in a variety of measures, such as increasing the capacity of renewable energy in the energy mix, increasing efficiency of energy utilization, and ensuring universal access to electricity and clean cooking fuels. **Rajnath Ram**, NITI Aayog, in conversation with *TCA Avni* for *Energy Future* talks about the role technology will play in energy transitions, the challenges for the renewable energy sector, and the role of NITI Aayog in the changing energy landscape.

India has been taking significant steps to achieve sustainable energy development and has been investing in a variety of measures, from increasing capacity of renewable energy in the energy mix to increasing efficiency of energy utilization, while simultaneously working towards ensuring universal access to electricity and clean cooking fuels. However, the NITI Aayog has also stated that coal will remain a dominant source of energy for the foreseeable future. Could you tell us about how do you see the energy portfolio evolving?

As of now, in the overall energy basket, the share of coal is about 47%, oil about 32%, gas about 6.5%, and balance is renewable and clean energy. NITI Aayog carried out modelling exercises with India Energy Security Scenario (IESS), 2047, and under different build-up scenarios, it has been observed that coal will remain a major occupier of the overall energy basket, with a range of 37–40%. Oil will reduce from 32% to 22–23%. The share of gas will go up significantly as we are investing a huge sum of money in building up infrastructure and creating pipelines, shifting some of the heavy transportation system to LNG, and expanding the city gas distribution network. In the Northeast region, a lot of pipeline infrastructure is coming up. All this will increase the gas share in the overall economy from around 6% to 13% by 2030 as per our estimates. Renewables will increase. They are currently around 2–3% and will go to around 10% of the overall energy basket. Biomass will be around 12–13% because we are now focusing on CBG (compressed biogas) and bioethanol to address the issue of stubble burning.

Could you also talk a little about what do you see specifically as the role technology will play in energy transitions?

Technology will definitely have a significant role in the energy sector. In coal, for example, we are pushing more towards ultra-critical and supercritical technology. Cost will increase, but that is the way coal should be used in future. Coal gasification is also being pursued by the government in a big way. Technology-oriented efficiency solutions are also being taken up – increasing the efficiency of solar cells in the solar sector, reducing the losses in the energy system, promoting storage technologies so that renewable-based firm power becomes a reality, making the system more IT based, and bringing new technology into the sector.

The coal sector has now opened up for more investment, and even FDI (foreign direct investment) has been permitted to 100% for commercial mining. This will bring new technology and improve our efficiency, allowing our coal production rate to go up. So, technology has definitely a role to play in improving the sector and its efficiency in its overall value chain.

Given the diverse character of renewables, the increasing share of renewables in the energy portfolio will pose a number of challenges on the electricity grid. In this connection, could you please talk a little about the technical concerns in dealing with the integration of renewables to the grid?

There are challenges with the renewable sector. First, they are variable – you get solar power only in the day when the sun

is shining. Likewise wind power is highly dependent on the wind blowing. This poses challenges for the grid although it is characterized as a priority sector for dispatch. While the government has come out with RPO obligations, states have to meet their obligations. After meeting obligation, what will they do with that extra power which may be generated beyond this RPO? That power also needs to be incentivized, and some kind of mechanism needs to be developed to create storage to ensure that this energy is not lost.

NITI Aayog has prepared the Draft Advance Chemistry Cell Manufacturing Policy, which is under finalization by the government, to incentivize battery manufacturing so that capacity is created in the country. We are also looking at grid level storage solutions, storage at places where pumped hydro is suitable and integrating that with solar plants, and at the possibility of integrating both wind and solar to take care of the balancing aspect.

On the other side, at the regional level and at the state load dispatch centre, the forecasting has to be perfect so that there are no problems in feeding renewables into the grid. So, forecasting is another aspect where the government has been coming into intensively and is setting regulations and guidelines. Some minimum deviations have been put forward such that deviations in forecasting should not be more than 15% and this can be further narrowed down once the learning is achieved by the sector. Here, I think developers and investors are also facing some problems because they don't know how accurate their forecast would be, and if there are any deviations beyond the prescribed limit, they would have to pay a penalty. Instead of the current method of individual forecast, where individual developers make their forecasts and give them back to SLDCs,[1] if there will be aggregated level players who can take all the forecasts and then inform the dispatch centre about the kind of renewable coming in during a specified period of time, that would help integrate renewables to a great extent.

