# Rooftop Revolution: Uncovering Patna's Solar Potential

October 2014

# Acknowledgement



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Printed on 100% recycled paper

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# Preface

## Patna: The beginning of an energy revolution in India

"Rooftop Revolution: Uncovering the Solar Potential of Patna" is an in-depth analysis of the potential for rooftop solar in Patna, the capital of the most energy starved state in the country. The report comes at a time when there's a new government at the centre and a new Chief Minister in the state. With the existing aspirations for 24*7 electricity supply in the city yet to materialize, there is an urgent necessity for the state capital to generate electricity smartly and sustainably to lead the way forward in achieving Bihar's energy independence.

*Demand for electricity has outstripped supply in Bihar*

Bihar's ambition to move from an energy-starved state to an energy-sufficient state has been in the pipeline for a very long time. The centralized power grid system has clearly failed to reach out and deliver energy to India's most energy-poor state. Bihar, today suffers due to an intermittent power supply and the promise of a reliable electricity supply even in the near future is riddled with inefficiencies.

In the last six years, the demand for electricity in the state has grown at an annual rate of about 8% and the power supply position has been very inadequate, leading to a very high peak demand deficit. As per Central Electricity Authority (CEA), anticipated peak power deficit in Bihar is 26% and the energy deficit is 15% for year 2014-15[1]. With the proposal to spot purchase all the deficit power from private and unsecured players, the state not only will burden the electricity department and the common man but it will also result in a short-lived relief. A sustainable shift from the inefficient centralized energy delivery system to a diversified decentralized energy delivery system is thus the need of the hour to ensure that the ambitions and aspirations of Bihar are realized.

## Patna can "solarize its rooftops"

Patna's stable economic growth in the last five years has definitely put this ancient city back in the limelight of India's investor audience. Renewable energy, especially solar energy, is a term or technology that is not a stranger to Patna. Solar inverters are widely used in the capital city to battle the long power cuts. In the last few years, the electricity supply situation in the city has improved by leaps and bounds and the Bihar Renewable Energy Development Agency (BREDA) has been working proactively in bringing various reforms in this sector. With an ambitious promise of supplying power to all, the state's power department has been shuffling all the cards to make the ends meet. But it's still a long way before one can breathe easy on both Patna and the state's energy woes. The increasing dependence on central grid and private suppliers has set an imbalance in the pricing economics of the electricity tariff.

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1 CEA Load Generation Balance Report 2014-15, **http://bit.ly/1evyRKI**





It's a climacteric moment for Bihar in this 21st century to strike a balance in its energy delivery system and validate the fact that the decentralized approach has ensured and delivered the aspirations of the people in urban and rural Bihar while the centralized system has been failing. The state should look to diversify its energy mix in the capital city by adopting rooftop solar on government, commercial and residential buildings. By Patna going the solar way, close to half of the city's consumption can be diverted to the rest of the state where there is energy poverty. It's time we eradicate the word energy poverty being associated with Bihar and head to more inclusive and sustainable development.

*Patna must adopt rooftop solar for government, commercial and residential buildings*

From the learnings of our work in Patna, the enthusiasm for solar exists not only in the state capital but throughout Bihar among politicians, bureaucrats, technocrats and the common people and we will ensure that it continues to grow. What is still lacking is a Patna-specific in-depth assessment of the opportunities and challenges to an effective adaptation of rooftop solar. The first step towards positioning rooftop solar as a solution is to understand its potential in the city. We have initiated this report written by BRIDGE TO INDIA to serve that purpose. We hope that it will provide the city's stakeholders with the insights and data needed to ensure the solar revolution in Patna lives on and switches off darkness.

**Ramapati Kumar**
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# Executive Summary

In 2011, the per capita electricity consumption of Patna, the capital city of Bihar, was only 601 kWh[2] and even though it is a capital of one of India's largest states, this is 23% lower than the national average of 780 kWh[3] and significantly lower than the global average of 3,044 kWh[4]. This shows that the city is still very far from providing enough power to its population.

Bihar relies on power generated outside the state for about 70%[5] of its requirements. The state suffers from very high transmission and distribution (T&D) losses of around 38%[6]. This leads to frequent power outages. In the state capital, Patna, they range between two and nine hours a day. The power deficit is a key bottleneck for industrial and commercial growth as well as higher standards of living.

*Power outages in Patna range between two and nine hours a day*

The key challenges faced by Bihar State Power Holding Company Ltd. (BSPHCL) include an ageing infrastructure, pilferage of power, a high cost of power generation, rapidly rising demand and ineffective energy accounting. All of these lead to financial losses and curtail the SEB's abilities to improve the situation.

Patna is the key driver of Bihar's economy. An improved power situation in the city can help bring much needed investments into the state. For this to happen, Patna needs to de-couple itself from the overall power situation in the state and the region.

Patna should become a leader among cities and consider transformational changes in its power supply that will not only solve the city's problems but also change the way it is perceived economically and politically.

Currently, the Bihar government plans to set up several coal-based power plants to meet the state's power requirements internally. However, there is a nation-wide shortage of coal. Cost of imported coal is rising. The utilization factor of coal plants is falling. Even if the supply of coal is secured, pollution would increase substantially. Relying on coal alone is a risky proposition. Solar power, an energy source that is both easily and quickly installed and can be deployed in a distributed manner across Patna's million rooftops, should be a key building block of Patna's energy future,

*Generation from solar rooftop systems will avoid the huge T&D losses in the state*

If the power is generated at the point of consumption, the huge T&D losses can be avoided. Moreover, solar can help reduce the dependence on coal deliveries and on power producers from other states. In the beginning, solar power could help meet day time power requirements and conventional power could continue to meet peak demand for the evening and night time. Gradually, solar can start playing a more active role in eradicating the power deficit of the city.

This can be a financially sound investment. In Bihar, the Average Power Purchase Cost (APPC) for utilities has increased by 190% since 2005, but the

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2 CEED and BRIDGE TO INDIA analysis
3 Combined Business Plan for North Bihar Power Distribution Company and South Bihar Power Distribution Company, by BSPHCL, in 2012 **http://bit.ly/1icUnqz**
4 World development indicators, by World Bank, **http://bit.ly/1pSBvSq**
5 "Combined Business Plan for North Bihar Power Distribution Company and South Bihar Power Distribution Company", by BSPHCL, published in 2012, **http://bit.ly/1icUnqz**
6 Tariff order, Bihar Electricity Regulatory Commission, published in 2013, **bit.ly/1oN4iZO**





tariffs have increased by only 30% in the same period. As a result, the erstwhile Bihar State Electricity Board (BSEB) incurred significant losses amounting to ₹16,180 m ($270 m) or ₹1.01/kWh ($0.017/kWh) for the power sold in 2011-12[7]. A higher adoption of distributed solar will lead to private sector investments and help reduce the burden on the state.

*BSEB loses ₹1 for each kWh of power sold*

Based on the rooftop space availability for optimum solar power generation, we estimate that Patna has a geographical potential to install 759 MW of rooftop solar. This is significantly greater than the anticipated peak summer power demand of around 600 MW in 2014. It might not make sense to realize the entire solar potential and thereby generate excess power in the city. This excess power would need to be transmitted to other consumers in the state outside the city limits through investment in the grid. Also, such a high share of solar power would likely lead to issues related to balancing of loads and the local grids. Therefore, for the purpose of this study, we propose that 20% of the city's power requirement comes from solar. This will not pose technical challenges or require costly investments into the grid infrastructure. It would still allow for a solar capacity addition of 277 MW by 2025.

The question then is: how can Patna go solar? Solar without storage is already very close to matching the cost of power from new coal plants. However, while storage can make solar a back-up power supply, it is still expensive and can distort the dynamics against adoption of solar. The challenge is to ensure a stable power supply before asking a customer to adopt commercially attractive solar (without storage). To solve this conundrum, we propose a phase-wise adoption of solar without storage. Adoption of solar can start in the areas with the fewest power cuts. The industrial areas in Patna and some of the residential areas in the city, for example, already receive a fairly reliable power supply. Mass adoption of solar power in these areas will allow for greater supply of power for other areas. This excess power can then create another area of reliable power. Subsequently, adoption of solar in this new area of reliable power can again have the similar impact and the process can be replicated through the city.

*Patna could add 277 MW of solar capacity by 2025*

In the beginning, the government will need to invest into making the proposition viable for private investors. This can be done in the form of tax incentives, generation based incentives (GBI) and/or upfront capital subsidies. Distributed solar power is expected to reach parity with landed cost of conventional power for the government by 2019 and with the tariff for the consumer by 2021. Based on the roadmap provided in this report, if the government invests ₹1,496 m ($25 m) for a GBI, it will save ₹5,892 m ($98 m) in the next ten years.

Over time, as solar power becomes more competitive, policy makers can focus more on facilitating rather than incentivizing solar power for the end consumers. In the long term, solar power will make Patna more resilient and independent.

**Dr. Tobias Engelmeier**
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BRIDGE TO INDIA Energy Pvt. Ltd.

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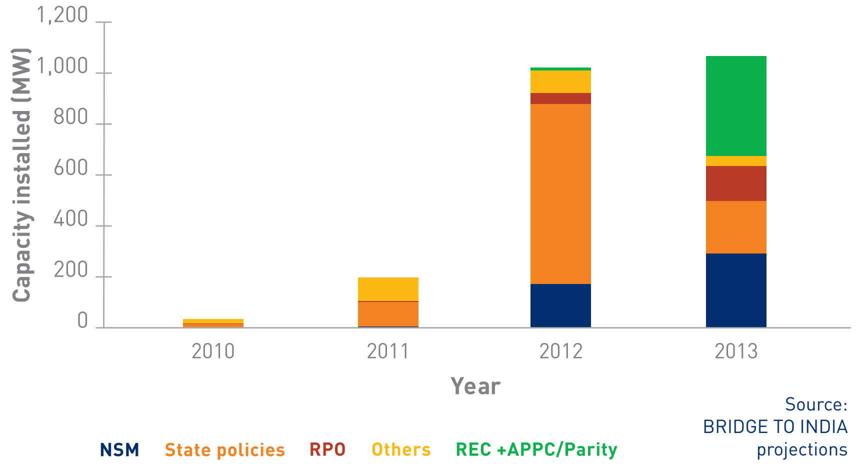
7 Combined Business Plan for North Bihar Power Distribution Company and South Bihar Power Distribution Company", by BSPHCL, published in 2012, **http://bit.ly/1icUnqz**

# 1 Solar power in India

In the past, solar in India has been driven by government incentives, provided mostly in the form of feed in tariffs (FiTs). The initial push for solar came from the Gujarat solar policy and the National Solar Mission (NSM).

### Figure 1: Year-wise utility scale solar PV installations in India by 2013[8] (in MW)

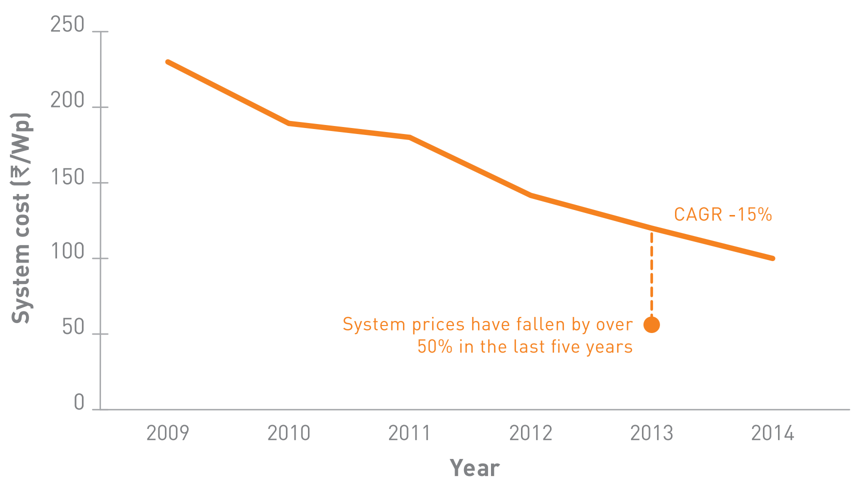



Source: BRIDGE TO INDIA projections

*The prices for solar PV systems have decreased by around 50% since 2009*

The prices for solar PV systems have decreased by around 50% since 2009[9]. As a result, solar is developing into a mainstream source of energy that can reduce power deficits and help states become self-reliant for their energy needs. Tamil Nadu, Telangana and Andhra Pradesh[10] have announced solar installation targets that go beyond what is required to meet their respective mandatory renewable purchase obligations (RPOs). Gujarat already exceeds its RPO target with the current installed solar capacity.

### Figure 2: Solar system prices over last five years (₹/Wp)[11]

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8 BRIDGE TO INDIA projects database. REC – Renewable Energy Certificates, APPC – Average Power Purchased Cost

9 BRIDGE TO INDIA market analysis

10 The state of Andhra Pradesh has in 2014 been split into two parts. One is called Telangana and the other retains the name of Andhra Pradesh.

11 BRIDGE TO INDIA analysis







While solar costs have been falling, the cost of coal, India's primary source of power, has been rising at 8% per annum[12]. Problems associated with coal linkages have been drying up investments for new coal fired power plants for the last couple of years.

*While solar costs have been falling, the cost of coal, has been rising at 8% per annum*

This is the reason why states are now looking at solar as a means to quickly and competitively add new capacity to make up for a growing power deficit. Other states, in addition to Gujarat, Telangana and Andhra Pradesh mentioned above, that are actively allocating ever more solar capacities include Karnataka, Punjab, Madhya Pradesh and Uttar Pradesh.

The closing gap between the cost of conventional sources of power and solar, especially at the customer end[13], is causing solar policies to shift from being incentive driven to becoming increasingly facilitation driven: i.e. they are looking to minimize the state incentives in lieu of providing parameters for a functioning market for distributed, privatized power generation. This includes regulatory changes such as the introduction of net-metering and improved energy accounting. Such steps will increase the deployment of solar power through private investment and reduce the financial burden on the states. Additionally, it will reduce the power deficit for the states.

As a result, there is a push for rooftop solar power across several Indian states. Net metering policy has been introduced in Delhi, Andhra Pradesh, Uttarakhand, Punjab and Kerala. West Bengal, Tamil Nadu and Karnataka have net metering proposals at the draft stage. Additionally, Gujarat has introduced a gross metering policy. A market that has so far been dominated by FiT-driven, centralized, large-scale power projects is now ready to endorse more facilitation driven distributed, rooftop solar.

## 1.1 Current key developments in the power sector in Bihar

*Bihar is heavily dependent on NTPC (70%) for its power needs*

The split of the erstwhile state of Bihar in 2000 into the smaller state of Bihar and a new state called Jharkhand has placed Bihar in a vulnerable position with respect to its power supply. After the split, Bihar has been left with only two small power stations with capacities of 320 MW and 220 MW. Jharkhand, on the other hand, got three plants of 840 MW, 420 MW and 130 MW capacities[14]. Ever since, Bihar has relied on additional allocation of power from the center. The peak power demand in Bihar has risen significantly. However, generation capacity of only 44 MW (hydro)[15] has been added till date. The state is dependent on National Thermal Power Corporation (NTPC) for its power needs. In 2011-12, around 1,450 MW (70%) of Bihar's power demand was met by NTPC. This makes the state government highly dependent in terms of energy planning and budgeting[16].

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12 "Final coal report", World Institute of Sustainable Energy, published 2013, **http://bit.ly/N6BhI4**
As per CERC estimates the cost of domestic coal is increasing at 6.7% annually and the cost of imported coal is increasing at 13% annually.
Central Electricity Regulatory Commission, published 2013, **http://bit.ly/1hOKorL**
"Rising fuel imports for power generation", CRISIL, published 2013, **http://bit.ly/1bXWzfN**

13 The conventional power that is delivered to the customer via transmission lines has substantial hidden expenses, including technical losses, distribution losses, transmission charges and distributions charges. Solar, on the other hand, can be generated directly at the point of consumption.

14 Energy Department of Bihar, Website, **http://bit.ly/L808d8**

15 Energy Department of Bihar, Website **http://bit.ly/L808d8**

16 "Combined Business Plan for North Bihar Power Distribution Company and South Bihar Power Distribution Company", by BSPHCL, published in 2012, **http://bit.ly/1icUnqz**

Bihar State Electricity Board (BSEB) was split into five parts and Bihar State Power Holding Company Ltd. (BSPHCL) was made the apex holding company. BSPHCL has four subsidiaries which include two distribution companies (DISCOMs), a transmission company and a generation company. The two DISCOMs are: North Bihar Power Distribution Company Ltd. (NBPDCL) and South Bihar Power Distribution Company Ltd. (SBPDCL). The transmission company is Bihar State Power Transmission Company Ltd. (BSPTCL) and the generation company is Bihar State Power Generation Company Ltd. (BSPGCL). BSPHCL is making large financial losses (further explained in chapter 3). To improve the situation, the Bihar government has been taking several steps. These include:

*Bihar is one of the eight Indian states to have opted for the debt-restructuring program for DISCOMs*

### 1.1.1 Debt restructuring

Bihar is one of the eight Indian states to have opted for the debt-restructuring program for DISCOMs offered by the central government[17]. The program will provide liquidity to the BSPHCL. The debt is a result of systematic under-recovery of costs due to artificially low power prices and high transmission and distribution losses. The electricity board has incurred losses every year. Erstwhile BSEB made a loss of ₹16,180 m [$270 m] in the financial year from April 2011 until March 2012[18]. As per the restructuring program, 50% of the outstanding short-term liabilities will be taken over by the central government. In return, the DISCOMs will need to take steps to become financially viable by increasing operational efficiency and raising tariffs[19].

### 1.1.2 Privatization of DISCOMs

The debt-restructuring plan also requires the involvement of privately held enterprises in the distribution sector through, for example a franchise model. Bihar has initiated the franchising of power distribution starting with four cities. Distribution operations at Gaya have already started in June 2014[20]. The capital city of Patna has been facing delays in franchising due to cancellation of bidding on various occasions. Franchises for the cities of Muzaffarpur, Gaya and Bhagalpur were recently awarded to Essel Adi Smart, India Power and SPML Infra, respectively.

*The Bihar government plans to install a total of 16,000 MW of new power plants by 2020*

### 1.1.3 Setting up of new power plants

The Bihar government plans to install a total of 16,000 MW of new power plants by 2020. Out of this, 9,920 MW is to be contributed by private independent power producers (IPPs) during the current, twelfth five year plan (2012-2017). The Bihar government wants to retain the right to claim 25% of the total power produced for the state itself. The implementation of this plan could help solve Bihar's power problems[21].

However, the current investment climate with regard to coal-fired power plants is not conducive. The fact that the most state distribution companies (including Bihar's), which would be the main off-takers for new power, are still making

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17 "Financial restructuring of power DISCOMs", by Ministry of Power, published in 2012, **http://bit.ly/N0qSNJ**
18 "Combined Business Plan for North Bihar Power Distribution Company and South Bihar Power Distribution Company", by BSPHCL, published in 2012, **http://bit.ly/1icUnqz**
19 "Financial restructuring of power DISCOMs", by Ministry of Power, published in 2012, **http://bit.ly/N0qSNJ**
20 Business Line, "India Power begins distribution operations at Gaya", **bit.ly/VmBk7j**
21 Bihar State Power holding Company, Website, New Projects **http://bit.ly/1exHK7X**





heavy losses, is considered as a large risk by investors and banks. In addition, there is a shortage of coal and the cost of coal is rising. Considering these factors, the aim to plug Bihar's power gap with coal-fired plants is unlikely to achieve.

### 1.1.4 Up-gradation of existing power plants

In addition to the new planned capacity, the BSPHCL is also renovating the plants of Barauni (2 x 110 MW) and Muzzaffarpur (2 x 110 MW). Further, the Bihar government has prepared a master plan for the augmentation and strengthening of the state's power transmission network over the next ten years. The plan calls for an investment of ₹163 billion ($2.8 billion)[22]. The BSPHCL and Power Grid Corporation of India Ltd. (PGCIL) have set up a joint venture for upgrading the transmission network.

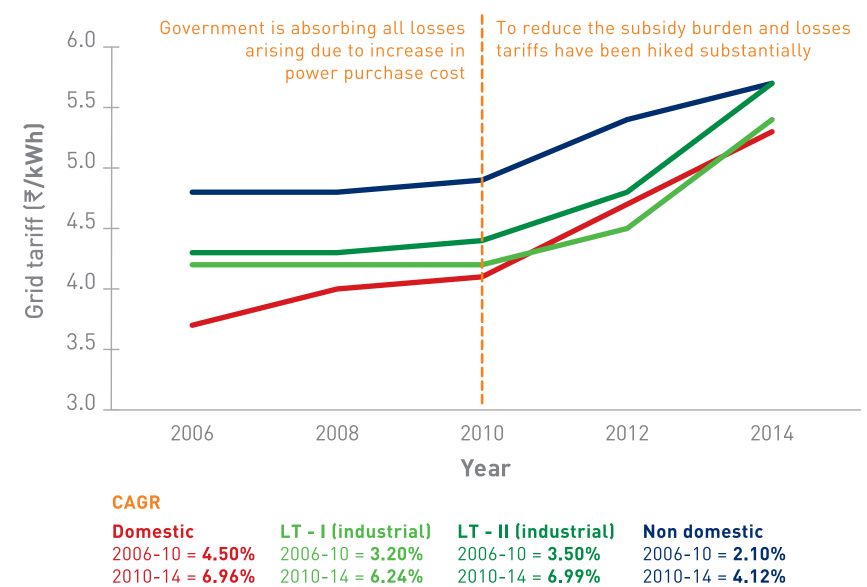
*The power tariff in Bihar has seen significant rise after 2010*

### 1.1.5 Check on power theft

To counter power theft, BSPHCL conducts more random checks on all power consumers, including government buildings, to identify power theft due to meter tampering and illegal power lines. Those found guilty are disconnected. The power distribution company has set a target to thereby enhance revenue collection from ₹2,500 m ($42 m) per month to ₹4,000 m ($67 m) per month in 2013-14[23].

A key result of all these efforts and investments will be a likely increase in tariffs, which is already visible (see figure 3). This trend matches that in other regions, where the power industry has been reformed. For example, tariffs in Delhi increased by around 70% post privatization of DISCOMS in 2002, while power supply has become very reliable[24]. A similar development is likely in Patna.

### Figure 3: Trend of grid power prices in Bihar[25]

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22 Times on India (2013) **http://bit.ly/1lzCNlw,** (confirmed with BSPHCL)
23 The Economic Times (2013) **http://bit.ly/1fOKvCv**
24 Tariff orders, Delhi Electricity Regulatory Commission, 2002-2014, **http://bit.ly/1mZzvVO**
25 Tariff order, Bihar Electricity Regulatory Commission, 2013-14. LT-I includes contract demand between 5-15 kWp. LT-II includes contract demand between 25-99 HP **http://bit.ly/1i5SEHa**

## 1.2 Can Patna be an innovation leader in power?

The peak power demand in Bihar in 2013-14 was 2,465 MW[26]. The state itself, however, only has a power generation capacity of 584 MW (540 MW coal and 44 MW hydro)[27]. The peak shortfall of about 70%[28] is met through power purchase agreements with central power generators and through purchases on the spot market.

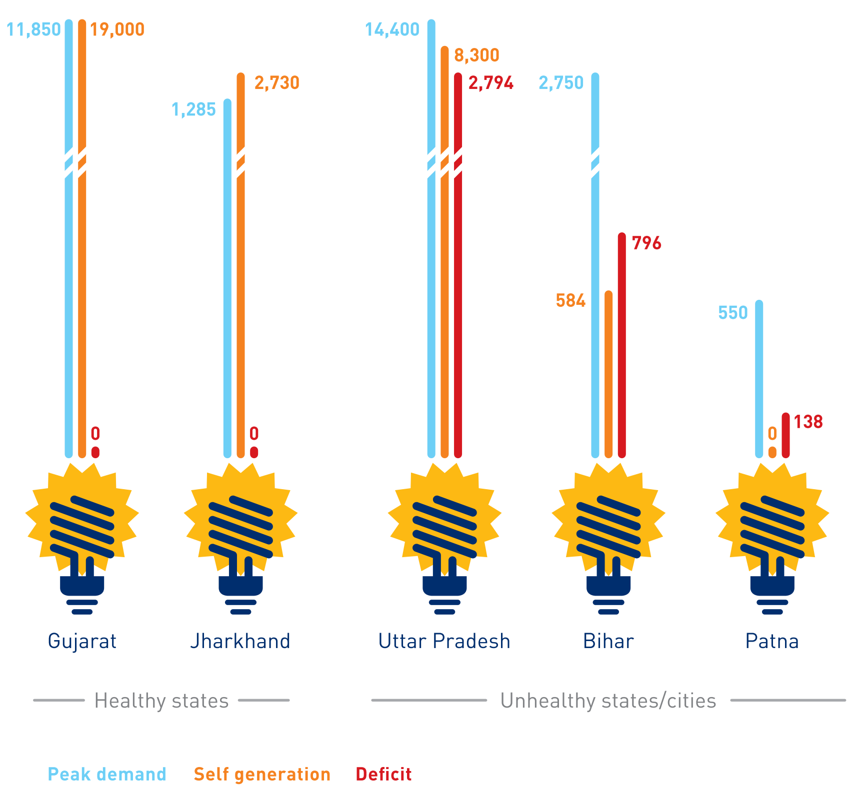
Over dependence on import of power puts Bihar in a vulnerable position as it becomes increasingly difficult to predict future procurement costs, leading to unplanned expenditure and financial stress. The peak power demand is anticipated to be 2,750 MW in 2014-15 with power deficit of 26%[29]. The power deficit is a concern across India as a whole.

*The anticipated power deficit in Patna is 26% (2014-15)*

Fossil fuels, therefore, cannot be the only answer to removing the power deficit. Renewables in general and solar in particular do not suffer from such uncertainties. They can be installed quicker and the cost of power is much more predictable. Solar in particular can be installed in and near the load centers and large capacities can be planned in a short duration of time.

Patna, as a city, is not isolated from the deteriorating power situation in Bihar. The state has registered growth of over 10% consecutively for past three years. In two of those three years, Bihar has the highest growth rate among all Indian states[30]. As a capital, Patna has been a key contributor to this growth. For the city to continue growing, it will need to de-link itself from the power situation in Bihar. Patna needs to think out of the box.

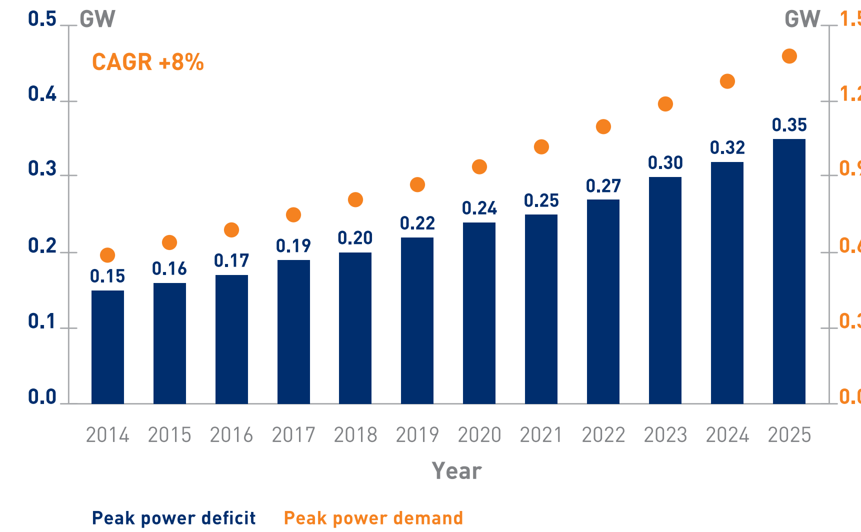
### Figure 4: Power scenario comparison between healthy and unhealthy states (all figures in MW)[31]








### Figure 5: Development of power demand and deficit in Patna[32] (in GW)




*The per capita electricity consumption of the city of Patna was 23% below the national average*

In 2011, the per capita electricity consumption of Patna was only 601 kWh[33] and even though Patna is a capital of one of the 29 states in India, this is 23% lower than the national average of 780 kWh[34] and significantly lower than the global average of 3,044 kWh[35].

For our analysis, we assume that power demand in Patna, in the long term, would follow the trajectory of larger cities such as Delhi or Kolkata. In terms of per capita electricity consumption, Patna is currently where Delhi was in 1990 (~600 kWh/year)[36]. Delhi's power demand has since increased at 7-8% annually[37]. Patna's power demand growth will be at least this high (could be even higher).

*In terms of per capita electricity consumption, Patna is currently where Delhi was in 1990*

Currently, the city is not industrialized. It remains largely residential. The city has an immense potential for economic growth, driven by population growth, industrialization and rising household incomes. Currently, Patna's economy is characterized by small, commercial services. Availability of electricity is crucial to sustain and grow commerce. Patna as a city does not have its own comprehensive plan to cater to its increasing power demand. On the current trajectory, the city's power situation will likely get worse and power outages will become more frequent, stifling economic growth.

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26 "Load generation balance report", by Central Electricity Authority, published in 2014, **http://bit.ly/1evyRKI**
27 Energy Department of Bihar, Website **http://bit.ly/L808d8**
28 "Combined Business Plan for North Bihar Power Distribution Company and South Bihar Power Distribution Company", by BSPHCL, published in 2012, **http://bit.ly/1icUnqz**
29 Ibid.
30 Planning Commission of India, Data table; **bit.ly/1k6Z2OD**
31 "Load generation balance report", by Central Electricity Authority, published in 2014, **http://bit.ly/1evyRKI.**
"Energy statistics", by Ministry of Statistics, published in 2014, **http://bit.ly/1pgq1HL**
32 Projections for Patna's power demand based on growth of Delhi's power demand between 1990 and 2000. Ratio of power deficit and power demand assumed to be constant as of 2013. Times of India (2013), **http://bit.ly/1nc0Sj4**
33 CEED and BRIDGE TO INDIA analysis
34 Combined Business Plan for North Bihar Power Distribution Company and South Bihar Power Distribution Company, by BSPHCL, in 2012 **http://bit.ly/1icUnqz**
35 World development indicators, by World Bank, **http://bit.ly/1pSBvSq**
36 "Inventory Of GHGs And Other Urban Pollutants From Energy Sector In Delhi And Calcutta", by Institute of Global Environment Strategies, published in 2002, **http://bit.ly/1jLsDdm**
37 Delhi planning website, **http://bit.ly/1fBmZLD**

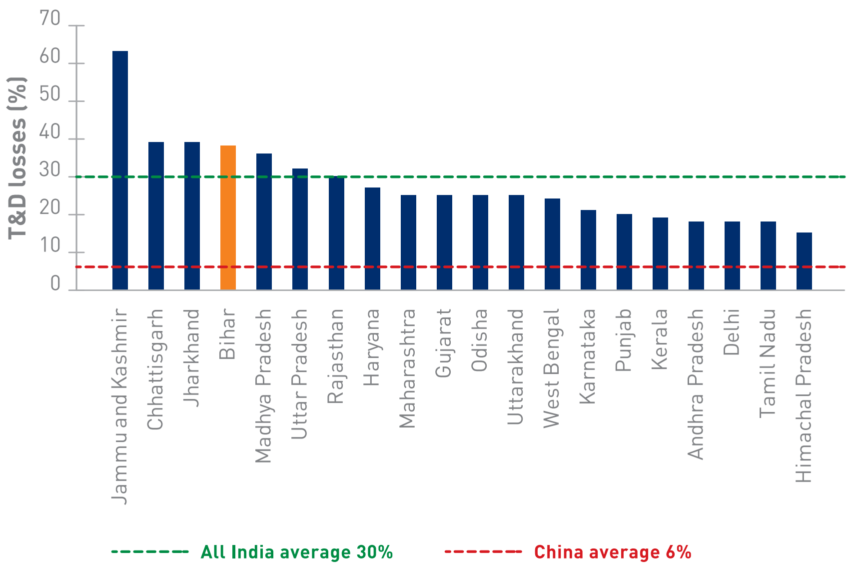
# 2 Solar rooftop as a solution for Patna

In the previous chapter we have outlined the importance for Bihar to generate power within the state to reduce its dependency on external resources. In addition, we also outlined the need for Patna to become more energy independent. Patna needs to be resilient to the fluctuating power situation across the state and reduce the dependence on state's current Achilles heel – imported grid power.

*Distributed generation can make Patna energy independent*

Both problems have a common solution: distributed, on-site energy generation. Renewable sources such as wind, biomass or hydro do not make sense for Patna due to the unfavorable location or lack of resources. A more realistic solution is to install grid-connected, distributed solar PV on rooftops. Currently, grid-connected power plants work best when supplemented with grid power, thus avoiding the need for costly storage technology. Such power plants have the potential to substantially reduce the persistent day-time power deficit, which would in turn reduce the number of outage hours during the day. Following such an approach will make a larger share of conventional power available during the evening peak deficit hours or at night without increasing the expenditure[38]. In addition to provide for the much-needed power, rooftop solar, in particular, would also ensure that the power generated within the city is not lost in the distribution grid (38%[39]).

## Figure 6: State-wise T&D losses[40]




*Power generated on rooftops would not be lost in the distributed grid (losses: 38%)*

Frequent power outages in Patna lead to added costs for battery-based inverters and inefficient, expensive diesel generators. Power from battery-based inverters can cost twice as high as the grid tariff and power from diesel gen-sets costs as much as three times the grid tariff. This significantly increases the cost of living and doing business in Patna.

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38 Solar would not be able to meet the entire power deficit as it stands today due to technical limitations that are explained in chapter 5

39 Tariff order, Bihar Electricity Regulatory Commission, in 2013, **bit.ly/1oN4iZO**

40 "Working of State Power Utilities and Electricity Departments", by Planning Commission, published in 2012, **http://bit.ly/1gp49IR,** page 36





## 2.1 The type of solar solution required for Patna

Bridging the total power deficit in the short term, by using solar power alone is not feasible. Solar will only be a part of the solution in the beginning. Efficiency improvements in power consumption and generation from other sources of power will also play an important role. Solar with storage will be a comprehensive solution, but the storage costs are currently still prohibitively high.

*Patna could adopt rooftop solar in a phased manner*

Grid-tied solar PV systems, on the other hand, integrate directly into the existing power infrastructure with only a limited requirement for new, solar specific infrastructure. However, these grid-tied systems require a stable grid with little or no power outages, minimal voltage fluctuations, smart meters for efficient energy accounting and improved demand forecasting tools. Investing in this infrastructure for the entire city would be a more long-term solution than investing into storage. Also, Patna needs to upgrade its grid infrastructure in any case.