At the same time, the Central Electricity Authority (CEA) is also working on the power system's flexibility, where during the peak demand, whether it is in the evening, morning, or during the day (as happens when there are very sunny days), the thermal power can be also pumped into the system to take care of the balancing act. So, these are the technical issues which the POSOCO, CEA, and CERC need to work on closely.

[1] State Load Dispatch Centers

While accurate forecasting would allow us to better predict generation from renewable sources, power output from coal power plants is limited in its ability to flexibly ramp up and ramp down. Given this, how would these power sources be managed?

Thermal power plants will help when there is a huge demand and supply gap. Suppose in the evening when you don't have solar, the demand goes up. You will have an idea that during this time your demand is going to pick up. In that case, you can take thermal power generators into confidence and they will be assured of uptake of the power that they would supply during that period of time.

Again, it is a balancing act that needs to be played by POSOCO, with CEA providing technical assistance. In the case of renewables, what we can address are the issues of curtailment, the requirement of ancillary services, or where the power is infirm. In that particular point of time, we can use some storage technology to store power.

Could you also talk about how would the current financial stress in the sector impact the evolving energy mix?

That is a very critical point. In the entire value chain of the power sector, if the DISCOMs are not revived, it will be very difficult to see how any such changes can happen. We are facing problems of payment delays. Some of the DISCOMs are not financially well off enough to pay the developers, and the payments have been delayed for quite a long time, as much as 16–18 months. So, the financial restructuring of DISCOMs is highly necessary, because they are the key players in the entire value chain. In the case of renewable energy, for example, if SECI or the states come for tendering solar power, they have to ultimately enter into long-term PPAs with the DISCOMs. Despite their contractual obligations, DISCOMs are not paying the developers, as they are themselves not financially sound.

So their losses need to be reduced and that is the number one priority. Then, DISCOMs have to go for either PPP mode or privatized mode or franchise model. We have to adopt the Odisha model, as it is a good example. NITI Aayog has been pushing for reforms in the distribution because both UDAY 1 and UDAY 2 have failed. So the question becomes: what next?

We should definitely go for restructuring the DISCOMs because they are the key. If DISCOMS are not reformed, the sectors will have the same problem.

Haven't Odisha's DISCOMs been restructured multiple times?
This has been an evolving process. In fact, long back the Ministry of Power had come out with the Restructured Accelerated Power Development and Reforms Programme (R-APDRP), where the government provided funding to DISCOMs for implementing measures to lower AT&C losses. The government has been taking up such kinds of initiatives. However, if the billing and collection efficiencies are not good, then that is a lacuna. In fact, in this budget you might have heard that the Ministry of Power has come out with a plan for implementing prepaid and net metering by 2022.

There have been concerns about the billing and collection efficiencies with prepaid metering as well. News reports in 2019 had highlighted concerns that consumers might use illegal connections or bypass their meters.[2] How would these challenges be addressed?
These are infrastructure issues. The government is also coming out with underground cabling systems, which will resolve these challenges.

As traditional models of generation, transmission, and consumption change, what do you see as the role of institutions? Is the current governance framework adequate to address challenges which these will create?
Traditional institutions have to be strengthened. We are coming out with several schemes. Recently, the rooftop scheme has also been modified, and now the DISCOMs will act as an aggregator and all the rooftop solar projects will be through the DISCOMs. There are schemes like the decentralized solar pumps and generation of solar power from agricultural lands to either feed into the grid or be consumed locally. So this is just a starting process. There will need to be a lot of investment to establish infrastructure. Net metering policies will also come into play if rooftop generators want to sell to the DISCOMs. If net metering is not proper, then it will not serve the purpose. And the same will apply for the KUSUM scheme, where you have solar pumps or you have generation of power from the farms, where the power is to be sold to DISCOMs.

So, what is required is a lot of investment in infrastructure and more towards the IT-based applications. Where the manual interventions can be restricted somehow, the system can be

[2] Details available at https://www.hindustantimes.com/lucknow/1-3-prepaid-power-consumers-have-not-recharged-meter-for-months/story-5b057U25lehtye4xcuVn4M.html

strengthened. That is the prime focus of the government. NITI Aayog is also discussing block chain and artificial intelligence technologies. These are the new applications of IT through which a lot of things can be improved.