A good approach for Patna would be to adopt solar in a phase-wise manner. Adoption of solar should start with those areas with the fewest power cuts. The industrial areas in Patna, for example, already receive a fairly reliable power supply. This can be the starting point. Mass adoption of solar power in the industrial areas can lead to surplus power availability in that area. This excess power can be routed to another area, where it can bridge the deficit, creating a new area with reliable power. Subsequently, solar can be adopted in this new area with reliable power. The process can be replicated through the city.

This phased capacity addition would need to be accompanied by key regulatory and infrastructural interventions such as the introduction of net-metering and an overall improvement in grid infrastructure in the long run. The policy measures are further elaborated later in this report.

## 2.2 Patna's existing solar landscape

*Implementation of net-metering and an overall improvement of the grid infrastructure would help significantly*

Without a dedicated solar policy in place, Patna's existing solar landscape primarily comprises of small private companies that provide mostly off-grid or hybrid (grid-tied, but with storage) solutions.

In early 2013, Bihar released a tender[41] for 100 MW of utility scale solar. However, this tender was not pursued and the projects were not allocated.

The government currently offers tenders for small-scale projects that include rooftop solar systems at government buildings. Some of these systems have been installed at the Bihar Chief Minister's residence, the Patna museum and the Chief Justice's residence. There have also been government tenders for public solar lighting. These are mostly demonstration projects.

If solar is going to play an important role in Patna, the city will need an aggressive, dynamic and comprehensive ecosystem encouraged by a predictable and attractive policy framework.

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41 Tender document **http://bit.ly/1b3uTdd**

# 3 The economic case for solar in Patna

In the previous chapters, we have established the importance of solar in Patna to reduce the power deficit and resulting outages. In this chapter we discuss the role of solar in hedging against the rising cost of conventional power generation, wastage of resources due to inefficient backups and the financial liability of T&D losses.

*APPC for the utilities has increased by 190% since 2005, but the tariffs have increased by only 30%*

## 3.1 The economic cost of grid losses and undersupply

In Bihar, the number of power consumers has grown at 14% annually between 2005-06 and 2011-12, compared to a 6.8% growth in the sale of power[42]. Clearly, the growth in power demand has not been matched by the growth in supply. Prices have also not kept up. Average power purchase cost (APPC) for the utilities has increased by 190% since 2005, but the tariffs have increased by only 30% in the same period[43]. As a result, the erstwhile BSEB incurred significant losses amounting to ₹16,180 m ($270 m) or ₹1.01/kWh[44] ($0.017/kWh) for the power sold in 2011-12[45].

Distribution of power in Patna is hampered by an ageing infrastructure, pilferage of power, high cost of power generation, rising demand and energy accounting[46]. All of these eventually lead to a financial loss, power deficit and an ultimately stifled economic development. Due to the poor financial condition of the BSPHCL, a viscous cycle is set in motion: with no money to invest towards improving grid infrastructure or to match the rising power demand with supply, the conditions are getting worse.

*The government is losing ₹0.5 for every unit of electricity sold to households*

The BSPHCL's APPC excluding transmission charges is expected to be ₹3.82/kWh ($0.07/kWh) for financial year 2014-15[47]. Considering the coal shortage faced by thermal power plants in India, the APPC could be higher. After adding transmission charges and T&D losses, the cost of delivering power works out to be ₹5.8/kWh ($0.1/kWh). However, power is being sold at ₹1.7/kWh ($0.03/kWh) to agricultural consumers, at ₹5.3/kWh ($0.09/kWh) to domestic and small industrial (LT I), and at ₹5.7/kWh ($0.1/kWh) to large industrial (LT II) and commercial consumers[48]. Thus, the government is losing money by selling every unit of electricity. Domestic segment has the largest consumer base and the current loss to government is ₹0.5/kWh ($0.008/kWh). If the trend continues, in 2025, the landed cost of conventional power is expected to be ₹16.1/kWh ($0.27/kWh) compared to the expected domestic tariff of

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42 "Combined Business Plan for North Bihar Power Distribution Company and South Bihar Power Distribution Company", by BSPHCL, published in 2012 **http://bit.ly/1icUnqz**
43 "Combined Business Plan for North Bihar Power Distribution Company and South Bihar Power Distribution Company", by BSPHCL, published in 2012 **http://bit.ly/1icUnqz**
BRIDGE TO INDIA analysis
44 Total financial loss/total units generated
45 Tariff order, Bihar Electricity Regulatory Commission, in 2013, **http://bit.ly/1mZE4j1**
"Combined Business Plan for North Bihar Power Distribution Company and South Bihar Power Distribution Company", by BSPHCL, published in 2012 **http://bit.ly/1icUnqz**
46 "Combined Business Plan for North Bihar Power Distribution Company and South Bihar Power Distribution Company", by BSPHCL, published in 2012 **http://bit.ly/1icUnqz**
47 Tariff order, Bihar Electricity Regulatory Commission, in 2013 **http://bit.ly/1oN4iZO**
48 Tariff order, Bihar Electricity Regulatory Commission, in 2013 **http://bit.ly/1mZE4j1**

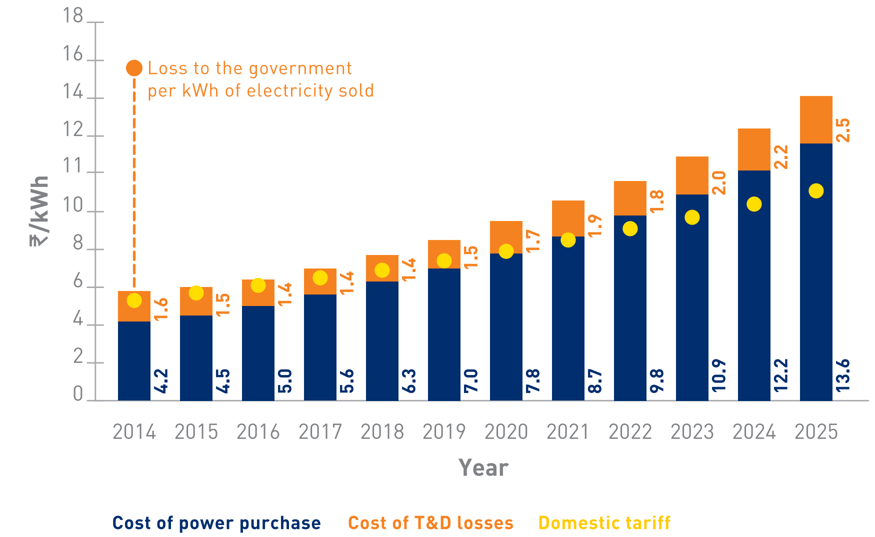




₹11.1/kWh ($0.18/kWh), which would result in a loss of ₹5/kWh ($0.08/kWh) based on the assumption that tariff hikes are in line with the average of the past 4 years (2010-14)

*Parity of solar with domestic tariffs will likely be reached by 2021*

**Figure 7: Landed power cost in Bihar based on APPC and cost of T&D losses (2014-2025)[49]**




## 3.2 Viability of solar

If we project the landed cost of power generation, domestic tariff and the viable solar tariff till 2025, we observe three key factors.

*The government would have to incentivize rooftop solar to accelerate adoption. In turn, it will benefit from savings post 2019*

1. The government makes a loss due to the difference between the cost of power purchase and tariffs at which power is sold. As stated above, this loss is expected to increase, if the hike in tariff remains at the current level.
2. At the consumer end, large-scale adoption of solar will not take place until it is an economically attractive option. Currently, the viable solar tariff[50], for a 3-5 kWp system without storage, in Patna, is around ₹11.9/kWh[51] ($0.20/kWh) compared to the domestic grid tariff of ₹5.3/kWh ($0.09/kWh). Parity of solar with domestic tariffs will likely reach by 2021. Therefore, to accelerate adoption of solar, the government would need to incentivize it to make it financially more attractive to consumers. An overall account of estimated expenditures under various incentive mechanisms is provided in chapter six
3. The government will benefit from savings post 2019, once the cost of solar reaches parity with the landed cost of conventional power.

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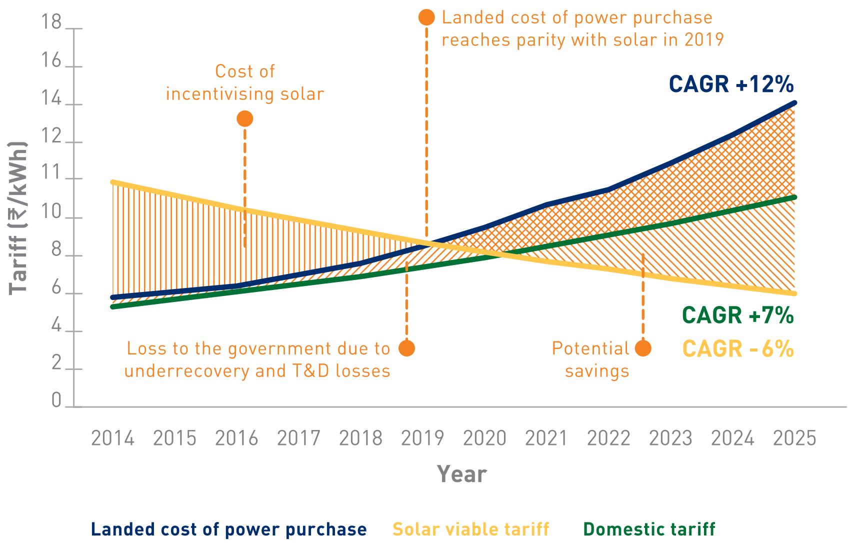
49 Average power purchase cost (APPC) and T&D losses for 2013-2016 given in BERC tariff order (2013-14) page number 35. Projections for 2017-2020 made based on CAGR of 2013-2016 numbers. T&D losses reach 22% in 2018 and 18% in 2022. They are not expected to go below that till 2025. All years represent financial years, i.e., 2011-12 is represented as 2012.
Tariff order, Bihar Electricity Regulatory Commission, in 2013, **http://bit.ly/1mZE4j1**
50 The tariff at which consumers get a 15% return on their solar investment
51 Assuming a system cost of ₹100,000 per kWp, CUF of 17% and IRR of 15%

**Figure 8: Comparison of domestic tariff, landed cost of grid power and solar viable cost[52]**

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52 BRIDGE TO IINDIA analysis
Tariff order, Bihar Electricity Regulatory Commission, 2013, **http://bit.ly/1mZE4j1**
"Combined Business Plan for North Bihar Power Distribution Company and South Bihar Power Distribution Company", by BSPHCL, published in 2012 **http://bit.ly/1icUnqz**
Assumptions - we have based our study considering the domestic and the LT-I industrial tariff (₹5.3/kWh) as Patna's electricity consumption is currently dominated by these two sectors. Further, we have based the future escalation in the tariffs based on the escalation between years 2010-14, as this rise accurately reflects the magnitude of tariff increase in future.



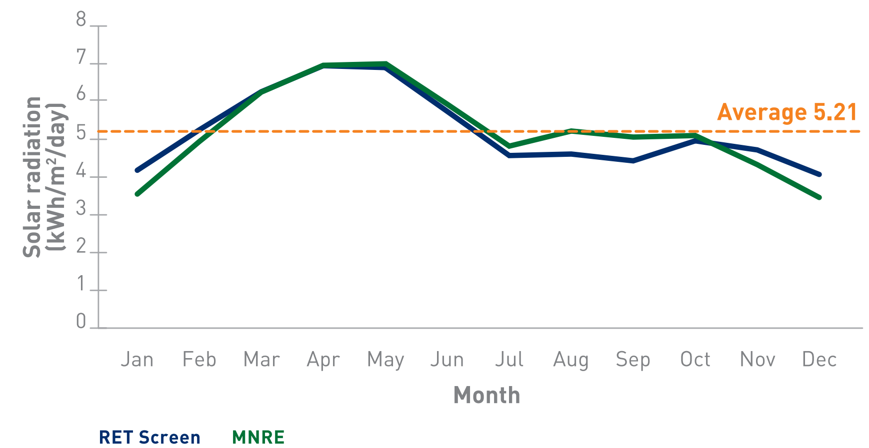


# 4 Solar resource availability for Patna

Solar irradiation is the amount of radiant solar energy available per unit area and is usually expressed in terms of kilowatt-hours per square meter per day (kWh/m$^2$/day). This can be used to generate power by way of technologies such as solar PV systems.

*The average solar irradiation of Patna is over 5 kWh/m$^2$/day, which is 90% higher than Berlin/Germany - a leading solar city*

**Figure 9: Annual irradiation data for Patna, Bihar[53 54]**




The average solar irradiation of Patna is over 5 kWh/m$^2$/day[55]. Such a level of solar irradiation is good[56]. With this, the city of Patna receives more sunshine than many other cities of the world that have installed significant amounts of solar. Berlin, for instance, has a daily irradiation of 2.73 kWh/m$^2$ and an installed capacity of 98 MW as of 2013[57].

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53 NASA Surface meteorology and Solar Energy, **http://1.usa.gov/1aJKPUk**
54 MNRE India Solar Resource Maps, **http://bit.ly/1npe1mu**
55 India Solar Resource Map 2010 NREL
56 It is not as high as the western and southern states of India. Rajasthan, Gujarat, Tamil Nadu, Maharashtra, Andhra Pradesh and Karnataka, have an average irradiation of around 6 kWh/m2/day and are considered to be the most solar suitable regions in the country. The highest irradiation in the world is 7-8 kWh/m2/day in some regions of North Africa.
57 Synergy environ website, 2014, **http://bit.ly/1hzTTeX**

## 4.1 Patna's geographic potential for solar rooftop installations

The total land area of the Patna Urban Agglomeration Area (PUAA) is around 136 km$^2$.

### Figure 10: Map of Patna


*The estimated solar-suitable rooftop space in Patna can accommodate 759 MW of solar power*

For this analysis, we take into consideration the land area of Patna to be 105 km$^2$, which excludes agricultural land, recreational land, water bodies and vacant land. Patna's built up area/raw rooftop space that is potentially available for solar power generation is around 22 km$^2$. Raw rooftop space includes only built-up structures that can accommodate the size and weight of solar installations[58]. The solar-suitable rooftop space is the unobstructed and shadow-free rooftop area that receives optimal sunlight for solar power generation[59]. The estimated solar-suitable rooftop space in Patna is around 9 km$^2$, which can accommodate 759 MW of solar power[60].

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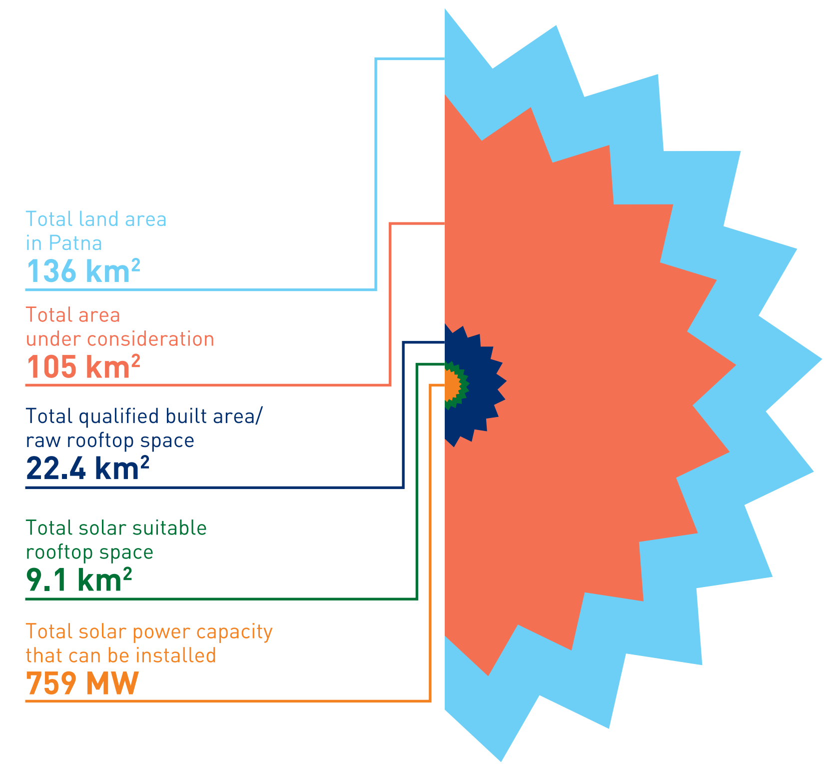
58 Raw rooftop space is computed after excluding poorly constructed or unfit building structures, roads, green patches and irrelevant sub categories such as poultry farms or religious buildings. (Refer to the annexure chapter "Methodology for calculating the solar rooftop potential in Patna" for details on the calculation.)

59 Solar suitable roof top space excludes parts of the rooftop that are obstructed by objects and rooftop structures like water tanks, storage rooms, air-conditioning units, water heating units, etc. as well as parts of the roof that have a shadow. This space estimation varies for different land area types. (Refer to the annexure chapter "Methodology for calculating the solar rooftop potential in Patna" for details on the calculation.)

60 Based on Bridge to India's estimate that 12 m2 of rooftop space is required for a 1kW solar power installation. 1 MW (1,000 kW) of solar requires 0.012 km2 (12,000 m2) of space.



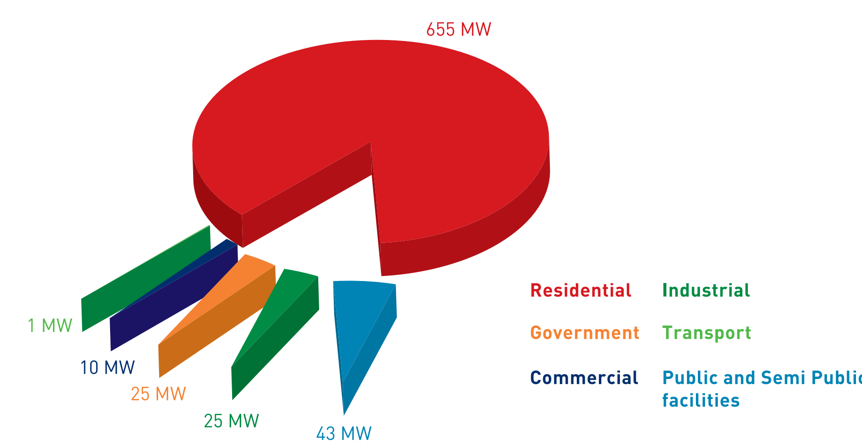
### Figure 11: Deriving Patna's rooftop space for solar




*Patna's residential buildings account for 86% of the city's solar potential*

Patna's residential buildings make up 86% of the solar potential. This is followed by public and semi public facilities with 6% of the potential. Government buildings, industrial buildings and commercial buildings have 3%, 3% and 2% of the total potential, respectively. Transport sector, which comprises of areas under airports, railway stations, bus depots and bridges, accounts for <1% of the potential. The methodology for computation of solar potential is explained in the annexure chapter "Methodology for calculating the solar rooftop potential in Patna".

### Figure 12: Potential of solar PV on different types of buildings in Patna (MW)



### Table 1: Solar suitable rooftop area available in different land categories[61]

| Land area type | Total qualified rooftop area (km²) | Solar suitable rooftop area (km²) | % of solar suitable rooftop space | Solar potential (MW)[62] |
|---|---|---|---|---|
| **Residential** | 19.6 | 7.9 | 40% | 655 |
| **Public and semipublic facilities** | 1.1 | 0.5 | 45% | 43 |
| **Industrial** | 0.5 | 0.3 | 65% | 25 |
| **Government** | 0.8 | 0.3 | 40% | 25 |
| **Commercial** | 0.4 | 0.1 | 35% | 11 |
| **Transport** | 0.01 | 0.01 | N/A | 1 |
| **TOTAL** | 22.4 | 9.1 | | 759 |

## 4.2 Solar potential from the perspective of the grid infrastructure

*Solar can easily supply 20% of the peak demand without destabilising the grid*

As discussed in the previous section, Patna's geographic rooftop solar PV potential is estimated at 759 MW. However, with a peak power demand of only around 600 MW in 2014, 759 MW of solar power would not be required. Theoretically, the power could be transmitted out of the city. However, installing such a capacity would lead to wastage and technical challenges around balancing[63] the grid.

In addition, there is a larger question of whether the grid infrastructure can handle such a large amount of solar power. In our report on the solar potential of Delhi "Rooftop Revolution: Unleashing Delhi's solar potential"[64], we assumed the grid could accommodate 20% of intermittent solar power without requiring significant infrastructure investments. This is based on estimates of grid-ceiling factors from New York and Germany[65].

For the purpose of this analysis, we have also capped the solar potential for Patna at 20% of the peak demand for the city. As seen in figure 14, by this measure, Patna can only accommodate 120 MW of grid connected solar PV power projects as of 2014. However, the potential will increase as Patna's demand for power increases and the grid capacity infrastructure will improve alongside to accommodate the increase. By 2025, Patna would have a solar potential of 277 MW.

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61 Please refer to the annexure for details
62 Based on Bridge to India's estimate that 12 $m^2$ of rooftop space is required for a 1kW solar power installation. 1 MW (1,000 kW) of solar requires 0.012 $km^2$ (12,000 $m^2$) of space.
63 Solar is an intermittent source of power. This means that there could be a sudden drop in power in case of an unexpected cloud cover. To counter this, a balancing mechanism is required to feed in power when solar is under performing.
64 "Rooftop Revolution: Unleashing Delhi's Solar Potential", page 31 **http://bit.ly/1b0aUlj**
65 According to the NREL study on "Interconnecting PV on New York City's Secondary Network Distribution System", PV penetration levels of 20-30% are considered safe for radial distribution grids. For more details about challenges of PV penetration and suggested solutions see the report "Connecting the Sun", November 2012 by the European PV Industry Association accessed at **http://1.usa.gov/1pSEASm** , **http://bit.ly/1o8b1bP**

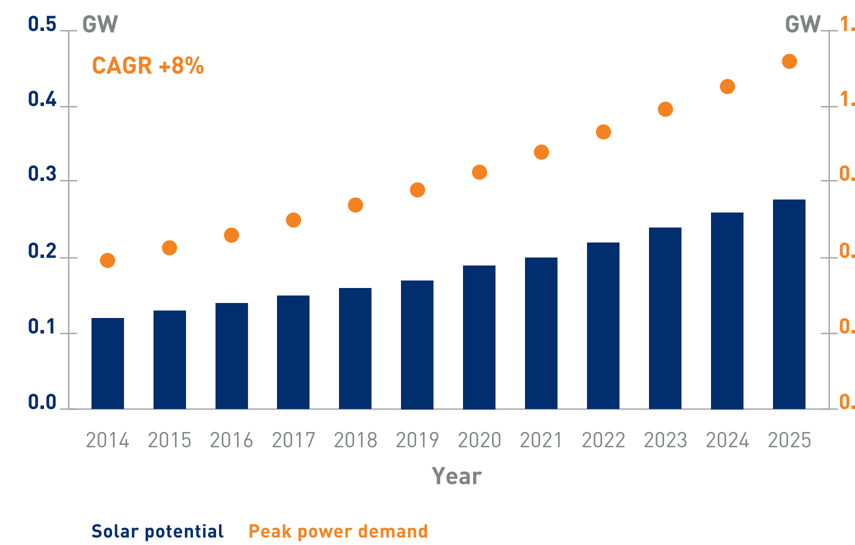




It is important to note that the grid-ceiling factor is not a fixed number. With improvements to manage the balancing aspects of the grid, this limit can be pushed higher. For example, in Germany, out of 153 GW total installed power capacity, solar PV accounts for around 36 GW and wind accounts for another 33 GW. Together, renewables constitute ca. 45% of the total installed capacity[66]. In 2012, Germany published a comprehensive plan of upgrading its grid infrastructure to achieve 80% renewable energy penetration by 2025. For this, it plans to set up 2,100 km HVDC lines to transmit 10 GW of power. In addition, it plans the build over 2,800 km of new transmission lines to transmit renewable power along with additional balancing capacity. The total up gradation is expected to cost around $26.7 billion[67]. This simply goes to show that the solar grid potential can be increased through targeted infrastructure investment. For the purpose of this analysis, however, we assume that there is no solar specific investment in Patna into the grid[68].

*Solar grid potential can be increased through targeted infrastructure investment*

### Figure 13: Solar potential vis-a-vis Patna's peak power generation[69] (in GW)

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66 "Electricity production from solar and wind in Germany", Fraunhofer Institute, published 2013, **http://bit.ly/1ktSgCk**
"36 percent of Electricity in Germany to be Generated from Renewables by 2020", by Frost and Sullivan, published in 202, **http://bit.ly/1gbRAKV**
67 Europa.eu website, **http://bit.ly/NyQPEM**
68 For details, please refer to chapter 7 (policy recommendations)
69 Solar potential calculated as 20% of peak power demand, based on the grid ceiling factor

# 5 Solar spillover: a roadmap for Patna to reach 277 MW of solar by 2025

*Patna should aim at setting up grid-connected solar systems in areas with less than two hours of power cuts*

There is a strong reason for Patna to go solar. There is also a significant rooftop potential of 277 MW. The next question is, how and when to do it. As briefly described before, adoption could be phase-wise, creating islands of reliable day time power supply. While solar can bridge a substantial part of the day time power deficit, other sources of power are required to completely eliminate the evening and night time deficit – at least as long as storage is not a commercially attractive option[70].

Patna can be divided into areas with very different power supply situations. Some have less than two hours of outages in a day. This includes: Magistrate Colony, Ashok Nagar, Doctor's Colony and all the industrial areas in the city limits. The second category is areas with 2-4 hours of power outages. This includes: Bankmans Colony, Professor Colony and Khajpura Colony. Then, there are areas with even higher power outages. They include: Chitragupta Nagar Colony, B.M. Das Road Colony and Digha Colony.

Going step by step, Patna should first aim at eliminating the power outages of the areas that have less than two hours of power cuts. Grid-tied rooftop solar capacity addition can then be promoted in these areas. The surplus electricity during daytime from these areas can be transferred to areas, which had slightly more power cuts. This will ensure that the grid in the areas with slightly higher power cuts also becomes reliable for adoption of grid-tied rooftop solar installations.

*Solar would become viable for consumers in 2021 without any incentives*

Patna could start by installing 10-12 MW of solar annually for the initial four years. In the beginning, the majority of installations would be on industrial rooftops (25 MW potential). Then, the residential segment would take up. The following assumptions have been considered in charting a roadmap:

1. The capacity addition will start off slowly as the ecosystem for solar develops. It will pick up pace after 3-4 years.
2. In the initial years, new infrastructure will be set up for demand and weather forecasting, net metering policy will be implemented and existing meters will be replaced with smart meters.
3. Smart meters will first be implemented in areas of good grid connectivity.
4. The first game changing enabler would come in 2019, when the cost of solar reaches parity with the landed cost of conventional power. From this point, the government starts saving money on every kWh of rooftop solar.
5. The second game changing enabler would come in 2021, when the cost of solar reaches parity with the domestic grid tariff i.e. solar will become viable for consumers without any incentives. At this stage, consumers will go solar irrespective of any incentives given by the government.
6. The additional solar capacity will meet most, if not all, of the day time deficit. While the evening and night deficit would need to be bridged by conventional power or stored power.

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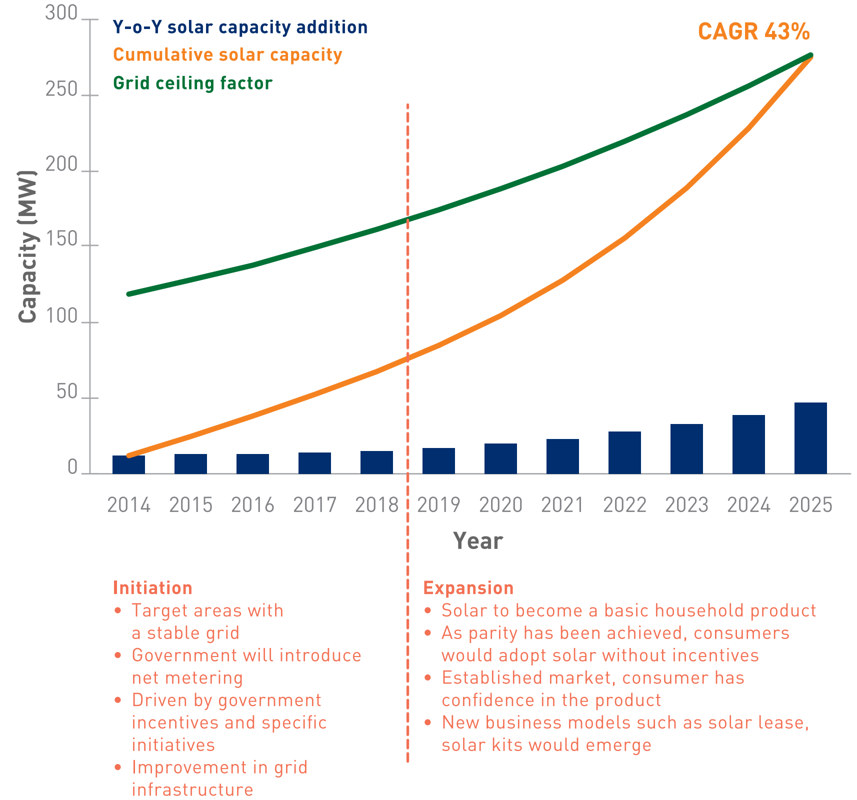
70 Please refer to policy recommendations for details

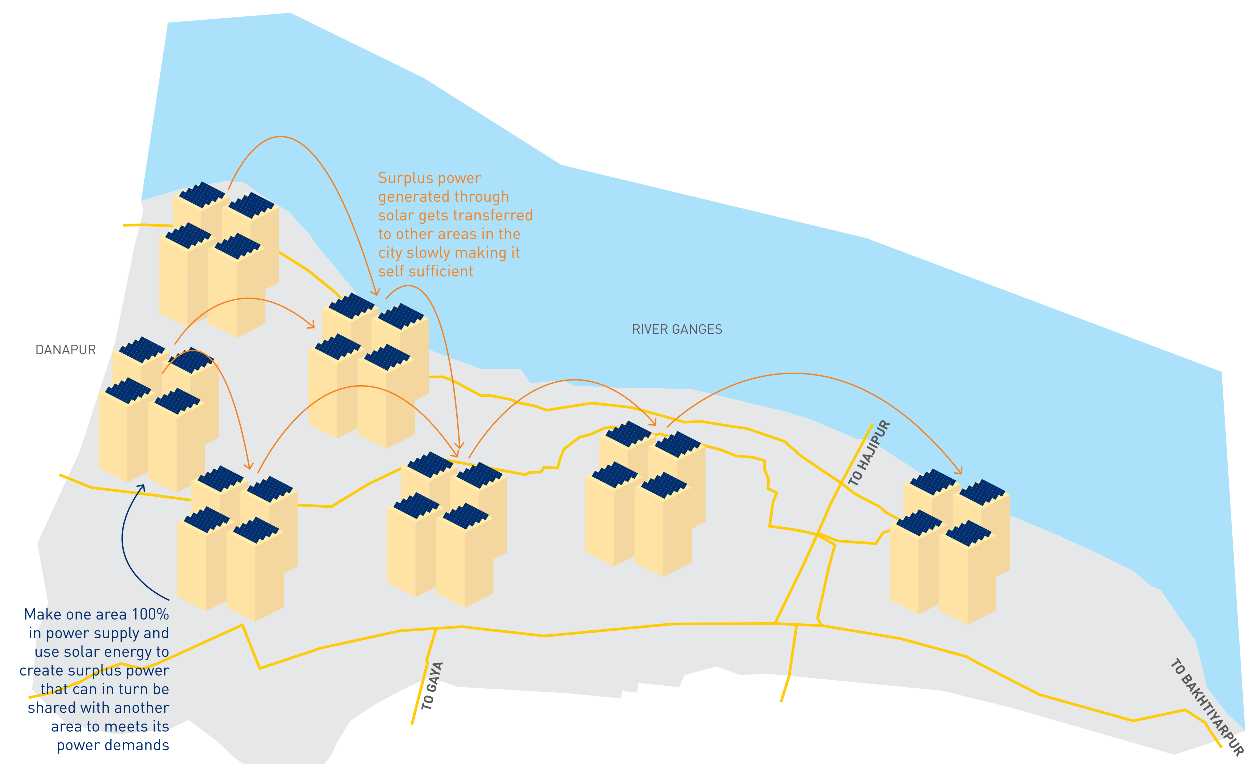




## Figure 14: Roadmap for solar in Patna[71]




## Figure 15: Solar spillover effect

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71 BRIDGE TO INDIA analysis

# 6 The required government support

*The government needs to create an ecosystem as soon as possible for a steeper decline in soft costs*

When is the best time for the government to start supporting solar? Should Patna start today, or only once parity is reached? We believe it should start now already, because the government needs to help create an ecosystem of suppliers and installers with experience and track records so that as soon as parity for consumers is reached, the market can fast expand. Consumer awareness and consumer market confidence will also play a key role and they grow only gradually over multiple years. In addition, the faster the government ramps up solar capacity addition, the steeper will be the decline in the soft costs associated with the installation of the system (labor, maintenance, civil etc.) and parity will be achieved faster.

In chapter 3, we mentioned that the government is already incurring a loss of ₹0.5/kWh ($0.008/kWh) for each kWh delivered to residential consumers in Patna. This can increase to ₹5.0/kWh ($0.08/kWh) by 2025. In the following section, the calculations for incentives are performed by considering the landed cost of conventional power as the actual cost of power to the government.

## 6.1 Capital subsidy

A direct capital subsidy is the easiest way for the government to incentivize solar, because it involves a single transaction. The subsidy simply brings down the system cost to a level, where it becomes an attractive investment proposition. Until 2014, the MNRE subsidy (30%), for example, has spurred around 40 MW of solar rooftop installations all over India[72].

The major drawback of a subsidy scheme is that it is not linked to actual generation and plant performance. This typically leads to overpriced and underperforming systems and attracts businesses that focus more on skimming off the subsidy than on implementing a functioning system. Buyers of systems, in turn tend to opt for the cheapest product in the market, which leads to low quality standards. In the past, this has led to many inefficient and unreliable systems being installed, which has tarnished the reputation of solar in certain markets.