So how do you see the policy landscape evolving?

Well, we are working with the ministries that will be implementing this. The ideation has taken place here, and we are taking the ministries on board. If they agree for the change for implementation of new kinds of IT-based technologies, we can take it forward. We set up various groups here to discuss with relevant stakeholders – that is how policies evolve. This is just the starting point. I think a lot of changes will happen in the coming years. Investments are coming up and manual interventions are being minimized.

You may recall that long back the government had come out with a feeder separation programme, but that has still not happened. Many of the states have not complied with it. So, this is the problem. In the policy space, we are constantly in touch with the relevant ministries – the Ministry of Power, the Ministry of New and Renewable Energy – and the system will evolve gradually. It is happening.

Could you talk a little about the recent review of energy policies which the IEA had done with NITI Aayog recently?

NITI Aayog has been working and collaborating with IEA on certain policy issues and in areas where we feel we need their support in terms of technical know-how for their experience on interventions and global best practices. India is an associate member of the IEA. While the IEA does in-depth reviews of the member countries, this is the first time that they have done this review for India.

A group of experts from IEA came here and we organized meetings with all the relevant stakeholders and ministries, including the Ministry of Environment, Forest and Climate Change, the Ministry of Power, the Ministry of Coal, the Ministry of Petroleum, the Ministry of New and Renewable Energy, and their associated institutions. We had meetings with BEE and PCRA, as well as with knowledge partners, where institutions like TERI were consulted. The idea was to independently assess the distinct policies of India. So, all the five sectors (excluding atomic energy) were assessed, and they have come out with their recommendations. There were several rounds of consultations with the ministries. We provided some feedback, they had some comments, we justified our stand or provided relevant information, and so on. Based on all these inputs and feedback, they came out with this report. This was an independent assessment to understand whether the policies are right or wrong and if there is any need for change in the policies.

And they have come out with some very good results on the government initiatives on rural electrification and clean cooking access. However, a lot of improvement is still required in some areas, and for these they have put out their suggestions.

You mentioned that atomic energy was not covered in this?

Nuclear power has not seen much growth. There are issues around the supply of fuel and the nature of agreements with different governments. It also has a separate regulatory commission which looks after the various issues pertaining to nuclear fuel, safety norms, standards, and so on. So, we leave it to them to independently assess, since it is also more strategic in nature.

Thank you for taking the time to have this discussion. To conclude, could you talk a little about what you see as the role NITI Aayog will play in the changing energy landscape?

NITI Aayog's role is important where there are any cross-sector issues or policy challenges where interventions are required. Ministries can become limited by their boundaries and may find it hard to talk to each other. They have to take independent decisions, but don't always have mechanisms to evaluate what will be the effect of their decisions on other sectors. That is where the role of NITI Aayog becomes prominent. Take energy, for example, we don't have a single ministry. We separate ministries for power, coal, petroleum, and renewable energy, but energy encompasses all of them, as well as the supply side and demand side issues. So this is where we play an important role.

To give an example, the erstwhile Planning Commission had drafted the Integrated Energy Policy, which was adopted in 2006, and we are now finalizing the new Energy Policy. The inter-ministerial consultation is over almost, and we will be submitting the draft report to the Cabinet very soon to take up further. EF

Rajnath Ram is Adviser (Energy) at NITI Aayog

CURRENT R&D RENEWABLE

Investigation on the Structural Behavior of Superconducting Magnetic Energy Storage (SMES) Devices

Journal of Energy Storage, Volume 28, April 2020, 101212
Gaurav Vyas and Raja Sekhar Dondapati

In the present work, hybrid composite material is proposed to be used as a mandrel in solenoid type SMES. In this work, different composite samples such as double layered carbon, single and double layered Kevlar, and hybrid composite made of carbon and Kevlar are treated in liquid nitrogen (LN_2) and tested for mechanical behavior. An experimental investigation is carried out to investigate the mechanical behavior of composite samples to be compatible for SMES applications. From the investigation, it is observed that the strength of composites increased when treated in LN_2. Further, cryo-treated double layered carbon and Kevlar are found to be desirable for SMES applications. EF

Economic Evaluation of Solar-Driven Thermochemical Conversion of Empty Cotton Ball Biomass to Syngas and Potassic Fertilizer

Energy Conversion and Management, Volume 209, 1 April 2020, 112631
Himanshu Patel, Fabian Müller, Pratyush Maiti, and Subarna Maiti

The study considered four different plant capacities, 5 MW_{Syn}, 10 MW_{Syn}, 15 MW_{Syn}, and 20 MW_{Syn}, in terms of syngas power and two different methods for synthesis of potassic fertilizer: (1) fractional crystallization and (2) selective precipitation. The key process parameters, such as energy efficiencies and mass flow rates, based on experimental results were studied in-depth with a sensitivity analysis. It was found that the heliostat field was the most expensive component of the plant, while the synthesis of potassic fertilizer was economically feasible for all the tested plant capacities. The selective precipitation was found to be gainful than the fractional crystallization. The levelized cost for the liquid fuel via Fischer–Tropsch synthesis was estimated at 0.90 USD L^{-1} for the 20 MW_{Syn} plant. The trends indicate that the levelized cost for the liquid fuel could further be reduced by increasing the plant capacity. The solar steam gasification of empty cotton boll biomass has the potential to mitigate the CO_2 emissions by 86% compared to the conventional fossil fuels. The potassic fertilizer recovered from the residual ash can cover 31% of the annual potassic fertilizer requirement of the cotton fields that originally supplied the feedstock. EF

Performance Investigation of Nanocomposite Based Solar Water Heater

Energy, Volume 198, 1 May 2020, 117295
Swaroop Kumar Mandal, Samarjeet Kumar, Purushottam Kumar Singh, Santosh Kumar Mishra, and D.K. Singh

In this research, the effects of using phase change material (PCM) doped CuO nanocomposite as the storage medium on the performance of a solar water heater have been experimentally investigated. By varying the wt% of nano CuO, the gap between the absorber plate and the glazing, the effect on the outlet temperature is examined. The maximum temperature of outlet water has been recorded as 60.1 °C using nano CuO-PCM composite over base PCM under similar conditions. As the mass fraction per wt% of nano CuO increases in PCM, the thermal conductivity, heat flow, and thermal efficiency increase. Better results have been found to be achieved by using 1.00 wt% CuO-PCM nanocomposite. The thermal conductivity of pure wax is found to be about 0.21 W/mK, while 1.00 wt% PCM-CuO nanocomposite has thermal conductivity of 0.36 W/mK. It is noticed that there is an appreciable increment in the efficiency of solar water heater with the variation of three observed parameters, namely, time, temperature, and solar intensity. EF

Analysis of Degradation in Residential Battery Energy Storage Systems for Rate-Based Use-Cases

Applied Energy, Volume 264, 15 April 2020, 114632
Partha Pratim Mishra, Aadil Latif, Michael Emmanuel, Ying Shi, Killian McKenna, Kandler Smith, and Adarsh Nagarajan

This article examines the impact of residential battery energy storage (BES) systems' operational modes on the life of the battery under several climatic conditions and battery chemistries. The sharp increase in residential BES installations has been a result of decreasing costs of batteries, increase in rate structure motivated applications such as solar self-consumption and time-of-use energy management, and customers purchasing these systems for backup power. Although these different modes of operations provide a combination of increased bill savings, reliability of supply, and energy sustainability to the customer, their operational characteristics vary significantly between use-cases. The authors analyse the operation of residential BES systems under different rate-based use-cases, for different battery chemistries and cell designs, and under different environmental conditions. This is conducted by simulating the control of BES operations using rate-based cycling algorithms and analysing the prognosis of multiple battery lifetime models that consider complex nonlinear dependencies of operational stress factors, such as state-of-charge, depth-of-discharge, and temperature on degradation. Significant variation in battery life are observed owing to the differences in characteristics of the uses-cases coupled with environmental conditions and battery chemistries. EF

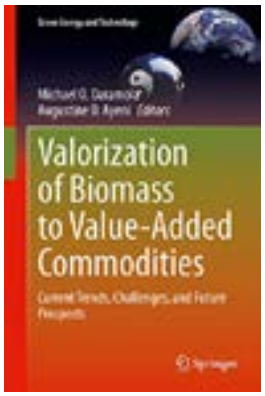
Method to Improve Performance of Building Integrated Photovoltaic Thermal System Having Optimum Tilt and Facing Directions

Applied Energy, Volume 266, 15 May 2020, 114881
Somil Yadav, S K Panda, and Caroline Hachem-Vermette