*An additional subsidy of 20% on top of the 30% MNRE subsidy would make rooftop solar viable*

If Patna opts for a subsidy approach, it should learn from past experiences and develop a more effective mechanism. The framework should monitor the quality of equipment installed and the performance of the systems through their lifetimes. This can be achieved by putting in place standards and processes. The challenge is to not make such a framework excessively bureaucratic or costly for the industry.

As per the current landed cost of conventional power, the government in Patna would need to provide an additional subsidy of 20% on top of the 30% MNRE subsidy (assuming it is available) in order to bridge the viability gap between the cost of solar and the grid tariff (the total subsidy to the consumer would be 50%). The quantum of subsidy required will reduce every year as we expect the grid tariffs to rise and the viable solar tariff to fall. In 2015, the subsidy required

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72 Ministry of New and Renewable Energy

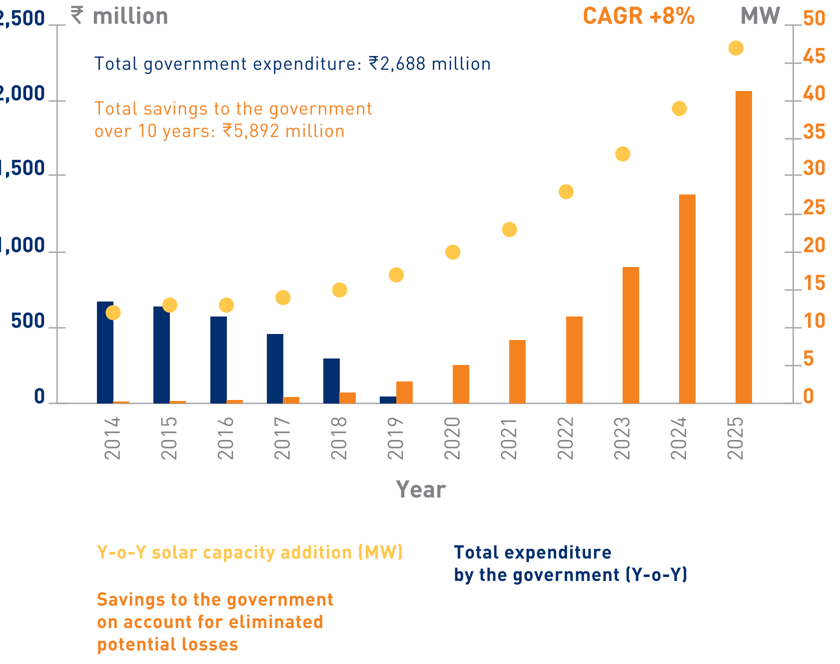




will be only 39% in 2016 and 2% in 2019. Subsidies won't be required from year 2020 onward. The subsidy required is illustrated in figure 16. In total, the government would need to invest ₹2,688 m ($45 m) over five years. In return, the government would accrue savings on account of avoiding losses to the tune of ₹5,892 m ($98 m) over the next ten years.

*A capital subsidy of ₹2,688 m over five years would help save ₹5,892 m over ten years*

**Figure 16: Annual expenditure under a proposed subsidy mechanism[73]**




## 6.2 Generation based incentives

*Under a GBI mechanism, an investment of ₹1,496 m over seven years would help save ₹5,892 m over ten years*

In contrast to the subsidy mechanism, GBIs don't reduce up-front costs. They generate additional periodic revenue, typically based on the generation that makes the ROI of the plant more attractive. In this way, the government can monitor the performance and the consumers will be motivated to spend extra to purchase quality systems. This mechanism is more cumbersome than the subsidy mechanism to implement, as it involves periodic accounting of energy and checking for pilferage or malpractices. However, it is easier to finance as government expenditure is spread out over multiple years. Also, the total government expenditure is lesser than that of subsidy route.

Under this mechanism, Patna would need to make an investment of ₹1,496 m ($25 m) spread over a period of seven years. The annual spending does not rise above ₹300 m ($45 m).

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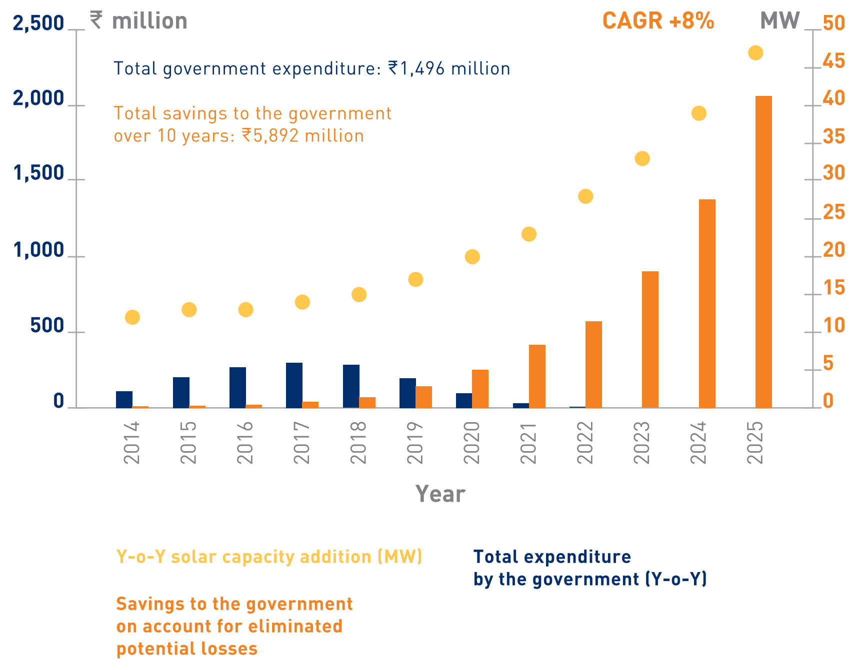
73 BRIDGE TO INDIA financial model

**Figure 17: Annual expenditure under the proposed GBI mechanism[74]**




## 6.3 Single window, low cost, long term financing

*A soft loan program coupled with the GBI program could reduce the government investment to ₹341 m*

A low cost financing mechanism (also called "soft loan") seeks to address both the up-front liquidity barrier of the solar system and the viability of a solar power plant. The ideal loan program should offer subsidized, lower interest rates (4-6%) with a long repayment tenure and low transactional expenses. Similar to the subsidy scheme, an effective mechanism to monitor the quality of equipment has to be incorporated.

A loan program at 5% interest rate would reduce the subsidy burden of the state from around ₹2,688 m ($45 m) through only subsidy route to ₹1,085 m ($22 m) via low cost financing route with subsidy. In case the soft loan program is coupled with the GBI program, the cost to the government will go down from around ₹1,496 m ($25 m) to ₹341 m ($6 m). Soft loans could be backed or even directly administered by impact funds from international development banks, foundations or dedicated private funds.

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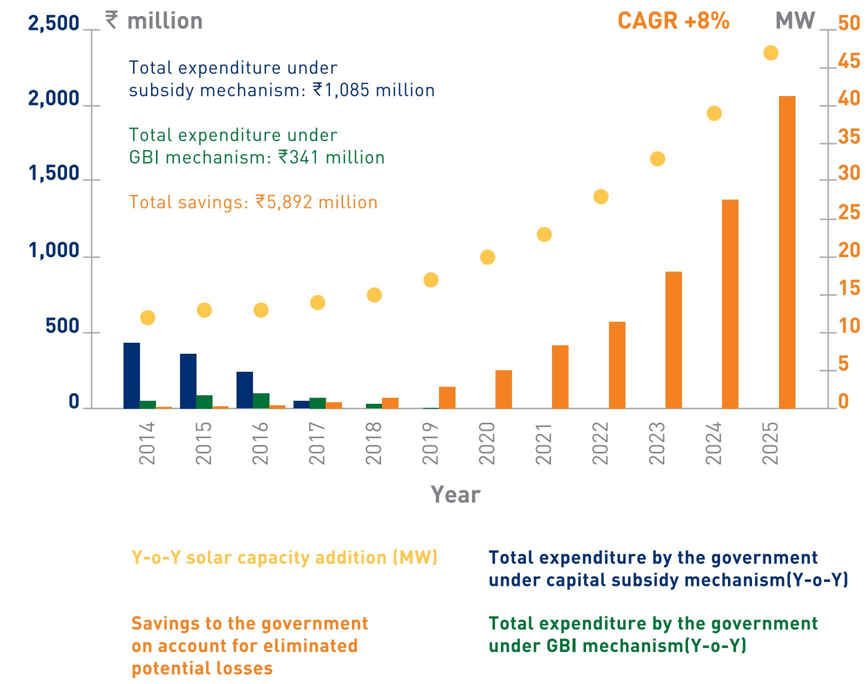
74 BRIDGE TO INDIA financial model

75 BRIDGE TO INDIA financial model
We expect Bihar government to raise development fund at 4% interest rate for solar deployment. With 5% default rate and 0.75% transaction cost, government will be able to provide low cost financing at 5% for rooftop solar installations.






**Figure 18: Annual expenditure under subsidy or GBI mechanism, including a soft loan mechanism[75]**




## 6.4 Group purchasing

*With community ownership, the cost of solar power can be further reduced*

Already an established program in the United States, this makes a lot of sense for Patna, keeping in mind the district-by-district approach we have proposed for adoption of solar. Patna could organize district events wherein multiple home owners of a single neighborhood can come together to purchase solar power plants with loan programs and incentives. Scale would help reduce system costs and the government could minimize the time spent per application. Such a program could be combined with any of the previous support programs to make it more attractive. This is also perhaps the easiest program for the government to implement.

In the US, Valley Collaborative Renewable Energy Procurement (SV REP) was a program launched by Silicon Valley Network's Public Sector Climate Task Force, in partnership with the County of Santa Clara, California in 2010. The program aimed at bringing municipalities together to identify potential solar sites on municipal properties, negotiate a better group rate with contractors, and create a standardized financing and procurement process. Nine local governments participated in the SV REP project. As a result, 70 installations at 40 locations totaling 14.4 MW were identified. The sites – government facilities such as offices, fire stations and community centers – were bundled into large, medium and small rooftop plants, and quotes were requested from installers for each bundle. Other than achieving more favorable contract terms, the project resulted in significant savings for the program participants by way of reduced installation costs (ca. 12%) and reduced administrative costs (75-90%)[76].

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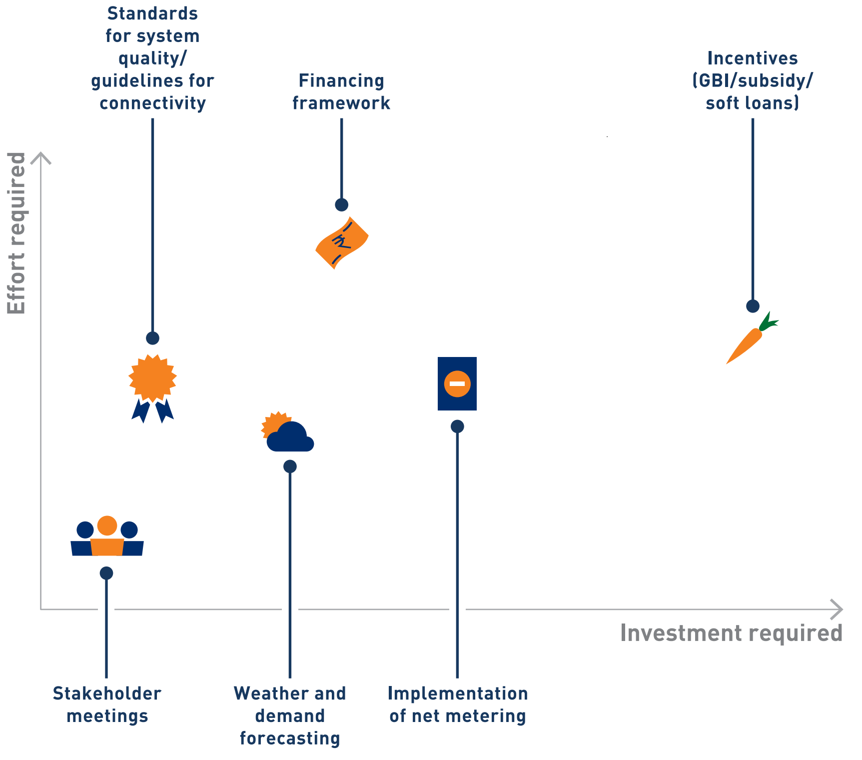
76 SF Environment website, **http://bit.ly/1fUKOwL**

# 7 Government policy recommendations

In addition to the commercial viability of solar, discussed above, the development of a successful, efficient and productive solar market in Patna would require overcoming other, non-commercial barriers, too. These barriers include grid connectivity, energy accounting (net metering), quality benchmarks, performance monitoring mechanisms, consumer awareness and a trained workforce among other things. Patna is well positioned to remove many of these barriers to clear the way for widespread adoption of solar power.

**Figure 19: Overview of policy recommendations**




*The government set standards for solar equipment to ensure quality*

## 7.1 Standards for system quality

First and foremost, it is extremely important that the government sets standards for solar equipment to ensure that the quality of installations is not compromised. Sub-standard quality may lead to consumers doubting the technology itself, which in turn could discourage more consumers from going solar. This would have a detrimental effect on the overall development of the market. One such measure, initially, could be a regular monitoring of installers. Another could be an online rating mechanism, which encourages customer feedback. In addition, there are a number of standards and certifications on products and processes that can be implemented.





## 7.2 Financing framework

Banks are still generally reluctant to provide financing solutions to solar as the bankers at the last mile who are scrutinizing the projects are often not yet well enough informed about the technology. The primary issue faced by banks in providing such loans is the bankability of the product.

The government could help through making available important information on irradiation, generation and overall plant performance to create more knowledge and transparency in the market. It might also be worthy option to create a dedicated non-banking financial company (NBFC) for providing loans to the end-customers. Once other lenders start understanding the investment product and as the market grows, they will likely develop competitive financial solutions for infrastructure and consumer finance.

The government could also consider setting up a risk guarantee fund for banks to lend more readily. This is currently being implemented, for example, by the Solar Energy Corporation of India (SECI).

*The government could also consider setting up a risk guarantee fund for banks to lend more readily*

## 7.3 A robust incentive support system

It is of the utmost importance that any incentive scheme is transparent and reliable. The incentives promoting solar should be backed by funds. The state government in its budget could either allocate funds for this purpose or a 'green cess' could be imposed on bulk consumers or polluting industries. The effectiveness of an incentive, no matter how attractive it is, depends on its timely disbursement. The disbursement mechanism should be simple (single window) without procedural delays or unnecessary paperwork. For example, in the case of group purchasing model suggested, the incentives could be cleared on the spot for a single locality.

## 7.4 Stakeholders meetings

The government should bring together all stakeholders who can be instrumental in helping promote the adoption of solar. These would include the various regulatory bodies such as BREDA, BIADA, BERC, the power utilities, central government agencies, civil society representatives, installers and financial institutes. These meetings could help address concerns of the various stakeholders. Potential concerns include: the DISCOMs' fear of a loss of revenue or of the effect of opening up the grid to private power producers and intermittent power sources, financiers' questions about the bankability of solar and incentive schemes, or government bodies who might not understand the economics of solar. Stakeholder meetings can also bring together facilitating agencies such as resident welfare associations (RWAs) that could play a crucial part in deployment. Such interactions would ensure that roadblocks are identified early on and can be addressed in a comprehensive manner.

## 7.5 Implementation of net metering

Net metering compensates consumers for any part of the solar generation that is not consumed at that instance. Excess power can be exported to the grid and (for accounting purposes) can be subtracted from the total power drawn from the grid. Peak load for residential consumers occurs during the morning and evening hours, compared to the solar peak generation during the afternoon. From the customers' perspective, net metering can take care of such imbalances without the need for storage. Similarly, most commercial consumers have a peak in the afternoon and only run partial loads during holidays. Any excess power generated on holidays can be drawn back during peak hours during the month or accounted for in the monthly bill.

Currently, installed power meters across the country are typically not equipped for bi-directional flow of current (i.e. also back from customers to the grid). For net metering this would have to be changed. This would essentially require upgrading the transformers and relays as they are designed to trip whenever a reverse flow of current occurs. Based on estimates from stakeholders[77], the cost of upgrading meters and transformer relays would be around ₹5,000 ($83) per connection.

Implementation of net metering in Patna would need to follow the same roadmap as followed by solar i.e. upgrading of meters should first be carried out in areas with a good power supply. Then it could be implemented in a phase-wise approach.

*Advanced forecasting tools and protocols will ensure the optimum utilization of solar systems*

## 7.6 Guidelines for connectivity

Patna has a significantly weaker grid and far more outdated infrastructure than Tier I metro cities such as Delhi, Mumbai and Bangalore. Therefore, the grid connectivity challenges will be tougher. Voltage and frequency fluctuations, unintentional islanding, reverse power flow, increased wear on utility equipment, and reactive power imbalances are some of such issues. With the help of detailed connectivity standards and protection devices, these challenges can be mitigated to a large extent. IEC-61850, for example, is an international set of guidelines that describes various standards and protocols for interconnection of devices with the grid. IEC is followed in e.g. Germany and the USA.

## 7.7 Improved forecasting techniques

To achieve the targets stipulated in the roadmap smoothly, Patna would need to adopt improved demand and weather forecasting techniques. Patna's current power management has limited diagnostic, accounting, control and forecasting capabilities. While long-term forecasting is easier to perform, it is a challenge for most DISCOMs to perform short-term forecasting of both demand and energy output (i.e. weather conditions).