This paper aims at investigating the influence of water flow over the BIPV (building integrated photovoltaic) roof of a two-storied single-family house on the performance of the proposed optimally tilted semi-transparent BIPV thermal system having different facing directions. The periodic nature of insolation, ambient air temperature, BIPV cell temperature, slab temperature, water flow temperature, and room temperature have been considered while solving energy equilibrium differential equations. The insolation values used in the energy equilibrium equations are computed by employing periodic HDKR (Hay, Davies, Klucher and Reindl) model, which is based on anisotropic sky concept. Results indicate that the average BIPV cell temperature is reduced annually by approximately 10 °C and efficiency is enhanced by 6% when a water flow rate of 1.1 kg s^{-1} is provided over the BIPV roof. It is also observed that on the most critical day of the year, the temperature of outlet water is 11.5 °C higher than that of the inlet water temperature, which resulted in 4 kW extraction of exergy. EF

Valorization of Biomass to Value-Added Commodities: Current Trends, Challenges, and Future Prospects (Green Energy and Technology)

This book presents the most up-to-date technologies for the transformation of biomass into valuable fuels, chemicals, materials, and products. It provides comprehensive coverage of the characterization and fractionation of various types of biomass and details the many challenges that are currently encountered during this process. Divided into two sections, this book discusses timely topics such as the characterization of biomass feedstock, pretreatment and fractionation of biomass, and the process for conversion of biomass to value-added commodities. The authors bring biomass transformational strategies that are yet to be explored to the forefront, making this innovative book useful for graduate students and researchers in academia, government, and industry. EF



Editors: Michael O Daramola and Augustine O Ayeni
Publisher: Springer
Year: 2020

Applications of Modern Heuristic Optimization Methods in Power and Energy Systems (IEEE Press Series on Power Engineering)

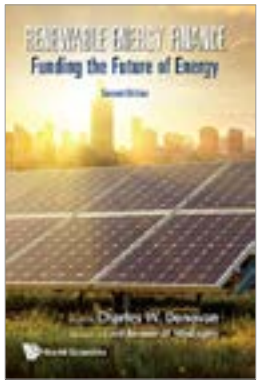
Applications of Modern Heuristic Optimization Methods in Power and Energy Systems begins with an introduction and overview of applications in power and energy systems before moving on to planning and operation, control, and distribution. Further chapters cover the integration of renewable energy and the smart grid and electricity markets. The salient features of the book are as follows:

- Explains the application of differential evolution in electric power systems' active power multi-objective optimal dispatch
- Includes studies of optimization and stability in load frequency control in modern power systems
- Describes optimal compliance of reactive power requirements in near-shore wind power plants
- Features contributions from noted experts in the field. EF

Editors: Kwang Y Lee, Zita A Vale
Publisher: Wiley-IEEE Press
Year: 2020

Renewable Energy Finance: Funding the Future of Energy

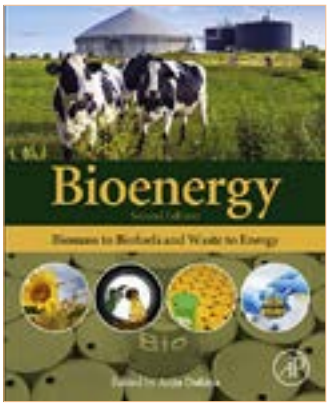
The book describes in extensive detail current best practices and evolving trends in clean energy investing. With contributions by some of the world's leading experts in energy finance, the book documents how investors are spending over $300 billion each year on financing renewable energy and positioning themselves in a growing global investment market. This second edition documents, with practical examples, the ways in which investors have funded over $2.6 trillion in solar, wind, and other renewable energy projects over the past decade. The book will be a go-to reference manual for understanding the factors that shape risk and return in renewable energy, the world's fastest growing industrial sector. EF



Author: Charles W Donovan
Publisher: World Scientific Publishing Company
Year: 2020 (2nd edition)