Forecasting for conventional power planning is done on a daily basis already. However, integration of solar power would require forecasting and planning to be more frequent and accurate as even a single cloud can impact generation output. Close track of cloud movements and accurate weather predictions would enable utilities to manage solar effectively and also optimally utilize different power resources at its disposal. While it is nearly impossible to achieve 100% accuracy, advanced forecasting processes can mitigate a large part of this risk. This will also reduce the need to procure short-term expensive power.

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77 Central Electricity Authority and Puducherry Electricity Authority, BRIDGE TO INDIA industry research and projects




## 7.8 Master plan 2031 for Greater Patna to include a "smart solar city"

*The master plan 2031 must include a provision for a smart and responsive grid*

Urban development ministry of Patna is about to release the draft of master plan 2031 for Greater Patna. We recommend that this plan must include provisions to ensure that Greater Patna can truly become a smart solar city. Some of the structural recommendations that must be added are:

1. **Power distribution and grid management infrastructure**
   The city must aim for a properly regulated private distribution of power. At the time of inviting bids for interested private parties, provisions for a smart and responsive grid must be put forth. A mandate for developing Greater Patna into a solar city must be ensured. This would require state-of-the-art power distribution infrastructure and grid management hardware and software,
2. **Planning for a smart solar city**
   The city planners must ensure that all the new construction in the city is 'solar ready'. This would mean the following: north-south aligned construction of buildings, clutter free rooftops, similar height for all construction in an area, minimum obstruction on the south side of each rooftop and a minimum structural strength required to accommodate solar installations.
3. **Securing financial assistance for a solar city**
   The state must try to tie up for sufficient funds under the central schemes such as 'smart cities' plan and 'solar cities' plan. The state must also commit to its own funds to ensure that the work is planned, started and completed in a professional manner.

*The city planners must ensure that all the new construction in the city is 'solar ready'*

# 8 Business models for rooftop solar adoption

There are several models that can facilitate adoption of rooftop solar power plants. We have elaborated on two key models that we believe are suitable for Patna.

## Traditional sales channel

*A key product innovation for speedy adaptation in Patna could be an all-in-one, easy to install solar kit*

The most common business model for solar deployment in India today is to simply sell a complete plant or system. This is typically done by an EPC company or a local installer. Alternatively, individual components (such as modules or inverters) for small systems are sold directly to an end customer. The plant owner pays 100% of the PV system cost upfront. This model (sometimes referred to as the "capex"[78] model) is pursued by most solar companies, including Tata Power Solar, Emmvee Photovoltaics and Moserbaer.

The model is ideal for consumers that are able and willing to invest the entire amount for a solar system upfront. A key USP of this model is that it allows industrial and commercial consumers who own the system to claim tax depreciation benefits (80% tax depreciation in the first year). In Patna, however, where the residential sector is by far the largest, such a model might soon face limitations.

A key product innovation that would speed up adaptation in the residential sector in Patna could be solar kits. Solar kits are all-in-one, easy to install solar power plants that can easily be installed by a local electrician or even the user, just like a normal household inverter. These kits should be 1-3 kWp in size. This market could be further facilitated by banks willing to provide consumer loans.

## Third party ownership (RESCO[79] model)

*Third-party ownership models include the lease and the PPA model*

This model is ideal for consumers who do not wish to invest a significant amount upfront. A third party investor would finance the plant, obtain necessary permissions, build it and operate it – and then sell the power to the customer.

In addition to not having to make the original capital investment, the advantage for the consumers is that they do not have to go through the process of installing, operating and maintaining a power plant. For the investor, the key value is the long-term revenue stream.

The two sub-models for third-party ownership are:

1. **Lease model**: The plant owner offers the power consumer a fixed monthly or quarterly payment option irrespective of the amount of units consumed.
2. **PPA model**: The consumer and the plant owner agree on a fixed per kWh price for solar power over a period of time (typically 10-25 years).

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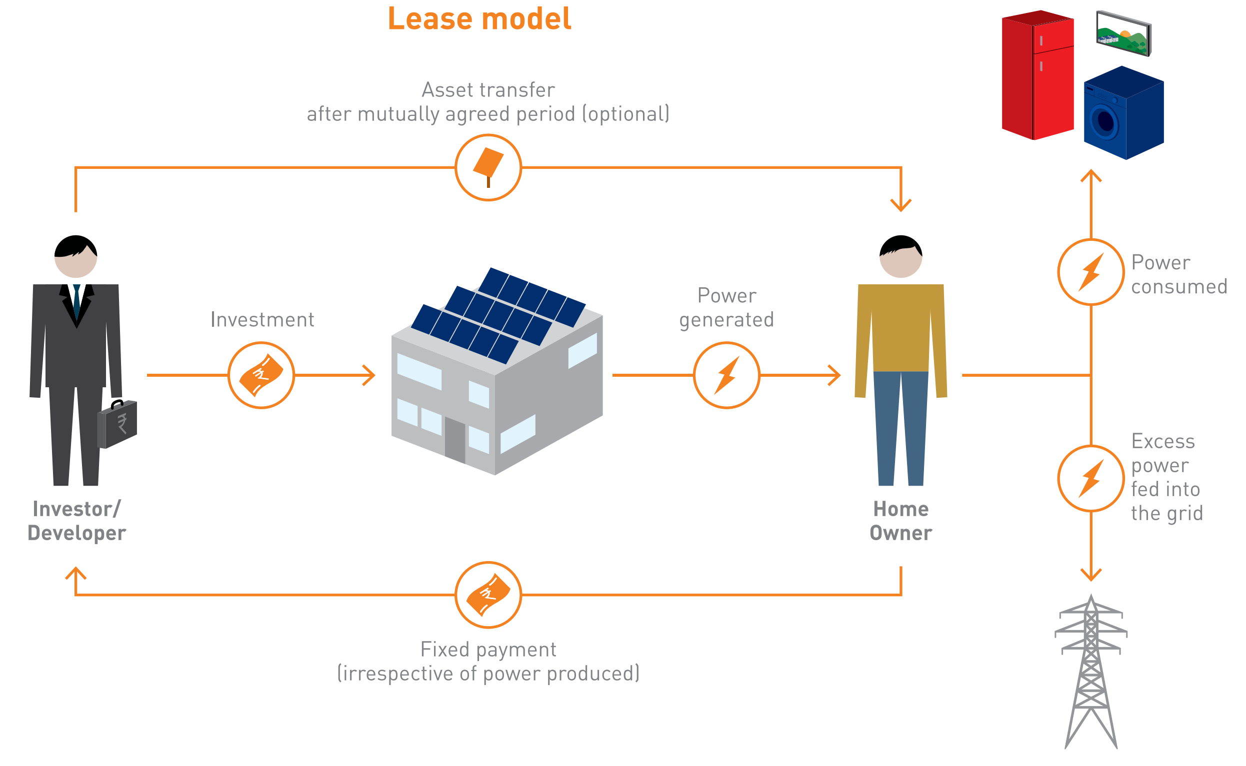
78 CAPEX is the capital expenditure or expenditure on the total cost of a power plant.
79 Renewable Energy Service Company



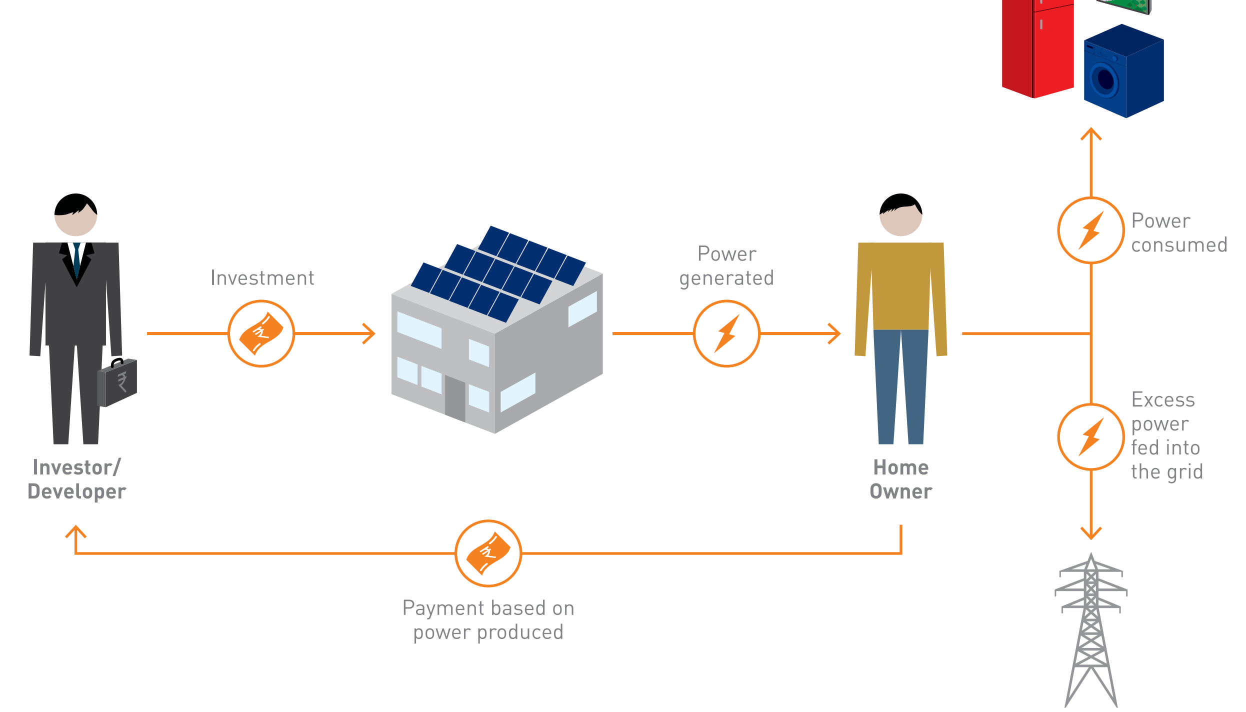


During the tenure of the agreement, or at the end of it, the consumers typically have the option of buying out the power plant at a mutually agreeable or a pre-determined price. A challenge associated with this model is the bankability of consumers and timely payment of bills.

### Figure 20: Lease model




### PPA model



In addition to the business models discussed above, we believe a community ownership model would be more effective.

## Community ownership concept

*A community ownership concept can increase individual system sizes and reduce costs*

As opposed to the traditional model of a single project on a consumer's rooftop, there are ways to pool consumers and rooftops in a community model. The main benefit is that it increases the size of the project and reduces the system and transaction costs.

Such a model would be good for apartment complexes or residential colonies. If most residential consumers are willing to invest, resident welfare associations (RWAs) can initiate the process. This will give the customers the benefit of scale. Furthermore, EPC companies can tie up with investors and become RESCOs[80] for such projects.

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80 Renewable Energy Service Company (RESCO) installs a power plant, in this case solar, on an operational expenditure model. The customer pays for the electricity as consumed.




# 9 Benefits to stakeholders

## 9.1 Benefits to Patna's DISCOMS

*Distributed solar power generation can decrease the variability and have a positive influence on grid stability and voltage fluctuation*

Support from utilities is key to the development of grid-connected rooftop solar. Utilities need to facilitate the interconnection of individual solar systems to the local grid network. In the absence of commercially viable storage solutions, such interconnection would allow the evacuation of any excess solar power generated (and hence avoids wastage) to grid and is needed for drawing power when solar is not available. The experience and knowledge of utilities in managing the grid, balancing power and billing the end consumers will be a key piece of the solar puzzle.

Small grid connected, distributed generators located across Patna would require the utility to plan for a lower and more volatile power demand. Up to a certain limit, distributed solar power generation can have a positive influence on grid stability and voltage fluctuation. This increase in spatial distribution decreases the variability to a significant extent[81]. Also, the overall power lost in distribution grids reduces as more power is generated at the point of consumption.

Utilities should see solar as part of their overall supply strategy. In the long term, the utilities should play the role of a power producer and invest in solar themselves. Moreover, by adding solar, the utilities can further reduce their dependence on borrowed power. Solar will become a very important part of India's energy mix. This should be regarded as an opportunity, rather than a threat.

## 9.2 Benefits to Patna's government

Apart from the advantages of energy independence, reduced power deficit and reduced financial losses, there would be several societal benefits associated with the adoption of solar power.

### Reduced pollution

*Solar could reduce the level of pollution by partially replacing polluting diesel gen-sets operating within the city*

As per the Bihar State Pollution Control Board, Patna is the most polluted city in the state and one of the most polluted cities in the country. The values for respirable suspended particulate matter (RSPM), for example, are very high. Near Gandhi Maidan it is around 233 micrograms per cubic meter (ig/m$^3$) almost four times the permissible level of 60 micrograms per cubic meter[82]. This, in turn, has led to an increase in the number of respiratory disorders and cases of heart diseases. For the city with such high residential population proportion, this number of RSPM is alarming. It is important for the government to make a gradual shift to cleaner sources of power such as solar to improve the health and lives of all residents. Solar could reduce the level of pollution by partially replacing polluting diesel gen-sets operating within the city.

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81 BRIDGE TO INDIA is currently performing a study on the impact of distributed generation on the power grid.

82 Times of India (2014) **http://bit.ly/1a3caQL** (confirmed with Bihar State Pollution Control Board)

## Employment

Solar has the potential to create new jobs in the city for the sales/development, installation and maintenance of the plants. As per our report on "India's Solar Transformation: Beehives vs Elephants", residential rooftop installation could create 39 jobs per MW along the entire value chain[83].

*Power provided by solar has the potential to reduce the need of expensive alternatives such as diesel*

## 9.3 Benefits to consumers

Provision of additional power at a lower cost, in the power deficient city of Patna, is the primary benefit that solar provides to the city's residents. Several parts of Patna face long power outages during the searing hot summer. Residents have to rely on expensive devices such as battery-based backups and diesel gen-sets. Not only do these devices have a cost of procurement, but the power generated by them is substantially more expensive than grid power. Stored power can cost around ₹10/kWh ($0.17) considering a four hour backup requirement and replacement of batteries every four years. Diesel power can go up to ₹17/kWh ($0.28). The additional power provided by solar has the potential to reduce the need of expensive alternatives such as diesel. Further, rooftop solar plants installed within the city give an added advantage of energy independence to residents. As a local, de-centralized source of power, rooftop solar allows consumers to be in control of their electricity supply and less dependent on the grid.

Solar also mitigates the risk of future power tariff increases. Considering that the state DISCOMs run large financial losses and the fact that conventional power is becoming increasingly more expensive, tariffs are bound to rise. Though the power tariffs in Patna had been kept stable till 2010, a 31% hike since 2010 shows that an adjustment is taking place at a quicker pace.

*Solar mitigates the risk of future power tariff increase*

The story of Delhi is instructive. T&D losses in 2002 were as high as 48%[84] and power distribution in Delhi was privatized. As a result, T&D losses in Delhi have reduced to less than 20% in 2013[85]. At the same time, power tariffs in the city increased by more than 70% since then to monetize the investments[86].

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83 "India's Solar Transformation: Beehives vs Elephants", under India Solar Decision Brief, **http://bit.ly/Vq9pmR**

84 Delhi Electricity Regulatory Commission, public hearing in the matter of tariff for FY 2013-2014, **http://bit.ly/LcLMbp,** page 22

85 "Working of state Power Utilities and Electricity Departments", by Planning Commission, published in 2012, **http://bit.ly/1gp49IR**

86 Tariff increase for domestic consumers from 2002 to 2012 DERC tariff orders **http://bit.ly/1mZzvVO**



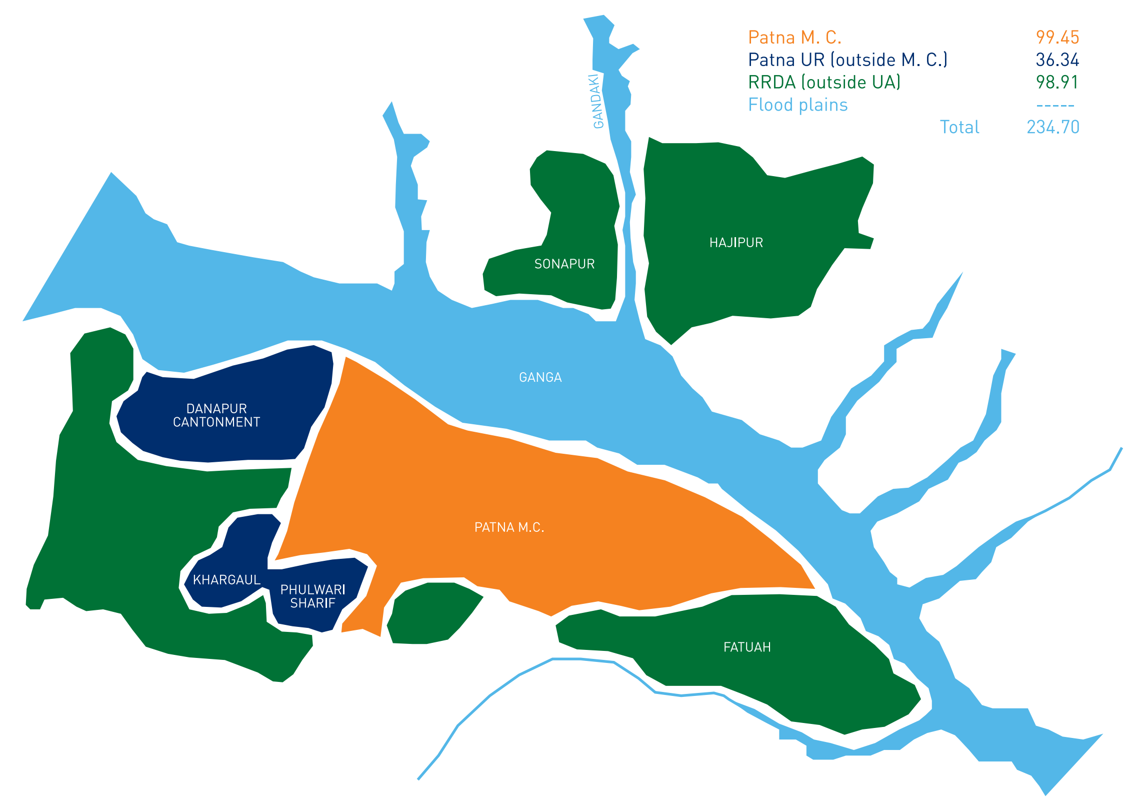


# 10 Annexure

## 10.1 Methodology for calculating the solar rooftop potential in Patna

For the purpose of administration, different areas of jurisdiction have been defined for the city of Patna, these are: Area under the Patna Regional Development Authority (PRDA), the Patna Urban Agglomeration Area (PUAA), and area under the Patna Municipal Corporation (PMC). The PRDA has the largest area that comprises of three districts of Bihar namely, Patna, Saran and Vaishali. The total area under the PRDA is 234.70 km$^2$. The PUAA comprises of the PMC area plus Phulwari Sharif, Khagaul and the Danapur Cantonment. The total area under the PUAA is 136 km$^2$. The area under the PMC mostly includes the Patna city area and has an area of 99.45 km$^2$.