Bioenergy: Biomass to Biofuels and Waste to Energy

This book examines current and emerging feedstocks and advanced processes and technologies that enable the development of all possible alternative energy sources, including solid (wood energy, grass energy, and other biomass), liquid (biodiesel, algae biofuel, ethanol), and gaseous/electric (biogas, syngas, bioelectricity). It includes new project case studies and a section on the impacts of biomass use for energy production, provides a comprehensive overview and in-depth technical information on all possible bioenergy resources (solid, liquid, and gaseous), including cutting-edge topics such as advanced fuels and biogas, integrates the current state-of-the-art coverage on feedstocks, cost-effective conversion processes, biofuels economic analysis and environmental policy, and features quizzes for each section that are derived from the implementation of actual hands-on biofuel projects. EF

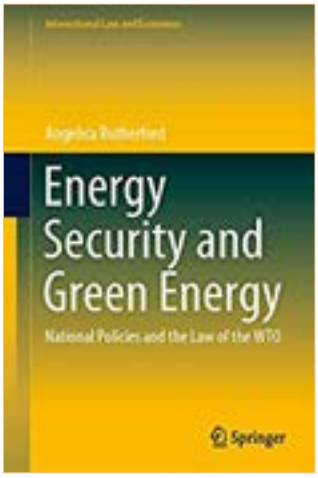


Editor: Anju Dahiya
Publisher: Academic Press
Year: 2020 (2nd edition)

Energy Security and Green Energy: National Policies and the Law of the WTO (International Law and Economics)

This book shows how the links between energy security and national and international law and policies on green energy pose challenges to a transition towards a green energy system. Based on empirical work carried out in two very different country case studies – Great Britain and Brazil – this book attempts to foster a better understanding of the role played by energy security in constructing and deconstructing green energy policy initiatives.

The broad range of views raised in national contexts leads to legal disputes in international forums when attempts are made to address the issues of this energy security/green energy interplay. As such, building on the findings of the case studies, this book then analyses the interplay between energy security and green energy development in international trade law as encapsulated in the law of the World Trade Organisation (WTO). EF



Author: Angelica Rutherford
Publisher: Springer
Year: 2020

RENEWABLE ENERGY TECHNOLOGY DEVELOPMENT

Engineers develop way to improve efficiency and heat tolerance of devices

When it comes to increasing electric storage efficiency and electric breakdown strength, the ability of an electrical system to operate at higher voltage and temperatures with great efficiency increasing one traditionally has led to a decrease in the other. Penn State researchers recently developed a scalable method that relies on engineered materials to increase both properties. Using dopants – small engineered materials also called metamaterials – the researchers altered the dielectric capacitor to increase storage capacity while also increasing electric charge efficiency, meaning the capacitor can withstand greater voltage with very little energy loss at temperatures higher than 300 degrees Fahrenheit. Researchers have used interface effects in nano-dopants to increase both the storage efficiency and the electric breakdown strength with a very small quantity of dopants and at a low cost. Increasing the electric breakdown strength in a capacitor will enable the device to handle higher temperatures without a failure in the system. This is an important trait in many electronics and electrical systems, including electric cars, industrial drills, and electric grids. Equipment used for deep drilling also will potentially benefit from having an increased temperature threshold and a smaller, less expensive capacitor. The electric grid will potentially benefit from this new technological development, particularly in terms of the increased

energy efficiency and higher electric breakdown strength.

https://www.sciencedaily.com/releases/2020/04/200421112504.htm

Development of new photovoltaic commercialization technology

A team of researchers from the University of Toronto have identified the cause of the performance degradation in CQD PV devices and developed a material processing method capable of stabilizing the performance of the devices. Quantum dots have excellent light absorbance and are capable of absorbing light over a wide range of wavelengths. Hence, they have gained expectation as a key material for the next-generation photovoltaic devices. The researchers investigated the causes of performance degradation by continuously exposing them to illumination and oxygen for long periods of time, similar to the actual operating conditions, in order to improve the stability required for the actual commercialization stage of CQD PV devices. As a result, it was identified that the iodine ions on the surface of the quantum dot solids were removed via oxidation, resulting in the formation of an oxide layer. This oxide layer resulted in the deformation of the quantum dot structure, thereby decreasing the efficiency of the device.