### Figure 21: Segmentation of administrative blocks in Patna




For the purpose of this report, area under the PUAA has been considered, as it not only includes the main city but also the upcoming surrounding areas of the Danapur Cantonment, Khargaul and Phulwari Shariff. While the Danapur Cantonment is an army colony, Khargaul and Phulwari Shariff are suburbs that have increasingly populated and have witnessed the emergence of new residential colonies and commercial buildings such as malls and office buildings.

The premise of our analysis relies on information provided by the land use plan[87] developed by the Patna Municipal Corporation (PMC), the city

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87 Land use plan refers to the City Development Plan for Patna developed by the Bihar Urban Development Agency in 2006

municipality that administers the civic amenities and planning of the city. Though a Master Plan 2021 for Patna is being drafted, it has not been completed as yet. As we did not have a comprehensive land development plan to work with, our analysis is based on logical assumptions derived from conversations with related field experts. Information such as average plot sizes, measurements of individual buildings and area occupied by roads and civic amenities, has been calculated by using online mapping tools (Google Earth and Google Maps). Qualitative information (Such as quality of construction) about areas was obtained through site visits and from insights provided by architects[88], real estate developers, and other related agencies (such as the Bihar Industrial Area Development Agency).

Our analysis uses the framework used by the land use plan, which classifies the entire land area of the city into 10 categories: 'Residential', 'Commercial', 'Industrial', 'Recreational', 'Transport', 'Public and Semi-Public facilities', 'Government', 'Water bodies' 'Agriculture' and 'Vacant land'. Our analysis excludes the categories – 'Water bodies', 'Vacant Land' and 'Recreational', which include regional parks, water bodies and historical monuments. This is because most of these areas do not have built structures that can provide roof space. Further, any construction/alteration in such areas would require permissions from the Patna Municipal Corporation and the Ministry of Culture. The category 'Agriculture' has been further excluded from our analysis as it mainly comprises of land for cultivation with minimum actual built space that is required for rooftop solar installations.

For categories 'Residential', 'Commercial', 'Industrial', 'Transport', 'Public and Semi-Public facilities' and 'Government', we first determined the total land area available for designated uses from the information provided by the land use plan. We then discounted for roads, civic amenities, and irrelevant sub categories, if any, to reach the total plotted area. This discounting factor for trees, roads and pedestrian paths ranges from 40-60% for different land area types[89]. Further, we computed the area of built structures (raw rooftop space) either as per the specific development controls (coverage rates) pertaining to the type and size of plot area (wherever available) or by using an estimated coverage rate. Only built structures that were of sturdy concrete constructions were included in the computation of the potential rooftop space, such that they could bear the weight of the solar rooftop installations. Finally, we discounted for space that was obstructed with objects and structures and space that was shadowed to determine the solar suitable rooftop area that receives optimal sunlight for solar power generation. For each category, other factors specific to the categories were further discounted. For example, in the case of public and semi-public buildings, religious buildings and burial grounds were discounted.

For area category 'Transport', we have used a bottom up approach. This is because the cumulative figure provided by the land use plan includes area occupied by roads, bridges and railway tracks as well. Hence, we have mapped the areas of the built structures to reach a more representative figure.

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88 Architectural experts include: Sri Sachchida Nand, Architect (Bihar State Housing Board), Shri. Hari Shankar Singh, Architect (Urban Development and housing Department, Govt. Of Bihar), Mrs. Anamika Nandan, Assistant Professor and Co-coordinator, (Architecture Department of Birla Institute of Technology, Patna), Dr. A. K. Singh, Associate Professor and Incharge of Department, (Architecture Department of Birla Institute of Technology, Patna)

89 The discounting factor was considered after analyzing sample sites for each land area types and after consulting architectural experts.





## 10.2 Computation of the solar suitable rooftop space for different land areas

### 10.2.1 Residential buildings

The total residential area as per the land use plan 2006 is 82.30 km$^2$. Out of the total residential area, 92% is unplanned. This means that only 4m$^2$ of the residential area has been planned by the City Municipality, where buildings constructed follow development controls. The unplanned residences largely disregard the building bye laws. Hence, for the planned residences a ground coverage rate of 60%[90] has been considered. For unplanned residences, it is assumed that as much as 85% of the plot area is occupied. The total built area is thus computed to be 41 km$^2$. From this, slums, that occupy 0.42 km$^2$, have been discounted and 30%[91] of residential buildings that are old and are of substandard construction quality are discounted. Further, another 30% is discounted to exclude low-income residential colonies that may not be able to shell out the investment required for rooftop solar installations. The qualified rooftop area after discounts amounts to 19.64 km$^2$.

The rooftops of residential buildings have certain obstructions by way of water tanks, drying clothes' and storage space. Despite this, significant space remains unoccupied because most rooftops are not used for rooftop gardens or leisure activities like in the case of a metropolitan city like Delhi. Hence, the solar suitable space of residences is assumed to be around 40%[92] of the rooftop area.

Sample colonies that were considered include Kankar Bagh, Patliputra Colony and Sri Nagar Colony, Chajju Bagh, Ashok Nagar etcetera.

### 10.2.2 Commercial buildings

This land area type includes retail shopping centres, commercial centres, wholesale markets and smaller shops and utility stores.

To determine the solar suitable rooftop space offered by commercial buildings we have used cumulative figures provided by the land use plan. The development controls for this land area type are not available. However, the urban development and Housing Department of Bihar stipulates the coverage area for shopping malls and multiplexes as 50% for the entire state of Bihar. Average ground coverage rate hence taken for the analysis after assessing sample sites is a reasonable 40%. The total land area designated for commercial use is around 2.98 km$^2$, which offers a built area/rooftop area of around 0.36 km$^2$.

Around 60%[93] of commercial buildings comprise of small shops, stand alone convenience stores and utility shops. We discounted a reasonable 40% of the total area that belongs to such small-sized shops. Such buildings have an area less than 400 m$^2$. But the roof is mostly cluttered with chillers and water tanks. Solar suitable roof space is generally less than 15%. These small buildings are

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92 Unoccupied, unobstructed roof space of colonies was determined by assessing samples in Kankar Bagh, Patliputra Colony, Kazanchi Road, Sri Nagar Colony and Ramna Road. The solar suitability of rooftops ranged from 25-50%. We have assumed a reasonable 40% for the purpose of this report.

93 As per our interactions with architectural experts

hence discounted from our analysis. We further discount 30%[94] for old building structures from the remaining area of commercial buildings to get the total qualified rooftop area of 0.36 km$^2$ for our analysis.

As per our analysis of commercial buildings using Google Maps, their rooftops are cluttered with cooling towers, ventilating shafts and water tanks, reducing the solar suitable roof space. The percentage of solar suitable space for commercial consumers has been determined after analysing sample commercial areas such as P and M Mall and Hotel Chanakya. The solar suitable area is a mere 35% as larger commercial buildings tend to have structural barriers or elevations, such as domes, glass panels etcetera.

### 10.2.3 Industrial Buildings

Within the PUA, the only industrial area is the Patliputra industrial area, which mainly comprises of metal goods manufacturing, export oriented agro products such as rice mills, tea and sugar packaging and electrical goods servicing. Most large industries fall outside the purview of the PUA area while still within the boundaries of the PMRD area.

For data on industrial buildings, we used cumulative figures provided by land use plan issued by the Bihar Urban Development Agency. The total land area in Patna that is designated for Industrial use is around 2.38 km$^2$. Out of this area, 60% of the area has been assumed to be available for industrial plot development, which amounts to around 1.43 km$^2$. The built area/raw rooftop area available for solar rooftop installations is around 40%[95] of the total area available for plot development, which gives rooftop space of around 1 km$^2$. We discount 10% of the area for structures that might be old and not suitable for solar installations. Our analysis further discounts 10% for very small industries. Very small industries (such as electrical goods servicing and repairing) have been excluded, as they are too small to accommodate the size of solar installations that could meet their power needs. The total qualified rooftop area after discounts is 0.46 km$^2$.

Based on our analysis of samples through Google Maps and site visits, plot sizes in industrial areas commonly exceed 600 m$^2$. Even with roof space occupied by boilers, cooling units and shafts, industrial buildings tend to offer the maximum solar suitable rooftop space among all categories of around 65%. This gives solar suitable rooftop space of 0.30 km$^2$.

### 10.2.4 Government buildings

This category includes areas belonging to government courts, government office complexes and land allocated for undetermined government use. In our analysis, we have considered unoccupied government land as built-up land based on an understanding that the city of Patna will eventually be entirely built. Government buildings are commonly concrete structures with average plot sizes upwards of 1,000 m$^2$. This means they are likely to provide reasonable unoccupied unobstructed roofspace for solar installations

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94 Like residential, most commercial buildings in Patna are old constructions. There are only 7-8 new shopping malls are in place. Recently new office complexes have been developed, however, mainly in the outskirts. Some of these fall in the areas of Phulwari Shariff and Khargaul as well.

95 Coverage rate as per BIADA (Bihar Industrial Area Development Agency) official





The total land area designated for government use is around 2.11 km$^2$ [96] and 80% of the area i.e.1.69 km$^2$ is assumed to be plotted for development. The total built area/rooftop area available for solar power installations is 50%[97] of the plotted land area, which is 11.3 km$^2$. We further discount 10% of the area for structures that might be old and unable to bear the weight of solar installations. Thus, the total qualified rooftop is 0.76km$^2$. The solar suitable rooftop space offered by government buildings is assumed to be around 40%[98], which is fairly larger than other land area types, considering their rooftop space is commonly free from elevator shafts and cooling towers. There are structural barriers in case of some buildings that may cause shadowing but largely the roof space is unobstructed. The solar suitable rooftop space of government buildings is 0.30 km$^2$.

### 10.2.5 Public and semi-public facilities

Public and semi-public facilities include hospitals, educational institutions, universities, colleges, social and cultural complexes, stadiums, police stations, fire stations, religious buildings, burial grounds and crematoriums. Such buildings are commonly large, well-built structures that provide a fair amount of unoccupied rooftop space. In addition to that, government bodies administer many of these buildings (approximately 30%), which is an added advantage as the government can play a direct role in ensuring that these facilities install rooftop solar installations.

The total land area designated for public and semi-public facilities is around 6.51 km$^2$. We exclude religious buildings and burial grounds from the total area as they do not have much built up space to begin with. In addition to that, a solar plant may not be wanted at such a place. Further, 40% is discounted for trees, roads and other open spaces giving total plotted area of 3.61 km$^2$. Of the plots, it is assumed that around 35%[99] is built giving a total built area/raw rooftop area of 1.26 km$^2$.

Among such buildings there may be structures that are old and unable to bear the weight of solar installations (these include police stations and fire stations). A discount of 10% is taken for such buildings to reach a qualified rooftop potential of around 1.14 km$^2$.

Based on our analysis through Google Maps and site visits, the solar suitable rooftop space on all public facilities is around 45% (Sites include Indira Gandhi Planetarium, Loyola School, Patna University Main building). This takes into consideration that rooftops of most public facilities are occupied by water heating systems, cooling towers, and elevator shafts. Thus, solar suitable rooftop space is a total 0.51 km$^2$.

### 10.2.6 Transport buildings

The category for "Transport" includes all areas under airports, railway stations, bus depots, railway tracks, road and bridges. For the purpose of this analysis, instead of considering the area provided by the land use plan we have used a

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96 As per the Land Use Plan by the Bihar Urban Development Agency

97 As per interactions with architectural experts

98 The % for solar suitability has been determined after mapping areas of sample sites (Patna High Court, Patna Secretariat and Raj Bhawan) and using online mapping tools

99 An estimate based on consultations with architectural experts. Ground coverage not available from the government.

bottom up approach. This is because there is very little built area under such transport facilities to begin with. Hence, we have used online mapping tools to individually map and compute the built solar suitable area for each transport facility (Railway stations: Patna Railway Station, Gulzarbagh Railway Station, Patliputra Station, Patna Sahib Station, Rajender Nagar terminal, Danapur Railway station, Patna airport and bus depots: Mithapur Bus stand and Gandhi Maidan depot). The total solar suitable rooftop area for buildings under this category is around 7,202 $m^2$.

## 10.3 Rooftop solar PV systems

This section deals with the overview of a solar PV system, working of a PV system, different components, their sizing and connections. Further, we have analyzed relevance of storage in PV systems, the importance of net metering and the typical PV system sizes across different consumer segments.