They developed a ligand substitution method with potassium (K) to improve the low efficiency of the device. Here, potassium iodide, which prevents the oxidation of iodine, was deployed on the surface of quantum dot solids to undergo a substitution process. As a result of the application of the invented method, the device maintained its

continuous performance rate of over 80%, which is its initial efficiency rate, for 300 hours.

https://www.sciencedaily.com/releases/2020/04/200410162408.htm

A clear semiconductor based on tin could improve solar power generation

Mobility is a key parameter for semiconductor performance and relates to how quickly and easily electrons can move inside a substance. Researchers have achieved the highest mobility among thin films of tin dioxide ever reported. This high mobility could allow engineers to create thin and even transparent tin dioxide semiconductors for use in the next-generation LED lights, photovoltaic solar panels, or touch-sensitive display technologies. Semiconductors are fundamental to most of the technology and are the basis of computer chips, solar panels, and more. They demonstrated the highest mobility in a thin film of tin oxide ever achieved. Improved mobility enhances not only the conductivity but also the transparency of the material. The more transparent a semiconductor can be, the more light it can let through. The researchers have made a tin oxide thin film that allows visible light and near-infrared light to pass. This is a great benefit to the power conversion efficiency of photovoltaic solar panels, but other uses could include enhanced touch-screen displays with even better accuracy and responsiveness, or more efficient LED lights.

https://www.sciencedaily.com/releases/2020/04/200422091155.htm

Scientists tap unused energy source to power smart sensor networks

Scientists have developed a new mechanism capable of harvesting the wasted magnetic field energy and converting it into enough electricity to power the next-generation sensor networks for smart buildings and factories. A team of scientists developed a device that provides 400% higher power output compared to other state-of-the-art technologies when working with low-level magnetic fields, such as those found in our homes and buildings. The technology has implications for the design of smart buildings, which will require self-powered wireless sensor networks to do things such as monitoring energy and operational patterns and remotely controlling systems. Researchers designed paper-thin devices, about 1.5 inches long, that can be placed on or near appliances, lights, or power cords where the magnetic fields are strongest. These fields quickly dissipate away from the source of flowing electric current. These results provide significant advancements towards sustainable power for integrated sensors and the wireless communication system. The scientists used a composite structure, layering two different materials together. One of these materials is magnetostrictive, which converts a magnetic field into stress, and the other is piezoelectric, which converts stress, or vibrations, into an electric field. The combination allows the device to turn a magnetic field into an electric current. The device has a beam-like structure with one end clamped and the other free to vibrate in response to an applied magnetic field. A magnet mounted at the free end of the beam amplifies the movement and contributes towards a higher production of electricity.

https://www.sciencedaily.com/releases/2020/04/200401100454.htm

Engineers make a promising material stable enough for use in solar cells

A team of researchers have found a way to make halide perovskites stable enough by inhibiting the ion movement that makes them rapidly degrade, unlocking their use for solar panels as well as electronic devices. The discovery also means that halide perovskites can stack together to form heterostructures that would allow a device to perform more functions. Perovskites have the potential to be even more efficient than silicon because less energy is wasted when converting solar energy to electricity. And because perovskites can be processed from a solution into a thin film, like ink printed on paper, they could be more cheaply produced in higher quantities compared to silicon. A perovskite is made up of components that an engineer can individually replace at the nanometre scale to tune the material's properties. Including multiple perovskites in a solar cell or integrated circuit would allow the device to perform different functions, but perovskites are too unstable to stack together. The team discovered that simply adding a rigid bulky molecule, called bithiophenylethylammonium, to the surface of a perovskite stabilizes the movement of ions, preventing chemical bonds from breaking easily. The researchers also demonstrated that adding this molecule makes a perovskite stable enough to form clean atomic junctions with other perovskites, allowing them to stack and integrate. EF

https://www.sciencedaily.com/releases/2020/04/200429155654.htm

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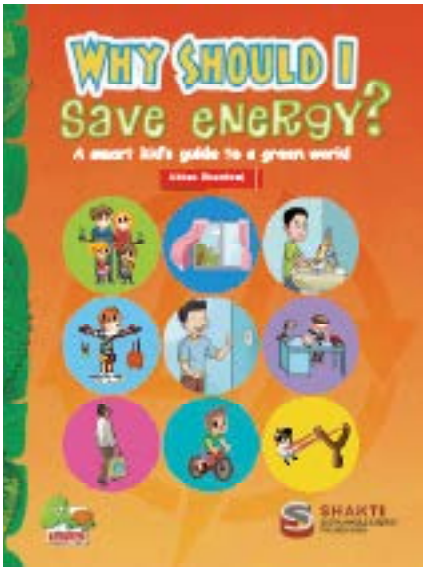

WHY SHOULD I Save eNeRgY?