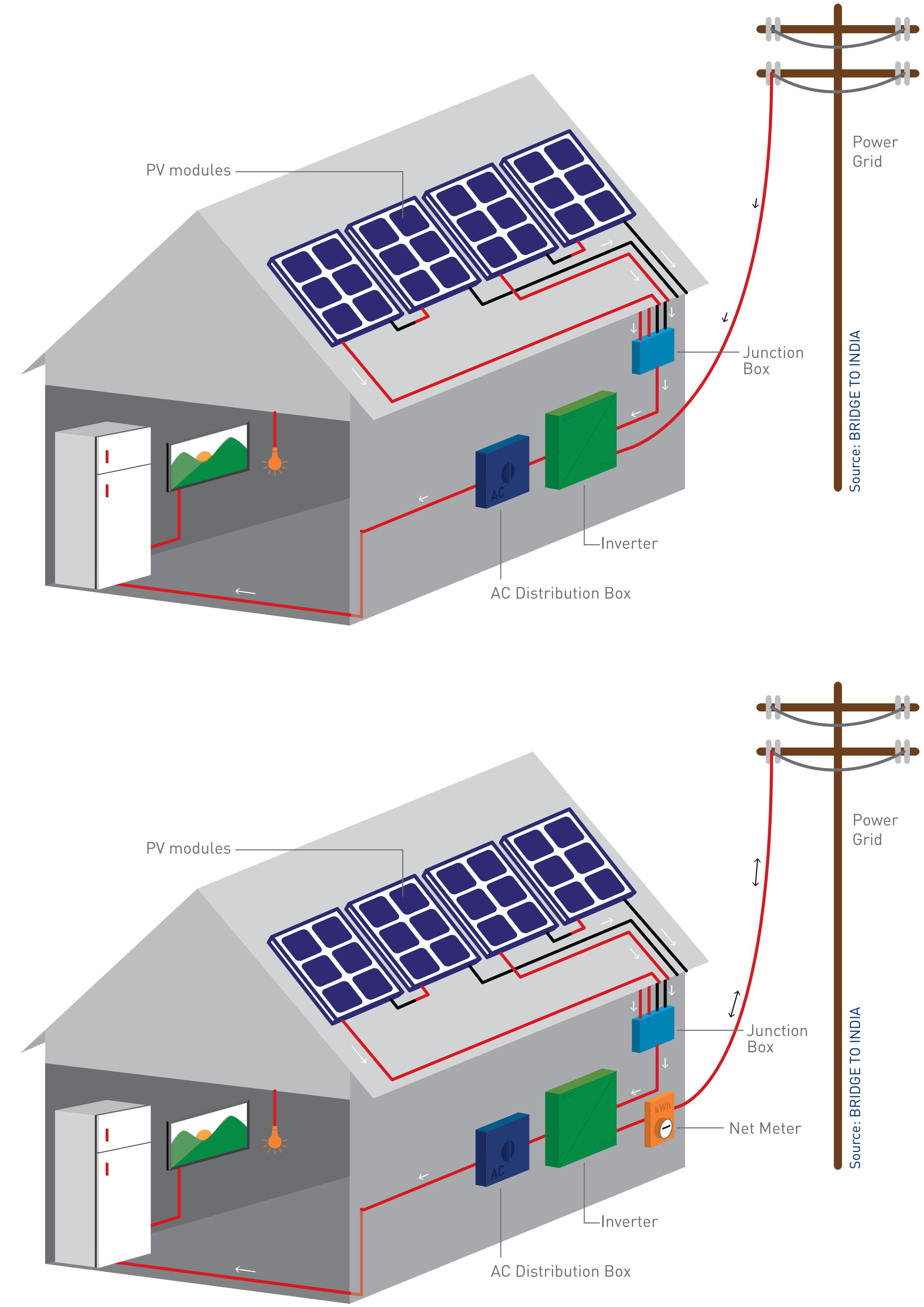
### Functioning of a PV system

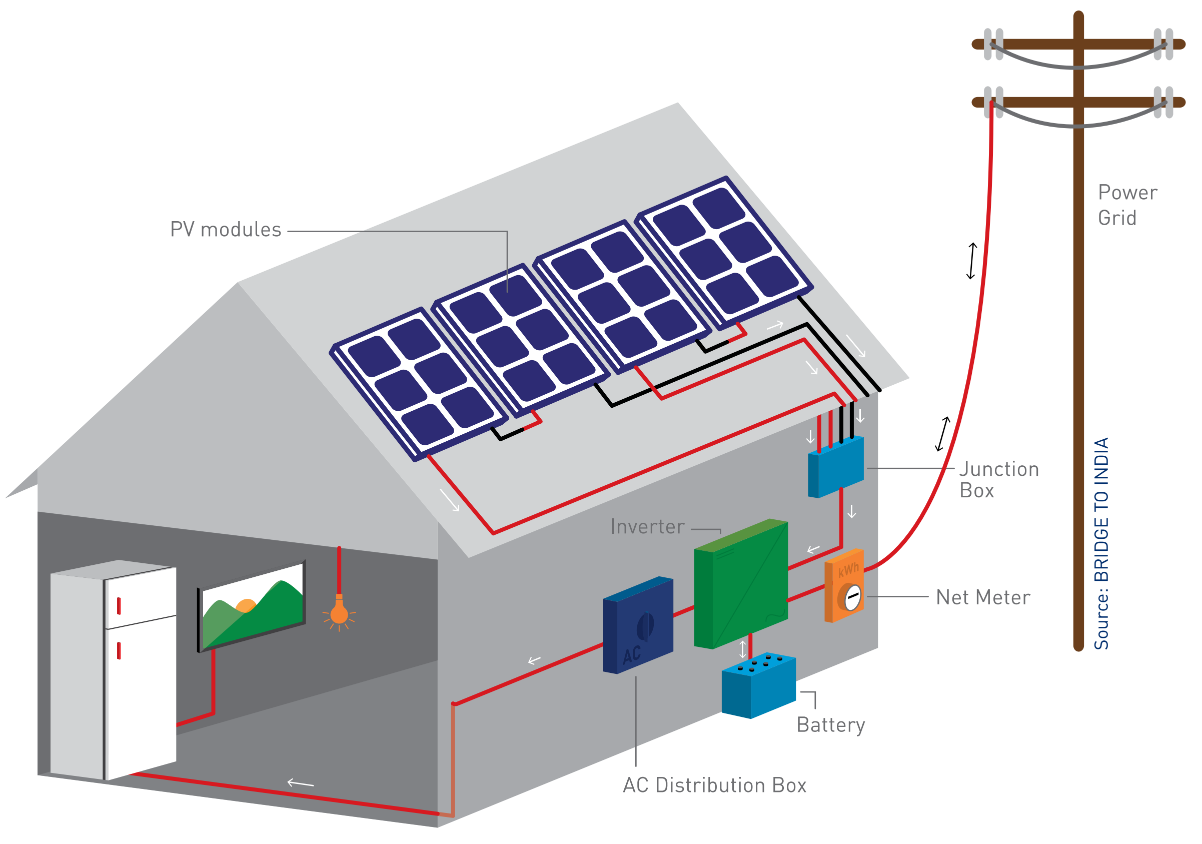
A solar PV power plant converts sunlight into electricity. It does so without any moving parts (unless it has a tracking system) and without generating either noise or pollution. A solar PV system can be installed at any un-shaded location such as on rooftops of buildings, car parking sheds, empty land, or even on top of canals and roads. Typical system sizes range from 240 watts to 100 MW. There is very little difference in the technical design between small kW-sized plants (typically de-centralized, off-grid) and large, MW-sized plants (typically centralized, grid-connected). Solar plants can easily be scaled using independent, modular components such as PV modules, inverters and batteries. The rooftops of buildings would be ideal for the installation of solar PV in Patna because of the high cost of land in the city as compared to the rest of the state. A typical rooftop solar PV system for a household is between 1-10kW. For larger buildings, such as offices or malls, it can reach 100 kW or more. Given Patna's average irradiation of 5-5.5 kWh/$m^2$/day, a kW of installed solar PV can generate 4-4.5 kWh of power during daylight hours. This generated electricity is equivalent to the amount of power needed for running four tubelights (40 W each) and two fans (60 W each) for 16 hours a day.





**Figure A1: Solar PV system**






A solar PV system consists of the following key components
1. Solar PV array (group of modules)
2. Solar inverter
3. Battery
4. Interconnecting devices (junction box, cables, distribution box)

The PV array consists of solar modules interconnected with each other. The modules convert the energy from sunlight, are held on structures made of galvanized iron, mild steel or aluminum and are inclined at a horizontal tilt, facing either south or east-west.

The modules are designed to generate current at either 12 or 24 volt. Inverter models can differ in their input voltage requirements in the range of 12 to 1,000 volt. A junction box connects the modules in series or parallel to achieve the optimum voltage required by the inverter.

Solar modules produce direct current (DC). Almost all electrical appliances in India, however, require alternating current (AC) to operate. The function of converting DC to AC is carried out by the inverter. In the case of a battery backup system, the inverter is also connected to the batteries and is responsible for managing the charging and discharging of the batteries.

The output point of the inverter is connected to the distribution box, which consists of a meter, fuse, a miniature circuit breaker (MCB), and load connections. Cables connect the solar modules, junction boxes, inverters and distribution boxes.



The capacity of the solar PV system depends on the amount of electricity (kWh) required per day by a consumer and the shadow and obstruction free space available on the rooftop. For example, a 2 kWp load operating for 10 hours requires a PV system of 5 kWp[100]. Further, 1 kWp of solar PV requires 12m$^2$ of shadow free area. Therefore, a 5 kWp system would require 60 m$^2$. In addition, if the consumption occurs during non-sunshine hours (6:00 pm to 6:00 am) or in case the consumption is not uniformly sufficient throughout the day[101], batteries to store energy might be added.

Another factor, which affects the system design, is the timing of electricity consumption. For example, residential consumers in Patna have a peak demand during the morning (6:00 am – 10:00 am) and evening (6:00 pm – 10:00 pm). These are not peak sunshine hours (10:00 am – 4:00 pm). Residential demand tends to be lower during the day as household members become engaged in daily activities, mostly outside the house (e.g. adults going to work and children going to school). Thus, the peak power production of a PV system does not match the peak demand of residential consumers in Patna. For industrial and commercial consumers, on the other hand, solar generation coincides more closely with peak demand as most of these sites operate through the day.

Solar PV systems could be sized to not exceed the load demand during the day. If they are larger, and solar power is being generated that exceeds consumption at that point in time, wastage can be avoided by storing the excess power. Alternatively, excess power could be injected into the grid. In this case, metering would be required to measure energy transactions between the PV system and the grid

## Rooftop solar PV with storage

Storage in solar PV systems is required to provide stable backup power when the solar energy is not available (at night) or not adequate to meet the entire load demand. Solar energy is an intermittent source of power. The power generation can vary with a change in sunshine due to, for example, a sudden cloud cover. Batteries can be used to store solar power to safeguard against a short-term fall in solar power generation. Intermittency can also be avoided by connected the solar PV system to the grid. In this case the grid provides the extra energy at times of inadequate sunshine.

Another application of storage is to protect against grid outages. During an outage it is possible that solar generation is inadequate to meet the load demand (e.g. if it occurs outside sunshine hours). In such a case, the stored energy can be utilized to provide a stable output of power. If the grid condition is good and power outages are rare, batteries would probably be avoided as they add significantly to the system cost, adding 25%. Batteries also need to be replaced every three to five years. Since Patna does not experience long power cuts, batteries need not be an essential part of the PV system. Storage might, however, be an attractive option for Patna's DISCOMs as it can be utilized to offset expensive peak load power.

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100 The size of a solar PV system is usually higher than the operational load as solar has an average Capacity Utilization Factor (CUF) of 18% as compared to 80% for coal power plants. 1 kW of solar gives 4 kWhs at a CUF of 18%. So, For 20 kWhs of power, we would need a system of 5 kW.

101 If loads have no fixed time of operation or might be operational over a couple of hours. For example there can be a 10 kW load being powered for just 2 hours a day. This would require a system of 5 kWp. A 5 kWp system cannot generate enough electricity to power a 10 kWp load at any time of the day; Hence we require batteries that store energy

 

## Rooftop solar PV with net metering

There are two common ways in which owners of kW-scale rooftop solar PV plants can be compensated for feeding electricity into the grid: FiTs and net metering. For FiTs, solar power generated and fed into the grid is measured through a separate meter and then given a price (the FiT) through which the owner is compensated for the electricity generated. The advantage is, that the price for solar power and the amount of solar power generated can be determined independently. This method is useful where either the cost of solar power far exceeds the cost of grid power and/or where the generation of solar power far exceeds the on-site consumption needs. A risk is the potential for fraud through channeling non-solar power through the solar meter and thus inflating the amount of power for which the – usually high – solar FiT is paid. A household-level FiT is offered in, for example, Germany.

Under net metering, on the other hand, conventional electricity and solar electricity are traded at the same tariff. The billing in this case is based on the net energy imported (energy consumed minus energy generated and fed into the grid). In case more energy is generated than consumed, the utility can adjust the excess in a future billing period (this would be akin to "banking" the power), rather than giving a monetary compensation, as in the case of FiTs. However, over the long term, the amount of solar power that can be generated and monetized through net metering will be limited by the amount of power consumed, where, at most, the consumer can feed as much power back into the grid as he draws from the grid so that the electricity bill is "zero". Net metering is popular in, for example, the USA and Japan.

Several Indian states have already started taking steps towards facilitating net metering in India. Five states of Tamil Nadu, Andhra Pradesh, Uttarakhand, Gujarat and West Bengal have already finalized the guidelines for net metering. Proposal for net metering is in the draft stage for Kerala, Delhi, Karnataka and Punjab.

The CEA has initiated steps to set standards and guidelines for the integration of solar PV systems in to the grid. A report on grid connectivity of solar PV is under formulation at the CEA. A draft is to be shared with the public for comments by end-June. The CEA's move is based on its acknowledgement that decentralized solar PV can play a key role in bridging the country's energy deficit and is set to take off now. During our interactions with senior officials at the CEA, we were told that "solar PV is the future for this country, and we have to make sure that there are standards and guidelines in place to support its integration with the grid". Various metering arrangements covering grid interaction of a PV system with battery, without battery, with different load battery back-ups, with different load DG back-ups, and with DG and battery back-up combinations, have been laid down in the draft report.

# 10.4 Solar PV grid connectivity challenges and solutions

## Voltage fluctuation and imbalance

The solar energy generated by a PV system is dependent on the availability of sunlight. Power generated can vary drastically throughout the day, sometimes within seconds, because of, for example, cloud-cover and weather changes.





This causes rapid voltage fluctuations that can hamper devices linked to the transmission network and can, in some cases, overheat and even melt the power lines. Inverters can be designed to regulate PV system voltage and provide for communication between the grid operator and the PV inverters. Such communication can allow for improved control of voltage fluctuations in the entire grid.

Further, voltage fluctuations can take place due to the improper functioning of an inverter and can be problematic if these fluctuations move outside specified values. Excessive under-voltage can cause "brownouts" characterized by the dimming of lights and inability to power some equipment. Excessive over-voltage can damage and decrease the life of electronic equipment. To avoid such scenarios, voltage fluctuations need to stay within specific limits[102], beyond which the PV system is required to automatically disconnect from the grid.

## Transmission of unwanted current into the grid

The current in the grid which is supplied for end-use is AC. The current generated by the solar PV system is DC. This is stored into the battery system (if there is one), also in DC, and then converted into AC by the PV inverter, which in turn is either fed into the grid or consumed. There is a possibility that the PV inverter passes unwanted DC current into the AC driven network of the grid, which can lead to overheating of distribution power transformers, power losses or damages. This injection of DC power into the grid can be avoided by using an isolation transformer at the output of the inverter. An isolation transformer would block transmission of DC signals from one circuit to the other, but allow AC signals to pass. Coupled with an isolation transformer, inverters are able to feed electricity into the grid with a maximum permissible DC component of 1% in the AC current.

## Electrical disturbance caused by non-linear loads

Electrical disturbance (the permanent modification of the voltage and current sinusoidal wave shapes), generating harmonics, is created by the presence of non-linear[103] components in an electrical system. Harmonics in the power grid can overload equipment, interfere with telephone circuits and broadcasting and lead to metering errors. Typically, total voltage harmonic distortion, individual harmonic distortion and total current harmonic distortion produced by a PV system should not be allowed to exceed 5%, 3% and 8% respectively, such that electrical disturbances do not affect the quality of power in the grid.

## Unintentional islanding

Unintentional islanding occurs when a solar PV system continues to supply electricity to the grid in the event of a larger grid failure. This can cause safety issues for technicians and the general public as a power line that might be considered off is, in fact, still powered. Unintentional islanding is a well-known problem and, therefore, most inverters now possess anti-islanding features whereby PV systems are automatically disconnected from the grid in the event of a power outage. In addition to that, a manual disconnect switch could also be provided in the PV system to isolate the grid connection. Despite these measures, unintentional islanding remains a particular concern when PV and other systems without anti-islanding features, such as diesel generators, are connected to the same line section. These machines may mimic normal grid conditions, causing the PV inverters to stay online and create unintentional islanding. At the moment, there are no finalized solutions to this problem.

## Reverse power flow and voltage fluctuations

High levels of PV penetration may cause reverse power flow. Reverse power flow occurs when in the case of weak or/and long networks, voltage rises when consumption at the consumer's end is low and the power fed into the grid by the PV system is high. In such a case, voltage increase may cause the electricity to change direction and flow through the transformer to the higher voltage. This is can lead to heating up of the distribution transformer and transmission lines. Another problem can arise when the power generated by the large number PV systems reduces at once due to the inherent intermittent nature of solar. This sudden reduction in power can destabilize the grid.






# 11 Glossary of Terms

| | |
|---|---|
| **APPC** | Average Power Purchase Cost |
| **BSEB** | Bihar State Electricity Board |
| **BSPGCL** | Bihar State Power Generation Company Ltd. |
| **BSPHCL** | Bihar State Power Holding Company Ltd. |
| **BSPHCL** | Bihar State Power Holding Company Ltd. |
| **BSPTCL** | Bihar State Power Transmission Company Ltd. |
| **CAPEX** | Capital Expenditure |
| **CEA** | Central Electricity Authority |
| **CERC** | Central Electricity Regulatory Commission |
| **CUF** | Capacity utilization Factor |
| **DISCOM** | Distribution Companies |
| **EPC** | Engineering Procurement and Construction |
| **FiTs** | Feed in Tariffs |
| **GBI** | Generation Based Incentive |
| **kWh** | Kilowatt hours |
| **kWp** | Kilowatt peak |
| **LCOP** | Levelized cost of Power |
| **LCOP** | Levelized Cost of Power |
| **MNRE** | Ministry of New and Renewable Energy |
| **MW** | Mega-watt |
| **NBFC** | Non-Banking Financial Company |
| **NBPDCL** | North Bihar Power Distribution Company Ltd. |
| **NSM** | Jawaharlal Nehru National Solar Mission |
| **NTPC** | National Thermal Power Corporation |
| **OPEX** | Operational Expenditure |
| **PGCIL** | Power Grid Corporation of India Ltd. |
| **PPA** | Power Purchase Agreement |
| **PUAA** | Patna Urban Agglomeration Area |
| **PV** | Photovoltaic |
| **RESCO** | Renewable Energy Service Company |
| **ROI** | Return on Investment |
| **SBPDCL** | South Bihar Power Distribution Company Ltd. |
| **SECI** | Solar Energy Corporation of India |
| **T&D** | Transmission & Distribution |

BRIDGE TO INDIA is a consulting company with an entrepreneurial approach based in New Delhi and Munich. Founded in 2008, the company focuses on renewable energy technologies in the Indian market. BRIDGE TO INDIA offers market intelligence, strategic consulting and project development services to Indian and international investors, companies and institutions. Through customized solutions for its clients, BRIDGE TO INDIA contributes to a sustainable world by implementing the latest technological and systemic innovations where their impact is the highest.

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CEED-Center for Environment and Energy Development (CEED) was registered in November 2012 as a non-profit organization under Section 25, Companies Act, 1956. CEED is an organization dedicated to finding solution for "toxics free future" and to end "energy injustice" in all manifestation. The idea for CEED was conceived by a group of young professionals with vast amount of experience in the field of environment. CEED has eminent board members from the society to guide us for mission validation or ensuring compliance of the strategy.

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