A smart kid's guide to a green world

Abhas Bhardwaj

• 2020 • 210 x 280 mm • 56 pages
• Hardback • ISBN: 9788179935798
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Did you know that energy consumption by humans has increased by at least 30,000 times in the last 5000 years? In Delhi alone, there are over 80,000 trucks that run on the city roads every night. They emit un-burnt fossil fuels from their exhausts. Isn't it terrifying that over 1 million seabirds and 100,000 sea mammals are killed by pollution every year?

Why Should I Save Energy? is a comprehensive book that will introduce children to different forms of energy, history of fossil fuels, great scientists and their inventions, and more importantly, to the problems our planet faces with depletion of natural resources. Filled with eye-opening facts, beautiful pictures, multiple activities, and a quiz that helps reinforce learning; this book is the perfect guide to help you become an energy saver.

Table of Contents

About the Author

Abhas Bhardwaj has studied botany and economics. Currently, he works as a market researcher. He has an avid interest in the environment and likes to share his enthusiasm with young minds. In his inimitable style, he likes to approach serious questions with humour.

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NATIONAL AND INTERNATIONAL EVENTS

NATIONAL

2nd International Conference on Renewable Energy and Sustainability
July 29–30, 2020
Hyderabad, India
Website: http://www.icres.in/

International Conference on Renewable Energy Systems (ICRES2020)
August 26–28, 2020
Chennai, India
Website: https://www.icres2020.org/

IEEE International Conference on Smart Technologies for Power, Energy, and Control
September 25–26, 2020
Visvesvaraya National Institute of Technology, Nagpur, India
Website: http://vnit.ac.in/stpec2020/

15th Sustainability Summit (Virtual)
September 8–10, 2020
Website: https://www.sustainabledevelopment.in/summit/

Solar Rooftop Summit
October 20–22, 2020
Pragati Maidan, New Delhi, India
Website: http://www.solarindiaexpo.com/

INTERNATIONAL

2020 International Conference on Clean and Green Energy Engineering
August 4–6, 2020
Istanbul, Turkey
Website: http://www.cgee.org/

Solar Energy Systems Conference '20 (Virtual)
August 12–14, 2020
Website: https://www.aiche.org/cei/conferences/solar-energy-systems-conference/2020

Twelfth International Conference on Future Energy
August 14–15, 2020
Crowne Plaza Albuquerque, Albuquerque, USA
Website: https://www.integrityresearchinstitute.org/cofe.html

3rd International Conference on Renewable Energy and Environment Engineering
August 16–18, 2020
Lisbon, Portugal
Website: http://www.reee.net/

International Conference on Energy System and Renewable Energy Technologies
August 20–21, 2020
Bangkok, Thailand
Website: https://waset.org/energy-system-and-renewable-energy-technologies-conference-in-august-2020-in-bangkok

RENEWABLE ENERGY AT A GLANCE

Ministry of New & Renewable Energy			
Programme/Scheme wise Physical Progress in 2020-21 & Cumulative up to May 2020			
Sector	**FY- 2020-21**		**Cumulative Achievements**
	Target	**Achievements (April-May 2020)**	**(as on 31.5.2020)**
I. GRID-INTERACTIVE POWER (CAPACITIES IN MWp)			
Wind Power	3000.00	12.60	37756.35
Solar Power - Ground Mounted	9000.00	176.24	32288.73
Solar Power - Rooftop	2000.00	111.30	2626.60
Small Hydro Power	100.00	0.00	4683.16
Biomass (Bagasse) Cogeneration	200.00	0.00	9200.50
Biomass (non-bagasse) Cogeneration)/Captive Power	50.00	5.00	674.81
Waste to Power	30.00	1.20	148.84
Total	**14380.00**	**306.34**	**87383.99**
II. OFF-GRID/CAPTIVE POWER (CAPACITIES IN MWEQ)			
Waste to Energy	10.00	2.33	200.53
SPV Systems	500.00	1.85	980.24
Total	**510.00**	4.18	**1180.77**
III. OTHER RENEWABLE TECHNOLOGIES(Capacity in Nos.)			
Biogas Plants (in Lakhs)	0.60	0.00	50.50

Source: www.mnre.gov.in

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ISSN 2278 – 7186